USER'S MANUAL

MT1560

HEAVY-DUTY AVR

Starting
& Charging
Systems Tester

Snap-on®

Electrical Rebuilder's ERA FOUNDED 2001 ASSOCIATION

Safety Warnings & Cautions

1. Be sure to read this instruction manual completely before using this tester. Save this manual as it contains important safety and operating instructions you may need to refer to at a later date.
2. Always wear approved eye protection when working near batteries.
3. Batteries produce highly explosive gas. Observe these instructions, and those of battery and vehicle manufacturer.
   a. Keep cigarettes, sparks, and open flame away from battery at all times.
   b. Testing should be done in a well ventilated area.
   c. Make sure load control knob is off (rotated fully counterclockwise) before connecting load leads.
   d. Be sure all test leads are connected as instructed before proceeding with a test.
   e. Avoid making accidental connection between battery terminals through tools, jumper leads, etc.
4. Use a suitable battery carrier when transporting batteries.
5. If considerable time is spent handling/servicing batteries, wear protective clothing.
6. Always disconnect ground connections on all batteries before servicing the electrical system.
7. On marine applications with inboard or inboard/outboard engines, make sure area is well ventilated and that bilge blower is operating.
8. Keep self, clothing and test equipment clear of all moving or hot engine parts.
9. Unless instructed otherwise, the parking brake should be set and the gear selector in neutral (standard transmission) or park (automatic transmission) and the drive wheels blocked before performing a test with the engine running. Engine must be disabled when performing starting system tests.
10. Exhaust gas contains deadly poison. When testing vehicle with engine running, test in well ventilated area or route exhaust gas outside.

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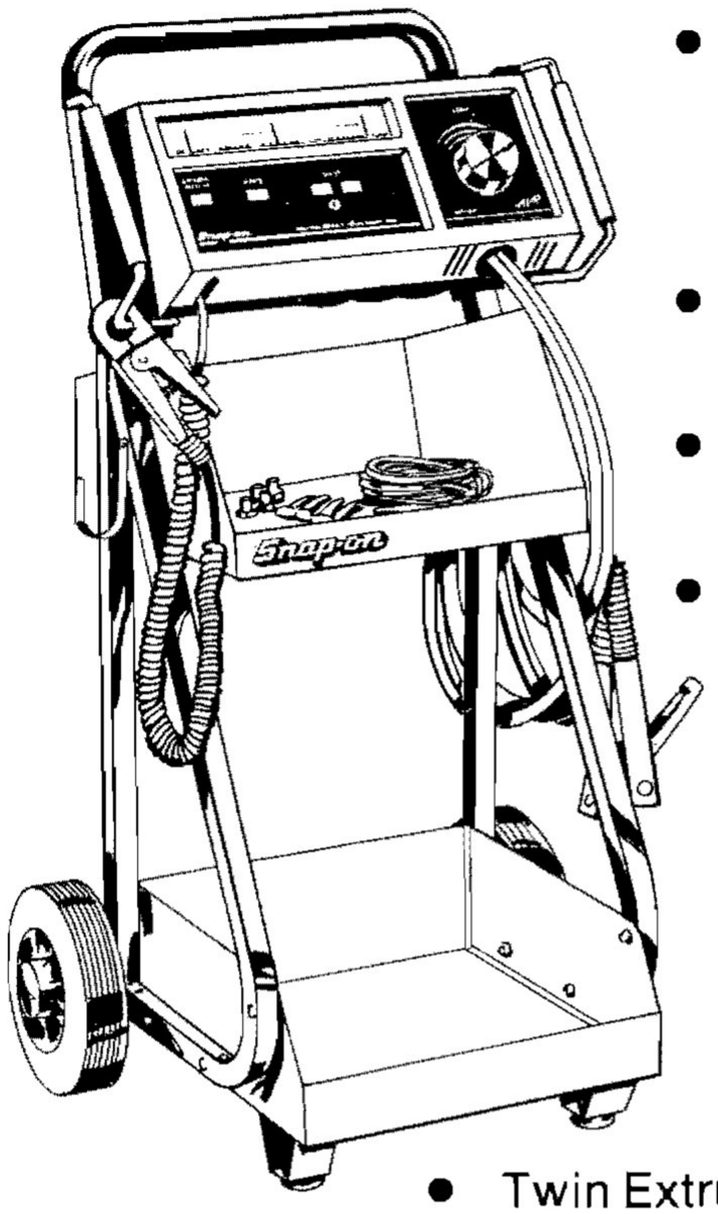
MT1560 Heavy-Duty AVR

The MT1560 Heavy-Duty AVR combines the functions of an ammeter, voltmeter and adjustable carbon pile - the three test instruments essential for testing batteries, starters, solenoids, alternators, voltage regulators, switches and their related circuitry. This tester incorporates many design features to make basic testing and detailed troubleshooting safer, faster, easier and more accurate.



