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MANUAL OF STANDARD PRACTICE FOR
HUMAN FACTORS IN MILITARY VEHICLE DESIGN

Robert E. Hedcock

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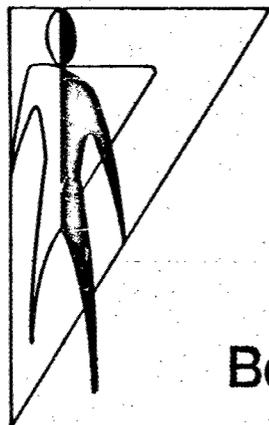
Francis M. McIntyre

August 1962

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HUMAN ENGINEERING LABORATORIES



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HUMAN FACTORS IN MILITARY VEHICLE DESIGN

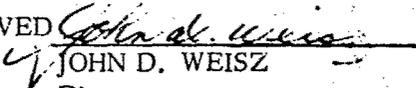
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ABSTRACT

Human factors engineering recommendations for military vehicles in the areas of operability, maintainability, and safety are listed. These recommendations are oriented toward use by human factors specialists. Neither the areas of interest nor the contents of these areas is exhaustive.

An attempt has been made to indicate relational values of various recommendations in order to facilitate trade-off decisions.

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MANUAL OF STANDARD PRACTICE FOR HUMAN FACTORS IN MILITARY VEHICLE DESIGN

INTRODUCTION

This is a manual of standard practices for Human Factor (HF) considerations for military vehicles. It is to be used as a guide for both government agencies and their contractors in the design, development, and production of vehicles for the Army and other government agencies utilizing these vehicles.

This manual is not intended as a weapon system specification, but is intended primarily to deal with the automotive portions of vehicles. It will be employed also in the Human Engineering Test and Evaluation of vehicles built for the Army. The manual is organized to give an indication of the relative importance of the recommendations. Each recommendation has been judged to fit in the following categories:

a. Guidelines -- These are general orientations to the recommendations which immediately follow them. They are intended to show the intent of the area of interest and give an indication of relative importance, so that specialists can make intelligent trade-offs in the design and development of equipment.

b. Desirable -- Recommendations which will increase efficiency and render equipment more operable and serviceable. It is related to "Shortcoming" as defined in OCTI 900-2-61.

c. Essential -- Recommendations which will remove safety hazards or prevent probable serious equipment damage. This term is related to "Deficiency" as defined in OCTI 900-2-61.

PURPOSE

Specifically, the information and criteria contained in this document shall be used in preparing contracts, procurement directives and proposals for concept design, other similar documents, and development of Test and Evaluation Programs. It is intended for use by competent specialists in cooperation and consultation with design engineers, in order to utilize and

incorporate HF considerations at the earliest possible stage of design and development. In instances where these criteria cannot be met, or where further interpretation is needed, cognizant and qualified HF specialists for the procurement organization shall be consulted to secure optimum design in accordance with accepted human engineering principles.

Where this document conflicts with military characteristics or other applicable specifications, the discrepancy will be brought immediately to the attention of the cognizant project manager.

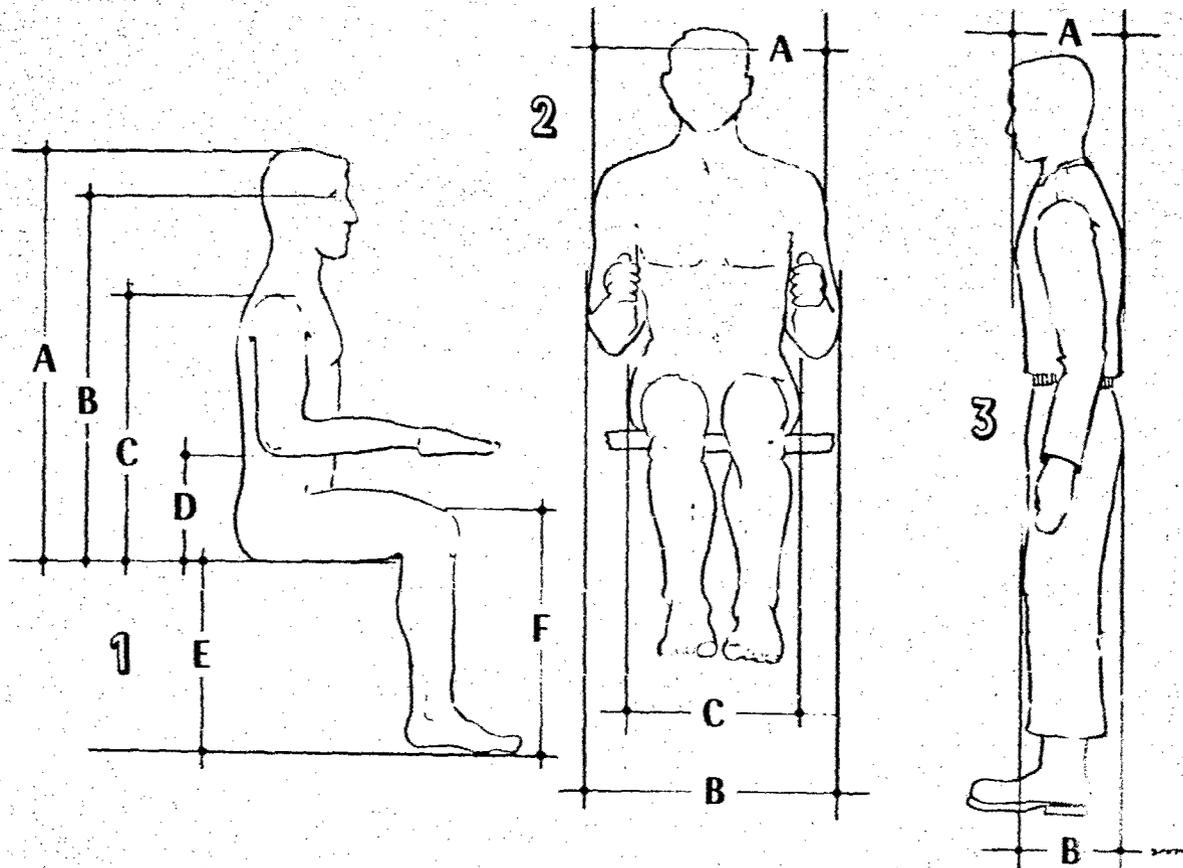
BACKGROUND

There are no current HF documents specifically oriented to the needs of Army automotive equipment. Current usage has relied on data and parameters available in standards prepared for other services, which have had some application to the specific requirements of Army automotive developments, e. g., Mil-Std 803.*

Future plans and development of Army automotive equipment indicate an increased complexity in operation and maintenance in number and kind, to satisfy the future requirements of combat. There will be increased emphasis on the personnel who must operate and maintain the equipment. While training can be expected to produce somewhat more qualified personnel in the future, there still remains an increasing requirement for simplicity and sequential organization of tasks.

* In addition, other instances of HF standards have been usually confined to smaller areas or to limited detail in general specifications. Thus the need for a single detailed standard for automotive equipment is apparent.

Body Dimensions

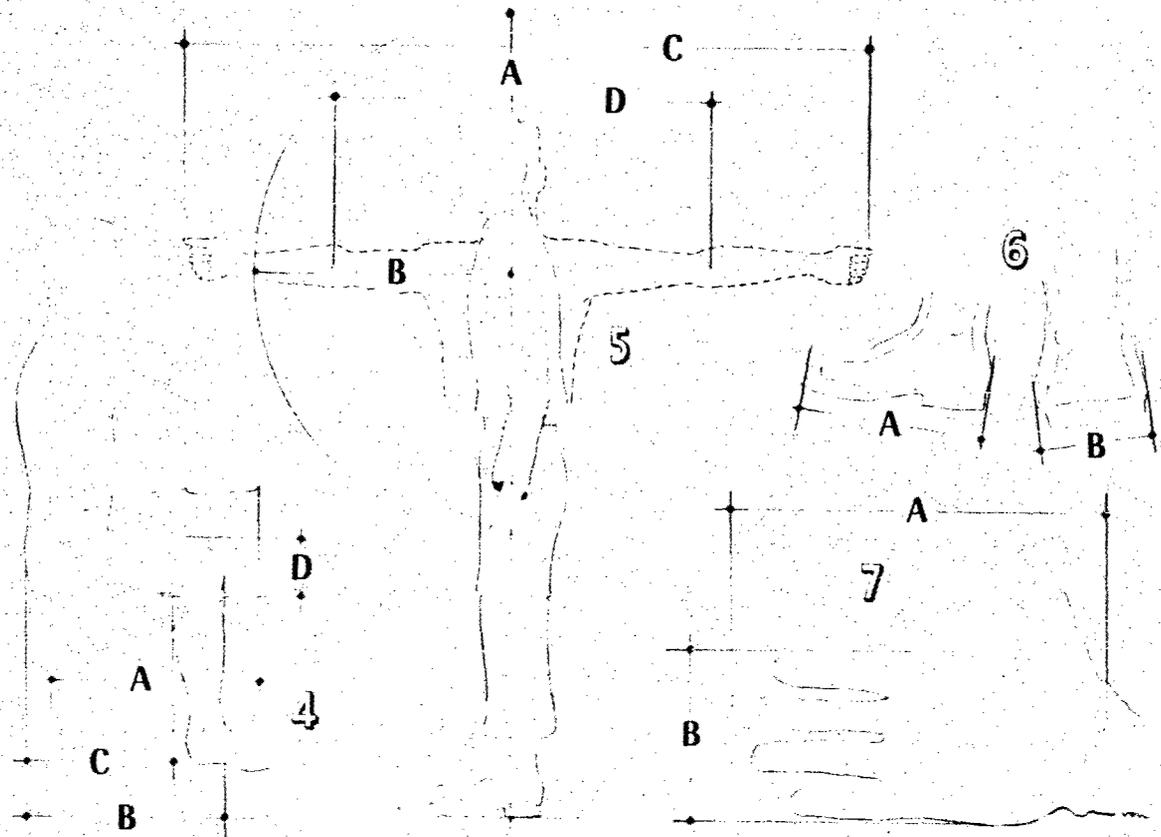


		SMALL MAN	LARGE MAN	LARGE MAN (Heavy Clothing)
HEIGHT	Height (stature)*	65.5	74.0	75.0
	1A Sitting height (erect)*	33.5	38.0	40.5
	1B Eye height (normal sitting) (internal canthus)	28.0	31.5	32.0
	1C Buttock-shoulder height (acromial height)	22.7	26.5	27.0
	1D Buttock-elbow height	7.4	10.8	10.8
	1E Seat height (popliteal height)	16.7	19.2	19.2
	1F Knee height	21.0	24.5	25.0
WEIGHT	Weight (pounds) (no equipment)	130.0	201.0	226.0
TRUNK	2A Shoulder width (bi-deltoid)	16.5	20.0	26.0
	2B Elbow width (bi-epicondylar-elbows)	15.3	20.3	31.5
	2C Seat width	13.0	16.5	23.0
	3A Chest depth	7.5	11.0	15.5
	3B Abdominal depth	8.0	13.0	18.0

*Allow 2.6 inches for helmet.

+Small man represents the 5th percentile -- only 5% of the population are smaller than the values given. Large man represents the 95th percentile -- only 5% of the population are larger than the values given.

For Use In Equipment Design



		SMALL MAN	LARGE MAN	LARGE MAN (Heavy Clothing)
HEAD	Head length (front to back)**	7.2	8.2	11.5
	Head width (side to side)**	5.6	6.4	11.0
HAND	7A Hand length	7.0	8.2	9.5
	7B Hand width	3.2	3.8	5.5
ARM	4A Elbow-finger length	17.3	20.1	21.3
THIGH	4B Buttock-knee length	21.5	25.5	27.5
	4C Seat length	17.5	20.5	20.5
	4D Thigh clearance height (thigh thickness)	4.8	6.5	8.0
FOOT	6A Foot length	11.0	12.7	15.3
	6B Foot width	4.0	4.5	6.3
REACH	5A Overhead reach (functional)	77.8	89.5	89.5
	5B Arm reach--anterior (functional)	29.0	35.0	35.0
	5C Arm span	65.9	75.6	78.0
	5D Elbow span	34.0	39.0	41.0

**Helmet length = 12.0 inches, width = 10.3 inches.

SECTION I

SMALL-MOVEMENT CONTROLS

SECTION I

SMALL-MOVEMENT CONTROLS

A. GENERAL (Table 1, page 25)

1. (Essential) Handles, levers, pedals, knobs, and wheels shall be capable of effective operation by the 5th thru the 95th percentile personnel wearing arctic clothing including gloves and thermal boots.
2. (Guideline) Controls shall be designed and located so that they are not susceptible to accidental activation.
3. (Guideline) When activation of critical controls can result in equipment or personnel hazards, they shall be guarded appropriately against accidental operation.
4. (Essential) The method used to guard the control shall not interfere with its operation unless such interference is a definite requirement.
5. (Essential!) The following methods of guarding against inadvertent operation are recommended:
 - a. Locate and orient the controls away from the normal sequence of control movements.
 - b. Recess the control or place physical barriers around it.
 - c. Cover the control.
 - d. Provide interlocks so that extra movement or prior operation of another control is required.
 - e. Design and build the control so that definite or sustained effort is required to actuate it.
6. (Guideline) All controls having sequential operations involved with a particular function or operation, or which are operated together, shall be grouped together with their associated displays where such grouping most adequately serves the operator task.

7. (Guideline) The most important and frequently used controls shall have the most favorable position in reference to:
 - a. Ease of reach
 - b. Right-hand operation
8. (Desirable) Operating controls, instruments, and vision devices shall be placed to be available to the operator in order of their importance and frequency of use.
9. (Desirable) Operating controls, instruments, and vision devices shall be placed in proper position and sequence to be immediately available to the operator for most efficient use.
10. (Guideline) It must be remembered that the most important controls may not be the most frequently used controls; therefore, the criticality of the control sequence must also be considered.
 - a. (Guideline) Arrangement of functionally similar or identical primary controls shall be consistent from panel to panel and from operating position to operating position.
 - b. (Guideline) Controls shall be distributed so that no one limb is overburdened.
 - c. (Guideline) Control movements shall conform with those of the controlled display or equipment components.
 - d. (Desirable) The use of one control shall not interfere with another unless they are purposely interlocked in sequence.
11. (Guideline) Adequate control mechanisms shall be provided to properly operate equipment and shall be positioned for safe and efficient use.
 - a. (Essential) Appropriate ports and mirrors shall be used to provide visibility; e.g., the vehicle driver shall be able to observe the vehicle winch drum from the control operating position.

