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ATSC COLD WEATHER TESTS WINTER 1944-1945

ARMY AIR FORCES

AIR TECHNICAL SERVICE COMMAND

Wright Field **Dayton, Ohio**

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ATSC COLD WEATHER TESTS

WINTER 1944-1945

By

Climatic Requirements Office
Service Engineering Branch
Engineering Standards Section
Service Engineering Subdivision
Engineering Division

Approved: Harlan Y. Smith
HARLAN Y. SMITH, Colonel, Air Corps
Chief, Engineering Standards Section

For the Director:
Content and classification authenticated by:
L. C. Craigie
L. C. CRAIGIE, Brig. General, USA
Deputy Chief, Engineering Division

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This opportunity is taken to express the appreciation of Air Technical Service Command for the cooperation and assistance in the cold weather test program contributed by the Cold Weather Testing Detachment of the Proving Ground Command, and the Technical Representatives of the various manufacturers represented. The cold weather performance of Army Air Force aircraft and equipment showed a marked improvement over previous years and data and information was gathered which will make possible yet more improvement by next winter. The evident success of the past winter's test program would not have been possible without the facilities and personnel furnished by Cold Weather Test Detachment and the technical aid contributed by manufacturers' Technical Representatives.

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INTRODUCTION

In order to save space and reduce the bulk of this report to a reasonable size, many charts, tables, photographs, and appendixes have been omitted from the reports of Sections III, IV, and V. However, reference to these data has not been omitted from the portion of the reports printed. Anyone desiring reports in their entirety may obtain them by writing to the Director, Air Technical Service Command, Wright Field, Dayton, Ohio, Attention: TSESE-4F3.

1. The purpose of this report is to describe the program conducted at Ladd Field, Alaska, by Engineering Division of Air Technical Service Command to test AAF aircraft and equipment under conditions of extreme cold during the winter 1944-1945, and report the conclusions and recommendations resulting therefrom.

2. The Air Technical Service Command is wholly responsible for the development and procurement of aircraft and equipment for the Army Air Forces that will operate satisfactorily at all temperatures down to —65°F outside air temperature. To insure meeting this requirement tests and investigations must be conducted upon which to base corrective engineering of reported and anticipated deficiencies. As part of this program the Engineering Division installed instrumentation and test equipment on several current model airplanes and conducted experimental and developmental tests at Ladd Field, Alaska.

3. The ATSC test program was planned, organized supervised by the Climatic Requirements Office of Engineering Division. Project engineers of the various Engineering Division Laboratories were present to conduct tests on and observe malfunctions of their respective installations and equipment. Various aircraft and equipment manufacturers' technical representative attended in order to gain first-hand knowledge of the difficulties of cold weather operation, aid in operation of their equipment, and obtain data and information which would be used to improve the performance and utility of their equipment.

4. Section I describes the organization and conduct of the test program.

5. Section II summarizes the more important conclusions arrived at as a result of the tests.

6. Section III is the final reports written by the project officers of the Climatic Requirements Office.

7. Section IV is the final reports written by project officers and engineers of the various Engineering Division Laboratories.

8. Section V is reproduction in part or whole of reports written by Technical Representatives to their respective organizations.

9. The Appendix contains miscellaneous information such as airplane models, flying time, hourly temperature data, and personnel attending the tests.

SECTION I

Organization and Conduct of Cold Weather Test Program Winter of 1944-1945

1. Air Corps interest in cold weather operation dates back several years. In 1938 the Cold Weather Test Detachment was established as an independent Air Corps activity at Fairbanks, Alaska, to conduct tests, determine the aircraft requirements for cold weather operation, and recommend corrective action. The first tests by that Detachment were conducted during the winter of 1940-1941. These tests and the ferrying of airplanes over the Alsib and North Atlantic routes revealed critical deficiencies in AAF aircraft and equipment when operated in extremely low temperatures, and the advent of war in the North Pacific emphasized the importance of developing aircraft that would operate in all arctic theaters.

2. Starting in the winter 1942-1943 Engineering Division, ATSC has conducted extensive test programs each year at Ladd Field in conjunction with the Cold Weather Testing Detachment. In 1943 the Cold Weather Testing Detachment was placed under the administration of Proving Ground Command. Since that time the Detachment has been responsible for service test of all standard production aircraft and equipment, while Engineering Division has been responsible for all experimental and developmental testing.

3. The coordinating office for all cold weather development and testing in ATSC is the Climatic Requirements Office of the Engineering Division. Climatic Requirements office is responsible for planning, organizing, and supervising test programs for Engineering Division at cold weather test bases, evaluating and consolidating test results, aiding and following up the Engineering Division Laboratories to insure solutions to reported and anticipated deficiencies, after proper coordination establishing the aircraft and equipment requirements for cold weather operation, and informing Procurement Division and industry the requirements and action to be accomplished.

4. The procuring of test airplanes, instrumentation, and installation of test equipment therein, organization and supervision of actual testing, and the flying and maintenance of airplanes, was performed by the Extreme Temperature Operations Unit of Climatic Requirements Office. The airplanes tested by Engineering Division during the past winter are listed in Table II of the Appendix. The bulk of the instrumentation and test equipment was installed in the airplanes at Dayton Army Air Field, Vandalia, Ohio, during the summer and fall of 1944. Certain installations were also made at contractor's plants. The installations were made at the direction and with the help of Engineering Division Laboratory project engineers and contractor's engineers.

5. Each test airplane was assigned a project officer who acted as project engineer and pilot for his own airplane. At the conclusion of instrumentation in the United States the airplanes were flown to Ladd Field where the test program was gotten underway approximately 1 December 1944. It was the responsibility of the project office to insure that all tests requested by Laboratory engineers and contractor's representatives were completed as nearly as was feasible, and that the maximum benefit was derived from the test program on their respective airplanes.

6. The Cold Weather Testing Detachment furnished to Engineering Division hangar space and shop facilities, enlisted maintenance and flight crews, office facilities, extra pilots when required, airplane servicing, supplies, spare parts, and other facilities.

7. Cold Weather Testing Detachment procured two or more of each current production airplane upon which to conduct tests to determine their operational suitability. These airplanes contained no instrumentation or experimental installations. CWTD also performed service tests on all available types of standard ground and accessory equipment. In addition it performed some service tests on experimental equipment for ATSC. The airplanes service tested by CWTD are listed in Table III of the Appendix. CWTD submitted reports on their tests to Headquarters, Proving Ground Command.

8. The Air Technical Service Command personnel and manufacturer's representatives attending the tests are listed in Tables IV and V of the Appendix.

SECTION II

Summary of Conclusions

1. Temperatures at Ladd Field during the past winter were above average. Table I of the appendix gives hourly temperatures during the months of November, December, January, and February. During the winter —40°F or colder was reached on three days. The lowest ground temperature was —45°F. A few airplanes experienced lower ground temperatures at Northway, Alaska, and Snag, Canada. However, in spite of the lack of extremely low temperatures certain deficiencies were noted, and recommendations can be made that, if complied with, will improve the operability of aircraft down to —65°F. In general, it can be stated that current production aircraft are operable down to —45°F and are greatly improved over previous years, but certain items are not as satisfactory as is desirable or possible. It is anticipated that at temperatures below —45°F AAF aircraft may not be entirely satisfactory for all tactical operations that may be required of them. Following is a brief summary of some of the more important conclusions reached as a result of the 1944-45 test program. These and other conclusions and recommendations are discussed in more detail in the reports in Sections III, IV, and V.

a. SURFACE CONTROL SYSTEMS. Practically every airplane had at least on control or trim tab that was stiff at —40°F. Investigation revealed that very little stiffness was caused by congealing of the lubricants. The primary cause of stiff or frozen controlls was differential expansion and contraction of component parts or mountings. Cable tension could not be maintained, especially on larger airplanes. Cable tension regulators were of value.

b. RUBBER HOSE. Standard winterized hydraulic and instrument hose was satisfactory. Standard oil and coolant hose was not entirely satisfactory, but new types tested experimentally were good.

c. WEATHERSTRIPPING AND FUSELAGE SEALS. There were numerous instances of rubber and synthetic seals breaking, cracking, or becoming so hard that canopies, doors, etc. could not be opened or closed with ease or sealing properties were lost.

d. PLASTIC PARTS. There were several instances of plastic canopies, domes, and windshields cracking due to differential contraction of the part and the mounting.

e. HYDRAULIC SYSTEM. In general hydraulic systems were good, except in a few instances where unwinterized parts or packing were used. O-ring and chevron packings were both successful, although the o-ring was preferred. Filters and accumulators were satisfactory. The P-47, C-46, and B-24 were the only airplanes having appreciable hydraulic trouble at low temperatures.

f. PROPELLER FEATHERING. Feathering of Hamilton Standard propellers was not satisfactory at low temperatures. The experimental system using hydraulic fluid for feathering in conjunction with grade 1100A engine oil governing was not appreciably better than the standard system using grade 1100A oil for feathering. Either system was satisfactory when using experimental synthetic engine oil PP0265. However, the latter solution is not considered satisfactory inasmuch as PP0265 is not available in quantity nor well enough proven for general use.

g. AIRPLANE SPACE HEATING. Heat was not adequate at all crew stations in many airplanes. Combustion heaters were chronically unable to operate at high altitudes or low temperatures. Heat exchangers were more reliable but were not always adequate. No airplane had appreciable heat available on the ground.

h. DEFROSTING AND DEICING OF TRANSPARENT AREAS. There was practically no deicing or defrosting available on the ground, which is critical in cold climates. Some airplanes were not satisfactory in flight.

i. WING AND EMPANNAGE DEICING. Heavy icing was not encountered during the tests, therefore the adequacy of these systems was not determined.

j. PROPELLER DEICING. Sufficient icing was not encountered to test the propeller deicing. However, the hub generator type with electrically heated blade shoes was unsatisfactory from a maintenance standpoint.

k. SNOW AND ICE TIRES. The ice grip tires with metal inserts did not have sufficient traction on icy runwaqs to hold the airplane when running up the engines.

l. DILUTION OF ENGINE OIL. In general very dependable. A few airplanes had too slow rate of diluent flow, or had poorly designed oil tank systems that would not properly segregate diluted and undiluted oil, resulting in overly long dilution periods or making high percentages of dilution impossible. Improved tank and hopper designs tested experimentally showed great improvement.

m. SCAVENGING OF DILUTED ENGINE OIL. All airplanes equipped with in-line engines were subject to spewing and loss of highly diluted oil at high power. The P-51D and P-38L did not safely handle over 10% to 15% dilution and the P-63A was able to handle 30% dilution only because it had an oil and air separator which caught the spewed oil and turned it back into the oil system. If other means do not prove successful it may be necessary to install air-oil separators in all in-line engines when operated in the arctic.

n. CARBURETOR AIR HEAT. Adequate and selective carburetor heat is required for engine operation below 0°F, both on the ground and in flight. All turbo-supercharged airplanes, except the P-38, and some non-turbo airplanes were deficient. Carburetor air heat is required for smooth engine operation, to prevent spark plug fouling, increase fuel economy, and prevent carburetor icing.

o. FLIGHT AND NAVIGATION INSTRUMENTS.

(1) Electrically driven gyro flight instruments are superior to air driven for low temperatures.

(2) Unwinterized types of vacuum selector valves were unsatisfactory.

(3) Winterized manifold pressure drain valves were satisfactory.

(4) All instruments should be front mounted.

(5) Failure of air driven gyro horizon indicators was excessive.

(6) Precession of air driven gyro instruments is too fast and erection too slow at low temperatures.

p. PRESSURE GAGE SYSTEMS. Autosyn pressure transmitter systems are superior to A-1 transmitters from the standpoint of reliability and maintenance.

q. GUN AND FIRE CONTROL SYSTEMS. Warping of the B-29 fuselage at low temperatures possibly decreased the accuracy of the fire control system.

r. BOMBING EQUIPMENT.

(1) Heating covers are necessary on bombsights, stabilizers, and C-1 automatic pilots.

(2) On the B-24 the leakage of cold air around the nose turret affected the operation of the bombsight and reduced the bombardier's efficiency.

s. RADIO AND RADAR. In general, very good. Some difficulty was experienced with stiffness of lubricated shafts at low temperatures. Precipitation static was especially hazardous in the arctic due to lack of landing fields or ground radio facilities.

t. ELECTRICAL EQUIPMENT.

(1) Starters burned out due to attempted cold starts. Direct cranking starters were as effective as inertia starters and there was less breakage from shock load at low temperatures.

(2) Propeller feathering at low temperatures caused electric fuses to blow out, with loss of generator power. Two-engine airplanes should have circuit breakers located accessible to the crew.

(3) Provision should be made to heat the auxiliary power unit in the airplane.

u. ENGINE STARTING.

(1) Cold starting with ordinary gasoline and without application of hot air heating is not feasible below 0 to —10°F.

(2) Fuel priming systems should be materially improved.

(3) Satisfactory systems using highly volatile fuels should be developed for extremely low temperature starting.

(4) More rapid means of heating the engine and accessories should be developed.

(5) In some instances failure of accessories is the limiting factor in cold starting.

(6) Carburetor air heat is considered necessary for rapid warm-up and smooth engine operation.

(7) Poor combustion due to poor distribution of the fuel-air mixture is aggravated by low temperatures.

(8) Oil system must be capable of high dilution and proper segregation.

(9) Use of PPO-265 engine oil materially aided starting and warm-up.

v. ENGINE OPERATION IN FLIGHT. In general the same problems are encountered in the arctic as in any other theater. The fact that instruments and accessories are cold before take-off may affect their behavior. Carburetor air heat is considered necessary. Good distribution of fuel-air mixture is important.

w. AIRPLANE SERVICEABILITY. Arctic operation has revealed that any item that improves ease of maintenance or serviceability is of greatest importance. Intense cold and bulky clothing make operations extremely difficult that would be relatively simple in temperate climates. The following items may mean the difference between airplanes getting in the air or remaining on the ground:

(1) Drains should be self-locking so that safetying is unnecessary. Danger from frozen condensate makes daily drainage necessary at low temperatures.

(2) Drains should be made easily accessible, either by use of extension handles, access doors, or relocation.

(3) Oil drainage should not drain onto any part of the airplane because the oil will congeal and gum up mechanisms.

(4) Batteries should have quick disconnects.

(5) The external power plug should be so located that it can be quickly disconnected without personnel entering the propeller blast.

(6) Instruments should be front mounted and pressure gage lines should be provided with accessible fittings for ease of servicing.

(7) Pressure transmitters should be made accessible for ease of maintenance and servicing.

(8) Large doors should be provided for entrance of ground heater ducts at effective locations so that it will not be necessary to remove cowling.

(9) Engine, wing, empennage, and canopy covers are necessary when the airplane is parked on the ground to prevent formation of frost on plane surfaces and windshields, and increase the efficiency of ground heaters.

(10) Dependable and adequate ground equipment is necessary. This includes ground heating units, auxiliary power carts, maintenance shelters, floodlights, etc.

(11) Adequate clothing must be provided, both for outdoor wear on the ground and for use in flight. It must be so designed that frost bite or freezing will not be encountered, yet avoid bulkiness and weight that would prevent performance of duties.

SECTION III

Final Reports of Project Engineers of the Climatic Requirements Office

This Section consists of final reports written by the individual pilot-engineers on each airplane, and other special project engineers assigned to the Climatic Requirements office. Certain supporting data and explanatory detail has been omitted in order to reduce the bulk of the report. Much of the data omitted is covered in the reports of the Laboratory Project Engineers in Section IV.

Cold Weather Tests 1944-1945

Prepared by L. C. Smith, Major, A. C.

A. PURPOSE

1. To report on the organization, administration, and results of the 1944-1945 cold weather tests conducted by Engineering Division at Ladd Field, Fairbanks, Alaska, and offer recommendations for future test programs.

B. AUTHORITY

1. TI-2000, dated 8 November 1944, subject, Winterization of Aircraft, and ATSC Regulation 6-1, subject, Extreme Temperature Program.

C. FACTUAL DATA

1. The Air Technical Service Command is wholly responsible for tests necessary to insure full operation of Army Air Forces aircraft down to —65°F.

2. In order to conduct the required tests the Climatic Requirements Office of Engineering Standards Section, Engineering Division, was assigned current models of signed:

3. Test installations and instrumentations were made on the test airplanes at the request of the various Laboratories of Engineering Division.

4. The airplanes were flown to Ladd Field, Fairbanks, Alaska, during the fall of 1944 for tests under extreme cold weather conditions during the winter of 1944-1945.

5. The instrumentation and testing of the airplanes was under the supervision of the Extreme Temperature Operations Unit of the Climatic Requirements Office, hereinafter referred to as ETOU. Figure 1 is an organization chart of ETOU at Ladd Field.

6. Representatives of the various Engineering Division Laboratories were present at Ladd Field during the winter to conduct tests and observe malfunctions on their respective installations and equipment. Representatives of Supply and Maintenance Divisions attended to observe the tests and study supply and maintenance procedures at arctic bases.

7. All base facilities, including hangars, shops, transportation, quarters, messing, etc., were furnished by the Cold Weather Testing Detachment of the Proving Ground Command and the Alaskan Division of the Air Transport Command. Enlisted flight crew men and maintenance personnel were furnished by Cold Weather Testing Detachment.

8. With the exception of two officers borrowed from Cold Weather Testing Detachment, all test pilots were furnished by ETOU.

9. Technical representatives of various aircraft and equipment manufacturers attended in order to gain first-hand information on the difficulties of cold weather operation, aid in operation of their equipment, and obtain data and information which would be used to improve the performance and utility of their product.

10. The Phillips Petroleum Company and Transcontinental and Western Air each operated an army cargo airplane at Ladd Field under contract to the Engineering Division. These airplanes were used for testing specification fuels of various volatilities to determine the low temperature operating limits of the different fuels for starting and flight operations.

11. A discussion of this Factual Data and the following Conclusions and Recommendations is included in the Discussion.

12. The Cold Weather Testing Detachment of the Proving Ground Command conducted service tests on current production type AAF aircraft and equipment simultaneously with the ATSC test program.

D. CONCLUSIONS

1. It is concluded that current AAF aircraft and equipment are suitable for tactical and service operations down to outside ground temperatures of —45°F, the lowest temperature encountered at Ladd Field during the last two winters.

2. The tests were not conclusive as to the suitability of AAF aircraft and equipment in ground temperatures down to —65°F due to lack of sufficiently low temperatures during the test period. However, the tests indicated that operation can be expected at —65°F if crews are properly trained and correct cold weather operating procedures are strictly adhered to.

3. The tests indicated that certain items have not been developed to their full possibilities. Among these items are:

a. Carburetor air heat

b. Oil systems and oil tanks

c. Scavenging of diluted oil in liquid cooled engines

d. Feathering of hydromatic propellers

e. Cabin and cockpit heat and ventilation

f. Deicing and defrosting of transparent areas

g. Low temperature oils and greases

h. Airplane surface control systems

i. Rubber and synthetic inclosure seals and weather-stripping

j. Starting of aircraft engines in low temperatures

Additional information on the above items is included in the Discussion.

4. Jet propelled aircraft are the most satisfactory for low temperature operation from the standpoint of quick starting, reliable operation and low maintenance.

5. Temperatures at Ladd Field are not consistently low enough to guarantee adequate testing of AAF aircraft and equipment down to —65°F.

6. The rapid rate at which cold testing chambers are being completed and put in operation at Wright Field will permit solution of many cold weather problems at a much earlier date than was possible with the previous method of conducting tests only during a few winter months at remote overseas bases.

7. Much advantage was realized from Air Technical Service Command and Cold Weather Testing Detachment conducting tests together at the same base. This method increased the number of airplanes of each type on which ATSC engineers could make observations, and Cold Weather Testing Detachment was able to utilize the technical knowledge of ATSC engineers.

8. It is concluded that the system whereby pilot project officers are assigned to each airplane and are held responsible for following through and reporting on all tests on their respective airplanes is the most successful method yet used.

9. The movement of ATSC aircraft and personnel and the successful accomplishment of the test program were seriously hampered by the delay and difficulty in obtaining orders for overseas travel.

10. Supply—Considerable difficulty was encountered at Ladd Field with test equipment and supplies that were shipped from Wright Field becoming lost, delayed or misplaced. This was due mainly to the fact that many items arrived at Ladd Field early in the season before any ETOU personnel were present to look after them, and due to the system whereby all Cold Weather Testing Detachment and ETOU supplies were put in one common pool.

E. RECOMMENDATIONS

1. It is recommended that immediate action be taken in Engineering Division to develop the items mentioned in Paragraph D, 3 to their fullest possible extent. An accelerated program of tests and investigations of these items should be pursued throughout the coming spring and summer so that satisfactory solutions will be available next winter.

2. The results of the above investigations should be incorporated in the latest type airplanes and tested under cold weather conditions next winter.

3. It is recommended that for future ATSC cold weather tests the following procedure be followed. After decision is made as to what airplanes are to be tested, a pilot project officer be assigned to each airplane at the earliest possible date. These officers should have had previous Alaskan experience, and should preferably be those used by ETOU last winter. The project officers will be responsible for seeing that the proper instrumentation and test installations are made on their respective airplanes. They will coordinate the desires and requirements of the Engineering Division Laboratories and the airplane manufacturers, and will personally supervise all installations. Work should start approximately 1 June of the summer preceding the test season. Special attention should be given to installation of the latest solution to the problems listed in D, 3. It is recommended that as much installation as possible be made at manufacturers' plants in order to retain the manufacturers' interest and make an installation that is practical from a production standpoint. Upon completion of the installations the project officer will fly the airplane to the test base and will conduct all tests required by Laboratory and manufacturers' engineers, and other tests at the discretion of this office.

4. A cold weather test base should be established at some station having sufficiently low temperatures to indicate the satisfactoriness of AAF aircraft and equipment down to —65°F. If possible, this base should have at least 30 days per winter when temperatures are below —40°F and at least 7 days below —60°F. The location most nearly meeting these requirements, and also being feasible from the standpoint of other considerations, is Fort Yukon, Alaska. A comparison of temperatures and weather at Fairbanks and Fort Yukon is given in Tables I and II.

5. Consideration should be given by higher authority to conducting a tactical test of AAF aircraft and equipment under arctic conditions. This test would consist of setting up advance bases and working out tactical and combat problems under conditions of extreme cold. These tests should be conducted by some organization which has had no previous arctic experience. ATSC and Cold Weather Testing Detachment personnel would act only as observers and advisors.

6. Means should be set up whereby travel orders for personnel participating in cold weather tests may be cut at Headquarters, ATSC, without going to Washington, D. C.

7. In the future Climatic Requirements Office should have at least one person at the test base before 1 October in order to care for Wright Field shipments and supplies, and a separate supply storage should be set up and maintained for ATSC equipment.

Discussion

1. *Background of ATSC Cold Weather Tests*

a. Air Corps interest in cold weather operation dates back several years. The first concerted effort to investigate and evaluate cold weather operating requirements was the establishment of the Cold Weather Test Detachment as an independent Air Corps agency at Fairbanks, Alaska, in 1938. The first tests by that Detachment were conducted during the winter 1940-1941. As a result of these first tests, and the advent of war in the North Pacific, the Service Engineering Branch was designated in July, 1941, as the coordinating agency within Engineering Division, Material Command, for development of equipment and means for insuring satisfactory operation of aircraft in cold weather.

b. Starting in the winter 1942-1943, Engineering Division has conducted extensive winter test programs each winter at Ladd Field in conjunction with the Cold Weather Testing Detachment. In 1943 the Cold Weather Testing Detachment was placed under the administration of Proving Ground Command. Since that time Cold Weather Testing Detachment has been held responsible for service test of all standard production aircraft and equipment, while Engineering Division, ATSC, has been responsible for all experimental and developmental testing.

c. Plans for the 1944-1945 test program were laid at conferences at Eglin Field, Florida, on 9 May and 1 July 1944, attend by representatives of OC & R, Materiel Command, Proving Ground Command, Army Air Forces Board, and Cold Weather Testing Detachment. A tentative program and plan of action for Materiel Command in the 1944-1945 tests was submitted to Proving Ground Command, Army Air Forces Board, and M.M. & D. on 6 June 1944.

2. *Authority for ATSC Cold Weather Tests*

a. With the advent of war the necessity for satisfactory operation of AAF airplanes in arctic theaters was immediately evident. Under dates of 14 and 22 March 1943 the Director of Military Requirements stated:

". . . in the future all combat airplanes and cargo airplanes, C-60 class or larger, for the AAF will be so constructed that all parts thereof will function normally at all temperatures down to —65°F outside air temperature . . . the Materiel Command would be held responsible that all such aircraft produced would be capable of operation under extreme conditions of cold to temperatures of —65° . . . The tests necessary to insure full operation of all aircraft down to —65° are considered wholly the responsibility of the Materiel Command and Ladd Field Cold Weather Test Detachment will undertake any test requested or desired by the Commanding General, Materiel Command."

b. CTI-1300, dated 22 April 1943, provided for satisfactory functioning of production combat airplanes and cargo airplanes, C-60 class or larger, between the temperature range of —65°F to +160°F, so that such airplanes can be used in any or all theaters of operation with a minimum of penalty.

c. Current cold weather tests and development are conducted under authority of TI-2000, dated 8 November 1944, subject Winterization of Aircraft, and ATSC Regulation dated 18 December 1944, subject Extreme Temperature Program. TI-2000 provides that Engineering Division will conduct tests and continue prompt action to accomplish engineering necessary to remedy current and anticipated deficiencies and assure that all AAF aircraft and equipment will function satisfactorily in all climates. Regulation 6-1 defines the requirements and functions of the various elements of ATSC with regard to the Extreme Temperature Program.

3. *Organization in ATSC for Cold Weather Development and Testing*

a. The coordinating office for all cold weather development and testing in ATSC is the Climatic Requirements Office, Service Engineering Branch, Engineering Standards Section, Service Engineering Subdivision, Engineering Division. Climatic Requirements Office is responsible for planning, organizing, and supervising test programs for Engineering Division at cold weather test bases, evaluating and consolidating test results, aiding and following up the Engineering Division Laboratories to insure solutions to reported and anticipated deficiencies, after proper coordination establishing the aircraft and equipment requirements for cold weather operation, and informing Procurement Division and industry the requirements and action to be accomplished.

b The procuring of test airplanes, instrumentation and installing of test equipment therein, and organization and supervision of actual testing, is the responsibility of the Extreme Temperature Requirements Unit of the Climatic Requirements Office.

c. Each Laboratory of Engineering Division has an office or officer that is responsible for winterization within that Laboratory. This office works closely with the Climatic Requirements Office.

4. *Relation of ATSC to Cold Weather Testing Detachment of Proving Ground Command*

a. The Air Technical Service Command is charged with development, procurement, inspection, supply and maintenance of all AAF aircraft and related equipment.

b. The Proving Ground is responsible for conducting proof and service tests, and special studies and investigations of AAF aircraft and equipment, to determine its operational, functional and tactical suitability.

c. The Cold Weather Testing Detachment originally established and built Ladd Field for cold weather test purposes. However, with the establishment of the Alsib ferry route Ladd was taken over by the Alaskan Division, Air Transport Command. Certain base facilities were retained by Cold Weather Testing Detachment and these have been constantly enlarged so that in spite of the great volume of ATC and Alsib traffic the facilities were entirely adequate for ATSC and Cold Weather Testing Detachment tests during the past winter.

d. Cold Weather Testing Detachment furnished to ATSC hangar space, office space and equipment, complete shop service, office help, enlisted maintenance and flight crews, workshop space, spare parts, airplane servicing, quarters, messing, weather information, photographic service, extra pilots when needed, transportation, shipping and receiving, and other operation and housekeeping services.

5. *Instrumentation of Aircraft for* 1944-1945 *Tests*

a. Instrumentation and test equipment was installed in the test airplanes at Dayton Army Air Base, Vandalia, Ohio, during the period 15 July to 15 November 1944. All work was under supervision of ETOU and was performed by civilian mechanics under contract from Commonwealth Aircraft, Inc., Kansas City, Kansas. The installations were made at the direction and with the help of project engineers in the various Laboratories.

6. *Miscellaneous Administrative Details*

a. Climatic Requirements Office issued invitations to manufacturers of aircraft and equipment to send technical representatives to the tests. The names of the manufacturers invited were suggested by Laboratory engineers and Cold Weather Testing Detachment. Winter clothing and transportation of technical representatives to Ladd Field were provided by Cold Weather Testing Detachment.

b. Climatic Requirements Office requested overseas travel orders and made arrangements for winter flying clothing for all ATSC personnel.

7. *Organization and Operation of ETOU at Ladd Field*

a. The ETOU organization at Ladd Field consisted of:

(1) Chief. In charge of all planning, organization and operations.

(2) Executive Officer. Acted as assistant chief, planned and administered the over-all test program, formulated policies, conferred with the Commanding Officer, Ladd Field, and Commanding Officer, CWTD.

(3) Administrative Officer. Acted as supply, personnel and transportation officer, supervised the ETOU office, signed correspondence, took care of routine administrative details.

(4) Operations Officer. Scheduled all test flights, supervised pilots and flight crews, signed clearances, insure compliance with safe flying practices.

(5) Engineering Officer. In charge of all maintenance, repairs, and test installations. Supervised all maintenance personnel. In conjunction with CWTD engineering officer schedule ATSC airplanes and work in hangars and shops.

(6) Project Officer for each test airplane. Each acted as project engineer and pilot for his own airplane. Insured that all tests requested by Laboratory engineers were performed. Responsible for the servicing and maintenance of their airplanes. Wrote progress and final reports on the tests and operation of their respective airplanes.

(7) Laboratory project engineers. Each Laboratory furnished engineers and officers to conduct tests on equipment and instrumentation they had previously installed at Vandalia. Tests were scheduled with the operations officer and airplane project officers.

(8) Technical Inspector. Master sergeant with several years experience as aircraft mechanic and foreman in Engineering Division Shops. Also acted as trouble shooter and assistant to engineering officer.

(9) Maintenance and Flight Crews. Cold Weather Testing Detachment furnished approximately 70 enlisted men to act as flight crews and line crews. In general two men were assigned to each fighter, four men to each medium bomber, five men to each medium heavy bomber, and seven men to each heavy bomber. Each crew was expected to perform all normal maintenance on their respective airplanes. For major repair jobs men were borrowed from other airplanes.

(10) Office force. Cold Weather Testing Detachment furnished one stenographer and two typists for the duration, and other typists as required. These girls were employed in preparing progress and final reports for all ATSC personnel. Cold Weather Testing Detachment furnished one enlisted engineering clerk to keep airplane forms, personnel records, etc.

(11) Other personnel. Cold Weather Testing Detachment furnished bombardiers and co-pilots when necessary. ETOU furnished one navigator, two radio operators, one B-29 crew chief, and one draftsman.

b. A test schedule was set up for each airplane at the beginning of the test period. Each evening a flight and test schedule was posted for the following day.

c. Each airplane project officer maintained a daily log of tests conducted, test results, malfunctions and other pertinent data.

d. Each airplane crew chief maintained a special Form 41-B which contained special columns of information desired by project engineers.

e. Each Laboratory project engineer was required to submit a final report on each of his projects before leaving Ladd Field.

f. Each airplane project engineer submitted a progress report on his airplane on the first of each month and a final report at the end of the test period.

8. *Discussion of Recommendations for Continued Development*

a. CARBURETOR AIR HEAT—Tests during the last two winters have established the fact that carburetor air heat is necessary for smooth engine operation when outside air temperatures are below approximately 0°F. Some engines would not run on the ground without carburetor heat at temperatures below —35°F. Low carburetor air temperatures resulted in torching, smoking and engine roughness. The P-38 was the only turbosupercharged airplane that had an adequate production type carburetor heat installation for operation on the ground and at low altitudes and low powers. It was shown that proper use of carburetor heat resulted in marked fuel economy and greatly improved the ability of the engine to change from cruise to emergency power without faltering. Future investigations should determine the carburetor air heat requirements for all ground and flight operating conditions and determine the most effective installation for different airplane types.

b. OIL SYSTEMS AND OIL TANKS—Additional development is necessary to provide oil systems that will be entirely satisfactory with respect to oil dilution, deaeration, and scavenging characteristics. Some oil tank hopper designs do not provide sufficient segregation of diluted and undiluted oil, while others allow the hopper to become depleted when the oil in the tank surrounding the hopper is congealed, thus starving the engine. All oil systems were fairly satisfactory down to —45°F, but trouble can be expected with some airplanes if lower temperatures are encountered. This is primarily a problem of general improvement and standardization of oil system design.

c. SCAVENGING OF DILUTED OIL IN LIQUID COOLED ENGINES—All airplanes equipped with liquid cooled engines were prone to spew and throw out of the breather highly diluted oil at takeoff power. The P-51 would not handle over 12% dilution, the P-38 not over 15% to 20%, and the P-63 was able to handle high dilution only because it had an oil and air separator which caught the spewed oil and turned it back into the system. This problem has been somewhat minimized by development of a synthetic engine oil that does not require as much dilution as regular oil. This problem will increase in gravity as temperatures go down and oil dilution is increased.

d. FEATHERING OF HYDRAULIC PROPELLERS—Hydromatic propellers consistently fail to feather at low outside temperatures due to congealing of engine oil in the propeller dome. Extensive tests were conducted during the winter using separate systems containing hydraulic fluid for feathering. These systems proved more satisfactory than normal systems but added weight and equipment. Synthetic engine oil met with a lower pour point than regular oil greatly improved feathering. Provision for better circulation of oil in the feathering system is a desirable improvement. This problem is still deficient at extremely low temperatures.

e. CABIN AND COCKPIT HEAT AND VENTILATION—Many of the airplanes were deficient in adequate distribution of heat and fresh air at crew stations. Seldom is heat available on the ground. Most combustion heater systems fail to function at high altitudes. This problem has encountered difficulty in solution because it adds weight to the airplane and most airplanes are operating where heat requirements are not critical.

f. DEICING AND DEFROSTING OF TRANSPARENT AREAS—No airplane had adequate deicing and defrosting on the ground. Very few were adequate in flight. This problem ties in with that of cabin and cockpit heat.

g. LOW TEMPERATURE OILS AND GREASES.—This is a continuing problem of developing improved oils and greases that will have a minimum of torque at low temperatures and will not evaporate, run out, or deteriorate in hot or damp climates. This problem is not critical, inasmuch as satisfactory lubricants have been developed for most applications, and improvement is continuing.

h. AIRPLANE SURFACE CONTROL SYSTEMS—Several instances of surface controls getting stiff or freezing at low temperatures were encountered during the winter, mainly due to differential contraction of the air frame and the control components. Trouble was encountered with control cable tension. This is a general design problem which should be investigated thoroughly.

i. INCLOSURE SEALS AND WEATHERSTRIPPING—On several airplanes seals became brittle and cracked or broke. On some airplanes great difficulty was encountered in closing and opening doors and canopies due to loss of resilience in the seals. It is believed that satisfactory compounds are available and extra effort should be exerted to install suitable seals whenever required.

j. STARTING OF AIRCRAFT ENGINES IN LOW TEMPERATURES—It can be definitely stated that cold starting with standard aviation gasoline below about 0°F to—10°F is not practical nor possible with any degree of consistency. However tests have indicated that by development of satisfactory priming systems engines can be started with standard gasoline at much lower temperatures than at present. Experiments have also indicated that cold starts can be made down to —65°F by use of special priming fluids, but a final solution which would be practical and applicable to service airplanes has not yet been arrived at. Quick starting of fighter aircraft without recourse to an hour or more application of heat is very important. In addition to cold starting investigations, development should continue on means of heating the engine with circulating hot oil and coolant, which means would be much faster than the hot air heating now used.

9. *Travel Orders*

Authority should be obtained whereby ATSC personnel participating in tests in Alaska can obtain travel orders at Wright Field instead of from Washington, D.C. During the past winter it was necessary to request orders approximately one month in advance to assure receiving them on time. Due to the great time lapse other intervening circumstances often made it impossible for personnel to leave when expected and as a result the orders required amendment which required another three to four weeks. After arriving at the test base it was often necessary for personnel to return to the states for a few days to make additional installations in airplanes or take care of other duties, in which case it was necessary to request new orders, as before. Due to the short season during which weather conditions are satisfactory for testing, time is of the greatest importance. As a result the test program was seriously hampered and quite often personnel traveled without proper authorization in order to complete their mission.

Table I

COMPARATIVE NUMBER OF COLD DAYS AT FAIRBANKS AND FORT YUKON, ALASKA

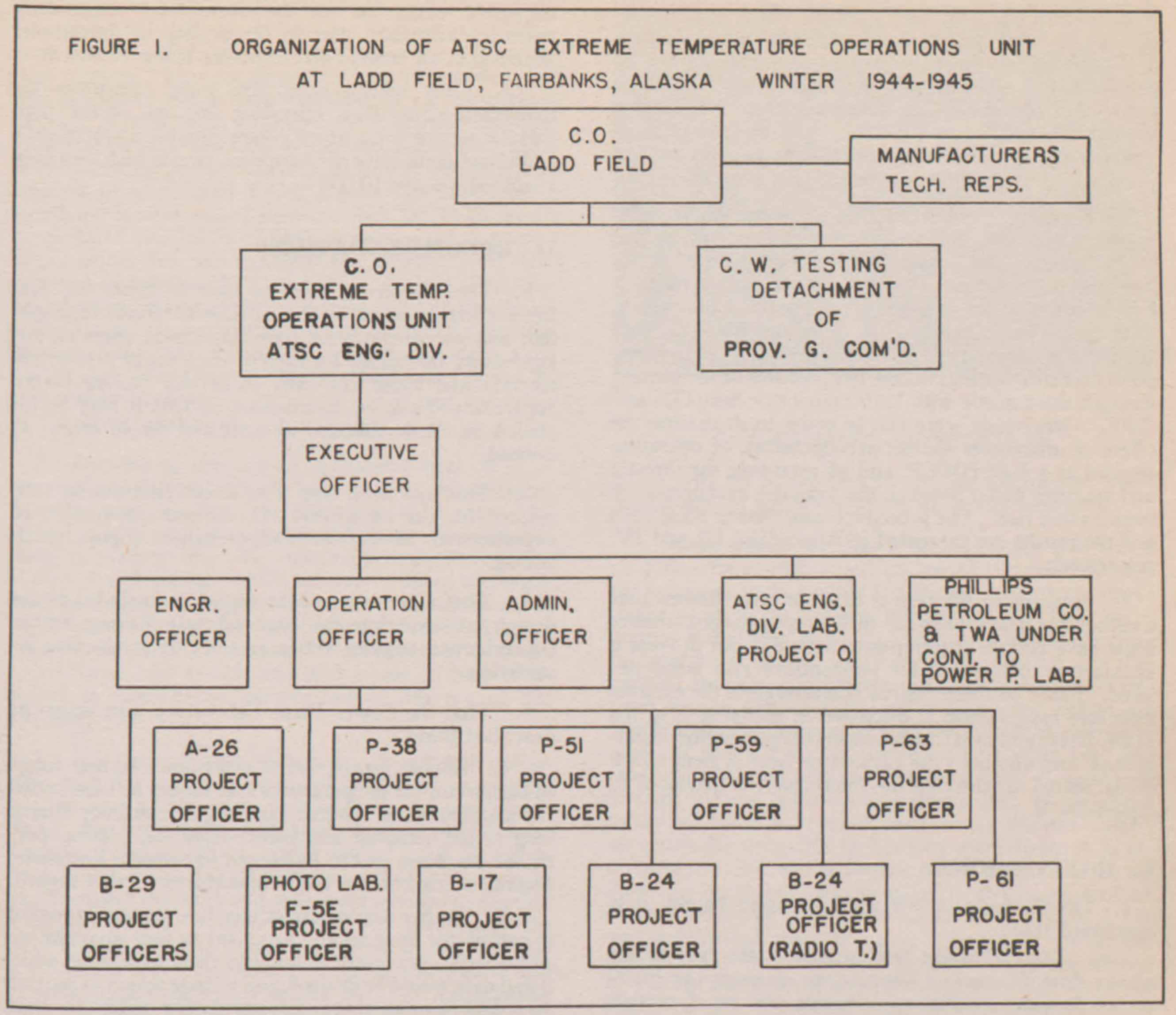
Winter	Number of Days Temperature Was						Yearly Minimum	
	—40°F or colder		—50°F or colder		—60°F or colder			
	Fairbanks	Fort Yukon	Fairbanks	Fort Yukon	Fairbanks	Fort Yukon	Fairbanks	Fort Yukon
1930-31	0	9	0	0	0	0	—37	—46
1931-32	27	41	15	18	0	0	—54	—57
1932-33	25	44	3	28	1	3	—60	—67
1933-34	35		21		5		—66	—68
1934-35	4		0		0		—42	
1935-36	22	53	11	29	0	16	—59	—71
1936-37	7	30	1	17	0	4	—50	—65
1937-38	16	39	1	14	0	1	—50	—64
1938-39	6	19	1	8	0	2	—51	—60
1939-40	1	12	0	3	0	0	—42	—52
1940-41	1	19	0	8	0	3	—42	—65
1941-42	3	19	0	7	0	0	—44	—58
1942-43	24		3		0		—51	
1943-44	2		0		0		—45	
1944-45	3		0		0		—45	

COMPARATIVE TEMPERATURES AT FAIRBANKS AND FORT YUKON, ALASKA

Month	Monthly Mean		Monthly Mean Minimum	
	Fairbanks 37 yrs.	Fort Yukon 24 yrs.	Fairbanks 11 yrs.	Fort Yukon 20 yrs.
November	3.4	— 5.5	— 4.2	—11.5
December	— 7.1	—20.3	—16.1	—28.3
January	—11.3	—20.8	—20.6	—27.4
February	— 1.2	—15.6	—17.3	—26.1
March	9.6	0.3	— 6.2	—12.2

AVERAGE MONTHLY NUMBER OF CLEAR DAYS

Month	Fairbanks	Fort Yukon
November	8.4	11.7
December	10.3	13.9
January	11.2	14.1
February	9.7	14.1
March	11.2	15.8



Carburetor Heat for Turbo-Supercharged Engines

Prepared by E. C. Theiss

A. PURPOSE

1. To report on the tests of the accessory section type carburetor heat system installed on the B-24J Serial No. 44-41378 and the exhaust manifold type system installed on the B-17G Serial No. 43-38221 during the cold weather test program 1944-45 at Ladd Field, Fairbanks, Alaska, which were run in order to gather data for the development of carburetor heat systems for turbo-supercharged engine installations and to make a general study of the problem.

B. FACTUAL DATA

1. Carburetor heat for turbo-supercharged aircraft engines has been considered unnecessary in some quarters. It was contended that ice would not form because of heat of compression of the turbos and high pressure carburetors. This has since been proven otherwise and it has also been found that carburetor heat is necessary for aiding fuel vaporization and distribution at extreme low temperatures as well as for combating carburetor ice as is pointed out in Appendix I.

2. Two carburetor heat systems, one termed an accessory section type, which allowed flow of air from the accessory section through the inter-cooler, was installed on a B-24J and the other which ducted hot air from a shroud around the exhaust manifold to the induction system was installed on a B-17G. A description of these systems and thermocouple installations is given in Appendix II.

3. Tests were run on each of these systems in order to determine their performance at various power settings and altitudes. The exhaust manifold system was somewhat instrumented in order to be able to make a comprehensive study of the various arrangements of the system, to obtain an indication of heat losses and gains through the induction system, and the effect of high and low power throttle settings on the temperature of air passing through the throttle with both carburetor heat ON and OFF. Other tests were run in order to determine the effect of intercooler shutter arrangements, of operating engines at a high BMEP, and of retarding the throttle and applying turbo boost on the available carburetor air temperature rise. The procedure used during these tests and the results are presented in Appendices III and IV, respectively.

4. Analysis of the results of these tests showed that a carburetor heat system for turbo-supercharged engines must have certain requirements before it can provide a satisfactory carburetor air temperature rise when desired. Based on these desired characteristics the exhaust manifold type system is discussed in applying it to the B-24, B-17, and other turbo-supercharged engine installations, and another type carburetor heat system which ducts heated air through the intercooler, is proposed in Appendix V.

C. CONCLUSIONS

1. On the basis of the tests discussed herein, it is concluded that:

a. The carburetor heat system of the type which allows flow of accessory section air through the intercooler provides neither an adequate nor rapid enough carburetor air temperature rise and since the available rise is adversely affected by decrease in outside air temperature, it is not satisfactory.

b. A carburetor heat system which ducts heated air from the exhaust manifold will, if heat losses are held to a minimum, provide an adequate and rapid carburetor air temperature rise.

c. The general method for obtaining a carburetor air temperature rise on both the B-17 and B-24 type aircraft, namely by closing intercooler shutters, is insufficient at all power settings and altitudes at which the tests were run.

d. With an effective means of closing off intercooler air, such as entrance shutters, use of air filters may provide an additional carburetor air temperature rise tending to double that available from the heat of compression of the turbos.

e. The exit type intercooler shutters are completely ineffective for closing off intercooler air.

f. The entrance intercooler shutters of the single gate type approach the effectiveness of a completely sealed off intercooler and must be used in conjunction with a carburetor heat system to prevent critical loss of the available heat supply.

g. Operating engines at a high BMEP and/or by retarding the throttle and applying turbo boost has a negligible effect on the carburetor air temperature normally available, that is by closing of intercooler shutters, at all powers and altitudes below 15,000 ft.

h. Only with a substantial inital carburetor air temperature rise does operating engines at the high BMEP setting for a given power provide a worthwhile additional carburetor air temperature rise and then only at altitudes above 10,000 ft.

D. RECOMMENDATIONS

1. That action be taken to have a carburetor heat kit, preferably based on the exhaust manifold type system and use of entrance type intercooler shutters, designed and fabricated for each of the present production aircraft and those currently in service having turbo-supercharged engine installations so that it may be installed on all northbound aircraft and on all others as desired.

2. That entrance type intercooler shutters be considered for use on all aircraft, whether production or experimental, having turbo-supercharged engine installations.

3. That a carburetor heat system be included in the design of experimental type aircraft having turbo-supercharged engines either as a kit or production installation.

4. That the Power Plant Laboratory take action as described below:

a. Initiate a program to determine the best range of carburetor air temperatures that should be maintained for maximum fuel economy and engine efficiency during long range bombing and escort missions, placing particular emphasis on the B-29, and to consider automatic control of carburetor air temperatures in this regard.

b. Gather data on carburetor heat as used in regard to carburetor de-icing and as an aid to fuel vaporization and distribution, make a study to determine what additional data would be desired, and initiate action to acquire such data in order that requirements for carburetor heat may be more accurately and completely set up than they are at the present time.

c. Prepare a specification covering carburetor heat systems for turbo-supercharged aircraft engine installations as soon as sufficient data is available.

BACKGROUND

1. Development work on carburetor heat for turbo-supercharged engines has been neglected because it was thought unnecessary. It was believed that the induction system of such engines could not ice because of high pressure carburetors and heat of compression of the turbos. It was found that icing was possible and that the heat rise available from compression by the turbo was not sufficient to prevent or eliminate carburetor ice. Consequently such aircraft as the B-17, B-24, B-29, and B-32's were not provided with a carburetor heat system. Within the last two years, however, experience and tests have shown that combating of carburetor ice was not the only need for carburetor heat. It has been proven a necessity as an aid to fuel vaporization and distribution at extremely low outside air temperatures for all conditions of flight but especially during take-off and landing. Liquid cooled engines because of their inherently poorer distribution characteristics have been

much more critical in this regard One notable example was that of the P-38 which could not be flown at temperatures below —35°C since engines could not be started and kept running. Hence a carburetor heat kit was designed and fabricated and is now installed on all northbound aircraft of this type. Because of the improved fuel vaporization and distribution that carburetor heat made possible, fuel economy was also improved. During cold weather tests at Ladd Field, Alaska this past winter, simulated bomber escort missions with the P-38, which necessitated long hours of flight at relatively low power, use of carburetor heat to maintain a carburetor air temperature of between 20°C and 30°C, showed that fouling of plugs was prevented and full power was available at the target without cutting out of engines as was the case when the same mission was performed without the use of carburetor heat. Also a substantial savings of fuel was realized which appreciably increased the range of the escort fighter.

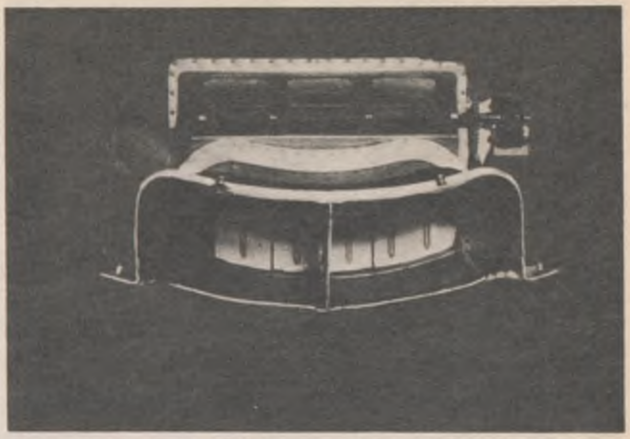
2. Because of the lack of carburetor heat on B-24 type aircraft difficulties have been recently encountered. Bombing missions from the Aleutians to Japanese controlled islands and on Japanese shipping have experienced carburetor icing which made it necessary to operate at high power settings which severely reduced the available fuel supply. Induction system icing encountered by liberators being ferried over the North Atlantic route by the RAF became so serious that they designed a carburetor heat system and took action to have it installed at modification centers before delivery of the airplane.

3. It is believed that the benefits gained with carburetor heat not only as a means of combating carburetor ice, but also as an aid to fuel vaporization and distribution for low temperature operation are sufficient to warrant increased effort in the development of carburetor heat systems for all type aircraft. The following pages present the work and tests accomplished to develop a carburetor heat system suitable for specifically the B-17 and B-24 type aircraft and generally for any aircraft with a turbo-supercharged engine installation and to accumulate data which will be useful in establishing more complete requirements for carburetor heat.

Description of Carburetor Heat Installations

A. ACCESSORY SECTION TYPE SYSTEM

1. This type carburetor heat system was installed on the No. 2 engine of Air Technical Service Command cold weather test airplane B-24J Serial No. 44-41378. The duct ahead of the intercooler on the No. 2 engine was reworked and was provided with two sets of gates one located at the front end of the duct, Figure 1, and the other on the accessory section side of the duct, Figure 2, so that with heat ON the intercooler intake air would be cut off ahead of the intercooler and warm air from the accessory section would be allowed to flow through the intercooler. The gates were operated by an electric motor through gear segments. The intercooler shutters on this engine were disconnected from the drive motor and safetied open, and the wiring was rerouted and connected to the motor which drove the carburetor heat gates. In order to allow control of the carburetor heat gates a momentary contact type switch was installed



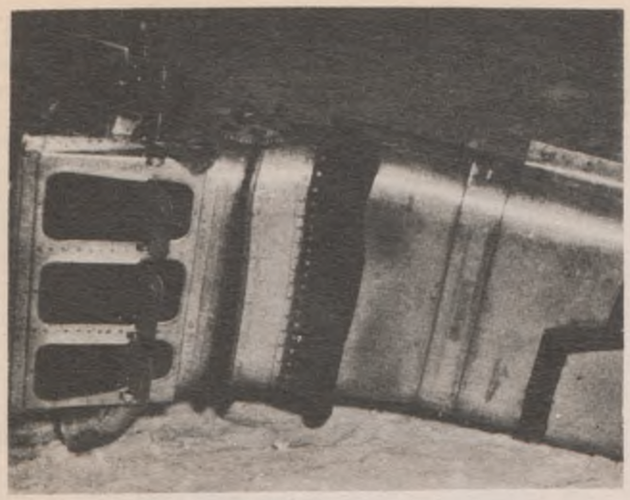
B-24 Intercooler Duct—Front Gate

in place of the intercooler shutter switch for the No. 2 engine and an applicable name plate was provided.

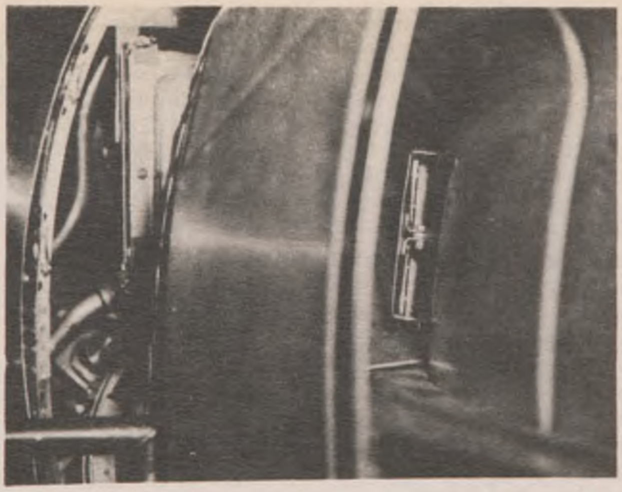
2. This system was based on the theory that warm air from the accessory section would circulate through the accessory section gates and thence through the intercooler when carburetor heat was turned ON, thus utilizing the intercooler as an interwarmer without affecting carburetor air in any way except for heating. It was realized that the effectiveness of this system would depend on the temperature of the accessory section air which in turn varies directly with the outside air temperature. It was not known, however, just what heat rise could be obtained and just how critically it would be affected by low outside air temperatures. In an effort to control the flow of warm air through the intercooler, an adjustable scoop 5¼ inches long controllable in ⅛ increments from 0 to 1¾ inches, which could be actuated from the bomb bay, was installed in the inside wall of the carburetor air intake duct as shown in Figure 3. It was anticipated that the scoop opening at which the greatest heat rise could be obtained at any power setting and altitude could thus be determined since a compromise had to be made between the amount of pressurization of the accessory section and the quantity of cooling air which would enter the accessory section through the pressurizing scoop.

B. EXHAUST MANIFOLD TYPE SYSTEM

1. An exhaust manifold type carburetor heat system was installed on the No. 1 engine of Air Technical Service Command cold weather test airplane B-17G Serial No. 43-38221. It consisted of a stainless steel shroud around the exhaust manifold, Figure 4, from which hot air was ducted from the right rear side of the upper shroud to the induction system below the air filter by means of a 4¼ inch I.D. flexible aluminum tubing wrapped with strip asbestos as shown in Figure 5. Since the hot air duct was tapped into the induction system ahead of the air filter valve as shown in Figure 6, turning the air filter ON on this engine allowed flow of hot air instead of filtered air. A gate was provided at the rear of the shroud to minimize as much as possible the loss of heat and hot air from the carburetor heat shroud. This gate was actuated through a pulley system from the air filter valve motor, as shown schematically in Figure 7, in such manner that it closed when carburetor heat was



B-24 Intercooler Duct—Accessory Section Gate



B-24 Accessory Section Pressurizing Scoop

put ON, and opened with carburetor heat OFF (see figure 4). A separate switch was provided so that carburetor heat could be selected on this engine without having to turn the air filter ON on each of the other engines. The filter light indicated whether carburetor heat was ON or OFF. The production intercooler shutters were considered an integral part of this carburetor heat system since they provided for selectivity of a carburetor air temperature with or without carburetor heat being ON. A separate switch was provided so that carburetor heat could be selected on this engine without having to turn the air filter ON on each of the other engines. The filter light indicated whether carburetor heat was ON or OFF. The production intercooler shutters were considered an integral part of this carburetor heat system since they provided for selectivity of a carburetor air temperature with or without carburetor heat being ON.

2. It was believed that the maximum heat rise with the system as installed could be improved if necessary by restricting the air flow through the filter and by increasing the temperature of the air from the shroud. In order to accomplish this, two air filter restrictor plates, one with a 4 inch diameter opening or orifice and another with a 2¾ inch orifice, were fabricated as shown in Figure 8 for installation below the air filter according to Figures 9 and 10, and a helical vaned shroud insert, Figure 11, which was designed to slow down the flow of air through the shroud and give it a whirling, turbulent, motion, thus increasing the area and time of exposure to the exhaust manifold, was fabricated for installation in the shroud.

C. THERMOCOUPLE INSTALLATIONS

1. In order that the effect of the various combinations of air filter restrictor plates with the plain and helical vaned shrouds on the temperatures of the air flowing through the induction system might be determined and to provide a temperature survey of the induction system with carburetor heat ON or OFF, iron-constantan thermocouples were installed at the locations shown in Figure 12 and as described below:

Selector Switch Point No.	*Location*
B-14	Left rear side of carburetor adapter below carburetor throttle and above plane of fuel injection. The thermocouple was exposed to the jet effect of the throttle at low powers.
B-15	Inlet side of supercharger about 5⅞ inches above supercharger deck as shown in Figure 13.
B-16	Hot air duct just prior to entering elbow below the air filter as shown in Figure 5.
B-17	In elbow below air filter as shown in Figure 5.

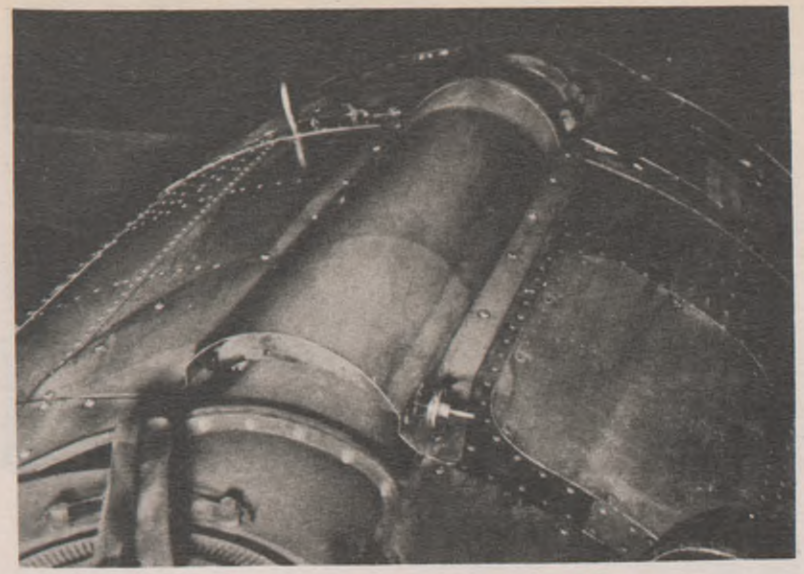
These thermocouples were connected to the B selector switch mounted on a table on the right side of the radio compartment.

Carburetor Heat Test Results

A. ACCESSORY SECTION TYPE SYSTEM

1. The results of the test on this carburetor heat system with the accessory section pressurizing scoop closed are shown in Figure 1 which was plotted from Table I, Appendix III. These results showed that the heat rise available by closing the intercooler shutters was negligible for all powers below normal rated and altitudes below 10,000 ft. The maximum heat rise available was 13°C at 1100 hp and 15,000 ft. which is more than twice the next greatest heat rise which was 6°C at 1100 hp at 5000 and 10,000 ft. The carburetor air temperature rises available from the experimental carburetor heat system on the No. 2 engine were appreciably better than that available merely by closing the exit shutters on the No. 1 engine. The maximum heat rise available with this test system was 40°C at 1100 hp and 15,000 ft. altitude. At a normal cruise condition 600 hp at 2000 ft. altitude a carburetor heat rise of 11°C was available. This condition may be considered comparable to the 65% of normal rated power setting at which a 50°C heat rise was desired at sea level. According to this, carburetor heat requirements were met only 22% which was not considered sufficient. The heat rise available during ground warm-up and during the traffic pattern and final approach for landing was negligible.

2. The effect of carburetor air filters on the maximum carburetor air temperature for both production and test methods of obtaining carburetor heat tests is also shown in Figure 1. It is indicated that the additional heat rise provided by turning the carburetor air filters ON on the production engine was negligible at all powers and alti-

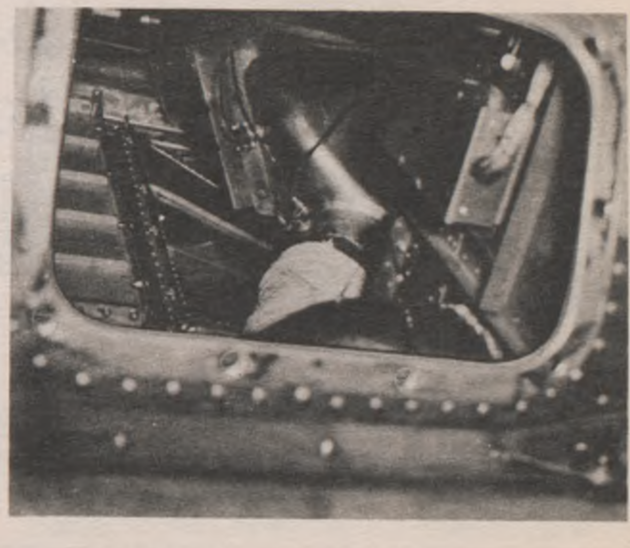


B-17 Exhaust Manifold Shroud

tudes. The use of the carburetor air filter in conjunction with the carburetor heat system on the test engine gave a greater heat rise, at least double that available for the production engine. During the final approach it was shown that no heat rise could be obtained by closing the intercooler shutters on the production engine or by turning carburetor heat ON on the test engine, while putting filters ON had no effect on the heat rise on the production engine, an 8°C carburetor air temperature rise was available on the test engine. The peculiarity of the air filter providing a greater heat rise on the No. 2 engine than on the No. 1 engine was attributed to the fact that a greater portion of the filter was covered by the nacelle on the No. 2 engine. A check of other data, however, indicated that the filters gave the greatest additional heat rise wherever the initial heat rise, whether due to a blocked off intercooler or the carburetor heat system, was the greater. Since the air filters were turned ON only after the carburetor air temperature with Heat On, regardless of the hot air source, had stabilized, the behavior of the air filter may be explained by the fact that the air being drawn through the filter lost less of its heat on the engine with the greatest original heat rise.

3. The test on the accessory section carburetor heat system wherein the pressurizing scoop was actuated revealed that opening of this scoop failed to increase the carburetor air temperature over that available with the pressurizing scoop closed. In fact allowing the scoop to remain open with carburetor heat ON tended to cause a slight decrease in the carburetor air temperature. The results of this test were plotted in Figure 2 from Table II, Appendix III.

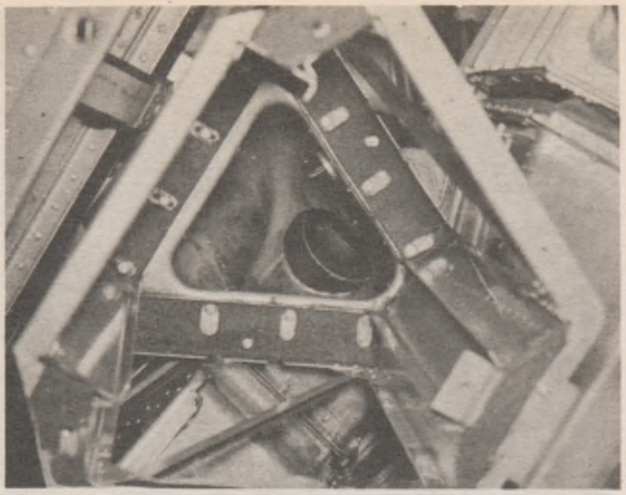
4. Since it was expected that most of the heat rise obtained by means of this accessory section type carbu retor heat system was obtained from the entrance shutters the carburetor air temperature rises for corresponding power setting were picked from Figure 1 and Figure 2 of this Appendix, which are results of the tests on the carburetor heat system and entrance shutters, respectively, and were plotted in Figure 3. Analysis of this chart showed there was some carburetor air temperature rise added to that available from the entrance type intercooler shutter which might be attributed to flow of warm air from the accessory section through the intercooler. The data available was not sufficient to make any definite conclusions. However, the carburetor air temperature rise attributable to flow of air from the accessory section apparently only became appreciable at the high power settings. This might be because only then was there a great enough reduction in pressure on the exit side of the intercooler to draw air from the accessory section. Even so the added heat rise below 10,000 ft. was slight, being a maximum of 6°C. At 1100 hp and 15,000 ft. an additional heat rise of 27°C was obtained but this cannot be accepted as correct because the heat rise using the entrance shutter was too low for the altitude and power setting at which the test was run. This was probably due to the fact that 8 in-hg less turbo-boost was used on the test run with the entrance shutter than that on the carburetor heat system. If the carburetor air temperature rise for the entrance shutter were correct that available from flow of accessory section air through the intercooler would probably not exceed 10°C.



B-17 Carburetor Heat System Ducting

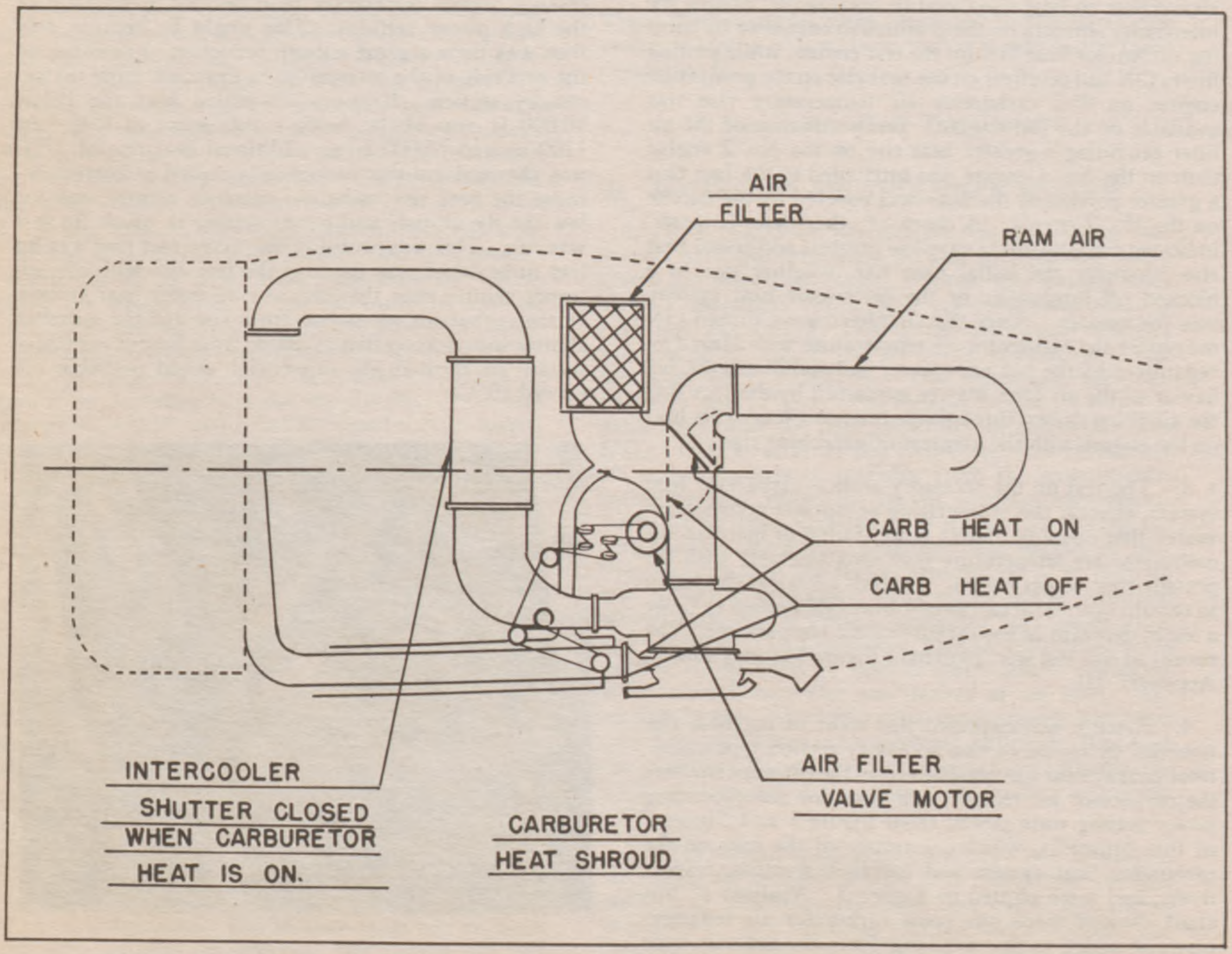
B. EXHAUST MANIFOLD TYPE SYSTEM

1. The results of the various carburetor heat tests on the No. 1 engine of the B-17G were plotted in Figures 4, 5, and 6 from Tables III to IX inclusive. The carburetor air temperature rise due to both the intercooler shutters and the filters shown in Figure 6 for engine No. 4 were averages of this data for all tests and has been included so as to provide a basis of comparison for the carburetor air temperature rises for the various arrangements of the exhaust manifold system on engine No. 1. As might be expected the greatest carburetor heat rises were available at the high power settings for both the experimental and production engines at all altitudes. The arrangement of the carburetor heat system which gave the greatest heat rise was that having the plain shroud and the No. 2 restrictor plate below the air filter. This arrangement caused a maximum drop in manifold pressure of 4 in-hg for 1000 hp at 10,000 ft. and 15,000 ft., and 600 hp at 15,000 ft. The corresponding drops in manifold pressure caused by turning on the air filters on engine No. 4 were 3 in-hg, 3 in-hg, and 2 in-hg. The manifold pressures were brought up to the original settings as described in paragraph 5, Section C of Appendix III. The operation of the carburetor heat system using the No. 2 (2¾″ diam. orifice) air filter restrictor plate and the plain shroud cannot be considered completely satisfactory, although it gave the greatest heat rise, since restriction of air flow was too great to allow normal operation. This arrangement,

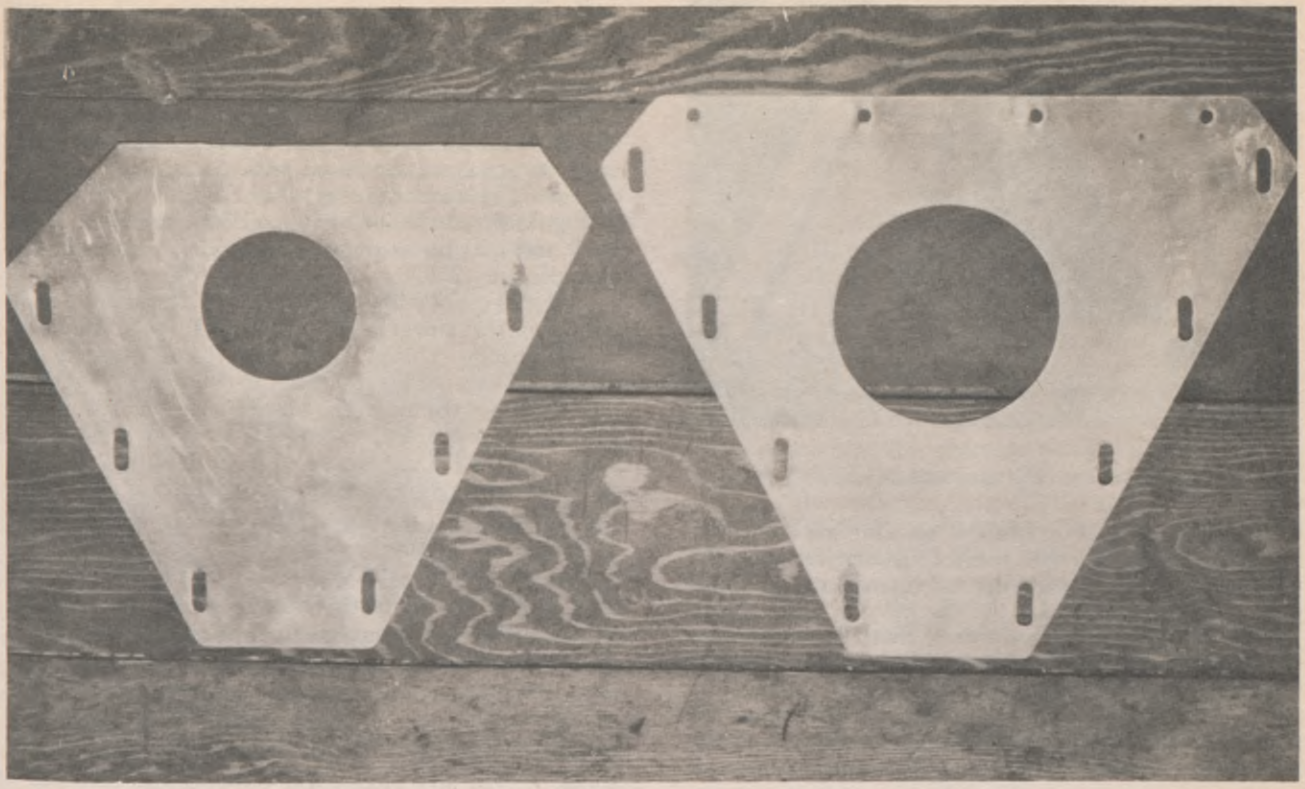


B-17 Filtered and Hot Air Intake

however, came to 60% of meeting the carburetor heat requirement of having a carburetor air temperature rise of 50°C at 65% of normal rated power at sea level. The production engine installation met this requirement by 6% when both intercooler shutter was closed and the air filter was ON. The data for the 600 hp test at 2000 ft.



Schematic Diagram of Shroud Gate Pulley Control System

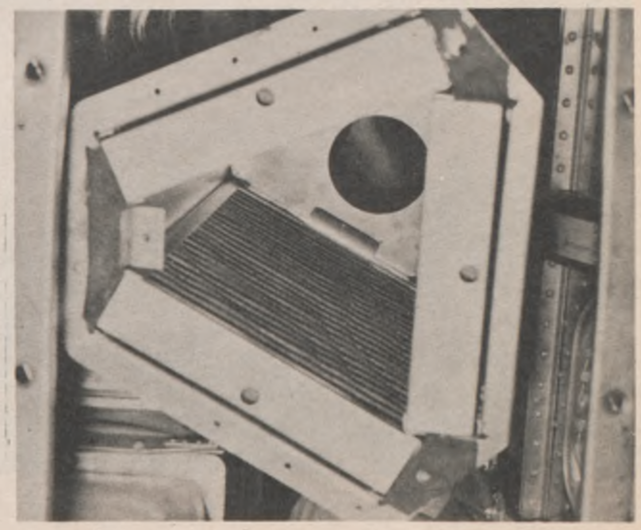


B-17 Air Filter Restrictor Plates

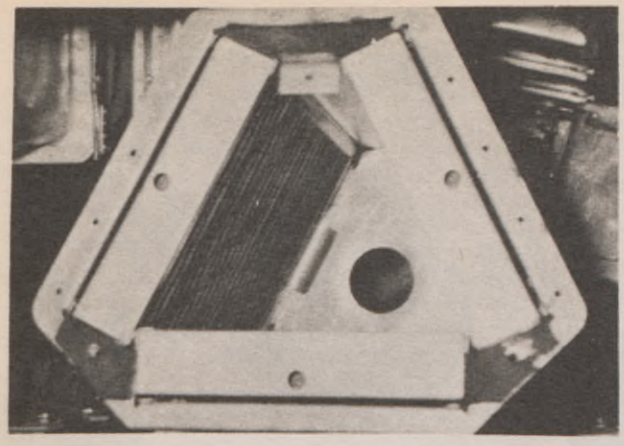
which was sufficiently close to the 65% of normal rated power and sea level requirement to allow comparison was used in establishing the percent conformance with requirements, referred to above. At altitudes of 10,000 ft. and above the heat rise available with this system was considered sufficient. During the traffic pattern and final approach carburetor air temperature rises of 30°C and 34°C, respectively, were available with this arrangement of the carburetor heat system while only 3°C and 7°C were available from the production engine. These heat rises are considered sufficient to prevent engines from cutting out because of poor vaporization and distribution for these flight conditions but it is not known if it is sufficient to prevent or eliminate carburetor ice.

2. The next best arrangement of the exhaust manifold carburetor heat system on the B-17G which gave the maximum carburetor air temperature rise and at the same time allowed feeding of the engine with no greater pressure drop that that experienced by turning on the air filters on the production engine installation was that using the plain shroud and the No. 1 (4″ diam. orifice) air filter restrictor plate. At 600 hp and 2000 ft. a carburetor air temperature rise of 22°C was available which is only about 44% of that required as compared to the 3°C average heat rise on the production engine which comes to only 6% of meeting requirements described before. As shown in Figure 6 the heat rise available decreased with decrease in power and increased with increase in altitude as might be expected, however, the results of tests No. 1 and 2 plotted in Figures 4 and 5 indicated that at powers less than 600 hp the carburetor air temperature rise tended to increase. Sufficient data to verify this tendency are not available. The carburetor air temperature rise available during the traffic pattern and final approach were each 24°C which were 6°C and 10°C less than the arrangement using the No. 2 (2¾″ diam. orifice) air filter restrictor plate. These heat rises are not considered quite adequate for this condition of flight.

3. In an effort to determine the additional heat rise that would be available with perfect sealing intercooler shutters was the first test on the exhaust manifold type carburetor heat system re-run with the intercooler intake on engine No. 1 completely blocked off and the intercooler shutters closed. The results of this test shown in Figure 5, revealed that an additional heat rise averaging at least 9°C may be obtained at the low power setting to 15,000 ft. altitude and during the traffic pattern and final approach, while at the high power setting



Air Filter Restrictor Plate installed (4″ orifice)



Air Filter Restrictor Plate installed (2 3/4" orfice)

to 15,000 ft. altitude only about an additional 4°C heat rise could be realized with perfect sealing shutters. The production intercooler shutters were entrance type having a single gate pivoted at the vertical axis. The effectiveness of these shutters are more thoroughly discussed in Section C of this Appendix. This shutter should be investigated in order to improve sealing characteristics. Since it is a single gate type leakage possibilities should be relatively slight. Probably the modification that would be of greatest benefit would be the addition of another gate at the exit side of the intercooler to prevent circulation of nacelle air into the intercooler from the rear but here again the mechanical complication and weight addition might not warrant the additional carburetor heat rise that could be realized.

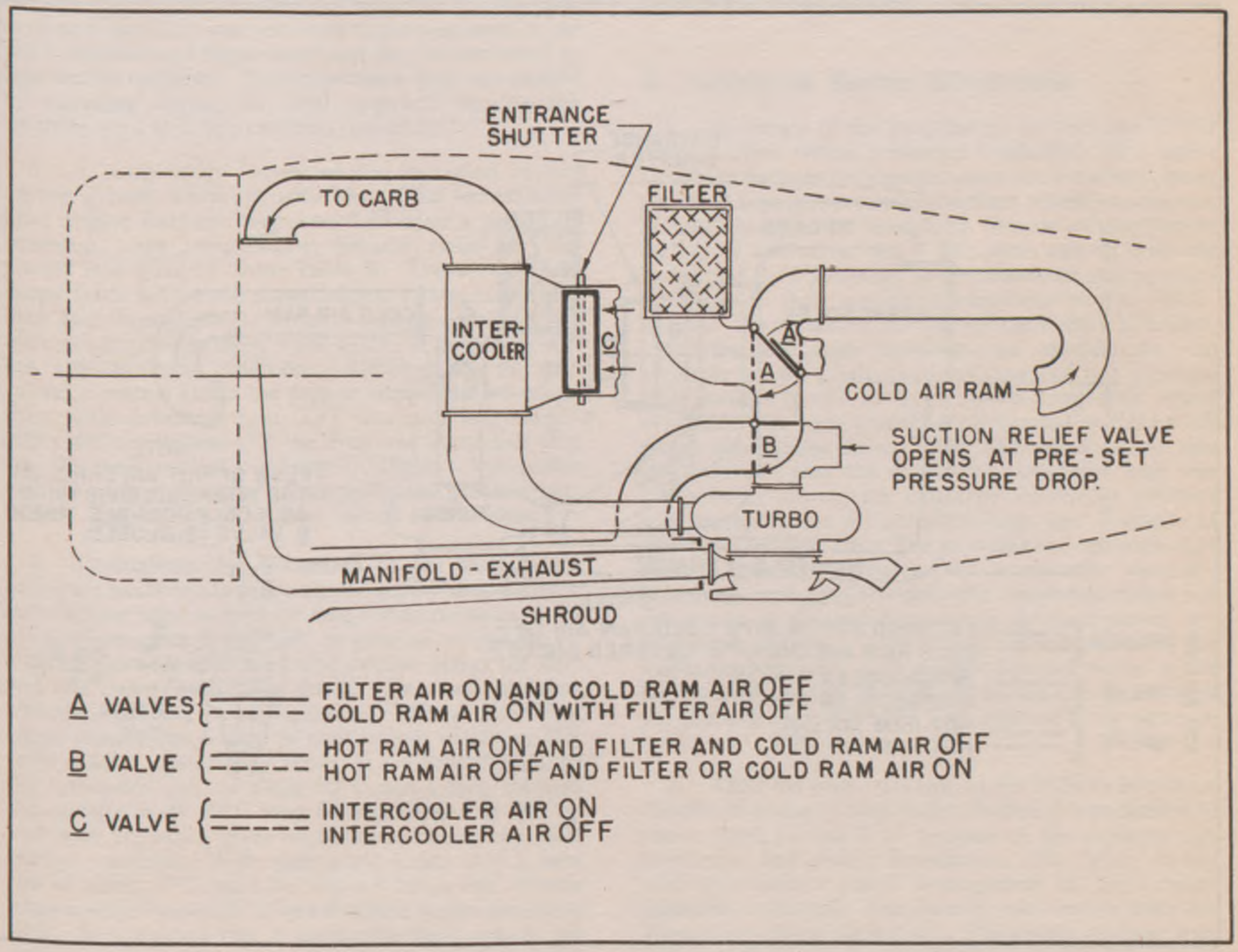
4. To further simplify this carburetor heat system it would be desirable to do away with the gate at the rear of the carburetor heat shroud. In order to determine how effective this gate was in adding to the available carburetor heat rise, test No. 6, wherein the helical vaned shroud insert was installed in the shroud and the air filter was left open, was repeated with the shroud gate removed. The comparative results of this test were plotted in Figure 6. At 2000 ft. 8°C and 5°C were lost at the 1000 and 600 hp settings respectively. At the higher altitudes only 2°C to a maximum of 6°C was lost with the latter at the 600 hp setting at 15,000 ft. There was an indication that the greatest loss of heat was at the lower power settings. This probably was because the suction of the engine was not great enough to completely overcome the velocity of the air in the shroud when the rear of the shroud was open and to pull all air from the shroud hence most of the air was taken from the filter. Closing of the shroud gate apparently increased ram effect thus allowing a greater portion of hot air than cold filtered air to be taken by the engine. The lower hot-filtered air mixture temperatures at thermocouple B-15 for Test No. 7 as compared to No. 6 from the temperature surveys, Figures 7 to 16 inclusive, substantiate this analysis. These results showed that the gate at the rear of the shroud was beneficial especially at the low power settings where the need and the difficulty of obtaining sufficient carburetor air temperature rise was critical. However, because of the added weight and mechanical complication involved a gate such as this was not warranted for the benefits derived. In order to cut this source of heat loss to an absolute minimum the space at the rear of the carburetor heat shroud should be blocked by a plate welded to the

Helical vaned exhaust shroud insert

shroud. This should not be completely closed off. Possibly a quarter of the area nearest the manifold should be left open to allow circulation of the air between the exhaust manifold and both upper and lower shrouds to prevent burning out of the exhaust manifold while the carburetor heat system is not being used. It was for this reason that the rear of the shroud on the test system was provided with a controllable gate which would close when carburetor heat was turned ON and open when heat was turned OFF.

5. The result of the tests which were run on the helical vaned shroud with varying combinations of the air filter restrictor plates in order to determine its effectiveness in increasing the temperature of the air from this source and consequently increasing the carburetor deck temperature rise were plotted in Figure 6 and temperature surveys for each of these tests are given in Figures 7 to 16 inclusive. Examination of these results show that the helical vaned shroud improved the performance of the carburetor heat system only slightly over that obtained with the plain shroud. The temperature of the air from the hot air duct using the helical vaned shroud was only 5°C to 8°C higher than that using the plain shroud and then only at the low power settings. At high powers the effect of the helical vanes was negligible. This was probably due to the fact that at low powers, because of the lower velocity, of the air flowing through the shroud, the helical vanes were more effective in inducing a whirling motion in the shroud, and hence increased the time of exposure to the exhaust manifold. Since the use of vanes offered greater restriction to air flow than the plain shroud a greater quantity of air was drawn from the filter to feed the engine, which resulted in a loss of most of the heat gained by means of the vanes. It is believed the weight addition due to use of helical vanes in the shroud is not warranted by the slight additional carburetor heat rise that would be available even in carburetor heat systems where the air from the hot source is not tempered with cold air. Use of a finned exhaust manifold which is worthy of investigation would be of much greater benefit.

6. During one of the ground tests which were run immediately after the engines were started and again just prior to takeoff it was noted that the carburetor air temperature tended to increase with warm-up time so a series of ground tests were performed for various shroud and air filter arrangements. The results of these tests were plotted in Figure 18 from Table X. Analysis of these results showed that the only substantial heat rise that could be obtained during ground warm-up was when the air was only taken from the exhaust manifold. This test showed that an 8°C rise was available 1 minute after heat was turned ON and a maximum of 25°C rise 14 minutes after heat was turned ON. A more rapid heat rise would be preferred which might be available from a system modified as suggested later in this Appendix. No

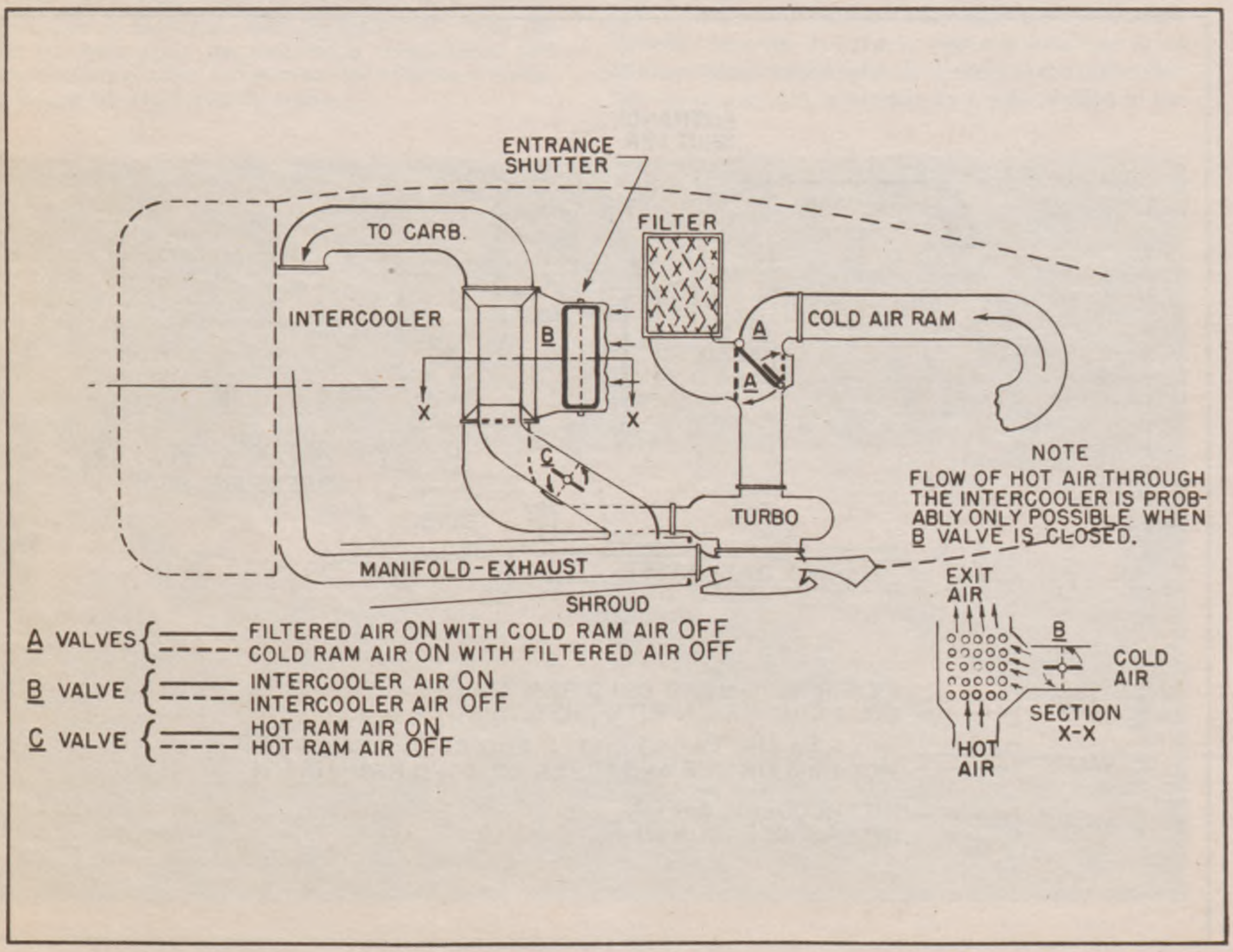


Schematic Diagram of Exhaust Manifold Type Carburetor Heat System heat rise was available from the production system which utilizes closing of the intercooler shutters and turning on of the air filters to obtain a carburetor deck temperature rise.

C. INDUCTION SYSTEM TEMPERATURE SURVEYS

1. The results of the induction system temperature surveys were plotted in Figures 7 to 16 from Tables III, and V to IX inclusive. With carburetor heat OFF and intercooler shutters open a temperature rise from before the turbo to the carburetor deck was experienced which varied from about 4°C at 2000 ft. for both the 1000 and 600 hp settings to 20°C and 10°C for these power settings respectively, at 15,000 ft. The heat rise at the intermediate altitudes tended to follow a hyperbolic curve. With carburetor heat ON and the intercooler shutters closed a maximum rise in temperature before the turbo of 45°C at 2000 ft. to 67°C at 15,000 ft. was experienced. However, the resultant of the heat gains and losses through the turbo, intercooler, and ducting for all tests on shroud and air filter arrangements showed a heat loss for both 600 and 1000 hp settings at 2000 ft. 15°C and 7°C, a loss for the 600 hp setting at altitudes of 5000 and 10,000 ft. of 16°C and 8°C and a gain for the 1000 hp setting at altitudes of 5000, 10,000, and 15,000 ft. of 9°C, 20°C, and 30°C, a gain for the 600 hp at 15,000 ft. setting of 8°C. As might be expected the greatest temperature drop was for the 600 hp settings at the 2000 and 5000 ft. altitudes because of the time of exposure of induction system air to the intercooler and ducting was greater than for the high power setting and because of the lack of turbo boost. A general analysis of these heat losses indicated that a heat rise before the turbo may be cut by a third at the carburetor deck at low altitudes and low power settings. As altitude increased to 15,000 ft. for the low power setting, the heat rise at the carburetor deck tended to approach that available immediately before the turbo because the heat rise available from the turbo offset the heat loss through the intercooler and ducting. At the high power setting for all altitudes the air temperature rise prior to the turbo was almost maintained at the carburetor deck at the low altitudes. The heat rise at the carburetor deck tended to increase over that before the turbo at an altitude between 5000 and 10,000 ft. because the heat of compression from the turbo began to exceed the heat losses in the induction system. The decrease in temperature rise before the turbo to the carburetor deck for the traffic pattern and final approach condition was very similar to that experienced for the 2000 ft. 600 hp condition.

2. Another phase of the temperature survey was the temperature drop through the throttle. This temperature drop was greatest for the low power setting and altitude flight conditions which were about 30°C and



Schematic Diagram of Proposed Inter-Warmer Type Carburetor Heat System

16°C at 600 hp and 2000 ft. and 25°C and 10°C at 2100 - 25 on the traffic pattern with carburetor heat ON and OFF respectively. Inspection of the curves showed that the temperature drop through the carburetor with carburetor heat ON was greater than with heat OFF for all power settings and altitudes at which the test was run. Some of this may be explained by the fact that heat loss by radiation to the carburetor would naturally be greater when carburetor heat was ON but this would be only a fraction of the drop that actually occurs especially at the low power settings. No suitable explanation can be offered, but it is worthy of more extensive investigation since it directly affects carburetor heat requirements. The temperature drop through the carburetor throttles was greater for the 600 hp setting than for the 1000 hp setting at the 2000 and 5000 ft. altitudes, but at the higher altitudes the difference was not apparent. This was caused by the venturi effect of the throttles when partially closed for the low power setting which caused a pressure drop with the corresponding drop in temperature. It was not known why the venturi effect of the throttle was not so apparent at altitudes of 10,000 and 15,000 ft. especially since the same manifold pressure was maintained by the turbos. In fact there was a tendency for the temperature drop through the throttles to be slightly greater for the high power setting than for the low power setting at these altitudes which was in direct opposition to theory. No satisfactory explanation can be offered for this behavior. During the final approach for landing flight condition no drop in temperature through the throttle was noted for heat OFF, while the temperature drop with heat ON was relatively slight compared to the other conditions of flight tested and may be attributed to heat lost by radiation. No temperature drop was caused by throttling during the final approach because the throttles were wide open with an rpm of 2500.

3. A temperature survey of the induction system during ground warm-up with heat OFF immediately after engine start and with heat ON after a period of warm-up when temperatures became stabilized was plotted in Figure 17 from Table X. The temperature drops from before the supercharger to the carburetor deck and through the throttles were again evident but were not as great as those noted before at the low power low altitude flight conditions. Although the throttles caused a venturi effect the drop in temperature through them with carburetor heat OFF was apparently negligible, while with heat ON the drop was about half that for the most critical condition in flight - low power settings at low altitudes. Apparently the greatest part of this temperature drop was caused by radiation.

4. Throughout this discussion of the temperature surveys it has been shown that turbo supercharged engine installations because of their long induction system and intercoolers make it difficult to provide sufficient air with sufficient heat at the turbo inlet to offset the duct and intercooler heat losses during low power and low altitude flight, and ground operation. The data described above showed that a drop in temperature with heat ON from a point immediately ahead of the supercharger to the carburetor deck of about 20°C and a drop through the carburetor of 30°C may be experienced at 600 hp and 2000 ft. which gives an indication as to the most critical condition. With such great losses only a heat rise of about 7°C could be realized below the throttle while a rise of about 15°C was obtained at the carburetor deck. It is evident that a carburetor heat system for turbo-supercharged engines which could meet carburetor deck temperature rise requirements at this power setting, 600 hp at 2000 ft., would probably be satisfactory for all other conditions of flight and ground operation. In order to get an idea of what kind of heat rise would be available if the air with carburetor heat ON were taken only from the hot source and not allowed to mix with air from the filter one of the ground tests were run with the filter completely blocked off. The results of this test shown in Figure 17 revealed that the heat rise just before the turbo and at the carburetor deck was increased by 20°C. Since the hot air temperature rise over the OAT before mixing with filtered air was about 60°C for this warm-up condition as compared to 80°C at 600 hp 2000 ft., the heat rise before the turbo and at the carburetor deck for this flight condition might be increased by at least 30°C which would give a total rise at the carburetor deck of 60°C. Naturally the lower the outside temperature the greater will be the heat lost through the ducting and intercooler especially at this critical condition of flight. However, by making the shroud around the exhaust manifold as long as possible, by taking air with heat ON only from the hot source and providing a relief valve if the system offers enough restriction to cause a pressure drop at high powers, by keeping the hot air duct as short as possible and tapping into the induction system as near as possible to the turbo inlet, by lagging the hot air duct, and by insuring that the entrance intercooler shutters are completely sealing, it is believed that a carburetor heat system for turbo-supercharged engines which will provide a satisfactory carburetor air temperature rise during any condition of flight and ground operation will be possible.

D. Intercooler Shutter Effectiveness

1. As shown in the temperature surveys one of the major factors which prevented availability of a satisfactory carburetor deck temperature rise with the exhaust manifold type carburetor heat system tested was the loss of heat through the intercooler because of ineffective sealing of intercooler air. Tests were run on both the B-24J and B-17G in order to determine the sealing characteristics of their respective intercooler shutter installations. The results of the test on the B-24 which compared the maximum carburetor air temperature rise available for the production exit type and test entrance type shutters to that available with a completely sealed off intercooler were graphically presented in Figure 19, which was plotted from Table XII. Analysis of this chart showed that the maximum carburetor heat rise available by closing the exit type intercooler shutters was negligible for all power settings and altitudes at which the test was run. The experimental entrance type shutters provided carburetor air temperature rises approaching those available with the completely sealed off intercooler at all conditions except the high power settings and altitudes. The sealing characteristics of the mechanical entrance type shutter became worse at the high power settings because leakage of the air through the shutters became greater with increase in the pressure head.

2. After the tests were run on the B-24 to determine the effectiveness of intercooler shutters it was decided to run a check on the B-17 because of the difference in intercooler and shutter installation. The "plain shroud and no restrictor plate" arrangement of the exhaust manifold carburetor heat system was re-run with the intercooler intake blocked off. The results of these tests shown in Figure 5 were plotted from Table IV and are compared to the results obtained from the test on this

system using the production shutters in Figure 20. The increase in the carburetor air temperature rise for the various power settings varied from a minimum of 3°C to a maximum of 10°C. There was a tendency for the additional carburetor air temperature rise due to the complete closure of the intercooler to decrease with the increase in power. This was probably due to the fact that velocity of carburetor air through the intercooler at high powers was so great that although the production shutters are not perfectly sealing the time that any quantity of air was exposed to the intercooler, was so small that the heat transfer possible was also held to a minimum, while at low powers the flow of air was decreased, thus increasing the time of exposure to the intercooler and the amount of heat transfer to the intercooler air leaking or circulating through the production shutters. It should be noted that the tests with the sealed intercooler intake were run at OAT's approximately 10°C lower that those for the production shutters hence the heat rise from the sealed intercooler may be somewhat less than they would be had they been run at the same outside air temperature. This test should have been run possibly by blocking off the intercooler air on one of the production engines such as No. 2 and taking simultaneous reading on another of the production engines such as engine No. 3 on which only the production shutters would be used for blocking intercooler air. However, it was desired to determine the maximum available heat rise on the exhaust manifold type carburetor heat system if the intercooler air could be sealed off completely so separate tests at the same power settings and altitudes were run.

3. Other data has been accumulated which substantiated as well as supplemented what has been said above. Induction system temperature readings before the turbo and after the intercooler at the carburetor deck shown plotted in Figures 7 to 17 for the tests on the various arrangements of the carburetor heat system gave an indication of the loss of heat through the intercooler. These charts also showed that the loss of heat at the intercooler was greatest for the low power setting and low altitude. This is critical because this flight condition is that where a large heat rise is required because of the great temperature drop through the throttle. More effective closing of the intercooler would be a definite aid in providing a satisfactory carburetor air temperature rise. Even with effective closing off of the intercooler loss of heat would be quite great, possibly double that in the rest of ducting, but maybe only half the total loss experienced with the present production shutters. Sufficient data has not been obtained so that the heat losses may be broken down.

4. Comparison of the effectiveness of the production intercooler shutters on the B-24J with the production shutters of the B-17G indicated that the shutters on the latter airplane were the more efficient. The B-24 was provided with a venetian blind type shutter with visibly poor sealing characteristics as evidenced by Figure 2 of Appendix III which shows these shutters closed. The B-17G was equipped with a single gate type entrance intercooler shutters. From the tests on the B-24J where the production exit shutters were compared to the experimental entrance type shutter, it was indicated that the entrance type shutter was much more effective in closing off intercooler air. These tests supplemented by those on the B-17G and previous experience on the P-38 all prove the value and necessity of the entrance type intercooler shutter. Because of the very poor performance of exit type shutters on the P-38 during cold weather tests and because of the necessity of preventing loss of heat with carburetor heat ON, entrance or nose intercooler shutters were made a production change on this aircraft. The exit type shutter, as has been known for some time, and which has been substantiated by tests discussed herein, is ineffective and its usefulness decreases with temperature.

5. Apparently at some time designers feared the use of entrance shutters on any type of temperature regulator because of the possibility that impact ice might lock them open or closed. It is believed that needless caution has been exercised in avoiding the use of this type intercooler shutters. First of all the intercooler shutters should be closed during operation in visible or impact icing conditions so as to prevent carburetor icing. Should the shutters then be locked in the closed position the danger for detonation would be remote because the temperature and altitude range at which it is possible for impact ice to occur are such that the heat rise available from compression by the turbo even at high power settings is insufficient. Further, the possibility of icing of the entrance type shutter either open or closed depends to a great extent on its location in the intercooler air ducting. Both the B-17 and B-24 allow entrance intercooler shutter installations at a location in the intercooler air ducting which would forestall the possibility of icing.

6. It is believed that the effectiveness of an entrance type intercooler shutter can be held to a maximum if the installation is made as near to the intercooler as possible. In this way the volume of air that can circulate through the intercooler tubes and thus effect loss of heat from the induction system air by transfer can be held to a minimum. This circulation of a large volume of air whether caused by turbulence or convection may be one of the principle causes for the ineffectiveness of the exit type intercooler shutter. Even with the use of an efficient entrance type shutter circulation of nacelle air into the intercooler from the rear may be responsible for some heat loss, however, it is expected that it would be slight.

7. An investigation that would yield important and interesting data would be one where the following intercooler shutter arrangements would be compared to a perfectly sealed off intercooler.

a. Exit shutters with mechanically perfect sealing characteristics.

b. Entrance shutters with mechanically perfect sealing characteristics.

c. Variation of the location of the entrance or exit shutters ahead of or behind the intercooler to determine the effect of location on the efficiency of each of these shutters.

d. Variation of leakage on entrance and exit type intercooler shutters in order to determine its effect on each type.

e. A combination entrance and exit type intercooler shutter which would not only cut off intercooler air but would keep heat transfer from the intercooler, to the surrounding air to an absolute minimum.

It is believed that the combination entrance and exit type intercooler shutter arrangement would be the most efficient but it is not known if it is worth the added weight and complexity. The entrance type shutter, however, without necessitating increase in weight or complexity over the exit shutter allows a considerably more effective means of blocking off intercooler air.

E. USE OF HIGH BMEP AND OVERBOOST AS AN AID TO CARBURETOR HEAT

1. The results of the tests run to determine the effect of BMEP and overboost on the available carburetor air temperature rise from closed exit and entrance shutters, and sealed off intercooler on the B-24 were plotted in Figure 19 of this Appendix. It was found that at altitudes of 2000 and 5000 feet the effect of high or low BMEP, and retarding the throttle and applying turbo boost on the maximum carburetor heat rise available from any of the intercooler arrangements mentioned above was negligible. At 10,000 feet at 825 and 600 hp the high BMEP added 9°C and 5°C, respectively, to the available carburetor heat rise on the sealed intercooler engine while the heat rise on the engines with exit and entrance type intercooler shutters was negligible. At 15,000 feet and 825 hp 5°C was added on the available carburetor heat rise on the engines having the sealed and entrance shuttered intercoolers, and 4°C on the engine with exit shutters. The added heat rise at 15,000 ft. for the 600 hp was 12°C on the engine with the sealed intercooler, 7°C on the engine with the entrance type intercooler shutters, and no additional rise on the engine with exit shutters. It should be noted that power settings chosen for the low and high BMEP were at the extremes of the BMEP range for a given power except for the 825 hp at altitudes of 10,000 and 15,000 ft. where the high BMEP setting was a mean setting. Hence the heat rise obtained at this power setting or BMEP value represented only a portion of that which would be available if the power setting having the highest BMEP value for that power would have been used.

2. In order to ascertain the effect of retarding the throttle and applying turbo boost, and high and low BMEP on the carburetor air temperature rise available when used in conjunction with the experimental carburetor heat system and with the closing of the production intercooler shutters on the B-17G, a test was run similar to that on the B-24J. The results of this test graphically presented in Figure 4 and supplemented by the temperature surveys in Figures 21, 22, 23, and 24 verified those obtained on the B-24 tests. As before the effect of BMEP and retarding of the throttle and applying turbo-boost as an aid to carburetor heat at altitudes of 2000 and 5000 feet was negligible. At an altitude of 10,000 ft. the high BMEP power setting with the experimental carburetor heat system ON added at 750 hp and 600 hp at 10,000 ft., 5°C and 7°C, while 4°C and 9°C were added at 15,000 ft., respectively. The additional heat rise obtained by the high BMEP at these altitudes and powers on the production engine tended to be appreciably less. It should be noted that these heat rises were those figured from the COLD to HOT carburetor air temperature for the same power condition. Examination of the temperature surveys referred to above showed that operating engines at the high BMEP power setting increased the cold carburetor air temperature over that available from the low BMEP setting and the amount of rise increased with altitude. Hence all heat rises due to high BMEP described above should be computed from the COLD carburetor air temperature at the low BMEP setting. Accordingly the carburetor air temperature rises due to a high BMEP power setting at 750 hp and 600 hp at 10,000 ft. should be 7°C and 10°C and at 15,000 ft., 9° and 14°C. Correcting these temperature rises to a common base temperature before the turbo, since they are due to compression by the turbo, would give carburetor air temperature rises of 4°C, 4°C, 9°C, and 11°C, respectively. Since for the B-24 tests the COLD carburetor air temperature for the low BMEP setting was the same as that for the high BMEP setting for all added heat rises described in paragraph 1 of this section, except that at 600 hp and 15,000 ft., they may be considered corrected. The corrected heat rise at 600 hp and 15,000 ft. should be 15°C instead of 12°C. These added heat rises, which were caused by the greater turbo-boost used at the high BMEP power settings, tended to increase with altitude, and with decrease in power at a given altitude. In all cases where such tendency was evidenced it was due to more turbo-boost.

3. It was expected that the application of overboost and/or operating engines at a high BMEP would increase the temperature drop through the throttle for a given power. Analysis of the temperature surveys showed that the increased drop through the throttle for those powers where it is apparent, was so slight as to be negligible and for others the variation was such that no definite conclusion could be drawn.

4. General observations based on the above discussion are that operating the engines at a high BMEP or by retarding the throttle and applying turbo boost for a given power provided an additional carburetor air temperature rise only at altitudes of 10,000 ft. and above and then only when used in conjunction with carburetor heat which gave a substantial initial carburetor air temperature rise. This method of obtaining a carburetor air temperature rise is considered ineffective when used only in conjunction with closing intercooler shutters and not necessary when used in conjunction with a carburetor heat system.

Desired and Proposed Carburetor Heat Systems for Turbo-supercharged Engines

A. CARBURETOR HEAT FOR THE B-17 TYPE AIRCRAFT

1. From the tests on the exhaust manifold type carburetor heat system on the No. 1 engine of the B-17 it was evident that the system as installed was not completely satisfactory. This system, which was applicable to the outboard engines may be definitely improved and a sufficient carburetor deck temperature rise should be possible if the following modifications were accomplished:

a. The system as installed did not allow selection of cold ram, hot ram, or filtered air as desired. Instead, only cold ram and a combination of hot ram and filtered air could be selected which was undesirable. To correct this and at the same time eliminate the feature, wherein uncontrollable mixing of air from the filter with that from the carburetor heat shroud occurred, the hot air duct should be tapped into the induction system on the suction side of the supercharger after the air filter valve. A motor driven valve which would close off the cold ram air and allow flow of hot air from the shroud into the induction system should be provided. The hot air duct should have a large enough cross-sectional area so that together with a relief valve the engine would be furnished sufficient air at all power settings and altitudes without abnormal operation of the turbo. A valve such as an Airesearch suction relief valve Part No. 90138-6, which is set to open at a pressure differential between the hot air and atmospheric pressure of 1.96 psi or 4 in-hg, should be installed in the hot air ducting. Use of such a valve would insure that air would be drawn solely from the shroud, which is the hot source, at all low power settings where the need and the difficulty of obtaining a large carburetor air temperature rise was the greatest.

2. Other modifications necessary would be to block off all the area at the exit end of the carburetor heat shroud except for about a 5/16 inch around the exhaust manifold, and to increase the cross-sectional area of the lower shroud at the forward end and allow it to taper back to the minimum required area so as to increase the ram effect of the system.

3. In order to provide carburetor heat on the inboard engines an entirely different problem presented itself on B-17 aircraft having the heat exchanger type heating system. The exhaust manifolds on the inboard engines of these aircraft are already utilized to provide heat to the cockpit and cabin. To draw heat from these cabin heat shrouds would not be advisable because it would seriously detract from the efficiency of the heating system, hence ducting of air from around the exhaust collector ring is the only other solution. It is not known if such an arrangement would provide a satisfactory carburetor air temperature rise or how adversely it would affect the output of the heating system. The system described in paragraph 1 above, for the outboard engines would be applicable to the inboard engines of aircraft having the glycol heating system. A more complete discussion of the exhaust manifold carburetor heat system is given in paragraph 1 Section C.

B. CARBURETOR HEAT FOR B-24 TYPE AIRCRAFT

1. In order to furnish a satisfactory carburetor heat system for this airplane the first item that must be provided is an entrance type intercooler shutter in lieu of the production installed exit type shutters. On all B-24 aircraft that are equipped with boot type surface deicers and spot type heaters in the heating system the exhaust manifolds on all engines will facilitate installation of the exhaust manifold type carburetor heat system such as that described in paragraph 1 of Section C.

2. The B-24 that has the heat exchanger type heating system and thermal deicing has a heat exchanger in the exhaust manifold. A hot air duct for carburetor heat tapped into this heat exchanger would detract from the heating and surface deicing system which would not be acceptable. The feasibility of a shroud around the exhaust manifold ahead of the heat exchanger is not known, but it might bear investigation. As in the case of the B-17 the next best system would be to duct heated air from the exhaust collector ring. Such a system has been suggested after quite extensive tests by the RAF. This system did not provide a completely satisfactory carburetor air temperature rise so an additional heat rise was made available by means of a manual override on the turbo regulator so that the waste gate could be closed and allow overboosting of the carburetor deck. The basic system with the entrance type intercooler shutter is similar to the system shown schematically in Figure 1 but the heat losses will be greater since the distance of the source of heat from the turbo inlet would be much greater. Overriding of the turbo is not a desirable feature of this system because of its effect on carburetion. Such abnormal engine and turbo operation would be entirely unsatisfactory for maintaining a desired carburetor air temperature during long range missions.

C. CARBURETOR HEAT FOR OTHER TURBO-SUPERCHARGED ENGINE INSTALLATIONS

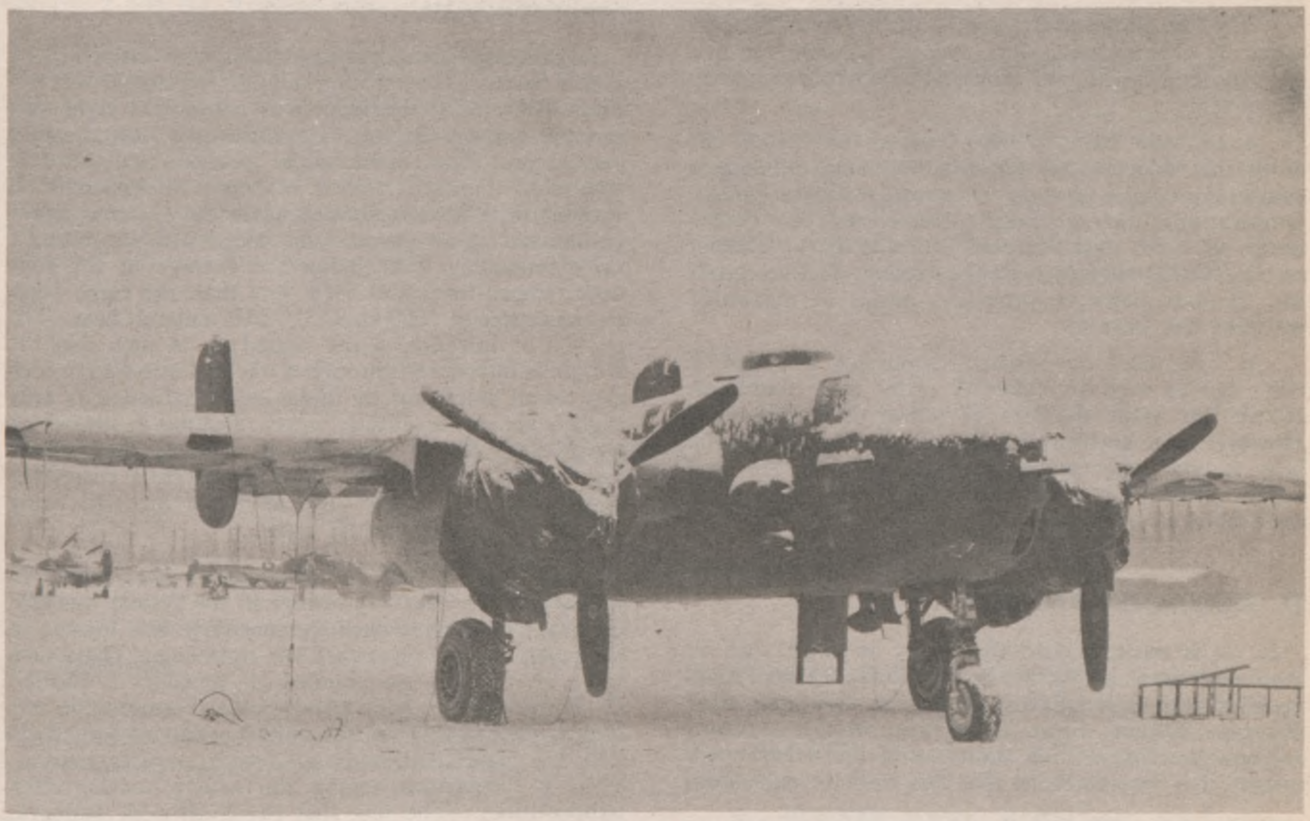
1. At the present time the best type carburetor heat system for the turbo-supercharged engine is the exhaust manifold type system used in conjunction with entrance type intercooler shutters. As shown in this report it is possible to provide a sufficient carburetor deck temperature rise by ducting the hot air from a shroud around the exhaust manifold, if the shroud is sufficiently long, if the hot air ducting to the turbo inlet is as short as possible and adequately lagged to keep heat losses to a minimum, and if the air from the hot source is not allowed to mix with cold air especially at low power settings. A schematic diagram of this system is shown in Figure 1. To be considered operationally suitable the carburetor heat system must allow selection of either cold ram, hot ram, or filtered air, and the ability to maintain a fixed carburetor air temperature for a given power setting and altitude. This necessitates the installation of a valve which will either allow flow of hot or cold air into the turbo. The valve motor may be connected either to a mometary contact type switch or to a simple OFF and ON switch. Using the former switch with the intercooler shutters closed the hot air valve would be opened enough so that the desired carburetor air temperature might be maintained. Using the two position switch which would allow either full open or full closed position the desired carburetor air temperature could be selected and maintained by opening the intercooler shutter as desired. Installation of a relief valve, possibly an Airesearch Part No. 90138-6, which is set to open at a pressure differential between the hot air pressure and atmospheric pressure, of 1.96 psi or 4 in-hg, or Part No. 90138-12 which is set to open at 1 psi or 2 in-hg, should be made in the hot air ducting. It is not known which would be the better but a pressure drop greater than 4 in-hg, should not be allowed because normal engine and turbo operation is then affected.

