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MILITARY STANDARDIZATION HANDBOOK

TRUCKS AND TRUCK TRACTORS; TACTICAL (MILITARY) DESIGN CHARACTERISTICS OF

FSC-2320

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15 October 1965

TRUCKS AND TRUCK TRACTORS; TACTICAL (MILITARY) DESIGN CHARACTERISTICS OF

1. This standardization handbook was developed by the Department of Defense in accordance with established procedure.

2. This publication was approved on 15 October 1965 for printing and inclusion in the military standardization series.

3. This document provides basic fundamental information on design characteristics of truck and truck tractors. It will provide valuable information and guidance to personnel concerned with the preparation of specifications and the procurement of trucks and truck tractors. The handbook is not intended to be referenced in purchase specification requirements

4. Every effort has been made to reflect the latest information on design characteristics of trucks and truck tractors. It is the intent to review this handbook periodically to insure its completeness and currency. Users of this document are encouraged to report any errors discovered and any recommendations for changes or inclusions to Commanding General, U.S. Army Tank Automotive Center, Attn: SMOTA-RSS, Warren, Michigan 48090.

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FOREWORD

This standardization handbook is intended to be used in the design of new tactical trucks, truck tractors and the modification of existing tactical vehicles.

The purpose of this standardization handbook is for use by anyone associated with tactical vehicle design, whether at a Government agency or at a civilian agency designing or producing trucks for the Government. The over-all philosophy of the standardization handbook is not necessarily to restrict or limit design, but rather to summarize what the Government expects in a tactical truck or truck tractor with respect to the function, materials, manufacturing quality and workmanship, dimensional limits and the special military characteristics of that tactical truck or truck tractor.

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COMMENTS

LIST OF TABLES

INDEX

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1. SCOPE

1.1 The standardization handbook is not complete in itself for the engineer to accomplish the design of a tactical truck or truck tractor. It is a supplement to the more complete and detailed documents that define a proposed vehicle, such as contractual requirements, Federal of Military specifications and standards, drawings, and the handbooks, specifications, and standards of professional societies that are acceptable to the Government. The objective of the standardization handbook is to state in summary form what the Government desires in all tactical trucks and truck tractors.

2. REFERENCED DOCUMENTS

2.1 The following documents of the issue in effect on date of invitation for bids or request for proposal, form a part of this handbook to the extent specified herein.

SPECIFICATIONS

Federal

RR-W-410	- Wire Rope and Strand.
RR-W-420	- Wire Rope, Steel, Highway Guard (Highway Guard Cable).

Military

MIL-T-704	- Treatment and Painting of Material.
MIL-W-1511	- Wire Rope Steel (Carbon) Flexible, Performed.
MIL-F-3541	- Fittings, Lubrication.
MIL-G-3545	- Grease, Aircraft, High Temperature.
MIL-W-3903	- Wire Rope Assemblies, Single Leg (Sling Type).
MIL-C-5425	- Cable; Steel (Corrosion-Resisting), Flexible, Preformed (for Aeronautical use).
MIL-H-5606	- Hydraulic Fluid, Petroleum Base, Aircraft, Missile, and Ordnance.
MIL-W-5693	- Wire Strand, Steel (Corrosion Resistant) Preformed (Aircraft Applications).
MIL-W-6015	- Wire Rope, Steel, 6 by 19, High-Strength (for Aircraft Launching and Arresting).
MIL-L-6082	- Lubricating Oil; Aircraft Reciprocating Engine (Piston).
MIL-L-6085	- Lubricating Oil, Instrument, Aircraft, Low Volatility.
MIL-L-6086	- Lubricating Oil, Gear, Petroleum Base.
MIL-J-6193	- Joints: Universal, Plain, Light and Heavy Duty.
MIL-W-6940	- Wire Strand, Steel, Nonflexible (Preformed).
MIL-L-6880	- Lubrication of Aircraft, General Specification for.
MIL-G-7187	- Grease; Graphite, Aircraft Lubricating.
MIL-G-7711	- Grease, Aircraft, General Purpose.
MIL-S-7742	- Screw Threads, Standard, Optimum Selected Series: General Specification for.
MIL-L-7808	- Lubricating Oil, Aircraft Turbine Engine, Synthetic Base.

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MIL-L-7870	-	Lubricating Oil, General Purpose, Low Temperature.
MIL-S-10379	-	Suppression, Radio Interference, General Requirements for Vehicles (and Vehicular Sub-Assemblies).
MIL-B-13501	-	Bearings and Bushings, Brass and Bronze, Machined or Formed.
MIL-S-17780	-	Springs, Steel.
MIL-F-18240	-	Fastener, Externally Threaded, 250^{0}F., Self-Locking Element for.
MIL-G-23827	-	Grease, Aircraft and Instrument Gear and Actuator Screw.
MIL-R-52243	-	Retainer, Bridge Pin.

STANDARDS
Military

MIL-STD-193	-	Painting Procedures Tactical Vehicles.
MIL-STD-210	-	Climatic Extremes for Military Equipment.
MIL-STD-1273	-	Vehicles, Wheeled; Definition of Terms Related to.
MS 3500	-	Battery, Storage, Lead-Acid, Waterproof.

DRAWINGS
U. S. Army

8377310	-	Wiring Diagram, Truck, 24 Volt.

PUBLICATIONS
Army Regulations

AR-705-8	-	Department of Defense Engineering for Transportability Program.
AR-705-15	-	Operation of Material Under Extreme Conditions of Environment.
FM 101-10	-	Staff Officers Field Manual-Organization Technical and Log Data.
TM 55-508	-	Landing Craft Operators Handbook.

Special Regulations

SR-705-125-10	-	Fordability Requirements for Future Tactical Vehicles.
SR-705-325-1	-	Electrical Systems in Motor Vehicles.

Technical Bulletins

TB-34-9-30	-	Fordability Agreement.
TB-34-9-31	-	Immersion Requirements for Ground Forces Equipment.

(Copies of specifications, standards, drawings, and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

3. DEFINITIONS

3.1 Definition of terms related to vehicles. Definition of terms related to Military Tactical Trucks and Truck Tractors should be in accordance with MIL-STD-1273.

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4. GENERAL REQUIREMENTS

4.1 Military characteristics.

4.1.1 Extent of military characteristics. The extent of military characteristics common to various tactical type wheeled transport vehicles is as described in 4.1.2 through 4.1.22. This handbook enumerates military characteristics which are common to various tactical type trucks or truck-tractors, and also supplements other statements of military characteristics which pertain to specific vehicles.

4.1.2 Limitations. Vehicles should not exceed the weight and dimension limitations prescribed in Army Regulation AR-705-8 unless otherwise indicated in statements of military characteristics for specific vehicles.

4.1.3 Feasibility. During the development phase, it may become evident that attainment of stated characteristics will require incorporation of certain impractical features, unnecessarily expensive of complicated components or devices, costly manufacturing methods or processes, critical materials, or restrictive patents which may be detrimental to the military value of the item. In this event, before such characteristics are incorporated in final design they should be referred, through staff channels, to the principal using agency for reconsideration.

4.1.4 Training. To the extent consistent with other requirements, vehicle design should be such as to minimize the time, special equipment, and special publications required to train personnel, both for operation and maintenance.

4.1.5 Physical characteristics.

4.1.5.1 Effectiveness. Vehicle should incorporate the optimum combination of specified characteristics, and provide maximum practicable effectiveness for its intended purpose.

4.1.5.2 Ruggedness. Vehicle and all parts thereof should be sufficiently rugged in design, materials and fabrication to withstand the stresses, wear, and abuses of military service for extended periods of time without undue failure, and without requiring excessive servicing or adjustment.

4.1.5.3 Simplicity. Simplicity of design is desirable. When other required characteristics are attainable only by complicated design, the extent of complexity should not be such as to increase cost or difficulty of development, production, operation, maintenance, or training.

4.1.5.4 Economy. Cost of development, production, operation and maintenance should be minimum compatible with efficiency, the time and effort available for development, and the urgency of the requirement.

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4.1.5.5 Weight. Vehicle should have maximum practicable weight to facilitate towing and transport, and to provide maximum practicable mobility over mud, sand, snow, and water crossings. To this end, design should utilize light weight construction and light weight non-critical materials to the maximum extent consistent with other requirements.

4.1.5.6 Bulk. Overall dimensions should be the minimum practicable, consistent with other requirements, and should not exceed the limitations prescribed in Army Regulation AR-705-8 to the maximum practicable extent. Parts projecting beyond the principal contours of the vehicle should be removable or retractable to provide minimum bulk for shipment.

4.1.5.7 Vulnerability. General design should be such as to minimize vulnerability to damage from external causes, and to facilitate repair in the event of such damage. Projecting parts should be adequately rugged or protected to minimize damage during transit, transport or storage.

4.1.5.8 Safety and human engineering. Design should provide adequate safety and convenience for personnel when entering or leaving, or performing any necessary operation within, on, or under the vehicle.

4.1.5.9 Appearance. External appearance should, to the extent practicable, conform generally to the appearance of other comparable United States Army vehicles. Distinguishing features that may facilitate identification should be avoided.

4.1.5.10 Concealment. Vehicle should be so designed as to minimize the possibility of its detection from a distance, due to reflection from glass or bright metal, lights on or within the vehicle, or unnecessary features.

4.1.5.11 Noise. Vehicle should be so designed and fabricated as to minimize noise caused by exhaust from engine, air flow from fan, drumming of sheet metal, squealing of brakes or tires, rattling of loose parts, or other avoidable causes.

4.1.5.12 Paint. Vehicle should be prepared, painted and finished with accordance with MIL-STD-193 or MIL-T-704 as specified by the using service. The current color requirements of the applicable using service should be ascertained and applied.

4.1.6 Performance

4.1.6.1 Applicability. The characteristics apply to the vehicle with applicable body, in new condition, with maximum rated cross-country pay load or applicable mounted equipment and without a towed load.

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4.1.6.2 Payload. Vehicle should be suitable in all respects for transporting, under all applicable conditions of military service, the payload or mounted equipment specified in the Military Characteristics Vehicles (MCV) sheets pertaining to the specific vehicle.

4.1.6.3 Mobility. Vehicle should be capable of operation over unimproved roads, the poorest type trails, and open, rolling and hilly cross-country terrain in arctic temperature and tropic zones, through mud, snow, and sand, and over prepared roads.

4.16.4 Speed. Vehicle should be capable of operating over applicable terrain at sustained speeds, as specified in the MCV pertaining to the specific vehicle, for extended periods of time without damage.

(a) Vehicles should be capable of sustained maximum speed at an engine revolutions per minute (rpm) which does not exceed the maximum recommended by the engine manufacturer.
(b) Vehicles should be capable of sustained minimum speed at an engine rpm which does not result in rough, irregular operation.
(c) Vehicles which accompany foot troops should be capable of operation at a minimum speed of 2 1/2 miles per hour (mph).

4.1.6.5 Riding qualities. To the maximum extent compatible with other requirements, vehicle should protect its load or mounted equipment from excessive shock and vibration resulting from uneven terrain, from jolting, swaying, and rapid acceleration or deceleration during air, rail, or marine transport, and from other causes.

4.1.6.6 Maneuverability. Vehicles should be capable of being maneuvered in minimum practicable space without undue difficulty, and should have a minimum practicable turning radius and clearance diameter.

4.1.6.7 Fording. Vehicle should be capable of shallow fording and, when specified in the statement of characteristics for the specific vehicle, capable of deep fording in accordance with the Department of the Army regulation specified in Special Regulation SR 705-125-10.

4.1.6.8 Slope operation. Vehicles should be capable of operating without stalling, slipping, upsetting, or other undesirable effect, on ascending or descending longitudinal slopes up to 60 percent and side slopes up to 20 percent, unless otherwise specified in the statement of characteristics for the specific vehicle.

4.1.6.9. Braking. Truck or truck tractor, by application of service brakes, should be capable of being safely held and controlled while ascending or descending a 60 percent incline. The brakes should also be capable of bringing the truck or truck tractor, to a complete, safe stop on level roadway in the

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minimum practical stopping distance. Since Federal and State highway braking regulations are primarily intended as limits for marginal, “in-use” truck and truck tractors, these regulation limits should be multiplied by 75 to 80 percent to obtain new truck and truck tractor limits.

4.1.6.9.1 Parking brakes. Truck or truck-tractor, without towed vehicle should be capable of being held by parking brakes on ascending or descending slopes up to 40 percent.

4.1.6.10 Cruising range. Trucks and other self-powered vehicles should be capable of operating on good roads over average rolling terrain at 35 mph average speed, without towed load and without replenishing fuel supply, for the distance specified in the statement of characteristics for the specific vehicle.

4.1.7 Climatic.

4.1.7.1 Ambient conditions. Vehicle, when properly serviced should be capable of satisfactory operation, and safe storage and transport, under conditions of weather, climate, temperature, solar radiation, humidity, and barometric pressure in altitudes from sea level to12,000 feet, in accordance with Department of the Army regulations as specified in Army Regulations AR 705-15.

4.1.7.2 Service products. Servicing should include use of service products such as gasoline, lubricants, hydraulic fluids, antifreeze compounds or preservatives compatible with applicable climatic environment. They should meet the minimum quality requirements of the latest revision of the applicable standard specifications.

4.1.7.3 Tropicalization. Vehicle should withstand, without undue damage, the effects of tropical conditions, particularly fungus, dense road dust, mud, salt-laden air, and the wind-driven rain, sand and sea-spray encountered in tropical storms.

4.1.8 Transportability.

4.1.8.2 Air transport. Vehicle should be suitable in all respects for transport used in the phase of airborne operations specified for the specific vehicle.

4.1.8.2 Railway transport. Vehicle should be capable of safe transport, without major disassembly, over United States and foreign standard and wide gauge main line railways at normal speeds.

4.1.8.3 Marine transport. Vehicle should be suitable in all respects for loading into, and transporting in, applicable cargo ships and landing vessels.

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4.1.8.4 Tie-downs. Tie-down points of suitable design, numbers location and capacity should be provided for securing vehicle for securing rail and marine transport.

4.1.8.5 Lifting eyes. A minimum of four lifting eyes suitable in design, location and capacity for use with standard slings should be provided for hoisting vehicle, with applicable loads aboard ships.

4.1.8.6 Van-type vehicles. On van-type vehicles, when body is demountable from chassis for transport, tie-down points and lifting shackles should be provided on both body and chassis and identified to prevent misapplications. Suitable skids, preferably integral with body structure, should be provided to facilitate handling and loading.

4.1.8.7 Towing shackles. Shackles or other means for attachment of tow chains and tow bar should be provided on front or rear of vehicle, when applicable,

4.1.9 Design and construction.

4.1.9.l Utility. Vehicle should be designed primarily to provide optimum effectiveness for its basic uses. To the extent compatible with the primary objective, design should consider possible utilization or adaptation for other military uses requiring a similar vehicle.

4.1.9.2 Materials. All materials should be suitable in every respect for the intended purpose and to the maximum extent practicable should be materials commonly used in the United States automotive industry. Materials which require fabrication or repair techniques with which military maintenance personnel are not currently familiar, should not be used if a more conventional material can be substituted without sacrifice of effectiveness or desired characteristics. When materials that might become critical at any future time are used to minimize weight or provide other desirable qualities design should be such that appropriate less critical materials can be substituted.

