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HEL-TM-21**U. S. ARMY**Technical Memorandum ~~21~~**REFERENCE SET****DO NOT REMOVE****HUMAN ENGINEERING EVALUATION****OF TRUCK, 1/4 TON, 4x4, XM151**Edward C. Weiss
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June 1956

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Technical Memorandum No. 21
Human Engineering Evaluation of
Truck, $\frac{1}{4}$ ton, 4 X 4, XM151

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A B S T R A C T

PURPOSE

The purpose of the present study was to provide an evaluation of the $\frac{1}{2}$ ton truck, XM151, in terms of its man-machine relationships. An attempt was also made to provide some optimum specifications to serve as a guide for future design.

In addition, appropriate comparisons were made with the M38A1, which the XM151 will supercede if placed in production. Finally, user information was provided as a supplement and partial validation of the preceding evaluation and recommendations.

RESULTS

The XM151 offers some definite improvements over the M38A1. It provides very superior riding qualities for a vehicle of this type, which should increase comfort and therefore tend to reduce driver fatigue. The four speed transmission in conjunction with its location is a definite advantage over previous models in terms of ease and simplicity of operation. While the suspended foot pedals are an improvement, they have not been utilized to their best advantage. The location of the starter represents a vast improvement over the M38A1 where it was placed in an almost inaccessible position. The ball joint front suspension provides steering characteristics which are in a sense, too responsive and may have to be reduced to provide more positive control.

However, the XM151 is deficient in certain respects. The accessibility, especially to the rear compartment is restricted. The visibility and seat height and adjustability could be improved. The instrument panel is inferior to that of the M38A1 in terms of the lack of necessary components and its location in relation to the driver's line of sight.

RECOMMENDATIONS

The XM151 represents a net improvement over earlier models from a human engineering standpoint. However, it should not be placed in production until certain deficiencies are corrected, so that its basic potential can be realized to full advantage.

Several areas which should be subjected to empirical examination are as follows:

1. Determination of the optimum accelerator - brake relationship.
2. Study of the forces required for the various foot controls.
3. Determination of the most efficient angulation for the foot pedals.
4. Analysis of the requirements and ways to improve the forward, rear and side vision.

5. Analysis of the information which should be presented by the instrument panel and a determination of the optimum display location and components.

6. Study of the optimum seat relationships for driver and passengers.

7. Determination of the optimum design and arrangement of hand controls.

8. Study of the safety aspects and requirements for a vehicle of this type.

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A HUMAN ENGINEERING EVALUATION OF TRUCK, $\frac{1}{4}$ TON, 4X4, XM151

The original designation of the $\frac{1}{4}$ ton series of trucks was that of command and reconnaissance vehicles. The increased demands of modern warfare have necessitated the expansion of this mission to include a variety of activities ranging from ambulance duty to recoilless rifle carriage.

The efforts to meet these increased demands have resulted in a series of modifications of the original W. W. II concept. However, these attempts did not provide a satisfactory solution because of certain inherent limitations in the original design which have been further emphasized by the present need for light weight, high performance vehicles capable of being transported by air. The improved technology of recent years has made possible some new approaches. The XM151 represents an endeavor in this direction.

From the human factor standpoint, it is highly desirable that an effort be made to evaluate new concept vehicles in their embryonic stages. Such studies, if conducted in conjunction with the engineering development would prevent the occurrence of many of the more common man-machine deficiencies, or allow corrections to be made while they are still feasible. Further, a programmatic approach in this type of applied research for a family of vehicles, such as wheeled vehicles, would supply a source of generalizations for use by design engineers. This latter type of information has not been obtained for Army equipment. Designers in this area are frequently forced to extrapolate from findings pertinent to non-military, Air Force and Navy materiel and derived from samples which may not be representative of the Army population.

STATEMENT OF THE PROBLEM

The purpose of the present study is two-fold. Its first function is to evaluate the $\frac{1}{4}$ ton truck, XM151 from the operator standpoint, with cognizance given to the problems of passenger comfort and safety. Secondly, an attempt will be made to provide some generalizations for an optimum, hypothetical vehicle of this class.

WORKSPACE DIMENSIONS

In order to evaluate the various dimensions, seating, controls, etc., of a vehicle in terms of user effectiveness, it is necessary to have some idea of the physical measurements of the people for whom the equipment is designed. The measurements which delineate human body size are known as anthropometric measurements.

There are several sources of anthropometric measurements based on the Army population available in the literature (22, 26, 28). McFarland (22) presents some data based on Army drivers; however, these subjects do not differ as to their physical dimensions from those based on soldiers representing the Army in general.

Anthropometric data are usually presented in percentile form in order to evaluate equipment for the requirements of 90% of the population - that portion between the 5th and 95th percentiles. The average and other measures of central tendency are not adequate for design purposes, although their usefulness can be increased by including some measure of the variability or dispersion associated with them such as the standard deviation (18, 22).

Another important item of consideration in this area is the degree of correlation which exists among the various body dimensions (23). Thus, a person in the 5th or 95th percentile in height and weight will tend to be in the 5th or 95th percentile as described by other body measurements. However, this tendency is only an approximation. Height exhibits a moderate correlation with body lengths, while weight is related to body thickness.

There are two distinct types of anthropometric measurements that are necessary when human dimensions are considered in the design of equipment. Static anthropometrics is the most familiar type. These measurements are taken on various parts of the individual when he is in a stationary position. However, it has become apparent that there is also a need for dynamic anthropometrics, or measurements which describe the individual's ability to perform various activities relevant to the operation of the equipment. While this latter type of information does exist to some degree for aircraft cockpits, etc., there is, unfortunately, a paucity of data pertinent to land vehicles.

Various cautions are necessary in order to effect the most efficient application of anthropometric material. For example, the clothing worn should be taken into consideration and additional space allotments should be made for heavy arctic gear. Likewise, it is sometimes necessary to shape and space certain controls so that they can be manipulated when the hands are encased in mittens or heavy gloves. Frequently, an additional inch or less will greatly benefit the individual at the extremes beyond the 5th and 95 percentiles. Another aspect is the rigid unnatural position the subjects are forced to assume when static measurements are taken. It has been found that 2 inches should be deducted from the erect sitting height to account for the normal slump (12, 21).

Appendix A presents some anthropometric measurements which have been found to be especially relevant to the design of land vehicles (21, 28). Measures of the body dimensions described below can be found in this appendix. The material has been derived from McFarland's (22) data for Army drivers whenever possible. However, in some instances, the only figures available were based on civilian drivers.

To this point we have dealt primarily with measurements of man in a static position. It is now necessary to consider some of the aspects of dynamic anthropometrics.

King (18) has examined the maximum boundaries of the work area for the operation of manual controls in aircraft cockpits. The sample was drawn from a population of naval aviators and the results are described diagrammatically in Figure 1.

In some instances, such as the forces required for hand and foot controls, optimums have not been presented in the literature for wheeled vehicles. In other cases, such as the location of hand and foot controls, the determination must be specific to the particular vehicle being considered. It might, therefore, be pertinent at this time to briefly outline the procedure for determining this information.

Two groups of test subjects, numbering at least five subjects in each group, should be selected so that one group approximates the 5th percentile in anthropometric measurements, and the other the 95th. They should then be placed in a vehicle, or mockup, which duplicates the actual situation as closely as possible, and the adjustments made while the task is performed until each group is accommodated. Usually, it is possible, if sufficient adjustment is provided, to adequately accommodate 90% (5th - 95th Percentiles) of the population.

It is now possible to proceed with an evaluation of the XM151, including comparisons with the M38A1 where applicable. The ensuing recommendations are of two types. First, specific suggestions are presented for the vehicle and its components as it presently exists. Secondly, an attempt has been made to supply some generalizations for an optimum vehicle. This latter material was gleaned from a review of the pertinent literature. Much of it is in the form of hypothetical proposals which have been submitted without benefit of empirical examination in terms of their suitability for the subject equipment. It cannot be over-emphasized that due consideration must be given the military, engineering and economic feasibility of incorporating these proposed optima into any specific vehicle.

FIXED LIMITS OF THE WORKING SPACE

<u>Gross Interior Dimensions</u>	<u>XM151</u>	<u>M38A1</u>
Length - dash to rear	75 3/4"	69 1/4"
Width - front compartment	54 1/2"	55 1/2"

The gross dimensions of a vehicle must, of course, be determined by the compromise between the military requirements and engineering considerations. Therefore, an evaluation of these dimensions in terms of human factors would not be particularly apropos. However, it should be noted that the XM151 provides a larger interior space than the M38A1 by what appears to be a more efficient utilization of the overall vehicle dimensions. This is especially noticeable in the rear compartment where more floor space is provided for rear seat passenger comfort, or cargo capacity.

Distance (in.) forward of
seat reference point

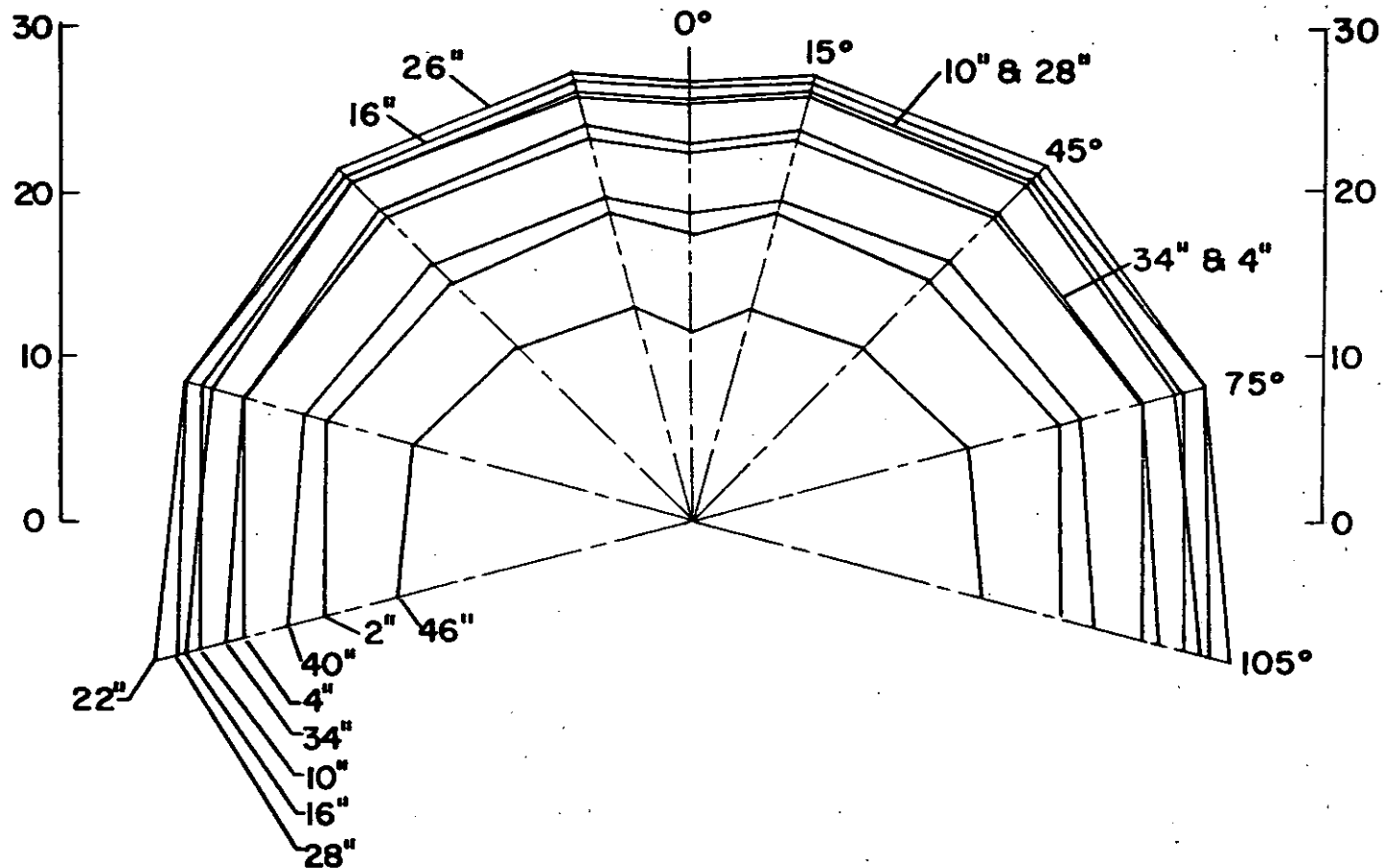


Figure 1. Maximum distances which can be reached by 97% of the population at each position. The elliptical arcs indicate maximum boundaries for this group for operation of manual controls at various horizontal levels. Seat back 13° from vertical (18).

Proposed Optima

The anthropometric measurements delineated in Appendix A of this report suggest the following dimensions:

1. The vehicle must accommodate a man 5' 4" tall, weighing 127 lbs. (5th Percentile) and dressed in light summer uniform.
2. The vehicle must provide for a man 6' 1" tall, weighing 192 lbs. (95th Percentile) and dressed in heavy winter clothing.
3. There should be at least three inches of clearance above the head of a man in a normal sitting position for minimum comfort and safety.
4. McFarland (22, p. 145) suggests the following proportions:
 - a. 22" - 24" across the shoulders
 - b. 18" - 24" across the knees
 - c. 25" - 28" across the elbows
 - d. 28" above the floor with respect to knee and thigh.

Gross Weight

One of the primary objectives of the XM151 development was to effect a weight saving of 500 lbs over the M38A1. While this has been accomplished, it has been found necessary to place a 500 lb. weight in the rear of the vehicle to facilitate fording. This was necessitated by the fact that the vehicle tends to float until it ships sufficient water to sink. The floating sensation often invokes a feeling in the drivers that the vehicle is going to capsize and they sometimes abandon it.

It is conceivable that this condition will be alleviated by a normal passenger and cargo load. However, there are many instances when the vehicle will be returning empty from a combat zone for supplies with the driver as the sole occupant. If a major ford were blocked by a single vehicle or several in a convoy, a main supply line could be disrupted. Therefore, this deficiency should be corrected. One possible solution would be to increase the size and number of drain holes which would permit more rapid filling of the vehicle.

Entrance and Egress

The XM151 presents some difficulties in this area, especially for larger men clad in heavy winter clothing. The opening wells are not deep enough for easy accessibility as shown in Figure 2 and Figure 3. However, Development and Proof Services personnel at Aberdeen Proving Ground, Md., have stated that because of the welded construction employed, any attempt to deepen these openings might affect the structural integrity of the vehicle.



Figure 2. Difficult Entrance.



Figure 3. Difficult Egress for Man with Short Legs.

Secondly, the curvature of the left front leg of the right front seat causes this leg to strike the shift tower when the seat is folded forward (Figure 4). This hampers access to the rear compartment. Further, because of the design and location of the shift tower, it is difficult to enter the rear compartment by going between the front seats. When side curtains are in place, or a winterizing kit is installed, it is extremely difficult to enter or leave the rear compartment.

The running board is a slanted, smooth, surface only 2½" wide. It is probably not intended for use as a step, but unless the well opening is deepened, some such aid is needed, especially to improve the egress of shorter men.

RECOMMENDATION: The left front leg of the right front seat should be altered to permit the seat to fold forward through a greater arc. A step should be provided for both of the front opening wells. The M38A1 is more acceptable in these regards, especially in terms of accessibility to the rear compartment.

<u>Length of Horizontal Floor</u>	<u>XM151</u>	<u>M38A1</u>
Front of driver's seat to toe pan	14½"	12"

PURPOSE: To provide adequate foot space for a comfortable rest position in conjunction with movement, entrance and egress without interfering with foot controls mounted on the toe pan.

ANTHROPOMETRIC MEASUREMENT: Foot length with additional allowances for heavy arctic foot gear.

RECOMMENDATION: 11" - 15" (31).

<u>Height of Dash Above Horizontal Floor</u>	<u>XM151</u>	<u>M38A1</u>
Horizontal floor to bottom of dash	17½"	14½"

PURPOSE: To provide sufficient space for unobstructed operation of foot controls.

ANTHROPOMETRIC MEASUREMENT: This would require dynamic measures specific to a particular vehicle. It would be dependent upon the location of the driver's seat in reference to the foot pedals and dash and would involve measures of the leg below the knee.

RECOMMENDATION: A height of 18" - 20" will not only assure leg clearance, but will also provide a more optimum position for hand controls and display information which are mounted on the dash. The XM151 more closely approximates the optimum range in this respect than the M38A1.

Angle of Toe Pan

XM151

M38A1

Included angle with the horizontal

135°

135°

PURPOSE: To provide the correct angulation for mounting the foot controls and provide a comfortable foot rest for the left foot.

RECOMMENDATION: An examination of passenger cars and sport cars revealed an apparent correlation between toe pan angle and the height of the seat above the horizontal floor. Thus, the lower the seat, the steeper the toe pan angle as in sport cars; while in standup delivery trucks, the angle is large or 180°. Therefore, an optimum should be determined for any particular vehicle. However, in view of the present height of the seat in the XM151, it appears that a more obtuse angle of approximately 150° (10, 15) would provide a more comfortable foot rest.



Figure 4. Inaccessibility to Rear Compartment due to Seat Leg Striking Shift Tower.

SEATING - OPERATOR'S SEAT

While a great deal of study has been devoted to the design of aircraft, railway, tank, and other seats, relatively little relates to the field of wheeled vehicles. Furthermore, very little pertinent research was conducted on a population of Army drivers. Obviously, a train passenger seat designed to accommodate both sexes and all ages with maximum comfort as the only criterion, presents quite different problems from those encountered in the design of an efficient seat for use in a military truck.

Height of the Seat Above the Floor

XM151

M38A1

Front of seat above horizontal floor

17"

14"

PURPOSE: To avoid discomfort to the under part of the thigh due to excessive pressure from the front of the seat.

ANTHROPOMETRIC MEASUREMENT: Underside of the thigh to the floor.