2. Another carburetor heat system which is a development of the accessory section type carburetor heat system tested on a B-24 and discussed in this report is shown in Figure 2. This is merely a proposed system since no data is available on its performance. It consists essentially of ducting hot air from a shroud around the exhaust manifold into the intercooler. Such a system demands the use of entrance type intercooler shutters so that ram air can be closed off ahead of the intercooler and thus will not prevent flow of the hot air. It is believed that the ram effect at the hot air shroud will be sufficient to flow the hot air over the intercooler tubes. The amount of ram and area of ducting which will provide the greatest possible heat transfer to the carburetor air are all factors of design and test which must be determined. It is not known whether or not the rapidity of carburetor heat rise would be sufficient to allow use of this system as a means of combating carburetor ice. It is believed that this system would provide all the heat rise desired at

all altitudes and power settings. In fact the ram effect of the slipstream on the ground might force sufficient hot air through the intercooler so that a substantial carburetor air temperature rise can be realized. Control of the carburetor air temperature could be affected by opening or closing the hot air valve, the intercooler shutters, or both. Some of the probable advantages of this system are ability to select cold ram, hot ram, or filtered air; it lends itself to the control of the carburetor air temperature either manually or automatically; the flow of induction system air is unaffected by the application of heat; and the greatest carburetor air temperature rise would be available at the low power settings because the time of exposure of a particle of air to the intercooler (interwarmer when heat is ON) would be greater than at the high power settings.

B-25 Carburetor Heat System

Prepared by Walter I. Thieme, Capt. A. C.



B-25J-22 Airplane No. 44-29258

A. PURPOSE

To report on the tests conducted on the exhaust gas carburetor heat system installed on ATSC B-25J-22 winterization airplane No. 44-29258.

B. FACTUAL DATA

Tests on the subject carburetor heat system to date can be divided into two general classes; the system as installed in production, covered in Appendix I, and the system as modified by the use of an experimental baffle, covered by Appendix II. Appendix III shows a graphic comparison of the two systems at 2300 rpm, 31″ MP, and full carburetor heat.

C. CONCLUSIONS

1. On the basis of tests run to date, the following are the conclusions concerning the standard exhaust gas carburetor heat system on B-25J airplanes.

a. In this system, stratification of the heat layers is extreme. As shown in Appendix I, at 2300 rpm, 31″ MP and full carburetor heat the temperature of the temperature-compensating altitude valve was 44°F less than average of the four carburetor deck temperatures.

b. Because of the failure of the temperature-compensating capsule to represent the average temperature of the incoming air, the mixture is changed when carburetor heat is applied. In this case, the altitude valve is in the stream of cold air from the ram air scoop while the heated air is admitted along the sides, resulting in a richening of the mixture.

c. Carburetor heat cannot be successfully used to reduce engine roughness and smoking because of the stratification and richening effect.

d. The heat rise with this system is slight at low powers and small openings of the entrance flap, but increases rapidly around the one-half open position.

2. On the basis of tests run to date, the following are the conclusions concerning the carburetor heat system with the experimentally modified baffle.

a. As shown in Appendix II, stratification was greatly reduced. At the same 2300 rpm, 31″ MP and full heat setting mentioned in *a* above, the altitude valve was 2°F warmer than average of the four deck temperatures. This is shown graphically in Appendix III.

b. The altitude valve represents the mean temperature of the incoming air, making possible the use of carburetor heat to aid vaporization without richening the mixture.

c. On the basis of tests to date, this system has aided the reduction of smoking, torching and engine roughness at high powers. However, tests are limited, temperatures have not been extreme, and this system is not set forth as a "cure-all" for the above troubles on R-2600-29 engines with the Holley "HB" carburetor. It does, however, provide a means of uniformly warming the inlet air.

d. As much as one-half carburetor heat (60°F rise) can be used for take-off under cold conditions. Above this value the loss of power is considerable. However, the problem is one of providing adequate heat to aid vaporization without seriously reducing engine power, for which the one-half heat position is considered a maximum.

D. RECOMMENDATIONS

1. It is recommended that steps be taken such as the modification of the baffle mentioned in this report in order to provide uniform carburetor air heating with this type system. Since Lend-Lease B-25J airplanes are now arriving at this station with the exhaust gas system, it is recommended that this work be expedited.

2. In order that partial carburetor heat settings be as uniform as possible, it is recommended that the heat entrance doors be marked to show the one-fourth, one-half, and three-quarter open positions.

3. It is recommended that Air Technical Service Command Power Plant Laboratory consider incorporation into the Handbook of Requirements of a maximum allowable temperature variation of the temperature-compensating device and of the carburetor upper deck during all carburetor heat positions.

Appendix I

FACTUAL DATA

1. Attempts to use carburetor heat to reduce the smoking and torching at high powers of the R-2600-29 engine equipped with the Holley 1685 HB carburetor led to these tests on the carburetor heat system. The first comprehensive test was run 29 December 1944, the data from which is given in Appendix I, Exhibit A. The thermocouples, shown in the photograph in Exhibit A, were located under the head of an altitude valve screw and two in the throat of the carburetor above the venturi. These two at the carburetor deck were under the rubber inlet flange and were located in the middle of the rear side and two-thirds of the way forward on the right-hand side, each protruding approximately three-fourths of an inch from the wall. The data secured on this test show a wide variation in deck temperature at higher cruise powers, with the altitude valve temperature remaining as much as 35°F below the higher deck temperature. Three minutes was allowed for conditions to stabilize before temperature reading were taken at the different power and heat settings. The carburetor heat doors were marked so the conditions of partial heat could be controlled as nearly as possible.

2. Two additional thermocouples were installed, one at the front of the carburetor deck and one at the left side. The one at the front was nearer the right side and the one on the left is two-thirds of the distance to the rear. The thermocouple locations and the data secured 2 January 1945 are shown in Appendix I, Exhibit D. This test showed again the extreme stratification at higher powers and heats, with the altitude valve remaining 44°F below the average of the four deck temperatures and 54°F less than the right front thermocouple at 2300 rpm, 31″ MP and full heat. The method of introducing the heated air is such that the hot air is introduced through a one and one-fourth inch gap on all sides, but the point of introduction is only slightly above the altitude valve, resulting in heated air along the walls of the carburetor while the altitude valve, which is this carburetor's temperature correction device, remains in the relatively cold air still being admitted from the ram air scoop.

3. A third series of temperatures was taken 12 January 1945. The only change in the system was that the front carburetor deck thermocouple was located in the center instead of toward the right side. These data and a photograph are included in Appendix I, Exhibit C. Unfortunately, the altitude valve thermocouple was broken during this set of readings, but a comparison with the pilot's carburetor air temperature is possible, as is a comparison among the widely varying deck temperatures. The fact that the front deck temperature was comparatively lower after moving it to the center shows an area of excessive heat at the right front corner.

Appendix II

1. In an attempt to reduce the stratification and provide better temperature correction when carburetor heat is used, the inlet baffle between the ram air scoop assembly and the carburetor was modified. The modification consisted of extending the lower edges 1¼″, thus sealing off the present hot air inlet to the carburetor. The following holes, shown in the photograph in Appendix II, Exhibit A, were cut in the baffle to admit the heated air:

> Four 2″ diameter on bottom 2½″ from front
> One 3″ diameter semi-circle on each slanting side

One 2″ diameter on each side 2½″ from rear
Entrance Area - Production design - 30 sq. inches
Entrance Area - Experimental design - 26 sq. inches

2. It is intended in the modified design that the majority of the heated air be introduced through the four holes in the bottom of the baffle. These holes as located are in the low pressure area downstream of the slanting door which rises to close off the ram air inlet as carburetor heat is applied. Photographs of the new installation and the data from tests conducted 15 January 1945 are contained in Exhibit A of Appendix II. All thermocouple readings are listed "as taken", but the subsequent discovery of a fixed error in this particular potentiometer shows these thermocouple readings should all be increased 10°F. At any rate, the good agreement between the altitude valve temperature and the deck temperatures is clearly shown. Temperatures of the No. 1 and No. 9 intake pipes are also shown.

3. Additional tests at cruising power and temperatures during simulated take-off's with the new baffle are shown in Appendix II, Exhibit B. Since take-offs with appreciable carburetor heat with the standard baffle are subject to considerable stratification and engine roughness, no comparative figures for take-off temperatures between the standard and experimental baffles are possible. Note that testing on the new baffle is limited and that it is not suggested as a cure-all for the smoking and torching of this type installation. It does give a more uniform heat rise and has to date aided the problem. With the experimental baffle the following average heat rise was secured at take-off power:

¼ heat - 20°F
½ heat - 55°F
¾ heat - 80°F

Since the problem involved is one of providing adequate heat for vaporization without seriously reducing engine power, one-half carburetor heat with the experimental baffle is now used as a maximum.

4. Other tests, such as temperatures of the altitude valve during run-up, glide, landing and go-around have been conducted. These will be included in a final report on this subject, together with data on slightly different baffle now being installed. The ship will be left instrumented in the carburetor system as long as possible to allow any additional tests desired to be conducted.

5. As far as can be determined at this date, there are no deleterious affects of using this experimental baffle, other than the loss of power expected when carburetor heat is used. The flow of the heated air is undoubtedly restricted somewhat, but take-off power with one half heat can be secured. A second experimental baffle will incorporate more inlet area. As far as can be determined, normal, no-heat take-off, climb, cruise, or high speed has not been affected.

Cold Weather Test of A-26B Airplane

Prepared by: Charles H. Tillson, 1st Lt., A.C.

A. PURPOSE

1. To report on the cold weather testing of A.T.S.C. A-26B, serial number 41-39182, at Ladd Field, Fairbanks, Alaska, for the winter of 1944-1945.

B. FACTUAL DATA

1. The minimum ground temperature encountered during testing of A-26B, No. 41-39182, was —37°F. and the mean temperature of the coldest day was —26°F. The lowest temperature encountered in flight was —32°F., to which the aircraft was exposed for one hour and thirty minutes.

2. For a record of flying time and ground temperatures during the test period, see Appendix I.

3. Listed below are the items tested and the results obtained.

a. Synthetic oil (PPO 265).

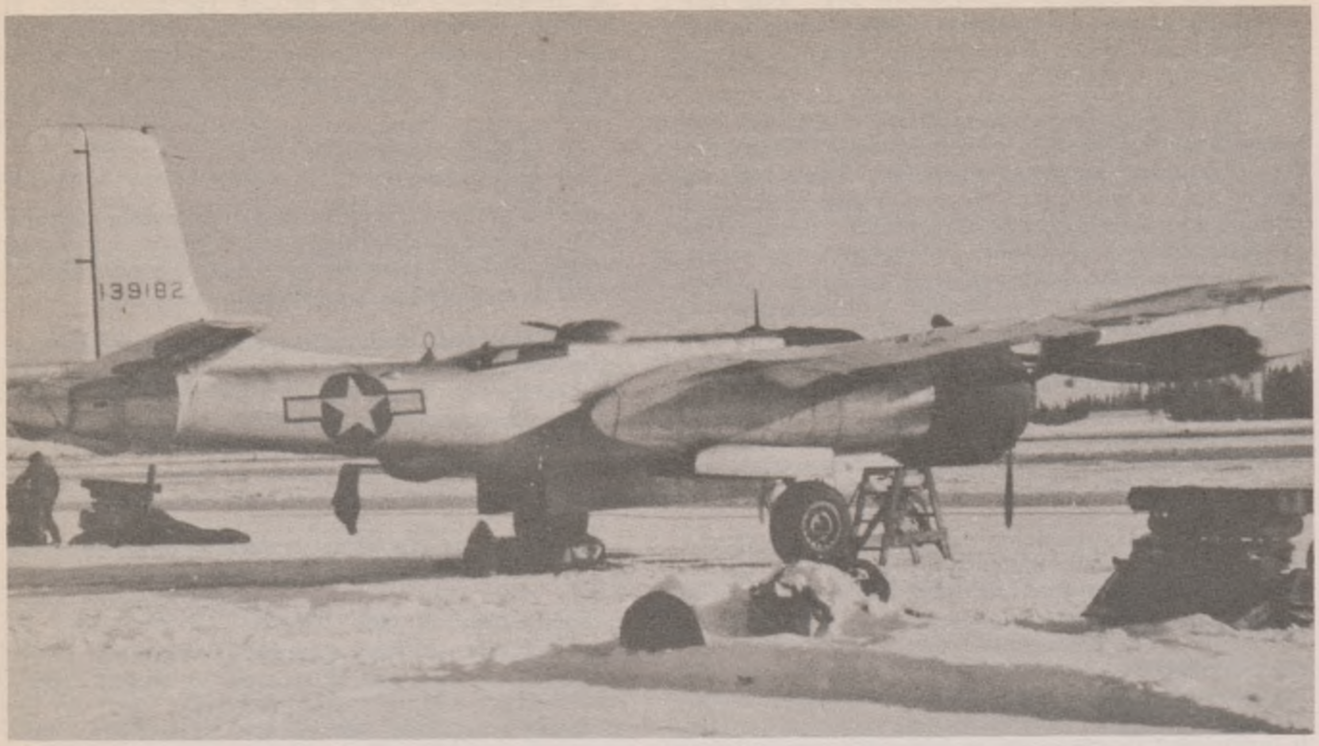
(1) For purpose of comparison, synthetic oil PPO 265 was used in the No. 2 engine, 1100A oil in the No. 1 engine. No difficulties with either PPO 265 or 1100A oil were experienced. It was noted that PPO 265 oil required less time for ground warm up and consistantly ran approximately 5°C. warmer in flight than did 1100A oil. Although no feathering tests were conducted on this airplane at low temperatures, results from tests conducted on other E.T.O.U. aircraft show that PPO 265 oil is a definite aid to propeller feathering.

b. Hydraulic system, landing gear shock struts, seals and packings.

(1) For purpose of service testing, "O" ring packings were placed in the left hand main and nose struts. Scraper rings, a revised air valve, and experimental non-inflammable hydraulic fluid were placed in the left hand main strut. These items gave satisfactory results throughout the entire test period. It was never necessary to add air to any of the struts, or to re-service the hydraulic fluid or replace any of the seals and packings. For difficulties encountered with the landing gear and the hydraulic system, refer to Appendix II.

c. Synthetic rubber engine mountings.

(1) Synthetic rubber engine mountings were mounted in the right engine for service test. After 125 hours flying time, it was found that the buffer rings, which are part of the MR-36 dynafocal mount intended to absorb excessive engine torque caused on starting the engines and which are mounted between



A-26 B

the engine bracket and the face of the dynafocal mounts, were loose on the top four mounts. It was also possible to get vertical movement of one-half inch of the engine simply by pulling out and in on the propeller. It was thought that this was an abnormal condition as it did not exist on the left engine. The synthetic engine mounts were removed and standard dynafocal mounts installed. One of the synthetic rubber cores was found to be cracked. This mount was sent to the Aircraft Laboratory for examination.

d. Rubber and synthetic hydraulic, instrument, fuel and oil line hose connectors.

(1) Throughout the testing season, no malfunctions or deficiencies of the above named items were experienced.

e. Weatherstripping and fuselage seals.

(1) At a temperature of a —21°F. the fuselage seals around the pilot's compartment became brittle and broke.

f. Propeller controls and feathering systems.

(1) Tests were conducted on the feathering system to determine the electrical loads while feathering and the time required for feathering. The average time for feathering was 8.0 seconds for the No. 1 engine, 9.2 seconds for the No. 2 engine, at an average temperature of 30°F. The electrical loads did not exceed the output of single generator operation which is 200 amps.

g. Cabin, cockpit and rear gunners compartment heating.

(1) The production installed Stewart-Warner heaters in this airplane are considered obsolete but were tested in an attempt to establish the necessary requirements to properly heat and defrost this airplane. For further details, see Appendix III.

h. Wing and engine covers.

(1) Standard wing and engine covers are considered satisfactory.

i. Snow and ice tires.

(1) The spring-insert type snow and ice tire is considered an aid to braking in loose snow. On glaze ice or hard packed snow, it is impossible to get any braking action with these tires. The relative horse power for the weight of this airplane is such that it is impossible to brake and hold while running the engine above 1200 rpm when on glaze ice or hard packed snow.

j. Adequacy and selectivity of carburetor heat,

(1) Production installation is considered satisfactory. No occassion to use carburetor heat other than to aid fuel vaporization on the ground has been experienced. At a temperature of —20°F., a heat rise of 40°C. has been attained.

k. Oil and fuel, vent lines and breathers, Y drains, fuel and oil tank sump drains.

(1) Throughout the entire test season, there has been no freezing of condensate in any of the oil and fuel, vent lines or breathers. Self-locking Y drains are installed and are a great advantage. They should be installed on all winterized airplanes. No self-locking fuel drains are installed, but are not considered an advantage for this airplane as it is not necessary to drain the fuel sumps on every pre-flight inspection. It is considered that the production installed fuel drains are safer than the self-locking fuel drains.

l. Flight and navigational instruments.

(1) This airplane has the E-1 electrical gyro horizon and the C-1 directional gyro compass installed. These instruments have given satisfactory service for 125 hours flying time at all the temperatures encountered throughout the testing season. At a cockpit temperature of —30°F., they erected immediately and gave evidence of no more than usual precession.

m. Engine instruments.

(1) The oil pressure gauge line from the A-I pressure transmitter to the pressure gauge, was serviced with hydraulic fluid, Spec. No. AN-VV-O-366a, for cold weather operation. This installation and all other engine instruments gave satisfactory operation throughout the entire test period.

n. Armament.

(1) The armament of this airplane consists of two remotely-controlled turrets, two .50 caliber machine guns to each turret. The all-purpose nose installed is so designed that any of the following combinations of guns can be installed and controlled by the pilot: six .50 caliber machine guns, two 37 mm. cannons or one 75 mm. cannon. Tests were conducted to prove the reliability of the A-26 armament at low temperatures. (Refer to Appendix IV for further information on armament.)

o. Radio and electrical equipment.

(1) No deficiencies or malfunctions of radios or electrical equipment occurred due to low temperatures.

p. Engine starting and operation.

(1) The priming system was modified by connecting the priming system fuel take-off ahead of the restricted fitting instead of after it, thus providing more fuel for priming, and considerably reducing the time of priming. All starts throughout the entire test period were made with ease, never using more than five seconds prime. This is considered a definite advantage for engine starting at low temperatures. No deficiencies or malfunctions of engine operation were experienced.

q. Location of the external power plug recepticle.

(1) The external power plug was moved from the inside of the left wheel well to a point just opposite on the out-board side of the left nacelle. The access door was spring loaded so that the battery cart plug could be pulled without entering the slipstream. This item is essential for operation at low temperatures and should be on all winterized airplanes.

C. CONCLUSIONS

1. Operation of the standard A-26B aircraft at temperatures down to —40°F. is posslble if the following changes are incorporated:

a. The engines serviced with synthetic oil to insure propeller feathering.

b. Winterized brake seals installed, all hydraulic seals and packings winterized.

2. Operation of the standard A-26B is simplified and improved if the following changes are incorporated:

a. Self-locking Y drains installed.

b. Cabin heating be increased and a positive method of ground windshield defrosting be provided.

c. The external power plug receptacle moved to the out-board side of the left engine nacelle.

3. Testing indicates that the experimental equipment installed in the subject airplane is satisfactory or unsatisfactory to the temperatures encountered as indicated below:

a. "O" ring packings, scraper rings, revised air valve and experimental non-inflammable hydraulic fluid, left hand main strut—satisfactory.

b. Hydraulic fluid feathering left engine—satisfactory, but synthetic engine oil (PPO 265) will give better results.

c. Priming take-off before restriction—satisfactory. tory.

d. E-1 electrical gyro horizon and C-1 directional gyro compass—satisfactory.

D. RECOMMENDATIONS

1. It is recommended that the changes listed in paragraph C 1 and C 2 above be incorporated in future production airplanes for low temperature operations.

Cold Weather Test of B-17G Airplane

Prepared by: Frank G. Bastian, 1st Lt., A.C.

A. PURPOSE

1. To report on the cold weather testing of A.T.S.C. B-17G-80-BO Serial No. 43-38221 at Ladd Field, Fairbanks, Alaska, for the winter of 1944-45.

B. FACTUAL DATA:

1. The minimum ground temperature encountered during the testing of B-17G No. 43-38221 was —45°F and the mean temperature of the coldest day was—30.2°F. The lowest temperature encountered in flight was —72°F, to which the aircraft was exposed for 45 minutes.

2. A record of flying time and ground temperatures during the test period is given in Appendix I.

3. Listed below are the items tested and the results obtained:

a. Lubricants and hydraulic fluid.

(1) Engines Nos. 1 and 4 were lubricated with synthetic oil (PPO No. 265). Engines Nos. 2 and 3 were lubricated with 1100A oil. No deficiencies were noted with either type oil but a definite advantage of the synthetic oil over the 1100A oil was noted in that it aided propeller feathering and was considered more suitable for winter operation. See Appendix II.

b. Rubber and synthetic hydraulic, instrument, fuel and oil line hose and connectors.

(1) All hose and connectors were standard, and no failures or deficiencies were experienced. Standard winterized low pressure instrument hose with experi-

mental detachable end fittings were installed. Detachable end fittings were satisfactory and it is suggested that they be made a standard installation.

c. Weatherstripping and fueslage seals.

(1) Fuselage seals around doors and escape hatches were satisfactory.

d. Hydraulic actuating systems and shockstruts.

(1) No difficulties requiring more than routine maintenance were encountered.

e. Hydraulic fluid seals and packings.

(1) Both the standard "V" type packing in the right main landing gear and the experimental "O" ring packing in the left main landing gear operated satisfactorily. The "V" type packing allowed the shock struts to operate a trifle more smoothly than the "O" ring packing did.

f. Surface control systems.

(1) Mechanical type cable tension regulators were installed in the main aileron control system and a special grease was used for lubrication of part of the control system. See Appendix III.

g. Propeller controls and feathering systems.

(1) Extensive feathering tests were conducted to evaluate the relative merits of the standard feathering system, the use of a high speed feathering pump with the standard system, the hydraulic oil feathering system, and the feathering merits of the Aeroproducts propeller. See Appendix IV.

h. Cabin, cockpit, waist and tail gunner's compartment heating.

(1) Two Stewart Warner 200,000 BTU/hr. combustion heaters, Model 911A, were installed, one in each wing. The heaters rarely operated above 25,000 ft. A better system of ignition and metering of fuel is suggested, if the heaters are expected to operate at high altitudes. At low altitudes the heaters were satisfactory.

i. Defrosting and deicing of windshields and transparent on ground and in flight.

(1) No provisions were made for defrosting or deicing of the windshield.

j. Deicing of wings, empennage and propellers.

(1) Weather conditions during the test period did not require the use of the deicing equipment, but functional tests were conducted. Deicing of wings and empennage was electrically controlled. The air was distributed through the operaton of solenoids which operated in sequence through an electric timer (Eclipse Timer No. 1010). This timer operated satisfactorily at temperatures above -5°F. Below this temperature, the timer failed to operate and inflation of the de-icing boots was impossib e. Fabric deicer boots (Goodrich Type II) were installed and functional tests were conducted. The fabric boots were very satisfactory.

k. Wing and engine covers.

(1) Waterproof paulin, Stock No. 2000-733000, made by Crawford Mfg. Co. was used on this aircraft. Covers shrunk in size after they became cold and wet and breaks and tears occurred readily. Observation of paulin, Stock No. 2000-666500 (not waterproof) on other aircraft indicated that the untreated covers did not tear so easily. It is also suggested that bungee cord, rather than rope, be used to tie the covers in place.

(2) Engine covers were satisfactory. Leather straps on the zippers would make it easier to put on the engine covers.

l. Snow and ice tires.

(1) The synthetic rubber non-skid tires held up very well during the testing period. Approximately 200 landings were made with the tires. U. S. Rubber Company tires, type S-6 with a compound of 70% GRS and 30% natural rubber, were installed on the main wheels. General Tire and Rubber Company type L-4J tire was installed on the tail wheel. The tires did not incorporate ice grip springs or "bottle caps" and skidded easily on packed snow or ice covered runways.

m. Dilution and scavenging characteristics of oil system.

(1) No discrepancies with the oil dilution or scavenging systems were noted.

n. Accessibility and effectiveness of oil and fuel drains.

(1) It is suggested that a hinged door be made on the bottom side of the ring cowl for better accessibility to engine sump drain. This will prevent oil from running on the inside of the ring cowl. The Koehler, Part No. K-1450D, self-locking drains which were installed on the "Y" drains of this aircraft were very satisfactory. It is suggested the self-locking drains also be installed on the fuel drains and wherever applicable. The small preheat doors on either side of the nacelle were much too small for the use of ground heater ducts. It is suggested that the pre-heat doors be made approximately 12 inches in diameter. The hose extension from the oil tank sump drain through the cowling was very satisfactory and should be made a permanent installation so that the inside of the nacelle may be kept clean.

o. Adequacy and selectivity of carburetor heat.

(1) Extensive tests were conducted on carburetor heat at various altitudes and various power settings. See Appendix V.

p. Freezing of condensate in oil, fuel lines, vent lines and breathers.

(1) No unusual troubles were noted.

q. Flight and navigation instruments.

(1) No failures were noted. At temperatures below —15°F. the Jack and Heintz flight indicator be came sluggish in movement.

r. Engine instruments.

(1) No failures or deficiencies were experienced.

s. Guns and fire control equipment.

(1) No tests were made on this equipment.

t. Bombing equipment.

(1) One test was conducted on the electric bomb release shackles and operation was satisfactory.

u. Radio equipment.

(1) On several occasions during the test period, the "gain" set screw on the VHF radio had vibrated off its set position which caused an off-frequency transmission which was weak and garbled, and a high pitch side tone could be heard when the microphone button was depressed. It is suggested that a method of *locking* the "gain" set screw be installed to insure against movement through vibration.

v. Electrical equipment.

(1) No failures or deficiencies were experienced.

w. Engine starting.

(1) Consistent starting of the engines without preheat at temperatures below —30°F. was not possible even though oil dilution for that temperature was sufficient.

x. Engine operation in flight.

(1) No discrepancy in flight operation was noted.

C. CONCLUSIONS

1. Operation of the standard B-17G aircraft at temperatures down to —40°F. is possible if the following changes are made:

a. Engines serviced with synthetic oil for easier starting and to insure propeller feathering.

b. Winterized hydraulic seals installed and winterized hose and connectors installed.

c. Approved lubrication for control and trim tab system be provided.

2. Operation of the standard B-17G can be simplified and improved if the following changes are made:

a. Heating of airplane be accomplished by use of heat exchangers, or if a combustion heater is used, a better system of ignition be incorporated in the system.

b. K-1450D-6 self-locking drains be used wherever applicable.

c. Quick disconnects for batteries be made a standard installation.

d. Oil tank sump drain be extended and routed through the cowling.

e. A hinged door be made on the bottom of the ring cowl for accessibility to engine sump drain.

3. Testing indicated that the experimental equipment installed in the subject airplane is satisfactory or unsatisfactory to the temperatures encountered as indicated below:

a. The Stewart Warner 2000,000 BTU/hr. combustion heaters, Model 911A, operated up to 30,000 ft. on only two flights. At low altitudes (below 20,000 ft.) subject heaters operated satisfactorily. At altitudes above 20,000 ft. and temperatures below —55°F. operation was rarely satisfactory. The heat supplied to the pilot's compartment met winterization requirements but in the navigator's compartment and radio compartment heat supplied met only approximately 80% of winterization requirements.

b. Feathering of the Aeroproducts propeller at temperatures below —50°F. was unseccessful with all other oils except AN-VVO-366a. An increase of nitrogen pressure in the accumulator was also necessary. Mechanical failure was also considered to be partly the cause for unsuccessful feathering. Data were submitted in Propeller Laboratory reports for 1944-45. Further development of propeller is suggested. The hydraulic feathering system used in conjunction with the Hamilton Standard propeller was very unsuccessful. The use of synthetic oil with the standard feathering system was the most satisfactory method for low temperature feathering.

c. Both "V" type paacking and "O" ring packing were satisfactory.

d. Carburetor heat system on No. 1 engine did not meet the requirements for carburetor heat at 65% of normal rated power at sea level, with the shroud and restrictor plate combination which would not handicap normal engine operation.

e. High speed feathering pump was not satisfactory.

f. Control system lubrication Tg 455 grease was satisfactory.

g. Synthetic rubber tires were satisfactory.

h. Cable tension compensators were unsatisfactory.

i. Plastic ring cowl cracked due to vibration.

j. Synthetic rubber engine mounts were satisfactory.

k. Dole Valve Company vacuum selector valve, Part No. Exp - 2165, was satisfactory.

l. The experimental deicer boot actuating system was satisfactory at temperatures above —5°F. At temperatures below —5°F. it failed to operate.

m. Goodrich type 11 fabric deicer boots were satisfactory.

n. Engine instruments, flight instruments and Gyro Fluxgate compass were satisfactory.

D. RECOMMENDATIONS

1. It is recommended that the changes listed in C 1 and C 2 be incorporated in future production airplanes.

Cold Weather Test of B-24J Airplane

Prepared by: Donald W. Mills, 1st Lt., A. C.

A. PURPOSE

1. To report on the cold weather testing of ATSC B-24J No. 44-41378 at Ladd Field, Alaska, for the winter of 1944-45.

B. FACTUAL DATA

1. The minimum ground temperature encountered during the testing of B-24J, No. 44-41378, was —45°F, and the mean temperature of the coldest day was —30°F. The lowest temperature encountered in flight was —59° F, to which the airplane was exposed for 20 minutes.

2. For a record of flying time and ground temperatures during the test period, see Appendix I.

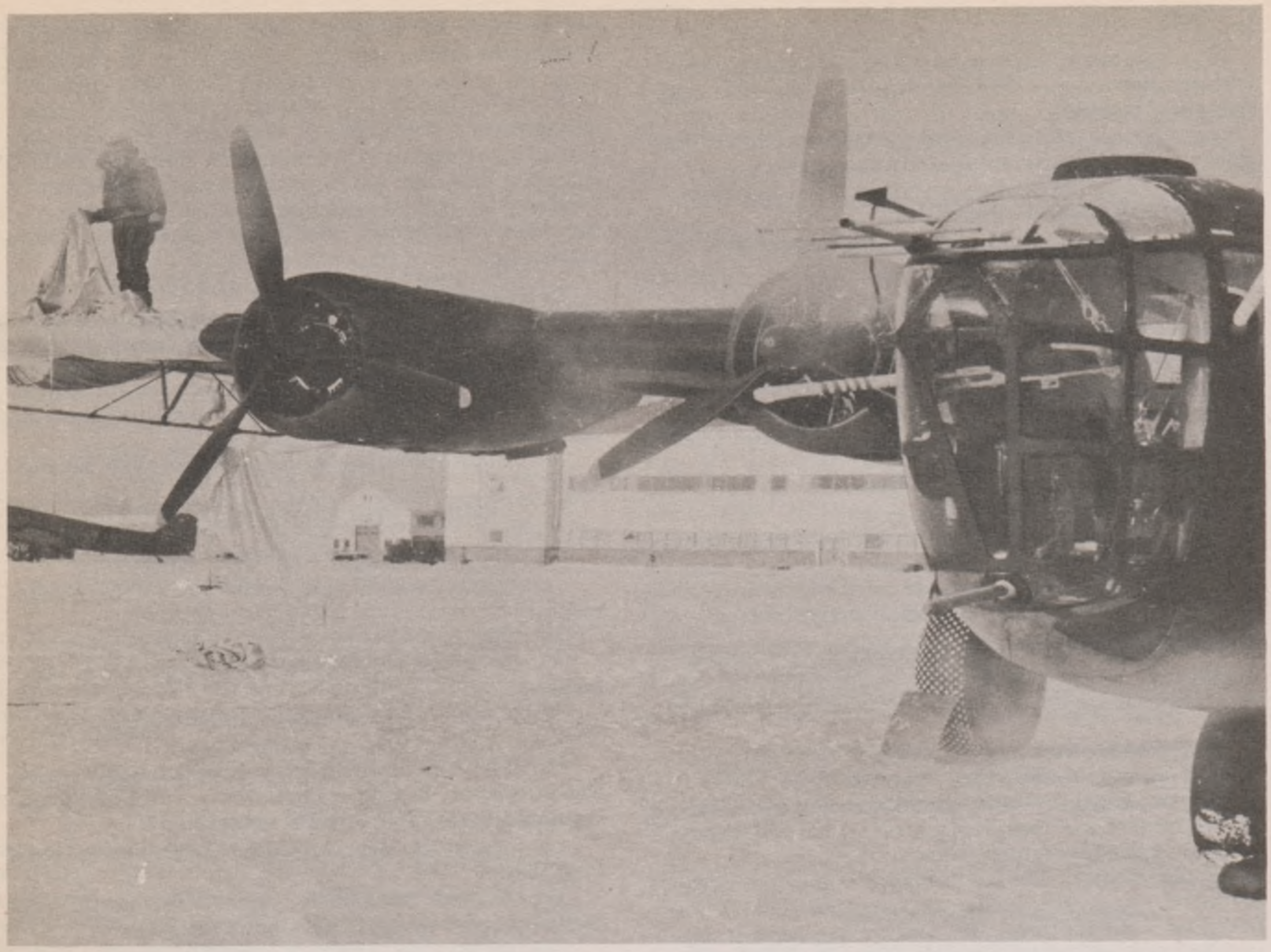
3. Listed below are the items tested and the results obtained:

a. Lubricants and hydraulic fluid.

(1) Synthetic oil PPO-265 was used in all four (4) engines for the entire test period. On No. 2 engine a test feathering system (See Appendix IV) was installed which used hydıaulic fluid AN VVO-366B for feathering. See Appendix II.

(2) Test lubricants were used in the bombsight and in four (4) starters which were installed on 20 January 1945. See Appendix II.

b. Rubber and synthetic, hydraulic, instrument, fuel and oil line hose and connectors.



B-24 Preflight

(1) All connectors were satisfactory and no deficiencies were noted.

c. Weatherstripping and fuselage seals.

(1) All fuselage seals and stripping were very satisfactory and clear view panels did not leak.

d. Hydraulic actuating systems and shock struts.

(1) Experimental "O" ring packings were installed on the left main gear and the nose gear, and were satisfactory. Tear-down inspection will be made at Wright Field.

(2) The flap actuating system malfunctioned at temperatures of +20°F and below, in that the flap handle would not remain in down position without applying constant pressure. It was found that back pressure in the lines due to increased viscosity of fluid by cold temperature was causing increased operating pressure, thus causing the handle to kick out early. A run-around valve was installed to release this back pressure, and since installation no malfunctions were noted.

e. Hydraulic and fluid seals and packings.

(1) Upon oil change of all engines from 1100 to PPO 265 and after approximately 25 hours of operation, all four propeller blade seals leaked as the weather became warmer or ship was put in the hangar. When oil was cold, no leakage was noted. All blade seals were changed, and leakage was again controlled for another 50 hours, at which time they started leaking very slightly.

(2) No other leakage or malfunction was noted on subject airplane.

f. Surface control system.

(1) The main control cables on all B-24's are now being equipped with hydraulic compensators, which consist of a hydraulically-actuated piston which will vary tension with change in temperature. These compensators proved satisfactory to a temperature of —49°F. However, it is the opinion here that they are satisfactory only in climates for which the tensions have previously been set. (See Appendix III).

g. Propeller controls and feathering systems.

(1) In an attempt to obtain satisfactory feathering below —40°F, a test feathering system using hydraulic fluid AN-VVO-366A or B was installed on No. 2 engine. This system consists of a hydraulic reservoir and feathering pump located in the bomb bay and a feathering pump located in No. 2 nacelle. See Appendix IV.

h. Cargo, cabin and cockpit space heating.

(1) There is no heating system installed for heating of the bomb bays or rear compartment.

(2) The cockpit and cabin heat was very satisfactory at all altitudes and temperatures. The subject airplane was the heated wing model which used heat exchanges for cockpit heat.

(3) The installation of the A-15 Emerson nose turret is not air-tight. A flight was made to 12,000 feet and with an airspeed of 180, the measured airflow coming in the bottom of the turret was 1800 feet per minute.

This leakage made heating of the forward compartment impossible.

i. Defrosting and deicing of windshields and transparents on the ground and in flight.

(1) Defrosting and deicing of all cabin windows and windshields was very satisfactory at all temperatures on the ground and in flight. Bombardier's compartment was satisfactory in flight due to cold air stream from nose turret, but was unsatisfactory on the ground.

j. Deicing of wings, empennage and propellers.

(1) No data was recorded due to the fact that no icing conditions were encountered.

k. Wing and engine covers.

(1) Engine covers were used only two times, and on both occasions were satisfactory. These were the standard Crawford Mfg. Co. covers.

(2) Test wing covers manufactured by the Crawford Mfg. Co. were installed, but they were unsatisfactory due to improper fit around engine nacelles. These covers had been waterproofed and had interlinking method of attachment, which was very satisfactory.

(3) Standard B-24 wing covers manufactured by Crawford Mfg. Co. were satisfactory for all necessary use and were used for all operation.

l. Snow and ice tires.

(1) No difficulties were encountered with ice-grip tires which were installed on subject airplane. Type of tires was S-6, 16-ply, nylon, 56", numbers U4K1 and U4K2. Nose tire was S-6, 10-ply, rayon, 36" L4L1.

(2) Braking on ice was satisfactory and no appreciable slippage was encountered.

(3) The only trouble encountered as a result of 208 landings was three tube failures, two of which were main tubes and one nose wheel tube. Main tube failures were due to slow leakage around valves, and nose tube was a pulled valve.

m. Scavenging and dilution characteristics of oil system.

(1) No scavenging tests were run, but engines scavenged all normal dilutions.

n. Accessibility and effectiveness of oil and fuel drains.

(1) A test Koehler, self-locking "Y"-drain, part No. 0-1450D-6, was installed on No. 3 engine, and was greatly preferred over the standard type drain, due to greater ease of operation.

(2) The installation of the oil tank sump drain in the inlet line to the feathering pump was a great help in accessibility to draining. The hinged access door provided on the nacelle to facilitate drainage of the drain cock on the inlet line to feathering pump is also of great advantage.

o. Adequacy and selectivity of carburetor heat.

(1) Due to inadequacy of carburetor heat on B-24 airplanes, an experimental system was installed on No. 2 engine. For discussion of system and results, see Appendix V.

p. Freezing of condensate in all lines and breathers.

(1) All operation was satisfactory and no difficulties were encountered.

q. Flight and navigation instruments.

(1) With cockpit heat ON, all instruments operated satisfactorily at all outside temperatures. However, with no heat in cabin, flight instruments were inoperative at temperatures of —35°F and below.

r. Engine instruments.

(1) All equipment was standard, and no malfunctions or deficiencies were encountered.

s. Guns and fire control equipment.

(1) The standard upper turret dome was cracked and broken because of greater shrinkage of airplane and not enough tolerance in dome. This situation was also noticed on other B-24's at this base.

(2) The problem was remedied by filing approximately 1/16 of an inch off the inside diameter of the bottom of the dome. Operation thereafter was satisfactory.

t. Bombing equipment.

(1) No malfunctions or deficiencies noted.

u. Radar and radio equipment.

(1) The SCR-296G Radio Compass at temperatures of —30°F or below would require a warm-up of from 10 to 15 minutes for proper operation.

(2) All other radio installations were satisfactory.

v. Electrical equipment.

(1) The external power plug located on the right of the fuselage just forward of the bomb bay was removed just to the rear of the nose compartment forward of the No. 3 propeller on the right side. This installation was very good and was much more comfortable to the crew when disengaging the external power plant. The access door was spring loaded, and the installation was such that the slip stream aided in keeping the door closed.

(2) Recommendation is made that this installation be made on all B-24's for winter operation.

w. Engine starting.

(1) Engine starting was satisfactory in all attempts with proper dilution and heat being added prior to starting. Cold starts were attempted twice at temperatures of —30°F and below with no results.

(2) One cold start was accomplished by placing a heater duct on the carburetor air filter, and turning on the filter to draw warm air into the engine.

x. Engine operation in flight.

(1) All engine operation in flight was satisfactory.

(2) The result of the mixture of PPO-265 oil with AN-VVO-366A hydraulic fluid in No. 2 engine was very satisfactory. Samples have been sent to Wright Field for analyzing and further data will be available from the Power Plant Laboratory.

C. CONCLUSIONS

1. It is concluded that:

a. Operation of a standard B-24 aircraft down to —45°F is possible if the following essential changes are made:

(1) Engines serviced with synthetic oil PPO 265 to make propeller feathering possible.

(2) Run-around valve be installed in hydraulic system to relieve back-pressure.

(3) Upper turret dome be fitted with 1/16" more tolerance.

b. Operation of standard B-24 aircraft down to —45°F can be simplified and improved if the following changes are made.

(1) A more adequate carburetor heat system installed.

(2) External power receptacle relocated.

(3) Nose turret sealing improved.

(4) Self-locking Y-drains with hinged access doors installed.

(5) A means of heating the belly turret, tail turret and waist gun sections, be provided.

c. Testing indicates that the experimental equipment installed in the subject airplane was satisfactory or unsatisfactory to the temperatures experienced as indicated below.

(1) Carburetor heat system—unsatisfactory.

(2) Landing gear packing—satisfactory.

(3) Propeller feathering system—satisfactory.

(4) Landing gear "run-around" valve—satisfactory.

(5) Snow and ice tires—satisfactory.

(6) Minneapolis-Honeywell formation stick—satisfactory.

D. RECOMMENDATIONS

1. It is recommended that the changes listed in C.1.(a) and C.1.(b) above be incorporated in future production airplanes.

Cold Weather Test of B-25J Airplane

Prepared by: Walter I. Thieme, Capt., A. C.

A. PURPOSE:

1. To report on the cold weather testing of ATSC B-25J-22 No. 44-29258, at Ladd Field, Alaska, during the winter of 1944-1945.

B. FACTUAL DATA:

1. The minimum ground temperature encountered during the testing of the subject airplane was —56°F. and the mean temperature during the coldest 24 hour period was —37°F. The coldest engine start was at —55°F. and the coldest take-off was at —42°F. These temperatures were encountered at Snag, Yukon Territory, 13 to 15 February. No lower temperatures were encountered in flight.

2. For a record of flying time and ground temperatures during the test period, see Appendix I.

3. Listed below are the items tested and results obtained.

a. Lubricants and Hydraulic Fluid.

(1) Synthetic engine oil, PPO-265, was used with good results on both engines. Since this oil was used in both engines, no direct comparison with 1100A oil is possible, but it is the opinion of operating personnel that engine starting, warm-up, and propeller feathering were improved over 1100A.

b. Hyraulic, instrument, fuel and oil line hose and connectors.

(1) Goodyear R-80, R-50, R-8, and R-5, Goodrich H-40, H-4, H-30, and H-3, and Hewitt Rubber Co. T-4 types of experimental oil line hose were tested on this ship. Materials Laboratory personnel state that, with the exception of the Goodrich H-3, the experimental hose has proved to be superior to the standard AN-H-26A or AN-22-H-456A, with regard to cold flow. No blown oil lines were encountered with either production or experimental types. No difficulties were encountered with instrument, hydraulic or fuel hoses.

c. Weatherstripping and Fuselage Seals.

(1) Hatch and window seals have been generally unsatisfactory. In order to freely open and close the front and rear hatches, a longitudinal strip had to be cut from the weatherstripping. The seals along the pilot's and co-pilot's sliding windows were permanently deformed and ineffective. Seals with better cold weather characteristics are recommended.

d. Hydraulic actuating systems and shock struts.

(1) Leakage of hydraulic fluid from the tail turret was experienced in Ohio during warm weather and the continued leaking during the winter cannot be classed as primarily winterization difficulty. For difficulties encountered with the carburetor heat rise actuating system, see Item O. All other hydraulic systems were entirely satisfactory. Experimental non-inflammable fluid was used in the left main and nose struts, with no difficulties or leakage encountered.

e. Hydraulic and fluid seals and packings.

(1) No difficulties encountered.

f. Surface control systems.

(1) Operation of all primary and trim-tab controls at —56°F. was satisfactory and not difficult.

g. Propeller controls and feathering system.

(1) Cold weather feathering tests were not conducted on this airplane. However, using synthetic oil and normal dilution procedures, pre-flight feathering checks were conducted without any failures, although under cold conditions, several seconds were required after the button was pushed before the RPM would begin to drop.

h. Cabin, cockpit, and cargo space heating.

(1) Since this ship was not instrumented to give cabin heat temperatures, no information can be given as to whether winterization requirements were met. However, from an operational point of view, the system was generally satisfactory. The heaters have approximately 80 hours of operation, with no difficulties and no maintenance performed, although their output is known to be reduced. Ground operation of the forward heater for 30 minutes on 14 February 1945 could only raise the pilot's compartment temperature from —48°C to —38°C. The cause for this poor heating is unknown, as the unit had previously operated satisfactorily on the ground and subsequently raised the pilot's compartment temperature to 0°C. in flight, although the free air temperature had also increased. Leakage around the hatch and sliding windows causes much of the turret heaters' output to be blown back through the tunnel. For this reason, outlets forward, say under the package gun ammunition boxes, would be more satisfactory. In general, the necessary arctic clothing, plus the airplane heating system, was satisfactory for the temperatures encountered.

i. Defrosting and deicing.

(1) Due to the generally satisfactory operation of the defrosting system, the clear-view panel was never installed. Under quite cold conditions, where the ground defrosting is necessary to prevent frost formation while taxiing, heater operation is limited by insufficient battery reserve to operate the heater blowers, radio, and necessary electrical equipment. No solution to this difficulty is seen with this type of installation.

j. Deicing of wings, empennage, and propellers.

(1) Satisfactory under moderate icing conditions encountered.

k. Wing and engine covers.

(1) Satisfactory.

l. Snow and ice tires.

(1) Spring-insert type ice grip tires have been used on this ship for 110 hours and 120 landings. Their operation has been satisfactory and little wear is evidenced to date. From experience flying Lend-Lease B-25's equipped with the bottle cap tires, it is concluded that the "bottle cap" has better ice-gripping qualities but apparently does not wear as well.

m. Dilution and scavenging characteristics of oil system.

(1) Scavenging was satisfactory with 28% dilution, the highest percentage tried. To give a greater fuel pressure drop when diluting, an .093 orifice was installed in the dilution fitting. With this fitting installed, 8 minutes gave 28% dilution.

n. Accessibility and effectiveness of fuel and oil drains.

(1) In the opinion of maintenance personnel, the self-locking drains are satisfactory and desirable, although leakage of the oil tank sump drain has been experienced. The Koehler K-1700B fuel drains are particularly well liked. The Y-drain is regularly drained but the oil tank sump is not, as very little condensate is encountered except when extreme temperatures are encountered.

o. Adequacy and selectivity of carburetor heat.

(1) Installed on this airplane is the exhaust-gas carburetor heat system which is now in production on B-25J airplanes, Extensive tests conducted throuughout the winter have shown this system to be unsatisfactory as presently installed. The main unsatisfactory feature is that the heated air is introduced in such a manner that it stays along the sides of the carburetor throat. The relatively cold air still being admitted from the ram airscoop strikes the altitude valve, resulting in a richening of the mixture when carburetor heat is used. This feature prevents the successful use of carburetor heat on take-off as an aid to vaporization and distribution in cold weather. Appendix II reports how this difficulty was corrected and the suggested changes in the carburetor heat system. Refer to report "B-25 Carburetor Heat System" in this Section. This heat system meets requirments of 90°F heat rise at 65% normal rated power.

p. Freezing of condensate in oil and fuel lines, vent lines, and breathers.

(1) Failure of the right engine to develop fuel pressure on 17 December was traced to ice completely filling the main fuel line in the bombbay between the boost pump and the cross-feed connection. All fuel drains had previously been checked and were still found to flow gasoline, although the flow from the front main tank was slight. The ship was put in the hangar, warmed, and 1½ to 2 gallons of water drained from the right front main fuel tank. Because of the quantity involved and since the other tanks werefree, it must be concluded that the water was admitted from or during servicing. This incident showed that:

(*a*) Freezing occurred in the fuel line even though it is not trapped and there are drains above and below it.

(*b*) The flow of fuel from a drain is not a reliable indication that no ice exists.

(*c*) In cold weather operation, the only time accumulated moisture in the fuel system can be removed is after the ship has been exposed to melting temperatures for some time.

q. Flight and navigation instruments.

(1) No difficulties encountered.

r. Engine instruments.

(1) Trouble with the A-1 type of transmitter has been confined to one case where the fuel pressure rose to 9 psi in flight. However, previous troubles and trouble on other ships have caused the writer to lose faith in the indications of this type of gauge.

(2) From both maintenance and operational standpoints, the value of the A-1 transmitter over the autosyn or magnesyn type instrument is questioned.

s. Guns and fire control equipment.

(1) Armament Laboratory personnel concluded that the eight gun nose charging system was satisfactory for the temperatures encountered. At —56°F. the compressor operated very slowly and was a heavy load on the electrical system, but in the subsequent flight it built up the pressure to the cut-out value.

t. Bombing equipment.

(1) No bombing tests were conducted on this airplane.

u. Radio and radar equipment.

(1) At —40°F. the tuning control of the radio compass was so stiff it could not be turned. After approximately 20 minutes of operation of the airplane heaters the unit could be tuned and approximately 10 minutes later it would operate on the "compass" position.

v. Electrical equipment.

(1) Three failures have occurred with the induction vibrator, Bosch VJH24B5X, either due to ground or burning out. These failures are being investigated by the Power Plant Laboratory and no conclusions are available.

w. Engine starting.

(1) No "cold starts" were attempted with this airplane and the reliability of cold starting below —20°F. is questioned. For operation under arctic conditions, the use of external heat is, at the present time, the most practical method of starting.

x. Engine operation on the ground and in flight.

(1) See Appendix III.

C. CONCLUSIONS

1. It is concluded that operation of the standard B-25J airplane is possible down to —30°F. if:

a. The diffuser plate is installed below the carburetor.

2. Operation of the B-25J airplane down to —30°F. can be improved if:

a. The carburetor heat system is modified.

b. Synthetic oil is used to aid propeller feathering.

c. The radio compass is made more reliable.

d. A restrictor is installed in the oil dilution tee to give a fuel pressure drop when diluting.

e. The weatherstripping is improved.

3. Operation of the B-25J below —30°F. requires:

a. Improvement of the distribution, fuel vaporization or carburetion beyond its present status, or—

b. The increasing of the available manifold pressure so takeoff manifold pressure can be secured when using carburetor heat to correct the above conditions.

4. Testing indicates that the experimental equipment installed in the subject airplane is satisfactory or unsatisfactory to the temperatures experienced as indicated below:

Synthetic rubber engine mounts	—	Satisfactory
Non-inflammable strut fluid	—	Satisfactory
Test oil hose	—	Satisfactory
Automatic oil dilution control	—	Inconclusive

D. RECOMMENDATIONS

1. It is recommended that the changes listed in C1 and C2 above be incorporated in future production airplanes, and that action be taken on the problem in C3 above to permit satisfactory operation at temperatures below —30°F.

Cold Weather Test of B-29 Airplane

Prepared by: Joseph A. Festersen, 1st Lt., A. C.

A. PURPOSE

1. To report on the Cold Weather Testing of A.T.S.C. B-29, serial number 42-34612 at Ladd Field, Fairbanks, Alaska for the winter of 1944-1945.

B. FACTUAL DATA

1. The minimum ground temperature encountered during the testing of B-29, No. 42-24612 was —29°F. and the mean temperature of the coldest day was —26°F. The lowest temperature encountered in flight was —74°F., to which the aircraft was exposed for 80 minutes.

2. For a record of flying time and ground temperatures during the test period, see Appendix 1.

3. Listed below are the items tested and the results obtained.

a. Lubricants and hydraulic fluid.

(1) No malfunctions.

(2) Engines 1-4 have synthetic oil No. PPO 265 and engines 2-3 have No. 1100 oil. Superchargers of all engines have hydraulic fluid No. 366A. All other lubricants and hydraulic fluids are standard.

(3) Hydraulic fluid in engine superchargers showed no appreciable leakage at temperatures of plus ten to fifteen degrees F. and colder, but leaked up to ¼ gallon per hour at temperatures of plus twenty to thirty degrees F. on the ground. At air temperatures of minus ten degrees F. and colder, no appreciable amount of fluid was used but at 0 degrees F. and warmer ½ gallon was used in three hours of supercharger action.

b. Rubber and synthetic, hydraulic, instrument, fuel, and oil line hose and connectors.

(1) No malfunctions.

(2) Standard installations.

c. Weatherstripping and fuselage seals.

(1) No malfunctions.

(2) Standard installations.

d. Hydraulic actuating systems and shock struts.

(1) Main shock struts were low every fifth day with a load of 117,000 lbs. gross weight on airplane overnight and temperature of —15°F. and colder. No leakage was apparent.

(2) Standard Installations.

e. Hydraulic and fluid seals and packings.

(1) No malfunctions.

(2) Standard installations.

f. Surface control system.

(1) No. malfunctions.

(2) Standard installations.

(3) Cable tensions were measured and found to be below normal as follows:

	Normal	Reading	Reading
Ailerons	100 lbs.	65 lbs.	62½ lbs.
Rudder	100 lbs.	57½ lbs.	51 lbs.
Elevator	150 lbs.	55 lbs.	47½ lbs.
Aileron trim tab	40 lbs.	11 lbs.	10 lbs.
Rudder trim tab	30 lbs.	32 lbs.	30 lbs.
Elevator trim tab	60 lbs.	18 lbs.	15 lbs.

Ground temperature at time of first reading was plus ten degrees F.

Ground temperature at time of second reading was minus six degrees F.

Tensions on cables were adjusted to normal at a ground temperature of plus seventy-five degrees F.

g. Propeller controls and feathering system.

(1) No malfunctions.

(2) Standard installations.

(3) See appendix II for results on "Feathering Tests" and "Electric Propeller Head Tests".

h. Cabin, cockpit, and cargo space heating.

(1) No malfunctions.

(2) Standard modified B-29 heating system.

(3) Comparison of cabin and outside air temperatures.

Outside air temperature	*Cabin air temperature*
—50°C	20°C
—40°C	24°C
—30°C	28°C
—20°C	30°C

Turbo-supercharger control on No. seven position. Airplane was not preheated.

B-29 Airplane No. 42-34612

i. Defrosting and deicing of windshields and transparent on the ground and in flight.

(1) Nose glass will frost before take-off if the airplane is not preheated. The defrosting system will take the frost off within five minutes after take-off. Nose glass will ice at altitude if there is no heat being used, the defrosting system will take it off.

(2) Standard modified B-29 defrosting system.

j. Deicing of wings, empennage and propellers.

(1) No malfunctions.

(2) Standard installations.

(3) Deicer boots and propeller anti-icer fluid were used twice and worked satisfactorily. Ice encountered was approximately one quarter to three quarters of an inch.

(4) Vacuum selector valve freezes and cannot be moved manually. No condensation was found in the valve but with heat applied valve moved freely, indicating metal binding in valve at low temperatures.

k. Wing and engine covers.

(1) No malfunctions.

(2) Standard installations.

(3) Covers were used raily and were very satisfactory.

l. Snow and ice tires.

(1) No malfunctions. (71 landings).

(2) Standard 56" rayon tires. (snow and ice).

m. Dilution and scavenging characteristics of oil system.

(1) No malfunctions.

(2) Dilutions, fuel flow from dilution orifice, burn off, and scavenging tests were made on the ground and in flight. All tests were satisfactorily completed and complete data is being reported by Power Plant Laboratory, Wright Field.

(3) See Appendix III for dilution conclusions.

n. Accessability and effectiveness of oil and fuel lines.

(1) No malfunctions.

(2) Sump drains rerouted and lengthened on all engines. These lines have worked very satisfactorily.

o. Adequacy and selectivity of carburetor heat.

(1) No malfunctions.

(2) Standard installations.

p. Freezing of condensate in oil, fuel, coolant, vent, and breather lines.

(1) No malfunctions.

(2) Oil tank vent lines were rerouted and straightened to eliminate traps. These lines have worked very satisfactorily.

q. Flight and navigation instruments.

(1) Gyro instruments are sluggish and return to normal slowly.

(2) Standard installations.

(3) Complete vacuum system checked and cleaned, a test gage was installed at various places of system to check vacuum and all instruments were changed.

(4) Pilot believes this is a characteristic of the plane and not a cold weather malfunction.

r. Engine instruments.

(1) No malfunctions.

(2) Standard installations.

s. Guns and fire control equipment.

(1) Guns have not been fired.

t. Bombing equipment.

(1) Bombing equipment has not been used.

u. Radio and radar equipment.

(1) No malfunctions.

(2) Standard installations, no radar installed.

(3) Radios have worked very well and have given good range and clarity of signal. Following radios installed.

a. XMTR BC-375-E Rec BC-348M
b. SCR 274-N
c. REC AM/ARN-7
d. REC RG-39
e. SCR-RC-36
f. IFF-695-A
g. VHF-SCR-522

v. Electrical equipment.

(1) No malfunctions.

(2) Standard installations.

w. Engine starting and operation in flight.

(1) Airplane is equipped with fuel injection service test engines.

(2) See Appendix IV for results.

C. CONCLUSIONS:

1. If the engines are properly diluted, it is possible to start and operate a B-29 airplane down to a temperature of —20 degrees F. If heat is applied to the engines before starting, the engines can be started and operated at temperatures below —20 degrees F. Proper dilution of Synthetic PPO 265 oil has been satisfactory on cold starting down to —20 degrees F. No temperatures lower than —20 degrees F. were encountered so it isundetermined how cold the temperature can get and still obtain satisfactory results from cold starting.

It is the opinion of the Project Officer that if enough of the fuel could be vaporized at temperatures below —20 degrees F. then it would be possible to make cold starts and get satisfactory results at temperatures of —40 degrees F. and below.

2. The following recommendations are made to simplify and improve the operation of the B-29 airplane.

a. Air lock fasteners be installed on access doors to oil "Y" drain and oil sump drains on Engines Nos. 2 and 3.

b. Straighten oil tank vent lines to eliminate traps.

c. Lengthen and route overboard, oil sump drains on engines 2 and 3.

d. Lengthen oil sump drain lines on engines 1 and 4, move petcock to end of line and install a small access door in the main bottom access door to make petcock accessible.

e. Orifice openings be enlarged on the dilution "Y" fitting which is located between the Master Control Unit and the Oil Dilution Solenoid. The present fitting has too small an opening, preventing a high enough fuel flow rate to obtain a high percent of oil dilution.

SUMMARY OF APPENDIX IV

Conclusions of Pilot, Project Officer on Arctic Operation of B-29 Fuel Injection Engines.

1. The fuel injection engines have been very satisfactory during the winter tests. Engine operation in flight and starting has been satisfactory. Fuel consumption has been equal, or better than, the carburetor type engine. Engine warm-up has been much shorter and cylinder head temperatures have run 10°C to 20°C cooler on take-off and cruise. Engines have started in temperatures of +10°F. very satisfactorily, but when starts were attempted at —20°F. engines failed to start without using the primer; therefore, it is inadvisable to discontinue use of primer in future production engines until further tests have been performed.

2. Starting procedure, as outlined in Test Program submitted by the Power Plant Laboratory for both Bendix and Bosch injection systems, gave the best starting results in starting without use of primer. Stopping procedures as outlined in T. O. 02-1-29 are satisfactory, except for the fact that oil locks occured in the bottom cylinders. To prevent this, the propellers were pulled a minimum of eight blades twice at 15 minute intervals after stopping engines.

Cold Weather Test of B-29 Airplane

Prepared by: Stuart H. Murphy, Maj., A. C.

A. PURPOSE

1. To report on the cold weather testing of ATSC B-29-11-MO, AAF Serial Number 42-65214 at Ladd Field, Fairbanks, Alaska for the winter of 1944-45.

B. FACTUAL DATA

1. The minimum ground temperature encountered by the subject airplane was —45°F and the mean temperature of the coldest day was —30.2°F. The lowest temperature encountered in flight was —58°F. to which the airplane was exposed for two hours.

2. For a complete record of flying time and temperature, see Appendix I.

3. Listed below are the items tested and the results obtained:

a. Lubricants and hydraulic fluid.

B-29 Airplane No. 42-34612

(1) No. 2 and 3 engines were serviced with synthetic oil PPO-265 for comparison with regular oil grade 1100A in Engines No. 1 and No. 4. No signs of engin roughness or excessive sludge were noted. Hydraulic fluid was satisfactory.

(2) Left landing gear retracting motors, surface control locks, and elevator trim tab controls were lubricated with special winter lubricant. Operation was satisfactory to —45°F on the ground and —58°F in flight. For difficulties with flap operation see Appendix V.

b. Rubber and synthetic hydraulic, instrument, fuel and oil line hose and connectors.

(1) Installations were standard and no malfunctions were noted.

c. Weatherstripping and fuselage seals.

(1) Considerable air leakage was noted at altitudes between 25,000 and 30,000 ft. Cabin altitude cannot be maintained at 30,000 ft. on one engine. Leakage cannot be confined to any definite location, but numerous small leaks have been found which are not practical to repair during test season. This deficiency cannot be attributed to cold weather.

d. Hydraulic actuating systems and shock struts.

(1) "O" ring packings were used in the left main landing gear and nose gear. All struts were satisfactory and showed no signs of leakage.

e. Hydraulic and fluid seals and packings.

(1) No malfunctions or deficiencies were noted except for leakage of the nose wheel shimmy damper at low temperatures.

f. Propeller controls and feathering systems.

(1) Considerable trouble was encountered with the electric governor heads. Failure was in resistor and clip breakage and could not be attributed to cold weather.

(2) Hydraulic fluid feathering systems were installed in engines 1 and 4. Feathering tests were conducted in temperatures as low as —58°F. Tests indicated that the regular feathering system with synthetic oil operates considerably better than hydraulic feathering system with regular oil grade 1100 inasmuch as 1100 grade oil congeals in propeller dome at low temperatures. See Appendix II. Complete data are available from TSELA-3C8. (Propeller Laboratory).

g. Surface control systems.

(1) Flights were made in temperatures down to —58°F, and controls were noticed to be slightly stiff. However, this stiffness was not excessive.

h. Cabin, cockpit and cargo space heating.

(1) The airplane arrived with supercharger flight covers removed, which greatly reduced the heat output of the standard heating system. Two test Stewart Warner combustion heaters, one in the nose for emergency defrosting and the other to heat the auxiliary power unit were installed. The nose heater, which is fan operated, more than maintains comfortable temperatures in the cockpit down to —35°F and serves excellently as a defroster. This installation could not be made standard as it was necessary to remove front sighting station to make the installation. The auxiliary power unit heater, ram pressure operated, served satisfactorily as a heater in flight. This heater should be fan operated in order to use it as a ground heater in starting auxiliary power unit. These heaters are inoperative above 18,000 ft.

(2) It is believed that a nose heater is important and that it could be located on the ceiling between pilot and co-pilot for defrosting on the ground and emergency in flight. A heater of 15,000 BTU's per hour, fan operated, with a shroud directing heat to the carburetor air intake is believed sufficient for the A.P.U.

(3) Two Surface Combustion heaters installed in the bomb bay in the cabin supercharging ducts for cabin heating did not operate satisfactorily. See Appendix III. Complete data are available from TSEPL-3H4 (Equipment Laboratory).

i. Defrosting and deicing of windshield and transparent areas on the ground and in flight.

(1) Standard defrosting system was inadequate for defrosting on the ground and in flight before the supercharger shroud covers were installed. With covers installed, flight defrosting was improved but ground defrosting was not adequate as it is impossible to obtain sufficient cabin air flow. The Stewart Warner test heater installed in the nose served as an excellend ground defroster and served equally well in flight.

j. Deicing of wings, empennage, and propellers.

(1) Test fabric deicer shoes, Goodrich Type 11, were installed. Operation was satisfactory, and no failures were noted. Propeller anti-icers were operative but were not used under icing conditions.

k. Wing and engine covers.

(1) Wing and horizontal stabilizer covers were satisfactory but engine covers were impractical due to the excessive time required to install them.

l. Snow and ice tires.

(1) Synthetic-rubber, 18-ply-nylon, impregnated-wire, ice-grip tires were installed. Fifty-two landings were made on these tires and no failures or excessive wear was noted. Traction of these tires was satisfactory, however, considerable braking distance was required with severe ice conditions. Traction was sufficient for engine run-up.

m. Dilution and scavenging characteristics of oil system.

(1) Oil dilution system operation was satisfactory. "T" 1/8-inch pipe fittings were installed at the carburetor in place of the "Y" fitting to shorten dilution period. Even dilution of the system appears to be obtained, and no malfunctions were noted.

n. Effectiveness and accessibility of oil and fuel drains.

(1) Oil tank sump drains were rerouted slightly and lengthened, and "Y" drains were also lengthened in order that oil from these drains flows overboard and not into the cowling. Operation was satisfactory, and the installation was a definite maintenance advantage over the standard airplane. No difficulties were experienced with fuel drains.

o. Adequacy and selectivity of carburetor heat.

(1) Carburetor heat was entirely inadequate. For carburetor heat data, see Appendix IV.

p. Freezing of condensate in oil, fuel and coolant lines, vent lines, and breathers.

(1) Oil tank vent lines were straightened and rerouted slightly to eliminate traps which might cause freezing of condensate in lines. No difficulties were experienced.

q. Flight and navigation instruments.

(1) An electric-driven directional gyro and flight indicator were installed in addition to standard installations. Operation of the test directional gyro was satisfactory. Other flight instruments were unsatisfactory as two new horizons were replaced on pilot's side and one new horizon on co-pilot's side.

(2) Automatic pilot and formation stick operated satisfactorily. Air position indicator was ground checked and found to operate satisfactorily.

r. Engine instruments.

(1) No malfunctions other than routine maintenance were experienced. A-1 transmitters were satisfactory.

s. Guns and fire control equipment.

(1) Ground and air firing tests were run, and operation was satisfactory. Detailed firing tests were reported.

t. Bombing equipment.

(1) No tests were made.

u. Radio and radar equipment.

(1) The standard radar dome was found to fracture when cold if the nose turret was fired and the cartridge cases hit the dome. An improved airflow radar dome was tested and found to stand up much better under the impact of cases. A complete report was made by the Aircraft Radio Laboratory.

v. Electrical equipment.

(1) Two Eclipse, direct-drive starters were installed on engines two and three. Operation was satisfactory.

(2) A type D-2 Auxiliary Power Unit was installed and was operated by remote control from the engineer's station. Operation was satisfactory, and the unit was very dependable. Solenoid arrangement on throttle should be improved as the present system gives a very abrupt movement from idle to open throttle.

(3) Considerable difficulty was experienced with binding of the flaps at low temperature. See Appendix V.

w. Engine starting.

(1) Engines started easily in temperatures down to —20°F by application of some heat. It was noted that plugs foul easily and if engine was not started on the first attempt considerable roughness was noticed after the engine started.

x. Engine operation in flight.

(1) Operation was satisfactory, except for two engine failures. No. 1 engine showed metal on the sump plug, presumably a gear tooth, and No. 2 engine had a valve failure.

y. Miscellaneous.

(1) Vacuum system. The rearrangement of the vacuum system proved satisfactory. Vacuum selector valve did not freeze in temperatures down to —58°F in flight. Another B-29 at this station had considerable trouble with valve freezing with standard vacuum installation.

(2) Oil cooler controls. A test Airesearch floating-type oil temperature control with thermostatic valves, jack-screw actuator, and a UAP No. U3785 oil surge valve on No. 1 engine operated satisfactorily. See Appendix No. VII.

(3) Cabin regulators. Cabin altitude regulators operated satisfactorily in flights to 30,000 ft.

(4) Blister failures. One failure of the old type top gunner's blister was experienced.

(5) Carburetors. The test double-coated diaphragm and wide-angle poppet valve installed in No. 2 engine carburetor operated satisfactorily.

C. CONCLUSIONS

1. It is concluded that:

a. Operation of a standard B-29-11 aircraft down to —45° is possible if the following essential changes are made.

(1) Flaps be made operable at low temperature.

(2) A winterized shimmy damper be installed.

(3) PPO 265 oil used to aid cold starting, minimize spewing and make low temperature feathering possible.

(4) Defrosting and cabin heat systems made adequate. Heat must be provided for APU in flight and on the ground.

(5) Engine vent lines rerouted to prevent freezing of condensate in traps.

(6) Adequate carburetor heat be provided.

(7) A winterized vacuum selector valve be provided.

(8) A radar dome be installed which will stand up when nose guns are fired.

b. Operation of a standard B-29 down to —45°F would be simplified and improved if the following desirable changes were made.

(1) Immersion type oil heaters are unnecessary and provisions for their use may be deleted from airplane.

(2) Self-locking oil and fuel drains should be installed.

(3) Improved engine covers should be provided.

(4) Dilution fuel flow should be increased.

(5) Electric driven gyros, or winterized air gyros, should be provided.

(6) Handbook of Pilot's Operating Instructions should be revised. See Appendix VI.

(7) Cowling opening for preheat should be increased in size.

c. Testing indicates that the experimental equipment installed in the subject airplane is satisfactory or unsatisfactory to the temperature experienced as indicated below.

(1) E-1 gyro horizon and C-1 directional gyroscope (electrically driven)—satisfactory.

(2) Janitrol bomb-bay heaters in cabin air ducts —unsatisfactory.

(3) Stewart Warner nose and APU heaters—satisfactory.

(4) APU remote control—satisfactory if control over throttle is smoothed out.

(5) Goodrich Type 11 deicer boots—satisfactory.

(6) Modified deicer boot actuation—satisfactory.

(7) Experimental vacuum pump selector — satisfactory.

(8) "O" ring main and nose wheel strut packings—satisfactory.

(9) Synthetic oil PPO 265—satisfactory.

(10) Relubrication of control locks, elevator tabs and retracting motors—satisfactory.

(11) Hydraulic fluid feathering system — unsatisfactory as improvement is negligible.

(12) Increased dilution fuel flow—satisfactory.

(13) Rerouted engine vent lines—satisfactory.

(14) Self-locking "Y" drains with drainage hoses—satisfactory.

(15) Formation stick—satisfactory.

(16) Eclipse direct drive starters—satisfactory.

(17) Allison cold-start system—unsatisfactory.

(18) Revised vacuum system and vacuum selector—satisfactory.

(19) Airesearch oil temperature control—satisfactory.

(20) Double coated carburetor diaphragm — satisfactory, pending tear-down inspection.

(21) Airflow radar dome—superior to standard dome on impact strength.

(22) Synthetic main and nose wheel tires—satisfactory.

(23) Test feathering pump—satisfactory.

D. RECOMMENDATIONS

1. It is recommended that the changes listed in C.l.a. and C.l.b. above be incorporated in future production airplanes.

Cold Weather Test of C-47A Airplane

Prepared by: Beach Barrett, Capt., A.C.

A. PURPOSE

1. To report on the cold weather testing of A. T. S. C. C-47A-30-DK, Serial Number 43-48088, at Ladd Field, Fairbanks, Alaska, for the winter of 1944-45.

B. FACTUAL DATA

1. The minimum ground temperature encountered was —45°F and the mean temperature of the coldest day was —30.2°F. The lowest temperature encountered in flight was —53°F at 23,000 feet, to which the airplane was exposed for 30 minutes.

2. For a record of flying time and ground temperatures during the test period, see Appendix I.

3. Listed below are the principal items tested and results obtained.

a. Lubricants and Hydraulic fluid.

(1) Synthetic engine oil, PPO 265, was used in No. 2 engine and 1100A in No. 1 engine. The synthetic oil had the advantage of a lower viscosity index, which aided starting and feathering and decreased dilution time. (See Appendix II)
Although the Air Transport Command reported engine roughness attributed to synthetic oil, no roughness was ever encountered in the No. 2 engine of this ship. The only disadvantage observed was the increase in minor oil leaks with synthetic oil.

b. Rubber and Synthetic hydraulic, instrument, fuel and oil line hose connectors.

(1) No difficulties were experienced with connectors, which were standard.

c. Weatherstripping and fuselage seals.

(1) The cargo door seal cement failed to keep the seal bonded to the door, and it was never successfully cemented back in place. All other seals were satisfactory.

d. Hydraulic actuating systems and shock struts.

(1) Both the standard shock strut packing in the right gear and the test "O" rings in the left gear required no servicing with air or fluid all winter. Landing gear, flaps and cowl flaps operated normally.

e. Hydraulic and fluid seals and packings.

(1) No troubles requiring more than routine maintenance were encountered. All packings were standard except for one landing gear shock strut "O" ring.

f. Surface control systems.

(1) Standard controls and trim tabs were satisfactory.

g. Propeller controls and feathering systems.

(1) The standard propeller controls were satisfactory. Extensive feathering tests were run in which the effect of hydraulic oil for feathering, synthetic oil, and a special high-speed pump were observed. (See Appendix II).

h. Cabin, cockpit and cargo space heating.

(1) The standard heating system provides adequate heat for the pilot's, navigator's, and radio operator's compartments and for defrosting windshields. However, the output of the standard system is insufficient for the cargo compartment. The effect of an experimental Janitrol combustion heater and of glass wool insulation in the cargo compartment was tested. (See Appendix III).

i. Defrosting and deicing of windshields and transparents on the ground and in flight.

(1) Raymond type defrosting panels and experimental tri-methyl phosphate de-icing fluid were tested. (See Appendices IV-A and IV-H).

j. Deicing of wings, empennage and propellers.

(1) An experimental electrically operated deicer boot actuating system worked satisfactorily only down to —45°F. (See Appendix IV-B). No icing conditions heavy enough to test the propeller anti-icing system were enncountered.

k. Wing and engine covers.

(1) A set of waterproof wing covers proved to be unsatisfactory (see Appendix IV-C). The standard engine covers were rarely used because the weather was so clear that there was no reason to cover the engines.

1. Snow and ice tires.

(1) The airplane was equipped with synthetic rubber S-6 ten-ply tires on the main wheels and one S-6 rayon tail wheel tire. The tires were satisfactory and skidding was not excessive with the test tires which incorporated no ice-gripping springs or "bottle caps". For tire service test results, see Appendix IV-D.

m. Dilution and scavenging characteristics of oil system.

(1) The United Aircraft Products automatic dilution control was tested extensively and was found to be inaccurate and of little value. (See Appendix IV-E). Engines scavenged satisfactorily at all times.

n. Accessibility and effectiveness of oil and fuel drains.

(1) The drains are generally satisfactory except that there is no drain in the tank to engine "oil in" line. This makes it impossible to comply with one of the principal rules of cold weather operation, namely to check the "oil in" line for the presence of fluid oil before each start.

o. Adequacy and selectivity of carburetor heat.

(1) The carburetor heat available meets winterization requirements completely (See Appendix V). Selectivity is satisfactory, and full carburetor heat rise can be obtained in 30 to 45 seconds.

p. Freezing of condensate in oil, fuel and coolant lines, vent lines and breathers.

(1) No freezing has been observed in any of the lines.

q. Flight and navigation instruments.

(1) All flight and navigation instruments operated satisfactorily except that the gyros in the automatic pilot took several minutes to start at —40°F. The electric E-1 gyro horizon, C-1 directional gyro and air driven A-11 Bank and Turn indicator lubricated with ANG-3 grease all operated normally at —40°F., but the cockpit warmed up so rapidly after take-off that their operation could not be checked accurately while they were still cold. The caging knob of the E-1 horizon freezes solid at about —40°F. The A-3A automatic pilot required three control box replacements none of which was attributed to temperature.

r. Engine instruments.

(1) The engine instruments were satisfactory except for the direct connected engine oil pressure gages. The use of hydraulic fluid introduced to the lines through a servicing tap on the panel was a help, but test restrictions installed at the gages to reduce fluctuation were unsatisfactory at —40°F., as oil pressure took fifteen minutes to come up to normal.

s. Radio and radar equipment.

(1) No difficulties were experienced beyond routine deficiencies which could not be attributed to cold weather.

t. Electrical equipment.

(1) Feathering of propellers under cold conditions throws a load of approximately 150 amperes on one generator for up to fifteen seconds as the feathered engine slows down or is unfeathered. The standard 100 ampere current limiters blew out on the first tests and were replaced with 200 ampere limiters, which never blew. The operation of the D-2 power plant was very satisfactory, but below —40°F. heat had to be applied to start if it is lubricated with SAE 10 oil. (See Appendix IV-F).

u. Engine starting.

(1) The limited number of cold starts made indicated that a start down to —30°F. without heat or special priming is possible, but that starter failure is likely. At lower temperature, either heat or priming with a volatile fuel is necessary. (See Appendix IV-G).

v. Engine operation in flight.

(1) Engine operation in flight was normal.

C. CONCLUSIONS

1. It is concluded that:

a. Operation of a standard C-47A airplane down to —45°F. is possible if the following essential changes are made:

(1) Engines must be serviced with synthetic oil PPO 265 or equivalent to make propeller feathering possible.

(2) An oil pressure gage system which will register at low temperatures must be installed.

(3) A "Y" or "straight through" drain must be provided in the engine oil in lines.

(4) Either an approved winterized starter must be installed or the present Jack and Heintz starter used

for direct cranking only at temperatures below —30°F. when cold starting.

(5) Current limiters in the generators must be 200 ampere capacity to prevent complete power failure if an engine is feathered.

b. Operation of a standard C-47A airplane down to —45°F. can be simplified and improved if the following changes are made:

(1) T. O. O1-4ONC-51 should be rescinded and pertinent cold weather operation instructions included in 01-4ONC-1 as outlined in Appendix VI.

(2) Additional cargo compartment heat similar to the Janitrol demountable heater kit, or cargo compartment insulation, or both should be provided.

(3) A permanently attached cargo door seal should be provided.

(4) Self-locking fuel and oil drains should be provided throughout.

(5) A set of wing and tail covers which come fitting the airplane, and which have a simple method of attachment should be provided. It is desirable that these covers be waterproof and diffiicult to rip and that they neither stiffen up or shrink excessively in use.

(6) The battery cart plug should be moved to the outboard side of a nacelle and provided with a spring loaded door.

c. Testing indicates that the experimental equipment installed in the subject airplane was satisfactory or unsatisfactory down to the temperatures experienced as indicated below.

(1) The Janitrol demountable heater kit operated satisfactorily, but would provide heat rises required only if the cabin is insulated.

(2) The E-1 gyro horizon, C-1 directional gyro and relubricated A-11 Turn and Bank were satisfactory except for the direction of rotation of the card on the C-1 gyro and the caging knob of the E-1.

(3) "O" ring shock strut packings were satisfatory.

(4) Electrically timed Eclipse deicer boot actuating system was satisfactory only to —45°F.

(5) Automatic oil dilution was unsatisfactory.

(6) The oil cooler thermostat override operated satisfactorily.

(7) Synthetic rubber tires were satisfactory.

(8) Hydraulic oil used for propeller feathering was beneficial, but greater improvement is possible by using synthetic oil.

(9) Synthetic oil, AN PPO 265 was satisfactory.

(10) The Allison-type cold start system was a definite aid to cold starting.

(11) Increasing the size of the engine primer restriction was unnecessary.

(12) Tri-methyl phosphate windshield de-icer fluid was satisfactory.

(13) Push type manifold pressure drain valve was satisfactory.

(14) Cargo compartment glass wool insulation greatly aids heating, but should be covered with a protective surface.

(15) Test restrictions installed in the oil pressure gages were unsatisfactory.

D. RECOMMENDATIONS

1. It is recommended that the changes listed under C.l.a. and C.l.b. be incorporated in future production airplanes.

Cold Weather Test of C-54B Airplane

Prepared by: Beach Barrett, Capt.,A.C.

A. PURPOSE

1. To report on the cold weather testing of ATSC C-54B Serial No. 43-17157 at Ladd Field, Fairbanks, Alaska, for the winter of 1944-45.

B. FACTUAL DATA

1. The minimum ground temperature encountered during the testing of the subject airplane was —38°F and the mean temperature of the coldest day was —29.7°F. The lowest temperature encountered in flight was —58°F at 23,000 ft., to which the airplane was subjected for 30 minutes.

2. For a record of flying time and ground temperatures during the test period, see Appendix I.

3. Listed below are the items tested and the results obtained.

a. Lubricants and hydraulic fluid.

(1) Natural oil, 1100A, was used at all times. No difficulties beyond normal high viscosity at low temperatures were encountered.

b. Rubber and synthetic hydraulic, instrument, fuel and oil line hose and connectors.

(1) No difficulties were encountered with standard installations.

c. Weatherstripping and fuselage seals.

(1) The seal around the left-hand emergency exit leading out to the wing became unglued. Other seals were satisfactory.

d. Hydraulic actuating systems and shock struts.

(1) The nose wheel strut required servicing with air at frequent intervals. The Schrader air valve was replaced once, and a steel washer was used without completely curing the trouble. Left strut had an "O" ring; right and nose struts were standard. There was no fluid leakage from the main struts, and actuating systems required routine maintenance only.

e. Hydraulic and fluid seals and packings.

(1) No difficulties requiring more than routine maintenance were encountered. Cup seals on the manifold between the relief valve and pressure regulator leaked continually. These seals were replaced with "O"

rings, which corrected leakage but are not considered satisfactory, as parts were not designed for an "O" ring. Auto pilot servo unit packing gave considerable trouble owing to original misalignment of the unit.

f. Surface control system.

(1) Extensive control tension tests were run for the Aircraft Laboratory. It was observed that after soaking the airplane at —58°F for 30 minutes in flight, the elevator and rudder controls had about 1 inch of free play, indicating slack cables. The ailerons did not have any play. The trim tabs were all stiffer than normal, but could be set without undue exertion.

g. Propeller controls and feathering system.

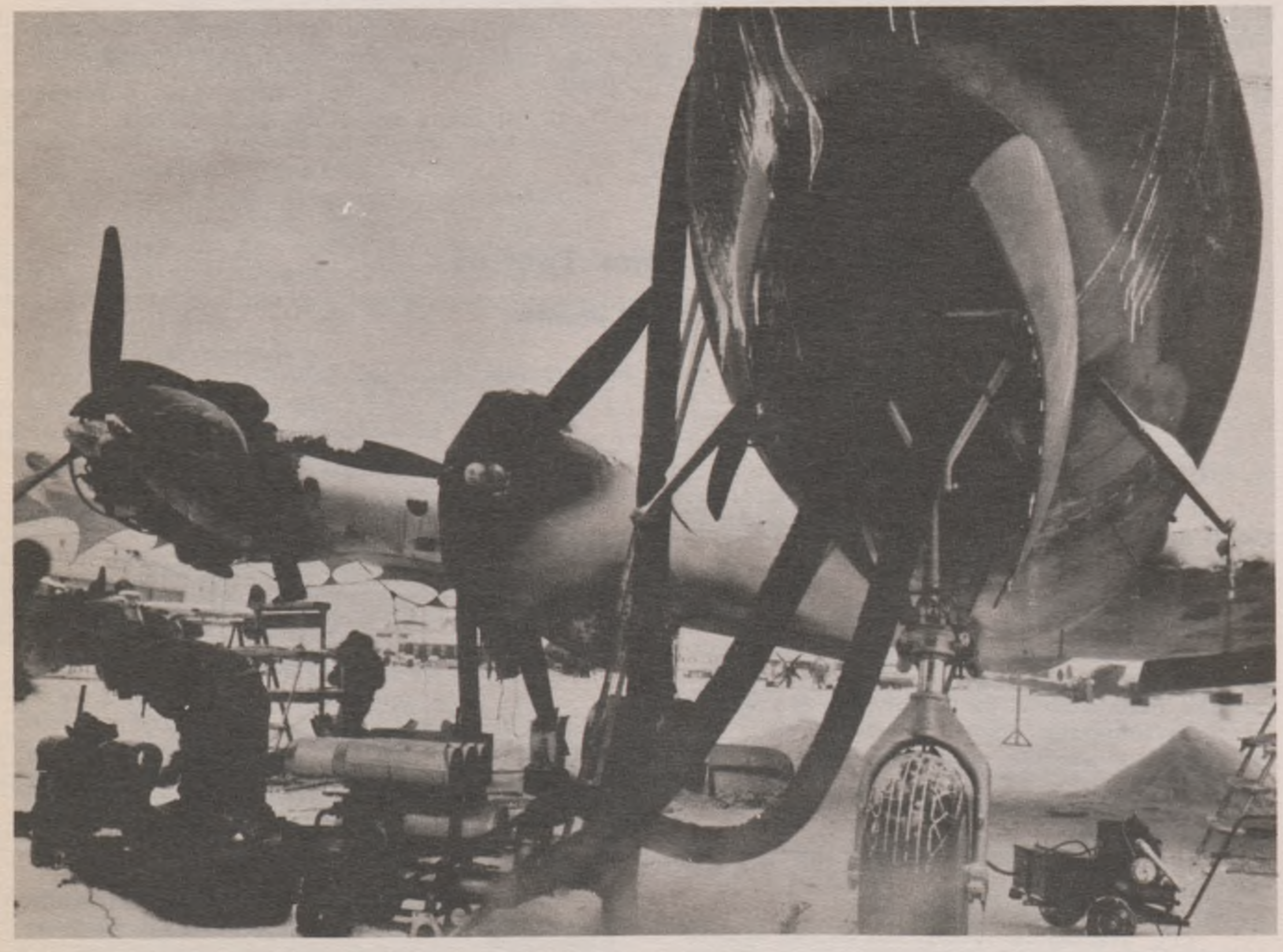
(1) The propeller feathering pumps of No. 1 and No. 4 engines were fed from 5-gallon, hydraulic-fluid tanks in the nacelles. With 1100A oil in all engines, it was impossible to feather any engine after soaking 30 minutes at —58°F. The propellers feathered satisfactorily after soaking for an hour at —23°F, feathering in five to ten seconds with three of the four buttons held in to accomplish feathering. Apparently, the hydraulic feathering system is not the answer to low temperature feathering, although it may be some slight benefit. Neither the standard nor hydraulic fluid system could be relied on to feather below —45°F with 1100A oil in the engine. Tests on other airplanes indicated that synthetic oil, PPO 265, would materially aid low temperature feathering. When attempting to feather at —58°F, No. 1 engine blew a governor gasket, necessitating an emergency landing. No difficulties were experienced with propeller controls.

h. Cabin, cockpit and cargo space heating.

(1) The heating system was revised to the latest modification proposed for production airplanes and is similar to the C-54E. The system incorporated high voltage spark plug ignition of the main heater, fuel modulation, and improved Minneapolis-Honeywell control. A bulkhead under the rear cargo compartment wall was installed and the compartment was insulated. Extensive tests were run on the heating system, which was generally very satisfactory. The heating system was capable of holding the airplane at the desired temperature of 70° under all test conditions. The temperature variation with respect to position in the airplane and with respect to time was satisfactory. Complete heater test data was reported by Douglas Aircraft. No mechanical trouble was experienced after the test system was installed.

i. Defrosting and deicing of windshields and transparent areas on the ground and in flight.

(1) The airplane incorporated Raymond type dual windshields with cast curved glass in the clear view panels. The nose heater could be operated on the ground and give satisfactory defrosting on the ground and in flight. There was not enough heat supplied to the dual panels to deice in flight, but the windshield could be kept clear by using the alcohol system to prevent ice formation. Difficulty was experienced with the removel of ice that was allowed to accumulate before operation of the de-icer.



j. Deicing of wings, empennage and propellers.

(1) Icing conditions severe enough to give a real test of the wing deicers were never encountered. It was observed that the deicers would function normally after soaking 30 minutes at —42°F. Electric hub generators and resistance-type blade deicers were installed on four engines. When the system operated it appeared to deicers the propellers satisfactorily, but electrical troubles were so numerous that there were rarely more than one or two blades on each propeller functioning. The system will require considerable development before service use is practical. For malfunctions of propeller deicer system, see Appendix II.

k. Wing and engine covers.

(1) Untreated wing covers were generally unsatisfactory, because they froze to the wing surfaces and became stiff when frozen. No holes were provided for the static eliminators. The quick removal system was a help, but required so much time at installation that it often was not used.

1. Snow and ice tires.

(1) Standard snow and ice tires with spring-type ice grippers were used. Tires were satisfactory and would hold sufficiently to run up the engine.

m. Dilution and scavenging characteristics of engine.

(1) Scavenging tests indicated that the engines would not satisfactorily scavenge 30% diluted oil when the entire tank was diluted and take-off power was held for 5 minutes. However, when the airplane was diluted to 30% in the normal manner and a normal take-off was made, it scavenged properly. Dilution and boil-off tests were run. For dilution data see Appendix III. Dilution and priming solenoids leaked continually through the cores, and four replacements were necessary.

n. Accessibility and effectiveness of oil and fuel drains.

(1) A self-locking valve was incorporated in the engine oil line, and was satisfactory. Main fuel tank drains would not operate at 0°F and below. Sump drains were not self-locking, but were readily accessible.

o. Adequacy and selectivity of carburetor heat.

(1) Extensive testing of the carburetor heat system indicated that the standard system met requirements and had good selectivity and rapid heat rise. For carburetor heat data, see Appendix IV.

p. Freezing of condensate in oil and fuel lines, vent lines and breathers.

(1) No freezing of condensate was observed.

q. Flight and navigation instruments.

(1) For test purposes, electrically driven gyroscopes (E-1 gyro horizon and C-1 directional gyro) and a winterized drift meter were installed. A gyro flux-gate compass was also installed. No difficulties were encountered with the test instruments attributable to cold weather.

r. Engine instruments.

(1) Repeated difficulties were experienced with the A-1 type pressure transmitters in the oil pressure gages, but these were not attributed to cold weather. Other instruments were satisfactory except for continual failures of head temperature gages due to poor connections at the thermocouple or firewall.

s. Radio and radar equipment.

(1) In addition to normal radios, an SCR 508, SCR 522 and a Bendix Loop radio compass were installed. No difficulties beyond normal service failures were encountered.

t. Electrical equipment.

(1) No difficulties attributable to cold weather were encountered. A test D-2 auxiliary power unit was installed and operated satisfactorily except for the exhaust line, which was not properly installed. The unit started satisfactorily without heat down to 0°F using 1120 oil.

u. Engine starting.

(1) No extensive cold starts were attempted. Difficulty was experienced in starting No. 3 engine at 0°F or below unless some heat was applied, when it started normally. No reason could be found, and the remaining engines would start cold at —10°F.

v. Engine operation in flight.

(1) Operation in flight was satisfactory except for a failure of No. 1 engine. The forward diaphragm of the intermediate rear crank case, which separates the gear box from the blower throat, failed in the vicinity of the impeller shaft sleeve. The failure was in the magnesium casting. Numerous failures of the exhaust collector and tail pipe were experienced until a modified system was installed. These failures were not due to cold weather.

w. Firewall emergency shut-off valves.

(1) At temperatures below zero, the shut-off valves would not operate satisfactorily with the airplane cold. This was probably due to contraction of the aluminum valve body onto the steel plug. A new valve is being installed in the C-54E airplane.

C. CONCLUSIONS

1. It is concluded that:

a. Operation of a standard C-54B airplane down to —40°F is possible if the following essential changes are made:

(1) Engines serviced with synthetic oil or other changes made to improve propeller feathering.

(2) Winterized emergency firewall valves installed to prevent binding at low temperatures.

b. Operation of a standard C-54B airplane down to —40°F can be simplified and improved if the following changes are made:

(1) Heating system modified to proposed production design, incorporating high-voltage, spark-plug, heater ignition; improved electronic control; and fuel modulation.

(2) Fuel tank sump drains should be made self-locking, and main fuel tank drains should be winterized.

(3) Technical Orders should be revised according to Appendix V.

(4) Cargo compartment should be insulated.

(5) Satisfactory wing covers should be developed.

(6) The hydraulic manifold between the relief valve and the pressure regulator should have an improved seal.

c. The experimental equipment installed in the subject airplane was satisfactory or unsatisfactory at the temperatures experienced as indicated below:

(1) Hydraulic propeller feathering—unsatisfactory because the slight improvement in feathering did not offset the added weight, complications, fire hazard, and limited feathering supply available.

(2) Modified cabin heating system — satisfactory.

(3) Electric directional gyro and artificial horizon—satisfactory.

(4) D-2 auxiliary power plant—satisfactory.

(5) Synthetic engine mounts — satisfactory pending teardown inspection at Wright Field.

(6) Landing gear "O" ring—satisfactory pending teardown inspection at Wright Field.

(7) Electric propeller hub generators and blade deicers—principle was satisfactory, but equipment was mechanically unsatisfactory.

(8) A-1 pressure transmitter relocation—satisfactory for reservicing transmitters, but interfered with remainder of installation.

D. RECOMMENDATION

1. It is recommended that the changes outlined in C 1a and C 1b above be incorporated in future production airplanes.

Cold Weather Test of P-38L Airplane

Prepared by: John W. McGuyrt, Capt., A.C.

Maintenance Using Heated Nose Hangar

A. PURPOSE

1. To report on the cold weather testing of ATSC P-38L-1 Serial No. 44-24050 at Ladd Field, Fairbanks, Alaska, for the winter of 1944-45.

B. FACTUAL DATA

1. The minimum ground temperature encountered during the testing of P-38L-1 No. 44-24050 was —45°F and the mean temperature of the coldest day was

—30.2°F. The lowest temperature encountered in flight was —60°F to which the aircraft was exposed for 2 hours.

2. For a record of flying time and ground temperatures during the test period see Appendix I.

3. Listed below are the items tested and the results obtained:

a. Lubricants and hydraulic fluid.

(1) Grade 1100A oil was used in the left engine and synthetic oil, PPO 265 was used in the right engine. As in most ETOU airplanes the synthetic oil showed a higher coefficient of heat transfer and the warm-up period was from one to four minutes less on the synthetic oil.

(2) The AN-VV-O-366A hydraulic oil was used in main hydraulic system and as a lubricant for the left supercharger. It was satisfactory in both cases.

b. Rubber and synthetic hydraulic, instrument fuel and oil line hose and connectors.

(1) Low pressure instrument hose with detachable fittings was installed for service testing and was satisfactory. All other hoses and connectors were satisfactory.

c. Weatherstripping and fuselage seals.

(1) At —20°F the front canopy seal became hard and brittle, consequently it is impossible to secure canopy latches at temperatures below this. The cockpit seals along the side windows and the throttle quadrants became stiff, creating an unsatisfactory condition.

d. Hydraulic actuating systems and shock struts.

(1) "O" ring packings in nose and left main landing gear and scraper ring, AN-6231-37 in left gear show no signs of malfunction. Right gear was equipped with chevron type packings. The right shock strut collapsed twice. The lower part or piston of the strut was removed and the brass cap was loose enough to be turned by hand. The "O" ring seal in the cap was replaced and strut reassembled and reinstalled in cylinder of strut. It functioned properly for approximately 15 landings, then collapsed again. The "O" ring seal in the cap was replaced again.

e. Hydraulic and fluid seals and packings.

(1) The "O" ring seals in the flap and landing gear selector valve leaked at short infrequent intervals but no corrective action was required.

f. Surface control system.

(1) No failures or deficiencies were noted.

g. Propeller controls and feathering systems.

(1) Teleflex controls installed for both governors were satisfactory. No malfunctions were experienced requiring other than periodical maintenance.

h. Cabin and cockpit heat.

(1) The quantity of heat in flight was sufficient but was not well distributed.

i. Defrosting and deicing of windshields on the ground and in flight.

(1) The defrosting system was satisfactory in flight, but unsatisfactory on the ground due to lack of rammed air.

j. Wing and engine covers.

(1) The wing and engine covers were satisfactory except that the securing ropes on wing covers are too complicated.

k. Snow and ice tires.

(1) "Spring insert" ice grip tires were installed on the airplane. The plane made 145 landings with no noticeable wear. The traction of the tires was poor on packed snow and on ice the traction was very unsatisfactory.

l. Dilution and scavening characteristics of oil system.

(1) Scavenging and dilution were unsatisfactory. See Appendix II.

m. Accessibility and effectiveness of oil and fuel drains.

(1) Extension drain lines were installed on the oil tank sump drain to prevent oil from draining on the firewall. All other drains were satisfactory.

n. Adequacy and selectivity of carburetor heat.

(1) There were no provisions for carburetor heat on this aircraft but nose shutters are incorporated in production model P-38's.

o. Freezing of condensate in oil, fuel and coolant lines, vent lines and breathers.

(1) Quantities of ice formed around the oil breathers but never completely closed the breather line.

p. Flight and navigation instruments.

(1) Type B-21 standby compass was unsatisfactory due to large deviation error that could not be corrected. Type F-4 airspeed indicator installed for service test was satisfactory.

q. Engine instruments.

(1) No malfunctions were noted.

r. Guns, fire control and bombing equipment.

(1) No tests were conducted on this equipment.

s. Radio and radar equipment.

(1) A radar chaff dispenser was installed and tests conducted for the Radio Laboratory. Mechanical failures in the dispenser were encountered and the tests were unsuccessful.

(2) All radio equipment was satisfactory.

t. Electrical equipment.

(1) All electrical components functioned properly.

(2) RP-43 spark plugs were installed in left engine for service tests. They were still very satisfactory after 40 engine hours.

u. Engine starting.

(1) The lowest temperature at which cold starts were attempted was —45°F. The engines would not start on gasoline at this temperature. Propane was then used through auxiliary cold starting unit and the engine started in approximately 1½revolutions of the propeller and ran smoothly on the propane mixture. After warm-up period gasoline was then used but the engine ran so roughly it had to be shut down. This roughness was caused by the extreme low outside air temperature consequently poor vaporization of fuel. An adequate carburetor heat installation would have corrected this.

v. Engine operation in flight.

(1) Rough engine operation was experienced but once. The ground temperature was —35°F. Again extreme roughness was encountered due to poor vaporization of fuel. The carburetor air temperature was —26°F, and the carburetor adapter temperature was —49°F. The engines operated so roughly that the plane had to be landed shortly after takeoff. It is important to note the engines run smoothly at —58°F O.A.T. at 30,000 ft., yet they will not operate properly at low altitudes or ground level at —35°F such as was encountered on this particular flight.

C. CONCLUSIONS

1. Operation of a standard P-38L type aircraft down to -45°F is possible if the following essential changes are made:

a. Intercooler nose shutters installed together with carburetor heat to insure proper vaporization of fuel at temperature of -35°F and below.

b. The oil scavenging characteristics of the Allison V-1710-111 and -113 must be improved to satisfactorily scavenge the percentage of diluted oil necessary at these temperatures. This condition can be improved by servicing the engines with synthetic oil.

c. All canopy seals hydraulic seals, hose and hose connectors be fully winterized.

2. Operation of a standard P-38L type aircraft can be simplified and improved if the following changes are made:

a. Self-locking drains be installed at "Y" drains, oil tank sump drains and fuel tank sump drains.

b. Lines be installed on the oil tank sump drains so the oil will drain overboard instead of into the accessory section.

3. Testing indicates that the experimental equipment installed in subject airplane was satisfactory or unsatisfactory to the temperatures experienced as indicated below:

a. O-ring packings in nose and left main gear were satisfactory.

b. Scraper ring AN6231-37 in left main gear was satisfactory.

c. Artificial horizon with special bearing and lubricant was satisfactory.

d. B-21 standby compass was unsatisfactory be cause of its location.

e. Ice grip tires were satisfactory for wear but the traction characteristics on ice were unsatisfactory.

f. Aluminum oil coolers and floating type oil cooler temperature controls were satisfactory.

g. Modified carburetor on left engine was satisfactory.

h. Teleflex controls on propellers were satisfactory.

i. RP-43 spark plugs installed in left engine were satisfactory.

D. RECOMMENDATIONS

1. It is recommended that the changes listed in C 1 and C 2 above be incorporated in future production model P-38 type airplanes.

Cold Weather Test of P-51D-10 Airplane

Prepared by: James H.Brown, Capt.,A.C.

A. PURPOSE

1. To report on the cold weather testing of ATSC P-51D-10 Serial No. 44-14476 at Ladd Field, Fairbanks, Alaska, for the winter of 1944-45.

B. FACTUAL DATA

1. The minimum ground temperature encountered during the testing of subject airplane was -45°F and the mean temperature of the coldest day was -30.2°F. The lowest temperature encountered in flight was -65°F to which the aircraft was exposed for one hour.

2. A record of flying time and ground temperatures is embodied in Appendix I.

3. Listed below are the items tested and the results obtained:

a. Lubricants and hydraulic fluid.

(1) No deficiencies noted.

b. Rubber and synthetic hydraulic, instrument, fuel and oil line hose and connectors.

(1) Six pieces of the new experimental hose, types H-30 and H-30 N, were installed in the coolant system and one piece of R-80 hose and two pieces of H-40 were included in the oil system. All new hose was connected with the Aero Seal clamps and torqued to 25" pounds. After 42:05 hours of engine flight no leakage had been noted nor had any additional torquing been necessary. Instrument and fuel hose was standard and gave no difficulty. One piece of AN-ZZ-456A coolant hose leaked at -8° due to cold flow. The new experimental hose showed decidedly improved cold flow characteristics.

c. Weatherstripping and fuselage seals.

(1) No seal was provided around the emergency canopy release handle in the cockpit. The entire handle was surrounded by an air space of ⅛ to ¼ inch allowing a draft of cold air to enter the cockpit.

d. Hydraulic actuating systems and shock struts.

(1) Flap and landing gear operation was normal. It was necessary to change one low pressure type tail strut air valve, which had developed a slow leak. A high pressure type valve was installed, and no difficulties were encountered thereafter.

e. Hydraulic and fluid seals and packings.

(1) At -20°F the end cap static seal (AN6230-5, Miller Winterized) in the left main landing gear actuating strut leaked badly when in the up position, but the strut did not leak when bench tested at room temperature. Leakage had been caused by low temperature shrinkage of the seal, but when a new seal of the same type was installed, no further difficulty occurred down to -65°F.

(2) Propeller leakage was excessive on this aircraft from the time of its departure from Vandalia. As progressively lower outside air temperatures were encountered and more dilution used, the condition became worse. Under normal cruising conditions at altitudes below 10,000', light oil deposits would become noticeable on the windshield panels after 20 minutes and the accumulation would increase until forward visibility

was dangerously impaired. All seals within the propeller (Hamilton Standard Hydromatic, Assembly No. 142-680) were successively replaced without eliminating the leak. The propeller was removed and oil tested at room temperature with No. 10 oil but did not leak at abnormally high pressures. It appeared that the accumulation on the windshields was heavier than the total loss evident on the propeller blades, so the engine thrust bearing, propeller governor control and vacuum pump were investigated but only minor leaks were found. A new propeller (Hamilton Standard Hydromatic Assembly No. 142178) was installed but light leakage on two blades occurred on the first flight. Since the propeller did not leak under severe shop oil testing, it was concluded that low temperatures or centrifugal force was causing the trouble. Tests and observation will be continued.

f. Surface control systems.

(1) Trim tabs became slightly stiff after being exposed in flight to a temperature of —65°F for one hour.

g. Propeller controls and feathering systems.

(1) No deficiencies noted.

h. Cabin, cockpit and cargo space heating.

(1) Heating data obtained was inadequate but it indicated that heat distribution within the cockpit was fair. Wearing specified artic flying apparel, the pilot was comfortable at 35,000′ at an outside air temperature of —65°F. The heat available during ground operation was negligible. Use of the windshield defrosting unit increased cockpit temperatures.

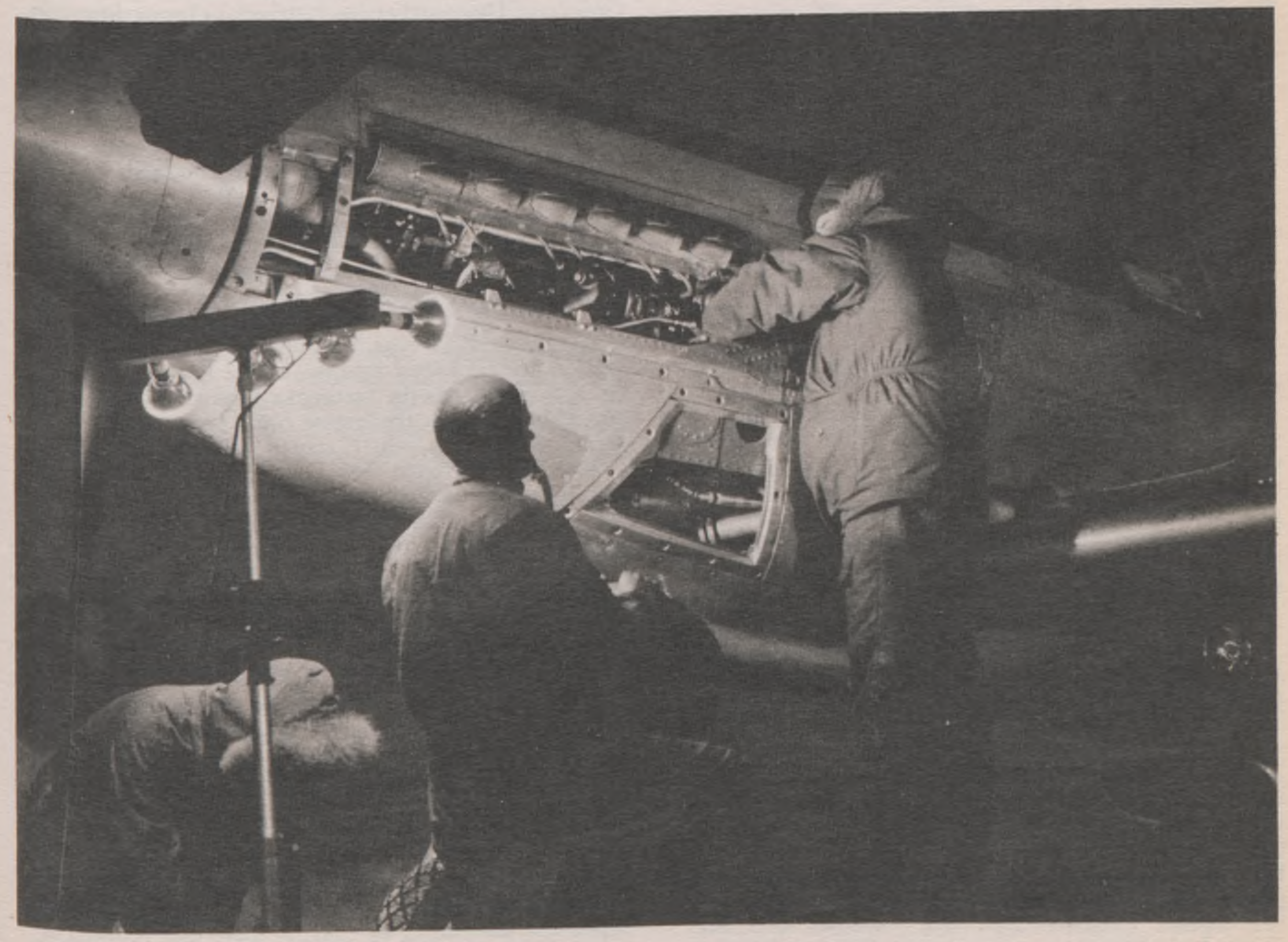
i. Defrosting and deicing of windshield on the ground and in flight.

(1) External frosting of the windshield panels due to condensation of exhaust gases occurred at very low temperatures. Subject aircraft had no provision for external defrosting. CWT P-51D-10 type aircraft (No. 4513 and No. 4484), were equipped with two external defrosting outlet ducts, one each to the left and right windshield panels, but their pilots reported that it did not provide complete defrosting. The ETOU P-51 had standard production defrosting equipment, consisting of one hot air duct outlet to the left and two to the center windshield panels. A severe ground internal frosting condition was encountered only once while taxiing at an outside air temperature of —45°F. Heavy frost formed on the inside of all windshield panels and the bubble canopy but cabin heat and defrosting systems gave sufficient visibility in two minutes to allow safe taxiing.

j. Wing and engine covers.

(1) Standard wing covers made of muslin material left much to be desired from the standpoint of ease of placement and removal. They soon became moisture laden and froze stiff, remaining this way the greater part of the season. They had to be thawed out before they could be used and then they were very difficult to remove, having frozen to the wing surfaces.

(2) Standard engine covers were used. The snug fit of the cover made it very difficult to install unless it



Standard outdoor maintenance on P-51 at 10 A. M.

was perfectly aligned. Alignment difficulties were aggravated when the cover became soaked with oil or coolant and froze stiff. The zipper type fastener was very unsatisfactory as the packed snow, ice, dirt or congealed oil made it impossible to zip, and the actuating clasp was too small to grasp firmly with gloves on. In the morning, engine covers were often removed before preheat was applied to the engine section because it was easier to preheat without the cover than to match up the heater duct holes. Considering the tight cowling on this type aircraft and the relatively small air space between the engine and the cowling, heat loss was comparatively low and the time period required to adequately preheat was quite short with or without covers. The protection feature of the cover was very good but unnecessary. Some covering for the engine exhaust stacks is considered necessary but it is felt that a stack cover or individual stack plug would suffice.

k. Snow and ice tires.

(1) The tail wheel tire (Goodyear S-6 C-4R1, Flat Tread) proved satisfactory. The ice grip tires installed on the main wheels were very unsatisfactory. These were the B. F. Goodrich 27" SC Nylon (H4X2 and H4X4) with the impregnated coiled wire as a traction feature. A total of 62 landings were made, of which, 18 were on concrete or asphalt, the remainder on ice and snow. After 25 landings, 45% of the impregnated wire was missing, leaving several bare strips up to 10" in length. After 50 landings, 75% of the wire was missing. Traction was very poor and engine and magneto checks could not be performed on ice or hard packed snow without skidding.

l. Dilution and scavenging characteristics.

(1) Highest priority was given to dilution and scavenging tests due to the serious oil spewing on the Packard V-1650-7 engine. Spewing tests with pre-mixed dilutions were run concurrently on the subject aircraft and on the CWT P-51D-10 No. 44-14484 equipped with the production Packard V-1650-7 engine for comparison. The present production Packard -7 engine did not meet scavenging requirements, nor did the modified -7 engine. The modified engine with the experimental Thompson Centrifuge Pump successfully handled premixed dilutions up to and including 30% without excessive spewing. See Appendix II.

m. Accessibility and effectiveness of oil and fuel drains.

(1) Accessibility and effectiveness of oil and fuel drains was unsatisfactory on the production aircraft but modifications accomplished at Vandalia were satisfactory. The addition of a main engine fuel strainer access door at Ladd Field greatly facilitated access to this unit. Main fuel tank sump drains were not self locking. Due to their location in the main coolant scoop it was difficult to service them.

n. Adequacy and selectivity of carburetor heat.

(1) Carburetor heat was unsatisfactory from both the standpoint of total available heat rise and selectivity. The production aircraft arrived with no provision for carburetor heat. A standard kit of the obsolete type was installed, and the "Ram Air-Filtered Air" selector lever was very hard to actuate. The two CWT P-51D aircraft assigned to Ladd Field (No. 4484 and No. 4513) were equipped with an improved lever arrangement and the lever could be operated with ease. The maximum heat rise attainable in the ETOU P-51 at 65% rated power at 1000' with the solid filter doors installed was 47F degrees. Extensive tests were conducted up to altitudes of 25,000 feet, maximum rise of 63F degrees being obtained at that altitude. The mean average heat rise calculated from readings taken at four altitude levels between 1500' and 25,000' with maximum continuous, normal cruising and long range cruising power settings was 57F degrees.

o. Freezing of condensate in oil, fuel, and coolant lines, vent lines and breathers.

(1) Ice or congealed oil frequently appeared in the oil tank sump drain line. No other deficiencies were noted.

p. Flight and navigation instruments.

(1) No deficiencies noted. The standard type artificial horizon with special heavy bearings (New Departure type 34B) and special lubricant (AN-G-3 grease) functioned satisfactorily.

q. Engine instruments.

(1) No deficiencies noted. The direct connected oil pressure gauge line was serviced at Vandalia with hydraulic fluid Specification No. AN-VV-O-366. No additional servicing was required.

r. Guns and fire control equipment.

(1) No deficiencies noted. No tests conducted.

s. Bombing equipment.

(1) No deficiencies noted. No tests conducted.

t. Radios and radar equipment.

(1) Reception on SCR-522 and Detrola (200-400kc) was very poor in snow storms.

u. Electrical equipment.

(1) The external power receptacle door was not self-closing. It is understood that production aircraft now have a satisfactory modification but no Technical Order could be found giving instructions for modification of aircraft in service.

v. Engine starting.

(1) Cold starts were made at temperatures down to —20°F. If the engine had been properly diluted it usually started without much difficulty. At least four or five seconds of priming was necessary and after the engine started it was necessary to prime in order to keep it running smoothly. Cold starts could not be made consistently below —20°F without preheat. Preheat below —20°F in order to reduce the possibilities of failure of accessories was considered advisable.

(2) CWT Detachment experimented with heated intake air on P-51 type, ducting heat from a Herman-Nelson ground heater into the engine induction system via attachments to the air intake filter doors. Without any additional heat the engine could be started at temperatures down to —40°F shortly after the ducts were attached. The engine was then run until sufficiently warmed up to run smoothly, shut down to remove ducts, and restarted. Whereas this method would get the engine running in less time, it offered no solution to the possibility of failure of accessories when making cold starts below —20°F. It is questioned as to whether the time saved by not pre-heating the usual engine sections offsets the time lost if an occasional failure occurs.

w. Engine operation in flight.

(1) As lower outside air temperatures were encountered, loading up and subsequent spark plug fouling occurred much more readily. On several occasions after taxiing to take-off position extreme engine roughness accompanied by an emission of black smoke from cylinders No. 1 and No. 2 of the "B" bank occurred as the manifold pressure was increased for magneto check. This could be cleared up by advancing the manifold pressure to 30" Hg. or more for a short period. It was found that the loading up could be materially reduced or totally eliminated by warming up and taxiing with the mixture control on the idle cut off side of the normal

"RUN" (Auto-Lean) position, manually switching into "HIGH" blower and using carburetor heat. Engine roughness developed in flight below normal cruise power unless some carburetor heat was used.

x. Accuracy and adequacy of information in the Handbook of Pilots Operating Instructions and the Handbook of Instructions for Arctic Operations.