- b. (Essential) Control systems shall provide operator feedback.
- c. (Essential) Normally, feedback links are provided to operators as a matter of course. However, it must be remembered that, unless the operator has all necessary current information about a continuing process, his efficiency and speed are decreased in proportion to his lack of information. Some areas where feedback is critical, for example, are as follows:
 - (1) Steering resistance and angular position of wheels on steering axles when traversing rough terrain or during winter operation.
 - (2) Seating must not be so softly sprung that the operator can, unknowingly, destroy equipment.
 - (3) Winch operation must be observed, etc.
- 12. (Desirable) Elastic resistance that increases nonlinearly with the operation of guidance controls, e. g., the joystick, shall be employed to improve the "stick feel" for the operator.
- 13. (Essential) Proportional controls, including engine throttles, shall relate properly the force and movement of control action to the action of the immediate device being controlled.
- 14. (Essential) Proportional controls shall not have dead spots, but control action may be disproportionately rapid where it is not critical, or slow where finer adjustment is necessary.
- 15. (Essential) Controls conventionally located and operated shall have a conventional purpose and shall not require peculiar or unique coordination for proper, safe operation, e. g., brakes or shift.
- 16. (Essential) Control location and movement shall be consistent for all equipment used by the operator and shall be logically related to the action of the equipment being controlled.
- 17. (Desirable) Control action shall be easily predicted and shall relate naturally to the desired result.

18. (Desirable) Control operations shall require a minimum of movements, particularly with gear shifting.
19. (Desirable) Successive control movements shall pass easily from sequence to sequence with a minimum change in position and/or direction.
20. (Guideline) Not all control movements should necessarily be simple and easy. A certain minimal amount of stimulation is required for personnel to perform efficiently. For instance, a task analysis of an operation may indicate that an increase in complexity or a requirement for greater concentration from the operator can increase operational efficiency. However, a careful analysis of the problem must be made before adopting such a procedure.
21. (Essential) Controls employed in rapid sequence shall have a uniform direction of motion.
22. (Essential) Control operation position shall be easy to find and identify.
23. (Guideline) Control knobs shall be located or labelled so that the operator will not obscure any associated indicator while operating them, particularly while wearing arctic clothing.
24. (Desirable) Control reference positions, such as neutral or maximum limits, shall be indicated positively and shall be easily identifiable under blackout conditions.
25. (Desirable) Discrete control positions, such as the gear-ratio selection, shall be no more than one step away from a reference position in any control operating direction.
26. (Guideline) Hand-operated controls shall be positioned to facilitate operation. Clearance shall be provided for insertion and removal of hands and for operating controls while wearing arctic mittens.
27. (Guideline) Adequate performance envelopes shall be provided. A performance envelope may be defined as the three-dimensional space necessary for an operator to perform an assigned task.

B. PUSH BUTTONS

1. (Desirable) Push buttons shall provide an audible snap click to indicate activation.
2. (Guideline) Finger or hand push buttons are used for momentary contact or for activating a locking circuit in a high-frequency-use situation.
3. (Desirable) The finger or hand push button surface shall be concave to fit the finger, or, if this is impractical, the surface should provide a high degree of frictional resistance to prevent slipping.
4. (Guideline) Foot push buttons shall be used in instances in which the operator will probably have both hands in use at the same time.
5. (Guideline) Foot push buttons are prone to accidental activation.
6. (Desirable) A guard shall be provided on all push buttons where prevention of accidental activation is imperative (see Para. 2 through 4).

C. TOGGLE SWITCHES (Table 3, page 29)

1. (Guideline) Toggle switches shall be used for those control functions which require two discrete positions, or where space limitations are severe.
2. (Guideline) Three-position toggle switches shall be used only when the use of a rotary selector switch is not possible. (Exception: Where a requirement exists for three-position, spring-loaded, momentary-contact toggle switches.)
3. (Desirable) Toggle switches shall be vertically oriented with up for ON and down for OFF. (For conventional control movements see Table 3.)
4. (Guideline) Toggle switches shall be mounted horizontally only for consistency with controlled-function orientation or equipment orientation.
5. (Guideline) Toggle switches prone to activation shall be guarded when inadvertent activation is considered serious. A list of suggested types of guards follows:

- a. Channel
- b. Recess
- c. Ring
- d. Complete cover - used where avoiding accidental activation is of primary importance.

D. ROTARY SELECTOR SWITCHES (Fig. 1, page 22)

1. (Guideline) Rotary selector switches are used for discrete functions when three or more positions are required. They will not be used normally for a two-position function unless ready visual identification of switch position is of primary importance.
2. (Guideline) No more than twelve positions shall be incorporated into one 360-degree rotary control. In order to minimize the possibility of erroneous observation, control positions shall not be 180 degrees from each other.
3. (Desirable) Provide stops at the beginning and end of the range of rotary control positions.
4. (Essential) Pointer knobs shall have tapered tips which shall be so positioned in relation to the scale as to minimize parallax, using moving pointer knobs on fixed scales.
5. (Guideline) Shape coding is recommended when a group of rotary controls are so situated as to cause confusion (Fig. 2).

E. CONTINUOUS ROTARY CONTROLS (Table 3, page 29)

(Guideline) Continuous rotary controls are used for changing or adjusting continuous variable. The result of such adjustment should be readily apparent to the operator. The following types are commonly employed:

a. Knobs

(Guideline) Knobs are used where little force and precise, accurate adjustments of a continuous variable are required.

(Guideline) Knobs are particularly adaptable to shape coding.

b. Cranks

(Guideline) Cranks are used primarily for tasks involving many rotations of the control.

(Guideline) Design the crank grip handle so that it turns freely about its shaft.

c. Hand Wheels

(Guideline) Hand wheels are used when the break-out or rotational forces are too great to be overcome with a one-hand control.

(Guideline) Indentation or knurling shall be built into the hand wheel to aid in holding it.

(Guideline) A spinner handle may be attached to the hand wheel if many rotations are required.

(Guideline) The hand wheel shall rotate clockwise for "on" and counterclockwise for "off" (Table 3).

(Guideline) Direction of motion shall be indicated on, or immediately adjacent to, the hand wheel by means of double-ended arrows and appropriate legends.

(Desirable) Hand-wheel-type valve controls shall operate in the conventional manner and shall be provided with a double-ended arrow with "open" or "close" at or beside the tip of each arrow.

(Desirable) Multirotational controls shall be used where high precision is required over a wide range of adjustments.

SECTION II

GROSS-MOVEMENT CONTROLS

SECTION II

GROSS-MOVEMENT CONTROLS

A. CONTINUOUS LINEAR CONTROLS (Levers) (Table 1, page 25)

1. (Guideline) Use levers when a large amount of force or displacement is needed.
2. (Guideline) Lever handles shall be coded when levers in close proximity to each other are not readily discriminable from each other.

B. PEDALS (Table 1, page 25)

1. (Guideline) Pedals are used when a large amount of displacement force is required, and foot action is desired.
2. (Desirable) Pedals shall have non-slip, self-cleaning surfaces, e. g., open grid.
3. (Desirable) Treadle-type pedals shall be provided with heel-retaining plates at their lower edges to prevent the operator's foot from being dislodged in cross-country operation.

C. MOBILE CONTROLS (Table 2, page 28)

1. (Essential) Controls shall not be affected detrimentally by the distortion of the vehicle and displacement of components.
2. (Essential) Mechanical transmission controls, such as gear-shift and parking-brake controls, shall not be affected by dirt, mud, or moisture.
3. (Essential) Sufficient manual steering shall be provided to enable the vehicle to be brought to a safe stop, and to be driven at low speeds, without the aid of the power assist.
4. (Essential) Service and parking brakes shall be protected to prevent moisture, mud, and ice from locking the brakes or degrading brake performance.

D. MANIPULATION OF CONTROLS (Table 3, page 29)

1. (Essential) Control mechanisms for a driver shall be arranged or located on the left side of the cab.
2. (Desirable) Support shall be provided for the following in making fine or continuous adjustments:
 - a. Elbow (for gross hand movements)
 - b. Forearm (for fine hand movements)
 - c. Wrist (for finger movements)
3. (Essential) Controls for operations which are supervised by the operator shall be located in a manner which will enable the operator to maintain supervision while operating these controls.
4. (Desirable) Clearance from the top of foot pedals (or any obstruction in front of the seat) to the bottom of the steering wheel shall be at least 26 inches.
5. (Desirable) Knee clearance shall be provided at least 28 inches in front of the seat back, with the seat adjusted to its most extreme rear position, and 24 inches in front of the seat in its forward position.
6. (Desirable) The angle between the upper and lower leg, when operating foot controls, shall be between 105 and 135 degrees; 120 degrees is optimum.
7. (Desirable) Treadle-type pedals, such as the accelerator, shall be located 38 inches horizontally from the back of the seat, adjusted to its most extreme rear position, and 33 inches when it is forward.
8. (Desirable) The foot throttle and brake controls shall be separated by at least 2-1/2 inches.
9. (Desirable) The brake pedal, when fully depressed, shall project above the accelerator (at least 1/4 inch).
10. (Essential) Controls shall not require a reach of over 28 inches from shoulder to the control.

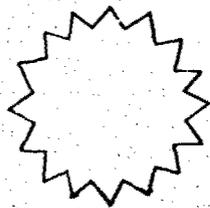
11. (Desirable) The operator shall be capable of manipulating the following controls without strain from the normal driving position: steering controls, gear-selection levers, engine controls, brake controls, rear-view mirror adjustment, clutch, and communication controls.
12. (Essential) The steering wheel shall be positioned for optimum ease of operation and shall have at least four inches between the outer edge and the nearest projection of the vehicle or equipment.
13. (Essential) Foot-operated controls, such as those for the clutch, brake, and throttle, shall be so located to be quickly controlled and operated without strain or contortion for an operator while wearing thermal boots.
14. (Essential) Foot pedals shall accept the weight of an operator's foot without initiating control action.

E. CONTROL CODING (Fig: 1, page 22)

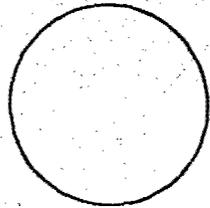
1. (Essential) Controls shall, by their shape and position, be easy to identify and separate from each other during operation under stress or in blackout.
2. (Guideline) Since tactical blackout is one of the conditions under which military vehicles must operate, consideration must be given to the design of necessary controls and displays for use under these conditions, e. g., shape or location coding for controls, and red lighting for displays.
3. (Guideline) Common coding methods shall be used when available. The applicability (advantages and disadvantages) of each coding method shall be determined in accordance with Table 5.
4. (Guideline) The five most common methods of coding are: Location, Shape, Size, Labeling, and Color (Table 5, pg 48). They shall be used as follows:

a. Location

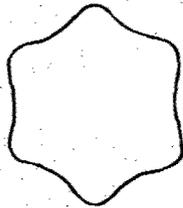
(Desirable) Controls associated with similar functions shall be in the same relative location from panel to panel.



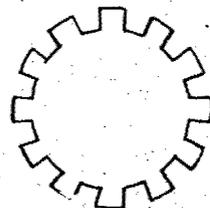
1. Lighting System



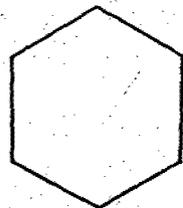
2. Ignition System



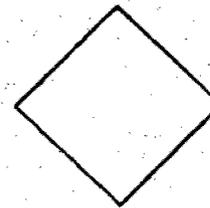
3. Fuel System



4. Power Train



5. Special Purpose Equipment



6. Accessory Equipment

Fig. 1. Recommended Shapes to be Used for Coding of Operating Controls.
(Selection of shapes is based on existing data concerning
shape discriminability and meaningfulness of shape. USA
Human Engineering Laboratories Technical Memorandum 22-61.)

b. Shape

- (1) (Essential) The shapes in Figure 1 shall be used for the controls indicated, when shape coding has been determined to be required.
- (2) (Essential) Edges on the parts of the control that must be grasped shall not be so sharp as to cause injury to personnel.

c. Size

(Guideline) When possible, use only two or three different sizes of controls. Controls for performing the same function on different equipment shall be consistent in size.

d. Labeling (Fig. 2, page 27 - Table 6, page 49)

- (1) (Desirable) The label shall be located either on the control or immediately adjacent to it (above, if possible), where this is consistent with eye level of observer.
- (2) (Guideline) Labels shall be brief.
- (3) (Desirable) The nomenclature shall clearly indicate the function being controlled.
- (4) (Desirable) Highly similar names shall be avoided.
- (5) (Desirable) Abbreviations, where required, shall be in accordance with SR-320-50-1.
- (6) (Essential) Abstract symbols (squares, Greek alphabet, etc.) shall not be used unless their effectiveness and general acceptance have been adequately demonstrated.
- (7) (Guideline) Letters and numerals shall be standardized as specified in Table 6.
- (8) (Guideline) Where lists of material or where maintenance instructions are needed, they shall not be placed or hung on operating panels.

Color Coding (Table 8, page 51)

- (1) (Guideline) Common color coding methods will be used. Where color coding is selected as a coding scheme for controls, the procuring activity will insure uniform application of the approved code throughout the system.
- (2) (Essential) Where personnel selection procedures do not reject color blind personnel, color coding will not be used as the primary discriminant.
- (3) (Guideline) In general, only four colors will be used for control coding (in addition to the customary black or grey control color):

<u>Color</u>	<u>Federal Standard 595</u>
Red	11105
Green	14187
Amber	13538
White	17875

- (4) (Guideline) The use of colors other than those listed above is not recommended for display coding. If an additional color is absolutely necessary, blue 15123 is acceptable.
- (5) (Essential) When it is considered imperative to relate a control to its corresponding display by means of color coding, the display and control shall be of the same color.
- (6) (Desirable) The color of controls shall be such as to provide ample contrast with the backgrounds.