RECOMMENDATION: In conjunction with the following suggestion regarding vertical seat adjustability, it is recommended that the seat be placed 14" to 15" above the floor (23, 24, 31). This should provide proper support for the thigh as well as adequate forward vision for all statures. The XM151 may cause some discomfort to shorter men in the former instance while the eye height of tall drivers will be in line with the area left uncleared by the wipers.

Vertical Adjustment

XM151

M38A1

Range of vertical seat adjustability

none

none

PURPOSE: To provide an optimum sitting eye height for adequate visibility.

ANTHROPOMETRIC MEASUREMENT: Normal sitting eye height.

RECOMMENDATION: The difference between the 5th and 95th Percentiles in normal sitting eye height is approximately 4". However, it has been suggested (19) that it is only necessary to raise the 5th percentile to the height of the 50th percentile because the 95th percentile has little advantage over the 50th percentile in terms of visibility from the drivers position of a land vehicle. This latter opinion would require only 2" of vertical adjustability.

However, in order to provide accommodation for the extremes of the population under all conditions, it is recommended that 4" of vertical adjustment in 1" intervals be provided when the minimum height of the seat above the floor is 14" (16, 24).

Horizontal Adjustment

XM151

M38A1

Range of horizontal adjustability

2" in 1"
intervals

none

PURPOSE: To insure access to foot controls.

ANTHROPOMETRIC MEASUREMENTS: Buttock-knee length and knee height.

RECOMMENDATION: An adjustment of 5" to 6" in 1" intervals should account for nearly all eventualities (16, 23, 24). While the XM151 does not approach the optimum in this regard, the 2" of adjustment provided does give some recognition to the problem.

PROPOSED OPTIMUM: Angular adjustability which permits the seat height to increase as it is moved forward might also be helpful.

Seat Depth

XM151

M38A1

Depth of Seat

16½"

16"

PURPOSE: To provide a comfortable seat which does not cut the leg below the knee.

ANTHROPOMETRIC MEASUREMENT: The area from the buttock to the back of the calf.

RECOMMENDATION: A seat depth that is too short causes pressure on the underside of the thigh of long-legged people while one that is too long cuts the lower leg below the knee on short-legged people and forces them to slump forward in order to bend the leg at right angles (12). It has been found that when a seat is designed only for comfort, and a slumped position is permissible, a longer length should be considered. However, when it is necessary for the occupant to sit erect in order to perform a specific task, a shorter length is desirable (4).

A seat depth of 16" to 19" appears to offer the best compromise for the present situation (10, 16, 23) and both vehicles are adequate in this respect.

Seat Width

XM151

M38A1

Width of seat.

20½"

18"

PURPOSE: To provide optimum comfort for 90% of the Army driver population.

ANTHROPOMETRIC MEASUREMENT: Width of seat.

RECOMMENDATION: A minimum seat width of 19" (23) should be adequate for 90% of the population. An additional inch or two might provide additional comfort for changing position on long trips. The XM151 is within the optimum range and is superior to the M38A1 from this aspect.

Height of Seat Back

XM151

M38A1

Height from rear of seat bottom

12 3/4"

18 1/2"

PURPOSE: To provide a comfortable back rest and adequate support when applying pressure to the foot pedals.

ANTHROPOMETRIC MEASUREMENT: Trunk height.

RECOMMENDATION: A back rest height of 18" to 20" should provide adequate support (23). The M38A1 is within the optimum range in this dimension. While the XM151 is comfortable for a short period of time, there are indications that driver discomfort and unnecessary fatigue might result on long trips when there is a tendency to lean back and depend on the back rest for greater support.

It has also been suggested that the seat back be slightly S shaped to conform to body curvature (22).

Width of Seat Back

XM151

M38A1

Width of seat back

20"

17"

PURPOSE: To provide adequate support for the back and shoulders.

ANTHROPOMETRIC MEASUREMENT: Shoulder width.

RECOMMENDATION: A back rest width of 21" will be suitable for approximately 90% of the population. However, another inch will go far in providing additional comfort and accommodating large men (12, 23).

The XM151 more nearly approaches the recommended back rest width of 21" than does the M38A1, but an additional inch or two is recommended.

Seat Angulation

XM151

M38A1

Angle of seat bottom with the horizontal

13°

9°

Angle of seat back with the vertical

13°

15°

Angle of seat back with the seat bottom

90°

96°

PURPOSE: To provide a comfortable position with adequate provision for operating the foot controls.

ANTHROPOMETRIC MEASUREMENT: This requires dynamic measurement involving an adjustable mock-up seat.

RECOMMENDATION: The angles listed above were all measured from under-pressed surfaces. That is, they were taken from the seat surfaces when the seats were unoccupied. The following optimum angles have been suggested in the literature (10, 16, 22, 31).

Angle of seat bottom with the horizontal	8° to 11°
Angle of seat back with the vertical	20° to 25°
Angle of seat back with the seat bottom	99° to 107°

The M38A1 approximates the suggested ranges except for the angle of the seat back with the vertical. The XM151 does not exhibit the recommended angulation.

<u>Distance from Dashboard to Seat Back</u>	<u>XM151</u>	<u>M38A1</u>
Dash to seat back where it joins seat bottom.	33" (seat in hindmost position)	29½"

PURPOSE: To provide adequate space between driver's knees and dashboard obstructions. It is also necessary to consider the operation of hand controls mounted on the dashboard with respect to effective anterior arm reach. The driver should be able to operate these controls with a minimum distortion of the normal driving position.

ANTHROPOMETRIC MEASUREMENTS: Buttock-knee length with allowance for movement and protrusions from the dashboard. Effective, or dynamic anterior arm reach.

RECOMMENDATION: It will be recalled that from 5" to 6" of horizontal adjustment were recommended. Contingent upon this condition 25" to 26" of clearance between the seat back and dash should be provided with the seat in the forward position and 30" to 32" with the seat in the hindmost position. Since the shoulder is somewhat forward of the seat back, these dimensions should provide for what is considered effective anterior arm reach of 26" to 28" (18). Anterior arm reach does not correlate too highly with other body measurements. Therefore, tall men requiring extra knee length, but having a short arm reach, will be accommodated in both respects.

It should be noted that while the XM151 and M38A1 provide adequate knee length, men with short arm reaches are forced to make dynamic motions. In other words, they have to lean forward from the normal driving position to operate such controls as the light switch, choke and throttle.

<u>Distance from the Brake-Clutch to the Back of the Seat</u>	<u>XM151</u>	<u>M38A1</u>
Brake-clutch to back of seat	36" (seat in hindmost position)	35"

PURPOSE: To enable sufficient force to be applied to the brake and clutch pedals and to provide for adequate leg movement.

ANTHROPOMETRIC MEASUREMENT: Dynamic measurement of buttock-knee and lower leg movement.

RECOMMENDATION: A clearance of 36" to 38" with the seat in the most forward adjustment and 41" to 44" with the seat in the rearmost adjustment (11, 22). The XM151 is adequate within the limits of horizontal seat adjustability provided. The M38A1 is not within the specified range.

<u>Height of the Roof Above the Seat</u>	<u>XM151</u>	<u>M38A1</u>
Seat to Roof	36 $\frac{1}{2}$ "	37"

PURPOSE: To provide clearance for the operator's head.

ANTHROPOMETRIC MEASUREMENT: Erect sitting height.

RECOMMENDATION: A clearance of 3" is required between the driver's head and the roof of the vehicle (22). Therefore, the roof should be a minimum of 37" above the seat with the seat in the highest position of vertical adjustment and 41" with the seat in the lowest position of adjustment to accommodate 90% of the population (23).

The XM151, as presently constituted, with no vertical seat adjustment, would not adequately accommodate even the 5th percentile in the erect sitting position (Figure 5). If the normal sitting height is used as the standard, the head clearance is adequate from the 5th to 35th percentiles. Obviously, therefore, 65 percent of the driver population would be inconvenienced in this regard. It should also be noted that the anthropometric measurements cited in the appendix do not include headgear.

Road tests of the XM151 have revealed that the top is not sufficiently taut. This factor, combined with the inadequate clearance, causes the roof to strike the driver on the head under highway speeds. Therefore, the roof braces, rear tie down rings, etc., should be improved in addition to the head clearance.

Right Front Passenger Seat

The right front passenger seat cushion configuration in both vehicles is identical to that of the driver's seat. However, in the XM151, no horizontal adjustment is provided as in the driver's seat.

Very little study has been devoted to passenger seats in either passenger automobiles or military vehicles. In the former, it is probably because the front seat is continuous with the driver's seat and in the latter because comfort is a secondary consideration where an operational function is not involved.



Figure 5. Inadequate Head Clearance for Tall Men Dressed in Arctic Clothing.

<u>Rear Seat</u>	<u>XM151</u>	<u>M38A1</u>
Depth of seat	15½"	14"
Width of seat	36¼"	32½"
Height of back	15½" (6½" gap + 9" pad)	16" (10" gap + 6" pad)
Height above floor	9¼"	6½"

The low height of the rear seats above the floor in both vehicles is inadequate from the standpoint of comfort and safety. The passengers are forced to keep their legs in an awkward position and have little opportunity to brace themselves adequately when traversing rough terrain (Figure 6)

However, the XM151 represents an improvement by providing more leg room and a higher rear seat than earlier models. While the vehicles are necessarily small in overall size, due to military specifications, the XM151 has provided a more efficient and spacious rear compartment than the M38A1.

Horizontal Distance from Lower Edge of Steering Wheel to Seat Back

	<u>XM151</u>	<u>M38A1</u>
Horizontal Distance	14" (seat in hindmost position)	15 3/4"

PURPOSE: To provide sufficient space between the abdomen and steering wheel to allow freedom of movement and reduce injuries in the event of sudden stops.

ANTHROPOMETRIC MEASUREMENT: Abdomen depth.

RECOMMENDATION: McFarland (23) recommends a minimum of 15" at the mid-point of horizontal seat adjustability. Thus, the M38A1 is satisfactory in this regard while the XM151 does not provide the minimum space requirement.

Vertical Distance from Bottom of the Steering Wheel to the Horizontal Floor

	<u>XM151</u>	<u>M38A1</u>
Vertical distance.	23"	22"

PURPOSE: To provide adequate space for free leg movement and facilitate entrance and egress.

ANTHROPOMETRIC MEASUREMENT: Dynamic measurement of knee height.

RECOMMENDATION: There should be a minimum clearance of 25" (23). It can be seen that neither vehicle is satisfactory in this respect.



Figure 6. Cramped Position of Tall Man in Rear Seat.

Distance from Lower Edge of Steering Wheel to the Brake-Clutch

XM151

M38A1

Steering wheel to brake-clutch distance 25"

25½"

PURPOSE: To avoid striking the leg on the steering wheel when operating the foot pedals without dysmmetric movements.

ANTHROPOMETRIC MEASUREMENTS: Dynamic measurement of knee height.

RECOMMENDATION: There should be a minimum of 26" of clearance (23). This dimension, of course, depends upon the location of the seat, the angles of the pedals, etc. However, the XM151 and M38A1 are not adequate for men with longer legs approximating the 70th to 95th percentiles or 25% to 30% of the population (Figure 7).

Table 1 contains a summary of the preceding discussion and evaluation of the interior dimensions and working space of the XM151 and M38A1.

C O N T R O L S

A primary consideration in the design of hand controls for use in vehicles is the location of the controls with respect to quick and accurate operation, with a minimum of visual aid. The optimum position for this type of operations is directly in front of the driver, between waist and shoulder height (22). Shape coding will aid the operator to discriminate among various controls avoiding unnecessary confusion and costly mistakes.

Controls should fit normal habit patterns and move in "natural" directions. An increase should be indicated by a forward, upward or clockwise movement (28).

The preferred order for control operations is as follows: fingers, hands, forearms, arms, shoulders, and trunk. The fingers, of course, offer the most sensitive and accurate control movements.

The literature presents a number of recommendations in regard to knob shapes, sizes and forces required for tracking tasks and other operations which require extreme accuracy. It is questionable whether such considerations are pertinent to the design of a throttle, choke, or other hand controls which are involved in motor vehicles. In any case, the automotive design engineer should weigh the criticalness of the situation and any expected gains against the cost factors involved when extrapolating from such data to a particular vehicle.

The paramount considerations in the design of foot controls are the operation forces required and pedal angulations, especially the relative angulation of the brake and accelerator pedals. Very little work has been done in these areas which is relevant to truck design. Pedal forces have been determined for rudder bars in aircraft and some studies have been conducted for tanks. However, it would not be advisable to apply these findings to truck design, especially that of light trucks, for various reasons. The seat pedal relation-



Figure 7. View Showing the Awkward Leg Movement Necessary to Operate the Brake.

TABLE 1

SUMMARY OF INTERIOR DIMENSIONS

Item	XM151	M38A1	Recommended
<u>Fixed Limits of the Working Space</u>			
Length of horizontal floor	14½"	12"	11"-15"
Height of dash above floor	17½"	14½"	18"-20"
Angle of toe pan	135°	135°	150°
<u>Operator's Seat</u>			
Height of the seat above the floor	17"	14"	14"-15"
Vertical adjustment	None	None	4" (minimum in 1" intervals)
Horizontal adjustment	2" (1" intervals)	None	5"-6" (1" intervals)
Seat depth	16½"	16"	16"-19"
Seat width	20½"	18"	19"-21"
Height of seat back	12 3/4"	18½"	18"-20"
Width of seat back	20"	17"	21"-22"
Seat angulation			
Angle of seat bottom with the horizontal	13°	9°	8°-11°
Angle of seat back with the vertical	13°	15°	20°-25°
Angle of seat back with the seat bottom	90°	96°	99°-107°

TABLE 1 (CONT.)

Item	XM151	M38A1	Recommended
Distance from dashboard to seat back	33" (seat in hind-most position)	29½"	25"-26" (seat forward) 30"-32" (seat back)
Distance from the brake-clutch to back of seat	36" (seat in hind-most position)	35"	36"-38" (seat forward) 41"-44" (seat back)
Height of the roof above the seat	36½"	37"	41" (seat in lowest position)
<u>Steering Wheel</u>			
Horizontal distance from lower edge of steering wheel to seat back	14" (seat rear)	15 3/4"	15" minimum
Vertical distance from bottom of steering wheel to horizontal floor	23"	22"	25" minimum
Distance from lower edge of steering wheel to brake-clutch	25"	25½"	26" minimum

ships are widely divergent, the maximum forces required differ for various vehicles and this factor is also affected by the amount of power assist which is provided. Thus, the optimum leg angle for exerting a maximum force and the optimum angle for comfort are different. A tank requires a compromise arrangement because a maximum force may be required for the brake in order to hold the vehicle on a steep grade. However, a light vehicle such as a $\frac{1}{4}$ ton truck, would rarely require a maximum effort but an easily accessible pedal with a comfortable leg position is desirable. Therefore, these determinations should be arrived at through empirical investigations for any specific vehicle or class of vehicles. Such data will eventually engender a series of generalizations. Theoretical predictions might also be derived by way of mathematical equations which would have to account for human body size, maximum force required, etc.

Steering Aspects

	<u>XM151</u>	<u>M38A1</u>
Type of Material	hard rubber	hard rubber
Surface	ribbed & knobbled	ribbed & knobbled
Number of Spokes	3	3
Diameter of Wheel	17 $\frac{1}{4}$ "	17 $\frac{1}{4}$ "
Rim Circumference	54"	54"
Length of Steering Column	30 $\frac{3}{4}$ "	29 $\frac{1}{2}$ "
Angle of steering column to horizontal	35°	45°
Angle of steering wheel to horizontal	55°	45°
Diameter of steering post	1 $\frac{1}{2}$ "	1 $\frac{1}{2}$ "
Width of horn button	1 $\frac{3}{4}$ "	1 $\frac{1}{4}$ "

The ribbed and knobbled surface of the steering wheels offered by both vehicles is easily gripped under most weather conditions.

A study by Kaphart (16) recommends a steering wheel angle of 45° with an acceptable variation from 43° to 48°. However, the 55° of the XM151 does not appear to be the source of any inadequacy. In conjunction with providing adequate knee and thigh clearance, the steering wheel should not interfere with the driver's view through the windshield or obstruct his vision of the instrument panel. Both vehicles are satisfactory with respect to these latter considerations.

PROPOSED OPTIMUM: In order to provide for an infinite degree of accommodation, an adjustable steering wheel and steering column have been recommended.

Steering Ratio

The ball joint front suspension on the XM151 is an improvement over earlier models of $\frac{1}{2}$ ton trucks. This feature combined with the 20 to 1 steering ratio makes the vehicle extremely maneuverable and easy to steer.

RECOMMENDATION: Development and Proof Services test personnel have recommended that the 20 to 1 ratio be reduced to approximately 17 to 1. Apparently the ease of steering provided by the 20 to 1 ratio led the drivers to attempt tight turns at top highway speeds, which the vehicle could not safely negotiate. They feel a smaller ratio will tend to reduce this overconfidence in the operators. While the test drivers concerned are probably not representative of the Army driver population, similar reactions might be elicited as any group gained familiarity with the vehicle.

Distance from the Rim of Steering Wheel to the Directional Signal Lever

PURPOSE: To allow for operation of the turn signal lever without removing the hand from the wheel.

ANTHROPOMETRIC MEASUREMENT: Dynamic measurement of finger length.

RECOMMENDATION: It is difficult for the operator to give adequate hand signals when the side curtains are in place because of the size and position of the opening provided. Further, if a hard top is supplied and the vehicle is driven in the continental United States, turn signals are almost mandatory.

Therefore, it is recommended that turn signal kits be provided to be installed on vehicles operating in appropriate areas. The control lever should be placed not more than 24" from the rim of the steering wheel to enable finger tip operation (24).

Light Switch

The standard Army light switch employed by both vehicles has been the subject of some controversy. It is designed to prevent the inadvertent operation of the headlights under blackout conditions. The light switch is located to the right of the steering column on the XM151.