(1) See Appendix III.

y. Miscellaneous.

(1) The Simmonds SA-5 Automatic Manifold Pressure regulator, installed for service testing, performed in a reliable and smooth manner. There appeared to be some sluggishness (lag) at low power settings while taxiing below —20°F and it responded sluggishly when dilution above 10% was used. It could not be accurately determined whether this difficulty was the fault of the regulator or not. It was noted that the regulator became particularly sensitive when the manifold pressure exceeded 60" Hg. With ram air and in low blower it was possible to draw 61" Hg. manifold pressure at 10,000 and when in high blower the same pressure could be drawn at 25,000. These were the altitude limits and in each case, manifold pressure dropped off rapidly at higher levels.

C. CONCLUSIONS

1. It is concluded that:

a. Operation of a standard P-51D-10 aircraft down to —40°F is possible if a carburetor heating system is installed to aid fuel vaporization.

b. Operation of a standard P-51D-10 aircraft down to —40°F can be simplified and improved if the following changes are made:

(1) The aircraft is equipped with improved coolant, oil and fuel line hose such as the H-30, H-30N, H-40 and R-80 having improved cold flow characteristics.

(2) An oil tank is developed having better segreation characteristics to allow higher dilution and to alleviate oil spewing.

(3) Spark plug gap settings are increased to .022" to alleviate plug fouling.

(4) Steady "High Blower" switch is provided in the cockpit to speed warm-up and allow taxiing in high blower to minimize loading up tendencies.

(5) An improved carburetor heat system is provided making possible a greater total heat rise and greater selectivity.

(6) An improved engine breathing and scavenging system is developed to prevent oil spewing at high power settings with dilution values above 10.5% or an air-oil separator such as the Thompson Centrifuge Pump to capture spewed oil and return it to the oil tank installed.

(7) The engine breather outlet vent relocated when the Thompson Pump is installed to reduce the fire hazard created by its present location on the left side of the engine cowling.

(8) A drain line through the carburetor air intake scoop provided to drain engine fluids overboard instead of allowing them to enter the induction system.

(9) Eliminate the trap in the oil tank sump drain line to prevent accumulation and freezing of condensate. Re-route the line so the drain fitting is accessible through an access door. An approved self-locking drain cock such as the Koehler 1610-B should be installed on the line to facilitate servicing.

(10) An approved self-locking straight through oil system drain such as the Koehler K-1610B with an extended handle should be installed so it can be actuated from the opening provided by cutting an access door in the right rear corner of the lower engine cowling. A drain line to route drainage through the lower engine cowling should be installed.

(11) An access door in the left rear corner of the lower engine cowling below the main fuel strainer should be installed to facilitate servicing. This door should also be designed to serve as a ground heater duct.

(12) Install approved self-locking drain cocks such as the Koehler 1610B on main fuel tank sumps.

(13) Eliminate the trap in the oil tank to engine vent line to prevent accumulation and freezing of condensate by raising the point where the two vent lines join and become one.

(14) Fabricate wing covers of a moisture resistant material which will not freeze and become stiff, yet will be pliable enough to be easily placed and removed.

(15) Eliminate the present design engine cover, substituting a single cover for engine exhaust stacks.

(16) Increase the size of the tail gear down lock access door to facilitate servicing.

D. RECOMMENDATIONS

1. It is recommended that the changes listed in C, 1, a and C, 1, b above be incorporated in future production airplanes.

Cold Weather Test of P-59A Airplane

Prepared by: Howard T. Markey, Capt. A. C.

A. PURPOSE

1. To report on the cold weather testing of ATSC P-59A1-BE Serial No. 44-22610 at Ladd Field, Fairbanks, Alaska, for the winter of 1944-45.

B. FACTUAL DATA

1. The minimum ground temperature encountered during the testing of P-59A No. 44-22610 was —45°F and the mean temperature of the coldest day was —26°

F. The lowest temperature encountered in flight was —70°F to which the aircraft was exposed for fifteen (15) minutes.

2. A record of flying time and ground temperatures is embodied in Appendix I.

3. Listed below are the items tested and the results obtained:

a. Lubricants and hydraulic fluid.

(1) Twenty-one test flights were made at altitude to compare the relative merits of AN-06-A, AN-03L, PPO-280 and 3580 oils as turbine lubricants and to observe the effect of lagging on lubricant temperatures. At —40°F ground temperature excessively high oil pressures were obtained with AN-03L. AN-06-A oil was the most extensively tested and, although oil pressures of 30 lbs. were obtained on cold starts at —40°F, no detrimental effects were noted.

(2) No difficulties were experienced with any lubricants used on the airplane.

(3) No malfunctions were noted relating to the hydraulic fluid used in the brake system and struts.

b. Rubber hose and connectors.

(1) No deficiencies noted during test period.

c. Weatherstripping and fuselage seals.

(1) The cabin seals became hard and brittle at ground temperature of —45°F but did not interfere with the operation of the hatch and it was noticed that, in flight, the hot compressed air flowing thru them caused the tube seals to function properly.

d. Shock struts.

(1) No malfunctions occurred during the test period.

e. Fluid seals and packing.

(1) No deficiencies noted.

f. Surface control systems.

(1) The elevator trim tab controls froze tight in flight at —45°F. See Appendix II.

(2) The aileron and elevator controls were found to be slightly stiff near the neutral position on the ground at —45°F.

g. Cabin heating.

(1) Six test flights were performed with a view to recording cockpit temperatures.

(2) The cabin anemostat was installed on two of these flights and cabin heat distribution was found to be satisfactory, with all cabin thermocouples reading within 10° of each other.

(3) The heat rise inside the cabin was completely satisfactory, enabling the pilot to fly without gloves at outside air temperatures of —70°F. The cabin temperature can be satisfactorily regulated by the pilot.

(4) Ground heating of the cockpit is not satisfactory. This is not considered necessary, however, in view of the mission of the airplane, insofar as quick

P-59 Airplane

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take-offs are the rule and sufficient and rapid heat rise is available in flight.

h. Windshield defrosting.

(1) The windshield defrosting system operated satisfactorily in flight, providing a heat rise of 100° in three minutes.

(2) The windshield defrosting system is completely ineffective on the ground, due to the lack of a source of ram air.

i. Wing and engine covers.

(1) A set of wing and engine covers were locally designed and manufactured, since no P-59 covers were available.

(2) The subject covers proved completely satisfactory throughout the period, insofar as they included an attached flap to cover the engine air scoop and an attached pocket to cover the tail-jet. The covers were quickly removable because only two attachments were used on each one-piece combination wing-and-engine cover.

j. Snow and ice tires.

(1) The "bottle-cap" type ice tires installed did not hold the airplane on ice and proved no more satisfactory than ordinary tires.

k. Dilution and scavenging system.

(1) It was found that no dilution procedure was required down to —45°F.

(2) An oil dilution system is not considered necessary in this type power plant in operation at temperatures of —45°F and above.

l. Accessibility and effectiveness of oil and fuel drains.

(1) The fuel drains proved entirely satisfactory during tests.

(2) No oil system drain is provided.

m. Freezing of condensate in lines.

(1) Though all lines were drained daily, no condensate was noted in any oil or fuel line throughout period.

(2) Water was drained from the pitot-static line drain on two occasions. The pitot-head, located atop the vertical stabilizer, remains uncovered while on the ground.

n. Flight and navigation instruments.

(1) The pitot-static tube is mounted inverted atop the vertical fin.

(2) All instruments are rear-mounted and are not easily removable.

(3) No free air thermometer is provided.

(4) The experimental Skinner air-oil filter proved unsatisfactory, allowing oil to enter the vacuum regulators.

(5) The vacuum regulators were re-located at Vandalia and installed on the inclined beam aft of the barometrics and this location was found entirely satisfactory. One inherent defect in the vacuum regulators is the fact that they do not become effective until the pressure rises to 8″ hg. which is not reached until almost maximum engine RPM is obtained.

o. Engine instruments

(1) Filler check-valves were installed in order to service the selsyn oil pressure transmitter and lines in accordance with T. O. 05-70-6. This is not deemed necessary as a result of the 1944-45 winter tests, in view of the fact that the thin oil used was found to be freely flowing at —45°F.

(2) The oil pressure gage overran its maximum indication of 25 lbs. and began to read on opposite scale when cold starts were attempted at —45°F. The oil pressure was measured at 35 lbs. on an auxiliary gage. After three minutes engine operation the gage returned to normal.

p. Electrical equipment.

(1) Difficulty was experienced in bringing the turbine up to the minimum of 1200 RPM for starting. By using the auxiliary power source and the airplane battery starts were made when starts using only the auxiliary power source failed. Equipment was not available for measuring the load required for starting, but it was noted to be excessive.

(2) The landing gear and flaps were operated satisfactorily in flight at temperatures of —50°F after the airplane had been soaked thereat for 45 minutes. In using only one generator it was found that an average rise of 25 amperes was registered when flaps were raised and lowered and when gear was lowered, but that over 150 amperes was registered when gear was raised.

q. Engine starting.

(1) Complete cold starts were satisfactorily made at all temperatures down to —45°F.

(2) No pre-heat was used at any time throughout period while attempting to start the engines.

(3) A higher initial fuel pressure is required for starting as temperatures decrease, ranging from 50 lbs. at +30°F to approximately 95 lbs. at —45°F. It is necessary to maintain a minimum of 50 lbs. pressure until engine goes "over the hump" or engine will quit running.

(4) It is emphasized that no cold weather difficulties were experienced with the basic engine itself. All difficulties encountered were those found in the accessories.

(5) Three starter fuel pumps seized and became defective, one seizing enough to shear the shaft coupling key. This is believed due to the differential contraction of the aluminum housing and the steel pump gears.

(6) The barometrics did not allow maximum RPM of 16,500 as the temperature decreased. From the maximum of 16,500 RPM at +20°F the RPM dropped with the temperature until a low of 15,600 RPM was the maximum available at —45°F. It is believed that the evacuated bellows in the barometric does not compensate for temperature, as borne out by the fact that maximum RPM was available when bellows was replaced with a threaded screw at —45°F ground temperature.

r. Engine operation in flight.

(1) The engines overspeeded on all flights, making it necessary to retard the throttles constantly while climbing.

(2) Twenty flights were made to altitudes providing outside air temperatures of —35°F to —65°F and all engine thermocouples were read. Tests were run with lagging installed and without lagging and it was noted that, though all temperatures were lower without lagging, no detrimental effects resulted in engine operation.

(*a*) Although maximum take-off RPM of 16,500 will not be available as temperatures decrease, sufficient thrust exists for normal take-off, due to the dense air and indeed, under certain conditions even more thrust may be realized on take-off at —45°F at 15,600 RPM than that obtained at 16,500 RPM at +45°F.

(*b*) Higher starting fuel pressures are required and it is necessary to maintain at least 50 lbs. fuel pressure until engine goes "over the hump".

(*c*) The auxiliary power source used must be a good one and it may be necessary to supplement it by turning "on" the airplane battery switch.

(*d*) Initial oil pressures on starting are as high as 35 lbs. but these return to a normal of 11-13 lbs. after three minutes engine operation at 6000 RPM.

(*e*) It is necessary, at present, to retard the throttle in a climb, due to the lack of barometric action at cold temperatures.

C. CONCLUSIONS

1. It is concluded that:

a. Operation of a standard P-59A aircraft down to —45°F is possible if the following essential changes are made:

(1) The elevator trim-tab controls be redesigned to prevent freezing at —45°F.

(2) A source of ram air, possibly a take-off from the cabin pressure manifold, be found to provide a blast of hot air between the double panels of the windshield thereby defrosting it before taxiing.

(3) The steel-geared starting fuel pumps be replaced with a bronze bushing pump or similar type which will not seize at low temperatures.

(4) A satisfactory air filter be installed in the gyro instrument pressure lines.

(5) The oil pressure indicator system be redesigned to handle surges on starting.

b. Operation of a standard P-59A aircraft down to —45°F can be simplified and improved if the following changes are made:

(1) The barometrics should be redesigned to incorporate a method for compensating for changes in temperatures as well as changes in atmospheric pressures.

(2) Wing and engine covers be designed as one piece and manufactured for issue.

(3) An oil system drain and self-locking draincock be provided.

(4) Installation of flush-type static source and separate pitot head. The pitot head should be located where it can be easily covered when plane is on the ground.

(5) Replace rear-mounted instrument with front-mounted type.

c. Testing indicates that the experimental equipment installed in the subject airplane is satisfactory or unsatisfactory to the temperatures experienced as indicated below:

(1) Skinner air-oil filter—Unsatisfactory.

(2) Relubricated A-11 Bank and Turn Indicator—Satisfactory.

D. RECOMMENDATIONS

1. It is recommended that the changes listed in C 1a and C 1b above be incorporated in future production airplanes.

Cold Weather Test of P-61B Airplane

Prepared by: Homer J. Andre, Capt., A.C.

A. PURPOSE

1. To report on the cold weather tests conducted on Air Technical Service Command P-61B-2NO, serial No. 42-39402, at Ladd Field, Fairbanks, Alaska, for the winter of 1944-45.

B. FACTUAL DATA

1. The minimum ground temperature encountered during the test period for this aircraft was —36°F and the mean temperature of the coldest day was —17.7°F. The lowest temperature encountered in flight was —53°F at 25,000 feet, at which time the aircraft soaked for 50 minutes.

2. The test period on this aircraft ended on 23 February 1945, at which time the aircraft crashed, killing 1st Lieutenant J. R. Payne, who was flying a service test at the time. The aircraft and all equipment were damaged beyond salvage value; the cause is unknown.

3. For a record of flying time and ground temperatures during the test period, see Appendix I.

4. Listed below are the items tested and results obtained:

a. Lubricants and hydraulic fluids.

(1) Lubrication of right engine was standard SAE 1100A oil, while the left engine was using PPO 265. The left propeller hub was lubricated with ANG-3 grease and the right hub with ANG-4 grease. Speed reducer unit on left propeller was lubricated with ANO-4 oil and the right with AN-VVO-366 oil. Left main landing gear strut and nose wheel strut were filled with experimental noninflammable hydraulic fluid for comparative test against standard fluid in the right strut.

(2) All lubricants and hydraulic fluids used were satisfactory. PPO 265 showed the following advantages over 1100A oil: shorter warm-up time, required less dilution, and acted as a solvent in keeping engine parts clean. The only deficiency in this oil was its tendency to cause minor oil leaks.

b. Rubber and synthetic, hydraulic fuel and oil line hose and connections.

(1) No malfunctions noted other than oil leakage caused by loose oil line connections which were located in very inaccessible locations for tightening. See Appendix IIA.

c. Weatherstripping and fuselage seals.

(1) Seals around pilot's sliding windows became stiff at temperatures below +10°F. Rubber to metal cement failed to hold seals around rear of nose wheel doors when cannons were fired. The seal around pilot's entrance hatch was inadequate to hold air blast out of cabin when nose wheel was extended.

d. Hydraulic actuating systems and shock struts.

(1) Trouble was experienced throughout the test period with the main landing gear dropping out of the up and locked position during flight, while the gear handle was in the neutral position. The cause of this malfunction was not determined but, upon recommendation of the Northrop representative, the gear handle was left in up position after take-off and the trouble did not occur again. It is believed this was caused by thermal expansion of the hydraulic fluid exerting pressure on the up lock pistons causing them to release the up locks.

(2) No malfunction of any shock struts was noted. During the test period the struts required no servicing with either air or fluid.

e. Hydraulic and fluid seals and packings.

(1) Experimental "O" ring packings installed in both the nose and left hand main gear struts operated satisfactorily throughout the test period.

(2) Curtiss blade nut seals installed on both propellers as standard equipment leaked grease excessively on altitude flights where free air temperatures were below —40°F. See Appendix IIB.

f. Surface control systems.

(1) No malfunctions during test period. Controls have shown no indication of stiffness with temperatures as low as —53°F at 25,000 feet, at which time the aircraft soaked for 50 minutes.

g. Propeller controls and feathering systems.

(1) The test installation of Simmonds Corsey propeller control on left engine proved very satisfactory and is superior to the standard cable control system both in freedom of artion and sensitivity. See Appendix IIC.

h. Cabin and cockpit heating.

(1) Heating test run on the surface combustion heating units proved the system to be inadequate for low temperature or high altitude operations above 10,000 feet. See Appendix IID.

i. De-frosting and de-icing of windshields on ground and in flight.

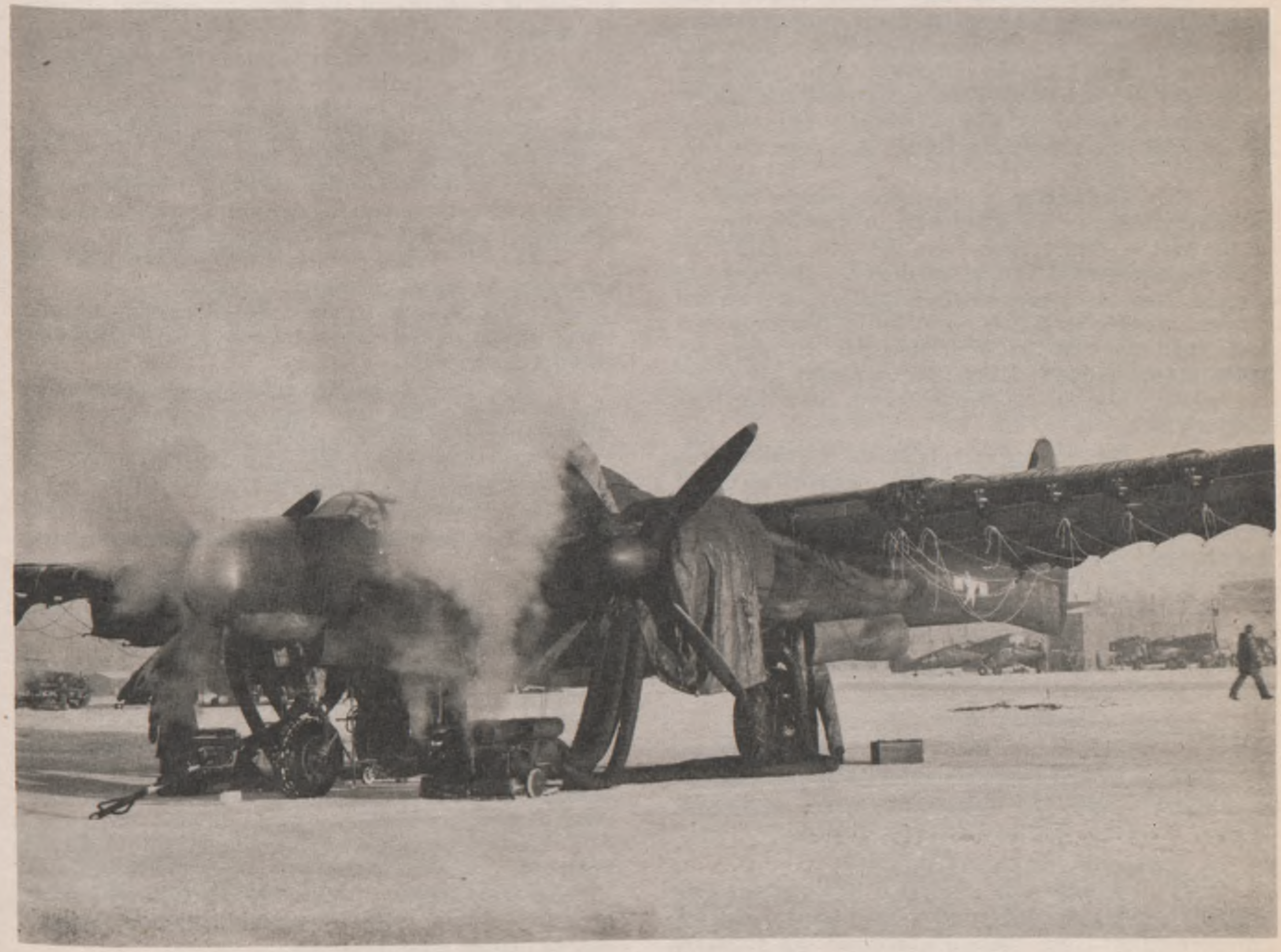
(1) Tests run on this system indicated it to be inadequate and generally unsatisfactory for the purpose for which it was designed. See Appendix IID.

j. Deicing of wings, empennage and propellers.

(1) No tests were scheduled on this standard equipment and weather during the test period did not require its use. However, functional tests were run at 25,000 feet and O.A.T. of —53°F with no malfunction or deficiencies noted after soaking for 50 minutes.

k. Wing and engine covers.

(1) No malfunctions or deficiencies



P-61 Preparing for starting

l. Snow and ice tires.

(1) Synthetic rubber ice-grip tires with inserted springs were installed for service testing, two S-6 12-ply rayon 47"SC serial No. R4S-1 and R4S-2 on the main wheels and one S-6 8-ply 33"SC serial No. R4T1 on the nose wheel.

(2) Approximately 95 landings were made on these tires, 25 having been made on hard surfaced runways free of snow or ice. The tires showed excessive wear on trailing edge of buttons and loss of 25% of inserted springs. Ice grip characteristics on glaze ice was unsatisfactory at run-up power but was a little better than standard tires on hard packed snow surface.

m. Dilution and scavenging characteristics of oil system.

(1) No scavenging tests were scheduled but extensive tests were run on the experimental United Aircraft Products automatic oil dilution unit. Dilutions of 10%, 20% and 30% were run with varying oil and free air temperatures. See Appendix IIE. The production system of oil dilution was satisfactory this year since the restricting orifice was drilled out with No. 47 drill.

n. Accessibility and effectiveness of oil, fuel and water drains.

(1) Koehler self-locking "Y" drains and type K1700-B 1 and 2 drain cocks were used throughout the aircraft with no malfunctions or deficiencies noted. All drains this year were well located for accessibility.

o. Adequacy and selectivity of carburetor heat.

(1) The carburetor heat on this aircraft was derived from mixing hot exhaust gasses from an exhaust stack with ram air in a carburetor pre-heat casting, and diverting it directly into the carburetor. This system met winterization requirements but was undesirable due to the lack of selectivity of control and the stratification of air entering the carburetor, causing unreliable carburetion.

(2) Carburetor pre-heat could not be used on this aircraft when the engines were in auxiliary blower, so the heat of compression from the blower had to be used for any deicing in the carburetor. The heat rise derived from this system was inadequate. Experimental forward intercooler shutters installed by Northrop Aircraft improved the heat characteristics but were not 100% effective due to leaks. See Appendix IIF.

p. Freezing of condensate in oil, fuel, vent lines and breathers.

(1) No freezing of condensate in any line was experienced during the test period. Re-routing of oil tank and vent lines on P-61B this year eliminated condensation traps. Engine breather lines were experimental installations and worked satisfactorily. See Appendix IIG.

q. Flight and navigation instruments.

(1) No malfunctions were noted other than general sluggishness of air-driven gyro instruments at cockpit temperatures of below -10°F.

r. Engine instruments.

(1) The engine fuel pressure gauge unit required frequent servicing at both sides of the pressure transmitter to keep the instrument correct on altitude flights. No other malfunctions were noted.

s. Guns and fire control equipment.

(1) Service tests conducted indicated no malfunction on this equipment other than normal maintenance troubles. Tests were discontinued due to warm weather after 4175 rounds of .50 caliber and 2100 rounds of 20 m.m. ammunition had been fired for functional check on equipment. Lowest temperature encountered was -7°F.

t. Bombing equipment.

(1) No tests conducted and no deficiencies noted.

u. Radio and radar equipment.

(1) No malfunction noted; SCR 522 receivers and transmitters installed in fighter aircraft are deficient in their restricted range when in mountainous country making their use in the Arctic limited. They are, however, very satisfactory in their clear reception in snow showers.

v. Electrical equipment.

(1) Production type immersion water heaters for the water injection system wing tanks were found to be of inadequate capacity to prevent freezing of pure water in the lines. Experimental electric line heating blankets used on the right hand water system lines and pump were also too low in capacity to prevent freezing. See Appendix IIH.

w. Engine starting.

(1) No malfunctions noted, due to the unusual weather during this test period. A minimum of dilution and external heat was used for starting.

x. Engine operation in flight.

(1) No malfunctions or deficiencies noted.

C. CONCLUSIONS

1. It is concluded that:

a. Operation of a standard P-61B aircraft down to —36°F is possible if the following essential changes are made:

(1) The intercooler shutters on lower side of engine accessory section are removed.

(2) Engine breather lines, insulated and rerouted in the same manner as was tested on right engine of subject airplane. See Appendix IIG.

(3) Water injection system is modified with adequate immersion heaters and line heaters to prevent freezing of pure water. See Appendix IIH.

(4) Condensate traps in oil tank vent lines are eliminated as tested on subject airplane.

b. Operation of standard P61-B aircraft down to -36°F can be simplified and improved if the following changes are made:

(1) Incorporation in future production aircraft of an adequate heating and defrosting system, including double panel windshields in bullet resistant glass sections.

(2) Use on all future production aircraft of winterized drain cocks, Kohler K1700-B type 1 or 2 and self-locking "Y" drains. The number of self-locking "Y" drains in the wheel well can be reduced by rerouting oil lines.

(3) Redesign of landing gear air bungee system to prevent leakage of high pressure air from filler valves and seals at low temperature.

(4) Fabrication of improved winterized Curtiss blade nut seal to prevent grease leakage at -40°F temperature.

(5) Installation of full closing intercooler shutters before the intercooler of future production aircraft to make adequate carburetor heat available while operating in auxiliary blower.

(6) Installation of nose wheel door cannon fire interrupter switch of winterized type on all P-61 aircraft.

(7) Change of size or relocation of oil line immediately behind engine vacuum pump to facilitate change of this unit in the field.

(8) Relocation and grouping of all electrical wiring, tubing, etc., in accessory compartment of engine

nacelle to facilitate engine maintenance in cold weather.

(9) Use of PPO 265 synthetic oil for winterized aircraft to aid engine starting and warm-up.

c. Testing indicated that the experimental equipment installed in subject airplane was satisfactory or unsatisfactory to the temperatures experienced as follows:

(1) Northrop Aircraft experimental intercooler shutter kit - partially satisfactory. See Appendix IIF.

(2) Winterized nose wheel door cannon fire interrupter switch - satisfactory.

(3) Winterized self-locking drain cocks Kohler K-1700-B H2 type - satisfactory.

(4) Self-locking "Y" drains - satisfactory.

(5) Simmonds Corsey propeller control - satisfactory. See Appendix IIC.

(6) Experimental "O" ring packings and noninflammable hydraulic fluid - satisfactory.

(7) Stainless steel rack and pinion in standard propeller governor - satisfactory.

(8) Special electric propeller speed reducer relief fitting in hub - satisfactory.

(9) Moulded type connector plugs in propeller governor system - satisfactory.

(10) Production water injection system - unsatisfactory. See Appendix IIH.

(11) Production modified main landing gear auxiliary door - unsatisfactory due to loosening of hinges and linkage.

(12) Production cabin heating and defrosting system - unsatisfactory. See Appendix IID.

(13) United Aircraft Products oil dilution control valve - unsatisfactory.

D. RECOMMENDATIONS

1. It is recommended that the changes listed in C.1.a. and C.2.b be incorporated in future production airplanes.

Cold Weather Test of P-63A Airplane

Prepared by: Byron W. Allgood, 1st Lt., A. C.

A. PURPOSE

1. To report on the cold weather testing of ATSC P-63A-10-BE, Serial No. 42-70255, at Ladd Field, Fairbanks, Alaska, for the winter of 1944-45.

B. FACTUAL DATA

1. The minimum ground temperature encountered during the testing of P-63A No. 42-70255 was -34°F and the mean temperature of the coldest day was -26°F. The lowest temperature encountered in flight was -28°F, to which the airplane was exposed for 15 minutes.

2. For a record of flying time and ground temperature encountered, during the test period, see Appendix I.

3. Listed below are the items tested and the results obtained:

a. Lubricants and hydraulic fluid.

(1) Grade 1100A oil was used for engine lubrication. Texas Company grease, TG455, was used on all moving parts in the elevator and rudder trim tab. Other lubrication was in accordance with T.O. 01-110FP-5, dated 20 December 1943, and revised 15 August 1944, with the exception of the propeller reduction gears on which Specification No. AN-O-3 Light was used. Hydraulic fluid, Specification No. AN-VVO-366a was used in the landing gear, oleo struts, and brake system.

(2) No malfunctions occurred from lack of lubrication, and no stiffness of the control system was noted at temperatures as low as -34°F.

b. Rubber and synthetic, hydraulic, instrument, fuel, and oil line hose connectors.

(1) Installations were standard, with the exception of the experimental synthetic test hose installed at the following places by the Materials Laboratory:

(a) H-40 "Oil Out" line on the surge valve.

(b) R-80 "Oil In" line on the surge valve.

(c) R-8 "Return Line" from oil cooler to oil tank.

(d) R-1 "Return Line" from oil cooler to oil tank.

(2) No malfunctions were encountered in either the standard or experimental hose.

c. Weatherstripping and fuselage seals.

(1) A five-inch strip of the rubber used for sealing the cockpit doors became loose at the beginning of the test season, but no further deficiency occurred, and it is presumed to have been caused by defective cementing at the factory.

d. Hydraulic system, shock struts, seals and packings.

(1) No malfunctions of the hydraulic brake system were encountered. The shock struts were equipped with "O" ring packing, and it was unnecessary to service either main strut with fluid or air. The nose strut was serviced with air and hydraulic fluid only once, directly after arrival of the airplane. No replacement of seals or packings was necessary.

e. Surface control systems.

(1) No malfunctions or stiffness was observed in any part of the surface control system. No noticeable changes in cable tension occurred due to temperature variations. The control system and trim tabs operated freely at temperatures down to -34°F.

f. Propeller controls.

(1) The Standard P-63 propeller control is combined with the throttle lever, and propeller speeds depend upon the manifold pressure selected with the throttle lever. This arrangement was satisfactory for normal operation and simulated combat flying, but im-

practical on a test airplane on which tests call for specific manifold pressures and propeller speeds. As the automatic arrangement was subject to slight variations, an old style throttle quadrant formerly used on the P-39 type airplane was substituted.

g. Cockpit heating.

(1) An ample heat supply is available for cockpit heating. A better distribution of the heat, however, would be desirable. For data on heat rise and distribution see Appendix II.

h. Defrosting and deicing of windshield and cockpit enclosure on the ground and in flight.

(1) Adequate defrosting of the windshield or cockpit enclosure for ground operation could not be accomplished with the system installed on this airplane. However, light frost was removed from the inside of the cockpit enclosure after take-off. This is considered inadequate. For further information refer to Appendix III.

i. Wing, empennage and exhaust stack covers.

(1) Standard untreated cloth wing and empennage covers were used during the test season. No cloth engine and canopy cover was furnished. Exhaust stack covers were used to keep snow from blowing into the engine. See Appendix IV.

j. Snow and ice tires.

(1) The tires installed on this airplane were the diamond-tread type with coiled steel springs imbedded in the tread.

(2) These tires were subjected to a total of 100 landings, of which approximately 27 were made on a dry, hard-surface runway, with the result that a few inserts were lost. This is entirely to be expected and should not be considered a fault of the tire. Only a few inserts were lost since operation on snow and ice runways was begun. Loss of inserts caused no damage to the plane, and no appreciable damage to the tires. Any margin of traction gained by the use of this type tire over a standard rubber tire is doubtful, as skidding will occur on icy surfaces at engine powers at or below those required for magneto check before takeoff, depending on the type surface on which the airplane is parked.

k. Dilution and scavenging characteristics of oil system.

(1) Extensive scavenge tests were run which indicated good scavenging characteristics of the original engine, Model V-1710-93 modified with the improved engine front cover with built-in baffling at the engine breather, and with the aid of the Bell Aircraft design oil separator. For data on these tests see Appendix V, tests Nos. 1, 2 and 3 on engine Model V-1710-93.

(2) Scavenge tests on the new engine Model V-1710-117, which was installed in this airplane were also conducted. For factual data on these tests see Appendix V, tests Nos. 1, 2, 3 and 4 on engine Model V-1710-117. This series of tests was run using a new design oil tank on which additional information was desired, but which had little or no effect on the scavenging characteristics of the engine as shown on Test No: 4, which was run as a re-check and on which the standard tank was re-installed.

l. Accessibility and reliability of oil and fuel drains.

(1) Oil and fuel drains in general were accessible and reliable. Some improvements as to the type drain used for arctic operation could be made, however, as well as the re-location of access doors for better accessibility. For further discussion refer to Appendix VI.

m. Adequacy and selectivity of carburetor heat.

(1) An adequate supply of carburetor heat is furnished on this airplane. Selectivity is easily accomplished by a control located in the cockpit. For data on this installation see Appendix VII.

n. Freezing of condensate in oil, fuel and coolant lines, vent lines and breathers.

(1) No freezing in the lines or breathers was experienced. However, the drain line from the oil tank sump originally had several small bends which probably would have collected moisture and frozen if the line had not been removed and straightened at the modfication center at Vandalia, Ohio.

o. Flight and navigation instruments.

(1) The standard directional gyro sometimes spun in moderate or steep turns. No cause was determined, and these instruments are usually replaced when malfunctions are noted. Other instruments operated satisfactorily.

p. Engine instruments.

(1) The engine oil pressure indicator and reduction gear-box oil pressure indicator fluctuate occasionally in flight. This was believed to have been caused by high performance engine operation during testing of the airplane, and as readings were satisfactory and reliable, the instruments were not replaced.

q. Guns, fire control equipment and bombing equipment.

(1) No tests were scheduled on this equipment for the season.

r. Radio equipment.

(1) No malfunctions of the radio equipment were experienced during routine operation. No specific tests were scheduled.

s. Electrical equipment.

(1) No malfunctions of the electrical equipment or system have occurred.

t. Engine starting.

(1) On a cold start at Galena, Alaska, (See Appendix VIII) a successful cold start was made using grade 130 fuel. However, when the airplane was started approximately two hours later on return to Fairbanks, oil was observed leaking from the core of the Young oil cooler. This cooler was equipped with a surge valve which served to by-pass the gow of oil through the cooler at excessive pressures to avoid bursting the cooler.

(2) Since it could not be determined whether the malfunction was due to a faulty cooler, or failure of the surge valve to relieve pressure within the cooler, a Harrison cooler was installed, with the original surge valve used at the time of failure. As sufficiently low temperatures have not been encountered while the airplane was available for test, further data is not available.

u. Engine operation in flight.

(1) No malfunctions have occurred.

C. CONCLUSIONS:

1. It is concluded that:

a. Operation of the P-63 type airplane is possible down to —28°F. if the following essential changes are made:

(1) Routing of the oil tank sump drain line. engine breather lines and vent lines is such that no moisture traps exist.

b. Operation of the P-63 type airplane can be simplified and improved if the following changes are made:

(1) Distribution of cockpit heat is improved so as to give a more even temperature throughout the cockpit.

(2) A method of eliminating frost within the cockpit enclosure caused by breathing of the pilot dur-

ing ground operation would be of great value.

(3) All cloth covers used for protection of the airplane on the ground should be of sufficient size for adequate covering, and be equipped with simple fasteners.

(4) A dependable self-locking drain should be made and used at all points at which drainage is accomplished. Access doors should be of sufficient size, and conveniently located to simplify duties of ground crews wearing necessary arctic clothing.

(5) All direct-connected pressure indicating instruments should have fittings on the instrument panel to facilitate servicing of the lines.

(6) The access doors in the wings used when servicing the landing gear struts should be enlarged.

(7) A spring of sufficient strength to hold the door closed should be used on the external power receptacle door.

(8) The engine priming solenoid should be connected to the pressure side of the restricted fitting in the oil dilution line.

(9) Battery quick-disconnect assemblies should be used to facilitate removal of the battery.

c. Testing indicates that the experimental equipment installed in the subject airplane has proved satisfactory in operation during the test season.

(1) Texas Company grease, TG-455—satisfactory.

(2) Synthetic test hose—satisfactory, subject to further inspection by the Materials Laboratory.

D. RECOMMENDATIONS:

1. It is recommended that the changes listed in C.1.a. and C.1.b. above be incorporated in future production airplanes.

SECTION IV

Final Reports of Project Engineers and Observers of the Engineering Division Laboratories, Maintenance Division and Supply Division

This section consists primarily of final reports written by the project engineer and officers of the various Engineering Division Laboratories. Considerable supporting data and exhibits have been omitted from these reports, only the essential material being included. However, reference to the missing data is included in the portion printed. Anyone desiring complete reports may obtain them by directing correspondence to the Director, Air Technical Service Command, Wright Field, Dayton, Ohio, Attention: TSESE-4F3.

Final Report of Cold Weather Tests on Airplane Structures and Controls

Prepared by: *A. S. Anderson, Capt., A. C. Aircraft Laboratory*

A. PURPOSE:

1. To report results of Extreme Temperature Operations Unit tests conducted and service problems confronted during operation of airplanes subjected to cold weather conditions at Ladd Field, winter of 1944-45. This report covers the period from 1 December 1944 through 10 February 1945.

B. FACTUAL DATA:

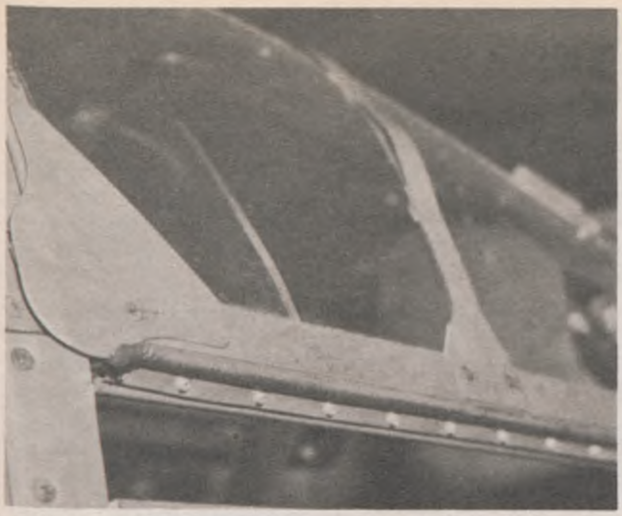
1. TEMPERATURE TEST RANGE. Few extremely cold days were experienced, resulting in inadequate data being collected during ground tests. The coldest period was the 5th through the 7th of December, 1944. The lowest official temperature during that time was minus 41 degrees F. The mean temperatures for 5, 6 and 7 December 1944 were minus 30.3 degrees F., minus 37.1 degrees F., and minus 29.7 degrees F., respectively. Official temperatures for the test period, compiled by the Ladd Field Weather Office, are included as Appendix VI of this report.

2. FLYING TIME. Appendix I is a list of the airplanes assigned to the Extreme Temperature Operations Unit, the date of their arrival at Ladd Field, and flying times through 8 February 1945. An approximate average of 70 flying hours per airplane was attained in Alaska during the period 1 December 1944 to 10 February 1945.

3. REFERENCE REPORTS. Progress reports were submitted on 15 and 31 December 1944 and on 15 and 31 January 1945, to the attention of TSEAL-2L.

4. SERVICE DIFFICULTIES. Service and maintenance difficulties experienced during this period are listed in Appendix II, this report. Comments as to the probable causes and the corrective actions taken are included.

5. CONTROL SYSTEMS. Winter tests of 1942-3 and 1943-4 indicated that without application of heat, either at engine nacelles, fuselage compartments or both, practically all AN-G-3 lubricated airplanes at minus 40 degrees F. and below had at least one main control or trim tab which required excessive control force to operate. The problem was condsidered to entail differential expansion and contraction between component parts or mountings and lubrication. During the current winter, tests of a large number of airplanes of the same type and approximate serial numbers, and tests of the same control systems of similar airplanes lubricated with different greases were made to further explore this problem. Indications were that at extreme low temperatures, airplanes lubricated with the same grease would vary considerably in required control forces. A lubricant having



Plastic hatch

a low temperature torque approximately one-quarter of the standard AN-G-3 apparently did not cause an appreciable difference in control forces required at low temperatures. Appendix III contains tests made of control forces.

6. CONTROL CABLE TENSIONS. It was recognized that adequate design data were not available for large airplanes on the temperature differentials obtained in flight between the airplane skin and cables. This, in turn, did not permit accurate calculation of cable tensions. It was assumed that future large airplanes would operate in a free air temperature of minus 65 degrees F., have insulated fuselages and compartment temperatures in the vicinity of plus 70 degrees F. For the purpose of collecting pertinent data, tests were made, which partially explored the problem. These tests included investigation of standard and compensated cables, and cables with mechanical and hydraulic regulators. Airplanes tested were one B-17G, two B-24J's, one A-26 and one C-54B. Appendix IV covers temperatures of free air, fuselage skin, compartments and cables and cable tensions.

7. ENGINE MOUNTING ISOLATORS. Experimental engine mounting units were installed in one each, B-24J, B-17G, A-26B, B-25D, and C-54B airplanes for the purpose of service testing. These appear to be satisfactory with the exception of those in the A-26B. Further details as to cold starts attempted, resulting in excessive vibration, may be obtained from the project engineer of each airplane. A discussion of the unsatisfactory condition of the A-26B synthetic mounting units is given in Appendix V of this report. No trouble attributed to cold weather was experienced with standard mounting units.

8. PLASTIC INSTALLATIONS. The plastic parts listed below were installed on the airplanes indicated for service testing. They have given satisfactory service and are in good condition.

a. Ring cowling, upper segment.... B-17G 43 38221
b. Waist gunner's door.................... B-24J 44 41378

All standard plastic parts functioned satisfactorily with the exception of one P-38 canopy, one B-29 top sighting station blister, one P-47 canopy, one B-24 Martin upper turret dome and eight C-46 pilot's windshields. Details are covered under service difficulties, Appendix II.

9. STRUCTURAL SEALING PARTS. Practically all sealing strips used in door and other exits, rudder pedal openings and window ventilators did not fracture or otherwise fail at temperatures encountered but became too stiff at approximately minus 30 degrees F. and below and did not function satisfactorily. The only failures noted were two C-46 rudder pedal openings, one hatch seal on an A-26 and one P-38 hatch seal. Detailed Unsatisfactory Reports or letters on these failures were forwarded.

10. WINDSHIELD DOORS. Negligible flying in icing weather was performed. No tests on windshield doors were made during periods of poor visibility.

C. CONCLUSIONS:

1. It is considered that the lowest temperatures obtained did not afford adequate proving below minus 25 degrees F. Items which operated satisfactorily below this temperature are noted in this report.

2. The average flying time per Extreme Temperature Operations Unit airplane of approximately 70 hours is considered to constitute a fair proving test period as far as the time element is concerned.

3. Information obtained on control system forces further indicates that component parts and their mountings were more deficient than lubrication and caused excessive stiffness below minus 40 degrees F. Deficiency is attributed to differential expansion and contraction of component parts and their mountings.

4. Indications are that control cables of all airplanes are not able to maintain design tensions throughout the temperature range minus 65 degrees F. to plus 160 degrees F. For the operating temperatures encountered, most airplanes, upon arriving from the States, required resetting of the cable tensions to meet operating tensions prescribed in Technical Orders. This is considered an hazardous practice, as the movement of the airplane to a higher operating temperature area without resetting of cables might result in excessive cable tensions, with the resulting excessive strain on the fittings. With the advent of larger airplanes with insulated, heated compartments, additional trouble in cable tension changes may be expected.

5. The Pacific Scientific Company's mechanical type

Plastic turret

cable tension regulators installed in B-17G airplane, Serial No. 43-38221, regulated the aileron cable tension satisfactorily in the temperature range of plus 70°F. to approximately minus 40°F.

6. The United Aircraft Products Company's hydraulic type cable tension regulators installed in production by Consolidated-Vultee Aircraft Corporation in B-24 airplanes proved satisfactory after the cable tensions had been reset for the ambient temperatures encountered.

7. The special aileron control cable installed in B-24J airplane, No. 42-51660, regulated satisfactorily at flight temperatures as low as minus 60 degrees F. However, there were no heaters operating and cable temperatures approximated that of the fuselage skin.

8. Plastic parts conforming to current installations are considered satisfactory to minus 40 degrees F. The failures occurring during the test were attributed to obsolete design or faulty installation.

9. Conclusions on experimental synthetic mounting units will depend on disassembly inspection at Air Technical Service Command, TSEAL-2E.

10. Door, window and hatch seals do not have sufficient flexibility to insure adequate sealing at low temperatures except where seals are bolted on plane or otherwise rigidly secured.

D. RECOMMENDATIONS

1. Tests should be conducted to obtain supplementary data on flight operation of control systems of large airplanes with insulated, heated compartments under conditions of highest differential temperature between fuselage skin and cables. These should include additional flight testing of compensated cables and cable tension regulators.

2. Chamber work should be conducted to determine in the range of minus 65 degrees F. to plus 160 degrees F.:

a. Characteristics of control system component parts.

b. Characteristics of complete control systems installed in airframes in accordance with conclusions of Paragraph D2a.

3. The control systems of one or more airplanes which are to remain under the control of the Air Technical Service Command should be lubricated with extreme temperature greases and oils to obtain service life tests of low temperature lubricants. This refers to lubricants having considerably lower torques than the current standard greases and oils.

4. Control systems should be tested in the cold chamber in a temperature range covering anticipated airframe skin and cable operating temperatures. The purpose of this work would be to develop cable control systems which will meet proper design tension requirements throughout the rang minus 65 degrees F. to plus 160 degrees F.

5. All airplane door, window and similar sealing strips should be developed to function satisfactorily throughout the range minus 65 degrees F. to plus 160 degrees F.

6. Airframes should be designed and fabricated in accordance with "Design of Aircraft and Aeronautical Equipment for Operation in Extreme Climatic Conditions." Current issue is Engineering Division Technical Note, Serial No. TN-TSESE-1.

Cold Weather Testing of Landing Gears and Hydraulic Systems

Prepared by: W. R. Maslin, 1st Lt., A. C. Aircraft Laboratory

A. PURPOSE

1. To comment on performance of landing gear and hydraulic system operation under conditions experienced during the cold weather testing season of 1944-45 at Ladd Field, Alaska.

B. FACTUAL DATA

1. Temperature conditions experienced this season were extremely moderate, and therefore did not afford much opportunity for conclusive cold weather testing. The temperatures ranged as follows:

MONTH	HIGH	LOW	MEAN
November	+30°F	—16°F	+7.3°F
December	+40°F	—41°F	+1.1°F
January	+43°F	—30°F	+2.8°F

2. Temperature data for the month of February has not yet been compiled, however during the three day period, February 12-14, as listed in paragraph 3 below the temperature reached a low of —45°F.

3. Only 6 days in the entire season can be considered satisfactory for cold weather test purposes and these are as follows:

DATE	HIGH	LOW	MEAN
December 5	—24°F	—34°F	—30.3°F
December 6	—35°F	—41°F	—37.1°F
December 7	—19°F	—40°F	—29.7°F
February 12	—20°F	—36°F	—27.8°F
February 13	—16°F	—45°F	—30.2°F
February 14	— 1°F	—36°F	—17° F

4. The following type airplanes were on test:

A-26B	C-46A	P-51D
B-17G	C-47A	P-59A
B-24J	C-54B	P-61B
B-25J	P-38L	P-63
B-29	P-47D	

5. During the cold days mentioned in Paragraph 3 none of these airplanes were grounded due to landing

gear or hydraulic system failures. During the cold weather only three (3) airplanes had leaking landing gear, the F-5E airplane and both P-47D airplanes. The left landing gear of the F-5E airplane, which was equipped with winterized chevron packings leaked fluid twice during the season. Tightening of the packings stopped the leakage both times. The P-47D airplanes leaked fluid past the packing every time the temperature reached —40°F. After the first case of fluid leakage at —40°F the struts were disassembled and the packings had been chipped. Three (3) winterized synthetic chevron packings (Linear LT-90V) and two (2) leather chevron packings were installed on each strut, however the struts leaked again at —40°F. At those times the correct wrench for tightening these struts was not available. Therefore it is not known whether or not the leakage could have been stopped by tightening the struts. The struts on the P-47D airplanes were not able to retain air pressure in the bottom chamber and were continually going flat. See Appendix V for detailed P-47 landing gear difficulties.

6. All hydraulic systems were filled with AN-VV-O-366A hydraulic fluid. At —40°F sluggish actions of some units were noticed. The B-24J landing gear and flaps could not be operated at all without holding the selector valve handle in the desired position. The A-26B airplane at —36°F required four (4) attempts to finally retract and lock all three landing gear. The brakes on the P-38J airplane were sluggish at —47°F (at Northway), however steering and taxiing of the airplane was still possible.

7. Generally, the hydraulic systems under the conditions of this winter operated satisfactorily and caused little leakage. Those airplanes equipped with winterized "O" ring packings caused less leakage than those airplanes equipped with winterized chevron packings. No trouble was experienced with hydraulic filters. No trouble was experienced with accumulators using winterized diaphragms or winterized "O" rings. No low temperature trouble was experienced with winterized flexible hose. The following list is a general record of the hydraulic troubles experienced this winter on each type airplane. Appendix II gives detailed information regarding the hydraulic troubles on each type airplane.

a. A-26B type airplane.

(1) Sluggish landing gear retraction at —36°F. This occurred only on one of the two A-26B airplanes at this station.

(2) Nose gear doors failed to close due to contraction of a brass turnbuckle at —16°F.

(3) Nose gear failed to retract due to snow and ice in retracting mechanism, causing the mechanism to jam and to be bent. There was practically no leakage of the hydraulic units in this type airplane caused by cold weather.

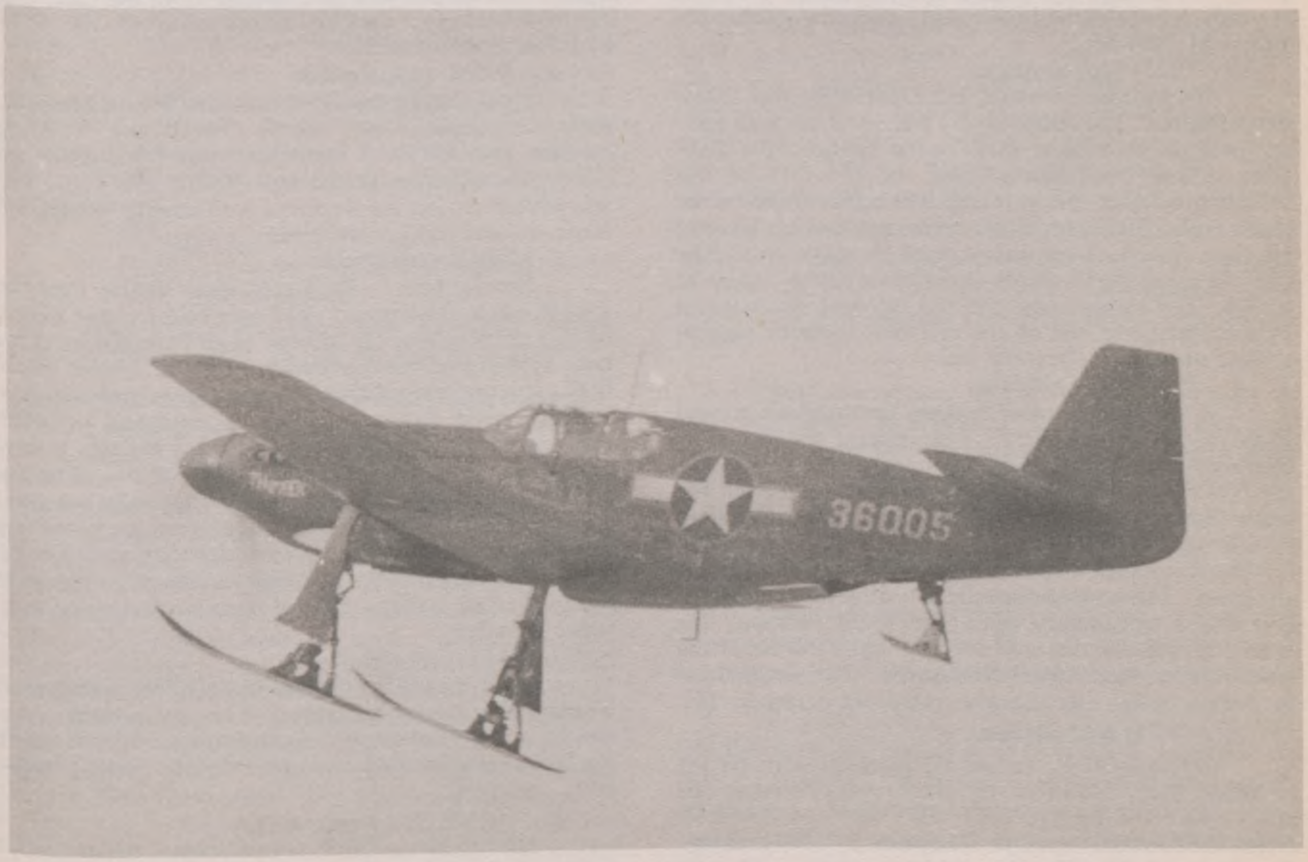
b. B-17G type airplane.

No hydraulic trouble caused by low temperatures.

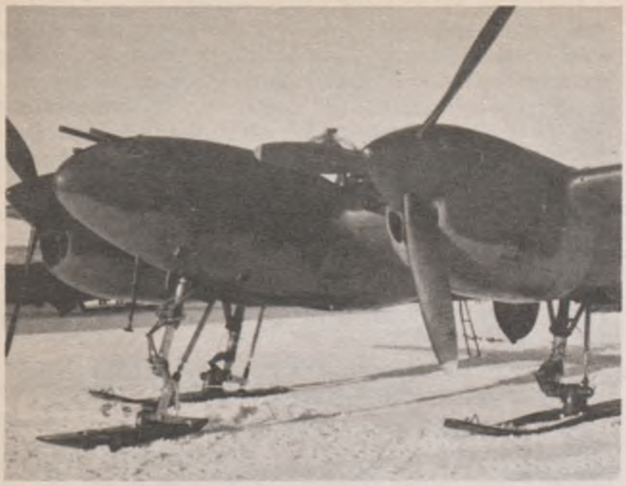
c. B-24J type airplane.

(1) Landing gear and flap selector valve handles had to be held in the desired position (up or down) at temperatures below +20°F. Two B-24's were adjusted so the selector valves would operate normally to O°F. See Appendix VII for detailed information and tests conducted on this trouble.

(2) The JO3 restrictor valve on the landing gear of one B-24M stuck at —40°F but was freed with heat. This occurred twice in one day. However this had not occurred on any of the B-24J type airplanes so can



P 51 with snow gear extended in flight



P 38 with snow gear

P 38 snow gear extended in flight

be assumed to be an isolated case. No hydraulic units leaked due to low temperatures. Some leakage occurred around the middle swivel joint of the main landing gear actuating cylinder swivel connection. Four (4) cases of this leakage occurred at temperatures ranging from +15°F to —40°F. In all cases the "O" rings appeared to be slightly worn. It is assumed they were winterized packings although the winterized mark had worn off.

d. B-29 type airplane.

The B-29 had no hydraulic trouble caused by low temperatures. A service test was conducted on AN 364 lock nuts and AN 902 gaskets, which were installed on the brake control valve and in the removable hydraulic panel. No trouble was caused by these parts. This was the only scheduled hydraulic test conducted during the winter of 1944-45.

e. B-25J type airplane.

No hydraulic trouble was experienced due to low temperatures. The Allied B-25J's had trouble with leakage past the cross flow valve in the landing gear actuating cylinder and leakage past the end caps of this actuating cylinder due to insufficient compression on the static seal. These problems were not caused by cold weather. The leakage was stopped thru the cross flow valve by changing the angle of the brass poppet from 45° to 44°. The leakage past the end cap seal was stopped by machining the end of the cylinder, therefor putting greater squeeze on the static seal.

f. P-38L type airplane.

A slight amount of leakage occurred on several P-38L airplanes at —40°F. This leakage stopped of its own accord at —40°F and did not necessitate removal of the "O" ring. The F-5E airplane leaked fluid from the brake reservoir at —40°F when the camera heaters were turned on. This leakage was due to fluid expansion. Lockheed installed a special brake system on two P-38L airplanes. The temperature did not drop low enough to give this a satisfactory test. The P-38L without this special installation did not have any brake trouble at the temperatures encountered this season. For detailed information on this special brake system see Appendix III.

g. P-47D type airplane.

During —40°F weather all hydraulic units seeped or leaked fluid. However, the planes were flown at this temperature and all hydraulic units could be operated. After the first cold spell in December 5-7 the packings were changed. The Vee rings which were removed were winterized (—65°) Vee rings and winterized Vee rings (—65°) were reinstalled, however seepage continued on some of the units below 0°F. The landing gear door cylinders and flap actuating cylinders were the worst offenders. It was noted that during inspection of the units following the first cold spell in December that the packings around the piston rod where leakage had occurred, were not even tightened finger tight which is the specified amount of squeeze on those packings. During the last cold spell February 12-14 the wing flap cylinders and landing gear door cylinders were again leaking, and seepage occurred about up-locks and landing gear actuating cylinder. Seepage as referred to above can be interpreted as meaning less than one drop of hydraulic fluid per minute dropping from the unit. See Appendix II for detailed information on the P-47 hydraulic system troubles.

h. P-51D type airplane.

No hydraulic trouble was caused by cold temperatures. No leakage was visible around any actuating cylinder at —40°F. A static seal caused leakage when the system was pressurized at —20°F. This static seal was winterized but was replaced with another winterized static seal and leakage stopped.

i. P-61B type airplane.

During both —40°F cold spells at this Post the P-61B was in the hangar. The only cold weather effects on this airplane was the leakage of air from the accumulator system and the emergency nose gear system below 0°F. It is understood that other activities report inability to retain air in this system. An experimental air bottle and valve were installed and tested for leakage at low temperatures. For details see Appendix VI. The accumulator air system was tightened continually but pressure could not be maintained. Therefore the plumbing was removed and standard winterized air valves were installed directly into the accumulator and surge chamber. No further air leakage resulted from the accumulator or surge chamber.

j. P-63A type airplane.

No hydraulic trouble on this airplane was caused by extremely low temperatures. The parking brake control froze due to entrapped condensation, which froze in the brake cable housing, and prevented the parking brake from operating.

k. C-46A type airplane.

During the —40°F temperatures, the unloader valves stuck on four occasions. These unloader valves are a Douglas design, built by Vinco. This sticking was

Snow gear properly chocked

freed by additional heat on two occasions, by rapping the valve with a hammer on one occasion, and by bleeding the system on one occasion. One continuous cause for actuating cylinder leakage was due to the poor sealing ability of the end cap seal of the landing gear actuating cylinders, and the flap actuating cylinders. Leakage occurred around the piston rods of the flap actuating cylinders and the booster valves. These rods were sealed by winterized chevron packings. Leakage occurred on some of the brake swivel fittings, the flap actuating cylinder swivel fittings and the landing gear actuating cylinder swivel fittings. This leakage occurred at all temperatures depending on the amount of wear on these units. All swivel joints on this plane had winterized "O" rings. Many of these "O" ring packings were replaced after 300 hrs. service. The winterized "O" ring packings had to be replaced every 300 hours in the tail up and down lock actuators. Continual internal leakage through the landing gear selector valve caused the landing gear to drop in flight. This occurred with four different selector valves. These selector valves were Adel Part No. 9821. Not winterized.

l. C-47A type airplane.

No hydraulic trouble was caused by cold weather.

m. C-54B type airplane.

This airplane was not at this Base long enough for a conclusive service test of the hydraulic system.

8. Service tests were run this winter on landing gear "O" ring packings and chevron packings. No leakage occurred around the piston with either "O" ring or chevron seals. The "O" rings used were —65° packings and the chevron seals used were —65° synthetic chevron and leather chevron packings. The chevron type packing for these landing gears were in accordance with T. O. 01-1-132, Winterization of Landing Gear Shock Absorber Struts. Struts using "O" ring packings were filled with AN-VV-O-366a hydraulic fluid. Struts with chevron type packings were filled with Specification No. 3580 hydraulic fluid. Three struts using the "O" ring packings were filled with an experimental fireproof hydraulic fluid. There was no leakage or malfunction of any of these landing gears. Upon return of these planes to Wright Field these struts were inspected and found to be corroded rendering the experimental fluid unfit for further use. Appendix I contains a detailed list of the struts on service test. The only struts leaking fluid past the packing were the two (2) cases mentioned in Paragraph B-5 above and the C-54 nose strut. The chevron packings in the nose strut were tightened several times. This tightening temporarily stopped the leagage. Soon after the third tightening this airplane left for the States where it was instrumented by Douglas engineers. At that time the chevron packings were removed and an "O" ring seal with leather washers on each side of the "O" ring was installed. No fluid leakage has occured since this installation, however this airplane was not at this station long enough at low temperatures for a service test on this installation.

9. Some shimmy damper leakage occurred at —40°F. One of the two B-29 airplanes here at —40°F temperature leaked fluid from around the wingshaft of the shimmy damper. It was necessary to fill this unit each day during the —40°F weather. The flange clamping cover was tightened and leakage stopped but a rise in temperature may have caused the leakage to stop. The shimmy damper on the other B-29 did not leak at all. Both shimmy dampers referred to were the same type and both had yellow dot approval. The Allied P-63 airplanes had some leakage around the vent plug, however, this leakage stopped with more careful servicing.

10. There was no failure of either brake systems or the brakes during the temperatures encountered this season. All brakes were —65°F brakes.

C. CONCLUSIONS

1. Under the comparatively warm weather conditions of this winter both the —65° "O" ring packing and the —65° synthetic and leather chevron packings were satisfactory for use as shock strut seals, however "O" ring seals are better from an installation standpoint.

2. Shock struts filled with AN-VV-O-366a hydraulic fluid operated satisfactorily at —40°F. Shock struts filled with Specification 3580 hydraulic fluid operated satisfactorily at —40°F. Shock struts filled with the experimental fireproof hydraulic fluid operated satisfactorily at —40°F. Although shock struts with 366a and 3580 hydraulic fluid performed equally as well, 366a hydraulic fluid is used in all hydraulic systems and the use of 3580 could be discontinued, thereby only one type of hydraulic fluid would be used on all airplanes. But due to corrosive action experiments have been discontinued.

3. Hydraulic systems in general are satisfactory to the temperatures encountered this season. Units with —65°F "O" ring packings cause less leakage than units with —65°F chevron seals. Minus 65°F "O" rings wore rather rapidly in some cases on swivel fittings on both the C-46 type airplanes and the B-24 type aircraft. (Reference Appendix II).

4. The brake master cylinder reservoir on the F-5E aircraft leaked fluid when the camera heaters were turned on —40°F due to lack of a seal against expansion.

5. All units of the P-47D type airplane leaked during the first low temperature (—40°F) spell due to chevron packings not being tightened sufficiently at installation. Adjustment of the chevron packings is impossible without removal of the unit from the airplane. Leakage was also due to poor sealing of the static seal around the end cap of the actuating cylinders.

6. C-46 type airplane had leakage about the actuating cylinder end caps due to poor sealing of the static seal. The Douglas unloader valve stuck at —40°F temperatures. The landing gear selector valves (Adel) leaked internally around the poppets.

7. The P-47 type airplane shock strut could not retain air pressure at temperatures below +20°F due to the leakage past the transfer valve.

8. P-61 type aircraft air systems leak air at sub-zero (Fahrenheit) temperatures.

9. The P-63 type aircraft parking brake line became inoperable due to the freezing of condensation at the bottom of the cable housing.

10. The effect of scraper rings cannot be determined until inspection of these struts is made at the Air Technical Service Command.

11. The A-26 type airplane nose gear lock linkage became fouled with snow and ice which caused the nose gear to fail to retract.

P 51 snow gear retracted in flight

D. RECOMMENDATIONS

It is recommended that:

1. Low temperature (—65°F) "O" ring packings be used in shock struts rather than —65°F synthetic and leather chevron packings.

2. Shock struts be filled with AN-VV-O-366a hydraulic fluid.

3. Further investigation be carried on for an "O" ring seal that has good wear and strength characteristics as well as satisfactory low temperature characteristics.

4. A method of sealing the reservoir against fluid expansion be developed.

5. "O" ring be used in the actuating cylinders of the P-47 airplanes and that a satisfactory method be found to stop leakage around the cylinder end caps on this airplane.

6. The C-46 actuating cylinders be redesigned in order to stop leakage around the cylinder end caps, and that a new —65° approved type unloader valve be installed, and a new —65° approved type of landing gear selector valve be installed on the C-46 airplane.

7. A transfer valve that will seal air satisfactorily to —65°F be developed and installed on the P-47 airplane landing gears.

8. A satisfactory emergency air nose gear extension for the P-61 airplane be installed that will operate and retain air pressure at —65°F, and that a method of charging and maintaining air in the accumulator and surge chamber at —65° be installed.

9. The cable housing on the P-63 brake line be drilled at the lower end to allow drainage of condensation.

10. A shield be placed over the nose gear lock linkage on the A-26 airplane.

11. The conclusions and recommendations be directed to the attention of the airplane contractors involved.

Alaskan Field Test of Emergency and Survival Equipment

Prepared by: H. B. Washburn, Jr. Personal Equipment Laboratory

A. PURPOSE

1. To submit to strenuous and prolonged field test a number of items of cold climate emergency equipment contained in the E-12a and E-16 Emergency Kits (AAF), as well as additional selected Quartermaster and commercial articles. Great care was taken in the choice of the equipment tested, so that all items which have been used and recommended are readily available in quantity either through military or commercial channels.

2. This test was conducted with a view towards studying the exact present status of the Emergency equipment available to the Search and Rescue Sections in Alaska, as well as to determine the operating policy of these organizations. Every effort was made to ascertain ways in which the Air Technical Service Command can be of greater service to them.

Rescue equipment test

B. FACTUAL DATA

1. PERSONNEL: Two members of the party of four were selected to represent a typical pilot and passenger who might be forced down in northern terrain. Neither one of these officers had had any previous northern experience whatever, and neither was an experienced camper. One had never camped before at all. The third member of the party was an officer with limited previous Alaskan experience, but with rather extended camping experience in the United States in connection with his profession as a geologist. The fourth had had many years of camping experience in Alaska, the United States and Europe. Three members of the party were assigned to the Personnel Equipment Laboratory, Air Technical Service Command and one represented the Arctic, Desert, Tropic Branch of AAFTAC at Orlando, Florida. By such a selection of personnel, it was judged that the test could best be conducted with a maximum of safety and efficiency in the field and result in a balanced report, accurately reflecting the needs of the stranded flyer in this theatre.

2. REGION: It was desired to conduct this test under as wide as possible a variety of cold-climate conditions and in as restricted as possible an area, so that the party could operate speedily and in close cooperation with one of the well-established northern Search and Rescue organizations. For this basic reason, the area between Wonder Lake, Mt. McKinley National Park, Alaska, and Colorado Station in Broad Pass on the Alaska Railroad was selected. This region is readily accessible to both Ladd and Elmendorf Fields and lies only about 135 miles southwest of the former.

Camps were occupied (See detailed Itinerary in Appendix I) in dense timber, tundra, willows and on glacial ice and snow at altitudes ranging from 1800 to 11,000 feet above the sea. Thirty-nine consecutive days were spent in tents in the open. The entire expedition from Wonder Lake to Colorado Station consumed a total of 48 days, five nights at the beginning and five nights at the end of the trip being spent in cabins. Almost every type of inland northern terrain in which AAF aircraft are liable to be forced down was encountered in some part of this 65-mile trek across the backbone of the Alaska Range in winter.

The Alaskan rather than the Greenland-Iceland area was chosen for this test because of the existence of the AAF Cold Weather Test organization at Ladd Field and the established relationship between this field and the Air Technical Service Command for experimental work.

3. COOPERATION: Outstanding cooperation, assistance and advice were rendered the test party not only by the Cold Weather Test Detachment and Search and Rescue Section at Ladd Field, but also by the Search and Rescue Section at Elmendorf Field. All aerial liaison, test of signal equipment and aerial delivery was effected by the Search and Rescue Section at Ladd Field. By extra-ordinary coincidence, the Elmendorf Search and Rescue Section was conducting an investigation of an airplane crash in the immediate vicinity of the main test camp of the test party on Muldrow Glacier. This made posssible almost continual contact and interchange both of ideas and equipment while in the field under genuine operating conditions. One member of the test party spent 12 days with this investigating expedition, ate their food, used certain articles of their clothing, slept in their tents, and became familiar at first hand with the problems encountered by one of these missions operating in extremely difficult terrain, some of it as high as 12,000 feet.

Aerial photographs by the Ladd Field Photo Section, taken in accordance with radio instructions, were delivered by air to the ground party, and provided a detailed map for the final trip from Brooks Moraine to Colorado Station, a region in which the maps are rather poor.

4. WEATHER: (See detailed Weather Record in Appendix II). The time of year (fall and early winter) chosen for this test was selected in order to assure what are believed to be the worst possible combination of conditions of weather, surface-travel, and lack of daylight. The test was originally planned for late September and October, but unavoidable circumstances delayed it a full month. For this reason fishing equipment was given no test whatever and hunting equipment was only used a small amount—not sufficient to warrant a report to be written on it, except after consultation with a number of local bush pilots, officers, and experienced enlisted men.

In general, the weather encountered was much milder than the average, and the traveling conditions were fair (See details in Appendix II). An abnormal amount of snow (50″) fell in two successive blizzards at the end of the trip, somewhat delaying progress during the last week. However, the project was completed on schedule, at Colorado Station, on the 48th day. The minimum temperature encountered was —41.0 degrees Fahrenheit, on December 5, 1944. The maximum was +33.5 degrees on October 20, 1944. The average minimum for the entire expedition was +1.0 degree.

C. CONCLUSIONS

1. Emergency Rescue Equipment should be grouped into four important categories:

a. That worn on the person of the flier.

b. That carried in the airplane.

c. That dropped to grounded personnel to facilitate survival or rescue.

d. That used by the personnel of Search and Rescue parties whose duty it is to visit the scene of a crash for the purpose of evacuating personnel or investigating the cause of the accident.

This investigation and report deal with the articles involved in (*c*) and (*d*) above. The vital importance of the equipment in (*d*) does not seem to have been fully appreciated to date.

Emergency food equipment and clothing test

2. A single all-inclusive Arctic Emergency Kit such as the E-12a cannot possibly provide equipment suitable to meet the great variety of field and weather conditions met in all parts of the north at all times of the year without resulting in great weight and bulk, as well as the universal delivery and storage of a high percentage of useless items. At present it is the frequent habit of local Search and Rescue Officers to unpack these kits and to store their component parts for use when, as, and if they are needed.

3. The best solution to this problem seems to be:

a. To issue a small basic kit containing a considerable number of important items of universal value.

b. To make available to Search and Rescue organizations a selection of essential AAF and Quartermaster equipment, delivery containers and parachutes, so that they can themselves prepare supplementary packages which will best meet the local and seasonal conditions attending any particular emergency.

4. The E-16 Emergency Sustenance Kit is not considered satisfactory except possibly as a bare existence or survival ration to be carried in the airplane in case of emergency.

5. The present Quartermaster Ten-in-One Ration is a readily-available, ample ration which is well packaged for free dropping to grounded personnel. It was not originally designed specifically for cold-weather use. Hence it is lacking in sufficient quantities of certain key items such as tea bags, powdered soup, sugar and possibly jam. In its present form, this ration is sufficient for only 6-7 man-days of food if normal outdoor eating habits are followed. Soup is not included at all, and the other three items listed above will be found insufficient if the ration is stretched to ten man-days.

6. For trail use by rescue parties and for use under extreme arctic conditions, a special FOOD SUPPLEMENT should be prepared for use with each box of Ten-in-One Ration. This should be packaged in some practical, sturdy container which is already in existence and available. A good trail ration for cold weather can be

made up from this supplement in addition to the light basic items from the regular Ten-in-One Ration. Under these conditions, the heavy canned items of the Ten-in-One can be discarded by a ground party when it is necessary to move.

7. Foraging equipment, such as guns, and fishing tackle, should be carried in the airplane or on the person of the pilot. There is very little need for dropping much equipment to grounded personnel, as all necessary food and other supplies can easily be delivered or brought to them as soon as they have been located.

8. Average personnel forced down in the north cannot be expected to travel any distance cross-country without experienced assistance or guiding. Such personnel should stick by their airplane as long as there is any chance whatever of being located. They should travel afoot only:

a. When directed to do so by an authorized Search and Rescue Officer.

b. When they know themselves to be so far off course that discovery by searching parties or aircraft may be considered impossible, and then only after a period of five days.

c. When certain help is within extremely easy walking distance.

9. When evacuation by airplane or other means of transportation is not considered practical, Search and Rescue ground parties will be sent to aid grounded personnel in getting to civilization.

10. Such Search and Rescue ground parties need the best and most up-to-date trail and field equipment and food, as the conditions which they face are often considerably worse than those encountered at any time by Army Ground Forces personnel in this theatre. Such equipment is not now generally available to Search and Rescue Organizations, and in certain cases they are not even aware of its existence. Action should be taken in order to make available to them many items of AAF and Quartermaster equipment, the issue of which is at present restricted to specialized personnel by the Tables of Basic Allowance.

11. Some means should be provided at regular intervals for keeping all Search and Rescue Officers well informed of the latest developments in all types of equipment and rations which are to be made available to them.

Emergency equipment test

D. RECOMMENDATIONS

1. The procurement of the E-12a Arctic Emergency Kit should be suspended as soon as it can be replaced by a small basic two-man kit containing all common items of universal emergency value. This kit should be procured and issued by the Air Technical Service Command to all cold-weather Emergency Rescue organizations, in appropriate quantities, at the earliest possible date. Recommended contents for this kit are listed in Appendix VII.

2. The above kit should be supplemented by the various items of equipment and satisfactory containers listed in Appendix VIII. Action must be taken to make as many as possible of these items of equipment available to all cold-weather Search and Rescue organizations in the immediate future. The local Search and Rescue Officer should requisition a sufficient stock of these items to meet all requirements of his area. Upon arrival at his base, these items should be stored for Search and Rescue by the local Quartermaster and not issued to anyone else for any purpose. It should be the responsibility of the local Search and Rescue Officer and not the Base Quartermaster or Air Corps Supply Officer to see that a reasonable stock level of all this equipment and rations is maintained. Using the items available in this stock, the Search and Rescue Officer can at all times easily prepare aerial delivery packages or outfit a special ground party with food and equipment which will meet his local regional and seasonal requirements.

3. In view of the vital importance of emergency rescue operations to safeguard the life, health and morale of all AAF organizations, and furthermore, in view of the almost negligible quantity of cold-weather emergency equipment which is required to meet the needs of the AAF, it is recommended that no hesitation be made to purchase superior items of suitable commercial clothing or equipment which may be readily available at the present time, in place of issuing certain inferior articles of existing AAF and Quartermaster equipment until the supply thereof is exhausted.

4. The present Quartermaster Ten-in-One Ration should be dropped to all grounded personnel in cold-climate regions in place of the E-16 Sustenance Kit.

5. A special package of light, concentrated foods should be developed and issued to supplement every two cartons of Ten-in-One Ration used under arctic conditions or when a search party must travel to the scene of a crash on the ground. Recommended contents for such a kit are listed in Appendix IX. The urgent need for this kit demands that all component parts be readily available in the desired quantities at the present date.

6. Foraging Equipment, such as guns or fishing tackle, should be carried in all aircraft operating in the north, but are impractical for use in actual emergency rescue operations after discovery of the lost airplane and its occupants.

7. In order to keep all Search and Rescue Officers acquainted with the latest and best equipment and rations that are available to him, either through Air Corps Supply or his Base Quartermaster, a quarterly Emergency Equipment Bulletin should be issued by the Personal Equipment Laboratory.

8. At least one individual should be assigned to following through to a conclusion the project undertaken by this Test Expedition. He should work with Project Engineers, manufacturers and the Coordinator of Personal Equipment, in order that all problems concerned with this project may be assured constant attention until completion.

Equipment test

Portion of Appendix IV

IV. Comments on the Various Rations

A. K RATION

1. The K rations used on this test were old, so some of the following comments will not apply to the latest type K rations. Special attention is invited, however, to the comments on the cold-weather use and behavior of the K ration.

2. Constant use of cheese as the tinned component of the dinner unit is considered unfortunate as one quickly becomes tired of cheese. It is understood that steps are being taken to provide other materials in place of some of the cheese in the latest rations.

3. The old style K-1 biscuit is considered the poorest biscuit consumed on the entire trip. This merely confirms earlier opinions upon the basis of which the K-1 biscuit was discarded. The K-1a, K-2 Johnson, K-4 and K-5 biscuits appearing in the later D units of the Ten-in-One ration are considered much better.

4. The bouillon powder from the supper unit is very good.

5. The fruit bar in the old K ration is mediocre and extremely hard to unwrap. It should be replaced by the Dromedary bar made by Hill Co., N. Y., or by some other more suitable fruit bar. Attention should be given to the packaging of these bars, for in cold weather unwrapping them can be a mean problem. It is understood that this problem is under consideration and awaits only a suitable solution.

6. The tinned components in the K ration are difficult to eat and rather unpalatable when frozen. On the trail it is not always possible to thaw them out. The practice in our group was to warm the rations at breakfast by putting them in boiling water. They were then carried in the pocket or under the shirt next to the belly where they remained warm until lunch.

7. A K ration is difficult to eat without some sort of liquid. On the trail on cold weather, liquid is usually not available. This detracts considerably from the value and palatability of the K ration.

8. Removal of the dextrose tablets from the latest K rations is indorsed, as these tablets were found much less satisfactory than a fruit or chocolate bar.

9. In cold climates the hard candies, such as Reed's Mints, appearing in some of the D units of the Ten-in-One ration are less welcome than a chocolate bar or fruit bar would be.

B. C RATION

1. Only the old style C rations with three different meat components were consumed.

2. In general the constituents are bulky and filling, and the round C-biscuits are good.

3. The cocoa beverage powder appearing in some of the biscuit units is excellent.

4. In cold climates, at least, the hard candies in the biscuit units are less satisfactory than soft candies of the chocolate and caramel types. The trend in recent C rations to include a fudge disc and candies other than the hard type is approved.

5. Of the three meat units available, the meat and vegetable stew is judged the best. The addition of a great variety of meat units is heartily indorsed as it is very easy to become tired of the C ration in its old form.

6. The C ration is well designed for individual use and rationing. The development of 6 different menus in the latest C rations is an excellent idea.

7. In cold weather the meat components freeze. They are rather unpalatable in the frozen state and hard to get out of the can. Naturally, cooking frozen rations is difficult and time consuming.

C. TEN-IN-ONE RATION

1. This is a very satisfactory ration for emergency use by static parties and is considered the best single Quartermaster ration available for that purpose.

2. It is well packaged for free dropping from the air, and many examples of successful aerial delivery by this method are on record. In one search and rescue mission at least 10,000 pounds of Ten-in-One ration were delivered in this manner with almost 100% success.

3. For use in cold weather this ration could be considerably improved by the addition of tea and soups. A little more sugar would also be desirable. For men working hard under cold weather conditions, the ration is sufficient to feed only 6 or 7 rather than 10 men.

4. Some of the heavier items in the ration are unsatisfactory for trail use.

5. Of the jams supplied in this ration, fig was too heavily emphasized. More of other types of jam such as grape, plum, strawberry, etc., are desirable. It is understood that this need is recognized.

6. The hard candies (Reed's peppermints, Root beer, Butterscotch) in the late D-1 units of Menu No. 1 are less desirable than a chocolate or fruit bar.

The supplement outlined in Appendix IX is recommended to provide the desirable cold weather items, to modify the ration for trail use, and to adapt it to the Army Air Forces needs.

D. MOUNTAIN RATION

1. Only a small amount of this ration was used and conclusions regarding the suitability of the entire ration are not possible. Even though the ration has been obsolete for nearly two years, considerable stocks are still held in some Quartermaster warehouses. This ration contains several good items of dehydrated food which are recommended for inclusion in the Ten-in-One supplement.

E. E-16 RATION

1. No real test was made of this ration. It contains many good items, notably dehydrated meat and rice, compressed cereal briquettes, which are excellent, and soups.

2. It is fundamentally an existence ration rather than a working ration. As such it is suitable for carrying in an airplane as insurance against a possible emergency, but is should not be dropped to grounded personnel when some other ration, such as the Ten-in-One, is available.

3. The only justification for a ration of this kind is its possible use as part of the survival equipment carried on the plane. It is not needed as an aerial delivery ration.

F. MODIFIED E-16 RATION

1. Three men lived for 5 days on this ration at Base C. During this period their physical activitiy was limited to work around camp and walks on snowshoes up to 8-10 miles without packs. Their activity would properly be classed as light to moderate. For the first three days no particular effect was noted other than an increasing hunger. By the 4th and 5th days the men had to force themselves to undertake even mild exertion. They also tired easily, and the hungry feeling became annoyingly strong. Certain items such as soup and biscuits were consumed in slightly greater amounts during the first three days of the test than called for in the ration which is designed for 4 rather than 3 men. Four men used the ration for the last two days of the test. Even the fourth member who lived on the ration for only 2 days was happy to have other food at the end of the period. There seems to be little question but what this ration is satisfactory in emergencies for a bare sedentary existence, but it certainly is not a working ration and should not be dropped to grounded parties for that purpose. It is well designed for easy equable rationing, although the use of cereal in compressed briquettes would be a further improvement. The following comments were made with the knowledge that this is an existence ration.

2. Like the E-16 this ration could be carried in the plane in case of emergency, but it is hardly suitable for dropping to grounded personnel if some other ration is available.

3. The dehydrated green pea soup made by the Eureka Food Co. is very good. It mixes easily and is ample for four men.

4. The amount of salt included (1 lb.) is probably too large. It would be better to have the salt packaged in small 2 oz. containers like that of the Diamond Crystal Salt in the Mountain ration. The perforated top on these latter containers has good closure.

5. The meat component for the evening meal seems too scrimpy. Pork is badly over-emphasized in all the meat units. Such items as pemmican, dehydrated meat and rice, or dehydrated corned beef hash would be desirable in place of some of the pork or pork and egg combinations.

6. In general, breakfast was the most satisfactory meal. The Pillsbury whole wheat and soy cereal is excellent, although it would be easier to use if furnished in compressed form.

7. The type II Biscuit, Square, Wholewheat, in this ration is considered the best of all the biscuits eaten on the test.

8. The ration contains a generous sufficiency of butter and coffee.

9. The fruit bars are sufficient in number and of good quality (Dromedary, Hill Co.).

10. The number of chocolate bars should be doubled from ten to twenty.

11. Two small cans, 4½ oz. of powdered whole milk should be added.

12. The books of matches should be replaced by matches in boxes.

13. The sugar is just about right in quantity, and the use of lump sugar saves wastage and facilitates rationing.

14. Not all the lemon powder was used. The suggestion is offered that orange powder should be substituted for at least half of the lemon powder.

15. No difficulty with bowel movements experienced.

G. TEN-DAY WALK-OUT RATION

1. This ration proved moderately satisfactory although larger quantities of food could have been used.

2. More chocolate bars, biscuits and meat were needed, fewer fruit bars and less coffee and butter could have been used.

3. More dehydrated meats and vegetables were needed, particularly the latter, but they were not available at Base C where the ration was made up.

H. FOUR-DAY WALK-OUT RATION

1. This ration was much like the Ten-Day Walk-Out ration since it was made up of remnants from the latter with additions from the Ten-In-One ration.

2. This ration provided more food per man than the Ten-Day Walk-Out ration and had better balance on such items as butter, coffee, bacon, biscuits and breakfast meats. It proved satisfactory for the two days it was used.

I. QUARTERMASTER EXPERIMENTAL FOODS

1. Only a small part of this food consisting of pemmican, dehydrated cheese and crackers and cereal briquettes was received.

2. All of these items were found to be good. The pemmican is excellent, but one 3-oz. bar per man per meal is not enough for a working ration in cold weather. The compressed cereal is good although not necessarily superior to other types of cereal in the compressed form. The dehydrated cheese and crackers were found to be excellent when grated into soup.

V. Miscellaneous Food Notes.

A. WRAPPING OF FRUIT BARS.

1. The wrapping on all fruit bars is unsatisfactory

when they are cold. It is practically impossible to unwrap the fruit bar in the K-ration. The Hill Co.'s Dromedary bar is better, but even so is far from perfect. A good tough wrapping which would not tear easily and which will come away from the bar readily in cold weather is most desirable. This problem is being attacked by the Quartermaster Subsistence Laboratory.

2. It is desirable to have cereals in the form of pressed bricquettes. This helps prevent wastage and is a great aid in rationing. The briquettes should not be so firmly compressed that it is difficult to break them up for consumption. The briquettes in the E-16 ration are better in this respect than those in the Quartermaster experimental foods.

3. Soups should be of a variety easily mixed and prepared. Some of the cream soups made by Borden and Co. and appearing in the Mountain ration are very hard to mix. The Quaker Oats Co , green pea soup or the green pea soup prepared by the Eureka Food Co. mix very easily.

4. Bacon should be included in rations, but in moderation.

E. Of all the biscuits eaten on this test, the Type II Biscuit, Wholewheat, Square, is considered the best. The newer type square biscuit appearing in some of the late Ten-in-One rations wrapped in a Sumar Soda Cracker is better than the old Square C biscuit. Most of the biscuits appearing in the D units within the Ten-in-One rations are better than the early K biscuits. The K-5, K-4, are particularly good, and the K-1a and Johnson K-2 are also very satisfactory.

5. For most large rations such as sugar, the Ten-in-One is best supplied in the lump form. This prevents wastage and aids in equitable rationing The major need for granulated sugar is in cereal, and the pre-mixed cereals now appearing in most rations already have sugar added. In cases where additional sweetening is desired, lump sugar can be used, at least such was the experience on this test.

6. Of the various salt containers used, that from the Mountain ration put up by the Diamond Crystal Salt Co. was the best. It is a small cylindrical cardboard container with perforated top and good closure thereof. It contains 2 oz. salt.

7. Among the meat components supplied in the K, E-16, modified E-16 and Ten-in-One ration there is a great over-emphasis on pork. More beef should be used, if possible, in the various canned meat units. A constant diet of pork is tiring and for one member of the party actually revolting. This man lost 15 pounds during the test.

Appendix V

Aerial Delivery

1. A detailed synopsis of all articles delivered to this expedition from the air, either by parachute or free-fall, may be found at the conclusion of this appendix.

2. Forty-four separate parcels were delivered during the course of the test expedition. Flights were made on twelve different days, and two wheel-equipped airplanes (AT-11 and UC-64) were used to effect delivery. Twenty-six loads were delivered with 24-foot standard cargo parachutes (25 yellow, 1 red), nine loads were delivered free-fall and 9 message-containers with mail and instructions were dropped.

3. Of this total of forty-four parcels, only two were lost. None which were located suffered any permanent damage. Two A-6 containers blew several hundred yards across a partly-frozen swamp after delivery at Cache Creek, because nobody was on the ground to receive them. Both were wetted and then frozen, but after thawing and drying the contents they were in excellent condition.

4. A high windstorm occurred two days after the delivery of the 11 loads which were parachuted at Cache Creek, two weeks before the ground party reached them. Several of the canopies re-inflated and seven of the loads (see synopsis) were dragged distances up to over ¼ mile from where they were observed to land. Loads numbered B-6 and B-9 were so badly buried in fresh snow or blown so far from their original landing-point that they were never re-located.

5. As a result of the experience described in paragraphs 3 and 4 above, and several similar experiences encountered on the 1942 Alaskan Test Expedition, it is highly recommended that the development of an automatic release mechanism be expedited by the Parachute Branch. Such a release need not be attached to more than one of the risers.

6. At least 75% of the equipment dropped by parachute could have been delivered free-fall in A-6 or other suitable containers or bundles, but a thorough test of a considerable number of standard cargo parachutes under arctic conditions was desired. Not a single parachute failure was encountered.

7. The large A-4 container proved too heavy and awkward to be practical. Even when loaded with relatively light cargo, its great bulk made it difficult to get out of the airplane and exceedingly hard to move around on the ground. The A-6 container was much more practical, partly because its size limited the weight of the load one could put into it to a reasonable maximum, and partly because it is rugged and easy to handle both in the air and on the ground. The duck bag from the A-6 container made a most valuable barracks or storage bag which was used constantly on the ground by all members of the party.

8. The best all-round color for parachutes in this area is believed to be bright yellow-orange. This should apply to personnel as well as cargo. The color of the streamer on the standard message-container is very close to an ideal color. The standard yellow parachute used by the test party is believed to be too light in color for best results. Chrome-yellow-orange should prove the most practical color for use in both summer and winter in a variety of northern terrain. The dark red cargo parachute takes on a black appearance only a few hundred yards away, even when spotted on snow.

9. Several different types of articles were dropped free-fall—notably the cartons of Ten-in-One ration and the ten-gallon iron gasoline drum. Several of these landed in very hard packed snow but suffered no appreciable damage. Free-fall delivery was effected best from altitudes of approximately 100 feet. The A-6 container makes an excellent container for free-fall loads of moderate weight (up to approximately 70 lbs, depending on type of contents and packing). Free-fall

loads should be packed, when possible, in units of approximately 50-70 pounds. Items such as tent poles should never be dropped singly, but should be securely tied in bundles with ends well padded.

10. Over 100 gallons of stove-gasoline were dropped free-fall by the 11th Air Force C-47 search and rescue party in standard US Army 5-gallon gasoline cans. Many of these fell on hard wind-packed snow, but only two or three out of more than thirty were damaged enough to result in loss of contents. All of these cans were vented during flight just prior to delivery in order to relieve internal pressure in 10,000-foot landing. Lack of any practical means of getting the gasoline *out* of these cans after delivery resulted in far more loss and spilling than damage or loss in delivery.

11. A small parachute (approximately 18′) would probably be of great value in the delivery of emergency cargo. If the A-6 container is used, it is almost impossible to load it to a reasonable weight for the 24-foot chute. If it is loaded to that weight, then it is not easy to handle either in the air or on the ground. All personnel questioned believed that such a chute would have wide usage. It would still be amply large for use as an emergency tent or tent-fly. Its small size and light weight would make it easier to pack and handle by inexperienced personnel. It is worthwhile to note that in the case of a delivery of 7 A-6 containers, each loaded with 100 lbs of cargo, the weight of the chutes alone will come to more than 25% of the net cargo delivered, and their bulk will be nearly 30% of the packed cargo.

Appendix VI

Signalling

1. GENERAL STATEMENT: A variety of signal equipment was used by the expedition while in the field. Although a long, systematic series of tests of this equipment were not carried out, it was constantly used for communicating with planes delivering supplies and equipment. Certain definite conclusions were reached and are set forth in this appendix.

2. PYROTECHNICS:

a. The Red Parachute Flare (*Type M-11*) was undoubtedly the most effective pyrotechnic used. When fired from the Very pistol, it gave a very brilliant light and burned for approximately 20-30 seconds after the parachute opened. However, the maximum altitude of its trajectory is only 150 feet when fired at the proper angle. In five cases (out of 30 flares used) the parachute failed to open properly or the flare did not ignite. If used in entirely open country, this flare could be seen for about 30 seconds under optimum conditions but in tall timber it may clear the top of the trees for only a few seconds, or possibly not at all. In clear weather these flares were observed at night up to 20 miles. In the daytime, they were clearly visible for 10 miles, but would not have attracted attention unless the observer was looking at exactly the right spot at the right time.

b. The Signal, Aircraft, Double Star (*AN-M-41*) was also tested in comparison with the M-11 Parachute Flare. In case of forced landing, this flare would probably be the one available for signalling since it is the type normally carried in planes. Because of the low altitude attained and its short duration, this proved to be the poorest signal tested. It could be seen only if the searchers were looking exactly at the right spot where the flare was fired.

Parachute used as tent

c. Conclusions: From the experiences of this field test and from considerable discussion with Russian Arctic Ferry Route pilots it appears that none of the available pyrotechnic signals are satisfactory for use on land in totally uninhabited areas, such as the Arctic. All available flares are either too short-lived or fail to reach a sufficient altitude, and all appear to have been designed to be shot downward from an airplane rather than upward from a pistol.

d. Recommendations: That immediate steps be taken to develop a sky-rocket-type projector and a red parachute flare which will reach an altitude of at least 500 feet and descend slowly. The red color is mandatory on account of the brilliant white light of the stars in the arctic night. The need for such a flare is most urgent. An ample supply should be carried on all aircraft.

3. SMOKE GRENADES:

a. The Grenade, Smoke, M-3 burns for approximately two minutes and gives off a thick red smoke which hangs low over the ground but thins out rapidly after burning ceases. In open country this smoke is very effective, but in dense timber (especially in extreme cold) it has a tendency to blanket the ground well below the tops of the trees.

b. The Grenade, Smoke, M-8 burns approximately 3½ minutes and gives off dense grayish smoke. The smudge from this grenade is more dense and tends to disperse more slowly than the M-3 red variety. It also rose higher when used in timber, but in cold weather leveled off the moment it reached the tree tops.

c. Conclusions: Smoke flares are more useful in air-ground recognition in the daytime—parachute flares at night or in timbered country. The red smoke (M-3) is by far the easiest to see but does not last long enough. As a result of this test and conferences with Alaskan pilots, the M-3 seems to be the only practical flare for use in the Arctic under average conditions throughout the year.

4. SIGNAL MIRRORS:

a. Whenever sunlight is available in reasonable quantities, the mirror is the most positive means of emergency ground-to-air signalling. In various parts of the Arctic and in very mountainous areas farther south the mirror may be practical for only part of the year, but its value at other times is so great that it should be a key item in all emergency kits and vests

b. The ESM/1 Mirror (standard AAF) was used throughout the test program with outstanding results. When sunlight was to be had, it was *by far* the best means of attracting aircraft to a ground party under all conditions except in dense forest.

c. An Experimental Mirror Devised at the U. S. Bureau of Standards and considerably smaller (3″ x 4″) than the standard model was given a very thorough test by the ground party. By means of a small (1″ diameter) red hemisphere with a ¼″ peepsight, attached to the back of the mirror, the illusion is created of a tiny red "ball" floating in the sky at the point where the mirror's flash is being projected. A sheet of red and a sheet of green transparent celluloid were furnished to be placed over the mirror to make red and green as well as white flashes. The sighting of this mirror proved to be very simple and positive, compared with the relatively complex reflection-sighting of the ESM/i/ The red flash was excellent, but the green overlay did not have enough pigment to make a green flash that was easily distinguished from the white. Both mirrors were visible up to 20 miles away so that the plane circled over camp until the flyers were sure the ground personnel was all right.

d. Conclusions: The signal mirror is still the most effective means of emergency signalling as long as sunlight is available.

e. Recommendations: That a project be initiated at once to develop further models of the new type mirror described in paragraph *c* above, so that tests can be run in the immediate future to compare its effectiveness and ease of operation for totally inexperienced personnel with that of the standard type.

5. SIGNAL PAULINS

a. Signalling tests were run using both the standard AAF signal paulin and a special experimental signal panel of fluorescent red rayon.

b. The Standard AAF Paulin which is carried in every multiplace raft and almost every emergency kit was used throughout the program for attracting attention and signalling messages to the observing airplanes. During the last two weeks of the test this paulin was the only means of communication between the ground party and the airplane. Great difficulty was experienced by the ground personnel in folding the large standard signal panel in such a way that the folds would correspond to those set forth in the Pilot's Information File. This was due to the rectangular shape of paulin, the signals being designed for a square paulin. The rectangular shape presumably makes the paulin more useful as a sail or sun shade in life rafts but certainly impairs its use for signalling. The test party finally cut the large paulin down to a square thereby increasing its efficiency for signalling but decreasing its value as a ground cloth or shelter.

c. The Experimental Fluorescent Red Panel. Airplane observers and ground personnel reported repeatedly that there was no comparison between the visibility of the red fluorescent cloth and the blue-yellow standard signal paulin. They said that it was possible to see the red cloth at an "unbelievable distance" and that they had "never experienced anything like it before." The size of the red cloth (6′ x 3′) used during the test was small in comparison to the large standard signal paulin (7′ x 10.5). Since both sides of the fluorescent cloth were red, it was impossible to use it for transmission of the standard panel signals. Its main use during the trip was to attract attention and to mark positions so that they could be easily relocated at a later date.

d. Conclusions: Signal paulins are of vital importance to a ground party—especially in case radio communication cannot be established. Use of the standard paulin (when cut square) by this party was entirely satisfactory. However, the fluorescent red panel had a much higher visibility.

e. Recommendations: The problem of making *square* signals with a rectangular paulin should be investigated at once. A square paulin about 8′ x 8′ is desirable. A project for development of a fluorescent red signal paulin with a dark blue reverse side should be undertaken at once. It is understood that this material loses its fluorescent property when wet, so a waterproof bag should be supplied with early test models while determined efforts are made to develop means of making the cloth at least somewhat water repellent.

6. BODY SIGNALS

a. Tests were run at Brooks Moraine Camp to check the standard body signals as described in the Pilot's Information File. The body signals tested were interpreted correctly from the air. Body signals were used on only one other occasion, as the signal paulin and radio were more than adequate for all necessary communication.

7. RADIO EQUIPMENT:

a. Handy-Talky Radio Transmitter-Receiver, BC-721: This light portable outfit was used constantly for air-ground liaison at both the Cache Creek and Brooks Moraine camps. With batteries warm and set in perfect shape, the range was: airplane command set (at 3000 ft. altitude) receives Handy-Talky 7-8 miles; Handy-Talky receives plane 25-30 miles. During field test (dependent on warmth of batteries) the Handy-Talky was received only 1-3 miles by the aircraft and could receive aircraft only 10-12 miles. The best range was obtained by pointing the antenna at the airplane. This set proved so small, light, and simple to operate that it is considered the ideal air-ground liaison unit for rescue work where a highly portable short-distance outfit is desired. However, a practical means of keeping the batteries warm must be used.

b. Forest Service Radiophone Type SPF (Model AF-SC-486A): This outfit was used exclusively at the Brooks Moraine camp and proved highly dependable and simple to operate. With the light, portable batteries the complete set weighs 21 pounds in its canvas carrying case. the set alone weighs 9 pounds. The power output is 2½ watts. With batteries warm, the range was: airplane command set (1000-3000 ft. altitude) received SPF 14-15 miles; SPF received airplane 20 miles. Various Army Airways stations up to 500 miles away as well as distant U. S. shortwave broadcast were received regularly. This set has considerably more power than the Handy-Talky. It was operated only on phone. The CW range would be considerably greater. It is ideal for a base camp or as a set to carry throughout a rescue mission that is supplied from the air. It can be operated successfully after an hour's instruction (or careful reading of the manual) by an individual with no previous radio training. Once tuned and set up properly for fixed operation, it can be used almost as simply and reliably as a telephone over distances up to approximately 10 miles. A portable "end feed" type antenna was used exclusively.

c. The SCR-578 ("Gibson Girl") was given a test at the Brooks Moraine camp but found to be most inefficient even under ideal operating conditions. Clear transmission was received only directly above the camp. Signals could be read 20 miles over visual lines and only 6-8 miles northward where a low range of hills cut off reception the moment the station was blanketed visually.

In both cases the airplane was tuned to the signal before it started away to test range—an ideal condition for maximum range reception. The antenna was stretched for its full length along the surface of the snow-covered glacier and counterpoised with an equal length of antenna wire attached to the ground terminal and extended in the opposite direction.

d. Operating Problems: The Handy-Talky is highly dependent on intervisibility of stations for reliable operation. The SPF is most efficient when used over visual lines, but can be operated where stations are *slightly* out of sight of each other. Both sets should be considered and are requiring 100 per cent intervisibility of stations for practical performance over anything but the shortest of distances.

The problem of keeping batteries warm is of great importance. A warm Handy-Talky was parachuted to Brooks Moraine camp where the ground temperature was approximately 0 degrees F. and immediate communication between plane and ground was established up to 4-5 miles. *After one hour* of almost continuous outdoor communication, this Handy-Talky could be heard by the airplane when it circled 2000 ft. high directly over the ground station. During all later air-ground contacts both SPF and Handy-Talky were *operated from inside a warm tent*. Batteries were removed from both sets when not in use and kept in a bag at the peak of the tent where it was warmest at all times. The SPF had a short 3½ ft. cable between set and batteries, permitting batteries to be tied higher in tent than the set and hence kept reasonably warm. The Handy-Talky batteries had no such extension. If the sets were lashed in the peak of the tent or kept in warm sleeping bags, heavy frosting resulted when they were brought down to colder temperatures for use. Microphones of both sets frosted badly during use and should be covered by vinyl-coated cloth cap for protection. Such a cap was not provided with either set. For optimum results in arctic weather both sets should be equipped with extension cable, as light and flexible as possible, to connect batteries to set. This should be at least 6-8 feet long, thus allowing set to be kept in easy operating position while batteries are at peak of tent, in sleeping bag, or inside the clothes of the operator. With warm batteries these sets both operated perfectly under moderate subzero conditions.

8. CONCLUSIONS:

(1) The Handy-Talky and the SPF Forest Service Radiophone are considered ideally suited for use by ground search and rescue parties on test expeditions.

(2) This test showed the SCR-578 "Gibson Girl" to be less valuable than the SPF as a ground-air emergency signalling devise.

(3) For reliable operation under arctic conditions, all emergency radios should have a flexible 6-8 ft. battery cable, so that the batteries can be kept in some remote warmer position at all times, or at least during and immediately before transmission.

(4) There is definite need for a 30-40 watt phone CW transmitter-receiver unit with power plant for operating at an advanced base 100 or more miles from a main airbase and from which ground parties might start on a search mission. *Such a set has had to be made at Ladd Field* and its need is very great. It must be simple, compact, rugged and foolproof and its power plant must not be such that arctic weather will render it useless.

9. RECOMMENDATIONS:

(1) The Handy-Talky and SPF Radiophone should be made available as fast as possible to all AAF Search and Rescue organizations and *issued on a frequency that is a standard AAF communication channel suitable for this PURPOSE*.

(2) Both these sets should be modified to include a 6-8 ft. flexible battery cable which can easily be plugged or unplugged from set.

(3) Development should be undertaken on lightweight advanced-emergency-base transmitter and receiver to operate either phone or CW and with minimum output of 30 watts. This set must have a practical power plant included and be *very simple to operate*.

(4) Work should be started on development of an aerial delivery container for the Walky-Talky radio like that already made by the Search and Rescue flight at Edmonton, plans for which are being forwarded.

Appendix XI

Comments on AAF Clothing

In reading the comments below, it is of vital importance to note that all opinions or evaluation are based on use of equipment *on the ground*, unless clearly stated otherwise.

Articles are graded as follows: Superior, Excellent, Good, Fair, Unsatisfactory.

1 SUIT, FLYING, INTERMEDIATE

It is assumed that suit will be the basic outer garment worn by northern flyers except under extreme winter conditions. It is not nearly so practical or versatile for use on the ground as the Mechanic's Arctic Suit.

Jacket, (Type B-15a) *Excellent*

a. Neck and upper chest of this jacket are too tight when slide fastener is fully closed and when a sweater and wool shirt are worn over standard heavy underwear.

b. Quality of knit cuffs and waistband can be improved considerably.

c. When slide fastener is fully closed, collar is off center. Furthermore, mouton of collar does not make positive closure at throat, resulting in uncomfortable contact with top of stiffened fly-flap.

d, Throat-latch should be reset to make a comfortable (*not tight*) closure at throat. Button is now badly out of position. This feature of jacket is rarely used. It is suggested that efforts be made to determine whether or not it is required under combat conditions.

Trousers (Type A-11a) *Excellent*

a. Leather pull-tabs on slide fasteners are weak.

Clothing test hike

A thong-type of pull tab with knot should be used on long leg-slide fasteners, as they are *very* difficult to grasp firmly enough at present to exit if hands are numb.

b. Exterior flaps which hide side-pass-thru pocket slide fasteners are unnecessary and become snagged in slide fastener rather frequently.

2. SUIT, MECHANIC'S, ARCTIC

This suit, or parts of it, were used almost continually by all members of the party during the last five weeks of the test. The general design and insulation are considered adequate. Lack of slide fasteners is considered a serious handicap. It is believed that, if modifications listed below are accomplished, the jacket of this suit will not only be satisfactory for AAF Mechanics and ground crews in Arctic weather, but could also replace the bulky Jacket, Flying, Type B-11.

Jacket (Parka) (Type D-2) *Good*

a. A full-length, separable, heavy-weight slide fastener was urgently requested by all bases visited. Two of the four jackets used in this test were modified to include a Crown No. 7 separable slide fastener (full-length) in outer shell, with great success. This fastener was so rugged that there is clearly no need for an auxiliary outer button-flap on this garment, although a 2" inner flap to serve a a wind-seal is necessary. Alpaca lining was snapped to outer shell. Great care should be taken to effect comfortable and positive throat closure.

It was urgently requested by representatives of the Alaskan Division, ATC, that, *regardless of any action taken to develop a new and better Mechanic' Parka, immediate action should be taken to provide for slide-fastener modification of all such parkas already produced.*

b. In view of the above modification, it will be necessary to re-balance design of this entire garment.

c. Hood design should be altered to conform better with shape of neck and head. The present design does not provide entirely adequate protection for forehead. Heavy alpaca lining unnecessary—soft woolen blanketing would be adequate.

d. Sleeve should be normal size at cuff, not tapered.

Trousers, Type B-2 *Good*

a. Full-length, heavy weight, separable slide fasteners should be inserted in Front exactly as in Intermediate flying trousers.

b Alpaca lining need only be carried halfway from knee to ankle. Lower leg is adequately protected by boots and ski sox. Presence of heavy alpaca adds excessive bulk and makes wearing mukluks extremely difficult. The alpaca linings of these trousers were never worn except in the most extreme weather, and should be snapped to outer shell to facilitate easy removal.

3. SHOE, FLYING, FELT (Type F-2) *Superior*

a. Used without the electric insert, over two pairs of heavy wool sox, this shoe proved to be excellent for all use on ground under dry snow conditions down to 35°F. With its rubber heel and composition soles, it was the most practical shoe used around camp. One pair was used for over 150 miles of walking on extremely rough ice and snow terrain.

4. SHOE, WINTER, (MUKLUK) (Type A-14) *Unsatisfactory*

a. The last over which this shoe was made does not conform to the shape of the human foot wearing the assembly of socks supposed to be used with it. It is too narrow and shallow at toe; too wide at the heel.

b. Rubber toe-cap accentuated tightness and cold at toe.

c. Instep lacings placed in wrong position to perform their function properly.

d. Sole and heel could be considerably lighter and still give ample protection to foot. Mukluks should be *light*—these (including sox) weigh as much as a heavy pair of shoepacs.

e. Fabric upper should be as high as QMC mukluk and of much more durable material.

5. GLOVES, SHELL, LEATHER (Type F-2) (with electrical insert) *Fair*

a. Specifically designed as a flying glove. Was used on this test only to determine usefulness under emergency conditions. It has the drawbacks of all five-fingered handwear, but gave adequate emergency protection down to approximately + 10° F.

6. INSERT, GLOVE, RAYON *Good*

a. A useful, but not at all essential article under emergency ground conditions. Wear out very rapidly.

b. Should be made ambidextrous.

c. Similar gloves made from Nylon were tested and found to *feel* colder and showed no indication of being any more durable.

7. GLOVE, WINTER, FLYING (Type A-11a) *Good*

a. Satisfactory for emergency ground use down to approximately plus 10° F.—if exercising, down to approximately 0° F. These gloves are satisfactory for use at much greater temperature extremes but only when worn for short periods of time.

b. The D-3a Mechanic's Glove and woolen insert are sturdier and more practical for ground wear and general use under emergency conditions, if a 5-fingered glove is desired at all.

8. GLOVE, WINTER, FLYING (MITTEN) (Type A-12) *Unsatisfactory*

a. General design, lack of moccasin cut, stiffness, and sewn-in liner result in unnecessary bulkiness and inadequate protection under extreme conditions.

9. HELMET, PILOT'S WINTER (MOUTON) (Type B-9) *Fair*

a. This hat is considerably more beautiful than it is practical.

b. Its weight (9 oz.) is approximately 40% greater than practical civilian work-hats of similar design.

c. Rayon and tackle twill should be replaced by poplin outer shell and double light weight wool-flannel lining with quilting stitch.

d. 100% Alpaca should replace the clumsy mouton if available.

e. Hatband is conspicuously absent and lining should be attached firmly to outer shell.

f. Should be cut deep enough so that it protects forehead, tip of ear and neck simultaneously.

Power Plant
Cold Weather Test Program

Prepared by: Wm. Weitzen, Power Plant Laboratory

A. PURPOSE

1. To comment generally on pertinent features and major tests of the winter of 1944-45 with respect to power plants and power plant equipment.

B. FACTUAL DATA

1. The following items will be discussed in detail in the report:

a. Engine oil spewing and breathing characteristics.

b. Cold starting with special priming fluids and ordinary aviation gasoline.

c. Oil dilution with regular grade 1100 oil, special oil PPO (synthetic) 265 and dilution, and engine crankability.

d. General operation.

2. See Appendices I, II, III and IV.

C. CONCLUSIONS

1. The R-2000-7 engine installed in the C-54B airplane does not satisfactorily comply with winterization directives with respect to handling diluted oil under take-off power conditions.

2. The Packard Rolls-Royce V-1650-7 engines, used in P-51 airplanes, both with and without the improved scavenging system as embodied in special engine No. 330964, do not satisfactorily comply with the above directive. These engines are especially poor in that oil loss occurs with as little dilution as 15%. Operation of these airplanes with even 20% normal dilution is considered hazardous.

3. The V-1710-93 engines installed in the P-63A aircraft are not satisfactory with respect to handling diluted oil if the Bell air-oil separator is removed. The improved front engine cover devised by Allison and Wright Field does not provide much improvement; spewing occurred with 15% dilution when the separator was removed.

4. The P-63A installation of the V-1710-93 engines utilizing an air-oil separator successfully and satisfactorily handles 30% premixed, diluted oil without any oil loss.

5. The V-1710-111 engine (right) of the P-38L aircraft does not satisfactorily comply with winterization directive on oil spewing. Oil loss occurred with 25% premixed dilution; no oil loss occurred with 25% normal dilution.

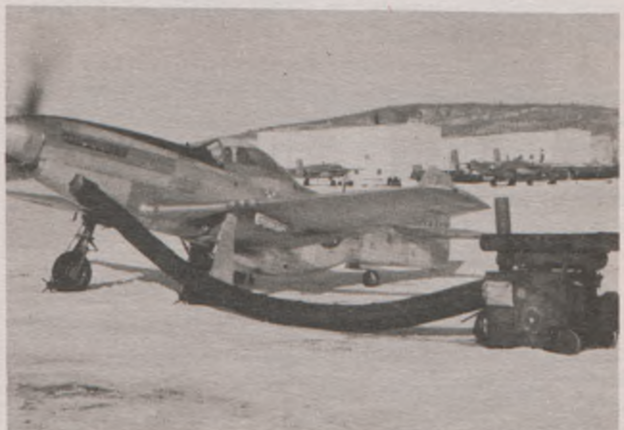
6. The V-1710-113 engine (left) of the P-38L aircraft does not satisfactorily comply with the winterization directive on oil spewing. Oil loss occurred with 20% premixed and 20% normal dilution; no oil loss occurred with 15% normal dilution. This engine is considered unsatisfactory and hazardous for operation with over 20% dilution.

7. Cold starting of present combat type aircraft engines using ordinary aviation gasoline can neither be consistently nor satisfactorily accomplished below the range of 0°F to —10°F—with small variations in the range with various engine types.

8. It is the opinion of Power Plant personnel, based on experiences in Alaska, that cold starting of aircraft engines through the medium of special fuels and equipment or through the use of advanced priming systems and ordinary aviation gasoline, offers several definite advantages to the Army Air Forces and that continued effort to determine a final solution to this problem is fully justified.

9. The existent priming systems, and requirements therefor, used by the Army Air Forces are totally inadequate and unsatisfactory. There are definite indications that vast improvements of the inherent starting ability of U. S. aircraft engines can be made by specific studies of the subject.

10. Special cold starting equipment can satisfactorily start engines completely cold down to temperatures obtained during the winter of 1944-45. Cold room studies have shown that successful starts can be made consistently with the proper equipment at the minimum temperatures set up by the winterization directive. The installation of the special starting equipment is an individual airplane problem and requires additional investigation. Further work is also required before a satisfactory kit can be made.



Heating engine compartment to facilitate starting and warming up

11. Continued cold room studies of oil systems, including oil tanks, dilution systems, and temperature controls are indicated and are considered necessary to eliminate the unsatisfactory conditions existing in some Army Air Forces aircraft.

12. It is necessary that the airplane contractors devote additional engineering to the design of oil systems, with particular emphasis on the factors outlined in Appendix III, paragraph f.

13. Additional data, to be obtained in cold rooms, are required to correlate the effects of low temperatures on different engines using diluted Grade 1100 engine oil and diluted synthetic PPO 265 engine oil. The present data available on actual—not extrapolated—viscosities of both Grade 1100 and PPO 265 engine oil with and without gasoline dilution should be greatly augmented.

14. The use of PPO 265 engine oil has shown itself to be of definite advantage to engine operation under cold weather conditions. The work on this oil, or similar engine oils having low temperature characteristics, should be continued by both the Air Technical Service Command and the industry. This oil should be considered again for use next winter by all activities operating in the Arctic.

15. Vacuum pumps are the only accessory on engines which prevent cold cranking of engines, as they fail under these conditions due to congealed oil in the pump. Definite action is required to provide vacuum pumps, or vacuum pump installations, which will not fail when rotated under extreme cold conditions.

D. RECOMMENDATIONS

1. It is strongly recommended that the Power Plant Laboratory Low Temperature Building be completed as quickly as possible and put into operation. The use of these cold rooms would immensely benefit the cold weather program and make it possible to secure solutions to certain problems in a minimum of time. These cold rooms would remove the uncertain variable of weather from present tests, and permit fundamental data to be secured in the laboratory rather than at a cold base such as Ladd Field.

2. It is recommended that the Allison Company and the Packard Company be required to continue their efforts to make their engines comply with winterization requirements.

3. It is recommended that Air Technical Service Command provide impetus to this improvement program on the V-1650 and V-1710 engines.

