10 August 1966

Materiel Test Procedure 2-2-803*
Aberdeen Proving Ground

U. S. ARMY TEST AND EVALUATION COMMAND
COMMON ENGINEERING TEST PROCEDURE

HUMAN FACTORS ENGINEERING (VEHICLE)

1. OBJECTIVE

The objective of this MTP is to determine whether vehicle and vehicular equipment have conditions which will cause stress and fatigue in the assigned crew.

2. BACKGROUND

For equipment to be properly and effectively utilized, it must be designed for specific user personnel, e.g., personnel of a certain size and with certain mental and physical capabilities. In addition, the designer must consider the tactical situation under which the personnel will be operating and using the equipment. Conditions of stress and fatigue may be present and affect both man and machine in varying degrees.

In a tactical situation, reduced effectiveness may occur that is caused not by any basic inability of the troops to perform but by the fact that the individual soldier is overloaded both mentally and physically. Equipment must be designed for operational simplicity, particularly when personnel distractions are anticipated. Complexity of equipment is also undesirable from the viewpoint of requirements for reliability and maintainability.

The ability of men to operate the equipment, together with the quality of equipment performance, accounts for the capability and efficiency of the entire system. The vehicle designer has access to a wealth of data regarding limitations in human performance, as well as the conditions that produce optimum performance. A finished product, whether it be a vehicle or component, must provide the comfort, ease of operation, and environment that will promote maximum proficiency in the crew of a vehicle.

3. REQUIRED EQUIPMENT

a. Arctic Clothing
b. Helmets (tankers and combat)
c. Basic Equipment and Ammunition Load for all Vehicles
d. Sound Level Meters and Recorders as described in MTP 3-2-811 and MTP 2-2-615
e. Portable Pyrometer or Thermocouple
f. Infrared Carbon Monoxide Analyzers and Recorders as described in MTP 2-2-614
g. Dust Respirators
h. Goggles

*Supersedes Interim Pamphlet 60-305

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i. Tear Gas or Equivalent
j. Temperature/Humidity Chamber and Wind Machine
k. Vehicle Test Course
l. Air Flow Indicator
m. Humidity Indicator
n. Anemometer

4. REFERENCES

A. Maximum Noise Level for Army Materiel Command Equipment, Aberdeen Proving Ground, Maryland HEL Standard S-1-63B, June 1965
B. Human Factors Engineering Design Standard for Vehicle Fighting Compartments, Aberdeen Proving Ground, Maryland, HEL Standard S-2-64, May 1964
C. Human Engineering Factors Requirements for the Development of U. S. Army Materiel, Aberdeen Proving Ground, Maryland, HEL Standard S-4-65, January 1965
D. Human Factors Engineering Design Standard for Wheeled Vehicles, Aberdeen Proving Ground, Maryland, HEL Standard S-6-66 (Proposed)
E. AR 705-15, Operation of Materiel Under Extreme Conditions of Environment, with Change 1 dated 14 October 1763
F. MTP 2-2-503 Maintenance
G. MTP 2-2-614 Toxic Fumes
H. MTP 2-2-615 Security From Detection
I. MTP 2-2-616 Night Performance
J. MTP 2-2-708 Vehicle Heaters - Personnel
K. MTP 2-2-808 Field Shock and Vibration
L. MTP 3-2-811 Noise and Blast Measurement
M. MTP 3-2-603 Gun Control Systems
N. MTP 3-2-605 Accuracy Firing of Vehicular Mounted Weapons
O. Automotive Test Facilities, Development and Proof Services, Aberdeen Proving Ground, Fourth Edition, May 1966

5. SCOPE

5.1 SUMMARY

This MTP describes the procedures for evaluating the human engineering aspects of vehicle design with respect to conditions which will reduce operational effectiveness. Outlined in this pamphlet is guidance of space versus anthropometrics; ease of operation of vehicles and their components (including weapons), effects of climate and other environmental elements such as fumes and dust, shock and vibration, noise, and darkness.

5.2 LIMITATIONS

This test is limited to the detection of problem areas. Detailed comparisons of vehicle components with recommended design objectives are not part of this test.

6. PROCEDURES

6.1 PREPARATION FOR TEST

6.1.1 Pre-Test Operations

a. Record the model, serial number, and manufacturer of the test vehicle.

b. Load test vehicle with actual cargo, or a simulated payload, and basic load of ammunition.

c. Select complete crew for test vehicle.

