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U. S. ARMY

Technical Memorandum 8-60



HUMAN FACTORS ENGINEERING EVALUATION  
OF THE  
M60 MAIN BATTLE TANK

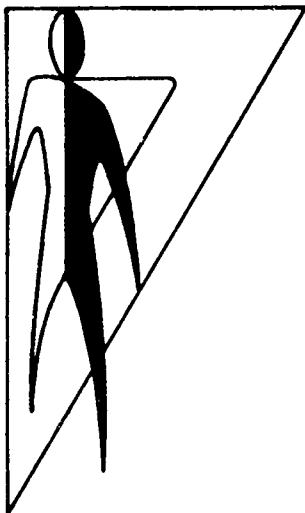
Kermit D. Foster

June 1960

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MARYLAND



Technical Memorandum 8-60

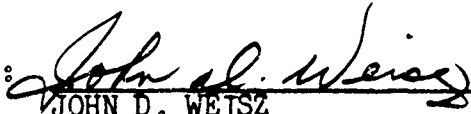
HUMAN FACTORS ENGINEERING EVALUATION  
OF THE  
M50 MAIN BATTLE TANK

By

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June 1960

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#### ABSTRACT

This study reports the results of an evaluation of the M60 Tank from a human factors engineering standpoint. The report is primarily concerned with noise evaluation and crew area evaluations to determine their conformity with human factors design practices.

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HUMAN FACTORS ENGINEERING EVALUATION  
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INTRODUCTION

At the request of the Ordnance Tank-Automotive Command (OTAC), Centerline, Michigan, a study was initiated by the Systems Research Laboratory of the U. S. Army Ordnance Human Engineering Laboratories, to evaluate the M60 MAIN BATTLE TANK, from the Human Factors Engineering viewpoint.

All human factors evaluations were coordinated with Development and Proof Services (D&PS), Aberdeen Proving Ground, Maryland, on a non-interference basis as requested by the Engineering Division of OTAC. The Armor Board at Fort Knox, Kentucky, was contacted in an effort to coordinate additional human factors evaluations with the "user tests" being conducted there. Due to conflicting time allotments at various locations, e.g., Ft. Knox, Camp Edwards, very little could be accomplished for this evaluation.

Major areas of attention in this human factors engineering evaluation were those critical to effective operation of the vehicle, and which appeared to be correctable without major redesign. This approach was felt to be necessary because of the advanced developmental state of the M60.

SOUND MEASUREMENTS

Sound pressure levels (re. 0.0002 microbars) were recorded in the turret (hatches open) during firing of the 105mm gun and found to be as follows:

1. Average - 165.5 db
2. Maximum - 167.5 db
3. Minimum - 163.3 db

Sound pressure level inside the turret is above the maximum level of 150.0 db (re. 0.0002 microbars) set by the Office of the Surgeon General.

A complete sound analysis is submitted as Appendix I of this report.

An octave band analysis of noise in the turret at speeds of 30 mph (high range) and 10 mph (low range) was also conducted. At 500 cycles per second, the sound pressure level exceeds the Human Engineering Laboratories' maximum sound pressure level standard for that octave band by 3 db. This deviation from the recommended limit is negligible and no action, in terms of additional sound attenuation, is recommended.

The complete octave band analysis is submitted as Appendix II of this report.

#### TANK COMMANDER

The deficiencies found in the Tank Commander's area are primarily concerned with anthropometrics. More specifically, they involve the work-space layout of the Commander's area and the efficient use of equipment under the tactical and environmental conditions required. Deficiencies found in the Tank Commander's area are listed below:

1. Headroom in the XM19 commander's cupola, with the commander wearing the steel helmet with liner or the anticipated combat vehicle crewman's helmet (which is similar in size to the steel helmet with liner), was found to be inadequate. When using the M28C periscope the Commander's helmet lip contacts the periscope causing difficulty in adjusting the eye to the periscope eyepiece.

The closed hatch cover allows only one-half inch clearance with the top of the helmet of the 95th percentile soldier. This condition seriously interferes with free head movement.

2. The traverse and elevation cranks in the commander's cupola do not provide sufficient hand clearance, gloved or ungloved, for efficient operation.