4.1.9.3 Durability. To the extent practicable, materials or treatment of all parts should be such as to provide adequate resistance to rust, corrosion, fungi, and deterioration in service and storage. Where impracticable to provide such resistance as an inherent property, design should be such as to permit suitable preservative treatment to prevent deterioration during extended periods of storage under adverse condition.

4.1.9.4 Quality. Except where superior quality is essential to provide required characteristics, design, materials, and workmanship shall be in accordance with first class commercial practices

4.1.9.5 Interchangeability. Design should incorporate the minimum practicable number of different types and sizes of fastening devices and other parts. To the extent practicable, components and accessories should be interchangeable with similar parts of other military vehicles.

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4.1.9.6 Standard parts. Use of special parts should be kept to the minimum. Where parts already in the military supply system are not applicable standard commercially available parts should be used wherever practicable. However, any design of component which will improve performance, simplify operation or maintenance, or reduce cost of production or operation of the vehicle should be considered.

4.1.9.7 Loose parts. Loose parts should be kept at a minimum. Wherever practicable, small parts should be attached to larger parts, or otherwise retained to minimize loss.

4.l.9.8 Ground pressure. Overall design should be such that unit ground pressure under vehicle tires will be the minimum practicable.

4.1.9.9 Clearance. Angles of approach and departure clearances under axles and amidships, and clearance between prime mover and towed vehicle should be the maximum consistent with other considerations

(a) Angles of approach and departure should be not less than 35 degree under full load, if practicable.
(b) Clearance under chassis amidship should be such as to avoid interference when vehicle is loaded into aircraft (22 degree ramp angle) or Landing Ship, Tank (LST) (30 degree ramp angle).

4.1.9.10 Truck chassis.

4.1.9.10.1 Engine. Engine should be suitable for use of Army standard engine fuel (gasoline and diesel), and should be of adequate capacity to enable vehicle to meet all stated performance requirements.

4.1.9.10.2 Air cleaner. Air cleaner should be a high efficiency type, and of sufficient capacity to effectively protect the engine during eight hours of operation under severe dust conditions (see 5.3.6).

4.1.9.10.3 Steering. Steering gear should be such as to enable the driver to control vehic1e during all phases of operation without difficulty or excessive fatigue.

4.1.9.10.4 Transmission and transfer case. Transmission and transfer case should be of suitable design to provide maximum practicable ease of gear shifting, and should have such ration as to minimize required frequency of gear shifting during normal operation.

4.1.9.10.4.1 All wheal drive. Means should be provided if practicable, to engage and disengage front wheel drive, unless an interaxle differential is provided, and to shift to or from any gear in any range, without damage while vehicle is in motion.

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4.1.9.10.5 Axles. Axles should be full-floating type, and should provide positive drive to all wheels having traction, if practicable.

4.1.9.10.6 Tires and wheels. Unless otherwise specified tires and wheels should be Military Standard size and type. Sufficient clearance should be provided to permit use of tire chains or traction devices. A suitable carrier for the spare tire and wheel assembly should be provided. Handling and accessibility should be of prime importance.

4.1.9.10.7 Radiator. Height of radiator should be the minimum practicable to provide optimum vision for the driver.

4.1.9.11 Cab. Cab should be the fully enclosed type, readily convertible to open type unless otherwise specified. Seating should accommodate two men or, if practicable, three men. Design should include suitable provision for comfort, visibility and safety of personnel for entrance and exits and for convenience in operating vehicle controls. Rigid components of cab should be sealed, soundproofed, and insulated.

4.1.9.12 Body. Body should provide maximum practicable clear floor space consistent with other requirements. Wheel housings, where necessary, should involve minimum practicable reduction in floor area, and should have flat top surfaces to facilitate stowage of cargo or mounting of equipment. Height of body floor above ground should be the minimum practicable.

4.1.9.12.1 Construction. Body should be adequately supported and reinforced to withstand the conditions of military services and which might cause drumming noise, wear of bolts or other fasteners or fatigue failures.

4.1.9.12.2 Mounting. Except where chassis frame is integral with body, the body should be securely fastened to chassis, but readily removable for repair or replacement. "J" bolts should not be used. "U" bolts or twin studs are acceptable. On channel type frame side rails, reinforcement is required in mounting areas to prevent crushing of the channel. Where body is independently rigid or of semi-rigid structures mounting should be such as to distribute the load as uniformly as practicable and to permit normal flexing of the chassis frame. A relatively long or rigid body should incorporate suitable provision to permit frame to flow relative to the body, to avoid concentrated bending stresses.

4.1.9.13 Brakes. All trucks and truck tractors should be equipped with service brakes on all wheels, and with parking brake or brakes. Brake design should incorporate sealing, shielding, or other provision to prevent damage by mud, water, or sand, or suitable means to minimize the adverse effects thereof and should consider adequate means for dissipation of the heat generated during mountainous usage. Design should permit brakes to be adjusted externally without difficulty by organizational maintenance personnel.

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4.1.9.14 Inter-vehicular brake connections. Suitable provisions should be made for transmitting air pressure, or other medium for service brake operation, from prime mover to towed vehicle, where applicable. Receptacles should be provided on pintle-equipped trucks and truck tractors, and hose or other suitable means for connection to such receptacles should be provided on track tractors.

4.l.9.14.1 Air-over-hydraulic. Trucks equipped with air-over-hydraulic or air brakes should include suitable provisions for connecting to the brake system of another truck, at front and rear, for controlling brakes of a truck being towed by another truck during emergency operation.

4.1.9.l4.2 Brake hose. Brake hose (or cable) should be of adequate length so as to not restrict maneuverability of the prime mover or towed vehicle when coupled together under any applicable conditions. Suitable provision should be made to prevent kinking entanglement dragging abrasion or pinching of the brake lines.

4.1.9.14.3 Receptacles. Receptacles for connecting brake lines should be located not more 21inches from the axis of the pintle, nor more than 15 inches from the axis of the semitrailer.

4.1.9.15 Stowage. Suitable compartments, brackets, or other provision should be included to accommodate storage of tools and other required vehicular equipment.

4.l.9.16 Winch. When specified, front-mounted winch should have a capacity approximately equal to curb weight of vehicle, and cable of length not less than 150 feet. Winch should be designed with suitable safety features.

4.1.9.17 Lower fifth wheel. Lower fifth wheel should be Army standard type, providing both lateral and longitudinal oscillation. Truck tractors and dollies for towing semitrailers less than 20-ton capacity should have fifth wheel to fit 2-inch kingpin. Truck tractors for towing semitrailers of 20-ton capacity and larger should have heavy-duty fifth-wheel to fit 3 1/2 inch kingpin.

4.1.10 Maintenance.

4.1.10.91 Simplicity. Simplicity of design is necessary to assure ease of servicing, adjustment, repair and parts replacement under field conditions in the minimum practicable time, requiring the lowest possible degree of skills and variety and complexity of tools and equipment.

4.1.10.2 Accessibility. Components should be so located and installed as to permit ready removal and replacement without requiring removal of other components or control parts, which otherwise need not be removed. Special emphasis should be placed on accessibility for Organizational and Field Maintenance of those components and parts which am subject to wear, adjustment or replacement. Grease and oil seals and fittings, and fastening devices such as bolts, nuts and screws, should be readily accessible.

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4.1.10.3 Work aids. Aligning devices, piloting or guide features lifting eyes, adequate working clearance provision for suitable visibility and other aids should be provided wherever such features will add materially to the ease of installing, removing or adjusting parts.

4.1.10.4 Connections. To the extent practicable, plugs and receptacles and multiple line connectors should be utilized in the electrical system. Detachable and attachable fittings should be used in hydraulic and pneumatic systems, to facilitate replacement and repairs. Connections should be readily accessible and identifiable. They should not be made complex or of limited reliability merely to provide "quick disconnect" characteristics.

4.1.10.4.1 Piping. To the extent practicable, separate piping vent lines, fittings and manifolding should be minimized, and superseded by integral porting and manifolding cast or machined in other parts or components.

4.1.10.5 Tools. To the extent practicable, design should permit maintenance and adjustment operations to be effected with standard, commonly available hand tools with minimum requirement for special tools. Special tools, where required, should be designed for maximum practicable suitability for a variety of uses.

4.1.10.6 Lubrication. Maximum practicable use should be made of permanently lubricated assemblies or assemblies not requiring lubrication, in order to reduce the necessity for organizational maintenance lubrication, provided such considerations do not result in complexity and increased overall maintenance at the higher echelons. Items requiring regular lubrication should be designed and installed to permit such lubrication without disassembly wherever practicable. Installation of grease and oil seals should provide maximum accessibility for replacement, and, where feasible, wearing surfaces of seals should be renewable.

4.1.10.7 Arctic conditions. Design and mounting of major assemblies and sub-assemblies should to the extent practicable, permit replacement or adjustment under arctic conditions by personnel wearing heavy arctic clothing, and without draining liquids. Controls, handless accessibles, or other parts requiring routine handling should be capable of effective operation by personnel wearing heavy arctic clothing.

4.1.11 Electrical system. The schematic wiring diagram shown on Drawing 8377310 should be used as a guide.

4.1.11.1 Voltage. Vehicle should be equipped with Army standard 24-volt, DC electrical system in accordance with Special Regulation SR 705-325-1.

4.1.11.2 Suppression. Vehicle electrical system should be suppressed to prevent radio interference in accordance with MIL-S-10379.

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4.1.11.3 Water-proofing. All parts of electrical system should be suitable water-proofed against casual water and to provide required shallow fording capability. Critical parts should be capable of complete waterproofing by kit application, to provide deep fording capability in accordance with Special Regulation SR 705-125-10.

4.1.11.4 Inter-vehicular connection. Electrical system on pintle-equipped trucks and truck tractors should include a receptacle for connecting a jumper cable for transmitting electric current from towing vehicle to a towed vehicle. Receptacle should be equipped with waterproof cover, opening upward. Receptacle should be located not more than 15 inches from the center of pintle eye, or from the center of semitrailer front crossmember.

4.1.11.5 Jumper cable. Jumper cable should be provided on truck tractors. Jumper cable should be of adequate length so as to not restrict maneuverability of towing vehicle or towed vehicle when coupled together, under any applicable conditions. Suitable provisions should be made to prevent kinking, entanglement or dragging of jumper cable, or damage due to being pinched between the two vehicles.

4.1.11.6 Interior type. Van-type body intended to provide working or living quarters for personnel should be equipped with a 24-volt and 110-volt interior lighting. The 110-volt AC system should include appropriate convenience source. The 24-volt lights should be operable from the electrical system of the prime mover.

4.1.12 Equipment and accessories. Vehicle should include all equipment and accessory features required by current directives, and as necessary for effective operation and use, as specified in individual statements of characteristics. These should include, where applicable:

(a) Pintle, Army standard of suitable size and type.
(b) Winch (front-mounted or otherwise, as appropriate).
(c) Power take-off, SAE type.
(d) Full torque power take-off.
(e) Bumper or bumperettes.
(f) Tow hooks.
(g) Brush guards.
(h) Tools (OVE).
(i) Chains or traction devices.
(j) Air cleaner.
(k) Oil filter.
(l) Gasoline filter.
(m) Engine speed governor.
(n) Shock absorbers.

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(o) Tire inflation hose and gauge.
(p) Liquid container brackets.
(q) Pioneer tool bracket.
(r) Rifle bracket.
(s) Name, data, and caution plates.
(t) Check blocks.
(u) Leveling jacks.

4.1.13 Provisions for special kit operations. When specified in statements of characteristics for specific vehicles, design should permit the installation of the following kits, in the minimum possible time and with minimum skilled labor, employing only 1st and 2nd echelon tools without requiring alteration in the basic vehicle.

(a) Deep water fording kit.
(b) Arctic kit.
(c) Desert kit.
(d) Air brake kit.
(e) Electric brake kit.
(f) Electric conversion kit, 24/6-volt.
(g) A-frame kit.
(h) Radio installation kit.
(i) Ground-mine protection kit.
(j) Armored cab kit.
(k) Primer pump kit.
(l) Slave cable kit.

4.1.14 Environmental and terrain regulations. The vehicle should be designed to conform to requirements of Army Regulation AR 705-15. The vehicle should be capable of operation in air temperature range of –65°F to 125°F, and of storage in air temperature of –65°F to 155°F.

4.1.15 Order of priority of characteristics:

(a) Performance
(b) Durability and reliability
(c) Configuration
(d) Transportability
(e) Kit requirements
(f) Environmental and terrain requirements
(g) Associated equipment

4.1.16 Dimensions. The height or silhouette of all portions of vehicles of contractor type should be as low as practical. Clearances between tires and other parts of self-propelled vehicles should be such that tire chains or other traction devices can be readily installed and used on all wheels. Caution should be used in checking clearance to insure that the Tire and Rim Association maximum tire growth

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recommendations are taken into considerations. SAE Handbook, SAE J683, citing commercial tire-to-fender clearances, should be regarded as the minimum acceptable. The dimension should permit air transportation of the vehicles; without disassembly, in the smallest appropriate type of aircraft.

4.1.17 Environmental resistance characteristics. Suitable parts, with special treatments if necessary, should be incorporated in military vehicles to insure that the design provides effective resistance against any harmful effect of environmental factors.

4.1.17.1 Resistance to dust and water. The vehicle and all its components (without special equipment or use of kits) should be of such design that its normal functioning will not be impaired by dust, sand or water that enter during operation under adverse conditions such as dust or sand clouds, normal water fording, heavy rains, mud puddles, or by condensation of moisture. When equipped with a fording modification kit, the vehicle should be suitable for operation under the conditions set forth in the contract or in the detail specification.

4.1.18 Kit and material installation. The vehicle and all its components should be designed for later (field) installation or stowage of:

(a) Modification kits in the shortest possible time with the fewest possible alterations in the vehicle; and
(b) Other items of military equipment, as required in the contract or detail specification, without unnecessary difficulty in spaces properly arranged and prepared on appropriate chassis, cab and body surfaces.

4.1.19 Design characteristics military-type vehicles. Vehicles developed under the supervision and control of the Department of Defense should be constructed as specified in the detail (vehicle) specification. Unless otherwise specified, in the event of any conflict between the requirements of specifications and drawings, the Armed Service Procurement Regulation Order of Precedence should apply.

4.1.20 Resistance to extreme temperature. Insofar as is practical the vehicle and all its components should be designed:

(a) To operate satisfactorily under severe conditions of weather and climate at temperatures for –25°F (without benefit of solar radiation) up to 130°F even though exposed at times to maximum solar radiation.
(b) To operate satisfactorily (with the addition of a suitable modification kit) under extremes of weather and climate at temperatures from -23°F down to 65°F, without benefit of solar radiation.

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(c) To withstand storage for periods of not less than 3 days duration at a temperature as low as -80°F, and for periods as long as 4 hours per day at a temperature ±160°F, without suffering deterioration or any other effect of temperature that might permanently impair their use and functioning.

4.l.21 Anti-detection features. Individual characteristics or other distinguishing features that identification or detection from a distance should not be unnecessarily incorporated in vehicles of contractor types in particular the design should minimize possibility of detection through:

(a) Road dust disturbed by exhaust gases from the vehicle engine or air-flow from the cooling system.
(b) Smoke or flame caused by the engine exhaust gases.
(c) Light or glare from exposed glass or bright metal parts, or from nonessential illumination on or within the vehicle at night.
(d) Operating noises, caused by engine, gears, belt drives, exhaust gases, sheet metal (drumming), loose parts (rattling), or brakes (squealing).