McFarland (22) described it as a well conceived design which presented few difficulties. Sleight (28) on the other hand, was disturbed by the fact that occasionally two hands are required to operate it (Figure 8). The present evaluation found that the switch could be operated with one hand, but that it tended to stick on occasion in which case both hands were required. Arctic gloves also tended to restrict one hand operation. While this condition is not serious if the vehicle is standing still, it could be the cause of an accident if it occurred while the vehicle was in motion. Even with one handed operation, men with shorter arms have to lean forward unnecessarily from the normal driving position.



Figure 8. Two-handed Operation of the Light Switch with Arctic Gloves.

RECOMMENDATIONS: The WW II type of single switch with the safety lock for blackout protection was easy to operate, but the positions could not be labeled. Sleight (28) recommends two toggle switches. The direction of movement for the headlight switch is vertical while the blackout switch is horizontal, but this arrangement still permits the possibility of confusion. Other possibilities are described in Figure 9 as a guide for future design.

<u>Throttle</u>	<u>XM151</u>	<u>M38A1</u>
Shape	elongated oval	elongated oval
Length	2"	2"
Location	6 $\frac{1}{4}$ " right of steering column	6 $\frac{1}{4}$ " right of steering column

RECOMMENDATION: The shape of the throttle is easy to grasp with two fingers even with gloved hands. Sleight (28) has suggested mounting a raised letter T on its surface for coding purposes so that the choke could utilize the same easy to grasp design without confusion even in the dark. However, this coding might not provide adequate discrimination especially for a gloved hand. Therefore, a type of shape coding is recommended as described below.

<u>Choke</u>	<u>XM151</u>	<u>M38A1</u>
Shape	round	round
Diameter	2"	2"
Location	6 $\frac{1}{4}$ " right of steering column	2" left of steering column

RECOMMENDATION: The small round knob is somewhat difficult to grasp especially with gloved hands. The elongated shape of the throttle is better for a control which is pulled out to operate rather than turned (Figures 10 and 11). If the present round knob were increased in size it would provide a sufficient lip or edge that could be easily grasped even with an arctic mitten.

The choke should be placed above the throttle since the two are frequently used successively.

SUGGESTED LIGHT SWITCHES

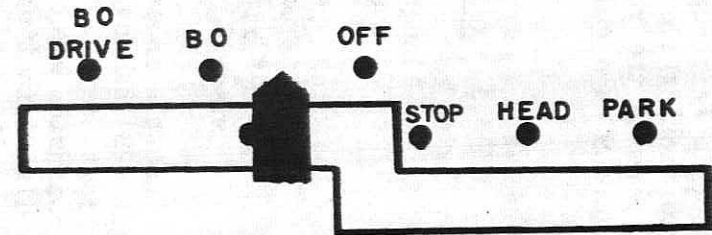
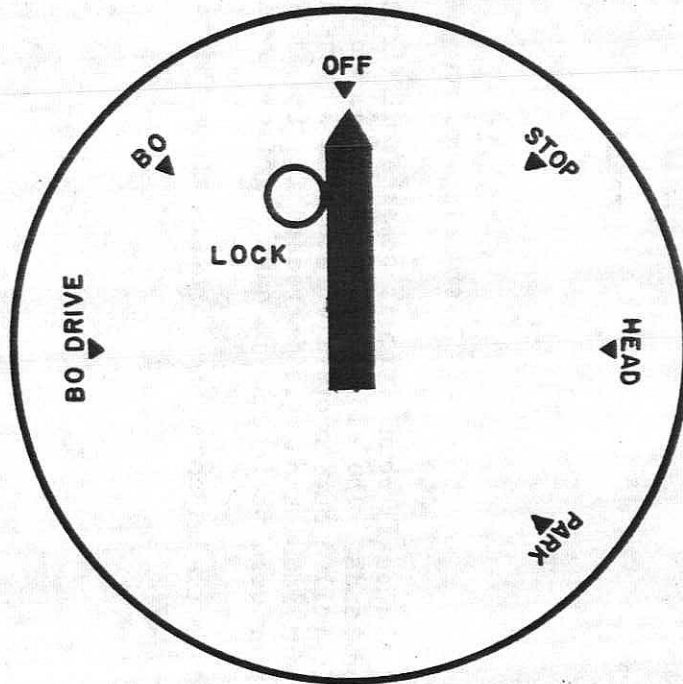


FIGURE 9



Figure 10. Operating the Throttle with Arctic Gloves.



Figure 11. Operating the Choke with Arctic Gloves.

Ignition Switch

XM151

M38A1

Length

1 $\frac{1}{2}$ "

1 $\frac{1}{2}$ "

RECOMMENDATION: The ignition switch is well designed for ease of operation. The location on the left side of the dashboard in the XM151 presents a minimum of problems in terms of inadvertent operation, or confusion with other controls, such as the light switch.

It is recommended that an additional position be added to the right of "on" to include the starter. This will be discussed more fully in the section dealing with the starter.

Gear Shift

XM151

M38A1

Location

Center

26 $\frac{1}{2}$ " from
left side

Length of Arm

14" from top
of tower

15" from top
of base

Shift tower XM151

Height

16"

Width

14"

Distance from Accelerator

1 7/8"

RECOMMENDATION: The XM151 differs from previous models in that four forward speeds are included in the regular transmission. Another innovation is the shift tower which rises from the front floor board.

The transfer case has been eliminated because the additional low gear in the transmission is considered sufficient for all power needs. This represents a major improvement. First, because the need for reaching far to the right for the small transfer lever, a source of dysmmetric, or awkward movements, is eliminated. Secondly, it is usually necessary to come to a complete halt in order to shift into low range of the transfer case. While the front wheel drive is usually engaged for cross country travel, the low range of the transfer case is only used in extremely difficult situations. In many instances, terrain which requires the low range is not so obvious as to enable the driver to anticipate the need until his forward progress begins to be impeded. At this point, momentum is the greatest asset to continued progress, but the stop required for down shifting completely nullifies this advantage. The low gear on the XM151, however, can be engaged while the vehicle is in motion without loss of momentum.

However, certain modifications are indicated for the XM151 transmission. The reverse gear is presently located to the right of third (second gear position in a three speed transmission) and a spring lock prevents accidental engagement. However, when this spring wears, through continual use, it is possible to nick the reverse gear when going from second to third because of the thrust type motion involved. It is recommended that the reverse position be

placed preferably to the left of the first (or low low) gear position or as another alternative, to the right of fourth. (Figure 12).

Another two or three additional inches in the length of the shift lever arm might be of aid to men with shorter arms when they attempt to shift into first, third or reverse gears. Information from Development and Proof Services has also indicated that certain cooling problems within the transmission cause the shift tower to become rather warm. Due to the proximity of the tower to the driver's right leg, it is recommended that either adequate cooling or protective insulation be provided.

PROPOSED OPTIMUM: The steering column is a more suitable place to mount the gear shift lever in terms of minimizing distracting driver movements.

<u>Front Wheel Drive</u>	<u>XM151</u>	<u>M38A1</u>
Location	5 3/4" to left of center on shift tower	3 1/2" right of gear shift on floor board.
Length of Arm	7 1/2" from top of tower	14 1/2"
Diameter of knob	1 1/4"	1 1/4"

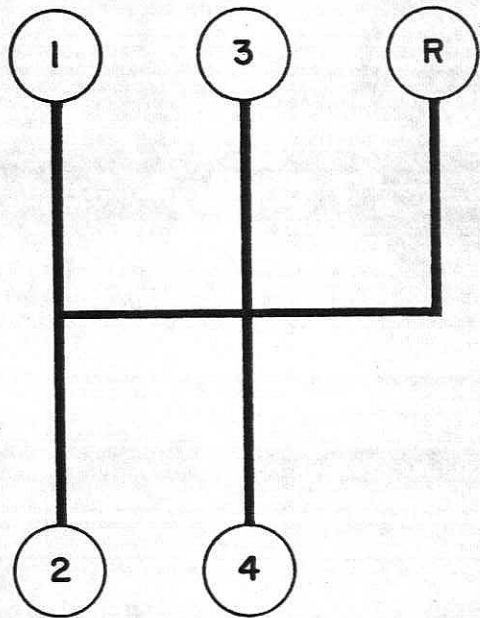
RECOMMENDATION: The front wheel drive in both vehicles can be engaged without declutching. However, with the particular vehicles examined in the course of this study, the front wheel drive in the XM151 was easier to engage.

The front wheel drive lever in the XM151 is more advantageously placed than that in the M38A1 and does not distract the driver from the normal driving position. However, the relationship of the front wheel drive lever and emergency brake arm in the XM151 is worthy of examination. Due to the angles of the two levers with the vertical and the arc through which they travel, an overlap occurs when the emergency brake is in the off position and the front wheel drive is not engaged. This could cause difficulty in an emergency situation or when the driver is reaching for the controls without looking at them. Secondly, it is possible when disengaging the front wheel drive for a slight slip of the hand to partially engage the emergency brake, especially when wearing heavy arctic gloves (Figure 13). It is recommended that the emergency brake arm be moved slightly to the rear and that the front wheel drive lever be lengthened slightly and the angle corrected, to avoid the overlap with the emergency brake. This would not only eliminate the aforementioned condition, but would also aid men with a shorter arm reach.

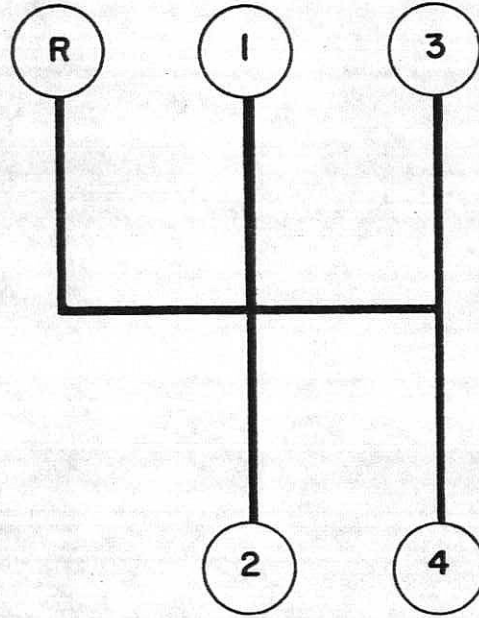
PROPOSED OPTIMUM: A warning signal to indicate when the front wheel drive is engaged should also be considered, since even experienced drivers occasionally forget to disengage it upon returning to a hard surfaced road after cross country operations have been terminated. A small flag or other mechanical device might prove more suitable than a light because of the need for blackout precautions, although the latter might be controlled by appropriate connections with the light switch.

SHIFT PATTERNS

31

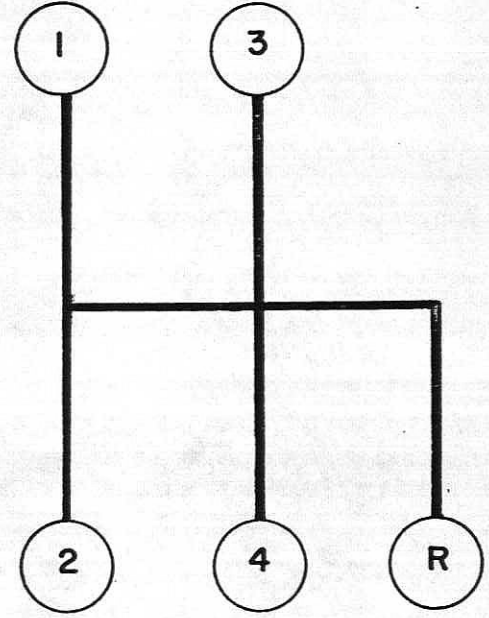


PRESENT SHIFT
PATTERN



PREFERRED

OR



RECOMMENDED SHIFT PATTERNS

FIGURE 12



Figure 13. Operational Interference of Front Wheel Drive and Emergency Brake Levers.

Emergency BrakeXM151M38A1

Location

4½" to left of
center on shift
towerbetween front
seats

Length of arm

8 3/4" from top
of tower

Diameter of release button

3/4"

Type of release

push button

trigger

RECOMMENDATION: The emergency or parking brake in the XM151 is more advantageous by way of accessibility, method of operation, and forces required. It is rather deceiving in that the force required is slight and the length of arc traveled is small yet the action is quite positive. Corrective measures were discussed in the above section which dealt with the front wheel drive lever.

Accelerator PedalXM151M38A1

Length

2 3/4"

8"

Width

1 3/4"

1 3/4"

Angle with horizontal

60°

55°

Surface

smooth metal

ribbed metal

Clearance with footrest

¼"

Diameter of footrest

1"

RECOMMENDATION: The suspended accelerator pedal in the XM151 is reminiscent of that in the A model Ford and is deficient in many respects. Although neither the XM151 or M38A1 provide any insulation for protection against heat or slippage, the surface of the pedal in the M38A1 offers better footing for mud-caked boots than the smooth surfaced pedal in the XM151. In addition, the shape of the pedal in the M38A1 provides a foot rest while the foot rest in the XM151 traps the welt of the driver's shoe when the accelerator is depressed below the top of the rest (Figure 14). The accident producing potential of this situation is obvious. Should the present accelerator be retained, the foot rest should be redesigned or removed completely.

It is recommended that an accelerator pedal similar to that found in passenger cars be installed. This need not obviate the suspended linkage as may be witnessed from most modern automobiles. However as McFarland (24) has pointed out, most foot pedals presently existing tend to overlook the foot size of the driver population. The accelerator pedal should be 3" wide and 9" to 10" long considering the space limitations. Optimum dimensions, anthropometrically speaking, would be 4" to 4 3/4" wide and 11" long (24). The M38A1 is more adequate than the XM151 in this regard.

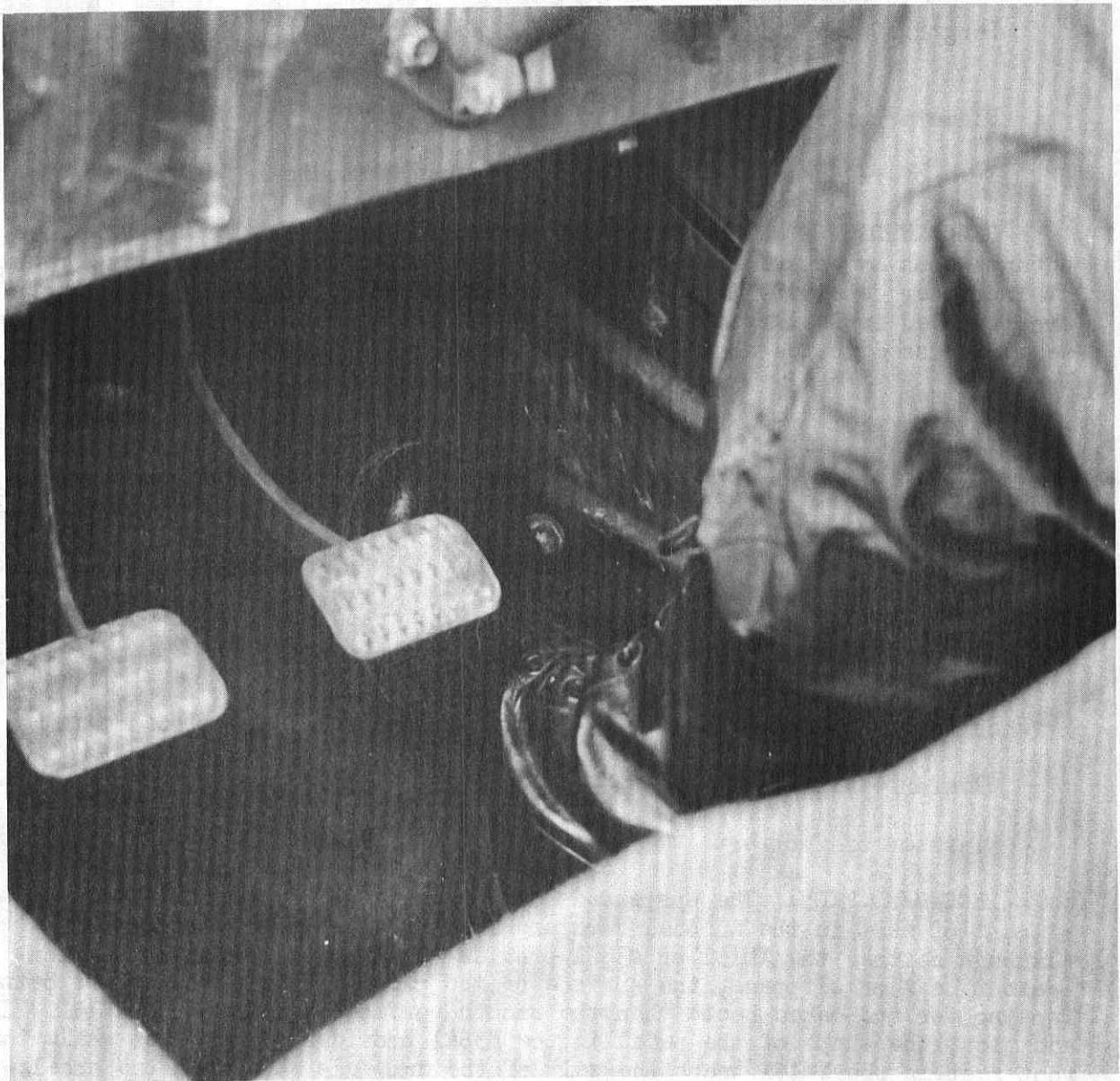


Figure 14. Foot Caught Under Accelerator Foot Rest.

User information has revealed that drivers of Army vehicles tend to use the hand throttle when driving in the desert because of the heat generated by the accelerator pedal. In order to prevent this occurrence and also to insure adequate footing, even with ice encrusted or mud caked boots, a ribbed rubber insulation is recommended. This insulation could even be provided in the form of replaceable caps.