TABLE 1

Controls - General

CONTROLS	RESISTANCE		DISPLACEMENT		DIAMETER		MISCELLANEOUS	
	MIN.	MAX.	MIN. (BETWEEN ADJACENT POSITIONS) 30°	MAX. TOTAL 120°	MIN.	MAX.	MIN.	MAX. (LENGTH)
TOGGLE SWITCHES	10 oz.	40 oz.		TOTAL 120°	TIP 1/8 in.	TIP 1 in.	LEVER ARM 1/2 in.	LEVER ARM 3/4 in.
LEVERS	HAND 2 lbs. JOYSTICK 5 lbs.	FORE - AFT ONE HAND 30 lbs. LATERAL ONE HAND 20 lbs.	**	FORE - AFT 14 in. LATERAL 35 in.	FINGER GRASP 1/2 in. HAND GRASP 1 1/2 in.	3 in.	DEPENDS ON MECHANICAL ADVANTAGE NEEDED (SIZE & LENGTH)	
HAND WHEELS & CRANKS	5 lbs. (AT RIM; ONE HAND 30 lbs. TWO HANDS 55 lbs.)	**	**	**	7 in. RIM CROSS SECTION (H. W.) 3/4 in.	21 in. 2 in.	1/2 in. 20 in.	
FINGER AND HAND PUSH BUTTON	FINGERTIP 10 oz.	FINGERTIP 40 oz.	1/8 in.	THUMB OR FINGERTIP 1 1/2 in.	FINGERTIP 1/2 in. EMERGENCY CONTROLS THUMB OR HEEL OF HAND 3/4 in.		**	**
FOOT PUSH BUTTON	FOOT WILL NOT REST ON PUSH BUTTON 4 lbs. FOOT MAY REST ON PUSH BUTTON 10 lbs.	20 lbs.	1 in.	ANKLE FLEXION ONLY 2 1/2 in. LEG MOVEMENT 4 in.	1 in.	*	**	**
ROTARY SELECTOR SWITCH	12 oz.	48 oz.	BETWEEN ADJACENT DETENTS 40° (SPECIAL REQUIRE- MENTS TO 90°)		**	**	**	**
PEDALS	FOOT WILL NOT REST ON PEDAL 4 lbs. FOOT MAY REST ON PEDAL 10 lbs.	ANKLE FLEXION ONLY 20 lbs. LEG MOVEMENTS 180 lbs.	1 in.	ANKLE FLEXION ONLY 2 1/2 in. LEG MOVEMENT 7 in.	**	**	**	(SIZE) 1 in. x 3 in.
KNOB	**	**	**	**	FINGERTIP GRASP 1 in. PALM GRASP 1 1/2 in.	FINGERTIP GRASP 4 in. PALM GRASP 3 in.	FINGERTIP GRASP 1/2 in.	*

* Not limited by operator performance
** No. Information available

LEGEND

Fig. 2. Recommended Symbols for International Control Legends

- | | |
|-------------------------------|--------------------------------|
| 1. Horn | 18. Interior Light |
| 2. Windshield Wiper | 19. Fog Light |
| 3. Direction Indicator | 20. Low Beam |
| 4. Radio | 21. High Beam |
| 5. Heater Switch | 22. Parking Light |
| 6. Heater Regulator | 23. Blackout Headlight |
| 7. Cabin Ventilation | 24. Blackout Clearance Light |
| 8. Ignition Switch | 25. Snorkel |
| 9. Starter | 26. Clutch |
| 10. Spark Advance | 27. Front Wheel Drive |
| 11. Battery Slave | 28. High Ratio Gear |
| 12. Primer Pump | 29. Neutral |
| 13. Choke | 30. Up/Down, Top/Bottom |
| 14. Hand Throttle Control | 31. Winch |
| 15. Fuel Tank Selector Switch | 32. Winch Brake |
| 16. Main Light Switch | 33. Power Take-Off Engaged |
| 17. Instrument Panel Light | 34. Power Take-Off Not Engaged |

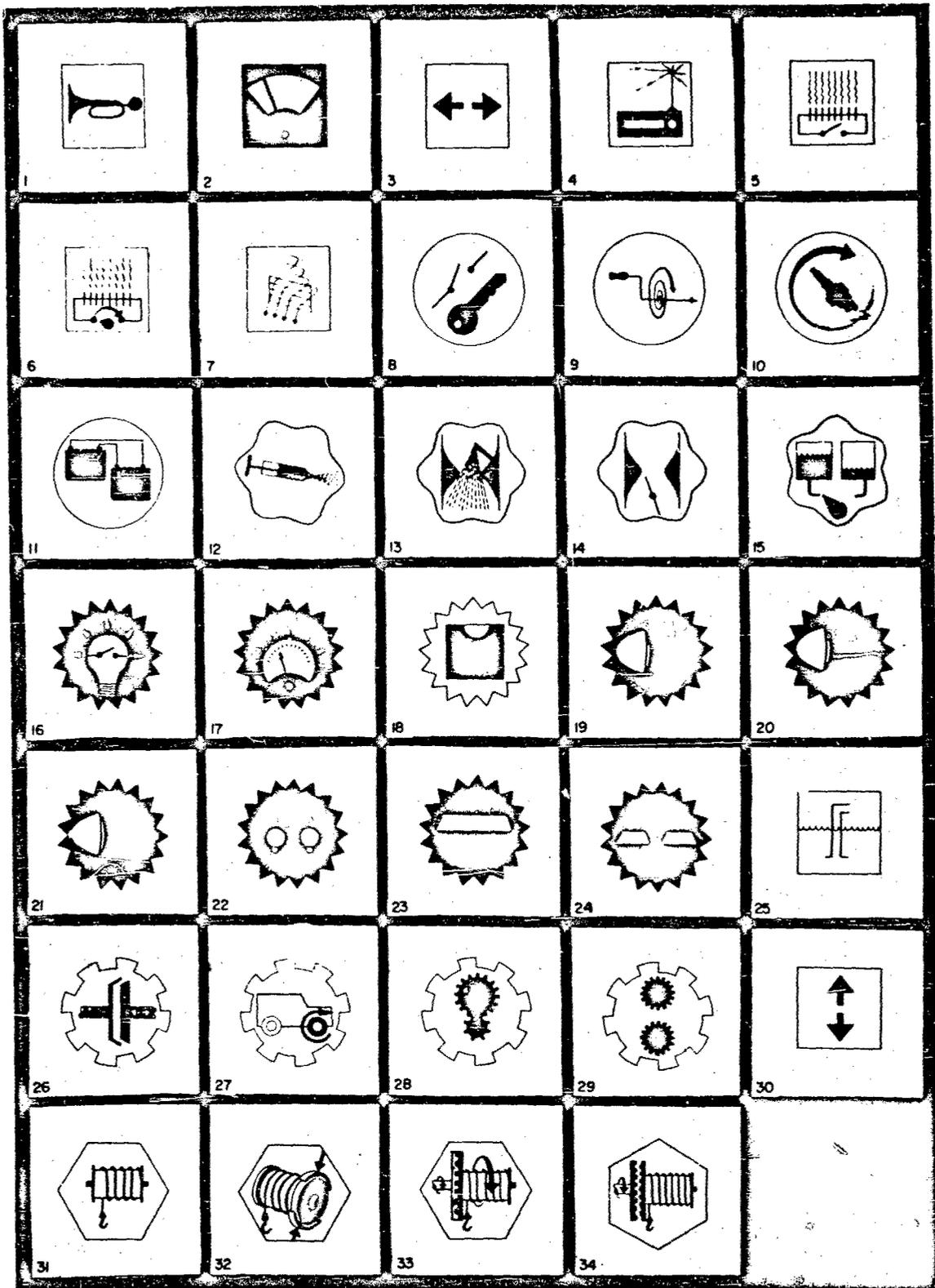


Fig. 2. Recommended Symbols for International Control Legends

TABLE 2
Recommendations for Specific Vehicle Controls

<u>Desirable</u>	<u>Size</u>	<u>Displacement</u>	<u>Force</u>
Accelerator	5" x 12"		2-6 lbs.
Foot Dimmer Switch	1-1/4" x 1-1/4"	D-Shaped Button	15 lbs.
Service Brake (Hydraulic Controls)	4" x 10"	3"	15-35 lbs.
Foot Parking Brake	4" x 5"	4"	20-30 lbs.
Foot Brake Release	2" x 3"	1-1/2"	5 lbs.
Choke	3/4"	1"-2-1/2" (from Dash)	2 lbs.
Throttle	3/4"	2-1/2"	2 lbs.
Windshield Wiper Control	1" x 1/2" (pointed knob)	90°	2 lbs.
Steering Wheel	20" Dia. 3/4" Grip	16.1" - 32.1" (from chest)	5 lbs.
Horn Button	1/2" x 3" (round)	1/2"	2 lbs.
Turn Signal Control	8" to 10" x 1/4" Rod	2"	2 lbs.

TABLE 3

Conventional Control Movements

Function	Control Action
1. On	Up, right, forward, pull (switch knobs)
2. Off	Down, left, rearward, push (switch knobs)
3. Right	Clockwise, right
4. Left	Counterclockwise, left
5. Up	Up, rearward
6. Down	Down, forward
7. Retract	Rearward, pull, counterclockwise, up
8. Extend	Forward, push, clockwise, down
9. Increase	Right, up, forward
10. Decrease	Left, down, rearward

Reference: D&PS Tech Development Objective
Guide -- Truck 5 Ton

SECTION III

VISUAL DISPLAYS

SECTION III

VISUAL DISPLAYS

A. GENERAL (Table 5, page 48)

1. (Desirable) The information displayed to each person who operates a piece of system equipment shall be limited to that information which is necessary to the specific actions or decisions required of him.
2. (Desirable) Information shall be displayed only to the degree of specificity and accuracy required for the specific operator action or decision which is associated with it.
3. (Desirable) Information shall be presented to the operator in a directly usable form; that is, requiring no interpolation or decoding by the operator.
4. (Desirable) Information necessary to different activities, e. g., operation and trouble-shooting, shall not be combined unless these are comparable functions requiring the same information.
5. (Desirable) If scale interpolation is required, it must not introduce a probability of error which exceeds the degree of accuracy needed.
6. (Desirable) Neither lag nor parallax in indicators shall introduce detrimental errors.
7. (Essential) Displays shall be so designed that the failure of the display or display circuitry shall be apparent immediately and readily to the operator.
8. (Essential) Failure of display circuitry shall not cause a failure in the equipment associated with the display.

9. (Desirable) All displays necessary to support an operator activity, or sequence of activities, shall be grouped together, e.g., sub-system grouping.
10. (Desirable) Displays shall be arranged in relation to one another to reflect the sequence of use or the functional relations of the components they represent in order of preference.
11. (Desirable) Arrangement of displays shall be consistent from application to application within the limits imposed by other provisions of this section.
12. (Desirable) If compatible with the other items in this section, the most-frequently-used displays shall be grouped together.
13. (Essential) The instrument displays shall be so located that they can be seen from the operator's working position. Speedometer, tachometer and warning indicators such as air-pressure, coolant temperature and oil-pressure gages shall be located immediately adjacent to the operator's normal field of vision.
14. (Desirable) Whenever it is desired to set apart, for purposes of ready identification, distinct, noncritical functional areas, i. e., those not associated with emergency operation, these areas shall be outlined by black lines approximately 1/16 inch wide -- Black color No. 37038, Federal Standard 595.
15. (Essential) Functional areas of emergency or extremely critical operations shall be set apart by a 3/16 inch red border -- Red color No. 31136, Federal Standard 595.
16. (Essential) Adjustable-intensity red blackout lighting shall be provided.

B. TRANSILLUMINATED INDICATORS (Table 6, page 49)

1. (Guideline) Transilluminated indicators presently used are of two general types: (1) simple-type indicators, e. g., pilot lights, bull's-eye lights, jewel lights, etc., and (2) single- and multiple-type legend indicators. Legend lights shall present information in the form of meaningful words, numbers, symbols, or accepted abbreviations.
2. (Guideline) Transilluminated indicators are used primarily to display to the operator qualitative information which requires either an immediate reaction or that his attention be attracted to an important change in system status.
3. (Guideline) Transilluminated indicator lights, used solely for maintenance and adjustment, and referred to infrequently, shall be covered during normal operation but shall be readily accessible and visible to the operator or maintenance man when required.
4. (Guideline) Master action, master warning, or summation lights to indicate the condition of the entire subsystem shall be set apart from the lights which show the status of the subsystem components and shall be larger.
5. (Guideline) Lights shall not be used solely to indicate switch or control position unless the switch position cannot be made apparent by proper design and labeling of the control.
6. (Essential) Lights shall be used to indicate that the desired equipment response has been achieved and not merely that the activating switch has been thrown.
7. (Desirable) Lamp filter caps and legend plates shall be physically coded or captive to preclude the possibility of an interchange.
8. (Guideline) Simple-type indicator lights shall be used whenever feasible.
9. (Essential) Spacing between the adjacent edges of simple-type round indicator light fixtures shall be sufficient to allow ample room for unambiguous labeling and convenient bulb removal.

10. (Guideline) Coding -- Simple-type indicator lights shall be color coded in conformance with para. F5a, and, in addition, shall be coded in size and apparent brightness as specified in Table 6, page 49.
11. (Essential) When simple-type indicator lights are used for emergency conditions, i. e., personnel or equipment disaster, such functions shall be indicated by a one-inch-diameter flashing red light.
12. (Desirable) Master summation indications, system or subsystem, shall be one-inch-diameter steady red or green lights.
13. (Desirable) Indication of all other conditions shall be by 1/2-inch-diameter steady lights.
14. (Essential) One-inch-diameter lights shall be discriminably brighter than 1/2-inch-diameter lights.
15. (Desirable) With the exception of small flashing white call-lights, used commonly on communication panels, no other flashing lights shall be used.
16. (Desirable) A master lamp-test control shall be incorporated on control panels utilizing indicator lights. Where not feasible, each indicator shall be designed for "press-to-test" bulb testing. Devices which can test the operation of all indicators at once are more desirable.
17. (Desirable) When a control is associated with a transilluminated indicator, the indicator light shall be so located as to be immediately and clearly associated with the control. In almost all instances, the light should be located above the control.
18. (Desirable) The brightness of transilluminated indicators shall be visible but not dazzling under the expected ambient illumination level.
19. (Desirable) Indicators shall not be so bright as to dazzle the operator.
20. (Desirable) A dimming control with preselected ranges shall be provided for use under varied ambient illumination, except for danger lights.