- Advanced Circuitry - Provides high degree of accuracy and reliability, added tester protection in cases of over-voltage or crossed lead wires, and minimizes effects of radio frequency interference (RFI).
- 1200 Amp Current Range - Provides the capability to test heavy-duty electrical systems.
- Fan Cooled Carbon Pile - Shortens cooling period between tests and extends life time of carbon pile.
- LCD Displays - Large and easy to read, especially in bright light.
  - Individual Amps & Volts Digital Displays - Simultaneously display amperage and voltage readings.
  - Amps & Volts Bargraph Displays - Graphically shows test measurements and fluctuations in these measurements.
  - Compact Current Probe - Allows current measurements in restricted areas.
  - Zero AMPS Key - One-touch "0" adjustment.
  - Twin Extruded Load Leads - Less cumbersome to use, or store on instrument stand. Fewer tangles.
- Load Indicator - Displays "LOAD" to signal user that carbon pile is engaged.
- Time Indicator - Displays "15 SECONDS" when maximum recommended load period has elapsed.
- Heavy-Duty Instrument Stand - Large two wheel design provides easy mobility and maximum stability. Convenient storage shelves for optional battery service tools and YA168A Heavy-Duty Battery Charger.

The MT1560 Heavy-Duty AVR is designed and built to meet the needs of today's professional automotive, heavy-duty vehicle and marine technicians. It offers the combination of advanced circuitry, high-quality components and the finest in workmanship ... all backed by the Snap-on "GOOD AS GOLD" Limited Warranty.

Specifications

Ammeter (Digital Display): 0 to 1200 ADC in 1 AMP increments
(Bar Display): 100 to ± 500 ADC in 10 AMP increments
Voltmeter (Digital Display): 0 to ± 99.9 VDC in .1 VOLT increments
(Bar Display): 0 to ± 30 VDC in .5 VOLT increments
Carbon Pile Load: 500 AMPS (maximum)
Input Impedance (External Volts Test Function Only): 10 megohms
Carbon Pile Time Indicator: 15 seconds

Operating Power Requirement Range: 4.0 to 40.0 VDC
(Load Dump Protection to 100 VDC)
Operating Temperature Range: 0° F to 150° F
Storage Temperature Range: -50° F to 175° F
Tester Lead Lengths - Load: 10 ft.
Current Probe: 10 ft.
External Volts: 15 ft.

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FOR YOUR SAFETY, READ THIS MANUAL THOROUGHLY BEFORE OPERATING THE MT1560 HEAVY-DUTY AVR

