ARMORED MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY

PROJECT NO. 1 - COLD WEATHER OPERATIONS

Report On

Sub-Project No. 1-11 - Influence of Cold Upon the Efficiency of Personnel

Project No. 1-11 INFORMATION COPY 25 May 1944

ARMORED MEDICAL RESEARCH LABORATORY
Fort Knox, Kentucky

Project No. 1-11
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25 May 1944

1. PROJECT NO. 1 - Cold Weather Operations, Sub-Project No. 1-11, Influence of Cold Upon the Efficiency of Personnel.

a. Authority - Letter Commanding General, Headquarters Armored Force, Fort Knox, Kentucky, File 400.112/6 GNOHD, dated September 24,1942.

b. Purpose - To determine the influence of exposure to cold upon the ability of men to perform certain psychomotor tasks.

2. DISCUSSION:

a. The consensus of opinion from experienced Arctic observers indicates that life under conditions of extreme cold affects both physical and mental efficiency. It is impossible to obtain quantitative data since most statements are based upon personal experiences. It appeared therefore, that study of the functions of the central and peripheral nervous systems might reveal measurable alterations in the promptitude and quality of response of the nervous system to various stimuli. Reaction time and responses to different stimuli are quantities readily capable of exact measurements by means of suitable apparatus.

b. Tests have been made on subjects living continuously in the cold and on others periodically exposed to low temperatures. The data and conclusions obtained from these sensori-motor tests will be presented in this report.

3. CONCLUSIONS:

a. The reaction time to visual stimuli is not altered by a cold environment.

b. Dexterity of the fingers and hand strength are markedly diminished by exposure to cold.

c. The best glove combinations now available, (the M-1943 shell and insert) are not capable of either keeping the hands warm or maintaining their functional efficiency.

4. RECOMMENDATIONS:

a. That in design, additional emphasis be placed on the capacity of hand wear combinations to maintain dexterity and functional efficiency of

the hand and fingers.

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The observed loss in efficiency due to exposure to cold has not been very clearly defined by field observers. The common impression appears to be that the performance of specified tasks requires the services of more man hours--the commonly stated ratio varying from two to four times that required to do the job under temperate environmental conditions. Comprehensive time studies have not been made. Such problems cannot be adequately studied in the laboratory. However, related problems, such as hand strength and finger dexterity are capable of analysis and solution. The hands and their adequate protection are of prime importance to a soldier, since they must be used continually and efficiently in the handling and repair of weapons and personal equipment.

During the past year considerable information has been obtained in an attempt to clarify these problems. These studies were conducted at -20°F (-28.9°C) with zero wind velocity. This temperature was selected because it was considered to be the lowest temperature at which both the personnel and the vehicular equipment of the Armored Command would be able to function without the occurrence of serious breakdowns. Observations were made during two types of cold exposure:

a. Long term--up to fourteen (14) days of continuous residence in the cold room, and

b. Short term - acute exposures of three (3) hours duration.

The tests employed in these studies were:

(1) Simple Visual Discrimination Reaction Time
(2) Johnson Code Test
(3) The gear assembly test devised at the laboratory
(4) Hand Grip Test - dynamometer

Twenty-two (22) men who lived in the cold chamber for periods of eight (8) to fourteen (14) days were subjects for one group of experiments. These men were exercised outdoors for ten days and then were brought into the air conditioned laboratory (temperature 70°F relative humidity 50%). After four days in this environment they entered the cold room, temperature -20°F, and remained there continuously for from eight (8) to fourteen (14) days. After arising from their sleeping bags, their daily routine consisted of the following: psychomotor tests, breakfast, a one-hour walk at 2.5 miles per hour, a period of quiet sitting for two hours followed by lunch. After lunch there was an hour's walk also at 2.5 miles per hour, a half hour of heavy work, another hour's walk, psychomotor tests and then supper. The evenings were free periods with entertainment in the form of motion pictures. Partial escape from the cold was possible by the provision of a small hut in the cold chamber, the temperature of which was above zero but below freezing. The men usually retired early in the evening to their sleeping bags. These men wore

the six piece arctic assembly with mukluks and felt boots (Alcan type). The handwear used was the M-1943 mitten combination.