4.1.22 Fungus resistance. Nonmetallic parts should be of a material or be given a treatment that will prevent fungus growth under extreme conditions of humidity and temperature. Non-metallic parts should be treated in accordance with the detail specification or as specified on the applicable drawing, and if so specified should be as approved by the procuring agency.

5. DETAIL REQUIREMENTS

5.1 Development and design. A military publication entitled "Maintenance Criteria" presents the most recent views on the development and design of military vehicles. An extract from the publication follows. It summarizes the most important considerations to be made during the future development and design of military vehicles.

5.1.1 Ground vehicle development objectives. Ground vehicle development should:

(a) Accomplish a reduction in the different types and models of vehicles used by the Army in the field.
(b) Achieve a reduction in the cube and weight of vehicles to facilitate air-transportability.
(c) Approach unity as a goal for the curb-weight to pay-load ratio.
(d) Attain true cross-country mobility, including complete and prolonged independence of roads and the ability to float on inland waterways.
(e) Eliminate the requirement for special tools and for special skills in maintenance.

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(f) Recognize the operator as a part of the vehicle system all reduce operator training time.
(g) Emphasize reliability durability and maintainability.
(h) Exploit the use of modular assemblies as a means to accomplish interchangeability of assemblies and components.
(i) Make the maximum use of pre-lubricated and throw-away parts and assemblies.
(j) Fully explore the utilization of parts, assemblies and components already in the inventory, in preference to introducing a new item of supply.
(k) Utilize commercial components of advanced designs when superior performance is assured.
(1) Assure a reduction of fuel requirements and broad appetite for all types of fuels.
(m) Design with a realization of the need for a design so clearly mass-producible, that its deficiencies in production will be minor in nature and easily corrected prior to issue.
(n) Define design life or wearout limits to a degree that will insure a clear margin of safety over the prescribed mileage performance goals.

5.1.2 Ground vehicle design objectives.

5.1.2.1 General. For Phase I (1960-963) maximum effort was centered on the product improvement of current standard and development vehicles increased reliability, durability and maintainability will be paramount considerations. For Phase II (1964-70), a 10 ton maximum weight limit for divisional equipment and a 30 ton maximum weight limit for Army equipment will emphasize reduction of weight and cube of components and vehicles. Vehicle design will feature the use of pre-lubricated assemblies of sealed design, expected to be "thrown-away" rather than repaired. The more complicated assemblies will be designed to be repaired by field maintenance. Components will be designed to have inherent long-life or inherent capability for easy remanufacture by fourth echelon companies. Vehicle designers will rely on commercially available components of advanced design, shielded from the environment, as necessary to meet the maintenance criteria. Army designed components will be developed, where no commercial component is available, or could survive in the military environment.

5.1.2.1.1 Reliability concepts. Unless specific exception is indicated by program authority, the following reliability objectives will apply to vehicles developed for use of the armed forces.

a. During Phase I, ground vehicles had a 90 percent probability of completing the following mileages in a military environment.

(1) Wheeled and tactical vehicles: 10,000 miles with only organizational (1st and 2nd echelon) maintenance, and 20,000 miles with only organizational and field (1st, 2nd, 3rd, and 4th echelon) maintenance.

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b. During Phase II ground vehicles should have a 90 percent probability of accomplishing the following in a military environment:

   (1) Wheeled and tactical vehicles: 25,000 miles with only organizational maintenance.

c. In the designing of military vehicles every effort should be directed toward the consideration and inclusion of the following:

   (1) Use of modular or "throw-away" assemblies or parts.
   (2) Reduction in weight and quantity of parts and components.
   (3) Simplification of vehicular operational requirements (operator and maintenance functions).
   (4) Crystallization of component design prior to application.
   (5) Increased use of standardized pro-tested components.
   (6) Wear-out limits which are defined to a degree that will insure a clear margin of performance over the reliability objectives.

5.1.2.2 Lubrication concepts.

5.1.2.2.1 Minimizing field maintenance. One of the facets of the problem to reduce or minimize field maintenance of vehicles is relubrication intervals and the number of lubricants employed. It is basic philosophy in lubrication engineering to have a minimum number of lubricants and also take advantage of possible multipurpose capabilities of these lubricants.

5.1.2.2.2 Ultimate aim for the maintenance of vehicles. The ultimate aim for the maintenance of vehicles regarding lubrication and related functions is a single all-temperature, all purpose fluid to function as a lubricant and a hydraulic medium, a single grease type lubricant-where component design dictates grease, to employ polymeric materials to replace conventional bearing surfaces, reduce oil-can point lubrication with solid lubricants. Along with the single lubricant principle is the lifetime lubrication of components.

5.1.2.2.3 Lubricants in Phase I and Phase II. In Phase I, (a) lifetime lubrication was available for suspension systems, final drives and transmission, (b) a superior all-purpose grease was expected to satisfy the entire range of sealed bearings in Army equipment, (c) employment of all all-purpose petroleum fluid satisfying the requirement for hydraulic brake system was expected. In Phase II, a multi-viscosity all-purpose fluid lubricant to function in hydraulic systems, engine lubrication and brake fluids. Grease points will be reduced to employ solid film lubricants or polymeric materials.

5.1.2.3 Design against corrosion. Materials resistant to corrosive action for special applications, development of new materials processes which will improve physical properties and corrosion

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protection, and development of new applications for new corrosion resistant materials as they become available, are the goals in this field. Some initial success was attained in Phase I, however, the major accomplishments are anticipated in Phase II. The program includes as follows:

(a) Development of superior protective coatings for light weight magnesium alloys used in the construction of airborne vehicles.
(b) The development of an anti-seize compound for general application to mating surfaces to promote ease of disassembly and maintenance of items such as track end torsion bars.
(c) The development of paintable wood preservatives to prolong the active use of wood construction in services.
(d) The development of water base paints and primers to eliminate explosion and personnel hazards and provide superior surfaces for metals and non-metals.
(e) The development of vacuum metal deposition in lieu of electroplating continued study of the feasibility of cathodic protection to prevent corrosion.
(f) The development of protective coatings to withstand high temperature.
(g) In the field of elastomers, antiozonants and antioxidants are being incorporated in rubber for their continued preservation in storage and in service.
(h) In the field of plastics major emphasis is toward lighter weight components constructed from noncritical materials and as a bonus feature, corrosion resistance is a fundamental property of these materials.
(i) In the field of bearings, phenolic sleeves have passed field tests on tank spindles with a saving in weight, no possibility of corrosions and a reduction in part numbers in the Military Supply System.
(j) Currently, plastic balls are being developed for use in light and heavy applications and aluminum races are under development which will eliminate completely, both rusting and fretting corrosion, and brinelling during transport.
(k) A most desirable feature of plastics is the repairability of plastic fuel cells without emptying of body structure and of their metallic adjuncts, by means of a field repair kit that has been released.

5.1.2.4 Standard Government grouping. The method used by the Government to facilitate identification and selection of parts is to arrange components primarily on the basis of their function rather than location.

5.1.2.4.1 Group 01 – Engines. During Phase I, continued use was made of reciprocating engines, although the Diesel cycle started to replace the Otto cycle engine.

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During Phase II more compression ignition engines and gas turbines will begin to appear. The level of maintenance required for spark ignition engines will be reduced slightly due to better fuel injection fuel filters and air cleaners. Compression ignition engines will reduce organizational maintenance with the exception of greater emphasis on filters. Field maintenance for compression ignition engines will similarly be reduced but depot maintenance will be more difficult because of closer rebuild tolerance requirements. Gas turbines will reduce the maintenance level at all echelons and will make possible the rebuild of the engine in the field maintenance level. This is made possible by the relatively simple unit replacement of vital engine elements. Gas turbine engines inherently require less maintenance than reciprocating engines. The gas turbine eliminates such items as spark plugs, injector, air cleaner and mufflers. Therefore organizational, field and depot maintenance will decrease appreciably.

5.1.2.4.2 Group 02 - Clutches. The use of conventional clutches is generally restricted to the transport fleet and will become increasingly rare in the future. No significant change in maintenance requirement in anticipated although durability of the components will be improved so that maintenance intervals may be lengthened.

5.l.2.4.3 Group 03 - Fuel systems. Compression ignition injection systems, first found in Phase I, will become dominant in Phase II. Maintenance of spark ignition fuel systems, both carburetor and injection units, will remain at present levels. Compression ignition systems will markedly decrease maintenance at the organizational and field maintenance level, since these units are inherently more durable than spark ignition equipment and must be handled with minimum disturbance. Depot maintenance of compression ignition injection systems will be more difficult due to the close tolerances involved. The advent of simple and compound dry type air cleaners will reduce maintenance at the organizational and field maintenance levels.

5.1.2.4.3.1 In Phase I, the use of plastic fuel tanks reduced maintenance considerably.

5.1.2.4.3.2 In Phase II, the introduction of gas turbine engines should affect a marked reduction in fuel system maintenance as clean, filtered fuel is not essential.

5.1.2.4.3.3 Immersion fuel pumps, having already made their appearance as a cure for vapor lock, will appear on all series of vehicles starting in Phase I and continuing through Phase II.

5.1.2.4.4 Group 04 - Exhaust systems. Exhaust systems for spark ignition engines will show slightly reduced requirements due to the use of movers more durable materials. Exhaust systems for compression ignition engines will show greatly improved durability because the use of turbochargers on this type of engine, removes the requirement for a conventional muffler. Turbine exhaust systems will require virtually no maintenance.

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5.1.2.4.5 Group 05 – Cooling systems. Phase I cooling systems made increasing use of liquid coolants. Phase II cooling systems will utilize both liquid and air. During Phase I, organizational and field maintenance was increased to some degree where liquid cooled engines replace air-cooled machines. During Phase II, the advent of sealed cooling systems and self cooled turbines will reduce cooling system maintenance in all echelons to a level of somewhat below that of today.

5.1.2.4.6 Group 06 - Electrical system. During Phase I, a revision in requirements allowed the use of a splash proof electrical system, particularly in floatable vehicles, in place of the currently specified waterproof, shielded systems. Although maintenance will, itself, not be greatly affected, this change resulted in a significantly improved logistic situation because of the availability of such splash proof systems commercially. During Phase II significant improvements in component durability and reliability matching the life of the vehicle are expected. Throw-away concepts in design and modular type construction will prevail. Specific improvements in the following types of electrical components are of significance.

5.l.2.4.6.1 Regulators. Regulator designs for use during Phase I were static types, having no moving parts. They will be proofed against the environment and will require no adjustment or maintenance during their operating life of 3,000 hours or more. Advances in technology and new materials may make it possible to reduce size and cost for Phase II.

5.1.2.4.6.2 Rectifiers. For Phase I, Silicon rectifiers in totally inclosed, oil-cooled containers, replaced the Selenium rectifiers. The new rectifiers will be proofed against the environment, thus requiring no maintenance.

5.1.2.4.6.3 Batteries. For Phase I, the development of a hi-impact plastic case battery with flush terminals and vents eliminated breakage, terminal post seal damage, and provided a longer life battery. During this same period, application of Nickel-Cadmium batteries in arctic operation aided maintenance through longer service life.

5.l.2.4.6.4 Ignition system. For Phase I, ignition systems used surface discharge spark plugs which operate more efficiently under spark plug fouling conditions and eliminate the need of spark plug cleaning and electrode gapping. Spark plug life will be in excess of 500 hours as compared with present plugs having a useful life of 300 hours which require frequent maintenance. Distributor life will be 2,000 hours with complete elimination of maintenance. For Phase II efforts will be made to simplify design, use better materials, and reduce costs.

5.1.2.4.6.5 Starter motors. Starter motors for Phase I were characterized by waterproof construction sedated bearings, longer brush life, and standardization between vehicle families. For Phase II, starter motors life and elimination of maintenance will be improved mainly through the use of better and less costly materials. Efficiency will be improved with size and weight reduction achieved.

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5.1.2.4.6.6 Instrumentation. For Phase I, mechanical type speedometers and tachometers were used, which are smaller and more rugged and will reduce maintenance. For Phase II, an effort will be made to provide a combination Speedo-Tacho with less mechanical moving parts, and with magnetic pick up and transistorized amplification of signal that will be applicable to all military vehicles and need little or no maintenance and utilize 50 percent less volume.

5.1.2.4.6.6.7 Lamp bulbs. Present lamp bulbs are weak and fail due to vibration. For Phase I, improved filament material was used in lamp bulbs. For Phase II, electro-luminescent type materials will be considered for Instrument Panel, B. O. Marker, and self-luminating instruments. This new process will not be affected by vibration and will burn at 100 percent efficiency for at least 8,000 hours.

5.1.2.6.4.7 Group 07 – Transmissions. Phase I used conventional and semi-automatic transmissions for trucks and semi-automatic transmissions for combat vehicles. During Phase II, transmissions will be mostly semi-automatic with hydrostatic devices being introduced with later combat vehicles. Conventional transmissions will require present day levels of maintenance at all echelons. New semi-automatic transmissions, taking advantage of considerable military and commercial experience will permit the lengthening of service intervals. Organizational and field maintenance will be reduced but depot operations will become more complicated. Hydrostatic transmissions will continue the downward trend for organizational, field and depot maintenance.

5.1.2.4.8 Group 08 - Transfer case. Conventional transfer cases, as well as power shifted units, were continued in Phase I wheeled vehicles. During Phase II, transfer cases, as separate components, will become scarce. Transfer cases in combat vehicles will be integral with other power train elements during Phase I and II. Maintenance of conventional cases will remain at current levels. Organizational and field maintenance of power shifted units were increased during Phase I but will decrease during Phase II.

5.1.2.4.9 Group 09 – Propeller shaft. No appreciable changes are anticipated except that pre-lubricated, lifetime bearings will reduce the necessity for lower echelon maintenance.

5.1.2.4.10 Group 10 - Differentials and final drives. During Phase I, combat vehicles used both separate and integral differentials and final drives. Phase II vehicles will introduce hydrostatic steer systems. Service requirements for these elements will be gradually reduced. These reductions will be due to improved materials and design techniques since no reduction in complexity can be anticipated.

5.1.2.4.11 Group 11 - Front and rear axles. The predominant characteristics of development type axles will be the drive-through feature and torque proportioning differentials. Neither of these advances should increase or decrease maintenance requirements.

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5.1.2.4.12 Group 12 - Brakes. Sealed disc brakes appeared in Phase I, resulting in substantially improved life of linings and other brake components under adverse conditions. The resultant reduction in maintenance will be offset in some degree by increased inaccessibility to the brake cavity. Introduction of the hydraulic retarder in Phase I automatic transmissions will increase normal brake life and reduce maintenance.

5.1.2.4.13 Group 14 - Controls. Vehicle controls such as steering, braking, accelerator and throttle controls will not change. These items have been product improved and standardized for a number of years and are durable, and little reduction in maintenance is required or expected.

5.1.2.4.14 Group 15 - Frame and brackets. This is considered to be one of the areas of greatest change. The introduction of the floating capability, in Phase I introduced a whole new concept of construction and maintenance. It paralleled experience with the M147E2 Amphibious Truck (DUKW) and resulted in an increase of maintenance time for unit replacements. Improved materials, production standards and longer component life will be offsetting factors. The greatest emphasis will be placed on improving field maintenance techniques for repair of unitized structures comprised of plastics, aluminum and magnesium.