21. (Desirable) For panels to be used outdoors, provisions shall be made to prevent reflected sunlight from making the indicator appear as illuminated.
22. (Desirable) The flash rate for flashing warning lights may vary from 3 to 5 flashes per second with "on" time approximately equal to "off" time.
23. (Essential) The indicator shall be so designed that, if it is energized and the flasher device fails, the light will come on and burn steadily.
24. (Desirable) For critical functions, the indicator shall be located within 30 degrees of the normal line of sight.
25. (Guideline) Use lights and all other indicators sparingly. The indicator shall display only that information necessary to effective system operation.
26. (Guideline) For ease of maintenance, bulbs shall be removable from the front of the display panel without the use of tools.
27. (Guideline) Coding -- Legend lights shall be color coded in conformance with para. F5a on coding, and their function shall be further coded in the following manner: (a) size, (b) brightness, and (c) flash coding.
28. (Essential) Legend lights required to denote (a) personnel or equipment disaster -- flashing red, (b) caution or impending danger -- amber, and (c) master summation go/no-go -- green or red, shall be obviously larger and preferably brighter than all other legend-type displays.
29. (Guideline) Legend light lettering shall be visible and legible whether or not the display is energized. This applies to single-legend displays rather than to multiple-legend displays. Size and other lettering characteristics (type of print, opaque vs. translucent letters) shall be determined by the procuring activity.

30. (Essential) Multiple-legend displays having legend plates stacked one behind the other shall be so designed that when a rear legend is illuminated it will not be obscured by the forward legend.
31. (Essential) The rearward legend plates on multiple-legend displays shall be so placed as to minimize parallax, i. e., so the entire legend can be seen if the observer is within 30 degrees of the normal line of sight.
32. (Guideline) If legend plates on multiple-legend displays have different color codes and if the legend plates are stacked one behind the other, the rearward legends shall have contrast (between the legend and its background) equal to the front legends.

C. MOVING-POINTER FIXED-SCALE TYPE INDICATORS

1. Scale-type indicators shall be used in cases where:
 - a. (Desirable) It is necessary to display qualitative or quantitative information in combination with trend and direction-of-motion information.
 - b. (Desirable) Strictly quantitative information is to be displayed.
2. (Desirable) Clockwise movement of the pointer shall increase the magnitude of the reading.
3. (Essential) In cases where positive and negative values around a zero value are being displayed, the zero shall be located at the 12 o'clock position.
4. (Essential) The positive values shall increase with clockwise movement of the pointer. The negative values shall increase with counterclockwise movement.
5. (Desirable) The numerals shall be placed inside of the graduation marks to avoid constriction of the scale. Where space is not limited, the numbers may be placed outside of the marks to avoid having the numbers covered by the pointer.

6. (Essential) Movement of the pointer up or to the right shall increase the magnitude of the reading.
7. (Essential) Where positive and negative values around a zero value are being displayed, the positive values shall increase with movement of the pointer up or to the right, and the negative values shall increase with movement of the pointer down or to the left.
8. (Essential) Movement of the pointer up or to the right shall result from:
 - a. Clockwise movement of an associated rotary control, or
 - b. Movement upward, forward, or to the right of an associated lever or switch.
9. (Desirable) The pointer shall be located to the right of vertical scales and at the bottom of horizontal scales.
10. (Desirable) Except for multi-revolution, continuous-scale instruments, such as the clock, there shall be an obvious scale break of not less than 1-1/2 divisions between the two ends of the scale.
11. (Guideline) For ease of monitoring a group of circular scale-type indicators, if a stable value of given operating conditions is present, the displays shall be arranged (a) in rows, with horizontal pointer alignment under normal operating conditions, i. e., all pointers line up on the 9 o'clock position, or (b) in column, with vertical pointer alignment, reflecting normal operating conditions, i. e., all pointers line up on the 12 o'clock position.
12. (Guideline) Practically and economically it is not always feasible to follow the recommendation outlined above. It is important, however, where only a general indication of a condition is being monitored, that the normal position should have all dials pointing in approximately the same direction.

D. MECHANICAL DISPLAYS (Table 7, page 50)

1. (Guideline) There are various types of mechanical displays. The common of these are (a) direct reading counters, (b) moving pointers with fixed scales, (c) flags, and (d) pointers. The recommended application for these indicators is summarized in Table 7.
2. (Desirable) Counters shall be used where quick, precise reading is required.
3. (Desirable) Counter numbers shall change by snap action in preference to continuous movement.
4. (Desirable) Space between counter numerals shall be no more than $1/2$ the numeral width.
5. (Desirable) Counters shall be mounted as close as possible to the panel surface to maximize viewing angle and minimize parallax and shadows.
6. (Desirable) The height-to-width ratio of numerals for counter displays should be 1:1 rather than 5:3 as recommended for dials and scales.
7. (Desirable) Counter numbers shall not follow each other at intervals faster than about 2 per second, if the observer is expected to read the numbers consecutively.
8. (Desirable) Counters used to indicate sequencing of equipment shall be designed to reset automatically upon completion of the sequence. Manual provision for resetting shall be provided.
9. (Essential) The rotation of the counter-reset knob shall be clockwise to increase the counter indication or to reset the counter.
10. (Guideline) Instrument dials shall be approximately 2-3/4 inches in diameter, with major markings in white against a black background, spaced at $1/2$ inch intervals on the circumference of the dial.
11. (Essential) Instrument pointer or scale movements shall be sufficient to permit quantitative readings at the required degree of accuracy, and to note significant variations.

E. VISIBILITY AND READABILITY

(Desirable) The following scale marking and numbering practices are recommended:

1. Whenever possible, scales shall start at zero.
2. Scale graduations shall progress by 1, 2, or 5 units, or decimal multiples thereof.
3. The increase in numerical progression shall read clockwise, from left to right or from bottom to top.
4. Whole numbers shall be used in numbering major graduation marks.
5. The number of minor or intermediate marks shall be no more than nine, and fewer if possible.
6. Maximum contrast shall be used between scale face and markings.
7. All numbers shall be upright at the reading position.

F. CODING

1. (Desirable) Optimum use shall be made of coding techniques for:
 - a. Discrimination between individual displays.
 - b. Identification of displays related functionally.
 - c. Indication of the relationship between displays.
2. (Desirable) Applicable coding techniques shall be selected from the following methods: color, size, location, and shape.
3. (Guideline) All coding shall be uniform within the system and shall be established by agreement with the procuring activity.
4. (Essential) Where personnel-selection procedures do not reject color-blind personnel, color coding will not be used as the discriminant.

5. Coding -- The following color-coding schemes shall be employed:

a. Indicator Lights

- (1) (Essential) Red -- Red shall be used to alert an operator that the system or any portion of the system is inoperative, and that a successful mission is not possible until appropriate corrective or override action is taken.
- (2) (Desirable) Amber -- Amber shall be used to advise an operator that a marginal condition exists in system effectiveness, or that an unsatisfactory or hazardous condition is developing or exists; but that the system can still operate, e. g., battery approaching replacement time.
- (3) (Essential) Green -- Green shall be used to indicate that the condition of a unit or component is in tolerance or satisfactory, and that it is all right to proceed.
- (4) (Desirable) White -- White shall be used to indicate system conditions not intended to provide a right-or-wrong implication, or indicate transitory operating conditions, and where such indication does not imply success of operations, e. g., power on.

b. Scales (Banding)

- (1) (Guideline) Where given operating conditions always fall within a certain range on the scale, these areas shall be made readily identifiable by means of coding.
- (2) (Guideline) Coding may be used to convey such information as: (a) desirable operating range, (b) dangerous operating level, (c) caution, and (d) undesirable, inefficient, etc.
- (3) (Essential) Color coding shall not be used if the instrument must be read at any time under colored lights.

c. Color for Indicator-Face Surface Banding* (Table 4, page 47)

- (1) (Guideline) Color-coded markings and bands shall be utilized to (a) optimize meter reading performance to make it obvious at a glance whether the indication falls within acceptable limits or at the desired value; (b) make it equally obvious when the indication falls within a "danger" range requiring immediate corrective action; (c) preclude the possibility of misreading numbers on the dial face surface or of mistaking the desired numerical value (Table 4).
- (2) The following colors are recommended as an optimally discriminable set of four colors for banding indicator faces. These colors are appropriate for outdoor daylight use or indoor use under incandescent or fluorescent illumination, or use with a special reddish-orange night illumination, details of which are available from Human Engineering Laboratories on request.

(Guideline) Each color marking shall have a clear-cut meaning.

- (a) (Essential) Red indicates a dangerous condition requiring immediate corrective action. A range shall not be banded red simply because it deviates from the desired operating point or range. However, red bands may be used legitimately to indicate conditions under which equipment damage or personnel injuries are apt to result.
- (b) (Essential) Green indicates the normal operating point or range; it shows the desired reading or the acceptable range of readings.
- (c) (Guideline) Blue is used in conjunction with green to indicate a secondary desired reading or range of readings. When there is overlap between the primary and secondary banded ranges, a separate scale should be

* It must be emphasized that it is not necessary to use all colors on each and every meter.

used for each banded range, with the primary scale positioned closer to the index arc than the secondary scale. When there is no overlap between primary and secondary banded ranges, the banding may then be incorporated on a single scale, provided there are no associated danger ranges. The more-frequently-used range should be shown in green; the less-frequently-used in blue. If a selector switch or similar component is used to control the display, the dots or index mark on switch bands showing positions of the selector should be colored blue when the associated indication is to be read in the blue range. Uncolored index-marks, dots, or switchbands showing selector positions indicate that the reading should fall within the green range of the display.

- (d) (Guideline) Brown may be used if absolutely necessary to indicate a tertiary overlapping range. The use of three or more overlapping operating ranges shall be avoided except where no other solution can be utilized expediently. A brown index mark should be used as appropriate in conjunction with a selector switch or similar component.
- (e) (Guideline) Amber shall not be used as a meter banding color because it indicates neither normal operation nor danger. Hence, its meaning can be conveyed adequately by leaving such ranges unmarked (white).

d. Labeling: Controls and Displays (Table 6, page 49)

- (1) (Guideline) Each control and display shall be identified as to function.
- (2) (Guideline) Labels shall appear on or immediately adjacent to (preferably above) the controls and displays to be identified.
- (3) (Guideline) Labels shall be so located as to preclude association of the label with a wrong control or display.
- (4) (Desirable) The location of labels in relation to controls and displays shall be consistent on all system equipment.

- (5) (Essential) Labels shall be brief.
- (6) (Essential) Nomenclature shall indicate clearly the function being displayed or controlled.
- (7) (Desirable) Abbreviations, where required, shall be in accordance with SR 320-50-1.
- (8) (Guideline) Lettering on the panels shall be black color No. 37038, Federal Standard 595.
- (9) (Desirable) Capital letters shall be used in preference to lower case. However, lower case, if not too small, may be more applicable to extended instructions.
- (10) (Desirable) Abstract symbols, e. g., squares, Greek alphabet, shall be used only as determined by the procuring agency.
- (11) (Desirable) Meaningful symbols in common usage are acceptable, e. g., the percent sign, plus sign, etc.
- (12) (Guideline) The outside covering of a manufactured part shall be stamped or coded with relevant information concerning electrical, mechanical and lubricational characteristics of the part.
- (13) (Desirable) Terminals shall be labeled with the same code symbols as the wire attached to them.
- (14) (Desirable) Stencilled labels shall not be used.
- (15) (Guideline) Labels shall not be hidden by units and parts, e. g., labels on the chassis shall not be placed under the parts which they identify.
- (16) (Desirable) The numerals and letters on instrument dials, panels, and consoles shall be designed to afford maximum legibility for all conditions of use.
- (17) (Desirable) The following recommendations apply to general flood-illuminated, indirect-illuminated, and transilluminated numerals and letters (Table 6).

(18) Numeral Style

(Desirable) The width of the numerals shall be $\frac{3}{5}$ of the height except the number "4", which shall be one stroke width wider, and the number "1", which is one stroke in width. The stroke width shall be $\frac{1}{6}$ to $\frac{1}{8}$ of the numeral height.

(19) Letter Style

(Desirable) The width of the letters shall be $\frac{3}{5}$ of the letter height except for the letter "i", which is one stroke in width, and the letters "m" and "w", which shall be about $\frac{1}{5}$ wider than the other letters. The stroke width should be from $\frac{1}{6}$ to $\frac{1}{8}$ of the letter height. The style shall be similar to Alternate Gothic No. 2.

G. INSTRUCTION PLATES (Data Plates)

1. (Guideline) Data plates in each section of the vehicle, cab, van motor area, etc., shall be:
 - a. Consistent in size and shape.
 - b. Logically oriented to each other.
 - c. Visible to the operator.
2. (Guideline) Data and caution plates shall present only information necessary to the operator, preferably in diagrammatic form.
3. (Guideline) Caution plates shall show:
 - a. Maximum permissible road speed in each gear range.
 - b. Specified data concerning draining of the cooling system.
 - c. A minimum of any other information essential to the efficient operation of the vehicle.
4. (Guideline) Gearshift instruction plate shall show applicable data concerning operating positions of shift handles for transmission and transfer case mechanisms.

5. (Guideline) When applicable, power take-off and winch-control instruction plates shall be furnished.
6. (Guideline) Operating instructions shall be placed conspicuously near the operating controls.
7. (Guideline) Instructions shall read from left to right.
8. (Guideline) Vertical labels shall not be used.
9. (Guideline) Instructional diagrams shall be oriented logically to the objects to which they pertain.
10. (Guideline) Instructions shall show control movement in planes parallel to the movement of the actual controls.
11. (Guideline) Instructions used most often in operating equipment shall be located nearest to the operators' field of vision.
12. (Guideline) Identification and instruction markings shall be embossed, stamped or etched on the part. If space is limited, substantial plates for the marking of units attached to, or immediately adjacent to, the part may be used.

TABLE 4

Specific Recommendations for Meter Banding Colors

Red	- ASA Specification - Monochromatic 616-14-59 Approximate Munsel Value: 5R 4.5/14
Green	- ASA Specification - Monochromatic 511-29-26 Approximate Munsel Value: 5G 6.1/11
Blue	- ASA Specification - Monochromatic 462-7-61 Approximate Munsel Value: 8PB 3.1/12
Brown	- ASA Specification - Monochromatic 592-12-37 Approximate Munsel Value 1 YR. 4.1/14

TABLE 5
ADVANTAGES AND DISADVANTAGES OF VARIOUS TYPES OF CODING

Guidelines	ADVANTAGES	LOCATION	SHAPE	SIZE	LABELING	COLOR
Improves visual identification.	X	X	X	X	X	X
Improves non-visual identification (tactical and kinesthetic).	X	X	X	X		
Helps standardization.	X	X	X	X	X	X
Aid identification under low levels of illumination and colored lighting	X	X	X	X	X*	X*
May aid in identifying control position (setting).		X			X	
Requires little (if any) training; is not subject to forgetting.					X	
DISADVANTAGES						
May require extra space.	X	X	X	X	X	
Affects manipulatability (ease of use) of the control.	X	X	X	X		
Limited in number of available coding categories.	X	X	X	X		X
May be less effective if operator wears gloves.		X	X	X		
Control must be viewed (i.e., must be within visual areas and with adequate illumination present).					X	X

* True only when transilluminated.