The acute exposures consisted of periods of three hours at temperatures of approximately -15°F. Seventy men (fifty white and twenty negro) were used in these tests, the only psychomotor test made on them being the grip strength test. These men were dressed exactly alike, (Arctic Zone Issue M-1943) and were exposed to the cold on three successive mornings.

Johnson Code Test

This test is presumed to measure responses at a cortical level. However, since the test requires the use of a pencil to write down single letters of the alphabet, the test had for our purposes additional value as a measure of finger dexterity. An initial period of instruction and practice was given to each man prior to the first experimental session, in order to familiarize him with the tests and to advance his performance beyond the stage of rapid learning. The extremely long learning curve which was found to occur with this test was a handicap. Although the Johnson Code Test was performed with and without mittens, (wool, trigger finger) the results presented are only those when the mitten was worn. Two tests were given at each session. The data are presented in terms of corrected scores, the time required to perform the test adjusted for the errors made. In this test, the poorer performer has the higher score.

Since the individual curves had the same general configuration, an average curve is presented in Fig. 1. The men appeared to reach an equilibrium state in their scores just prior to entering the cool environment and remained close to this level during their stay at +72°F. Their performance was markedly inhibited by an environment of -20°F. The influence of cold on ability to perform the Johnson Code test is apparently masked by an uncompleted learning curve as is evident from the tests made in the follow-up period at a cool environment (+72°F.) which reveal continuing improvement in accordance with the trend line.

There is immediately a question as to which of the two factors acting in this test, cortical activity or finger dexterity, are primarily affected by the cold. Since there was no increase in the number of errors made by the men--the possibility that cortical activity may be impaired appears to be ruled out. It is probable therefore that the influence of cold is most evident in loss of finger dexterity.

The abilities to approximate the fingers and to flex and straighten the basal joints are presumeably affected by exposure to cold. The movements requiring the apposition of the thumb and fingers are concerned in many grasping and manipulative movements; activities such as writing, buttoning coats, working radio knobs, etc. become difficult.

Gear Test

Ten of the twenty-two subjects were tested on the time required to

dissemble and reassemble a Peep differential ring gear assembly. The subjects wore wool mittens and were required to use a hammer and an open-end wrench in addition to the hands for this manipulative test. Eight recessed nuts and bolts held the assembly together. A period of time for practice was again allotted the subjects to get them beyond the learning stage before actual testing began.

In general the results of this test were similar to those found for the Johnson Code Test. All men gave poorest performances when doing the test in the cold. In the cold environment, the average performance for the best two men was increased from approximately two and a half minutes in the cool to four minutes in the cold. Like all tests of this type there was a considerable difference in the amount of deterioration that occurred; the best subjects showed the smallest degree of change and the poorest the greatest change.

Simple Visual Discrimination Reaction Time

The discriminative reaction time, two choices, was measured by a one hundredth second standard electric time clock, the lighting of one of two neon tubes being used for the stimulus. This test was used as a measure of speed and precision. Each subject was given fifty trials and the average of all trials was used to indicate his performance. This test, while easy to give, also has a long learning period and is not readily applicable to studies of short duration. Minor inattentiveness can also produce considerable variation in performance.

Fig. 2 illustrates the typical responses observed in all of the subjects tested. The early portion of the learning curve is omitted. No alteration in reaction time was detected either during the exposure to the cold or as an after-effect of cold exposure. In ten (10) of the twenty-two (22) men given this test, we noted a sharp decrease in response on the first evening test in the cold environment. Following this initial lower response, the reaction times returned to their former values and exhibited only minor fluctuations thereafter. In general it appears that cold has no influence on speed, precision, nor reaction to visual stimuli as measured by this test.

Tests were made not only at the beginning and the end of a day's work but also during the day immediately following a bout of exercise. No effects due to fatigue were observed.

