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Aircraft Armament	Power Supply, Electrical	Vehicle, Wheeled
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Boat	Vehicle, Amphibious	Weapon Subsystem
Electrical Power Requirements	Vehicle Component	Weapon, Vehicle Mounted
Electrical System (Vehicle)*	Vehicle, Tracked	*New

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Provides procedures for evaluating vehicle electrical system performance including power supply for weapon and other subsystems. Discusses power load planning, test temperatures, initial inspections, instrumentation. Describes tests at rated and 75% rated voltage for engine starting power, individual/cumulative internal component requirements. Other tests cover generator/alternator performance, electromagnetic interference, high/low temperature effects, water/humidity effects, reliability, and weapon subsystem demands. Applicable to electrical systems of wheeled and tracked vehicles; helicopters;

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US ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

DRSTE-RP-702-101
*Test Operations Procedure 2-2-601 20 June 1977
AD No.

ELECTRICAL SYSTEMS (VEHICLES AND WEAPON SUBSYSTEMS)

1. SCOPE. This TOP provides tests for evaluating the performance of military vehicle electrical systems including their capability for support of weapon subsystems and other on-board equipment. It applies to electrical systems of wheeled and tracked vehicles, helicopters, and small, armed boats equipped with lead-acid batteries, nickel-cadmium batteries, or other special type batteries.

Independent tests of automotive batteries are not included, but the performance of the battery is an important factor in starting tests as covered in paragraph 5.1.1 and TOP/MTP 2-2-650.

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

ITEM	REQUIREMENTS
Controlled-temperature chamber (para 5.5)	Large enough for test vehicle, temperature range from -50° to +135° F ± 5° (-45.6° to +57° C ± 2.7°)

*This TOP supersedes MTP 2-2-601, 23 February 1967.

ITEM	REQUIREMENTS
Humidity test chamber (para 5.6)	Large enough for test vehicle, temperature controllable up to 120° ± 5° F (48.9° ± 2.7° C) and relative humidity 95% ± 5%
Fresh and salt water fording test facilities or natural test sites as required	As required by specification. Test facilities as described in TOP 2-2-612.
Facility generator	As described in para 5.7.1

2.2 Instrumentation.

ITEM	MAXIMUM ERROR OF MEASUREMENT*
Voltmeter	±0.5% of full scale range
Ammeter	±1% of full scale range
Wattmeter	±1% of full scale range
Multichannel oscillograph and appropriate voltage dropping resistor	Voltage and current to ±2% of recorded value
Tachometer	Engine rpm to ±2% of full scale range

*Values may be assumed to represent ±2 standard deviations; thus the stated tolerances should not be exceeded in more than 1 measurement out of 20.

3. PREPARATION FOR TEST.

3.1 Review of Data.

a. Review the results of the overall vehicle inspection performed in accordance with TOP/MTP 2-2-502 and the weapon characteristics compiled in accordance with TOP/MTP 3-2-500. Review safety evaluation data obtained to date based on TOP 2-2-508 for the vehicle and 3-2-503 for the electrical and electronic components of the fire control system.

b. Study MIL-STD-1275 1/ for limits of transient voltage characteristics of 28-volt d-c electrical power circuits of military vehicles.

1/ MIL-STD-1275, Electrical Circuit, 28-Volt DC Transient Characteristics for Military Vehicles.

c. Review TOP/MTP 2-2-650 for engine cold starting procedures (para 5.5).

3.2 Fording. Arrange for the electrical system tests after fording (para 5.6) if not previously performed.

3.3 Initial Inspection.

3.3.1 Electrical System Components.

a. Examine the electrical system components for conformance with design specifications and AR 705-19, 2/ for adequacy of connections and workmanship, and for damage from transportation or prior operation of the system.

b. Record:

(1) Nomenclature of important components, including capacity for the generator/alternator and voltage regulator and rated voltage and ampere hours for the battery.

(2) Maximum current, voltage, and power requirements and the operating specification for each electrically operated vehicle assembly.

(3) Any defects in the electrical system.

3.3.2 Mechanical Components. Check the mechanical components that are driven by the electrical system to assure that they operate freely, are properly lubricated, and otherwise operate in normal manner.

3.3.3 Safety Features. In addition to the above, inspect the electrical system for the following:

a. Accessibility of field replaceable electrical hardware for testing, maintenance, and simplicity of removal.

b. Protection afforded the battery from the shock of high explosives and from penetrating hits.

c. Presence of circuit breakers for overload protection as depicted in the test vehicle's electrical wiring diagram.

d. Protection afforded personnel from contacting live electrical circuits (see MIL-STD-454D 3/).