3. The adjusting mechanism of the commander's seat is cumbersome and permits neither rapid nor easy height adjustment. When being raised, the tube on which the seat is mounted binds with the one into which it telescopes, causing an undesirable amount of effort and time to be expended for the completion of this simple task.

4. The commander's seat, when his hatch is open, is not serving a useful purpose. Few commanders could sit while positioned with head and shoulders out of the hatch. The fifth percentile soldier would have an inadequate view for necessary surveillance of surrounding terrain while operating from this position. As a result, the seat is adjusted to a lower level, turned up out of the way, and the commander stands. Under this condition the seat is used only when ranging which constitutes a very small portion of the commander's time.

5. With the commander's seat in stowed position access to the radio volume control is blocked by the seat back. The volume control can be reached by turning the seat out and away from the junction box, however, it then strikes the commander in the side. Lurching of the vehicle could cause the commander's body to be thrown against the seat back catching his hand between the seat and junction box and causing possible injury.

6. The seat, when stowed, chafes against the commander's leg in addition to causing him to assume an unnatural position when standing on the platform. This could be remedied by making the seat removable or correcting the structure to enable the seat to fold back clear of the commander.

7. The seat support (seat in stowed position) is constantly chafing against the commander's leg when the commander is standing.

8. The wire-mesh seat is uncomfortable in all crew positions and for the same reasons as those listed in the driver interviews. (No. 3 under Tank Driver Section).

9. With the commander's hatch closed, the override control is located conveniently. However, while riding with head and shoulders out of the hatch, most men can grasp only the top of the control. Lowering the commander's platform to provide a better grip reduces the view of surrounding terrain. Though the control is adequate, and since the commander rides in the open position a major portion of the time, it is recommended it be redesigned to provide a better grip while operating from this position. This might be accomplished by raising the control or by reshaping the handle to include an additional portion projecting to the rear and at right angles to the present handle.

10. Lettering on gun switch in commander's position is indented into the panel and the entire plate painted white. Since there is no contrast between lettering and plate, reading becomes impossible under certain lighting conditions. If the lettering was filled with black paint, reading qualities would be good under both white and red light.

#### TANK DRIVER

The fundamental human factors problem with all tank crew positions relates to anthropometrics and work-space layout. The deficiencies in the driver's area have mainly to do with limb angles while driving and the layout of equipment within the compartment. Deficiencies noted during the investigation are listed below:

1. The driver's accelerator is located on the sloping hull necessitating an uncomfortable as well as a fatiguing leg position while "buttoned-up". This result is caused by violation of anthropometric considerations in the vehicle's basic design and cannot be corrected at this stage of development.

2. Location of the driver's brake pedal is such that the steering wheel interferes with leg movement while braking. Operational difficulty will increase as the driver's clothing bulk increases (winter, arctic).

3. The test drivers at Development and Proof Services, Aberdeen Proving Ground, Maryland, were interviewed for opinions of the driver's seat. All felt that the seat was inferior to previous types and all experienced excessive discomfort after short periods of time. The reasons given are as follows: (1) seat was too hard, (2) seat did not give adequate support to the buttocks because of its convex shape and the lack of compression of the spring wire-mesh body.

4. The driver's compartment hatch lock (upper left hand corner of the compartment) is so positioned that it is difficult to grasp either bare handed or while wearing gloves. Lengthening the handle about 1-1/2 inches is one possible solution to the problem.

5. The hatch cover closing handle is both difficult to reach and extremely hard to operate because of its location above and directly behind the driver's shoulders. Either a new closing mechanism should be designed or a journal bearing incorporated into the present one.

6. The driver's escape hatch is recessed such that mud and water accumulate on the release mechanism. This condition could render the hatch virtually inoperable under the conditions that would require its use. An engineering design study of this problem seems warranted as this is a general problem not confined to this vehicle alone.

7. The method of color-coded banding used on the driver's instrument panel does not optimize meter reading. Color banding is located on the panel instead of the dial face causing erroneous readings from angles other than straightaway. In addition, it is subject to general abuse and will become undistinguishable in a short period of time.