5.1.2.4.15 Group 16 - Springs and shock absorbers. The present leaf springs for wheeled vehicles will gradually be replaced by coil, torsion bar and air spring systems. These improvements will result in a substantial increase in life expectancy of springs and result in lessening of shock on the completed vehicles. Maintenance on shock absorbers should be reduced approximately 10 to 15 percent during this period, due to the development of improved Teflon Seals and Self-Lubricating Connecting Eye Bearings. It is anticipated that both the springs and shock absorbers will be capable of 4,000 miles of maintenance-free operation during Phase II. This will be made possible through the development of improved internal components of direct acting shock absorbers, development of friction hydraulic type shock absorbers and the development of the hydropneumatic suspension systems.

5.1.2.4.16 Group 17-18 - Sheet metal, body and cab. These sheet metal items, as we know them today, will be incorporated into the frame structure of unitized designs. The maintenance problems associated are outlined in 5.1.2.4.14. A sealing problem inherent to the floating capability will be introduced into the cab and body. It in believed that this sealing problem restricted to the unit structure with floating capability will be less than a series of sealing problems inherent to each component of present vehicles with fording capability.

5.1.3 Austerity guides. With the austerity of military vehicles in mind, the following should be considered:

(a) Economy of original vehicle design and material without sacrifice of functionability and durability.

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(1) Design within reasonable limits and factors of safety for the purpose of conserving materials and manufacturing processes, and for maintaining a minimum weight of the component or the vehicle.
(2) Utilize the most economical material that offers the desired properties; for examples consider the application of a surface coat that resists corrosion to a cheaper steel rather than the use of an expensive alloy steel or expensive non-ferrous metal.

(b) Economy and procurability of spare parts.
(c) Utilization of standard military parts.
(d) Economy and durability of vehicle accessories and on-vehicle equipment (OVE).
(e) Economy of fuels and lubricants.
(f) Economy of expendable kits such as deep water fording kits,
(g) Design of the vehicle that permits the installation of kits with a minimum of vehicular modification, factory drilled mounting holes.
(h) Ease of maintenance. (see 5.6)

5.2 Standardization.

5.2.l Nongovermment standards.

5.2.1.1 Application. There are many existing nongovernment standards codes, and specifications which are acceptable and desirable for use in the design of tactical trucks. Nongovernment standards should be used, in the absence of applicable government specifications and standards to the maximum extent possible in the development and design of government equipment and in the preparation of Military and Federal Standards and equipment.

5.2.1.2 Source. Previously the Department of Commerce published a National Directory of Specifications which was an excellent source of nongovernment and government specifications and codes. Since it is not currently being published, there is no up-to-date comprehensive source of nongovernment standards. For this reason only the following associations and societies that maintain widely known standards have been included:

(a) American Institute of Electrical Engineers
(b) National Electrical Manufacturers Association
(c) Radio, Electronic and Television Manufacturers Association
(d) Institute of Radio Engineers
(e) National Safety Council
(f) American Standards Association (engineering and safety standards)
(g) National Fire Prevention Association
(h) National Board of Fire Underwriters

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(i) American Society of Mechanical Engineers
(j) Society of Automotive Engineers
(k) American Society for Testing Materials
(l) American Welding Society

5.3.1 General.

5.3.1.1 Purpose. It is not the purpose to provide a means of rating or evaluating the equipment but to inform the designer of all areas which must be considered during the design of tactical vehicles. The detail specification will govern the designer in the application of the design factors. The importance of each will vary to some degree for different items of equipment. Therefore, the order in which they are presented does not necessarily follow the order of their importance. The designer will be responsible for analyzing each factor as to its overall importance.

5.3.1.2 Climatic environment. The military must conduct operations in any area of the world. Tactic trucks may be required to operate satisfactorily in any or all areas; exotica, desert, tropic, or temperate. Frequently the desired function cannot be physically performed except under controlled conditions of temperature and humidity. Operating personnel cannot perform required functions under conditions of climatic extremes. Effect climatization by the simplest and most economical means consistent with the use of the equipment. Equipment designed for arctic use often costs much more than a similar item suitable for use in temperate areas since the quantity of equipment required to have a particular climatic capability may be a relatively small percentage of the entire military inventory for any one item, it is often not economically feasible to have all items of any one type of equipment designed to meet all conceivable climatic environments. Acceptable means of meeting climatization requirements include:

(a) Design of equipment for use under all climatic conditions.
(b) Design of equipment for exclusive operation in a particular condition.
(c) Design of equipment with portions of climatization modifications elements or climatization kits can be simply and readily used to meet special climatic requirements.
(d) Modification of equipment designed only for a particular climatic area, for use in other climatic areas by applying specifically engineered modification elements.
(e) Development of techniques for use of equipment in special climatic areas, without physical change of the equipment.
(f) Development of packaging requirements and procedures to meet the special climatic conditions at the same time, and on the same priority, as the equipment itself.

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5.3.3 Temperature. Temperature extremes, their effects, and preventive measures are well known and documented. In addition to the treatment of temperature as a single design environment, consider the combined effect of temperature extremes with other environments. Those environments which must be considered with each temperature extreme are presented in 5.3.3.1 through 5.3.3.2.4.

5.3.3.1 High temperature. Design for high temperature extremes for all geographical regions should be as specified in MIL-STD-210.

5.3.3.1 Metals. The usual temperatures encountered by tactical vehicles in storage, or when exposed to solar radiation in tropical or desert areas, are not sufficiently high to cause any change in mechanical properties of metals which would result in failure of the material itself when in service.

5.3.3.1.2 Nonmetals. Prolonged exposure to temperatures higher than the usual daily variations, for instances storage temperatures of 160°F will cause many materials to lose strengths soften or runs become gummy, or lose their adhesiveness. For high temperature operation, use care in the selection of nonmetallic materials. Consider using some of the varieties of temperature resistant glass or material such as tetrafluoroethylene resin group, which have a maximum exposure temperature in the neighborhood of 340°F.

5.3.3.1.3 Combined environments. High ambient air temperatures more often destroy materials by accelerating some other destructive force than through a direct effect. For example, a continuing combination of elevated temperature and moisture exposes materials to attack by a variety of insects and micro-organisms facilitates the action of light in photosynthesis and intensifies chemical decomposition process. Effects of the following environments should be considered:

(a) moisture
(b) salt spray
(c) shock and vibration
(d) sand and dust
(e) insects

5.3.3.3.2 Low temperature.

5.3.3.2.1 Metals. Metals undergo changes in properties as they become cooler. These changes cause parts to become more susceptible to failure in areas of high stress concentration. This makes evident the importance of avoiding abrupt changes in cross section and providing generous fillets wherever possible. In some instances, particularly where dissimilar metals are used, variations in the coefficient of expansion may cause binding of moving parts where close tolerances are employed.

5.3.3.2.2 Nonmetals. At low temperatures leather becomes stiff and cracks, and it is usually ruined if it becomes wet and freezes. Do not use leather for either arctic or warm climate applications unless no other material in available which has greater fungus resistance and is otherwise satisfactory

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for the purpose, or unless used in a moisture free environment. Fabrics, in general, retain their flexibility, even at extremely low temperatures, provided they are kept dry; if they accumulate moisture and then freeze, they can be folded or stretched only with great difficulty. Glass, porcelain, and ceramics, although sensitive to rapid temperature changes, are not normally affected by extremely cold temperatures. However, a warm blast of air or a thermal shock of any kind may cause this material to shatter while at low temperature. The proper plastic for a low temperature application must be chosen with care. Consider the stresses and temperature under which a plastic must perform, and understand thoroughly the fabrication process. There are numerous plastics which remain flexible and retain their thoroughness at reasonably low temperatures (minus 30°F). In the ethylene polymer group, polyethylene and polyurethane are tough and durable, but begin to stiffen at minus 30°F and become brittle at minus 94°F. In choosing rubber materials and compounds for low temperatures to which they must perform, how long they must operate at this exposure, and whether or not they will be under stress. As temperature decreases elastomers become progressively more difficult to bend or stretch.

5.3.3.2.3 Fuels. Low temperatures do not cause degradation of fuel, but diesel and similar fuel oils tend to congeal. Contamination by moisture, dirt, or other foreign matter may result in operational failures.

5.3.3.2.4 Lubricants. At low temperature, the viscosity of oil and grease increases with a resultant danger of bearing failure. However, careful selection of lubricant and proper design of the lubricating system will eliminate lubrication failure.

5.3.4 Moisture. Forms of moisture to be considered include humidity, rain, snow, ice, and salt spray. The primary effects of moisture are corrosion fungus rotting, damage to and shorting of electrical equipment, contamination of fuels, frozen moving parts, increased loading, and slippery traction surfaces. Design equipment to withstand humidity and rain extremes, and snowfall as specified in MIL-STD-210, there are no formalized military requirements covering design for icing conditions. Design vehicles to withstand salt spray as specified in the detail specification or by the procuring activity.

5.3.4.1 Corrosion. Corrosion has the most serious effect of moisture with respect to vehicles. This is especially true in areas near salt water. Because of its conductivity, salt spray produces a need for insulation of dissimilar metals to minimize electrolytic effects. Use a sacrificial metal such as zinc, aluminum, or magnesium to protect iron; or use pure aluminum to protect copper-aluminum alloys. High purity metals resist attack better than low purity metals because they lack the "cell" forming impurities that usually cause electrolytic degradation. Alloys generally are less resistant than pure metals although the addition of magnesium to aluminum or nickel to iron ordinarily improves corrosion resistance. The

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most successful employment the principle electrolytic protection has been the application of high purity aluminum to copper - aluminum alloy, resulting in a laminated material called "Alcad". It has made possible the use of high-strength aluminum alloys without danger of deterioration by corrosion. Corrosion can be minimized by proper design, selection of materials, and surface protective measures. Cover exposed surfaces completely by some form of protective coating or surface plating, and employ chemical corrosion inhibitors wherever practical.

5.3.4.1 Dissimilar metals in contact. The relative location of metals on the electroactivity chart may be found in most engineering handbooks. The location of this chart determines the electric potential generated between two different metals when placed in contact in the presence of an electrolyte, the metal nearest the top of the chart acting as the anode. The farther apart on the chart the greater is the electric potential between the two metals, and other factors being equal, the faster is the rate of electrolytic action or corrosion. A property of certain materials known as passivity can be utilized to prevent the harmful effects of corrosion. Passivity, as used here refers to the fact that certain metals from an adherent impervious surface layer of oxide that impedes and finally prevents further oxidation. Aluminum, certain aluminum alloys, stainless steels, and titanium, display this phenomenon. Cadmium with chromate or phosphate treatment, or zinc plate on brass, copper, and steel reduces the voltage of the couple formed with aluminum and magnesium alloys, thus, reducing corrosion tendencies. Cadmium with no surface treatment is suitable only within pressurized or sealed spaces where it is not exposed to the corrosive action of humid air over 60 to 85 percent relative humidity. Certain aluminum alloys, such as 5052, 5056, and 6061, perform better than the more common alloys.

5.3.5 Fungus decomposition. Fungi are a form of lower plant life, gaining subsistence either by decomposing non-living organic substances or, by attacking living plants and animals. Like all other living organisms the fungi require moisture for their growths. The relative humidity of the atmosphere exerts an extremely important influence over fungus growth. Most forms require 70 to 100 percent relative humidity and temperatures above 50°F. Fungi are capable of bringing about oxidation, reduction or hydrolysis of many different kinds of organic compounds. Most fungi require oxygen but do not require light for growth. Fungi can be a serious problem especially in tropical areas of the world where the most favorable climatic conditions for their growth are found. They will attack untreated materials such as fabric covers, electrical wire coverings, glued joints, wood, paper, plastics, and leather. Corrosion of metals can be accelerated because the fungi absorb water. In equipment design, protection should be provided by incorporating a fungicide into the materials, or by using a volatile fungicide nonnutrient matters, a coating which is moistureproof and fungusproof, or by reducing the humidity to a degree where fungus growth will not take place.

5.3.6 Sand and dust. Design equipment to withstand blowing sand and dust as specified in MIL-STD-210. Sand and dust can fill the smallest crevices and openings, thereby rendering parts inoperative. Install suitable shields or covers to protect wearing surfaces, such as bearings; and provide

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filters for the induction systems of engines and shelters. Do not place instruments in positions where sand and dust can affect their operations.

5.3.7 Atmospheric pressure. With increasing altitude, various changes of the ambient conditions occur. These changes take place mainly in temperatures, density, pressure and in the speed of sound. Water vapor shows a marked decrease with increasing altitude. For air transportation equipment must be capable of being transported at an altitude of 50,000 feet, which is equivalent to atmospheric pressures of 1.7 psi. Equipment should be designed to operate under conditions specified in MIL-STD-210.

5.3.8 Safety. Provide maximum safety to personnel and equipment during the installation, operation, storage, transportation, and maintenance phases of all equipment. Insure that there are no built-in injury potentials. If unavoidable injury potentials do exist, provide adequate warning placards or decals. Design all components for functional safety with repeated use over long periods of time under all environmental conditions anticipated for the item. Provide adequate margins of safety for all structures. Enclosing, guarding, and insulating features should be furnished on systems and components which are inherently hazardous. All walk and step surfaces should be provided with a nonskid footing. Non-functional sharp edges, projecting points, and excessive length of fastening devices should be avoided. Vehicles should be of a design to operate in compliance with existing rules and regulations. Placement and installation of safety features should be evaluated to preclude damage or destruction of these features as a result of operations in severe Military tactical environments.

5.3.9 Interchangeability. Interchangeability means the ability to easily substitute assemblies, and parts without physical or electrical modifications of any parts of the system or assemblies, including cabling, wiring, and mounting, and without resorting to component or part selections. It does not necessarily imply or adequately cover identity of components but it does imply functional as well as physical interchangeability. The interchangeability and replaceability of subsystems, assemblies, and components in the field is highly important. Consider the following:

(a) Insofar as practicable, provide engine interchangeability with other equipment requiring similar horsepower.
(b) Keep all parts that are subject to removal and replacement, standard and uniform.
(c) Keep the number of different kinds of components and parts to a minimum.
(d) Base designs upon the use of standard parts, wherever practicable, rather than those of special manufactures.
(e) Do not base designs upon the use of parts made by only one manufacturer when equivalent parts are available from several other manufacturers.

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(f) Insure that all parts with the same manufacturers parts number are completely interchangeable.
(g) Insure, as far as practical, that mechanical and electrical interchangeability is possible between assemblies subassemblies, and replacement parts, regardless of manufacturer or supplier.
(h) Design parts to permit maximum tolerance of assembly tooling.
(i) Provide positive identification of parts, as to function where they are physically but not functionally interchangeable. When feasible avoid physical interchangeability in cases where functional interchange of the parts or assemblies cannot be permitted.

5.3.10 Supply support. Supply support deals with the supply system problem of having the proper type and amount of any commodity at any specific location at the time it is needed and in a usable condition. Important factors affecting supply are environment, standardization, transportability maintainability reliability, versatility and vulnerability.

5.3.11 Cost. Design equipment for minimum manufacturing costs consistent with the mission of the equipment. Consider the desired design life, operational concepts, interchangeability procurability and reliability, as dictated by the mission. The main factors affecting cost are materials and labor (see 5.3.11.1 and 5.3.11.2).

5.3.11.1 Materials. Select materials that represent an optimum balance between strength and cost considerations. Weight is not as major a consideration for vehicles as is rigidity, strength, and cost, unless specifically required to meet extraordinary operational factors.