2/ AR 705-19, Electrical System in Motor Vehicles.

3/ MIL-STD-454D, Standard General Requirements for Electronic Equipment.

e. Provision for adequate drainage of accumulated fluids and condensation from electrical assemblies and enclosures.

3.4 Planning the Power Load. The electrical supply system of a vehicle must provide electrical power for starting (engine heating and cranking), for supporting the central power system or engine (fuel pumps, ignition, controls), for auxiliary functions (communication, computers, lights), and for mechanical power for components (motors for hydraulic systems, fans, gun controls).

The vehicles usually have two sources of electrical power: a generator or an alternator-rectifier combination, and a battery. The battery is used to supply starting power for the vehicle and to supply electrical power during short periods of time when peak demands cannot be satisfied by the generator or alternator-rectifier. The generator or alternator-rectifier provides charging power for the battery. To the extent that the battery must supply frequent heavy demands for electrical power, the charge in the battery can be depleted. Subsequent heavy demands for power thus compromise the vehicle electrical supply system so that it cannot meet the power requirements. This condition can cause failures of the various vehicle systems to operate properly, particularly those systems requiring large amounts of power. Hence, overload requirements under realistic service conditions must be ascertained by tests.

The requirements document(s) will usually specify that the weapon system fire a certain number of rounds in a given length of time, with the generator and battery providing the necessary power without a major delay for recharging. If such information is not provided, an estimate is made of the most demanding firing missions that may confront the system, taking into account maximum ammunition load, maximum ammunition on a belt, reloading time, and the duration and number of targets that could be expected in view of the system mission. An additional factor that must be considered is the possible demand on the power supply that may develop from other power uses either during the firing (illumination, for example) or after the firing (starting the engine of the vehicle, for example).

3.5 Facilities and Instrumentation. Assure that facilities and instrumentation conform to minimum requirements.

4. TEST CONTROLS.

4.1 Initial Inspection. Personnel thoroughly familiar with the system will perform the initial inspection (para 3.3).

4.2 Test Temperatures.

a. Make power measurements initially under moderate ambient temperature conditions. Record ambient temperatures, in-vehicle temperatures, and solar radiation intensity when applicable, not less frequently than every 2 hours during testing.

b. Repeat key power measurements at high and low temperatures (para 5.5). Temperature affects not only the ability of the mechanical system to operate smoothly but also the characteristics of the power sources. The requirements document may state specific temperatures or reference AR 70-38. The following temperatures are applicable to the climates of AR 70-38: 4/

Intermediate cold: -25° F (-31.7° C)
Cold: -50° F (-45.6° C)
Extreme cold: -70° F (-56.7° C)
Intermediate hot-dry: 110° F (43.3° C) peak, plus solar radiation
Hot-dry: 125° F (51.7° C) peak, plus solar radiation

For most tests involving high and low temperatures, follow the procedures and test temperatures of TOP 2-2-816.

5. PERFORMANCE TESTS.

5.1 Rated Voltage Tests.

5.1.1 Engine Starting Power.

5.1.1.1 Method. To determine starting power requirements, use a fully charged battery in prime condition. Turn off all electrical systems within the vehicle, start the engine, and record the following data:

5.1.1.2 Data Required.

a. Maximum power (watts) supplied for starting at specified minimum temperature.

b. Maximum current (amperes) drawn for starting at specified minimum temperature.

5.1.2 Individual Internal Component Requirements.

5.1.2.1 Method.

a. Instrument the vehicle as shown in figure 1. Put a current-carrying resistor in series with the line feeding the main distribution bus of the vehicle. This resistor provides a voltage drop that is used to drive one channel of the oscillograph marked V_2; V_1 is another oscillograph channel. A d-c ammeter may be used instead of the resistor

4/ AR 70-38, Research, Development, Test, and Evaluation of Materiel for Extreme Climatic Conditions.

and oscillograph channel if the load elements are not expected to produce significant transient response; V_1 in this case can be a d-c voltmeter.