8. Driver's panel has two blank areas. If these areas are not to be used, the panel should be rearranged to take better advantage of available space. The panel, in general, is poorly designed: indication light colors are not compatible with the functions they represent (see gunner, par. 5), and lettering is small with continuity broken by protruding screw heads. The panel should be divided into sections with the most important and frequently used section to the left and within easy reach and view of the driver. Each section should have its controls and indicators arranged according to their functions in the normal sequence of operation. The utilization of a standard "off-the-shelf" panel is undoubtedly the major factor involved. However, the Systems Research Laboratory does not concur with its use in this vehicle or in any vehicle that is at such variance with past practice in engine control and instrumentation. Although, unfortunately, economy may dictate the use of standard instruments and controls, their positioning and arrangement should be in consonance with the driver's operations and work-space layout.

9. There is no protective padding on the rear rim of the driver's hatch. It is recommended that such padding be installed to prevent injury to the driver.

10. Although there is a fire extinguisher and release control for engine fires, there is no indicator to provide early detection and warning to the driver. Accessibility of external remote activating handle is satisfactory.

#### TANK GUNNER

Major defects which were evident in the gunner's position, along with the Systems Research Laboratory's comments, are listed below:



1. The gunner's working area, though task performance is possible, is very restrictive and extremely uncomfortable even for a short period of time. A redesign of the seat for better back support and greater variety and range of adjustment would eliminate some of the discomfort.

2. Both ingress and egress are problems caused primarily by the gunner's seat design and location. The seat could be suspended from the side of the basket and designed to fold down and out of the way for easy access to and from the gunner's position.

3. It is suggested that the action of the manual traverse be improved by having both a high speed and vernier-type control for faster slewing and more accurate final adjustment when laying on targets.

4. During night operation the turret pressure gage cannot be read without the aid of a flashlight; white light, at such a time, would destroy the dark adaptation of the gunner. The gage should be tipped forward to an angle of  $40^{\circ}$  and red illumination should be provided.

5. Indicator lights for both guns and turret power are red with switches in the "on" position. Red lights should be an indication of a malfunction or dangerous condition. Green indicators should be used to indicate a "ready" or operating condition.

#### TANK LOADER

The loader, when not performing his particular task, has more room and freedom of movement than any other member of the crew.

While traveling cross-country, the loader can brace himself on a number of objects within the immediate area. This appears to be satisfactory and no additional hand holds need be provided for body support. However, the seat back should be redesigned for better support and additional clearance between the seat and turret ring should be provided.

In past interviews with tankers, a comment frequently expressed by loaders was the desire for some type of vision device. This is desirable not only in terms of increasing the available means for maintaining surveillance, but at the same time it accounts for a well established desire in everyone to be able to see. In addition, another value is that under those conditions, through equipment damage or through the right combinations of wind and obscuration causes, the loader's periscope, being remote from and on the opposite side of the gun from the fire control periscope, may allow sensing of fire under conditions that would make the target invisible to the gunner. In general, this agency feels that within the limitations imposed by structural and ballistic considerations, every possible means should be taken to enhance the quantity and quality of vision from combat vehicles.

In February 1960, D&PS conducted a study to determine whether or not turret space was sufficient for proper loading. It was decided by D&PS personnel that loading could be accomplished, but room was inadequate for rapid and normal loading procedures. In March the Armor

Board also conducted a study and found it acceptable from the users' viewpoint, however, the rounds used were not those which will be used as standard M60 ammunition.