5.3.11.2 Labor. Design vehicles so that they can be manufactured with special labor skills and man-hours consistent with good manufacturing practices.

5.3.12 Maintainability. Maintainability is that quality or the combined features and characteristics of equipment design which permit or enhances the accomplishment of maintenance by people of average skill under the adverse environmental conditions of service use. Give thorough consideration to eliminate maintenance problems in the design, selection, and arrangement of components and equipment. Consider maintenance features as safety features. Consequently, the maintainability of an item or system is a feature which must be evaluated during the earliest stages of design. The objective, from the standpoint of field service is to maintain the desired amount of equipment in operating condition., with a minimum expenditure of maintenance facilities and crews. In order to achieve this, give adequate consideration to producing maintainable equipment. Design the equipment so that:

(a) Procedures for adequate maintenance are consistent with average human effort, ability, and attitude.

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(b) Reliable operation is not based on precise maintenance procedure and practices.
(c) Rapid and simple service and repair without necessity of a helper mechanic can be performed.
(d) Requirements for special tools and equipment are minimized.

NOTE: For recommended practices that increase maintainability see 5.6.

5.3.13 Procurability. Procurability is the design quality which expresses the degree to which the requirements of any eventual volume production have been integrated into the preliminary in order to utilize the available production factors to the maximum possible extent and to minimize the need for specialized production factors. Procurability encompasses factors like producibility, production capacity and expansibility. Producibility describes the degree of manufacturing efficiency achieved through liberal employment of specialized production equipment and techniques. Production capacity is defined as the sum of all factors of production in a defined situation such as the national production capacity, or that portion thereof which is allocated to military production. Expansibility is defined as the design characteristics which enable the production rate to reach its peak rapidly and also to be readily adjusted to changes in quantity requirements.

5.3.13.1 Specialized production techniques. Commercial articles are made producible through production redesigns. This redesign, initiated upon successful completion of the experimental tests, reengineers the article to modern, efficient, and profitable quantity production methods and thereby determines the production equipment and skills necessary for efficient fabrication. Specialized production techniques are then developed if required, specialized skills are trained, and eventually the article becomes producible after all the specified production factors have become available. The time and money required to achieve producibility is well justified. The cost is balanced by earnings from quantity production, and the time factor applies equally to all competitors in the business.

5.3.13.2 Achieving procurability. Procurability can be achieved, if preliminary design eliminates, or at least reduces, those factors which are known to be production bottlenecks. This requires extremely close cooperation between preliminary design personnel and production specialists. It is a challenge to the designer's ingenuity to stay within the limitation imposed by available labor skills and production capacity rather than to lean on a subsequent production engineering effort. The factors in 5.3.l3.2.1 through 5.3.13.2.6 require particular attention.

5.3.13.2.1 Tooling requirements. Tooling requirements can be reduced in two ways, namely by designing away from tooling requirements through simplicity in configuration, or by facilitating the toolmaking itself. The first way is representative of the preliminary designer's effort, and the second way

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is strictly in the domain of the production specialists. The combination of the two efforts, effected during the preliminary design phase, can eliminate one of the most serious production bottlenecks.

5.3.13.2.2 Special machinery and manufacture processes. The increasing percentage of mechanized labor poses supply problems to the supporting industries, sometimes even on general purpose machinery. This becomes particularly serious in the case of specialized machinery which has long lead time. Under the procurability concept, the availability of any machinery specified for quantity production becomes the controlling factor for the beginning of the production phase. Under the procurability concept, the designer makes the fullest possible use of the available production capacity and avoids unique designs which require specialized machinery. However, if specialized machinery is mandatory for the realization of functional superiority it then must be made available in time to meet the planned production schedule. It is the preliminary designer's responsibility to make such needs known to the production specialist early enough during the preliminary design phase. Determination of the machinery required is closely related to the manufacturing processes to be employed. If the strength characteristics demanded of a part are achievable through either one of various processes such as forging, casting, sheet metal build up, welding riveting or banding, the designer should carefully weigh the economic factors controlling the particular situation before he commits the design to a particular production methods.

5.3.13.2.3 Special labor skills. The consideration to be given to special labor skills is very similar to the-consideration of specialized machinery. A design is procurable only if it employs those labor skills which are readily available at the time of production. The employment of special skills which are in short supply must be reduced to a minimum.

5.3.13.2.4 Materials. Procurability is greatly affected by the materials specified by the designer. Readily obtainable long-supply materials are ideal from the standpoint of procurability large amounts of critical materials decrease the procurability of a design appreciably. Redesign of an experimental article to eliminate the use of critical materials is time consuming and, therefore, not normally permissible under the procurability concept. Justification for such redesign may exist when new non-strategic materials have become available subsequent to design initiation. General rules for efficient manufacture such as high utilization of raw materials, apply specifically to materials which are in short or critical supply. Such materials should, therefore, not be subjected to manufacturing processes which convert a high percentage of the raw material to chips or scrap.

5.3.13.2.5 Simplicity of design. The designer should analyze the details of his design from the viewpoint of their impact on the effort to produce the item. Close cooperation with production specialists during the preliminary design phase enables the designer to realize substantial production saving through simplicity of configuration elimination of non-essential design features maximum manufacturing tolerances, multiple usage of parts, short manufacturing cycles and similar features.

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5.3.13.2.6 Standardization. Standardization parts, in this instance are defined as parts which are common or can be made common to various applications. If a part is already available which is capable or the function demanded by the system, it should be utilized in order to reduce the design and development effort. This is also desirable from a cost standpoint since the unit manufacturing cost goes down with the quantity produced. This possibility of modifying available designs for this purpose should also be considered by the designer.

5.3.14 Performance. A definition of performance includes such factors as serviceability, durability, safety, vulnerability, compatibility, maintainability, and reliability. The effectiveness of any vehicle system is contingent on the proper functioning or each of its systems and their necessary interaction. To achieve these two objectives, the designer must be aware or the extreme importance of the latter. He must understand the necessity for familiarizing himself with the other subsystems which he is not designing. This familiarization is difficult at times, especially in cases when no contractor has responsibility for system development. The most important and effective step toward a solution of this problem is the designers' appreciation of the necessity for coordinated design effort on all components, of the system. The quality of comparability is not unique to military items. However, problems attending the achievement of compatibility in a system are a penalty associated with the introduction of complexity, and it is in this area that military requirements are considerable more severe. The design of equipment must be aimed at development items that are capable of carrying out a program of continuous operation with maximum efficiency in performance. Equipment must be as trouble-free as possible and, in many cases, capable of automatic operation to reduce to a minimum the number of operating personnel required. The designer must insure that the equipment will perform its mission satisfactorily, safely, and reliably when used under conditions of environmental extremes.

5.3.15 Reliability. Reliability of an item may be defined as the ability to perform satisfactorily within a given range of conditions and with a minimum of maintenance. An item of vehicular equipment is reliable if its actual performance satisfies the required performance with minimum down time for repair. Consistently good performance is of greater value then occasionally superior performance.

5.3.15.1 Achievement of reliability. The achievement of reliability is largely a function of good design practice and the designer's recognition of the need and the importance of reliability. To this end, the designer should ascertain, as realistically and an early as possible, the specifications of the task, the environmental conditions, human aspects, and emergency conditions likely to be encountered.

5.3.15.2 Improving reliability. Where the reliability of components is seriously affected by environments, the designer often can improve its reliability by controlling its environment, employing such devices as shields, covers, beating mechanisms, relocation of components and use of additional components such as filters and air cleaners, jewelry, judicious selection of material types or designs,

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such as castings or forgings versus components built from welded plates, will often provide increased reliability at the same or lose cost. The selection of lubricants is exceedingly important for equipment to be used in cold climates.

5.3.15.3 Increasing reliability. In general, reliability is inversely proportional and directly proportional to simplicity. Making a design as simple as possible, commensurate with the function desired of the item, will increase its reliability. In accomplishing this the designer must avoid designing multiple functions into an item and should keep the parts making up a system, as well as the inter-action demanded of them, to an absolute minimum. He also must consider the simplest means of performing maintenance, service, and inspection functions. Redundancy in a technical sense is the installing in a parallel arrangement more than one part, circuit or component having the same or a satisfactory substitute function, for the purpose of increasing reliability. For example, in a system with one component that fails often, the system reliability could be greatly increased by installing two of the components so that either one would keep the system in operation. Numerically there would then exist a redundancy of two for the components.

5.3.15.1 Limits on reliability. The designer is cautioned to apply redundancy with discretion cause of its impact on complexity and its economic import. He should also keep in mind that redundancy will not increase reliability if the redundant components are not capable of withstanding the actual environment to which they are subjected. The necessity for the use of redundancy admits the unsatisfactory reliability expectation of the primary system and indicates a requirement for continued effort on the improvement of the deficient components. The emphasis for perfection should be uppermost in the designers efforts rather than the added complexity which comes whenever redundancy must be employed temporarily to obtain needed reliability.

5.3.16 Lubrication. Friction is the force that resists sliding motion. The designer's problem is to reduce this force to a feasible minimum for the purpose of increasing efficiency of operation and decreasing wear between moving parts. The frictional force is most easily reduced by use of lubricant and bearings.

5.3.16.1 Thick film lubrication. Design for hydrodynamic or full fluid film formation whenever possible. This is advantageous because of the laminar flow characteristics of the lubricant between the sliding surfaces with resistance to motion due entirely to the viscosity of the lubricating film. Thick film lubrication is most commonly applied to low and medium load and medium speed conditions.

5.3.16.2 Thin film lubrication. Design for thin boundry film lubrication when hydrodynamic lubrication cannot be obtained due to high bearing pressure of line or point type lubrication, low speed short reciprocating motion. With no laminar flows film formation is solely by reason of the bearing

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surface attraction for the lubricant. It is this film alone which stands between lubrication as it is generally understood to be and metal-to-metal contact under condition of operation which do not permit the formation or maintenance of a hydrodynamic film.

5.3.16.3 Lubricants. The ideal lubricant should have the following qualities:

(a) Minimum cohesion among its own molecules.
(b) Maximum adhesion to the lubricated surfaces.
(c) Minimum changeability due to oxidation, pressure, or temperature.
(d) Adequate detergency.
(e) Compatibility.

5.3.16.4 Design influences. Design vehicular equipment to:

(a) Avoid high bearing pressure which creates a need for extreme pressure lubricants.
(b) Use heat resistant oil seals of synthetic material for high temperature application. Synthetic seals require a finer surface finish on the mating part than is required for leather seals, but the additional service life and reliability offset the additional surface preparation.
(c) Use materials, part fits, and gaskets which assure satisfactory operation of the equipment with any of several approved lubricants. This allows the equipment to operate over a broad environmental range by changing lubricants as necessary.
(d) Use guard housings to protect moving components and to create a reservoir for continuous lubrication.
(e) Provide automatic controls when economically feasible to prevent damage if the lubricating system fails.
(f) Provide permanently lubricated components to eliminate periodic lubrication. This can be done by using sealed housing, sealed bearings or impregnated bushings.

5.3.16.5 Selection of lubricants. Select lubricants that perform successfully under operational and storage use. The general characteristic of present lubricants are briefly described in 5.3.16.5.1.1, 5.3.16.5.1.1 and 5.3.16.5.1.2.

5.3.16.5.1 Oils. Mineral oils are obtained by the refining of crude petroleum. Since correct use of mineral oil depends to a large degree on its physical properties, carefully consider its application to insure proper lubricating properties. Animal or vegetable oils are rarely used directly as lubricants since they tend to oxidize into a varnish-like layer at normal operating temperatures. The chief uses are in the manufacture of greases, and as a compounding agent in mineral oils.

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5.3.16.5.1.1 Synthetic oils. Synthetic oils have been developed to meet special situations where mineral oils are not adequate. They are generally polyalkylene glycols silicones, diesters, organic chlorine compounds, and polymer oils. Each of these oils has qualities far superior to mineral oil. The usual qualities are a high and stable viscosity under and resistance to oxidation. Their use includes lubrication of rubber products, textile fibers, gears, compressors, and small electric motors.

5.3.16.5.1.2 Additives. Additives have been developed for the same reason as synthetic oils. Properly formulated they fortify mineral oils to meet normal tank-automotive requirements over the necessary temperature range of operation. Additives are usually used as follows:

(a) Anti-oxidants
(b) Detergents
(c) Viscosity index improvers
(d) Oiliness agents
(e) Extreme pressure compounds
(f) Pour point depressants

5.3.16.5.2 Greases. A lubricating grease in its most common form is a smooth, plastic mass being essentially a mixture of a metallic soap and petroleum lubricating oil. Other ingredients imparting special characteristics may also be included such as anti-oxidants, rust inhibitors and wear additives. Originally, each grease exhibited some outstanding characteristic such as heat, resistance, mechanical stability or water resistance. Now multipurpose greases combined in a single product exhibit the more desirable characteristics normally found in each of several products thus reducing the number of grades necessary to meet the varied lubrication demands. Synthetic greases of various thickening agents and synthetic base oils with better performance but higher cost are used in special applications such as lifetime sealed bearings extreme high or low temperature requirements and gasoline and oil resistance. Generally, the conditions of operation that establish demands beat met by grease are as follows:

(a) Anti-friction bearings with heavy shock loads and the necessity of infrequent lubrication.
(b) Journal bearings with slow speeds, heavy loads high temperatures and contaminants.
(c) Oscillating bearings with inability to form a full fluid film and high shock loads.
(d) Cams and rollers with difficulty in delivering lubricant and attaining proper distribution.
(e) Reciprocating flat surface bearings of flat sliding surfaces and slow speeds.

5.3.16.5.3 Solid lubricants. The normal basis for determining the lubricating value of solid lubricants is their laminar molecular structure, high load-carrying ability and low friction coefficients.

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They are generally stable at elevated temperatures (-750 °F and up) and are used alone in the powdered form and also in combination with a thermo setting resin binder as a bonded film. When bonded films are used in conjunction with conventional oils and greases, the load-carrying capacity of the oil or grease is increased and also extends endurance life. Typical uses for solid film lubricants are: hinges, plain bushings, and other slow speed sliding assemblies.

5.3.16.6 Recommended lubricants. Select and apply lubricants according to the instructions outlined in MIL-L-6880. In addition, the following lubricants, should be used whenever possible, since they are in world-wide use and am readily available.

(a) Reciprocating engine oil - Use oil conforming to MIL-L-6082.
(b) Turbine engine oil - Use oil conforming to MIL-L-7808
(c) Lubrication oils other than engine oils - For low temperature, general purpose low temperature, and low volatility instrument applications use oils conforming to MIL-L-6086, MIL-L-7870, and MIL-L-6085 respectively.
(d) Greases - Use greases, for various common applications, conforming to the following specifications:

  (1) Minus 65° to plus 250°F – MIL-G-23827.
  (2) Minus 100° to plus 225°F - MIL-G-23827.
  (3) Minus 40° to plus 250°F - MIL-G-7711.
  (4) Plus 300°F - maximum – MIL-M-G-3545.
  (5) Extremely high pressure and low pressure: MIL-G-23827.
  (6) Graphite: MIL-G-7187. Use this grease for lubrication of plain bearings.

(e) Hydraulic fluids - Use hydraulic fluids conforming to MIL-H-5606.

5.3.16.7 Provisions for lubrication. To minimize the need for operator relubrication, provide permanently lubricated components or other units not requiring relubrication, whenever possible. Use lubrication fittings conforming to MIL-F-3541.