Grip Pressure (Hand Strength)

It was possible to make a study of the grip pressure exerted by seventy (70) subjects on each of three successive days of exposure to the cold. These men sat quietly for three hours each morning in the cold room at an ambient temperature of -10 to -14°F. They were dressed in similar clothing and all wore the same glove combination, viz. mitten, trigger finger insert, wool M-1943 and mitten, shell, trigger finger M-1943. Each man's grip was measured prior to entering the cold room and again immediately preceding his exit after three (3) hours of quiet sitting. The outer shell mitten was removed and the

hand strength measured with the wool mitten on the hand. A hand dynamometer, calibrated in kilograms, was used to measure the hand strength.

The average grip pressure exerted by the men was approximately 53 kilograms. This was decreased to some 45 kilograms when the mittens were worn (Table 2). The subjects showed wide variability in hand strength. After the men had sat for three hours at -10°F to -15°F there was an average decrease in grip strength of about twenty-eight (28) per cent (Table 1). There was no difference between the white and colored soldiers. The colored groups were in the cold for only two and one half hours instead of three hours required of the white soldiers. The frequency distribution of the alterations in hand pressure for all subjects is shown in Fig. 4. It is evident that there is a wide distribution in the extent of weakening which occurred. For some unexplained reason hand strength was not diminished in approximately two (2) per cent of the trials.

At the time that the men squeezed the dynamometer, just before leaving the cold room, sixty-five (65) per cent of them reported their hands to be "painfully cold", twenty-seven (27) per cent had hands that were just "cold" and eight (8) per cent had hands that were only "chilly". However, most of this last group had reported their hands to be cold with varying degrees of pain sometime during the previous hour and a half. No correlation was found between the subjective report of the severity of pain experienced in the hands and the extent to which grip pressure had decreased.

The loss in hand strength became apparent quickly in some of our subjects. Fig. 3 illustrates the behavior of one of these men. At the end of the first half hour a decrease of about twenty (20) per cent was observed although the subject's hands were still "comfortable". Even when he reported his hands to be only cold, he had a diminution in strength of approximately fifty (50) per cent. When control observations were made at the same time intervals at a comfortable ambient temperature (+75°F) only minor variations were found in the pressure exerted.

These data present a picture of the interference with strength and dexterity when men are exposed to cold environments. In general, interference is greatest for the man with the smaller grip strength and least for the man with the greater grip strength. It is also shown that the best glove combination available does not provide adequate insulation to permit men to maintain their hands at their optimum efficiency. Any loss in strength or dexterity is of extreme importance to Armored personnel. For example, nuts and bolts tightened in a warm environment could not be loosened by a cold hand nor tightened sufficiently to prevent a mechanical breakdown. The loss in hand strength and finger dexterity in cold environments indicate the need for extreme care in the design of equipment for cold weather operations.

APPENDIX

Encl #1

TABLE I

The Influence of Exposure to Cold
On the Grip Strength of White and Colored Soldiers

Day of Exposure	PER CENT LOSS OF GRIP PRESSURE			
	WHITE		COLORED	
	Right Hand	Left Hand	Right Hand	Left Hand
1	31.5	28.4	29.0	30.3
2	28.6	27.7	30.1	27.0
3	26.9	30.0	27.1	24.2
Average	29.0	28.7	28.7	27.2

TABLE II

Grip Strength of White and Colored Soldiers
At a Comfortable Ambient Temperature

	GRIP STRENGTH IN KILOGRAMS			
	WHITE		COLORED	
	Without Mittens	With Mittens	Without Mittens	With Mittens
MEAN	51	44	55	46
RANGE (maximum)	37 - 71	25 - 68	33 - 85	30 - 72