Clutch and Brake Pedals

Clutch Pedal

	<u>XM151</u>	<u>M38A1</u>
Width	3½"	3 3/8"
Depth	2¼"	2½"
Surface	diamond studded metal	diamond studded metal
Pedal travel	8½"	5¼"
Distance between clutch and brake	2 7/8"	3"
Pedal surface angle with horizontal	45°	65°

Brake Pedal

	<u>XM151</u>	<u>M38A1</u>
Width	3½"	3 3/8"
Depth	2¼"	2½"
Surface	diamond studded metal	diamond studded metal
Pedal Travel	approx. 2"	approx 1".
Horizontal distance between brake and accelerator	2¼"	2"
Vertical distance from accelerator to top of brake	5"	2 3/8"
Pedal surface angle with horizontal	45°	65°

RECOMMENDATION: The brake and clutch pedals will be discussed simultaneously due to their similarity of design and operation. The space limitations will, of course, dictate the feasibility of any suggested changes in pedal dimensions. It is suggested that the width of the pedals be increased to 4" and the depth to 3" and an even more optimum width would be 4 3/4", space permitting (24). This permits the driver to exert the same pressure on the pedals while reducing the lbs per sq. inch of pressure on his foot.

The XM151 has not utilized the suspended pedal design to maximum advantage. However, it appears to be potentially more effective than that in the M38A1. While exact quantitative data are not available, the length and angles of the lever arms as well as the angulation of the pedal surfaces should be given consideration. Certainly, the clutch pedal travel of 8" is excessive and could readily be reduced to the more ideal 5" to 6" (13), (Figure 15).

One of the most important aspects of foot controls is the accelerator-brake relationship. Any reduction in the leg travel required will help reduce the braking reaction time which is so crucial in emergency situations. Accelerator brake angulation which permits the foot to pivot from the accelerator to the brake may provide the most rapid braking action. However, care must be taken that the foot is not trapped by the welt of the shoe catching under the pedal to which it is being transferred. McFarland (24) suggests that one solution might be to make the angle formed by the brake pedal and the horizontal more acute than the angle formed by the accelerator and the horizontal. Other remedies might include sloping the underside of the pedals in order to eliminate sharp angles.

The same recommendation in regard to ribbed rubber insulation as was made in the case of the accelerator pedal also applies here.

Starter

XM151

M38A1

Location

under
clutch

under dash behind
gear shift lever.

RECOMMENDATION: The starter button is probably the least accessible control on the M38A1. It requires a stretched and distorted leg movement to actuate the starting motor. The starter button on the XM151 is contacted by fully depressing the clutch pedal which is a definite improvement over the M38A1. It offers the added safety advantage that the vehicle will not leap forward if an attempt is made to start it while in gear since the clutch will be disengaged. Depressing the clutch also reduces the load on the starter motor by eliminating turning over the transmission linkage.

However, the starter button can be contacted directly by the foot without depressing the clutch. Field tests report that this has been done on occasion because of unsatisfactory clutch pedal contact with the starter button due to slight deformations of the clutch pedal support arm. This finding has been confirmed by a CONARC Board Number 2, deficiency report NR 268, which states that the clutch pedal arm is deflected sideways under foot pressure and with continued use becomes permanently deflected thus failing to engage the starter. It is also difficult for men with short legs to properly engage the starter.

It is recommended that a more optimum design could be accomplished by including the starter in the ignition switch. The starting position might best be included to the right of the "on" position. (29)

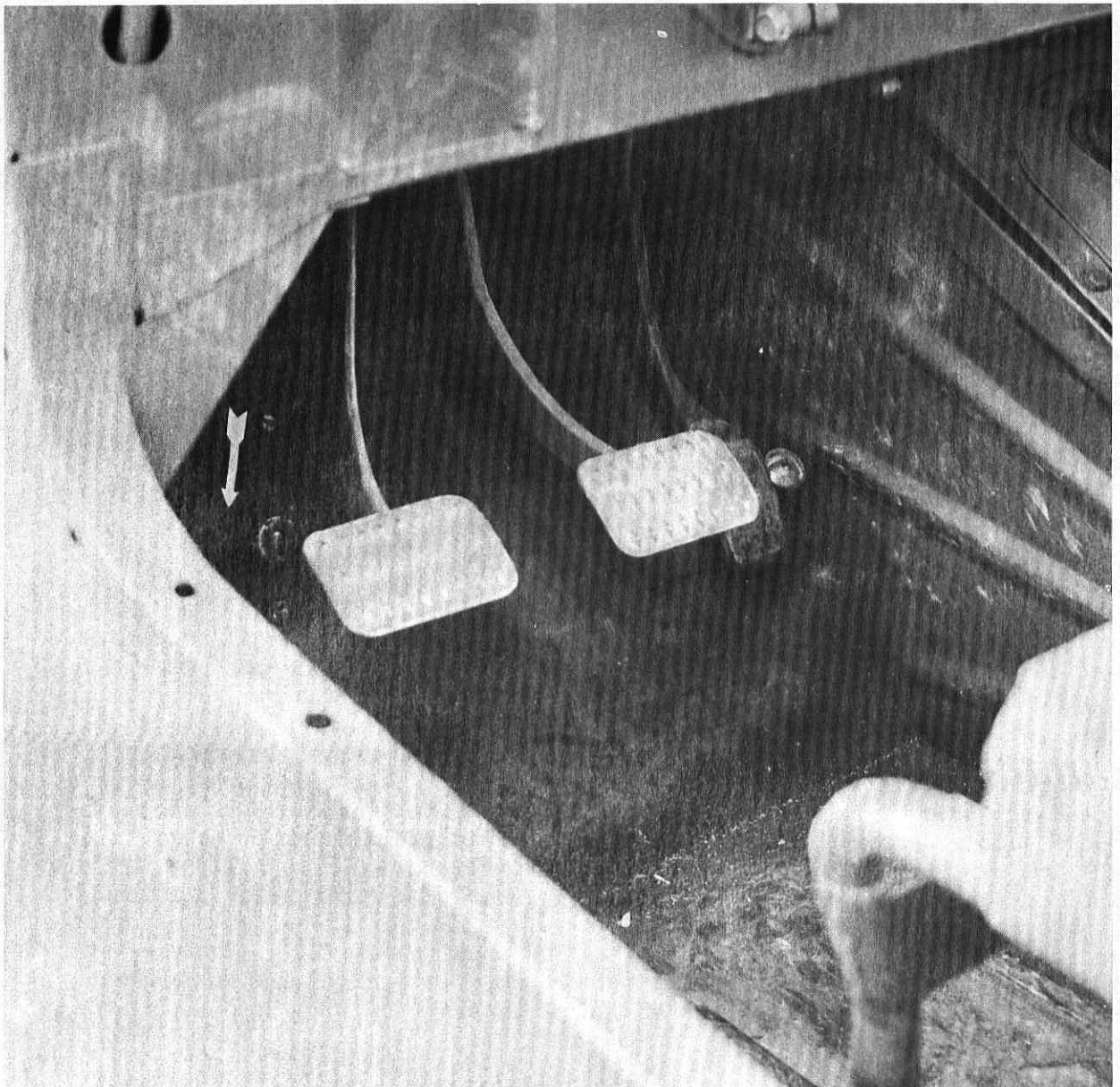


Figure 15. View of Suspended Pedals. Arrow Shows Position of Starter.

Dimmer Switch

	<u>XM151</u>	<u>M38A1</u>
Location	extreme left side on toeboard	10" in from left side on toeboard
Diameter	1"	1"
Height	2"	1½"

RECOMMENDATION: The dimmer switches in both vehicles appear to be adequate and present no particular problems. Perhaps a slightly greater diameter would help prevent slippage in the event the soles of the driver's shoes are wet or muddy. Since the switch is always located by feel, a slightly larger diameter might also make it easier to locate.

The important consideration is that the switch be located far enough to the left of the toeboard so that there is ample room for the driver to rest his left foot without placing it on the dimmer switch or having it trapped under the clutch pedal.

D I S P L A Y S

Displays supply information to the operator of a machine which is necessary or at least helpful to the proper control of the equipment. While the majority of displays are visual in nature, it is possible to receive information of this type by way of the other senses.

In some machines, such as aircraft, where the amount of information the operator must rely on is constantly increasing, the demand upon the visual sense is greatly overworked. While much experimental work must be accomplished before acceptable solutions become available it seems probable that the other senses can be utilized more extensively in order to relieve the visual burden. Automotive displays are not nearly so numerous or critical to the operations as those employed by aircraft, but it is quite likely that even in this area the visual sense is relied upon too heavily. However, at present the most definitive and reliable research offerings are concerned with maximizing the effectiveness of visual displays.

DISPLAY COMPONENTS

	<u>XM151</u>	<u>M38A1</u>
Display information	speedometer ammeter	speedometer ammeter fuel gage oil pressure gage temperature gage

Recommendations: The XM151 does not present the usual complement of display information. While the weight saving in terms of the dials and their linkage is probably not too great, the cost reduction through a number of vehicles might be considerable.

Any consideration of the information necessary for an adequate display panel in a transport vehicle should give cognizance to the following questions:

1. Is sufficient information presented for the proper operation of the vehicle?
2. Will the omission of certain displays result in increased wear and maintenance?
3. Will the omission of customary display information cause the vehicle to be viewed as inferior or expendable by using personnel, resulting in excessive abuse?

The answer to the first question might be partially determined by the Army driver regulations. Thus, trip tickets and certain maintenance schedules require an odometer. Likewise, in order to observe legal speed limits, as well as not to over-speed in a particular gear range, a speedometer is required.

The second question is concerned with whether the operator receives sufficient indication of mechanical malfunctioning such as low oil pressure. The third question must ultimately also deal with operational procedures but it is basically attitudinal in nature. Its impact is of special significance when dealing with a sample of the American population because of the standards derived from our highly refined technology.

Obviously, definitive and conclusive answers can be obtained only by a long range study of the vehicles in the field. However, since no such austere vehicles are currently an item of issue, any present recommendation must be conjectural in nature.

After due consideration of the aforementioned questions, in conjunction with the results obtained from the user survey, it is recommended that the following displays be considered minimum for this class of vehicles:

speedometer and odometer
ammeter
fuel gage
oil pressure gage
temperature gage

Location of the Instrument Panel

	<u>XM151</u>	<u>M38A1</u>
	center of dashboard	center of dashboard

RECOMMENDATION: The instrument panels in both vehicles are mounted in the center of the dashboard and are therefore to the right of the driver's seat. However, the seat-dash relationships are such that the driver is afforded a better view of the instrument panel in the M38A1 than the XM151. In the latter,

the speedometer is visible from the normal driving position, but the driver is forced to lean to the right in order to view the ammeter. This situation could, on occasion, result in an accident (Figure 16).

It is recommended that the instrument panel be located directly in front of the operator between eye level and 30° below eye level. However, positions up to 45° below eye level are considered satisfactory (1, 30). Further, any dial requiring binocular vision should be within 60° left and right of straight ahead (17), (Figure 17).

Instruments should be normal (90°) to the line of sight for the best viewing angle (28). This requires that an instrument panel be sloped at 45° angle from a vertical dashboard.

The normal viewing distance should be 28" if the operator is to adjust controls or switches on the panel (1, 18, 30).

<u>Speedometer</u>	<u>XM151</u>	<u>M38A1</u>
Location - center of speedometer to steering column	12½"	10"
Diameter	3¼"	3¼"

RECOMMENDATION: The diameter is adequate for the quantitative-like reading (see following section on optimum presentation) involved at the normal viewing distance (22). However, the speedometer in both vehicles violate one of the first rules of good dial design by presenting more information than is necessary. A mark at 0, 5, 10, etc., is recommended rather than the marks at every position, 0, 1, 2, 3, etc., since it is seldom if ever necessary to read the speedometer with that degree of accuracy.

<u>Ammeter</u>	<u>XM151</u>	<u>M38A1</u>
Type of scale	tri-colored	numbered
Diameter	1 3/4"	1 3/4"

RECOMMENDATION: The diameter of 1 3/4" is satisfactory for the normal viewing distance of 28" (29). The tri-colored scale employed in the XM151 appears better suited for the type of quantitative reading (see section below on optimum presentation) than the numbered scale used in the M38A1. However, an arrangement which permits the green to indicate the safe or normal reading rather than the yellow would be more suitable.

An Optimum Display

The following represents an attempt to depict an optimum display for light vehicles such as the XM151 (Figure 18). It is probably not the one best design possible if, indeed, such should exist. Rather, it is offered as a guide for

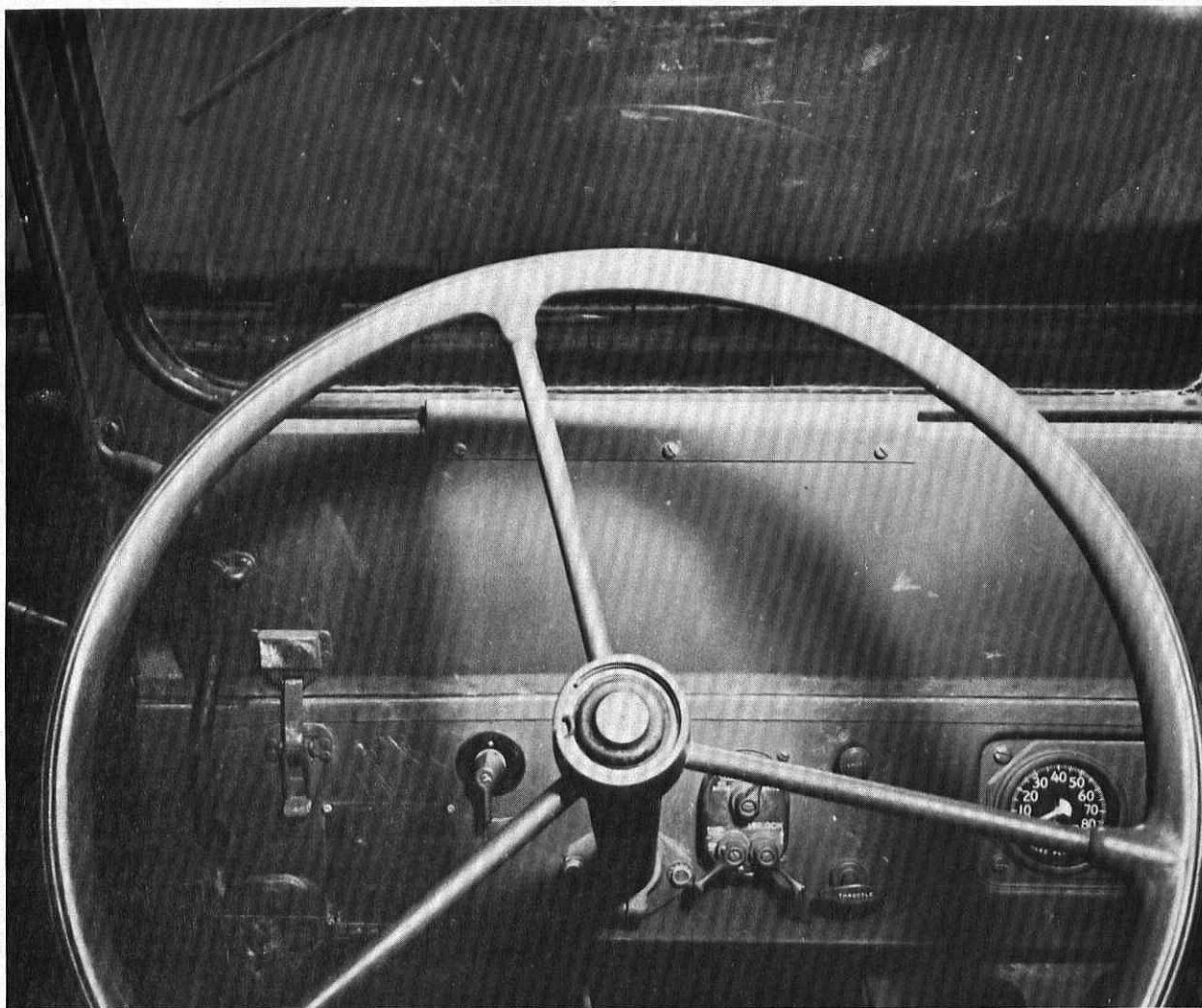


Figure 16. The Instrument Panel from the Driver's Eye Level.

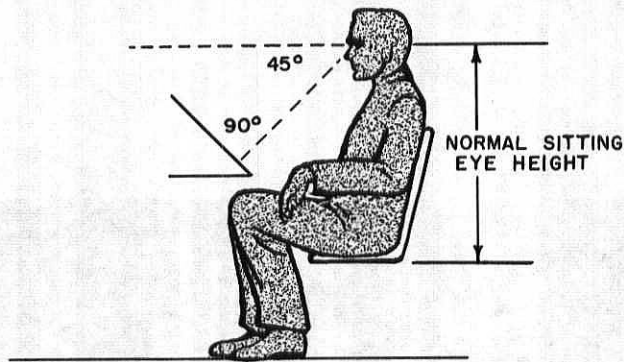


Figure 17. An Optimum Display Location.