4. It is recommended that operating instructions be provided for C-54 aircraft having R-2000 engines to prevent oil loss when operating under Arctic conditions when heavy dilutions are likely to be encountered. This airplane, while not complying with the directive on oil spewing, is operable with some precautions and does not involve the hazards encountered with fighter aircraft.

5. It is recommended that work and engineering development be continued by the Power Plant to evolve a satisfactory cold starting system for Army Air Forces aircraft engines.

6. It is recommended that a project be initiated to include priming system and priming nozzle development so as to secure the fullest benefits during starting with ordinary aviation gasoline. The goal of such a project should be successful starting with aviation gasoline down to at least —30°F.

7. It is recommended that action be initiated by the Air Technical Service Command to provide ample quantities of PPO 265 for use by all activities operating under Arctic conditions during the winter of 1945-46.

8. It is also recommended that the Fuel and Oils Branch of the Power Plant Laboratory endeavor to obtain aircraft lubricating oils having characteristics similar to or better than those of PPO 265 for winter operations.

9. It is recommended that impetus be given to the aircraft industry by the Air Technical Service Command to continue study of, and further improvement of oil systems, through the medium of a report which will emphasize the factors listed in Appendix III, paragraph f, and explain fully and concisely the importance and effects of these items on cold weather operation of oil systems.

10. It is recommended that action be taken immediately to provide vacuum pumps which will not fail on cold starts, as this one item is the only accessory now preventing cold cranking of aircraft engines. Corrective action considered should include other means than dilution of the vacuum pump as there are certain objections to acomplishing this by dilution of the vacuum pump.

Appendix I

Engine Oil Spewing and Breathing Characteristics

1. Existing winterization directives demand that aircraft engines be capable of operating under take-off power conditions for 5 minutes with engine oil diluted to 30% by volume, without any oil loss from the engine breathers. Ground run-up is limited to 5 minutes prior to take-off. This requirement is based on past unsatisfactory experiences with several types of engines which were not capable of handling diluted oil without a loss, which resulted in subsequent loss of the entire or partial oil supply and forced landings. The condition for handling diluted oil exists primarily in the Arctic, and therefore is considered a winterization requirement. At the present, AN engine specifications are incorporating this basic requirement with a modification to permit testing under summer temperature conditions.

2. Past experience and testing have shown that present production radial engines were satisfactory with the exception of the P. & W. R-2000. The in-line liquid cooled engines—V-1710 and V-1650—were not satisfactory. Tests have never been conducted under Arctic conditions with the R-2000 engine. Both the Allison Company and the Packard Company have been striving to improve the breathing characteristics of their respective engines. The Allison Company, in conjunction with Wright Field, devised a new engine front cover for their "E" engines which power the P-63 aircraft. This was known to be an improvement over past engines, but was

still not considered completely satisfactory. The Packard Company developed an improved scavenging system in their engine, and as a final step resorted to a mechanical centrifuge. The North American Aviation Company altered the engine breather external installation in the P-51 aircraft for better performance.

3. The Bell Company, cognizant of the engine condition, installed an air-oil separator in the engine breather line to trap escaping oil and prevent oil loss when using diluted oil.

4. Tests were conducted during the winter on the 3 aircraft utilizing the above mentioned engines: the C-54B, the P-63A, and the P-51D.

5. The test results are tabulated below: Deleted. The P-51D spewing test results with the Thompson Centrifuge installed will be covered in an addendum to this report.

6. Changes have been made in the present production Allison engines which involve the use of 100% counterweighted crankshafts. The P-63 tests mentioned above were the —93 engine without this new crankshaft. Later model P-63 airplanes will have the —117 and tests on this airplane will be covered in the above mentioned addendum. Check tests were conducted on the P-38L aircraft, having the —111 and —113 engines which have the 100% counterweighted crankshafts. These results are tabulated below: Deleted.

Appendix II

Cold Starting with Special Priming Fluids and Ordinary Aviation Gasoline

1. The problem of cold starting aircraft engines is still, to some extent, a controversial one. There are experienced personnel, perhaps set in their ideas, who feel that heat is the only way to operate in the Arctic. Conversely, however, many believe that heat, while useful in many applications, involves too much extra maintenance, heating equipment, and primarily TIME. Observations made by Power Plant personnel tend to verify this, particularly with respect to the smaller combat aircraft. The problem may be put into two parts: (These opinions are necessarily personal and based on experience; some are questionable and open to controversy.)

ADVANTAGES

Cold Starting

1. Time saved in starting. A cold start may be made in 1 minute.
2. Requires less equipment such as heaters, which increase the man-hours of maintenance on any base.
3. Saves fuel used by heaters and decreases supply problem with respect to heaters.

Heat By Hot Air Heaters

1. Theoretically easier on engines and adds to their life.
2. Theoretically easier on engine accessories.
3. Generally speaking it requires less care in performing dilution.

DISADVANTAGES

Cold Starting

1. Theoretically rough on engines and decreases engine life.
2. Necessitates a good dilution procedure and care by the crew chief.
3. Increases starter loads to some extent.
4. Requires "winterized" accessories.
5. Requires auxiliary cold starting equipment either as ground units, or as an integral part of the aircraft.
6. Requires a special starting fuel with its resultant supply problem.

Heat By Hot Air Heaters

1. Involves much time in setting up heaters, and the actual heating process increases with decreased temperatures.
2. Requires extra man-hours to set up heaters, engine covers, and maintain the equipment.
3. Requires much extra equipment such as heaters and fuel to run them.
4. Presents a hazard under some conditions due to the omission of dilution and the subsequent danger to tanks, lines, and coolers, which may not be heated due to their location.

2. The above comparison of the "pros" and "cons" of cold starting may be seen more pictorially in the photographic record prepared by the Power Plant Laboratory. This will give more of an idea of what using heat and cold starting involves.

3. Attached hereto is a table of cold and hot starts made during a cold period, which illustrates to some extent the problem involved. Such data, accumulated over a period of a month or more in all types of weather, would show very concisely the correlated picture of dilution, crankability, engine variables, and engine starting ability, all with varying free air temperatures. Such a record, however, requires personal supervision and strict control over a number of personnel assigned only to that job. It shows that cold starts with aviation gasoline are not dependable beyond the range of approximately 0°F. to —10°F. In fact, the ability to start varies from engine to engine; the important factor apparently being the priming system. For example, the in-line engines, V-1710 and V-1650, show a definite ability to start more readily with gasoline than any of the radials. The Pratt and Whitney radials with individual cylinder priming of the top cylinders also appear to start more readily than the Wright engines with induction system priming. There have been claims made by reputable sources that cold starting with gasoline is possible down as low as —50°F. This, of course, does not mean with existing aircraft priming systems, where there are definite signs that the cylinders are not being supplied with vaporized fuel, or raw fuel. The inability to start many engines is due to lack of vaporization of the fuel. This is shown by the fact that heating the induction system, or supplying hot air to the intake has enabled engines to start under cold conditions.

4. The definite superiority of Packard engines with

respect to cold starting is considered due to their priming nozzles and system. The RAF and RCAF have made many priming nozzle studies with subsequent improvement in priming systems and cold starting ability. It is believed that suitable priming systems, using ordinary aviation gasoline, could be evolved which would lower the present minimum starting temperatures by as much as 30°F. If this were proved to be true, the use of cold starting equipment and fuels might prove unnecessary as some compromise with heat may prove to be the most satisfactory solution at the extreme of the low temperature range.

Appendix III

Oil Systems, Oil Dilution with Regular Grade 1100 and PPO 265 Engine Oils, and Engine Crankability

1. Again, as has been the case in previous years, the problem of dilution played a prominent part in the test program. It can be said that the efforts of the last two years' tests on dilution showed results in that the general attitude towards dilution was far more liberal and, on the whole, dilution was far more dependable and satisfactory. Standard dilution time period determinations were made on all aircraft by Cold Weather Testing Detachment and Extreme Temperature Operations Unit. All the data obtained are being prepared graphically on the standard forms by the Cold Weather Testing Detachment and will eventually serve as the basis for revision of existing Technical Orders on dilution wherever necessary. In the main, the data collected will be summarized in Technical Order 02-1-29. These revisions and corrections will be initiated by the Power Plant Laboratory after collaboration with the Cold Weather Testing Detachment. The comments on the individual aircraft will be contained in the specific airplane reports.

2. The general oil system situation is improved over last year. In the spring of 1944, conclusions and recommendations were made based on the findings of the winter test seasons of 1942-43 and 1943-44, which clarified certain factors in oil system and tank design heretofore considered negligible or unknown. These factors, such as segregation or dilutability, and warm-up were not critical as long as operations were conducted in the temperate zone. The use of the more common types of Army Air Forces combat and cargo aircraft in the Arctic, however, accentuated these factors and the malfunctions resulting therefrom. Some action has been taken to overcome design faults, but results were not forthcoming in sufficient time to comment conclusively on them. For example, a new type P-63 oil tank was furnished to Extreme Temperature Operations Unit and is currently in the P-63A, No. 42-70255 airplane. It has shown a definite improvement in shortening the dilution time schedule, in providing good segregation, and in enabling the full oil capacity to be used with 30% dilution. Further tests are necessary though and this tank will be the subject of a report when as many data are obtained as possible. More important, probably, is the fact that several manufacturers have evinced an interest in oil system design and this will undoubtedly show results shortly.

3. The B-24 oil tank is a new and larger model than the previous types. It is improved and provides sufficient hopper capacity to eliminate the poor segregation shown last year, which prevented obtaining 30% dilution with high tank levels. However, the warm-up characteristics could not be tested due to insufficient cold weather and this factor needs additional checking.

4. The A-26 oil tank is similar to last year's unsatisfactory model and reference is made to the data contained in the Cold Weather Testing Detachment report on "Oil Systems" of 1943-44.

5. All in all, the efforts of this past season point again to the necessity of thorough cold room testing of oil system details before release to production. Many of the items discovered so laboriously under field conditions could be easily found by controlled cold room testing.

6. The following factors affect the satisfactoriness of a complete oil system insofar as Arctic, or cold weather, operation is concerned and are tabulated below to present a complete picture of the situation:

Oil Tank

a. Segregation and hopper-sump details.
b. Warm-up characteristics of hopper and tank.
c. De-aeration characteristics of tank.
d. Susceptibility to external heat or cold.
e. Accessibility to sump and drainage points.

Oil System

a. Cooler characteristics with regard to warm-up, anti-congealing, and surge protection.
b. Thermostatic or temperature controls used in the system.
c. Routing of oil lines and elimination of traps.
d. Accessibility and ease of accomplishing "Y" drainage.

Miscellaneous

a. Operability of the dilution system—mainly fuel flow to the oil system.
b. Effectiveness of the dilution operation in providing fluid oil throughout the oil system and engine.
c. Effect of low temperatures on accessories, mainly the vacuum pump.
d. The effect of low temperatures on various engines and the necessity of correlating engine types, available starter torques, and oil viscosity.

7. The above items should be made the subject of a separate report and clarified in detail to the extent necessary to provide complete understanding of the problem to all interested parties.

8. Insofar as dilution of grade 1100 oil is concerned, for all practical purposes it is accomplishing its objective; i.e., providing sufficiently fluid oil so that crankability is obtained. Temperatures low enough, or in the range below —40°F. were not obtained and the desired testing at low temperatures could not be accomplished. The main question still to be determined is whether or not the amount of dilution required by the Technical Order for —50°F and below is correct or what are the maximum oil viscosities which will provide crankability with present starters. These data can and should be obtained in the cold room.

9. In addition to the service test being conducted by the Alaskan Wing of Air Transport Command over the northern ferry route with PPO 265 oil on C-47 airplanes, a quantity of this synthetic oil was supplied to the Cold Weather Testing Detachment and Extreme Temperature Operations Unit for use on their service aircraft during the winter test program. The Alaskan

COLD STARTING AND CRANKABILITY RECORD

PPO—Synthetic oil PPO 265

1100—Grade 1100 A or P regular oil

*—indicates photographic record

T.S.—Too stiff

—10 / —5 = —10 was average of previous 10 hours / —5 was O.A.T. at time of test

Date 1945	Time	O.A.T. °F	Airplane Type & No.	Engine No.	Oil Used	Previous Dilution Minutes	Oil Flow at "Y" Drain	% Dilution at "Y"	Prop Cranking RPM Prestart	Remarks
Feb 7	0900	—4 / —9	B-24J No. 1378	1	PPO	0	....	....	24	Three starting attempts on gasoline failed.
				2	PPO	0	....	....	24	First starting attempt on gasoline successful.
				3	PPO	0	....	....	24	Third starting attempt on gasoline successful.
				4	PPO	0	....	....	24	Second starting attempt on gasoline successful.
Feb 13	1000		B-24J No. 1378	1	PPO	2½	Yes	18½	....	No. 3 and No. 4 engines attempted starts on gasoline. Not even a fire resulted from each engine. No attempts therefore on No. 1 and No. 2.
				2	PPO	2½	Yes	4(?)	....	
				3	PPO	2½	Yes	16	36	
				4	PPO	2½	Yes	15	29	
Feb 13	0900	—37 / —43	B-17G No. 8221	1	PPO	2½	....	22	28	No cold starts on gasoline successful on any engines.
				2	1100	6½	....	38	....	
				3	1100	6½	....	38	31	
				4	PPO	2½	....	16	28	
Feb 13	0900	—37 / —43	B-25J No. 9268	1	PPO	2½	Yes	9	T.S.	Crew chief believed engines too stiff for cranking.
				2	PPO	2½	Yes	9	T.S.	After 1 hour heat engines started on gasoline.*
Feb 13	1000	—37 / —40	C-47A No. 8088	1	1100	2½	....	....	....	* Unsuccessful start on gasoline.
				2	1100	2½	....	....	....	Broke starter.
Feb 13	1030	—37 / —40	B-29A No. 5214	1	PPO	3	....	....	T.S.	Engines No. 2 and No. 3 have experimental direct cranking starters. After 1 hour heat, cranking speeds were 18, 15, 13 and 15 RPM. After another hour heat, speeds were 31, 19, 18, and 22 RPM. After 1 hour at 1100 starting attempts on gasoline and butane failed*. All started on gasoline after 2 hours heat at 1415.
				2	PPO	3	Yes	2(?)	T.S.	
				3	PPO	3	Yes	2½(?)	T.S.	
				4	1100	3	....	....	T.S.	
Feb 13	0915	—37 / —43	P-38L No. 4050	1	1100	6½	No	....	....	*First butane attempt successful.
				2	PPO	3½	Slow	....	36	*Three gasoline attempts unsuccessful. Their second butane attempt successful.
Feb 14	0930	—29 / —34	P-38L No. 4050	1	1100	2½	....	....	32	*Butane starts on both engines successful.
				2	PPO	3 added to Feb. 13	....	....	32	
Feb 14	1000	—29 / —33	C-47A No. 8088	1	1100	7½	....	....	42	*Butane starts on both engines successful.
				2	1100	7½ Total of Feb. 13 and Feb. 14	....	....	48	
Feb 14	1100	—29 / —30	B-24J No. 1378	1	PPO	4	....		27	Started by piping hot air into filter.
				2	PPO	4	....		28	*Unsuccessful starting attempt on gasoline.
				3	PPO	4	....		27	Attempts considered useless.
				4	PPO	4	....		24	Attempts considered useless.
Northway								FM AM		
Feb 14	0800	—50	B-25J No. 9113	1	1100	12	No	30 / 26	....	No starts attempted. Lack of oil flow unexplainable.
				2	PPO	6	Yes	14 / 7	....	
								½ / ½		
Feb 14	0820	—50	C-46A No. 6803	1	PPO	6	Yes	25 / 23		Felt free to turn.
				2	1100	10	Yes	34 / 20		Felt free to turn.
Feb 14	0840	—50	B-24 No. 377	1	1100	6	Slow	22		Stiff.
				2	1100	6	Slow	24		Turned.
				3	PPO	4	Yes	12		Turned.
				4	PPO	4	Yes	18		Turned.
Feb 14	0900	—50	C-45 No. 7157	1	1100	6	Yes	36 / 35		Very free to turn.
				2	PPO	4	Yes	28 / 23		Very free to turn.
Feb 14	0920	—50	C-45 No. 894	1	PPO	4	Yes	22 / 21		Very free.
				2	PPO	4	Yes	26 / 27		Very free.
Ladd Field Feb 15	0930	—4 / +1	P-38L No. 4050	1	1100	10½	....	....	....	*First attempts on both with gasoline successful.
				2	PPO	6 Total added to Feb. 14	....	....	....	
Feb 15	0940	—4 / +2	P-61B No. 9402	1	PPO	3	....	....	19	*First attempts on gasoline successful for both. No. 1 ran rough for about 1 minute.
				2	1100	5	....	....	20	
Feb 15	0830	—4 / +1	B-17G No. 8221	1	PPO	0	....	....	26	Second attempt on gasoline suc-
				2	1100	1	....	....	28	Second attempt on gasoline suc-
				3	1100	1	....	....	31	First attempt on gasoline suc.
				4	PPO	0	....	....	24	First attempt on gasoline suc.
Feb 15	0820	—4 / +1	C-47A No. 8088	1	1100	....	....	....		First attempt on gasoline suc.
				2	1100	....	....	....		First attempt on gasoline suc.
Feb 16	0830	7 / 7	B-24J No. 1378	1	PPO	0	....	....	30	No. 1 and No. 2 started easily on gasoline.
				2	PPO	0	....	....	32	
				3	PPO	0	....	....	....	No. 3 and No. 4 not attempted.
				4	PPO	0	....	....	32	
Feb 16	0840	7 / 7	B-17G No. 8221	1	PPO	0				All four engines started successfully on first attempt on gasoline.
				2	1100	1				
				3	1100	1				
				4	PPO	0				
Feb 16	0850	7 / 7	P-61B No. 9402	1	PPO	0			30	Started on gasoline. Fired in 10 seconds and ran rough for 1 min.
				2	1100	3			35	First attempt of 45 seconds no fire. Second attempt successful.

Wing service test will not be covered in this report. Reference is made to Memorandum Report by the Extreme Temperature Operations Unit dated 10 January 1945, Serial Number TSEAL-4-M, subject: "Investigation of Reported Engine Roughness during Service Test of PPO 265 by Alaskan Division, Air Transport Command". This described in detail some of the problems encountered through the use of this oil. A final report will be issued by the Alaskan Division when the service test of this PPO 265 oil is completed.

10. The Cold Weather Testing Detachment has used this oil liberally on many of their airplanes. In most instances it has been used in conjunction with regular grade 1100 oil so as to provide a comparison during the winter season. The Cold Weather Testing Detachment will issue reports covering the individual airplanes and a general report on oil systems, which will include as much detailed data as was gathered, and all individual pilot and crew chief reactions.

11. The Extreme Temperature Operations Unit also used synthetic oil throughout the season on various aircraft to compare its advantages with regular grade 1100 oil. Inclosure 2 of Power Plant Progress Report No. 4 shows how the use of synthetic oil was divided among the Extreme Temperature Operations Unit airplanes. Here again, the individual pilot and crew chief reports will provide the best indices of the suitability and advantages of this oil.

12. The use of synthetic engine oil, PPO 265, has shown itself to be of advantage as predicted last year. This oil, with its pour point some 30° below that of Grade 1100 oil and its much higher Viscosity Index, eliminates the necessity for dilution down to approximately —10°F. Additional data pertaining to its Viscosity-Temperature relationship slightly altered the estimates of last year, which resulted in a prediction that dilution could be eliminated down to approximately —15° to —20°F. This upward revision, however, does not nullify to any great extent the benefits to be derived from this oil. A review of the table under "Crankability and Cold Starting", covered above in this report, gives some indication of the advantages of this oil with respect to eliminating dilution. Additional crankability data correlated with dilution time periods were to be secured by Cold Weatner Testing Detachment and Extreme Temperature Operations Unit; the value and accuracy of these data are somewhat questionable inasmuch as reliance upon untrained personnel had to be resorted to in gathering them. However, when the season is completed, a compilation of these data from Cold Weather Testing Detachment and Extreme Temperature Operations Unit will be made and an analysis attempted.

13. In addition to the above, the use of PPO 265 showed definite improvement in feathering and unfeathering operations, and there has been a reported acceleration of engine oil warm up rates.

Oil Tank Hopper Design

Prepared by: Wm. Weitzen, Power Plant Laboratory

Since promulgation of airplane oil system requirements and details as covered by Section III of Technical Note, TN-TSESE-1, dated 1 November 1944, pages 21 through 24, additional information has been collected which further elaborates or eliminates some of the factors previously outlined. As mentioned in the Technical Note, some of the requirements had at the time of issuance of the Technical Note, not yet been proved. Now the general oil system situation has crystallized into definite requirements which are further described below.

Three major performance requirements in which ATSC is interested are segregation, deaeration, and warm-up. Handbook requirements are now set up to obtain the above characteristics by the following means:

A. SEGREGATION

As described in the Technical Note a hopper design as outlined will provide practically perfect segregation and good dilution characteristics. Briefly, this hopper should have two inwardly opening flap valves at the bottom through which makeup oil can flow with a minimum pressure drop to the circulating oil system. This hopper should also have an increased section at the top above the maximum oil system level which will contain the increase in volume due to the addition of diluent to the extent of 30% by volume of the circulating oil. The details of the propeller feathering arrangement will not be covered here.

A tank incorporating this principle was built by the Bell Aircraft Corporation last year for use in a P-63 airplane. It was flown and dilution tested at Ladd Field, Alaska, with satisfactory results. Insofar as dilution and segregation were concerned, a dilution of 25% in the circulating system was obtained in six minutes as compared to approximately nine minutes with the standard system. With the new tank, dilution samples taken from the main portion of the oil tank showed negligible dilution, indicating good segregation.

B. DEAERATION

The use of a wide, flat pan or similar flow pan at the top of the hopper, as shown in the Technical Note sketch, has been shown to be relatively useless insofar as accomplishing any degree of deaeration. A long series of tests conducted by the Gulf Research and Development Company eliminated this means for providing deaeration. The important result of their test work has shown that time is the most important item if deaeration is to be accomplished. Tests also conducted by the Navy Department on their type oil system has shown that when the main oil flow was through the entire tank, involving a good deal of time for air bubbles to escape from the oil, that good deaeration was accomplished automatically. On the basis of these tests and other information secured at ATSC, it has been decided that the use of a diverter oil system will provide a good, practical means of deaeration in the oil system. Diverter valves of various types are at present being made by Standard Aircraft Products, AiResearch Manufacturing Company, and United Aircraft Products. These valves are mounted atop the oil tank and will provide for returning the inlet scavenged oil either through the hopper or through the main portion of the tank. Diversion of the oil results from the temperature change, this temperature change being due to injection of the diluent at the temperature element of the diverter valve. Valve design is planned to provide for quick shifting of the flow from the main tank to the hopper when diluent is injected into the valve. This will minimize the amount of dilution which enters the main portion of the tank. Conversely, however, in order to provide warmup of the main portion of the tank, diversion after a cold start must be retarded for several minutes or until sufficient warmup has been accomplished in the main portion of the tank to permit oil flow through this part of the tank. One means of providing this retarded action of the diverter valve in one direction is to make the heat flow path from the oil stream to the temperature element a long and tortuous one. This will not affect the rate of action in the reverse direction since it is possible to inject the diluent directly over the temperature element and thus provide quick response.

C. WARMUP

Provision of the above two characteristics necessitates a positive and assured means of oil tank warmup. It is obvious that if perfect segregation is provided, the main portion of the tank will be undiluted and will congeal in due time. After cold starting, oil flow will take place through the hopper until the diverter valve switches over to main flow. If, at this time, a fluid path has not been created through the main mass of congealed oil, the pressure pump will be starved with subsequent disastrous results. Tests at Wright Field have indicated that present type hoppers, if provided with fins, have greatly increased warmup characteristics and in a matter of minutes will sufficiently decongeal the oil between fins and, in their close proximity, to permit oil to flow alongside the hopper from top to bottom to the outlet of the tank. As a suggestion, fins utilized by the ATSC were approximately 1″ wide, 1/16″ thick and extend vertically from top to bottom of the hopper. In a tank design in accordance with the above items, a safety feature to prevent hopper depletion might be incorporated in the form of an additional inwardly opening flap valve located near, and just above, the maximum oil level. It might be possible with this arrangement to have a congealed tank at the time of diverter valve action and have the returned scavenge oil still flow to the oil tank outlet through this upper flap valve which will open inasmuch as the returned scavenge oil builds up on top of the mass of congealed oil. The operability of such a feature would depend largely on the details of the tank design.

It will be possible with oil system having the above characteristics to calculate with reasonable accuracy dilution periods for any particular airplane, inasmuch as the volume of circulating oil will be definitely known. With respect to dilution itself, late requirements have eliminated the use of the "Y" restrictor fitting, part No. AN-4077, and replaced same by part no. 44B26171 or part No. 44B26172. The solenoid valve, AN-4078, has also been relegated to an obsolete status and either United Aircraft Products solenoid valve, part No. U-3100, or Koehler Aircraft Products solenoid valve, part no. K-1170B, is preferable. All of these items are approved.

Oil Spewing Tests on P-51D Airplanes with V-1650-7 Engines, Part 1

Prepared by: Wm. Weitzen, Power Plant Laboratory

A. PURPOSE

1. To report on tests conducted on V-1650-7 engines installed on P-51D airplanes to determine whether or not the breathing system complies with Specification AN-9500-C, paragraph D-31q.

B. FACTUAL DATA

1. Previous experience with Packard built Rolls Royce engines have indicated very unsatisfactory oil breathing characteristics. This engine loses engine oil through the breathers with relatively small amounts of oil dilution under both takeoff powers and lower power conditions.

2. As a result of the unsatisfactory condition being experienced on this airplane, the Packard Motor Car Company initiated an investigation to eliminate this spewing characteristic and to make the engine satisfactory for use with 30% diluted oil. The Packard tests resulted in a slight modification in scavenging system design (reference is made to Packard Company Report No. 221 dated 18 July 1944) which improves the breathing situation but was not claimed to make the engine completely satisfactory. In addition, the Packard Company conducted tests with an engine driven external centrifuge, designed by the Thompson Products Company, which centrifuge was claimed to make the engine satisfactory.

3. The revised Packard scavenging system was incorporated in special engine No. 330964, which engine was in E.T.O.U. P-51D airplane No. 44-14476. The C.W.T.D. P-51D airplane had a standard V-1650-7 Packard engine. Both of these airplanes have the revised North American valve cover box breather system which is supposed to facilitate engine breathing and assist in eliminating oil spewing.

4. Spewing tests on these airplanes were conducted in a normal fashion under service conditions. The airplane would be diluted to a pre-determined amount through the regular dilution system in order to have diluted oil in the engine, oil lines, and oil cooler; then the

oil tank would be drained and filled with a premixed quantity of diluted oil. Takeoff is attempted at takeoff powers within 5 minutes after starting up the engine. This power would be maintained for 5 minutes unless spewing became excessive. A mirror was mounted on the wing to enable the pilot to observe spewing. Oil tank levels were measured by a dip stick before and after each flight. A photographic motion picture record was taken of the results of each flight and is available for inspection upon request.

5. See Appendix I for test data of the various flights.

C. CONCLUSIONS

1. The standard Packard V-1650-7 engine and the special Packard V-1650-7 engine No. 330964, with revised scavenging system as presently installed in P-51D aircraft utilizing the North American breathing system, are completely unsatisfactory with respect to oil spewing and do not comply with specification AN-9500-C, paragraph D-31q.

2. The engine breathing and spewing characteristics are so bad that it is doubtful whether safe operation under combat conditions can be conducted with dilutions over 10%, unless special dilution and warm-up measures are taken.

D. RECOMMENDATIONS

1. It is recommended that Packard Motor Car Company take prompt and extensive action to improve the breathing characteristics of the V-1650 type engine so as to provide compliance with specification AN-9500-C, paragraph D-31q.

Part 2

A. PURPOSE

1. To report on additional tests conducted on V-1650-7 engines installed in P-51D airplanes equipped with Thompson centrifuge separator in the engine breather outlet.

B. FACTUAL DATA

1. Reference is made to Factual Data contained in the basic report.

2. Three flight tests were made with 15, 20 and 30% dilution with the Thompson centrifuge. The results of all three tests were approximately the same. In each case, a small amount of oil could be seen on the fuselage after the flight, and in all cases this could be considered negligible.

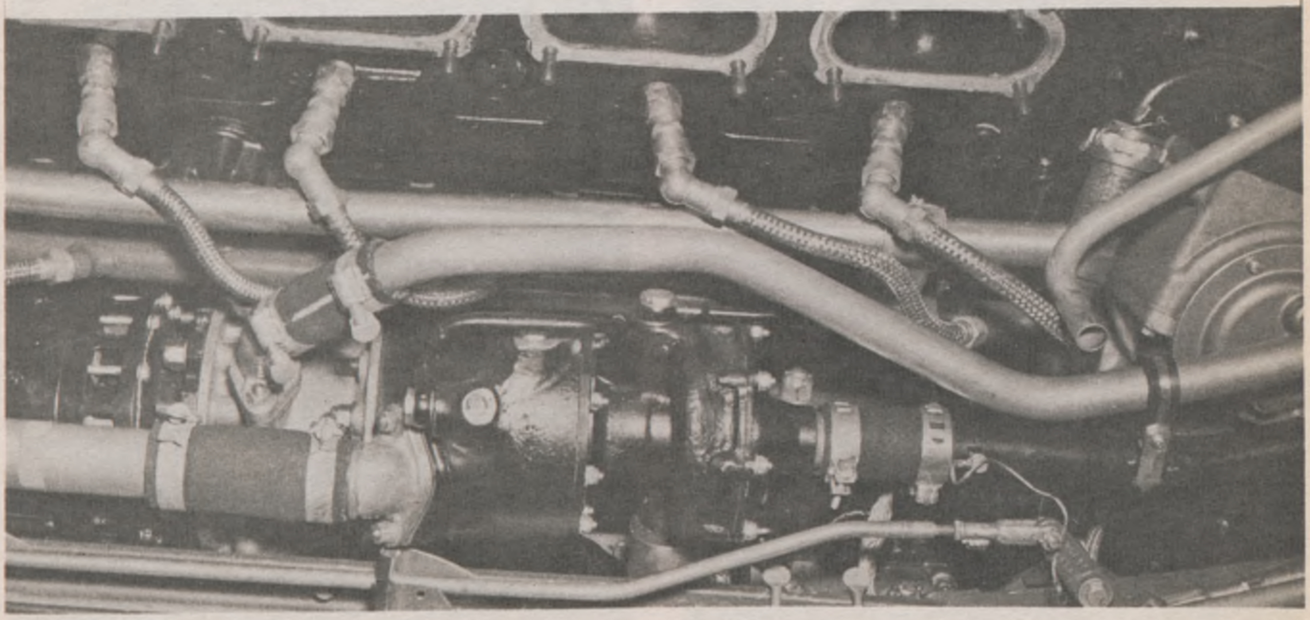
3. See Appendix I for test data of the various flights, and photographs taken after each flight are shown in Exhibit A.

C. CONCLUSIONS

1. The Packard V-1650-7 engine with revised scavenge system and the Thompson centrifuge installed in the breather outlet is capable of handling 30% dilution under takeoff power conditions with a negligible oil loss. Insofar as operation is concerned, this arrangement is considered satisfactory for service usage.

D. RECOMMENDATIONS

1. It is recommended that the Packard Motor Car Company and the Power Plant Laboratory determine whether or not the installation of this Thompson centrifuge is satisfactory and safe insofar as durability, life and engine operation is concerned.



Oil separator, mounted between after cooler and generator on P-51 D

Engine Breathing Tests with Diluted Oil on C-54B Airplane with R-2000-7 Engines

Prepared by: Wm. Weitzen, Power Plant Laboratory

A. PURPOSE

1. To report on tests conducted on the C-54B airplane to determine compliance with AN-9500-C, paragraph D-31q.

B. FACTUAL DATA

1. To determine compliance with Specification AN-9500-C, paragraph D-31q, the E. T. O. U. airplane C-54B, No. 43-17157, was used for the test at Ladd Field, Alaska.

2. Engine No. 1 was chosen as the breather outlet is visible from the pilot's compartment and the radio operator's window.

3. Prior to the test, the engine system is diluted in the normal fashion to give the approximate desired dilution in the engine, cooler, and oil lines. Then the oil tank is drained completely and refilled with pre-mixed 30% by volume diluted oil.

4. The test data are shown in Appendix I of this report.

5. Due to the short time the airplane was available for test purposes, additional runs could not be secured to elaborate on the abve data.

C. CONCLUSIONS

1. On the basis of these tests, the R-2000-7 engines and installation in the C-54B airplane does not comply with AN-9500-C, paragraph 31q. Even though the O. A. T. was approximately 12°F. above the maximum specified in paragraph D-31q, it is not considered that a small lowering of the O. A. T. would have materially altered the breathing characteristics of the engine.

D. RECOMMENDATIONS

1. It is recommended that action be taken by Pratt and Whitney Aircraft Division to improve the breathing characteristics of the R-2000-9 engines so as to comply with Specification AN-9500-C paragraph D-31q.

Ice found in fuel inlet line

Draining fuel tank sump

Oil Spewing Tests on V-1710 Engines Conducted at Ladd Field During 1944-45

Prepared by: Wm. Weitzen, Power Plant Laboratory

A. PURPOSE

1. To report on engine breathing oil spewing tests conducted on V-1710-93, -111, -113 and -117 engines installed in P-63A and P-38L aircraft to compare with the present requirements as described in Specification 9500C, paragraph D319.

B. FACTUAL DATA

1. On the basis of tests conducted during the winter of 1943-44 the "E" type Allison engine was known to have poor breathing characteristics with the result that oil spewing occurred with moderate dilutions. The Allison Company worked continuously on this problem and evolved in conjunction with Air Technical Service Command a baffled engine front cover, in accordance with drawing No. 54808, which modification materially improved the breathing characteristics of the type "E" engines. Previous tests conducted at Ladd Field during 1943-44 on the V-1710-89 and -91 "F" engines installed in P-38 aircraft indicated these installations were relatively satisfactory.

2. The Bell Aircraft Company worked simultaneously on this problem and evolved a system utilizing an air-oil separator, Type B-11, which was installed in the engine breather line, and a venturi in the scavenge oil line to which the separator drain was connected. Insofar as the Bell Company was concerned, this air-oil separator in conjunction with venturi, Part No. 33-674-036-1, accomplished the desired result and prevented oil loss with 30% diluted oil.

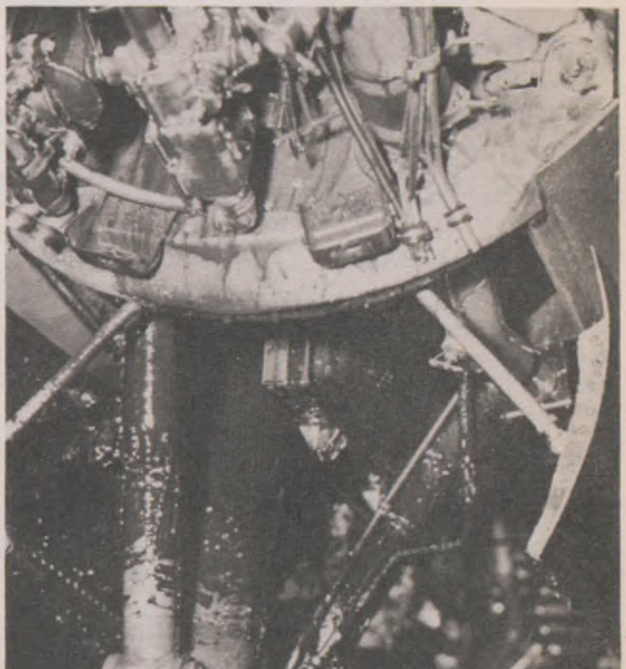
3. At Ladd Field, for the winter test program of 1944-45, there were available for tests one P-63A with an Allison V-1710-93 engine which had the modified engine front cover, and several P-38L airplanes with -111 and -113 engines. These latter two engines were new models having twelve counterweighted crankshafts, (sometimes referred to as 100% counterweighted crankshafts). The V-1710-93 engine still retained the old crankshaft and plans were made to incorporate in the airplane at a later date a V-1710-117 engine also having the twelve counterweighted crankshaft.

4. Oil spewing tests were conducted on the P-63A and P-38L aircraft in accordance with procedures previously established. In conducting these tests, the oil system is diluted in the normal fashion to a desired amount to provide dilution in the engine oil, oil lines, and oil cooler; then the oil tank is drained and filled with a premixed quantity of diluted oil. In testing, takeoff is usually accomplished within 5 minutes after starting the engine. Takeoff power is maintained for 5 minutes unless excessive spewing occurs in which case a power reduction is made. On the P-63 airplane, a mirror is installed on the wing to enable the pilot to watch for engine spewing. On the P-38 airplane, only one engine is tested at a time and there is no convenient way for the pilot to detect spewing.

5. The initial tests conducted were on the P-63A having the standard installation of B-11 air-oil separator and production venturi, No. 33-674-036-1. Results of this test are shown in Appendix I. This airplane satisfactorily handles 30% diluted oil.

6. Tests were then conducted on the P-38L aircraft. The "F" engines and installation do not have any special anti-spewing provisions. The results of these tests are tabulated in Appendix II. Also see Exhibits A and B.

7. The test results on the P-38 airplane showed that the V-1710-111 engine (right hand engine) is not as unsatisfactory as the V-1710-113 (left hand engine). Some of these tests were duplicated on the cold weather test P-38 airplane to confirm the results obtained on the E. T. O. U. P-38 airplane, AAF No. 44-24050.



Result of oil spewing

8. One check run was made on the P-63 airplane with the air-oil separator removed and the two engine breathers teed together in an arrangement similar to that previously used on the P-39 type aircraft. This brief check indicated oil spewing with as little as 15% total dilution.

9. The V-1710-117 engine was then installed in the P-63A airplane for further testing. This engine had, in addition to the standard production separator used previously, the latest Allison modifications including:

a. a front breather screen of enlarged exit area,

b. a rear breather restriction, and

c. a front oil pump elbow tube.

In addition, the breather outlet was scarfed 3° forward for pressure as per Bell Technical Memorandum 63:670:84 dated 18 November 1944. This installation satisfactorily handled 30% premixed dilution as shown in Appendix III. Also see Exhibit C.

C. CONCLUSIONS

1. All the Allison engines tested, the V-1710-93, -111, -113, and -117 engines, are unsatisfactory by themselves insofar as oil spewing is concerned. These engines would not comply with the requirements now established in Specification AN-9500-C, paragraph D-31q.

2. The P-63A type aircraft with the Bell air-oil separator, Type B-11, and venturi No. 33-674-036-1, satisfactorily handles 30% diluted oil when using the V-1710-93 engine or when using the V-1710-117 engine with the latest Allison modifications.

3. The P-38L type aircraft cannot satisfactorily handle 30% diluted oil under takeoff power conditions. The left engine, V-1710-113, is worse than the right engine, V-1710-111, and is sufficiently critical to impose a severe handicap to combat operation. The V-1710-113 engine can handle only up to 15% dilution while the V-1710-111 engine can handle up to 25% dilution.

D. RECOMMENDATIONS

1. It is recommended that the Allison Division continue their test program in an effort to improve the breathing and spewing characteristics of these later engines which, with the twelve counterweighted crankshafts, are more unsatisfactory than previous model engines.

2. It is suggested that the Lockheed Company consider the incorporation of some type of air-oil separator, or similar arrangement, in their P-38 type aircraft to eliminate this unsatisfactory oil spewing condition.

Oil Dilution and Spewing Tests Conducted on the C-69 Airplane

Prepared by: S. Barron, 1st Lt., A. C. Power Plant Laboratory

A. PURPOSE

1. To report the results of tests conducted on the C-69 airplane, Army Air Forces No. 43-10314, with respect to the oil dilution system breathing characteristics of the R-3350-35A engine, and the dilution, warm-up, and operational characteristics of the C-69 oil tank.

B. FACTUAL DATA

1. Dilution tests were conducted to determine the time periods necessary to obtain specified percentages of dilution. Appendix I contains the description of the oil tank and the discussion of the test. Dilution and boil-off curves are included as Appendix III.

2. Tests using 20% and 30% prediluted grade 1100 oil in engine No. 1 were accomplished, maintaining takeoff power for five minutes in order to determine the scavenging and breathing ability of the present installation. Test data is contained in Appendix II. Discussion of test is contained in paragraph *c*, Appendix I.

3. See Appendix I, paragraph *d*, for discussion of the flight operational data on the oil tank of engine No. 1, which was the only oil tank with thermocouples. See Appendix IV for warm-up curves.

4. Due to the late arrival of the subject aircraft, this report on dilution and spewing tests is submitted in addition to the general CWTD report written at Ladd Field (S.T. No. 10-45-1).

C. CONCLUSIONS

1. The oil dilution system is unsatisfactory. Six minutes of dilution is the maximum amount that can be applied to the present system. This provides only 10% dilution which is sufficient for an anticipated starting temperature of +10°F.

2. The R-3350-35A engine, as installed in the C-69 airplane, satisfactorily handles 30% prediluted grade 1100 oil.

3. There are indications that under extreme cold temperature conditions portions of the oil tank can congeal and remain congealed during operation. This may result in hopper depletion after some oil consumption.

4. Inacessibility of the oil tank precludes obtaining samples for a thorough analysis of the dilution characteristics of the tank with respect to segregation and diluent flow rate.

D. RECOMMENDATIONS

1. It is recommended that the oil dilution system be

modified to correct the present unsatisactory condition.

2. It is recommended that no more than 6 minutes (10% dilution) be attempted for cold starting and that heat be used in addition to 6 minutes dilution at temperatures below 10°F.

3. It is recommended that further oil dilution tests be conducted on this type aircraft to obtain samples from the oil tank or an accurate evaluation of its dilution characteristics.

4. It is recommended that further tests be conducted to determine dilution and warm-up characteristics of the oil tank after cold soaking at extreme low temperatures, both on the ground and in flight.

Appendix I

A. DESCRIPTION

1. This aircraft does not contain the type of oil tank usually found in Army Air Forces aircraft. Each engine oil tank is located immediately outboard of its engine nacelle and is integral with the wing. The top and bottom are formed by the wing leading edge-skin, the inboard end by the nacelle skin, the other end and sides by bulkheads. Each tank is vented to its engine crankcase and provided with fittings for immersion heaters at the inboard and outboard ends as well as at the oil filler-well screen. The conventional aircraft oil tank is generally constructed with the hopper located centrally. The subject oil tank hopper is located at the inboard wall of the oil tank. This prevents making use of a sufficient amount of the hopper wall area considered necessary to warm up the surrounding oil in the tank during extreme low temperature conditions.

a. Tests were performed on the C-69 airplane in the same manner as on the various other Army Air Forces aircraft at Ladd Field during the winter of 1944-45. The dilution and boil-off results are included in Appendix IV. As shown in Appendix IV, diluting for 11 minutes produces only 17% dilution. From an evaluation of this set of curves, it is concluded that 6 minutes (10% dilution) is the maximum practical operational limit of dilution for anticipated cold starts (+10°F.) and that in addition, the application of heat is necessary for starting at temperatures below 10°F.

b. In general, the ability of an oil tank hopper to segregate the oil in the circulating system from that in the tank surrounding the hopper is shown by analysis of samples taken from various sections of the oil tank. This would indicate whether a tank design change or changing the diluent flow rate would be necessary for the improvement of the dilution system. Since oil tank samples could not be obtained, this portion of the problem remains unsolved.

c. To determine if the R-3350-35A engine could satisfactorily handle 30% prediluted grade 1100 oil, the oil system of engine No. 1 was completely drained and refilled with 20% prediluted grade 1100 oil. Take-off was accomplished as soon as practicable with no reduction in power on engine No. 1 for five minutes after take-off. Engines Nos. 2, 3 and 4 were operated in the normal manner. No spewing or excessive oil loss occurred through the engine breathers. The test was repeated with 30% prediluted grade 1100 oil with similar successful results. From this, it can be concluded that 30% prediluted grade 1100 oil can be successfully handled at high powers by the R-3350-35A engine installation. The data for these runs are shown in Appendix II.

d. Flight tests were conducted at temperatures down to —45°F. to secure data on the warm-up and operational characteristics of the oil tank. Readings were taken during 6 flights and plotted in graphs, Appendix IV. It can be seen from valves of point No. 18, which is located at the outboard end of the oil tank, that there are indications of the possibility of oil congealing occurring at extreme low temperatures. As previously stated, this tank is not of the conventional design and it is therefore recommended that further tests be accomplished at temperatures down to —65°F. to obtain additional information on the characteristics of this type of oil tank.

Test Stand Cold Starts on a V-1650-7 Engine Equipped with a Speed Density Pump

Prepared by: J. W. Whittle, Power Plant Laboratory

A. PURPOSE

1. To determine the cold starting characteristics of a V-1650-7 engine equipped with a speed density pump.

B. FACTUAL DATA

1. Appendix I—Discussion.

2. Appendix II—Test Data.

3. Appendix III—Airplane cold starting and crankability record.

C. CONCLUSIONS

1. The cold starting characteristics of the peed-density pump are satisfactory.

2. Cold starts with the present fuels are dependent upon the effectiveness of the engines' priming system.

3. Engine roughness encountered in a cold start and during the following warm-up period could damage the engine or installation.

D. RECOMMENDATIONS

1. It is recommended that the starting characteristics of the speed-density pump be considered equivalent to the standard carburetors.

Appendix I

INTRODUCTION:

1. The following is considered to be a few of the determining factors which pertain to effecting a cold start on other than fuel injection engines.

a. On engines equipped with an ignition boost system, cranking speed is not a critical item.

(1) One of the purposes and the result of satisfactory oil dilution is to effect a cold weather cranking torque which is equivalent to the cranking torques encountered under summer conditions. See Appendix III "Airplane Cold Starting and Crankability Record" prepared by Mr. Wm. Weitzen, Pvt. R. G. Dunn and Lt. S. Barron.

(2) It is understood that the Navy uses 30 RPM as a minimum design value. Engine starts can and are being made under summer conditions at approximately 8 RPM; this is being done on the test stands in making starts for torsional vibration runs and on the flight line in the ships of two and three hundred horsepower which are not equipped with starters.

b. The order of the importance of the priming system, fuel metering system, and manifold system depends on the volatility characteristics of the fuel.

(1) In the case of a fuel which volatilizes readily at the temperature under condition, the fuel metering (carburetor) system is of major importance; thus, the need for a priming and manifold system which aids fuel volatilization decreases.

(2) In the case of a fuel which has poor volatility characteristic for the temperature being investigated, the priming system is of major importance followed by a manifold design which affords a maximum amount of liquid or wetted area.

TEST PROCEDURE:

A. AIRPLANES.

1 Flight line cold weather starting technique on any given airplane will vary in procedure between the different crews. However, it is general practice that if the engine is too stiff to pull the propeller through (indicating insufficient oil dilution) or if some of the cylinders do not fire during the first few attempted starts (indicating insufficient volatilization of the fuel), the ground heating equipment is utilized. Any radical deviations from this general procedure may result in damaged accessores, scoured cylinder walls, or cylinder hydraulic lock. This damage or possible failure cannot be risked on an engine which is installed in an airplane.

B. TEST STANDS.

1. On the test stand, in order to obtain comparative data, it was necessary to develop and standardize on a test procedure that would be suitable for any temperature which may have been encountered. A series of starting tests showed that where heat was not used, better results were obtained, with the longer priming periods. The cold starting procedure developed for the subject engine consisted of:

a. Pulling the propeller through two revolutions.

b. Priming for a minute.

c. Priming and cranking for a minute.

d. Repeating the minute of priming followed by a minute of priming and cranking until a start was effected.

2. The engine was equipped with the standard V-1650-7 starter, ignition system, and priming system. A speed-density pump was installed in place of the Bendix Stromberg carburetor and a 4 blade 7 foot diam. test club was used for absorbing the power. Electrical power was supplied by the conventional 24 volt airplane ground energizing unit wired in parallel with the stands 24 volt system which consisted of two heavy duty 12 volt batteries hooked in series. A G-9 fuel pump with a relief valve setting of fifteen pounds was used for maintaining priming pressure. The entire engine coolant system was located in the test cell and subjected to the existing free air temperature, while the after-cooler coolant heat exchanger and oil system was located in the operator's room which was held at 50 or 60°F.

TEST RESULTS:

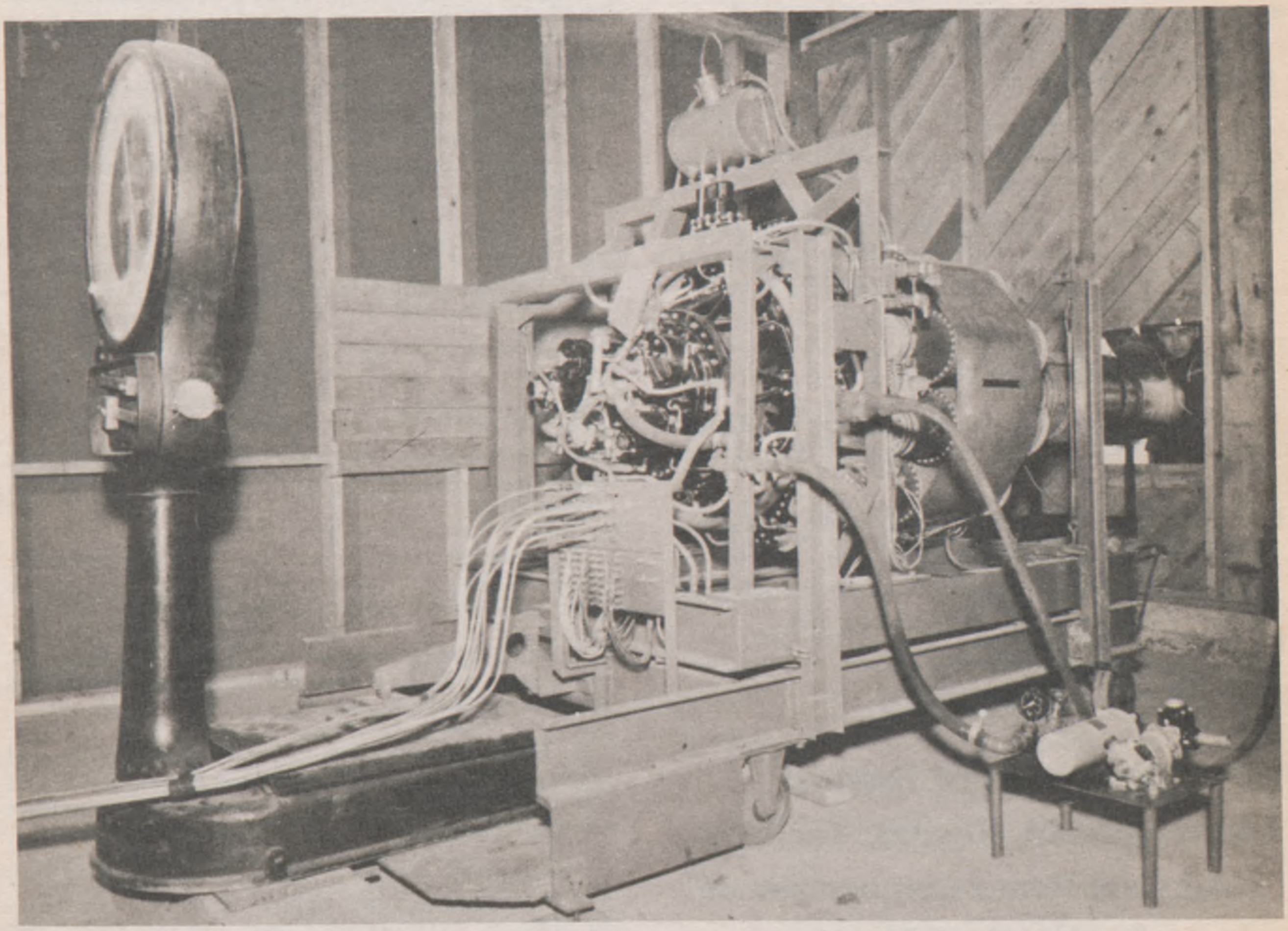
1. Appendix II is a record of four starts made under the coldest temperatures which were encountered during the test season. The engine temperature for tests 1, 2 and 4 were approximately —22°F. The engine temperatures for test No. 3 were near —18°F.

2. Minus 22 degrees Fahrenheit is believed to be the minimum temperature at which the Packard engine can be started on Grade 130 fuel. These starts and warm-up periods in tests 1 and 2 can only be accomplished through use of the primer system. The excessive primer warm-up periods are also characteristic of cold starts on the carburetor equipped V-1650- engines. It is believed that excessive primer warm-up periods are due to the necessity of warming the coolant in the after-cooler before satisfactory fuel vaporization and carburetor operation is possible. Starts under these conditions result in extreme engine roughness and are not desirable for safe airplane operation. On the basis of this information, it is estimated that cold starts using grade 130 fuel could be satisfactorily accomplished at an engine temperature of —15°F without endangering the engine.

3. Tests three and four were made with fuel RAF-V-44 No. 24. These starts using a more volatile fuel and not requiring a primer warm-up period, indicate that the cold starting characteristics of the speed-density pump are satisfactory.

Ladd Field Cold Weather Engine Test Stands

Prepared by: *Joseph W. Whittle, Power Plant Laboratory*



Jet engine test stand

A. PURPOSE

1. To discuss the development and the testing facilities of the Ladd Field Engine Test Stands.

B. FACTUAL DATA

1. Appendix I is a discussion covering the history, development, testing facilities, and a cold room comparison of the subject stands.

2. Appendix II contains the following correspondence which covers in detail the progress made on the stands during the test season of 1944-45.

a. Exhibit A—Letter to Major W. Woodard, dated 9 November 1944.

b. Exhibit B—Excerpt from Power Plant Progress Report No. 2, dated 21 December 1944.

c. Exhibit C—Excerpt from Power Plant Progress Report No. 3, dated 13 January 1945.

d. Exhibit D—Excerpt from Power Plant Progress Report No. 6, dated 7 March 1945.

e. Exhibit E—Letter to Major W. Woodard, dated 16 March 1945.

f. Exhibit F—Excerpt from Power Plant Progress Report No. 7, dated 30 March 1945.

3. Appendix III contains drawings showing the present and proposed modifications of the stands and instrumentation.

C. CONCLUSIONS

1. The summer of 1945's proposed instrumentation, modification, and completion of test cells one through four will provide facilities for the cold weather sea level or altitude calibration or endurance testing of 3000 HP air-cooled aircraft engines.

2. The stands are the only cold weather engine test stands in the United States or Territory of Alaska.

3. The stands are the only test house where sufficient refrigeration is available to be able to conduct cold weather calibration or endurance tests of any duration on conventional aircraft engines.

4. Engine tests that are being run in cold rooms can be conducted at a much lower cost without too much inconvenience due to weather variations.

5. The stands are the only test house where sufficient refrigeration is available to conduct cold weather calibrations on jet-propulsion units.

6. After this year, the stands and engines with a limited number of personnel will be available during the summer months for conducting the standard types of calibration or endurance tests.

D. RECOMMENDATIONS

1. It is recommended that cells numbers one through four be finished and instrumented as tenatively approved and proposed.

2. That the completion and modification of the four cells be completed by August 1945.

3. That the test programs and engines for the season of 1945-46 be available by 15 September 1945.

Appendix I

Discussion of History, Development, Testing Facilities and Cold Room Comparison of Engine Test Stands

INTRODUCTION

1. The subject building is known as the Cold Weather Testing Test House, building number 338, and is located at Ladd Field, Alaska.

2. This six-cell test stand is jointly operated during the winter months by the Cold Weather Testing Detachment of the Army Air Forces and the Power Plant Laboratory of the Engineering Division of Wright Field.

3. The responsible officer in charge of this project is 1st Lieutenant S. Barron of the Cold Weather Testing Detachment of the Army Air Forces.

4. The building is supplied and maintained by the Cold Weather Testing Detachment of the Army Air Forces. The instrumentation of the stands and the test engines are furnished by the Power Plant Laboratory of the Engineering Division of Wright Field. During the test season, October 15 to March 15, the personnel required to operate the stands are jointly supplied by the two organizations, while during the summer months, the stands are maintained by personnel of the Cold Weather Testing detachment.

HISTORY

1. The building was originally designed for the block testing of overhauled engines. Construction, the erection of the concrete walls, was started the summer of 1942, after which the demand for an engine overhaul stand was eliminated; this resulted in the project's being discontinued.

2. During the winter test season of 1943-44, the need for a cold weather engine test stand was recognized; plans were made to utilize two Jacobson Engine Block Test units in conjunction with the partially finished test house.

3. In February of 1944 the project was assigned to 1st Lieutenant S. Barron. At the end of that year's test season, drawings for the completion of the test house were started; these drawings were completed in July of 1944.

DEVELOPMENT

1. Construction, completion of the partially finished engine block test building, was started the latter part of August 1944.

2. Drawings numbers one and two, Appendix III, show the plan and elevation views of the stands at the start of the winter season, November 1944.

3. The major portion of the work done during the test season of 1944-45 consisted of the development and the proving of the test stands.

4. The details covering the development of the test house and the adapting of a Jacobson Engine Block Test unit to the building are described in the correspondence and photographs which are included as Appendix II.

5. The stands are the first of their kind; that is, they are the only cold weather engine test stands in the United States or Territory of Alaska. For this reason and because the original building was designed for engine overhaul block testing, it was necessary to make and test numerous modifications of the building and methods of installation of the test equipment.

This work or development of a satisfactory cold weather engine test stand is not considered complete by any means, but the experience gained during this last test season is being applied to the completion of cells 3 and 4 and the necessary modification of cells 1 and 2.

6. The modifications of the test house and the methods of installing the test equipment, all of which will be incorporated into cells 1 through 4 during the summer of 1945, are shown in drawings one through seven. These modifications provide for the following items:

a. Provisions for obtaining proper air flow into the propeller. This is necessary in order to be able to maintain a constant engine rpm and even cooling of air cooled engines.

b. Provisions for utilizing the maximum amount of propeller clearance that can be made available without making major changes to the building. This will facilitate the use of airplane flight propellers that are required for engine calibrations on a torque stand.

c. Provisions for a test cell exhaust system which provides for a minimum amount of back pressure, behind the propeller. This will increase the horsepower capacity of the cells by eliminating the re-circulation of air and exhaust gases through the propeller. Erratic recirculation would cause rpm fluctuations and possibly uneven cooling in the case of air cooled engines.

d. Provisions for streamlining and obtaining a minimum number of obstructions to the airflow directly behind the propeller. A nearby unstreamlined obstruction can cause excessive propeller stresses and/or engine rpm fluctuations.

e. Provisions for the use of a maximum amount of overhead plumbing in the operator's rooms. This will go a long ways towards the elimination of the freezing and the failure of steam and water pipes and valves.

f. Provisions for obtaining efficient lighting of the stands. This is an important item, inasmuch as half of the test running has and will be done at night.

g. Provisions for the most efficient utilization of the building's heating facilities. Small modifications will make additional heated working space available.

7. These drawings one through seven have not been checked or officially approved. Upon their completion they will be submitted to the Commanding Officer of the Cold Weather Testing Detachment, who has tentatively approved them, and to the Commanding Officer of the Resident Engineers of Ladd Field. It is believed that only minor changes will be made in these drawings and plans for the work to be accomplished during the summer of 1945.

8. In making plans for the completion of cells 3 and 4 it was necessary to give some thought to the possible completion of cells 5 and 6 and to their utilization for the test season of 1945-46.

In order to facilitate the making of these plans and in order to eliminate the possibility of making an installation in or a modification to cells 5 and 6 whch would have to be removed if the test cells were to be completely utilized for engine tests at a later date, drawings numbers seven and eight were made. The only purpose of these two drawings is to provide tentative plans for the entire completion of the test house in the event that the project warrants final completion at a later date. At the present, neither the equipment nor the personnel for the operation of six cells are available.

Plans for the test season of 1945-46 will utilize cell number 5 and operator's room number 3 for a jet engine installation, which is very portable, while cell number 6 and the adjoining space will be used as a temporary office and storage room.

9. In addition to the previously mentioned drawings, the following plans are being made for more complete instrumentation of the stands and engines:

a. Ducting and equipment for measuring engine air consumption and simulating altitude induction pressures.

b. Incorporating mercury switches and an electric stop watch on the fuel scales to provide for a more accurate means of determining fuel consumptions.

c. The use of more mercury monometers or providing sensitive manifold pressure gages to be used for measuring carburetor drops and deck pressures.

d. The use of torque-meters on all radial engines.

e. The complete thermocoupling of all test engines.

f. The development of an accurate means of measuring cranking torques.

g. The development of a reliable rpm counter for use on cold starts.

h. Provisions for controlling engine fuel flow by the use of needle valve throttling on the carburetors where this is possible and by the use of special reworked mixture control plates on the other types of carburetors.

i. Providing special re-worked flight propellers for the larger engines.

j. Providing thermocouple wire and potentiometers.

k. Providing radial engines with cowl shutters to control cylinder temperatures.

TESTING FACILITIES:

1. Upon completing the planned instrumentation and modification of the stands, facilities will be available for conducting the following types of tests on engines of 3000 horsepower and less:

a. Cold starts.
b. Distribution and fuel volatility tests.
c. Fuel metering tests.
d. Oil dilution and crankability investigations.
e. Spark plug fouling tests.
f. Fuel consumption.
g. Oil consumption.
h. Air consumption.

2. These tests and the various engine variables which are involved may, with the exception of altitude exhausting, be controlled and investigated under either sea level or simulated altitude conditions.

3. The significance of these facilities is not realized until it is pointed out that during the months of December, January and February of 1944-45 there was a total of 166 hours of temperatures below a —20°F. and that this season was supposedly the mildest winter Fairbanks had had in twenty years. This temperature is equivalent to a standard altitude temperature of 22,000 feet; that is, sufficient refrigeration and time were available to conduct a complete altitude calibration or endurance test on any engine.

4. In addition to the cold weather winter test programs, the stands and engines, after this year's modifications, will be available for any summer months with a limited number of personnel for the conducting of any type of calibration or endurance test.

COLD ROOM COMPARISON:

1. Cold rooms are ideal for investigating cold starts, crankability, and oil dilution characteristics of aircraft and engines but are not practicable in the case of calibration or endurance testing of aircraft engines.

2. The liquid cooled engines are best adapted to cold room calibration and endurance testing. Endurance testing does not require accurate power measurements; during this type of test, satisfactory power compliances are maintained through the use of the speed, manifold pressure, and carburetor air temperature relationship. In the case of calibration work where accurate power

measurements are required, it is necessary to use a dynamometer for absorbing and measuring the power developed; to date, a satisfactory torque meter has not been developed for the in-line engines.

3. The refrigeration required to obtain —20°F. operating conditions for a liquid cooled engine is an appreciable amount. Using average operating conditions, the following rough heat balance can be made:

Using an F/A ratio of .075,
Using a BSFC of .55 #/BHP-HR,
Using a 2000 BHP engine,
Using a thermal efficiency of 35%,
Using a heating valve of 21,400 BTU/#
Amount of air consumed = 14,600 #/hr.
Amount of fuel consumed = 1100 #/hr.

a. Refrigeration required to remove the heat from the air consumed by the engine assuming a specific heat of .2 and a temperature drop from a +50°F. to a —20°F. is

Approximately 22,500 BTU /Hr.
or 2 tons of refrigeration.

b. Refrigeration required to handle the radiation losses of the engine assuming the coolant and oil heat exchangers are located outside of the cold room and that the exhaust gases are also discharged outside of the cold room would be

Brake thermal efficiency	= 26%
Heat rejected to coolant	= 30%
Heat rejected to oil	= 4%
Heat rejected to exhaust	= 38%
Radiation Losses	= 2%

With this extreme temperature differential the radiation losses would be high, probably 2%.

Required refrigeration to handle radiation losses would be

Approximately
(.35) (1100) (21,400) (0.02) = 165,000 BTU/Hr.
or 13 tons of refrigeration.

4. The foregoing assumptions result in an estimated refrigeration capacity of 15 tons required to operate a 2000 BHP liquid cooled engine in a cold room at —22°F. In the case of an air-cooled engine using a propeller to absorb the power and which did not exhaust outside of the cold room, the refrigeration required would be approximately equal to the thermal efficiency of the engine for a 2000 HP engine; this would be approximately 515 tons.

TEST WORK COMPLETED ON THE STANDS DURING THE SEASON OF 1944-45:

1. Two engines were run, a V-1650-7 and an R-1830-65. Thirty hours of testing were conducted on the V-1650-7 engine, while 50 hours of operation were obtained on the R-1830-65.

2. Details of the type of tests conducted are discussed in Exhibit F of Appendix II.

3. Analysis and discussion of the test results will be available at a later date in a final report entitled, "Ladd Field Test Stand Results."

Fuel Volatility Flight Test Program

Prepared by: W. J. Rusnack, Capt. A. C. Power Plant Laboratory

A. PURPOSE:

1. To report on a conference held at Wright Field with representatives of aircraft engine manufacturers, aviation fuel industries, and the military services in regard to fuel volatility flight test work accomplished at Ladd Field, Alaska.

B. FACTUAL DATA:

1. A conference on fuel volatility flight test work was held in the Power Plant Laboratory, Wright Field, 28 March 1945 and was attended by the following:

R. T. Agster Phillips Petroleum Company
E. V. Albert Transcontinental and Western Air, Inc.
Carl Blakely Pratt and Whitney Aircraft Division
G. A. Bleyle Wright Aeronautical Corporation
E. A. Droegemueller Pratt and Whitney Aircraft Division
J. O. Eisinger Standard Oil Company of Indiana
R. E. Ellis Standard Oil Development Company
Sam Gibbons Wright Aeronautical Corporation
C. O. Henneman Phillips Petroleum Company
R. D. Kelly United Airlines
L. A. McReynolds Phillips Petroleum Company
R. A. Walker Transcontinental and Western Air, Inc.
Eric Bloomfield, Lt., U.S.N.R. Bureau of Aeronautics
M. K. McLeod, Captain, A.C. Air Technical Service Command
W. J. Rusnack, Captain, A.C. Air Technical Service Command
R. E. Klein, 2nd Lt., A.C. Air Technical Service Command
A. Hundere Air Technical Service Command

2. The fuel volatility flight test program is being conducted at Ladd Field, Alaska, by Phillips Petroleum Company on C-49K airplane and Transcontinental and Western Air, Inc., on C-46 airplane under Contracts W-33-038-ac-6628 and W-535-ac-35716, Special Service Order No. 3, Fiscal Year 1945, respectively.

3. A summary of the data presented at the conference appears in Appendix A.

4. The test engineers from Transcontinental and Western Air, Inc., and Phillips Petroleum Company were recalled from Ladd Field to review the work accomplished on the airplanes so that definite plans could be made to most efficiently utilize the remainder of the test time at Ladd Field.

5. General discussion of the problem of volatility and the specific troubles encountered by the C-49K and C-46 airplanes took place, which led to the general opinion that one of the main factors affecting cold temperature operation is the ability of the engine to distribute fuel evenly.

6. The problem of evaluating the effect of fuel volatility was discussed, but it was agreed that final conclusions and interpretation of results could not be justified until a complete analysis of all the test data was made. For further discussion of results see Appendix B.

7. After considerable discussion it was decided to continue the program as originally set forth and pay particular attention to special groups of fuels. An outline of this program is given in Appendix "C".

C. CONCLUSIONS:

1. Operation of the C-49K airplane is satisfactory on the heaviest of the test fuels down to —21°F. at maximum power cruise conditions, and down to —6°F. at maximum economy cruise power.

2. Operation of the C-46 airplane is satisfactory on the heaviest fuel down to 0°F. at approximately maximum economy cruise power.

3. Operation of the C-49K on V-7 fuel, which has a volatility approximately equal to AN-F-28 fuel, was satisfactory down to —2°F., which was the lowest temperature at which it was run. Based on operation of the heaviest fuels, it would appear to be satisfactory down to approximately —40°F.

4. Operation of C-46 airplane on V-7 fuel with a volatility approximately equal to AN-F-28 fuel is satisfactory down to +2°F at which point engine misfire was obtained at approximately maximum economy cruise power.

5. Fuel volatility can cause improper engine operation at low carburetor air temperatures. The minimum carburetor air temperature at which normal operation can be obtained on any given fuel at any given engine speed is primarily determined by the induction system design.

6. In order to obtain a valid analysis of the test data accurate determinations of the ASTM distillations of the test fuels should be made.

D. RECOMMENDATIONS

1. It is recommended that fuel volatility flight test program be completed under conditions outlined in Appendix "C", and that resulting data be analyzed with the object of establishing a correlation between fuel characteristics and actual engine performance.

2. It is recommended further that the Coordinating Research Council be requested to have its Aviation Fuels Division Exchange Group determine the ASTM distillation curves of the test fuels.

Hamilton Standard Propeller Feathering Tests

Prepared by: *J. F. Schmidt, Capt., A. C. Propeller Laboratory*

A. PURPOSE

1. The purpose of the subject test is threefold and consists of the following:

a. To test the special hydraulic fluid feathering system and determine its operating limits;

b. To compare the feathering operation of the hydraulic fluid feathering system to the present standard bleed back feathering system;

c. To investigate and determine any other means or installations that will possibly facilitate the feathering operation at low temperatures.

B. FACTUAL DATA

1. A description of feathering systems that were installed and tested on the various airplanes is available in Appendix I. A complete record of all flights conducted and the test data obtained, along with paragraphs, are included in Appendix II; these data are arranged in separate tables for each airplane. The flight data are arranged in chronological order.

2. The following is a brief summary of the test results obtained on each airplane during the test period:

a. B-29, Serial No. 42-65214.

(1) At minus 22° F. all the feathering systems operated satisfactorily on the subject aircraft.

(2) At minus 45°F. premature button operation was encountered on the hydraulic fluid systems used in conjunction with 1100 engine oil; this condition was also encountered on the standard systems using synthetic engine oil but not as frequently. It was noted at this temperature all propellers still fully feathered even though the feathering buttons had to be bumped to accomplish the operation.

(3) At temperatures between minus 45°F. to minus 58°F. the hydraulic fluid systems used in conjunction with 1100 engine oil encountered difficulty. The distributor valve would shift during the feathering operation. This was undoubtedly caused by heavy and/or congealed 1100 engine oil on the outboard side of the

dome piston. The standard system using synthetic engine oil still allowed the propeller to be fully feathered even though the feathering button had to be bumped several times during the operation. The standard system incorporated with the Pesco 777 pump and utilizing synthetic engine oil still operated normally at the lowest temperatures enountered (See Appendix II, Table I—graph). It was noted that this system required more time to operate; however, the operation was slow but steady at all temperatures encountered.

(4) The synthetic oil has made it possible to feather at extreme temperatures, and where other systems failed, beacuse it did not congeal and remain sufficiently fluid to be forced out of the dome gradually during the feathering operation.

b. B-24J, Serial No. 44-41378.

(1) The hydraulic fluid feathering system used in conjunction with the synthetic engine oil operated satisfactorily at all temperatures encountered and was a little faster than the standard systems used with synthetic engine oil. It may be said, however, that all four feathering systems were satisfactory down to minus 45°F.

(2) The standard 1100 engine oil was then used in all four engines. It was noted that at minus 45°F. none of the systems were satisfactory. The hydraulic feathering system would not feather the propeller due to congealed 1100 oil in the propeller dome. Likewise, the standard systems were sluggish and only in one case did the propeller feather and that required considerable manipulation of the feathering button and required 23 seconds to accomplish the feathering operation. The distributor valve shifted with all other propellers and the results were unsatisfactory (see Appendix II, Table 2, baragraph).

(3) It is noted that synthetic oil is a merit and makes it possible to feather propellers at low temperatures since it does not tend to congeal.

c. B-17G, Serial No. 43-38221.

(1) The hydraulic fluid feathering system used in conjunction with regular 1100 engine oil operated satisfactorily down to minus 45°F. At temperatures between minus 45 to minus 55°F., the operation is questionable and requires much manipulation of the feathering button and occasionally the distributor valve shifts to the unfeathering position. At temperatures below minus 55°F. and down to minus 65°F., the subject system used with 1100 engine oil is definitely unsatisfactory.

(2) The standard feathering systems used with synthetic oil were found to be operable at extreme low temperatures although the operating times are longer than normal. The feathering operation may be described as steady but somewhat slow from minus 45 to minus 65°F.

(3) A new type pump (IE-521 EC) was installed on Engine No. 1 and operated with synthetic engine oil. It operated satisfactorily; however, it could not be relied upon. On several occasions this system using the new pump would reduce the rpm but then the rpm would gradually increase and in this way establish a wandering condition. Actually, more testing is necessary before this particular type pump is stated as satisfactory or unsatisfactory. At present, however, it is not considered an improvement in the feathering operation on this aircraft. (See Appendix II, Table 3, baragraph).

(4) It is to be noted that the greatest improvement in propeller feathering is contributed to the synthetic oil which did not congeal at extreme low temperatures and made it possible to feather the propeller.

d. C-47A, Serial No. 43-48088.

(1) The hydraulic fluid system used in conjunction with 1100 engine oil was considered to give satis-

Sludge deposited in propeller dome from synthetic engine oil

factory operation at the temperatures encountered. The lowest temperature was minus 49°F. On one occasion, (minus 33°F.) the propeller could not be fully feathered; this was apparently due to stiff or thick 1100 engine oil in the propeller dome.

(2) The standard system used with synthetic engine oil showed that it was possible to feather fully the propeller at temperatures down to minus 52°F. On several occasions the propeller could not be feathered and it appeared as though the pump was starved or possibly airlocked. It was later noted that the feathering pump had a ¼ inch air bleed line connected to the high pressure side of the pump relief valve. It is believed that this bleed line was a source of leakage when the feathering pump operated and thus caused the several unsuccessful feathering operations encountered.

(3) A new type Pesco, IE-521-EC pump was installed on the standard system. This pump was tested in several different ways to determine its operating abilities.

(*a*) It was first tried in conjunction with standard 1100 engine oil. This test showed that excessive trials were required to feather the propeller at comparatively moderate temperatures (minus 31°F.).

(*b*) In the second test the previously mentioned air bleed line was connected between the intake side of the subject pump and the main engine oil "in" line. This line served to bleed air from the system and to furnish some oil to the pump when the feathering reserve oil becomes thick. The test showed that the system was improved but still rather sluggish at minus 40 degrees.

(*c*) The third test was made by changing from the 1100 engine oil to the synthetic engine oil. This proved satisfactory at the temperatures encountered; however, in one instance the new type pump showed very slow and indifferent operation even though the temperature was reasonably high (plus 12°F.).

(4) It is noted that the synthetic engine oil tends to assist the feathering operation. The new type pump IE-521-EC is not considered satisfactory until the slow or indifferent operation can be eliminated.

(5) At the beginning of the test period, electrical difficulty was encountered. The generator fuses were blown out during the feathering operations. This

difficulty is presented in a separate report, listed in Appendix III, References.

e. C-54B, Serial No. 43-17157.

(1) The hydraulic fluid system used in conjunction with 1100 engine oil is considered satisfactory down to minus 45°F. Feathering operation below this temperature is definitely handicapped because of thick and/or congealed oil in the propeller dome. Operations below minus 45°F. are definitely unsatisfactory.

(2) The standard feathering system on this aircraft may be considered satisfactory down to minus 40°F. Temperatures below this cause questionable operation and may be considered wholly unsatisfactory below minus 45°F.

(3) It is obvious from the test data on this aircraft that hydraulic fluid is not the "cure" for low temperature feathering operation when used in conjunction with 1100 engine oil.

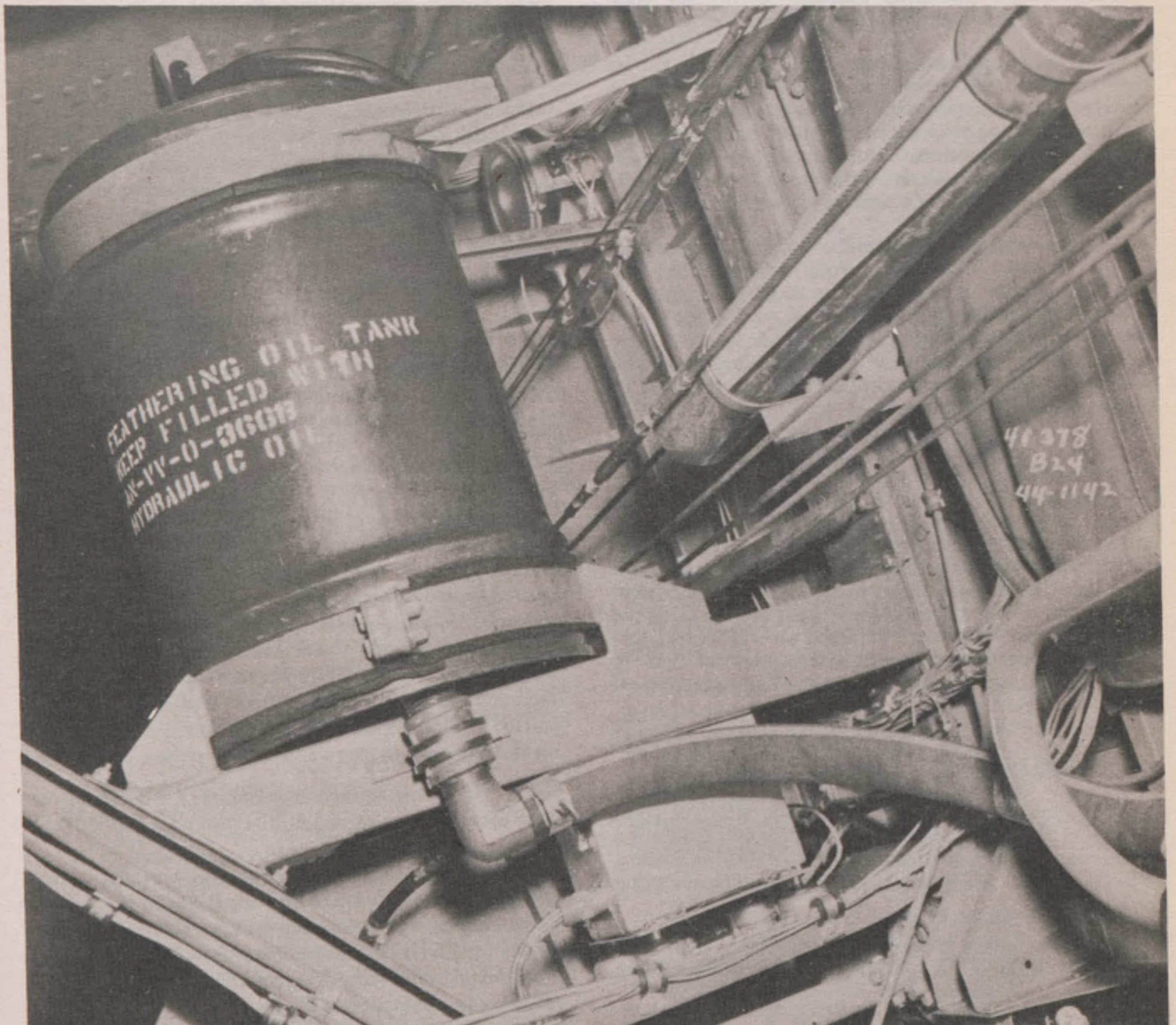
f. A-26B.

This aircraft was not tested at extreme low temperatures since it was not equipped with oxygen facilities. The systems, both hydraulic and standard, were satisfactory at the temperatures encountered, which were considered moderate. The electrical loads were checked during the feathering operations and were not found to be excessive on the two engined aircraft. (See Appendix IV, References).

g. C-47, ATC Aircraft.

Considerable sludge was found in the dome and piston assemblies of several aircraft propellers. This condition was more noticeable on engines operating with synthetic oil. A report was submited on the 5th of December 1944 entitled, "Hamilton Standard Propeller Sludge Conditions".

5. The new type Pesco feathering pump, model E-777 operated satisfactorily although it appeared to require more time to complete the feathering operation than the standard Pesco 301 pump. The E-777 pump shows pos-



Hydraulic propeller feathering tank mounted in bomb bay of B-24 airplane sibilities when used with synthetic engine oil or possibly with some lighter oil.

6. The Pesco pump, model IE-521-EC gave questionable operation and was not considered a merit to the feathering operations. Further investigation is necessary to determine its possibilities.

7. It is concluded that more careful inspections and cleaning operations should be conducted on the Hamilton Standard Propeller dome and piston assemblies during each 100-hour aircraft inspection. This is definitely a necessity in arctic regions of operation to avoid excessive amounts of hard sludge in the propeller dome assemblies in that this condition causes feathering malfunction.

D. RECOMMENDATIONS

The recommendations stated below have been derived from the flight tests and observations concerning the arctic propeller feathering program during the cold weather test period of 1944-45 in Alaska.

1. It is recommended that synthetic engine oil be used in all multi-engined aircraft for arctic operation whether in conjunction with the separate hydraulic fluid feathering system or the standard bleed back feathering system, as this synthetic oil facilitates and assists the propeller feathering operation due to its lack of congealing in the propeller dome and hub assemblies.

2. If the above recommendations should be approved by the Propeller Laboratory, Power Plant Laboratory and the Materials Laboratory, it is furthur recommended that the propeller dome and piston assembly be cleaned during each 100-hour aircraft inspection, in accordance with existing T.O. No. AN-03-20CC-1 to prevent the formation of sludge in the dome, or oftener if excessive sludge deposits are encountered.

3. It is recommended that the new type Pesco pump model E-777 be further service tested to determine its possible merits.

4. It is recommended that on the C-47A aircraft, the feathering pump intake line be relocated at the main oil tank end. The new location should be made at the bottom of the main oil tank beneath the hopper and utilizing the modified sump with increased stand pipe. This was recommended after the cold weather test period of 1943-44 and if this change has been incorporated, the above need not be heeded.

C. CONCLUSIONS

The following conclusions were made after the completion of the arctic feathering test program conducted during the cold weather test period of 1944-45 in Alaska. The conclusions are based on low temperature operation only:

1. The standard bleed back feathering system used with 1100 engine oil is not satisfactory at temperatures below minus 40 degrees F.

2. The separate hydraulic fluid feathering system, whether centralized or independent, when used in conjunction with 1100 engine oil, is only satisfactory down to minus 45°F. The feathering operation tends to be limited by the viscosity of the 1100 engine oil in the propeller dome and hub assembly which congeals when soaked at minus 45°F. or at lower temperature. This conclusion is based on low temperature operation only and emphasizes the problem of heavy or congealed 1100 engine oil in the propeller hub and dome assemblies at extreme low temperatures.

3. The standard bleed back feathering system, when used in conjunction with synthetic engine oil (Spec. PPO-265) is considered satisfactory down to minus 65°F. The feathering operation below minus 45°F. is generally slower than normal; however, the feathering operation is complete since the synthetic oil still flows under the subject operating conditions. The viscosity of the synthetic oil at low "operating" temperatures is not excessive and this oil can be forced out of the dome during the feathering operation.

4. The separate hydraulic fluid feathering system, when used in conjunction with synthetic engine oil, is considered satisfactory down to minus 65°F. At temperatures below minus 45°F. the time required to feather was greater than normal; however, the feathering cycle could be completed. The nature of the synthetic oil at extreme low "operating" temperatures is such that it cannot be "rushed" but insists on a gradual flow regardless of the fluid medium used in the feathering pump. On this basis the separate hydraulic fluid feathering system, although satisfactory, is not deemed necessary for arctic operation since the feathering operation can be accomplished with the standard bleed back system when used in conjunction with the synthetic engine oil. In the event, due to factors not considered in this report, that the separate hydraulic fluid feathering system is used as a standard installation on production aircraft the synthetic engine oil should be used in the engines for arctic operation.

5. When the engine oil system (bleed back feathering system) is used it is recommended that dilution lines be installed in the intake line to the feathering pump as close as possible to the main oil tank sump. This should be accomplished when the bleed back feathering system is used with 1100 engine oil or synthetic engine oil. By thorough dilution of the feathering line, the oil will not tend to congeal in the line when the aircraft remains outside under extreme low temperature conditions. This will facilitate rapid bleed back operation when the engine is started before flight. This installation is recommended on all multi-engine aircraft operating in the arctic regions.

6. The following recommendations are listed for possible consideration regarding the propeller feather problem:

a. The hot air propeller deicing installation now being tested may be utilized to keep the propeller hub and dome reasonably warm and prevent the congealing of regular engine oil at low temperatures. If this were possible the propeller icing problem and the feathering problem may be eliminated with one system.

b. Another possible way of eliminating the feathering problem may be to use reverse cams in the dome piston, thus moving the piston away from the congealed mass of oil when feathering, instead of the present condition where this mass must be forced out to fully feather.

Final Report on the Aeroproducts A532FX6 Propeller

Prepared by: Hoyt B. Graham, Jr., 1st Lt., A. C. Propeller Laboratory

A. PURPOSE

1. To service test the A532FX6 propeller and study maintenance difficulties.
2. To test various oils and greases and determine the minimum temperature at which each would operate satisfactorily.

B. FACTUAL DATA

1. Number of hours to date on installation—200. Mechanical troubles encountered:

a. Weak spring in ball check valve.

In three feathering valves there were one heavy spring and two light springs. To date only one of the latter is known to have failed. First, when the propeller accumulator failed to charge, it was found that the ball had slipped through the inside of the spring. This spring was repaired and re-installed. During a later disassembly it was found that four turns of the spring on the end next to the ball had compressed it beyond its elastic limit.

b. Nitrogen leakage.

At first the accumulator always lost some nitrogen when the accumulator was on the ship and sometimes leaked when the accumulator was in the shop. After the last installation (5 March) no nitrogren leakage was observed. Leakage was attributed to three things:

(1) Nitrogren filler valve—the original valve assembly was not winterized. To be specific, a brass seat in the valve cap is not satisfactory. It should be synthetic rubber.

(2) Etching of accumulator.

Etching occurred wherever an "o-ring" seal (AN-6227-46) made contact with bare steel. For more details see paragraphs 6(c), 6 (d), and 23(b) of reference 2 and also pictures in reference 3. The Materials Laboratory of Wright Field will conduct further investigation of the seals used and determine if the seals were at fault.

(3) Normal operation of accumulator.

During the feathering cycle some nitrogen seemed to leak past the piston seal.

c. Oil and grease leakage.

The two seals (AN6230-23) on the outside of the accumulator practically always leaked. It was very difficult to install the accumulator and it was by chance if these two seals were not damaged. It was noted that even if the seals were not damaged, propeller oil was usually found in the hub. See reference 4, paragraph 5(g).

d. Difficulty in tripping feathering valve.

This was encountered only when the propeller was stationary, as was the case on the ground or when unfeathering in flight. This condition was made worse by the control installation but the root of the trouble was in the propeller itself. To try to correct the trouble, leaves were removed from the trigger spring on the feathering valve but no appreciable difference was noted between three leaves and one leaf installations.

e. Loosening of Regulator Nut.

In two instances the regulator nut worked loose while in service. A two-foot bar and heavy hammer were used to tighten the nut but neither the bar nor hammer was necessary to remove the nut during disassembly.

f. Propeller overspeeding when unfeathering.

On several occasions the propeller was completely out of control at 2700 to 3000 rpm, sometimes momentarily and once for 20 to 30 seconds at 2900 rpm. The take-off setting for this installation was 2500 rpm. The governor was thought to be the trouble but careful inspection failed to support that theory. To date the cause is still not known. For details on overspeeding, see reference 2, paragraph 5(a), and reference 4, paragraphs, 3(b), 6(c), and 6(d).

g. Windmilling.

At the beginning of the test season it was noticed that in feathering, the propeller would sometimes start to feather normally, windmill at 100 to 200 rpm, stop suddenly, and then back up part of a revolution. At the end of the test season when the spare propeller was installed, this same condition was again encountered. No satisfactory explanation is known.

h. Feathering twice on one accumulator charge.

Several attempts were made on a flight (14 March) to feather, unfeather, and feather again immediately. The idea was to conserve oil in the accumulator by using the governor down to about 400 rmp. The experiment was partly successful but was hardly practicable even for practice feathering. See reference 4, paragraph 11.

i. When the feathering valve failed, it was found that the propeller could be feathered by means of the pump and governor. If the engine power was kept on and the mixture not cut off until the rpm was around 400 or 500 rpm, the propeller could be feathered in about 50 seconds. Without power—that is, cutting off the throttle and mixture and then reducing the rpm—the time required was doubled and sometimes the propeller would not feather at all but windmilled at 100 rpm.

2. DATA ON OPERATION:

a. Ordinarily the propeller feathered in 2.5 to 5 seconds. As the low temperature limit for any oil was approached, the time went to about 8 or 9 seconds. When an oil got too stiff, the time jumped up to 75 to 120 seconds, if it feathered at all. Mechanical malfunctions would, of course, affect the feathering time but only a few readings were obtained between 15 and 75 seconds. Since there were practically no "in-between" readings, it was not difficult to determine if an oil was satisfactory or not.

b. Data on oils and greases:

(1) ANG-4 and ANO3L—satisfactory down to minus 25°C. (—13°F.)

(2) ANG4 and ANO6a—satisfactory down to minus 45°C. (—49°F.)

(3) ANG4 and AN-VVO-366a—ground checks indicated that this combination would operate at a lower temperature than oils previously used. Due to mechanical trouble with the propeller, flight checks proved nothing. See ANG3 and AN-VVO-366a. Also see reference 2, paragraph 22 and reference 4, paragraph 3.

(4) ANG3 and AN-VVO-366a—the minimum temperature for this combination is not known but it operated satisfactorily down to minus 57°C. (—70°F.) See reference 4, paragraphs 6 and 9 for detailed data.

C. CONCLUSIONS

1. During the 1944-45 Cold Weather Test season, the following conclusions were reached regarding the operation of the A532FX6 propeller when the proper oil was used:

a. Governing action was faster and more sensitive than other standard installations.

b. Feathering operation was faster than other standard installations.

c. The propeller was a self-contained unit and did not depend on the rest of the airplane for oil supply or electrical power.

d. Installation, removal, and repairs on the propellers were simplified. Only two special wrenches were required.

e. Operation of the feathering system did not prove dependable because of:

(1) Windmilling at 100 to 200 rpm when feathering;

(2) Overspeeding when unfeathering;

(3) Accumulator leakage. This was chiefly oil leakage and occurred during operation of propeller in flight.

f. The FX6 had the disadvantage that two minutes time was necessary for charging the accumulator. See reference 4 paragraph 11. In case of emergency, the propeller could not be feathered if one feathering cycle had just been completed.

2. Conclusions reached concerning oils and greases:

a. No conclusion was reached as to the relative merits of ANG3 and ANG4.

b. AN-VVO-366a operated satisfactorily between plus 32°F. and minus 70°F.

c. AN-03L operated satisfactorily between plus 32°F. and minus 13°F.

d. AN-06a operated satisfactorily between plus 32°F. and minus 49°F.

D. RECOMMENDATIONS

1. The Propeller Laborattory should make further service tests on later model Aeroproducts feathering propellers with emphasis on solving problems of:

a. Seal leagage;
b. Overspeeding when unfeathering;
c. Windmilling when feathering;
d. Difficulty in tripping feathering valve.

2. In future tests, more positive propeller control linkage should be used.

3. The accumulator should be charged so that at the coldest temperature anticipated in flight there would be a minimum nitrogen pressure of 400 psi (400 psi at minus 65°F. would be about 450 psi at 0° and 480 psi at plus 60°F.)

4. Oils to be used:
a. Above 0°F. use ANO3L;
b. Below 0°F. use AN-VVO-366a or AN-VVO-366b.

Report on the Curtiss Electric Propeller Equipment

Prepared by: J. F. Schmidt, Capt., A. C. Propeller Laboratory

A. PURPOSE

1. To conduct a service test with special Curtiss propeller installations on the subject airplanes, recording any malfunctions or equipment failures.

B. FACTUAL DATA

1. Summary of tests on P-38L aircraft, serial No. 44-24050.

a. The special propeller installations on the subject airplane were completed on or about 23 September 1944. The hours of operation, at this time, were 16 hours and 40 minutes. The airplane arrived at Ladd Field, Alaska, on 2 December 1944 and had accumulated 46 hours and 15 minutes of operation. On 1 March 1945 the tests on the ship were considered completed and the operating time was 157 hours and 17 minutes. The special installations concerning the propellers will remain on the airplane until it is delivered to Wright Field, at which time the service test iaems will be removed and forwarded to the Curtiss Propeller Plant for inspection.

b. A complete description of all propeller installations on the aircraft is furnished in Appendix I, Table I.

c. The maintenance required on this airplane throughout the test season is discussed and listed chronologically in Appendix 2, Table I.

d. The propeller controls, utilizing the Teleflex "push pull" control installation did not require any special maintenance on this aircraft during the test period. Several loads are shown at various temperatures in Appendix III, Table I.

2. Summary of tests on P-61B aircraft, Serial No. 42-39402.

a. The special propeller installations were accomplished at Vandalia, Ohio, and at this time the airplane had 29 hours of operation. The aircraft was then returned to the plant for further installation at which time the Simmonds Aerocessories propeller control was installed on Engine No. 1. The airplane arrived at Ladd Field, Alaska, on 7 December 1944 and had acquired 60 hours of operation. On 23 February 1945 the tests were closed-out on this aircraft due to a crash. The total time of operation on this ship was 120 hours and 45 minutes. The service test equipment on the aircraft will not be available for inspection.

b. A complete description of all propeller installations on this ship are shown in Appendix I, Table 2.

c. The maintenance required on the subject aircraft during the test period is included chronologically in Appendix II, Table 2. It is worth noting that the major portion of maintenance was due to grease leakage from the propeller blade nut seals.

d. A comparison of the Simmonds propeller control and the standard pulley-cable installation is shown in Appendix III, Table 2. This type of Simmonds control with the 180 degree radian head required no maintenance whatsoever during this test season.

C. CONCLUSIONS

1. It is concluded that the following equipment and lubricants gave satisfactory operation on the P-38L and the P-61B aircraft during the test period of 1944-45:

a. Governor Installations.

The two types of governors, namely, the standard governor with the stainless steel rack and pinion and the lubricated cap type governor gave satisfactory operation.

b. Lubricants

(1) The ANG-3 and ANG-4 greases were satisfactory and did not interfere with the operation of the propellers.

(2) The ANO4 oil and the AN-VVO-366 hydraulic fluid contributed to the satisfactory operation of the speed reducer units.

c. Relief Fittings

The grease relief fittings were satisfactory and did not show any signs of "grease throwing" from operation.

d. Seals

The shaft nut seal and shaft seal gave efficient sealing throughout all operations.

e. Electrical Modifications

The moulded connector plugs and the straight through brush block terminal connections did not fail or cause any difficulties.

f. Propeller Controls

(1) The Teleflex push pull controls installed between the firewall and governor operated satisfactorily on the P-38L, and are considered comparable to the standard pulley and cable type controls.

(2) The Simmonds Aerocessories push-pull controls are considered superior to the standard pulley cable type of control on the P-61B aircraft.

2. It is concluded that the following seal installations are not considered satisfactory:

a. The blade nut seals used on the P-61B propeller assemblies showed definite indication of grease leakage during operation at temperatures below minus 40°F.

b. The blade nut seals and the blade shank seals used on the P-38L propeller assemblies are questionable since some grease leakage was experienced. The blade shank seal is considered to be the most probable source of leakage.

c. The speed reducer spline and housing seals on the P-38L showed signs of wear after approximately 100 hours of operation. This is not necessarily a cold weather problem; however, these seals should be improved before used as standard part installations.

3. The above conclusions are based on the operation of the subject installations and equipment during the cold weather test period.

D. RECOMMENDATIONS

1. The following are the recommendations concerning the special propeller installations on the P-38L and the P-61B aircraft:

a. The stainless steel rack and pinion should be further tested and possibly incorporated as a standard governor part. The lubricated cap type governor, although satisfactory, does not merit change since this involves a change in the governor body and in the long run accomplishes the same result as the stainless steel parts mentioned above.

b. The ANG-3 grease should be continued as the hub lubricant, since it is a standardized low temperature grease in frequent use on aircraft.

c. The speed reducer lubricant, namely ANO4 oil, is satisfactory and should be used. It is worthwhile noting at this point, however, that the Materials Laboratory is considering ANO6a oil as a superior low temperature oil with improved lubricating qualities.

d. The speed reducer grease relief fitting is recommended as a standard part.

e. The shaft nut seal and shaft seal are recommended as satisfactory for cold weather operation.

f. Continued service tests should be conducted on the moulded connector plugs and straight through type brush block terminal connections.

g. The Teleflex control should be further service tested at extreme temperatures and an improved method of anchoring the conduit to the swivel connection is recommended. (For more details on this control see Report on Teleflex Operation and Maintenance during Cold Weather Test Period of 1944-45.)

h. The Simmonds Aerocessories control is recommended for use on the P-61B and later models of this aircraft.

i. The blade nut seals and blade shank seals should be improved and more extreme temperatures tests conducted. The grease leakage problem still exists at low temperatures.

Cold Weather Tests on Teleflex Controls

Prepared by: H. B. Graham, Jr., 1st Lt., A. C. Propeller Laboratory

A. PURPOSE

1. To test Teleflex propeller control installations on the P-38L and B-17G under cold weather operations.

2. To test the effect of temperature and compare two different lubricants in two identical Teleflex controls mounted in a panel. Pictures in Appendix III.

B. FACTUAL DATA

1. P-38L, AAF Serial No. 44-24050.

a. Hours on installation at time of report—136.

b. Maximum loads to operate controls—12-lb. average at —43°C (—45°F) after soaking all night. For complete data see Appendix I.

c. Maintenance troubles—At 100-hour inspection (86 hours on Teleflex) found conduit had slipped part way out of split nut in swivel coupling, at forward end of left engine installation. Also found chaffing between conduit and support clamps. See pictures Appendix III.

2. B-17G, AAF Serial No. 43-38221.

a. Hours on installation at time of report—175.

b. Loads encountered—Varied irregardless of temperature. Minimum: 6 lb., maximum; about 30 lb. See Appendix II.

c. Maintenance troubles—Mainly ends of conduit slipping out of split nut. See Appendix II.

3. Teleflex test set-up on panel:

a. Length of test: 12-5-44 to 2-21-45.

b. Specimen No. 1 lubricated with Aero Mobilgrease LO-H1 PD 535A, (Spec. ANG3). Complete data and charts in Appendix III. With a five pound weight on one end it took about 12¼-lb. shot on the other end to operate the control. The load for the first try each morning was very little different from the daily average for three other tries. The load curve was practically flat down to —35°C (—31°F). Below that temperature it showed signs of increasing. Lowest temperature observed was —40°F.

c. Specimen No. 2 was lubricated with Standard Oil Company of Indiana SG-4455, also manufactured in accordance with Spec. ANG3. No. 2 had the same general characteristics as No. 1. It took slightly more load to operate (about 14¼ lbs. on the flat part of the curve). Temperature variations had more effect on this control than on No. 1.

C. CONCLUSIONS

1. P-38L:

a. Operation—satisfactory, but no improvement over standard system.

b. Installation—probably lighter in weight. Should be considerably easier to install under factory set-up.

c. Maintenance and safety—method of fastening ends of conduit is definitely unsatisfactory.

2. B-17G:

a. Operation—unsatisfactory.

b. Installation—Should be easier in production.

c. Maintenance and safety—method of fastening ends of conduit unsatisfactory and not safe. See Appendix II for chronological record of troubles encountered.

3. Test Panel No. 2 was harder to operate, especially at low temperatures.

D. RECOMMENDATIONS

1. Use AN-742 "cushion" type clamp for conduit support.

2. Flare ends of conduit so that clamp nut can get positive grip on conduit.

3. On future tests install Teleflex 100% and not in connection with other experimental equipment, as with the propeller on the B-17.

4. Obtain spare parts and keep them with the ship.

5. Regarding test panel—switch lubricants to see if differences noted were due to lubricants or to the controls.

6. Future tests with other than actual aircraft installations should be made under controlled atmospheric conditions.

Cold Weather Tests on Eclipse Electric Governor Control Heads

Prepared by: J. F. Schmidt, Capt., A. C. Propeller Laboratory

A. PURPOSE

1. During the winter of 1944-45 it was desired to:

a. Check the operation of the electric governor control heads on standard aircraft installations.

b. Check the operation of subject heads on ground "mock-up" installations at various temperatures.

c. Record any service difficulties encountered on B-29's and B-24's using this equipment.

B. FACTUAL DATA

1. Electric head-test information obtained from four different aircraft; namely

B-24J, Serial No. 44-41378 (See Appendix I, Table I)

B-24J, Serial No. 42-51660 (See Appendix I, Table II)

B-29, Serial No. 42-24612 (See Appendix I, Table III)

B-29, Serial No. 42-65214 (See Appendix I, Table IV)

a. The test data as shown in the Appendix shows that in most cases the operating time tends to increase as the temperature decreases. There are exceptions, but these are usually due to part failures in the unit.

b. In one instance, on the B-29 (214), when the heads soaked at temperatures below -40°F., two of the electric heads became inoperative; however, after heat was applied, they were normal. This is the most critical example encountered throughout the winter.

c. The following information was obtained on the No. 3 electric head of the B-29.

(1) At -14°F. it required 12.9 seconds to operate from Inc. to Dec. RPM position.

(2) At -45°F. it stuck and would not operate until heat was applied.

(3) This is by no means general but is a specific case showing the *effect* of temperature on operation in this particular incident.

d. It may also be noted from the test data in the Appendix that operating times on four electric heads installed on one aircraft tend to vary. This necessitates setting the RPM on each control separately.

2. Electric head test data obtained from the ground "mock-up" installations can be observed under the Appendix; namely:

Head Serial No. B.A. 5338, Appendix II, Table V

Head Serial No. B.A. 17992, Appendix III, Table VI

Head Serial No. A.F. 43-34351, Appendix IV, Table VII

Head Serial No. A.F. 43-34353, Appendix V, Table VIII

a. The electric head and governor assemblies were mounted on a test board and set outside for the winter test. A switch and indicator light were used in the electrical circuit. The operating time was obtained by a stop watch. The power was furnished by a Waukesha power unit and the operating voltage was maintained at 28 volts. The procedure was to turn on the switch, starting from the Inc. RPM position, and start the stop watch. When the indicator light went on, showing that the electric head had reached full low RPM position, the watch was stopped and the time recorded. A series of these readings were recorded throughout the test season.

b. It is interesting to note that the subject heads were operated daily and no malfunction, mechanically speaking, was encountered. On the other hand, electric heads installed on aircraft encountered numerous failures. This tends to show that electric head failures are in practically all cases due to the engine vibration and not due to the unit itself.

c. The operating times tend to increase as the temperatures decrease, and in one case, the time required was above the maximum limit of 20 seconds. The soaking periods were generally 24 hours.

d. The following tabulation is set up to show the operating times against decrease in ground temperatures after soaking for at least 24 hours at temperatures from +30°F. to that indicated. The times recorded on this sheet are the first readings after the soaking period.

	Time Required From Inc. to Dec. RPM Position On			
Temp. °F.	Head Nn. 1	Head No. 2	Head No. 4	Head No. 3
+36	11.4	13.4	......	......
+32	12.5	13.1	......	13.9
+30	......	12.5	13.9	13.8
+28	......	14.2	14.3	13.7
+23	......	14.6	......	13.3
+22	......	15.5	15.3	15.5
+21	12.2	15.7	......	......
+17	......	......	13.7	13.8
+16	......	15.8	14.3	13.8
+14	11.6	......	14.2	13.7
+10	12.4	16.0	14.9	14.0
+ 9	......	......	14.8	14.0
+ 8	......	19.3	......	......
+ 7	......	......	14.5	13.9
+ 3	12.5	18.6	......	......
+ 2	......	......	14.5	14.0
+ 1	......	17.9	......	......
0	......	19.0	......	13.9
— 1	12.1	......	......	......
— 4	12.8	21.1	......	......
— 5	......	......	......	......
— 6	......	19.1	16.5	14.5
— 8	......	20.0	......	......
—10	12.8	22.4	......	......
—11	......	23.7	......	......
—12	13.8	23.1	......	......
—13	......	......	......	......
—22	......	......	......	......
—23	......	17.2	15.8	14.7
—31	......	14.4	14.1	14.0
—33	......	12.6	13.7	13.8

The above values are averages obtained at the various indicated temperatures.

3. Service difficulties encountered on electric control heads during the test season:

a. The failures experienced were numerous and in most instances were either due to resitors, resistor clips, and/or open armatures.

b. In Appendix III of this report, reference is made to service reports which were forwarded to the laboratory during the test season.

C. CONCLUSIONS

1. The electrical control head operation is considered satisfactory at temperatures as low as -40°F.

2. No conclusions have been reached on the operation of subject control heads at temperatures below -40°F. and as low as -65°F. since sufficient data is not available.

3. From the maintenance standpoint, the electric head controls are unsatisfactory since the part failures are entirely too numerous.

4. These conclusions are based on tests, observations, and maintenance problems experienced during the cold-weather test period of 1944-45.

D. RECOMMENDATIONS

1. In order to reduce the maintenance problems on electric head controls, it is recommended that:

a. The resistor and resistor clip be eliminated from the assembly.

b. The armatures be more thoroughly inspected for "opens" before assembly at the plant.

2. More tests be conducted at temperatures below -40°F. and down to -65°F. to determine effects on operating characteristics.

Report on the Electric Anti-Icing Generators Installed on the C-54B

Prepared by: J.F.Schmidt, Capt., A.C., Propeller Laboratory

1. The purpose of this report is to present the Laboratory with the problems encountered on the subject anti-icing equipment.

2. The problems and difficulties encountered up to 15 February 1945 were included in the previous progress report dated 23 February 1945. It is now desired to present the problems which were experienced since then.

3. On 23 February 1945, the cracked shield was removed from the No. 3 Generator, Serial No. D-35 and a new one installed. The spare generators were received on the previous day. The reinforcement ring was also installed with the new armature shield in order to prevent the new shield from being cracked at the bolt holes. (The accumulated operating time on the generator was 239 hours and 55 minutes.)

4. On 27 February 1945 the generators on No. 1 and No. 2 engines were again checked:

a. Prop No. 1. Generator Serial No. D-46, the following was noted:

(1) The lead between the fire wall and the field cannon plug showed a short circuit condition. It was found that the wire had worn and was grounding out through the metal conduct. This lead was removed and repaired.

(2) One armature cannon plug had failed. The prongs in the male portion of the plugs were broken off. This was replaced with a new cannon plug.

b. Prop No. 2, Generator Serial No. D-45, the following was noted:

(1) During runup the indicator warning light blinked and the prop generator was thoroughly inspected. It was found that the field ground connection had failed. This was a soldered connection and apparently vibration caused the failure. The break was repaired and the propeller generator then worked satisfactorily.

5. On the 4th of March, 1945, the operating time on the generators was 244 hours and 35 minutes. It was reported that the warning indicator lights on No. 1, 2, and 4 were blinking during operation. An inspection was conducted and the following was noted:

a. Prop No. 1, Generator Serial No. D-46.

(1) The armature showed on "open" in one plug. The solder connection at the receptacle was broken.

(2) The lead connecting the blade element to the armature showed a break or open.

b. Prop No. 2, Generator Serial No. D-45.

The generator checked out satisfactorily according to the continuity meter. The indicator warning light, however, still blinked when the engine was operating and the deicer switch was turned on. There was probably an open which only shows up when the engine is operating.

c. Prop No. 3, Generator Serial No. D-35.

The generator checked out satisfactorily.

d. Prop No. 4, Serial No. D-30.

One armature plug showed an open. The soldered connection at the receptacle was broken.

6. At this time, the aircraft was scheduled to leave this field and the deicers could not be repaired. The elements on these propellers were coated with some anti-icing compound No. 314 as a temporary means of ice protection. When the ship returns to this post again, it is planned to remove the electrical deicers and install the standard alcohol system.

7. The service test conducted on the subject installation during the OUT period of 1944-45 indicates that the electric generator deicers are not satisfactory from the maintenance standpoint. It is the opinion of this detachment that the generators should be more carefully manufactured and rigid inspections should be stressed on the final assembly stage.

8. It was noted that the resistance of the blade elements have remained approximately the same through the entire test period. The resistance of the elements ranges from 4.5 ohms to 5.0 ohms on all elements installed.

9. No actual icing tests have been conducted on the subject equipment during this test period, however, the problem of maintaining these units is evident.

Service Tests of Experimental Oil and Coolant Hose Installed with Aeroseal Type Clamps

Prepared by: *T. F. Brick, 1st Lt., A. C. Materials Laboratory*

A. PURPOSE

1. To determine the performance characteristics of experimental fuel, oil and coolant hose at extreme low temperatures.

B. FACTUAL DATA

1. Due to difficulties encountered on premature failures of fuel, oil and coolant hose line connections in cold weather, winterization service tests were conducted on numerous aircraft at Ladd Field, Fairbanks, Alaska, during January and February, 1945. Data were collected on various manufacturer's experimental hose to determine bulging and hardening properties, leakage periods and loss of clamp torque with relationship to "cold flow". Numerous cold starts were attempted in an effort to record the ability of the hose to withstand high surge pressure incident without bursting or blowing from the connection. Additional tests were conducted on methods of hose installation to facilitate ease of application at low temperatures.

2. Previous data accumulated in laboratory tests and Unsatisfactory Reports received by Air Technical Service Command show the above deficiencies are encountered at temperature limits below 20°F.

3. The discussion under Appendix I outlines the completed service tests.

4. Torque data of all hose tested on fuel, oil and coolant lines, together with the type aircraft used are graphically presented in Appendix II, Figures 1 to 8.

5. Photographic presentation of various installations may be found in Appendix III, Figures 1 to 11.

6. Photographic evidence of abnormal "cold flow" in specification coolant hose is shown in Appendix IV, Figure 1.

7. Temperature data for the period January and February, 1945, are found in Appendix V, Figures 1 and 2.

C. CONCLUSIONS

1. All test hose used on the oil lines, with the exception of S-1, S-2 and H-3, which leaked, adequately survived the service test.

2. All test hose used on the oil lines will perform satisfactorily at extreme low temperatures.

3. All test hose used on coolant lines with the exception of R-80, 3-braid, which leaked prior to twenty-five (25) hours of engine time and which leaked excessively at —43°F., is satisfactory for use in extreme low temperatures.

4. All test hose performs more satisfactorily than specification hose inasmuch as less clamp torquing is required and little or no leakage is observed.

5. Adhesion of braided construction to the tube should be improved on coverless hose.

6. "Cold flow" is still a factor with which to contend, although it is less severe on test hose than on specification hose.

7. All hose hardens considerably at temperatures below 20°F.

8. Improper methods of installation and excessive clamp torque can be a contributing factor toward premature failure of hose.

D. RECOMMENDATIONS

1. The Materials Laboratory (TSEAL-4) will take the following action:

a. Continue service testing experimental hose with the objective toward obtaining a satisfactory all purpose hose to serve in the fuel, oil and coolant lines of Army Air Forces aircraft.

b. Acquaint all interested rubber companiees with the problems covered by this and previous reports so that additional laboratory work may be continued on the methods of best eliminating the "cold flow" and fraying characteristics of coverless type hose.

Appendix I

Service test installations were made on fuel, oil and coolant lines of Cold Weather Testing Detachment and Extreme Temperature Operations Unit aircraft based at Ladd Field, Fairbanks, Alaska. The types of hose used are as follows:

a. Goodyear R-8	Cotton braid, neoprene tube and cover
b. Goodyear R-5	Rayon braid, neoprene tube and cover
c. Goodyear R-50	Rayon braid, neoprene tube, no cover
d. Goodyear R-80	2 and 3 cotton braids, neoprene tube, no cover

e. Goodrich H-40	Rayon braid, buna tube, no cover
f. Goodrich H-30	Cotton braid, buna tube, no cover
g. Goodrich H-30N	Cotton braid, buna tube and cover
h. Goodrich H-4	Rayon braid, buna tube and cover
i. Goodrich H-3	Cotton braid, buna tube and cover
j. Hewitt T-4	Rayon braid, neoprene tube and cover
k. Goodyear R-1	Specification AN-ZZ-H-456-A, Cotton braid, buna N tube and cover
l. U. S. Rubber Co.	S-1 and S-2, Specification AN-H-26, cotton braid and neoprene tub and cover.

All aeroseal type hose clamps were torqued to values indicated in graphs with a "Skyway Torque Control Wrench", which is designed to tighten to a specific amount and then cut out. Wrenches of twenty-five (25) and twenty (20) inch pounds were used during the testing period. The correct procedure for clamp torque was considered important, as many hose failures can be traced to improper determination of clamp torque values due to the fact that wrenches of the above mentioned type have not been provided—a condition since rectified by the issuance of Technical Order 04-1-17, dated 25 January 1945.

In previous service tests it had been the policy to retorque clamps after each flight, but during the winterization tests it was decided to apply no additional torque on clamps until leakage occurred or the aircraft were grounded due to engine change, experimental installations affecting the coolant and oil systems or inspection periods.

Clamp torque losses on experimental hose were checked weekly by means of a special recording wrench. Daily inspections were made each morning before preflighting for leakage, excessive hardening or any malfunctioning of hose which would interfere with effective operation of the aircraft.

Graphic explanation in Appendix II reveals torque loss values of clamps and their relationship to "cold flow" in the hose.

Extreme caution was exercised during the installation of test hose in order that no kinking, stretching or excessive bending was allowed to take place. Maintenance personnel were cautioned that all hose was to be cut to the required length and under no circumstances were clamps to be installed over the beaded nipples. A condition such as this was noted on one (1) P-51 aircraft where double hose clamps had been used on a 2-½" coolant line. Hose clamps were positioned to insure proper relationship between the band and the hose, the band and the head and the wings of the tightening screw so that a maximum of space was provided for use of the special recording torque wrench to evaluate "cold flow" loss in the hose.

Numerous methods to facilitate hose application over the nipples were used. It was found that all hose could be applied readily by using a lubricant of oil. However, it is believed that this method creates a problem inasmuch as maintenance personnel may be prone to use oil as an aid to installation on self sealing hose. Again, it is felt that an oil lubricant may at some time cause a slipping action to take place between the tube and the nipple and during a cold start or semi-cold start act as the impetus in allowing a connection to blow loose.

