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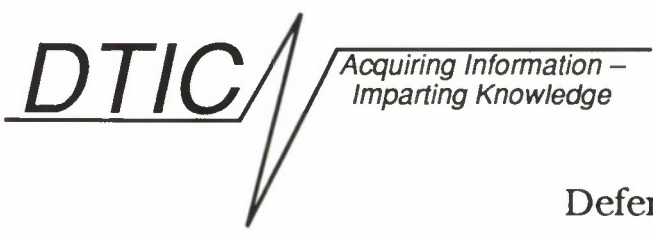
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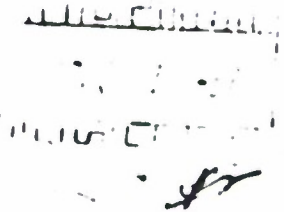
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Technical Memorandum 14



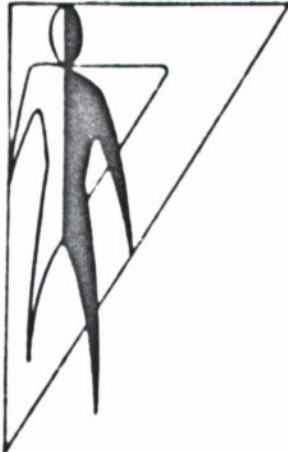
MEASUREMENT OF TEMPERATURES IN VARIOUS
ORDNANCE EQUIPMENT UNDER THE DESERT ENVIRONMENT

Stanley L. Revesman
Frederick W. Schulze



February 1956

HUMAN ENGINEERING LABORATORIES



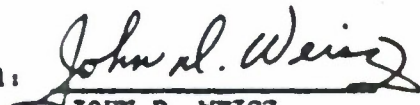
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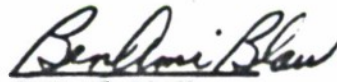
Technical Memorandum No. 14
Measurement of Temperatures in Various
Ordnance Equipment Under the Desert Environment

Stanley L. Reevesman
Frederick W. Schulze


Reviewed:


JOHN D. WEISZ
Chief
Psychology Division

Approved:


BENAMI BLAU
Director

Reviewed:


CHARLES S. CRUSE
Chief
Engineering Division

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Human Engineering Laboratory
Aberdeen Proving Ground, Md.
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A B S T R A C T

During the summer test program of 1955, a survey of temperatures encountered by operators of Ordnance equipment was conducted at Yuma Test Station, Yuma, Arizona, by Human Engineering Laboratory personnel. The purpose of this survey was to obtain these temperatures for simulation purposes in laboratory test situations and for defining the range of temperatures pertinent to Ordnance equipment used in the desert.

MEASUREMENT OF TEMPERATURES
IN VARIOUS ORDNANCE MATERIEL
UNDER DESERT ENVIRONMENT

One of the important environmental problems encountered in human engineering research is the effects of temperature on the efficiency of the human operator. Most of the equipment presently designed by the Ordnance Corps is expected to be used efficiently in both the arctic and desert environments. Little is known, however, about the temperatures encountered in Ordnance equipment under these conditions. In a recently completed literature survey for the Human Engineering Laboratory, H. J. Bond and R. B. Sleight* stated the following:

"A problem for which no references have been found is that of the ability to operate the controls of equipment which have become heated to near or above the pain producing temperatures, conditions which frequently occur under the midday desert sun. A human engineering investigation of the extent to which psychomotor performance is related to the temperatures of operating controls of equipment would be valuable in setting optimum requirements for design of such controls."

In order to determine the scope of this problem, it was suggested that a survey be made as to the temperatures encountered in equipment used in the desert environment. Temperatures obtained in such a survey would be useful for simulation purposes in the laboratory and for defining the range of temperatures pertinent to Ordnance equipment.