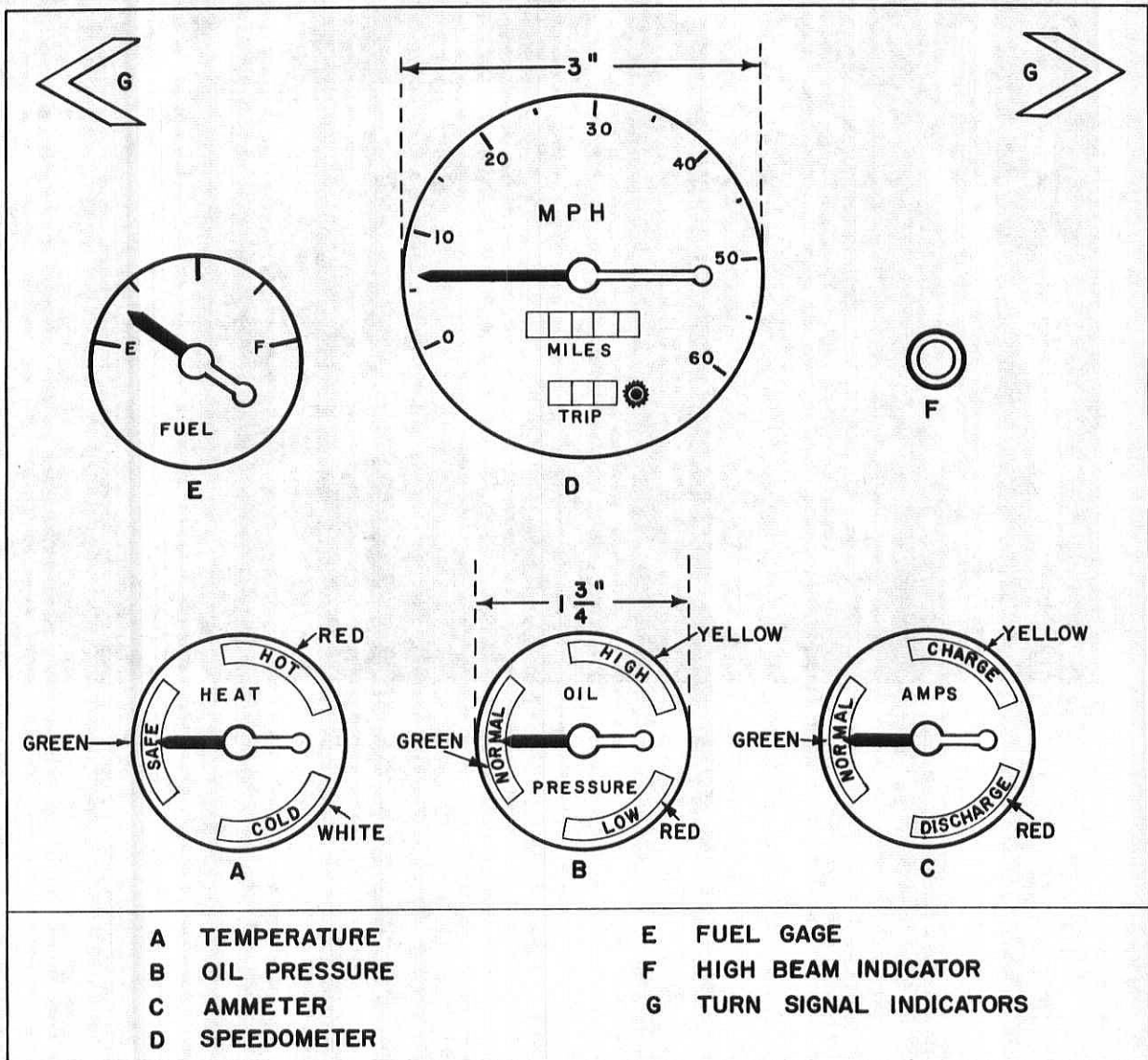


Figure 18. A Suggested Optimum Display.

designers of display equipment as a concrete example in the application of human engineering principles.

ASSUMPTIONS: Any hypothetical design is based on certain assumptions which should be validated before the plan is accepted.

1. While many automobile manufacturers now employ warning lights as oil pressure and ammeter indicators, it is assumed that useful information is omitted. Thus, a battery that is overcharging may also be faulty or the voltage regulator in need of adjustment. However, a red warning light only indicates a discharge.

2. Sleight (28) has suggested that a direct counter might be more properly employed as a fuel gage than the conventional moving pointer type. His reason is that the interest is in the amount of fuel rather than proportions of a full tank. However, this would require a knowledge of the fuel capacity of the vehicle, plus some knowledge of the fuel consumption. In short, the driver would probably have to translate the information back to the more familiar proportion of the tank data in order to judge whether or not it was necessary to refuel. Therefore, this report recommends the moving pointer scale display.

3. It is assumed that turn signals should be included in vehicles operating in the Continental United States and other non-combat areas.

4. It is assumed that a trip counter, included in the speedometer display, would be useful for drivers proceeding according to a map or other instructions in cross country operations.

If a trip indicator is included in the speedometer, the counter should increase with clockwise rotation of the knob.

The high beam indicator should be a steady light. Sleight (28), however, has recommended the word "HIGH" illuminated by a steady white light. Naturally, any type of high beam indicator should only be operative when the high beam is on.

The turn signal indicators should be flashing white lights in the form of < and > chevrons.

Operating Instruction Plate

The operating instruction plate on the XM151, which depicts the shift pattern for the transmission and the front wheel drive and states the maximum permissible road speeds for each gear, is mounted on the left of the dashboard. It might be more advantageously mounted on the slanted surface of the shift tower in nearer proximity to the controls with which it is associated (Figure 19). In this position the neophyte driver could avoid the necessity of shifting his eyes from the left of the dash to the shift tower. The plate might also be mounted where the instrument panel is located if the latter is moved as recommended.

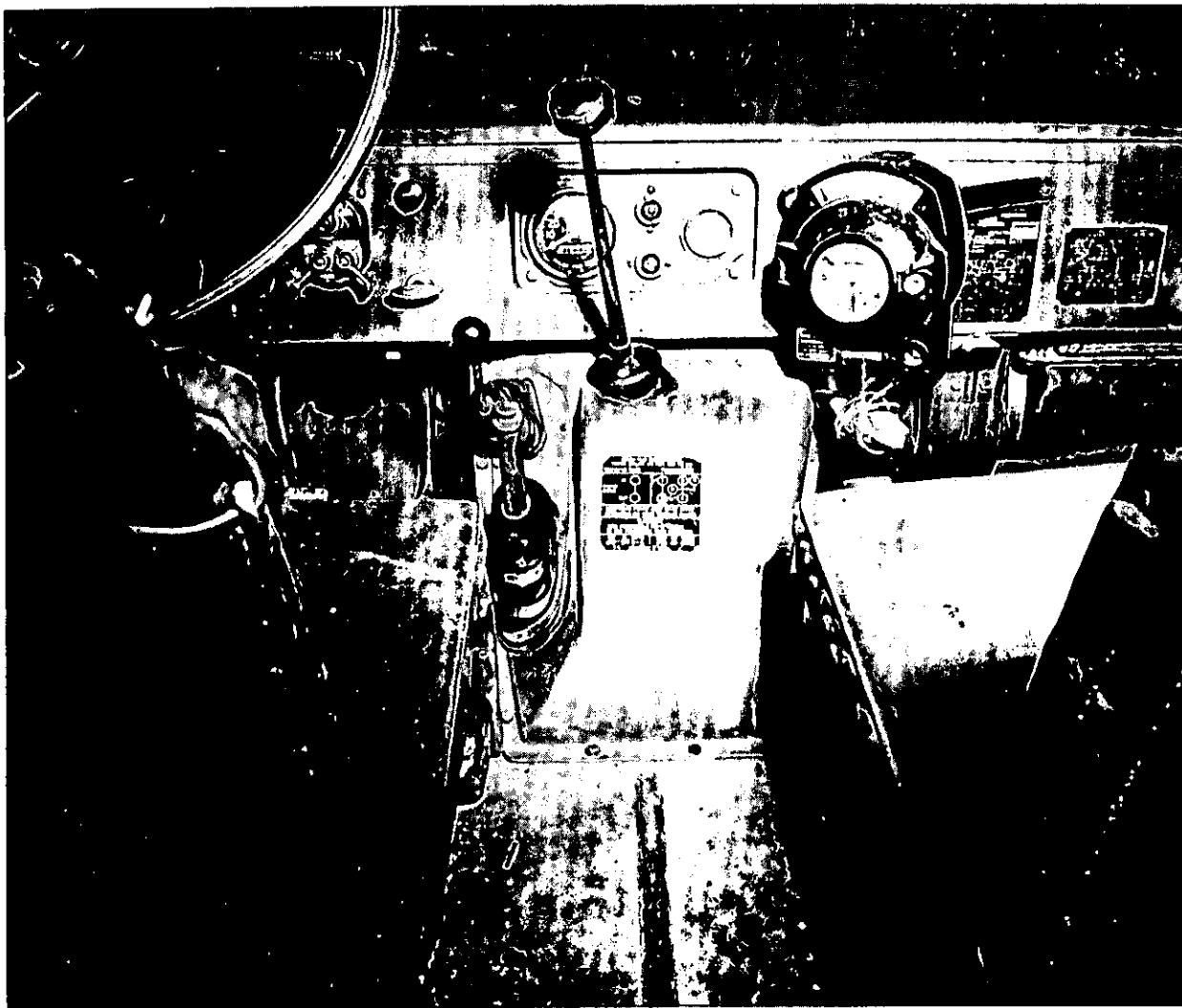


Figure 19. Instruction Plate Mounted on Shift Tower.

V I S I B I L I T Y

It has been reported by the National Safety Council that obstructed vision is a partial cause of about one out of ten automobile accidents. This information would appear to warrant considerably greater effort in the design of windshields and wipers from a functional rather than from a style viewpoint.

<u>Windshield</u>	<u>XM151</u>	<u>M38A1</u>
Number of panels	2	2
Width	26 $\frac{1}{4}$ "	27"
Height	12 $\frac{1}{4}$ "	12"
Area/panel	321.56 sq. in.	324 sq. in.
Total area	643.12 sq. in.	648 sq. in.
Height to top of glass from horizontal floor	46"	43 $\frac{1}{2}$ "
Angle with vertical	15°	20°

PURPOSE: To provide a maximum unobstructed forward vision.

ANTHROPOMETRIC MEASUREMENT: Normal sitting eye-height.

RECOMMENDATION: The military requirement of the low silhouette and the need for maximum visibility are somewhat incompatible. The XM151 is inadequate for a large portion of the population because of the height of the seat above the floor and the lack of vertical seat adjustability, which places the line of sight of taller drivers at the top of the windshield on a line with the un-cleared area of the wiper pattern and wiper motor (Figure 20).

The M38A1 is somewhat better in this respect because of the lower seat height, although this advantage is somewhat nullified by the lower center of gravity and thus increased floor to top of windshield height provided by the XM151. Since the overall height of the vehicle, with the windshield and top up, is determined by the roof support bracket, an additional few inches could be added to the height of the windshield with little alteration to the silhouette. This would do much in providing adequate visibility for tall drivers as well as increasing the head clearance.

The short flat hood of the XM151 provides better forward vision than the M38A1 by allowing a view of the road closer to the vehicle as is evidenced by the following data.

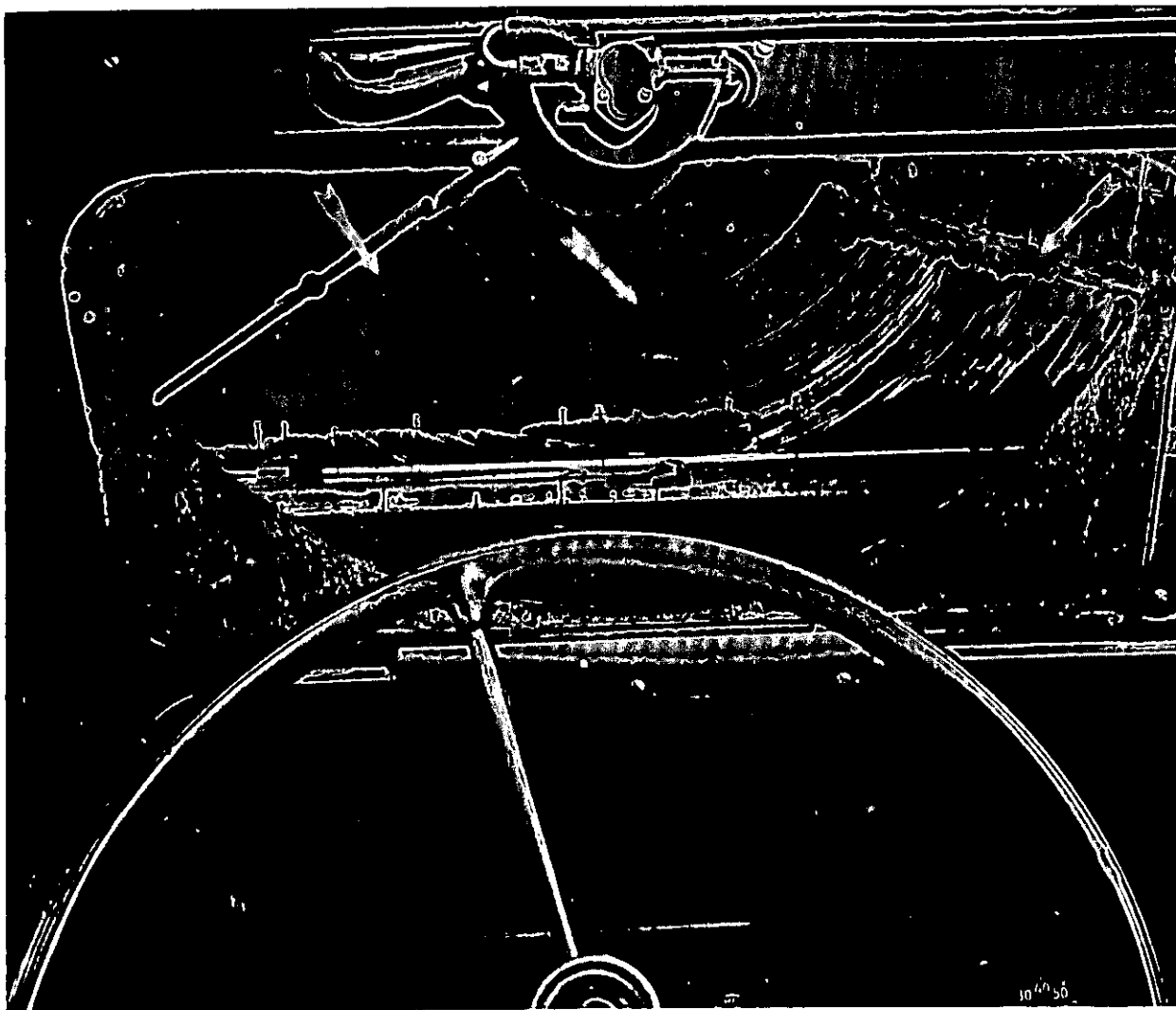


Figure 20. Forward Vision of Man in 95th Percentile. Arrow points to area left uncleared by wiper.

The measurements represent the horizontal distance from the driver's eye to where the road becomes visible:

	<u>XM151</u>	<u>M38A1</u>
Subject 5th Percentile of sitting eye-height	18.83'	21.58'
Subject 95th Percentile of sitting eye-height	18.00'	20.25'

The subject in the 5th percentile had the seat in the foremost position of adjustability in the XM151 and the subject in the 95th percentile in the hindmost. The M38A1 does not provide horizontal seat adjustment.

The 6" advantage afforded the 95th percentile is not in conflict with previous statements regarding the inadequate vision of tall men provided by the XM151, since the normal line of sight is not directed downward at the angle required for the above measurements.

It is also recommended that a one piece windshield be installed in the XM151, thus eliminating the need for the center post. In addition, there is no apparent structural reason for not increasing the glass area by utilizing part of the metal area in the lower portion of the windshield. This would allow the seat to be lowered without interfering with the visibility of short drivers and at the same time enhance the vision of the taller ones.

PROPOSED OPTIMUM: Research has shown that forward vision can be improved to a greater degree by narrowing the corner posts than from the wrap around windshield (19). This results from the fact that wrap around windshields frequently present areas of distortion. Secondly, current wipers cannot adequately clean curved windshields and the air flow is such that curved windshields get dirtier than side windows which, of course, can also be lowered in the advent of an emergency. Therefore, it is recommended that corner posts be narrowed as much as possible within the limits of structural feasibility.

<u>Wipers</u>	<u>XM151</u>	<u>M38A1</u>
Location	top of windshield	top of windshield
Length of blade	8 $\frac{1}{4}$ "	8 $\frac{1}{4}$ "
Radius of sweep	13 $\frac{1}{2}$ "	13 $\frac{1}{2}$ "
Arc of sweep in degrees	120°	120°
Areas cleared/blade	163.5 sq. in.	163.5 sq. in.
Area cleared by both blades	327 sq. in.	327 sq. in.
Percent of total area cleaned by both blades.	51%	50%

WipersXM151M38A1

Control

variable

variable

Location

extreme left
on windshieldleft of
windshield

RECOMMENDATION: The wipers should be placed at the bottom of the windshield in order to facilitate the vision of tall drivers by eliminating the dead space of the sweep arc from their line of sight. This would not affect the vision of the shorter men including those in the 5th percentile, since their sitting eye-height is above this area. In conjunction with this relocation of the wipers, the length of the blades should be increased to the maximum of mechanical feasibility and an automatic return to the off position would also be helpful.

PROPOSED OPTIMA: King, Sutro and Kydd (19) state that the best wiper pattern for a rectangular windshield is a straight line motion, extending to both sides. However, even this arrangement would require two blades because of the time involved for one blade to complete a full sweep.

The above mentioned writers are presently designing a variable angle wiper which they claim is simple in design and readily adaptable to most vehicles. With this arrangement, they feel that two wiper patterns or sometimes three should provide adequate visibility for most windshields. Until this new variable angle wiper is perfected, they recommend that three conventional wipers be employed instead of the usual two.

Windshield washers are recommended for military vehicles as well as filter attachments for night driving on rear view mirrors (19, 28). However, sun visors and tinted glass must be employed with caution. Sun visors obscure upward vision for viewing traffic lights, low bridges, and vehicles descending an opposite slope. Glass which is tinted too darkly reduces already diminished night vision to the danger point. A narrow strip of transparent tinted glass along the top of the windshield is one solution.

Rear VisionXM151M38A1

Side mirror diameter

5"

5"

Rear window

Width

19 $\frac{1}{2}$ "18 $\frac{1}{2}$ "

Height

12 $\frac{1}{4}$ "11 $\frac{1}{4}$ "

Area

238.87 sq. in.