NOTE: Vehicles are designed to accommodate personnel with physical characteristics in the 5th through 95th percentile range (Fig. 1). Crew personnel, preferably both large and small men, should be selected from this category, since any observed physiological difficulties are reported as deficiencies only if the pertinent anthropometric measurements of the subject are within these percentiles.

6.2 TEST CONDUCT

NOTE: Observation for human factor problem areas are made by test personnel throughout the entire test program. When operating difficulties, safety, or physiological problems are encountered, the human engineering standards of References 4A, 4B, 4C and 4D pertaining to the respective areas shall apply as guidance.

6.2.1 Crew Stations and Anthropometrics

a. With the normal crew complement in the test vehicle dressed for a temperature (70°F) climate and combat equipped (tankers helmets, personnel weapons, etc.) determine, using personnel who fall within the military anthropometric data of Figure 1, the following:

1) Operating space available to:

   a) Operate controls comfortably and efficiently
   b) See vehicle path of operation
   c) Read instruments with the seat in its normal position (i.e., seat in "buttoned" or "unbuttoned" position for tanks)
   d) Remain clear of moving parts (gun recoil)
   e) Move as required (Tank gun loader requirements)

2) Compatibility of vehicle seats

   a) For crew comfort when seated for long periods of time
   b) With crew member movements when performing their duties

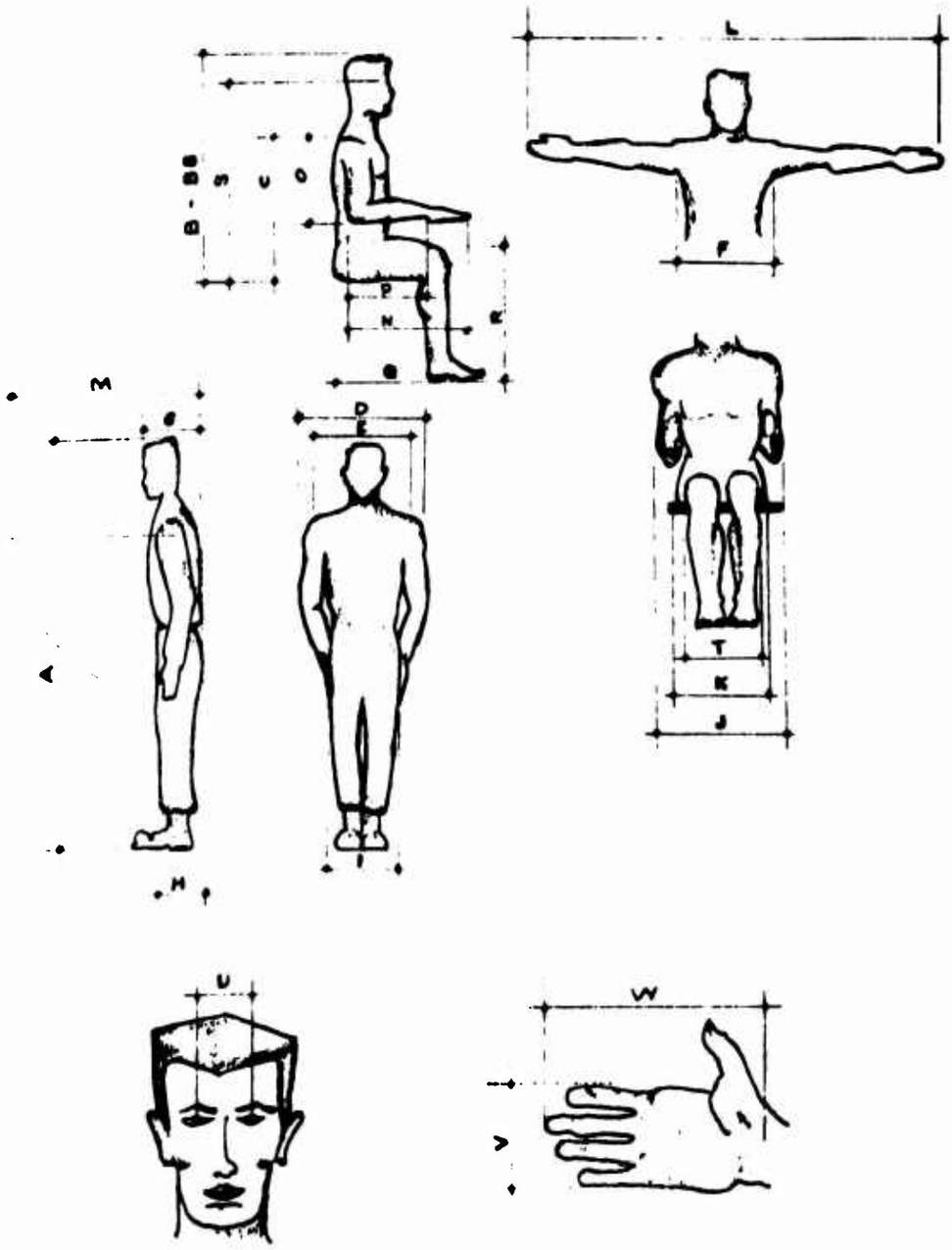

Figure 1. Military Anthropometric Data

Clothed Body Dimensions of Soldiers[a]

