ARMORED MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY

Report On

PROJECT NO. T-7 - TEST OF CARBON MONOXIDE HAZARD FROM ENGINE IN LIGHT TANK, M24

Project No. T-7

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19 April 1945

Serial

U.S. Armored medical research laboratory
Fort Knox, Ky.
Project no. T-7

ARMORED MEDICAL RESEARCH LABORATORY
Fort Knox, Kentucky

Project No. T-7
SPMEA 470.8-2

19 April 1945

1. PROJECT No. T-7 - Test of Carbon Monoxide Hazard from Engine in Light Tank, M24.

a. Authority: 2nd Indorsement by Surgeon General to Letter, Office of Chief of Ordnance, 470.8/2194 Tanks, SPOTT, 29 January 1945.

b. Purpose: To investigate the carbon monoxide hazard in the fighting compartment of subject vehicle from contamination by exhaust fumes.

2. DISCUSSION:

a. In earlier tests of the M24 light tank by this Laboratory (Project No. 44 - Physiological and Operational Characteristics of M24 Tank, 8 November 1944) attention was called to the possible carbon monoxide hazard in the crew compartment arising from engine exhaust fumes during the operation of the winter ventilation system. The present tests were conducted to provide more detailed information with respect to the cause, magnitude, and means of correction of this hazard.

b. Detailed test procedures and results are presented in the Appendix.

3. CONCLUSIONS:

a. Hazardous carbon monoxide concentrations are found within the fighting compartment from exhaust gases entering the engine air intake when the vehicle is stationary with engine idling and wind is from the rear.

b. Danger of crew compartment contamination from this source is largely eliminated through changes in direction of discharge of engine exhaust gases to prevent short-circuiting to the air intake.

4. RECOMMENDATIONS:

a. Redesign exhaust tail pipes to eliminate contamination of air entering fighting compartment by engine exhaust fumes.

NOTE: The recommendations as set forth in this project have been concurred in by Col. Fred W. Makinney, Chief of Staff, Armored Center.

Submitted by:
Robert H. Walpole, Capt., FA

Willard Machle

APPROVED _____
WILLARD MACHLE
Colonel, Medical Corps
Commanding

1 Incl.
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APPENDIX

1. Earlier studies of the carbon monoxide hazard in the M24 Tank (AMRL Project No. 44, 8 Nov. 44) indicated that present ventilation of the crew compartment is inadequate for effective control of gun fumes. With respect to the scheme for winter heating by diversion of air from the engine air intake, attention was called to a potential CO hazard resulting from possible contamination of this air with carbon monoxide from the engine. Subsequent study by OCO-D made it appear doubtful that such contamination by re-circulation of air within the engine compartment could take place, owing to the outward air stream which is maintained. The purpose of the present study was to determine more accurately the source, magnitude and possible means of eliminating the hazard, the presence of which was indicated in the earlier study.

2. Test Procedures

a. Tests were conducted to determine:

(1) Effect of wind direction

(2) Situation in moving vehicle

(3) Relative influence of open or closed floor panels (for inspection and/or winter heating).

(4) Influence of position and direction of discharge of engine exhaust terminals.

b. Carbon monoxide concentrations were determined with the MSA CO Indicator, calibrated before and after test. Samples were taken at the center of the turret, approximately at breech height.

c. In all tests the tank hatches were closed. The vertical bulkhead doors were also closed in these tests.

3. Results of Tests

a. Effect of wind direction - (Tank stationary, engine idling at 900 rpm, all hatches closed, vertical bulkhead doors closed, floor panels open). Results, presented in Table 1, show clearly, that carbon monoxide builds up in the crew compartment to disturbing concentrations only when the wind is from the rear.

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APPENDIX

TABLE 1

EFFECT OF WIND DIRECTION

Stationary Vehicle

a. Wind, Head - Average Velocity 6.6 mph
Test Duration - 20 Minutes
Maximum CO Concentration - 0.005%

b. Wind, From 90° Left - Average Velocity 5.4 mph.
Test Duration - 20 Minutes
Maximum CO Concentration - 0.009%

c. Wind, From 90° Right - Average Velocity 6.3 mph.
Test Duration - 20 Minutes
Maximum CO Concentration - 0.002%

Wind, Tail Test Time, Min.	% CO	Av. Wind Velocity mph
0	0.030	8.4
1	0.037	"
3	0.049	"
5	0.040	"
10	0.044	9.6
12	0.026	"
13	0.032	"
14	0.040	"
15	0.028	12.0
16	0.030	"
17	0.022	"
18	0.030	"
19	0.034	5.6
20	0.040	"

b. Situation in Moving Vehicle. Two tests were conducted--one driving at approximately 10 mph into a head wind and the other at the same speed with a tail wind. Wind velocity in both tests equal. The results in Table 2 indicate that no hazard exists under these conditions.