208.12 sq. in.

Material

plastic

plastic

RECOMMENDATION: The extent of the rearward vision was determined by a method described by Pike (25). The vehicle was placed with its longitudinal axis parallel to a line which corresponded to the white center line of a highway. An observer was seated in the vehicle and allowed to adjust the side mirror for maximum rearward vision. The distance behind the driver's head at which the line disappeared, was measured and is defined as the distance x . Then while the observer remained seated in the same position, the examiner walked back and forth at fixed distances behind the vehicle and the observer called out when he appeared and disappeared from view in the mirror. From these determinations, the angular extent of rearward vision was measured and this is defined as the angle θ . In addition, the distance behind the vehicle where the line first became visible was measured and this is defined as the distance y (Figure 21).

Two observers, one in the 5th and the other in the 95th percentile of sitting eye-height, participated and the results were identical in both cases.

	<u>XM151</u>	<u>M38A1</u>
x	∞	∞
θ	15°	11°
y	$14' 7''$	$22' 5''$

Ideally, the distance x should be equal to infinity as is the case with the XM151 and the M38A1. The angle θ should be as large as possible and in this respect, the XM151 was slightly better than the M38A1 (Figures 22 and 23).

Both vehicles compared favorably with the British Army vehicles evaluated by Pike when the British vehicles also were equipped with but a single side mirror. However, when an interior mirror was included in addition to the side mirror, Pike found the angle θ greatly increased.

Therefore, it is recommended that a rear view interior mirror be installed. However, in order for this mirror to be effective, the plastic material of which the rear window consists should be replaced with a material which will remain transparent under all conditions. The present plastic scratches so easily that for all practical purposes, the rear windows in both vehicles are merely translucent. The size of the rear windows should also be increased as much as possible.

A blind spot occurs in the side mirror for vehicles which are attempting to pass when they reach a position just to the rear of the driver's seat. This might be alleviated by a mirror of different design such as a curved oblong shape. Some additional consideration should also be given the mirror support arm so that the mirror will remain in a fixed position even when the vehicle is negotiating rough terrain. It has also been observed that the side door tends to displace the mirror when it is opened and it is difficult to readjust the mirror with the door in place from the driver's seat.

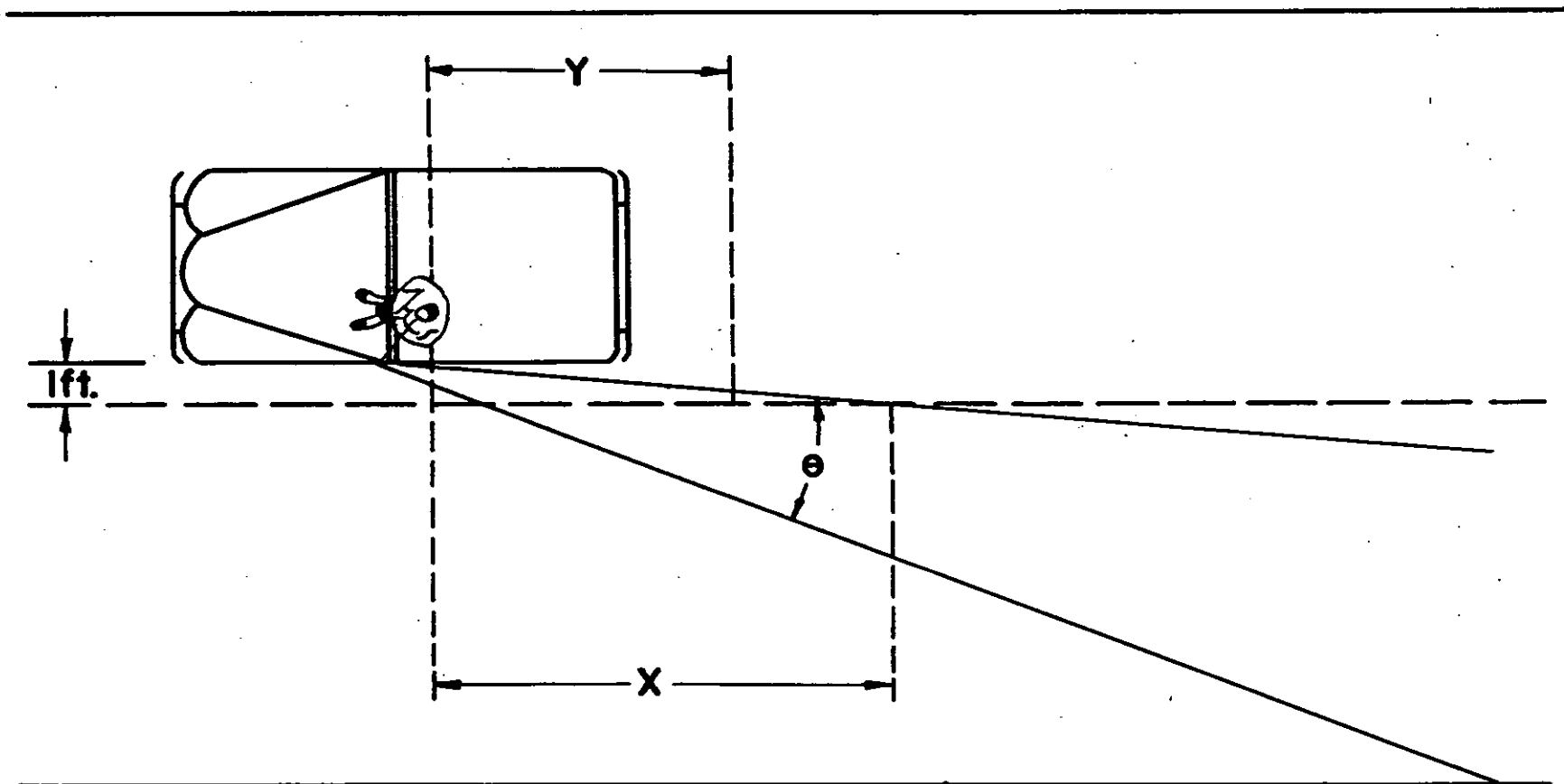


Figure 21. Diagrammatic Presentation of Rear Vision Measurements.

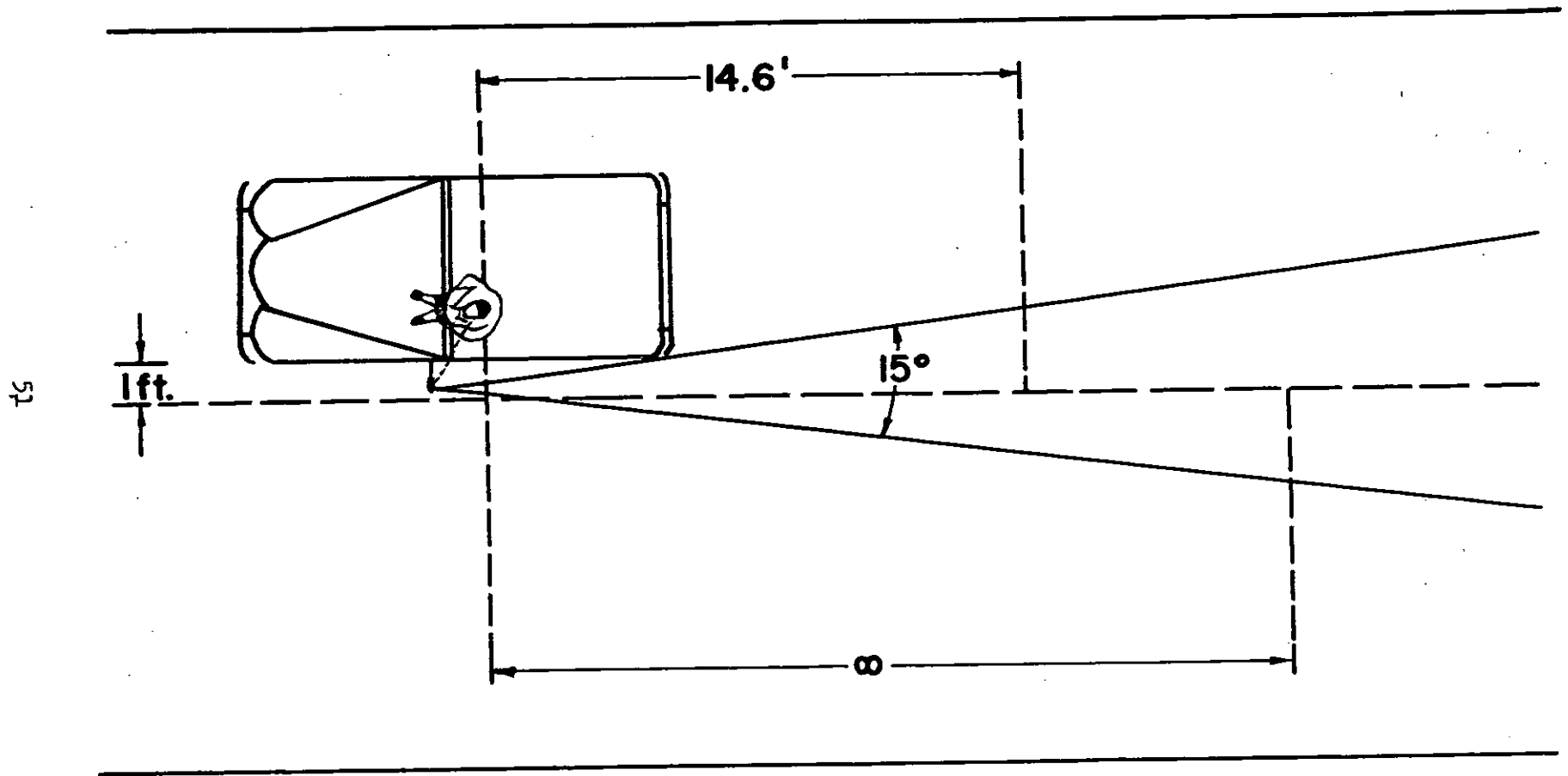


Figure 22. Measures of Rear Vision for the XM151.

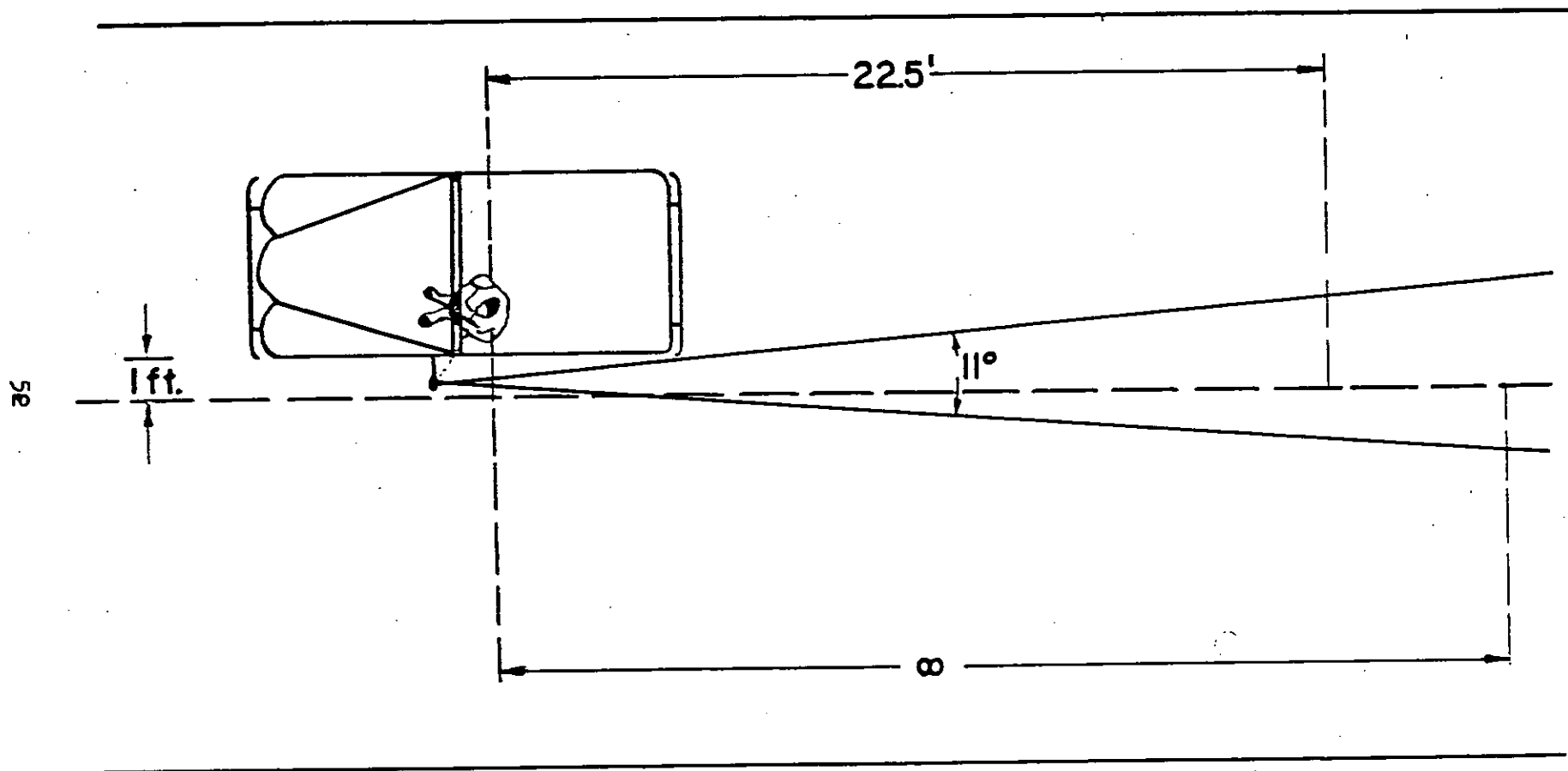


Figure 23. Measures of Rear Vision for the M38A1.

SAFETY AND COMFORT

A report by McFarland (24) cites the following statistics in regard to accidents in the United States Army for the period 1947-49. Motor vehicles were the cause of over fifty percent of all fatalities which occurred during this period. General purpose and special equipment vehicles ranked first among accident causing agents, and accounted for thirty-five percent of the total. Even in the Korean combat area, accidents accounted for one-half of the hospital cases and of this number, seventy percent were attributable to land vehicles. These figures more than justify an evaluation of the safety and comfort aspects of Army vehicles. McFarland (24) concludes that any control which is difficult to operate, any instrument which is difficult to read, any unnecessary obstruction to vision, or any discomfort which induces unnecessary fatigue may result in an accident.

Obviously, more attention should be paid to programs for driver selection and training in addition to improved vehicle design. However, since accidents occur even under the most optimum conditions, the problem arises of how to better protect the occupants of motor vehicles and increase their chances of survival in the event they are involved in a mishap.

The most pressing need is to increase the protection for vehicle passengers under conditions of sudden deceleration and impact forces of 14 ft./sec² or greater. Research has shown that the human body if properly restrained can withstand a force of more than 29 g's and can be stopped from a velocity of 50 mph within six inches without injury. However, a speed of 15 mph can be fatal if the head is not checked during rapid deceleration. Theoretically, a person restrained by a shoulder harness should be able to survive a collision with a brick wall where the vehicle stops in 2 feet from a velocity of 57.4 mph (24).

McFarland (23) has found that the most uncomfortable stops are those made in short distances at low speeds of approximately 20 mph. Surprisingly, the occupants were much more likely to be thrown forward against the windshield or dashboard during these stops than from those made at high speed. Apparently, at higher speeds the brakes are unable to stop the vehicle quickly enough to cause a sudden change in speed.

In the event a vehicle is struck from the rear, an occupant is at rest with respect to the vehicle and is thus forced back in the seat. However, since his head is above the level of the seat back, it is snapped backward. The result may be a broken neck or chronic pains. Therefore, if it is possible to anticipate a collision of this type, it is best to slouch down in the seat and press the back of the head and neck firmly against the seat back. However when head on collisions occur, the body held in place by a seat belt will decelerate at the same speed as the vehicle, while the head is whipped forward and may crack against the dashboard or other forward obstruction since the body will tend to pivot about the seat belt. Therefore, in the event of this type of collision, it is best to bend forward with the head shielded by the arms.

McFarland (23) recommends flat surfaces with some degree of energy absorbing ability. A similar material is now available for many passenger cars although its energy absorbing ability should be examined. Foam rubber, although it provides a soft cushion, has been found unsuitable because the head bounces off and the return bounce can be murderous. Therefore, an energy absorbing plastic is recommended.

It is recommended that restraining devices be considered, preferably a shoulder harness arrangement with seat belts as the minimum. Such devices must provide for the necessity of rapid evacuation of the vehicle in a combat situation. It should also be recognized that regardless of how well such devices are designed, in order to be effective they must be worn whenever the vehicle is operated. However in a combat zone an exception may be necessary, because the rapid evacuation of the vehicle as well as other considerations might take precedence over safety. Obviously then, a thorough indoctrination program would have to be initiated in order to enlist the cooperation of user personnel in such a program since it would be impossible to enforce by regulation alone.

A note of caution should be injected at this point. Most seat belt studies have involved closed, steel topped vehicles where the chances for survival are enhanced by the individual being held in place, even in the event of a roll over. Army drivers have indicated that they feel it is better to be thrown clear of an open or canvass topped vehicle should it roll over. If this opinion is valid, the advisability of including restraining devices might have to be evaluated against the frequency of head on collisions as opposed to roll over accidents. The value of roll bars might also be examined.