	Percentiles 5th	95th
Weight (Pounds)	141.9	210.2
Dimensions (Inches)		
A Height	67.8	75.8
B Sitting Height	35.1	39.4
C Shoulder Height, Sitting	21.4	29.3
D Shoulder Breadth	16.7	19.6
E Bi-Acromial	-	-
F Chest Breadth	11.0	13.6
G Chest Depth	8.4	10.8
H Buttock Depth	7.6	10.2
I Hip Breadth, Standing	12.6	15.0
J Elbow Breadth	15.7	20.4
K Hip Breadth, Sitting	13.2	16.0
L Span	65.9	75.6
M Max. Reach from Wall	35.4	41.7
N Forearm-Hand Length	17.6	20.2
O Shoulder-Elbow Length	13.2	15.4
P Elbow-Center of Fist	-	-
Q Buttock-Knee Length	21.9	25.4
R Knee Height	20.1	23.3
S Eye Height, Sitting	29.4	33.5
T Knee-to-Knee Breadth	7.2	8.8
U Interpupillary Distance	2.3	2.7
V Hand Breadth	3.2[b]	3.7[b]
W Hand Length	6.9[b]	8.0[b]
GI Shoe Length	11.0	12.7
GI Shoe Width	4.0	4.5

[a]Wearing basic uniform of underwear; khakis, OD's, or Fatigues; socks, shoes; helmet and liner. Additional data including nude dimensions are included in HEL Standard S-2-64.

[b]Without gloves.

Figure 1. Military Anthropometric Data (Cont)

3) Existance of Physiological Difficulties

NOTE: Any observed physiological difficulties are reported as deficiencies if the pertinent anthropometric measurements of the subject are within the percentiles of Figure 1, i.e., a report that a large man's head touches the cab roof in a truck is a valid objection only if the man is within the group between the 5th and 95th percentile of the Army population. If the military characteristics would not be violated, however, an increase in cab height to accommodate beyond 95th percentile could be recommended.

b. Repeat step a with the crew dressed in arctic clothing.

6.2.2 Ride Quality Factor

Determine crew comfort to vehicle velocity, acceleration, and jerk by performing the procedures described in MTP 2-2-808 and comparing the results with Figure 2.

6.2.3 Noise Factors

Determine the effects of various external and internal noises, using the measuring techniques described in MTP 2-2-615 and MTP 3-2-811 to obtain noise level measurements, on the crews ability to perform their duties without being subject to undue stress due to deterioration in auditory acuity (either temporary or permanent) or the mental and/or physical disturbances which are caused by unacceptable noise frequency levels.

Table I lists the maximum acceptable steady state noise level, developed by the test vehicle and its auxiliary equipment, to which the crew shall be exposed.

TABLE I

Maximum Acceptable Steady State Noise Level

Octave Band Limits (CPS)	Sound Pressure Level (dB re 0.0002 microbar)
37.5 - 75	120
75 - 150	115
150 - 300	109
300 - 600	101
600 - 1200	93
1200 - 2400	89
2400 - 4800	89
4800 - 9600	91