During the summer of 1955, a survey of temperatures encountered by operators of Ordnance equipment was conducted at Yuma Test Station, Yuma, Arizona. A portable pyrometer was used to obtain all temperatures found in the tables. The results of this survey are tabulated on the following pages. All temperatures which exceed $116^{\circ} F$ in the tables are indicated with an asterisk. These temperatures exceed the subjective pain limen as defined by Loewenstern and Dallenbach.**

* Bond, H. J. and Sleight, R. B., Human Factors in the Design of Desert Equipment, Applied Psychology Corporation, Contract No DA-36-034-Ord 1642, December 1954

** Ibid., page 43

TRACKED VEHICLES

THE M59 ARMORED INFANTRY VEHICLE

Table 1 contains the mean temperatures of selected controls and positions on the M59 armored infantry vehicle. These temperatures were derived at a mean ambient temperature of $104.7^{\circ} F.$ and a mean ground temperature of $127^{\circ} F.$ It should be noted that the vehicle temperatures tend to exceed both the ground and ambient temperatures. This is probably due to the circulation of engine heat throughout the vehicle.

Table 2 demonstrates the mean temperature on another M59 at a mean ambient temperature of $89.5^{\circ} F.$ Even at this, most temperatures of components are well in the pain producing area.

TANK, 90 MM GUN, M48

Table 3 demonstrates the mean temperatures on the M48 during an inspection control test on the hilly course at Yuma Test Station. Ambient temperature was $105.6^{\circ} F.$ and ground temperature $133.5^{\circ} F.$ It should be noted that the interior temperatures exceed ambient, but in this case do not come up to ground temperatures. The outer surfaces exceed ground temperatures.

Table 4 demonstrates the mean temperature on an M48 tank combat loaded with hull-bottom-steel plate while traversing the hilly course. Mean ambient temperature was $101.1^{\circ} F.$ and ground temperature was $129^{\circ} F.$

TANK, 76 MM GUN, M41A1

Table 5 demonstrates mean temperatures on the M41A1 during a road load run on the dynamometer course with commander's and loader's hatches closed. Mean ambient temperature, $109.8^{\circ} F.,$ mean ground temperature, $132.2^{\circ} F.$

Table 6 contains air measurements on the M41A1 tank while static. All hatches were closed.

TANK, 120 MM GUN, T43E1

Table 7 demonstrates mean temperatures on selected parts of the T43E1 tank during firing tests. The rounds were stored outside the tank. Mean ambient temperature was $103^{\circ} F.$ and mean ground temperature, $127^{\circ} F.$ It should be noted that the mean temperatures of the rounds would require asbestos gloves for handling. The rate of firing was approximately 14 rounds per hour.

T93. PILOT CARGO TRACTOR

Table 8 demonstrates temperatures encountered in the prototype model of the T93 pilot cargo tractor, towing a 16½ ton load over the hill cross-country course.

It can be noted that the ambient temperature did not exceed 97° F. at any time during the test. However, many of the temperatures encountered in the equipment were well above this level due to solar radiation and diffusion of engine heat.

TABLE 1

M59 A.I.V., COMBAT LOADED

MEAN OF 5 READINGS DURING AN INSPECTION CONTROL TEST

	Mean	Range
Steering Bar Grip	120.7°	113 - 126°
Shift Knob	121.3°	113 - 128°
Accelerator Pedal	122.0°	113 - 130°
Shift Tower	119.0°	111 - 125°
Driver's Seat	119.0°	111 - 125°
Driver's Floor Board	119.8°	111 - 126°
Commander's Foot Rest	118.5°	109 - 125°
Seat Backs (Passenger)		
Right Front	123.3°	117° - 132°
Middle	134.0°	124° - 146°
Rear	136.0°	129° - 140°
Left Front	123.0°	115 - 130°
Middle	138.7°	125° - 150°
Rear	135.7°	127° - 145°
Crew Air	122.6°	112 - 133°
Ambient Temp.	104.7	100 - 106
Ground Temp.	127.0	110 - 132

TABLE 2
 THE M59 A.I.V., COMBAT LOADED
 SIX MEASUREMENTS ON VARIED DAYS OF RUNNING

	Mean	Range
Steering Bar Grip	120°	103 - 138°
Shift Knob	115	100 - 128°
Accelerator Pedal	122.3°	100 - 138°
Driver Floor Board	121.7°	96 - 144°
Commander Floor Board	126.3°	100 - 150°
Seat Backs (Passenger)		
Right Rear	132.9°	122 - 148°
Right Front	120.8°	105 - 128°
Left Rear	133.1°	119 - 150°
Left Front	115.1	95 - 128°
Ambient Temperature	89.5	80 - 92