The MT1560 ... *Functional Description*

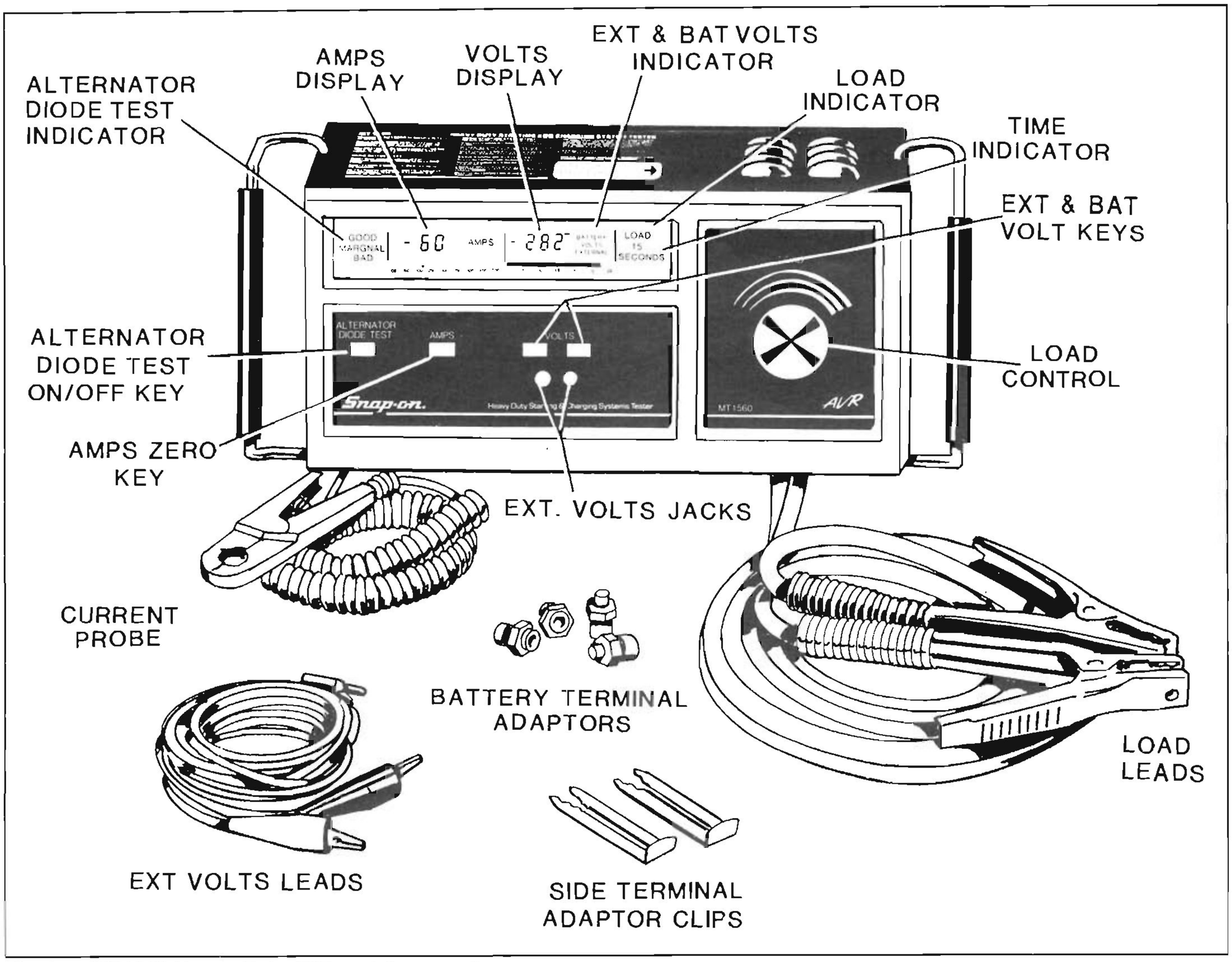

Fig. 1 — MT1560 Heavy-Duty AVR and Accessories.

LOAD LEADS - Have several functions in addition to applying current draw for load tests. They contain a messenger wire which powers the tester. The messenger wires are also used to monitor voltages present at the load leads when the tester is in the "BATTERY VOLTS" function. Load leads are connected as follows: red handled clamp is attached to positive side of circuit and black handled to the negative side of circuit.

When load leads are connected, a full LCD display will appear momentarily. If it does not disappear after a few seconds, disconnect and reconnect the load leads.

> *WARNING: When connecting or disconnecting the load leads, always make sure that the load control knob is in its off position (rotated fully counter-clockwise). Failure to do so will cause arcing that could ignite the explosive gases produced by batteries.*
>
> *NOTE: This tester has a fan cooled carbon pile. The fan operates whenever the load leads are attached to a voltage source.*

CURRENT PROBE - Measures current flow (amperage) through any diameter wire that allows the jaws to close completely. Probe senses polarity and has a current direction arrow. When arrow is pointed in the direction of current flow, the AMPS reading is positive. When arrow is pointed opposite direction of current flow, the AMPS reading is negative. When used with the optional YA187 Amps Amplifier, current measurements as small one-tenth amp are possible.

EXTERNAL (EXT) VOLTS LEADS - Provide a convenient means of performing voltage available and voltage drop testing. They are plugged into corresponding color-coded jacks on the front of the tester. Red is positive and black negative.

EXTERNAL (EXT) VOLTS JACKS - Receptacles for the external volts leads, are color-coded: red for positive lead and black for negative lead. To perform voltage tests with the EXT leads, the load leads must be connected to a tester power source. The EXT key must be pressed for the meter to display EXT voltage measurements.