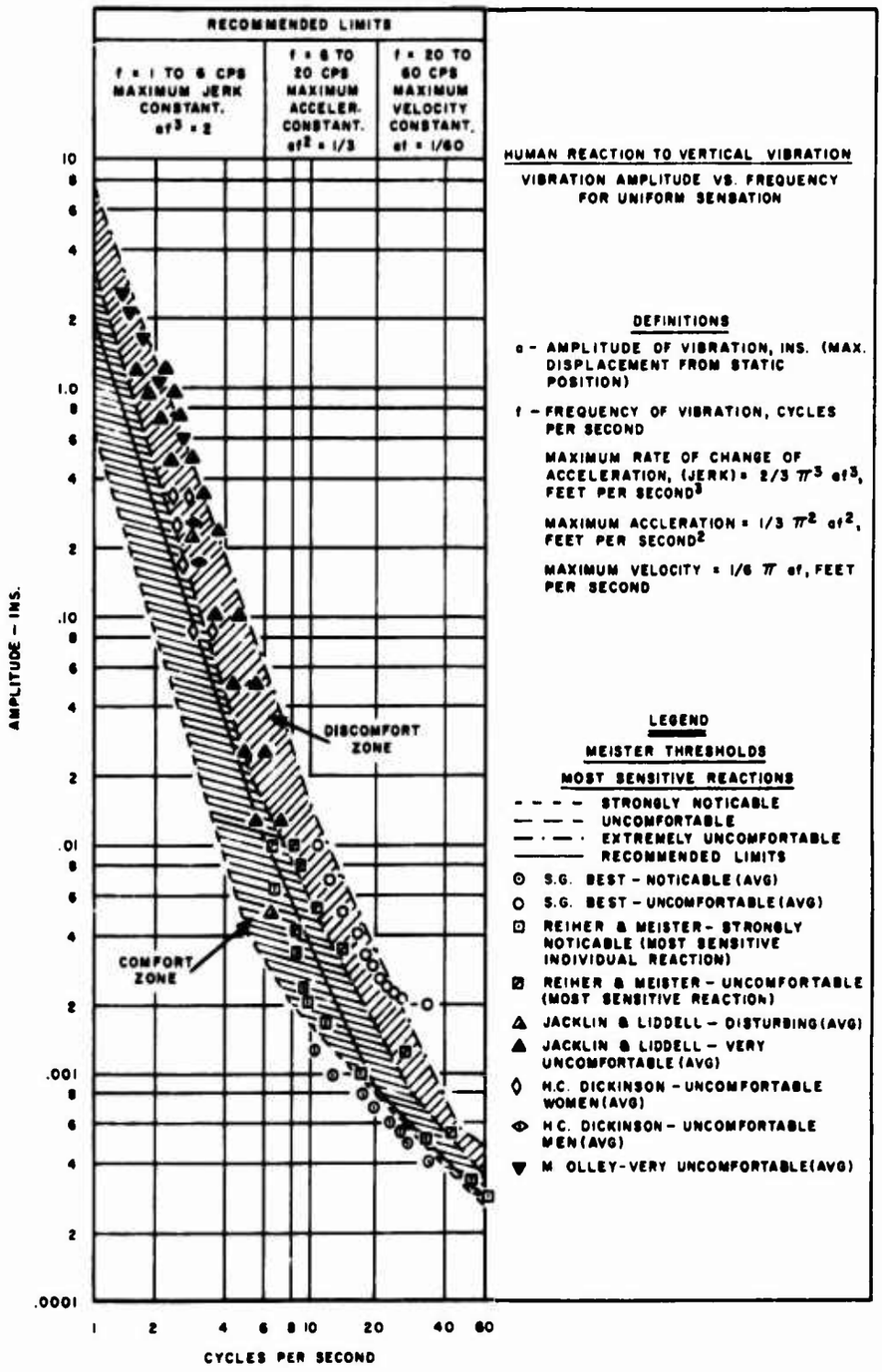

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FIGURE 2 - HUMAN REACTION TO VERTICAL VIBRATION

NOTE: Every effort shall be made to isolate the principle source of unacceptable noise levels by selective elimination of components or variations in operating conditions. Small improvements should not be overlooked as a reduction of as little as 3db at high noise levels is beneficial.

6.2.4 Temperature

Temperature is the environmental condition that has the greatest effect upon the human body. The optimum temperature for personnel varies according to the nature of the tasks performed, clothing worn, the relative humidity in warm climates, and the wind velocity in cold climates.

6.2.4.1 Temperature/Humidity Conditions

Determine the ability of those vehicles with air conditioning systems to reduce the temperature-humidity conditions in the vehicle to the environment of Table II and Table III under the conditions stated:

a. Emplace the vehicle, with all windows, doors, or hatches closed in a temperature-humidity chamber

b. Apply the following conditions to the chamber:

1) Temperature of 105°F
2) Absolute humidity of 13 grains/ft^3

c. Operate the test vehicles air conditioning system and record the temperature and relative humidity obtained in the vehicle.

d. Repeat steps b and c for a temperature of 95°F and absolute humidity of 13 grains/ft^3.

e. Repeat steps b and c for a temperature of 85°F and an absolute humidity of 13 grains/ft^3.