TABLE 6

Numeral and Letter Size

Nature of Markings	Low Brightness (Down to .03 ft. L)	High Brightness (Down to 1.0 ft. L)
Critical markings - position variable. (Numerals on counters and settable or moving scales.)	.20 to .30	.12 to .20
Critical markings - position fixed. (Numerals on fixed scales, control and switch markings, emergency instructions.)	.15 to .30	.10 to .20
Non-critical markings. (Instrument identification labels, routine instructions, any markings required for initial familiarization only.)	.05 to .20	.05 to .20

From WADC TR 54-160

The table above gives recommended numeral and letter heights in inches for a 28-inch viewing distance. For other viewing distances, multiply the given values by distance in inches divided by 28.

TABLE 7

Mechanical Displays - Recommendations

Method of Use	Moving Pointer	Counter	Flag
Quantitative Reading	Fair	Good. Minimum time and error in obtaining exact numerical value.	Do not use.
Qualitative Reading	Good. Location of pointer easily detected. Numbers and scale need not be read. Position change easily detected.	Poor. Numbers must be read. Position changes not easily detected.	Good. Presence of flag easily detected.
Setting	Good. Simple and direct relation of pointer motion to motion of setting knob. Pointer position change aids monitoring.	Good. Most accurate monitoring of numerical setting. Relation to motion of setting knob less direct than for moving pointer. Not readable during rapid setting.	Not Applicable
Tracking	Good. Pointer position readily controlled and monitored. Most simple relation to manual control motion.	Poor. No gross position changes to aid in monitoring.	Not Applicable
Comments	Requires greatest exposed and illumination area on panel. Scale length limited unless multiple pointers are used.	Most economical of space and illuminated area. Scale length limited only by numbers of counter drums.	Useful for qualitative reading. May take little room.

TABLE 8
Indicator Lights - Color Coding

Desirable Indicator	Red	Amber	Green	White
1/2 inch diameter steady	Malfunction, action stopped, failure, stop action.	Delay, check, recheck.	Go ahead, in tolerance, acceptable, ready.	Functional or physical position, action in progress.
1 inch diameter steady	Master summation, (system or subsystem)**	Extreme caution (impending danger)	Master summation, (system or subsystem)**	Not Applicable
1 inch diameter flashing (3 - 5 sec.)	Killer warning* (personnel or equipment)	Not Applicable	Not Applicable	Not Applicable

Adapted from Mil Std 803 USAF

* These indicators shall be discriminately brighter than 1/2-inch indicators.

** The red master-summation indicator shall be used to indicate malfunction, action stopped, failure, stop action; the green summation-indicators will be used to indicate go ahead, in tolerance, acceptable, or ready.

SECTION IV

AUTOMOTIVE SUB-SYSTEMS

SECTION IV

AUTOMOTIVE SUB-SYSTEMS

A. GENERAL

1. Configuration and Location of Components

- a. (Guideline) Components shall be designed, located, and installed to provide ample visibility, accessibility, and working clearances for the specified servicing, cleaning, adjustment, removal, and installation, safely and without damage to parts or assemblies.
- b. (Guideline) Components shall be designed for removal and installation in the most advantageous sequence to accomplish maintenance in the field.
- c. (Guideline) Conflicting maintenance sequences shall be resolved in favor of increasing the efficiency of the lower echelons of maintenance.
- d. (Desirable) Components shall be so arranged that they can be inspected, adjusted, removed, or replaced readily with minimum disturbance to other parts.
- e. (Essential) Direct access shall be provided when a frequent maintenance operation will require disassembly not needed otherwise.
- f. (Essential) It shall not be necessary to conduct higher-echelon maintenance to gain access for lower-echelon services.
- g. (Desirable) Recoverable subassemblies, which are reconditioned at the organizational and field-maintenance levels, shall be removed and replaced without removal or repositioning of major assemblies other than mating subassemblies, e. g., starters, generators, power-take-offs, bilge pumps, external power-assist assemblies, connecting cables and lines.

- h. (Desirable) Major assemblies other than structure shall be capable of being removed and replaced without removal of other major assemblies except for those which are handled with them as a unit, e. g., engines, transmission, and axle assemblies.
- i. (Desirable) Parts and assemblies, including connecting lines and cables, shall be located so they do not interfere with removal of components.
- j. (Desirable) Accessories, receptacles, shrouding and similar items, which are not supplied as a part of basic replacement assemblies, shall be clustered in ways which permit them to be easily attached and detached as units.
- k. (Desirable) Care shall be taken to prevent interferences which will preclude proper access.
- l. (Desirable) Large components difficult to remove shall not prevent access to those less difficult.
- m. (Desirable) If placing one component behind the other cannot be avoided, the one requiring less frequent access, or presenting greater difficulty to remove, shall be placed in the rear.
- n. (Essential) Components shall be placed, or the structure designed, so that structural members shall not prevent proper access to these components.
- o. (Desirable) Subassemblies shall be mounted to the housing rather than attached to each other, so only the subassembly to be replaced must be removed.
- p. (Desirable) Components shall not be placed in recesses or located behind or under floor boards, seats, hoses, pipes, or other items which are difficult to remove.
- q. (Essential) Components shall be placed to allow sufficient space for use of test equipment and other required tools without difficulty or hazard.

2. Ease of Handling (Table 9, page 77)

- a. (Desirable) All units designed to be removed or replaced shall be provided with handles or other suitable means for grasping, handling, and carrying.
- b. (Desirable) Handles or grasp areas shall be located over the center of gravity of the unit to prevent the unit from swinging or tilting when lifted.
- c. (Essential) Handles and grasp areas shall be so located that at least two inches of clearance from obstructions is provided during handling.
- d. (Essential) Lifting handles shall meet the criteria of Table 9.
- e. (Desirable) Handles shall be so positioned that they will not catch on other units, cables, lines, structural members, etc. Where such interferences are unavoidable, handles shall be stowed separately in obvious and well-marked locations, as near as possible to their place of use.
- f. (Desirable) Lift eyes shall be as few as is practicable.
- g. (Desirable) Lift eyes shall be permanently attached and shall be sufficiently large to accept common rigging-cable hooks and clevises.
- h. (Desirable) Lift eyes shall be far enough above the CG of the component to stabilize it, but not so far that they may make it difficult to maneuver.
- i. (Guideline) Within a reasonable length of time after a vehicle is halted, personnel shall be capable of performing maintenance operations without danger of burning themselves.
- j. (Guideline) Components which must be manhandled under these conditions, such as particularly heavy items which will not cool in a reasonable length of time, shall be provided with eyes, insulated handles, or other suitable lifting devices.

k. (Guideline) Covers, drawers, and components which are difficult to grasp, or cannot be handled without endangering delicate parts, shall be provided with handles or shaped to facilitate handling.

l. (Guideline) Handles, or hand holds, shall facilitate balancing objects safely when lifting or carrying them.

3. Weight of Components

a. (Essential) Units shall be small and light enough for one man to handle and carry, i. e., weight of removable units shall be held below 45 pounds.

b. (Essential) Units in excess of 45 pounds shall have provision for two-man lift where the lifting height is not in excess of five feet and where the total weight is not in excess of 90 pounds.

c. (Essential) Units weighing over 90 pounds shall have provision for mechanical or power lift.

d. (Essential) All units weighing 45 pounds or more shall be prominently labeled with their weight.

4. Accessibility

(Guideline) Accessibility of components shall be consistent with the anticipated mortality rate of the components and the anticipated need for maintenance services, derived from reliability data and related supply and maintenance experience.

a. Visual Access

(1) (Guideline) Where only visual access is required, the following practices shall be followed in order of preference:

(a) Use an opening with no cover whenever practical.

(b) Use a plastic window if dirt, moisture, or other foreign materials are a problem.

(c) Use a break-resistant glass window if physical wear, heat, or contact with solvents will cause optical deterioration or distortion.

- (d) Use a quick-opening metal cover if glass will not meet stress or other requirements.

b. Physical Access (Table 10, page 78)

- (1) (Guideline) The following practices shall be followed in order of preference, where access is required for tools, test leads, and service equipment only:
 - (a) Whenever practical, use an opening with no cover.
 - (b) Use a sliding or hinged cap if dirt, moisture, or other foreign materials are a problem.
- (2) (Desirable) Openings and work spaces provided for adjusting and handling units shall be ample to permit the required activity by personnel wearing arctic clothes and, where required, an adequate view of the components being manipulated. (For minimum access requirements, see Table 10.)

c. Doors and Covers

- (1) (Guideline) All access covers or doors not completely removable shall be self-supporting in the open position, unless gravity normally holds them in position.
- (2) (Desirable) If instructions applying to a covered component are lettered on a hinged door, the lettering shall be oriented properly for reading when the door is open.
- (3) (Desirable) Sliding, rotating, or hinged units to which rear access is required shall be free to open or rotate their full distance and remain in the "open" position without being supported by hand.
- (4) (Desirable) The method of opening a cover or door shall be obvious.
- (5) (Desirable) An instruction plate shall be attached permanently to the outside of the cover where the above requirement cannot be met.

- (6) (Desirable) It shall be obvious when a cover or door is in place but not secured.
- (7) (Desirable) Sharp edges and corners shall be avoided on doors' covers.
- (8) (Desirable) To expedite reinstallation, removable inspection-access doors shall be interchangeable or shall have a size and shape which makes evident their proper position.
- (9) (Essential) Covers or doors shall not be prevented from opening or being removed by obstructions such as turret, on-vehicle equipment, or structural members.
- (10) (Essential) When a hinged cover is used, a space equal to the sweep volume of the cover shall be provided, i. e., opening of the cover is not obstructed by body frame, brackets, etc.

d. Fasteners for Covers and Doors

- (1) (Guideline) Hinged doors or covers shall be provided with quick-opening captive fasteners.
- (2) (Guideline) The minimum number of fasteners shall be used consistent with floatation, ballistic, or safety requirements.
- (3) (Desirable) Maximum use shall be made of tongue-and-slot-catches to minimize the number of fasteners required.
- (4) (Guideline) The number and type of fasteners used shall be the minimum commensurate with requirements for stress, bonding, etc.
- (5) (Desirable) The same size and type of fasteners shall be used for all covers and cases.
- (6) (Guideline) Captive fasteners shall be used.

e. Mounting Bolts and Fasteners

- (1) (Essential) Screws or bolts with different threads shall be of different sizes.
- (2) (Desirable) Where compatible with stress and load considerations, fasteners for mounting assemblies, subassemblies, etc., shall fasten or unfasten with a maximum of one complete turn.
- (3) (Desirable) The number of turns required to tighten or loosen bolts shall be minimized.
- (4) (Desirable) Hand-operated fasteners are preferred, but those requiring standard hand tools are acceptable.
- (5) (Essential) Fasteners requiring non-standard tools shall not be used.
- (6) (Desirable) Bolts requiring high torque shall be provided with external grip heads.
- (7) (Desirable) Captive bolts and/or nuts shall be used to prevent loss.

f. Cases and Drawers

- (1) (Guideline) The proper orientation of a unit within its case shall be obvious, either through design of the case or by appropriate labels.
- (2) (Guideline) Cases shall be designed to be lifted off units, rather than lifting units out of cases.
- (3) (Desirable) Cases shall be made sufficiently larger than the units they cover so that wires and other components will not be damaged when the cases are removed or replaced.
- (4) (Desirable) Guides, tracks, and stops shall be provided to facilitate handling and to prevent damage to units and components.

B. BATTERIES

1. (Guideline) Storage batteries shall be capable of being exchanged by one man in no more than 10 minutes, using on-vehicle equipment only.
2. (Desirable) Batteries and their compartments shall be capable of being cleaned and serviced without removal of other components.
3. (Essential) Positive and negative battery terminals shall be of different sizes to prevent incorrect assembly.
4. (Desirable) Battery retaining devices shall be fastened with fasteners that can be removed without hand tools, or shall use the same bolt or nut size as the battery terminal clamps.
5. (Guideline) Batteries shall be mounted on roll-out racks, slides, or hinges. It shall be convenient to extend these components without disconnecting them.
6. (Guideline) Battery access covers shall be fastened with quick-release fasteners. The mounted position of the access cover shall be obvious. Where a hinged cover is used, sufficient clearance shall be allowed for opening the door.

C. CANVAS AND ACCESSORIES

1. (Desirable) The tarpaulins and bows covering the bed of cargo vehicles shall be capable of providing a 75-inch clearance from the cargo floor, to provide head clearance for men working inside the vehicle.
2. (Desirable) One man shall be able to gain access to the cargo compartment from front or rear with a tarpaulin and curtains in place within three minutes.
3. (Desirable) Tarpaulin bows, ropes, and snaps shall be easy to unfasten, and bows shall be easy to remove from sockets under wet, muddy, and/or freezing operation conditions by personnel wearing gloves.
4. (Desirable) Tarpaulin bows (especially wooden ones) shall be designed to resist seizing in their sockets because of moisture, rust, or dirt.
5. (Desirable) Tarpaulins and cab tops shall be shaped and supported to shed waste, and preclude formation of water or ice pockets, whether the vehicle is parked or in operation.
6. (Guideline) Cab tops, tarpaulins, and curtains shall be protected from chafing and flapping.
7. (Guideline) Tarpaulin and cab-top bow sockets shall be provided with adequate drain apertures.
8. (Desirable) The cab shall be capable of conversion from open to closed type, and vice versa, by one man in ten minutes or less.
9. (Desirable) Tarpaulin, end curtains, and bows shall be capable of removal or installation by two men in no more than ten minutes.
10. (Guideline) Tarpaulins and end curtains shall be inherently fire-resistant or treated to be fire-retardant.
11. (Guideline) Pins and other retaining devices shall be provided with the largest working clearances which will still permit them to be retained properly.

12. (Guideline) Pins and other retaining devices shall be removable and replaceable by men wearing arctic gloves.
13. (Guideline) A retaining chain shall be provided to prevent the loss of retaining pins and devices.