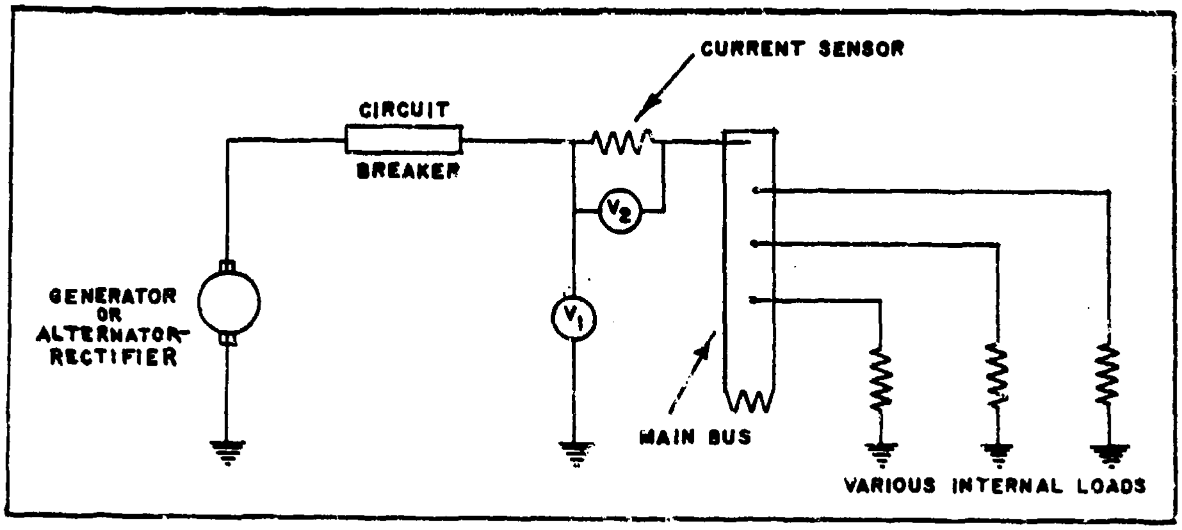


Figure 1. Measurement of Internal Component Demands.

b. Turn off all electrical systems within the vehicle. Start the vehicle engine, adjust the speed to normal cruising speed, and disconnect the battery. Activate each internal electrical load* in turn, read the current and voltage, then turn off the load. The increase in current occasioned by turning the electrical load on is the current requirement of that load. The generator capacity should exceed the total current requirements. This difference is available for charging the battery if required.

*NOTE: If the assembly has more than one operating position, turn it to the position requiring the most current. Vehicle electrical systems are designed to operate with the battery supporting the generator/alternator when the engine is running. In-rush currents to large motors (turret) can result in collapse of alternator output if battery support is absent.

5.1.2.2 Data Required. For each component:

a. Starting power surge (watts) supplied by the system.

b. Starting current surge (amperes) drawn from the system.

c. Steady state power supplied by the system.

d. Steady state current drawn from the system.

e. Current delivered to the battery by the generator/alternator.

f. Electrical assembly operating characteristics, as required.

g. Engine rpm.

5.1.3 Cumulative Internal Component Requirements.

5.1.3.1 Method. Observe the voltage each time an electrical load is turned on (5.1.2.1b above). The voltage regulation of the vehicle electrical system (without battery) can be determined by activating each electrical load, in turn, and leaving it on.* Under this cumulative electrical system load (less battery) the voltage should not fall below the rated battery voltage. If it does, the battery cannot be charged when supplying maximum current to the vehicle electrical system.

*NOTE: For assemblies that cannot be on at the same time - e.g., vehicle heater and air conditioner - operate the equipment that draws the most current. (See note at end of 5.1.2.1b above.)

5.1.3.2 Data Required.

a. Peak power surge supplied by the system as each assembly is started.

b. Peak current surge drawn from the system as each assembly is started.

c. Operating power supplied by the system.

d. Operating current drawn from the system.

e. Current delivered to the battery by the generator/alternator.

f. Electrical assembly operating characteristics, as required.

5.2 75-Percent Rated Voltage Test.

5.2.1 Method.

a. Vehicles Equipped with Lead-Acid Batteries. To determine whether the vehicle engine is capable of starting at 75 percent of the system's rated voltage, repeat the test in paragraph 5.1.1 at the reduced power. Reduce the voltage by putting the appropriate sized resistor(s) between the chassis and the chassis side of the battery. (This will simulate a battery producing 75% of normal rated voltage in parallel with the generator/alternator.)

b. Vehicles Equipped with NiCad or other Special Batteries. When the vehicle is equipped with special batteries, obtain the discharge characteristic curves for the individual battery from the battery manufacturer. Discharge the battery to 75 percent capacity (as indicated by voltage on the voltage-vs-time curves) by applying an adjustable resistive load across the terminals to discharge at a constant current. The discharge rate must not exceed the maximum indicated on the curves. (In no case should a NiCad battery be discharged to a point where any cell in the battery drops to 0 volts. If discharge is not terminated, the remaining cells will charge the low cell in the reverse direction which will severely shorten the life of the cell.) After the battery has been discharged to 75 percent capacity, start the engine and record the engine starting power data outlined in paragraph 5.1.1.2.