TABLE II. OPTIMUM TEMPERATURES AND RELATIVE HUMIDITIES FOR ACCOMPLISHING LIGHT WORK WHILE DRESSED NORMALLY*

In Warm Climate		In Cold Climate	
Temp., °F	Rel. Hum., %	Temp., °F	Rel. Hum., %
70	100	65	100
75	50-100	70	40-100
80	15-100	75	0-100
85	0-65	80	0-60
90	0-40	85	0-30
95	0-20	90	0-10
98	0-10		

*Air movement 15 to 25 ft. per min. (HEL Standard S-2-64)

TABLE III. TEMPERATURE-HUMIDITY MAXIMUMS FOR RELIABLE WORK DURING PROLONGED EXPOSURE

Temp., °F	Max. Rel. Hum., %
85	100
90	70
95	50
100	30

6.2.4.2 High Temperature Conditions

Determine the ability of the vehicle's air conditioning system to overcome the effects of a hot-dry climate and maintain a temperature, within the vehicle, of no greater than 98°F as follows:

a. Emplace the vehicle with all doors, windows, or hatches closed where it shall be subject to the upper limit hot dry climatic conditions.

1) Ambient air temperature (4-6 feet above ground) of 120°F
2) Ground temperature of 145°F
3) Solar radiation at a rate of 360 BTU/ft^2 hr.
4) Wind speed of 6 knots

NOTE: If the above conditions cannot be met, subject the test vehicle to an ambient temperature of 120°F for a minimum of 4 hours.

b. Operate the air conditioning system for maximum output and record the following:

1) Stabilization temperature
2) Time required to reach temperature stabilization.

6.2.4.3 Low Temperature/Wind Chill Conditions

Determine the ability of the vehicle's heating system to overcome the effects of wind chill and maintain a temperature, within the vehicle, of no less than 0°F as follows:

a. Emplace the vehicle with all doors, windows, or hatches closed in a temperature chamber equipped with a wind machine or circulation system.

b. Apply conditions which will cause a wind chill factor of 2000.

NOTE: See Appendix A for wind chill factor conditions.

c. With the vehicle heating system at maximum output (see MTP 2-2-708) record the temperature at which the vehicle stabilizes.

d. Repeat steps b and c for a wind chill factor of 1500.
e. Repeat steps b and c for a wind chill factor of 1000.

NOTE: Prolonged exposure of an ungloved man to temperature below 55°F often results in a stiffening of the fingers, thus degrading performance in manual tasks.

6.2.4.4 Vehicle Temperature

Record any vehicle condition which shall affect crew operation such as:

a. Proximity of hot engine exhaust to crew.
b. Components, which come in contact with crew members, which become excessively hot or cold.
c. Presence of drafts.

6.2.5 Fumes and Ventilation Effects

Moderate concentrations of obnoxious or objectional fumes can impair efficiency without actually having toxic effects. When these fumes cannot be controlled at the source it is necessary to provide ventilation. Figure 3 indicates the effect specific concentrations of carbon monoxide have upon the crew for given exposure times.

6.2.5.1 Fume Tests Without Ventilation

Perform the following when the vehicle is without a ventilation system or the system is inoperative:

a. Install carbon monoxide analyzers and recorders as described in MTP 2-2-614.
b. Perform the tests described in MTP 2-2-614 and record the concentration of toxic fumes.

6.2.5.2 Ventilation Tests

Perform the following when the test vehicle has a ventilation system:

a. Determine the amount of minimum air flow:

NOTE: A minimum amount of 15 cubic feet per minute of fresh air flow is required, per person, assuming no strenuous physical activity, engines off and weapons not being fired.

b. Repeat the procedure of paragraph 6.2.5.1 with adverse winds of up to 30 mph, and the ventilation system operating.
c. Determine the ability of a positive pressure ventilation system to:

1) Prevent the entrance of CBR agents by exposing the test

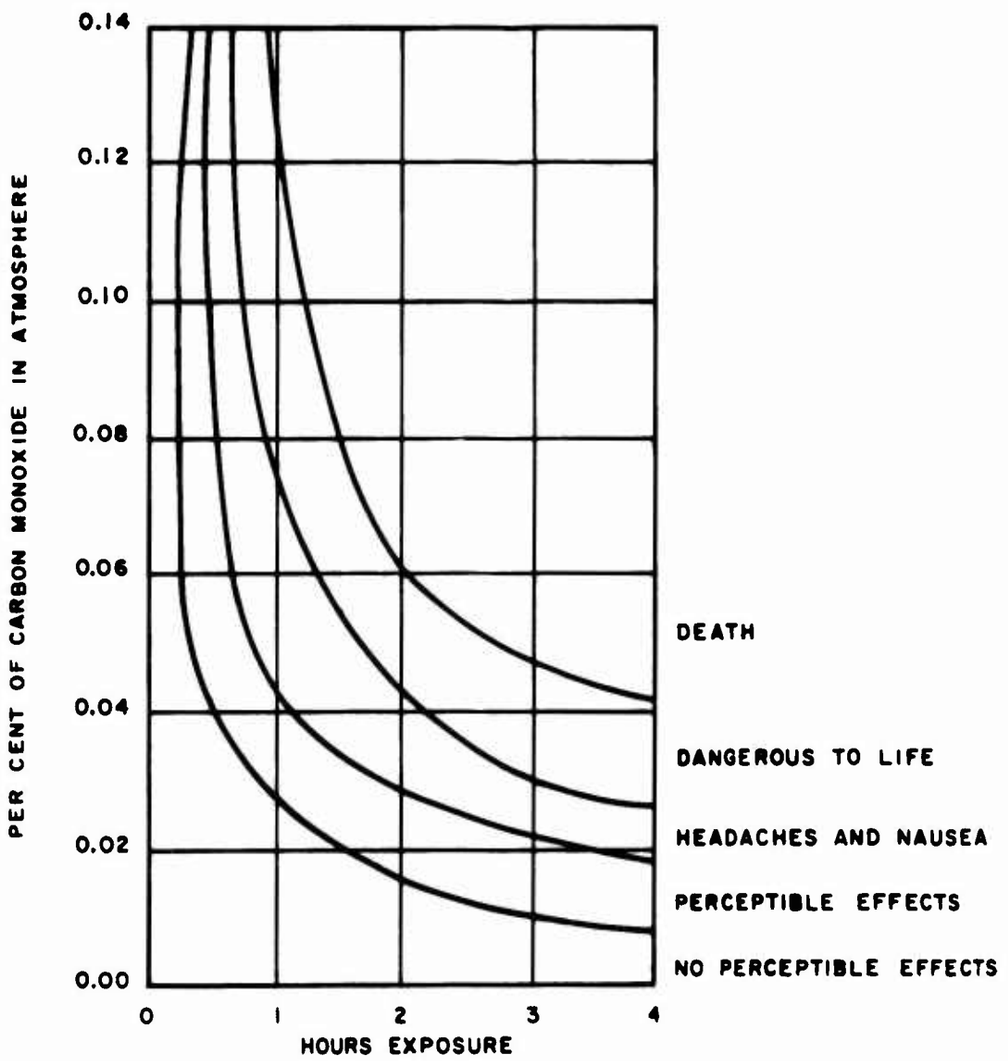

FIGURE 3. EFFECTS OF CARBON MONOXIDE FOR A GIVEN TIME ON HUMAN BEINGS

vehicle to tear gas.

2) Prevent dust from entering crew compartment while performing the procedures of paragraph 6.2.6.1.

6.2.6 Dust, Mud and Water Tests

6.2.6.1 Dust Test

a. Operate the test vehicle over a course similar to the Perryman Cross-Country Course No. 2 at the Aberdeen Proving Ground (Reference 4M) under dry (dust) conditions. When required goggles and respirators shall be provided.

NOTE: The course is laid out on a loop of moderately irregular terrain. The soil includes Sassafras Loam, a silty loam having 17.3 percent clay content, and Sassafras slit loam, a silty loam having less than 15 percent clay.

b. Determine the following:

1) Vehicles dust dissemination characteristics
2) Effect of dust produced on crew
3) Location of dust entry points

6.2.6.2 Mud Test

a. Operate the vehicle over the test course used for the Dust Test (paragraph 6.2.6.1) after soaking the course with water to form mud.

b. Determine the following:

1) Vehicles mud disseminating characteristics
2) Effect of mud on crew and their ability to perform their functions
3) Location of mud entry points

6.2.6.3 Water Tests

Operate the vehicle over flooded areas and determine the following:

NOTE: Flooded areas are such that the water is high enough to cause splashing and inconvenience but not capable of flooding air intakes or vents, crankcase and transmission vents, engine exhaust and intake or causing shorting of ignition wires.

a. Vehicles water splashing characteristics
b. Effect of water on crew and their ability to perform their functions.
c. Location of water entry points.