5.3.16.7.1 Location of lubrication fittings. Locate lubrication fitting so that they are readily accessible for servicing and replacement, placed to minimize harmful environmental and operational effects, and provided with tubing so that remote and inaccessible lubricated points may be lubricated from a fitting that is accessible. Use a minimum number of fittings compatible with adequate lubrication. Avoid using more than one size fitting on any single item of equipment. Consider using a central lubricating system for applying lubricant to all points where lubrication to required. Central system will reduce the amount of extraneous material that often enters through the standard lubrication fittings. Design for continuous lubrication if there is a likelihood that the equipment will not be hand lubricated

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regularly. Continuous lubrication provides lubricant for both lubrication and cooling, The two most common methods of continuous lubrication are:

(a) The automatic oiler, either wick-fed or gravity.
(b) The oil ring which drags lubricant from a sump to the bearings.

5.3.17 Human factors.

5.3.17.1 Arthropological. The design of an item which is dependent, to any degree, on the human effort expended on it for its use must conform, configuration wise, to the physical limitations of the human body. Refer to the human Engineering Handbook for applicable human engineering data.

5.3.17.2 Training. Vehicles should be designed to minimize the need for extensive skills and to be as automatic as practical with a minimum of controls and adjustment. Many of the military personnel are on their first tour of active duty. As such, their level of training and experience is not comparable to that of commercial operators. Some aids to minimize this problem are enumerated below:

(a) Provide clear and durable instructions that are visible to the operator from his normal position.
(b) Wherever possible, design controls to prevent damage if operated at the wrong time or in the wrong manner.
(c) Design components so that they cannot be installed the wrong way, such as incorporating the use of blind splines.
(d) Assure functional interchangeability as well as physical interchangeability for all interchangeable parts.
(e) Insure that adequate maintenance and operating practices are consistent with average human effort, ability, and mental attitude.
(f) Do not base reliable operation on precise maintenance procedures and practices.

5.4 Design restrictions.

5.4.1 Automotive engines. Automotive type, internal-combustion engines should be designed in accordance with the detail specification.

5.4.1.1 Engine definitions.

5.4.1.1.1 Tactical engines. The term "tactical engine" is defined as an engine used in a vehicle having exacting military characteristics and designed primarily for use of forces in the field engaged in combat or tactical operations, or to provide direct logistic support by service elements to such forces engaged in combat or tactical operations, or for the training of troops for these operations.

5.4.1.1.2 Administrative engine. The term "administrative" engine is defined as an engine used in a vehicle primarily of commercial design intended for use as bases, depots, depots, air stations, and

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other shore establishments where specialized use and road and climate conditions are not such as to require a tactical vehicle.

5.4.1.1.3 Gasoline engine. The term “gasoline engine” is defined as an internal-combustion engine dependent upon an electric spark, or similar means, for ignition of the fuel-air mixture in the combustion chambers. Although fuels other than gasoline, such as kerosene benzine, alcohol, propane or butane may be used, and while fuel may be delivered directly by injection instead of carburetors, if combustion is normally initiated by electrical ignition the engine shall be considered a “gasoline engine” within the scope of this definition.

5.4.1.1.4 Diesel engine. The term "diesel engine" is defined as internal-combustion engine, dependent for ignition of the fuel-air mixture in the combustion chamber, upon heat generated by compression of the air in the combustion chamber. While the engine may be fueled with gasoline, instead of the less volatile distillate ordinarily employed, and although electric spark plug or glow plugs may be used to facilitate starting, the engine shall be considered a "diesel engine", within the scope of this definition, if ignition is normally dependent upon the heat of compression.

5.4.1.1.5 Air-cooled. The term "air cooled" engine is defined as which is cooled by direct transfer of excess heat to the ambient air.

5.4.1.1.6 Liquid-cooled. Engines the term "liquid-cooled engine" is defined as an engine which is cooled by transfer of excess heat to a circulating liquid, which in turn transfers the heat to the ambient air or other heat-absorbing media by means of a radiator or heat-exchanger.

5.4.1.1.7 Four-stroke-cycle engine. The term "four-stroke-cycle engine" is defined as one in which a power stroke occurs at every fourth stroke, or every second complete cycles of each piston.

5.4.1.1.8 Two-stroke-cycle engine. The term "two-stroke-cycle-engine" is defined as one in which the powerstroke occurs at every second stroke, or every complete cycle of each piston.

5.4.1.2 Design considerations. Consider these suggestions before finally determining automotive engine design. Provide power plant interchangeability. In general, the bell housing tap locations are the only common points among various engine makes. Diesel and spark ignition engines of the same horsepower and built by the same manufacturer are rarely interchangeable, and interchangeability between engines of different manufacturers is almost nonexistent. For military purposes, power plant interchangeability is essential. Only through interchangeability can adequate stocks of engines be maintained. Also, through engine interchangeability, maintenance personnel can readily shift engines from one vehicle to another to prevent an idle machine from stopping an entire operation. To attain the benefits of engine interchangeability:

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(a) Specify the location of engine mountings for an engine of a given horsepower to a common reference plane.
(b) Locate holes in the mounting frame to accommodate engine mountings of different make.
(c) Specify engine bell housings to conform to SAE standards.
(d) Design the engine and supporting parts as a single unit, include the cooling and lubrication system and their associated accessories.
(e) Specify a radiator for diesel engines based on the rate of heat ejection from the spark ignition engine. The more efficient diesel engine rejects less heat, while producing equal brake horsepower.
(f) Provide a radiator design adequate to withstand the high shock loads created by diesel engines.
(g) Locate and shape the radiator outlet and inlet to obtain radiator interchangeability.
(h) Consider the use of a common engine block with identical mounting points for both diesel and spark ignition engines.
(i) Investigate the common usage of such items as crankshafts connecting rods, valves, bearings, timing gears, and cam shafts.
(j) Specify clutches based on the high instantaneous torques realized from diesel engines.
(k) Locate any center line of the fan at a common point.
(l) Locate any stacks, such as muffler and air cleaner stacks, at common location. Use quick disconnect features with common locations.
(m) Use common instruments and locations where possible, by varying lead wire lengths or tube lengths.
(n) Consider using the same bore and stroke for all engines in the design of a series of engines to attain maximum interchangeability of parts from engine to engines.
(o) Use common filler caps where possible.
(p) Specify two-piece spockets to permit interchanging sprockets without the removal of the sprocket hub.
(q) Provide adjustment indicators and timing marks on the engine instead of requiring a separate measuring unit.

5.4.2 Bearings. Use Military standard bearings whenever possible. Use nonstandard bearings when standard bearings are not suitable. Nonstandard bearings should be procurable from at least two sources. All parts which have the same manufacturer's part number should be directly and completely interchangeable for both installation, and performance. Avoid the use of matched parts or selective fits.

5.4.2.1 Sleeve bearings. Sleeve bearings are used to support shafts or journals from a housing, between which there is a relative motion. These bearing may be flanged for precise centering or for absorbing thrust. A lubricant is required between the moving parts to reduce friction. The selection of the proper sleeve bearing depends on the type of application, the maximum pressure, the speed, the film

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lubrication factor, and the dimension limitations. Incorporate sealing provisions in all sleeve bearing installations to prevent the ingress of contaminant between the moving surfaces. Machined or formed bearings of brass and bronze should conform to MIL-B-13501. Use standards commercially available sleeve bearings, whenever applicable.

5.4.2.2 Clearances. Insure that diametral clearances between bearings and shafts permit satisfactory operation under the conditions of temperature, speed, and load which will be encountered in each installation. Provide end clearances for joints which require relative rotation of the parts connected by using spacers or shoulder bolts in order to preclude seizure by overtightening the assembly nut.

5.4.2.3 Split bearings. If split bearings are used, consider the plane of the split to provide ease of disassembly for example, split the crankshaft bearings on an engine connecting rod to permit bearing removal through ports without having to remove the crankcase cover.

5.4.2.4 Anti-friction bearings. Use anti-friction bearings where sleeve bearings are unsuitable. Antifriction bearings are applicable for higher speeds then sleeve bearings. Use standard anti-friction bearings. Contact reputable bearing manufacturers for detail date of the types of antifriction bearings available.

5.4.2.4.1 Applications of antifriction bearings. Antifriction bearings have many applications. Each type has special characteristics which are applicable in different situations. The following list provides a guide for the proper application of anti-friction bearings:

(a) For small, high speed applications, use ball bearings.
(b) For large, heavily loaded applications, use roller bearings.
(c) For flexible shaft or angular deflection applications, use self-aligning ball or spherical roller bearings.
(d) For free shaft axial displacement applications, use cylindrical roller bearings.
(e) For limiting shaft axial deflection under load applications use opposed mounted thrust bearings angular-contact ball bearings, or tapered roller bearings.
(f) For heavy thrust load applications, use spherical roller thrust bearings.
(g) For minimizing bearing friction under normal load applications, use self-alining ball bearings or cylindrical roller bearings.
(h) For movement loading applications use nonself-alining bearings.

5.4.2.5 Accessibility. In view of the possible necessity for bearing replacement and for changing the lubricant to suit widely varying temperatures and conditions at which certain ground equipment may operate, provide the greatest possible accessibility to facilitate either removal or purging and relubrication in the installation.

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5.4.2.6 Failure. The normal failure in anti-friction bearings is fatigue flaking of the raceways or of the surface of the rolling elements. All antifriction bearings will ultimately fail this way unless improper designs poor mounting, or faulty maintenance cause premature failure. Some common causes of failure are:

(a) Inadequate capacity
(b) Insufficient or improper lubrication
(c) Inefficient seals
(d) Out-of-round housing bores
(e) Tapered housing bores
(f) Misalinement.

5.4.3 Universal joints.

5.4.3.1 Plain universal joints. Design and select plain bearing universal joints in conformance with MIL-J-6193 giving full consideration to potential operation under extreme conditions of dust, beat, and cold. They may be used in all installations or other applications where they are subject to intermittent operation. For service use, the universal joint shall not be operated at an angle greater than 30 degrees when measured between the axes of the hubs. When used in power driven system, at speeds of 175 rpm or more, the angle should not exceed 15 degrees. In applications involving operations at less than 1000 rpm provide adequate shields and self lubrication to prevent rust and corrosion. When joints are to be operated at 1000 rpm or high in power drives, enclose them in a housing and run in an oil bath. Do not use plain bearing universal joints, covered in MIL-J-6193, in power drives where the speed exceeds 2,000 rpm. Obtain deviations for the use of plain bearing joints at conditions other than those cited above from the procuring activity after submission of detail engineering data covering the installation. Make provisions for disassembly of torque shafts in which universal joints are installed without disassembly or removal of pins from the universal joints. To assure constant velocity use paired joints. When paired joints are used on a shaft, install the joints with inspection holed in the saw flange in adjacent ends of the paired joints.

5.4.3.2 Anti-friction bearing universal joints. Anti-friction bearing universal joints may be used in applications where high speed and particular operational requirements preclude the use of plain bearing universal joints covered by MIL-J-6193.

5.4.4 Gears. Design gears so that they will align and mesh properly and will operate without interference. Design gears to permit fabrication on standard machines to commercial tolerances. Consider using laminated, cast, molded, steeped, or rolled gears where load and speed permit. Use materials, such as plastics and metals, as applicable. Gears may be used to transmit power at high or low speeds, under high or low loads, or they may be used to maintain the position of components relative to the equipment or other components. Use standard, commercially available gears when feasible.

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5.4.5 Springs. Design springs in accordance with MIL-S-17780. See the Tool Engineers Handbook, McGraw-Hill Book Company V.M. Faires' Design of Machine Elements, the MacMillan Company and the Society of Automotive Engineer Handbook.

5.4.6 Fasteners. Use fasteners which are applicable for the operational usage of the equipment. In most instances equipment can be fabricated by welding, but, because of maintenance factors, operational usage, or transportability, it is often necessary to use bolts and nuts, screws, pins, or rivets. In general, use commercially available fasteners which are interchangeable with military fasteners.

5.4.6.1 Bolts. Use bolts when it is necessary to remove and replace items on equipment. Design equipment so that commercially available bolts can be used. When practical, install all bolts with heads up or in other position that will minimize the loss of the bolt if the nut is lost. In addition install bolts in position for ease of maintenance. Provide all structural bolts with sufficient shank length to insure that not more than one thread is within the bolt hole of the material being bolted. Use standard spacer washers under the nuts in conjunction with longer bolts where it is necessary to eliminate threads in bearing or where it is desirable to protect the surface from injury while tightening the nuts.

5.4.6.2 Self locking screws and bolts. Use self-locking screws and bolts in accordance with MIL-F-18240.

5.4.6.3 Screw threads. Use unified screw threads unless cause for deviation can be justified in addition:

(a) Provide minimum thread engagement of screws and bolts equal to one diameter.
(b) Do not design frequently disassembled tapped or threaded parts from soft metals or nonmetals. When soft metals or nonmetals must be used, consider using inserts.
(c) Avoid loads in bearing on threaded areas of attaching parts.

5.4.6.3.1 Unified screw threads. Unified screw threads are described and explained in MIL-S-7742. Unified and American National threads have substantially the same thread form, and threads of both standards, having the same diameter and pitch, are mechanically interchangeable. Consider using inserts for nonmetals soft metals, and casting application to:

(a) Provide protection against thread corrosion and seizure.
(b) Reduce wear and stripping of tapped threads.
(c) Permit use of smaller, fewer, or shorter cap screws to provide the necessary holding strength.
(d) Repair damaged threads.

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5.4.6.4 Nuts. Use commercially available nuts for all applications. Use self-locking nuts whenever nuts are subjected to excessive vibration. Where the bolts and nuts are used in place of rivets or are not required to be removed for maintenance or repair, use plain nuts locked by peening. Weld and clinch nuts should be employed to the maximum extent possible to:

(a) Prevent loss of the nut during repair and replacement
(b) Permit removal of the bolt without requiring a holding wrench on the nut especially when a helper mechanic is essential.

5.4.6.5 Screws. Use commercially available screws whenever applicable. Consider the correct type of screw head for the function to be performed. Do not use self-tapping screw on panel, doors, or covers that are frequently removed for service or maintenance.

5.4.6.6 Flathead screws. Use flathead screws where it is necessary to have a flat surface, such as inside hinges. Countersink flathead screw only into materials thicker than 1 1/2 times the height of the screwhead. Use dimpling in the thin material in place of countersinking.

3.4.6.6.1 Special screws. Do not use off-sized, specially threaded, or proprietary screws.

5.4.6.7 Pins.

5.4.6.7.1 Clevis pins. Use clevis pins where they are not subjected to continuous operations and where the reversal of stresses and the chances of becoming loose are negligible. Install them so that their heads are up, and safety them with standard cotter pins or with standard bridge pin retainers. Retainers should conform to MIL-R-52243 and should be captive chained or cabled to the items.

5.4.6.7.2 Taper pins. Use taper pins in all permanent connections where absence of play is essential. Safety such pins with castellated or self-locking nuts. Project the small ends of the pins through the connected parts into spacer washers, permitting the nut to draw them up tight.

5.4.6.7.3 Cylindrical pins. Cylindrical pins may be used for permanent assembly where rivet heads would be objectional. Safety such pins by peening the ends into shallow countersunk recesses.