Outer covering cracked on aromatic resistant oil hose

The method of pre-insertion before actual installation was found to be the most satisfactory. Various sizes of nipples were inserted in a vise, and cut lengths of hose were forced over the nipples a number of times. This expanded the hose and actual installation was accomplished with a minimum of effort and without the use of lubricants. By the use of this method it was observed that a mechanic's hands were free from oil and the branding identification of the hose was not obliterated or rubbed off by constant reworking.

All hose became extremely hard at temperatures of 20°F. All test hose had been stored in Stout houses exposed to climatic conditions, so that it was necessary to warm each piece over a blower for twenty (20) minutes before it was flexible enough for installation purposes. Hose stored in coils in localities such as this becomes brittle at temperatures below zero. In attempting to straighten the coils it was found that the braided and rubber covers cracked, thereby rendering the hose useless.

Throughout the testing season much experimentation was done in the cold starting of engines. Actual normal starts without the use of pre-heating were accomplished on Extreme Temperature Operations Unit B-25 and P-51 aircraft at outside air temperature down to —10°F. with adequate oil dilution. In no case were experimental oil hose lines burst or blown from their connections during these operations.

A semi-cold start was made on Extreme Temperature Operations Unit B-25 at —55°F. after one (1) hour of heat from a small heater. No deficiencies or malfunctioning of test hose lines was noted on engine start or after eight (8) hours of flying time.

A successful cold start at —12°F. was made on Extreme Temperature Operations Unit P-63 using grade 130 fuel. However, when the aircraft was started two (2) hours later, oil was observed leaking from the Young-Houde cooler. It could not be determined whether the malfunction was due to a faulty cooler or failure of the surge valve to relieve pressure within the cooler. Previous failures of surge valves in P-39 and P-63 aircraft have been a cause of premature oil hose failures and, assuming that the above condition may have been in the surge valve, it is well to note that no failures occurred on H-40 and R-80 hose as a connection on the "oil in" and "oil out" lines to the surge valve.

Experimental oil hose installed on B-29 and B-24 aircraft has performed successfully during the testing period.

Experimental fuel hose installed on B-25 aircraft performed satisfactorily in that little "cold flow" was noted. However, the majority of hose was tested in fuel vent lines where little or no pressure is experienced.

A considerable amount of trouble has been encountered at Ladd Field on leaking coolant lines in P-51 aircraft.

This condition is not only critical during cold weather but may be found on extremely mild days. Leakage in coolant hose is usually noted the morning following the previous day's flight after the aircraft is allowed to stand overnight on the flight line. Only experimental test hose of the types H-30, H-30N, R-80, 2 braid and R-80, 3 braid, were used in the coolant systems of the aircraft. Installations were made at those places where coolant temperatures were thought to be severe. With the exception of leakage being observed on R-80, 3 braid hose at different times, all hose performed adequately.

Clamp torque losses were extreme at all times. R-80 3 braid hose leaked excessively at a temperature of —43°F. The leak was stopped by retorquing both clamps to twenty-five (25) inch pounds.

During the three (3) days of sub zero temperatures, specification hose was closely watched. Leakage was observed in these lines every morning. Clamp torque was found to read less than two (2) inch pounds. In a number of cases, raising the clamp torque to twenty-five (25) inch pounds failed to retard the flow of coolant. It was necessary to use a wrench to tighten the clamps, causing excessive strain on the hose and in a number of cases compressing the outer rubber cover through to the fabric.

Many man hours as well as flying time were lost in removing the cowling to find these leaks. Leakage in inaccessible localities caused the aircraft to be grounded and their removal from the flight line to the hangars.

At inspection periods, clamps were loosened from the experimental hose and examination made for "cold flow". Little was noted on the cover but further examination of the tube revealed "cold flow" to be prevalent thus accounting for clamp torque loss. No bulging of the hose was observed at any time, although all hose with the exception of H-3ON had frayed on the ends. All test hose on the coolant lines had hardened considerably, although H-3ON hose was found to appear softer than the others. The latter statement is one of conjecture as the "finger feel" method was used. Until such time as a durometer reading can be taken on hardness, it is believed advisable to make no decisions on the qualities of hose in this respect.

No trouble was encountered on any oil lines in P-51 aircraft. It is believed all test hose will give adequate service.

Lubrication of Aircraft Control Systems

Prepared by: S. C. Britton, Major, A. C. Materials Laboratory

A. PURPOSE

1. To determine low temperature limit of practical operation of control systems of current production aircraft available for test and determine the effect, if any, the lubricant used in the systems has on this limit.

B. FACTUAL DATA

1. Cold weather tests made during the two preceding winters have indicated that airplane surface control systems generally would become critically stiff when temperatures dropped below —40°F. to —50°F. Last winter's tests indicated that further improvement in the low temperature torque value of the AN-G-3 grease used would not materially lower this low temperature operating limit. In this winter's test program on control systems it was planned to determine whether any improvement had been made in any of the systems, obtain more extensive data on control systems of airplane models previously tested, and obtained data on airplanes not previously tested.

2. An experimental lithium base grease (Texas TG-455) having approximately one-fourth the average low temperature (—67°F.) torque of Standard AN-G-3 greases was used to relubricate completely several control systems in order to check again the effect of this variable on control stiffness at low temperatures (Note *b*, Table I.)

3. Table I summaries the data obtained at various temperatures on forces necessary to move surface controls on the ground after standing overnight. Figure I gives a graphical summary of these data on the larger airplanes tested. The extremely low tempratures desired for test (below —50°F.) were encountered on but a few of the airplanes. However, the following observations can be made:

a. In several instances remarkable check results (considering the roughness of the methods used) were obtained between different airplanes of the same model. However, in a few cases there was a wide variation noted, particularly in B-24 trim tabs and B-29 main rudders.

b. Trim tabs were generally more critical at low temperatures than main controls.

c. Considerable difference exists in the control forces required by different models of airplanes, even in the same class. Fighter aircraft are generally much better as to control stiffness at low temperatures than heavier models.

d. In a number of systems the force necessary to work the control sharply increased around —40°F., for example, B-17G aileron trim tabs, B-24J main elevators, B-29 main elevators and rudders, and all C-46A trim tabs. It is believed that such a sharp break is the result of factors other than the lubricant. In other cases, such as the B-17G rudders, the increase was more gradual. It is believed that this indicated the effect of gradual stiffening of the grease with decrease in temperature.

e. Where the experimental grease was used to lubricate controls, no significant improvement in control forces was noted at the lowest temperatures encountered.

f. The most critical control systems below —40°F. appeared to be the following:

(1) B-17 aileron trim tab;
(2) B-24J main elevators and rudders;
(3) All B-24J trim tabs;
(4) B-24J control locks;
(5) B-29 main elevator and rudder;
(6) B-29 aileron and rudder trim tabs;
(7) C-46A, all trim tabs.

g. The P-61 aileron, which was quite critical at low temperatures on last year's tests, was found to be quite satisfactory at low temperatures on the model (P-61B) tested this year. This improvement appeared to be due to the change in spoiler hinge bearing design which was changed form grease lubricated bronze bushings to oilite bearings. Ball bearing supports might be even better.

4. Data on P-63 controls are given in Table II. In this case readings were taken on a number of lend-lease airplanes as well as the one assigned to Extreme Temperature Operations Unit. It will be noted that all surface controls of this model airplane were entirely satisfactory down to the lowest temperature encountered. This was a marked improvement over the P-39Q airplanes tested last year.

5. Measurement of control stiffness on the ground presents only a part of the information required to evaluate control performance at low temperatures. Data must also be obtained during actual flight at low air temperatures, after taking off at comparatively low temperatures. Accordingly, the project officer-pilots of Extreme Temperature Operations Unit airplanes were asked to give their opinions of control performance of their airplanes in flight. This information is summarized in Table III. It will be noted that most systems were satisfactory in flight at lower temperatures than were available for test on the ground. On the other hand, a number of the controls found to be stiff on the ground were critical in the air. Those included B-17 aileron trim tabs and B-29 aileron and rudder trim tabs.

6. The P-59A elevator trim tab system was found to be completely inoperative in flight at temperatures below —40°F. In order to localize the stiffness, if possible, elements of the control system were gradually taken out of operation until free operation was obtained. Removal of the final actuator did not help, but after removal of the vertical chain drive in the tail, free operation was obtained at —55°F. After replacement of the chain and removal of the flexible drive shaft, a flight was made and again the control was stiff, indicating that the final chain drive is critical. Further work is being accomplished as of the date of this report.

7. C-46A trim tabs were again found to be critical below —45°F. and would become completely inoperative between —50°F. and —55°F. The final actuator of the rudder trim tab of one airplane (No. 42-96803) was relubricated with TG-455, but very little, if any, improvement was noted. However, at a ground temperature of —49°F. when all trim tabs of both airplanes were inoperative, heat was applied to the final actuator only, and the tabs quickly became free.

8. No complaints have been reported with respect to wing flap operation except in the case of B-29 No. 42-65214. Trouble was first noted on 12 February. Ground temperature was —20°F. (with previous 12 hour low of —35°F.) After flying about 20 minutes at 1500 ft. at —24°F. the flaps were lowered for a landing but could not be actuated more than 25 degrees. Trouble was again experienced on a later landing the same day and the flap motor failed. The following morning at —45°F. actuation was tried with the emergency motor and the flaps were found to be completely inoperative. After replacing the main flap motor and applying heat to the rear bombay, satisfactory operation could still not be obtained (ground temperature approximately —25°F.). After applying heat to the flap actuating screws for 30 minutes, the flaps were actuated, down in 17 seconds. However, during the 12, 13 and 14 February, when temperatures ranged between —20°F. to —45°F., B-29 No. 42-24768 operated with no difficulties being reported due to flap operation. It was reported that No. 42-65214 was manufactured by Glenn L. Martin Co., Omaha plant and No. 42-24768 by Boeing Aircraft at Seattle. No information was available as to lubricants applied at the two plants.

C. CONCLUSIONS

1. The surface control systems of Army Air Forces airplanes as now designed and lubricated will be operable down to approximately —40°F. Some systems, such as noted in paragraph 3(f) of Factual Data will become critical between —40°F. and —50°F., but a great many airplanes appear to be satisfactory at —50°F. and below.

2. It is indicated that the controlling factors limiting satisfactory operation of aircraft surface controls at low temperatures are those relating to mechanical design, airplane manufacturing procedures and inspection rather than the low temperature properties of the lubricant used (AN-G-3). In view of high temperature difficulties recently reported, further lowering of the torque requirements of Specification AN-G-3 does not appear to be advisable at this time.

3. Improvement can be made in the performance of controls, using present lubricants as indicated by the improvement made in P-63 and P-61 controls.

4 Improvement can be made in C-46 trim tab operation by improving the performance of the final actuator.

5 Improvement can be made in C-46 trim tab operation by improving the performance of the final elements in the system.

6. Low ground temperatures will affect control operation considerably more than low air temperatures in flight. Hence, any improvement made in ground low temperature operation will result in less difficulty in flight.

D. RECOMMENDATIONS

It is recommended that:

1. No change be made at present in the low temperature torque requirements of specification AN-G-3.

2. Cold room tests be made on aircraft control system to determine torque in the range between —65°F. and +160°F.

a. Characteristics of control system mechanisms and assemblies;

b. Characteristics of complete control systems as installed in production aircraft.

In view of the possible influence of lubrication on these characteristics, such tests should be made a joint Aircraft Laboratory-Materials Laboratory project.

3. Attention be given to the immediate improvement of low temperature operation of the critical systems noted in Paragraph 3 (f) of Factual Data.

Lubrication of the P-63 Airplane

Prepared by: *S. C. Britton, Maj., A. C. Materials Laboratory*

A. PURPOSE

1. To determine low temperature performance characteristics of several P-63 components, as affected by their lubrication. In particular, the following were to be studied:

a. Lubrication of the extension engine reduction gear. This test is to include determination of oil temperatures in flight and torque required to turn the gear at low temperatures.

b. Lubrication of surface controls systems.

c. Lubrication of Aeroproducts Propeller.

B. FACTUAL DATA

1. The program covering lubrication of the engine reduction gear is a continuation of a similar study made during last winter's tests on the P-39 gear box. The most important use for gear oil covered by Spec. AN-O-3 is in reduction gear of E-series Allison engines and the data obtained on these tests will be used to establish the viscosity limits of the winter or light grade of the oil. At low temperatures, the viscosity of the gear box oil will be controlled by its influence on the torque required to turn the gears or by its effect upon pumpability of the oil. The oil temperatures measured in flight will be a major factor in determining how viscous the oil must be at higher temperatures.

2. AN-O-3, light grade oil was used for lubrication of the gear box in all tests conducted. Gear oil temperatures were determined under various conditions of speed, load altitude, and air temperature; a total of 12 flights were made. The temperatures obtained in flight at rated power (2600 RPM and 42.5 inches Hq manifold) at 5000 ft., 14,000 ft. and 21,000 ft. are shown in Figures 1, 2, and 3 respectively. From the data given, it will be noted that (a) an appreciable time of operation at high power is required to warm the oil to equilibrium (b) the oil temperature reached depended upon the outside air temperature (c) considering the air temperatures at altitude to be representative of winter conditions, the maximum gear oil temperature to be expected will be approximately 180°F. Oil temperatures obtained when higher powers are used, such as in a climb, are given in Table I. Temperature equilibrium is probably never reached under such conditions since comparatively short time limits are placed upon operation at such powers, and a maximum oil temperature of 185°F. is obtained. Thus, temperature compares with a maximum of 155°F. obtained last year on the P-39 oirplane.

3. The gear box torque was obtained, independent of the torque imposed by the rest of the engine by disengaging the engine at the extension shaft coupling. Torque Measurements were made with a simple spring balance. The results of the torque measurements at various low temperatures are given in Table II. It will be noted that (a) the torque required to turn the gears at low temperatures is very low and (b) this torque is practically independent of the temperature within the temperature range studied.

4. Surface controls of the P-39 airplane, particularly trim tabs, were found to be critically stiff at temperatures of —40°F. and below in last year's tests. Thus, similar information was sought on the P-63 airplane during this winter's tests. Rudder and elevator trim tab systems of the E. T. O. U. P-63A airplane were relubricated with TG-455 and control stiffness measured at low temperatures on both this airplane and lend-lease P-63's. Details are given in report TSEAL-4-M4966-II. In general, considerable improvement was noted at low temperatures over P-39 airplanes.

5. Aeroproducts propeller tests have indicated that AN-O-3, light grade would be suitable as a regulator oil for winter operation. This winter's performance was in the nature of a check service test on this recommendation. Although operation of this airplane was not accomplished at extremely low temperatures (below —25°F.) no difficulty was experienced at the temperatures encountered.

6. Other lubrication of the P-63 airplanes appears to be satisfactory for low temperatures since no low temperature malfunction affected by lubrications have been reported on either test or lend-lease airplanes of that model.

C . CONCLUSIONS

1. The limiting performance factor governing low temperature viscosity of the lubricating oil for the Allison

E-series engine reduction gear is the pumpability of the oil. The oil in the gear box contributes little or nothing to engine stiffness and resultant loss of crankability at low temperatures.

2. Engine stand tests evaluating load carrying capacity of light grade gear oil and governing selection of viscosity grade of this oil should be run at oil temperatures not exceeding 185°F.

D. RECOMMENDATION

1. It is recommended that pumpability tests be carried out in the cold room to more accurately define the low temperature viscosity requirements of AN-O-3, light grade oil. Until such tests can be completed, the pumpability data from last winter's tests can be used.

2. Present winterization lubrication instructions covering the P-63 airplane be continued in force.

Turbosupercharger Lubrication

Prepared by: S.C. Britton, Maj., A. C. Materials Laboratory

A. PURPOSE

1. To determine performance characteristics of turbosupercharger lubricating oils at low temperatures, with particular reference to:

a. Pumpability of the lubricant;

b. Oil temperatures in flight;

c. General evaluation of the performance of low temperature oil recommended by Extreme Temperature Requirements Sheet No. 56-2.

B. FACTUAL DATA

1. Current instructions for lubrication of turbosupercharger bearings not lubricated by the engine oil system call for use of grade 1065 engine oil (Spec. AN-VV-O-446) at ground temperatures down to 0°F., and hydraulic oil (Spec. AN-VV-O-366) for sub-zero temperatures.

2. The above recommendations have not been entirely concurred in by the supercharger manufacturer because:

a. It was felt that low oil temperatures might be encountered in high altitude flights when summer grade oil is used, with resultant sluggish flow of oil and imperfect lubrication;

b. If excessively high oil temperatures are reached in flight when ground conditions require use of AN-VV-O-366 oil, the base stock might evaporate from the oil, leaving a sticky residue of viscosity index improver on the supercharger bearings;

c. An all temperature oil is desired. Accordingly, Spec. 3580 hydraulic oil has been recommended for supercharger lubrication. However, this oil has the following disadvantages:

(1) Cold room tests have shown the oil to be too heavy at low temperatures (below —30°F.) for satisfactory pumpability.

(2) This oil also contains a viscosity index improper which could cause the same trouble noted above, although the base stock of 3580 is somewhat less volatile than that used in AN-VV-O-366 oil.

(3) The oil is obsolete and stocks are no longer being procured.

3. In order to meet the need for a suitable all-temperature turbo-supercharger lubricant as indicated above, it has been tentatively recommended that newly developed AN-O-6a oil be used. The tests described herein were prepared in order to obtain information to substantiate this recommendation.

4. Pumpability tests were conducted on P-38L No. 44-24050, using Spec. AN-O-6a oil (Texas TL-534). A by-pass petcock was installed in the oil scavenge line and observations on the flow characteristics immediately after starting the engine at low temperature were made. These observations and an evaluation of the pumpability of the oil are given in Table I. Satisfactory pumpability was obtained down to the lowest temperature encountered (—46°F.)

5. In order to obtain information on supercharger oil temperature in flight, thermocouples were installed on the oil in and oil out lines of Nos. 1 and 2 engines of B-17G No. 44-24050. Flights were made under normal cruise conditions at various altitudes. The data obtained is summarized in Table II. It will be noted that in this installation rather low oil in temperatures are obtained at high altitudes, low enough in fact, that it is doubted that grade 1065 engine oil would be pumpable. However, this should be a function of the installation since the ambient air in installations such as the P-38 is higher than outside air because the supercharger oil tank and lines are mounted in the wheel well.

6. AN-VV-O-366 oil has been used to lubricate all externally lubricated turbosuperchargers on ships assigned to low temperature testing at Ladd Field for the past two years. No reports of bearing failures of the nature indicated in par. 2 above have been received.

C. CONCLUSIONS

1. Spec. AN-O-6a oil will satisfactorily lubricate turbosuperchargers down to ground temperatures of —45°F. or lower.

2. Low oil temperatures are obtained in some installations in flight at low temperatures indicating the desirability for having an all temperature turbosupercharger lubricant.

3. AN-VV-O-366 hydraulic oil will satisfactorily lubricate turbosupercharger under arctic operating conditions.

D. RECOMMENDATION

It is recommended that:

1. As soon as an adequate supply is available, oil meeting Spec. AN-O-6a be used as an all-temperature lubricant for turbosuperchargers (other than for those lubricated by the engine oiling system).

2. AN-VV-O-366 oil be considered as a satisfactory turbosupercharger oil for sub-zero temperatures until AN-O-6a is available.

Starter Lubrication

Prepared by: S. C. Britton, Major, A. C. Materials Laboratory

A. PURPOSE:

1. To determine whether or not Eclipse starters lubricated with specification greases heavier than recommended by Extreme Temperature Requirements Sheet No. 56-2 will function satisfactorily at low temperatures.

B. FACTUAL DATA:

1. On the basis of previous test work, including last winter's tests on 4 Jack and Heintz starters installed on a B-17 airplane, the Materials Laboratory has recommended that starter bearing be lubricated with specification AN-G-3 grease and gears with specification AN-G-10 grease. However, Eclipse Division, Bendix Aviation Corporation has indicated that from their tests and experience it appears necessary to use a somewhat heavier grease to insure desired starter life under all conditions.

2. In order to determine the low temperature performance of starters lubricated with heavier greases, four Eclipse G6a starters were lubricated at the factory and installed on B-24J No. 44-41378 as shown in Table I, 3560E med. and GN-G-6 was used on two starters, representing standard greases now available in stock. TG-404 was used in the remaining two starters, representing the intermediate grease of Army-Navy specification greases to be available in the near future.

3. The performance of the starters at various temperatures down to —43°F is summarized in Table I. Entirely satisfactory performance was observed at all temperatures encountered.

C. CONCLUSIONS

1. Satisfactory low temperature performance of starters lubricated with intermediate type greases can be expected down to at least —45°F. It is probable that such lubrication will be satisfactory at much lower temperatures.

D. RECOMMENDATIONS

1. Technical orders covering lubrication of Eclipse starters require use of intermediate type greases for bearings and gears.

2. Further tests be carried on in the cold room to determine whether the specially lubricated starters used for this test will operate satisfactorily at —65°F. It is further recommended that yellow dot approval not be granted for Eclipse starters until and unless such tests are successfully completed.

Lubrication of B-29 Retracting Motor

Prepared by: S. C. Britton, Major A. C. Materials Laboratory

A. PURPOSE

1. To determine the lowest temperature of practical operation for retraction of B-29 landing gear with motors lubricated with intermediate-type grease.

B. FACTUAL DATA

1. Extreme Temperature Requirements Sheet No. 56-2 specifies use of AN-G-3 grease for lubrication of landing gear retracting and other similar intermittent duty motors.

2. However, in the case of larger units, such as used for B-29 airplanes, some doubt has existed as to whether a light, low temperature grease such as AN-G-3 would provide adequate lubrication at high temperatures. The motor manufacturer proposes using a lithium-base grease with an oil approximately twice as heavy as that used in AN-G-3 grease. The equivalent specification material is the intermediate type grease soon to be covered by an AN specification and represented by Texas TG-404. The low temperature torque of intermediate-type grease is, of course, not as low as for AN-G-3 grease and the question has arisen as to the performance of the heavier grease at low temperatures.

3. The test was run on B-29 No. 42-65214. The left landing gear motors were removed and returned to the factory (Eclipse-Pioneer Division, Bendix Aviation Corporation) where they were relubricated with Texas TG-404. The right landing gear retained the original factory lubricants, Royco 6A and Royco 50.

4. The performance of the gear was evaluated by measuring two factors; the electrical load required to raise the gear and the time required for retraction. Electrical load was measured using an ammeter with external shunts mounted in the power circuits to the motors, using calibrated leads back to the navigator's station where the readings were taken.

Readings were taken on first retraction on take-off on the first flight of the day. The ammeters were read every 5 seconds after the circuit was closed, since a considerable variation of load was noted over the retraction cycle. Data was also taken on the ground with the airplane on jacks in the hangar and on the ramp outside in order to get as large a temperature spread as possible. (These readings were taken when the airplane was jacked up for turret tests.).

3. The test results are tabulated in Table I. The lowest temperature at which readings could be taken was —20°F. No data was obtained at lower temperatures because the wing flaps were inoperative (See Part I, Lubrication of Aircraft Controls). However, over the temperature range in which tests were conducted, there was no noticeable trend of electrical load of retracting speed indicating difficulty at low temperatures. Some difference between the left and right gear readings exists, but since neither showed significant change with temperature, this is thought to be due to mechanical idiosyncrasies of the system rather than differences between the greases used to lubricate the two motors. It should be noted that the peak sustained load is quite high (260-275 amps) and undue increase in frictional horsepower could cause excessive loading of the airplane electrical systems.

C. CONCLUSIONS

1. Intermediate type greases will permit satisfactory operation of B-29 retracting motors down to at least —20°F. Malfunctions of other systems will limit operation of the B-29 airplane at temperatures higher than the limiting value for landing gear retraction.

D. RECOMMENDATIONS

1. Further work be accomplished in the cold room and cold hangar to evaluate the use of intermediate grease in B-29 landing gear, with final proof being obtained by cold weather flight tests. Tentatively, intermediate grease should be considered satisfactory for B-29 landing gear motor lubrication.

Performance of Non-Inflammable Hydraulic Fluid in Struts

Prepared by: S. C. Britton, Major, A. C. Materials Laboratory

A. PURPOSE

1. To determine the serviceability of a newly developed non-inflammable hydraulic fluid in struts under low temperature operating conditions.

B. FACTUUAL DATA

1. At the direction of higher authority, the Materials Laboratory has developed a hydraulic fluid considerably less flammable than the present petroleum base fluid. The viscosity of this fluid at low temperatures is higher than for the present AN-VV-O-366 oil, but lower than the old 3580 oil. Other properties, such as shear breakdown, lubricating value, rubber swelling, corrosion, etc., have been evaluated by laboratory tests which indicate generally that the oil should be suitable for service. The test described herein was set up to obtain some information on its performance in actual service, particularly at low temperatures.

2. The fluid was installed in struts of several E. T. O. U. airplanes at Vandalia in preparation for cold weather tests. Information on the installation of fluid and its performance during the test season is summarized in Table I. Operation was entirely satisfactory under all conditions encountered.

3. Arrangements have been made to have the struts returned to Wright Field for internal examination. More complete evaluation of the test will depend upon the findings of this examination.

C. CONCLUSIONS

1. The results obtained to date indicate that the non-inflammable hydraulic fluid developed by the Materials Laboratory is suitable for airplane shock struts under low temperature operating conditions.

D. RECOMMENDATIONS

1. It is recommended that more complete service tests be conducted to further evaluate the suitability of non-inflammable hydraulic fluid for military aircraft use. In particular, the fluid should be tested in main hydraulic systems.

Investigation of Reported Engine Roughness during Service Test of PPO-265 by Alaskan Division, ATC

Prepared by: S. C. Britton, Major, A. C. and Wm. Weitzen
Materials Laboratory and Power Plant Laboratory

A. PURPOSE

1. To determine cause of excessive engine roughness, "cut-outs", and similar troubles reported by operating personnel of Alaskan Division, ATC, since inauguration of service test of PPO-265 synthetic engine oil.

B. FACTUAL DATA

1. Service test on PPO-265 in Alaskan Division airplanes was begun 1 October when this oil was placed in service on all transport airplanes under Division supervision, including those operated by contract carriers. This test was initiated primarily to obtain a large amount of information on the value of PPO-265 as a winter grade engine oil. General information as to its serviceability in transport operation was also desired, although previous tests stand and service tests on various types of engine have indicated that this oil is a generally satisfactory aircraft engine lubricant.

2. Performance of the oil has apparently been satisfactory on the service test, and its value as a winter grade oil has been indicated by the fact that practically no dilution had been necessary up to 17 December 1944. However, a number of apparently unexplained cases of engine roughness, "cut-out", "burping", etc., had been reported by Army pilots since using the oil. A summary of typical complaints on one airplane is given in Appendix I. It will be noted that a few reports were received in October and that they ceased until the end of November. This is typical of all the airplane reports. By the first part of December, the number of complaints had reached a level where it was decided to discontinue the use of the oil entirely on the three Army-operated C-46 airplanes and continue on the right engine only on the ten Army-operated C-47 airplanes.

3. A summary of the amount of service on both grade 1100 and PPO-265 oil (up to 17 December) as well as an analysis of the complaints of engine roughness is given in Appendix II. It will be noted that while PPO-265 has been in service approximately the same number of hours on both right and left engines, more complaints had been received on the right engine. A large number of these were unexplained although an equal number were reported to be due to ignition trouble, followed by carburetor trouble, propeller surging, and a few miscellaneous other causes. The majority of the reports of engine roughness or "cut-out" have been received on three airplanes.

4. Information on performance of PPO-265 was also obtained from the contract carriers, Northwest Airlines and Western Airlines. Both of these organizations report no increased difficulty with engine roughness since using PPO-265, although a somewhat greater tendency to leak had been noted. Oil consumption was indicated to be somewhat less with PPO-265 than with grade 1100. There had also been an increased number of off-schedule engine changes since 1 October, although it is too early to state that there is a definite permanent trend in this direction. Refer to Appendices III and IV.

5. Considerable emphasis had been placed upon the amount and appearance of sludge in propeller domes, blade bearings and distributor valves since using PPO-265 in attempting to explain the engine roughness observed. The sludge in this oil is composed almost entirely of blow-by lead compounds and is not mixed with tarry material formed by oil decomposition and oxidation as is the case with ordinary mineral engine oil. This has resulted in a deposition of sludge in the propeller system of a harder than usual consistency, which might cause uneven propeller functioning with resultant surging. A number of instances of excessive quantities of propeller sludge deposits have been noted. It is not believed that this condition is general, because inspection of three propellers in the Army propeller shop at Edmonton showed only a moderate quantity of deposit. In the case of one propeller examined, very little sludge was found after 1163 total hours, comprising 675 hours on grade 1120 oil and 488 hours on PPO-265 and 145 hours after last dome inspection and clean-out. Further, more diligent cleaning of domes has not eliminated roughness difficulties, in some cases complete propeller changes have not helped, and test runs involving "exercising" the propeller in flight have not resulted in any improvement in operation.

6. In order to obtain a more definite idea of the nature of the roughness or "cut-out" reported, observations were made on one of the airplanes (No. 8160) on which numerous complaints had been received, during a regular flight from Edmonton to Fairbanks. Log of this flight is given in Appendix V. It was noted that after about six hours in flight, a short period (2-3 seconds) of roughness was observed with an accompanying momentary drop in tachometer reading of 50 to 75 RPM. This was repeated at intervals and was not eliminated by several procedures tried in flight. Increased power setting appeared to aggravate the trouble. Questioning of the pilots indicated that the roughness observed was typical of that being reported.

7. Later, airplane No. 8160 was obtained for more extensive flight check. A record of the test flights made is given in Appendix VI. Three test flights and one

short ferry flight were made, totalling 16.3 hours under various conditions of operation, during which no indication of engine roughness of any kind was noted. Since a number of minor mechanical adjustments were made at Whitehorse just prior to receiving the airplane at Fairbanks, it appears that the cause of the roughness previously observed is mechanical and may be only remotely related to the oil.

8. Noticeable greater leakage of PPO-265 past seals, gaskets, and other passageway has been noted. Considerable leakage past the main shaft seal into the blower section and into the lower intake pipes has been reported.

9. Previous to installation of the oil, most instances of engine roughness, which were occasionally quite troublesome, were found to be due to malfunction of various parts of the ignition system, particularly the magneto.

10. Operating personnel were generally of the opinion that changing back to grade 1100 engine oil eliminated difficulties due to roughness and in one instance it was reported that a complete fix was obtained on a return flight after making such a change. However, it cannot be stated with any certainty that other things were not also adjusted at the same time; and such reports, where uncontrolled changes have been made, are valueless.

C. CONCLUSIONS

1. Abnormal momentary engine roughness is being encountered in some engines in flight.

2. Data available do not indicate conclusively that PPO-265 used as engine oil is a direct cause of the engine roughness observed. In numerous instances, mechanical difficulties which ordinarily cause rough engine operation have been indicated to be the source of trouble. The most prevalent cause appears to be ignition trouble. However, some reports of roughness cannot be so explained and might be attributable to properties of the oil.

3. PPO-265 differs in a number of properties from regular engine oil, particulary.

a. Greater "creeping" or power to wet metal surfaces;

b. Different effect on rubber compounds used for seals and gaskets;

c. Lower inflammability;

d. Lower viscosity at temperatures below approximately 250°F.

The possible effect of these properties is indicated in the following paragraph.

4. There exist several possibilities in which the oil may directly or indirectly cause engine roughness. These are evaluated below:

a. Spark plug fouling due to oil leakage into induction system, with subsequent difficulty of cleaning plugs because of the low inflammability of the oil. This explanation has been considered one of the most likely but has not been supported so far by actual examination of the plugs.

b. Fouling of distributor points by oil leaking past magneto shaft seal. Some instances of oil on points have been reported and this would tend to cause roughness. However, in most instances where typical roughness is reported, satisfactory ground magneto check for RPM drop has been obtained.

c. Oil in ignition harness. Some instances of excessive amounts of oil in the harness have been reported. However, since the oil is an insulator, the possibility of this causing actual engine malfunction is remote.

d. Sludge in prop dome, blade bearings and seals and governor valve. This condition is discussed in Paragraph 5 of factual data, and from the data it is concluded that this explanation of engine roughness is not valid.

e. Valve sticking. This source of engine roughness could be caused by low oil flow due to plugging of oil passageways or valve stem deposits. The type of roughness or engine "cut-out" observed particularly after long running could easily be explained by valve sticking. However, consideration of properties of the oil as well as disassembly inspection of some engines which have used PPO-265 seem to preclude this explanation.

f. Plugging of Torsional Vibration Damper. This has been suggested by a Pratt and Whitney representative. Too much credence is not given to this suggestion in view of the type of roughness encountered, plus the fact that this vibration damper was designed to eliminate high order torsional vibration in the accessory end and smooth operation, insofar as can be detected without instruments, can be obtained with the pucks rigidly fixed to the crankshaft.

5. Increased rate of occurrence of off-schedule engine changes since using of PPO-265 gives some indication that entirely satisfactory lubrication is not always obtained. However, this does not seem to be directly associated with the cause of engine roughness and data taken over a longer period of time could easily reverse the trend noted.

D. RECOMMMENDATIONS

1. It is recommended that action be taken as given below, by the organizations indicated.

a. Alaskan Division, ATC.

(1) Continue oil service test on C-47 airplanes as now set up. On Army-operated C-47's use grade 1100 on left engine and PPO-265 on right engine.

(2) Take steps to prevent mixing or changing from one oil to the other on any engine. Stringent orders should be issued that either oil should not be changed at the discretion of operating personnel for "engine roughness" or similar reasons. Oil change for any reason should be considered an emergency procedure and should be done only on authorization by Maintenance at Division Headquarters. Adequate precautions should be taken to preclude accidental mixing ot oils at service bases.

(3) More careful maintenance should be accomplished in order to better isolate the various causes of engine roughness and correct those causes. In addition to normal accessory corrections, attention should be given the following, which are possibly affected by the oil:

(a) Magneto inspection. Check for oil leakage past drive shaft seal and evidence of malfunction of distributor and breaker points. Excessive seal leakage should be corrected by installing new seals. Also check magneto shaft for excessive looseness.

(b) Spark plug inspection. Check plugs for fouling. On engines where other procedures are not effective, change plug to IS 87 or equivalent.

(c) Remove, clean and inspect propeller dome every 100 hours in accordance with TO-03-20-5. If exceedingly large quantity of hard sludge is found in dome, propeller should be changed at the discretion of personnel in charge of propeller shop.

(d) An effort be made to include more complete details of maintenance and operation with PPO-265 in order that such difficulties as engine roughness may be better analyzed by engineering personnel. In order to accomplish this, the check sheet given in Table I should be added to the form now carried in the airplane, form 1 covering performance of PPO-265.

b. Engineering Division, Air Technical Service Command.

(1) Send representative to Headquarters, Alaskan Wing, to follow service test of PPO-265 full time for a minimum of 2 weeks.

(2) Take into consideration the various ways the oil might contribute to engine roughness as pointed out in this report, when making disassembly inspection of engines which have used PPO-265.

(3) Investigate effect of PPO-265 on various rubber compounds, particularly the type of compounds used for engine and propeller seals, such as accessory drive seals, cylinder flange oil ring seals, sump pipe seals, rocker box seals, and propeller blade and hub seals. It is recommended that such work be done in cooperation with the oil manufacturer.

(4) Investigate spark plug fouling tendency of PPO-265 as compared with mineral oil by means of single cylinder engine tests.

(5) Determine effect of various amounts and kinds of sludge in propeller domes and blades on propeller operation.

(6) Determine effectiveness of full-flow filters in removing blow-by lead compounds from PPO-265.

(7) Take steps to obtain better oil seals on R-1830 engines.

Cold Weather Observation with Respect to Bombing Equipment

Prepared by N. S. Lestz, Armament Laboratory

A. PURPOSE

1. To report observations in connection with behavior of bombing equipment during the winter of 1944-1945 at Ladd Field, Alaska.

B. FACTUAL DATA

1. The present winterization program of tests for bombing equipment has been carried out in the mildest winter period yet experienced, except for two cold snaps, since the inauguration of the winter tests at Ladd Field in 1942.

2. The daily maximum and minimum temperatures in degrees Fahrenheit for this winter period are contained in Appendix I to this report. Daily means and monthly means are also listed. The coldest snap for the period was recorded on February 12 to 14 when the low, —45°F so far experienced, was reached.

3. The ground checks and flight checks performed on bombing equipment have followed the pattern established in the previous winter periods, and the equipment checked (see Appendices II, III, and IV) have not, with the exceptions listed below, given trouble during the temperatures experienced:

a. Bomb racks P51-D airplane. These items were affected at —40°F. The locking latch was binding. Racks were thus hard to cock. Net effect was to increase bomb loading difficulties which are multiplied by the extreme temperatures acting on the personnel. The racks are generally difficult to load even though hooks are designed to be snapped into position by the bomb lugs. Personnel feel that the method of locking can be improved and that means for unlocking the hooks at the racks should be provided. The present shield on racks prevent unlocking hooks at the rack.

b. Bomb Release Interval Control, Type B-2a. A unit installed on the B-29 airplane was reported frozen when ground checked at —40°F. A study of facts avail able seem to indicate that the bombardier's master switch was frozen rather than the control. During this check no electrical current was available at the interval control or at the indicator lights. Both of these circuits are fed from the master switch circuit which, with the other toggle switches on the bombardier's panel that control the bombing circuits, was stiff and did not operate readily at —40°F.

c. B-24 Aircraft—The installation of the Type A-15 Emerson nose turret in these airplanes is not airtight. The airplane nose is exceedingly drafty in the immediate vicinity of the bombsight. A flight test was conducted in B-24J, 44-41378 to measure this leakage. At 12,000 feet, indicated airspeed 180 MPH, the airflow is 1880 feet per minute (a small gale), or approximately 20 CFM. Most of the air enters the compartment from beneath the bottom of the turret doors which fit improperly in the bottom of their bulkhead. Consequently the compartment is at the same temperature as the Outside air which in this test was ÷1.4°F. The cold affects the bombardier's efficiency of operation, and it also affects the bombsight, if it lacks the protection of its heating cover and is exposed overly long (20 minutes or longer), during a bombing run when the free air temperature is sufficiently low (—20°F. or lower). See succeeding paragraphs for details of bombsight operation.

d. Bomb Hoisting—The C-3 hoist and the webb straps were used for all bomb loading details. Equipment functioned well, but the time consumed to raise each bomb to its station in the airplane by this manual method worked difficulties on the personnel engaged in this work in cold weather. The webb strap was favored for cold weather use over the chain sling by personnel experienced with both types. The webb strap can be manipulated more quickly and can be handled with gloves. The C-6 hoist was not used. Airplanes with hoisting systems adapted for use with the C-6 hoist were not available. The C-3 motor drive set was used on four loading details, but difficulties in obtaining a source of 110 volts D.C. to drive it arose. (Both these items had been successfully used in previous winter tests).

e. M-Series Bombsights and Stabilizers—Low temperature effects varied for each of the sight and stabilizer assemblies tested when they were not protected by the operation of their heating covers. Bombsight and stabilizers were exposed to cold weather at all times except for routine maintenance on units in the shop. The caging knobs, levelling knobs, drift and turn knobs, rate and displacement knobs, telescope rheostats, rate racks, telescope motors, and displacement quadrants could be freely operated on some units while binding on others in temperatures of —20°F or lower. Stabilizers were unaffected in operation. All the cold weather malfunctions occured with bombsights installed on the B-24 airplanes. On these airplanes the sights although protected by their covers before missions, (except when installation of GBA prevented closing covers) were exposed to the cold during bombing runs and their various parts, enumerated above, became stiff and sometimes inoperative due to cold air blowing directly over the installation. Appendix IV gives a running account of the various malfunctions. On the other airplanes, B-25's, B-17's and B-29's, the bombsight installation is not subject to cold drafts, the compartments do not leak, and with the additional protection of the heated covers no cold weather malfunctions during operation occured. Inspection of the malfunctioning sights revealed in some cases an excessive amount of grease on parts. However, in the case of binding quadrants the parts were clean.

f. C-1 Automatic Pilot—No cold weather difficulties occured with these items where they were protected by their heating covers. Appendices III, and IV list the history of these units for this winter period. B-24J's, 44-41378 and 44-41377, had no C-1 automatic pilot heat-covers installed, resulting in sluggish operation of these units. Covers later installed on B-24J, 44-41377, prevented any further cold weather difficulties. The B-24M, 44-42190, had all covers installed by the factory except for the aileron servo, because of interference that would result with the elevator control chain drive which is close by this servo.

g. Lubrication— Two types of oil were used with the M-series bombsights, stabilizers and C-1 automatic pilots on test. Eight groups of equipment were oiled with the regular light bombsight oil while seven groups of equipment were lubricated with AN-O-6A oil. Appendices III and IV carry the record of the lubrication of the units. AN-O-6A oil, newly developed for bombsights, has a pour point of —70°F. It was not known definitely whether the L-oil used is of type covered by specification 3582-A or of the old type. The old L oil has a pour point of +4°F. The 3582-A oil has a pour point of —50°F. The oil used flowed freely at temperatures experienced. However, samples of L-oil used and also of the H-oil on hand were turned over to the Materials Laboratory representative for analysis at Wright Field. Of the seven sets of equipment oiled with the AN-O-6A oil, four were winterized before being sent to Alaska. The other three sets were units on test using L-oil (part of the eight groups mentioned above) and later flushed with the AN-O-6A lubricant for test. During the test gyro rotor bearing failures developed on five stabilizers and one bombsight. One of the stabilizers of the five and the one bombsight were lubricated with L-oil only. Three stabilizers, one of which failed twice, were lubricated with AN-O-6A oil only. The fifth stabilizer failed, first using L-oil, and then failed when AN-O-6A oil was used in it after its repair. Five groups oiled with L-oil and three groups oiled with AN-O-6A developed no bearing troubles. Of the units damaged, three were on B-17's and three we re used on B-24's. Some of the damaged bearings have been turned over to the Materials Laboratory representative for examination at Wright Field. The others are being returned to the Armament Laboratory for examinatiton. All the damaged bearings failed similary on stabilizer gyro rotors regardless of lubricant. In several of the failed bearings a reddish foreign substance similar in appearance to rust was found. The outer races of the bearings were also deeply scored. The gyro rotor locked end bearing was more severely damaged than the free end bearing. Failure of bombsight gyro rotor bearings, flight gyro rotor bearings, and servo bearings did not occur except for the one bombsight already mentioned. Lubrication of the foregoing units was similar and as frequent as with stabilizers. Because of the failure of bearings, shop tests for comparison of the L, the H, and the AN-O-6A oils were made with a check on the amount of oil being thrown from bearings. The maintenance shop at Anchorage Air Depot was also consulted regarding bearing failures. Other than the fact that bearings drawn from stock have been found defective, no information was available on bearing failures in this area. It was also learned that confusion exists concerning the L- and H-oils in use. Some of the old oil in stock is being used along with the 3582-A oil and the VV-O-581 oil recommended in place of the old H- and L-oils.

4. The following service difficulties with bombing equipment occured during tests:

a. Flight Gyros. Intermediate gear on roller cut-out stripped. Metal particles from gear entered bearing causing it to fail. Lower roller of cut-out stuck on another fight gyro. The pinion drive gear teeth were stripped. The metal chips from the gear scored the shaft of the roller cut-out.

b. Type C-13A Thermometers. These units are erratic. No two of the same airplane register the same temperatures.

c. B-2A Interval Control. Relays stick at room temperature as well as at outside temperatures below freezing.

d. Hydraulic fluid may drip into the flight gyro in B-24J airplanes in its present location besides the navigator's table. In airplane B-24J, 44-41378 the drip is excessive necessitating constant attention to flight gyro. This gyro was flooded.

e. B-7 Bombsight Mount. One failure occured. Bottom plate of the mount cracked at pivot block jaw and locking device was broken. Personnel lacking familiarity with the locking arrangement had forced it by brute strength. This mount was one of three carrying glide bomb units. No other failures found. Mounts have been found poorly adjusted especially at the pressure tips. The failed mount was one of these.

f. A-4 Releases. During installation weight of the release falls on the electrical connector. Pins in the connectors of three of the releases were twisted off as a result. A photograph of a release so damaged is being sent to the laboratory. The spring contacts of the receptacles, Type A-1, receiving the A-4 release connector pins have been found open after removal of releases. This failure of the inserts to close occured on B-29, 42-24768.

g. Aileron Servo—B-17G Airplanes. Installation of other equipment prevents access to this unit and dynamotor for servicing.

h. Servo units of Minneapolis-Honeywell manufacture. Reduction in the size of the inspection hole in the end-bell at the commutator makes it difficult to clean the commutator segments.

i. The Q-1A heated suit rheostat is not accessible for plugging in the Type A-1 bombsight heating cover on B-17G aircraft.

5. In tests with the glide bomb attachment (GBA), the rate of climb and descent failed to correspond to airplane rates of climb and descent. Wide discrepancies have been noted. No shop facilities were available to recalibrate these items and check their correctness. The units had registered correctly in calibration checks in the Armament Laboratory before installation in the airplanes.

6. Action has been taken to have returned to the Armament Laboratory bombsights, stabilizers, automatic pilots and GBA's which were installed on Wright Field test airplanes. The equipment is to remain with airplanes until their return to Wright Field. Proving Ground bombsight maintenance personnel have been requested to recalibrate bombsights and stabilizers and check automatic pilots before departure of aircraft and reoil units with AN-O-6A oil, noting any malfunction in data books of units.

C. CONCLUSIONS

1. The following conclusions are submitted with respect to the behavior of bombing equipment for the winter period 1944-1945:

a. Insofar as the severity of the weather is considered, the season has been very disappointing except for an occasional cold snap.

b. Bombing equipment is independent of the airplane for its efficiency of operation, more so than in previous winter tests, since the introduction of the all-electric bomb release system. Conquently, best results for determining cold weather behaviour of the equipment from a design standpoint can best be worked out in the cold room where temperatures can be controlled at will. However, the winterization field tests are considered necessary for new equipment still in the experental stage to check its feasibility for cold weather use form the point of view of field personnel. Flight conditions which can hardly be expected to be duplicated in every phase in the laboratory is another factor which must be considered in cold weather field tests.

c. The behavior of bombing equipment in the winter tests has been satisfactory and very dependable.

d. P-51D bomb racks would not have failed to operate with a bomb load. The difficulty from the cold arose only in the increased resistance to cocking.

e. Bombsights, stabilizers, and the C-1 Automatic Pilot for best operation in cold weather and where the units have been chilled on the ground, must be protected by operation of their heating covers. Only with conditions as on airplanes of the B-24 type may trouble be expected if the units are exposed any great length of time in flight in the cold.

f. Bomb hoisting difficulties would be reduced by use of the motor drive for C-3 hoist or by use of the motorized C-6 hoist.

g. The following conclusions are advanced for bearing failures, although for the complete picture design tolerances, the type of lubricant and conditions of bearings must be considered. It is felt from analysis of data in Appendices III and IV that the bearing troubles developed from the maintenance procedure followed. In every case of bearing failures in these tests, maintenance procedures followed a standard practice of a 30-day inspection or 25-hour operational inspection, whichever was first. Bearing failures occured because units were operated when bearings were dry. The occurrence of a reddish material of the appearance of rust in damaged bearings, whether they had been treated with L-oil or AN-O-6A oil, seems to bear out the fact that failures were from similar causes, namely, overstress resulting in corrosion fatigue (a break down of the metal structure due to stresses imposed). Bombsight (one exception noted on which rotor bearings had become extremely dry) and flight gyro bearings did not fail because stresses imposed on them are slight compared to those on the directional gyro which is imposed upon by the servo motor. More failures occurred with AN-O-6A oil used, because as tests showed, this light oil is lost from the bearings during gyro operation more easily than is the L-oil or H-oil. Consequently bearings become dry more quickly when AN-O-6A oil is used and require more frequent maintenance periods than with the L or H oils in use.

h. The method of lubrication on bombsights, stabilizers, flight gyros, and other C-1 equipment should be improved. The units are not readily oiled and the oil can be lost form the bearings during operation.

i. Breakage of the pins in the A-4 releases is believed to be due to careless handling at installation of the releases by personnel. The weight of the releases when suspended on the receptacles may have also caused the spring contacts to separate in the type A-1 receptacle boxes.

j. The design feature of unlocking the plates of the B-7 bombsight from its base has proved very desirable for personnel responsible for bombsight maintenance. Removal of stabilizers from aircraft is facilitated especially in cold weather. However it has been noticed that little attention is paid to properly adjusting mounts during service use.

D. RECOMMENDATIONS

1. The following recommendations are submitted with respect to the observations of behavior of bombing equipment for winter tests of 1944-45.

a. Action should be taken to correct the unsatisfactory condition of air leakage in B-24 type aircraft with the Type A-15 Emerson nose turret for the following reasons:

(1). To prevent bombsight operation from being adversely affected.

(2). To make the compartment more comforable for operating personnel thus increasing their efficiency of action.

b. Further steps should be taken to increase the efficiency of the method of bomb hoisting in order to shorten loading time over methods now in use to overcome the discomforts of cold weather on personnel.

c. Investigation of bearing failure that ocured on stabilizers should be undertaken, not only considering infrequent lubrication as a source of the trouble, but also considering the effects of cold on tolerances and whether the series of damaged bearings could be poor stock items.

d. Determine the frequency with which the bombsights, stabilizers and C-1 pilot should be lubricated and the types of oil to be used.

e. Investigate the possibilities of improving methods of lubrication on bombsights, stabilizers and the C-1 automatic pilot.

f. Investigate whether the weight of the A-4 release resting on its electrical connector at installation can result in broken pin connectors, and, whether it would be practical to improve the method of mounting by the addition of a locating pin to support weight.

g. Investigate whether the spring contacts of the receptacle Type A-1 for A-4 releases need strengthening.

h. Action be taken to have heating covers installed on C-1 automatic pilot units on B-24 aircraft and protect the flight gyro from possible drippage of hydraulic fluid. On B-24 aircraft in which the aileron servo is located near the elevator control chain, action should be taken to relocate it and furnish it with its heated cover.

i. If P-51D bomb racks of the present type are continued in use, the desirability for unlocking the bomb hooks at the rack should be investigated. This can be achieved by cutting away the shield at access points already provided on the rack for unlocking it. Removable dust shields should be provided if the present shield is cut away.

j. Reaction to extreme cold of toggle switches of the type used on bombardier's panels should be further investigated.

k. Action should be taken to make the aileron servo and dynamotor accessible on B-17 aircraft for servicing.

l. The discrepancies in the type C-13A thermometer installations should be investigated.

m. The inspection hole in the end-bell of MH C-1 automatic pilot servos should be increased in size.

n. B-17G aircraft in production should be furnished with an electric outlet in the nose for the type A-1 heating cover or the Q-1A rheostat in the nose should be relocated so that it is accessible for plugging in the cover.

Low Temperature Tests of the Eight (8) Gun Nose Installed on B-25J Airplane

Prepared by: O. E. Hopkins, Capt., A. C. Armament Laboratory

A. PURPOSE

1. The purpose of these tests was to prove the operational reliability of the pneumatic gun charger system at low temperatures.

2. The B-25J-22 was used for test because it had the only standard production installation of the charger system. This charger system is being proposed for numerous other installations and a low temperature test was desired before these production installations were made.

B. FACTUAL DATA

1. The eight (8) gun nose for the B-25 airplane is a standard production item designed to the requirements of the Southwest Pacific and the China-Burma-India theatres. It is produced in the form of a kit that will replace the nose on any B-25 airplane produced since the B-25B. The guns are arranged in two (2) banks of four (4) guns each. All guns are mounted on a cant to a common center wall of the nose. The links and cases are ejected through the center wall and are collected in the lower part of the nose. Each of the guns (including the package guns) is fitted with a Kidde Pneumatic Charger. The chargers are operated by three (3) solenoid valves, one for each bank in the nose and one for the package guns. The pressure is supplied by a Cornelius Compressor and three reservoir tanks mounted in the nose just aft of the guns. The solenoid valves have two (2) coils. The larger is the actuating coil and the smaller is used to hold the valve open after the actuating coil has opened it. This permits the guns to be operated on the hold back principle, i.e. the guns can be charged to the rear and held there to eliminate "cook-off" rounds and to speed cooling of the barrels.

2. The temperatures at Ladd Field during the test season of 1944-1945 have been unusually mild and, as a result, the tests were not conclusive. Only two failures due to low temperatures were found; however, it was not possible to duplicate these failures because of the mild weather and the continuous engine trouble on the airplane. One of these failures occurred on 18 January when one charger did not operate and one occurred on 14 February when the compressor would not start. Attached as Appendix I of this report is a record of all tests performed.

3. Several failures did occur during tests prior to 22 January; however, these failures could not be attributed to low temperatures. These failures were caused by the peening of the stem of the exhaust piston. The result of the peening was that the ball was held off center when the high pressure valve was open and when it was closed, the ball struck the nylon valve seat off center and made a dent in the seat. The ball would no longer seat properly and seal, and all of the pressure reserve was lost. As will be noted in Appendix I of this report, on 22 January new designed parts were installed and no further trouble was experienced. (See 19 February entry of Appendix I).

4. In the early part of December 1944, a visit was made to the Anchorage Air Base by the test officer, and it was learned that there was a B-25J-22 at that base with a defective charger. The airplane was being ferried to the 11th Air Force and had arrived at Anchorage with one gun held out of battery by the charger. The personnel atthe depot at Anchorage had removed and disassembled the charger. The valving rod had been found bent and peened and the washers that form a seat for the spring were bent and battered. A new valving rod had already been made up and the old one scrapped. The

charger was brought to Ladd Field and repaired by straightening the washers and replacing the valve seat. The charger then worked satisfactorily and was returned to Anchorage.

5. To facilitate maintenance of this equipment, the following items are noted:

a. Certain threads on the chargers and solenoid valves were found to be non-standard, for example 3/8-27. Threads should be made standard so that they can be retapped in case of damage.

b. The mounting holes on the solenoid valves need to be at least 1/16 in. further apart so that the valve can be removed with a socket wrench. Present dimensions require that the valves be removed with an open end wrench at the rate of 1/6 turn at a time.

c. The elevation boresight adjustment on guns Nos. 4 and 8 cannot be made with the gun installed. This results in "cut and try" methods of boresighting and the gun must be replaced and removed for every try.

C. CONCLUSIONS

1. The test season was too mild for the tests to be considered conclusive.

2. The modifications made of the chargers and solenoid valves on 22 January corrected the failures due to denting the valve seat as a result of peening of the piston stem.

D. RECOMMENDATIONS

None.

Low Temperature Tests of the Armament of A-26B Airplane

Prepared by: O. E. Hopkins, Capt., A. C. Armament Laboratory

A. PURPOSE

1. The purpose of these tests was to prove the operational reliability of the A-26B armament at low temperatures.

B. FACTUAL DATA

1. The armament of this airplane consists of two turrets remotely controlled form a periscope and a "All Purpose Nose." The nose is so designed that six (6) caliber .50 machine guns, two (2) 37 m.m. guns or one (1) 75 m.m. gun can be installed. The nose guns are all fixed forward and are fired by the pilot.

2. A record of all tests is included as Appendix No. 1 of this report. The turrets were operated at temperatures as low as —38°F. without malfunction. Several malfunctions of the guns occurred due to low temperature. The only low temperature trouble found was that the automatic stowing of the turrets is very slow at low temperatures. The eyepiece of the periscope frosted up severely when cold; however, cabin heat would eliminate this. The lower turret is extremely hard to service at low temperatures because of the necessity of having to wear gloves and bunglesome clothing. Three (3) hours were required to remove the guns at minus 40°F.

3. No cold weather problems occurred on the nose armament; however, numerous malfunctions did occur, as will be noted in Appendix No. 1 of this report.

4. The temperatures at Ladd Field were unusually mild during the test season of 1944-1945 and therefore the tests cannot be considered conclusive.

C. CONCLUSION

1. The temperatures during the test season were much too mild for the tests to be conclusive.

D. RECOMMENDATIONS

1. It is recommended that the inclosures for the "all purpose nose" be built to much closer tolerances or supplied purposely oversize and without the fasteners installed so that they can be fitted to each airplane.

Low Temperature Tests of B-29 Fire Control System

Prepared by: O. E. Hopkins, Capt., A. C. Armament Laboratory

A. PURPOSE

1. The purpose of these tests was to determine the operational reliability of the B-29 fire control system and to determine the effects of low temperatures on the system.

B. FACTUAL DATA

1. Attached as Appendix I of this report is the test procedure written for these tests. The procedure was followed through Paragraph 3 on B-29 airplane No. 42-65214. The tests in Paragraph 4 were covered by tests made by Cold Weather Testing Detachment on B-29 airplane No. 42-24768, assigned to that detachment. The tests in Paragraph 5 were not made because the gunners had not had enough practice to be rated and the low temperature weather for the season had passed when the time came to make the tests.

2. The data taken in accordance with the test procedure will be found in Appendix II of this report.

a. The data concerning the effect of temperature change on the turret level are fairly reliable; however, they should not be used as specific quantitative data. They should only be considered as qualitative data which indicate that further investigation along these lines should be made.

b. The data concerning the accuracy of the computor are as reliable as it was possible to make them without the use of a computor checker.

c. The turret slewing speeds were taken with a stop watch by a man watching the turret. The data are very unreliable because the man who took the speed at plus 76°F was in the hospital when the speeds at minus 25°F. were taken and the readings had to be taken by another man.

d. The data on the static pull necessary to move the turrets are accurate from a comparative standpoint. The pull varies with the angle of elevation of the guns; however, all readings were taken under the same conditions. Only three turrets are recorded because heat had been applied to the upper forward and the tail when the readings were made.

C. CONCLUSIONS

1. The level of the turrets does vary with a change in temperature. Since the specification calls for the turrets to be levelled to within 0.5 mills with respect to the lower forward turret, the variation due to temperature change warping the fuselage is of sufficient magnitude to warrant further investigation.

2. The fire control system will operate satisfactorily when the free air temperature is as low as minus 58°F. when cabin heat is on. No tests were made with the cabin heat off.

D. RECOMMENDATIONS

1. It is recommended that the change in turret level due to temperature change warping the fuselage be investigated further.

Cold Weather Operation of Stewart Warner Corporation Model 904A Ground Heaters

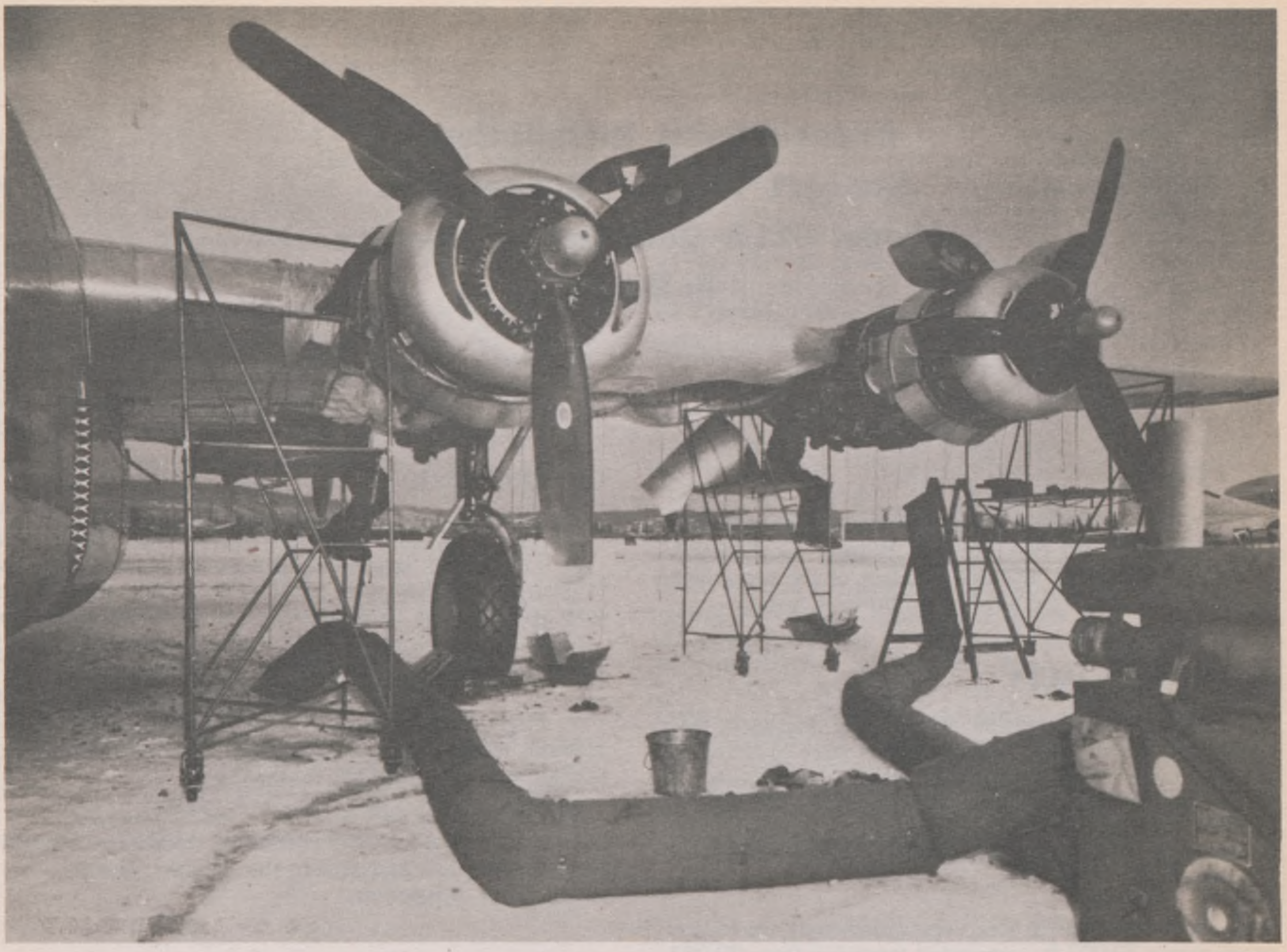
Prepared by: W. H. Giedt, 1st Lt., A. C. Equipment Laboratory.

A. PURPOSE

1. To report on the cold weather operation of two Stewart Warner Corporation Model 904A Gound Heaters during the 1944-45 test period at Ladd Field, Alaska.

B. FACTUAL DATA

1. The two test units were operated from 14 December, 1944 to 8 March, 1945. A record of the surface temperatures encountered during this period is included as



Engine overhaul—B-24

Appendix I of this report. The lowest temperatures were experienced during the period from 11 to 14 February, 1945, at which time the lowest temperature recorded was —45°F.

2. Attention is called to Appendix II for the operating and maintenance record of Stewart Warner Ground Heater, Model 904A, Serial No. X598.

3. Attention is called to Appendix III for the operating and maintenance record of Stewart Warner Ground Heater, Model 904A, Serial No. X599.

4. The engines required maintenance approximately 112 hours of operation. Maintenance on the heat exchangers was required approximately every 85 hours of operation.

5. The use of 73 octane fuel caused the formation of carbon deposits in the exchangers (see photographs Nos. 1 and 2). No similar deposits were noted with the use of 100/130 octane fuel.

6. It was noted at the close of the test period that the flexible ducts of the heater, Serial No. X598, were beginning to deteriorate.

7. Considerable difficulty was experienced in disassembling the heat exchangers due to the inadquacy of the bosses on the heat exchanger flanges. This unnecessarily increased the time required for heat exchanger maintenance.

8. Curves showing representative engine temperature rises during engine preheating are included as Appendix IV of this report. Engine preheating tests were run with a Stewart Warner Model 904A heater, an F-1 Utility heater, and a D-1 heater to obtain comparative data.

C. CONCLUSION

1. More maintenance was required on both the engines and the heat exchangers than is desired.

2. The return spring on the kick starter is not satisfactory.

D. RECOMMENDATIONS

1. Modifications should be made to the engine so that less maintenance is required.

2. The heat exchanger should be modified tosecure more satisfactory operation with 73 octane fuel.

3. The bosses on the heat exchanger flange should be made larger.

4. A stronger return spring for the kick starter should be provided.

Experimental Installation of Stewart Warner Corporation Model 911A Combustion Heaters in B-17G

Prepared by: W. H. Giedt, 1st Lt., A.C. Equipment Laboratory

A. PURPOSE

1. To report on cabin heating tests conducted in B-17G No. 43-38221 with two Stewart Warner Corporation Model 911A heaters installed in place of the secondary heat exchangers of the production heating system.

B. FACTUAL DATA

1. Under the supervision of company engineers two Stewart Warner Model 911A heaters were installed in place of the secondary heat exchanger now installed in production B-17G airplanes. The primary heated air system was disconnected. Attention is called to the photograph section of this report for further details of the installation.

2. Heater operation was very satisfactory up to approximately 20,000 ft., somewhat irregular from 20,000 to 25,000 ft., and definitely unsatisfactory above 25,000 ft. Although some malfunctions were noted in the operation of the thermal switch controls and the fuel metering controls, the primary difficulty above 20,000 ft. was ignition. For further information concerning the operation of the subject heaters during the flight testing attention is called to Appendix I.

3. Flight test data is included as Appendix II to this report. The following items are noted:

a. The highest temperature rises were obtained in the pilot's compartment. Heat supplied to this compartment was sufficient to meet winterization requirements.

b. Insufficient heat was supplied to the bombardier's and radio compartments to meet winterization requirements. Although the temperature distribution throughout these compartments was rather uneven, temperature rises observed indicate that approximately 75 to 80 percent of winterization requirements were met. Insulation of these compartments is a possible solution to this deficiency.

c. Although temperatures in the tail gunner's compartment showed that insufficient heat was supplied, it is not possible to make a definite statement to this effect, insofar as some of the ductwork in this compartment had been removed when the tail guns were removed and the compartment modified. However, it is felt that, if the airplane were to be heated by combustion heaters, use of a separate heater mounted in the waist compartment and supplying heated air to the tail compartment and for defrosting the waist windows should be considered.

C. CONCLUSIONS

1. The installation as tested was not satisfactory.

2. The subject heaters could be used for heating this type airplane if they were modified so as to give satisfactory operation up to the service ceiling of the airplane.

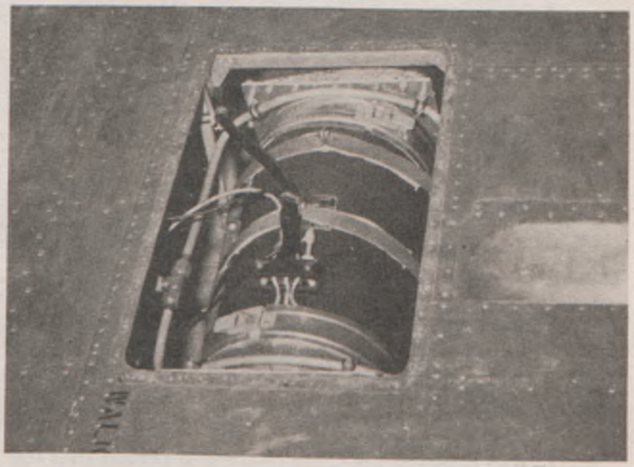
D. RECOMMENDATIONS

1. Flight tests should be conducted on improved combustion heater ignition systems and combustion heater operation at altitudes above 25,000 ft.

2. The thermal switch controls and fuel metering controls used in the subject installation should be removed from the airplane and sent to the Stewart Warner Corporation for inspection.

Appendix I

A. The Model 911A heaters as installed were supplied with ventilating and combustion air from scoops in the leading edges of the wings, and with fuel under pressure from the No. 2 and No. 3 engine pumps. The fuel-air mixture to each heater was controlled by a Stewart Warner fuel metering control (See Photograph No. 5).



Top view of surface combustion heater installed in place of the secondary heat exchanger. Note aluminum tubing above heater. Small holes in bottom side of this tubing discharge CO_2 in case of fire

Restricting solenoid valves used with the fuel shut-off solenoid valves permitted "Hi" and "Lo" control over heater output. Glow coil type ignition was used.

B. In general heater operation up to 20,000 ft, was satisfactory. Above 15,000 ft. on "Hi" output both heaters cycled on overheat. Above 20,000 ft. reignition of the heaters was very difficult. Results obtained on several different flights indicated that reignition above 24,000 ft. and at temperatures below —40°F. was impossible.

C. To obtain information on the cabin heating potentialities of the installation above 25,000 ft., the heaters had to be ignited at a lower altitude and the outlet air temperatures kept below the overheat value (250°F.) above that altitude. To accomplish this the fuel metering controls were moved from the wings into the radio compartment so that the fuel input to the heaters could be controlled in flight. Attention is called to the data of flight six in Appendix II taken at 30,000 ft., after heater operation to this altitude had been obtained by adjustment of the relocated metering controls. Although heater outlet air temperatures were held as close as possible to the overheat value during the climb, after leveling off at 30,000 ft. these temperatures dropped considerably. This was probably due to reduced ventilating airflow during the climb.

D. Data taken on flight six shows that, with the exception of the pilot's compartment, sufficient heat was not supplied to meet winterization requirements. However, it should be noted that the heater outlet air temperatures were not as high as possible, and, therefore the capacities of the heaters were not fully utilized. It is possible that with an improved type of ignition and proper adjustment of the fuel metering controls, sufficient heat could be supplied to meet winterization requirements.

E. After approximately 100 hours operation of the right heater it was noted that the fenwal switch in the Stewart Warner Thermo Switch Control controlling the restricting solenoid valve was apparently not operating properly. This was indicated by the fact that the light on the control panel (See Photograph No. 6) in the overheat circuit would go out when the heater went out on overheat, while the light in the restricting solenoid circuit would remain on. Replacement of the Thermo switch resulted in proper operation for a short period of time, after which the same malfunction was noted. This malfunction also appeared in the left heater control after approximately 150 hours of operation. Because of this the heaters were operated in "Lo" above 25,000 ft.

F. On a later flight after approximately one hours flight at 30,000 ft. and an outside air temperature of —65°F. with both heaters inoperative, attempts were made to start the heaters after descending to 24,000 ft. Although the right heater ignited, the left heater would not, apparently due to improper operation of the fuel metering control. It was noted that when the heater was turned "ON", the fuel pressure to the heater dropped to 0 psi. When the heater was turned off, the pressure to the heater rose to a value in excess of engine fuel pressure. Insofar as proper operation resulted when lower altitudes and warmer temperatures were reached, it is felt that the excessively cold temperatures encountered may have affected this control.

Cold Weather Tests of Heating Oil and Batteries on Types C-13 and C-13A Auxiliary Power Units

Prepared by: C. E. Wood, Capt., A. C., Equipment Laboratory

A. PURPOSE

1. To report experimental tests of various methods of heating the subject power plants with Prefection Stove Co. engine coolant heaters.

2. To report the performance of the coolant heaters used during the experimental tests.

B. FACTUAL DATA

1. GENERAL.

a. The crank case oil and the batteries on the standard winterized type C-13 A. P. U. do not receive sufficient heat from the heated coolant to permit starting their engines by cranking electrically.

b. Experiments were undertaken to find a simple means of supplying the necessary heat by utilizing:

(1) Heat from the exhaust stack of the Superfex Model 460 Coolant Heater (new blower type);

(2) Warm coolant from the engine block in a heat exchanger located under the batery;

(3) A mixture of warm coolant from the engine block and hot coolant from a Model 454 (Modified Standard Model 452) coolant heater in a heat exchanger located under the battery.

c. The experimental equipment was installed on two Type C-13 and one Type C-13A auxiliary power units described in Table I, page 125.

d. New types of coolant heaters, Superfex Model 460 and Perfex Model 454, were available and undergoing service testing by the Cold Weather Testing Detachment. The latter heater is a standard model 452 modified with a coil type coolant heat exchanger and electric ignition. Both models were used in these tests to study their performance.

2. BATTERY HEATING.

a. Standard Winterized Type C-13 A. P. U. Unit No. 25.

The following temperature measurements indicate typical results obtained with heat applied to the engine coolant only:

Date* 1945 Jan.	Average Period O. A. T.** °F.	Hrs.-Min.	°F. Average Temp. Rise above O. A. T. Cyl. Hd.	°F. Battery
18	—7	7:25	142	13
19	1	6:05	126	7

*Table I Exhibit A
**Outside Air Temperature

b. Exhaust Gas Heat Exchanger. Utilizing heat from the exhaust of the Model 460 heater provided a maximum temperature rise in the battery of 65 degrees at —39°F. with an average temperature rise of 57 degrees during a period of 8 hours and 55 minutes. See Table III, 13 February 1945 and Photographs Nos. 2 and 6, Exhibit B.

c. Mixing Hot Coolant with Warm Coolant from Engine Block, Unit No. 86. The average temperature rise in the battery on Unit No. 86, which was equipped with the by-pass shown in Exhibit C, was 39 degrees during the same period quoted in Paragraph B 2.b. The battery heater is shown in Exhibits D.1 and D.2 and Photograph No. 8, Exhibit B.

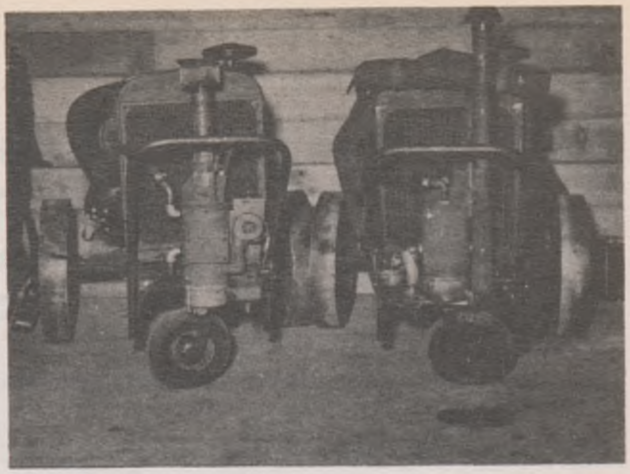
3. CRANK CASE OIL HEATING.

a. Standard Winterized Type C-13 A. P. U. Unit No. 25. The highest average temperature rise obtained in the oil of Unit 25 before application of the battery heater was 53 degrees at —7° F.O A.T., Table I, 18 January 1945. The average in the cylinder head was 136°F. The actual oil temperature at —33°F. O. A. T. was 5°F., Table III, 13 February 1945. The standard method, i. e., heating crank case oil by circulating hot coolant in the cylinder head of the engine, does not provide sufficient temperature rise to maintain the oil fluid at outside air temperatures below —40°F.

b. Heater Exhaust Pipe under Crank Case Unit No. 79. The average temperature rise in the oil of Unit 79 was 77 degrees at —26°F. average O. A. T. The additional heat obtained from the exposed exhaust pipe on Unit No. 79 produced a satisfactory temperature rise in the oil, and it is obvious that hot air only without heated coolant in the engine block would accomplish the same result. All considerations of housing the pipe to reduce fire hazard point to the advantage of using blast heat at lower temperatures.

4. CRANKING AND STARTING.

a. The use of external heat for cranking and starting Types C-13 and C-13A A. P. U.'s is necessary at outdoor temperatures below 10°F. A heating system should be developed to produce 70 degrees rise in the oil and batteries at —65°F. O. A. T.



Coolant heaters mounted on auxiliary power units

b. The Type R-1 generator on the Type C-13 A. A. P. U. cranks the engine satisfactorily at approximately 0°F. oil temperature; whereas, the Type P-1 generators on the Type C-13 A. P. U. do not crank the engines satisfactorily at oil temperatures below 10°F.

c. When operating at normal temperatures, the Type C-13A carries overloads of short duration with very little loss in speed of its engine. The type C-13 loses considerable speed and/or stalls.

5. HEATERS.

a. The Model 460 heater has a number of features that warrant improvement:

(1) Tilting affects the level of gasoline in the feed wick chamber, which, in turn, affects the rate of feeding gasoline to the burner and, therefore, the heat output.

(2) The height of the wick is adjustable and marked LOW and HIGH. Proper wick adjustment cannot be determined without making several trial settings if the A. P. U.'s stand on rough ground.

(3) The wire to the ignitor is not supported between connections and is not protected against mechanical damage.

(4) The wire is provided with a cord type connector but the using personnel do not always separate the

TABLE I

Identification No.	79	25	86
Manufactured by		The Wauhesha Motor Co.	
Unit Model	A-APU	C-APU	A-APU
Unit Serial No.	300148	305342	13289
Engine Model	1CK67-143	1CK67-C	1CK67
Engine Speed, rpm	1900	3000	1900
Order No.	42-18505P	43-66385	42-18505P
Crank Case Oil, Detergent, Spec. No.	2-104B	2-104B	2-104B
Capacity, KW	5	7.5	5
Volts	28.5	28.5	28.5
Amps	175	263	175
Generator Type	P-1	R-1	P-1
Gen. Mfr.	Westing-house	Jack and Heintz	Westing-house
Mfg. Type	91A987GR3	R-1	91A987GR3
Perfex Heater Model	460	460	454 (452 modified)
Wick Size	1/2"	1/2"	Standard
Method of Battery Heating	Heater Exhaust	Engine Coolant	Engine coolant with hot coolant by-pass.
Winterization Kit Applied	yes	yes	yes
Electric Starting (Std)	yes	yes	yes

connector when removing the ignitor resulting in breakage of the terminal lugs at the igniters.

(5) Some evidence points to leaking needle valves as causes of fires with the Model 452 heater. The Model 460 heater incorporates a similar float operated needle valve. It is believed greater closing pressure on the valves would be beneficial.

(6) Several operations are required to start or shut off the heaters, involving "wait periods" described in Appendix A, Paragraph B.3.a (6). Flight line personnel do not always wait the required two minutes for gasoline to reach the burner when starting the heater before pressing the ignitor switch. This overheats the ignitor element causing rapid deterioration. Likewise, when shutting off the heater, some persons fail to comply with one or another of the operations. This experience indicates the necessity for reducing the number of operations for starting and stopping the heaters.

(7) When the heaters are allowed to stand idle for a considerable period of time with the gasoline ON and the wick adjustment in the feeding position, the gasoline syphons from the burner by capillary action and drips to the ground. Igniting one of the heaters in this condition failed to produce a fire, but this has been the cause of fires with the Model 452 heaters.

(8). The condition mentioned in B.5.a. (7), causes an excessively high flame when the burner is ignited and flame emits from the stack.

b. Model 454 Heater.

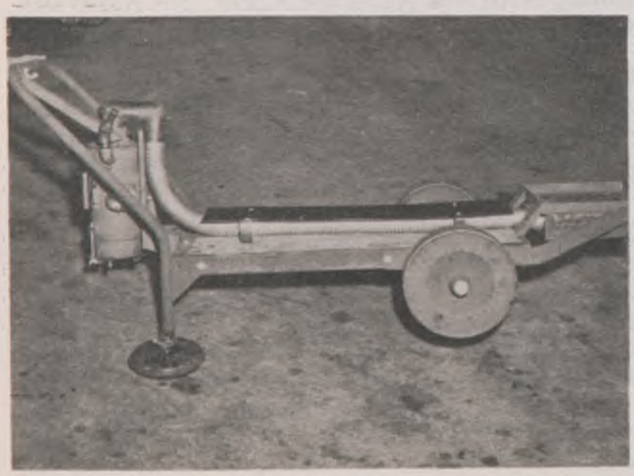
(1) The coil type heat exchanger being of small diameter tubing with 3/8" I.P.T. connections causes restriction to the flow of the coolant resulting in an excessively high temperature rise within the heater.

(2) The electric ignition and associated modification parts must be disconnected and the igniter must be removed to light the burner manually in the event the electric igniter fails. This is a difficult operation. Likewise, igniting the burner through the peep-hole is difficult.

c. The capacities of both models of heaters are more than ample to heat the coolant and batteries of Type C-13 A.P.U.'s.

d. The current drain from the battery to operate the blower on the Model 460 heater is negligible, 1/10th amp.

e. Wind had no noticeable effect upon the burner of the Model 460 heater when an A.P.U. was placed in the blast from the propeller of a Type B-25 airplane.



Coolant heater used to heat oil and battery of auxiliary power unit

The heater was approximately 6 feet from the propeller.

f. The sizes of the pipe connections in the heaters and also in the engine blocks of the auxiliary power plants were found to be too small for good functioning of the thermosyphon system.

C. CONCLUSIONS

It is concluded that

1. The following modifications, if incorporated into the Superfex Heater Model 460, will accomplish desirable improvements:

a. Incorporate the float and wick chambers in the base of the heaters, or as close to the burner as possible to reduce the changes in fuel levels that occur when the heaters are tilted.

b. Equip the float valve assembly with "snap action" to operate the needle valve and provide as much spring pressure on the needle valve as possible.

c. Provide a socket type receptacle for the igniter which will permit supporting the connecting wire on the heater and protecting it from mechanical damage. In this case, the igniter would have contacts to mate with the contacts of the socket and the cord connector would be unnecessary.

d. Mount the control switch on a junction box with the main fuse inside. Provide a means of access to the fuse that does not require the use of tools. Provide armored wire for the main lead and eliminate the fuse holder type cord connector.

e. Eliminate the "wait periods" in starting and stopping the heater. Each of these operations should be accomplished with one movement.

f. Provide larger pipe connections for coolant lines, preferably not smaller than one inch I.P.T. In cases where kits are supplied with the heaters and coolant lines are of rubber hose, the hose and connecting fittings should be AN standards available in Army Air Forces stock.

g. Provide flame quenching type smoke jacks.

2. The Model 460 heater has sufficient capacity to heat all components of the Types C-13 and C-13A A.P.U.'s and can be substituted for the Model 452 heaters now in service. The alterations to the heater bracket required to make the substitution can be accomplished by the Services.

3. The advantage of the electric ignition feature of the Model 454 over the former manually ignited Model 452 is largely outweighed by the poor performance of the new coil type heat exchanger. The expenditure of man hours to make the conversion is not justified.

4. The use of external heat for heating the components of the types C-13 and C-13A A.P.U.'s is required as follows:

a. Coolant (60-40 mixture of ethylene glycol and water) at temperatures below —40°F.;

b. Crank case oil, detergent, Specification 2-104B, at temperatures below 10°F.;

c. Batteries, at temperatures below 10°F.

5. Since the oil and crank case require the greatest amount of heat, primary heating should be applied to them and secondary or waste heat allowed to heat the coolant.

6. The exhaust method of supplying heat to the oil and battery was tested as a possible immediate remedy, yet it was recognized as not being the most desirable method, due to

a. Fire hazard, from oil accumulation on the floor of the enclosure coming into contact with the hot exhaust pipe;

b. Condensation from the products of combustion collecting in the exhaust pipe and battery heater.

7. The most advantageous method of accomplishing the conclusions of Paragraph C.5., would be with the use of hot air blasts under the crank case and battery. The winter enclosures for the Types C-13 and C-13A A.P.U.'s is sufficient insulation to maintain heat for warming the coolant.

8. Heaters, similar to the Model 460, could be designed with an air heat exchanger and a dual purpose blower; not only to provide forced draft to the burner, but also to force hot air through ducts to the crank case and battery.

D. RECOMMENDATIONS

It is recommended that

1. Battery heating kits be furnished to the services for application to winterized Type C-13 A.P.U.; the procurement to be on the basis of past procurement of winterization kits containing Model 452 heaters, and future procurement of kits containing the Model 460 heater. The battery heating kits to consist of the following:

a. Heater, Auxiliary Power Plant, Exhibit D-1;

b. Case, Auxiliary Power Plant Battery Heater, Exhibit D-2;

c. Necessary ¾" I.D. rubber hose and fittings to connect the battery heater to the coolant heating system in the manner illustrated by the Schematic Diagram, Exhibit C.

2. The procurement recommended in Paragraph D.1. be considered an immediate remedy to improve the utility of the winterized Type C-13 A.P.U.'s.

3. Procurement of the Model 460 Heater be limited to necessary requirements for

a. Replacing salvaged Model 452 heaters on existing Type C-13 A.P.U.'s;

b. Type C-13 A.P.U. winterization kits procured in the immediate future and until such time as an improved type heater is available.

4. The improvements suggested in Paragraph C.1., be incorporated into the Model 460 heater at the earliest date possible.

5. A project be initiated to develop a suitable hot air blast type engine and battery heater suitable for application in the field to Types C-13 and C-13A A.P.U.'s.

Generator and Starter Failures During Cold Weather Tests

Prepared by: C. E. Wood, Capt., A. C. Equipment Laboratory

A. PURPOSE

1. To report failures of aircraft electric generators and starters that occurred during the Cold Weather Test Program of 1944-45.

B. FACTUAL DATA

1. A list of all failures of the subject equipment is attached as Appendix I. Explanatory notes under "Remarks" state briefly the cause of each failure; however, attention is directed to the following specific items:

a. Item 4. All but one of the bolts holding the magnet frame to the mounting flange were found broken and it is claimed, by those who removed it, that the paint at the joint was not cracked. It was believed that the bolts had been drawn too tight when the generator was assembled, resulting in their being over-stressed. Inasmuch as the generator was not damaged, new bolts were applied and tightened to 125 lb. in. torque after which it was tested and re-applied to the same engine at the next 100-hour inspection. The new bolts have not failed to date, substantiating the belief that the original bolts were overstressed when applied.

b. Item 19. None of the starters on the airplane were mounted on 1/16" spacers to prevent contact between the meshing rod and the engine accessory shaft. There was evidence also of interference on No. 4 Engine, but no damage. There was no evidence of interference on Engines Nos. 1 and 2. Four starters, lubricated with special lubricants (Materials Lab. project) were installed, using the 1/16" spacers. There was considerable engine oil (synthetic) on the spline shafts and jaws of all starters. Also, the meshing mechanisms were stiff at cold temperatures. Two were set aside and tested after cold soaking at —37°F. (Avg. of previous 12 hrs.):

(1) Type 915, Model 4, Style F, Solenoid EA-123228, Serial Nos. A2292 and A2293. No. A2293 was equipped with an improved type solenoid.

(2) Both were very difficult to move by hand. Jaws would not return fully when released. Meshing operated satisfactorily with a warm battery, but would not operate with a 50% charged cold battery. No difference in operation could be detected that might be attributed to the improved type solenoid on No. A2293.

(3) The engine oil on the splines and jaw was judged to be the largest contributing factor to stiffness at cold temperatures.

c. Item 20. It was noticed that the starter applied, and then removed on 30 January 1945, had not been mounted on a 1/16" spacer. This was due to the lack of T. O. authority to apply the spacers.

d. Item 21. There was excessive oil in the gear case and in this instance, it had flowed into the motor around the outside of the bearing at the flywheel end (sliding fit).

e. Item 8. While the primary cause of the failures was congealed engine oil on the splines, Serial No. 3113 also had a worn solenoid valve sleeve which when meshed manually would cock and become immovable. The JH-999 solenoid was replaced, the jaws and splines were cleaned and relubricated, and the starters were replaced on the same engines after which they operated satisfactorily.

2. The failures resulting in burned out motors, broken jaws and spline shafts, except Item No. 19, occurred during attempted cold starts of engines.

a. In the cases where parts were broken, Item 12, broken jaw, was not due to oil in the clutch. Apparently, the clutch failed to function. The broken screw shafts, Items 17 and 18, may have been caused by oil in the clutches.

b. Motors were burned out by holding direct cranking ON too long. Frequently the temperatures encountered when cold starts are attempted are different from those anticipated when the engines were diluted, resulting in the engines being unduly stiff when starts are attempted

3. The failures referred to in Par. 2 are a repetition of those encountered and reported during the cold weather tests of 1943-44. A large part of the testing activity this season was again devoted to making cold starts, and inasmuch as the primary object of the tests was to ascertain if the engines could be started, possible resultant damage to starters was of secondary consideration and resulted in the failures cited.

4. There were, in addition to the failures listed in Appendix I, thirteen failures on Type P-63 Lend-Lease Aircraft wherein the JH-1729-35 bolts broke on Type JH5LR Starters. These, together with failures of the Jack & Heintz Equipment listed in Appendix I, were reported to the Jack & Heintz Company by their local representative.

5. All failures of Eclipse equipment were reported to Eclipse Pioneer Division of Bendix Aviation by their local representative.

C. CONCLUSIONS

1. The use of the inertia feature of combination starters, for making cold starts, should be discontinued in order to alleviate breakage in the starters.

2. The number of burned out motors is indicative of the status of the progress of cold starting, and until such time as the technique is perfected, similar results can be expected with existing starters.

D. RECOMMENDATIONS

1. That the information contained herein be referred to the project engineers for such action that they may deem necessary.

Type D-2 Auxiliary Power Plants, Cold Weather Tests

Prepared by: C. E. Wood, Capt., A. C. Equipment Laboratory

A. PURPOSE

1. To report the general performance of the subject power plants during the cold weather testing program.

B. FACTUAL DATA

1. There have been no electrical or mechanical failures of the power plants during the season and minor malfunctions of that character were in the nature of fouled spark plugs and minor adjustments.

2. It was recognized that, like any gasoline engine, they would be difficult to start at low temperatures. This was true of a unit installed in E. T. O. U. Airplane No. 43-48088, Type C-47A, which was extremely difficult to start at outside temperatures below 0°F. However, reports indicated that the Type D-2 units on Type B-29 airplanes (standard installation) were started at various temperatures (not recorded) much lower than 0°F.

3. The matter was investigated in flight on Type B-29, Airplane No. 42-65214, which is equipped with a Model 906 Stewart-Warner Heater for warming the A. P. P. The unit was equipped with thermocouples at the locations listed in Appendix A, and temperatures were recorded for a period of approximately 6 hours. They are listed in the Log of Observations and shown in graph form in Appendix I.

4. The results indicate that air leakage from the presurized cabin maintains the adjacent compartment, in which the A. P. P. is located, approximately 10°F. higher than O. A. T. in the range from —20°F. to —36°F. The A. P. P. cooled rapidly and followed the compartment temperature closely.

5. During descent, the compartment and A. P. P. temperatures increased more rapidly than O. A. T. and the engine temperatures followed closely. This explains the somewhat better results that were obtained in starting the A. P. P.'s in Type B-29 airplanes.

C. CONCLUSIONS

1. The results suggest possible modifications for warming the A. P. P.'s during flight.

a. They should be housed in a sturdy but easily removable enclosure, and heated by:

(1) Combustion type heater similar to the experimental application on Airplane No. 42-65214, but one not dependent on rammed air as this type cannot be used on the ground, or

(2) Waste cabin air conducted to the housing through a duct and controlled by a pressure relief valve at the duct entrance, or

(3) Thermostatically controlled electric heaters in the crank case oil and at the cam shaft locations, and cabin air piped to the carburetor.

D. RECOMMENDATIONS

1. That this report be referred to project engineers concerned for consideration in connection with studies of the subject now under way.

Electrical Loads, Feathering Propellers at Cold Temperatures and Hydraulic Pump Motors

Prepared by: C. E. Wood, Capt., A. C. Equipment Laboratory

A. PURPOSE

1. To report electrical loads encountered at low temperatures while feathering and unfeathering propellers actuated by hydraulic systems.

2. To report investigations of malfunctions of hydraulic pump motors used for propeller feathering.

B. FACTUAL DATA

1. Equipment involved:

a. Airplane Type C-47A-30-DK, No. 43-48088. Left Engine: Oil, Spec. 1100A. Propeller, Hamilton Standard (hydraulic). Propeller Fluid, Spec. AN-VVO-366 (Test installation). Right Engine: Oil, Synthetic, Spec. PPO-265. Propeller, Hamilton Standard (hydraulic). Propeller Fluid, Engine Oil (Standard installation).

b. Hydraulic Pump, Motor Driven, Pesco Model AR-280BH; operating pressure, max. 1200 p.s.i. (The by-pass relief valve spring had been replaced to reduce the max. operating pressure to 100 p.s.i.) Duty-Lift pump for delivering hydraulic fluid AN-VVO-366B from bomb bay tank to standard propeller feathering pump in nacelle, B-24J airplane. (Test installation).

c. Hydraulic Pump, Motor Driven, Pesco Model AR-280-BHC; B-17G Airplane; standard installation; engine oil, Synthetic Spec. PPO-265.

2. During propeller feathering tests while in flight on 29 December 1944, the main fuses for both engine driven generators were blown on the Type C-47 airplane described in Par. B.1.a. The propellers were feathered and unfeathered successfully. The airplane is equipped with a Type D-2 Auxiliary Power Plant which was used to restore power to the electrical system. The main generator fuses are 100 amp. capacity and located in the nacelles.

3. Electrical malfunctions in feathering systems of the hydraulic type have been fairly common during the test program. This is particularly true of the standard installation on engines filled with Spec. 1100A oil wherein viscous oil at low temperatures imposes heavy electrical loads on the system when the propellers are feathered On two engine aircraft, if one engine fails and the main generator circuit protector of the other generator opens when the propeller is feathered, the airplane is left with battery power only unless the circuit protectors are accessible to the crew.

4. To avoid repetition of the failure, 100 amp, circuit breakers (Spencer) were installed in place of the fuses in the Type C-47A airplane. They have successfully withstood the overloads of subsequent feathering tests, but information is not at hand to determine if their inverse time-current ratio is adequate to protect the circuits on all overloads that might be encountered.

5. Personnel conducting the feathering tests were requested to observe the electrical loads while feathering. The observations, together with pertinent data, are listed in Appendix I. The installations using hydraulic fluid are for test purposes only. The synthetic engine oil, Spec. PPO-265 is still in its testing stage; however, it is in use on A. T. C. airplanes, Type C-47, on regularly scheduled flights on the Alaskan Div.

6. Attention is directed to the current demand, Appendix I, with synthetic oil at —52°F. of 150 amps. and 125 amps. respectively, for the feathering and unfeathering operations, whereas, with regular Spec. 1100A oil at —26°F., the current demand was 190 amps. and 120 amps. respectively. With the latter oil, successful feathering is problematical at low temperatures. The results with the test systems using hydraulic fluid are quoted as a matter of interest only.

7. The motor described in Par. B.1.b. overheated while operating at the reduced load indicated and was stopped before complete burn out occurred. It had operated satisfactorily at 10,000 ft. Alt., 20°F, and failed approximately 30 minutes later when operated at high altitude, —33°F. The motor bearing at the pump end (sealed type ball bearing) was found to be rough and stiff.

8. The motor described in Par. B.1.c. was burned out and its corresponding bearing was found to be in the same condition. The motor and pump had operated satisfactorily on a previous flight at —56°F wherein the propeller feathered in 14 seconds and unfeathered in 7.3 seconds. It failed on the repeat test —59°F in 15 seconds, while feathering, by stalling.

9. The inner races of both bearings were corrugated washboard fashion. The evidence points to differential expansion, and contraction—expansion of the inner race from heat in the armature while the outer race was contracted from cold.

10. Other pump motor failures have been due to overloads while pumping viscous oil, principally the regular Spec. 1100A, during the propeller feathering tests.

C. CONCLUSIONS

1. PROPELLER FEATHERING.

a. Two-engine aircraft, equipped with main generator fuses having less than 300 amp. capacity, should be modified to conform to latest specifications requiring circuit breakers. The circuit breakers should have an inverse time-current ratio suitable for the current-time loads quoted in Appendix I.

b. The circuit breakers should be relocated accessible to the crew to permit re-closing in the event they open.

2. MOTOR BEARINGS.

a. The ball bearing failures described are due to either:

(1) Use by the manufacturer of contact fitted ball bearings, or

(2) The tolerances for machining the bearing fit on the armature shaft are too great and, in some instances, the inner races of the bearings are expanded when pressed onto the shaft.

D. RECOMMENDATIONS

1. That this report be referred to those concerned for such further action that they deem necessary.

Main Generators - Type B-29 Airplane, Cold Weather Tests

Prepared by: C. E. Wood, Capt., A. C. Equipment Laboratory

A. PURPOSE

1. To report on the operation of Type R-1 generators of two manufacturers when intermingled on one airplane.
2. To report difficulties experienced in paralleling generators on the Type B-29 airplane.

B. FACTUAL DATA

1. Three Type R-1 generators, engine driven, G. E. Model 26M73B-6, were installed on a Type B-29 airplane and intermingled with remaining J & H generators as follows:

a. Airplane No. 42-24612

Engine No. 1—Outboard JH-2000
Engine No. 1—Inboard JH-2000
Engine No. 2— G. E.
Engine No. 3— G. E.
Engine No. 4—Inboard JH-2000
Engine No. 4—Outboard G. E.
Date G. E. generators installed — 29 January 1945.

2. The G. E. generators, being interchangeable, were installed by the crew and allowed to remain in service without special attention. There have been no failures to date, nor malfunctions; however, it was reported that the adjustments for paralleling the generators were difficult with either type. This had no relation to cold weather.

3. Since it would not be possible, while on a cruising flight, to obtain a large electric load that would remain constant and remit making the necessary adjustments for paralleling, observations were made on a flight during which numerous landings were made. The operation of the landing gear and the wing flaps imposes the largest single load on the generators.

4. A log of observations is attached as Appendix I, which indicates the adjustments made to the voltage regulators. Since it was not possible to obtain a large steady load, it was not possible to check the division of load between the generators under such conditions.

C. CONCLUSIONS

1. It is not practical, nor is sufficient steady load available, to properly adjust the division of load between the generators on the Type B-29 airplane while in flight.

2. An external means should be provided for applying an electric load to the generators.

a. Preferably while the airplane is on the ground.

b. While on test flights for the purpose of adjusting the generator regulators.

3. It is possible to operate the airplane engines during cold weather a sufficient period of time to accomplish the adjustments without overheating the engines.

4. Any external loading means developed should be compact, easily portable and preferably of a fold-up type.

D. RECOMMENDATIONS

That those concerned give consideration to the problem presented in the conclusions of this report with a view toward development of a suitable means of loading engine-driven generators externally.

Power to Operate Landing Gear Retraction Motors at Low Temperatures, Type B-29 Airplane

Prepared by: *C. E. Wood, Capt., A. C. Equipment Laboratory*

A. PURPOSE

1. To report measurements of power input to landing gear retraction motors when operated at low temperatures.

B. FACTUAL DATA

1. Those present: Major S. C. Britton, AC, Materials Lab. Rep. Captain C. E. Wood, AC, Equipment Lab. Elect. Branch Rep. Mr. G. V. Roark, Tech. Rep., Texas Oil Company.

2. Equipment:

a. Airplane Type B-29 No. 42-65214.

b. Power Source—Type C-APU (Dual Unit).

c. Ammeters, with shunts in main retraction motor circuits.

d. Right retraction motor lubricated with Royco 6A and Royco 5O, standard factory lubricants.

e. Left retraction motor lubricated with Texas TG-204 (equivalent to proposed AN Spec. intermediate grease).

3. The primary purpose of the test was to ascertain differences in the lubricants at low temperature and this phase of the test is the subject of M/R, TSEAL-4-M4966-VII. It concludes that differences in operation of the landing gear that might be due to lubricants are not discernable at temperatures above —20°F.

4. Of interest to Dept. TSEPL-3, is the power required to raise the landing gear:

a. Airplane on jacks in hangar approximately 72 hours preceding test.

Gear	Test Temp. °F	Volts at A.P.U.	Amps at Intervals Indicated Seconds Int.	5	10	15	20	25	30	40	Time Up Seconds
1. Left	73	Low*	260	90	....	180	196	186	164	155	38
Right	73	Low*	260	100	....	185	200	210	203	180	46
2. Left	70	Low*	....	90	....	168	185	192	185	150	46
Right	70	Low*	180	95	....	175	193	202	205	200	51

* Excessive voltage drop in long cables to A.P.U. outside of hangar. Volts at A.P.U. 30V. Insufficient power to raise gear simultaneously.

b. Airplanes on jacks outside of hangar approximately 24 hours preceding test. Length of wire to A.P.U. approximately 10 ft.

Gear	Test Temp. °F	Volts at ret.mot.	Amps at Intervals Indicated Seconds Int.	5	10	15	20	25	30	40	Time Up Seconds
Single—1st Operation											
Left	—3	30*	260	115	160	175	185	163	......	......	30
	—3	30	295	115	170	204	205	195	180	......	30
Single—2nd Operation											
Left	—3	30	240	105	153	182	175	155	......	......	28
Right	—3	30	300	110	165	198	202	190	180	......	30
Simultaneous—3rd Operation											
Left	—3	30	......	95	120	170	190	165	150	......	28
Right	—3	30	......	110	160	195	202	190	......	......	31
Total				205	280	365	392	355			

* Volts at A.P.U. 28.5, no load.

C. CONCLUSIONS

1. The data contained in this report is submitted as information and no action is necessary.

Type C-12 Engine Driven Power Plant, Cold Weather Tests

Prepared by: *C. E. Wood, Capt., A. C. Equipment Laboratory*

A. PURPOSE

1. To report experiments in heating a Type C-12 Power Plant (Bardco) using a Superfex Model 460 Coolant Heater.

B. FACTUAL DATA

1. Four Type C-12 power plants, two manufactured by Bardco and two manufactured by Buda were received by the Cold Weather Testing Detachment for service

testing under cold weather conditions. This phase of the testing will be reported by the Cold Weather Testing Detachment.

2. Difficulty was experienced in providing a 240 V. 3 phase load and, after advice was received from the Base Engineer that it would not be possible to connect the power plants to any of the base facilities without extensive power line changes, it was decided to use a water rheostat. Although it was late in the season, one was constructed locally and put to use but there was not sufficient time to complete life tests.

3. This made a Bardco unit available for an experimental installation of a coolant heater, which was started 10 February and completed 16 February. Photographs are attached as Exhibit A, showing the installation located on the back wall of the engine compartment. This location was the only space available inside of the unit housing.

4. A coolant type battery heater (similar to the type used on Type C-13 A.P.U.'s) was installed in the bottom of the battery box and connected between the engine block and the coolant heater inlet. The heater outlet was connected to the coolant manifold on the engine with a ¼" copper tube vent line to the radiator.

5. The location of the coolant heater proved to be too high for adequate circulation of the heated coolant and the installation was altered by providing a hot coolant stand pipe reaching to the roof of the canopy. The hot coolant line was then connected to the pump outlet. Results were somewhat better, but circulation was still too slow. The experiments were discontinued as it was evident that the coolant heater would have to be located near the base of the engine for good results, and this could not be accomplished within the probable remaining period of cold weather.

6. Attention is directed to the blank panel in front of the radiator shown in the photographs. The radiator is not provided with a means of closure. Likewise, the side panels of the housing contain louvers without a means of closing them and the bottom of the compartment is open. A makeshift means of closing the louvers was provided for the experimental tests. The bottom was left open.

7. The Buda unit has a bottom closure but no means of closing the side louvers and radiator.

C. CONCLUSIONS

1. Reasonably tight enclosures should be provided for the engine compartment with a means of regulating the radiator and louver openings to:

a. Control the engine temperature while the unit is operating,

b. Permit closing the compartment while heating the engine.

2. A heater should be provided for cold weather operation to permit starting the engines after stand-by. The hot air blast type would be preferable to permit mounting in high location if necessary with the hot air conducted underneath the crank case, battery and carburetor through ducts.

D. RECOMMENDATIONS

1. The conclusions of this report are recommended for the consideration of the project engineers and such action that they deem necessary.

Oil and Fuel Pressure Gage Installations

Prepared by: T. C. Warner, Capt., A. C. Equipment Laboratory

A. PURPOSE

1. To report on the operation of various types of oil and fuel pressure gage installations in aircraft at Ladd Field, Alaska, during the winter of 1944-45.

B. FACTUAL DATA

1. Airplanes assigned to Extreme Temperature Operations Unit were winterized at the Dayton Army Air Base in accordance with Technical Order 05-70-6. All pressure transmitter lines were serviced by TSEPL-3G personnel. A record of maintenance required and troubles encountered with these installations is contained in Appendix I.

2. The amount of servicing required on the A-1 pressure transmitter on other aircraft at this field was more than that on Extreme Temperature Operations Unit aircraft. It was found that the old style, one piece caps (AN820-2) were still in use on many airplanes. They were replaced by the new style, two piece caps (AAF Stock No. 6300-541686) and the overall maintenance required has been decreased. The A-1 pressure transmitters have worked equally well at all temperatures encountered. The Technical Order requirement of servicing lines on 50-hour inspection is adequate. There have been some cases, however, where more frequent servicing was required. Servicing at 50-hour inspection alone is considered to be too often under low temperature conditions. Every effort should be made to improve this condition.

a. One trouble was encountered with fuel gage installations. On the P-61 the fuel gages consistently read below zero with engines off. Servicing of the lines would bring the gage back to zero but in a short time they would fall below zero again. This condition was also noted on other types of aircraft, the error varying from 0 to 3 psi. This was not apparent in oil gages due to the difference in the scale of the gages.

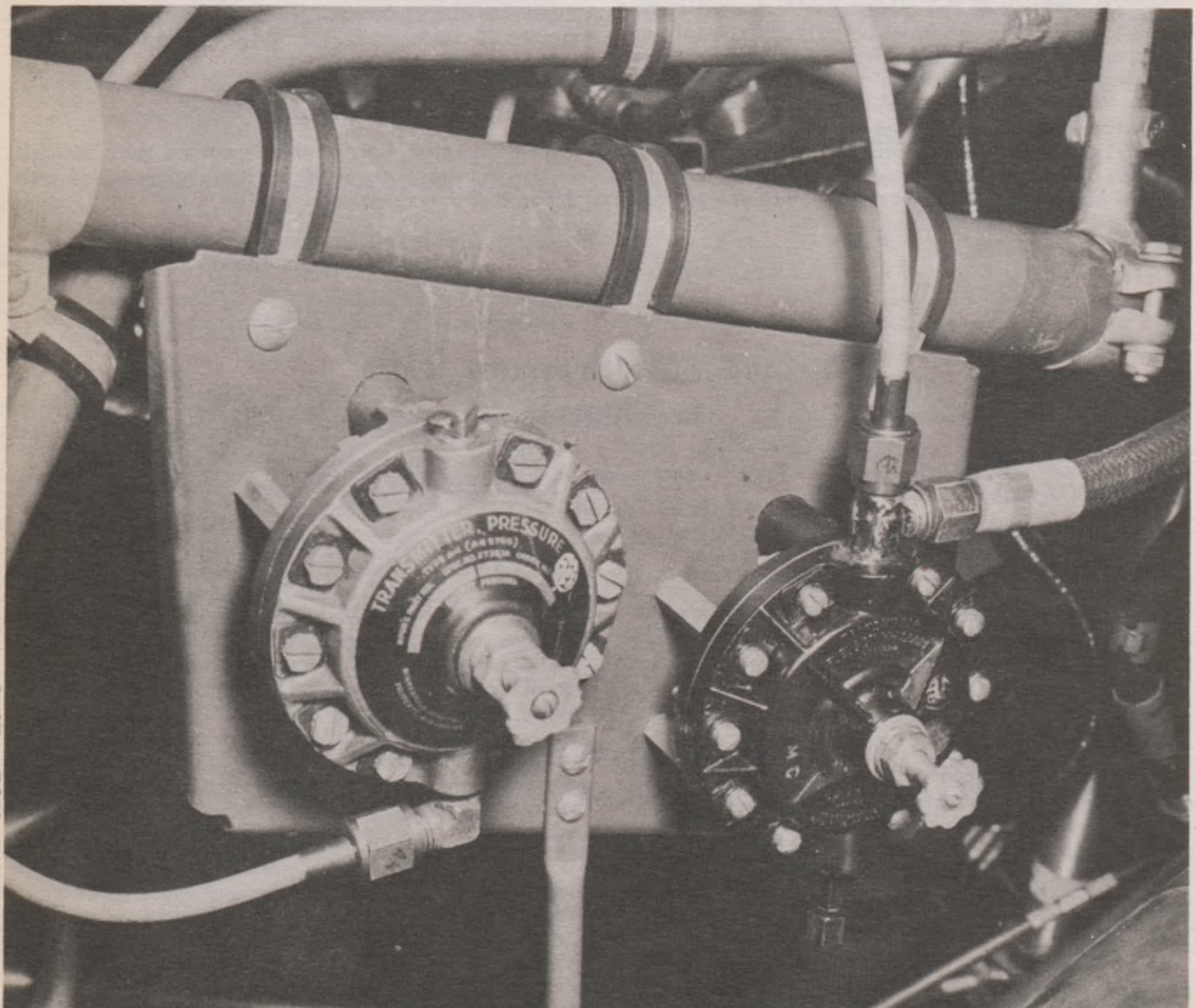
b. One C-47B and one C-54 airplanes were modified by installing a restricted gage fitting, Rochester Mfg. Co., Part No. 2162-R4A, in each oil gage line. Considerable trouble had been experienced with fluctuations in the C-47B and this was corrected by installation of the restriction. This installation has been satisfactory down to —37°C. (—35°F.) Fluctuations, to a lesser extent, were noted in the C-54 oil gages. The restriction has been an improvement and has been satisfactory; however, no low temperatures have been encountered with this installation.

3. The autosyn type pressure gage system has been satisfactory; only one indicator failed out of a total of 12 indicators and 24 transmitters in Extreme Temperature Operations Unit aircraft.

4. In the C-47A, considerable fluctuation has been present in the direct connected oil pressure gages. In an effort to correct this trouble, a restricted gage fitting, Rochester Mfg. Co., Part No. 2162-R4A, was installed. This restriction worked very well at moderate temperatures (down to —20°F.) but at —37°F. the oil pressure indication was only 50% of normal indication in flight. The restrictor was removed from this airplane.

a. From a winterization standpoint, direct connected gages are considered satisfactory except that they must be serviced frequently at low temperatures. A C-47A, operated by an Allied Government, was inspected and a new type of oil gage system noted. This airplane originally had an ordinary direct connected gage system. It had been modified to include a filler line from the tee, Part No. 43-A-14984, to the airplane hydraulic system. A needle valve installed on the instrument panel is provided to allow opening of this line from the hydraulic system to the oil gage line. This installation allows servicing of the line at any time without any equipment except that which can be permanently installed in the airplane.

5. P-63 aircraft, being ferried through this base, do not have the panel fitting installed in the cockpit for servicing the oil lines. The indicators are rear mounted and very difficult to remove from the panel for servicing. Consequently, maintenance personnel do not service the lines at the instrument but brake the line in the nose wheel well at an easily accessible connection. This clears the line from this point to the engine, but does not clear the line back to the gage.



A-1 pressure transmitters mounted on left engine support on all engines

C. CONCLUSIONS

1. The autosyn type oil and fuel pressure gage systems have been satisfactory in B-24 and B-17F aircraft.

2. The restricted gage fitting, Rochester Mfg. Co. Part No. 2162-R4A, operated satisfactorily in C-47B (type A-1 oil pressure gage system) but was not satisfactory in C-47A (direct connected oil pressure gage system).

3. Maintenance requirements on type A-1 oil and fuel pressure gage systems on service aircraft are higher than on either the autosyn (oil and fuel)or the direct connected (oil) type systems.

D. RECOMMENDATIONS

1. It is recommended that the modification described in Paragraph B-4 be considered for use in Army Air Forces aircraft for extreme low temperature operation.

2. It is recommended that the comparative advantages and disadvantages of autosyn and A-1 types of oil and fuel pressure gages be reviewed considering the information contained in this report in an effort to standardize one one type of remote indicating system for all combat aircraft.

Tests of Cabin Heating and Defrosting Systems of P-59A

Prepared by: W. H. Giedt, 1st Lt., A. C. Equipment Laboratory

A. PURPOSE

1. To report on tests conducted on the cabin heating and defrosting systems of P-59A No. 44-22610.

B. FACTUAL DATA

1. Description of cabin heating system.

a. The cabin is heated by regulated mixture of heated, pressurized air from the engines, and cold, ambient air from an inlet ram (see Photograph No. 1). The air flows through a control regulator, intercooler and anemostat into the cabin.

b. The cabin heating and pressurizing system is designed to maintain comfortable cabin temperature at a pressure greater than the equivalent of 25,000 feet altitude, up to 50,000 feet. From the pressure rings mounted on the front of each engine, hot, pressurized air bled from the engine compressor is conveyed inboard to a Y fitting on the centerline of the airplane. The regulated mixture of air for the cabin is conveyed from the mixing chamber, forward around the pressure safety valve, to the anemostat installed in the cabin floor forward of the main instrument panel. If the air is too hot, instead of going directly to the cabin, it is automatically conveyed through the intercooler before entering the cabin. The cabin is ventilated by an exhaust duct in the floor, directly under the pilot's seat. The exhaust air passes back to the regulator and through a valve out into the atmosphere.

c. Cabin temperature is controlled by a thermostat which energizes a split field series motor. The motor operates a butterfly valve in the cold rammed air inlet line and the hot air by-pass line, and a shutter valve in the mixing chamber. The temperature control linkage on the regulator, actuated by the motor, is adjusted so that when the shutter valve directs all the air through the intercooler, the cold rammed air valve is open and the hot air by-pass valve is shut. Below 15,000 feet altitude, where ram pressure exceeds the cabin pressure, temperature control is obtained by proper mixing of hot and cold air. Above 15,000 feet, when the cabin is pressurized, only the hot air source remains and the cabin temperature is controlled by passing through the intercooler, whatever fraction of the hot air is necessary.

d. Cabin ventilating airflow is determined by the size of all cabin openings and by the differential pressure between the cabin and the atmosphere. Part of this is cabin leakage; the remainder passes through the regulator exhaust valve.

e. The pilot's control of the system is mounted on the cabin floor just forward of the control column. This lever operates an emergency valve in the forward end of the engine air duct. Closing of this valve cuts off all hot, pressurized air, thus putting the heating and pressurizing system out of operation.

2. Description of cabin glass defrosting system.

a. The cabin glass and guns are heated by air taken from the tail pipe heater muff. Ambient air enters the heater muff through an inlet duct (see Photograph No. 2). It circulates completely around the tail pipe, gathering heat from the pipe and numerous thin steel fins. The heated air is conveyed out through the bottom of each tail pipe to a Y duct assembly, just inside the fuselage structure. A single duct conveys the heat forward through the fuselage to the gun compartment, where it flows to the cabin glass and guns (see Photograph No. 3). The control mounted underneath the instrument panel actuates a damper in the duct which controls the airflow. Photographs Nos. 4, 5, 6, and 7 show the double panel construction of the cabin glass.