6.2.7 Controls Tests

Perform the following:

a. Operate all controls, i.e., handcranks, handwheels, knobs, legend switches, levers, pedals, pushbuttons, rotary selector switches, toggle switches and thumbwheels, and determine:

1) Whether any control pressures cause fatigue when operated continuously.
2) Awkwardness to operate controls, i.e., improper location of controls or seat(s).

NOTE: Acceptable pressure standards are outlined in reference 4B. Frequency of the operation must be considered, since higher forces are acceptable for intermittent operations, i.e., operating a hatch, than for continuous movements, i.e., steering. Ideally, there should be a definite "feel" in controls so that the operator can sense such things as braking effort, steering, and force generated in winches and cranes.

b. Determine whether special design characteristics can be incorporated to facilitate control identification, thereby, aiding in the reduction of fatigue.

NOTE: Special design characteristics consist of recommendations such as: color coding for daylight identification, colored lights on control knobs, control knobs of various shapes for night operations, etc.

6.2.8 Instrument Visibility Tests

a. Determine the readability of the following types of instruments:

1) Check reading instruments (indicates at a glance if something is not happening) such as needle indication at zero.
2) Qualitative indication instruments (indicates something is or is not satisfactory within prescribed limits) such as oil and engine temperature indicators.
3) Quantitative indication instruments (indicates precise measurements) such as odometers, range finders and azimuth indicators.

b. Determine the ease of reading instruments and identifying warning lights as regards the following:

1) Location with respect to the operator normal position.
2) Seat adjustment (raised or lowered)

NOTE: 1. All instruments should be readable without movement of the head with the possible exception of drivers of combat vehicles operating in the raised seat position.

2. Warning lights should have sufficient brightness and be so located that they attract the attention of the operator without his direct glance.

6.2.9 Laying and Firing of Weapons

Tests shall be performed as described in the applicable procedures of MTP 3-2-603 and 3-2-605 to determine that the gun crew can meet military performance specifications under the following conditions:

a. Operators shall consist of personnel made up of men in the 5th through 95th percentiles.

b. Fire Control and firing tests shall be carried out in all types of climate with personnel appropriately dressed.

c. Record the effect of clothing and temperature on crew effectiveness.

6.2.10 Night Operations

The ability of the vehicle crew to operate effectively and efficiently during night operations shall be determined as described in MTP 2-2-616.

6.2.11 Driver Maintenance

Check the location of driver first echelon maintenance components (oil level, water level, air pressure, lubrication, etc. as described in MTP 2-2-503) to insure adequate accessibility, visibility, working clearances, and ease of adjustment, removal, installation and cleaning when the driver is barehanded and gloved.

6.3 TEST DATA

6.3.1 Pre-Testing Operation

Record the following:

a. Vehicle Model No.
b. Vehicle Serial No.
c. Vehicle Manufacturer
d. Vehicle Weapon(s), if applicable

6.3.2 Crew Station and Anthropometrics

Record the following:

a. Crew dress (arctic clothing, tropic clothing)
b. Adequacy of space to:

1) Operate controls comfortably and efficiently
2) See vehicle path of operation

3) Read instruments with the seat in a normal position
4) Remain clear of moving parts (gun recoil)
5) Move as required (Tank gun loader)

c. Compatibility of vehicle seats for:

1) Crew comfort when seated for long periods of time
2) Crew member movements when performing normal duties

d. Physiological difficulties (low cab roof, object close to eyes)

6.3.3 Ride Quality Factor

Data shall be collected and recorded as described in MTP 2-2-808.

6.3.4 Noise Factors

Data shall be collected and recorded as described in MTP 2-2-615 and MTP 3-2-811.

6.3.5 Temperature

6.3.5.1 Temperature/Humidity Conditions

Record the following:

a. Temperature in °F and relative humidity in % obtained in an ambient condition of 105°F and an absolute humidity of 13 grains/ft^3.
b. Temperature in °F and relative humidity in % obtained in an ambient condition of 95°F and an absolute humidity of 13 grains/ft^3.
c. Temperature in °F and relative humidity in % obtained in an ambient condition of 85°F and an absolute humidity of 13 grains/ft^3.

6.3.5.2 High Temperature Conditions

Record the following:

a. Environment (Solar radiation, 120°F only)
b. Stabilized temperature in °F
c. Time required for stabilization, in minutes

6.3.5.3 Low temperature/Wind Chill Conditions

Record the following for each wind chill factor used:

a. Wind chill factor (2000, 1500, 1000)
b. Temperature in °F to obtain wind chill
c. Wind velocity in mph, and direction (toward front of vehicle) to obtain wind chill.
d. Vehicle stabilized temperature at crew positions in °F.