Other factors which are responsible for unnecessary injuries when high impact forces occur are protrusions such as knobs, sharp edges, etc. (Figure 24). In this connection, the XM151 exhibits the following deficiencies:

1. The defroster deflectors on both sides of the windshield present sharp edges which could be easily modified.
2. The bolts which hold the center strip of the windshield in place extend into the vehicle. If this arrangement is necessary, these bolts could be reversed so as to protrude outside the vehicle.
3. The wiper motors project into the vehicle and provide a source of serious injury to the heads of front seat passengers.
4. If a rear seat passenger is not restricted by some restraining device, he could be seriously injured by the shift tower should the vehicle be forced to decelerate suddenly.
5. The diameter of the horn button which is $1\frac{3}{4}$ " should be increased so as to spread high impact forces over a wider area.
6. The steering wheel as presently constituted would seem to serve as an adequate energy dissipating device under average crash decelerations up to about 20 g's. With impact forces beyond this level, the rim and spoke assembly should be stressed so as to deform and absorb the energy instead of transmitting it to the operator's sternum or chest area. In this connection, a deep dish design would aid in increasing the time before the driver's chest comes in contact with the wheel hub.

In addition, the following areas also decrease the safety factor of the XM151.

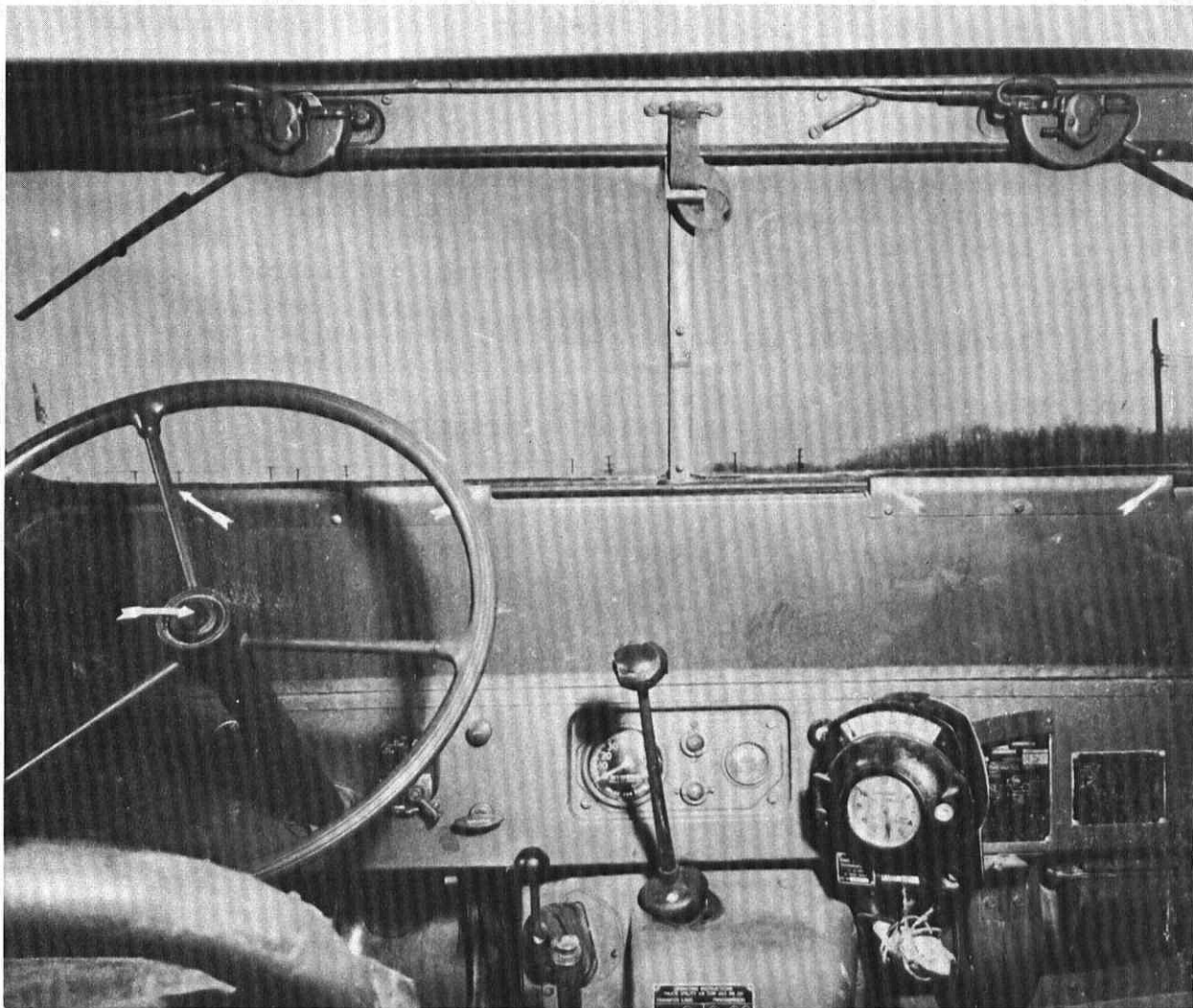


Figure 24. Frontal Area Showing Sharp Projections.

1. The front seat retaining brackets are not satisfactory. A more positive hold down is essential, especially for the assistant driver's seat. At present, the brackets are damaged by the seat legs and become flattened. This allows the seat to fly forward in cross country travel. While the driver has the steering wheel to help maintain his position, the hold bar of the M38A1 is not present in the XM151, for the assistant driver. This bar would have to be mounted on the windshield in the XM151 to be effective because the dash is too low and the use of a bar in this position would only accentuate the effects of sudden deceleration forces. It is also possible for the front seat to injure the foot of a rear seat passenger when it drops back in place.

2. The windshield clamps do not perform satisfactorily during cross country operation with the top down. The windshield tends to vibrate and the clamps unlock, permitting the windshield to fall with resulting damage to the glass and hood. This distraction could also result in an accident. In addition, the spring tension on the clamps render them hazardous to open.

3. The air vents in the XM151 are located in a dead air space and do not permit much air to enter the vehicle. It has also been determined that at certain road speeds the flow of air through these vents is reversed so that air is drawn from the vehicle instead of entering into it.

4. The exhaust pipe terminates under the driver's seat instead of extending to the side or rear of the vehicle. In conjunction with the air vent deficiency discussed above, this could be extremely dangerous when the vehicle is operating with a winterizing kit. In addition, it has been noted by CONARC Board Number 2 deficiency report, NR 267, that the exhaust raises dust clouds which make it easier to detect the XM151 than vehicles of the same size and hampers the vision of drivers to the rear.

5. The electric fuel pump is a potential source of hazard. A CONARC Board Number 2 deficiency report, NR 259, on the XM151 states that a leak in the carburetor float assembly caused the float to fill with gasoline which held the needle valve open. The electric fuel pump, which is in continuous operation after the ignition switch is turned on, filled the intake manifold, air cleaner, and any cylinder with the intake valve open, with gasoline. When these were filled, it continued to pump gasoline into the crankcase and ignition cover through the tubes of the engine ventilating system, causing a hydrostatic lock.

Gasoline in the ignition system cover is a dangerous fire hazard. The drivers conducting the CONARC Board Number 2 tests on the XM151 have been warned to turn off the ignition and examine the ignition system cover for signs of flooding if the engine does not start in a reasonable length of time. This necessary precaution will cause considerable delays on cold mornings when the engines are difficult to start for more normal seasons.

It is recommended that the electric fuel pump be re-evaluated in terms of an adequate by-pass system or replacement by a mechanical type pump.

In a more positive vein the longer wheel base, wider tread and lower center of gravity of the XM151 provide greater stability. The XM151 employs 15" wheels as compared to 16" on the M38A1. In fact, according to rough Development and Proof Services calculations, the XM151 is 40% more difficult to overturn than the M38A1. The independent suspension and coil springs on each wheel also provide a very superior ride for a vehicle of this type which should

tend to reduce driver fatigue. The construction of the seats in the XM151 aside from such factors as height above the floor, adjustability, angulation, etc., which were discussed previously, is quite adequate in terms of passenger comfort. This together with the improved riding qualities provide a much more comfortable vehicle than the M38A1.

A minor item is the lack of a glove compartment in the XM151. The location on the left side of the dash in the M38A1 provided a most convenient storage place for trip tickets, operator's manual, and other essentials.

MAINTENANCE

There are certain aspects of the XM151 which make it difficult to perform the 1st and 2nd echelon maintenance requirements. These items all appear to be readily capable of modification.

1. The front differential filler plug is difficult to remove and replace.
2. Brake shoe adjustments are difficult to make.
3. The vent plug on the transmission gear shift housing is difficult to remove for inspection and cleaning.
4. The master brake cylinder filler plug and opening hole are too small to adequately check and fill the brake fluid.
5. The generator regulator is of a sealed type and cannot be adjusted.
6. The latch for securing the raised hood to the windshield is difficult to release because there is not sufficient space for the driver to insert his hand (Figure 25).
7. The spare tire is mounted backwards which makes it extremely difficult to check and inflate because of insufficient space between the tire and the rear curtain (Figure 26).
8. The spare fuel can bracket is inadequate for holding the spare fuel can during cross country operation.
9. There is at present no provision for carrying pioneer tools on the vehicle.
10. The intake and exhaust valves are reportedly difficult to adjust.



Figure 25. Showing Difficulty of Releasing Raised Hood.



Figure 26. Difficulty in Checking Air Pressure in Spare Tire.

SUMMARY AND CONCLUSIONS

The purpose of the present study was to effect an evaluation of the adequacy of the XM151 in terms of operator efficiency. Secondly, some optimum specifications were provided as a reference for future design requirements.

In addition, a comparative evaluation was made of the XM151 and M38A1 since the latter is the last production vehicle of the $\frac{1}{4}$ ton class. Finally, user information was gathered in an effort to partially substantiate the results and recommendations which ensued from the preceding evaluation.

The basic engineering innovations which have been incorporated in the XM151 are reflected in various ways. The longer wheel base, wider tread, and lower center of gravity provide increased stability. Rough calculations predict that the XM151 is 40% more difficult to overturn. The independent suspension and coil springs on each wheel combine with the seating components to provide superior riding qualities which should tend to reduce excessive driver fatigue. The four speed transmission which is nicely situated for ease of operation is a definite advantage over previous models. The suspended foot pedals appear to possess latent possibilities but they have not been utilized to their best advantage. In this connection, the location of the starter is a marked improvement over the M38A1, where it was placed in an almost inaccessible position. The ball joint front suspension provides steering characteristics which are almost too responsive and may have to be reduced to provide more positive control.

Certain aspects of the XM151 are in need of modification. The accessibility especially to the rear compartment is inadequate. The instrument panel does not provide sufficient information regarding the operational condition of the vehicle. Its location with respect to the operator's line of sight is also inferior to that of the M38A1.

RECOMMENDATIONS

The XM151 is an improvement over earlier models in terms of the man-machine relationships. However, certain deficiencies prevent the full utilization of its basic potential and these should be corrected before the vehicle is considered for production.

Several areas which warrant further research are as follows:

1. Determination of the optimum accelerator-brake relationship.
2. Study of the forces required for the various foot controls.
3. Determination of the most efficient angulation for the foot pedals.
4. Analysis of the requirements and ways to improve the forward, rear, and side vision.
5. Analysis of the information which should be presented by the instrument panel and a determination of the optimum display location and components.

6. Study of the optimum seat relationships for driver and passengers.
7. Determination of the optimum design and arrangement of hand controls.
8. Study of the safety aspects and requirements for a vehicle of this type.

APPENDIX A ANTHROPOMETRIC MEASUREMENTS

(See McFarland, Ref. 22)

AGE (Army Drivers)

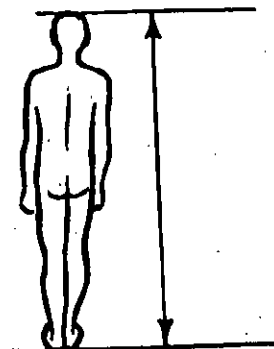
Number - 2380	Years
5th Percentile	19.49
95th Percentile	32.30
Median	22.44
Range	15-43

WEIGHT (Army Drivers)

Number - 2380	Pounds
5th Percentile	126.52
95th Percentile	191.67
Median	153.10
Range	100-271

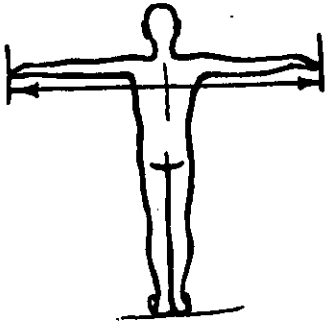
HEIGHT (Army Drivers)

Number - 2380	Inches
5th Percentile	64.21
95th Percentile	72.50
Median	68.23
Range	60.24-77.56



ARM SPAN (Civilian Drivers)

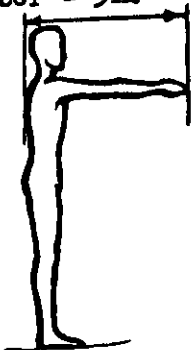
Number - 305



	Inches
5th Percentile	66.46
95th Percentile	75.47
Median	70.87
Range	62.89-77.83

ANTERIOR ARM REACH (Civilian Drivers)

Number - 312



	Inches
5th Percentile	32.95
95th Percentile	38.42
Median	35.75
Range	30.66-41.67

SHOULDER BREADTH (Army Drivers)

Number - 2373



	Inches
5th Percentile	16.56
95th Percentile	19.66
Median	17.92
Range	14.96-22.05

CHEST DEPTH (Army Drivers)

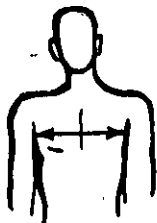
Number - 1662



	Inches
5th Percentile	7.27
95th Percentile	9.58
Median	8.31
Range	5.91-11.81
64	

CHEST BREADTH (Army Drivers)

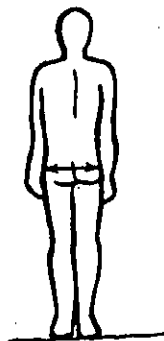
Number - 1652



	Inches
5th Percentile	9.99
95th Percentile	12.41
Median	11.12
Range	8.27-15.35

HIP BREADTH (Army Drivers)

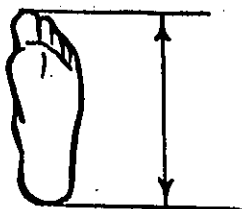
Number - 1656



	Inches
5th Percentile	10.28
95th Percentile	12.90
Median	11.42
Range	8.66-15.35

FOOT LENGTH (Army Drivers)

Number - 2359



	Inches
5th Percentile	9.65
95th Percentile	11.23
Median	10.44
Range	9.09-11.69

FOOT WIDTH (Army Drivers)

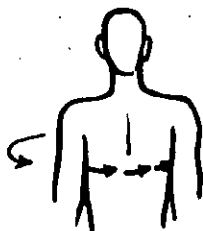
Number - 2369



	Inches
5th Percentile	3.50
95th Percentile	4.27
Median	3.89
Range	3.07-4.69

CHEST CIRCUMFERENCE (Army Drivers)

Number - 2375



	Inches
5th Percentile	33.05
95th Percentile	40.48
Median	36.31
Range	29.53-46.46

ABDOMINAL DEPTH (Army Drivers)

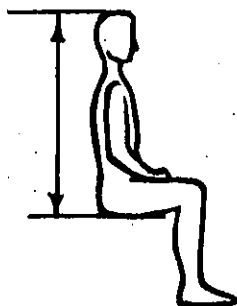
Number - 1665



	Inches
5th Percentile	7.97
95th Percentile	10.51
Median	9.03
Range	6.69-13.78

ERECT SITTING HEIGHT (Army Drivers)

Number - 2369



	Inches
5th Percentile	33.46
95th Percentile	37.85
Median	35.70
Range	30.71-41.34

NORMAL SITTING HEIGHT (Civilian Drivers)

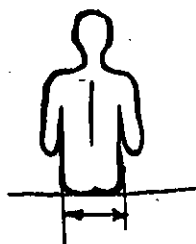
Number - 313



	Inches
5th Percentile	32.60
95th Percentile	36.58
Median	34.65
Range	30.71-37.80

SEAT BREADTH (Army Drivers)

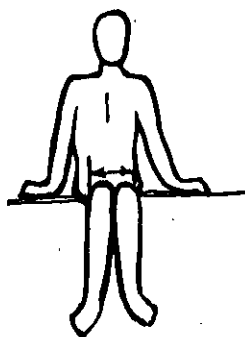
Number - 1656



	Inches
5th Percentile	12.65
95th Percentile	15.37
Median	13.84
Range	11.42-18.90

KNEE BREADTH (Civilian Drivers)

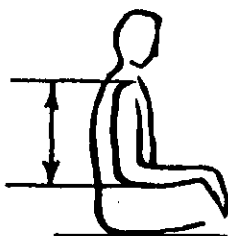
Number - 311



	Inches
5th Percentile	7.32
95th Percentile	9.17
Median	8.07
Range	6.69-11.02

SHOULDER-ELBOW HEIGHT (Army Drivers)

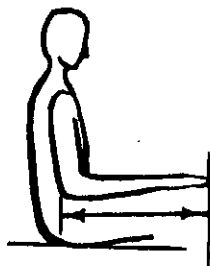
Number - 1650



	Inches
5th Percentile	13.01
95th Percentile	15.49
Median	14.26
Range	11.42-16.54

ELBOW-MIDDLE FINGER (Army Drivers)

Number - 1636



	Inches
5th Percentile	17.17
95th Percentile	20.07
Median	18.72
Range	14.96-22.05

TRUNK HEIGHT (Army Drivers)

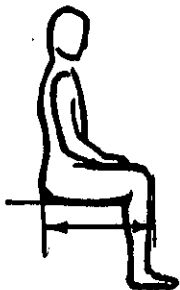
Number - 1671



	Inches
5th Percentile	20.92
95th Percentile	24.92
Median	22.96
Range	18.50-26.38

BUTTOCK-KNEE (Army Drivers)

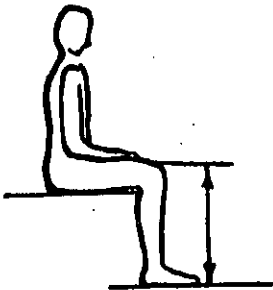
Number - 2353



	Inches
5th Percentile	21.49
95th Percentile	25.16
Median	23.33
Range	19.29-27.56

KNEE HEIGHT (Army Drivers)

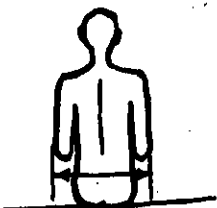
Number - 2376



	Inches
5th Percentile	19.78
95th Percentile	23.42
Median	21.56
Range	17.72-25.59

ELBOW BREADTH (Army Drivers)

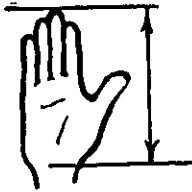
Number - 1664



	Inches
5th Percentile	15.35
95th Percentile	20.25
Median	17.48
Range	13.39-23.62

HAND LENGTH (Army Drivers)

Number - 2364



	Inches
5th Percentile	7.02
95th Percentile	8.19
Median	7.60
Range	6.61-8.82

HAND WIDTH (Army Drivers)

Number - 2372



	Inches
5th Percentile	3.17
95th Percentile	3.75
Median	3.46
Range	2.76-4.17

HAND CIRCUMFERENCE (Civilian Drivers)

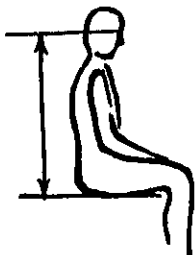
Number - 311



	Inches
5th Percentile	7.56
95th Percentile	8.90
Median	8.27
Range	7.16-9.53

NORMAL SITTING EYE HEIGHT (Civilian Drivers)

Number - 309



	Inches
5th Percentile	27.72
95th Percentile	31.61
Median	29.61
Range	26.38-32.68

APPENDIX B USER INFORMATION

It was deemed advisable to obtain user information from operators of the current $\frac{1}{4}$ ton equipment in order to ascertain the general problem areas. Thus, a supplemental evaluation could be provided to determine whether the XM151 was more or less adequate in these areas as well as offering a partial validation for the preceding recommendations.