5.2.2 Data Required. Same as in paragraph 5.1.1.2.

5.3 Generator/Alternator Performance Characteristics. This test is conducted to determine the correlation between the vehicle engine rpm and the generator/alternator output.

5.3.1 Method.

a. Piston Engines. Conduct the test with all electrical systems operating and with the engine first at idling, then at 25, 50, and 75 percent of rated rpm and maximum operating rpm.

b. Turbine Engines. Test turbine engine driven vehicles within the latitude of the recommended operating speeds.

5.3.2 Data Required. For each test speed:

a. Engine rpm.

b. Current supplied by the generator/alternator.

c. Voltage output of the voltage regulator.

d. Battery voltage.

5.4 Electromagnetic Interference Tests. Determine the electromagnetic interference characteristics of the vehicle's electrical system by the methods described in TOP 2-2-613 (noncommunications equipment) and TOP 6-2-542 (communications electronic equipment). These TOP's are based on MIL-STD's 461 5/ and 462. 6/

5/ MIL-STD-461A, Electromagnetic Interference Characteristics Requirements for Equipment.

6/ MIL-STD-462, Electromagnetic Interference Characteristics, Measurement Of.

5.5 Extreme-Temperature Tests. These tests are conducted to determine whether the complete electrical system can operate down to -25° F (-31.7° C) without preheating the battery, down to -50° F (-45.6° C) with preheated battery, and up to 125° F (51.7° C) for armored vehicles and 135° F (57.2° C) for unarmored vehicles. As indicated in paragraph 4.2, other temperatures may be prescribed.

5.5.1 Method. Place the vehicle, with fully charged battery and specified coolant and lubricant, in the temperature chamber and condition it until the battery electrolyte is within 2° F (or 1.1° C) of the required temperature. Then perform all tests described in paragraphs 5.1 through 5.3 to the extent feasible at each temperature.

5.5.2 Data Required. All applicable data from paragraphs 5.1.1.2, 5.1.2.2, 5.1.3.2, 5.2.2, and 5.3.2 for each temperature.

5.6 Water and Humidity Exposures.

5.6.1 Method.

a. Evaluate the effects of wetness or dampness on the electrical system after the vehicle fording tests described in TOP 2-2-612. Depending on the stated requirements for the item being tested, fresh water tests, salt water tests, or both may be required. After tests in the ocean environment, inspect electrical components for electrolytic damage and for corrosive effects of salt water and adjacent atmosphere as indicated in TOP 2-2-612.

b. Repeat the tests in 5.1 through 5.4 above, as appropriate:

(1) While the vehicle is still wet/damp.

(2) After the vehicle has dried out.

c. Expose the vehicle to a 48-hour humidity test at 120° F (48.9° C) and 95 percent relative humidity followed immediately by appropriate tests of 5.1 through 5.4 above.

5.6.2 Data Required.

a. Description of each fording test performed and any resulting electrolytic damage and corrosion.

b. All applicable data from paragraphs 5.1.1.2, 5.1.2.2, 5.1.3.2, 5.2.2, 5.3.2 and 5.4 obtained:

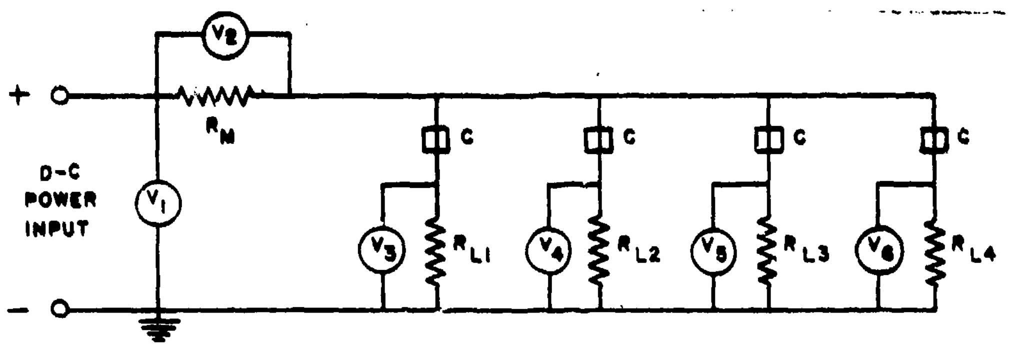
(1) While the vehicle was still wet/damp from fording tests.