#### SUMMARY

1. Work-space layout and anthropometric considerations were found to be deficient in all positions.
2. Communications by intercom is adequate. Communication without intercom ranges from difficult to impossible, depending upon the noise level generated by crew personnel activity and the amount of equipment operating.
3. Since there are controversial opinions between D&PS and the Armor Board concerning proper loading space within the turret, ease and speed of loading operations are questionable until the proper ammunition becomes available and further studies are conducted.
4. Clearances for ingress and egress for the turret and driver's positions are adequate. However, the driver's hatch is difficult to operate.
5. Storage of tools, spare parts, field equipment and weapons is satisfactory.
6. Ammunition storage is adequate.
7. Interior lighting is comparable to that of the M48 and affords adequate light, both white and red, for the crew members to perform their individual tasks.
8. Sound pressure level within turret, during firing of the main gun, is above that set by the Office of the Surgeon General.
9. Because of equipment availability problems, external noise for detection purposes could not be recorded. However, the M60 is comparable to the M48, which is not acceptable in this particular area.
10. Heating system is good, however, there is still some fear of noxious fumes by most people.
11. Ventilating is done by a blower system and is satisfactory for all positions.
12. No cooling is provided other than the ventilating system. This is not satisfactory for hot climates.
13. Displays and controls in the driver's position are not satisfactory.
14. Labeling of displays and controls is not satisfactory.
15. Optics used for gun laying are adequate and capable of performing the functions for which they were intended. Location of the gunner's telescope should be relocated for better access.

16. Manual gun controls should be improved. Powered gun controls are satisfactory.

17. Controls are not always compatible with arctic gloves; these are noted specifically under the "Commander" and "Driver" sections of this report.

18. External vision, while operating with open hatches, is good from the driver's position and satisfactory from the commander's cupola. When operating "buttoned up", vision from the M60 is no better than that of the M48 and is rated as inadequate by the Systems Research Laboratory.

19. The test schedule and availability of the M60 made it impossible for the Systems Research Laboratory to study the vehicle from a maintenance viewpoint. A maintenance study would require availability of the vehicle for several weeks.

In summary, it should be stated that no basic improvement over vehicles that have gone before can be detected in the human factors of the M60 configuration. In fact in certain respects, as requirements mount for even greater protection, increased fire power, better vehicular performance and lower silhouette, the crew finds it necessary to operate more equipment and carry out more complex tasks, in less time, in an ever-decreasing amount of space.

A cooperative program has now been established between the OTAC and the Human Engineering Laboratories for the application of human factors to the design of new vehicles. Shortcomings of the type indicated here, which are relatively superficial, and more important, the fundamental relationship that exists between the crew, their equipment, and the task to be performed, can be considered in the basic design of future configurations.

APPENDICES

- I. Noise Analysis of the 105mm Tank Gun in the M60 Tank.
- II. Octave Band Analysis.

## APPENDIX I

### NOISE ANALYSIS OF THE 105MM TANK GUN IN THE M60 TANK

- 1.00 Objective of Test: The purpose of this test was to determine the maximum, minimum and average sound pressure levels (re 0.0002 microbar) inside the M60 Tank during the firing on the 105mm Tank Gun with all the hatches open.
- 2.00 Item Tested: Tank, Medium, M60, Serial #1 w/gun 105mm, Serial Nr. 8765957.
- 3.00 Date of Test: 4, 5 and 7 August 1959
- 4.00 Location of Test: The weapon was fired on 4 and 5 August at Barricade A, Plate Range, Development and Proof Services, Aberdeen Proving Ground, Maryland. On 7 August the weapon was fired at the Railroad Range of the Plate Range, Development and Proof Services, Aberdeen Proving Ground, Maryland.
  - 4.10 Description of Test Area: Barricade A has three (3) concrete ten-foot walls, and is open at the top. The Railroad Range is a flat land bounded by open fields.
  - 4.20 Description of Sound Field: The sound field was a complex sound source located in a metallic reverberant chamber.
- 5.00 Description of Test: The microphone on 4 and 5 August was mounted on a small metal bar about 6 inches to the rear and 36 inches to the left of the breech of the gun at about the same height as the breech. The microphone was wrapped with a fabric material during all firings to keep microphone vibration to a minimum. The sound measuring equipment was placed about 40 feet to the rear of the tank and behind the concrete barricade. The microphone was in the same position for firings Nos. 1 through 4 on 7 August as firings on 4 and 5 August.