Encl # 2

AVERAGE SCORES ON THE JOHNSON CODE TEST DURING SUCCESSIVE CONTINUOUS EXPOSURES TO CONSTANT ENVIRONMENTAL CONDITIONS

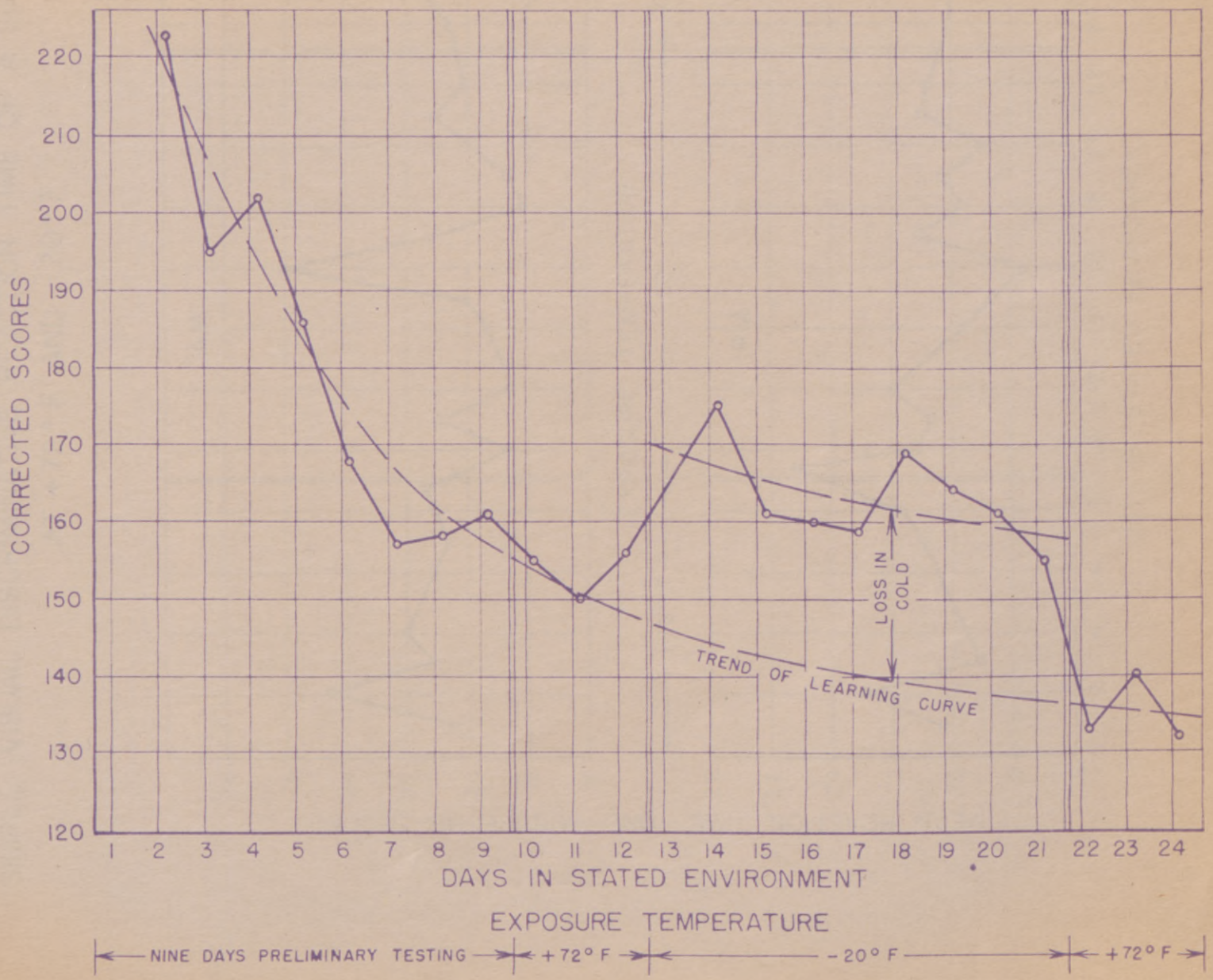
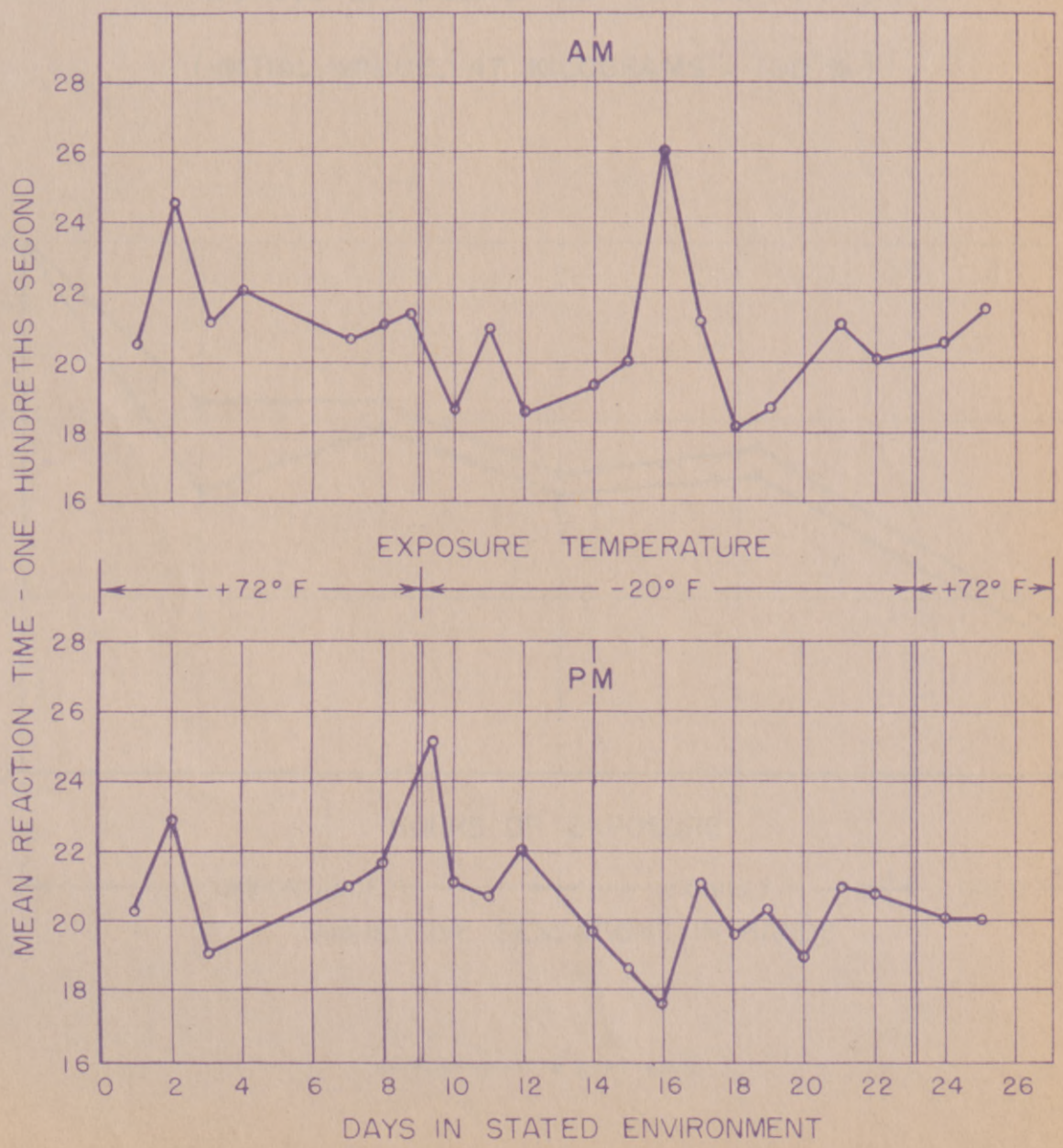