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AMPS DISPLAYS - Provide simultaneous digital and bargraph readings; digital readings from 0 to ±1200 in 1 amp increments, and bargraph readings from ±100 to ± 500 in 10 amp increments. The MT1560 will display amperage readings greater than 1200; however, they may be inaccurate and should not be relied upon.

VOLTS DISPLAYS - Provide simultaneous digital and bargraph measurements; digital readings from 0 to ±99.9 in 0.1 volt increments, and bargraph readings from 0 to ± 30 volts in 0.5 volt increments.

ALTERNATOR DIODE TEST INDICATOR - Indicates the quality of alternator output current as GOOD, MARGINAL or BAD to inform the technician of defective diodes and/or stator windings. This function should only be used when checking the quality of alternator output current during alternator current output tests. The indicator should be turned off, or disregarded, during all other testing.

ALTERNATOR DIODE TEST ON/OFF KEY - Switches alternator diode test function on and off.

LOAD INDICATOR - Displays "LOAD" when carbon pile load is engaged.

TIME INDICATOR - Displays "15 SECONDS" after recommended 15 second battery load period has elapsed.

LOW BATTERY INDICATOR - Displays "lo bAT", as illustrated below, when battery voltage at the load leads is less than 3.5 volts, which is the minimum power requirement for MT1560 operation. When voltage is increased to above 3.5 volts, "lo bAT" will continue to be displayed until the load leads are disconnected and reconnected.



EXTERNAL (EXT) & BATTERY (BAT) VOLTS KEYS - Used to select EXT or BAT volts function. EXT volts function is used when testing voltages with the EXT leads. To use the EXT volts function, the load leads should be connected to a DC power source of at least 6 volts. BAT volts function uses the load leads' built-in messenger wires to monitor voltages at the load lead connections.

EXTERNAL & BATTERY VOLTS INDICATOR - Displays either "BATTERY VOLTS" or "VOLTS EXTERNAL" to inform user which voltage test function meter is in.

AMPS ZERO KEY - Resets amps display to "0". Display is set to "0" after load leads are connected and before the current probe is connected.

LOAD CONTROL - Regulates carbon pile that will apply up to 500 amps current draw for performing battery load tests and starting and charging systems tests. The carbon pile is fan cooled, but is not intended for continuous use.

Caution: When the load control function is not in use, always make sure that the load control is in the off position (rotated fully counterclockwise). Failure to do so could result in excessive battery drain or possible permanent damage to the battery(ies).

BATTERY TERMINAL ADAPTORS (YA242) - A set of 3/8" NC male and female, are provided for threaded top terminal and side terminal batteries. The adaptors are required for accurate testing and to prevent damage to battery.

SIDE TERMINAL ADAPTOR CLIPS (YA169) - Provide more reliable test connections and easier access to battery side terminals. The adaptor clips are inserted through the handles of the load lead clamps as shown in Fig. A. They are connected to the battery by sliding them over the side terminal bolts. The adaptors can be stored inside of the load lead clamps as shown in Fig. B.

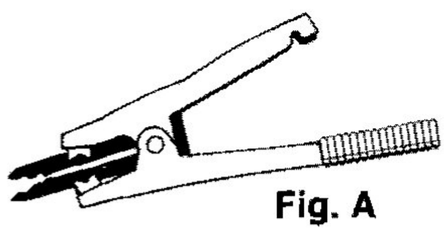

Fig. A

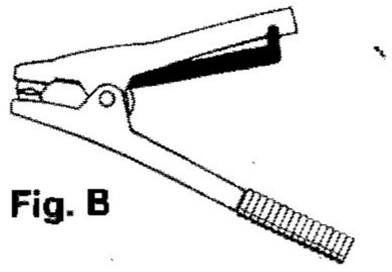

Fig. B

OPTIONAL EQUIPMENT FOR USE WITH THE MT1560

MTC1560	Vinyl Meter Cover
YA168A	Heavy Duty Battery Charger (fits Meter Stand)
YA313	Alternator/Regulator Test Lead Set
MT302	Remote Starter Switch (required for some tests)
BB4A	Battery Hydrometer/Thermometer (specific gravity testing of electrolyte)
FF100	Alternator Full Fielder (accepts all standard Delco, Ford and Chrysler regulator connectors)
FF101	Alternator Full Fielder (Delcotron SI series, Ford and Chrysler regulator connectors)
2005BSK	Battery Service Kit
MT137A	Digital Hand-Held Tachometer (no-load starter bench tests)
YA187	Amp Amplifier for amperage measurements as small as 1/10 amps.