D. DRAINS AND VENTS

1. (Desirable) The vehicle shall be designed to require few drain valves with simple, accessible, and dependable operating mechanisms.
2. (Desirable) Vents and drains shall be designed to prevent clogging from mud, ice, or other contamination.
3. (Desirable) Drain plugs and valves shall be designed to resist seizing, either in the open or closed position.
4. (Desirable) All drain plugs shall be of a minimum number of sizes, preferably of the same size, and have a socket (recess) to permit removal by a common hand tool.
5. (Desirable) Drains shall be provided and designed to empty components completely of lubricants and hydraulic fluids.
6. (Desirable) Drained fluids shall drain unobstructed to the outside of the vehicle without special equipment and without splashing into vehicle components.
7. (Desirable) Pneumatic system reservoir purging drains shall be readily available to the operator, and they shall drain the tanks completely.
8. (Desirable) A means shall be provided to remove water from cab and cargo body with vehicle either under way or at rest.
9. (Desirable) Drains and vents shall be located where they can be cleaned and checked easily by crew members.
10. (Desirable) Drains and vents shall be capable of easy identification and shall be located to allow closing and checking prior to operation of floating or swimming vehicle.

11. (Desirable) An instruction plate shall be provided showing procedure and location for drains and vents on floating or swimming vehicles.

E. ENGINES

1. (Desirable) Provide means for manually cranking the engine.
2. (Desirable) Engine timing marks shall be visibly accessible.
3. (Desirable) Engine timing marks shall have a reference point on the engine to permit a timing check when the engine is installed in the vehicle.
4. (Essential) Breathers shall be easy to remove and replace.
5. (Desirable) Engine governors shall be provided.
6. (Essential) Governors shall be made tamper-proof.
7. (Desirable) Fan belts and other drives requiring adjustment shall be simple and readily accessible.
8. (Essential) Oil-drain plug shall drain the pan completely without requiring the operator to move the vehicle.
9. (Desirable) Distributor or fuel injector shall be located in an accessible and unobstructed location.
10. (Desirable) Fuel and oil filters shall be located so that they can be cleaned and replaced without disassembly of other parts of the vehicle.

F. INTERVEHICULAR CONNECTIONS

1. (Essential) Intervehicular cables shall be of adequate length so as not to restrict maneuverability of towing vehicle when vehicles are coupled together, under any applicable conditions.
2. (Desirable) Suitable provision shall be made to prevent damage to intervehicular cables in use.
3. (Essential) Vehicles equipped with air-over-hydraulic or air brakes shall include suitable provisions for connecting to the brake system of another vehicle at the front and rear, and for controlling brakes of a vehicle being towed by another truck during emergency operation.
4. (Essential) Brake hoses (or cables) shall not be so short that they restrict maneuverability of the prime mover or a towed vehicle when coupled together, under any applicable conditions.
5. (Essential) Suitable provisions shall be made to prevent kinking, entanglement, dragging, abrasion, or pinching of the brake lines.

G. LADDERS AND STAIRS (Trailers and Vans)

1. (Guideline) Vertical ladders more than eight feet tall shall be avoided.
2. (Desirable) The following inclines shall be incorporated into vehicular ladder design:
 - a. 50° - 90° -- Incline recommended
 - b. 50° - 75° -- Inclined ladders shall have flat treads
 - c. 75° - 90° -- Inclined ladders may use rungs
3. (Desirable) Tread depth shall be three inches minimum and six inches maximum.
4. (Essential) The distance between the ladder treads or rungs shall be seven inches minimum and 16 inches maximum (12 inches is desirable).

5. (Desirable) The width between the side rails of the ladder shall not be less than 11-1/2 inches for ladders up to and including 10 feet in length.
6. (Desirable) Side rails shall be from 3/4 inch to two inches in diameter.
7. (Desirable) Rungs shall have a minimum diameter of 3/4 inch.
8. (Desirable) The distance between the center line of rungs, cleats, or steps and the nearest object in back of the ladder shall not be less than seven inches.
9. (Desirable) All vehicular ladders shall have hand grips.
10. (Desirable) The main ladder support may serve as a hand grip on ladders with rungs. Special hand rails shall be designed for ladders which are used at shallower angles.
11. (Guideline) One man shall be able to store and retrieve vehicular ladders in a minimum amount of time.
12. (Guideline) Catches and other mechanisms required for folding ladders shall be simple, easy to release and maintain, even when users are wearing arctic gloves.
13. (Essential) Rungs, treads, steps or cleats shall be self-cleaning and be of nonslip or nonskid design.
14. (Desirable) The major allowable weight required to lift and store ladders five or six feet above ground level, by one man without mechanical advantage, shall be 25 and 20 pounds respectively.
15. (Desirable) Stair rail heights above step treads shall be 34 inches \pm 1/2 inch to top of rail.
16. (Desirable) Vehicle mounting bar-type step shall be a minimum of six inches wide and have a minimum stand-off of three inches from mounting structure. Five-eighths inch round steel or one inch x 1/4 inch flat stock is recommended. Step treads shall not overhang the step below by more than one inch.

H. POWER PACKAGE DESIGN

1. (Guideline) A power package shall be incorporated in design wherever possible.
2. (Guideline) Power packages shall be removable as a unit.
3. (Guideline) Service and adjustment of subassemblies shall be performed without removal of the power package unit.
4. (Desirable) Quick-disconnect points shall be provided on power package, shall be designed to eliminate the possibility of being damaged during the removal or replacement of the power package, and shall conform to the following:
 - a. Centrally located.
 - b. Quick-disconnect type -- this includes electrical, fuel, linkage, final drivers, power-transforming shafts, exhaust, brakes, air ducting, etc.
 - c. Air hose to hydraulic lines with quick-disconnect points shall be provided with dummy mounting brackets.
 - d. Obvious to maintenance personnel.
5. (Desirable) Subassemblies shall not require removal prior to removal of power package.
6. (Desirable) Power package shall be capable of being test-run without requiring extensive adaptation, when off the vehicle.
7. (Desirable) Existing electrical and fuel lines shall be used to the maximum extent possible for removed power pack test-runs.
8. (Essential) Power packages shall have strong bearing surfaces or brackets to allow them to be placed safely on hard surfaces without damage to the power package and its projecting lines, fittings, oil pumps, fuel pumps, etc.

9. (Desirable) Power packages shall be designed to be stable when out of the vehicle.
10. (Essential) Power packages shall be designed so they can be removed without draining lubricants or coolants.
11. (Desirable) Guide tracks or slide-out racks shall be incorporated to facilitate the removal and replacement of the power package.
12. (Essential) Lift eyes shall be provided on the power package.
13. (Essential) Lift eyes shall be so located that they do not make it difficult or dangerous to maneuver equipment.

I. RADIATORS

1. (Essential) Size of the filler neck shall be compatible with existing fillers for efficiency of filling.
2. (Essential) There shall be a drain in the lower tank of the radiator to allow for completely draining it.
3. (Desirable) Drain shall have sufficient clearance and provide sufficient grip to allow for opening and closing with a gloved hand.
4. (Guideline) Drain shall be readily accessible to the 5th through the 95th percentile man.
5. (Desirable) Filler neck shall be positioned so that the operator can see the fluid level inside the tank. It shall not be necessary to add fluid to determine fluid level.
6. (Guideline) Upper and lower hose connectors shall be located to provide sufficient hand clearances for removal and replacement of hoses.
7. (Guideline) If lower echelon of maintenance is intended (through 3rd), silver solder shall be avoided in the construction of the radiator to facilitate repair.

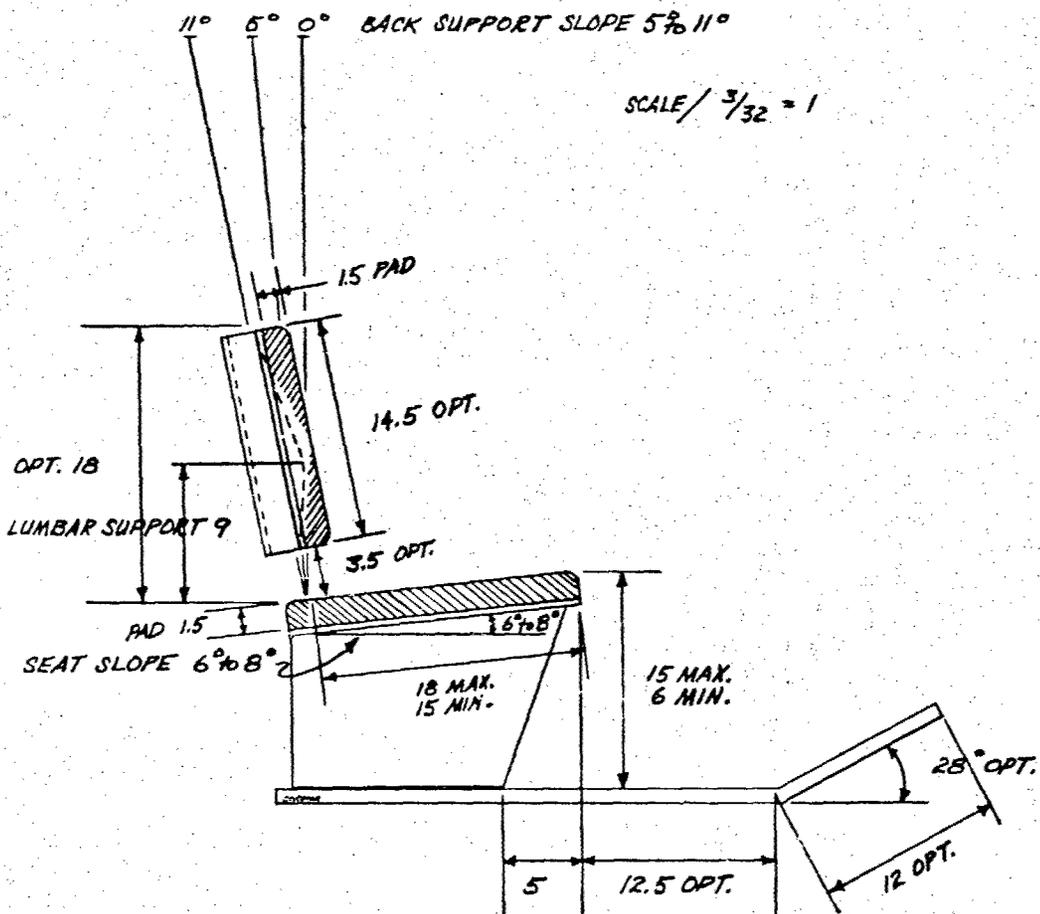
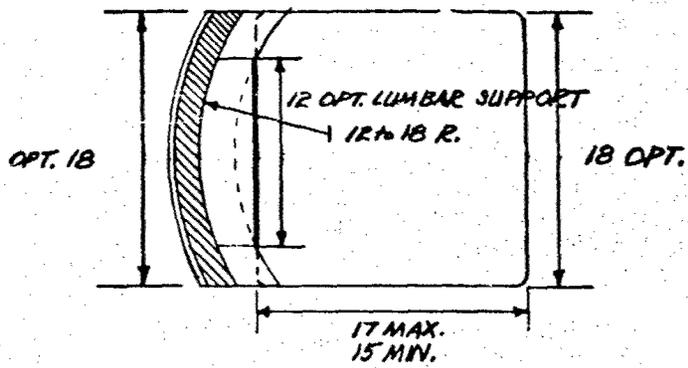


Fig. 3. Optimum Seating for Wheeled Vehicles

J. SEATING (Fig. 3, page 70)

1. (Desirable) Where the height of the seat above the floor varies, the requirement for leg room and the foot rest will vary inversely. As the distance from the floor decreases, the leg room increases and the foot-rest angles increase.
2. (Essential) The back-rest angle shall not exceed 125° (the seat portion remaining stationary).
3. (Desirable) If a lumbar-area support alone is used, the angle of tilt of the back rest may be decreased to 95° - 100° for an alert position.
4. (Essential) Seat padding shall be kept to a minimum and shall be horizontal across the area of the ischial tuberosities.
5. (Essential) A resilient-type foam shall be provided in place of plastic. The use of foam rubber is not desirable.
6. (Essential) Where only short-term confinement is expected and where retention in the seat under heavy vibration is a primary requirement, contour seats shall be used.
7. (Essential) Contour seats shall be designed to support the weight on the proper anatomical portion of the body suited to supporting weight (ischial tuberosities).
8. (Desirable) Safety belts shall be provided on all vehicles.

K. TIRES

1. (Desirable) Spare tire and servicing tools shall be readily available and shall be capable of being removed and stowed by one man using only OVM.
2. (Desirable) A pneumatic outlet and OVM pressure gage shall be provided to inflate and reduce pressure in vehicle tires on any vehicle employing air-over-hydraulic brake system.
3. (Essential) Air hose shall be of sufficient length to reach tires, including the spare tire.

4. (Essential) The spare tire shall be capable of being inflated and checked in the mounted position by a standard air gage.
5. (Essential) Dual tires shall be designed to allow the inflating and checking of air in both the outer and inner tire. Valve location shall enable the tires to be inflated and checked when tires are interchanged.
6. (Essential) Equipment used to stow and unstow spare tires shall be simple to operate and pose no possibility of injury to personnel.
7. (Essential) Spare wheel shall be capable of being removed and replaced with vehicle fully loaded.

L. TOOLS (Tables 11 and 12, pages 79, 80)

1. (Desirable) Design shall permit maintenance and adjustment operations with standard, commonly available hand tools and test equipment, with minimum requirements for special tools. Where special tools are required, they shall be designed for a variety of uses.
2. (Essential) Organizational maintenance shall be accomplished using on-vehicle equipment, General Mechanic's Tool Sets, Organizational Second-Echelon Sets, and organic recovery and handling equipment (Table 11).
3. (Essential) It shall be possible to perform field maintenance using equipment organic to the field-maintenance unit (Table 11).
4. (Essential) It shall be possible to perform maintenance operations at the echelons indicated using equipment shown in Table 11.
5. (Desirable) Wrench clearances shall be adequate for the required type of wrenches and the torques required. Box wrench clearance shall be provided where common hand tools are used at 50 ft-lb or greater torque.
6. (Essential) Counterbores around recessed bolt and nut heads shall be large enough to permit the use of maximum size sockets procured by the government (Table 12).

M. TURN SIGNALS

1. (Essential) All wheeled vehicles shall be equipped with turn signals.
2. (Desirable) There shall be an indicator to tell the operator that the turn signals are operating.
3. (Desirable) This display shall show the operator which direction the turn signals are indicating.

N. TRAILERS

1. (Essential) Trailer tires shall be interchangeable with prime mover.
2. (Desirable) Trailer towing-eye height shall conform to vehicle pintle height with landing wheel down.
3. (Desirable) Landing-wheel release and lock shall be capable of being hand- or foot-operated.
4. (Desirable) Trailer brake controls shall be located so that an operator can reach them while restraining, positioning, or moving the trailer manually.
5. (Desirable) Brake controls shall not be located on the road side (i. e., left side) of a trailer.
6. (Essential) Dummy connectors shall be provided on trailers that have permanently attached intervehicle connections.
7. (Desirable) Trailers with removable intervehicle cables shall have storage space for stowing cables adjacent to the connection point.