5.4.6.8 Rivets. Use rivets to attach parts together permanently or to assemble equipment. Because of the flexibility of the heads, do not use rivets when tensile strength is desired. Use commercially available rivets. Avoid using special rivets, such as flush-head rivets or blind rivets, except where standard rivets are not suitable. Use wire staples or metal stitching in place of rivets when possible.

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5.4.6.9 Edge distance. The sheet metal edge distances for location of rivets, screws, or other types of fasteners depends primarily upon the stress analysis of the joint. Provide for an edge distance of at least 1 1/2 rivet diameters in every case, and not less than 2 1/2 rivet diameter in lap joints.

5.4.7 Cables and wire rope. Use steel cables conforming to MIL-W-6940, MIL-W-1511, MIL-C-5693, or wire ropes conforming to MIL-W-3903 and MIL-W-6015. Do not use bolted clamps except when and where specified by the procuring activity.

5.4.8 Dimensional restrictions pertinent to the design of military vehicles.

5.4.8.1 Classes of restrictions. There are a number of physical restrictions on vehicle dimensions and weight which should be considered in the determination of the best design of military vehicles. Current Army regulations do not appear to cover all pertinent restrictions, nor is it certain, in cases for which regulations do exist that adherence is always mandatory. The following classes of restrictions are pertinent:

(a) Use of vehicle on highways
(b) Air transportability of vehicles
(c) Rail transportability of vehicles
(d) Considerations with respect to bridges
(e) Water transportability of vehicles

5.4.8.2 Use of vehicles on highways. The domestic legal limits of weights and dimensions vary from state to states. However, the following limitations apply in most states, State legal Maximum Limits of Motor Vehicles Sizes Weights Compared With AASNO Standards, prepared by Bureau of Public Roads July 1, 1958.

(a)	Over-all width	8 feet
(b)	Over-all length	50 feet
(c)	Over-all height	12 feet 6 inches
(d)	Axle load	l8,000 pounds

The following limitations are based on percent Army regulation, as set forth in Army Regulation AR 700-105. The military limitations noted apply to general purpose vehicles. The length limit pertains to the truck-semitrailer combinations.

(a)	Over-all width	8 feet
(b)	Over-all length	50 feet
(c)	Overall height	11 feet
(d)	Gross weight	78,000 pounds

5.4.8.2.1 Special purpose vehicle. For special-purpose and vehicles used in combat, the width and height limits are increased to 12 feet 6 inches. This general policy also limits vehicles with a wheel

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base of 10 feet or less to a gross weight of 36,000 pounds. For each of wheelbase greater than 10 feet, the gross limit increases 850 pounds.

5.4.8.2.2 Land transportability. Other limitations pertaining to the use of vehicle on highways are also covered in Army Regulation AR 705-8. The maximum permissible vehicle width for two-way highway traffic is approximately 10 feet. The maximum vehicle length noted previously is 50 feet. Vehicles of this length present problems in negotiating sharp turns. It is noteworthy that the rear unit of current army semitrailers does not exceed 28 feet in most cases. Axle load limits established by various states have been developed for standard commercial transport vehicles employing small-diameter high-pressure tires. Data are not available for estimating realistic axle load limits for vehicles using large-diameter low-pressure tires, such as found on GOER (Trucks, Cargo and Tanks 4x4) vehicles.

5.4.8.3 Air transportability. Limitations pertaining to length, (Trucks, Cargo and Tanks 4x4) width, height, and weight of vehicles to be air transported are listed in the following table for major types of transport aircraft.

Table I. Characteristics of cargo compartments for transport aircraft

Aircraft type	Length		Width		Height		Allowable
	ft	in	ft	in	ft	in	payload, lb
C-123B	28	9	9	2	8	2	13,000 a b
C-124c	77	0	11	3	11	6	47,600 c
C-130A	41	0	10	3	9	6	31,600 b
C-133A	81	10	11	2	11	2	95,000 c

(a) Phase I, assault-landed, radius of action 380 nautical miles, with no airhead refueling available.
(b) Phase II, air landed, radius of action of 380 nautical miles, with no airhead refueling available
(c) Phase III intratheatre airlift, range of 1000 nautical miles, with refueling available at destination.

5.4.8.4 Rail transportability. Limitations pertaining to weight, length and width of vehicles to be rail transported am listed in table II.

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Table II. Rail transportability data (FM 101-10)

Type	Capacity	Length		Width		Gauge
	Tons	feet	inches	feet	inches	
Foreign flatcar	30	34	5 7/8	7	2	Narrow
Foreign flatcar	40	40	0	8	7 1/4	Standard-broad
Foreign flatcar	80	46	4	9	8	Standard-broad
Foreign flatcar, depressed center	70	50	7	9	8	Standard-broad
Domestic flatcar	50	43	3	10	6	Standard
Domestic flatcar	70	49	11	10	3	Standard
Domestic flatcar	100	54		10	6 1/4	Standard

5.4.8.5 Maximum vehicle width. Maximum vehicle widths for various heights above platform in table III.

Table III. Maximum vehicle widths for various heights above platform

*Berne International				U.S. Main Lines				Narrow Gauge			
Height		Width		Height		Width		Height		Width	
feet	inches	feet	inches	feet	inches	feet	inches	feet	inches	feet	inches
0		10	4		0	10	8		0	8	6
6	3/4	10	4	6	3 1/2	10	8	5	4 3/4	8	6
6	2	10	4	6	4 1/2	10	8	5	6	8	6
6	11	9	1 1/2	7	1 1/2	10	8	6	3	2	0
8	9 1/2	6	6 1/4	9	0	10	8				
9	1/2	5	1 1/2	9	3	10	8				
9	5	3	7 1/2	9	7 1/2	10	0				
9	8 1/2	2	7 1/2	9	11	9	1 1/2				
				10	5 1/2	7	6				
				10	10 1/2	4	2				

*The Berne International is an important consideration. It establishes minimum specifications for railway clearances in various European countries.

5.4.8.6 Water transportability. The tonnage limitations and dimensions for typical landing craft and for 60-ton amphibious BARC are shown in table IV. The minimum tonnage restriction is 34 tons. With the exception of the LCM (6), all ramp widths permit the loading of vehicles which are 14 feet wide or over.

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Table IV. Characteristics of cargo area for landing craft (TM 55-508)

Type Craft	Ramp Width		Cargo Space				Capacity, Tons
			Length		Width		
	feet	inches	feet	inches	feet	inches	
IMC (6)	9	0	38	0	9	6	34
LCM (8)	14	0	42	0	14	6	60
LCU	14	6	72	0	30	0	150
BAR, 60 ton	14	0	38	6	14	0	60

5.4.8.7 Dimensions for hatches and density of cargo. The maximum and minimum dimensions for Liberty and Victory ship hatches are listed in table V. The low and high density of Army cargo is listed in table VI.

Table V. Maximum and minimum dimensions for hatches (FM 101-10)

Type	Hatch length				Hatch width				Between-deck height			
	Max		Min		Max		Min		Max		Min	
	feet	in.	feet	in.	feet	in.	feet	in.	feet	in.	feet	in.
Liberty Ship	35	0	20	0	19	10	19	10	22	6	7	10
Victory Ship	36	0	24	0	22	0	22	0	15	9	6	8

Table VI. Density of Army cargo (FM 101-10)

Cargo type	Low density lb/cu ft	High density lb/cu ft
Class I	23.8	
Class II		
MU	13.2	
AMEC	31.8	
MD	20.0	
ATAC (class II) [a]	27.8	
ATAC (class IV)		50.0
GL	27.4	
EL	13.2	
AAMC	20.8	
Class III [1]		
Bulk POL		45.0
Dry cargo	33.3	
Class V		55.6

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(a) Excludes complete vehicles
(b) An approximate value, some variation in density exists between fuels.

5.4.8.8 Immersion requirements for ground forces equipment (TB 34-9-31). The term "Immersion Proof" when specified in the military characteristics for the development of new ground forces equipment for the Armed Forces, unless otherwise specified, will mean that an equipment when ready for field transport after submersion in fresh or salt water to a covering depth of 3 feet for 2 hours, will:

(a) Be capable of operation at normal effectiveness immediately after being removed from the water.
(b) Suffer no subsequent harm from submersions provided the item is given normal maintenance within a reasonable time.

5.4.8.9 Fordability agreement (TB 34-9-30). The fordability agreements are as follows:

(a) The fordability policy of the Armies of the United States, United Kingdom, and Canada, as it pertains to future design of military vehicles will be governed by the statements in c (3) below.
(b) Furthermore, it is agreed between the three Armies that in the future, the terms "shallow fording" and "deep fording" will be the accepted military terminology to describe activities involving wading or fording. These terms are defined as follows:

    (1) Shallow fording - The ability of a vehicle equipped with built-in waterproofing to negotiate a water obstacle (with its suspension in contact with the ground) without the use of special waterproofing kits,
    (2) Deep fording - The ability of a vehicle equipped with built in waterproofing to negotiate a water obstacle (with its suspension in contact with the ground) by application of a special waterproofing kit.

(c) It is mutually agreed that:

    (1) All vehicles must be able to shallow ford and to deep ford in fresh and salt water to the maximum depth necessary to permit the accomplishment of their tactical mission.
    (2) All vehicles, normally used tactically, must be permanently waterproofed to permit shallow fording in fresh and salt water to the maximum depth possible, but not less than 30 inches except in the case of vehicles of the 1/4-ton size which will be not less than 20 inches, and in the case of tanks and armored care which will be not less than 42 inches.

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(3) All vehicles, normally used tactically, either with built-in waterproofing or by the use of simple attachments requiring a minimum amount of field modification and capable of being installed by the vehicle crew, must be able to deep ford for at least 15 minutes in fresh or salt water, to the following depths:

(a) All vehicles (except armored vehicles and trailed loads) 5 feet including wave height.

5.5 Structures.

5.5.1 Loading. The basis for all structural analysis are the loadings to be encountered in services. The forecasting of individual loading is necessarily founded on past experience and usually entails logical extrapolation to provide for future conditions. An unduly conservative assumption of loads is an unsatisfactory expedient because of the increased cost and reduced producibility generally resulting from such a practice.

5.5.1.1 Analysis. There are a variety of types and sources of loadings to be considered. Analyze each individually for its stress effect on the elements of the item of equipment. Select the most critical combinations of individual loads which are likely to occur simultaneously and re-evaluate the magnitude and distribution of stresses. It is likely that one load or combination of loads will be found to produce the highest stress level in one component part, while other single loads or combinations of loads will critically stress other elements. Avoid the elimination, by inspection or casual analysis, of any loading condition as a significant element of the over-all structural design. Loading may be disregarded in consideration of specific areas only when such areas are structurally isolated from the load application points.

5.5.1.2 Loading conditions. For any item of equipment, the loadings for which structural provisions must be made are the result of the various conditions of operation.

5.5.1.3 Dynamic loads. Dynamic loads may be involved either internally or externally. They imply accelerated motion such as vibratory conditions.

5.5.1.4 Static loads. Similarly, static loads may be implied in either the internal or the external loading cases. They are reacted, immediately at the point of application by internal stresses in structural members and ultimately, in the case of externally applied loads, by external reactions. Constant velocity may be involved but accelerated motion is not.

5.5.1.5 Equilibrium conditions. All the methods commonly used in the analysis of structures are based on the assumption that the external forces acting on the whole structure or any of its parts are in equilibrium. This assumption is correct when the entire structure, or the part of it in at rest or in

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unaccelerated motion. If it is in accelerated motion and inertia forces are added to the system in accordance with d'Alemberts principles the assumption is still justified.

5.5.1.6 Magnitude of loads. It is not possible even for a specific category of equipment to precisely define the magnitude of all probable loadings to be experienced. Because of the normal time phasing of structural analysis in relation to detail designs it is usually necessary to make broad assumptions as to the ultimate performance which will be attained. These must always be on the conservative sides. For preliminary analysis, disregard the mechanical efficiencies of power transmission mechanisms. To maintain a desirable degree of conservatism at this stage, apply the full power input as a source for component loads. Revised analysis may be made to reflect true detail loading established by the final design.

5.5.1.7 Environmental conditions.

5.5.1.7.1 Temperature. Aside from their effects on the properties of materials, high and low temperature extremes, as natural environments, have little structural significance. Loadings requiring structural considerations however, may be developed as a result of differential thermal expansion of structural members. In cases where the extraordinary temperature gradient is considerable, it may, depending on several related factors such as materials sizes and physical arrangements induce loads of significance. Normally, when thermal stresses of appreciable magnitude are encountered it is most expeditious to eliminate them by modification of the physical arrangement rather than dealing with them by developing adequate resistive strengths.

5.5.1.7.2 Moisture. Moisture in the forms of snow and ice imposes loads up to 20 pounds per square foot on the horizontal surfaces of military vehicles. Design all such horizontal panels and their supporting structure to withstand this loading. Combine with such other loads which may occur simultaneously.

5.5.1.7.3 Pressure. Design for pressure differential loadings resulting from operation at an atmospheric pressure of 11.4 pounds per square inch (equivalent to 6,000 feet altitude), from transportation (nonoperating) at an ambient pressure of 1.7 pounds per square inch, and from a maximum atmospheric pressure of 15.4 pounds per square inch.

5.5.1.7.4 Wind. Contact the procuring activity for identification of the particular wind velocity of MIL-STD-210 to be used. Use the standard cold sea level air density of 0.003089 slug per cubic foot for conversion of velocities to dynamic pressures.

5.5.1.8 Dynamic loads. Dynamic effects, such as acceleration, shock, and vibration, originate either in the operation of equipment or in its shipment. Develop dynamic operational loads from the

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specific conditions of service use. Design also for the most critical dynamic loadings incidental to shipment and handling.

5.5.1.9 Fatigue. Design all vehicles and components subjected to fluctuating loads to preclude fatigue or progressive fracturing for the life of the vehicle or components. Anticipate progressive fracturing in brackets by using gusset plates; in tubing, by using large bend radii; in machining parts, by providing generous fillets. Use other engineering design methods to overcome the effects of fluctuating loads caused by shock, vibration, and operational usage.

5.5.1.10 Accumulated damage. Design all vehicles and components to minimize the possibility of damage to other parts resulting from the prior failure or damage of another part. Minimize the possibility of component failure by a buildup of minor damages. Damage may accumulate in several forms such as:

(a) Small dents in the side panels which eventually fracture and allow water and dust into the equipment.
(b) Nicks and cuts on exposed wiring or plugs which eventually break down the insulation.
(c) Loose screws or nuts caused by rough handling or operational usage which allow components and parts to work loose and in turn, damage other components.

5.5.2 Stress analysis criteria - Limitations. As in the case of most theoretical formulas, the equations for predicting the actual intensity of stresses are not infallible. However, there are tools which, used judiciously, assist the designer in choosing a structure which, in most cases will be satisfactory from a load carrying standpoint. These equations cannot be used to compute directly the size and shape of a member, but can be used only to check a member after its dimensions have been estimated by some approximate means, together with due consideration of design limitations. The allowable stresses in members, especially those in compression and shear, are very difficult to predict with absolute accuracy unless a test of the structure is made. However, from tests of many different structural shapes and theoretical analysis methods of estimating, with a fair degree of accuracy, the allowable stresses of sections have been developed.