FIG. 1

FIG. 1

FIG. 2

SIMPLE VISUAL DISCRIMINATIVE REACTION TIME OF A SUBJECT AT +72° F AND -20° F



Encl #3

FIG. 2

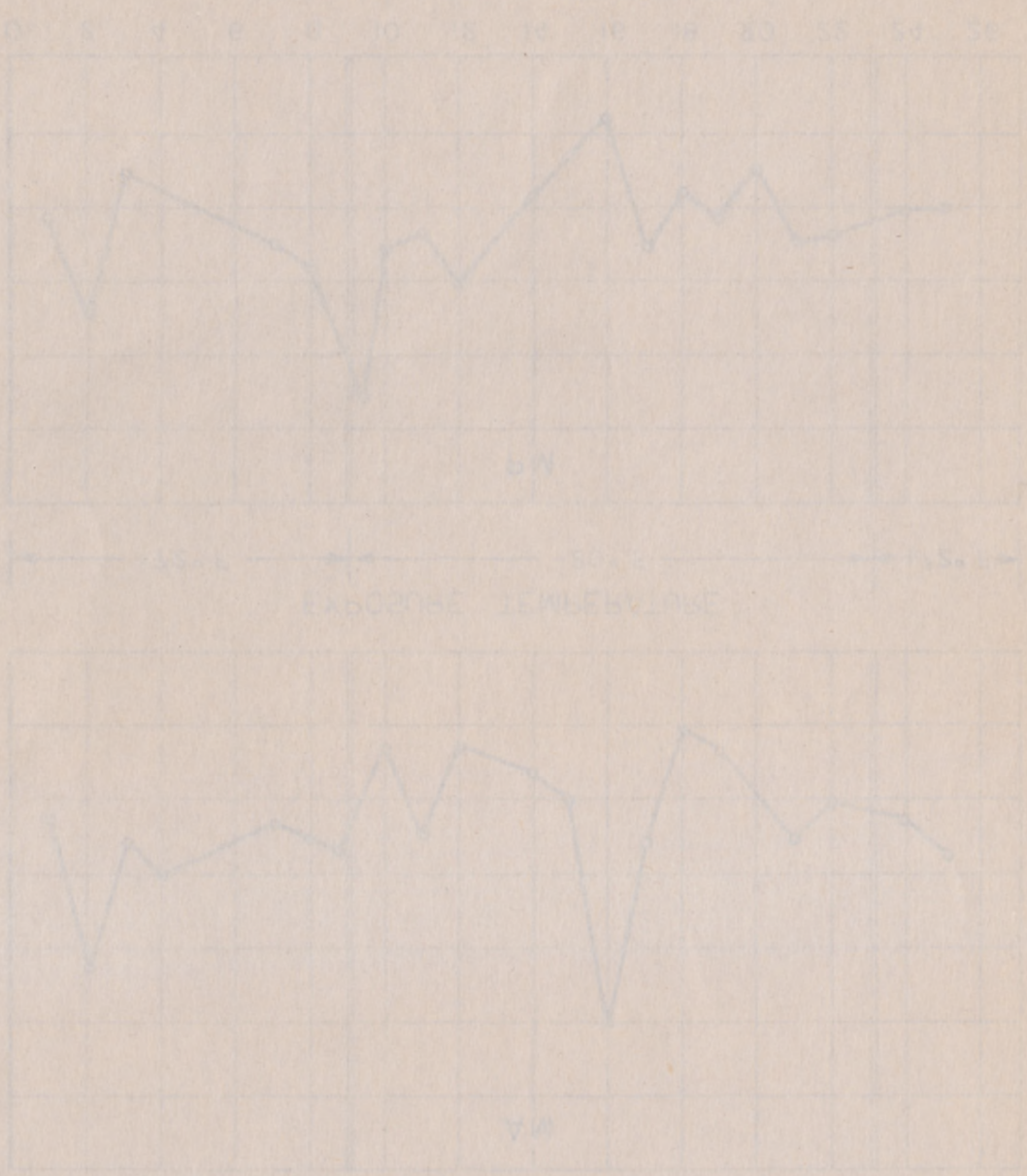


FIG. 3

CHANGES IN EXERTED PRESSURE (HAND GRIP) IN A SUBJECT DURING EXPOSURE TO -10° TO -14° F

(INITIAL VALUE, 47 KILOGRAMS = 100 %)