A sample of sixty $\frac{1}{4}$ ton truck drivers was interviewed by personnel of the Field Liaison section of the Human Engineering Laboratory. The sample must be termed accidental for purposes of technical accuracy but an attempt was made to make it is representative as possible.

The sample may be described as follows:

<u>Number of Men Interviewed</u>	<u>Unit</u>	<u>Location</u>
10	11th Ord. Co.	Ft. Dix, N. J.
18	716th M.P. Co.	Ft. Dix, N. J.
11	585th Sig. Co.	Ft. Monmouth, N. J.
9	501st Sig. Co.	Ft. Monmouth, N. J.
5	510th Sig. Co.	Ft. Monmouth, N. J.
<u>7</u>	B Co. 1st Bn. 2nd AC.	Ft. Meade, Md.
Total - 60		

1. Age

The average age was 25 years with a range extending from 17 to 43 years.

2. Height

Mean = 69.85 inches (5' 10")

Range = 64 to 76 inches (5' 4" to 6' 4")

3. Weight

Mean = 171.92 pounds

Range = 125 to 215 pounds.

4. Months in Army

Mean = 57.5 months (4 years, 9½ months)

Range = 5 months to 17 years.

5. Months as ½ ton Vehicle Operator

Mean = 50.2 months (4 years, 2.2 months)

Range = 1 month to 17 years.

6. Months of Driving, Military and Civilian

Mean = 103.9 months (8 years, 7.9 months)

Range = 10 months to 28 years

7. <u>Type of Vehicle Driven</u>	<u>M38</u>	<u>M38A1</u>	<u>BOTH</u>
Number of men:	39	5	16

It can be seen that according to mean figures this sample of Army drivers is slightly older and taller and a good deal heavier than the one described by McFarland in Appendix A.

SEATING

The men felt that the operator's seat should be adjustable. The short men complained in some instances of not being able to reach the controls, while some of the taller drivers stated that the dash was too close. One item was rather surprising in that some of the tall men stated that the seat was too low. This was in contradiction to the previous recommendations made in regard to forward vision. However, their request for seat adjustability indicates that they may have confused raising the seat with moving it back in order to lower their knees from a rather awkward position.

Generally speaking, the men wanted a more comfortable seat. Short, heavy men felt the seat was too narrow while other frequent suggestions were for a higher back rest slightly curved to fit the back, and softer seats with more padding.

A large majority (53 out of the 60 men interviewed) described the rear seat as inadequate. They stated that it was too narrow for more than one occupant and generally uncomfortable because it was too low and too close to the front seat. The latter point has already been partially remedied by the XM151.

CONTROL ASPECTS

1. Hand Controls - The men were asked which of the hand controls - throttle, choke or light switch was least satisfactory and why. The light switch was most objected to by 33 of the 60 drivers because it was too complicated and hard to learn. They also objected to the lock which sometimes requires two hands to operate.

There were also some objections to the throttle and choke. The short men stated that it was too far away. There were some statements to the effect that these controls tend to stick and are hard to operate. There were also some complaints in regard to the notches on the throttle. The small round knob provided by the choke was described as hard to grasp, as was recognized earlier in this report when the hand controls were evaluated.

The concept of a four speed transmission which would eliminate the transfer case was favorably received by 51 of the 60 operators. They felt it would eliminate the need for stopping to down shift and also prevent fumbling for the transfer case lever at night. However, they cautioned that it would have to be capable of supplying as much pull as the old arrangement.

A few men objected to the left hand position of the emergency brake in the M38. Others disliked the position between the front seats in the M38A1 because it hampers accessibility to the rear compartment while the mode of operation results in scraped knuckles.

Additional suggestions and comments included dissatisfaction with the horn (which sometimes fails to work) as well as a desire for a wider horn button or a horn ring. It is interesting that the wider horn button was requested to facilitate ease of operation rather than to distribute higher deceleration forces over a wider area, in view of the recent safety publicity on this subject. Mention was also made that the gear shift lever should be located on the steering wheel column.

2. Foot controls - It was interesting that only one of the men declared that he used the throttle on long trips. The others all used it only for starting and idling, according to their statements, while a few claimed they never used it. These statements receive some validation from the numerous objections to the notches on the throttle, which permit it to be set at a constant speed and would therefore be useful if the throttle was used in place of the accelerator while the vehicle was in motion. However, it should be noted that the men were not operating under conditions of extreme heat where the accelerator becomes too hot for prolonged foot contact.

Nevertheless, 22 men objected to the angle and position of the accelerator while 53 of the 60 drivers desired rubber insulation on the foot pedals. However, the reason given for desiring rubber pedals was to prevent foot slippage rather than for insulation. A few men objected to the rubber on the grounds that it would wear out too quickly while others recommended replaceable caps such as were suggested previously in this report.

Another objection attested to by 35 drivers was the difficulty in going from the accelerator to the brake. The pedals were described as being too close in horizontal distance which results in the brake overlapping the accelerator, thereby catching the foot. Secondly, the vertical distance was felt to be too large and thus requires excessive leg movement and increased brake reaction time.

The starter was regarded as awkward to operate by 52 of the drivers questioned. The XM151, of course, is greatly improved in this respect. However, many of the men suggested a push button starter mounted on the dash as a substitute.

DISPLAY ASPECTS

The interviewees were asked to rank the oil pressure gage, ammeter, temperature gage, and fuel gage according to amount of usage each received. The average rank of the oil pressure gage was 1.74, indicating the most use. However, the temperature gage received an average rank of 2.39, the fuel gage 2.73 and the ammeter 2.92 which indicates that they are considered equally important. In addition, in spite of the fact that an equal category was not specifically mentioned, 9 of the men said they used all the gages an equal amount. These findings are in agreement with the recommendation that all of the normal displays be returned to the XM151.

Warning lights were considered suitable replacements for the oil pressure gage and temperature gage by 35 of the drivers. The primary reason given was that warning lights attract attention more readily than gages. Some of the men who objected to the use of warning lights were concerned about the fact that the bulbs burn out quickly and without their knowledge. However, the majority felt that the lights did not offer sufficient information in that they do not indicate which direction a given deviation is from the normal.

Only 15 respondents stated that the instrument panel was difficult to observe while driving. The red panel lights did not provide sufficient illumination for night driving and the tendency of the dials to sweat and fog-up was also objected to. None of the men were involved in an accident or knew of an accident caused by the necessity of switching the eyes from the road to the instrument panel.

Despite these latter findings 30 men felt the display should be moved. They recommended that it be moved to the left and center around the steering column in line with the driver's forward vision. They also demurred in regard to the straight up and down position of the present panels and suggested that the bottom of the panel be tilted forward.

VISIBILITY

The forward vision was considered satisfactory although 18 men protested about the windshield wipers. They suggested electric motors for constant speed drive and wiper blades that have better contact with the windshield. None of the men discussed the wiper pattern arrangement spontaneously. However, 25 of 60 drivers felt the wipers should be located at the bottom of the windshield rather than the top when this question was specifically asked. Many of them made this recommendation because they objected to the blades falling from the rest position when located at the top rather than because the cleared area provided better vision.

The rear and side vision was intolerable to 49 of the 60 men and many of those who offered no objection stated that they had never driven with the vehicle buttoned up. They suggested a larger rear window made of glass or an improved plastic that would not scratch as easily. Apparently, the present

plastic is highly susceptible to fogging and some of the men prescribed improved ventilation.

A center mounted rear view mirror would be a welcome addition to 47 of the men provided the rear window is enlarged and remains transparent. It was stated that the side curtains make it difficult to view the present side mounted rear view mirror.

SAFETY AND COMFORT

The men admitted to 35 minor accidents and 18 major accidents as defined by an injury to a person and/or property damage in excess of \$100. These included civilian as well as military mishaps and are in apparent agreement with the accident data for the United States Army quoted earlier in this report.

In response to a question on how to improve passenger safety, 36 men suggested seat belts or reacted favorably to them when questioned directly. However, they stipulated that a fast and reliable release action be provided. Some recommended them for garrison use but felt they would hinder rapid evacuation of the vehicle in a combat situation. Others recommended them for passengers but not for drivers while a few expressed the opinion that seat belts are helpful but probably would not be used.

However, even those who objected to seat belts expressed the need for some sort of restraining device. Half doors were suggested as well as side safety straps which were available on WW II models. These latter were preferred to seat belts because aside from the expressed need to evacuate the vehicle rapidly in combat, it was felt that it is better to be thrown clear from a canvas topped vehicle in the event of a turnover.

The need for rapid evacuation of the vehicle motivated many suggestions for improved entrance and egress especially to the rear compartment. It will be recalled that the XM151 has been found particularly deficient in this respect. In this connection the hold bar for the assistant driver in the M38A1 was approved by 39 of the men as an aid to entrance and egress rather than as a safety device when traversing rough terrain. In fact, some mention was made of the fact that the hold bar represented a safety hazard in the form of a protrusion from the dashboard.

Turn indicators were desired by 54 of the 60 men since they felt it to be impossible to signal for a turn with the side curtains in place. A more adequate slit in the side curtain for this purpose was also suggested. A few men objected to turn indicators because of the cost involved and others only recommended them for use while in garrison.

Of the 60 men interviewed, 24 stated that they had not received any driver training in the army and the majority of the 36 who received training said it lasted for one week. While 38 men regarded the training as insufficient they, nevertheless, added that most accidents are the result of carelessness rather than poor training procedures. Whether they were expressing an actual opinion or felt it be to the most socially acceptable answer can only be conjectured. Only one man expressed the view that the vehicles themselves were the main source of accidents. In this connection, 29 men felt that the vehicles overturn easily and that training would help the situation. In addition these men recommended a lower and wider design. The XM151 incorporates such modifications and the stability is much improved.

Suggestions to improve driver performance included training for extreme conditions likely to be met in cross country operations as well as a variety of weather and climatic situations. In addition, they expressed the opinion that the courses should be more practical and include maintenance. They also felt that men who are forced to become drivers will make poor ones, but this may express a gripe inherent to the military situation.

MAINTENANCE

There were few items of dissatisfaction in this area. The drivers felt that the levels of maintenance for which they were responsible could be readily accomplished. The most frequently mentioned problem was that the battery cases tended to corrode and had to be removed for cleaning and this was rendered especially difficult for those batteries located in the cowlings.

A few men said that the master cylinder inspection hole was too small as is the case with the XM151. Several also felt that a tire pressure gage would be useful because they now have to guess at the air pressure.

For the most part, the user information corroborated the evaluation and recommendations of the present study. Indirectly, certain of the engineering innovations incorporated in the XM151 were granted added approbation and the deficiencies were further emphasized.

REFERENCES

1. Baker, C. A., and Grether, F. W. Visual presentation of information, WADC Technical Report No. 54-160, 1954.
2. Barber, J. L. and Garner, W. R., The effect of scale numbering on scale reading accuracy and speed. J. Exp. Psychol., 1951, 41, 298-309.
3. Barr, N. L. Visibility of cockpit instruments, J. Aviat. Med., 1950, 21, 328-346.
4. Chapanis, A., Garner, W. R., and Morgan C. T. Applied Experimental Psychology. New York: Wiley & Sons, 1949. 434 pp.
5. Department of the Army. 2½ ton 6x6 truck M135 (TM9-819A). Washington: U. S. Government Printing Office, 1951.
6. Department of the Army 2½ ton 6x6 cargo truck M34 (TM9-819). Washington: U. S. Government Printing Office, 1952.
7. Fitts, P. M., and Simon, C. W. The arrangement of instruments, the distance between instruments, and the position of instrument pointers as determinants of performance in an eye-hand coordination task. USAF Technical Report No. 5832, 1952.
8. Grether, W. F. and Connell, S. C. Psychological factors in check reading of single instruments. USAF Air Materiel Command Memorandum Report Number MCREXD-694-17A, 1948.
9. Grether, W. F., and Williams, A. C. Speed and accuracy of dial reading as a function of dial diameter and angular separation of scale divisions. Chap. 7 in Fitts, P. M. (Ed). Psychological research on equipment design. Washington: U. S. Government Printing Office, 1947, 276 pp.
10. Henry, J. P. A method for the assessment of seat comfort with a description of some results obtained with the pilot's seat of the Douglas BT2D Bomber. National Research Council, Division of Medical Sciences Report Number 489, 1945.
11. Hollis, J. R. Human engineering evaluation of truck ½ ton, 4x4, utility, M38A1. Human Engineering Laboratory, Aberdeen Proving Ground Technical Memorandum No. 12, 1955.
12. Hooton, E. A. A survey in seating. Gardner, Mass: Haywood-Wakefield Company, 1945, 101 pp.
13. Hugh-Jones, P. Some physiological aspects of tank driving controls, Part II, Characteristics of the clutch pedal. BPC 44/379, P. L. 153, Gt. Brit. MRC-MPRC, 1944.

14. Kappauf, W. E., and Smith, W. M. Design of instrument dials for maximum legibility. Part III. Some data on the difficulty of quantitative reading in different parts of a dial. USAF Technical Report No. 5914, 1950.
15. Kappauf, W. E. Design of instrument dials for maximum legibility. Part V. Origin location, scale break, number location and contrast direction. USAF Technical Report No. 6366, 1951.
16. Kephart, N. E., and Dunlap, J. W.. Human factors in the design of vehicle cab areas. U. S. Armed Forces Epidemiological Board, Commission on Accidental Trauma Annual Report, 1954-1955.
17. King, B. G. Functional cockpit design. Aeronaut. Eng. Rev. 1950, 11, 32-40.
18. King, B. G., Morrow, D. J., and Vollmer, E. P., Cockpit studies - the boundaries of the maximum area for the operation of manual controls. Naval Medical Research Institute, National Naval Medical Center Project X-651, Report No. 3, 1947.
19. King B. G., Sutra, P. J., and Kydd, G. H., Human visual capacities as a basis for the safer design of vehicles. U. S. Armed Forces Epidemiological Board, Commission on Accidental Trauma Annual Report, 1954-1955.
20. Kuntz, J. E., and Sleight, R. B. Legibility of numerals; the optimum ratio of height to width of stroke. Amer. J. Psychol. 1950, 63, 567-575.
21. Lacey, R. J. Suitability of the gray instrument panel for use in USAF aircraft. WADC, AML, Tech. Note WCRD 54-12, 1954.
22. McFarland, R. A., et al. Human body size and capabilities in the design and operation of vehicular equipment. Boston, Mass: Harvard School of Public Health, 1953, 239 pp.
23. McFarland, R. A. Human factors in vehicular design and operation with special reference to accidents. U. S. Armed Forces Epidemiological Board, Commission on Accidental Trauma Annual Report, 1954 - 1955.
24. McFarland R. A., and Moseley, M. A. Human factors in highway transport safety. Boston Mass: Harvard School of Public Health, 1954, 295 pp.
25. Pike, D. F. B. Rearward vision from the driver's seats of Army vehicles. Army Operational Research Group, Gt. Brit., Report No. 18/48, 1948.
26. Newman, R. W., and White, R. M. Reference anthropometry of Army men. Quartermaster Environmental Protection Section. Report No. 180, 1951.
27. Sleight, R. B. the effect of instrumen dial shape on legibility. J. Appl. Psychol. 1948, 32, 170-188.
28. Sleight, R. B., Bond, J. H., and Lerner, H. D., Human engineering appraisal of military general purpose vehicles. Human Engineering Laboratory, Aberdeen Proving Ground, Contract No. DA-36-034-ORD-1597RD, 1956.

29. Warrick, M. J. and Grether, W. F. The effect of pointer alignment on check reading of engine instrument panels. USAF Air Materiel Command Report Number MCREXD-694-17, 1948.
30. White W. J. The effect of dial diameter on ocular movements and accuracy of check-reading groups of simulated engine instruments. USAF, AML, Tech. Rep. 5826, 1949.
31. Woodson, W. E. Human engineering guide for equipment designers. Berkeley, Calif.: University of California Press, 1954.