5.5.3 Factor and margin of safety.

5.5.3.1 Calculation. If the designer can compute the actual stresses and obtain information regarding the allowable stresses for the member in question, it is possible to establish whether the structure is sound and also the degree of soundness or margin of safety. Margin of safety (MS) is calculated by the equation:

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$$MS = \frac{\text{Allowable stress}}{\text{Computed or actual stress}} - 1$$

The margin of safety for a structure which is ideal from a weight construction is zero, or that called for in specifications.

5.5.3.2 Interpretation. To the applied stresses or loads, apply the appropriate factor of safety dictated by the specification or by experience. Such factors bear a direct relationship to weight, cost, and other evaluation factors. Exercise care in selecting values which are reasonable. Avoid undue conservation resulting from arbitrary use of high factors of safety. To compensate for ignorance or to reduce analytical effort by this means is undesirable. Frequently, the apparent high cost of careful and well-founded analysis is justified by cost and weight reductions made possible in each unit of many to be produced.

5.5.3.3 Factor of safety. Factor of safety is a multiplying coefficient which increases the applied stress or load to a value which is directly comparable to some mechanical property in question. It is intended to provide indeterminate areas of structural design:

(a) Normal expected material variations influencing mechanical properties.
(b) Deficiencies in stress analysis techniques.
(c) Reasonable errors in the assumption of basic load systems.
(d) Manufacturing deviations from the theoretical engineering design.
(e) Minor deviations from the theoretical engineering design produced by wear in normal use.

5.6 Maintenance evaluation.

5.6.1 Ease of maintenance requirements.

5.6.1.1 Accessibility. Accessibility is fundamental to ease of maintenance. It should be possible to carry out maintenance operations in the shortest possible time under adverse working conditions. All equipment should be designed to facilitate:

(a) All servicing operations and particularly those required daily.
(b) Inspection without disassembly, both visually and by means of test equipment.
(c) Repair by exchange of assemblies or components.
(d) Rapid recovery of disabled vehicles.

5.6.1.2 Sturdiness. Design of components should take into account the possibility of damage by unskilled personnel working under field conditions.

5.6.1.3 Standardization. For each broad class of equipment, components and assemblies should be standardized to the maximum extents.

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5.6.1.4 Materials. Common and easily obtained grades of material will be used to the maximum to facilitate manufacture of minor parts in the field. Metals should be capable of being welded without difficulty wherever welding would offer economical repair.

5.6.1.5 Tolerances and finish. Tolerances and finish while achieving all functional requirements should be as can be maintained in mass production by manufacturers unaccustomed to Department of the Army requirements. Shrink fits are undesirable as they introduce difficulties in repairs.

5.6.1.6 Adjustments. Means should be provided to take up excessive backlash and play wherever possible. The number of pivots and bearing surfaces on which wear can occur should be kept to a minimum. Wherever practicable consideration should be given to the use of self-adjusting devices. Adjustment devices should be capable of being locked without disturbing the adjustment.

5.6.1.7 Fire proofing. All materials should be selected to obtain the maximum resistance to fire or they should be fireproofed.

5.6.1.8 Waterproofing. Built-in waterproofing, if provided should not interfere with the ease of maintenance requirement or introduce the possibility of further faults. Build-in waterproofing should be effective over the normal life of the equipment between overhauls, since an equipment with defective built-in waterproofing takes longer to prepare for fording than the normal equipment, furthermore, reliance on the built-in features may lead to unsuccessful fording through unsuspected faults. Water seals should not be subject to permanent deformation, but should retain elasticity for long periods in service and during storage. Most Army equipment may have to be forded and all designs should facilitate and simplify the measures necessary to apply waterproofing.

5.6.1.9 Protection against mud, dust, moisture, ice, snow, and oil. All working parts should be protected as far as possible against the effects of mud, dust, moisture, ice and snow. Parts which would suffer deterioration from oil contamination should be suitably protected. Particular attention should be given to excluding grit during fording. The methods adopted will vary according to the situation, from complete sealing to removable covers or a protective finish. Control rods, pipes, cables, and flexible drives, should be run in accessible positions; they should be arranged to avoid corrosion or icings. Electrical cables should be protected by metal conduits where necessary. Alternatively, cables may be run inside frame members, providing that they are accessible and not exposed to heat or to accumulation of oil or water. All cables should be waterproof and oilproof unless their location protects them adequately against oil and water. When sealing is necessary, the sealed parts should be capable of being dismantled and reassembled without difficulty or damage to the sealing faces, and without the use of any special technique or equipment. The equipment should only require the minimum of preservation

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the minimum of preservation against deterioration when stored and transported. Such preservation as is necessary should be easily carried out.

5.6.1.10 Tools, gauges and test equipment. The number of tools required to strip, repair and assemble a vehicle should be kept to a minimum and special tool requirements should be standardized as far as possible in each range of equipment. Equipment should be designed to accept testing, recording and timing apparatus when required. If at all possible, the equipment should be so designed that special test gear is not necessary. Development and provision of test equipment and special tools should be carried out at the same time as the equipment for which they are to be used; they should be accorded the same priority as that equipment.

5.6.1.11 Handling heavy components. All components which are too heavy to be conveniently removed and replaced by hand, and are not of convenient shape for slinging, should be provided with accessible standard lifting-eyes, or tapped holes to receive such lifting-eyes. The center of gravity and relevant weight should be marked on heavy or lengthy components such as gun-barrels.

5.6.1.12 Prevention of misuse. Fuel tank filler necks, brake air cocks, flexible cables, pipe runs and similar items should not be positioned where they are likely to be used as a convenient foot-hold, and thereby sustain damage. Critical adjustments, which the user is not permitted to carry out, should be sealed or otherwise secured so that it is difficult for the user to tamper with them.

5.6.1.13 Expectation of life of equipment. Consideration should be given to the development of the assemblies comprising an equipment with a view to ensuring that all such assemblies have the same order of life as the equipment. It is obviously impossible to achieve perfection in this respects but a reasonable compromise will result in fewer major repairs during the operational life of the equipment. Design of components subject to wear should take into account the possibility of future reclamation by the fitting of inserts and liners.

5.6.1.14 Recovery. Suitable connections for recovery apparatus are required on all mobile equipment. Snatch loadings on connections during towing and winching operations, should be born in mind during design. In this connection it is desirable that the means of attachment of the recovery connection to the equipment should limit the strength of the attachment, and that this means be easily replaceable such as the use of a shackle pin.

5.6.1.15 Preservation of wood. Wood used in the construction of equipment should be pressure impregnated with a suitable preservative that will permit subsequent paintings. Methods of construction should take into account warping and shrinkage that may occur due to climatic conditions.

5.6.1.16 Preservation of fabrics. All fabric items shall be rotproof and termiteproof before fabrication.

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5.6.1.17 Screw threads. All screw threads should be standard.

5.6.1.18 Bolts, nuts, studs and screws. All bolts, nuts, studs and screws used should conform to current standards. A minimum number of types and sizes will be used in any one range of equipment. Where possible, bolts and nuts should be used in preference to studs or cap screws. Where the use of a wrench is difficult, easily replaced captive or caged nuts should be employed. The use of self-locking nuts should be considered. Inserts should be used in light alloy castings to accept set screws or studs from which the nut has to be removed frequently. Quick disconnect type of fastener should be used on often removed panels.

5.6.1.19 Lubrication. Any one equipment should be designed to operate on as few different types and grades of lubricants as possible. Oil filters should be a standard range of sizes, and filter elements should be easily removed and replaced. A simple form of magnetic filter is desirable in all oil sumps. Wherever possible bearings which do not require any lubrication, such as self-lubricating bronze or rubber bushings should be used. The use of permanently lubricated bearings should also be considered. Grouping of lubrication points is desirable where individual points would be difficult to reach. Lubrication pipes should be protected against incidental damage. Grease fittings of the same size should be used throughout an equipment. Fittings should be placed so that they can be used with standard grease guns, and access plates should be provided where necessary to facilitate servicing. Where drain plugs with machine threads are appropriate, the proposed Military Standard Sizes of 5/8, 7/8, 1-1/4, 2 and 3 inches respectively and 12 pitch service threads and an external hex head should be used. Pipe plugs have not been standardized but plugs with a 1/2 inch square hole to accept the 1/2 inch drive flex handle available in 1/2 inch drive socket sets are preferable to external square heads. All gear boxes throughout a vehicle should use the same size drain plug. Oil seals should be easy to replace, and arranged to avoid blind fitting wherever practicable. Seal seatings and glands should be provided with adequate openings for driving out seals. Oil seals should not be subject to permanent deformation, but should retain their elasticity for long periods and during storage. Dip-sticks should be provided for measuring oil levels and they should be graduated to show the amount required for filling. If it is essential to avoid over-filling to prevent damage, level plugs are acceptable; they should be accessible.

5.6.1.20 Hydraulic and pneumatic systems. Hydraulic pressure check points should not involve disconnecting lines or fittings. Self sealing couplings should be used in hydraulic systems where disconnection has to be made frequently for maintenance purposes. Complex hydraulic and pneumatic systems should be identified by a system of color coding to assist quick recognition and maintenance. Drain cocks should be fitted to all air receivers and oil reservoirs. The handle should be so arranged that vibration will not tend to open the cock. It should be down when the cock is close.

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5.6.1.21 Fuel, oil and water tanks. Tanks should be prepared internally to resist corrosion and the interior of tanks should be accessible for inspection and cleaning. Fuel and water tanks should use standard filler necks and caps.

5.6.1.22 Drain holes. Wherever water is likely to collect, drain holes should be provided. This requirement should not prejudice waterproofing requirements.

5.6.1.23 Sheet metal parts. Simple sections of sheet metal work, without complex curves, are required to facilitate repair.

5.6.1.24 Splined shafts. Splined shafts should be provided with an adequate lead or chamber.

5.6.1.25 Chain drives. Enclosed chain drives for which periodic adjustment is necessary should be provided with an automatic adjuster.

5.6.1.26 Breathers. Breathers which may have to be changed between overhauls should be removable without excessive dismantling.

5.6.1.27 Cover and access plates. Access plates should be provided where necessary to facilitate access for inspection, servicing repair and adjustment. Cover and access plates should be secured with the sealing required. Such fasteners should be of the quick release type wherever possible.

5.6.1.28 Cylinder liners. Removable cylinder liners are preferable to solid blocks. Where solid blocks are provided, allowance should be made for reboring.

5.6.1.29 Crankshaft bearings. Crankshaft bearings of the prefitted type are preferable.

5.6.1.30 Modern developments. Modern developments such as chromium plating or other special techniques reduce wear on cylinders, piston rings, crankshafts, valves and valve gear of internal combustion engines should be incorporated whenever possible.

5.6.1.31 Starting controls. Controls for vehicle engine starting aids should be accessible to the driver while seated.

5.6.1.32 Air cleaners. Adequate air cleaners are required. They should be accessible and capable of being easily cleaned.

5.6.1.33 Radiators and oil coolers. Radiator and oil cooler cores should be protected from damage and blockage.

5.6.1.34 Drain cocks. Drain cocks should be closed when the handle is in the down position to minimize accidental opening. Where cocks are exposed to accidental disturbance, protection should be afforded.

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5.6.1.35 Belt drives. Fan and other drive belts should be directly accessible for quick adjustment or replacement.

5.6.1.36 Exhaust systems. Stainless steel bolts and nuts should be used for exhaust manifold pipe flange joints to resist corrosion. Flanges should be designed so that the bolt heads are prevented from turning when tightening or slackening the nuts. It is desirable that the exhaust system be self draining when the equipment is in level position. In order to avoid the need for frequent replacement of exhaust pipes and silencers, wall thicknesses should be heavy enough to resist corrosion and burning, particularly under adverse climatic conditions. Exhaust pipes and mufflers should not be positioned where the heat and fumes are likely to adversely affect other components or personnel. They should also be protected from damage when an equipment is moving over rough ground. Exhaust pipes and tail pipes should be separate units from the mufflers.

5.6.1.37 Fuel pumps. Mechanical fuel pumps should have a hand priming device. Fuel pumps should be readily replaceable as a roadside repair; if it is found to be impossible on a combat vehicle an alternative fuel supply system should be considered. Glass fuel pump covers should be avoided.

5.6.1.38 Fuel systems. There should be a 5 percent dead column below the effective level of draw-off of the fuel supply to the engine, to trap water. A separate cock or plug should be provided to drain off this contaminated fuel. Fuel systems should be easily drained for storage purposes to prevent gun formation. Adequate fuel filters are required. They should be readily accessible and easy to clean.

5.6.1.39 Avoidance of vapor locks. To assist in the avoidance of vapor locks in fuel systems under condition of a high temperature and altitude, the following points should receive attention:

(a) Fuel lines and particularly filters should be routed remote from exhaust systems or other sources of heat, or be lagged.
(b) If necessary a shield should be fitted to the fuel tank and carburetor to insulate them from local heat.
(c) Fuel pumps should be of sufficient capacity to deal with incipient vapor locks.
(d) If necessary, the system may be pressurized, but even then the measures listed above should not be neglected.

5.6.2 Electrical equipment.

5.6.2.1 Standardization. Standard electrical components should be used throughout the vehicle where applicable.

5.6.2.2 Slave connections. Standardized slave battery or inter-vehicle connections are required on engines normally started by electrical power.

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5.6.2.3 Electrical bonding. Electrical bonding should be readily removable where necessary to facilitate maintenance of the items being bonded. Bonding points should be accessible. Screws if used, should be fitted with the shakeproof washers.

5.6.2.4 Batteries. Batteries should conform to MS 35000. The size of battery should be adequate for the duty required under all operational conditions. Good accessibility for filling and for specific gravity and voltage tests is required. Batteries should be mounted away from sources of heat, and should be protected if in exposed positions. Battery holders should have easily operated clamping devices to hold the battery firmly in position and prevent damage from traveling or gun fired vibrations. Holders should be treated to prevent damage from acid. Batteries should be selected, installed and protected in such a manner as to enable them to function satisfactorily within the temperature limits. When vehicle includes wet cell batteries preparation for storage, at temperatures over 100°F or under 32°F shall include removal of batteries.

5.6.2.5 Instruments. To check for the correct operation of engine lubricating and electrical to assist in the diagnosis of defects, accurately graduated engine oil pressure gauges and ammeters are required. Instrument panels should be easily detachable or hinged and have quick release connections. Standard gauges, instruments and warning lights should be used.

5.6.2.6 Electric cables. Electrical cables should be coded to assist tracing of faults. Standard disconnects should be used throughout.

5.6.3 Transmissions drive and suspension. Torsion bars should be adjustable and replaceable without removing. Wherever possible torsion bar support units should be bolted rather than welded to vehicle frames or hulls. Torsion bars should be tapped to accept standard slide hammer pullers.

5.6.4 Wheels. Vehicles over 1/4 ton class or equivalent equipment should have split type wheels. Lifting and lowering devices for stowing spare wheels should be provided for wheels weighing more than 100 pounds. Wheel changing should be as simple as possible and within the capabilities of the vehicle crew without special tools or equipment. Wheel hubs should be lubricated by hand packing.

5.6.5 Brakes. The design should be such that mud cannot accumulate in brake drums; good accessibility for filling, bleeding and adjusting without removing the wheels.

5.6.6 Clutches. Where driving loads are heavy and intermittent it should be possible to remove the clutch without removing other assemblies. It is desirable that adjusting devices**,** particularly for heavy vehicles, should indicate the life remaining in the linings.

5.6.7 Propellor shafts. Propeller shaft slip joints should be blind splined to facilitate correct assembly. Propeller shafts should be removable without disassembling the universal joints.

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