TABLE 3

M48 TANK TEMPERATURES ON HILLY CROSS COUNTRY COURSE

4 OBSERVATIONS

	Mean	Range
Steering Wheel	107.5	107 - 108
Accelerator Pedal	107.5	107 - 108
Brake Pedal	107.5	107 - 108
Driver's Seat	107.5	107 - 108
Turret Roof Inside	122.5*	120° - 125°
Turret Roof Outside	122.6*	120° - 124°
Turret Air	111.5	110 - 113
90MM Rounds in Bustle	112.5	110 - 114
90 MM Rounds on Floor	108.0	104 - 110
OTM Box Surface	140°	130° - 150°
Ambient Temp.	105.6	104 - 107
Ground Temp.	133.5°	130 - 136

TABLE 4

M48 TANK, COMBAT LOADED WITH HULL-BOTTOM-STEEL PLATE
 HILLY CROSS COUNTRY COURSE - 7 OBSERVATIONS

	Mean	Range
Accelerator Pedal	108.1	100 - 112
Brake Pedal	108.1	100 - 112
Steering Wheel	108.1	100 - 112
Driver's Floor Board	108.1	100 - 112
Driver's Seat	108.1	100 - 112
Commander's Seat	108.1	100 - 112
Commander Over-Ride Control	108.1	100 - 112
Turret Floor	108.1	100 - 112
Turret Air	108.5	108 - 109
Outside Surfaces		
Hatches	118°	105 - 124°
Side of Turret	118°	105 - 124°
Ammo Boxes	118°	105 - 124°
Ambient Temp.	101.1	94 - 106
Ground Temp.	129.0	114 - 140

TABLE 5

M1A1 - ROAD LOAD RUN ON DYNAMOMETRY COURSE

COMMANDER'S AND LOADER'S HATCHES CLOSED - 5 OBSERVATIONS

	Mean	Range
Accelerator Pedal	113.8	113 - 114
Brake Pedal	113.8	113 - 114
Steering Grip	113.0	112 - 114
Driver's Seat	112.8	112 - 114
Driver's Floor	115.5	115 - 116°
Turret Air	114.6	112 - 116°
Turret Floor	114.0	112 - 116°
Commander's Seat	113.4	112 - 114
Commander's Controls	113.4	112 - 114
Outside Surfaces		
Turret Roof	130.4°	122°- 140°
OVH Box	136.4°	127°-147°
Commander's Hatch	124.0°	120°-134°
Gas Cover (shaded)	121.0°	120°-122°
Trans. Oil Check Cap	138.4°	130°-152°
Ambient Temp.	109.8	108 - 111
Ground Temp.	132.2	128 - 134

TABLE 6

M41A1 TANK - STATIC DATA
 ALL HATCHES CLOSED - 11 OBSERVATIONS

	Mean	Range
Inside Air	106.2	96 - 115
Outside Armor and Hatches	126.1°	115 - 136°
Ammo Box	132.3°	120° - 140°
Ambient Temp.	102.0	97 - 104
Ground Temp.	133.6	121 - 137

TABLE 7
 120MM GUN - T43E1 TANK DURING FIRING
 5 OBSERVATIONS

	Before Firing	After 3 Rds.	After 6 Rds.	After 8 Rds.
Breech Block	108	109	108	108
Firing Handle	110	110	113	112.5
Inside Turret Surface	110	112	113	113
Outside Surfaces				
OVN Box	150°	146°	138°	140°
Armor Plate	136°	134°	128°	128°
Rounds (stored outside)				
**Case	153°	154°	148°	152°
Shell	137°	140°	142°	140°
Fuse	136°	138°	138°	134.5°
Turret Air	103	105	106	107
Ambient Temp.	101	102	104	104
Ground Temp.	127	127	127	127