6.3.5.3 Vehicle Temperature

Record the following:

a. Proximity of crew to engine exhaust
b. Components which:

1) Overheat
2) Remain cold

c. Presence of drafts

6.3.6 Fumes and Ventilation Effects

6.3.6.1 Fume Test Without Ventilation

Data shall be collected and recorded as described in MTP 2-2-614.

6.3.6.2 Ventilation Test

Record the following:

a. Minimum fresh air flow in cubic feet per minute
b. Data as collected and recorded in MTP 2-2-614
c. Ability of positive pressure ventilation systems to:

1) Prevent CBR agents from entering the vehicle
2) Dust from entering the vehicle

6.3.7 Dust, Mud and Water Tests

6.3.7.1 Dust Test

Record the following:

a. Vehicle dust dissemination characteristics (fenders kick up dust)
b. Dust effect on crew (irritation, requires goggles)
c. Dust entry locations (cab floor)

6.3.7.2 Mud Test

Record the following:

a. Vehicle mud dissemination characteristics (fenders kick up mud)
b. Mud effect on crew (bad footing)
c. Mud effect on crew's ability to perform functions (knobs slippery)
d. Mud entry locations (cab floor)

6.3.7.3 Water Test

a. Vehicle water splashing characteristics (sand shield causes water spray)
b. Water effect on crew (obscures windshield)
c. Water effect on crew's ability to perform functions (rusts hinges)
d. Water entry location (under door)

6.3.8 Controls Tests

Record the following:

a. Control pressures which cause fatigue
b. Awkwardness of controls

6.3.9 Instrument Visibility Tests

Record the following:

a. Readibility of the following instruments:

1) Check reading
2) Qualitative
3) Quantitative

b. Reason specific instruments and/or warning lights cannot be seen with ease (radio transmitter light on too dim, vehicle generator indicator too far to right).

6.3.10 Laying and Firing of Weapons

Record the following:

a. Test temperature in °F and type of clothing worn (tropic, arctic)
b. Fire control data as collected and recorded in MTP 3-2-603
c. Firing accuracy and timing data as collected and recorded in MTP 3-2-605
d. Effect of clothing and temperature on the crew.

6.3.11 Night Operations

Data shall be collected and recorded as described in MTP 2-2-616.

6.3.12 Driver Maintenance

a. Record drivers clothing (gloved, ungloved)
b. Record the following for first echelon maintenance components:

1) Accessibility
2) Visibility
3) Working cleanliness
4) Ease of adjustment
5) Ease of Removal

6) Ease of installation
7) Ease of cleaning

6.4 DATA REDUCTION AND PRESENTATION

An appraisal of an Army vehicle from the point of view of human engineering is based primarily upon design considerations. Many compromises with established standards of comfort may be necessary to produce a practical vehicle fulfilling military goals. This will be true particularly in such areas as noise and vibration in tracklaying vehicles. The project engineer should nevertheless examine the data carefully to determine whether the vehicle as tested is designed as nearly as possible to those standards, considering its current state of development. Beyond that, serious shortcomings should be reported, the correction of which will then become an objective for improving the vehicle at hand or in planning future designs.

APPENDIX A

WIND CHILL FACTORS

Wind chill is a measure of cold discomfort derived from the rate of freezing of water when influenced by ambient temperature and wind. Figure A-1 shows the relationship of temperature and wind chill values and Table A-I is a qualitative description of human reaction to wind chill values.

Wind chill data can be obtained from local meteorological station when running outdoor winter tests, or can be computed using the following formula:

$$Ka = 0.248\ (14.95\sqrt{W} + 23.38 - W)\ (91.4 - T)$$

where: W = Wind speed in mph
T = Temperature in °F

When conducting temperature chamber-wind tests using a pre-determined value of Ka and an arbitrary value of either windspeed or temperature the following formula should be used:

$$T = 91.4 - \frac{Ka}{0.248\ (14.95\sqrt{W} + 23.38 - W)} \quad \text{or}$$

$$W = \left[\frac{-14.95 \pm \sqrt{223.5 - 4\left[\frac{Ka}{0.248(91.4-T)} - 23.38\right]}}{2}\right]^2$$

Table A-1. Human Reaction to Windchill Values

Windchill Value	Human Reaction
100	Warm
400	Pleasant
800	Cold
1000	Very cold
1200	Bitterly cold
1400	Exposed flesh freezes

Supersedes Page A-1, Appendix A, 10 August 1966