3. Flight test data is included as Appendix I to this report.

4. Flights 1, 3 and 4 were conducted with the cabin anemostat in place to determine temperature distribution throughout the cabin. Preliminary flights had indicated that the venturi meter, installed for measuring cabin airflows and heat inputs during flights 5 and 6, interfered with the distribution of heated air throughout the cabin. Attention is called to the following:

a. Temperatures throughout the cabin were within 10°F with the exception of the waist level. Temperatures at the right and left of the pilot at waist level were considerably lower than the temperatures near his foot or head level. It is likely that these were the result of the pilot, wearing heavy clothing, unintentionally pushing the thermocouples measuring these temperatures too close to the fuselage wall.

b. Data taken on Flight 4 shows that the heating system comes well within winterization requirements at high altitudes.

c. Because the the thermostat controls the cabin temperatures around 50°F and because sufficient low temperatures at low altitudes were not encountered during the testing period, it was not possible to check the maximum capacity of the heating system at low altitudes. However, comparison of heat inputs to the cabin at 1,500 feet and at 31,500 feet in Flights 5 and 6 indicates that the system has the necessary capacity to meet winterization requirements at low altitudes. This is further borne out by the fact that the average temperature rise in flight 4 reduced to the temperature rise at sea level and —65°F according to Low Temperature Requirements Sheet No. 54-128 is approximately 85°F.

d. On all flights a gradual increase of temperatures resulted as the flight progressed. Because the length of each flight is limited in this airplane, it was not possible to determine if equilibrium condtions had been reached or not.

e. During Run 3 of Flight No. 6 when the power setting was increased to high speed cruise conditions, the cabin airflow and heat input decreased rather than increased as anticipated. Cabin temperatures, however, did not drop. It is felt that this was due to improper regulator operation, insofar as irregularity in its operation had been noticed by the pilot. This would mean that more heat than was necessary was supplied by the heating and pressurizing system during Runs 1 and 2.

5. Flights 1 through 4 were conducted with thermocouples installed to read the inside and outside surface temperatures of the windshield glass (thermocouples Nos. 11, 12, 13, 14, 15 and 16). Flight No. 2 was conducted with the cabin heating system off in order to determine the windshield surface temperatures resulting from the use of the defrosting system by itself. Attention is called to the following points:

a. Outside windshield surfaces.

(1) Temperatures were maintained from 10 to 20°F above ambient air temperature.

(2) The center windshield surface was from 4 to 6°F warmer than the left and right windshield surfaces. Because of the construction of the system more heated air probably passed between the panes of the center windshield than between the side windshields.

(3) Slightly higher temperature rises were obtained at high altitude.

b. Inside windshield surfaces.

(1) Temperatures were maintained from 40 to 118°F about outside air temperatures and with one exception in Flight 2 and Flight 3, all surface temperatures were above 32°F.

(2) Higher temperature rises were obtained at high altitude.

6. Insofar as the windshield defrosting system depends upon rammed air for operation, ground defrosting was not satisfactory. On the relatively cold days (ground temperature —20°F) encountered during the testing period the moisture, which condensed on the inner surfaces of the windshield from the pilot's breath, was not removed until the airplane was in the air.

7. At no time during the testing period were windshield defrosting difficulties encountered in flight. This includes several short runs through clouds.

C. CONCLUSIONS

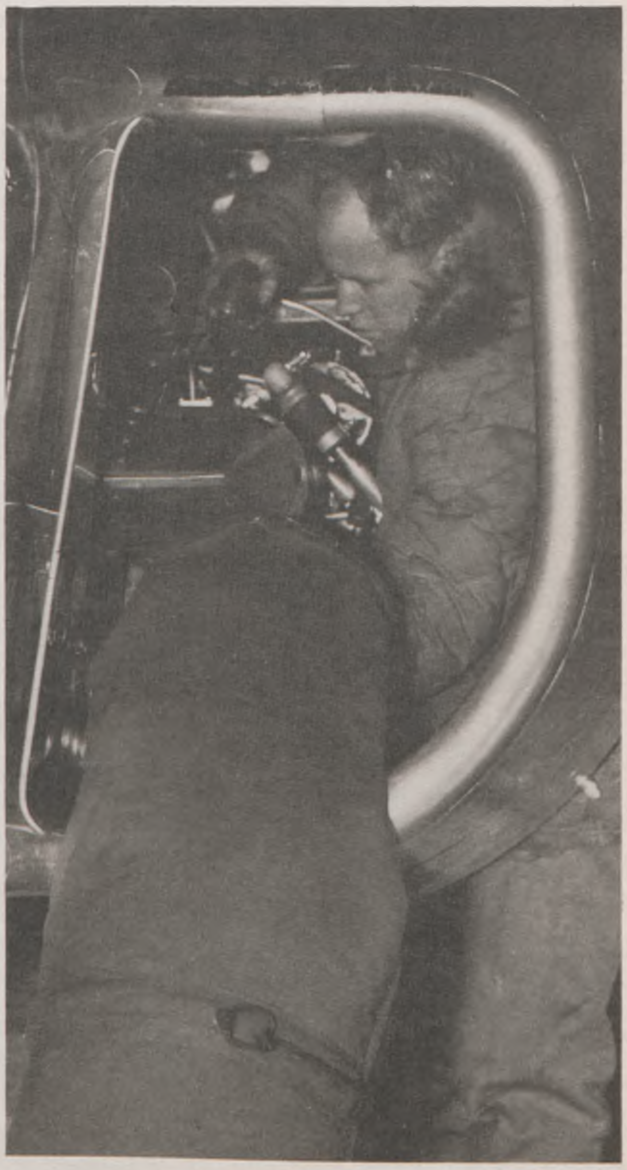
1. The cabin heating system as tested meets winterization requirements.

2. Windshield defrosting in flight was satisfactory under the conditions tested. However, more tests should be conducted in regions where the moisture content of the air is higher before the system is considered satisfactory.

3. Provisions should be made for windshield defrosting on the ground.

D. RECOMMENDATIONS

1. None.



P-59A turbine check-heater duct in use

Type E-1, Artificial Horizon Indicators Type C-1, Directional Gyro Indicators

Prepared by: T. C. Warner, Capt., A. C. Equipment Laboratory

A. PURPOSE

1. To report results of a low temperature service test on subject instruments.

B. FACTUAL DATA

1. The subject instruments are operated by 115 volt, 400 cycle, 3 phase alternating current. They were designed for low temperature use to overcome the difficulties encountered with standard air driven instruments.

2. Insofar as operation in flight is concerned, these instruments were designed to give the same indications as standard air driven instruments.

3. Four airplanes were equipped with the subject instruments and only one failure was encountered. This failure was due to a defective erection mechanism. The instruments operated satisfactorily at all temperatures encountered. The lowest temperature at the instruments, in flight, was —38°C (—37°F).

4. Two sets of instruments were kept as spares. The directional gyros were used to make a bench test to see if the latitude corrector on this instrument was satisfactory. The instruments were originally set at 40°N. latitude and were changed to 65°N. latitude. The amount of drift, measured on a ground test stand, was decreased by this change.

5. A photograph of one set of instruments installed in an A-26B aircraft is attached to this report as Exhibit A. Installations in other aircraft were similar to this one. A record of the tests is included in Appendix I.

6. As these instruments require 3 phase alternating current power, it was necessary to provide a separate power source for each installation. Holtzer-Cabot, Type MG-153 Inverters, operating from the airplane's direct current power supply, were used to provide power to the instruments. These inverters are too heavy (approximately 30 lbs.) to be considered for service use and they required considerable maintenance to supply the proper power to the instruments.

C. CONCLUSIONS

1. The Type E-1 Artificial Horizon indicator and the Type C-1 Directional Gyro Indicator operated satisfactorily at all low temperatures encountered.

2. The dial of the type C-1 directional gyro is unsatisfactory and the cover glass on the Sperry Instruments become foggy.

3. A more practical source of power must be obtained for the subject instruments before they can be recommended for service use.

D. RECOMMENDATIONS

1. It is recommended that the deficiencies in the C-1 Directional Gyro and the power supply be corrected before the subject instruments be used in Army Air Forces aircraft.

Type F-4 Airspeed Indicator

Prepared by: T. C. Warner, Capt., A. C. Equipment Laboratory

A. PURPOSE

1. To report results of a low temperature service test on one Type F-4 Airspeed Indicator.

B. FACTUAL DATA

1. One Type F-4 Airspeed Indicator, Army Air Forces Specification No. X-27512, Kollsman Part No. 865CK-03 Serial No. 113, was received for tests in a P-51D airplane. As there were no P-51D airplanes available for test work, the instrument was installed in a P-38L, Serial No. 44-24050.

2. Laboratory scale error tests, before and after installation, showed that the errors in the indicator remained almost constant during operation in low temperature conditions. Total time installed was 53 days and total flight time was 76½ hours. Test results are listed in Appendix I.

3. Comments received from pilots were favorable. The maximum speed pointer, varying with altitude, is desired by pilots who have flown this airplane. One pilot who was asked to observe this instrument requested that additional markings be placed on the dial at every 10 mph increment. Another pilot, flying transition, who was not informed about the F-4 Indicator, did not notice that this instrument differed from the standard type F-2 indicator. It has been generally agreed that the markings are satisfactory, although some pilots are anxious to know their exact speed at times.

C. CONCLUSIONS

1. The Type F-4 Airspeed Indicator is satisfactory for use in low temperature conditions.

2. The Type F-4 Airspeed Indicator is preferred to the Type F-2 for pursuit aircraft.

D. RECOMMENDATIONS

1. It is recommended that the Type F-4 Airspeed Indicator be used in place of the Type F-2 on pursuit aircraft.

Navigation Instruments

Prepared by: T. C. Warner, Capt., A. C. Equipment Laboratory

A. PURPOSE

1. To report results of tests on various items of navigation equipment.

B. FACTUAL DATA

1. Project engineers requested that tests of various items of navigation equipment be made during the cold weather testing program at Ladd Field, Alaska. All items were tested by Equipment Laboratory personnel with the assistance of 1st Lt. Roger E. Wahlberg, navigator. Items, such as the A-6 Navigation Case and Inverted Astrocompass, were used by Lt. Wahlberg in his position as navigator on the C-54B, Serial No. 43-17157. Unless otherwise noted, the statements contained herein are based on experience obtained using this equipment to navigate the C-54 aircraft.

2. "Type A-15 Watch". One watch, Serial No. AF44-249, was made available for tests. This watch was in use approximately two months before any tests were made. An average rate of —13 sec/day was obtained from 7 December to 7 January. An average rate of —15 sec/day was obtained from 22 January to 24 February. After approximately 3 months use, the stitching broke on the watch strap and the strap became badly worn at the hole which had been used for the buckle. The outer and inner dials were set on zero (1200 position) each day and observed for movement due to rubbing of heavy flying clothes on the watch stems. The outer dial moved a distance of 1 to 2 minutes each day while the inner dial remained on zero. The elapsed time dials were movable at a low temperature of —35°C (—30°F). Low temperatures were not encountered for a long enough period to make a rate test at any given temperature.

3. "Air Position Indicator". One A.P.I. was installed as standard equipment in a B-29 aircraft. Tests conducted indicate that this instrument operated satisfactorily. Results of tests are contained in Appendix I.

4. "Gyrosyn Compass". One installation was made at the Dayton Army Air Base on 2 November 1944 in the C-54. This installation was found to be faulty and was removed by the Project Engineer at Wright Field.

5. "Inverted Astrocompass". This instrument was used in the C-54, Serial No. 43-17157. Visibility is good, sufficient for all necessary observations. Compared to a standard astrocompass, it is much easier to set up and read operations. The slow motion drive mechanism makes it easier to move for a small change in reading and does not interfere with operation. As the astrocompass sits low in the dome observations cannot be made with body at a low altitude. In this airplane the instrument is very difficult to install when the plane is on the ground, and cannot be installed in the air. For test purposes, the instrument was left installed at all times.

6. "Polar Navigation Computer". This computer is designed for use above 75° latitude. There were no flights made above 70° latitude, thus it was impossible to test this item.

7. "Gyro Flux Gate Compass". Five standard installations of this compass were observed in B-17 (2), B-29 (2), and C-54 (1) aircraft.

a. In turns there was lag in some of the fluxgate compasses and over-reading in others. It generally took from 10 to 90 seconds before the compass would settle on desired heading. Otherwise, the compass was accurate.

b. The compasses were swung by observing celestial bodies with the astrocompass in flight for true headings. The compasses were compensated by means of the compensating device around the face of the master indicator.

c. The caging mechanism operated satisfactorily at all temperatures observed, +18°C to —40°C (+64°F to —40°F). Only one installation (C-54) had a low temperature push button on the amplifier. The coldest temperature encountered on this airplane was —30°C (—22°F). At that temperature, there was no need for this additional power to erect the gyro. The standard installations without the push button operated satisfactorily at —40°C (—40°F).

d. The gain control had no apparent effect on the sensitivity of the flux gate compass. This control was left at the normal (No. 3) setting on all installations. The highest latitude encountered was 65° 50′ and the shortest distance to the magnetic pole was approximately 2900 miles.

e. The navigator flew with variation set in the master indicator on several flights, but it is not recommended, as the present navigation system is set up for using compass headings and pilots are accustomed to using compass headings.

8. "A-6 Navigation Case". The case does not provide sufficient space to carry most types of sextants in their standard box. Without box, pockets are not provided for batteries, extra bubble chambers and other sextant equipment. The space provided for books and watches is not adequate. In aircraft with navigator as crew member, there is space provided for navigation equipment. Except on C-46 aircraft, the navigator's compartment is so compact that it is not possible to stow the A-6 case so it can be used conveniently in flight. The insert for plotting equipment is very satisfactory. Stands are provided, when necessary, in production aircraft, making it unnecessary to use the A-6 case as a stand. When completely loaded, the case is well balanced, but is very heavy and awkward to carry. The map pocket, when kept properly strapped, shows no appreciable wear over a six-months period.

9. "B-3 Driftmeter Installation C-54". This instrument was installed by the Project Engineer at Wright Field in the early part of January 1945. The driftmeter works the same as the standard B-3 with the addition of a "gyro boost" mechanism, for low temperature starting. Weather encountered was not cold enough to require the use of the gyro boost mechanism. Ice and frost formed on the inside of the view plate at free air temperatures of 0 to —15°C (+32 to +5°F) and cockpit temperatures of +20°C (+68°F). It is not possible to de-ice in flight.

C. CONCLUSIONS

1. There were no failures or excessive errors in Navigation Equipment due to exposure and use at the lowest temperatures encountered.

2. The mounting provided for the inverted astro-compass in the C-54 is unsatisfactory.

3. The Type A-6 Navigation case is too heavy and bulky.

4. The inside of the view plate on the B-3 driftmeter becomes covered with ice and frost at a free air temperature of 0 to —15°C and a cockpit temperature of +20°C.

D. RECOMMENDATIONS

1. It is recommended that the project engineers on the various items of Navigation Equipment correct the deficiencies noted in Paragraphs C2, C3, and C4 of this report.

Air Driven Gyro Instruments

Prepared by: T.C. Warner, Capt, A.C. Equipment Laboratory

A. PURPOSE

1. To report on operation of subject instruments installed in aircraft undergoing cold weather tests at Ladd Field, Alaska, during the winter of 1944-45.

B. FACTUAL DATA

1. Five installations of modified instruments were made in various airplanes for low temperature service tests. These instruments are of two types; namely, Sperry Artifical Horizon Indicator (Flight Indicator) Part No. 646040 with Type 34-B grease lubricated bearings, and Type A-11 Turn and Bank Indicator with bearings lubricated with Spec. AN-G-3 grease. These instruments were installed at the Dayton Army Air Base in September of 1944, and have been operating satisfactorily, with the exception that neither horizon would remain in the caged position in flight. Details of the test are contained in Appendix I.

2. Failures of Standard AN type Artifical Horizon Indicators is excessive. As established by reports from operating bases elsewhere, the life of this type instrument is exceedingly short, and failures are usually due to bearing troubles. In addition, it has been noted here that many gyros are replaced, due to troubles in the miniature airplane and the caging system.

3. There were several instances of Air Driven Directional Gyros and Artificial Horizons becoming sluggish or inoperative at temperatures between -23 and -35°C. (-9°F and -31°F. This low temperature failure is the same as noted last year under similar conditions. The normal application of heat before flight and the use of aircraft heaters in low altitude flight has minimized this problem during operations at this base. Air driven gyro instruments cannot be depended on for satisfactory operation when the cockpit is below -30°C. (-22°F). Some instances of satisfactory operation at instrument temperatures of -35°C. (-30°F) have been encountered whereas one failure occured at -23°C (-9°F).

4. Pilots of two B-29 aircraft assigned to this station complained about sluggishness of their gyro instruments, particularly the artificial horizon. The vacuum systems on these airplanes were thoroughly checked and found to be satisfactory. An additional vacuum gauge was differentially connected to the artifical horizon on the pilot's panel in addition to the standard gauge which is connected to the co-pilot's flight indicator. The vacuum reading was found to be correct at altitudes from 0 to 20,000 feet with and without cabin pressurization. Flight tests in both airplanes were made and it was found that the horizons (Ternstedt Part No. T-95100) were satisfactory on standard rate turns (180°/Min. - approximately 35° bank). In normal flight, however, the horizons appeared sluggish in that there was a short

lag in the instruments when the airplane was brought out of a turn. According to representatives from the Sperry and Jack & Heintz Instrument Companies, horizons are calibrated for a standard rate turn of 180°/min. at an airspeed of approximately 170 mph. In the B-29, in normal flights, turns are made at much higher speeds and slower rates of turn. In addition, turns are often made with considerable "sliding". These features of flight in this airplane cause precession in the gyros, which gives them the appearance of being sluggish. The erection mechanism in the instrument corrects this error when straight and level flight is maintained. The erection rate for standard instruments is 8°/min. It is felt that an improvement can be made by designing the instruments for a higher airspeed (larger bank-angle) and means of overcoming precession of the gyro, and increasing the erection rate should be investigated.

5. Jack & Heintz Flight Indicators, Part No. JH6500, in B-17 and B-24 aircraft particularly, have been objectionable due to excessive "spilling" of the gyro in flight, which required recaging of the instrument. This occurs when the gyro precesses more than 6° from the vertical causing the pendulous vanes (erection mechanism) to be ineffective. One new Jack & Heintz instrument, Part No. 6500A, was installed and operated satisfactorily. It is understood that all JH6500 instruments are to be modified to JH6500A at time of overhaul. This is believed important enough to require modification of all existing stocks of JH6500 instruments and granting of authority to organization commanders to order replacement of all JH6500 instruments in the field where trouble has been encountered. This condition is particularly evident in large aircraft where precession errors occur due to unbalanced forces on the gyros in long slow turns.

6. Type A-3A automatic pilot installations in C-47, P-61 and C-54 aircraft have been fairly satisfactory. Failures encountered are not attributed to low temperatures. In both the C-47 and P-61, intermittent trouble has been encountered with hunting in the rudder controls. On one C-47, one servo unit was continuously leaking and was changed after 74:25 hours. One pressure regulator was changed at 103 hours and the rudder control box changed at 113:05 hours. C-47B Lend-Lease Aircraft, processed through this station, have the A-3A pilot installed. The greatest amount of trouble in this installation has been with air relays and the oil filter. Two air relays which were sticking were examined and a slight film of gray substance was present on the shaft. In one relay there were 3 particles of foreign matter present. In both cases, cleaning of the shaft was all that was necessary to make the unit operable. The housing is made of magnesium and the shaft is steel; possibly this is corrosion starting between the two dissimilar metals. One Skinner Oil Filter, Part No. 27400, Spec. No. 94-27983-A, was removed because it leaked excessively. This unit had 30 hours operation. Cause of failure was in the washer between the case and the head of the filter. A photograph of this item is attached as Exhibit A to this report. This type of failure has been frequent, according to instrument maintenance personnel. However, only one case has been noted by the writer. The use of an "O-Ring" type washer in a recess in the head of the filter, similar to that employed in the gyro instrument filter, Spec. AN-F-9A, should correct this condition.

C. CONCLUSIONS

1. Artificial Horizon Indicators, Sperry Part No. 646040, with Type 34-B rotor bearings and standard type A-1 Turn and Bank Indicators with rotor bearings lubricated with AN-G-3 grease are as satisfactory for low temperature operation as present standard instruments with oil lubricated bearings.

2. Failures of Artificial Horizon Indicators are excessive. The reasons for these failures are mainly bearing failures and mechanical defects in the caging mechanism and the miniature airplane.

3. Standard Air Driven Gyro Instruments (with the exception of Turn and Bank Indicators) cannot be relied upon for satisfactory operation at instrument temperatures below —30°C. (—22°F).

4. The effect of precession and the slow erection rate (8°/min.) in standard instruments is more serious in large aircraft like the B-29 than in older, smaller types of aircraft.

5. Trouble encountered with "spilling" of Jack & Heintez Artificial Horizon Indicators, Part No. JH6500, has been corrected in Part No. JH6500A.

D. RECOMMENDATIONS

1. It is recommended that Artificial Horizon Indicators with Type 34B rotor bearings and Turn and Bank Indicators (Type AN5820) be procured with grease lubricated rotor bearings in place of present standard instruments.

2. It is recommended that instructions for relubricating instruments in service with grease at time of overhaul be prepared and included in applicable Technical Orders.

3. It is recommended that efforts be made to decrease the precession and increase the erection rate of artificial horizon indicators.

4. It is recommended that a new type sealing washer be developed for the Skinner Oil Filter, Part 27400, Spec. 94-27983-A.

5. It is recommended that laboratory corrosion tests be made on Jack & Heintz air relays to determine if the use of a steel shaft in a magesium housing is causing corrosion.

Type F-1 lifting bags used to raise wing of B-24 airplane

P-59 Instruments

Prepared by: T. C. Warner, Equipment Laboratory

A. PURPOSE

1. To report on operation of instruments in the P-59 airplane, serial number 44-22610.

B. FACTUAL DATA

1. One P-59 airplane was instrumented for low temperature service tests, at the Dayton Army Air Base. The following modifications and installations were made:

a. Skinner Air-Oil Filter, part No. 27400-VS, was installed in the pressure line to the gyro instruments just ahead of the Schwien Vacuum Regulators.

b. Pressure tubing was relocated from underneath the fuselage to the top, in rear of the cockpit, to make the Schwien Regulators, part Nos. 22500-1 and 22500-2, accessible.

c. Filler Check Valves (AN5832-2, gauge fitting No. 43A14984 and cap AN820-2) were installed as shown in Fig. 3, Detail B of Technical Order 05-70-6, on the engine side of the General Electric, Selsyn oil pressure transmitters on both engines. On autosyn and A-1 type pressure transmitters on other types of aircraft this is a standard winterization modification to enable servicing of the oil line with hydraulic oil to prevent congealing at low temperatures.

d. A type A-11 Turn and Bank Indicator, with bearings lubricated with AN-G-3 grease, was installed in place of the standard instrument for service test.

2. Test data are contained in Appendix I and photographs of the Skinner Air-Oil Filter, Schwien Regulators and the Instrument Panel are attached as Exhibits A, B and C respectively.

3. The Skinner Air-Oil Filter was designed to remove the oil from the air by means of a system of baffles and also to cleanse the air by means of a phenolic impregnated paper filter element. After approximately 50 hours flight time, examination of the filter showed that it was ineffective, as oil had passed through into the regulators and had not collected in the bowl of the filter.

4. The Schwien regulators were unsatisfactory when the airplane arrived because correct pressure for gyro operation could not be obtained. The regulators were found to be contaminated with oil and the No. 1 regulator was damaged. The regulators were cleaned, repaired and reinstalled in the airplane. Tests showed that there was one inherent feature of these regulators which was unsatisfactory; that was, the No. 2 regulator would not hold the pressure to 4″ Hg. until the pressure had first reached a maximum of 8″ Hg., at which time the regulator took effect and cut the pressure down to 4″ Hg. As this regulation did not occur until an engine rpm of approximately 14,750 was obtained (take off rpm was approximately 16,500), it was considered dangerous, as a slight change in the regulators, due to contamination or wear, might cause this regulation never to occur and the gyros would be operating continuously on 8″ Hg. pressure.

5. The oil pressure indication system should be modified to prevent initial presures from giving faulty indications. Additional troubles encountered with engine instruments are discussed in Appendix I.

6. The arrangement of flight instruments and the mounting of all instruments did not conform to Army Air Forces requirements. As all instruments were rear mounted, it was very difficult to replace any instrument on this airplane. A conventional type D-2 Airspeed Tube was mounted upside down on the empennage contrary to requirements of Army Air Forces installation specifications.

C. CONCLUSIONS

1. The experimental Air-Oil Filter, Skinner Part No. 27400-VS did not remove the oil present in the air flowing to the gyro instruments.

2. The Schwien Pressure Regulators, Part Nos. 22500-1 and 22500-2, did not properly regulate the pressure to the gyro instruments.

3. The oil pressure indication system was unsatisfactory when surge pressures over 25 psi were encountered on "cold starts" at low temperature.

4. The use of filler check valves, AN 5832-2, as required by Technical Order No. 05-70-6, was not necessary on this airplane.

D. RECOMMENDATIONS

1. It is recommended that the deficiencies noted in this report be corrected on future aircraft of this type by:

a. Modification of the oil pressure indication system by putting a stop on the transmitter at 25 psi or by adding sufficient restriction in the oil line to prevent surge pressures in the oil system from reaching the transmitter;

b. Conformance to Army Air Forces requirements on mounting and arrangement of instruments;

c. The use of a conventional vacuum system with air driven gyro instruments, electrical gyro instruments or a modification of the present pressure system designed to overcome the deficiencies noted herein;

d. Conformance to Army Air Forces specifications on the location and mounting of air speed tubes.

Cold Weather Testing of Type C-11A Electric Power Plant

Prepared by: *C. E. Wood, Capt., A. C. Equipment Laboratory*

A. PURPOSE

1. To summarize results of service tests performed by personnel of the Cold Weather Testing Detachment on the subject power plants.

B. FACTUAL DATA

1. The power plants were service tested approximately in accordance with the contemplated test program, an extract of which was forwarded to the above addressee as Appendix D of Status Report, Electrical Branch, Cold Weather Tests, Equipment Laboratory, dated 5 January 1945.

2. A complete report of the service tests will be submitted through regular channels by Cold Weather Testing Detachment.

3. The following results of these tests are of immediate interest to the A. T. S. C. project engineers:

a. The type of spark plugs (manufacture and nomenclature unknown) in the units were found to be unsatisfactory for making cold starts, believed to be due to oil deposit on the spark gap. These were exchanged for Champion Type HO-14S, which performed satisfactorily.

b. It was found that the units could be cold started at temperatures as low as 0°F. It was necessary to apply external heat for starting at lower temperatures.

c. The units operated satisfactorily at the lowest temperatures encountered, —43°F.

d. Out of a total of 700 accumulated hours of operation, there were approximately 60 man hours expended in maintenance.

e. Malfunctions were primarily due to the spark plugs mentioned in par. 3a, and cleaning and adjusting of magneto breaker points.

f. There was one failure—broken teeth in a magneto driving gear. The cause could not be diagnosed and it is considered an isolated case.

C. CONCLUSIONS

1. It is concluded that the Type C-11A Electric Power Plant is generally satisfactory for operation in cold temperatures.

a. Without the aid of external heat for starting, to a minimum temperature of 0°F.

b. With the aid of external heat for starting, to a minimum temperature of —43°F.

D. RECOMMENDATIONS

It is recommended that:

1. The type of spark plugs be changed to the Champion type HO-14S or equivalent having air gaps between the electrodes.

2. The project engineer investigate magneto performance with the adopted type of spark plugs.

Cold Weather Testing of Lamp Assembly, Rigid Drum Type Rotating Beacon, 24″ AN-L-4

Prepared by: *C. E. Wood, Capt., A. C. Equipment Laboratory*

A. PURPOSE

1. To report the performance of subject lamp assembly under cold weather conditions.

B. FACTUAL DATA

1. The complete assembly was mounted on a portable stand by personnel of the Cold Weather Testing Detachment and operated in the normal manner in the local test area from 12 December 1944 to 9 Feburary 1945, when it was removed for installation on top of the Ladd Field control tower.

2. Cold temperatures as low as —30°F. had no effect upon its operation, except that there were two cases wherein the lamp changers, after normal operation caused by burned out lamps, did not complete their movements

and stopped against the latch resulting in burned contacts. Increasing the rotating spring tension corrected the difficulty. It could not be ascertained whether these malfunctions were due to cold temperatures or original adjustment of the rotating springs.

3. Several of the rotating beacons are in service in this area and maintenance personnel have reported excessive maintenance of brushes and collector ring surfaces due to the collector rings either being out of round or mounted eccentrically. Collector ring surfaces become blackened causing sparking at the brushes and brushes wear rapidly in the brush holders.

4. Attention is directed to lubrication specifications in T. O. AN-08-20-33 which call for:

a. Thrust bearings to be greased with Gr. 375, Spec. 3560.

b. Worm gear to be greased with, oil, transmission, Spec. 2-28 or oil, mineral steam cylinder, Gr. 2, Spec. 2-32.

5. Advice from representatives of the Materials Laboratory indicates that:

a. Gr. 375, Spec. 3560 has been superseded by Grease, Spec. AN-G-3.

b. Oil, Mineral, Spec. 2-28, has been superseded by Grease, Spec. AN-G-10.

6. This report supplements letter from E. T. O. U. dated 7 January 1945 to Director, Air Technical Service Command, Attention TSEPL-3F, a copy of which is attached. (Exhibit I).

C. CONCLUSIONS

1. The subject lamp assembly operates satisfactorily at the lowest temperatures recorded, —30°F., except for the mechanical defects described.

D. RECOMMENDATIONS

1. It is recommended that:

a. Mechanical defects be brought to the attention of the Inspection Division and the manufacturers.

b. T. O. AN-08-20-23 be changed to specify the lubricants mentioned in Par. B5a and b.

Lamp Assembly, Rigid Drum Type Rotating Beacon, 24″ AN-L-4

1. The subject lamp assembly was placed in operation in the local test area 12 December 1944 for observation of its performance.

2. Performance has been satisfactory except the slip ring brushes became noisy (squealing) after 10 days of operation. The slip rings were found to have been machined with a sharp pointed tool, leaving thread-like ridges which resulted in poor brush contact and blackening of the slip ring surface.

3. It was also reported that in warm weather, grease from the warm gears drops on the brush holders and soaks the brushes.

4. It is recommended that condition stated in Paragraph 2 be brought to the attention of the manufacturers for correction on future production units and that drip shields be developed for application by the services to units now in use as well as on future production units.

Cold Weather Testing of Lamp Assembly, Type C-3 Acetylene Operated Flashing Beacon

Prepared by: C.E. Wood, Capt, A.C. Equipment Laboratory

A. PURPOSE

To report an experimental test made to eliminate the accumulation of frost inside the Fresnel lens of the subject lamp.

B. FACTUAL DATA

1. The lamp assembly was condemned as an obstruction marker or beacon for use with aircraft in M/R dated 6 January 1945, from ETOU to Director, Air Tech-

nical Service Command, beacuse of the accumulation of frost inside the lens.

2. The lamp as received had no means for preventing the products of combustion from coming in contact with the outer lens, resulting the condition reported.

3. Consequently, it was modified after being service tested, by sealing the air passage between the inner globe and outer lens at the top, and again placed in operation.

4. The alteration proved to be effective as there was no furthur accumulation of frost inside the lens.

5. Photographs Nos. 2 Appendix A, illustrate the extent of frost accumulation before the alteration was made, and Photograph No. 5 shows the baffle that was applied to correct the difficulty.

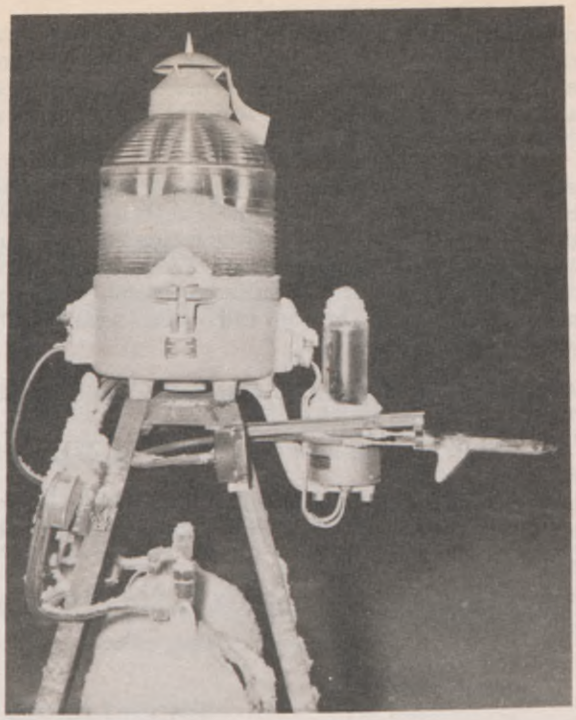
6. To determine if the baffle had any effect on the stability of the lamp in wind, an air speed indicator was installed on the lamp assembly, and it was placed in the blast of airplane propellers. The wind produced by the propellers was gusty and air speeds up to 75 mph were indicated with averages of approximately 40 mph. These winds failed to extinguish the pilot light, and the lamp operated satisfactorily. The lamp remained in a position where it was subjected to the propeller blasts from parked airplanes for a period of two weeks, and it operated satisfactorily during the entire period.

7. Light frost accumulated on the outside of the sun valve globe, but it had no noticeable effect upon the operation of the sun valve.

8. The flashing mechanisim operated satisfactorily at -48°F (measured at the lamp location) with factory installed diaphragms. The special low temperature diaphragms, furnished substitutes for use in case the original diaphragms failed, were not installed.

C. CONCLUSIONS

1. The lamp assembly, if provided with a means for preventing frost accumulation on the Fresnel lens, such as that mentioned in Par. B.5, will be entirely satisfactory for use as an obstruction marker or beacon light for aircraft.



Frost accumulation inside Fresnel lens

D. RECOMMENDATIONS

It is recommended that:

1. The manufacturers develop modification parts to seal the air passage between the inner globe and outer lens of the lamp assembly.

2. Modification parts with instructions for installation be furnished to the using services for installation in the field, and that the modifications be incorporated in future production of the lamp assemblies.

Cold Weather Test of Direct Cranking Starters, Power Input to Crank Cold Engines, Type B-29 Airplanes

Prepared by: C. E. Wood, Capt., A. C. Equipment Laboratory

A. PURPOSE

1. To report the performance of and power input to direct cranking type starters while cranking cold engines on a type B-29 airplane.

B. FACTUAL DATA

1. Equipment.
   a. Location. Ladd Field.
   b. Dates of Tests. 13 and 14 February 1945.

c. Airplane.	Type B-29-11-MO#42-65214.
d. Engine Type.	Wright Cyclone, R-3350-23A.
e. Type of oil.	Eng. Nos. 1, 2, 3—Synthetic, Spec. PPC-265. No. 4—Regular, Spec. 1100A.
f. Starters.	No. 1 Eng. J&H5E. No. 2 Eng. Eclipse 1416 Model 6, Style A, Serial #65. (Direct cranking type). Spline and jaw seal lubricated with Spec. AN-06-A oil. Installed 23 January 1945. No. 3 Eng. Eclipse 1416, Model 6, Style A, Serial #49. (Direct Cranking Type). Factory lubrication. Installed 23 January 1945. No. 4 Eng. J&H5E.
g. Engine Hours.	No. 1 14 hr. No. 2 12 hr. 30 minutes. No. 3 86 hr. 45 minutes. No. 4 86 hr. 45 minutes.
h. Power Source.	Model C, Auxiliary Power Unit, (Waukesha dual type) Capacity, 15 KW, Volts 28.5 d.c.

2. Advantage was taken of the coldest temperatures encountered during the cold weather testing period to determine the power required to crank the R-3350 engines. The lowest temperatures occurred on 13 and 14 February 1945, and test results are attached as Appendices A and B respectively.

3. Attempts were made to evaluate engine temperatures vs. cranking power. On 13 February, the engines were considered too stiff to attempt to crank without undue risk of damaging engine accessories and, further, that attempts to start would be unsuccessful and useless. Therefore, the engines were heated until, in the judgment of the crew, they were just free enough to attempt to start. Power input to starters was measured after which attempts were made to start the engines. These attempts were unsuccessful and the process was repeated. Immediately after starting, oil, carburetor air, and cylinder head temperatures were recorded as shown in Appendix A, Par. 9b. These and the measurements of oil dilution, were inconsistent and considered as not indicating the true condition of the engines. Therefore, it was decided to repeat the tests, using available thermocouples on No. 2 engine as an indication of engine temperatures; however, the engine had not been thermocoupled with this in view and it was recognized that they would not indicate temperatures within the engine. Nevertheless, it was the only means at hand of making any sort of comparison.

4. Procedures on 14 February 1945, as summarized in Appendix B, were repetitions of those summarized in Appendix A, except, due to the extreme stiffness of the engines, No. 1 (combination starter) was energized for 5 seconds only prior to meshing, and all three were direct cranked for 15 seconds only. No. 4 engine was "frozen" and no attempts were made to either crank or start it.

5. The engines cranked readily under the cold conditions summarized in Appendix B, Par. 5a, and cranking speeds were adequate for starting. It is believed the engines could have been started had it been possible to vaporize the fuel properly at these temperatures. During the unsuccessful attempts to start after heat had been applied for 15 minutes, Nos. 1 and 3 fired instantly and then ceased, apparently due to the intake of cold air, No. 2 engine did not fire. All three engines were primed to the extent that gasoline flowed from the blower drains.

6. In all starting attempts, No. 1 starter was energized for 15 seconds before meshing to note differences, if any, in starting ability due to the faster acceleration from the inertia of the starter flywheel as compared to the direct cranking starters. There was no apparent difference in starting ability. In one instance, clearly definable, the inertia of the starter was dissipated in one quarter of a turn of the propeller, indicating that the stored energy was of very little assistance to the starting.

7. There have been no malfunctions of the direct cranking starters on the subject airplane, nor of those on B-29 No. 42-4612 (solid injection engines). The latter airplane is currently in the U. S. for engine mount changes precluding making tests.

8. There is little probability of additional cold weather and no further reports will be submitted except to describe any malfunctions of the starters during the remainder of the test period.

C. CONCLUSIONS

It is concluded that:

1. Neither the lesser cranking speed nor the lack of the inertia feature of the direct cranking starters has any deleterious effect upon starting.

2. Direct cranking is advantageous in starting cold engines in that shock loading of starter and engine parts is less than with inertia starting.

3. Power input to the starters as ascertained by these tests does not represent the ultimate that will be encountered in starting large size cold engines.

4. It is not practical to make accurate determinations of power for cranking cold enginess on airplanes in service, due to the time required for thoroughly cold soaking and the vagaries of the weather.

5. The slipping clutch protective feature is unnecessary for cold starting as severe back firing does not occur, and that the feature is not more necessary in a direct cranking starter than in a generator or any other engine accessory.

D. RECOMMENDATIONS

It is recommended that:

1. Future test programs include the determination of cranking power for the largest sizes of engines after being cold-soaked in cold rooms, and that such tests be given a high priority.

2. Tests recommended in par. a above be coordinated with the Power Plant Laboratory and the Bureau of Aeronautics with a view toward accomplishing the tests with fuels, lubricant and/or oil dilution methods that may be adopted as cold starting standards.

3. With view toward reducing weight, studies be made of a torsional elasticity means of reducing shock stresses due to back firing as a substitute for the slipping clutch protective feature.

4. A copy of this report be forwarded to the Bureau of Aeronautics through whose cooperation the direct cranking starters were obtained for testing.

Instrument Hose and Fittings

Prepared by: T.C. Warner, Capt, A.C. Equipment Laboratory

A. PURPOSE

To discuss performance of instrument hose and fittings on aircraft assigned to this activity during the period from October 1944 through February 1945.

B. FACTUAL DATA

1. Standard instrument hose and hose assemblies installed on production aircraft have operated satisfactorily under the conditions encountered. This hose is made to Specification AN-ZZ-H-626a, and the hose assemblies are made to drawings AN 855, AN 856 and equivalent Army Air Forces drawings. The fittings are crimped on the hose and are not reusable. The hose is marked with a white code line indicating winterization approval. This approval was given to hose manufacturers when they had obtained a product satisfactory down to temperatures between minus 40 and minus 65 degrees F. The use of the yellow code stripe has been authorized some manufacturers, indicating minus 65 degrees F. approval; however, none of this was available for tests this winter.

2. White line hose with detachable (reusable) fittings, made by the Weatherhead Co., Cleveland, Ohio, and the Areo-Quip Corp., Jackson, Michigan, was installed in the instrument lines on one P-38 and one B-17G airplane. A total of 21-quarter inch I D and 2-three-eights inch I D assemblies was installed in pitot-static, oil, fuel, vacuum and fuel vent lines. The lowest ground temperature encountered was minus 40 degrees F. and the lowest free air temperature in flight was approximately minus 65 degrees F. There were no failures of these assemblies and they are still in use. From an engineering standpoint, hose assemblies with both the permament and the detachable end fittings have been satisfactory. The detachable end fittings were developed to enable hose replacements to be procured and stocked by large rolls of hose and seperate fittings instead of individual assemblies of varying lengths. However, experience here indicates that there is very little replacement necessary of instrument hose. The hose assemblies with detachable ends were installed on the P-38 and B-17 in October 1944 and have approximately 100 and 140 hours flying time, respectively. Exhibit "A", attached to this report, pictures the subject assemblies.

C. CONCLUSIONS

1. Detachable fittings manufactured by the Weatherhead Co. and the Aero-Quip Corp. for use with instrument hose are satisfactory for service use.

2. Low pressure instrument hose installed on production aircraft is satisfactory for low temperature operation.

D. RECOMMENDATIONS

It is recommended that either crimped on, permanent type fittings (AN 855 and AN 856) or detachable fittings as shown in Exhibit "A" be accepted with low pressure hose for instrument installations in Army Air Forces aircraft.

Instrument Vacuum Selector Valves and B-29 Vacuum System Part I

Prepared by: T.C. Warner, Capt, A.C.

A. PURPOSE

To report results of tests on Winterized Vacuum Selector Valves and Modified B-29 Vacuum System.

B. FACTUAL DATA

1. Installations of experimental valves were made in production airplanes as follows:

B-17G Ser. No. 43-38221
B-24J Ser. No. 42-51660
B-29 Ser. No. 42-65214
Dole Valve Co. Part No. EXP-2165
Johnson Service Co. Part No. SA-12304
Dole Valve Co. Part No. Q-2770-OV

These installations were completed in September of 1944.

In addition, the Vacuum System was modified on the B-29 to provide:

a. Better operation at low temperature;

b. Decreased weight of the system;

c. Elimination of Deicer Shut-Off Valve necessary in production installations to provide satisfactory instrument operation in case deicer boots are punctured.

2. Production installations of Vacuum Selector Valves in B-17, B-24, B-29 and A-26 aircraft were tested in comparison with the experimental installations.

3. Extreme low temperatures have not been encountered but tests made to date have shown that the valves listed in Paragraph B-1 of this report are superior to the production installations. Ground and flight tests of the Modified B-29 Vacuum System have shown that the Vacuum Selector Valve is superior to the production installation in addition to the elimination of the Deicer Shut-Off Valve and the saving of weight. (A weight saving of approximately 20 pounds was realized.)

4. This report is submitted at this time to present recommendations for changes in production aircraft. Any additional information obtained on the operation of the experimental valves and at extreme low temperatures during the remainder of the cold weather tests program this winter will be submitted as an amendment to this report.

5. Check valves installed in B-29 Aircraft Vacuum Systems have operated satisfactorily but do not have winterization approval. Valves installed are (1) Eclipse Aviation, Teterboro, New Jersey, Part No. 525 and (2) Kenyon Instrument Co., Huntington Station, Long Island, Part No. 19-100-3.

6. Test data are contained in Appendix I, and schematic diagrams showing the differences between the standard and modified B-29 Vacuum Systems are contained in Appendix II of this report. Details of this modification have previously been submitted by letter from the Equipment Laboratory to the Bombardment Branch, Procurement Division, Air Technical Service Command.

C. CONCLUSIONS

1. Vacuum Selector Valves installed in production aircraft are unsatisfactory for sub-zero operation; whereas, the experimental valves listed in Paragraph B1 are satisfactory.

2. The Vacuum System as modified on B-29 Ser. No. 42-65214 is superior to production installations.

D. RECOMMENDATIONS

1. It is recommended that only approved winterized vacuum selector valves be installed in production aircraft.

2. It is recommended that B-29 aircraft incorporate the vacuum installation as modified on Airplane Serial No. 42-65214.

3. It is recommended that check valves, Eclipse Part No. 525, and Kenyon Part No. 19-100-3, be considered for Winterization Approval.

Instrument Vacuum Selector Valves and B-29 Vacuum System, Part 2

Prepared by: *T. C. Warner, Capt., A. C.*

A. PURPOSE

1. To present additional information obtained on subject valves.

B. FACTUAL DATA

1. Original Memorandum Report (Ref. No. 54-28) dated 5 February 1945, was prepared recommending the use of the experimental vacuum selector valves in production aircraft, on the basis of tests in the temperature range from 0 to —25°C.

2. Additional tests have been completed at a ground temperature of —39°C. The three test installations, Dole Valve Co. Part Nos. EXP-2165 and Q-2770-OV and Johnson Service Co. Part No. SA-12304, were satisfactory; whereas, the production installations which were tested were not satisfactory.

C. CONCLUSIONS

1. Vacuum selector valves installed in production aircraft are unsatisfactory for sub-zero operation; whereas, the experimental valves tested are satisfactory.

D. RECOMMENDATIONS

1. It is recommended that the valves listed in Par. B-2 be granted winterization approval.

2. It is recommended that only approved winterized vacuum selector valves be installed in production aircraft.

Final Report from TSEPL-3G Representatives on Temporary Duty at Ladd Field, Alaska

Prepared by: T. C. Warner, Capt., A. C. Equipment Laboratory

A. PURPOSE

1. To present final results on instrument operation.

B. FACTUAL DATA

1. Representatives from TSEPL-3G were present at Ladd Field from approximately 2 December 1944 to 6 March 1945.

2. The major portion of the test work has been reported by individual items or groups of items, reference:

a. "Report on Service Tests (No. 2)" (Conducted by the C.W.T.D.) dated 27 Feb. Ref. No. 54-34.

b. "Instrument Vacuum Selector Valves and B-29 Vacuum System", dated 5 February, Ref. No. 54-28 and Amendment No. 1 dated 2 March, Ref. No. 54-35.

c. "Instrument Hose and Fittings", dated 14 February, Ref. No. 54-29.

d. "Air Driven Gyro Instruments", Memorandum Report No. TSESE-4-17, dated 26 February.

e. "P-59 Instruments", Memorandum Report No. TSESE-4-16, dated 26 February.

f. "Navigation Instruments", Memorandum Report No. TSESE-4-19, dated 27 February.

g. "Type F-4 Airspeed Indicator", Memorandum Report No. TSESE-4-20, dated 27 February.

h. "Type E-1, Artificial Horizon Indicators' Type C-1, Directional Gyro Indicators," Memorandum Report No. TSESE-4-22, dated 28 February.

i. "Oil and Fuel Pressure Gage Installations," Memorandum Report No. TSESE-4-29, dated 5 March.

3. The following items were tested and have not been reported before:

a. Manifold Pressure Drain Valves.

(1) Nine manifold pressure drain valves, made by the Weatherhead Mfg. Co., Cleveland, Ohio, were received on 24 January 1945. These valves were tested for leaks with an air pressure of 25 psi and a vacuum of 8 psi for a period of one minute. Two of the valves leaked under pressure and, therefore, were not used for test purposes. Six valves were installed in Extreme Temperature Operations Unit aircraft and one retained as a spare. The temperatures encountered were from +4°C. to —40°C. (+40°F. to —40°F.) The valves were used approximately 15 times in each airplane. The number of hours of flight time on each installation was:

P-38L (1) 25 Jan to 1 Mar—56 hours
B-29 (2) 27 Jan to 1 Mar—37 hours
B-17G (2) 30 Jan to 1 Mar—60 hours
C-47A (1) 31 Jan to 1 Mar—22 hours

(2) The valves operated satisfactorily at all times. The valves were installed in accordance with Army Air Forces Drawing No. S45B6557-1 or S45B6557-2. On the B-29 and C-47A, where the manifold pressure gages are mounted from the front of the panel, installation of the drain valve in accordance with Army Air Forces Drawing No. S45B6557-2 makes it very difficult to remove the gage from the front of the panel without first disconnecting the hose line (AN856-4) from the rear of the instrument. This destroys the advantage of front mounted gages and can be remedied by teeing the drain valve into the instrument line about 14 inches from the instrument (as shown in Army Air Forces Drawing No. S45B6557-1) instead of at the rear of the instrument. A photograph of the installation in the B-17G aircraft is attached to this report as Exhibit A.

b. Carbon Monoxide Signal Assembly.

(1) One type K-1 Carbon Monoxide Signal Assembly was installed as standard equipment in B-24J Serial No. 44-41378. The glass tube in the vacuum supply gage was broken when the airplane arrived at this base. As no replacements were available, the gage was removed and a type F-4 vacuum gage installed. In addition, the "A" lead was broken at the female receptacle (Amphenol No. AN-3102-14S-6S) at the top of the instrument. This was repaired by Sgt. J. Fox (TSEPL-3G) and the instrument was reinstalled for low temperature tests. There were no known concentrations of carbon monoxide available to test the accuracy of the instrument. Operation was tested by holding a lighted cigarette to the sampling tube in the cockpit. The signal assembly was located aft of the bomb-bay.

(2) On 1 March the airplane had 204:25 hours flying time. The instrument was tested at temperatures between 0°C. and —30°C. (+32°F. and —22°F.) The instrument operated satisfactorily at all times. Lowest ground temperature was —45°C. (—49°F.) and lowest free air temperature in flight was approximately —55°C. (—66°F.) During warm-up period the alarm relay always closed and the instrument stabilized in less than five minutes. On several occasions the instrument gave an alarm on or shortly after take-off. The pilot opened the windows and after a few minutes the alarm would stay off when the reset button was depressed. The longest period necessary to shut off the alarm was approximately ten minutes.

4. The mean temperature from 1 December to 1 March was approximately —16.5°C. (+3°F.) The lowest ground temperature encountered was —43°C. (—45°F.) and the lowest mean temperature for one day was —38.4°C. (—37.1°F.) Lower free air temperatures were encountered in many cases at altitude for short periods of time. Under these conditions only two failures, due to low temperatures, were encountered. One was air driven gyro flight instruments and the other, standard

installations of vacuum selector valves. Experimental installations of electric flight instruments and new types of vacuum selctor valves, designed to overcome these difficulties, performed satisfactorily at the low temperatures encountered (reference, paragraphs B-2b and B-2h of this report.)

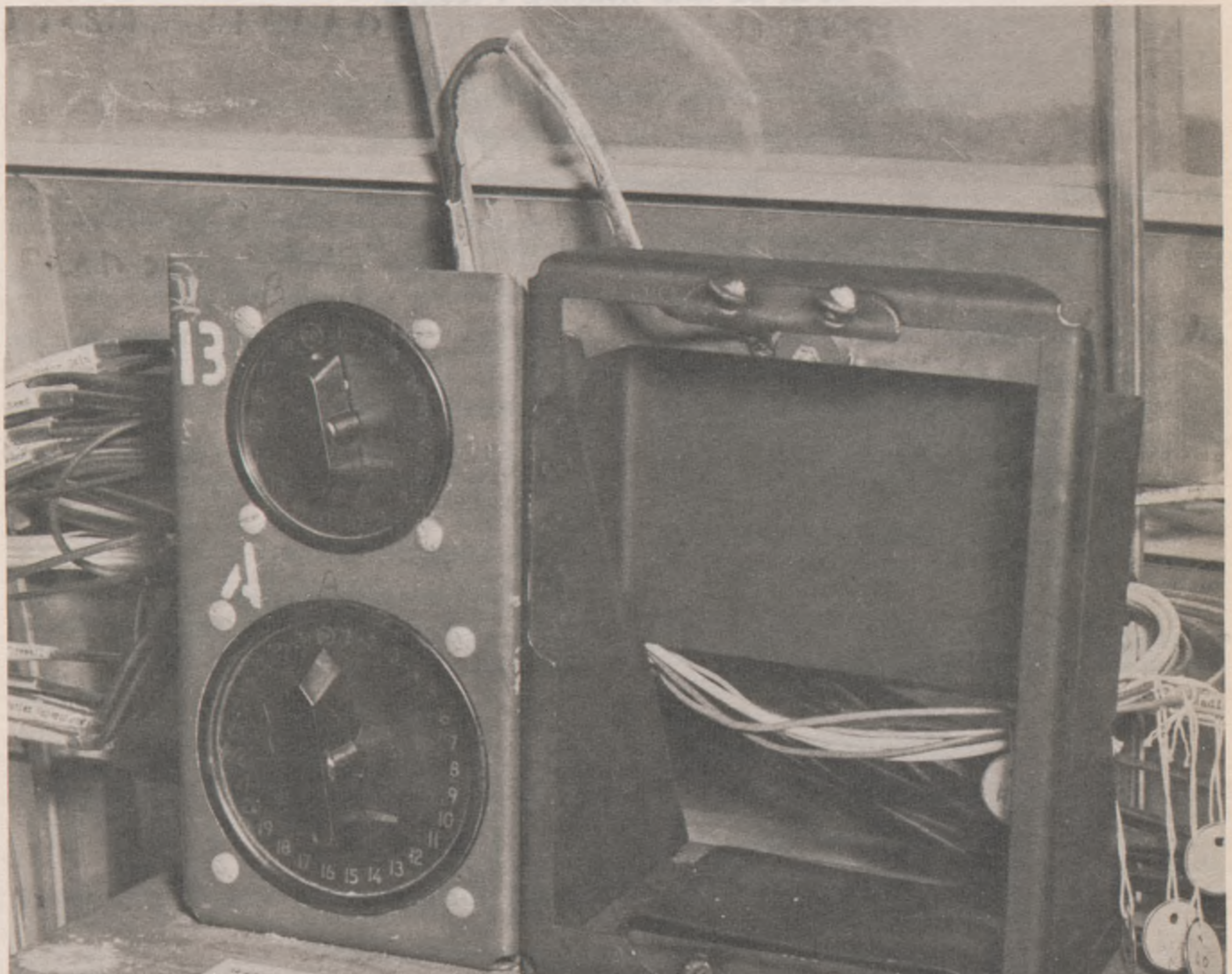
5. The maintenance required on standard equipment in production aircraft can be reduced considerably by stricter adherence to Army Air Forces Installation Specifications and Requirements. Items observed during test work and investigation of problems encountered by other organizations are listed below. These items are not to be construed as winterization or low temperature problems but are a source of trouble under any conditions. Where maintenance is involved, the troubles were much more noticeable here because of the difficulty of working in low temperature conditions.

a. Front mounting of instruments is not complete by any means. P-63, P-38, B-24 and B-29 airplanes are particularly difficult to work on because the instruments are rear mounted.

b. Suction gages on B-25 (G, H and J) and C-46 aircraft do not have a vent connection to the air inlet of the gyro instruments as required by Specification AN-I-5.

c. The A-1 pressure transmitters on the B-17G and C-54 aircraft were relocated to make them accessible for servicing. The pressure gage (oil and fuel) lines cannot be reached in the wing of the B-29 as there are no access doors near the lines. On one occasion it was necessary to heat the wing section between the engine and the firewall from the outside in order to free a line which had frozen.

d. Front mounting of oil and fuel pressure gages on the A-26 and P-61 airplanes is ineffective because of insufficient flexible hose on the instruments. In the P-61 the instruments could be serviced from the front but to remove an instrument it was necessary to disconnect the hose lines from the back of the panel. In the A-26 it was



Typical installation—thermocouple selector switch and bracket for potentiometer necessary to service the line and to disconnect the hose lines from the back of the panel.

e. As noted in Memorandum Report No. TSESE-4-17 dated 26 February, the number of failures of Gyro-Horizon Indicators is excessive.

f. There were many failures of cylinder head temperature gages due either to cracked cover glasses (at the adjusting screw) or broken leads.

C. CONCLUSIONS

1. Except as noted in Paragraph B-4, aircraft instruments operated satisfactorily at the lowest temperatures encountered.

D. RECOMMENDATIONS

1. It is recommended that Electric Gyro Flight Instruments be installed in aircraft for use in extreme low temperature conditions.

2. It is recommended that approved winterized vacuum selector valves be installed in production aircraft.

3. It is recommended that project engineers take steps to correct the items in Paragraph B5 to decrease the maintenance requirements on Army Air Forces aircraft.

Cold Weather Tests of the Type A-5, 35 mm Motion Picture Camera

Prepared by: W. G. Straube, 1st Lt., A. C. Photographic Laboratory

A. PURPOSE

1. To determine the functioning characteristics of the Type A-5 motion picture camera in sub-zero weather.

B. FACTUAL DATA

2. The Type A-3 camera was operated with film at temperatures varying from 0 degrees to minus 45 degrees Fahrenheit and at altitudes as high as 30,000 feet. The following malfunctions were noted:

a. Difficulty was encountered in threading the camera with brittle film.

b. The motor became too stiff at extreme low temperatures to satisfactorily operate the film driving mechanism.

c. Improper tolerances in the shuttle mechanism caused perforations to be torn and as a result film buckling occurred which caused the breakage of film.

d. The governor fails to function properly at low temperatures due to the breaking design and lubrication difficulties.

e. Tachometer fails to operate consistently at low temperatures due to improper type of lubrication.

3. Detailed engineering test data are available in the files of the Photographic Laboratory.

C. CONCLUSIONS

4. The Type A-5 motion picture cameras previously produced are not satisfactory for extreme low temperature operation.

D. RECOMMENDATIONS

5. That future additional cold weather tests be conducted on Type A-5 cameras now being procured in accordance with Specification No. 75-2468, dated 2 November 1944.

Cold Weather Tests of Stereo-Mounted K-35 (35 mm) Cameras

Prepared by: Carl B. Balcomb, Photographic Laboratory

A. PURPOSE

1. The purpose of this Report is to report results of tests of Stereo-mounted (35 mm) K-35 camera assembly during the 1944-1945 cold weather tests conducted by the Photographic Laboratory.

B. FACTUAL DATA

2. Subject experimental assembly, (see Appendix A), was designed for the making of three dimensional stereoscopic photographs of details of mechanical devices or planes in flight, for training or identification purposes.

3. Two standard commercial K-35 cameras were so mounted, with prisms, as to make possible the varying of interocular distance to produced natural depth effect in three dimension photographs of objects ranging in distances of from approximately four feet to fifty feet from the camera assembly. Means are also provided for the use of synchronized flash equipment.

4. Tests indicated that the full power of five batteries operating at approximately 70°F. was required to operate all elements of the assembly and that batteries mounted as a part of the assembly exposed to extremely low temperatures would not function.

a. The mounting of the solenoids were found to be unstable because the plastic body of the cameras failed to hold the mounting screws securely.

b. The triggers in the gun-grip handles required too great a pressure to effect contact which made it difficult to hold assembly level at moment of exposure.

C. CONCLUSIONS

5. It is concluded that for proper cold weather operation, a special battery case should be provided. This case could be hung from belt or shoulder straps near the human body and under heavy outer garments, and with an extension cord which could be plugged into the camera assembly.

6. That the solenoids should be mounted with bolts, washers and nuts in place of screws in threaded holes in the plastic body of the camera.

7. That "microswitch" triggers be used in place of the heavy spring action triggers now used.

D. RECOMMENDATIONS

8. It is recommended that when modified as suggested above, further tests of subject assembly be made under similar conditions.

Cold Weather Tests on the Types B-1 and B-1A, 16 mm Motion Picture Cameras

Prepared by: W. G. Straube, 1st Lt., A. C. Photographic Laboratory

A. PURPOSE

1. To determine the functioning characteristics of the Types B-1 and B-1A motion picture cameras in sub-zero weather.

B. FACTUAL DATA

2. The Types B-1 and B-1A camera were operated with film at temperatures varying from 0 degrees to minus 45 degrees Fahrenheit and at altitudes as high as 30,000 feet. The following malfunctions were noted:

a. The 12 and 24 volt motors supplied with the Type B-1A camera became too stiff at extreme low temperatures to satisfactorily operate the film driving mechanism.

b. The peep-sight type of viewfinder, which is usually furnished as a standard finder with both types B-1 and B-1A cameras is unsatisfactory for aerial utilization due to the danger of having the eye bruised or frozen when coming in contact with the finder eyepiece.

c. Both types of cameras as manufactured, are produced with tolerances which are too tight for cold weather operation and unless the film driving mechanism and moving parts are properly winterized, the camera does not function satisfactorily at low temperatures.

d. Difficulty is encountered in accomplishing the proper film take-up on the Type B-1A when 400 foot capacity magazines are used due to the spring belt system of take-up.

3. Detailed engineering test data are available in the Photographic Laboratory files.

C. CONCLUSIONS

4. The Types B-1 and B-1A motion picture cameras as delivered to the using activities is not satisfactory for extreme low temperature operation.

D. RECOMMENDATIONS

5. Types B-1 and B-1A motion picture cameras to be issued from supply depots to the using activities concerned with cold weather operations should be winterized in accordance with latest existing information by motion picture maintenance repair activities prior to shipment of cameras for cold weather utilization.

Cold Weather Tests on the Type A-7, 35 mm Motion Picture Camera

Prepared by: W. G. Straube, 1st Lt., A. C. Photographic Laboratory

A. PURPOSE

1. To determine the functioning characteristics of the Type A-7 motion picture camera in sub-zero weather.

B. FACTUAL DATA

2. The Type A-7 camera was operated with film at temperatures varying from 0 degrees to minus 45 degrees Fahrenheit and at altitudes as high as 30,000 feet. The following malfunctions were noted:

a. The 24 volt motor supplied with subject camera becomes too stiff at extreme low temperatures to satisfactorily operate the film driving mechanism.

b. Due to the design of the spider turret difficulty is encountered at low temperatures in rotating and seating the desired lens mount to the proper taking position.

c. The peep-sight type of viewfinder which is usually furnished as a standard finder with the Type A-7 camera is unsatisfactory for aerial use inasmuch as the eye cannot be placed close to the eyepiece without being endangered by freezing or bruising.

d. The camera as manufactured is produced with tolerances which are too close for cold weather operation and unless the film driving mechanism and moving parts are properly winterized, the camera does not function satisfactorily at low temperatures.

e. Difficulty is encountered in accomplishing proper film take-up when 400 foot magazines are utilized due to spring belt system of take-up.

3. Detailed engineering test data are available in the files of the Photographic Laboratory.

C. CONCLUSIONS

4. The Type A-7 motion picture camera as delivered to using activities is not satisfactory for extreme low temperature operation.

D. RECOMMENDATIONS

5. The Type A-7 motion picture cameras to be issued from supply depots to the using activities concerned with cold weather operations should be winterized in accordance with latest existing information by motion picture maintenance repair activities prior to shipment of cameras for cold weather utilization.

Water Repellent Jacket for K-17 or K-22 Camera

Prepared by: E. Leger, Capt., A. C. Photographic Laboratory

A. PURPOSE

1. To report the results of tests conducted to determine the value of a water repellent jacket for K-17 or K-22 camera for Army Air Forces use.

B. FACTUAL DATA

2. Several jackets were fabricated by Troy Sunshade Company, Troy, Ohio, in accordance with Army Air Forces Drawing No. X45G14761 for preliminary test purposes. See Photographs Nos. G-5168 and G-5170.

3. One jacket was subjected to extreme cold tests and water repellency tests in the laboratory. The results of both tests were favorable in determining flexibility of material at —60°F. and water repellent characteristics after being exposed to running water for 18 hours while fitted on a camera.

4. Two jackets were sent to the Tropical Test Detachment in Panama for tests. These tests were incomplete due to insufficient time available after the jackets had been received. However, as a result of these tests, the thread used in making the jacket was found to be unsatisfactory and has been changed to nylon to prevent attack by fungus. The seam has been treated to make it more water repellent.

5. Two jackets were sent with the cold Weather Detachment to Alaska and subjected to normal winter

operations in that latitude. It was not expected that the jacket would be used in extreme cold operations, but several minor changes have been accomplished as a result of these tests.

a. The binding has been made stronger around trunnion holes.

b. The drawstrings will be tacked to the material so that they will not be pulled out and become ineffective.

c. A heavier grade of material would be better, but not obligatory.

C. CONCLUSIONS

6. As a result of numerous laboratory and field tests, the jacket has been improved considerably over the original design. The jacket is now deemed satisfactory for the purpose for which it was intended, namely as a water repellent jacket for use with all focal length cameras of either the K-17 or K-22 type.

D. RECOMMENDATIONS

1. It is recommended that the subject jacket be listed in the Army Air Forces stock list and made available for the use of service activities.

Cold Weather Test of Color Film

Prepared by: B. D. Merrill, Capt., and S. P. Balcomb, C/WO

A. PURPOSE

1. To report on the cold weather test of color film conducted at Ladd Field, Alaska, during the winter of 1944-45.

B. FACTUAL DATA

2. Three rolls of aerial Kodacolor were exposed and processed, and the following observations recorded:

a. The required color balancing filter tests were made with little difficulty and the processed film demonstrated that the recommended filters gave the best results.

b. There were some difficulty in the handling of the gelatin filters required for the tests, as they became quite brittle and cracked easily at low temperatures.

c. There was no apparent loss of color film speed at the average temperature of approximately 25°F. found inside the aircraft. However, more exposure meter data will be necessary to definitely establish aerial film speeds under the rapidly changing light intensities found at extreme latitudes.

d. There was little difficulty encountered in processing aerial Kodacolor with the color kits. However, because of the difficulty in securing large water supplies, it was necessary to substitute successive rinses where the processing instructions called for washing in running water.

3. Some comparative tests were made using cut-sheet Ansco Color film and Kodachrome. Both types of film were generally under-exposed and the resulting photographs were too dark for accurate comparison.

C. CONCLUSIONS

4. It is concluded that aerial color film can be exposed and processed successfully under cold weather field condition with only the minor change of substituting successive rinses where the processing instructions called for washing in running water.

5. It is concluded that although the excessive changes of the gelatin filters required by the filter tests eventually caused cracking at low temperatures; these filters did perform satisfactorily when used in the recommended standard manner.

6. No conclusions could be made as to the comparative merits of Ansco Color film versus Kodachrome under cold weather conditions.

7. It is concluded that in extreme latitudes, where the sun shines for short periods only and then at very low angles, it is extremely important for good quality color photographs to secure reliable exposure data from dependable exposure meters.

D. RECOMMENDATIONS

8. It is recommended that personnel using color film in regions of extreme latitude be impressed with the importance of correlating the readings of a dependable exposure meter with test exposures on the type of color film they are using, and then strictly adhering to the use of that exposure meter.

9. It is recommended that instruction sheets for processing color film be amended to include data for successive rinses to replace washing in running water wherever the latter is unavailable.

10. It is recommended that further exposure meter data closely correlated to film exposure series be secured on future cold weather tests.

Cold Weather Test of the Type N-5 Kit, 16 mm Motion Picture Film Field Processing

Prepared by: R. D. Fullerton, 1st Lt. and S. P. Balcomb, C/WO

A. PURPOSE

1. To report results of cold weather tests conducted on the 16 mm Field Processing Kit, Type N-5, to determine its compliance with the requirements as set forth in Specification No. 31394 (Type K-2 Developer) and Specification No. 31395 (Type C-4 Prmter).

B. FACTUAL DATA

2. One Type N-5 kit manufactured by the Houston Corporation, Los Angeles, California, was submitted to the Photographic Laboratory for cold weather tests 27 November 1944.

3. The kit, as submitted, consisted of one Type K-2 developer with accessories, one Type C-4 printer, one 16 mm editor and splicer with comparator, and one darkroom cabinet.

4. The tests consisted of operation of the kit in normal room temperatures of from +55°F. to +75°F. in a Jamesway Shelter when the outside air temperatures ranged from —51°F. to +20°F.

5. Due to an inadequate water supply, it was necessary to operate the developer without the benefits of running water. The wash tank was filled with 4½ gallons of water and was drained and refilled after the processing of each 200 feet of film.

6. Table I shows the temperature range in which both negative and positive film was developed:

Table I

TEMPERATURE RANGE, PROCESSING SOLUTIONS, TYPE N-5 KIT

Negative Film Temperature	Minutes Development	Positive Film Temperature	Minutes Development
Plus 55°F.	17	Plus 62°F.	17
60	17	65	15
62	15	68	13
65	13	70	12
68	12	72	11
70	10		
72	9		

7. Seventeen minutes development was the maximum processing time possible with the K-2 developer. Although the film was somewhat under developed at +55°F., it was possible to make a print of satisfactory quality from the negative. Because positive film requires a longer developing time, it was not possible to develop this film at plus 55°F.

8. All solutions were allowed to freeze in the tanks of the developing machine for a period of 12 hours. Thawing out of the solutions was accomplished by using immersion heating elements. Because the hydroquinone of the developing solution had crystallized, it was necessary to heat the solution to +100°F. to completely redissolve it. The solutions were then used without apparent harm to the film. A thorough inspection and subsequent operation of the developing machine revealed that no damage was caused by the freezing.

9. Due to lack of running water, it was necessary to siphon the tanks by manual means.

10. Lacking the necessary tool, considerable trouble was experienced in making tight water-proof connections between the various water hoses and the developer.

11. Poor packing and crating of the kits resulted in broken plastic knobs on the risers and a loosened tachometer on the control panel.

12. The printer, Type C-4, performed satisfactorily at all room temperatures. However, due to the peculiar design of the aperture plate block a uniform lack of absolute contact was noted on all printed film.

13. The darkroom cabinet of the kits ultimately became a storage locker for miscellaneous items. Adequate darkroom facilities were available at all times and it was not necessary to use the cabinet for loading or rewinding.

C. CONCLUSIONS

14. It was concluded that:

a. The Type N-5 kit is satisfactory for field use in cold weather climates if the operating temperatures are maintained above +60°F. This is possible if the darkroom is only a Jamesway Shelter with outside temperatures as low as —51°F.

D. RECOMMENDATIONS

15. That the darkroom cabinet be excluded from the Type N-5 kit.

16. That a suitable wrench be made a part of each Type K-2 developer.

Cold Weather Tests with F-5E Airplane

Prepared by: A. C. Olson, Capt., and S. P. Balcomb, C/WO

A. PURPOSE

1. To report on the camera compartment heating, and window defrosting tests, conducted at the Cold Weather Test Detachment, Ladd Field, with an F-5E airplane, during 1944-1945.

B. FACTUAL DATA

2. An F-5E airplane No. 44-23602 was used for the camera compartment heating, and window defrosting tests. Several flights were made with the normal camera compartment heat; several flights were made with ducts to conduct the hot air to each window, and two flights with no heat provided to the camera compartment.

3. During each of the flights, the free air and camera compartment temperatures were recorded at each 5,000 foot level up to 30,000 feet and likewise on descent (See Appendix I). Three (3) pictures were taken at each of these altitudes.

4. The film from these flights was inspected with regard to window frosting or fogging. No signs of these were found at any altitude or under any of the compartment heating and window defrosting conditions. This was due to the low relative humidity of the atmosphere where the tests were conducted.

5. From the values of the temperatures in Appendix I, it can be seen that the general compartment heat produced the greatest difference between free air and camera compartment temperature. This is further illustrated in Figure I, which shows the plotted averages of four (4) flights with compartment heating and four (4) flights with defrosting ducts used. In both cases, the averaged free air temperatures are also plotted. This higher compartment temperature makes a better condition for camera operation. It has been found necessary, however, in other theaters of operation, to use the window defrosting ducts in order to keep the windows clear. In these areas, the relative humidity of the atmosphere is quite high and the windows fog easily, if the air is not blown across them.

C. CONCLUSIONS

6. In a theater of operations such as Alaska, the use of either window defrosting ducts or general camera compartment heat in an F-5E airplane is satisfactory for successful photography.

7. General camera compartment heat in an F-5E airplane affords a better camera operating temperature.

D. RECOMMENDATIONS

8. None.

Low Temperature Tests on Aerial Photographic Cameras

Prepared by: A. A. Koepfer

A. PURPOSE

1. To report on tests conducted at Ladd Field and at this Laboratory on experimental modifications of standard equipment, and also by the Proving Ground Command on standard equipment winterized in accordance with Technical Order No. 10-1-96, dated 20 October 1944.

B. FACTUAL DATA

2. Three experimental modifications were made on standard aerial camera equipment in an effort to improve operating performance at extreme low temperatures. The modifications were as follows:

a. The standard Type K-24 Aerial Camera was modified to incorporate thermostatically controlled internal heaters with fiber glass insulation.

b. A Type K-17 24″ shutter assembly housing was constructed of steel instead of the usual bronze to minimize binding and contractual interference caused by different rates of contraction between the bronze casting and the steel shutter links.

c. A Type K-22 24″ cone was modified to provide for circulation of hot air between the filter and the rear and front lens surfaces, and also the internal surfaces of the cone to prevent condensation from gathering at these places.

3. Tests on the internally heated Type K-24 camera revealed very satisfactory operation under all conditions experienced throughout the tests. The lowest temperature encountered was —55°F. Laboratory tests of this camera revealed satisfactory operation after storage at —65°F. for a period of 24 hours. One K-24 camera modified in this manner has been sent to England for tests to determine if the British concur in this method of insuring proper low temperature operation.

4. The steel shutter housing in the Type K-17 camera performed very satisfactorily at all temperatures down to —55°C. Laboratory tests at temperatures as low as —65°F. also indicated satisfactory operation.

5. Test on the hot air heated Type K-22 camera did not prove too successful. The definition on the negative is affected by turbulence caused when hot air passes across the lens surfaces. Also during test the passing of the hot air over the cold lens surfaces caused the lens to check. In view of these factors, this method of heating is not recommended and instead electrical heated filters and internal electrical heaters are to be provided.

6. Several cold weather tests were conducted by the Proving Ground Command on all standard type aerial photographic cameras which had been winterized in accordance with Technical Order No. 10-1-96 prepared by this Laboratory. Results of these tests were very good as satisfactory performance was obtained under all conditions at temperatures down to —62°F. Complete reports covering the tests on each type of equipment are available in the cold weather test file of this Laboratory.

C. CONCLUSIONS

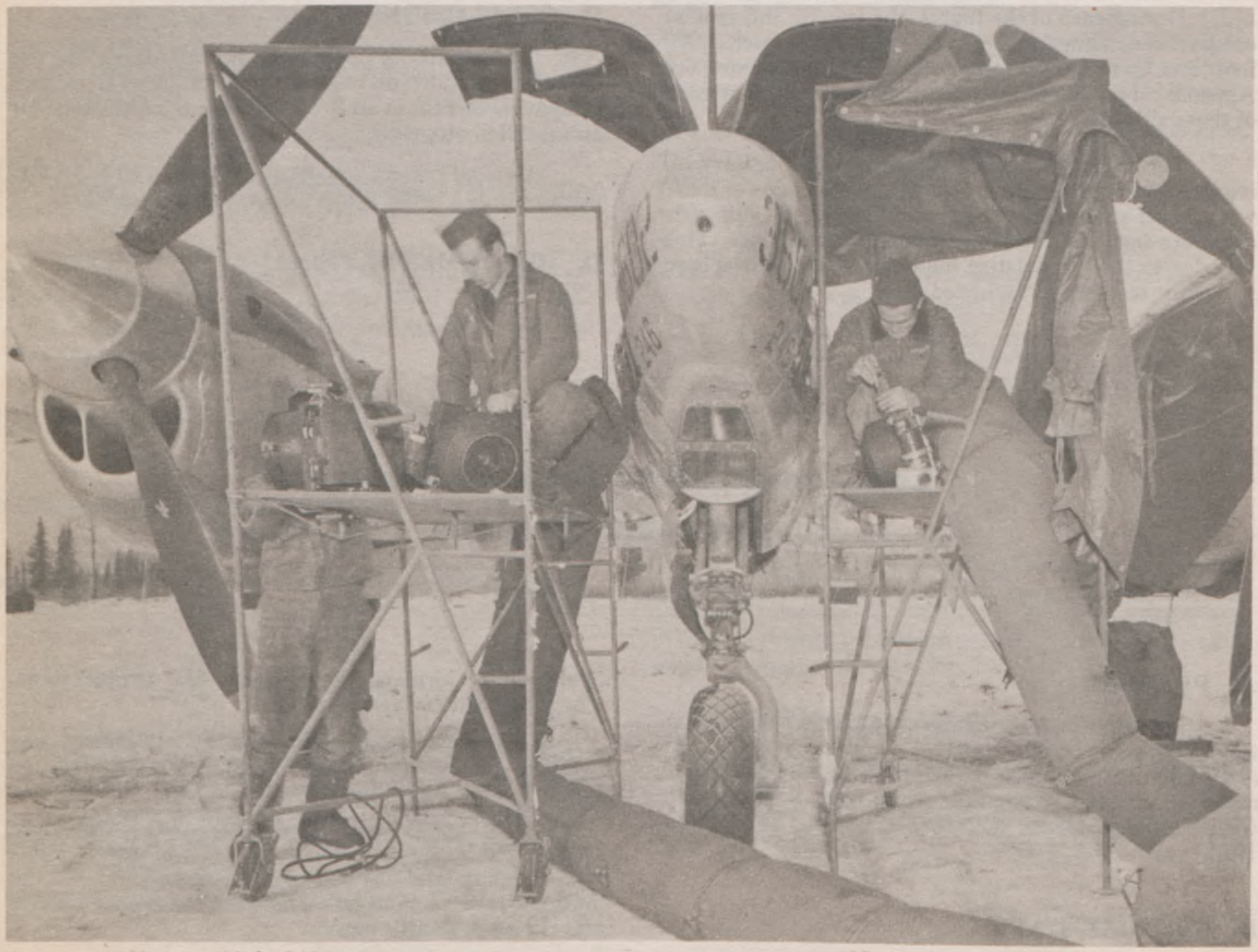
7. The above information relative to performance of aerial cameras operating at temperatures as low as —65°F. indicates that the problem has been greatly alleviated in the past two years. The prime factors contributing to reliable operation at low temperatures were:

a. The development of a new type of grease and oil each having excellent low torque characteristics at extreme low temperatures.

b. The elimination of contractual interferences between mating parts constructed of different materials by using similar materials and providing for additional clearances.

D. RECOMMENDATIONS

8. It is recommended that modification (a) and (b) of Factual Data Paragraph 2 be incorporated in future production of K-24 and K-17 aircraft cameras respectively.



Installing cameras—P-38

Ground Cameras

Prepared by: L. Woloshin & S. P. Balcomb, C/WO

A. PURPOSE

1. To report the results of the Cold Weather Tests of 1944-1945 insofar as they are applicable to ground cameras.

B. FACTUAL DATA

2. THE CAMERAS TESTED DURING THE WINTER OF 1944-1945 WERE:

a. Kodak 35 mm with rangefinder.
b. Type C-1 Ground Camera.
c. Type C-3 Ground Camera.
d. Type C-4 Ground Camera.

3. TYPE C-1 GROUND CAMERA.

a. The Type C-1 Ground Camera tested this winter is one that had previously been used during the tropic tests of 1944.

b. It was observed, upon unpacking the camera at the start of the cold tests, that the glued joints of the camera bed had become unfastened.

c. It is believed that this was due to the tropic tests in view of the fact that the malfunctioning occured prior to the time cold tests were conducted.

d. Tests were conducted at —14 degrees Fahrenheit on the shutter and lens assembly and it was observed that the cement between the elements of the lens had cracked. This malfunctioning of the Gundlach lens was also reported during the cold tests of 1942-1943 and 143-1944. Mechanical operation of the shutter was satisfactory at —14 degrees Fahrenheit.

e. Shutter speed tests were conducted on the shutter assembly at room temperature and at —7 degrees Fahrenheit. The marked 1/50th second speed was actually 1/25th second. It appeared that the cable release for this shutter was approximately 1/16th inch too short. It is not known if the contraction of the metal of the shutter was responsible or whether the difficulty was due to the particular cable release used. However, the cable release worked satisfactory at room temperatures, but inoperation of cable release at low temperatures were no doubt due to contraction of both release and shutter assembly.

f. Shutter speeds tests were made using a Mark Hurd shutter tester.

4. KODAK 35 MM CAMERA WITH RANGE-FINDER:

a. The Kodak 35 shutter became inoperable shortly after the start of the test program. Examination revealed that the spring operating the blade controller latch (Part No. 56840) had become free. The camera was repaired but did not operate perfectly. Of the two Kodak 35's used for stereo photography, one operated satisfactorly. The source of difficulty in the second camera was that the spool assembly; fllm take-up, (Part No. 77275) was not being released when pulled up. Examination revealed the bushing remained in the take-up position. After repair, the camera operated properly.

b. Continued operation of the camera revealed that the K-35 is not constructed rugedly enough for ardous usage.

5. THE TYPE C-3 GROUND CAMERA:

a. The camera used, (Serial No. 43-31248) with a Graphex Shutter, had been used during the cold tests of 1943-1944, and the tropic tests during the summer of 1944. At the coldest temperatures recorded during this year's tests (—51°F.) the Type C-3 camera performed well. The winterized flash unit made possible proper flash synchronization.

b. After continued use of the camera where a long series of successive photographs were taken, the back of the camera and rangefinder eye piece frosted and caused inconvenience to the camera operator. No tests were conducted to determine the value of placing felt or chamois on the metal parts of the camera back for protection of the photographer's face. It may be possible to avoid this difficulty by extending the length of the range finder eye piece about 1 or 1-1/2-inches. However, an increase of length may interfere with camera storage in the carrying case and, also, the eye piece may project too far from the protection from breakage offered by the camera body. However, a telescoping eyepiece might be designed which would eliminate this factor.

c. The Graphex shutter of the Type C-3 Ground Camera was checked at —7 degrees Fahrenheit using the Mark Hurd shutter tester. These speeds were:

Nominal Speed	*Actual Speed*
1/200	1/100
1/100	1/50
1/50	1/16
1/25 .... Too long a duration to be measured.	

During the Cold Weather Tests of 1943-1944, the same shutter was tested at —30 degrees aFhrenheit and at —43 degrees Fahrenheit. At these temperatures the shutter operated more slowly. A comparison cannot be made in view of the fact that during 1944-1945, no tests were made at temperatures lower than —7 degrees Fahrenheit.

d. Focal plane shutter operated satisfactory at temperatures down to 10 degrees above. Below this point the curtain did not release properly.

6. TYPE C-4 GROUND CAMERA:

a. Remarks applicable to the proper performance of the Type C-3 Ground Camera apply to the tests conducted on the Type C-4 camera. This is due to the similarity of design and construction of the cameras.

b. Shutter speeds checked at —7° Fahrenheit with the Mark Hurd Tester were:

Nominal Speed	*Actual Speed*
1/200	1/200
1/100	1/100
1/50	1/50
1/25	1/100

Reason for the failure of the 1/25th second during this test is unknown.

7. Some difficulty was encountered with the rangefinder on the C-4 Camera. This apparently was due to tension of the cam spring.

8. Before shipment to Alaska, all camera parts requiring lubrication were cleansed in naphtha gas and relubricated with Specification ANG-3a, Grease; Lubricating, with special camera lubricants added and Specification AN-0-6, Oil; Lubricating.

C. CONCLUSIONS

9. It is concluded that if properly winterized, the subject cameras will operate at temperatures down to the lowest encountered (approx. —43°F.)

10. It is also concluded that further study should be made of rangefinders with reference to cold temperatures and the frequency with which they become out of synchronization.

11. It is further concluded that lenses manufactured by the Gundlach Optical Company are not suited for cold temperature operation.

D. RECOMMENDATIONS

12. It is recommmended to TSBPR-4L and TSSEQ-8, that procurement of additional lenses for the Type C-1 ground camera be made only of those lenses whose lens elements are cemented with a cement that is known to be capable of withstanding temperatures as low as —65 degree Fahrenheit.

13. It is further recommended that only limited use be made of the K-35 mm (with rangefinder) when low temperatures are existant.

Report to Chief, Maintenance Division

Prepared by: P. E. Shanahan, Col., A. C.

1. PURPOSE

The purpose of subject temporary duty was to act as liaison officer between CWTD, Ladd Field, Fairbanks, Alaska, and Maintenance Division, Headquarters, ATSC, to observe CWT methods, procedures and resulting maintenance problems.

2. FACTUAL DATA

a. A brief description of the Cold Weather Test Detachment's organization, purpose and scope will be given in order that a clear picture may be obtained of the entire program. For your information, attached as Exhibit "A" is chart showing the latest proposed organization of CWTD.

(1) Cold Weather Test Detachment operates under the jurisdiction of the Commanding General, AAF Proving Ground Command, Eglin Field, Florida. Its reports are submitted through him to the AAF Board, Orlando, Florida, where recommendations concerning the results of the winter's testing are made and submitted to the Commanding General, AAF.

(2) Directives for the operation of CWTD emanate from Headquarters, AAF, and are based in part on recommendations submitted by the AAF Board. CWTD is in reality composed of two (2) main parts, CWTD proper, which tests first-run production equipment for cold weather operation, and Extreme Temperature Operating Unit (ETOU), which is a part of the Engineering Division, Headquarters, ATSC, and which operates under the Commanding Offiicer, CWTD, while technical control rests with Engineering Division, Headquarters, ATSC. In reality, ETOU operates almost independently. It has its own directives, its own methods and procedures, and operates under the Commanding Officer, CWTD, only in that it conforms to CWTD's policies which govern its operations at Ladd Field. Whereas CWTD tests first-line production equipment, ETOU is engaged in testing experimental equipment.

(3) CWTD utilizes and operates Watertown AAB, Watertown, South Dakota, as a staging field for CWTD operations in that CWTD personnel, both officers and enlisted men based at Ladd Field, are returned to Watertown AAB during the spring and summer months. While there, troop training is conducted, airplanes are prepared for the coming winter's tests and shake-down flights on them are accomplished. The coming winter's cold weather test programs are drafted, and supplies are gathered which will be needed at Ladd Field for those tests. These supplies are then in the main flown to Ladd Field, though some are shipped by other methods. Watertown originally was a Second Air Force heavy bomber base and has fine runways for heavy aircraft. It has one (1) medium size hangar and adequate control tower and weather facilities. It also has ample housing facilities for the entire CWTD personnel of approximately seventy-five (75) officers and four hundred (400) enlisted men. During the winter months a housekeeping detachment only is stationed there, and occasionally airplanes from Ladd Field fly there for emergency supplies.

(4) CWTD has available for its use when needed several satellite fields in the area adjacent to Ladd Field, including Nome, Point Barrow, Galena, Tanana, Northway, Tanacross, Big Delta and Satellite. These fields are located anywhere from 25 to 500 miles distant, and while they were not built for cold weather activities, they are readily accessible and available when the temperatures at these fields are enough lower than those prevailing at Ladd to make it worth while for CWT airplanes to go there. They are also used as refueling stops for CWT airplanes which in the course of their testing may be out on extended flights away from Ladd, such as gunnery missions out over the Bering Sea. As an example of how these fields may be used, Ladd Field very, very seldom

Ladd Field, Alaska

Fairbanks, Alaska

has high winds, and normally when extremely low temperatures predominate there the wind is dead calm, or almost so. Big Delta, on the other hand, is very often subject to high winds, 15 to 20 mph, with sub-zero temperatures, and the winds go as high as 50 to 60 mph gusty. A 30 to 40 mph wind with temperatures of near zero or even slightly above presents a terrific ground handling and ground maintenance problem, even when compared with temperatures of —50° with calm conditions. Normally most of interior Alaska gets those low temperatures because the cold air collects in the valleys and plains which are protected by mountains and where calm conditions prevail at the surface. Usually fields subjected to these very low temperatures always have a temperature inversion 1000 to 2000 feet over the field. Then, somewhere between the 5000 and 10,000 foot levels, the normal decrease in temperature with increase in altitude is encountered so that temperatures at the 25,000-35,000 foot levels are about the same as encountered anywhere.

(5) As previously mentioned, CWT conducts tests on latest production equipment. To do this, they have approximately seventy-five (75) officers and four hundred (400) enlisted and civilian personnel and about thirty (30) to forty (40) production aircraft of all types (see attached list, exhibit "B"). The organization has Headquarters and Headquarters Staff and various operating sections, including Heavy Bombardment, Medium Bombardment. Cargo, Fighter and ground equipment, which conduct the actual tests and prepare necessary reports.

(6) ETOU has approximately twenty (20) aircraft (see attached list, Exhibit "C"), most of which are late model production items. These aircraft are equipped with latest experimental equipment. Maintenance personnel are furnished ETOU from the CWT pool. Test pilots and engineering personnel are from the Engineering Division, Headquarters, ATSC, and are usually from that Laboratory concerned with the particular equipment on which tests are being conducted. Aircraft and accessories manufacturing concerns are invited to participate in cold weather tests by both AAF Proving Ground Command and Engineering Division, and their representatives are sent to Ladd Field for these tests.

(7) Since all existing cold weather test directives are written around temperature ranges from —65° to +165°, there has of late been considerable discussion as to the merits of interior Alaska as a suitable field of operations for cold weather testing. Army Service Forces have done considerable testing in the neighborhood of Fort Churchill, Canada, located on the west shore of Hudson Bay, and there have been suggestions made that Churchill would be more suitable than Ladd for AAF cold weather testing because of temperature as low as those prevailing at Ladd with much higher wind velocity which certainly increases the cold weather maintenance problem. However, a careful analysis of the conditions prevailing in both localities would seem to indicate that there is very little difference between the two. Average wind velocity at Churchill for the winter of 1943-44 was a trifle higher than at Ladd proper but no higher than at some of the satellite fields. Temperatures, on the other hand, were also a bit higher, both as to maximum and mean values, while minimum values were definitely lower at Ladd. There also is the fact to be considered that the AAF have many expensive, well equipped installations in the interior of Alaska while Churchill is Canadian. By summer of '46 it is expected that the climatic hangar now under construction at AAF Proving Ground, Eglin Field, Florida, will be completed, and this hangar should be ample to handle the Air Force's cold weather test program. The building is 200'x240', 70' high in the center. It will be equipped with refrigerating machinery capable of lowering the temperature to —70°. There are also provisions for artificial snow, sand, rain and sleet storms, as well as wind machines. There will be arctic, desert, and jungle test rooms.

b. Operations for the winter of 1944-45. Cold weather testing of both production and experimental equipment has been considerably hampered this season by unusually mild weather. Temperatures, —35° to —50°, were rare at both Ladd and its satellites, so all testing was of a necessity conducted in only moderately low temperatures. Results of the past three (3) winters' testing have indicated that the Air Forces have brought all equipment to that standard of perfection where it can probably operate satisfactorily down to —30° or —35°. There are still problems to be solved in —40° to —55° range.

(1) Current problems include hydraulic fluids, oils and greases, engine preheaters, control cables, pulleys and movable surface hinges. Problems encountered in these last three (3) items are not only those of lubrication but binding caused by misalignment due to unequal expansion and contraction. Hydraulic seals have been bad this winter, particularly on P-47 type aircraft. Greases and oils, especially the former, are not yet satisfactory for extreme low temperatures. Tests on synthetic lubricating oils have been promising. Also synthetic tires versus natural rubber tires are being tested, but the results are not available as yet.

(2) Snow and ice tires. These items of equipment are controversial. Some pilots do not believe they pay for themselves, especially on heavy aircraft. Other pilots claim they would not operate without them. Yet, one engineer, an officer of ETOU, stated that one pilot who was very strongly in favor of these tires did not know that his own airplane was not so equipped. The old "beer bottle cap" style tire has been supplanted by a conventional non-skid type tire with the non-skid elements strengthened and bolstered by small steel inserts. In general, pilots of Cold Weather Test activities did not seem to think that there was enough noticeable increase

Ice grip tire with steel spring inserts

in performance of the snow and ice grip tires on heavy, high performance aircraft to warrant their use. The Aircraft used by the undersigned was equipped with the old "beer bottle cap" style tires. The airplane was light and of low performance, and on glare ice runway, with a very light film of water over the ice, they were a help in taxiing . However, such runways were encountered only three (3) times, twice in Alaska and once at Patterson Field. The only noticeable difference was that a great deal more care had to be exercised in taxiing. Snow and ice grip tires are difficult to manufacture, thereby slowing production, and are more expensive. The mild weather prevailing at Ladd Field during the latter part of January gave excellent opportunities to test these tires, and Cold Weather Test personnel were making every effort to obtain information on this equipment during the mild weather period which caused slippery runways.

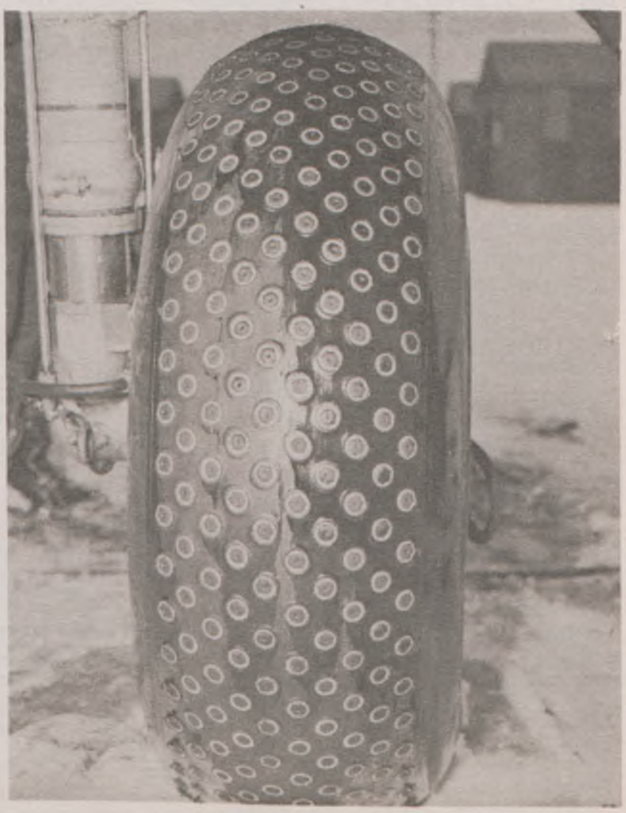
(3) Observations of the undersigned indicate that one of the biggest problems encountered in cold weather operation is the difficulties encountered by ground personnel in performing their duties. Field maintenance shelters are not yet adequate for use under all low temperature conditions, especially when low temperatures are accompanied by high wind velocities. Wherever adequate hangar facilities are available, cold weather problems are greatly reduced, but the moment primitive field conditions exist, ground crews get into trouble—the level of preventive maintenance drops, manhours to accomplish a given job increase enormously, and there is far more tendency for work to not be up to high standards. It is believed that more emphasis should be placed on ground handling equipment, mechanics' clothing, field shelters, etc.

(4) Photographic. Cold Weather Test Photographic Project Officer was contacted and stated that in general very little photographic trouble is being encountered this year. They have received photographic equipment improperly winterized, that is, lubricating agents had been improperly applied and gumming of shutters and other delicate moving parts had resulted. This matter has been reported to Photographic Maintenance Branch, Associated Equipment Section. The Base Photographic Officer, Ladd Field, stated that some balsam cemented compound camera lenses were still being received and that in extreme temperatures the compound lenses separated due to failure of the cement. Field developing laboratories still experience some difficulty in getting sufficient supplies of suitable water for use in their activities. Otherwise, photographic cold weather test problems are normal.

(5) *Communications equipment.* Maintenance difficulties with communications equipment available at Ladd Field, which included radar as well as radio, were slight.

(6) *Clothing, Emergency Kits and Survival Rations.* There is considerable evidence that these items of Air Force equipment are not completely satisfactory as yet for cold weather usage. Mr. Washburn of Personal Equipment Laboratory, Engineering Division, Area "B", contacted the undersigned and requested comments relative to the shortcomings of clothing, kits and rations. A copy of these comments is attached as Exhibit "D" and contains representative complaints made not only at Ladd Field but at other stations from Edmonton north.

(7) *Ground testing of engines.* At the present time there is no means at Ladd Field for operating aircraft engines on the ground under cold weather conditions. However, there is now nearing completion test blocks which were made from the old concrete structure originally set up for engine running stands by the 6th Air Depot Group. These testing stands were never com-



Ice grip tire with steel bottle-cap inserts after 67 landings pleted other than pouring the concrete tor the basic structures. Working from this as a base, the new cold weather test stands are being made and should be in full operation by next fall. These stands will then permit mounting both production and experimental type engines, either jet or conventional type, and running them under very low temperatures. Also, believed to be more important on a cold weather test angle, ground maintenance problems arising from cold weather operations may then be thoroughly exploited. In cold weather operation good maintenance is a major problem because of the severe conditions under which personnel must operate.

3. CONCLUSIONS AND RECOMMENDATIONS

a. If all Air Force equipment is to operate satisfactorily down to the extreme temperature range of —65°, which has been set up by directive from Headquarters, AAF, as the goal, then considerable work still remains to be done.

b. When the climatic hangar, AAF Proving Ground Command, Eglin Field, Florida, is completed and in operation, it should prove a very valuable tool for use in solving extreme cold weather problems.

c. If the Air Forces expect to operate in ground temperatures from —30° down to —65°, a great deal more emphasis must be placed on the development of suitable equipment for use on the ground. The efficient handling of aircraft, starting of engines, and, above all, the achievement of high maintenance standards will be factors of prime importance.

d. It is recommended that representatives of the Maintenance Division participate in the drafting of Cold Weather Test Programs in the same fashion as they now participate in 689 Inspections and Mock-Up Boards.

e. It is recommended that very close Liaison be maintained between the AAF Proving Ground Command and the Maintenance and Engineering Divisions, Headquarters, ATSC.

Report of Visit to Ladd Field, Alaska

Prepared by : R.C. Johnson, Capt, A.C. Maintenance Division

1. In compliance with par. 1 of Letter Orders No. 10-31-37 dated 31 October 1944, the undersigned proceeded to Ladd Field, Alaska, for the purpose of liaison on matters pertaining to maintenance in cold weather operation.

2. A representative of the Supply Division visited Ladd Field at the same time as the undersigned; therefore, no mention of the supply problems will be made in this report.

3. Base personnel contacted were the Adjutant, Air Inspector, Chief, Maintenance and Supply, Maintenance Officer, Technical Inspector and the enlisted personnel performing the maintenance.

4. Cold Weather Test personnel contacted were the Commanding Officer, Adjutant, Engineering Officer, Maintenance Officers, Technical Inspector and enlisted personnel performing the maintenance.

5. The maintenance in Cold Weather Test is broken down to types of aircraft-fighter, medium bomber, etc. A Maintenance Officer is assigned to each type aircraft and he is responsible to the Engineering Officer for their status. This system operates very satisfactorily, and the percentage of aircraft maintained in flyable status is very high.

6. A complete picture of the difficulties encountered when performing cold weather maintenance was not obtained, since —25°F was the lowest temperature registered. However, listed below are some approximate figures received from maintenance personnel making inspections on the aircraft.

a. The approximate time necessary to accomplish a normal 50 hour inspection at different temperatures is as follows:

Type Aircraft	Temperatures			
	0°F	—20°F	—40°F	—60°F
C-46	12 hrs.	16 hrs.	24 hrs.	40 hrs.
C-47	12 hrs.	16 hrs.	24 hrs.	40 hrs.
B-17	14 hrs.	18 hrs.	26 hrs.	45 hrs.
B-24	14 hrs.	18 hrs.	26 hrs.	45 hrs.
B-25	12 hrs.	16 hrs.	24 hrs.	40 hrs.
B-26	12 hrs.	16 hrs.	24 hrs.	40 hrs.
P-47	12 hrs.	16 hrs.	24 hrs.	40 hrs.
P-51	12 hrs.	16 hrs.	24 hrs.	40 hrs.
P-63	12 hrs.	16 hrs.	24 hrs.	40 hrs.

b. The approximate time *alloted* the crew chief to ready the airplane for flight is two hours.

7. Attached hereto is a list of Pre-flight and Daily Inspection items. This list was coordinated with both Base and Cold Weather Test maintenance personnel and approved.

8. The following recommendations were received by the undersigned:

a. That adequate tire tools be provided. The present Firestone Kit as issued is very unsatisfactory.

b. That T.O. 01-1-50 be revised to eliminate the necessity of requiring a man in the cockpit of an airplane when towing bars are being used to tow the airplane.

c. That T.O. 19-1-105 be revised to take care of activities operating from snow and ice covered fields (in process of revision).

d. That additional Aircraft Maintenance and Inspection Guides for The C-46, C-47, and C-54 be forwarded. (Being accomplished).

e. That T.O. distribution be expedited. (Checked with TSSEQ6C and was informed that they now have Overseas priority, which is the highest priority possible).

9. Information on Radar equipment is being forwarded to TSMTE5.

10. Recommendations:

a. That orders for all personnel visiting Ladd Field this winter specify that A.C. clothing will be issued at Great Falls instead of Q.M. clothing.

b. That the approved list of Pre-flight and Daily Inspection be included in all Aircraft Maintenance and Inspection Guides.

Report of Temporary Duty at Ladd Field

Prepared by: H. F. Helbig, Major, A. C., Maintenance Division

A. PURPOSE

The purpose of the subject temporary duty was to act as liaison officer between CWTD, Ladd Field, Fairbanks, Alaska, and Maintenance Division, Headquarters, ATSC, to observe CWT methods, procedures and resulting maintenance problems, with particular emphasis to engine maintenance problems.

B. FACTUAL DATA

1. *A brief description of the CWDT's organization follows*:

a. The Cold Weather Test Detachment operates under the jurisdiction of the Commanding General, AAF Proving Ground Command, Eglin Field, Florida. All reports are submitted through him to the AAF Board, Orlando, Florida, where recommendations concerning the results of the winter's testing are made and submitted to the Commanding General, AAF.

b. All directives for the operation of CWTD emanate from Headquarters, AAF and are based in part on recommendations submitted by the AAF Board. The Cold Weather Test Detachment is composed of two main parts, CWTD proper, which tests first run production equipment for cold weather operation, and an Extreme Temperature Operations Unit, which is part of the Engineering Division, Headquarters, ATSC. Basically ETOU operates almost independently under its own directives, methods and procedures, conforming only to CWTD's policy which govern its operation at Ladd Field, Alaska, and is engaged primarily in testing experimental equipment, as compared to testing of production equipment by CWTD.

c. There are several satellite fields available for both ETOU and CWTD in the area near Ladd Field, including Nome, Point Barrow, Galena, Tanana, Northway, Tanacross, Big Delta and Satellite. These fields are located anywhere from 25 to 500 miles distance, and while they are not built for cold weather testing they are readily accessible and available when temperatures are lower than those prevailing at Ladd Field. An example of how these fields may be used is indicated by the fact that Ladd Field very rarely has any high winds when temperatures are low. Big Delta, on the other hand, is subject to high winds with low temperatures; therefore, presenting a greater ground handling and ground maintenance problem than is encountered at Ladd Field, making it advisable to run various tests at this activity.

d. Since all existing cold weather directives are written around temperatures of —65° to +165°F., it is found that Ladd Field very rarely encounters temperatures below —35°; therefore, it would be advisable to select another location where lower temperatures prevail a greater percentage of the time for cold weather test. Attached is Engineering Division Technical Note TN-TSESE-1, (Exhibit #1) governing the design of Aeronautical Equipment for Operation in Extreme Climatic Conditions.

2. *Operations for the winter of 1944-45.* Cold weather testing of production and experimental equipment was hampered considerably the months of December and January by unusually mild weather. Temperatures of —35° to —50° were rare at both Ladd and Satellite Fields, so all testing was conducted only at moderately low temperatures. Observation, however, indicated that the AAF has brought all equipment to a standard where it is possible to operate aircraft with a reasonably amount of success at temperatures down to —30° or ——35°; however, at lower temperatures there are still many problems which will have to be solved before satisfactory operation can be accomplished.

a. Current problems at extremely low temperatures include hydraulic fluids, oils and greases, engine preheaters, control cables, pulleys and movable surface hinges. Problems encountered in the last three items are not only due to lubrication but also are affected by the large amount of expansion and contraction, and misalignment in large surfaces and cables. It was noticed that the hydraulic seals on P-47 airplanes are entirely unsatisfactory, and tests on synthetic lubricating oil PPO-265, at the time the writer was in Alaska, seemed to be very promising.

b. Ground testing of aircraft engines. At the present time there are no means at Ladd Field for operating aircraft engines outside of aircraft on the ground under cold weather conditions. There are, however, test stands being constructed at the present time for testing both conventional engines and gas turbine type engines. Attached are photos of both conventional and gas turbine test cells which have been constructed at Ladd Field. (Exhibit #2, pages 2A and 2B).

3. *The following is a brief resume of some of the engine difficulties experienced at Ladd Field*:

a. Oil hose failures on P-51 aircraft is prevalent during cold mornings. Inspection of the hose in the field disclosed that it was aromatic non-self-sealing hose. In

Maintenance using heated nose hangars

accordance with existing Technical Orders, this type hose is not recommended for oil systems but may be used if the regular hose is not available. For cold weather operation, it is recommended that only specified oil hose be used on these aircraft.

b. Attached is an estimated oil dilution schedule used by CWTD and ETOU for use with synthetic oil in various combat aircraft based on zero per cent dilution required for —15°F. and 20% required for —65°F. This schedule appeared to be satisfactory. (Exhibit #3, page 2C).

c. On 6 December 1944 the B-29 aircraft descended from 33,000 ft. at an outside air temperature of —46°C. and found that when 2,000 ft. altitude was reached the two propellers on engines using regular grade 1100 oil did not govern for approximately one minute. The propellers using synthetic oil performed satisfactorily. Dilution on B-29 aircraft was accomplished in accordance with Technical Order 02-1-29, and table shown below. The above data is preliminary data, however, it is considered that variations in oil tank level will not greatly effect the above dilution times.

Anticipated Free Air Temp. °F.	Dilution Time in Minutes	Approx. % Dilution
25	2	5
10	4	10
—5	9	15

d. An engine failure was experienced on the B-17G airplane on 16 December during the feathering test of hydraulic propeller feather system on #3 engine. The engine was feathered at 20,000 ft. and —30°C. Feathering was accomplished in 6-½ seconds, however, the oil system was not diluted. After ½ hour flight in this condition the propeller was unfeathered smoothly in eight seconds with RPM set at 1500, however, it increased gradually up to 2500 RPM and found that the governor had no control over the RPM. It was then noted that the oil pressure was zero. As the result of the failure to dilute prior to feathering the propeller during flight, the oil had become stiff and when the engine was turned over had caused failure of the supercharger blower bearings and supercharger cases. It is recommended that all future flight instructions for cold weather operation stress the importance of dilution prior to the feathering of propellers to prevent similar failures.

e. The attached photo, (exhibit 4, page 3A) shows ice which was removed from the fuel line of a B-25J. The line and ice was located in the bomb bay on the discharge side of the right wing fuel boost pump. The fuel drains had been checked the day before and the ice was located below the condensate trap. The reason for this condition was not determined.

f. Attached are photos showing P-38 aircraft after 30% dilution. This aircraft lost approximately seven gallons of oil in three minutes during take-off powers. This problem had not been solved at the time the writer left Ladd Field. (Exhibit #5, pages 3B, 3C).

C. CONCLUSIONS

1. If all AAF equipment is to operate satisfactorily in accordance with extreme temperature operation goals set up by the AAF, a great deal of additional development is necessary during cold weather testing.

2. Maintenance records available in this section, taken over four months at the ETOU, indicate a definite increase in maintenance required on aircraft proportional to the increase in temperatures.

3. Present shelters used by maintenance personnel are highly unsatisfactory under windy conditions.

4. From the maintenance viewpoint the P-59 aircraft with I-16 units installed operated very satisfactorily. Starting problems were at a minimum on this aircraft.

D. RECOMMENDATIONS

1. It is recommended that representatives of the Maintenance Division participate more actively in formulating cold weather test programs and are made a part of the test program, rather than acting as liaison representatives with no power or authority in the program.

2. It is further recommended that close liaison be kept between AAF Proving Ground Command and Maintenance and Engineering Divisions of this Headquarters.

3. It is the belief of the writer that aircraft engine starting problems would be greatly lessened by the use of hot circulators of coolant and oil prior to starting of tests. Such circulators are available but were not tested at Ladd Field during the 1944-45 season. Heat circulators would perform two functions; that of heating the oil, which in turn will heat the engine. It was definitely found that by applying heat to accessory case and air intake starting could be accomplished more easily. Hot oil and coolant circulators would heat the accessory section making far better volatilization of fuel and prevent excessive wear on parts due to stiff oil.

4. It is strongly recommended that guards for the fans on Herman Nelson heaters be furnished to prevent injury to personnel. Several mechanics at Ladd Field lost fingers due to the fact that there is no guard provided on these heaters. A simple screen over the fan would prevent this.

5. It is further recommended that CWTD advise this Headquarters immediately upon discovery of corrective measures on engines and equipment during cold weather operation. At the present time this information is not disseminated to this Headquarters until after it has cleared through the AAF Board and Headquarters, AAF. It is felt that this wastes much time in getting effective fixes disseminated to other operating activities. Under the present plan no definite decisions, only recommendations, are made by the CWTD, and action on recommendations must be taken by the AAF Board. By giving CWTD, which is right on the spot, power of decision, operating units in the field could benefit more quickly from the work being done at Ladd Field, and receive these benefits during the same winter.

Report of Visit to Ladd Field, Alaska

Prepared by: E. E. Murphy, Capt., A. C.

A. PURPOSE

1. The purpose of this travel was for liaison on matter pertaining to supply in cold weather operations.

B. FACTUAL DATA

1. At the time the undersigned arrived at Ladd Field, there was little flying activity. Planes and crews were just arriving and continued to arrive all through November. Practically the only flying being done at the time was routine local flights. All of the various sections of cold weather tests were engaged in setting up shop, and most of their buildings were still in the construction stage.

2. This was particularly true of the Cold Weather Test Supply Section. During the testing season 1943-1944, Supply had been located in the Main Hangar, and had been well organized. For some reason, in July of this year, it was moved out of there and the supplies left out in the open or in small Stout houses until the new technical supply buildings were completed. By early November, the two buildings were complete. However, bins were still being built, and there was no heat other than that furnished by a few small coal stoves and Nelson heaters operating outside the building. Use of Nelson heaters for this purpose was universal throughout. Steam heating equipment is on hand, but at the present rate of progress, will not be installed until late December or January, if then. Supplies were piled indiscriminately in both warehouses, in Stout houses, and in the open. A large quantity of project material was being held at Depot Supply until technical supply was organized.

3. Personnel in Cold Weather Test Supply consisted of two (2) officers and seventeen (17) enlisted men. However, of the 17 enlisted men, only four (4) were qualified supply men, the other thirteen (13) consisting of clerks and handlers, none of whom were familiar with supply procedures. This placed a heavy burden on the regular supply men. Conversation with the officers in charge of Cold Weather Test Supply and Depot Supply revealed that a rotation policy, as it is now set up, works to their disadvantage. Enlisted men who have become qualified supply clerks during the last two years are rotated to the United States. Their replacements, even though they have an M.O.S. of 826, are not supply clerks, and considerable time is lost in training these new men. In addition, many of these replacements have high enlist-

Snow Jeep

Fuel dump at a typical small Alaskan Air Field

ed grades, which limits the chances for promotion of the remaining qualified clerks. This situation has a decidedly disturbing effect on morale.

4. During the testing season 1944-1945, approximately fifty (50) of the latest models of fighters, bombers, cargo and liasion aircraft will be used. Special projects had been written in August, and by November approximately two-thirds of the material had reached Ladd Field. Projects as written seemed to be fairly complete, with a few exceptions. No project had been written for B-29 planes, three of which will be used. No class 03-E material was included, even though approximately twenty-five (25) of the ships now at Ladd Field are turbo supercharged. This was brought to the attention of Capt. Hamlin, the supply officer, and immediate action was taken by him, through Major Stratten, Proving Ground Command Liaison Officer at Wright Field, to secure delivery of the necessary supplies.

5. Supplies reach Ladd Field by several routes—by air from Edmonton, by boat and rail from Anchorage, and by the Alcan Highway. Considerable time is lost on routine shipments, due to trans-shipment at Tacoma and Anchorage. Such shipments take from three to five months to reach their destinations. Air and highway shipments are quicker, time running from two days to six weeks. One complaint made is that ATC often arbitrarily removes priority cargo destined for Ladd and routes it via Alcan Highway. The assertion was made, without any proof being offered, that priority Cold Weather Test shipments and routine ATC shipments, requisitioned much later, often arrive at Ladd on the same plane.

6. During the month of November, most requisitions were being filled by Depot Supply. This was due to the fact that very little material was available in Cold Weather Test Supply, since the buildings had just been completed. Only a small portion of available material had been unpacked and binned, and bin cards and locator files were non-existent.

If material was not in Depot Stock, it was requisitioned by radio directly through the Theater Branch in this Headquarters. Late in the month, this procedure was changed and requisitions were forwarded to Pacific Overseas Air Technical Service Command. The effect of this change is not known as yet. Personnel at Ladd Field were of the opinion that it would materially lengthen the time required to complete action.

7. The condition of the material arriving at Ladd Field is generally good. This, however, is due more to good luck than to good packaging. The following points were noted:

a. Of the larger assemblies, starters, generators and magnetos were originally well packed. However, shipping tickets on the outside container were lost, necessitating breaking open the moisture barrier in order to identify the material. Coolant radiators, oil coolers and test stands were not protected by moisture barriers and boxes were so poorly braced that several were damaged by rough handling.

b. Smaller assemblies, such as pumps, governors, relays, induction vibrators, were usually poorly packed. Pliofilm packed assemblies generally had moisture indicators showing red. In general, pliofilm seems to become brittle in cold air and cracks. In a large number of cases, assemblies packed in pliofilm evidently had been taken out of the original carton at the shipping activity and shipped separately. Rough handling naturally broke the pliofilm bags.

c. Numerous cases of over and under packaging were observed. One shipment of small gaskets, screws and fittings, weighing about four (4) ounces, came in a wooden box weighing ten (10) pounds. Another instrument occupying one (1) cubic foot was packed in a box occupying sixteen (16) cubic ft. On the other hand, many delicate instruments come packed only in the original cardboard container.

d. Rubber goods, such as inner tubes, expander tubes, and accumulator diaphragms, are frozen stiff when unpacked and must be thawed out. Supply men say this folding and freezing causes cracks that eventually lead to failure.

e. There is no cargo moving equipment available at Cold Weather Test Supply, and as a result, material is often damaged from rough handling. Labor crews unloading trucks in below zero weather are not apt to be too careful in their handling equipment.