(2) After the vehicle had dried out after the above tests.

(3) After the humidity test.

5.7 Weapon Subsystem Demands.

5.7.1 Method. To provide power to measure the current requirements of major current-consuming subsystems use a facility generator. The circuit is shown in figure 2.



R_{L1}, R_{L2}, R_{L3}, R_{L4} - various elements of the connected load.

R_M - current-measuring resistor of suitable current-carrying capability.

C - series-connected intervening controls (triggers, relays, switches, current limiter, etc.) that may or may not introduce additional resistance or impedance.

V - various tracks of the oscillograph.

Figure 2. Basic Circuit for Measuring Power Demand of Weapon Subsytems.

a. Set the generator voltage at the nominal voltage for which the subsystem has been designed, then fire the subsystem. V_1 monitors the input, and V_2 measures the current as a function of time. V_3, V_4, etc., indicate when various elements of the subsystem are energized and provide a means of analyzing the current demand on that basis. If current requirements of a particular element of the subsystem are required, suitable resistors can be placed in series with that element and the current recorded on the oscillograph. Make current measurements for each mode of fire of the weapon system.

b. Repeat the above procedure at 75 percent of rated voltage and at other supply voltages to determine the voltage range over which the subsystem will operate properly.

5.7.2 Data Required. As applicable to the type of armament, take measurements to establish the following:

a. The generator's steady-state current output, at rated speed and rated loads without an excessive temperature rise (para 4.2b).

b. The current output at normal operating speeds (paras 5.1 and 5.3).

c. The normal internal demands of the vehicle (paras 5.1.2 and 5.1.3), particularly of such elements that may be operating during the employment of the armament system. Selectively turn on electrically powered components until the highest load that could be expected with the armament operating is achieved.

d. Under various modes of operation and in various environments, the steady-state current demand of selected components of the armament system and the time period of each such demand for each typical period, particularly for one-time or cyclic elements. This will also include measurement of the amplitude, duration, and frequency of spikes, surges, and voltage fluctuations. (See MIL-STD's 461 and 462 for further guidance, depending on the system being tested.)

e. The minimum voltage (and resultant current) at which each component of the armament system will operate satisfactorily with the required steady rate of fire.

f. The effect of energization of various components in reducing the normally existing line voltage. (This will involve the use of battery power or some source of energy not provided with automatic voltage regulation.)

g. The magnitude and effect of voltage transients, spikes, electrostatic discharges, inductive arcing, or electromagnetic radiation of an intensity or frequency that would interfere with radio communication or prematurely ignite pyrotechnic devices.

5.8 Reliability.

5.8.1 Method. To determine the operating characteristics of the electrical systems over a specified period, make observations during the wheeled and tracked vehicle endurance tests conducted over specified courses for specified miles/hours (TOP 2-2-506).