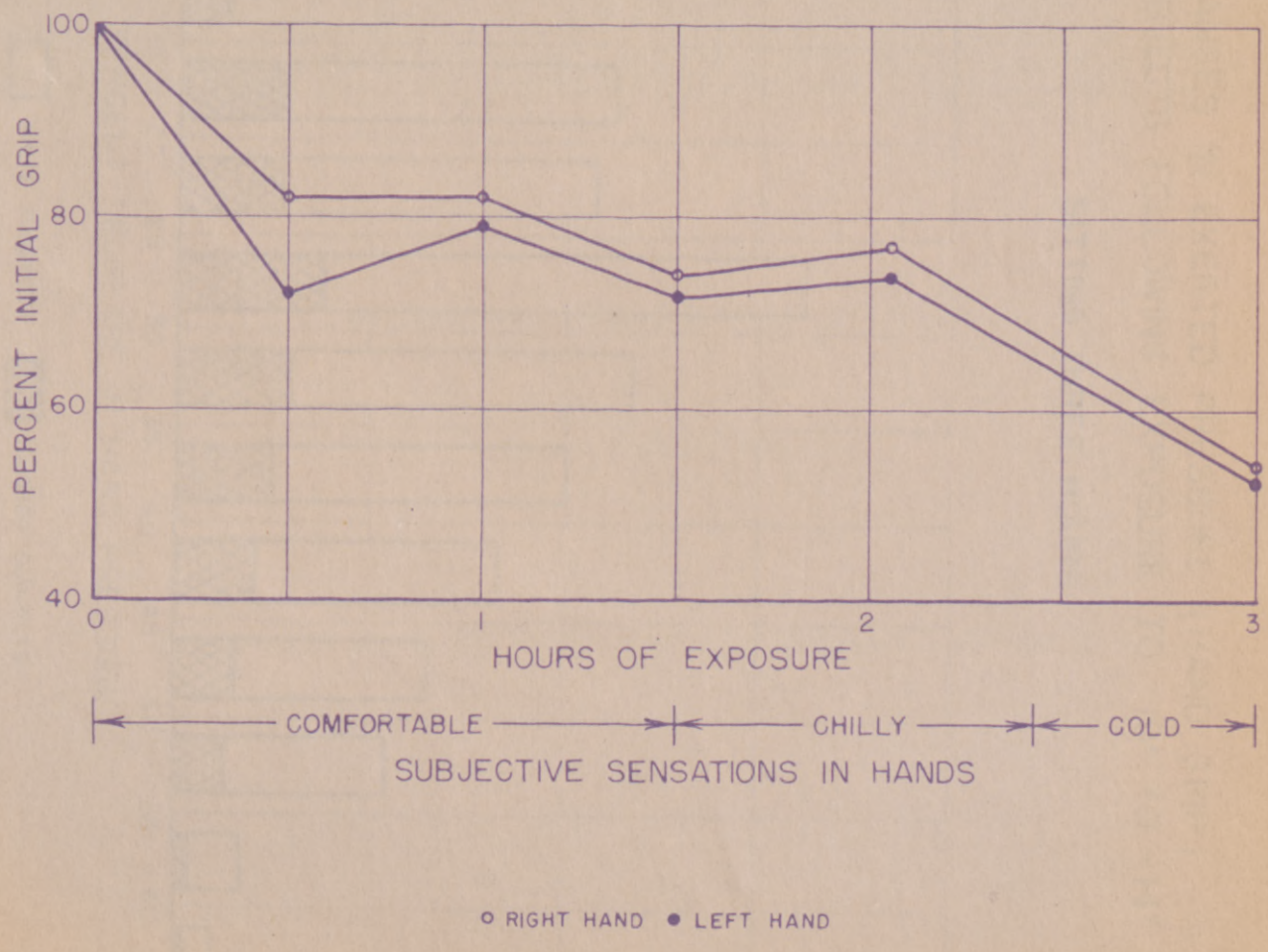


Chart #3

FIG. 3

CHANGES IN EXERTED PRESSURE (HAND GRIP)
OF 70 SUBJECTS