8. Major Hunter, Cold Weather Test Enginering Officer requested that some type of tire demounting equipment be furnished. At present, tires on C-46, B-17, B-24 and B-29 planes are demounted by laying the wheel flat on the ground, laying a twelve (12) inch plank on top of the tire, and driving a Cletrac or, in one case, an 18-ton earth mover, over the tire. This usually breaks the bead loose—and usually ruins the casing.

9. Equipment specified in Table of Allowances No. 1-1697 is generally inadequate. Requirements for equipment on this table, with the exception of heavy equipment, are greatly in excess of table quantities. This is particularly true of Class 05, 08 and 17 material.

10. Excess experimental equipment is causing a severe storage problem. At the present time, there are several carloads of excess skis, heaters and other types of equipment for which there is no foreseeable use. Some of this could be sold to commercial Alaskan Airlines, particularly the skis.

C. CONCLUSIONS

It is believed that Cold Weather Test Supply should be operating with reasonable efficiency by the end of December. Although hampered considerably by the change in warehouse location, untrained personnel, and poor working conditions, progress is being made towards the proper organization of that Section at Ladd Field. Circumstances beyond the control of depot personnel will, however, continue to impede progress. These include shipping delays, improper packaging, untrained replacements, and, to a certain extent, over-classification of documents relating to cold weather test, which has very definitely interfered with proper advance planning for the current testing season. In spite of these limitations, Supply is functioning effectively. To date, no aircraft have been grounded for parts for more than two (2) days.

D. RECOMMENDATIONS

1. That blueprints for tire demounting equipment be furnished Cold Weather Test Detachment.

2. That action be taken to obtain either Class 2 air priority for shipments to Ladd Field or to insure that present Class 3 air priorities now issued are adhered to.

3. That more attention be given to methods for packaging overseas shipments. While corrosion is not a problem in the Alaskan theater, if the condition in which material arrived in this theater is indicative of the condition in which it arrives in others, then serious attention should be given his problem.

4. That steps be taken to insure that replacement personnel are actually skilled in the M.O.S. that is assigned them.

E. ACTION ON RECOMMENDATION

Recommendations b, c, and d have been brought to the attention of the proper offices in this Headquarters by R & R. Action has been taken on recommendation (a) by supplying blueprints of tire demounting equipment currently used at FATSC to the Cold Weather Test Detachment.

Cold Weather Tests of Radio & Radar Equipment

Prepared by: P. D. Langrick, Capt., A. C., Aircraft Radio Laboratory.

I. EQUIPMENT SUBMITTED BY NAVIGATION LABORATORY

A. This Laboratory submitted the following Airborne and Ground equipment to be subjected to Cold Weather Testing for the winter season of 1944-1945. AN/ARN-7 Radio Compass. Army Air Forces Instrument Approach System is composed of the following units: AN/CRN-10 Localizer Equipment, AN/CRN-2 Glide Path Equipment and AN/MRN-1 Marker Beacon Equipment, and AN/MRN-2 VHF Radio Range Equipment.

B. AN/ARN-7 RADIO COMPASS.

1. The winterized version of this equipment did not arrive until the season was nearly over. After it was installed in the B-24, the equipment operated satisfactorily as the temperature did not drop below —25°F.

2. The regular production model AN/ARN-7 Radio Compass equipment, installed in the majority of airplanes used in conducting this season's cold weather tests, was checked daily and it was found that the loop was sluggish and at times hard to turn at temperatures below —25°F.

3. At temperatures below —30°F. a larger number of these sets of equipment would fail to function until the cabin temperature was raised to +40°F. or more. The causes for this malfunction could never be absolutely determined. In some instances, the replacement of control boxes from stock kept at room temperatures would cause the equipment to operate satisfactorily. In other instances, it was necesary to wait from 10 to 20 minutes for the sets to warm up sufficiently to raise the temperature of the electrolytic condensers to the point of functioning properly.

4. After being warmed up on the ground, the radio compass operated properly throughout the season, with the exception of a few malfunctions attributed to defective tubes, condensers and resistors.

5. In conversations with the Communications Officer of the U.S.S.R. Mission stationed at Ladd Field, it was found that the equipment installed in Lend-Lease airplanes was functioning substantially as reported in the above paragraphs.

6. **CONCLUSIONS** It is concluded, from an average taken from several hundred pre-flight checks on the AN/ARN-7 Radio Compass, that the equipment will operate satisfactorily in temperatures above —20°F. and in most instances will operate after waiting 10 to 20 minutes for the set to warm up when the temperatures are in the region of —30°F.

7. RECOMMENDATIONS

a. It is recommended that an investigation be undertaken to determine if the sluggish loop condition at —25°F. and below can be attributed to the lubricant used or if other malfunctioning is causing this sluggish condition of the loop mechanism.

b. It is recommended that all the electrolytic condensers in Receiver BC-R5/ARN-7 be replaced with paper or oil immersed condensers. It is the desire of the Communications Officer of the U.S.S.R. Mission that this be accomplished at the earliest possible date, as it will eliminate a constant source of trouble in Lend-Lease airplanes during the winter months, which prevail over the greater part of each year in Russia and Siberia.

C. AN/CRN-10 LOCALIZER EQUIPMENT.

1. This equipment did not arrive at Ladd Field until February, thereby missing the coldest part of the winter season. No difficulties were experienced with the equipment which could be attributed to the effects of the equipment being exposed to cold weather conditions.

2. It was necessary to replace several sets of rectifier tubes and one set of final amplifier tubes during the time this equipment was in operation.

3. The power supply Type PU-25/CRN operated satisfactorily throughout the testing period without being overhauled at any time.

a. The total time of operation was approximately 500 hours.

b. The equipment was installed 2000 feet from the west end of the north runway, which is the principal runway at Ladd Field.

4. CONCLUSIONS

It is concluded that this equipment operated in a satisfactory manner throughout the testing period.

5. RECOMMENDATIONS

None.

D. AN/CRN-2 GLIDE PATH EQUIPMENT.

1. This equipment did not arrive at Ladd Field until February, thereby missing the coldest part of the winter season. It was set up on 24 February 1945, 1400 feet from the approach end of the runway with the glide path set at 2½ degrees. Flight checks disclosed the course to be straight and flyable with sufficient clearance over the hill at the approach end of the runway. The glide angle was later raised to 3 degrees to give an added safety factor in clearing the hill.

2. It was necessary to move the equipment back to 2000 feet from the approach end of the runway and lower the glide angle to 2½ degrees due to the rapid rate of descent of airplanes of the B-26 and B-25 class.

3. In the five weeks that the equipment was undergoing tests, the only trouble encountered was caused by Type 8025 transmitter tubes and Type 836 rectifier tubes. Investigation of the first failure disclosed two fuses to be blown and the contacts on the center arm of Relay No. 1007 to be melted off. A new relay contactor arm was fabricated by Cpl. Westwick, to replace the damaged arm, as it was impossible to secure a replacement relay.

4. Further investigation of the equipment disclosed the failure to be caused by the simultaneous failure of two 8025 tubes, one in the driver and the second one in the final amplifier stage. In testing this equipment after the failure, Test Meter No. 2 became defective. This was attributed to the shorted elements in one of the defective 8025 tubes.

a. As it was impossible to secure a replacement meter, a two-inch meter of the same range was secured from the Alaska Air Depot.

b. On the last day of the tests, the equipment failed to function properly. Investigation disclosed the Type 8025 tubes in the final amplifier to be defective. This was attributed to a surge of higher than normal voltage from the 60-cycle alternator, caused by the gasoline engine driven power supply becoming defective, after running approximately 450 hours without a major overhaul. It was found that the gasoline engine was running at normal speed without a load, and that when the load was applied, the gasoline engine would run above normal speed for a short time and then slow down, causing the voltage to surge well above its normal value and then drop down to a lower value. No attempt was made to repair the gasoline engine, as the tests were concluded on this equipment and negotiations were being completed to turn over the Army Air Force Instrument Approach System equipment to Ladd Field. Total time of operation was approximately 450 hours.

5. CONCLUSIONS

It is concluded that the AN/CRN-2 equipment worked in a satisfactory manner throughout the testing period, with the exception of tube failures, which could not be attributed to the effects of cold weather.

6. RECOMMENDATIONS

a. It is recommended that a fuse for the protection of Meter No. 2 be installed.

b. It is recommended that the Type 8025 tubes with the magnesium getter be recalled and the new high vacuum type tube be used for replacement of the recalled stock and for all future uses of this type tube.

c. As the Type 8025 transmitting tubes and the Type 836 rectifier tubes have been a constant source of trouble this season, due to the fact that no test equipment was available to properly check these tubes, it is further recommended that either a tube checker capable of checking the two tube types be supplied with each set of equipment using these tubes, or some provision be made in the equipment for the proper checking of these tubes.

E. AN / MRN - 1 MARKER BEACON EQUIPMENT.

1. When this equipment was not undergoing cold weather testing, it was used as a Boundary Marker Beacon as an integral part of the Army Air Force Instrument Approach System.

2. Due to the necessity of placing the Boundary Marker Beacon in an exposed location between the road at the eastern end of the field and the Chena River and Field Regulations prohibiting vehicles from being parked in this area, it was necessary to remove the chest containing the transmitter and power supply from the jeep.

3. It operated in a satisfactory manner without any failures for a number of weeks.

4. The total time of operation was approximately 375 hours.

5. **CONCLUSIONS**

It is concluded that this equipment is entirely satisfactory for its intended purpose.

6. **RECOMMENDATIONS**

None.

F. ARMY AIR FORCE INSTRUMENT APPROACH SYSTEM.

1. The three sets of equipment, namely, the AN/CRN-10 Localizer Equipment, the AN/CRN-2 Glide Path Equipment, and the AN/MRN-1 Marker Beacon Equipment, were set up to be used as a unit composing an Army Air Force Instrument Approach System, less the outer and middle Marker Beacons.

2. The only difficulty encountered was of a minor nature, due to the metal construction of Hangar No 1. At first there were two pronounced bends in the course of the Localizer Path in front of this hangar.

3. The two bends in this course were eliminated when the antenna array was moved a short distance and more precise measurements were made to center the Localizer Path on the runway.

4. After the equipment was set up and flight-checked, it was run on a 24-hour-a-day basis and the airplanes with the proper installation of equipment made use of this system for the duration of the test period.

5. Several pilots, who had had no previous experience with this system, were very enthusiastic about it and were of the opinion that they could now bring in their airplanes in zero-zero weather at the fields equipped with Airmy Air Force Instrument Approach Systems.

6. **CONCLUSIONS**

It is concluded that this equipment is entirely satisfactory for its intended purpose and will work in a satisfactory manner throughout the temperature range it was exposed to for the duration of the cold weather tests for the winter of 1944-1945.

7. **RECOMMENDATIONS**

None.

G. AN/MRN-2 VHF RADIO RANGE EQUIPMENT.

1. This equipment arrived at Ladd Field on 13 January 1945 and was processed through the Cold Weather Testing Detachment Ordnance and Garage Sections. The K-53 truck was only partially winterized as it was not contemplated to move the equipment once it was set in position.

2. The truck and equipment were accepted from the above-mentioned sections on 18 January 1945.

3. Trouble immediately developed in the Onan power supply; the gasoline engine would run for from one to two minutes and then stop, and could not immediately be started again.

a. It was necessary to request assistance from the Maintenance Branch of the Cold Weather Testing Detachment Auxiliary Equipment Section to correct the fault that had developed in the PU-3 CRN/5 Onan Power Supply. Investigation by expert repairmen disclosed that the spring in the automatic choke had been reversed.

b. After this error had been corrected, the power supply was run for 48 hours, when trouble again developed. Considerable time was spent in finding the source of trouble, which was finally traced to the disributor cap, which is made of cast bakelite and which had developed a crack that allowed the high voltage energy to leak to ground, causing the engine to fire on one cylinder only. A new distributor cap was obtained and the PU-CRN/5 power supply operated in a satisfactory manner. The cracked distributor cap was directly attributed to cold weather, the lowest temperature at the time of failure being —15°F.

c. The coolant in the radiator of this equipment, as shipped from the factory, was inadequate for this region as it offered protection only to a temperature of —20°F. Therefore,4-1/2 quarts of Prestone were mixed with an equal amount of water and placed in the radiator; this mixture will not freeze until the temperature has dropped below —60°F.

d. It was our intention to install this equipment at a point approximately 2000 feet from the west end of the south runway and have the constant signal zone of the Eastern quadrant centered on the runway. This was impossible to accomplish, due to the inaccessibility of this portion of the clearing, which is across the river from the ends of the runways. Therefore, the equipment was set up approximately 2500 feet from the ends of the runways and centered between them. It should be pointed out that the instruction book does not contain adequate information regarding the keyer and bridge circuits and how to set up the cams in the keyer circuit, with particular emphasis on the phaser cams.

e. This was found to be true, as the equipment had been on test for only a short time when trouble developed in the keyer circuit and sufficient information could not be found in the instruction book to be of assistance in correcting the faulty keyer action. At about the same time the following facts developed: The plate voltage on the final amplifier stage dropped from a value of 420 volts to 100 volts. Investigation revealed no failure of any component parts. Several sets of rectifier and final amplifier tubes were tried in an attempt to discover whether the low voltage were caused by defective tubes; this failed to bring the plate voltage to its normal value.

f. It was found that the "D" and "U" quadrants had a lower output than that of the other quadrants. The "Line Voltage" position of the switch on the meter panel was found to be defective as it would not cause the meter to indicate the voltage unless the switch was held to one side. Fortunately, Mr. Wedin, an engineer from the Navigation Laboratory who has had considerable experience with the AN/MRN-2 VHF Radio Range Equipment was in the vicinity and his assistance was obtained to correct the faults which had developed in the equipment. Mr. Wedin's investigation disclosed that the low plate voltage to the final amplifier stage was caused by a defective 836 rectifier tube; further, that the major portion of these tubes from the Spare Tube Kit were defective. It was impossible to check properly the rectifier tubes, as there were no tube checkers available that would accomodate this tube.

g. The low output in the "D" and "U" quadrants was finally traced to a manufacturing defect in one of the antennae, as the connections were reversed. The antenna pattern became normal after this defect had been corrected. The defective keyer action was corrected when one set of cams was reversed. It is quite apparent that none of these defects can be attributed to the action of cold weather. This equipment operated in a satisfactory manner 24 hours each day for the rest of the test period. The total time of operation was approximately 650 hours.

4. CONCLUSIONS

It is concluded that this equipment will operate in a satisfactory manner 24 hours a day over the temperature range to which it was exposed during the test period. It was the consensus of opinion that this equipment left the factory without inspection.

5. RECOMMENDATIONS

a. It is recommended that the coolant in the radiator of the power supply PU-3 CRN/5 be changed from the present mixture, which will freeze at —20°F. to a mixture of 4½ quarts of Prestone and an equal amount of water, which will not freeze until the temperature has dropped below —60°F.

b. It is recommended that the amount of information on the keyer and bridge circuits and especially on how to set up the cams in the keyer circuit, be increased in the Instruction Book.

c. It is recommended that a tube checker capable of checking all the types of tubes used in the AN/MRN-2 equipment be supplied with each set of equipment.

d. After having experienced the great amount of difficulty before this equipment could be successfully placed under test, it was quite obvious that the equipment had left the factory without being properly tested and inspected. Therefore, it is recommended that steps be taken to see that the production AN/MRN-2 VHF Radio Range Equipment be properly inspected and tested before it leaves the factory.

II. EQUIPMENT SUBMITTED BY THE SPECIAL DEVICES LABORATORY.

A. This Laboratory submitted one Type AN/ANQ-2 Airborne Recorder and one Type AN/GNQ-2 Ground or permanent station type recorder, to be subjected to Cold Weather Testing for the winter season of 1944-1945.

1. Both recorders are of the rotating disc type, the turntable and disc turning at the unusually low speed of 10 to 11 revolutions per minute; this low speed is necessary to obtain 30 minutes of recording time on each side of an 8-inch disc.

2. With this low turntable speed, the intelligibility of the recorded speech is of a low order.

B. AN/ANQ-2 AIRBORNE RECORDER.

1. The original installation of this equipment in the Radio B-24 was made so that the radio operator had control over the equipment, which was plugged into the Interphone System so that voice recordings could be made by the pilots and engineers to assist in keeping records of their work.

2. As some flights were being made without a radio operator and the turntable is placed in motion by pressing the microphone switch, extensions were made from the pilot lights in Control Box C-99/ANQ-2 to a position on the instrument panel so that the pilot could tell when the turntable was in motion and when the recording time had elapsed.

3. Preflight checks made in temperatures down to —34°F. disclosed that the recorder operated in a satisfactory manner; the turntable started without difficulty and the speed was constant at 10 to 11 rpm.

4. A record was made while flying between an altitude of 10,000 and 15,000 feet. Upon returning, when the record was played back on the ground equipment AN/GNQ-2, it was found to be full of "wows", causing the speech to be unintelligible. Since, upon investigation, the speed of the turntable appeared to be constant, it became apparent that the "wows" were being caused by the vibration set up by the motors and the roll and pitch of the ship in turbulent air. By changing springs, more pressure was applied to the cutting stylus and with a new stylus the "wows" disappeared. The recorded speech quality is very poor with throat microphones, in fact, unintelligible at times, increasing in intelligibility with mask and hand-held (T-17) microphone.

5. **CONCLUSIONS:** It is concluded that this recorder operates in a satisfactory manner for its intended purpose and throughout the temperature range to which it was exposed during the cold weather testing of the winter season 1944-1945.

6. **RECOMMENDATIONS:** None.

C. AN/GNQ-2 GROUND OR PERMANENT STATION TYPE RECORDER.

1. This recorder will operate satisfactorily when kept at a minimum room temperature of +65° to +75°F. When exposed to lower temperatures, the turntable was very slow in picking up speed. After being subjected to

room temperature of —10°F. overnight and warming up to +55°F. in two and one quarter hours, the speed was one revolution in two minutes and ten seconds. A hot blast of air was applied for five minutes and the speed increased to eleven revoultions per minute. This was attributed to the lubricant used in the gear box and motor bearings. Major Britton was to have worked on the problem of finding a satisfactory lubricant, but left Ladd Field before doing so.

2. **CONCLUSIONS:** It is concluded that the AN/GNQ-2 Recorder will operate satisfactorily when kept at a minimum room temperature of +65° to +70°F.

3. **RECOMMENDATIONS:** It is recommended that a satisfactory lubricant be found for this equipment so that it will operate satisfactorily in temperatures down to 0°F.

III EQUIPMENT SUBMITTED BY THE COMMUNICATIONS LABORATORY.

A. This Laboratory submitted one Type AN/ARC-3 VHF Radio Set, to be subjected to cold weather testing for the winter season of 1944-1945.

B. AN/ARC-3 VHF RADIO EQUIPMENT.

1. This set of equipment is composed of an eight-channel crystal controlled transmitter, an eight-chanel crystal controlled receiver, associated dynamotors and control boxes.

2. One of its unique features is the automatic tuning that takes place upon changing channels.

3. It was thought by a number of persons that this particular feature would not stand up under arctic temperatures. The equipment was placed in operation several hundred times, during the winter season in temperatures ranging from +70°F. to —35°F. In every respect it is superior to the SCR-522 VHF equipment, having greater output, a more sensitive receiver with better audio quality, and ease of maintenance.

4. **CONCLUSIONS**

a. It is concluded that the AN/ARC-3 VHF equipment operates in a satisfactory manner for its intended purpose throughout the temperature range to which it was exposed during the cold weather testing of the winter season of 1944-1945.

5. **RECOMMENDATIONS**

a. None.

C. The following facts were noted during the winter season and are recorded here for the information of personnel of the Communications Laboratory.

D. AN / ART - 13. RADIO LIAISON EQUIPMENT.

1. This equipment works well under arctic conditions. Two or three instances of slipping autotune units were noted. Several high vacuum switches were found to be shattered. The above two items were attributed to low temperatures. Several instances of Resistor No. 215, 250 ohms being burned out were reported. Several complaints of variations in antenna current and output, with variations in temperature, were received.

2. A test set-up was made in an exposed location to investigate the variations in antenna current and output. In a temperature change from —34°F. to 0°F. the current as indicated on the Radio Frequency Ammeter varied 90% from the original set value when the antenna network was tuned at a certain temperature. It was further noted that the antenna current and output would return to normal when the equipment was subjected to the same temperature as that at which the original tuning adjustments had been made.

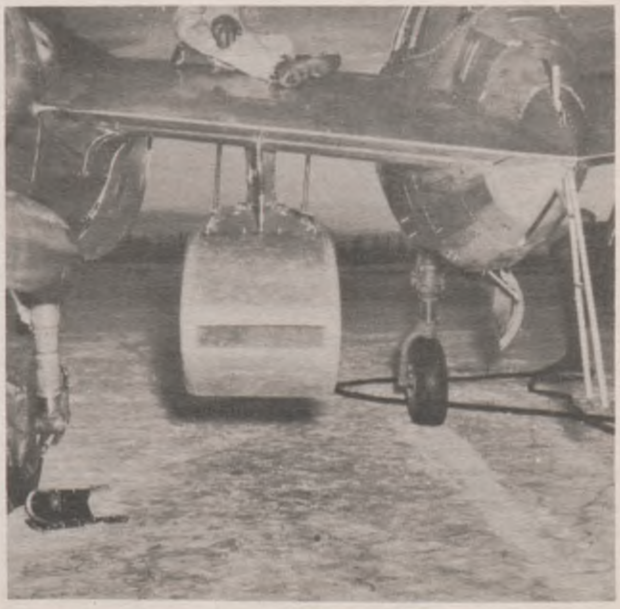
E. SCR-578-B SEA RESCUE EQUIPMENT.

1. Under the program of the Base Cold Weather Testing Detachment, the SCR-578-B and the newer two-channel set were subjected to cold weather tests. It was noted that the base unit had the same experience as the writer. Signals were received up to five miles without a ground; using a river ground, the signals were received up to eleven miles.

2. Counterpoises were tried, varying in length from two hundred to three hundred feet and were laid on top of the snow. The signals were received at distances up to 75 miles, on a few occasions up to 100 miles and reported one time as being received at 150 miles.

3. The balloons used were manufactured in May 1942 and would develop pin holes after being inflated from two to four hours. Only about one balloon in ten would stand up over a period of three or four days.

4. The lithium hydride generators would take well over an hour to inflate a balloon in temperatures below 0°F. For use in the arctic regions, it is recommended that a more rapid means of inflating balloons be found.



Chaff dispenser installed on P-38 airplane

IV EQUIPMENT SUBMITTED BY THE AUDIO LABORATORY.

A. This Laboratory supervised the installation of an AN/AIC-2 Interphone System in the Radio B-24 to be subjected to Cold Weather Testing for the winter season of 1944-1945.

B. AN/AIC-2 INTERPHONE SYSTEM.

1. This system worked satisfactorily throughout the winter season in temperatures as low as —56°F.

2. Early in the season the output transformer in the audio amplifier became defective. This occured at a time when some work was being done on the ship at the Alaska Air Depot, and without the knowledge of the writer a new output transformer was installed in the amplifier AN/26-AIC.

3. The defective transformer was requested from the Alaska Air Depot so that it could be returned to the Laboratory for investigation, but could not be recovered.

4. One complaint of low output was received. Investigation disclosed that the pilot was using high impedance earphones instead of low impedance earphones. A new set of low impedance earphones was installed in the pilot's helmet which corrected the difficulty.

5. CONCLUSIONS

It is concluded that this equipment operated in a satisfactory manner throughout the testing period.

6. RECOMMENDATIONS

None.

V EQUIPMENT SUBMITTED BY THE RADAR LABORATORY.

A. RADAR SET AN/APN-9 (LORAN).

1. Due to the distance between Ladd Field and the closest Loran Station, reception was dependent upon sky waves. Reception was found to vary considerably with time of day, as is characteristic of sky wave propagation. Signals were rarely seen above the noise level when the AN/APN-9 was operated in the air; a 200-foot "flat-top" antenna on the ground gave more consistent results. Good aerial results were obtained when later flights were made around the Aleutian Islands, within "ground wave" range of the stations. All islands and prominent land marks checked against the charts after applying appropriate corrections to the readings as obtained from Loran Correction Chartlets. Maximum ground wave reception obtained was 600 miles at 10,000 feet over water in the Radio B-24, using the "flat-top" antenna and no loading coil.

2. The set was checked and operated at temperatures down to —46°F. At this temperature the starting current with a 105.6 volt input was 2.4 amperes. All functions were normal after a 30 second warm-up period.

3. It was necessary once to replace the 3 BPI indicator tube because of a loose element in the tube. It is impossible to determine if the defect were a result of exposure to extremely low temperatures or faulty tube construction.

4. The receiver became intermittently insensitive due to a loose connection between the socket and cathode pin of Tube V-102. The socket construction was the cause of the fault.

5. After 20 hours of operation, it became necessary to adjust the grid voltage of V-131 in order to stop sweep jitter which had developed. This adjustment was done by means of adjusting variable resistor R-260. All tubes checked satisfactorily; as no circuit diagram was available, it was impossible to analyze the circuit for possible causes of the sweep jitter.

6. **CONCLUSIONS:** It is concluded that the operation of Radar Set AN/APN-9 was not adversely affected by the temperatures encountered during the cold weather testing at Ladd Field for the winter season of 1944-1945.

7. **RECOMMENDATIONS:** None.

B. RADAR SET AN/APN-12 (XA-1).

1. The wide band antennas normally used with this set were not available for cold weather tests. An SCR-729 type antenna installation was made in the B-24 "Radio Test" airplane for the test operation of the Radar Set AN/APN-12 (XA-1). This situation limited the useful operation of the set to the frequency band covered by the first three positions of the frequency selector.

2. Inspection of Receiver-Transmitter RT-11(XA) APN-12(XA-1) upon arrival revealed that the shield on the suppressor output cable had broken loose where it was soldered to J-106. The single spot of solder applied at this point gave insufficient mechanical strength and apparently broke from vibration during shipment.

3. The receiver became insensitive during a flight test. The failure was caused by a break in the B+ lead where it connected to R-128. Cause of the break was believed to be a nicking of the wire in the insulating stripping process during manufacture.

B-29 Radar dome damaged by ejected shell cases. Low temperatures caused embrittlement of dome

4. The center leaf of switch S-104 shorted to ground on the tuning mechanism mounting. This occurred when the follower was on the high point of the cam and momentarily grounded the 24 volts D.C. No ill effects were noted upon the operation but arcing each time the tuning mechanism was operated had extensively destroyed the rivet holding the bakelite follower to the switch leaf when discovered. Figures 23 and 24 show the damage caused by the arcing.

5. The modulation lead from X-202 to L-207 was badly frayed from chaffing at the point where it passes between the chassis and the vernier tuning mechanism. Figure 25 shows the amount of chaffing on this lead.

6. A flight test was made using the AN/APN-12 (XA-1) as a beacon at 176 Mc. It was interrogated by an SCR-729 operated in another aircraft flying at the same altitude (5,000 feet). The maximum range obtained of the front of both antennas was 85 miles.

7. The set was flight tested against an SCR-695 operated as a beacon with the antenna mounted 25 feet above the ground level. The maximum range was 55 miles at 10,000 feet. IFF in other aircraft whose elevation was unknown were received from 85 miles at the same time.

8. The set was used in connection with test flights against the AN/CPN-7 (BABS) and gave satisfactory results.

9. The pre-set frequencies remained within 0.5 Mc throughout the total set operation time of approximately 60 hours and a period of 70 days. The set arrived at Ladd Field late in the season (20 January 1945). Temperatures below —15°F. were experienced only once for a short period after the arrival of the set, during which period the set was undergoing repairs; thus, no significant temperature-frequency drift data is available.

10. **CONCLUSIONS:** Due to the limited scope of the available data, no definite conclusions as to the set's ability to function properly over long periods at low temperatures can be made.

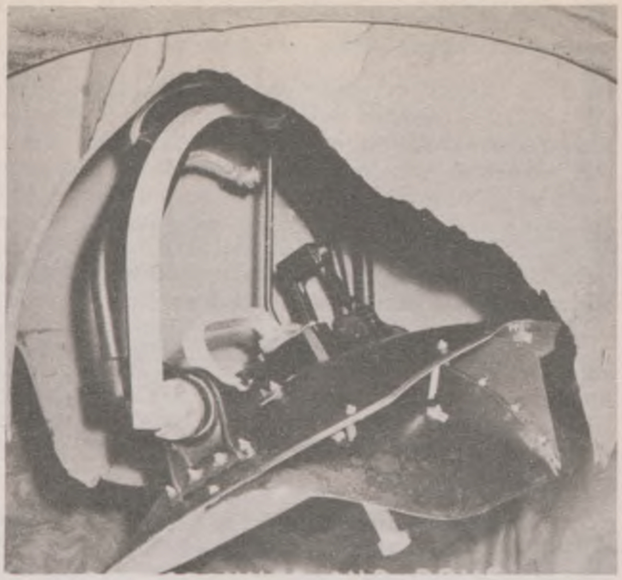
11. **RECOMMENDATIONS:** It is recommended that the mechanical difficulties noted above be remedied before continuing production of the set.

12. It was noted during flights on the AN/APN-12 that the simultaneous operation of the Interrogator and the IFF Receiver (SCR-695) in the same airplane caused the Marker Beacon Indicator to light. The indicator came on once every 2½ seconds, or once each cycle of the IFF frequency sweep. Marker Beacon Receiver BC-1033-A receives 75 Mc signals. A quarter wave open stub was attached across the antenna input terminals of the marker beacon receiver. Adjustment of the length of this stub eliminated the interference but did not detract from the normal operation of the receiver.

VI FINAL REPORT ON COLD WEATHER TEST OF THE AIRFLOW TYPE RADOME.

1. This radome was developed for use on the B-29 airplane, to replace the older round-type radome, which in its retracted position extended down farther than the new airflow type, which is of the fixed type. The older type offered greater wind resistance and at low temperatures had a very short life.

2. Tests. In the first test to determine the amount of damage to the radome caused by shell cases and links



Airflow type rodome damaged by ejected shell cases

ejected by the forward lower guns, 850 rounds were fired, scoring approximately 125 direct hits on the radome with five of sufficient force to tear several layers of canvas. The radome was exposed to a temperature of —40°F. for five hours and the firing occurred at a temperature of —34°F. at an altitude of 18,000 feet. Figure No. 26 is a general view of the radome, showing the damage caused by the ejected shell cases and links. Figure No. 27 is a close-up view of the section of the radome in which the shells and links struck with sufficient force to tear several layers of canvas.

3. Further tests were conducted in an attempt to find the number of rounds that could be fired from the lower forward guns, before the ejected shell cases and links punctured the radome. A total of 2175 rounds were fired at a temperature of —40°F. without inflicting further damage to the radome, other than scratches and small indentions.

4. Unfortunately, mechanical failure of the B-29 used for these tests made it necessary to discontinue the tests. Before the photographers arrived to take pictures of the sustained damage to the radome caused by the ejected shell cases and links, the crew filled in the large indentions with plastic compound and painted the radome, making it impossible to secure photographs of the sustained damage. Figure No. 28 is a head-on view of the radome. Figure No. 29 is a close-up view of the forward right side of the radome. Figure No. 30 is a close-up view of the left side that originally sustained the greatest amount of damage.

5. **CONCLUSIONS:** It is concluded that the new Airflow Type Radome is greatly superior to the older type and will stand a larger number of combat missions. After looking over the last three photographs, it is concluded that if the indentions caused by ejected shell cases and links are filled in with plastic compound and painted, that the radome may have an indefinite life.

6. **RECOMMENDATIONS:** It is recommended that some maintenance procedure as outlined in the above conclusions, be inaugurated.

VII EQUIPMENT SUBMITTED BY THE RESEARCH LABORATORY

1. Cold Weather Tests on Chaff Dispenser A-2 and Chaff CHA-28(3) were started by the Base Cold Weather Testing Detachment Radar Section. Due to circumstances beyond the control of this Section, it was impossible for them to complete the tests. At the request of Lt. Caldwell, the Aircraft Radio Laboratory representatives agreed to complete the tests.

2. Chaff (CHA-28[3]. Late in January a mission was flown to determine the amount of "bidnesting" of Chaff CHA-28(3) and to test the Dispenser A-2 under cold weather conditions. The Chaff was released at 500 feet in a free air temperature of +14°F. and the "bird-nesting" was estimated to be in excess of 50%. The dispenser worked perfectly at this temperature, both in the air and in preflight checks on the ground. Figures 31 and 32 are views of two types of "birdnesting" of Chaff (CHA-28[3]) that were encountered.

3. Chaff Dispenser A-2. In an attempt to test the dispenser at lower temperatures, a mission was flown at 29,000 feet and a free air temperature of —53°F., the gears in the stripper unit in the A-2 Dispenser apparently failed, allowing only four packages to be dispensed in about two minutes, when set up for dispensing forty packages per minute in the preflight check prior to take-off on this mission. Investigation disclosed that one of the gear pins was sheared off and the rachet bar badly worn. A new set of gears was requested from the Laboratory. When the new gear assembly arrived for the stripper unit, it came with a motor attached; as this motor was physically smaller than the older motor, it did not fit into the mounting brackets. Therefore, it was necessary to use the old motor and gear assembly and change the new gears to the old assembly. After this had been accomplished, and the dispenser had been attached to the P-38, it was set up to dispense sixteen packages per minute in the preflight check just prior to take-off on a mission to 30,000 feet. At this altitude, the dispenser was turned on for a two minute period and only two packages were dispensed. The temperature was —56°F. The unit was again made operative, and as no packages were dispensed after four minutes, the mission was considered to be a failure. Investigation disclosed the gear pin to be sheared off; no attempt was made to repair the damaged pin, as the P-38 was not available for further test work. This unit will be returned to the Laboratory for investigation of the failure. Figure 33 is a rear view of Dispenser A-2 installed on the P-38. Figure 34 is a view of the P-38 with the Dispenser installed. Note the auxiliary gas tank attached to the right wing. This is filled with a sufficient amount of water to rebalance the plane, which was thrown off-balance by the additional weight of the dispenser on the left wing.

4. **CONCLUSIONS:** It is concluded that the Dispenser A-2 will not function properly at low temperatures.

5. **RECOMMENDATIONS:** It is recommended that this unit be modified to work at high altitudes and low temperatures.

SECTION V

Reports of Manufacturer's Technical Representatives

This Section consists of reports of special or general interest written by the various Technical Representatives attending the cold weather tests. They are, in most part, excerpts or partial reproductions of the reports written, and the bulk of the supporting data has been omitted.

Allison Division of G.M.C.

H. S. Hanson

Until February 12, the weather was comparatively mild for cold weather testing, and, as a consequence, I have been spending considerable time with the Alsib ferry planes, trying to help with minor difficulties. Following are items of general interest and results of cold weather testing:

1. Just a few days ago the first P-63C Alsib airplane, with V-1710-117 engines, began coming through this base. Most of them thus far have been leaking a slight amount of oil through the cylinder block hold down stud seal.

In my opinion, this condition is not a serious one, but immediate action to correct this trouble should be taken at the factory. The U. S. S. R. does not care to accept the planes if the leakage is too great.

This condition has also been noted on some of the V-1710-111 and -113 engines at this base.

2. We have been keeping a record of the P-63 airplanes, passing through this base, from which RP43S spark plugs have been removed to correct engine roughness. Any indication of spark plug malfunctioning is corrected by replacing an entire set—intake or exhaust—as the case may be, rather than correcting any individual cylinder.

Thus far, the rate of replacement of the RP43S plug has been about the same as that for the spark plugs previously used. The cylinder most generally found to have the faulty plug has been number 6, right or left. By far the majority of plugs changed has been on the exhaust side.

After removal, the spark plugs are tested under 480 pounds of air pressure, and with 10,000 volts at the terminals.

Complete reports of our findings are being turned in to the service department.

3. On February 12, the temperatures took a rather sudden turn for the better and were down to —34°F at 8:00 A. M.

The only airplane on which successful cold starts were made was the P-59A with I-16 gas turbine engines. However, because of excessive oil pressure, it was necessary to shut down after about one minute of running.

Cold starts were tried on one C-47 airplane with R-1830 engines, both with normal butane and with regular gasoline, but were unsuccessful. However, both engines had been insufficiently diluted, and were quite hard to turn over.

All other airplanes on the field, which were in commission (32 out of 51), were either insufficiently diluted or were otherwise unable to start cold at this temperature.

4. On this same day, a flight was made in a P-38L airplane which had no provision for applying carburetor heat. The pilot maintained flight under 10,000′ to obtain coldest carburetor air temperature.

Extreme engine roughness was reported at powers below military rated, although at 2,000 R.P.M. and 30″ Hg manifold pressure the engine ran more smoothly in the auto-rich mixture position than it did in the auto-lean mixture position. The roughness was most noticed in the cruise power range, but roughness was noted even at take-off.

P-38J airplanes, with identical engines but with shutters in front of the intercooler, were able to take off without engine roughness. As provisions for heating the carburetor air were also installed, very good operation could be obtained at all other power settings.

5. On February 13, outside air temperatures were at —42°F for starting trials.

Both oil systems of the P-38L airplane equipped with the Allison cold starting kit had been diluted to permit the propeller to be pulled through by hand. Two unsuccessful starting trials were made with regular 130 grade aviation fuel on the right engine. No firing whatsoever was noted during this period. The Allison cold starting kit was then connected to the airplane. The engine fired intermittently for three 20 second cranking trials, and on the fourth trial began to run well. Evidently the engine had been badly flooded with 130 grade fuel during the first trials.

The left engine was started in the first few revolutions by using the Allison kit. Normal butane was used in the kit during these trials. However, after the engine was switched over to regular fuel it ran very poorly, and could not be kept running without excessive use of the primer.

Successful cold starts were also made on both of the I-16 engines in the P-59A airplane, but after a brief time lack of fuel pressure necessitated a shut down.

I believe these were the only cold starts made on the field on this day.

6. On February 14, at an ambient air temperature of —33°F, successful cold starts were made on both engines of the P-38L, and on both of the R-1830 engines in the C-47 airplane. These starts were made using normal butane as the priming fuel. Again the engines of the P-38L were rough when the switchover to regular grade fuel was made and constant priming was necessary to keep them running.

Considerable preheating was applied to the engines of three of the other P-38 airplanes at this base, and all were able to take off satisfactorily.

7. Comparison of a number of cold starting trials at this base has convinced me that field starting demonstrations can be made at from 10°F to 20°F colder than those possible in a cold room when good laboratory practice is adhered to. In my opinion, there are two possible reasons for this difference. These are:

a. Ambient air temperatures noted at the time of a field starting demonstration are not necessarily indicative of the temperatures throughout the engine and induction system. Examination of ground temperatures since the last flight usually reveal that the airplane has not been subject to the temperature at starting time, for a very long period. Sometimes it has been subjected to a colder temperature than that noted at starting time, but more often the opposite is true as the coldest temperatures are generally recorded in the early morning hours.

Cold room experience has shown that after only five to ten minutes of running at idling load, even an uncowled engine requires a very considerable period of cooling before an even low temperature base line is reached. A cowled engine, which has been run at high powers for several hours, must surely require longer to cool, even if constant low temperatures were obtained.

b. When cold starts are anticipated, the engine oil is usually diluted plentifully enough so that the propeller can be easily pulled through. No torque data is available for the starts made at this base, but comparison with my work in Detroit convinces me that it is usually a good deal less than that called for in the cold starting requirements of Specification AN-9500c.

8. To care for all contingencies and field variations, I advise that we recommend the use of special priming fuel on our engines for all cold starting below 0°F.

9. D. P. Heath, of the Socony-Vacuum Oil Company, has plotted curves to show the vapor pressure versus temperature of several fuels suitable for cold starting. The curve for normal butane is very nearly the same as that for the mixture of 60% iso pentane and 40% iso butane, which we found necessary starting at —70°F. Both cold room and field tests have shown that fuel of this composition can also be used for starting at temperatures near 0°F.

In view of the desirability of having a single, easily obtained fuel for all cold starting, rather than a blend for each temperature, I think that normal butane might be considered for use in our engines.

* * * * * *

A considerable amount of trouble has been experienced in the past week. This was seemingly initiated by the installation of RP43S spark plugs for service testing in two of the P-38L airplanes at this base. Summation of the difficulties is as follows:

1. Airplane P-38-1, No. 44-24697.

At 150 hr. inspection, new RP43S spark plugs were installed in both engines; intake and exhaust, and new jets were installed for T. O. compliance on K-8 carburetors (—6 setting).

On the first run-up after inspection, the magneto check at 2300 rpm and 27″ Hg showed a 300 rpm drop, which cleared up after a brief period of running.

The first flight, of forty minutes duration, was made by Col. R. Stewart, who reported the right engine as running rough. This roughness began after he had been flying for some time and could not be eliminated by carburetor heat or mixture setting. It seemed to increase in degree as the power increased.

When the ship was landed a magneto check on the right engine indicated a loss of 150 rpm on the exhaust distributor. The intakes checked ok.

The left engine operated satisfactorily throughout the flight.

A check flight of fifteeen minutes duration was then made by Captain R. Accord, who reported both engines as being rough, with the right engine excessively so.

RP43S plugs were removed from both engines and replaced with new LS87 plugs.

During the removal of the RP43S plugs, an abnormal amount of carbon and/or lead chunks was noted in several of the spark plugs and in most of the spark plug wells on both engines.

On the first flight after installation of the LS87 plugs. Capt. Accord reported smooth operation of the left engine, but the right engine was so rough that it was necessary to feather the propeller after a short time in the air.

After landing, inspection showed No. 2R cylinder to have no compression, as only the stem of the No. 3 exhaust valve remained in this cylinder.

Analysis indicates that several factors might have been the cause of the reported roughness and engine failure, such as:

a. Loosening of the combustion deposit, caused by installation of the new plugs or by the leaner operation of the new K-8 carburetor setting. At removal of the RP43S plugs, an abnormal amount of these deposits, in chunk form was noted in the spark plugs and wells.

Those in the right engine of this ship were decidedly grayer and more metallic looking than those in the left engine. This was probably due to the use of synthetic oil, Spec. PPO-265, in the right engine. (See my report, 1/20/45, Paragraph 7).

The abnormal amount of combustion deposit might have been caused by long operation of the engine with the excessively rich original setting of the carburetor.

b. The stems of all the exhaust valves on the removed engine seemed to be very dry and lead coated. It is possible that the failed valve may have been sticking open, thus causing inadequate heat transfer from the head of the valves.

The engine will be sent to the Power Plant Laboratory at Wright Field. I strongly urge that we have a competent inspector there at the tear-down. The manufacturer's number on this engine is A-056232, and the Model No. is V-1710-111. There were 141:10 hours on the engine at removal, and the last 112:15 hours were with synthetic oil in the system.

2. Airplane P-38L-1, No. 44-24696.

As on the other P-38 airplane, smaller carburetor jets and new RP43S spark plugs were installed in both engines at the 150 hour inspection.

The first flight, of three hours duration, was made by Captain Accord, who reported both engines somewhat rough and a drop of 100-120 rpm on both right magnetos at the conclusion of flight.

A second flight of one hour and ten minutes was made by Major Allerdice, who reported essentially the same condition of operation.

The RP43S spark plugs were removed, at which time the same conditions of combustion deposits in spark plugs and wells as in the other P-38 were observed.

LS87 plugs were then installed, and the pilot reported satisfactory operation after the first flight.

I do not believe that the plugs have been adequately tested. They should be reinstalled at a later date, when the test program permits. Most of the P-63A Alsib planes are now coming through with RP43S spark plugs, and no abnormal spark plug difficulties have been reported.

The V-1650 Rolls-Royce engine utilizes a spark plug somewhat similar to the RP43S in appearance. The original gap on these plugs was .012", at which setting a great deal of lead fouling occurred. This gap has been increased to .022", and the engines are reported as operating satisfactorily, with no excessive fouling.

If the RP43S plugs are reinstalled, I believe it might be well to run a comparative test with a larger gap setting. Please let me hear your objections to the use of a larger gap.

3. Two flights have been completed in the P-38L airplane, at long range cruise power settings. These tests are being conducted to determine the effect of carburetor air temperature upon fuel consumption. Although the results of the test were nullified by a leaking fuel selector valve, several interesting facts were noted. These point to the desirability of using carburetor heat in this installation.

Test number one was conducted under the following conditions:

1600 rpm
Manifold press. adjusted to give 170 I.A.S.
(25¾"Hg start, 24½" Hg finish)
Altitude 1000'
Carburetor heat off
Carburetor air temp = 0 to —12°C.
(Average —8°C.)
Oil temperature 62-64°C.
Coolant temperature 96-98°C.

The airplane was flown for four hours under the above conditions. At the end of two hours, a magneto check was made. Both engines were very rough on the right magneto, so they were brought up to maximum cruise for two minutes, and to normal rated power for another three minutes before resuming the long range cruise power setting.

After two more hours, the engines were advanced to normal rated power. Both engines were very rough, and the right engine actually cut out at 2300 rpm and 30"Hg.

The exhaust spark plugs were removed from both engines at the conclusion of this flight. The plugs from the right engine, which had been using Spec. AN-VVO-446 oil, Grade 1100, were very sooty as compared to those from the left engine, which had been operated on PPO-265 oil. The only deposit noticed on the plugs from the left engine was tiny beads of lead.

Flight number two was conducted under the same conditions as number one, except for the following:

Carburetor heat on.
Manifold press. adjusted to give 170 I.A.S.
(25" Hg start, 24" Hg finish)
Carburetor air temperature = 9-12°C, left:
18-21°C, right.

The magnetos were checked at the end of two hours flight and again at the end of three hours flight. They were found to be satisfactory both times.

At the end of four hours of flight, the carburetors air heat was turned off, and the engines were suddenly accelerated to war emergency power and held there for one minute. The left engine accelerated very smoothly. The right engine coughed once on the way up in power.

4. I believe that this test is an adequate indication that carburetor air heating is an advantage, or even a necessity, for long range operation at low temperatures. Also, you will note that a slightly higher manifold pressure was required to maintain a given air speed with cold carburetor air, as compared to warm carburetor air. This information, plus that sent in my report of 1/20/45, indicates that a loss in power for a given rpm and manifold pressure might be expected as the carburetor air is decreased below some optimum temperature.

Mr. Lee Chambers, of the Lockheed Aircraft Co., has long been working to develop an adequate carburetor air heating system for this airplane, and I believe that we should be able to furnish adequate information as to the best operating temperature for this heating system.

We are especially interested in obtaining mixture control data for the following range of operating condition (roughly):

1500 to 2200 rpm
—30°F to +50°F carb air temperature.
20" Hg to 34" Hg manifold pressure.

In other words, we believe that a duplication of the lower portiton of curve 0-259-A, dated 10-24-44, will show appreciably different results if run at the temperatures indicated above.

There are a comparatively large number of P-38L airplanes now being ferried through this base. As it is entirely conceivable that they will be used in long range work, I think that it will be to our immediate advantage to have this informaton. Please let me hear from you.

5. In company with M. K. Wood, of Bell Aircraft Company, Engineering Department, a short visit was made to the Alsib ferry base at Nome, to interview the pilots, crew chiefs, and engineering officers in regard to difficulties experienced with the P-63A airplanes going through that point.

All parties interviewed seemed to regard the airplane with a good deal of favor. As far as engines were concerned, the major complaint was "rough" engines.

The U. S. S. R. does not accept the airplane if the magneto drop exceeds 35 rpm, or at the most, 40 rpm, from an original setting of 2200 rpm and 28"Hg manifold pressure.

It is my personal opinion that this criterion is too critical. This seems especially true as pilots and crew chiefs do not always get the same results on successive run-ups of a given engine.

Bell Aircraft Corporation

Marvin K. Woods.

1. The remainder of this report will be devoted to general commentary and a concluding summary. Regarding the P-63, the oil dilution tests must be considered of first importance. Both the V-1710-93 and V-1710-117 engines were operated without spewing on oil diluted to 30%. The vapor separator in the breather lines was proven to be very helpful by reason of the fact that when it was removed, spewing occured on the dash 93 engine with oil diluted 15%.

During the time when dilution is necessary the amount of oil service into the oil tank should be limited to 10 gal. A certain amount of trouble was experienced along the ferry route when two or three gallons of gasoline was added to the oil system which had already been filled to the 13 gallon tank level with the result that the system was overloaded and oil was forced out of the breather lines.

2. I was surprised to find that the ferry pilots have been instructed to use 90°C. as the desired coolant temperature. This lower temperature has a serious effect on the amount of heat available for cabin and carburetor heat.

3. In running some of our reduction gear box tests we were required to operate at rated horsepower i. e., 42.5 inches H. G. 2600 R. P. M. As our synchronized schedule gives 40 inches 2700 R. P. M. it was necessary for us to install an old P-39 quadrant.

I checked several pilots, some of whom had combat experience, for their opinions regarding the synchronized quadrant. All agreed that it was very desirable during actual combat but they wanted to be able to select a schedule which would give them best specific fuel consumption when going to or returning from a mission. The new selective-synchronized quadrant should fill these requirements perfectly.

4. Carburetor heat is rapidly becoming an important consideration in cold weather operation. In the past, carburetor heat has only been appreciated during icing conditions. Fuel vaporization tests have established the effect of controlled induction temperatures on specific fuel consumption. Regulated heat also makes it possible for escort fighters to operate at low powers with a minimum of plug fouling. I predict that within a short time the provision to automatically control carburetor heat between 15°C and 20°C will become a requirement.

5. During the winter I was able to visit several of the ferry bases. The airplanes seem to be moving along with a minimum of trouble or complaint. The nearest approach to a chronic ailment was relative to RP-43S plugs. Whereas the rate of replacement for LS-86 plugs ran about one in every twenty airplanes, the replacements on RP-43S averages about one in every six. The biggest fault seems to be engine roughness on the exhaust bank. The bases I visited lacked a supply of RP-43S plugs so LS-86's were being used for replacements.

The usual amount of leaky oil coolers and struts were being encountered but at the time the extent was considered only that which can normally be expected.

The main criticism of the airplane itself was the lack of controllable aileron trim tabs which imposes considerable strain on the ferry pilot.

6. United Aircraft Products conducted a series of oil dilution tests on their automatic control valve which was installed on the P-63. The operation of their valve is based on the viscosity and pressure of the circulating engine oil. A selector switch opens the dilution valve. When the oil viscosity and pressure drops to the desired amount, the valve will automatically close. In checking their valve we found that when 10% dilution was desired the "Y" drain sample showed 16%. 20% desired gave 22% and 30% checked out correctly. These results prove that valve could be made to work satisfactorily because it is a simple adjustment to change the base line for the 10% requirement.

7. It appears as if the ultimate solution to cold weather engine operation lies in the development of a synthetic oil. These oils have the desirable characteristics of higher viscosity at high temperatures and lower viscosity at low temperatures. In other words, these oils have a flatter viscosity curve than natural crude oils. PPO-265 which was being tested in several airplanes this year still isn't the final solution but where the dilution period for regular oil was seven minutes, only three minutes were used with PPO-265.

Some further advantages being claimed for synthetic oil are:

a. has greater "creeping" or power to wet metal surfaces

b. not as injurious to rubber compounds for seals and gaskets

c. lower inflammability.

8. The following are the main points of interest brought to light on the P-59.

The first and foremost weakness lies in the engine accessories. Several starter fuel pumps had to be replaced, one had a broken coupling shaft, another had leaking seals. There were two other pumps that were removed and showed no visible defects when dismantled but the installation of new pumps corrected the starting troubles.

On our attempted cold starts at —40°F. both units started satisfactorily but we could only get 30# to 40# fuel pressure and a speed of 8,000 R. P. M. The main fuel pump was replaced and the unit ran satisfactorily. The following day under the same conditions the fuel pressure and R.P.M. again failed to build up sufficiently. This time the condition was corrected by replacing the barometric. The main fuel pump we had removed appeared in good order when inspected so the conclusion is that the barometric must have stuck both days.

The operation of the barometrics was especially bad. Several replacements were made. The last set used #T8902718 and #T8439317 were supposed to be of the latest design but there was no noticable difference in any of them. As the accompanying over-speeding curves show, the barometrics failed to regulate R. P. M. with changes of altitude. The curves also indicate the inability of the governors to keep the R. P. M. below 16,500 R. P. M. However, we did not replace or attempt to adjust the governors. I deem it highly advisable to cold room test all the engine accessories.

9. The elevator trim tab control gave trouble starting at about —30°F. To localize the trouble we disconnected the actuator and made another flight. The control was still almost impossible to move so this time the system was disconnected at the rear sprocket. This eliminated the trouble so we had proof that low temperature was affecting the system somewhere between the sprocket and actuator. From these tests we were not able to tell definitely whether or not the actuator might also be causing trouble and as we did not eliminate the cause in the sprocket, that question still exists.

10. The cabin heating system seems to be adequate. At 28,000 feet and 15,000 R. P. M. with an ambient temperature of —55°F. the lowest recorded cabin temperature was 24°F.

My first C.W.T. report mentioned a pilot's complaint of cold feet. At the time the anemostat was out and a venturi installed in the cabin intake air duct. After the venturi was removed there were no more complaints.

11. When the ground temperature went down to —40°F the cabin seal tube became very hard and yet we encountered no pressurization difficulties attributable to excessive leakage.

After about 75 hours the pressure regulator showed signs of erratic operation. In cycles of approximately five minutes duration the cabin altimeter would jump five to eight hundred feet and then surge back to normal in a few seconds. An inherent weakness in the regulator lies in its inability to instantly compensate for any change in conditions. For example, at 25,000 feet when R.P.M. was reduced from 16,500 to 15,000 a momentary 1,000 foot rise was noted on the cabin altimeter. The same thing happens when one unit is stopped and started in flight. These sudden changes of cabin altitude are very unpleasant to the pilot.

12. Several types of oil were tried out in the lubrication system. 3580 which is called for in the specification was removed before any very cold weather was encountered. It is primarily a hydraulic oil therefore a substitute is being looked for among the lubricating oils. When ground temperatures of —40°F were encountered the airplane was serviced with AN-O-6 in the left unit and WS-804 a synthetic development in the right.

After the first cold start both oil pressure gages registered 25 lbs which is the limit of the gage. The units were stopped and when the oil was found to run out of an open petcock the units were started once more. The oil pressure again went overboard. After about a minute the left gage dropped back to normal but the right gage became inoperative.

As 3580 is considerably heavier than AN-O-6 it is safe to assume that 3580 would not be suitable for temperatures down to —40°F.

My recommendation is that we get permission to use AN-O-6 instead of 3580 and further that we replace the present 25 lb. gage with one that will record up to 100 lbs. pressure.

13. There was no canopy cover available for the P-59 and as a result the windshield became covered with frost several times. This was easily removed by directing a heater duct into the cockpit for a few minutes.

Although none of the AAF airplanes I know of are able to defrost while standing still, our pilot was anxious to have this provision. His proposal was to tap a line into the compressor ring and lead it back to the intake of the heater muff. As the need did not seem to warrant such an elaborate installation we added a metal scoop to the muff hoping there would be enough increased ram to permit defrosting while taxiing. Due to the lack of suitable weather it was not possible to judge the effectiveness of the scoop.

14. The P-59 may require ground defrosting more than most fighters for the reason that it has no clear view panel and because the pilot is restricted from opening the canopy far enough to enable him to see out during take-off.

If some simple means for producing forced draft at the muff could be devised it would be a definite improvement.

15. We had hoped to collect data on the current draw of various electrical units but we were not able to calibrate and install a shunt in the various systems. The closest approach made was to record the ampere increase on the instrument panel when the flaps and landing gear were operated. These readings are given in flight No. 10 of the Temp. Survey.

16. The following observations were made on the P-59. (a) the booster coils would burn out after several unsuccessful starting attempts, (b) the generators would successful starting attempts, (b) the generators would not parallel especially at high altitude, (c) the air filters became soaked with oil after a few hours operation but with no apparent ill effects to the lubricating system.

Bell Aircraft Corporation

Lee McIntoch.

Along with numerous bombers, transports, and other fighters, two Bell Aircraft products, a P-59A-1, and a P-63A-10, were tested for cold weather operation this past winter by the Extreme Temperatures Operations Unit of Wright Field. Among the numerous aircraft represented, it can be stated without prejudice that the record of the P-63 and P-59 was outstanding in both cold weather operation and in the small amount of general maintenance necessary to keep them in commission.

The record of the P-63 is in large part due to the fact that nearly every winetrization item that gave trouble on the P-39 has been modified or improved on the P-63.

The record of the P-59 is due to several factors, including the fact that it is a good airplane, as evidenced by a 3,486 mile flight from a warm temperature to a cold temperature with only one stop that demanded any maintenance beyond refueling. Also, the jet propulsion engine was found especially adaptable to cold weather operation in that this engine will start at forty degrees below zero F with as much ease as it starts at 70 degrees above.

This report is not to be construed as a eulogy from the preliminary remarks, which are included solely to give credit where credit is due. No airplane in existence is yet ready to operate normally at —65°F, which is the present ultimate requirement. Though ground temperatures of only —40°F were reached this winter, it was sufficiently cold to prove the need for winterization modifications on present production models and cold room tests on items to be included on experimental models.

P 59A-1, No. 44-22610

It is the writer's intention to emphasize that cold weather data collected on the P-59 should be utilized both for winterizing the P-59, and, perhaps more important, winterizing the experimental aircraft and I-40 engine installation. Since these aircraft are of the same type, it is believed that winterization problems on the former will more than likely apply to the latter, and if proper steps are taken, the number of difficulties the new models might experience in cold weather can be held to a minimum. It is recognized that some of the items are directly the responsibility of General Electric. They are installed on an airplane bearing the name of Bell Aircraft, however, and since an accumulation of maintenance difficulties almost invariably accrues to the aircraft manufacturer, it is considered a not unwise step to do all possible to expedite improvements wherever improvements are needed.

A. FUEL SYSTEM

1. Barometric.

Although this item will not prevent an airplane from being flown in cold temperatures, it is inadequate and undesirable for cold temperatures for two specific reasons:

a. The thrust from an I-16 unit is dependent on RPM and air density. The critical or maximum RPM is 16,500. This is the RPM to operate the engine at for greatest thrust at any air density. Since at ground temperature below 35°F, and base altitude (455 feet), the barometric by-passes too much fuel, maximum RPM and thereby maximum efficiency are not attained for take-off. At —20°F, maximum RPM averaged 15,750 and at —40°F, only 15,600.

Due to this inadequacy of the barometric, on the I-16 test stand unit, it was of necessity removed and replaced with a needle valve for thrust measurement tests. Using the needle valve to regulate fuel pressure, 2500 lbs. thrust was measured at 16,900 RPM and 795 lbs. fuel pressure. Contrast this to 15,600 RPM and 250 lbs. fuel pressure at —40°F on the P-59 with the barometric adjusted to maximum RPM.

Providing an increased range of adjustment on the barometric would only partially answer the problem as it would then require adjustment at each change in temperature. If the barometric is to continue in use, it will require an automatic temperature control.

b. A number of test climbs were made, as the barometrics continuously allowed overspeeding in excess of 16,500 rpm at altitude. Starting at base altitude 450', with the throttle set at 15,000 rpm, rpm would increase to 16,500 at 14,000 feet, though the temperature decreased by 54°F during the climb and the throttle setting remained constant. It is not known how much overspeed in excess of 16,500 rpm could have been attained due to danger involved, though the pilot reported unintentional overspeeding to 17,000 rpm two or three times.

2. Governor.

In conjunction with *b* above, it is noted that the governor does not perform its function of preventing overspeeding. It is the understanding of the writer that a new type governor is being tested which will eliminate the need for a barometric. This new type governor should be adequately cold room tested before its production in quantity. Items of this type should not prove difficult to test in a cold room. It is suggested that in testing them, the following be taken into consideration—Fuel temperatures. From thermocouple reading taken on 22610, fuel temperatures remain at ground temperatures, i.e., if an airplane is on the ground for several hours at 0°F, this will be the approximate fuel temperature. Though the airplane go to —65°F at 30,000 feet, the fuel passing through the fuel governing system will still be at approximately 0°F.

3. Starter Fuel Pump.

A total of seven starter fuel pumps failed at Ladd Field. These included one failure due to a sheared shaft, two pumps with vanes binding on the dural pump casing, and four seal failures. The cause of these pump failures cannot be definitely assigned to cold weather, as these failures occurred at not unusual temperatures. No failures occurred at —40°F. The Pesco CWT Representative at Ladd Field informed me that G.E. is now being supplied with a modified starter fuel pump that has a seal designed for kerosene, a bronze pump casing, and that this modified pump has passed cold room tests at —65°F.

B. OIL SYSTEM

1. Engine Oil.

Of the three principal engine oils tested, WS804, AN-O-3 Light, and AN-O-6 Light, only AN-O-6 is recommended for use. Tests on WS804 and AN-O-3 showed high oil consumption, averaging up to two quarts per 1½ hour flight. Oil consumption using AN-O-6 was negligible. AN-O-3 has the additional disadvantage of causing high bearing temperatures. Tests on AN-O-3 oil were run in the hope that the same oil could be used in the thrust unit as is used in the P-63 reduction gear box. AN-O-6 oil shows good flow characteristics at —40°F and can be further tested in the cold room for flow at lower temperatures.

2. Engine Oil Pressure Gage.

This gage is inadequate for cold weather as high oil pressures are encountered at starting. The gage on the P-59 only goes to 25 lbs. It can become damaged by starting the engines at —40°F.

The following specific recommendation is made: An oil gage mockup using a restriction in the oil line or a 100 lb. gage should be cold room tested using AN-O-6a oil at —65°F to determine an installation that will meet this —65°F requirement.

3. Lagging.

At engine change on 22610, all lagging was removed from the left engine oil lines and tank. This was accomplished prior to the occurrence of the coldest temperatures encountered at Ladd Field this season. Since no differences in engine operation could be noted following the removal of lagging, the need for lagging in cold weather operation is questioned, and the recommendation is made that future cold weather tests be made with lagging removed.

C. COLD STARTING

The cold starting procedure for cold weather is different in one respect from starting at warm temperatures. Greater starting fuel pressures are necessary. A normal start may be made at 70°F with 50 lbs. fuel pressure. At —40°F, 75 lbs. fuel pressure is necessary. The P-59 starting fuel pump will build up 150 lbs. pressure which provides a generous factor for starts at temperatures below —40°F. It is the writer's understanding that the I-40 engine also provides a generous factor in this respect.

The barometric will sometimes stick when starting cold at low temperatures. The engine will start but rpm will not go above 8000 when this occurs, until heat is applied to the barometric, or it is removed and cleaned.

D. IGNITION

The only ignition trouble encountered was the need for replacement of six booster coils. The life of these coils can be lengthened considerably if the existing starting procedure is strictly adhered to. Some pilots, however, will take longer than others to start the engines and the insulation on the coils will melt down, resulting in shorting out. Although the C-1 booster coil is an easily procurable item and simple to replace, it would be advantageous from the standpoint of reliability and a concession to differences in pilot's alertness to incorporate a heavier booster coil.

E. CABIN HEAT

No definite requirements known to the writer have been set for cabin heat on a fighter aircraft. This, I believe, is an oversight, as cabin heating equipment seems to be dependent on whether or not pilots complain of being too cold in flight. I is my opinion that available cabin heat of room temperature (68°F) is not especially desirable or necessary on a fighter aircraft. Excessive cabin heat can encourage pilots to fly without cold weather clothing, which could result in serious consequences should an emergency arise.

Pilot on the P-59 did not complain of cabin heat. He stated the cabin was comfortable for him and that he could fly with his gloves removed.

Thermocouples installed at various points in the cabin showed good heat distribution and an average of 35°F in the cabin at 16,500 rpm with the heat control full on.

Unless specific cabin heat requirements are set up, no recommendations other than modifying the cabin pressure regulator to increase its life. This regulator on 22610 was good for over 60 hours before it began causing pressure fluctuations.

F. WINDSHIELD DEFROSTING

Until a canvas hatch cover was fabricated (a required item of cold weather equipment), the pilot complained of frosting windshields at ground run-ups and at taxiing out for take-off. With the nightly use of the canvas cover, frosting was in large part eliminated. On take-off and in flight, windshield defrosting was exceptionally good. No frosting was evident at any altitudes on any temperatures including —70°F at 32,000 feet.

As an experiment, small scoops were attached to the heater muff intakes to see if they would pick up any rammed air during taxiing. The installation of these scoops made little difference, however, as the rear impeller intake sucks air from the back of the engine nacelle and around the engine until speed is attained.

The present heater muff intake is located at the bottom of the muff where it can pick up dirt and any oil or kerosene leaking onto the inside of the engine cowl, and carry this matter to the inner surfaces of the windshield. Unless the engine installation is kept free from leaks and the cowl kept clean, this will occur. It is felt that this is a maintenance problem.

The windshield defrosting system adequately meets cold weather requirements for —65°F when the required canvas hatch cover is used to prevent frost from forming whenever the airplane stands outside overnight.

G. CABIN HATCH

The operation of the cabin hatch grew increasingly stiffer the colder the temperature. An attempted corrective remedy was tried by filing and smoothing metal surfaces wherever they appeared to be grooving or scraping. This did not decrease stiffness. After this attempt, it was noted that the rubber pressure seal tube became less and less pliable the colder the temperature and it exerted a pressure against the hatch wherever it was not securely and properly recessed in its mounting channel. Rubber was found on the hatch scraped from the lower rear right corner of the tube where the greatest pressure was exerted at low temperatures and where the tube was most noticeably not properly recessed. Proper installation of the pressure seal tube at the factory will eliminate hatch stiffness at low temperatures. An improved rubber which will remain pliable at low temperatures would also be advantageous.

H. CONTROL SYSTEM

1. All surface controls, with the exception of the trim tabs, operated satisfactorily on the ground and in flight. The main surface controls were slightly stiff on the ground at—40°F, but loosened up quickly after being moved a few times and after the engines were started.

2. Elevator Trim Tabs.

Stiffness of these units was excessive in flight at low temperatures. By the process of elimination, first disconnecting the flex cables from the actuators and finding the installation still stiff, and then disconnecting the rearward trim tab chain, and finding no stiffness, the trouble was isolated to the actuators and flex cables. Testing was discontinued on this unit when a 90° drive on the right actuator was accidentally broken during a T. O. change of the flex cables. Concurrently, a report was received from the Central Offices stating trim tab stiffness had been eliminated at the factory by successively cold room testing each item in the installation and taking corrective action on each item until the stiffness was eliminated.

3. Rudder Cable Tension.

The P-59 has the longest rudder cables of any production fighter produced by this company. An accurate check was made to find exactly how much temperature affected cable tension. The rudder cables were set at 175 lbs. tension at 60°F. At —35°F, the tension had dropped to 83 lbs.; at 0°F, tension was back up to 118 lbs., and at 12°F, 130 lbs. This shows a drop of approximately a pound per degree, F. Standards has informed me this drop in tension is not excessive. Should still longer cables be used on the later models, a cable tension regulator manufactured by U. A. P. is available. This item has been used successfully on the B-24.

I. FLAP INSTALLATION

At —40°F, ground temperature, it was noted that the flaps would not operate until after the engines had been run up, thereby causing some heat to be absorbed. This indicated a grease problem and several attempts were subsequently made to cause stiffness in the flaps so that the grease could be changed and the corrective action recommended. Flights were made to 30,000 feet and —65°F. The pilot flew as long as fuel would allow and then tried operating the flaps. In each case, the flaps operated normally. Since it was found impossible to cause the flaps to again become stiff, no corrective action could be taken which would show positive results.

It is recommended that a mockup of the flap installation be cold room tested at —65°F to again induce stiffness in order that the corrective action needed to eliminate the stiffness may be discovered.

J. LANDING GEAR

No winterization problem occurred on the P-59 landing gear. The shimmy damper did not leak, nor did the struts, which had the old type V-ring packing.

K. GENERAL RECOMMENDATIONS

Since airplane No. 42-22610 was the first jet-propelled aircraft to ever be tested in cold weather and it was never subjected to temperatures below —40°F, and it was also the only jet-propelled airplane tested, additional cold room testing of accessories and items which might require winterization would be desirable. It is recommended that all accessories on both the I-16 and I-40 engines, which have not been cold room tested, be subjected to temperatures of —65°F, and operated. Any modification found necessary should be effected by the proper manufacturer.

Bendix Products Division

Caesar Benassi.

P-38L. Using PD12K8 carburetors PL 395270-6. We made the setting change to —6. I received your service bulletin on this and many new flow sheets. Plugs were changed at the same time that —6 setting was made Spark plugs installed were RP-43. Reference my report No. 4 of January 18, 1945. These plugs replaced after some three hours and very badly messed up. It looked like gum carbon and lead deposits. It may not be the fault of the plug but due to the lever setting, the engine may be burning out accumulation of gum and carbon formations. Regardless, the plugs were an awful mess and had much of these bricates or pieces of formation which was grounding them out. LS87 plugs were installed. After some 17 hours, these have been replaced on the exhaust side of both engines as they fouled out. Some of them were not firing. These are much cleaner and show small amounts of this gum carbon or lead deposits. The story on the LS87 plugs was this. They started fuel consumption tests after installing them. First test was a four hour run with carburetor heat on, pulling low powers 1600 RPM and 24″ MP to 25″. This was to simulate bomber escort mission cruising approximately 170 MPH. The idea was to find out the effect and improvement that carburetor heat had on engine performance and fuel vaporization. The pilot flew four hours with carburetor heat on +9 to 12°C on left engine, +18 to +21°C on right engine at 1000 feet. After two hours of flying a mag check was taken and found O. K. At the end of four hours a mag check was again taken and found O. K. Carburetor heat was taken off and war emergency power was pulled in cold air. Both engines took it fine, excepting the right engine coughed once but immediately caught and went on. The exhausts were clean all the time. No torching has been reported at any power setting since —6 setting has been made. Left engine is using synthetic oil and right engine 1100 oil. Fuel consumption end of test was spoiled due to leaking fuel selector valves.

The next day the same kind of test was made with carburetor heat off with a temperature of approximately —10°C. At the end of two hours a mag check was taken and both right mags were very rough. A power run was attempted but engines were very rough. Back on test run for two or more hours. At the end of four hours, the pilot advanced the throttles to pull rated power but the engine was so rough that he was unable to. Both right mags were very rough. Pilot said, "the turbos were very black and when he increased power a carbon layer like foil peeled off turbo waste gates." From this preliminary test it seems that carburetor heat can be used to good advantage on long range high altitude cold temperature flights. More tests are being conducted on this. Lockheed is ahead of other turbo installations on carburetor heat tests and seem to be on the way to making it a success. They get their heat from a shroud around the exhaust pipe and dump it into the turbo air inlet side. At the same time close off ram cold air and have a nose shutter in front of intercooler to shut off intercooler air. They get the best effect by having this shutter in front of intercooler rather than after. They also have a pressure differential controlled unrammed cold air door in wheel well that opens up and allows cold air to mix with this hot air at high powers so that when pilot begins pulling high power this door will open to keep carburetor heat from going too high. But at the present time, the valve he is now using is set to open at approximately 3.9" Hg pressure differential which is too high and he estimates it will be necessary to have it open at 1.5" to 2.0" Hg for correct operation. He is using an Airesearch valve.

Republic has a carburetor heat control on the P-47D but it is not satisfactory. The heat rise is negligible on ground operation and low powers. They just take the heat from a shroud around the exhaust pipe and put it into the turbo air inlet. We may get some low power tests on these airplanes. The Wright Field E.T.O.U. Unit have some carburetor heat installations to make on B-17 and B-24 for test. I believe that when the value of carburetor heat for fuel vaporization is realized for long range, high altitude, low power missions rather than *just* removing ice, that more work will be done in this direction. It is a bad deal for the fighter pilots when they get to their destination after a long cruise at low powers and are unable to pull high powers due to plug fouling. It seems that the advantage of carburetor heat for such use has been very much neglected and I hope that we can gather enough information with further tests to prove its value in improving engine performance and efficiency.

In the past, carburetor heat has been looked upon only as medium of carburetor ice prevention or removal, and very little attention has been paid to its effects on engine performance and fuel consumption in long range cruise.

Very definite indications have been observed which leads one to believe the tactical advantages resulting from the use of carburetor heat have not been fully explored. It is my firm belief that with low power, long range, operation a noticeable fuel saving may be effected with the use of carburetor heat, when low cearburetor air temperatures are normally encountered. Furthermore, engine performance is definitely improved in low power cruise, in that spark plug fouling is reduced to a minimum. This also makes it possible to pull high powers from the engine even after several hours of long range, low power operation. In other words, a tactical aircraft could make extreme long range missions, pulling lower power for fuel economy, and yet the engines would remain "clean" enough to make safe operation at high powers possible.

It is believed fuel economy will be improved due to the increased vaporization effected by the use of carburetor heat. It is to be remembered excessive heat is also, therefore any carburetor heat system must have "controlled heat". For example, in a P-38 (Allison Engine) a minus 20°C carburetor air temperature is undesirable when pulling low power (1600 RPM—25") and any carburetor air temperature above plus 25°C is also undesirable. For 1600 RPM—25" MP it is believed a plus 20°C carburetor air temperature is the most economical for fuel consumption, and is also high enough to prevent spark plug fouling. Spark plug fouling is prevented by improving fuel vaporization and consequent combustion.

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We left for the 11th Airforce contact in the Aluetians on March 4th, and returned to Fairbanks on March 19th.

Before departing we had the pleasure of meeting General Johnson as he passed through here. It was he who requested our assistance. Thus we got an idea of what he expected to accomplish.

On the way out we spent a half day at the 11th Airforce Depot at Anchorage, where we advised them on the P-38 work.

We then proceeded on to Attu and Shemye. On this trip I had the pleasure of being associated with two very capable men—Captain Accord, C.W.T., P-38 project officer for the last two winters; and Lee Chambers, Lockheed, C.W.T. Representative for the past three winters, who have done a grand job.

Captain Accord has had two P-38L's on test this winter. Besides being a very good pilot, who knows every part of his airplane thoroughly, he also has considerable engineering ability.

Lee Chambers has worked very hard on the P-38 winterization and carburetor heat installation. It is due to his good work that Lockheed can now claim a satisfactory controllable carburetor heat installation on the P-38L. Because of the close cooperation of Mr. Chambers and Capt. Accord and the free hand given them by Col. Stewart and the C.W.T. Detachment, they were able to gather some very valuable information. By improving fuel vaporization and reducing plug fouling, this will go far toward improving low power, long range operations, thus allowing the P-38 to pull war emergency power after long range, low power escorts. So far, this carburetor heat control is installed only on 115 airplanes, most of which are being sent in this direction.

While in the islands, we lectured to mechanics, day and night, seven days a week. Mr. Chambers covered the heat control; Capt. Accord discussed the P-38L in general; and I dwelt on carburetion. The lectures were three hours long with a ten minute break each hour. We imparted much information, which, I am certain, will help them with these airplanes. Capt. Accord and Mr. Chambers assisted them in starting the modification of the carburetor heat control so that it would be held at any desired temperature.

The way it is now hooked up, the carburetor air filter lever, which was not being used, now controls the carburetor heat and cold rammed air valve. By moving this lever, which is near the mixture control in the cockpit, the cold ram air valve can be closed and hot air can be taken in from around the exhaust shroud and put in on the suction side of the turbo. The hot air shroud can stand enlarging for its restricts air flow as much as 8" of manifold pressure when used. This doesn't matter too much at low airflow, but can be corrected for altitude work by using partial heat. Also, an Airesearch relief valve should be put in this system to allow cold rammed air to automatically begin entering at approximately 2300 RPM 32.0" manifold in case a pilot forgets and starts pulling high powers with carburetor heat on. This would be a safety factor and so avoid damage to the engine.

They also installed two B9A switches in the cockpit just below the prop feathering switches to control a nose shutter in front of the intercooler. This shutter can be controlled by a small screw jack at any given position to give desired carburetor air by controlling the efficiency of the intercooler. This can be used alone or in conjuction with the hot air valve.

The pilot's operation of these ships was very poor as they had acquired many bad habits, such as:

1. Ground operation in auto-lean to keep plugs from fouling. This could have been accomplished in auto-rich and the use of the higher RPM after the engine started; also by having the idle mixture properly set

and by the use of carburetor heat. This resulted in two ships taking off in auto-lean position beacuse the pilot forgot to go to auto-rich for take-off One ship was damaged. The other pilot found his eror in time to save the ship.

2. Starting by using manual mixture control instead of primer. This is a serious fire hazard.

3. After using carburetor heat for ground run-up, forgetting to take it off for take-off.

4. High power operation, overworking and damaging engines. This was very unnecessary as they were not going anywhere, and it resulted in throwing rods and having entirely too much maintenance.

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I just received your Field Service letter of March 22, 1945 of comments by George Strobridge as to their findings in England on lead fouling and his comments on Ostrander's memo.

I felt that if they go out and do as we have in the past three winters up here, operate engines at low RPM with +20 to +30° centrigrade carburetor air temperature that they will eliminate plug fouling. We have fouling. We have operated P-38's as much as 115 hours on same plugs. We also found that rich cylinders get most of the lead. We have operated as long as 4 hours at one time, 1600 RPM and 25" MP without fouling plugs and carburetor heat on, then pulled war emergency power with heat off . However, at above setting without carburetor heat, the plugs would foul out in two hours with temperatures only —12° centrigrade. Then at the end of four hours, the plugs would be fouled so badly that it was impossible to pull even rated power as the plugs would not clean off and had to be changed. Might suggest they try some carburetor heat test to improve fuel vaporization, distribution and reduce plug fouling. I have been a booster for carburetor heat for cold operation for three years, and I believe that it is finally coming into play and that you will see a definate trend towards its use in the near future. After my first winter's operation up here, I returned to the plant and advised our engineering department to install carburetor heat on our test stand Allison engine and to work on a means of automatic carburetor heat control. I never received any information, so supposed it was never done. If so, we have missed much valuable data.

Allison has much information on carburetor heat and distribution. At one time, they did not recommend the use of carburetor heat, but in the past year, have learned much and have changed and are for it. I would appreciate it if Wally Knopp could acquire for us this data from Allison. Cold Weather Carburetor Heat Test, Report A2-127, Experimental Dept. by G.M. Grabbe, 4/1/44 to 4/30/44.

Yesterday, I attended a meeting with Major Anderson and Captain Alexander of A. T. C. and Bud Shaw of Allison. The discussion was on P-63 plug fouling. They changed 850 spark plugs last month and none of these had over 25 hours. The planes have been coming up operating at 2000 RPM and 30" of MP in auto rich position. I suggested the use of carburetor heat to +20 to +30° centigrade not to exceed 2250 and 32" of MP in autolean position. Auto lean being quite lean on this installation, I suggested, if they find it so, to operate towards or in auto rich as they found it necessary. They are going to put out a letter to this effect and train all pilots and mechanics to do this by having them fill out a check sheet with their operating information and if necessary check out pilots and mechanics on proper procedure for operation. Auto rich will be used on the ground at all times. Thus they expect to eliminate most of this plug fouling and rough engine operation. They have found some plugs improperly set in stock and will check all these before installation as well as torquing plugs when installing. The carburetor situation has been very good, only one being removed that was causing rough operation in A. I. This will be flow tested and I will get results. Trouble was in cruise range so I suspect idle spring setting.

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On my B-29 reports, I stated that the primer is essential for cold starting with fuel injection engines. Since studying my reports, I would like to add a few words of explanation. I feel satisfied that the primer can be eliminated for warm operation. For instance, we started engines at +20°F. in less than 70 seconds without priming, time after time. However, under the same conditions, with the primer we could start them in 15 to 30 seconds. We really don't know how low we could start without the primer, but we did get better starts with it. With direct injection, cranking speed makes a difference, and the faster the engine can be cranked the better. It is desired to crank at least 25 RPM for successful starts. We should also consider the method we used for starting and the lack of knowledge on our part. It did seem that ½ to 1" throttle opening was best, and sometimes cracking the engine 1 prop, RPM mixture A. R. before turning ignition on helped. This seemed like the best method, and we started in 25 to 30 seconds with it.

Better warm up operation was had when engine was run up to 1200 RPM as soon as oil pressure hit 40 lbs. It is sometimes necessary to hit the dilution solenoid slightly to maintain the above oil pressure. Auto lean operation at this time does reduce the exhaust torching, but does not seem to smooth out engine operation very much.

While I was in the Aleutians a meeting was held by the C. W. T. Cargo Section. It was attended by the P. & W., Wright Aeronautical, and Curtiss airplane representatives. The discussion was about the C-46 low power, rough engine operation and cutting out. I haven't been able to get the minutes of the meeting, but will do so or discuss the same with those who attended. From what little information I gathered, it was more of a sudden cutting out and it happened mostly to the right engine, although it has happened on the left. It happened on a straight level flight, low cruise, or let down in A. L.—usually at 1900 RPM, 25" M. P. A. R. or lower, and could be corrected by using carburetor heat or A. R., or by increasing manifold pressure to 27.0". High blower was not tried. ANF-28-130 grade aromatic fuel was being used. C-34S plugs were used. It also happens when the temperature is 0°F. or colder. I am satisfied that it is a distribution problem due to this type fuel at cold temperatures, using low powers, and not getting enough heat from the blower to help vaporize and distribute this fuel properly to each cylinder. I feel that this combination of low cruise at low temperature and this fuel is creating quite a distribution problem, and that the use of carburetor heat with this fuel is the answer.

I had the pleasure of meeting the Phillips 66 representative. He advised me that they ran into RPM fluctuation at low powers such as 1460 RPM and 2020 RPM, and 25.0" of M. P. in A. L. As near as he knew

A. R. carburetor heat or 27″ to 28.0″ of M. P. would eliminate this. After listening to my thoughts on this subject he invited me to take a ride some time, and see for myself what happens. This I will do if I have time.

There has been much said in regards to synthetic oil PPO-265. I have made it a point to discuss this oil with various ATC officers, enlisted men, and factory representatives attached to the Army. In practically all cases they feel that this oil is the cause for rough engine operation after a few hundred hours; and they can in most cases clear up the engine roughness by changing oil. Please do not get the idea that I am criticizing this oil or condemning it, for I have no such intentions. In fact, if it is given the right chance, I believe that it is the answer to some of our dilution problems. I feel that in most cases it was put into an engine and just allowed to carry on. It was expected to create wonders and wasn't given a fair chance. For instance, it is the opinion of most people I talked to that this oil will do the following things:

1. It will flow freely and penetrate more than 1100 oil.

2. It will clean an engine of sludge and gum.

3. It will burn cleaner at the exhaust.

Now let us consider the above comments or opinions:

1. If it flows freely and penetrates, it will reduce the necessity of oil dilution and should improve cold weather operation.

2. If it cleans the gum and sludge from the engine, in time, this gum and sludge will be flowing throughout the engine in the oil. This is not desirable as it will finally deposit this residue in the prop dome (Hydromatic), and, as the oil penetrates, more probably in the valve guides. For this reason we are bound to get engine roughness. Also, for this reason, this oil should be used only in a new engine that doesn't already have a quantity of gum and sludge accumulation. If used in an old engine, it should have some type screen to catch this sludge, or the oil should be run through a clarifier after the first 50 hours, and probably every hundred hours thereafter to eliminate the sludge and gum. This would be giving the oil a fair chance and might be an answer to all the trouble being encountered.

3. Since it burns cleaner, it would be more desirable.

This is only my opinion; but I would like to see it tried to see if it would eliminate the troubles encountered, as I do think that this oil could answer many problems.

I have been told that draining the synthetic oil and replacing it with 1100 oil has cured engine roughness; and that at times they have flushed engines with diesel oil and put in new synthetic oil and cleared up rough engines. If so, why wouldn't a clarifier do the same thing? I hope that this may be of help to some one.

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While in Anchorage, checked on the P-38L situation and it is coming along quite satisfactorily.

In fact, some of the news was very satisfactory and made me very happy. I met Colonel Semway who is Commanding Officer of the 54th Fighter Squadron at Attu and he said he had some information for us from the chain. He gave us what he knew about it and it amounted to this.

A group of the P-38L's had simulated a bomber escort with B-25's for 9 hours and fifteen minutes using approximately 64 gallons of fuel per hour. This was done at 1600-25″ one way with a twenty minute scramble of high powers at the supposed target, then returning at 1600-30″ to the home base with 270 gallons of fuel left in the tanks which was a good four hours reserve. They used carburetor heat on this mission. They had one 300 gallon belly tank and one 165 gallon belly tank and did not drop the tanks which would give them a slight loss in air speed. Being that they were worrying about fuel on a 9 hour mission, I feel that this will cause them to realize that Capt. Accord knew what he was talking about when he advised them of the powers to use to get 13 hours flying time from their fuel. I am certain this will give those pilots the confidence they needed and that they will learn more as they go along. Now I feel that the combination of Accord-Benassi and Chambers did much good on that trip, and feel that the trip was worthwhile.

Chandler Evans Corporation

H. H. Wallace

1. No report of malfunctioning of B-29 carburetors have been received by this writer to date. The complaint on B-24 carburetors is the same on all ships—difficulty in getting the engine to fire in the carburetor alone during cold starts. After a sufficient warm-up period, ground and flight operation are normal in all cases. However, during cold starts, at temperatures lower than —10°F., the engine will fire on prime but will not run with the carburetor alone until it has been running about three minutes or longer on the primer.

2. This was observed by the writer on the morning of January 19, 1945, on airplane No. 44-41377, when starts were made at —19°F. Each engine showed the same trouble with No. 3 engine, the worst offender.

3. The capacity of the primer was such that the engine would not go above 500 RPM with continuous priming. This is to be investigated by the writer this week.

4. Investigation of the load compensator balance line drip from the gurgle tubes showed No. 3 engine to flow the least. It was therefore decided to change this carburetor and install one of the four carburetors I brought from Ceco, Dayton. This was done and on cold start the next morning this engine ran on the carburetor as soon as it was put in auto-rich after starting.

Consolidated Vultee Aircraft Corporation

D. M. Moore

D. M. Moore

1. On a trip to Anchorage in November, airplane B-24J, Serial No. 44-41377 encountered ice. The crew chief reports the propellers and empennage iced while the wings remained clear. The alcohol system was not effective in eliminating the ice. When the engine speed was increased to 2400 RPM, the ice was thrown off; the numerous dents in the skin on the right side of the fuselage in line with the plane of propeller rotation are verification of the crew chief's story. A similar condition has been noted on a Model C-46 airplane at this base. Also observed ice on the leading edge of the blades of a Model B-29 airplane when it had been run in the hangar. The ice extended approximately eighteen inches beyond the end of the slinger outlets. Sandy suggests we extend the outlets to the hump on our blades, increase their diameter and incorporate fluid nozzle outlets to increase ejection velocity, and install icing strips to avoid denting the fuselage.

Ice research was conducted on an instrumented Model B-25 hot wing airplane at Minneapolis least year. Cameras were installed so photographic evidence could be obtained in flight. The North American Engineering Representative at Ladd Field this season is the engineer who covered the tests at the Ice Research Base. The results of the test indicate wing and empennage icing is is not nearly as critical as formerly believed; indicated air speed was reduced approximately 4 RPM when 1½ inches of rime ice was formed on the leading edge or the run back formed 3 inches high over the single spar. Landing characteristics were not impaired appreciably by these formations. On the other hand, numerous tests indicated propeller ice is critical. Prior to entering known icing areas the power setting, altitude and indicated air speed were recorded. The first warning of propeller ice was excessive vibrations of the engine; throw-off followed and the indicated air speed dropped—in some instances as much as 35 MPH. The engines were speeded to about 2300 RPM to throw-off the ice; when the original power setting was resumed at the same altitude, the indicated airspeed returned to the initial reading. When part of the ice is eliminated the unbalanced propeller produces vibration, ensuing rapid flexing and hunting of the blades in pitch change attitude, noted in stroboscopic observations, appeared to be responsible for the loss of throat rather than the change in blade contour produced by the ice.

Rime ice predominated in acclumulations on the blade at low propeller speed while glaze ice predominater at high speed. Ic accumulates faster at the low speed but the rime is much more easily eliminated by increasing engine speed; it may be impossible to eliminate glaze ice accumulated at higher engine speeds and still remain within recommended operating limits. Consequently, the North American representative suggests operation at the lower speeds and reving up at intervals to remove the ice. Operation in the lower range of engine speeds may hinder development of high power for carburetor deicing.

Discussion revealed that pilots and personnel engaged in ice research attribute the excessive empennage flutter encountered in our Model B-24 airplane at Minneapolis primarily to propeller ice rather than empennage ice; disturbance in the air stream and vibration originating at the propeller are believed responsible for resonant flexure in the tail.

2. Sandy has received information that Aleutian pilots are encountering carburetor ice on Model B-24 Series airplanes. Increasing power and/or changing altitude as recommended in the 1 September 1944 issue of the Standardization Handbook for B-24 Pilots published by the Second Air Force necessitates fuel consumption in excess of minimum cruise requirements. The additional consumption could easily be critical when icing weather prevails for several hours during a bombing mission.

We are planning to build some experimental muffs to cover part of the exhaust tail stacks; the muffs will be just below the carburetor ram air inlet passage so the interconnecting hot air ducting will be short. A valve to close the interconnecting duct and exhaust the muff air into the slip stream can be controlled by a cable from the intercooler shutter actuator. The temperature can be controlled by adjustment of the existing butterfly for selection of filtered air or rearrangement for selective setting of the intercooler actuator. A simple design that can be fabricated in any sheet metal shop would provide a quick and dirty solution for the Aleutian area without penalizing fuel economy. The muffs should also reduce the duration of rough engine operation when cold starts are desired.

CARBURETOR HEAT BY EXHAUST GAS INJECTION

1. Carburetor heat is supplied by exhaust gas injection on the Model B-25 airplane. Excessively rich operation was traced to stratification at the top deck; tests revealed a stream of cold air surrounded the altitude compensator, which also corrects for temperature. In addition, theory indicates richer operation can be anticipated when exhaust gas is dumped into the inlet air stream; fuel is injected in proportion to the mass density of the entering gas whether it be oxygen and nitrogen or carbon dioxide, water vapor and partial products of combustion. Further, the water vapor might conceivably augment the icing in the event of leakage of a small quantity of exhaust gas into cold air. Solid residue from exhaust gases may restrict impact tubes and change the carburetor metering characteristics. The foregoing reasons indicate carburetor heating by exhaust gas injection is not desirable.

OPTIMUM AIR TEMPERATURE FOR MAXIMUM RANGE

2. Tests are being conducted on the Model P-38 airplane to determine the optimum carburetor inlet air tem-

perature for maximum cruising range. Preliminary data recorded so far indicates approximately 3 percent economy can be affected by operating with air heated to 30°C. instead of using 0°C. inlet air. The 3 percent is believed conservative; fuel selector valves, inspected for elimination of internal leakage, have been requested so the test can be continued. The improvement in economy is attributed to increased fuel vaporization.

It is recommended provision for carburetor heat be incorporated on our experimental airplane, the bomb bay cells can be used as containers for fuel for a similar test. Take-off and landing can be effected with fuel in the wing tanks so the difference in weight of the bomb bay cells will show the fuel consumed during the test runs. The data is desired in the event we incorporate automatic control of carburetor air or intake manifold temperature; the warm air can be obtained from the manifolds in the heat exchanger system as outlined in my previous Cold Weather Test Reports. The effect on range should be noted on our cruise control charts.

INTERCOOLER SHUTTER EFFICIENCY

3. Cold Weather Tests on Model P-38 airplane, which has an intercooling system similar to ours, indicated circulation occurs in the cooling air duct when the aft side of the intercoolers is sealed; a similar conclusion was derived from tests on a Northrop Model P-61A airplane. Minor leakage through the butterfly located forward of the intercooler on one of the Model P-38 airplanes under test this season produces cooling of major magnitude; a shutter that will exclude all cooling air is found to be necessary.

Our failure to obtain appreciable heat rise, when turbo boost is applied on the Model B-24 airplane, indicated the carburetor air was being cooled almost as fast as it was heated; this condition exists with the intercooler shutters closed. Tests were conducted to support this contention and supply data for redesign by B-24 Project Engineering. A review of results reveals additional explanation is unnecessary. It is suggested work on the redesign be scheduled to coincide with our modification for carburetor heat.

A cracked throttle is not desirable because temperatures below the butterfly valve may be in the neighborhood of 60°F lower than is indicated on the carburetor air temperature gauge.

The data covering the Model B-17 airplane is submitted to indicate the characteristics of a muff around the tail stack. This experimental installation might prove adequate if the intercooler shutters were redesigned and relocated so 100% efficiency could be obtained. This installation is simple and can be incorporated easily on our airplanes in service which are not equipped with heat exchangers.

SURFACE CONTROLS

4. Shortly after the B-24J airplane arrived at Ladd Field the control cables were discovered materially looser than is specified in the Erection and Maintenance Instructions; they were tightened so a basic tension could be established for test purposes. Data recorded this winter indicates the tension variation in aileron control cables is greater than in either the elevator or rudder cables. The maximum tension noted in the aileron was approximately 79 pounds at +65°F when the aileron was in the hangar. The minimum tension was 61 pounds at —40°F. The variation amounts to 18 pounds over a temperature range of 105°F. A recommendation will be submitted to obtain test results covering a wider range of temperature.

At —62°F the tests show the tension in the aileron thermal control cables in airplane B-24J, Serial No. 42-51660 was 47.5 pounds and 50 pounds. At +1°F, the tension on the same cables was 52.5 pounds and 57.5 pounds respectively. The maximum variation is, therefore, 7.5 pounds for a temperature change of 63°F. No evidence of unsatisfactory performance was noted. This cable is standard 7 x 19 extra flexible construction; coefficient of expansion is 8.73 x 10-6; ultimate strength 3670 pounds; yield strength 1900 pounds.

The specialists from the Aircraft Laboratory think the tension regulator may prove ultimately superior to the thermal cable when the interior of the airplane is thoroughly insulated.

ENGINE OIL SYSTEM

5. Enclosure (C) shows the results of dilution tests on airplane B-24J, Serial No. 44-41377. The results indicate the hopper in our latest tank design is unsatisfactory; the diluted mixture in the circulating system overflows into the top of the reservoir. Enclosures (D) and (E) are the results of boil-off tests; they confirm the dilution of the reservoir outside of the hopper.

In spite of the low dilution requirements to provide for starting in mild weather this season, evidence of spewing has been observed on all Model B-24 airplanes at this base; maintenance is increased because the oil must be cleaned off of the nacelle fairing aft of the breathers. The quantity of oil lost in this manner is low as the oil consumption of the engines is considered normal. Discussion with Mr. William Hoffman, Chief Engineer for United Aircraft Products Corporation, reveals breather spewing has been eliminated by modification of the design of the oil system on a Lancaster airplane with a Packard built Rolls-Royce engine at dilution percentages as high as 25 to 30.

Tests conducted by United Aircraft Products Corporation on one of our reservoirs with the 3 inch diameter hopper show deareation of the oil is inadequate; entrained air by volume in the inlet oil is approximately 20 percent and entrained air in the line to the engine pump is approximately 18 percent under the test conditions. Mr. Hoffman was requested to forward copies of the test results to Mr. W. Ring, Chief Service Engineer, for my attention.

United Aircraft Corporation has designed an oil system for the Lancaster airplane which provides satisfactory performance for (1) dilution (2) deareation (3) warm-up (4) propeller feathering (5) spewing. The design is predicated on elimination of the feature where clean reserve oil is fed into the circulating system when the hopper supply diminishes; the reserve oil as well as the hopper oil is used in the circulating system. A discussion with the Specialist from the Fuels and Lubricants Section of the Power Plant Laboratory reveals Wright Field tests indicate the reserve oil in tanks of current design circulates in the system and invalidates the design theory. As the United Aircraft Products investigations and tests are subject to constant surveillance by the Engineering Division at Wright Field, a change in design specifications is anticipated. I also requested a copy of the drawing of a modified oil tank be included with the test results noted above. The data is desired to assist our engineers in modifying the oil system.

NOSE COMPARTMENT AND CABIN HEAT

6. On 10 February 1945 Sergeant Outlaw was bombardier in airplane B-24J, Serial No. 44-41377, during a bombing mission at 20,000 feet altitude when the outside air temperature was —40°F. He froze the little finger on his left hand; he considered it necessary to wear a mask to avoid freezing his face. This instance is cited to illustrate the consequences of inadequate heat in the nose compartment. Inquiry reveals the crews of all Model 24 Series Airplanes avoid riding in the nose, when possible, during Arctic flights on account of prevailing low temperatures.

Heating tests were conducted in airplane B-24J, Serial No. 44-41377 by means of thermometers secured to personnel; thermometers were located just outside of the clothing on top of the head at the waist and slightly above the ankle on the inner side of the leg. The pilot's ankle thermometer was on the left leg while the co-pilot's was on the right leg where they would not receive direct blast from the registers. The radio operator stood erect in the center of the compartment just foreward of the top turret; the bombardier stood erect in the nose compartment just aft of the bombsight; the pilot and co-pilot occupied their seats. Readings were recorded when sufficient time had elapsed for temperatures to stablize. Enclosures (F) and (G) show data obtained when all the floor registers in the pilot's compartment and the radio compartment were in the closed position—which does not shut off the hot air. The damper for the flexible top turret defrosting duct in the radio compartment was closed. The pilot's windshield defrosters were half open. The empennage deicing was off. The dampers in the right and left cabin heat ducts and the three miscellaneous equipment dampers in the nose compartment were wide open. Preliminary trials indicated these settings yielded the most even distribution of heat in the pilot's and radio compartment as well as directing the greatest possible quantity of warm air to the nose.

The foregoing tests reveal temperatures a few degrees above that of free air prevail around the bombsight and the air emerging from the pilot's and co-pilot's registers is too warm for comfort especially when wearing mukluks. The results of a bombing mission are dependent on the performance of the bombardier; best performance can not be obtained when he is cold—especially if his eyes are watering or his nose is running. In Arctic flying, it is just as essential not to become over-heated as to be sufficiently warm; excessive perspiration in foot gear may be the cause of frozen feet.

A study is suggested to locate and stop leakage of all outside air into the nose compartment—especially the leakage above the bombardier in the turret after-door sill. Additional heat is recommended for the nose compartment and better distribution in the pilot's compartment to eliminate the blast effect on the feet. A modification is already in processing, I believe, to provide heated air for the tail section. It is recommended investigation for nose section leakage be included in the airplane spot check schedule because of possible subsequent development as a result of changes and variations in production.

* * * *

1. The ensuing article, describing a proposed Heated Air System for the model B-24 airplane, is based on (1) observations of cold weather tests during the winter of 1944-1945 at Ladd Field, (2) discussions of operational and maintenance problems with personnel assigned by both the Army Air Forces and the aircraft manufacturers to participate in the Cold Weather Test Program and (3) a review of several previous reports on cold weather test, data in Technical Orders pertaining to Arctic operation data in Engineering Division Technical Note Serial No. TN-TSESE-1 covering design for extreme climatic conditions and data in manufacturer's publications covering cold weather operation. The article is prepared in an effort to consolidate problems incident to cold weather tactical operation and provide a solution adaptable to incorporation in short range production; the specialist from the Power Plant Laboratory has suggested this article may be of interest to personnel at Wright Field.

Heat exchangers are incorporated in the tail pipes on the four engines of production model B-24 airplanes so energy in the exhaust gas can be utilized to warm air for wing and empennage deicing, windshield, astrodome and turret defrosting and cabin heating. Scoops located in the oil cooler ram air ducts supply cold air to the exchanger intake ports. Insulated ducts convey a portion of the heated air from the inboard exchangers to a common junction in the fuselage, longitudinal ducts from the junction distribute the air fore and aft to the cabin and tail. The balance of the air flowing through the inboard heat exchangers is conveyed to the center section leading edge for deicing. The outboard exchangers supply heated air for outer panel deicing only. Thermostatically controlled dump valves at the exchanger heated air exhaust port divert the hot air to the atmosphere in the event the temperature becomes excessive. A carbon monoxide detector is incorporated in the airplane as a precautionary measure to warn the pilot in the event of heat exchanger leakage.

A redesign of the foregoing heated air system and some equipment is proposed to provide for the following functions:

1. Immediate Ground Starting.
2. Propeller Deicing.
3. Propeller Feathering and unfeathering at Low Temperature.
4. Engine Starting on Flight.
5. Attenuation of Engine Roughness During Warm-up.
6. Carburetor Deicing.
7. Improvement in Fuel Economy by Vaporization.
8. Short warm-up Period Prior to Take-off.
9. Wing and Empennage Deicing.
10. Cabin Heating.
11. Defrosting.
12. Altitude Operation of Auxiliary Power Unit.

IMMEDIATE GROUND STARTING

An auxiliary fuel burning heater in conjunction with a blower and heat exchanger on the auxiliary power unit would be designed to supply warm air to the heated air ducts in the proposed system. Part of this air would flow through a manifold, common to the four engine heat exchangers, and into the accessory compartment of each engine; a compartment temperature in excess of —20°F should be maintained when the free air temperature is —65°F. Critical locations such as oil and fuel drains would be protected with sumps or electrical elements to prevent ice from blocking the lines. The remainder of the warm air would be routed to the cabin to keep the battery and instruments at temperatures equivalent to those in the accessory compartment and provide a warmer atmosphere for Maintenance personnel. Warm air would be diverted to the carburetor intake of each engine during starting to insure adequate vaporization of fuel. Following procedure specified in existing Technical Orders should result in easy starting.

When the airplane is inoperative, the auxiliary power unit and heater would be in continous operation; design for operation at partial throttle would be expected to decrease maintenance. Continuous operation of the auxiliary power unit insures energy to supply localized electrical heating equipment. It is estimated one fire guard could attend to five airplanes.

PROPELLER DEICING, PROPELLER FEATHERING AND UNFEATHERING AT LOW TEMPERATURE AND ENGINE STARTING IN FLIGHT

Heated air deicing is reported to be under development at the Ice Research Base. Discussion reveals a feature in the design is a fairing over the propeller dome to provide for distribution of heated air to the blades; the heated air is also expected to warm the oil in the dome sufficiently so the propeller can be feathered and unfeathered at extreme low temperatures. The duct design provided for immediate ground starting should maintain sufficient temperature in the accessory compartment, while the engine is stopped, to insure starting when the propeller is unfeathered; dilution would be required prior to feathering to avoid congealing in the feathering line.

The heated air supply to provide for the foregoing operations would be obtained from the heat exchanger manifold in the proposed system.

ATTENTUATION OF ENGINE ROUGHNESS DURING WARM-UP CARBURETOR DEICING AND IMPROVEMENT IN FUEL ECONOMY

A mixing valve, thermostatically controlled by the intake manifold fuel-air mixture temperature, would be incorporated in the ducts leading from the common manifold to the individual turbo intake air ports; the cold air supply to the mixing valves would be obtained from the existing carburetor inlet air ducts. An override, controlled from the pilot's compartment, would be incorporated in the mixing valve as a safety precaution so the heated air supply could be blocked in an emergency.

The optimum fuel-air mixture temperature would be determined by tests; results of previous tests indicate it bears no uniform relation to the carburetor inlet air temperatures under various combinations of power and throttle settings. Based on current available information, it is expected to correspond roughly with a carburetor inlet air temperature of 70°F. Too low a temperature is detrimental to distribution of fuel in the fuel-air mixture resulting in exhaust smoking and loss of power; too high a temperature is detrimental to volumetric efficiency and depresses detonation limits. The thermostat governing the mixing valve would be adjusted to maintain the optimum fuel-air mixture temperature which would insure deicing of the carburetor.

The foregoing arrangement would attenuate roughness during warm-up, eliminate the problem of carburetor deicing and assist in obtaining maximum fuel economy under cruising operation. It would also eliminate the necessity for readjusting the carburetor idle setting when major changes occur in the free air temperature.

SHORT WARM-UP PERIOD PRIOR TO TAKE-OFF

The soaking period and temperature differential are the dominant factors which influence congealing of undiluted engine oil in the reservoir. A temperature in excess of —20°F in the accessory section is believed adequate to avoid congealing in the reservoir during soaking encountered in usual Arctic operation. Incorporation of decongealing fins on the hopper should insure feed of the diluted oil by the time it was required in the system. Dilution requirements for this temperature are not drastic so excessive breather spewing would not be anticipated. Test data indicates this temperature is adequate to avoid vacuum pump failures.

A cabin temperature in excess of —20°F combined with available electrical energy for localized heating would attenuate or eliminate the warm-up period for erection equipment and insure immediate operation of inverters. Continuous heat in the pads on the servo motors would eliminate control stiffness that might originate in these units.

A review of the foregoing considerations indicates the warm-up period prior to take-off at low temperatures can be materially reduced by adoption of the integral heating system.

WING AND EMPENNAGE DEICING, CABIN HEATING AND DEFROSTING

The application of heated air to wing and empennage deicing, cabin heating and defrosting is a recognized solution of these problems; further discussion is considered unnecessary.

ALTITUDE OPERATION OF AUXILIARY POWER UNIT

The blower incorporated on the auxiliary power unit would be designed to supply air under sufficient pressure for operation at altitude; this provision would ensure availability of an additional source of electrical energy and heat in emergency.

Discussion with the representative of the manufacturer of the heat exchangers incorporated on production model B-24 airplanes indicates a low percentage of heat available in the exhaust gases is utilized and heat exshangers of larger capacity can be procured. Inquiry reveals no unsatisfactory reports pertaining to the heat exchanger on the model B-24 airplane have been noted in spite of their use on airplanes in service for nearly a year. The results of cold weather tests this season indicate the carbon monoxide detector is easily checked by holding a lighted cigarette at the mouth of the pick-up behind the pilot; it is considered reliable by operating personnel.

The integral heating system is applicable to airplanes of other manufacture as well as to the Model B-24 airplane. It is hoped the foregoing article will stimulate further development of the heated air system and possible result in an experimental installation for better evaluation of its merits.

Curtiss-Wright Corporation

A. H. Nisita

1. BTRY. CART RECEPTACLE LOCATION

T. E. Battery cart receptacle in location of prop blast.

a. On glare ice, collisions with horizontal stabilizer have been narrowly avoided.

b. Very inconvenient for personnel in prop blast, especially at sub-zero temperatures.

Rec. & Conc.

a. That relocating the receptacle forward on the center line of the fueslage alleviates the aforementioned conditions and places the subject item in the most advantageous spot on the subject and other conventional twin and four engine airplanes.

b. That the ATSC should increase the car battery take off line by three feet, so that on convential gear aircraft (C-47, C-46) it would not be necessary to enter the propeller rotation area.

c. That the change be considered and acted upon by the contractor in the light of the above mentioned reasons.

2. MODIFIED JANITROL IGNITION PLUGS (56A97)

The subject plugs have been recently installed, one in each of the three subject aircraft operating at this activity, along side of the 438-MA—MB & MC series. Crew chiefs have been instructed to replace failures (if and when they occur) with the same type, so that comparative time may be adequately substantiated by a record of test on at least two units.

The Janitrol plug is the best design the writer has seen. In view of past experience, however, it remains for service life to tell an accurate story.

Rec. & Conc. It is recommended that the contractor design a plug along similar lines, using the same diameter and material in the electrodes; but protect and clean the porcelain by adding vent holes around the outside case and moving the porcelain down approximately one inch.

3. HEATER IGNITION PLUGS

T. E. a. A 438MA and a —16 standard production plugs were removed at 35 hours for a comparative check at this period. The MA center electrode had already begun to deteriorate.

b. A set of —16 plugs with 125 hours were still firing when removed from 24720. Note location of porcelain failure.

A. T. Replaced with one MB and one 56A97 plugs.

Rec. & Conc. a. That the present production plug porcelain design is unsatisfactory and should be eliminated in favor of a small stub type center electrode porcelain protected by a vented steel shield as previously recommended in this and other reports, closely modeled after the Champion D-8, which should be in the contractor's possession by this time.

4. CLEAR VIEW PANEL

Since the contractor is contemplating going to a flat glass windshield in the near future, photographs of the C-54 installation is submitted for engineering study. Note simple locking mechanism and method of heat application.

5. PILOT'S SIDE WINDOW

T. E. Innumerable complaints about the ineffectiveness of the subject airplane's pilot's side window in all types of weather have prompted this writer to investigate two of the best designs on the field. The B-29 subject unit was commented on my Report No. 3. For the contractor's evaluation, photographs of the C-54B installation are submitted.

Rec. & Conc. a. The present design is totally unsatisfactory for its intended purpose.

b. That the contractor consider the advantages of the above mentioned designs and incorporate similar features in a new or modified design of the subject aircraft's installation.

6. WINDSHIELD DEICING AND ANTI-ICING

In view of a projected flat glass windshield for future subject aircraft and in view of the fact that flat glass shields have bad anti-icing and deicing characteristics, photographs of the Douglas 3 way method of anti-icing and deicing on the C-54 are herewith submitted. Note the hot air blast aft in conjunction with a double pane, the wiper in the center and the alcohol nozzles at the apex of the windshield "V". Each unit is very efficient in itself and in severe icing do a very effective job of coordinated anti-icing or deicing.

7. HEATED CABIN AIR DISTRIBUTION

T. E. a. Stratification of ventilating air throughout the main cabin aft of the navigator compartment is distinctly noticeable in readings taken to date and last winter (1943-1944).

b. Stagnation of cold air masses from the forward side of the main cargo door, Sta. 501. to Sta. 704, is also evident and was reported last winter.

c. The above conditions are attributed to positive pressure of cold air masses radiating through the floor of the J compt. bulkhead 704, and through the ventilating louvres on the riser of the step into the J compt. This cold air is sucked out through the door openings that were heretofore mentioned.

A. T. Relative data will be submitted to the contractor in the very near future.

Rec. & Conc. a. In view of the subject aircrafts use as a troop and litter carrier, it is advised that the contractor improve the ventilating characteristics of the subject airplane.

b. Since it is understood that the contractor is considering thermostatic heater control, complete insulation of the main cabin is mandatory, as is a redesign of the ventilating system. INSULATION is not the ultimate answer. Thermostatic control will be very ineffective without a definite improvement in distribution.

c. Photographs 17 ' 18 show the selective heater outlets (spread and center) and the recessed floor return vents used on the C-54B. Note in Appendix 5, page 1. *THE ELIMINATION OF ALL BENDS* in the transition and flow ducts by placing the heater overhead in the main cabin (bunk compt.) and employing a single straight run. Appendix 5 also may be referred to for additional information on thermostatic control as successfully employed in the C-54B airplane.

8. PARKER FUEL SELECTOR VALVE

T. E. a. External leaks around the shaft have been noted below —30°F.

b. Internal leaks on three sides have been noticeable at any temperature for some time.

A. T. a. Original valve removed and a new winterized Parker valve, P. W. C56-4177 was installed. This also leaked externally between —30 and —50°F.

b. Th e original valve was returned to the Power Plant Lab. at Wright Field for investigation.

Rec. & Conc. a. That the subject units are entirely unsatisfactory for their intended purpose, and do not justify yellow dot approval.

b. That the old Adel selector valve gave no similar trouble for some time before they were removed in favor of the Packer, nor WERE THEY (ADEL) AS TROUBLESOME IN QUANTITIVE PROPORTIONS FROM THEIR INCEPTION ON SUBJECT AIRPLANES.

c. That the contractor consider the use of the Adel valve once again since it is recognized that the Packer unit is extremely critical.

d. That the new Packer units above 656-301 series will replace the present valves as soon as they arrive at this activity.

Douglas Aircraft Co., Inc.

J. F. Hill, A. Zimmerman, A. A. Hershfield.

C-54 Airplane

The heater installation, both nose and main cabin, gave excellent results, operating satisfactorily at all conditions of temperatures, altitude and speed within the operational range of the airplane on which they were installed. Test data makes possible calculations which prove the heater capacity to be in excess of the heat requirements of the airplane with insulating blanket installed.

The method of control by cycling the heaters gave excellent results in cabin temperature control.

Temperature distribution was very good within the operating range of the airplane under all conditions of flight and loading configuration. The placement of cargo in relation to air outlets and inlets had a marked effect on the temperature control. The litter installation proved exceptionally good for temperature distribution.

Ventilation rates were satisfactory, averaging 19 CFM/person at normal cruising speed.

The pilot's and co-pilot's cold air inlets are unsatisfactory, as is the side window defrosting system due to high pressure drop in the delivery ducts; also, valves in the duct system intended to shut off do not do so.

The following recommendations are made:

1. That all C-54's, A's and B's be brought to this general configuration to insure the best performance of the heating and ventilating system.
2. That the side window defrosting system be revised to obtain adequate flow.
3. That the shut-off valves be revised to incorporate positive shut-off.
4. That the foreward cabinstat be re-located from behind the bunk curtains.
5. That the nose heater exhaust be extended approximately one inch in length.
6. That the existing 5 gallon nozzles be replaced by 4½ gallon fuel spray nozzles.
7. That the control amplifier relay be changed to one of a larger capacity.
8. That the cold air inlets be revised for satisfactory operation.
9. That the forward toilet vent be revised to prevent odors from entering the crew's compartment.
10. That a school be inaugurated to instruct crew chiefs and operators in the operation of the Heat and Vent System.
11. That further study be devoted toward humidifying cabin planes.

INTRODUCTION

Service reports have indicated considerable dissatisfaction with the heating and ventilating system as installed in previous C-54 series airplanes in regard to temperature control, temperature distribution and reliability. The "E" system was designed to embody satisfactory solutions to all of these problems.

A series of tests was therefore run to prove the satisfactory operation of the heating and ventilating system, under moderate and extreme temperature conditions, as installed in the C-54E airplane, and with any additional improvements deemed necessary to better performance.

A C-54B airplane, Army Air Forces No.43-17157, was modified at the Santa Monica plant of the Douglas Aircraft Company, Inc. to incorporate the latest design features in the heating and ventilating system concurrent with present knowledge and proposed service changes

The following items were installed, changed or noted:

1. New ignition system embodying special spark plug and high tension spark ignition. This insures instantaneous ignition at all altitudes and temperatures.

2. Air bleed around spray nozzle. This moves the combustion area forward in the heater keeping the plug and spray nozzle clear of carbon.

3. Fuel flow regulator and new fuel system in place of the air flow regulator. This controls the air fuel ratio without introducing pressure drop in the combustion air stream, allowing high altitude operation.

4. New ductstat compensator in the control system circuit for the main heaters. This reduces the temperature swing in the ventilating air stream to the cabin to a negligible quantity.