Two microphones were used for the last four firings on 7 August. The microphones were mounted together in a second position, 15 inches to the rear and about 32 inches to the right of, and at the same elevation as the breech. Before each set of measurements the microphones were calibrated and the cable losses were determined. For the first set of measurements using only one microphone, the microphone cable was connected to a sound level meter to which a tape recorder and an impact meter were attached. In this measuring arrangement the sound level meter attenuator acts as an attenuator for the impact meter and as a fixed step gain control for the tape recorder. Because the input voltage requirements of the impact meter and the tape recorder are quite different and are controlled by the attenuator, simultaneous tape recording and impact meter operation are impossible.

For the firings on 4 August the impact meter measurement was chosen. On 5 August the tape recording technique was used.

On 7 August the microphone was placed in the position noted above and connected to a sound level meter attached to the tape recorder. A second microphone was mounted beside the first microphone and attached to a separate sound level meter and an impact meter. This arrangement provided a separate attenuator for the tape recorder and the impact meter. Tape recordings were made of the firings and the following measurements were obtained:

1. Quasi Peak Sound Level
2. Peak Sound Level
3. Time Average (0.2 seconds) Sound Level

6.00 Test Equipment:

6.10 Transducing Equipment:

6.11 Microphone, Massa Laboratories, Model M-141B, Serial Nr. 382.

6.12 Microphone, Massa Laboratories, Model M-141B, Serial Nr. 383.

6.20 Metering Equipment:

6.21 Sound Level Meter, General Radio (GR), Type 1551-B, Serial Nr. 148.

6.22 Sound Level Meter, GR, Type 1551-B, Serial Nr. 1226.

6.23 Impact Meter, GR, Type 1556-A, Serial Nr. 481.

6.30 Calibrating Equipment:

6.31 Transistor Oscillator, GR, Type 1397-A, Serial Nr. 880.

6.32 Sound Level Calibrator, GR, Type 1552-B, Serial Nr. 1779.

6.40 Recording Equipment:

6.41 Ampex Tape Recorder, Model 601, Serial Nr. 9-B-077.

6.42 Magnacord Tape Recorder, Model M-90AX Amplifier, Serial Nr. 01533, Tape Transport, Serial Nr. 01475.

7.00 Analysis of Data: The data was reduced and a significant difference between readings was noticed after firing number 6 on 5 August. All firings after number 6 were extremely high in db level with reference to the first six firings and also report number 630 by Bolt Beranek and Newman, Inc. on a test of a similar item.

The microphone cable was securely tied down to eliminate cable vibration for the first six firings. After the sixth

firing the microphone was calibrated and the cable was not tied down on the remaining firings.

A laboratory test was conducted on this microphone and another microphone of the same model and the results indicated that excessive error is introduced in measurement when the microphone cable is not securely tied down and allowed to swing or vibrate.

Only the first 5 measurements are reported because of the doubtful results from the subsequent measurements.

8.00 Test Results: Two different measurements are evaluated:

1. Peak Sound Level - The maximum positive sound at the microphone.

2. Time Average Sound Level - A measure of the average sound pressure level maintained over a period of 0.2 seconds. This measurement approximates the relative loudness levels as determined by the human ear.

The following measurements were obtained in this test:

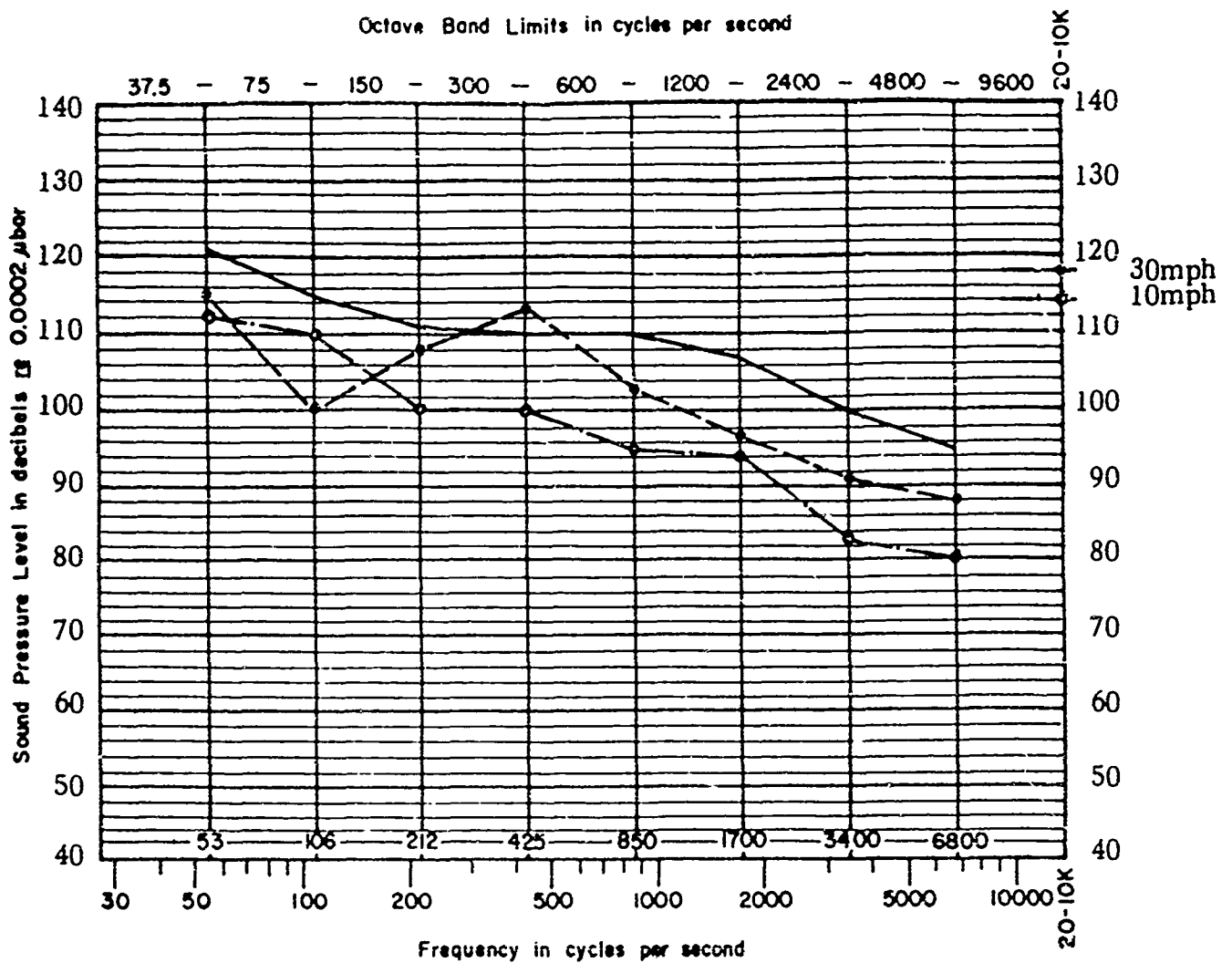
<u>Round No.</u>	<u>Quasi Peak Sound Level</u>	<u>Peak Sound Level</u>	<u>Time Ave. (0.2)(SL)</u>
1	163.3	165.3	147.3
2	166.3	167.5	148.8
3	164.5	166.5	146.3
4	161.3	163.3	148.3
5	<u>162.3</u>	<u>164.8</u>	<u>145.8</u>
Avg.	163.5	165.5	147.3
Max.	166.3	167.5	148.8
Min.	161.3	163.3	145.8

9.00 Conclusions/Recommendation/Comment: When the 105mm Tank Gun is fired, the sound level inside the turret of the M60 Tank is above an arbitrary maximum sound level of 150 db (re 0.0002 microbar) set by the Office of the Surgeon General.

APPENDIX II

OCTAVE BAND ANALYSIS

Octave Band Limits in cycles per second



- HEL maximum allowable sound pressure level limit for track-laying vehicles
- Average octave band level at 30 mph in High Range
- - - Average octave band level at 10 mph in Low Range

Fig. 1. Octave band measurements of the noise in the turret of the M60 Tank at 30 mph and 10 mph

Item tested: Tank, Medium M60, Pilot 1  
 Date: 9 Sep 1959  
 Engineer: GRG/BJK  
 Analysis: BJK  
 Date: 9 Sep 1959  
 Drawn: RD  
 Date: 9 Sep 1959/29 Jun 1960