FOLLOWING EXPOSURE TO -10° TO -14° F

SITTING THREE HOURS

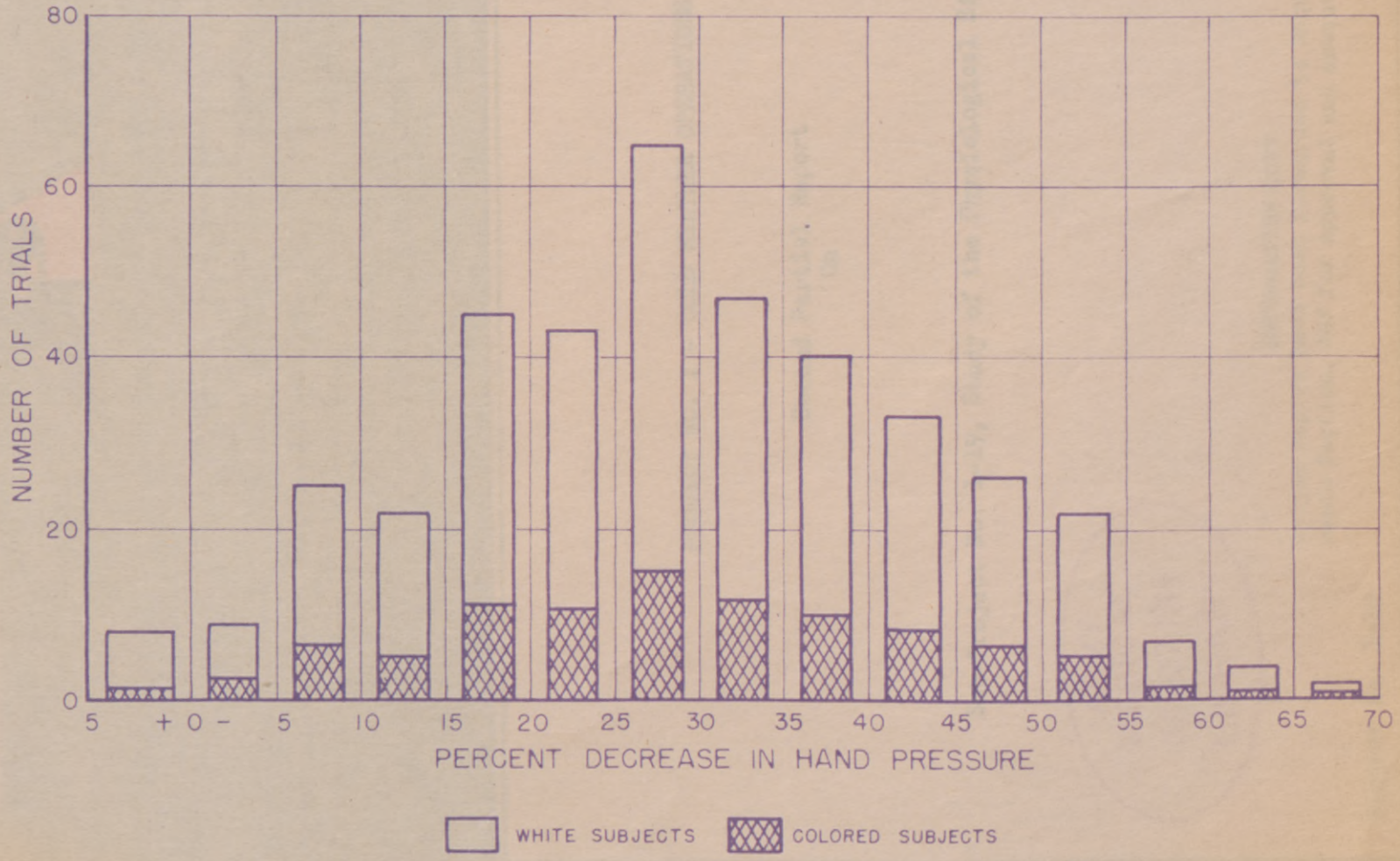


FIG. 4

FIG. 4

Chart #3