5. Variable Fenwall control for the nose heater. This permits the pilot to control the heat output of the nose heater and thus control the temperature of the crew's compartment.

6. Canvas bulkhead below the floor at fuselage Station 858. This prevents ventilating air loss into the tail cone, and controls temperature distribution in the cabin. (Refer to report No. SM10936).

7. Jet—or—spread-type Anemostats. These Anemostats give the cabin attendant control over the temperature distribution in the cabin.

8. Cabin air exhaust grilles. The Great Falls modification center installed a cabin insulating blanket which covered the intended air outlets. Therefore, exhaust grilles were necessary to obtain proper ventilation and temperature distribution.

9. Felt pad under cabinstat. This aids in elimination of error in the control system by lessening conduction losses from the cabinstat to the outside skin.

10. Army modification for windshield deicing and cabin insulation.

11. Valve handle on valve aft of cabin heaters. This allows operator control of air flow and is for use in case cargo only is being hauled in the cabin.

Following these modifications at the factory, the airplane was flown to Minneapolis, Minnesota to the Ice Research Base, and the instrumentation for the test was installed.

Tests were then conducted while the ship was flown to Ladd Field, Fairbanks, Alaska, where the test program was completed.

1. All configurations of seating arrangements, litter installations and cargo loads were investigated for temperature distribution in the occupied areas.

2. Operating characteristics of the heaters were obtained at various flight altitudes and speeds within the operating limits of the airplane on which the system was installed.

3. Ventilating system characteristics were obtained under various flight altitudes, speeds and attitudes.

4. Functional characteristics of the Army modification windshield deicing were observed and operational details of the side window defrosting system were checked.

5. Data were obtained to prove the satisfactory operation of the heater cycling control system as applied for temperature control in the occupied areas.

The airplane was flown in the most extreme temperature conditions obtainable, and data taken which would permit calculations to prove that the system as installed was capable of satisfying the most stringent conditions ever likely to be encountered.

CONCLUSIONS

1. Heaters—

Satisfactory operation of the heaters in this installation can be expected under any condition of speed, temperature or altitude within the operational range of the airplane on which they are installed.

If the installation is to be used in other C-54 series airplanes with higher operational ceilings, consideration should be given to the installation of 4½ gallon spray nozzles in place of the 5 gallon nozzles now in the main heaters.

Ample heat capacity is available from the installation to maintain comfortable temperatures in the cabin and crew's quarters under the most extreme conditions of speed, temperature and altitude likely to be encountered with the airplane. A 4½ gallon nozzle in the main heaters will supply ample heat to meet requirements.

2. Control—

a. The variable Fenwall control on the nose heater functions satisfactorily. However, a lower temperature setting control would improve the operational characteristics of the installations.

b. Cyclic control as applied to the main cabin heaters on the test installation gives very good results in cabin temperature control. The success of the system is probably the result of the combination of the following items:

(1) New ignition system insuring instantaneous ignition.

(2) New ductstat reducing the time lag in the control circuit.

(3) Air bleed around the fuel nozzle insuring continued instantaneous ignition by prevention of carbon deposits on the electrodes of the spark plug.

(4) Fuel flow regulation insuring proper air fuel ratios at higher altitudes.

Although no failures occurred in the control system, inspection of the relay contacts in the amplifier, after the test, indicated a larger capacity relay might be desirable.

Fairchild Camera and Instrument Corporation

W.C. Edwards

On 13 January I arrived at Ladd Field, Fairbanks, Alaska, to observe the results of cold weather tests being conducted by the Army Air Forces on aircraft camera equipment manufactured by the Fairchild Camera and Inst. Corp.

Immediately upon my arrival, I reported to the Commanding Officer of the Cold Weather Testing Detachment, and then visited the photographic huts which served as headquarters for the camera test. Here I met Captain Lewis, Lt. Schwartz, W/O Goodnight of CWTD, Proving Ground Command, and W/O Balcomb from Wright Field, who were actively engaged in testing procedures.

My stay at Ladd Field was to be limited to two weeks. During this period I intended to look over the aircraft camera and correct any possible mechanical troubles, discuss the operation of the equipment during the period prior to my arrival, offer suggestions to remedy any current failures during operations, and generally to observe the behavior of the cameras while they were used in extreme sub-zero weather.

EQUIPMENT BEING TESTED

The Fairchild cameras being tested included the K-22-6″, 12″, 24″, and 40″ models; the K-17B-6″ and 12″ models; K-18A; K-19B; and K-20 cameras; A-5A magazines; and the B-3B intervalometers.

PREVIOUS PERFORMANCE OF EQUIPMENT

In discussing the weather prior to my arrival with the Cold Weather Testing Detachment, I was told that to date the average temperature has been approximately 10° below zero. However, at one time for a few days the temperature was 54° below. Flights have been scheduled to different parts of Alaska where the temperatures were well below —50°. Today's flight at 30,000 feet was 64° below.

In discussing the equipment prior to my arrival with Captain Lewis and W/O Balcomb, they said comparatively few complaints have been registered against the Fairchild camera. The majority of complaints were due to their being disassembled and reassembled incorrectly after leaving the Fairchild factory. The disassembly had been done by the Army Depot to relubricate and winterize the cameras. The A-5A magazine had to be disassembled by the Cold Weather Testing Detachment to clean the grease from the metering clutch spring before the magazine could be used. The magazines brought in from stock that I checked were found to have the metering clutch spring packed with grease.

INFORMATION RESULTING FROM OBSERVATIONS

1. Power cable from A-5A magazine to camera body should be three inches longer.

2. Photocell cable K-19B. In extreme low temperatures the cable will freeze making it next to impossible to handle, also outside rubber cover will crack.

3. When cameras are winterized, all grease should be removed from the power receptacle and cable plug.

4. Focal plane curtain on K-22 camera should be made from more pliable material. The material now being used tends to stiffen in sub-zero weather and retards the action of the curtain.

5. There seems to be a question as to which of three greases is the beter; ANG-3a, TG-223, or TG-455.

a. ANG-3a has proven satisfactory in sub-zero weather.

b. TG-223. K-22, 24″, No. 42-58490, was greased by Wright Field, with TG-223 and sent to Panama last summer for the test, then sent direct to the CWTD at Ladd Field without winterization or changing the grease. To date the camera has operated satisfactorily in sub-zero temperatures.

c. TG-455 is being tested; however, not much seems to be definitely known about it as yet.

General Electric Co.

J. M. Robertson

P-59 AIRPLANE

I checked the oil in both units before removal from the plane and found that both starting fuel pumps were leaking kerosene through the seals. This brings the starting fuel pump failures to a total of nine. Removed Unit numbers are: L.B. 734119; R.H. 734136.

Saturday, February 10, the plane was removed from the hangar with the two new units installed. A trial run was made to check for leaks and any other possible malfunction. This trial run proved very satisfactory, with one small fuel leak found in the L. H. unit. After ground run up and check, Captain Markey made a one hour flight and was satisfied with the operation of both units. No report of fumes in the cockpit was reported after this flight.

Sunday, February 11, an attempted start was made on the units. Due to burned out booster coils this start failed. Proposed flight for Sunday was cancelled with prospects of cold weather for tests on Monday, February 12, 1945, with estimated outside air temperatures forecast for below —20°.

Monday, February 12, 1945, new booster coils were installed and cold starts were made on both units. The outside air temperature was —35°. The P-59 airplane was left outside on the line all weekend through Monday for these cold starts. There were a number of planes on the line, but the P-59 airplane was the only plane to start without heat application to the units or any part of the system at this —35° start.

During these starts, we were using ANO6 oil as a lubricant. High oil pressures were encountered on both units. These high pressures exceeded the range of the gauge, which is a 25 pound gauge. Oil flow checks were made through petcocks installed in the left hand unit oil system. Oil flow was considerably slower in comparison to normal conditions or even a —5° temperature.

The bearing temperatures remained normal during these starts and runs.

We were unable to build up fuel pressure on the L. H. unit. The highest pressure reached was between 70 and 95 pounds. Due to the lack of fuel pressure, our R.P.M. was limited to 5000 R.P.M. A new main fuel pump was installed on the left hand unit. This new pump solved our problem, and we were able to get the necessary fuel pressure.

Since there was no malfunction with the right hand unit, an hour's flight was made. During this flight the pilot took thermocouple readings and checked landing gear, etc. Upon completion of this flight, the oil was drained from the right hand unit and WS804 oil was used to replace the AN06A that was removed.

Tuesday, February 13, 1945, cold starts were attempted again with a —38° temperature. The left hand unit, which is our instrumented unit, has all lagging removed from the lines. At this —38° temperature we were unable to start the left hand unit again. We encountered the same trouble as in the previous day, namely low or insufficient fuel pressure. Pressure registered at this attempted start was 35 lbs.

I recommended that heat be applied to the gear casing accessories, dump and drip valve, fuel manifold ring, and also the throttle and barometric. I believe that there were ice formations in the fuel system, and that by applying heat to the system this theory could be checked. However, since changing main fuel pumps the previous day had solved our problem, those in charge decided to change another main fuel pump. Since this change overtook place outside, heat had to be applied to enable the crew to work under the extreme cold temperature.

I believe that this heat application solved our problem, because on disassembly of the first main fuel pump removed it appeared to be in good working condition with no visible defects. The number of the pump removed is Newpert No. 12 587-B, Serial No. PE242, R 62-19895".

Tuesday afternoon, the second main fuel pump was installed. Another start on this left hand unit, with a second new fuel pump installed, was not attempted until Wednesday, February 14, 1945.

Wednesday, February 14, 1945, a start on the left hand unit was attempted at a 34° outside air temperature. This was the first start attempted with the second new fuel pump on this left hand unit. We were able to get only 35 to 40 pounds fuel pressure, thus starting of this left hand unit failed again. I then recommended that heat be applied to the system, as suggested before. Heat was applied and attempts were made to centralize the heat on one accessory at a time. This failed because the equipment available was not adequate for such an application.

The barometric from the test stand was installed on the plane, and another start was attempted on the left hand unit. The left hand unit started this time. However, we had a temperature rise from —34° to —7°. I believe that this rise of temperature along with the heat application to the unit could have thawed out and broken up any ice formations in the system. To further prove this theory and eliminate the fact that changing of barometrics was the solution to our problem, I installed the barometric that was removed from the plane on to the unit on the test stand. The barometric, which was removed from the plane, worked fine on the test stand and no malfunctions were noticed.

On starting the left hand unit on the plane, we had 40 pounds fuel pressure for about 5 seconds. Under the same throttle setting as the 40 pounds were observed for five seconds, a sudden change of pressure was noted, at which time the fuel pressure surged to 75—to 100 pounds at which time the unit fired. This sudden change of pressure could have been ice formation in the system breaking loose.

In the starting of the left hand unit the starting motor turned out and the starting fuel pump failed. Failure of the starting motor was not mechanical failure and was no fault of the motor or unit. The starting motor burned out because a great deal of kerosene got into the motor from fuel pressure out put checks on the starting pump and main fuel pump. Failure was caused by the starting motor insulation catching fire and burning out.

Failure of the starting pump was caused by pickups on the pump casing under the gears. Results of these pickups and casing score were that the pump froze and could not be turned.

Two flights have been made since a new starting motor and starting pump were installed on the left hand unit. Both flights went off very well and no further troubles were encountered.

Arrangements are being made for the P-59 airplane to fly back to San Bernadino, California, instead of back to Dayton. No definite date has been made as to just when all the tests will be completed. However, I expect to leave here some time between the 3rd and 17th of March, at which time I will accompany the P-59 to its destination in the States as requested.

Monday, February 12, a calibration run was made on the test stand with the outside air temperature —35° This calibration run was made with the barometric disconnected, and a needle valve was used to replace it as mentioned in a previous report. ANO3L light oil was used as a lubricant for the first start. This oil was very unsatisfactory at this —35° temperature. A flow check showed us it poured like a heavy molasses, and the oil pressure registered on this first start was 175 pounds. Due to this extreme oil pressure, we did not attempt to run the unit over four or five minutes. During this time our bearing temperature remained normal.

ANO3L light oil was drained from the system and an approximate 2½ hour calibration run was made. Reading and data from this run are attached to the report.

Monday, at midnight, we drained the ANO3L light oil and replaced it with PPO-280.

Tuesday, February 13, 1945, a start was made. The outside air temperature was —38°F. The oil used on this start was PPO-280, and the oil pressure on this start was 90-100 pounds. We ran the unit for 4 minutes on this first start.

A second start, on which the indicated oil pressure registered 80 pounds at start, was made. Following this start, a 2 hr. 40 min. calibration run was made during the run. Oil pressure registered from 45 to 75 pounds, and the bearing temperature remained normal.

Wright Field Power Plant representatives requested an overspeed run during this calibration run. We reached top R. P. M. of approximately 16,925. In order to reach this R. P. M. we registered an indicated fuel pressure of 795 pounds. Thrust from this R. P. M. was 2522 pounds, which is the greatest amount of thrust recorded on any of the tests made to date.

On completion of this run we disconnected the governor from the system and connected the in and out line of the governor together. The reason for this was to decrease our fuel pressure on the overspeed runs, as shown on the attached data sheets. We also removed the PPO-280 oil and replaced it with ANO6A.

February 14, a calibration run was made with ANO6A oil, and the governor was disconnected as explained.

This was a one hour run, during which five sets of readings, including an overspeed run to 17000, were taken. There was a noted decrease in thrust as our outside air temperature had reached —14° when our last reading was tawen. However, at 17,000 R. P. M. we did get 2351 pounds thrust. With the governor disconnected from the system and the fuel in and fuel out lines connected together, our main fuel pressure dropped from 795 pounds to 625 pounds. The lube oil pressure remained normal throughout the run. 10 to 12 pounds lube oil pressure remained constant with this ANO6A oil in the system.

Lockheed Aircraft Corporation

Lee C. Chambers

1. I wish to call your attention to a recent Technical Order issued concerning "Oil Diluent Boil Off". In a previous report (C. W. T. Report No. 4), I remarked that the V-1710-11 & 113 engines would not scavenge diluted oil as well as the -89 and -91 engines. It is as a result of this reported condition that T. O. -75FF-44 was written. However, I believe the T. O. in question paints a blacker picture of the situation than actually exists. All scavenging test are conducted by pulling military power during take off and for a period of 5 minutes, then power is reduced to maximum continuous for 15 to 20 minutes. If excessive spewing occurs during this run, then the engine is considered unsatisfactory for dilution at the percentage tested. Since very few P-38's will ever be actually operated under the above described conditions the situation looks worse than it really is.

2. It is also posible to dilute to 30%, take off, and maintain military power for five minutes without spewing—provided the pilot uses manual oil temperature control, maintaining oil temperatures at 40°C. or below.

3. The P-38 Project Officer, Capt. Accord, contended that he could scavenge 30% diluted oil by using the method described above. To give a practical demonstration, a test was conducted on one of the C. W. T. P-38's. A summary of the test and results are presented herewith:

a. Dilution—

(1) The oil tank dip stick was checked before dilution began, and 9 gals. of oil was indicated. After 7 minutes dilution, the tank level was found to be 12½ gallons. This amounted to 3½ gallons gasoline added, or approximately 30% dilution.

b. Warm Up—

(1) The engines were started and the oil temperature regulator shutters were placed in the full closed position. The oil temperature read 30°C. and the oil pressure indicated 65#.

c. Take Off—Flight

(1) Just prior to take off the oil temperature regulator shutters were partially opened. Take off was made at 54" MP and 3000 RPM. This power was maintained for 5 minutes, all during the run careful check on oil shutter position was made to assure an oil temperature between 35° to 40°C. Oil pressure remained at approximately 70 P. S. I. A check was made at this power to see the relationship between oil pressure and temperature. The oil shutters were fully opened momentarily, and the temperature dropped to 20°C. and the pressure increased to 80 P. S. I. The shutters were immediately returned to a position which maintained a 35° to 40°C. oil temperature. After 5 minutes of military power the settings were reduced to 30"—2200 RPM. This power was maintained for 25 minutes, and the oil temperature was manually controlled at 50°—60°C. Oil pressure in excess of 60 P. S. I. was maintained at that temperature. The oil shutters were then placed in "Automatic" and an additional 30 minutes of flight was maintained at 2200—30". Oil temps. ranged from 77° to 81°C. and oil pressure read above 60 P. S. I. No oil spewing occurred during any part of the flight.

d. Conclusions—

(1) It is apparent that in an emergency, military power may be held for five minutes on a P-38L aircraft, which has been previously diluted to 30%, providing the engine oil temperature is manually controlled at 35°—40°C. It is also believed that max. continuous may be held for an additional 25 minutes in place of the 30"—2000 RPM, as described above, since oil spewing generally begins during or immediately after take-off (as soon as high oil temperatures are reached).

(2) It is believed that no harmful effects to the engine may result, since 30% diluted oil at 40°C. is still O. K. from the viscosity standpoint. The satisfactory oil pressures obtained would indicate this.

(3) Of course the above procedure could not be considered as a permanent fix for "oil spewing" problems, but until Allison corrects the trouble it could be used whenever it is necessary to pull military power for five minutes, and maximum continuous for fifteen minutes after take-off. If power is reduced immediately after take-off, no serious problem exists.

(4) After the above described test run, there was more oil at the secondary drive seal vents than at the engine breathers, and neither was abnormal.

* * * * * * * * *

1. The subject trip was made at the request of Brig. General Harry Johnson, and was for the purpose of acquainting the 11th Air Force personnel with the use of carburetor heat as a means for preventing spark plug fouling while operating in extreme long range power cruise. It was requested that Capt. R. K. Acord, C. W. T. P-38 Project Officer; Mr. Caesar Benassi, Bendix-Stromberg C. W. T. Representative; and myself make the trip and assist in lowering the existing P-38 Fuel Consumption rate.

2. Our first stop on this trip was at Anchorage, Alaska. There we visited the Alaska Air Depot. At this base all of the PD12-K8-5 carburetors on the P-38L's were being changed to K8-6 settings before delivery to the 11th Air Force. It was noted that several turbo-supercharger bearings had already been damaged by turbo torching as a result of operation with the excessively rich K8-5

carburetor setting. These turbos were being replaced or repaired.

3. Considerable trouble was also noted with regard to Paul Henry Switch and Airesearch Screw Jack Controls on the Carburetor Heat System. I instructed the mechanics concerning Screw Jack Load Switches, their operation, and the importance of having the shutter stops properly set to avoid burning out the electric screw jack motors as a result of exceeding the screw jack travel limits before sufficient load is applied to trip the load limit switch. The inter cooler nose shutter stops can be very satisfactorily adjusted to eliminate the above described condition. However, the Turbo Inlet Elbow Butterfly Screw Jack Actuator Linkage is very difficult to adjust to eliminate excessive screw jack travel limits, and all cases of Paul Henry switsch malfunctioning cannot be entirely eliminated without replacing switches or overhauling them as trouble is encountered. Enclosure (A) lists the number of malfunctions and failures encountered thus far with Airesearch screw jack, Paul Henry carburetor heat switches, and also windshield defroster motors and heaters. Failures of the latter named item have been inconsequential and may be considered nothing more than routine service difficulties. However, the abnormally high rate of failures and malfunctions of the screw jacks and carburetor heat switches, along with other operational difficulties, prompted me to take action as outlined further along in this report.

4. Upon reaching the 11th Air Force operational theater it was learned that the "three point carburetor heat control" (1) "OFF" (2) "INTERMEDIATE" (3) "FULL ON", was unsatisfactory for their operations. Both the "OFF" and "INTERMEDIATE" positions resulted in carburetor air temperatures which were too low for extended operation in long range, low power cruise; and the "FULL ON" position resulted in a carburetor air temperature which was too high. Thus, it was apparent that steps need be taken to give "*complete control*" of carburetor air temperature between the extreme of heat "OFF" to "FULL ON".

5. The Fighter Group Commanding Officer was well aware of the fact that long range fighter escort missions are utterly impossible when low carburetor air temperatures exist, as he was in charge of the simulated escort mission tests conducted last winter, wherein all of the P-38's used were forced to land 520 miles short of their objective as a result of spark plug fouling and poor engine efficiency. Consequently, he was very desirous in obtaining satisfactory operation of the carburetor heat system.

6. I suggested that it was possible to modify the carburetor heat control system and obtain the desired control of carburetor air temperature; that is, providing he could obtain Air Force approval on the necessary changes. I was requested to outline these changes for purposes of obtaining Air Force approval. The following outline of changes is presented along with comments as to the reason for suggesting the change. It will be noted that the final carburetor heat configuration is identical to John Pinaive's original design proposal before Wright Field insisted that we sacrifice complete carburetor air temperature control for the advantages to be gained by having both intercooler nose shutters and turbo inlet controls on one unit control system.

Carburetor Heat Control System Changes

a. Turbo INLET (Hot or Ram Air) Controls

1 Change:

(*a*) Remove Airesearch screw jack actuators.

(*b*) Substitute standard P-38L manual controls (Desert Air Filter Controls).

2. Reason for change:

(*a*) To eliminate the dangers attendant with Airasearch screw jack and Paul Henry switch malfunctioning.

(*b*) To allow independant operation of turbo inlet air valve, and intercooler nose shutter operation, which makes a complete control of carburetor air temperatures possible.

b. Intercooler Nose Shutter Controls

(1) Change:

(*a*) Rework travel limit stops to eliminate overtravel of screw jack actuator before load switches can operate.

(*b*) Remove Paul Henry switch and substitute two B-9A switches to control intercooler nose shutter positioning.

(2) Reason for change:

(*a*) To eliminate possibility of burning out screw jack motors.

(*b*) To eliminate danger of having an inoperative carburetor heat switch.

(*c*) To make complete control of carburetor air temperature possible.

c. Alternate proposal for intercooler nose shutter operation in the event kits are made available as shown in P-38/SB 290, which links the intercooler nose shutter to the exit flap and allows positioning of the nose shutter by varying the amount of closure on the exit flap toward the end of its travel.

7. The changes outlined above were submitted to Air Force and were approved for installations on the 11th Air Force P-38L's. Work has begun to accomplish both items A and B as outlined. These modifications must be completed before any long range fuel consumption tests can be accomplished. I would like very much to return to the Aleutions to assist in completing these modifications and be present during the fuel consumption tests, for I feel that I could assist still further in this problem; but, since my draft board will not extend my leave of absence beyond April 1st, I guess I will be returning very shortly.

8. Using as a guide the results of long range low power tests conducted at this station, and a report by the Allison Experimental Division titled "Effect of Cold Air on Engine Roughness", the following carburetor air temperatures were submitted as desirable for long range operations:

Engine R. P. M.	*Desired C. A. T. —°C.*
1600—2000	+20° to +30°
2000—2300	+10° to +20°
2300—3000	— to+10°

DO NOT EXCEED +40°C. A. T. AT ANY POWER

Should these carburetor air temperatures be maintained, it is this writer's firm belief that excessive spark plug fouling will not occur within the time limit dictated by fuel capacity and range.

9. One of the main factors contributing to the excessive fuel consumption experienced by the 11th Air Force on their P-38's was the pilot's limited knowledge of proper power selection, R. P. M. vs. M. P., and a tendency to operate at extremely high R. P. M. After

talking with the pilots, it was learned that the high R. P. M. was used in an attempt to prevent spark plug fouling. However, I believe they were using even higher R. P. M's. than necessary for that purpose. Nevertheless, improper power setting were an outgrowth of the necessity to eliminate plug fouling. Capt. Accord gave the pilots instructions on proper selection of economical power, using lof R. P. M.'s. and high manifold pressure, and at the same time warned them against exceeding the B. M. E. P. limits of the engine.

10. Mr. Benassi explained the dangers of leaky carburetor vapor floats as concerns the loss of gasoline through excessive vapor (gasoline) return to the reserve tank and its possible loss by flowing out the tank vents. He also suggested a check be made on these vapor returns and the altitude compensators before each long range mission.

11. The officers and enlisted men of the 11th Air Force were very cooperative, and I'm sure appreciated the assistance we were able to render.

12. While checking over the P-38L's fuel system the following points were discerned:

a. The PD12-K8-6 carburetors have a wide angle poppet valve and therefore do not have a #70 drill hole in the clover leaf.

b. The two check valves in the fuel system ((1) outer wing tank to strainer, (2) selector valve to strainer) will not allow bleed off of fuel pressure in the carburetor.

c. Due to the check valves and the absence of a drill hole in the clover leaf, high pressures are built up in the carburetor after a flight and resulting accumulative heat from the engine warms up the carburetor.

This condition may cause trouble in very warm climates, in that the high pressures may stick even the wide poppet valves. A drill hole in the clover leaf is unsatisfactory, especially with high boost pump pressures, in that a great deal of fuel may be dumped into the engine supercharger scroll and thus create a backfire hazard. Therefore, I recommend a combination check and relief valve be installed in the system which will by-pass the main system check valve and thus allow bleed off of carburetor fuel pressures while on the ground.

13. While in the Aleutians, some interesting effects were observed with regard to windshield deicer panel operation. Due to the high relative humidity in that area, the deicer panel made a wonderful rain chamber. Moisture in the air, passing through the intensifier tube and hence to the double paned windshield, would condense and collect between the two panes of glass. This would occur only on take-off, but the situation was extremely dangerous for visibility was greatly impaired. It was found necessary to take off with the right hand cockpit heater valve in the "FULL OFF" position to prevent fogged windshield. In flight, the windshield became clear again.

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Carburetor Heat Test Report

PURPOSE:

1. To determine whether sufficient carburetor air heat rise may be obtained with the P-38L carburetor heat configuration to satisfy requirements as outlined in the "Aircraft Designers Handbook".

2. To determine the effect of carburetor air temperature on engine performance in long range cruise.

3. To determine the effect of carburetor air temperature on fuel consumption in long range cruise.

4. To determine the effect of carburetor air temperature on engine warm up.

METHOD OF TEST:

1. *"Aircraft Designers Handbook" Requirements.*

a. Due to the lack of extremely cold weather this test was conducted with —18°F. outside air temperature in lieu of the —40°F. O. A. T. as required by the Design Handbook.

b. The aircraft was flown at 2,000 feet M. S. L. altitude, with 65% power (2300 RPM—35" M. P.), carburetor heat "on" and "off"; the carburetor air temperature was recorded for both conditions.

2. *Engine Performance in Long Range Cruise.*

a. The aircraft was flown at long range cruise power on four separate flights, each of four hours duration. Two flights were conducted with carburetor heat "on" and two with heat "off".

b. These flights were conducted at 1600 RPM and manifold pressure was adjusted to maintain 170 IAS to simulate a bomber escort mission

3. *Fuel Consumption.*

a. It was planned to conduct comparative fuel consumption tests with carburetor heat "On" and "Off", however, leaky fuel selector valves prevented accurate tests in this respect, so the idea was necessarily abandoned. However, sufficient evidence was collected to indicate appriciable saving in fuel may be made by proper control of carburetor air temperature. This evidence is pointed out in the conclusions of this report.

CONCLUSIONS:

The P-38L carburetor heat configuration will meet the requirements as out lined in the "Aircraft Designers Handbook". An outside air temperature of —40°F. was not possible for this test, however, a heat rise of 122°F. was recorded at 65% power (2300 RPM—35" M.P.), 2000' M.S.L. altitude, and with an outside air temperature of—18°F.; therefore it was concluded the carburetor heat system is capable of creating a 90°F. heat rise with an O.A.T. of —40°F.

2. Engine performance is greatly improved by the use of carburetor heat when operating in long range cruise power.

a. Spark plug life may be lengthened by as much as 70%.

b. Engine roughness due to low carburetor air temperature and attendant vaporization and distribution difficulties may be eliminated with the application of carburetor heat.

3. Indications that an improvement in specific fuel consumption may be expected with proper control of carburetor air temperatures was observed.

a. An increase in I.A.S. was affected only by increasing the carburetor air temperature, (RPM and manifold pressure remained constant). It is also logical to assume the mixture became leaner as the temperature increased since the air density was less at equal

RPM and manifold pressures. *In other words a greater air speed was obtained with identical RPM and MP, but with less fuel consumption.*

b. Another fuel saving, resulting from the use of carburetor heat, may be anticipated when flying long range escort missions, due to the fact that periodic high power engine run up for purposes of cleaning out spark plugs is not necessary when sufficient carburetor heat is applied.

c. For reasons as stated above, it is concluded that a minimum carburetor air temperature of plus 20°C. should be maintained when operating in long range cruise. The amount in excess of 20°C. should be kept to a minimum in order to avoid any loss in engine volumetric efficiency.

d. It is concluded the tactical advantages which may be made available through proper carburetor air temperature control should be more throughly investigated.

4. Cold starting and engine warm up are considerably improved with the use of carburetor heat.

a. The tactical advantage is considerable since a minimum of 50 per cent engine warm up time may be saved, and service life of the engine and accessories will be lengthened also.

b. By utilizing carburetor heat, low power ground operation may be performed for an extended period of time without danger of spark plug fouling. This allows lower taxi RPM and reduces the danger of taxi accidents on icy runways; for the same reason, brake life may be lengthened.

Northrop Aircraft, Inc.

C. W. Harris, Leo Collings.

Object

This report is written to summarize the data and results obtained from the operation of P-61B airplane AC 42-39402 by E.T.O.U. of Wright Field.

Procedure

All test data contained herein was obtained at the request of Northrop personnel and through the efforts of the pilot Project Officer, Capt. H. J. Andre. The discussion is segregated into sections dealing with the engineering design groups affected.

Conclusions

1. The temperatures prevailing during this year's cold weather operations were not low enough to provide for test data which would allow definite predictions as to operations at —65°F.

2. The intercooler shutter installation on this airplane is not entirely satisfactory in that it does not completely seal off the flow of air through the intercoolers.

3. Satisfactory operation of the engine breather lines can be obtained by lagging or insulating the full length of the breather line providing that the production routing of the line is changed to exit aft of an exhaust stack similiar to the installation used on the R.H. side of subject airplane.

4. Rerouting of the oil tank vent lines to avoid traps eliminated diffculties encountered last year on these installations.

5. Incorporation of insulated engine breather lines and elimination of traps in the oil tank vent lines eliminated low temperature difficulties to the extent that it is no longer considered necessary to install intercooler shutters on the P-61A and P-61B airplanes.

6. The Simmonds-Corsey propeller control operated entirely satisfactory at temperatures as low as —54°F.

7. All drain cocks used on subject airplanes are entirely satisfactory for temperatures encountered during this winter's test.

8. Water tank immersion heaters are not of sufficient capacity to maintain water temperatures above 32°F.

9. The heated line and pump system for maintaining satisfactory operation of War Emergency power, under low temperature conditions, is entirely unsatisfactory.

10. The cabin heating system is entirely inadequate for O.A.T. below +5°F.

11. The defrosting and defogging system is unsatisfactory.

12. Operating condition resulting from the proximity of the cabin heater exhaust port to the ventilating air inlet make it impossible to use the heating system for ground operation due to the presence of exhaust gas in the ventiliating air.

13. Oil temperature maintained by the automatic flap control resulted in entirely satisfactory operating conditions.

14. It is concluded that the most practical way of maintaining adequate gun breach temperatures on this airplane would be through the use of electrical "spot" type heaters on the gun.

Packard Motor Company

C. R. Jones

1. OIL DILUTION TESTS

Enclosures — Oil Dilution Tests: Tests completed on aircraft P-51D, No. 44-14476; engine V-1650-7, No. 330964, equipped with new type of scavenger screen and 1-⅛" scavenge lines, failed to properly handle any premixed diluted oil above 11%. Further tests were continued with 17% and 22% premixed diluted oil, and, from the pilot's reports and observations, the engine showed an excessive amount of oil spewing.

Enclosures—Oil Dilution Tests with Thompson Centrifuge Separator: Tests completed on aircraft, P-51D, No. 44-14476; engine V-1650-7, No. 330964, equipped with an experimental test unit, type known as Thompson Centrifuge Separator, successfully scavenged the gasoline vapors of 15%, 20%, and 30% premixed diluted oils.

Recommendations: If higher premixed dilutions than 30% are contemplated, further tests with the Thompson Centrifuge Separator should be continued. Pilot's report and samples taken indicate that 30% is close to the maximum of premixed dilution that the present unit will properly scavenge as now installed.

Crankcase gases from the Thompson Centrifuge Separator were expelled below and aft of the experimental test unit. Would suggest that further tests be conducted to determine the most advantageous position to release these highly volatile gases, due to fire hazard; and to prevent the possibility of any gases or fumes entering the pilot's compartment.

a. Tests completed on aircraft P-51D, No. 44-14484; engine V-1650-7, No. 324373, failed to properly handle premixed diluted oil of 11% and 20.5%. Further tests were concluded, and from past records 10% was taken as the maximum premixed dilution the engines, as now equipped with N. A. A. type of breathers, will properly scavenge without too much loss of oil.

2. SYNTHETIC OIL AND COOLANT HOSES

a. Aircraft P-51D, No. 44-14476; engine V-1650-7, No. 33-964. Type of hoses installed: E 30, E 40 and E 80.

Installation has been made on the following oil and coolant lines:

3 pieces, 2″ E 30 Header expansion tank to coolant line (R. H.).

2 pieces, 2″ E 30 Header expansion tank to coolant line (L. H.).

1 piece, 2-½″ E 30 Coolant pump to radiator.

2 pieces, 1-½″ E 40 Oil pump to Y drain.

1 piece, 1-½″ R 80 Oil tank to oil pump.

The first 25 hours of operation, using the above hoses, gave no visible appearance of any cold flow, though noticeable was the continued loss of hose clamp torque value for the first 25 hours. Apparently it takes this period of time for the hose and hose clamps to become set.

Original hose clamp torque was tightened to 25 inch lbs. and torque values as low as 5 inch lbs. have failed to disclose any coolant or oil leaks. The coldest weather these test hoses have been subjected to, as of to date, is —46°F.

Left side hose connection between expansion tank and coolant line was flown for 25 hours with a 2-inch space between expansion tank metal outlet and the metal coolant line. No defects were noticeable upon examination, and the hose was reinstalled. Aircraft P-51D, No. 44-14484; engine V-1650-7, No. 324373, and aircraft P-51D, No. 44-14513; engine V-1650-7, No. 327381, have several test pieces of E 30 and E 80 hoses installed and tests as of today seem most promising.

3. COLD WEATHER STARTS

a. Starting of a V-1650-7 or -3 engine at temperatures of —10°F. or less gives considerable trouble, due to very little if any fuel vaporization and unequal manifold distribution. Results of this condition makes a very rough engine, due to spark plug fouling. After the engine has started running, this condition continues for 8 or 10 minutes, then several minutes of 1500 to 1800 R. P. M. is needed to burn sufficient residue from the spark plugs before the engine will run smoothly. Opening the spark plug gap setting to .022 has helped the spark plug fouling to a fair degree, with no noticeable difference between an .018 spark plug gap setting and a .022 setting, relative to making a cold start.

Flight tests made with this spark plug gap setting have operated satisfactorily at altitudes of 35,000 ft. Heat rise by carburetor warm air is not sufficient to assist much during the warm-up period. The application of warm air through filter air ducts, prior to starting and during the warm-up period, decreases spark plug fouling and gives a smoother operating engine during warm-up. However, 8 to 10 minutes are necessary before engine oil and coolant temperatures become high enough for full power operations.

Engines, during take-off at low temperatures, smoke and torch badly and continue to do so for some length of time.

Recommendations: When using 100 to 130 Octane rated fuel at low temperatures, operating in this Arctic area requires more carburetor heat to assist in vaporizing the fuel.

Flow bench one P. D-18C1A carburetor at the minimum fuel air ratio for test flight. This would assist toward drawing some definite conclusions as to the cause for so much smoke to be present in the exhaust.

4. COOLANT LEAKS

Aircraft P-51D, No. 44-14484; engine V-1650-7, No. 324318; Coolant pipes inlet, part No. 608758, on both A and B cylinder block, show coolant leaks at center and end connections from seal, part No. 608782.

New seals were installed, and shortly afterwards leaks developed at the same locations. Tape was placed over the tubing where the leaks occured and the aircraft is still flying.

a. A check made on two other engines, No. 327368 and No. 327381, revealed that the coolant pipes, Part No. 608758, were free and could be easily turned by hand. More noticeable at temperatures below —20°F.

Recommendations: Further tests to be conducted with present seal and coolant pipe O. D. tolerance.

Perfection Stove Co.

E. J. Althouse

A. Object of Trip

The object of this trip was to observe annual winter tests conducted by Cold Weather Testing Detachment, Army Air Forces Proving Ground Command at Ladd Field, Fairbanks, Alaska, with particular reference to performance of Superfex Engine Heaters supplied by Perfection Stove Company, including 26 of the latest Model 460. At the conclusion of the tests at Ladd Field, all Army Air Force bases between Nome and Edmonton were visited; at most of these bases the Motor Transportation Officer and personnel using Superfex Engine Heaters were interviewed and at many, heaters were lighted and inspected. Several hundred heaters have been installed at these points.

Returning home from Ladd Field, travel as far as Edmonton was with an Army convoy. Included in the convoy was an Fl Tractor (Federal) upon which we had installed a 12 volt Model 460 Superfex Engine Heater.

B. Test Set Up by Air Technical Service Command

The specific test in which we had been invited to participate was one involving the installation and actual use of 25, 24 volt Model 460 Superfex Engine Heaters on as many C-13 Power Plants. We also had opportunity to observe the performance of 31 Model 452 heaters being used on the same work for the second winter, two of which were converted to Model 454 by the addition of electric ignitor kits. In addition to the 12 volt Model 460 heater used on the Federal Truck shown in Figs. 1 and 2, a second 12 volt Model 460 heater was installed on a C12—50 K.W. generator.

Test procedure by Air Service Technical Command requested ". . . . . that in general, modified units (C13 Power Plants) be used in the normal manner on the flight line for starting and testing aircraft and that . . . . items . . . . be observed as to general operating characteristics with particular emphasis on the following:

a. Perfection Heater

(1) Flame extinction by wind or propeller wash.
(2) Fire hazard.
(3) Inspection and service periods.
(4) Ease of out-of-doors maintenance.
(5) Coolant temperature rise obtained.
(6) Other malfunctions and causes.
(7) Effect of fan load on battery.

Below are my observations on these items:

1. Lighted heaters were drawn through or left standing in propeller washes repeatedly but none was ever extinguished by them. None was ever seen extinguished by wind or even suspected of having been so extinguished. Heaters were occasionally found with lever and switch in operating position but this was not due to extinction by wind or propeller wash but to having run out of fuel.

2. No fires were caused by the Model 460 heaters but I did see two fires on C13 Power Plants caused by sparks in the engine control box igniting gasoline spilled during refueling of the supply tank, common to both the engine and the heater. One fire occurred on a Model 452 and was due, in my opinion to the shut-off cock having been left open, permitting gasoline to capillary over the burner and burner housing; this gasoline being ignited by flame blown from the bottom of the burner, probably by a down draft. The fire thus started, quickly consumed the combustible gasoline line and added two gallons of gasoline to the fire. Such a fire could not occur with the Model 460 because fire cannot be blown out of the housed-in burner, and forced draft makes a down draft into the heater practically impossible.

3. I observed no regular inspection and service periods. On February 28th I removed the burner from No. 79 which is the unit Captain Wood and I had used most extensively for testing and which saw service on the line before and after we worked with it. Our records show 469 hours of use and with several weeks use on the line the unit probably had burned in the neighborhood of 600 hours, or well over half the burning time to be expected during a severe winter. The half of the burner away from the fuel inlet was as clean as though used for only a day; the other half had a coat of carbon and lead varying in thickness up to 1/32″ with here and there a projection of 1/16″. On either side of the fuel inlet was a ridge about 1/8″ high. The igniter looked like new. The igniter wick had its original shape and height and looked as though it would capillary gasoline as well as a new one but had lost some of its mechanical strength. This inspection would indicate that the Model 460 need to be serviced only at the end of the season.

4. No out-of-doors maintenance was attempted but no repairs were required that could not have been accomplished out-of-doors.

5. Coolant temperature rises were more than adequate; we were obliged to operate the heater at under capacity to avoid boiling the coolant at around zero temperatures. We reduced the burning rate on 23 heaters by cuting away two-thirds of the width of the control wick and on the other two by cutting way one of the two layers of the control wick. Both systems worked satisfactorily but the one-layer wick is recommended for production. We found that tilting the heater might increase or decrease the heat output so it is recommended that heaters be kept reasonably level during operation.

6. Other malfunctions and causes are:

a. Three broken igniter wire terminals. The new connector now used at the igniter will correct this trouble.

b. Three shorts in as many fused connectors which melted down the wiring; these probably were due to loss of the insulating sleeve. This trouble has been corrected by locating the fuse in the switch box.

c. One float collapsed, due probably to cold shrinking the air in the float. This is an unusual occurence that could happen to any metal float.

d. One burned out igniter, due to a short caused by its not being properly reinstalled in the burner; one igniter lost, probably for the same reason. Later type igniters seat more readily and are less likely to be found out of position.

e. Clips holding control wicks in place broke off in changing wicks. This is not a normal service operation but has been corrected by bending clips with a radius instead of at right angles.

f. Clips holding igniter wicks catch igniter. Our Engineering Department is studying this matter and will make necessary changes.

g. Fire would go out at low fire setting. This has been corrected by changing the position of "low" on the guide.

h. The most common cause of heater failure was a dead battery. While such failures cannot be charged to the heater, it is recognized that it would be more useful if the frequency of dead batteries could be reduced. The same thing could be said about the C13 Power Plant itself which depends upon the same battery. Therefore, we recommend that the installation of some such instrument as the Hickok Electrical Hydrometer be considered for each C13 Power Plant This would enable a crew member to quickly and easily determine when to allow the unit to run to recharge its battery.

7. Tests showed that the effect of the fan load on the battery was negligible.

C. Other Tests, Suggestions and Recommendations

1. No provision for warming the battery had been made in designing the C13 winterization kit. We ran battery warming tests, first using exhaust gases from the heater (see Figure 4), and later coolant circuits. The exhaust gas method not only did a better job of warming the battery but also added desirable warmth to the oil and used less fuel. Then too, the exhaust gas method eliminates the need to watch shut-offs to the battery circuit in warm weather, since coolant from a running engine could overheat a battery. In designing any new kit, provision should be made for warming the battery.

2. A canvas cover is hard to handle, may catch fire or get lost. An all metal engine compartment with louver covers that can be slid to an open position or removed during the summer is preferable. The engine compartment floor should be made of metal rather than plywood.

3. A Zenith sediment trap was included in the fuel line of each 452 and each 460 installation; no stoppage of fuel line due to ice or any other cause was experienced. The yarn filter on the inlet fitting is preferred over the screen formerly used.

4. An all-metal fuel line, not too rigidly installed, should be used wherever possible because of the additional fire hazard experienced with combustible feed lines. It a flexible, non-metallic section of fuel line is necessary, it should be at a point remote from the heater.

5. The fuel tank should have a gauge and be installed outside the engine compartment and away from the heater. Great care should be exercised in connecting fuel tank to heater to avoid possible leaks.

6. Screw holes on combustion chamber used to secure top cover should be moved 45° from their original location so as to be more accessible after heater has been installed. This change will be made in design of heater.

7. Four or five feet of 12 gauge wire should be furnished with each heater to avoid the necessity of requisitioning small amounts at the time of installation, and the possibility of installing heater with wire having excessive resistance.

8. A more rigid switch support was suggested, and the Office of Chief of Ordnance, Detroit has suggested that motor vehicle controls be on the dash rather than on the heater. For the C13 Power Plant it is recommended that controls remain on the heater. A new control is being developed so that it may be mounted in either location at time of installation. This control will be more rigid than the one tested at Ladd Field.

9. Shake tests conducted by Office of Chief of Ordnance showed a tendency for operating lever to shake down. No such tendency was observed on C13 Power Plant Installations nor on the Fl Tractor on the twenty-one hundred mile trip from Ladd Field to Edmonton, much of it over exceedingly rough terrain.

10. Test of the two types of resistors used to reduce the ignitor voltage from 24 to 6 volts showed that one of the one-ohm resistors built into the igniters burned out. We did have trouble with the external one-ohm resistor used with the Model 454; coolant ran into the wiring and shorted it. It is therefore recommended that the original built design be retained on the 460.

11. Redesigning the Model 460 so that a single motion would start it and another would stop it was suggested. Our Engineering Department is working on this idea and is of the opinion such a modification of the Model 460 could be made available for next year; this modification would probably involve but little more than replacing the present igniter and control unit.

12. To install the 25 Model 460 heaters on the C13 Power Plants we made use of kits designed originally for the Model 452 heater. To do this we were obliged to: (a) modify the heater and the mounting bracket, (b) procure wire, clips, and terminals, (c) procure a few pipe fittings, (d) procure an additional length of ¼" copper tubing or else an entire new fuel line. We did the latter so as to eliminate the combustible fuel line.

The first two installations each required the time of one man for two days. Less than one day for one man was required for each of the remaining 23.

This experience leads us to believe that any other kit originally designed for the Model 452 or 454 could be quite readily used to install a Model 460.

13. We found that difficulty in cold starting the engine of C13 Power Plants began to be experienced at around 10° above zero. We recommend that heaters be lighted when temperatures drop to that point.

14. Inasmuch as sustained temperatures of less than —50°F are rarely experienced anywhere in North America or in any part of the world held by the enemy at any time during the present conflict, and inasmuch as no Ethylene Glycol and water mixture will remain liquid at temperatures lower than —56°F, it is recommended that cold room tests of cold starting equipment be held at temperatures not below —50°F. Tests such as those attempted at Wright Field by soaking at —65°F are entirely impractical.

15. Engine Heater kits should be designed so the operator can light and extinguish them without raising the hood and without kneeling on the ground, preferably performing all operations from the cab. Consideration should be given to making kits already in use comply with these requirements; this work probably could be done in the field with materials already at hand.

D. Conclusions

Models 452 and 454 Superfex Engine Heaters have done the job for which they were designed; engines start in cold weather when the heater has been lighted.

Model 460, with its forced draft and other convenience features is a better heater; it was received enthusiastically everywhere it was shown. Especially liked were electric igniter, elimination of the long flue, its ability to burn in any kind of wind condition, freedom from fire hazard, and the easy access to its various parts. With the addition of the refinements outlined above, suggested by various people at Ladd Field, it will be still more convenient and practical.

Pratt & Whitney Aircraft Div.

C. F. Blakely

1. Free air temperatures during the past week have ranged between 30°F and —10°F. Because of these relatively mild temperatures, cold weather tests and engine operational difficulties due to cold weather have been held to a minimum.

2. The E.T.O.U. group at Ladd Field have completed some of the preliminary propeller feathering tests at low free air temperatures using an auxiliary non-congealing oil and electric pump for feathering the propeller. One test conducted on a B-17 at 20,000 feet altitude and —30°F free air temperature resulted in an engine failure. The propeller was feathered for one-half hour, and when the pilot endeavored to restart the engine, apparently the governor did not function because the engine speed increased to 2,500 RPM. The engine will not be completely disassembled at this base, however, visual inspection indicates that due to the oil congealing, several of the lower cylinder valve rocker arm push rods were bent and the engine impeller was split. This test indicates the need of using adequate oil dilution at low free air temperatures prior to completely feathering the propeller should the pilot have any intention of unfeathering the propeller in flight. One of the reasons for the necessity of unfeathering the propellers is that a bomber with a feathered propeller is the one which enemy planes will readily attack.

3. Another A.T.C. C-47 has landed at this base with peculiar operational characteristics. This phenomenon occurs as follows:

a. Usually after a few hours of flying or after the engine is thoroughly warmed up.

b. Has been described as a beat, burb, shake, surge, cut-out, vibration, etc.

c. The intensity may be anywhere from very violent to mild.

d. The vibration is usually noticed only in the cockpit.

e. There have been a few reports of yawing due to an apparent loss of power.

f. The frequency of this phenomenon varies from a few seconds in the case of the violent surges, to a continual vibration in the case of the mild periods. The very severe surges, which have been reported, have lasted only 2 seconds or more.

g. The phenomenon may occur once in a flight, several times, continually, or not at all for several flights and then suddenly re-occur. It usually starts out mild, builds up and then ceases.

4. The vibrations occur at the following conditions:

a. Any combination of manifold pressure and engine speed.

b. Oil, cylinder head, and carburetor air temperatures remain constant.

c. Air speed, altitude and free air temperature do not appear to materially affect or determine the conditions which bring on the above malfunctioning.

d. Carburetor setting, A.R., A.L., or Full Rich does not appear to influence this condition. Carburetors have been changed with no improvement noted.

e. Airplane installations with the above characteristics have had their magnetos and all spark plugs changed with no improvement noted. Magneto checks in flight or on the ground do not indicate fouled spark plugs or malfunctioning magnetos.

5. The first impression of anyone hearing these reports is to say "cockpit trouble" with perhaps a little ignition and carburetor malfunctioning. However, the stories of the trouble are too numerous to entirely discredit and they all follow the same pattern.

a. All cases reported have been with engines using synthetic oil which had been put into the system after several hundred hours of operation with regular oil.

b. No trouble of this sort has been reported on installations which had comparatively little or no running time prior to the adding of the synthetic oil.

c. In installations which were reporting this trouble, and which were then switched back to the regular oil, the trouble apparently cleared up.

d. Since the synthetic oil is a detergent oil, large amounts of carbon, lead, and sludge are released when the synthetic oil is added to a system which has completed several hundred hours on regular oil.

e. Probably not all of the foreign material released will find its way out of the engine.

6. Whether using synthetic oil in an engine which already has had several hundred hours with regular oil will definitely cause the above malfunctioning can only be proven by extensive laboratory tests. However, one way to correct the condition at this time appears to be the adoption of the policy of only using synthetic oil in new installations.

7. The only theories which sound at all plausible as to why this malfunctioning may occur with synthetic oil are as follows:

a. The adverse effect of using synthetic oil on spark plugs which have been specified for operation with regular oil.

b. A large amount of foreign material is removed from the engine a short time after the synthetic oil is added. An excess amount of this material may collect in the torsional vibration damper chamber in the rear crankshaft counter-weight. The "puck" may be breaking loose some of the material when the violent vibration occurs which causes the engine to smooth out. The frequencies of this vibration are not the same as those of the torsional damper, however, since the DC-3 cockpit is critical at some engine frequencies, the beats felt in the cockpit may represent the composite resonance of several units in the installation.

8. We are anxiously waiting for a tear-down inspection report from one of the engines which have been pulled for the above reasons. In the meantime, we will check all rumors of the above operational characteristics which appear at this base.

9. Any information on the effect of lead, carbon, and sludge deposits on synthetic oil will be appreciated.

* * *

1. A trip was made to the Army Air Base at Edmonton, Canada, for the purpose of attending the Army Conference on Operation with Synthetic Oil. The conference was conducted for the purpose of reviewing engine operation difficulties attributed to the use of the PPO-265 synthetic engine oil. The following persons were present:

Lt. Col. Williams	Captain Zimmerman
Major Woodard	Lieutenant Parker
Major Britton	Warrant Officer Olsen
Major Anderson	Warrant Officer Everest
Major Gill	William Weitzen
Captain Miller	Irvin Perras
Roger Savery	

2. Synthetic oil is fundamentally a vastly different oil than regular grade oils, i.e.:

a. The slope of the synthetic oil viscosity index curve is less than the regular grade oil viscosity index curve.

(1) The viscosity of the two oils is matched at 3000°F.

(2) At 210°F the regular grade 1100 oil is a 100 second oil while the synthetic oil is an 88 second oil.

(3) At 0°F the spread of the viscosity index of these two oils is terrfic.

(4) At —20°F the regular grade engine oil becomes solid and the synthetic oil becomes a 35,000 to 50,000 second oil.

b. The general lubrication qualities of the synthetic oil are believed to be approximately 50% better than regular oils. The oil should be far superior to regular grade oils at extreme high temperatures.

c. Chemical composition of this oil is very complex and completely different from regular oil. The ignition temperature is higher than the ignition temperature of regular oil.

d. The effects of the T. E. L. and gasoline on the lubrication qualities and spark plug fouling of engines using a synthetic oil have not been thoroughly investigated.

(1) Reports of engine malfunctioning generally occur during the warm spells preceding the cold periods in which oil dilution has been used with synthetic oil.

(2) The effect of fuel dilution on synthetic oil is more severe than with regular oil.

(3) Western Airlines are using synthetic oil in winter operation, but are changing the oil every 100 hours with much better success than other operations which do not change oil.

(4) The lead compounds formed in the engine when synthetic oil is used are not the same composition as the sludge compounds formed with regular oil.

3. At this time it is next to impossible to select an oil which is best for all parts of the engine. From the oil manufacturer's viewpoint, the modern engine should be built to use two different oils. One oil would be specified for lubricating the high temperature surfaces, such as cylinder walls; and the other oil would be specified for lubricating the comparatively lower temperature but higher pressure surfaces, such as main bearings, etc., low

4. Other items of note are:

a. Tests indicate that the inter-facial tension of this synthetic oil is not as good as with the regular grade oils, i.e., the oil has a greater "creeping" characteristic.

b. The oil has a slightly different effect on rubber compounds than the regular grade oil. There was an approximate 5% shrinkage of the rubber seals tested by soaking them in the synthetic oil.

c. Engines with 600 or more hours of running time appear to be giving the most trouble. There have been five or more instances where engine malfunctioning has cleared up when the power plant installation was switched back to the regular grade oil.

d. In one installation the trouble was cleared up by switching to LS-87 spark plugs, which is a hotter spark plug than the LS-86. This is not conclusive, however, since a Carburetor Automatic Unit was changed at the same time, and several automatic units were inadvertently shipped from the factory with oxygen sealed in the bellows.

e. Engine oil consumption usually increases when the synthetic oil is used, especially when the oil has been used for some time.

5. Synthetic oil has the following advantages:

a. Low temperature advantage for cold weather starting, since it requires less dilution.

b. Keeps the engine cleaner.

c. Oil is less inflammable. Reports from the theaters of combat indicate that most power plant fires are caused by oil leaks rather than fuel leaks.

6. At this time synthetic oil has the following disadvantages:

a. Lead sludge from this oil forms a type of putty, which may become heavy enough to cause malfunctioning of the propeller and governor assembly.

b. Although not conclusive, off-schedule engine changes appear to increase where operators have switched to synthetic oil. In some cases maintenance has increased as much as fifty percent where synthetic oil is used.

c. The occasional so called "cut out", occurring only in engines using synthetic oil, seems to be the chief complaint against its use.

d. Since the oil has a greater tendency to "creep", there is reason to believe that this oil is leaking past the impeller shaft oil seals in greater quantities than the regular grade oil.

Socony-Vacuum Oil Co.

D. P. Heath

In the operation of conventional aircraft engines at low temperatures, rough engine performance is frequently encountered. This roughness is sometimes caused by uneven distribution of the fuel to the various cylinders resulting from incomplete vaporization of the fuel. At the present time sufficient data are not available to estimate accurately the temperatures at which difficulties will be encountered with a given fuel and engine installation. Flight tests are now being conducted in an attempt to obtain this information. However, the general principles of fuel vaporization are well known and can be used to make a qualitative analysis of the problem.

The basis most widely used in analyzing the effects of fuel volatility on engine operation is the equilibrium air distillation (EAD). An EAD is obtained by supplying a definite fuel-air mixture to an equilibrium-air-distillaton apparatus and determining the percentages of fuel evaporated for the various temperatures at which the apparatus is maintained. Since the determination of an EAD curve is a difficult task, a correlation for determining such a curve from the ASTM distillation curve has been developed by Bridgeman (Nat. Bur. Standards, Research Paper 694, 1934).

The effects of fuel volatility on engine operation can also be estimated from the vapor pressure relationships of the fuel. The following 2 "rules" are used in this interpretation:

1. The fuel vapor occupies all of the space available at the vapor pressure of the fuel. The available space in this case is governed mainly by the engine displacement and speed.

2. The fuel vapor pressure is a function only of the temperature and the percentage of the fuel evaporated. Inasmuch as the necessary vapor pressure data are not normally available, and a trial and error computation is involved if the vapor pressure relationships are used, the calculation of equilibrium fuel vaporization conditions in an induction system is usually based on an EAD. However, the two "rules" given above are quite useful in the interpretation of vaporization problems.

The EAD curves of an average aviation gasoline are given in Figure 1 for a supplied fuel-air ration of 0.065 and absolute pressures of 20 and 28 in. Hg. and for 0.095 F/A and 20 in. Hg. From these curves it *appears* that at a manifold pressure of 20 in. Hg. and a fuel-air ration of 0.065, rough engine operation would be encountered at mixture temperatures below 52°F. However, the EAD curves represent equilibrium vaporization, a condition that probably does not exist in an induction system. In addition some induction systems can probably distribute a limited amount of liquid equally among the cylinders making complete vaporization unnecessary for satisfactory engine operation.

If equilibrium vaporization is obtained, an EAD curve alone will not give a complete picture of the conditions existing in the intake manifold. Computations must be made using the EAD as a basis to show the effects of mixture ratio and manifold pressure. A set of these computations effects of mixture ratio and manifold pressure. A set of these computations for a 1710 cu. in. engine are given in the table at the bottom of the page.

The amount of unvaporized fuel at equilibrium is an indication of the amount of liquid fuel the manifold will have to distribute and therefore may serve as a criterion of how rich the richest cylinders will operate. Similarly the fuel vapor-air ratio will indicate conditions in the leanest cylinders.

Cases I and II in the above table show the effects of mixture ratio on equilibrium vaporization. Richer mixtures cause a smaller percent of the fuel to be vaporized but cause a larger amount of fuel vapor to be formed. This brings about an increase in both the amount of unvaporized fuel at equilibrium and the fuel vapor-air ratio at equilibrium. The effect on engine operation of richening the mixture when vaporization difficulties are encountered would be to decrease the danger of detonation in the lean cylinders and to increase the amount of smoking and torching from the rich cylinders.

The effect of manifold pressure on equilibrium vaporization is shown by Cases II and III in the above table. Higher manifold pressures cause a smaller percent of the fuel to be vaporized at equilibrium, but cause slightly more fuel vapor to be formed. This brings about an increase in the amount of unvaporized fuel at equilibrium and a decrease in the fuel vapor-air ratio at equilibrium. The effect on engine operation of increasing the manifold pressure when vaporization difficulties are encountered is to increase both the danger of detonation in the lean cylinders and the amount of smoking and torching of the rich cylinders.

Increasing the mixture temperature by either increas-

	Case I	Case II	Case III
Manifold Pressure, in. Hg.	20	20	28
Engine Speed, r.p.m.	1800	1800	1800
Mixture Temperature, °F.	40	40	40
Air Flow*, lbs./min.	47.3	47.3	66.1
Fuel-Air Ratio, supplied	0.095	0.065	0.065
Fuel Flow, lbs./min.	4.49	3.07	4.30
Fuel Evaporated at Equilibrium, %	66	87	69
Fuel Vapor Formed at Equilibrium, lbs./min.	2.96	2.67	2.97
Unvaporized Fuel at Equilibrium, lbs./min.	1.53	0.40	1.33
Fuel Vapor-Air Ratio at Equilibrium	0.063	0.056	0.045

*Estimated from the displacement, speed, and temperature.

ing the engine speed or applying carburetor heat will help to alleviate vaporization troubles. Care obviously should be used in the application of carburetor heat in view of the resultant effect on volumetric efficiency and the tendency to detonate. However, it has been shown that a moderate use of carburetor heat, when vaporization difficulties are encountered, will lower the specific fuel consumption.

Sperry Gyroscope Co.

R. J. Pearson

1. The E-1 electric gyro horizon, Serial No. AF-43-0760, and the C-1 electrical directional gyro, Serial No. AF-43-0020, installed in a C-47A, Serial No. 43-48088, except for trouble with the horizon caging mechanism, have operated satisfactorily at the minimum temperature encountered. The minimum temperature at which a test was made occurred on February 13, 1945. The plane had been out over night at ground temperatures of —40°F. to —45°F. The inverter was turned on at a cabin temperature of —42°F. and the instruments started and erected correctly. In flight, the temperature at the instruments was —37°F. To date, the instruments have had about 1230 hours of operation.

2. At —37°F., it became impossible to turn the caging knob on the gyro horizon. A stiffness in the caging mechanism can first be noticed at about +5 to +15°F.

3. On Dec. 26, 1944, the Holtzu Cabot inverter used as a power supply for these instruments burned out three amp. fuses. The inverter was removed and checked. No trouble was discovered. It was put back in the plane and has operated satisfactorily since that time. (This same thing has occurred on the C-54 installation. Report of Feb. 20, 1945.)

4. When the C-1 was installed at the Dayton Army Air Base on October 15, 1944, the instrument glass fogged up as soon as the instrument was started. The plane was still on the ground. This condition persisted throughout the first flight. A 3/16″ hole was then drilled in the bottom of the case to correct the trouble. The fogging has not been noted since. There has been no difficulty of this type reported on any of the electric flight instruments in use at Ladd Field. The majority of them have not been drilled as mentioned above.

5. Considerable objection has been raised to the direction in which the C-1 dial rotates. The following is quoted from Capt. B. Barrett's December Progress Report of the C-47.

"All pilots who have used the directional gyro object strenuously to its dial arrangement. On a standard air gyro, when the aircraft heading is being increased the numbers move from left to right relative to the lubber line. The electric gyro has a vertically mounted circular mounted card, which rotates in the opposite sense to the air driven gyro. No one can see any justification for this difference, which causes considerable confusion to pilots who are used to the standard gyro. It is recommended that this instrument be modified so the card is numbered and rotates in the standard manner."

6. There appears to be marked increase in the reliability of electric driven gyro instruments relative to air driven gyros at low temperatures (below —20°F.), and it is felt that this increased reliability would justify the use of electric instruments in regions where cockpit temperatures below —2°F. are anticipated.

Lausen Engine Co.

L. R. Pierce

Five units—Stewart-Warner heaters—three "D-1" types and two "904-A" were used.

UNIT NO. 1

The "904-A" job, No. 1, with no engine changes except the use of a heavy valve spring operated continously under conditions as close to actual conditions experienced on the "line" for 623 hours.

To the best of my knowledge an oil change was made only three times during that period—oil being added at various times to maintain level in sump.

Some valve trouble was experienced at 232 hours. Old valves were removed—new ones installed and ground in were doing good work at time tests were stopped at 623 hours.

During this period of 623 hours very little trouble was experienced with magneto and parts. It was necessary, however, to adjust and dress breaker points only once during this run.

Lubricating oil used was No. 20 detergent.

Fuel used was 73 octane gasoline for approximately 400 hours and 100/30 octane was used exclusively for balance of run. Official record was kept by Sgt. Wm. O. King, C.W.T. Detachment, Wright Field, Dayton, Ohio, which will show accurately all details.

During the period from February 5th to February 12th temperatures daily ranged between —15° and —20°F. This unit started very easily without application of heat. On February 12th temperature dropped to —41°F. On that morning very little heat, applied for a two minute period from a similar heater was all that was required to start the engine with two pulls on the rope.

UNIT NO. 2 –"904-A" (Rotating valve and modified cam).

The engine used on this unit was standard in every respect except that the valves were modified in such a way as to permit them to rotate while off the valve seats and the cam contour was changed to permit a more rapid closing action to occur. The valve seat angles were cut to 47°, the valve face was left at 45°. A gear type oil pump was installed in place of the plunger type pump. This engine was not equipped with the latest style magneto which has a felt wiper for lubricating the magneto cam.

TEST

This engine was started on a test run on February 9th and ran continuously for 150 hours at which time it was necessary to readjust the points due to excessive wear of the breaker arm fiber caused by lack of sufficient lubrication.
(Note: This trouble has been remedied in later design magnetos through the use of an oil impregnated felt wick for lubricating the cam.)

Points were re-checked and lubricated and lubri-plate ignition point trouble again occurred at about 150 hours due to lack of lubrication on the cam. At this time the ignition or heat exchanger was faulty due to plug failure. No replacements were at hand and the run was discontinued.

UNIT NO. 3

Gear oil pump was installed and priming cup was used on restriction elbow at point of priming plug.

This unit started readily with use of primer at —41°F. Heat from "904-A" applied to both engine and Roots blower for two minutes period.

It was impossible to keep the above unit running until overheat switch was disconnected. No further trouble in operation was encountered. The unit was used at various places where heat was required and performed satisfactorily until tests were discontinued. The entire running time was 232 hours—good performance in general.

UNIT NO. 4

Modifications on this unit consisted of gear oil pump, rotating valves, intake and exhaust ports reamed out to 7/8" and polished exhaust lead was 3/4" pipe.

Starting qualities, with primer, were excellent requiring not more than three pulls on rope. Heat application previous to start did not exceed two minutes, also from a unit already in operation. The overheat switch on this unit disconnected on account of being faulty.

Uninterrupted operation of above unit 176 hours.

HEAT EXCHANGER COMMENTS

Due to an air leak around the heat exchanger ignition plug warm air from the heater was forced onto the engine causing excessive frost accumulation to form on the governor mechanism thus preventing it from functioning properly. To remedy this trouble a baffle plate was placed on the engine to deflect the air flow away from the engine.

KICK STARTER—(Supplied by the Stewart-Warner Company). Too much lost action and continual failure of clutch spring.

Summary of tests run this past season at Ladd Field is a definite opinion that very satisfactory engine performance over a period to exceed 200 hours without maintenance is available under present conditions—much better performance is anticipated from developments now in process.

The Texas Company

C. V. Roark

A. General Statements

1. The 1944-45 Cold Weather Tests conducted by units of the Army Air Force revealed that satisfactory petroleum products are available for operation of aircraft at ground temperatures as low as —40 to —45°F. When compared with previous experience the infrequent difficulties encountered reflect a considerable improvement in low temperature performance of airplanes that had been winterized and were accorded currently accepted servicing procedures such as dilution of engine oil and application of external heat to facilitate cranking and fuel evaporation when engines were started.

2. Atmospheric temperatures were considerably above normal for the locality, during the period 1 December through 17 February there were only a few days colder than —30°F. The few failures and instances of borderline performance indicate some further investigations should be given consideration in the effort to develop aircraft, accessories, equipment, and supplies, that can be used throughout the temperature range of —65 to —160°F. with the minimum of special servicing. The purpose of this review is not to detract from the present state of perfection of the airplanes but to suggest additional studies that may lead to their improvement.

3. A major problem in low temperature performance of aircraft is the tendency for manually operated and power driven parts to freeze or to become sluggish in action and require excessive force. There is a very wide spread habit to attribute such failures or borderline performances to inadequate lubrication but experience gained in low temperature test work has revealed that other factors are more often responsible than the specialized lubricants now available. These factors are usually involved in improper design or insufficient clearances in manufacture of parts and assemblies, unnecessarily complicated mechanisms or systems, excessive stresses and misalignment of parts during assembly, and inadequate provision for lubrication. The problem of proper clearances at extreme temperatures is of particular importance. It gains in significance when materials with different coefficients of expansion are involved. Some instances where the above factors contributed to unsatisfactory performance will be discussed later.

4. The frequent modification of airplanes and occasional revision of lubricant specifications have in some instances lead to misapplication of the latter. Development of all purpose oils and greases will mitigate this problem but continued effort should be given to dissemination of instructions and equipment so that proper servicing practices will be followed. Consideration could be given for holding periodic lubrication orientation classes so that engineering officers, pilots, crews and supply men will be kept abreast of developments.

5. Experimental work and service testing of lubricants involved performance of new experimental products compared with that of materials now in use, and trial of present products in new applications where specialties have been used in an effort to reduce the total number of items that must be carried in stock. Both types of work will be discussed under the subject of an experimental material where one was involved.

B. Products Tested

Ultra Low Temperature Greases

1. The experimental product, TG-455, meets all the requirements of Specification AN-G-3a for Low Temperature Lubricating Grease and has other attributes including ability to withstand extensive working, as in a very high speed ball bearing, without significant softening. Its resistance to torque (stiffness) at —67°F. is about one fourth that permitted and it can be cooled to —90°F. without exceeding torque limit at only —67°F. established in Specification AN-G-3a.

2. Five trim tab systems and a surface control lock system were completely lubricated with TG-455 to compare their performance with others carrying regular AN-G-3a Low Temperature Lubricating Grease. Past experience has pointed to the possibility that while AN-G-3a grease has satisfactory low temperature torque when new, it has insufficient margin of safety to allow for alterations in its composition that later occur and reduce its ability to remain sufficiently soft as low temperatures. If his possibiliy is verified the ultra low temperature type of grease with greater margin of safety is available.

3. Test data taken at ground temperatures down to —45°F. show a slight advantage in favor of the ultra low temperature grease. It is significant that only a few of the AN-G-3a lubricated main surface control, trim tabcontrol, and surface control lock systems were rated F (frozen) or VS (very stiff but operable). The grease apparently was able to cope with the ground temperatures experienced. When unsatisfactory performance did occur there were usually similar systems in other airplanes of the same type and approximate serial number that could be manipulated without excessive force; this points toward lack of uniformity between the mechanisms that should receive further attention.

4. In view of past experience more data were taken on heavy bombers than any other group of airplanes. Increase in stiffness as ground temperatures dropped suggests that at extreme temperatures one type of heavy bomber would have inoperable aileron trim tabs before other control system difficulties. In another type the surface control lock system is most critical followed by aileron and rudder trim tab and the elevator system. In a third heavy bomber type aileron and rudder trim tabs and the elevator and rudder systems were sensitive to cold weather.

5. Readings made on the ground coupled with reports of pilots indicate that at extreme temperatures aileron trim tabs may freeze and other trim tabs may become very stiff in one type of cargo ship.

6. Freezing of elevator trim tabs of a pursuit ship at high altitude and low temperature was traced to a portion of the system consisting of a chain running over three sprockets.

7. Main surface and trim tab controls of another type of pursuit ship that is the outgrowth of a now discontinued type, against which many complaints had been lodged particularly because of aileron trim tab stiffness, were found to function satisfactorily at the lowest temperatures encountered. The aileron trim tab system of the old model embodied a complicated coordinating arrangement with several chains and sprockets and has been eliminated in the currently produced airplane. However, the other control systems reflected considerable improvement. Data were taken on one of the airplanes with aileron and rudder trim tab systems lubricated throughout with ultra low temperature grease and on several airplanes lubricated with AN-G-3a grease.

8. Most of the difficulties were encountered in heavy airplanes with dual controls. It is suggested that consideration be given to simplifying the means of coordinating dual installations. Each individual control system usually involves in addition to final actuators one or more of the following: cables over drums and pulleys, chains and sprockets, torque tubes and gears, thrust rods and bell cranks, and flexible drive cables. A study of the different mechanisms might lead to the elimination of those least desirable with respect to friction, ease of lubrication and sensitivity to temperature changes and still permit the control system to have satisfactory weight, strength and tautness.

General Purpose Aircraft Lubricating Grease

1. The experimental Grease, TG-404, meets all requirements of Navy Aeronautical Specification M-675 for General Purpose Aircraft Lubricating Grease that was issued on 15 January, 1945 while the Cold Weather Tests were still in progress. Requirements include water

resistance, ability to lubricate very high speed ball bearings at elevated temperature for an extended period of time, and low torque at moderately low temperature; temperatures specified are 250°F. and —40°F. respectively. This type of grease is intended for use in anti-friction bearings, gear boxes, and plain bearings where both reasonably low temperature operation and high temperature stability are required. Suitable applications would be electric motor and generator bearings, wheel bearings and landing gear or other parts with pressure grease fittings. It is not intended to replace ultra low or AN-G-3a grease for factory lubricated, sealed bearings of control systems required to operate at extremely low temperatures.

2. The general purpose grease was applied to bearings of two starters to compare their performance with the regular grease Specification 3560-E, Medium Grade, High Melting Point Grease in two identical starters. None of the four starters experienced bearing trouble at relatively moderate ground temperatures encountered this past winter when the Cold Weather Tests were conducted. However, except when special starting fuel was tried out, external heat was applied to engines and accessory compartments. The four starters were scheduled for limited service tests inasmuch as bearings were not to be examined until Cold Weather Tests are completed.

3. The general purpose grease, TG-404, was placed in bearings of main wheel retracting motor or a heavy bomber to compare its performance with that of a similar motor in which bearings carried grease applied by the manufacturer, Royce 6A. Neither of these motors, nor four others in other airplanes of the same type failed to function at ground temperatures experienced during the 1944-45 Cold Weather Tests. It was noted, however, that the motor carrying general purpose grease raised the wheels in shorter time and consumed less current.

4. There was insufficient good test weather to switch motors and determine to what extent any excessive friction or binding of reduction gears, screw jacks or other units in the wheel retracting mechanisms may have influenced the load on these two motors.

Experimental Graphite Grease

1. The experimental graphite grease consisted of TG-404 in which 5% of graphite had been incorporated. It was applied to gears of the two starters carrying TG-404 in the bearings. Gears of the comparative starters were lubricated with ordinary Specification AN-G-6 Graphite Lubricating Grease. As stated before the four starters functioned satisfactorily. The gears were to be examined after completion of the Cold Weather Tests.

2. Specification AN-G-6 does not include low temperature torque nor high temperature stability requirements. Consideration might well be given to a study of these qualifications with reference to possible improvement of starter performance and life.

Aluminum Soap Grease, Specification AN-G-4, Grade AA

1. Specification AN-G-4, Grade AA grease is now designated for only a few uses on airplanes. It was formerly used on gears and blade bearings of some types of propellers but has been displaced by AN-G-3a grease for this application. Both products were tried out the past winter and performed without complaint, but at ground temperatures approaching —65°F., the aluminum soap grease may be too stiff. During the colder weather there was some grease leakage from a few propellers, this is a problem involving seal composition for low temperatures. With the advent of general purpose grease of the TG-404 type it is possible use of AN-G-4 Grade AA can be discontinued for the few pressure fitting applications where it is now called for.

Grease Summary

1. The field of greases for anti-friction bearings, plain bearings and gears can now be covered by the following available products:

Product	Usable Temperatures Low °F	High °F
Ultra low temperature grease	—90	160 (approx)
Lom temperature grease	—67	160 (approx)
General purpose grease	—40	250
High temperature grease	*	300

*AN-G5a, High Temperature Grease was not scheduled for cold weather testing; no low temperature torque is specified.

2. In order to determine value of the ultra low temperature grease as an all weather lubricant it is suggested that it be given a field service test including moderate and extreme summer temperatures. Servicing and operation of the airplanes involved should be carefully supervised to prevent inadvertent mixing with other lubricants.

C. Experimental Oils

General Purpose Oil

1. The Texas Company supplied a product identified as TL-534, which was developed to meet Specification AN-O-6a for investigation as a General Purpose Low Temperature Lubricating Oil. This is a well refined moderately light oil with ultra low pour point and it carries a rust inhibitor. It is intended for use in plain and anti-friction bearings but not to displace hydraulic and gear oils. The AN-O-6a Oil was used in several applications for comparison with performance of the regularly employed lubricant and of oils normally used for other applications. Two experimental synthetic oils were also tested.

2. The above applications and results obtained are summarized below:

Product	Satisfactory Operating Temperature, °F.
Turbosupercharger Lubrication	
AN-VV-O-366b Hydraulic Oil	—70
AN-O-6a	Below —45
WS-804 Synthetic	Incomplete data
PPO-280 Synthetic	Incomplete data
Jet Engine Lubrication	
*AN-VV-O-366b	OK at —45
AN-O-6a	Borderline at —36
WS-804	Somewhat above —34
AN-O-3, Light	Incomplete data
Aeroproducts Feathering Propeller, Flight Tests	
AN-O-6a	—70
PPO-280	—50
AN-O-3, Light, Low Temperature Gear Oil	Borderline at —35
WS-804	—10

* Product regularly used during very cold weather.

3. Altho AN-O-6a Oil proved satisfactory in turbosuperchargers and jet engines at ground temperatures experienced this winter another specification, Army No. 3606, has been drawn up to cover a similar oil but with-

out the rust inhibitor and with lighter viscosity at low temperatures. This new oil may be even more satisfactory in the above services. On basis of tests made during the winter AN-VV-O-366b remains the preferred oil for Winterized Aeroproducts propellers.

4. The AN-O-6a oil satisfactorily lubricated bearings of a number of gyroscope motors but in one type several bearings failed. All the bearings are self-aligning, double row ball bearings with fibre cages. The failed bearings differ from those in other gyros in that their cage is wider than the inner and outer race and can act as an oil slinger for the light AN-O-6a oil. The bearings ran dry and showed evidence of excessive thrust loads on the outboard rows of balls.

5. It is desirable to use light low pour test oil in these gyros to obviate use of heaters now required because of higher pour test of the more viscous oils now used. One or more of the following steps may be advantageous: eliminate overhang of ball cages, add seals to act as oil reservoir, substitute single row ballbearings with greater thrust capacity, lock both bearings and allow shaft to float within one of them, increase clearance between bearing and housing to accomodate temperature differential and expansion coefficient of the dissimilar metals.

Lubricating Oils—Summary

1. The 1944-45 Cold Weather Tests revealed that progress is being made in the development of oils for low temperature operation of airplanes. It is not so necessary, as in the case of greases, that these products be suitable for warm climates because oils are usually employed in circulating systems that can be quickly drained and refilled with heavier oils.

D. Fuels

Aircraft Engine Fuels (Gasoline)

1. Definite progress was made in the study of gasoline volatility requirements and application of carburetor heat.

2. External heat is now applied to engines and accessories to facilitate starting at temperatures below approximately 0°F. for radial air cooled engines and below —10 to —20°F. for in-line liquid cooled engines. Oil dilution facilities including gasoline scavenging capacities of the oil systems and improved low temperature greases for accessories would permit cold starting at lower temperatures. Problems that should receive further investigation include diluting the vacuum pump crankcase oil, or arrangement of a separate system with light oil, and use of a more volatile starting fuel. Because of the higher vapor pressure of volatile fuels and subsequent greater fire hazard use of droppable tanks or special ground facilities should be considered.

Western Electric Co.

E. W. Brinkerhoff

A. INTRODUCTION

This report contains a general summary of the performance obtained and experience encountered with radar equipment of Western Electric manufacture during the 1944-45 Cold Weather Tests. Western Electric was represented in these tests for a period of six weeks commencing January 16, 1945 ending March 3, 1945.

B. SUMMARY

All of the following information was obtained from routine operational flights and early morning pre-flights.

a. Radar Equipment

(1) Cold Weather Operation

Both SCR-717C and AN/APQ-13 radar equipments operated very satisfactorily during the cold weather experienced. The PE-218 C & D Inverters both employing the carbon pile type regulator reacted identically to that experienced during the Cold Weather Tests last year. For ambient temperatures of —30° to —40°F. the inverters started at a high voltage of approximately 125+ volts. The radar equipment suffered no damage during this initial high voltage period. However, the varying of the AC voltage which is characteristic of these inverters during variations in temperature around 0°F. render the operation of the AFC as unsatisfactory. Focus control is also very difficult during the AC voltage variations.

It is still impossible to operate the ON and OFF buttons of the Control Unit with the use of regulation flying gloves or mittens.

(2) Test Equipment and Employment

(*a*) Signal Generator (TS-35/AP)—this unit was available but dummy load (TS-231/AP) and T section (B41456) or CG98B directional coupler essential for accurate power measurements were lacking.

The stiffness, in sub-zero temperature, of the AN/RG-8/O wave guide to wave guide patch cable used in conjunction with the TS-35/AP for frequency measurement made extremely difficult working conditions. The two spring clips which are employed to fasten the patch cord to the test set are not strong enough to support the stiff patch cord.

(*b*) Power Meter (TS-36/AP)—this unit was also available but TS-35/AP was used when needed.

(3) Propagation of Microwaves

At no time during these tests which in this season involved over 600 operational hours were unusual ranges evidenced or atmospheric data obtained which would indicate the presence of anomalous propogation.

b. Availability of Airplanes

Absolutely no trouble was experienced this season in conducting radar test flights. A Douglas C-47B equipped with SCR-717C was available exclusively for radar test flights. A B-17 and two B-29's equipped with AN/APQ-13 were also available.

Operation of C-47B aircraft: the radome slows the C-47B down to unreliable single engined performance characteristics which is especially dangerous for cold weather operation.

c. Weather

Compared to last year the season had been equally as mild. The lowest recorded temperature for 1943-44 was —45°F. wherein —40°F. was the lowest for 1944-45. The temperature tables for the winter months 1944-45 are attached.

C. ORGANIZATION OF COLD WEATHER TEST DETACHMENT

The organization for CWT was essentially the same for this season as it was for the last with the exception of no civilian specialists from Aircraft Radio Labs also a sharp reduction in the officer personnel representing ARL.

a. RADAR EQUIPMENT

(1) System Performance and Operating Time

(*a*) SCR-717C

This equipment was installed in a C-47B and operated normally for a total time of 175 hours thereafter no attempt was made to keep further records of the time. The equipment was operated on the average of 5 hours a day continuously for a three-month period. The system was flown to and operated under various weather conditions experienced down to —45°F. Echoes with the ship docked in the bay were continually and reliably received every day from the Alaskan Range approximately 90 miles south of Ladd Field.

(*b*) AN/APQ-13

1. System in B-29—#768—this equipment was operated for approximately 100 hours of which 20 hours it operated at 30,000 feet and with air temperatures of —60°, —65°F., and 2½ hours with the air at altitude pressure in the cabin.

Photographs of the PPI scope on 2,500 mile flight at 30,000 feet ground speed 300 miles per hour air temperature —61°F. are included in Appendix I.

2. System in B-29—#214—this equipment was operated for approximately 171 hours of which 5 hours it operated at 30,000 feet with air temperatures of —60°, —65°F.

3. System in B-17—#587—this installation was mocked-up by and installed under Lt. E. E. Caldwell's CWT supervision at Ladd Field, Alaska; its operation was normal for over a period of 100 hours.

4. System as ground spare—operated for a period of 25 hours, system was "cannibalized" whenever necessary.

(2) Operational Notes

The following notes and operational difficulties are briefed:

SCR-717C

1. Couldn't pressurize RF or Modulator units, maintaining seal on units is extremely difficult at low temperatures, no work was done to determine what could be accomplished as extra gaskets were not available.

2. Loss of signals due to faulty 6AC7 in Synchronizer.

3. PE-218C Inverter carbon disc of voltage regulator burned, also burned brushes.

AN/APQ-13

1. Two crystals replaced in B-29's #214 and #268.

2. PE-218D inverter on B-29 #768 burned a set of brushes.

3. Search switch on B-29 #768 defective, icing believed cause of this trouble.

4. Radome on B-29 is serious problem at low temperatures, as material used is very brittle and fails when hit by shell cases, links and frag bombs; during a gunnery mission, one antenna was seriously damaged by shell cases and links which had penetrated the radome. At time of the writer's departure a new streamlined radome was being put through cold weather tests.

Inverters PE-218 C & D

PE-218D inverters were employed with AN/APQ-13 system. PE-218C was used in the SCR-717C system. The starting voltage of these inverters at —30° —40°F. was generally higher than 125 V. Consequently as the cabin temperature varied, the AC voltage accordingly varied.

Test Equipment

Patch cables becoming extremely stiff in subzero temperatures presented the major problem. (See Photographs Appendix I)

(3) Tests—Pre-flight Checks

(*a*) During the month of February, pre-flight data was taken on AN/APQ-13 installed in B-17 #587 to determine as close as possible the information desired in BTL letter dated January 3, 1945. For pre-flight data reference is made to Appendix II.

(*b*) Lack of Proper Test Equipment and Modification Kits. Of the four AS54A/APQ-13 antennas, two were of the X66170A variety, one X66170G and the other we were unable to determine since the radome in which it was mounted was never removed.

All four antennas lacked the rotary joint heater unit modification which would supply power and temperature control to the heater.

Modification kits were requested but never received. A TS-35/AP test set was available but dummy antenna (TS-231/AP) and T section (B41456) or CG98B directional coupler essential for accurate power measurements were not available.

Since the rotary joints were not heated, no spare gaskets were available and the equipment had considerable operating time. Checking for leaks in the transmission line was extremely difficult; two antennas were found, however, with audible air leaks in the plugs of the wave guide to coaxial transformer on the input side of the rotary joint. These leaks were due to improper soldering.

At temperatures of —40°F. it was possible to operate the sweep delay switch only under considerable hand presure.

With the varying AC voltage which apparently is a normal characteristic of PE-218D inverter during low temperature changes the AFC does not function properly. Variations in filament emission may have contributed much to this AFC condition.

Pre-flight data shows the variations—revolutions per minute of antenna in search and continuous rotation position.
variations—looks per minute in sector scan.
variations—antenna tilt time, degree of tilt
variations—in frequency of magnetron.
variations—of AC output of PE-218D inverter with temperature changes.

D. CONCLUSION

In so far as the radar equipment is concerned, the nature of these tests were purely operational. Owing to the fact that the weather was extremely mild, the cold weather data taken is of little consequence. The Army CWT program for Western Electric radar equipment was merely the performance of the gear while under assimilated combat operations. There was no planned program and no test data was desired. No test gear was available to subject the radar equipment to vibration tests. The excellent performance of the gear for over 600 hours of cold weather operations during which time gunnery tests and various other sources of shock and vibration were subjected to the equipment may be considered as a criterion of the equipments shock ability at sub-zero temperature.

Appendix

TABLE I

SURFACE TEMPERATURE

NOVEMBER 1944 LADD FIELD, ALASKA

Hr. / Day	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	Max.	Min.	Mean
1	27	29	28	28	27	26	23	23	21	21	22	23	24	25	26	26	21	21	22	25	25	25	24	24	30	21	24.4
2	23	23	22	22	21	20	18	16	13	12	12	14	16	18	20	23	22	20	20	16	13	12	11	11	25	10	17.4
3	10	10	9	8	8	8	7	7	10	9	13	15	19	19	20	19	19	19	14	13	11	8	8	8	20	7	12.1
4	7	7	6	6	5	5	6	6	5	6	6	12	14	19	22	19	16	15	12	13	15	15	12	11	22	4	10.8
5	8	8	5	5	4	4	4	4	4	2	4	5	11	13	16	17	15	12	8	7	6	6	4	3	18	2	7.3
6	3	3	0	1	4	2	2	3	3	2	12	12	15	17	16	17	17	17	17	16	15	12	9	7	18	0	9.2
7	5	4	3	4	4	4	3	3	2	1	3	6	6	8	9	9	10	10	10	10	10	11	11	11	12	1	6.5
8	11	11	11	11	11	10	10	9	10	12	12	15	18	17	17	17	16	16	15	15	14	14	14	13	19	10	13.3
9	12	11	11	9	9	9	9	9	9	9	10	10	12	12	13	12	10	8	6	5	5	5	6	5	13	5	9.0
10	3	2	2	3	2	0	0	0	1	3	3	5	5	7	7	7	7	5	5	5	5	5	5	5	8	–1	3.8
11	3	2	2	–2	–3	–8	–10	–9	–9	–12	–9	–7	–7	–2	2	2	1	–5	–9	–9	–11	–11	–13	–10	5	–13	–3.7
12	–11	–11	–13	–11	–9	–9	–10	–14	–14	–16	–16	–14	–14	–8	–3	–3	–6	–6	–8	–10	–10	–10	–10	–10	–3	–16	–10.2
13	–10	–11	–11	–10	–11	–12	–12	–11	–11	–10	–9	–7	–5	0	–1	–2	–4	–5	–5	–5	–5	–4	–2	0	3	–13	–6.7
14	2	3	4	4	4	4	5	5	6	6	7	7	8	9	9	8	8	5	5	5	5	5	1	2	10	–1	5.3
15	0	2	5	7	11	11	12	12	15	17	17	17	15	15	14	17	17	17	17	15	16	14	16	18	21	0	13.2
16	19	20	18	12	10	10	10	10	10	12	12	14	16	18	18	17	18	18	16	15	13	12	9	9	22	9	14.0
17	9	8	8	9	9	8	9	8	8	9	8	8	13	15	15	14	12	10	8	9	8	6	6	5	16	5	9.2
18	5	6	5	5	4	3	3	2	4	8	4	6	8	10	15	16	14	13	10	7	9	9	10	10	18	2	7.6
19	10	9	9	8	11	10	8	8	8	5	5	9	10	11	14	14	12	11	11	14	15	15	16	16	18	2	10.8
20	18	18	16	15	11	9	9	8	10	14	14	15	15	15	15	14	14	12	12	11	9	9	14	14	18	7	13.0
21	14	15	14	14	15	16	16	16	17	17	17	16	18	16	16	18	18	17	15	15	15	14	14	14	19	12	15.7
22	13	12	11	11	11	11	11	11	12	12	12	13	13	13	13	14	14	14	15	15	14	14	14	14	15	11	12.8
23	12	12	12	11	10	8	8	6	6	5	5	4	5	5	5	5	5	3	4	2	–2	–3	–3	–5	13	–9	5.0
24	–6	–6	–6	–6	–5	–4	–1	2	1	1	0	0	0	2	2	0	–2	–3	–3	–3	–3	–3	–4	0	2	–8	2.0
25	1	1	–1	–2	–3	–2	–2	–2	–2	0	–1	–1	0	2	1	1	0	0	0	1	–3	–3	–5	–4	2	–9	–1.0
26	–9	–9	–8	0	2	3	2	3	1	–1	0	4	6	7	7	6	6	0	–6	–6	–1	0	–2	–3	9	–9	0.0
27	–2	–2	–3	–4	–6	–5	–8	–5	0	0	–1	0	5	6	6	7	6	6	6	8	10	11	11	11	14	–10	2.4
28	12	12	12	12	12	11	9	9	8	7	7	5	4	4	3	3	3	4	5	5	6	6	6	7	14	3	7.2
29	7	7	8	8	8	8	11	10	7	6	6	6	6	6	6	6	5	5	4	3	2	2	2	1	11	0	5.8
30	1	2	4	3	2	2	1	3	3	1	0	–2	–2	–2	–5	–7	–8	–9	–11	–11	–11	–12	–11	–12	5	–14	3.4

TIME IS A. W. T. TEMPERATURES ARE IN DEGREES FAHRENHEIT MEAN FOR MONTH +7.3

TABLE I

SURFACE TEMPERATURE

DECEMBER 1944 | LADD FIELD, ALASKA

Hr. / Day	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	Max.	Min.	Mean
1	-13	-14	-14	-15	-16	-16	-16	-15	-17	-17	-16	-18	-14	-12	-10	-9	-8	-8	-7	-6	-6	-8	-8	-7	-6	-20	-11.8
2	-9	-10	-10	-10	-10	-8	-7	-7	-7	-5	-4	-4	-4	-3	-4	-2	-2	-2	-1	-1	0	0	1	1	1	-10	-4.5
3	0	1	1	1	1	1	1	1	2	2	0	-1	-3	-3	-4	-5	-4	-5	-6	-6	-6	-6	-7	-7	3	-8	-2.2
4	-7	-9	-9	-9	-9	-9	-9	-9	-9	-9	-10	-9	-10	-10	-10	-10	-10	-10	-11	-12	-14	-16	-18	-21	-7	-21	-10.8
5	-24	-24	-25	-26	-27	-28	-28	-31	-31	-28	-30	-30	-29	-32	-34	-33	-32	-32	-34	-34	-34	-34	-34	-34	-24	-34	-30.3
6	-35	-36	-36	-38	-41	-39	-38	-37	-39	-39	-37	-37	-37	-36	-36	-35	-35	-37	-35	-37	-37	-38	-38	-38	-35	-41	-37.1
7	-38	-38	-36	-35	-36	-38	-37	-38	-37	-35	-34	-32	-30	-29	-25	-23	-23	-23	-22	-23	-22	-21	-19	-19	-19	-40	-29.7
8	-19	-19	-18	-18	-17	-16	-15	-14	-12	-12	-11	-11	-10	-8	-8	-7	-8	-9	-9	-9	-12	-14	-14	-15	-7	-19	-12.7
9	-15	-15	-16	-17	-15	-15	-15	-15	-14	-14	-12	-13	-14	-13	-14	-13	-13	-14	-14	-16	-13	-12	-12	-11	-11	-18	-14.0
10	-12	-9	-6	-5	-2	5	7	8	10	34	35	36	38	39	39	38	35	35	33	33	33	34	33	30	39	-13	21.7
11	27	24	24	27	32	33	33	22	23	20	16	18	20	22	27	36	35	38	34	34	35	30	30	32	40	15	28.0
12	35	34	33	36	34	36	36	35	35	38	36	35	35	31	32	31	32	31	25	22	19	18	18	16	39	16	30.5
13	12	12	15	17	18	17	17	13	15	18	19	18	17	15	15	15	15	16	16	16	14	19	21	26	26	12	16.5
14	27	25	25	27	28	28	29	26	26	29	27	28	28	30	27	25	21	18	14	13	12	12	15	15	34	11	23.1
15	15	15	14	16	15	17	17	16	17	18	19	19	19	20	21	22	22	19	17	17	19	23	23	21	23	14	18.4
16	30	30	32	29	29	31	34	35	35	35	38	38	38	38	35	35	34	34	34	33	33	29	31	31	39	29	33.4
17	31	30	31	24	27	24	24	26	27	20	20	20	20	20	20	21	19	19	18	18	12	9	7	7	33	7	20.6
18	6	5	6	6	6	9	10	13	13	14	13	17	18	21	20	19	18	18	18	19	20	20	15	13	21	5	14.0
19	16	17	18	15	14	13	13	12	17	18	19	19	20	20	20	20	20	19	19	21	21	23	22	21	24	12	18.2
20	20	22	22	20	20	22	23	22	20	22	19	17	14	14	12	8	8	6	6	3	1	2	10	6	24	1	14.1
21	12	13	14	14	11	9	8	9	9	9	4	4	2	3	5	4	2	2	0	-1	3	0	-1	-2	15	-2	5.5
22	-2	-4	-5	-2	-3	2	2	7	9	11	11	12	10	10	6	4	1	1	-2	-4	-6	-6	-4	-4	12	-7	1.8
23	-5	-5	-6	-7	-8	-8	-9	-9	-8	-5	-6	-6	-2	-1	-1	-3	-4	-4	-2	1	-3	-2	-2	-2	2	-11	-4.4
24	-4	-6	-7	-8	-8	-7	-6	-7	-8	-9	-8	-10	-11	-10	-10	-12	-12	-13	-11	-11	-8	-7	-7	-10	-4	-15	-8.8
25	-11	-11	-11	-14	-12	-13	-13	-13	-13	-11	-12	-12	-11	-10	-10	-12	-12	-12	-15	-16	-16	-17	-18	-19	-10	-19	-13.1
26	-19	-20	-20	-21	-23	-23	-24	-24	-24	-23	-23	-21	-20	-15	-11	-9	-9	-7	-6	-2	-4	-11	-11	-11	-1	-25	-15.9
27	-11	-12	-16	-14	-12	-12	-8	-3	-1	-2	-4	-5	-4	-8	-5	-4	-5	-5	-6	-2	0	1	3	2	4	-17	-5.5
28	1	1	-2	-6	-7	-8	-8	-12	-12	-13	-14	-15	-17	-16	-18	-19	-20	-21	-24	-21	-22	-28	-28	-25	1	-30	-14.6
29	-15	-26	-29	-26	-27	-28	-28	-29	-28	-22	-26	-25	-13	-13	-11	-14	-15	-14	-16	-15	-14	-12	-13	-13	-9	-30	-19.7
30	-13	-10	-6	-4	4	5	5	7	8	8	9	10	10	10	10	10	10	10	10	10	9	8	8	4	11	-13	5.5
31	-1	-1	-3	-3	-4	-5	-5	-4	-4	-6	-14	-17	-18	-16	-15	-15	-18	-19	-20	-20	-24	-25	-25	-24	-1	-25	-12.8

TIME IS A. W. T. | TEMPERATURES ARE IN DEGREES FAHRENHEIT | MEAN FOR MONTH +1.1

TABLE I

SURFACE TEMPERATURE

JANUARY 1945 LADD FIELD, ALASKA

Hr. / Day	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	Max.	Min.	Mean
1	-22	-20	-16	-15	-14	-9	-7	-10	-10	-10	-9	-9	-10	-11	-9	-11	-11	-10	-10	-12	-12	-11	-8	-7	-7	-22	-11.4
2	-3	-3	-3	-3	-4	-4	-3	2	2	6	6	0	3	5	5	11	11	9	5	0	0	-5	-5	-7	12	-8	1.0
3	-7	-9	-11	-11	-13	-12	-13	-12	-14	-13	-11	-11	-10	-7	-8	-8	-8	-9	-10	-9	-10	-9	-9	-9	-7	-15	10.1
4	-7	-7	-5	-4	-5	-7	-9	-11	-12	-9	-9	-9	-7	-6	-6	-6	-7	-9	-10	-9	-8	-8	-8	-8	-4	-13	-7.8
5	-12	-12	-7	-13	-14	-11	-9	-9	-13	-5	-7	-7	-7	-2	1	-4	-13	-14	-15	-16	-16	-20	-21	-21	2	-22	-11.1
6	-21	-22	-22	-23	-23	-23	-24	-25	-26	-25	-28	-27	-27	-13	-2	-4	-5	-5	-9	-9	-13	-4	-3	-1	-1	-30	-16.0
7	6	6	6	6	6	6	6	5	5	3	2	1	-1	-2	-1	-3	-4	-5	-5	-3	-5	-4	-6	-4	7	-7	0.6
8	-5	-6	-9	-5	-5	-6	-5	-5	-6	-6	-4	-4	-3	-4	-4	-6	-4	-5	-10	-11	-11	-1	-3	-6	-1	-13	-5.8
9	-10	-12	-12	-11	-12	-12	-9	-7	-7	-3	-4	-5	-5	0	-3	-3	-5	-7	-3	-3	-3	-2	-2	-8	2	-15	-6.2
10	-9	-10	-9	-10	-12	-12	-10	-10	-12	-12	-11	-10	-9	-9	-8	-6	-6	-4	-4	-4	-4	-5	-5	-1	-1	-15	-8.0
11	-1	0	2	6	5	2	2	10	14	17	20	13	9	10	11	10	9	4	4	7	3	2	2	0	20	-1	6.8
12	-4	-3	-3	1	2	4	4	5	7	5	1	3	3	4	4	6	5	2	1	0	-1	-4	-5	-6	11	-6	1.3
13	-6	-7	-8	-9	-9	-10	-10	-11	-10	-11	-12	-10	-9	-6	-5	-6	-8	-9	-10	-10	-6	-6	-5	-8	-3	-14	-8.4
14	-8	-7	-9	-7	-7	-1	-1	0	1	1	2	3	4	5	5	3	3	-1	0	2	4	4	4	5	5	-11	0.2
15	5	4	3	3	0	0	0	-1	-6	-1	2	3	2	3	3	3	2	3	3	3	3	3	3	2	5	-6	1.9
16	-1	-9	-9	-15	-18	-17	-17	-20	-20	-17	-16	-15	-4	-4	-3	0	0	-3	-6	-6	-6	-6	-4	-4	2	-23	-9.2
17	-8	-12	-7	-5	-3	-3	-7	-5	-5	-6	-9	-8	-8	-2	-2	-8	-9	-10	-12	-11	-15	-16	-13	-12	-1	-19	-8.2
18	-12	-11	-12	-12	-14	-15	-14	-14	-12	-12	-9	-12	-10	-8	-6	-4	-1	1	1	8	10	6	0	0	11	-16	-6.3
19	-3	-2	-1	-2	4	4	3	-2	-4	-5	-6	-6	-6	-2	1	4	6	9	12	13	10	11	14	10	14	-8	2.6
20	13	14	16	16	19	19	20	24	21	20	19	21	20	23	22	22	20	18	18	14	14	7	4	4	26	2	17.0
21	5	5	5	10	10	18	18	11	18	17	17	17	17	22	23	24	21	22	21	20	19	21	21	19	25	4	16.7
22	19	17	15	15	9	8	8	12	17	16	16	18	19	17	17	11	10	10	10	9	7	2	1	-1	19	-1	11.8
23	-1	-4	-5	-8	-8	-6	-5	-6	-7	-8	-8	-8	-7	-6	-2	-1	-2	-2	-8	-11	-10	-12	-13	-14	1	-15	-6.8
24	-11	-11	-8	-6	-5	-2	-1	0	1	2	2	1	3	4	4	4	4	2	3	1	0	1	3	3	5	-15	-0.2
25	2	0	0	-2	-5	-7	-7	-3	-7	-7	-7	-10	-9	0	0	-1	-3	-4	-7	-8	-12	-12	-12	-13	4	-13	-5.6
26	-13	-12	-8	-6	-2	1	2	4	7	11	13	16	16	19	21	21	19	18	21	20	20	21	21	19	22	-13	10.4
27	25	21	23	18	14	16	16	26	26	30	30	33	32	34	34	40	35	34	37	35	31	30	30	32	41	13	28.4
28	32	30	29	31	33	37	35	36	36	37	34	34	36	38	40	42	36	35	35	34	33	32	32	29	43	29	34.4
29	24	24	22	18	19	19	24	30	28	28	29	29	32	33	33	29	31	31	30	29	28	21	20	19	36	17	26.2
30	18	15	15	13	12	12	12	15	12	14	14	18	24	26	26	25	27	27	23	24	25	17	20	16	32	10	18.8
31	15	10	9	9	10	9	9	4	3	2	3	7	10	12	17	14	13	11	6	6	7	3	4	2	17	0	8.1

TIME IS A. W. T. TEMPERATURES ARE IN DEGREES FAHRENHEIT MEAN FOR MONTH +2.8

TABLE I

SURFACE TEMPERATURE

FEBRUARY 1945

LADD FIELD, ALASKA

Hr. Day	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	Max.	Min.	Mean
1	1	0	0	-1	-2	-2	-3	-3	-4	-5	-4	-1	8	10	13	12	12	10	9	5	4	14	13	19	19	-6	4.4
2	15	21	19	11	9	4	4	4	1	4	9	8	16	16	22	22	22	22	20	20	18	16	17	11	23	-3	13.8
3	4	3	1	2	1	0	-1	-2	-2	-6	-4	1	4	6	12	14	14	7	4	1	2	-4	-6	-8	15	-8	1.8
4	-9	-10	-10	-12	-12	-12	-12	-9	-7	-5	-5	-2	2	3	5	6	6	6	6	6	6	6	6	6	6	-14	1.7
5	5	6	5	6	6	6	6	4	4	1	2	4	4	5	6	7	8	6	7	3	0	2	0	6	8	-2	4.5
6	8	7	8	6	5	4	4	3	1	2	3	7	11	12	11	11	10	9	9	8	7	4	2	0	13	-2	6.3
7	0	0	-5	-5	-2	-7	-7	-8	-9	-12	-7	-8	-5	-1	1	3	2	0	1	1	1	2	2	2	4	-15	-2.5
8	2	2	2	2	2	0	0	0	0	0	1	1	0	0	2	2	4	0	-3	-6	-5	-6	-11	-12	5	-14	-1.0
9	-10	-11	-10	-7	-5	-5	-5	-3	-2	-2	0	1	2	2	4	5	6	6	7	7	8	8	8	8	9	-14	0.5
10	7	6	6	5	4	4	4	3	3	2	0	0	1	4	6	5	5	3	1	0	6	5	3	3	8	-3	3.6
11	3	1	-1	-2	-5	-6	-7	-7	-9	-10	-12	-14	-15	-14	-16	-15	-16	-17	-18	-18	-19	-19	-20	-20	3	-20	-11.5
12	-20	-22	-24	-26	-26	-28	-28	-33	-34	-34	-30	-29	-29	-24	-22	-21	-20	-23	-25	-31	-35	-34	-34	-35	-20	-36	-27.8
13	-36	-36	-38	-37	-38	-37	-37	-40	-43	-40	-37	-32	-28	-17	-17	-16	-16	-21	-25	-26	-27	-27	-27	-27	-16	-45	-30.2
14	-27	-27	-29	-27	-26	-27	-33	-34	-34	-33	-30	-25	-13	-8	-2	-2	-2	-1	-4	-7	-9	-10	-9	-7	-1	-36	-17.7
15	-10	-8	-5	-3	-2	0	0	0	1	1	3	4	4	7	8	7	7	8	6	5	6	6	7	7	8	-12	2.5
16	7	7	8	8	8	8	8	7	7	8	8	13	13	17	17	15	13	13	10	5	2	2	1	1	18	0	8.6
17	2	4	6	6	7	7	8	7	7	8	8	11	12	17	19	19	19	20	19	19	15	13	13	14	20	2	11.7
18	6	5	6	5	5	9	7	5	4	7	7	8	15	21	23	23	22	19	20	17	15	18	18	17	25	3	12.6
19	17	13	14	9	8	7	6	11	11	11	10	10	10	12	13	13	13	12	12	12	10	10	10	9	18	2	10.9
20	9	6	6	4	4	5	8	9	5	6	4	7	13	14	19	20	21	19	17	10	7	7	8	6	22	1	9.8
21	8	6	7	8	9	9	9	9	6	6	6	11	13	13	16	17	17	17	15	15	14	13	12	10	18	1	11.1
22	11	10	9	11	12	12	12	9	10	8	12	12	17	18	21	22	19	18	20	20	18	22	22	22	22	7	15.3
23	21	20	18	18	20	23	23	31	32	35	37	37	38	41	43	46	44	45	43	35	33	31	27	23	48	17	31.8
24	24	24	22	23	23	23	27	27	28	29	30	37	40	40	39	40	39	38	38	39	40	41	38	35	41	18	32.7
25	35	32	29	29	29	31	31	31	32	30	29	29	28	30	30	31	32	31	29	29	26	23	24	21	35	21	29.2
26	17	12	10	13	10	7	7	6	7	6	8	12	18	28	30	30	30	29	29	25	28	26	26	26	33	2	18.8
27	25	28	26	29	28	28	28	27	29	30	32	34	32	33	33	32	32	32	32	31	30	29	27	26	34	25	29.7
28	26	25	25	24	22	21	19	19	13	15	21	21	25	27	28	27	27	26	23	22	22	19	19	22	30	11	22.4
29																											
30																											
31																											

TIME IS A. W. T. TEMPERATURES ARE IN DEGREES FAHRENHEIT MEAN FOR MONTH +6.9

TABLE II

ATSC DEVELOPMENTAL TEST AIRPLANES

WINTER 1944-45

Model	Serial No.	Date Arrived Ladd	Flying Time in Alaska, hr.	Remarks
A-26B	41-39182	12/2/44	93:40	
B-17G	43-38221	12/7/44	183:35	
B-17F	42-30981	12/10/44	62:00	Photographic Tests
B-24J	42-51660	11/11/44	202:05	Radio and Radar Tests
B-24J	44-41378	11/11/44	147:30	
B-25J	44-29258	11/25/44	87:15	
B-29	42-65214	1/1/45	88:20	
B-29	42-24612	12/21/44	122:50	Fuel injection engines
P-38L	44-24050	12/2/44	142:30	
P-51D	44-14476	12/7/44	44:15	
P-61B	42-39402	12/10/44	60:45	Crashed 24 Feb. Total loss
P-59A	42-22610	12/9/44	69:40	
P-63A	42-70255	12/9/44	77:10	
C-46	42-60983	Under contract to TWA for fuel volatility tests.		
C-47A	43-48088	12/9/44	121:50	
C-49K	43-2017	Under contract to Phillips Petroleum Co. for fuel volatility tests.		
C-54B	43-17157	11/11/44	52:35	
C-69	43-10314	3/29/45	24:10	
F-5E	44-23602	12/12/44	78:00	Photographic tests

TABLE III

CWTD SERVICE TEST AIRPLANES

A-26B	43-22426
P-38L	44-24696 44-24697
P-47D	42-28728 42-28744
P-51D	44-14484 44-14513
B-17G	43-38586 43-38516
B-24J	44-41377 44-41369
B-25J	44-29113 44-29114
B-29	42-24768
C-45F	43-35894 44-47157
C-46A	42-96803 44-77444
L-5B	42-99641 42-99642

TABLE IV

ATSC Personnel Attending

1944-1945 Cold Weather Tests

Extreme Temperature Operating Unit:

Lt. Col. N. C. Thyson	Chief, ETOU and C-54 Project Officer
Major L. C. Smith	Executive
Capt. Beach Barrett	Operations and C-47 Project Officer
Capt. W. I. Thieme	Engineering and B-25 Project Officer
1st Lt. H. G. Apostolakos	Administrative and Supply
Capt. H. J. Andre	P-61 Project Officer
Capt. J. H. Brown	P-51 Project Officer
Capt. J. McGuyrt	P-38 Project Officer
Capt. H. T. Markey	P-59 Project Officer
1st Lt. F. G. Bastian	B-17 Project Officer
1st Lt. J. A. Festersen	B-29 Project Officer
1st Lt. D. W. Mills	B-24 Project Officer
1st Lt. J. R. Payne	B-29 Project Officer
Capt. J. C. Reilly	C-69 Project Officer
1st Lt. C. H. Tillson	A-26 Project Officer
1st Lt. R. E. Wahlborg	Navigator
M/Sgt. W. H. Brown	Inspector
S/Sgt. C. E. Vincent	Radio Operator
S/Sgt. M. E. Parker	Radio Operator
Pvt. J. A. Litton	B-29 Engineer
E. C. Theiss	Aeronautical Engineer
S. J. Russell	Draftsman

Aircraft Laboratory:

Lt. Col. F. W. Warburton	Supervision
Capt. A. S. Anderson	Flight Control and Structures
1st Lt. W. R. Maslin	Hydraulic Systems

Armament Laboratory:

Capt. O. E. Hopkins	Guns, Turrets, Fire Control
N. S. Lestz	Bombing Equipment

Equipment Laboratory:

Major H. R. Collins	Supervision
Capt. C. E. Wood	Electrical Equipment
Capt. T. C. Warner	Instrument and Navigation
1st Lt. W. H. Giedt	Heating and Defrosting
Sgt. W. O. King	Ground Heaters
Cpl. V. A. Valey	Heating and Defrosting
Cpl. J. Fox	Instruments
Cpl. F. C. Symmes	Wing and Engine Covers

Materials Laboratory:

Major S. C. Britton	Lubrication
1st Lt. T. F. Brick	Hose and Tires

Photographic Laboratory:

Capt. J. J. Sylvester	Camera and Photo Equipment
1st Lt. C. E. Woodall	Camera and Photo Equipment
C/WO S. P. Balcomb	Camera and Photo Equipment
Sgt. R. W. LaValley	Camera and Photo Equipment
Sgt. L. E. Poncet	Camera and Photo Equipment
Cpl. R. L. Wright	Camera and Photo Equipment

Power Plant Laboratory:

Wm. Weitzen	Supervision, Oil Systems
J. W. Whittle	Engine Test Stand
C. W. Goodman	Packard Engine
A. L. Watts	Mechanic
S/Sgt. W. E. Bourne	Mechanic
Pvt. R. G. Dunn	Cold Starting

Propeller Laboratory:

Capt. J. F. Schmidt	Propeller Systems
1st Lt. H. B. Graham	Propeller Systems
S/Sgt. H. J. Frick	Propeller Systems

Aircraft Radio Laboratory:

Capt. P. D. Langrick	Supervision
1st Lt. D. H. Stouch	Radar
2nd Lt. D. S. Frankel	Communication and Navigation
Cpl. J. Westwick	Communication and Navigation

Personal Equipment Laboratory:

Major R. B. Bass	Emergency Equipment & Clothing
Major F. T. Foster	Emergency Equipment & Clothing
Capt. M. P. Learned	Emergency Equipment & Clothing
1st Lt. A. D. Ivlen	Emergency Equipment & Clothing
H. B. Washburn, Jr.	Emergency Equipment & Clothing
Sgt. N. Bright	Emergency Equipment & Clothing

Technical Data Laboratory:

S/Sgt. H. K. Hotchkiss	Photographic Record of Test Program
Sgt. J. V. Mascelli	Photographic Record of Test Program

Maintenance Division:

Col. P. E. Shanahan	Tactical Equipment
Major H. F. Helbig	Engines
Capt. R. C. Johnson	Aircraft
Capt. W. J. Renyck	Associated Equipment

Supply Division:

Major E. H. Krause
Capt. E. E. Murphy
Capt. J. A. Porter
1st Lt. J. H. Ball

Phillips Petroleum Co.:	Fuel volatility tests
R. T. Agster in charge. 17 civilians on contract to AAF.	

Transcontinental & Western:

E. V. Albert in charge. 10 civilians on contract to AAF.	Fuel volatility tests

TABLE V

Manufacturer's Technical Representatives Attending 1944-1945 Cold Weather Tests

Airesearch Mfg. Co.	E. Freitag
Allison Division of General Motors Corp.	H. S.. Hanson F. G. Dougherty
Bell Aircraft Corp.	M. K. Woods L. A. McIntosh
Bendix Aviation Corp.	K. S. Jackson C. Benassi J. P. Leahy C. W. Robins J. F. Carr
Chandler Evans Corp.	M. C. Cartney H. H. Wallace
Consolidated-Vultee Aircraft Corp.	D. M. Moore W. H. Sanderson
Curtiss-Wright Corp.	D. D. Waters A. H. Nisita
Douglas Aircraft Corp.	W. W. Thayer J. F. Hill D. W. Walters
Fairchild Camera & Instrument Corp.	W. C. Edwards
General Electric Co.	C. Meloun J. Robertson
Hamilton Standard Propellers	R. B. Carroll
Jack & Heintz, Inc.	G. P. Adams
Lausen Engine Co.	L. R. Pierce
Linde Airproducts Co.	C. H. Sweatt
Lockheed Aircraft Corp.	L. C. Chambers C. Schmidt C. Coleman
Minneapolis Honeywell Regulator Co.	R. C. Ruhland A. S. Knudson W. J. Field
North American Aviation, Inc.	J. A. Dunham
Northrop Aircraft Corp.	L. L. Collings C. W. Harris
Packard Motor Car Co.	C. R. Jones
Perfection Stove Co.	E. J. Althouse
Pratt & Whitney Aircraft Div.	S. D. Pearson C. Blakely R. Savery
Republic Aviation Corp.	J. McEwan
Socony-Vacuum Oil Co.	D. P. Heath
Sperry Gyroscope Co.	R. J. Pearson E. F. Reedy
Surface Combustion Div.	Lee Curtain M. Maeske
The Texas Co.	G. V. Roark
United Aircraft Products Inc.	A. C. Hoffman G. G. Karlsen J. D. Olcott W. D. Sherwood
Walter Kidde & Co., Inc.	R. W. Bowman
Western Electric Co.	E. W. Brinkerhoff
Union Oil Co.	M. S. Reynolds