TABLE 2

SITUATION IN MOVING VEHICLE

a. Wind, Head - Average Velocity 3 mph.
Test Duration - 14 Minutes
Maximum CO Concentration 0.006%

b. Wind, Tail - Average Velocity 3 mph.
Test Duration - 14 Minutes
Maximum CO Concentration - 0.008%

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TABLE 1

RETREAT TO MAIN DIRECTION

a. Wind: Head - Average velocity 6.6 mph
Test Duration - 50 Minutes
Maximum CO Concentration - 0.005%

b. Wind: From 90° Left - Average velocity 6.4 mph.
Test Duration - 50 Minutes
Maximum CO Concentration 0.005%

c. Wind: From 90° Right - Average velocity 6.3 mph.
Test Duration - 50 Minutes
Maximum CO Concentration - 0.005%

Test Time, Min.	% CO	Av. Wind Velocity mph
0	0.030	4.3
1	0.030	"
2	0.040	"
3	0.040	"
4	0.040	"
5	0.040	"
10	0.044	5.9
15	0.050	"
20	0.050	"
25	0.040	"
30	0.040	"
35	0.050	6.5
40	0.040	"
45	0.040	"
50	0.040	"
55	0.030	"
60	0.030	"
65	0.034	5.9
70	0.040	"

d. Situation in Moving Vehicle. Two tests were conducted--one driving at approximately 10 mph into a head wind and the other at the same speed with a tail wind. Wind velocity in both tests were light. The results in Table 5 indicate that no hazard exists under these conditions.

TABLE 5

SITUATION IN MOVING VEHICLE

a. Wind: Head - Average velocity 6 mph.
Test Duration - 14 Minutes
Maximum CO Concentration 0.005%

b. Wind: Left - Average velocity 5 mph.
Test Duration - 14 Minutes
Maximum CO Concentration - 0.005%

c. Relative influence of open and closed floor panels. With the tank stationary and a tail wind, the effect of closing the floor panels is to reduce somewhat the CO concentration in the crew compartment, as shown in Table 3. The concentration remains excessive, however, even under this condition of operation.

TABLE 3

OPEN, CLOSED FLOOR PANELS

Test Time, Min.	% CO	Av. Wind Vel., mph	Remarks
0	0	18.0	Horiz. Doors Open
3	0.014	18.0	"
8	0.024	18.0	"
11	0.038	18.0	"
13	0.031	18.0	"
20	0.026	18.0	"
23	0.031	15.6	"
28	0.016	18.0	Horiz. Doors Closed
33	0.014	15.6	"
38	0.016	18.0	"
43	0.022	15.6	Hroiz. Doors Open
48	0.024	12.0	"
53	0.030	18.0	"
58	0.026	15.6	"

d. Influence of direction of engine exhaust discharge. It is evident from the foregoing that the principal source of CO contamination in these tests was not back-flow of contaminated air from the engine compartment, but rather, the external return of engine exhaust gases into the air intake, resulting from the closeness of the discharge and intake openings on the rear deck and the vertical direction of discharge of the engine exhaust gases. To demonstrate this further, tests were run with diverting tubes placed over the engine exhaust terminals and carried forward beyond the air intake. Tests were conducted with a stationary tank (engine idling) and tail wind. Floor panels were open. The results, in Table 4, when compared with the levels recorded in Table 1, indicate clearly that the mixing of engine exhaust gases with the intake air is the source of trouble.

TABLE 4

EXHAUST DISCHARGE DIVERTED

Wind, Tail Test Time, Min.	% CO	Av. Wind Vel.,mph
0	0.005	-
5	0.016	17.0
10	0.005	15.6
15	0.005	18.0

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10	0.005	15.6
15	0.005	18.0

As a further demonstration, when carbon monoxide gas was deliberately introduced into the air intake or into the engine compartment, an immediate and pronounced increase in the CO concentration in the crew compartment was noted (Table 5).

TABLE 5

TRACING EXHAUST GAS FLOW

a. Tracer Gas Fed to Engine Intake:

Wind, Tail Test Time, Min.	% CO	Av. Wind Vel., mph	Remarks
0	0.005	10.8	
1	0.005	"	Start flow CO Tracer
2	0.035	"	Gas
2:40	-	"	Stop flow CO Tracer
3	0.148	"	Gas
4	0.061	"	
5	0.028	"	
6	0.019	"	

b. Tracer Gas Fed to Engine Compartment:

Wind, Tail Test Time, Min	% CO	Av. Wind Vel., mph	Remarks
0	0.007	17.0	
1	0.007	"	Start flow CO Tracer
1:30	-	-	Gas
2	0.052	"	
3	0.087	"	
4	0.056	"	Stop flow CO Tracer
5	0.043	"	Gas
6	0.019	"	
7	0.014	"	
8	0.012	"	

4. Discussion of Results. These tests point clearly to the engine exhaust gases as the source of contamination and indicate the marked influence of position and direction of discharge of the exhaust upon the magnitude of contamination in the crew compartment. Owing to the likelihood of prolonged exposure under conditions favorable to such crew compartment contamination, the CO concentration should not exceed 0.01%. Indeed, because of the apparent ease of correction, perhaps any evidence of contamination from this source should be regarded as unsatisfactory. The effects of breathing low concentration of carbon monoxide are not acute and may escape specific attention. For this reason, every precaution must be taken against unnecessary contamination. The means of correction employed in these tests was crude and served only to show that change in position and direction of discharge of exhaust fumes would be beneficial. Practical means for both production and field correction must be developed by the responsible agency.

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5. Winter Heating. With respect to the use of the winter heating facility, the possibility of crew compartment contamination from manifold leakage or other source of CO in the engine compartment has been demonstrated in these tests (introduction of CO gas into engine compartment). Acting upon the recommendation contained in the earlier AMRL report (8 Nov. 44), it is understood that OCO-D have provided signs on the bulkheads of M24 tanks warning against the opening of floor panels for heating. This warning sign is necessary.

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