** 2 Minutes after firing, case averaged 205° F.

TABLE 8

T93 PILOT CARGO TRACTOR

HILLY CROSS COUNTRY COURSE - 4 OBSERVATIONS

	Mean	Range
Accelerator Pedal	108.0	100 - 110
Steering Grips	105.0	98 - 112
Shift Knob	105.0	100 - 109
Shift Tower	109.5	105 - 114
Cab Air	101.5	98 - 103
Seat	106.0	101 - 110
Driver Floor Board	111.0	104 - 117°
Driver Seat Support	116.0°	112 - 120°
Middle Floor Board	114.0	108 - 120°
Middle Seat Support	124.0°	120° - 127°
Passenger Floor Board	116.0°	110 - 127°
Passenger Seat Support	129.0°	126° - 135°
Ambient Temp.	96.0	95 - 97
Ground Temp.	113.0	108 - 120

WHEELED VEHICLES

Tables 9-13 demonstrate the mean temperatures and the range of temperatures found on various surfaces of wheeled vehicles. All temperatures are the means of a number of readings while the vehicle was running. The velocity of the vehicles ranged from 30-55 mph.

Temperatures contained in the tables were limited by the extent of the survey. Factors such as road speed, grade, wind direction and speed, location of the sun, and engine condition would all have finite effects on the absolute value of the temperatures. Nevertheless, these data are considered indicative of typical conditions encountered.

It should also be noted that experimental floor mats were used in these vehicles. These mats tended to reduce the interior floor temperatures an average of ten degrees. This decrease was desirable for the long tests performed in Death Valley Park, California.

TABLE 9

D211 TRUCK, CARGO 2½ TON 6 π , AVERAGE SPEED 40 MPH

6 OBSERVATIONS

	Mean	Range
Accelerator Pedal	115.5	112 - 121°
Steering Wheel	109.5	104 - 114
Brake Pedal	116.5°	110 - 122°
Shift Knob	112.8	107 - 122°
Shift Tower	123.3°	113 - 131°
Hand Brake	119.5°	119°- 120°
Dash	109	108 - 110
Driver's Door	112.6	104 - 123°
Driver's Floor	116.0°	111 - 122°
Passenger's Floor	124.7°	124°- 127°
Hydraulic Check Cover	136.5°	126°- 137°
Cab Air	106.5	96 - 113
Ambient Temp.	106	97 - 113

TABLE 10
 M211 TRUCK, CARGO 2½ TON 6x6 WITH
 5 TON LOAD AND 2½ TON TRAILER
 6 OBSERVATIONS

	. Mean	Range
Accelerator Pedal	106.3	100 - 112
Steering Wheel	102.3	100 - 105
Brake Pedal	107.0	105 - 110
Shift Knob	105.0	99 - 110
Shift Tower	113.3	102 - 122°
Hand Brake	103.3	98 - 108
Dash Board	103.7	101 - 108
Driver Door Panel	110.0	106 - 120°
Driver Floor Mat	111.1	105 - 119°
Passenger Floor Mat	112.7	106 - 122°
Seats	101.0	97 - 103
Cab Air	94.0	92 - 97
Hydraulic Check Cover	115.0	108 - 120°
Ambient Temp.	92.0	90 - 95
Ground Temp.	109.0	99 - 127

TABLE 11

M37 TRUCK, CARGO, 3/4 TON, 4x4, WITH CANVAS TOP

1 TON LOAD PLUS 1600 LB. TRAILER

7 OBSERVATIONS

	Mean	Range
Accelerator Pedal	113.8	106 - 119°
Steering Wheel	111.6	110 - 114
Brake Pedal	112.4	105 - 117°
Clutch Pedal	112.0	105 - 117°
Shift Knob	111.1	108 - 120°
Shift Tower	123.1°	115 - 131°
Hand Brake	110.6	105 - 115
Dash Board	110.0	105 - 115
Driver Door Panel	111.4	108 - 116°
Driver Floor Mat	118.0°	114 - 122°
Passenger Door Panel	111.6	108 - 115
Passenger Floor Board	135.0°	108 - 145°
Seats	109.0	102 - 115
Cab Air	105.0	97 - 109
Ambient Temp.	102.4	97 - 105
Ground Temp.	130.0	120 - 140