O. WINCHES

1. (Essential) Winch cables shall be capable of being easily pulled out (played out) manually by one man.
2. (Desirable) Winch shall be capable of being operated both from cab and winch locations.

3. (Desirable) Winch and vehicle power trains shall be capable of being operated simultaneously.
4. (Essential) Instruction plates shall be provided for winch operation.
5. (Essential) Winch controls shall be capable of being operated by personnel while wearing arctic gloves, especially at a winch location.
6. (Guideline) Provisions for a spare shear pin and shear pin mount shall be provided adjacent to shear pin location.
7. (Essential) Winches shall have a safety feature to prevent winch cable from breaking under load. A no-back feature shall also be included to keep the vehicle from rolling or moving backwards after safety feature has been activated (shear pin shears).

P. WINDSHIELD WIPERS

1. (Guideline) Windshield washers are recommended and shall be provided where possible.
2. (Guideline) Electrically operated windshield wipers shall be preferred over vacuum operated wipers.
3. (Desirable) Windshield wiper motors shall be located at bottom of windshield.
4. (Desirable) Wiper shall clean a minimum of 60 per cent of windshield.
5. (Essential) Windshield wipers shall be self-parking when turned off.

Q. WIRING AND CONNECTORS

1. (Essential) Cables and wiring harnesses shall be routed to prevent repeated bending or twisting.
2. (Essential) Cables and wiring harnesses shall be protected from rubbing against rotating parts and from being cut or pinched by closures, structural members, normal personnel movement, and maintenance activities. Some examples of protection are: grommets, suitable clamps, shields and retainers (especially quick-disconnect leads).
3. (Guideline) Cables and wiring harnesses shall not be placed where they are likely to be walked on or used for hand holds. If they must be located in such undesirable places, they shall be provided with guards, which, if convenient to personnel, shall be designed as personnel access feature.
4. (Desirable) The aligning keys and slots in polarized electrical connectors shall engage before the electrical contacts do, to prevent improper energizing of circuits or damage to the connector pins.
5. (Essential) Where cables or wiring harnesses are subject to tensile strains, connectors shall be so designed and positioned that they can pull apart without damage.
6. (Desirable) Connectors shall be so located that cables need not be bent sharply to connect and disconnect them.
7. (Desirable) Electrical connectors, when disconnected, shall be designed to preclude accidental shorting by external objects.
8. (Essential) The female receptacle, rather than the male plug, shall be on the "hot" side of the circuit when the lines are disconnected.
9. (Essential) Cables and wiring harnesses shall be long enough to allow easy installation and removal, and to prevent them from interfering with the maintenance of other components.

10. (Essential) Cables, separate wires, and wiring harnesses on adjacent electrical connectors shall be made physically incompatible so they cannot be interchanged accidentally.
11. (Essential) Plug-type connectors shall be used to connect electrical assemblies to the equipment, so that it shall not be necessary to disturb soldered connections to remove assemblies at the direct-support field maintenance or lower levels.
12. (Desirable) Connectors shall require no more than one revolution of a tool to lock or unlock; no more than five remaining turns by hand shall be necessary.
13. (Desirable) Quick-release, spring-type fasteners shall be used in place of bolt fasteners to retain cables and wiring harnesses.

TABLE 9

Lifting Provisions

Weight to be Lifted	Handle Diameter	Finger Clearances	Handle Width
Under 25 lbs.	1/4 to 1/2 inch	2 inches	4 1/2 inches
Over 25 lbs.	1/2 to 3/4 inch	2 inches	4 1/2 inches
Lifted by gloved hand		2 1/2 inches	5 inches

TABLE 10

Minimum Apertures for One-Handed Tasks (Bare Hand)

Inserting empty hand held flat	2 1/4 by 4 1/4 inches
Smallest square hole through which empty hand can be inserted	3 1/2 by 3 1/2 inches
Using an eight-inch screwdriver with a one-inch diameter handle	3 3/4 by 3 3/4 inches
Inserting and tightening an AN item (outside diameter 1 7/8 inches)	4 by 4 inches
Inserting a box -- diameter of box:	+ 1 3/4 inches

Minimum Apertures for Two-Handed Tasks (Bare Hand)

Reaching through aperture with both hands to a depth of 6 to 25 inches	Height = 4 inches Width = 3/4 depth of reach
Reaching in full arm's length (to shoulders) straight ahead with both arms	Height = 4 inches Width = 19 1/2 inches

Adapted from Mil Std 803 USAF

TABLE 11
Tool Listing

LINE ITEM	FSN	SM 9-4	NOMENCLATURE	FORMER SNL
453890	5180-754-0654	5180-A01	TOOL KIT, Org Maint No. 1 Common	J 7-1
453905	5180-754-0653	5180-A17	TOOL KIT, Org Maint No. 1 Supplemental	J 7-2
453895	5180-754-0650	5180-A20	TOOL KIT, Org Maint No. 2 Common	J 7-3
453800	5180-754-0641	Loss to QM	TOOL KIT, Gen Mechanics MOS	J 10-4
453670	4910-754-0655	4910-A57	TOOL KIT, Auto Fuel & Elec Sys Repairman	J 10-8
440524	4910-754-0714	4910-A02	SHOP SET, Fld Maint Autmv Fuel Elec Sys	J 8-12
440544	4910-754-0705	4910-A38	SHOP SET, Fld Maint Autmv, Basic	J 8-13
440547	4910-754-0706	4910-A38	SHOP SET, Fld Maint Autmv No. 1 Supplemental	J 8-13
440638	3470-754-0708	3470-A03	SHOP SET, Fld Maint Machine, Basic	J 8-16
440640	3470-754-0738	3470-A03	SHOP SET, Fld Maint Machine, Heavy	J 8-16
440568	5180-754-0737	5180-B07	SHOP SET, Fld Maint Contact & Emerg Repair	

Reference SB 9-122, dated 11 January 1961
 J7---1 & 2 Echelon
 J8---3 & 4 Echelon
 J10--MOS

TABLE 12

Counterbore Allowances for
Standard Tool Sets

Screw Size	Hexagon Size	O. D. Socket
1/4	7/16	.683
3/8	9/16	.814
1/2	3/4	1.055
5/8	15/16	1.300
3/4	1 1/4	1.825
1	1 1/2	2.135

Tracked Vehicle Design Practices Guide
OTAC

SECTION V

VISIBILITY AND ILLUMINATION

SECTION V

VISIBILITY AND ILLUMINATION

A. VISIBILITY

1. (Essential) The operator shall be provided a 180° field of forward vision; 220° field of forward vision is more desirable. (In tracked vehicles, as large a field of view as possible is desirable.)
2. (Essential) In the normal driving position, the operator shall be able to view the ground 20 feet beyond the front of the vehicle. A view within 10 feet and the ability to see upward at least 15° above the horizontal is desired.
3. (Essential) Unless otherwise provided, the driver's seat shall be adjustable to permit the driver to view the ground within 10 feet of the front of the vehicle for greater visibility when maneuvering in restricted places.
4. (Essential) Door posts, windshield wiper motors, and other devices shall not obstruct vision.
5. (Desirable) Transparent materials used for windshields or windows shall neither distort nor obscure vision.
6. (Essential) Interior surfaces shall neither reflect nor cause glare to the operator.
7. (Desirable) Side closures shall be easily operated to permit the driver and assistant driver to look to the rear on their respective sides of the vehicle (not applicable to tanks).
8. (Guideline) A rear window shall be provided to give the driver visibility to the rear over the cargo bed.
9. (Desirable) Two glare-proof, rear-view mirrors shall be installed; one on each side of the cab. Mirrors shall be 16 inches by 6 inches, and shall be braced and clamped to prevent vibration obscuring the view. Mirrors shall be placed to provide the driver with vision to the rear or right and left from his normal operating position (not applicable to tanks).

10. (Essential) Red blackout lighting shall be provided for the instrument panel or individual instruments.
11. (Desirable) A map light shall be provided.

B. ILLUMINATION OF WORK AREAS (Table 13, page 85)

1. (Guideline) Sharp gradients in illumination shall be avoided (ratios of 10 - 1 or greater).
2. (Guideline) Local direct lighting shall be provided for equipment which is not lighted properly by the general diffuse lighting.
3. (Desirable) Recommended intensity levels and corresponding types of illumination for various visual tasks are presented in Table 13.

C. INTERIOR COLORS

1. (Essential) Interior surfaces of van and panel type bodies and vehicular equipment shall be painted in the following colors in accordance with Federal Specification TT-C-595, Colors for Ready-Mixed Paints.
2. (Desirable) Walls and ceiling, doors, fittings, and mounted equipment: Semigloss Light Green color No. 24533.
3. (Desirable) Floors: Lusterless or semigloss Ocean Gray color No. 36118.
4. (Desirable) When dark adaptation is required, blackout lights shall be red.
5. (Desirable) Brightness for dial reading shall be a minimum of five foot-Lamberts.
6. (Essential) Warning lights shall be at least five times as bright as their surroundings.

TABLE 13

Illumination Requirements

Task Conditions	Level (Foot Candles)	Type of Illumination
Difficult and prolonged visual tasks with objects of low brightness contrast; high speed, extreme accuracy required.	100 or more	Supplementary type of lighting. Special fixture such as desk lamp.
Small detail, fair contrast close work, speed not essential.	50 or more	Supplementary type of lighting.
Prolonged reading, rough assembly, general office, ordinary bench work.	30 or more	Local lighting, ceiling fixture directly over-head.

Adapted from WADC TR 54-160

SECTION VI

SAFETY AND PHYSIOLOGICAL REQUIREMENTS

SECTION VI

SAFETY AND PHYSIOLOGICAL REQUIREMENTS

A. GENERAL

Note: The following list contains only representative items.

1. (Essential) The critical position of controls used during hazardous operation shall activate a warning device in the affected area.
2. (Essential) A hazard alerting device shall be provided to warn personnel of impending or existing hazards, e. g., fire, presence of combustible or asphyxiating gas radiation, etc.
3. (Essential) A mechanical guard shall be provided on all moving parts of machinery and transmission equipment in which personnel may become injured or entangled. This includes pulleys, belts, gears, blades, etc.
4. (Essential) Handrails shall be provided at hazardous locations and wherever personnel may fall from an elevation.
5. (Essential) A safety bar, chain, or strap shall be attached across openings to prevent falling.
6. (Essential) Automatic shut-off devices shall be provided on fuel service equipment to prevent overflow and spillage.
7. (Essential) Portable hand-operated fire extinguishers shall be provided where fire hazards exist or may be created.
8. (Essential) Emergency doors and exits shall be constructed so that they are readily accessible, unobstructed and quick-opening to the outside.
9. (Essential) Suitable foot rests and grab rails shall be provided in the vehicle design for each member of the crew, except the driver.

10. (Essential) Safety straps shall be provided for open apertures adjacent to personnel seats, if they are below elbow height.
11. (Essential) Work platforms shall be provided with nonskid surfaces, preferably open grate, to allow rain or snow to pass through them.
12. (Essential) Handholds and restraining features shall be provided for a man standing in the cab on air sentry duty while the vehicle is in motion.
13. (Essential) Hand rests shall be provided for use by the driver when leaning out of the cab while backing.
14. (Essential) Malfunctioning of a component or system shall not needlessly endanger the safety of personnel, nor aggravate repair or recovery of the equipment.
15. (Essential) Features shall be provided in components essential to achieving even minimal performance, to permit equipment to complete its mission, although at significantly reduced performance, or with assistance.
16. (Essential) Audible warning signals shall be distinctive and unlikely to be obscured by other noises.
17. (Essential) Noise made by warning devices shall not interfere with proper operations of the equipment, i. e., if a low-air-pressure warning buzzer is used, it shall not be so loud that it will annoy or distract the operator during the starting or warming procedures.
18. (Essential) Components shall be so located and mounted that access may be achieved without danger to personnel, e. g., from electrical charge, heat, sharp edges and points, moving parts, and chemical contamination.
19. (Essential) Edges of components and maintenance access openings shall be rounded or protected by rubber, fiber, or plastic protectors to prevent personnel injury.
20. (Essential) Incorporate "No Step" markings where applicable.

21. (Essential) Jacking and hoisting points shall be clearly, conspicuously, and unambiguously identified.
22. (Essential) Insure that all liquid, gas, steam, etc., pipe lines are clearly, conspicuously, and unambiguously labeled or coded as to any specific personnel or equipment hazard properties.
23. (Essential) All electrical components, wiring, and connectors shall be routed above fluid levels in hulls and bilges of vehicles.
24. (Essential) Hatches shall have a positive lock for the open position. This lock shall be simple to operate and be capable of withstanding all the rigorous requirements of a tactical vehicle in a combat situation.
25. (Essential) Struts and latches shall be provided to secure hinged and sliding components against accidental movement which could cause personnel injury during maintenance operations.
26. (Essential) Limit stops shall be provided on drawers or fold-out assemblies which could cause personnel injury if not restrained.
27. (Guideline) Where practicable, vehicle exhaust and fuel systems shall be routed on opposite sides of the vehicle.
28. (Essential) Battery enclosures shall be vented to prevent the accumulation of inflammable gases.
29. (Essential) Bulk-fuel-transporting vehicles shall be vented vertically when the vent plugs fuse as the result of fire.
30. (Essential) Fire extinguishers shall be placed where they are readily accessible, but not immediately adjacent to points where fire would probably originate.
31. (Essential) Textiles and insulating materials, including tarpaulins and seat cushions, shall be inherently fire-resistant or treated so as to be fire-retardant.

32. (Essential) Conspicuous placards shall be mounted adjacent to high voltage, very hot, etc., equipment.
33. (Essential) Operations of switches or controls which initiate hazardous operations, such as ignition, crane moving, etc., shall require the prior operation of a related or locking control.
34. (Essential) Dangerous voltages shall not be located near internal controls such as switches and adjustment screws.
35. (Essential) Components and live wires that retain dangerous voltages when the equipment is off shall be located where a technician is not likely to touch them by accident.
36. (Essential) Electrical connectors shall be designed so external objects will not short them.
37. (Essential) Master switches shall not be in the ground side of the circuit but may break both ground and "hot" lead at the same time.
38. (Essential) Bleeding devices shall be provided for high-energy capacitors which must be removed during maintenance operations.
39. (Essential) Covers, structural members, and similar electrically neutral parts of electrical systems shall be grounded or protected from contacting personnel or tools.
40. (Essential) Vehicle electrical systems shall include suitable provisions to prevent sparking and other conditions which might cause fire or explosion when van usage involves volatile and/or combustible materials.
41. (Essential) Tools and equipment which are used in an explosive atmosphere shall be nonsparking and explosively safe, e. g., tools and inspection lamps used in fuel tanks.
42. (Essential) Suitable provisions shall be included for electrical grounding of vehicle structure and mounted equipment.
43. (Essential) Collision protection shall be provided by use of safety plate glass or synthetic non-splintering transparent materials in vision apertures.