5.8.2 Data Required. Operability of the electrical system, types of failures, and frequency of failures.

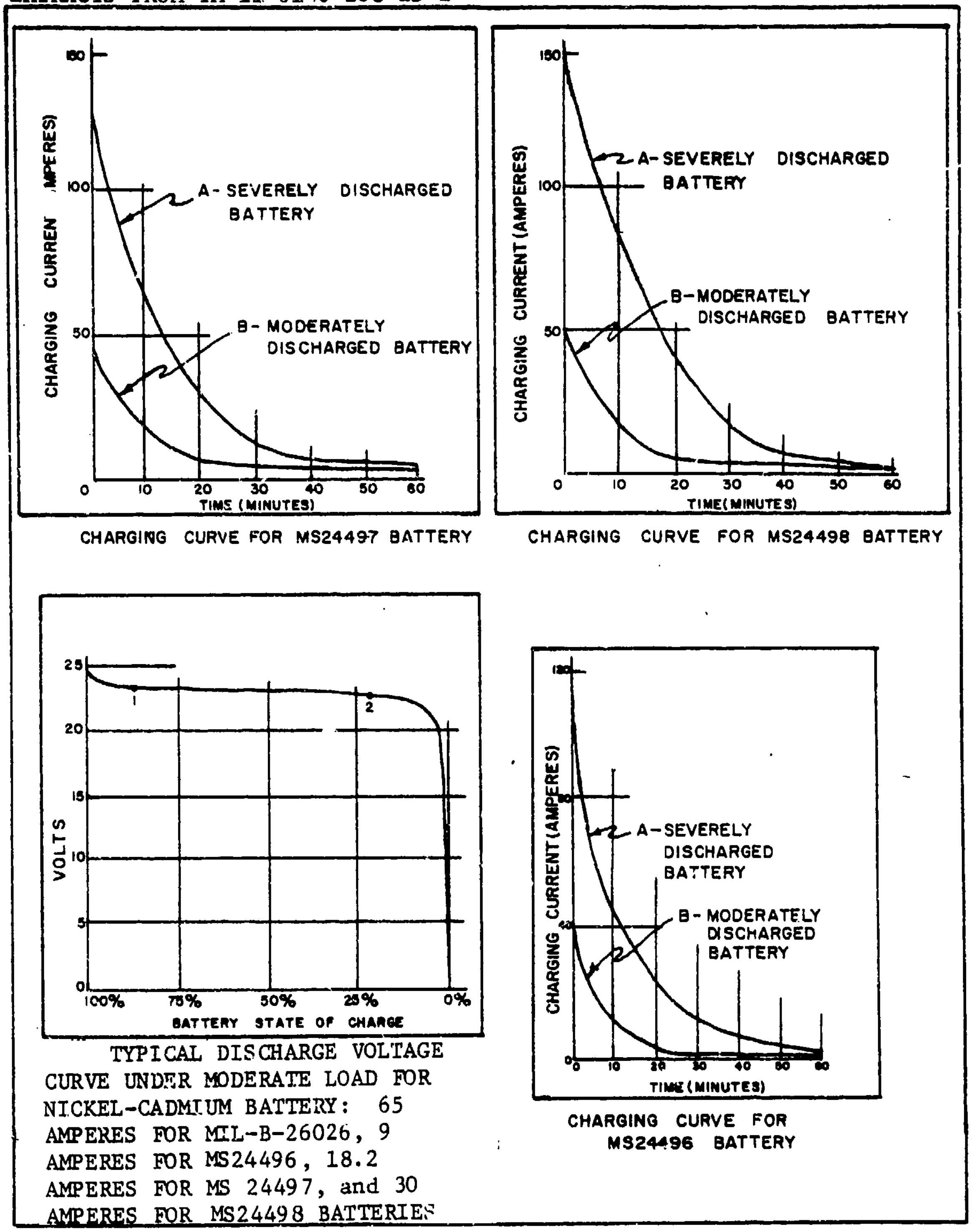
5.9 Maintenance Evaluation. Evaluate maintenance and maintainability as part of the overall system performance, addressing the applicable subelements described in AR 750-1 and TECOM Supplement 1. 7/ For further guidance in maintenance evaluation consult TOP's/MTP's 2-2-503, Maintenance (Vehicle) and 6-2-504, Maintenance/Maintainability.

6. DATA REDUCTION AND PRESENTATION. Read the oscillographic records and itemize the current requirements of all electrical loads and the weapon subsystem. In many cases the total current requirements exceed the capacity of the vehicle generator/alternator. Draw a mission profile and establish a current demand curve. Compute the demands in excess of the generator/alternator and compare them with the battery capacity. Curves of battery characteristics (see examples, fig. 3, extracted from TM 11-6140-203-15-1 8/) can be used to determine the condition of the battery during the mission. The electrical system is considered adequate if, upon completion of the mission, there is sufficient battery capacity to permit starting the vehicle on battery power.

7/ AR 750-1 and TECOM Suppl 1, Army Materiel Maintenance Concepts and Policies.

8/ TM 11-6140-203-15-1, Operator, Organizational, DS, GS, and Depot Maintenance Manual: Aircraft and Nonaircraft Nickel-Cadmium Batteries (General).

EXTRACTS FROM TM 11-6140-203-15-1



CHARGING CURVE FOR MS24497 BATTERY

CHARGING CURVE FOR MS24498 BATTERY

TYPICAL DISCHARGE VOLTAGE CURVE UNDER MODERATE LOAD FOR NICKEL-CADMIUM BATTERY: 65 AMPERES FOR MIL-B-26026, 9 AMPERES FOR MS24496, 18.2 AMPERES FOR MS 24497, and 30 AMPERES FOR MS24498 BATTERIES

CHARGING CURVE FOR MS24496 BATTERY

Figure 3. Typical Charging Curve at 28.5 Volts Constant Potential.