TABLE 12

M38A1 "JEEP" WITH EXPERIMENTAL FLOOR MAT AND EXHAUST EXTENSION

8 OBSERVATIONS

	Mean	Range
Accelerator Pedal	110.0	86 - 130°
Steering Wheel	106.0	86 - 125°
Brake Pedal	108.0	86 - 128°
Shift Knob	106.0	86 - 123°
Clutch Pedal	107.7	86 - 127°
Hand Brake	103.4	86 - 124°
Driver Floor Mat	109.6	90 - 126°
Passenger Floor Mat	109.0	93 - 126°
Seats	105.4	86 - 122°
Spare Tire	110.6	88 - 130°
Hood Surface	136.4°	87 - 145°
Radiator Cap	136.0°	87 - 147°
Oil Filler Cap	122.0°	87 - 141°
Ambient Temp.	96.6	85 - 104
Ground Temp.	118.0	86 - 143

TABLE 13

M170 TRUCK, AMBULANCE, FRONT LINE, 30 MPH BREAK-IN;

HARD SURFACE LEVEL ROAD; WITH CANVAS TCP

9 OBSERVATIONS

	Mean	Range
Accelerator Pedal	102.6	92 - 108
Steering Wheel	100.0	89 - 106
Brake Pedal	104.0	89 - 110
Clutch Pedal	104.0	89 - 110
Hand Brake	99.0	89 - 104
Dash Board	101.0	89 - 114
Driver Floor Mat	107.2	92 - 120*
Passenger Floor Mat	105.8	95 - 115
Seats	98.6	89 - 105
Cab Air	95.0	86 - 103
Ambient Temp.	96.3	88 - 103
Ground Temp	127.1	99 - 141

ARTILLERY AND AMMUNITION

BATTALION ANTI-TANK WEAPON - 105 MM RECOILLESS RIFLE

Table 14 demonstrates the mean temperatures encountered during firing of the BAT weapon. The means were derived from 3 or more readings at different times. These high temperatures become more operator oriented when it is realized that the sighting device for the weapon is mounted on the weapon at a distance of less than one foot from the barrel. A cook-off test conducted later at mean ambient temperature of 107° F. gave a mean barrel temperature of approximately 300° F., the range being from 131° F. to 570° F.

120 MM CUN, M1

Table 15 presents the temperatures at a 120 mm fired from an anti-aircraft mount. These temperatures are generally representative of all those encountered on field weapons, such as mortars and howitzers, under desert conditions.

Table 16 is concerned with the temperatures encountered on the 105 mm howitzer M2A1 firing HE inert M1 rounds.

SHELLS IN STORAGE

Table 17 demonstrates the temperatures of shells and cases stored in sunlight. These temperatures were obtained at a mean ambient temperature of 98.2° F. and ground temperature of 126° F.

TABLE 14

** TEST OF THE BAT WEAPON; 106 MM RECOILLESS RIFLE.

GROUND MOUNTED FIRING SHELL M344

3 OBSERVATIONS

	Before Firing	After Firing 3 Rnds.	After Firing 4 Rnds.	15 Minutes After Firing
Tripod Seat	134°	132.3°	134°	126.5°
Hand Wheel	109	122.0°	120°	
Breech Handle	114	124.7°	125°	123.5°
Tube - Near Muzzle	124°	145.0		125.0°
Mid Point		166.7°	186°	142.5°
Near Breech		175.0°		157.5°
At Breech		198.3°	217.5°	187.5°
Round: Casing	131.5°			
Shell	129.0°			
Fired Case:				
Near Closed End		192.5°		
At Middle		223.3°		
Near Open End		213.3		
Ambient Temp.	101	104.0	103	104
Ground Temp.	127	128.0	126.0	126