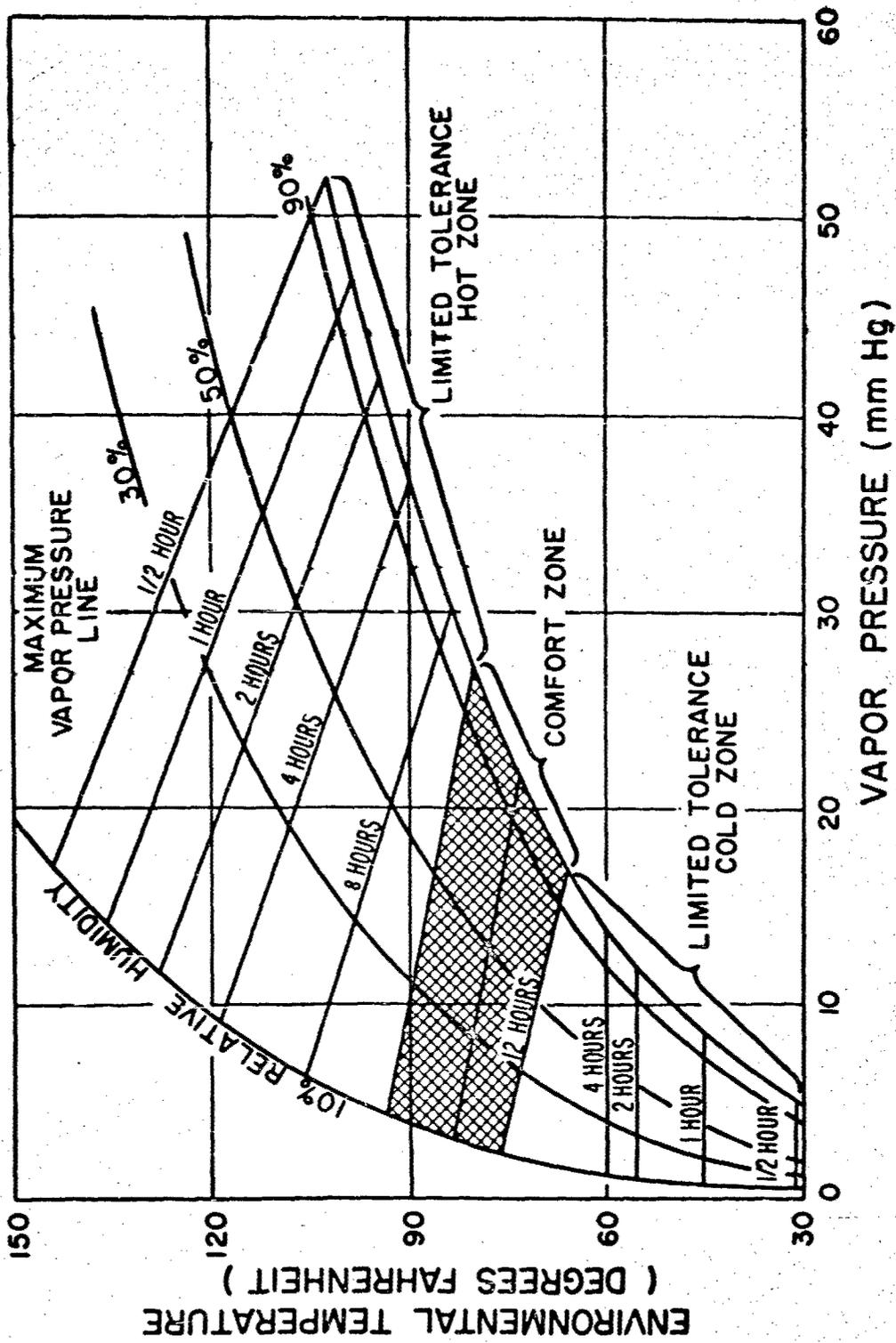
B. TEMPERATURE AND VENTILATION (Regulation and Control)

1. (General) Work at optimum temperature involves less physiological and mental adaptations and, therefore, less fatigue. Since mental and physical fatigue inevitably result from combat, a reduction in either is highly desirable. Figure 4 gives information on physiological limits of operation under various temperatures and humidities.
2. (Essential) The crew compartment shall be insulated to provide and maintain temperatures above 20° F.
3. (Essential) Fresh air shall be supplied at a minimum rate of 15 cu. ft./min. per person.
4. (Desirable) Ventilation systems shall provide a slight positive pressure within the compartments they service.
5. (Desirable) For cold-climate operations, incoming air shall be evenly directed and distributed into the compartment and shall not blow onto the faces, feet, or ankles of the crew.
6. (Essential) For hot-climate operation, the rate of random air movement around each crew member shall exceed 150 ft./min. This air movement is most effective in the region of the head and upper body.

C. NOXIOUS SUBSTANCES

Toxic Fumes (Table 14, Fig. 4)

1. (Guideline) The exhaust from internal combustion engines contains numerous hazardous substances. From the standpoint of practical health-hazard control, however, the most important constituents are carbon monoxide from gasoline-engine exhaust, aldehydes, and nitrogen oxides from diesel-engine exhaust. The concentration of constituents in the combustion products of internal combustion engines varies as a function of many factors.



Taylor. C. L. Thermal requirements for air craft cabins TSEAL-3-695-56

Fig. 4. Tolerance Limits for Combined Temperature-Vapor Pressure

2. (Essential) Exhaust systems shall be of substantial, leak-proof construction, and the exits will be located so that entrance of exhaust gases into cab or body will be minimized under all conditions of operation and wind.
3. (Essential) The concentration of combustion products in the cab or body shall not exceed the Threshold Limit Values as published annually by the American Conference of Government Industrial Hygienists (Table 14, page 99).
4. (Essential) Carbon monoxide shall not exceed limits as specified in Figure 5, page 96.

D. NOISE LEVELS (Table 15, page 100)

1. (Essential) The interior noise level of any wheeled vehicle shall not exceed the sound levels expressed in decibels indicated in Table 15.
2. (Essential) Exterior noise of any wheeled vehicle shall not exceed the current Automobile Manufacturers Association design standard for truck noise (125 sones at a distance of 50 feet from the center line of the lane in which the vehicle is traveling).

E. VIBRATION (Fig. 6, page 97)

(Essential) Vibration measured at any point in the passenger area of a vehicle should not exceed the limits shown in Figure 6, when measured in any plane with equipment which meets and is calibrated in accordance with the current standards of the American Standards Association, Inc.

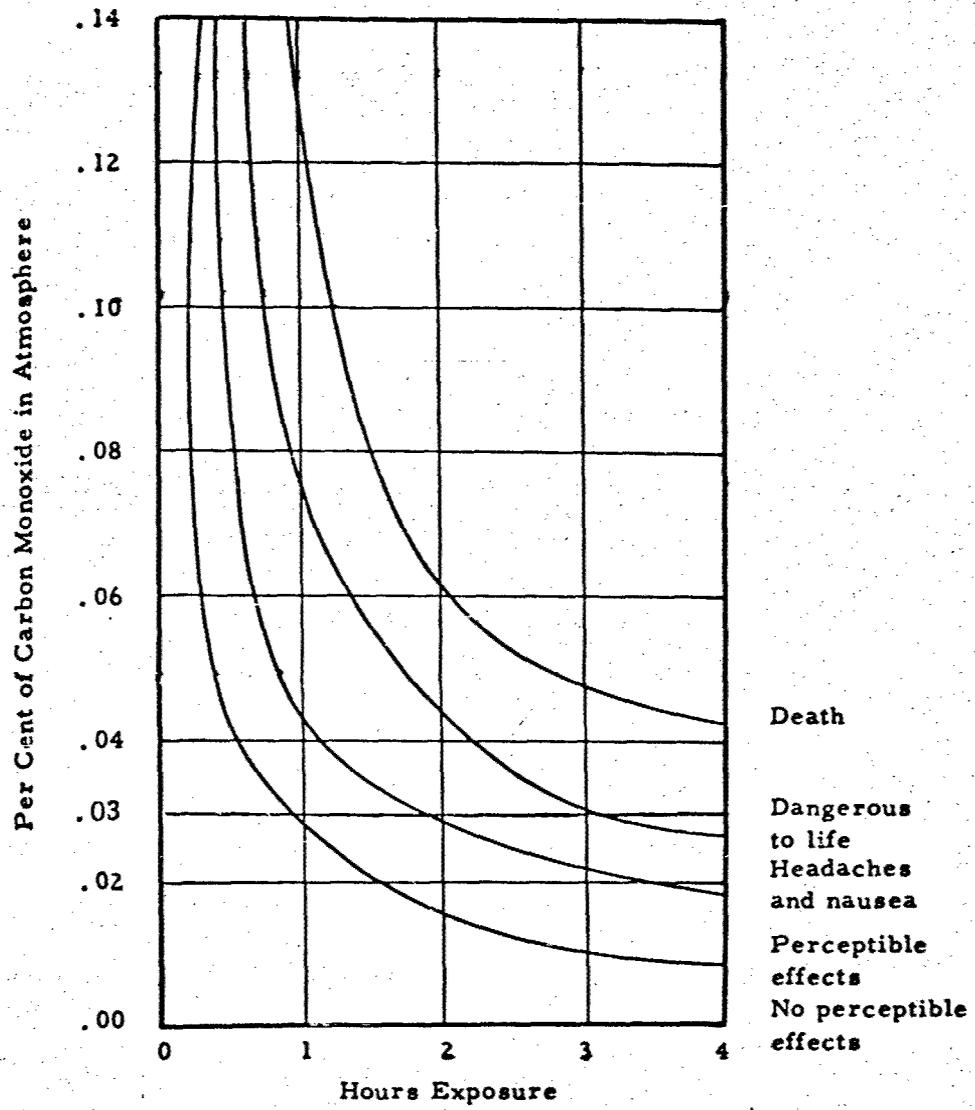


Fig. 5. Effects of Carbon Monoxide for a Given Time on Human Beings

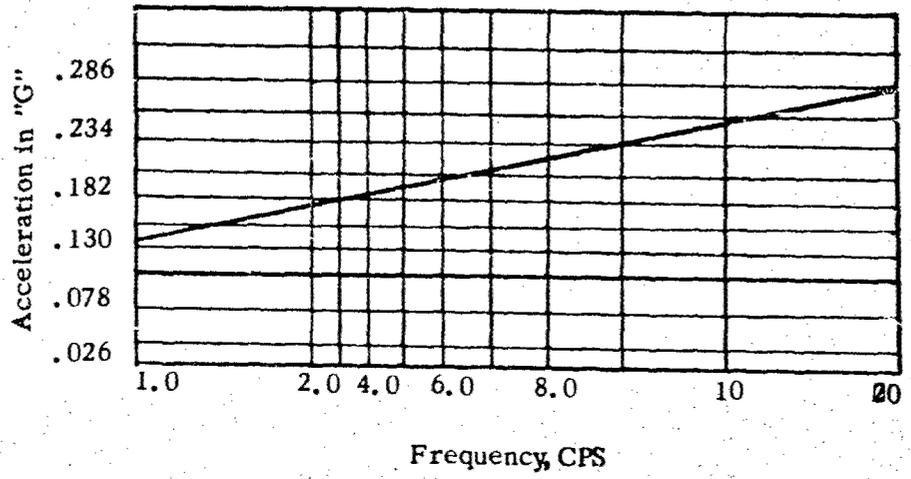


Fig. 6. Vibration Limits for Wheeled Vehicles

F. ELECTRIC SHOCK (Table 16, page 101)

1. (Guideline) The available data on death from electric shock are not sufficient to give precise numbers. However, for the purposes of this document, it shall be considered essential that sources of voltage exceeding 20 volts potential between terminals or between terminal and ground with voltage, whether on or off (capacitor retention), shall be guarded and provided with safety interlocks to de-energize and/or bleed capacitors.
2. (Guideline) The effect of electric shock on the individual will depend on the resistance of the body, the current path through the body, the duration of the shock, the amount of current and voltage, the frequency of the current, and the physical condition of the individual.
3. (Guideline) The body resistance depends on the size of the individual, the condition of his skin (broken or unbroken), and conditions of the immediate environment (wet or dry, etc.).
4. (Guideline) Skin resistance varies between c. 10^2 ohms and 2×10^6 ohms depending on skin condition and the amount of voltage and frequency (ac).

TABLE 14

Toxic Fumes

Extracted Threshold Limit Values for 1961*
(American Conference of Governmental Industrial Hygienists)

Benzene (benzol) --	25 ppm (parts per million)
Gasoline --	500 ppm
Carbon Monoxide --	100 ppm
Carbon Dioxide --	5000 ppm
Nitrogen Dioxide --	5 ppm
Aldehyde, from 5 -	200 ppm depending on specific type

* Maximum working limits per eight-hour day.

TABLE 15

Noise Limits*

Octave Band Limits in cps	Octave Band Level in db <u>re</u> 0.0002 Microbar
< 75	55
75-150	50
150-300	85
300-600	70
600-1200	60
1200-2400	50
2400-4800	40
> 4800	30

* re 0.0002 microbar measured in the right front seat while the vehicle is traveling 35 mph on a level concrete road surface, using the microphone of a sound level meter which meets the requirements set forth in American Standards Association Document S1.4-1961. Specification for General-Purpose Sound Level Meters.

TABLE 16

Possible Ventricular Fibrillation from Short Shocks
(Current in ma)

<u>Duration</u>	<u>DC</u>	<u>AC</u>	<u>AC</u>
		60 cps	10,000 cps
0.03 sec	1300	1000	1100
3.0 sec	500	100	500

from "The Effects of Electric Shock on Man - USAEC -
Safety and Fire Protection Bull. #7"

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2. Military Vehicle Design - Manual

Human factors engineering recommendations for military vehicles in the areas of operability, maintainability, and safety are listed. These recommendations are oriented toward use by human factors specialists. Neither the areas of interest nor the contents of these areas is exhaustive.

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