** Rate of fire was 12 rnds per hour

TABLE 15

120 MM GUN M1 ON AA MOUNT FIRING SHELL HE M73

17 ROUNDS FIRED DURING OBSERVATIONS AT

APPROXIMATELY 15 MINUTE INTERVALS

9 OBSERVATIONS

	Mean	Range
Elevating Wood Seat	115.4	108 - 120°
Elevating Hand Wheel	115.0	107 - 120°
Azimuth Wood Seat	115.9	108 - 124°
Azimuth Hand Wheel	113.8	108 - 120°
Breech Handle	112.7	106 - 120°
Clutch Lever	112.8	106 - 120°
Firing Lever	112.4	104 - 122°
Load, Ram, Switch Box	113.7	107 - 120°
Ambient Temp.	103.8	99 - 109
Ground Temp.	133.1	112 - 148

TABLE 16

•• 105 MM HOWITZER M2A1

	Mean	Range
Breech Ring Top Surface	117.7°	101 - 135°
Breech Block Operating Handle Sleeve	113.2	103 - 126°
Elevating Handwheel Knob	110.8	100 - 125°
Tube	170.0°	133° - 195°
Ambient Temp.	94.0	89 - 99
Ground Temp.	121.7	101 - 138

•• Rate of fire was 60 rounds per hour.

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TABLE 17

TEMPERATURE OF SHELLS AND CASES IN OUTDOOR STORAGE

MEAN AMBIENT TEMPERATURE, 98.2° F., MEAN GROUND TEMPERATURE 126.0° F.

Brass Case			Steel Case		
<u>76 MM</u> <u>M 26</u>	<u>120 MM</u>	<u>90 MM</u>	<u>Perforated</u> <u>106 MM</u>	<u>90 MM</u> <u>PI</u>	<u>75 MM</u> <u>SKYVEEDER</u>
116°	116°	116°	106	113	115
132°	129°	130°	114	131°	135°
131°	134°	136°	120°	135°	134°
133°	133°	140°	121°	137°	136°
134°	135°	142°	120°	137°	138°
128°	121°	127°	113°	120°	126°
139°	140°	138°	127°	154°	141°
153°	144°	148°	134°	146°	141°
140°	134°	143°	122°	134°	136°

Laying Down			Crated			
<u>Fiber</u> <u>Container</u>	<u>110 In.</u> <u>Flak</u>	<u>8 In.</u> <u>QR</u>	<u>280MM</u> <u>Black</u>	<u>155MM</u> <u>QR</u>	<u>8 In.</u> <u>QR</u>	<u>105 MM</u> <u>QR</u>
117°	100	110	107	104	108	110
132°	106	119°	116°	108	110	116°
134°	109	119°	119°	109	110	110
137°	110	120°	121°	109	110	111
138°	112	121°	122°	109	109	109
122°	115	125°	124°	114	115	111
145°	114	128°	123°	117°	115	120°
145°	117°	130°	124°	116°	112	115
135°	115	125°	125°	112	111	111

SUMMARY AND CONCLUSIONS

The data contained in this report were collected during summer desert tests at Yuma Test Station, Yuma, Arizona. They were collected to give some idea of the temperatures encountered by the operator of Ordnance equipment under desert conditions.

It should be noted that the ambient temperatures encountered did not appear to be extreme. In most cases they ranged between 90° F. and 105° F. and only in 3 or 4 cases did the ambient exceed 105° F. These temperatures are considered low for desert testing.

The asterisks in the preceding tables indicate temperatures encountered which are above the subjective pain limits of the operator as determined in Bond and Sleight*.

The general conclusions that can be drawn from these data, from the human engineering viewpoint, are:

1. Critically high temperatures appear to be predominantly caused by solar radiation.
2. The problem of high temperatures on Ordnance equipment under desert conditions appears to be quite crucial. With most equipment, operators are working in temperatures within the pain range for the bare skin.
3. The addition of both engine and transmission heat to the solar radiation effects in vehicles produce high temperatures at the man-machine links.
4. In the artillery and ammunition area, firing obviously produces high barrel temperatures. However, this was not the concern of this survey, since the barrels are not normally handled directly by the operators.
5. Further study should be performed in order to determine the effect of these temperatures on the efficiency of the man-machine system. Attention should also be given to the problem from the design point of view.

* ibid.

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