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Equipment and Testing Tips

1. Observe all vehicle and/or equipment manufacturer's cautions and warnings when testing with the MT1560.

2. Double check all test lead connections before performing any tests.

3. The alternator diode test function should only be used when checking the quality of alternator output during alternator current output testing. The test function should be turned off, or disregarded during other testing.

4. Always use the included adaptors for charging/testing batteries equipped with side terminals or threaded top post adaptors. Standard post batteries require no adaptors. Substituting a standard bolt for the proper adaptor may cause overheating and consequent damage to battery terminals.

5. Be sure of battery polarity when installing or charging a battery(ies). Reverse polarity may damage rectifiers and other components of the charging system.

6. The current probe operates by sensing the electromagnetic field that is produced by current flow through a wire. For reliable readings, the probe should not be placed close to strong magnetic fields, such as are present in generators, alternators, A/C & heater blower motors, etc.

7. Under some conditions, heavy-duty diesel engines may require peak amps values above the MT1560's 1200 amp current range. Although the MT1560 displays amperages higher than 1200, the readings will be inaccurate.

8. Amperage readings higher than the MT1560's maximum current range (1200 amps) will not damage the instrument; but inaccurate readings will result.

9. Use care when servicing vehicles equipped with series-parallel switches as the switch may be permanently damaged if improper service procedures are conducted. Most switches have a maximum current handling capacity of approximately 40 amps (accessory contacts) and are easily damaged by even simple procedures such as battery charging. Always refer to manufacturer's procedures.

10. Turn key or ignition switch "off" when removing or installing the regulator cover. On some models, to safely remove the regulator cover it is necessary to disconnect the battery feed to the regulator first.

11. Some manufacturers have a procedure for "restoring magnetism" in the rotor after alternator service. This should not be confused with polarizing DC generator charging systems. DO NOT polarize an alternator.

12. When a procedure calls for an "ammeter in series", the current probe can be connected around the wire in that portion of the circuit without breaking (disconnecting) the circuit. Just connect the load leads to a voltage source of 6 - 24 VDC to power the tester, zero the amps display, and you are ready to attach the current probe. If you are bench testing, or a procedure calls for an "ammeter in series" and there are no circuit connecting wires, use a jumper wire(s) to "build" the circuit. Current can then be measured by placing the current probe around the jumper wire(s).

13. The MT1560 may be connected to a battery that is being charged with a battery charger to monitor charging current and voltage. This is done by connecting the load leads to the battery terminals and clamping the current probe around either battery charger lead.

    NOTE: The amperage may be displayed as negative depending on which cable the probe is placed around and in which direction the probe's arrow is pointing. The display will indicate if the battery(ies) is readily accepting the charge; or not. Excessive voltage indicates poor charge acceptance.

14. Occasionally inspect the contacts on the current probe for dirt build-up or other foreign matter. Clean with CRC Lectra-Motive 05018 Cleaner or equivalent. Spray contacts with tube tip 1" away. Dry with air nozzle from a distance of 6" or more.

15. Tester appearance can be maintained by periodically cleaning with a soft, damp cloth. To remove grease, use a mild detergent. Do not use cleaning agents such as acetone, benzene, carbon tetrachloride, gasoline, toluene, etc. Spills, such as diesel fuel, gasoline, brake fluid, battery acid and penetrating oil should be cleaned immediately.

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The Battery

The battery(ies) is the "heart" of a vehicle's electrical system. It converts charging system electrical energy into chemical energy, stores the chemical energy, and then converts it back into electrical energy to: (1) power the electric starter, (2) provide current to the ignition system during starting (gasoline engines), (3) power lights and electrical accessories when the engine is not operating, and (4) supplement the charging system when electrical demand exceeds its capacity. It also acts as a voltage stabilizer for the entire electrical system.

With the battery common to the entire electrical system, its condition must be considered first when diagnosing a starting or charging system problem. Battery condition is best determined by performing the battery load test. The battery load test checks the strength or endurance of a battery to provide a more positive determination of the condition of a battery than hydrometer or voltmeter tests. A battery tested with these meters may test good when no load is applied, but may no longer have the capacity to start an engine under adverse conditions, such as sub-zero temperatures.

Before a battery is load tested it should be visually inspected for physical defects. The battery should also be tested to make sure it meets or exceeds the minimum state-of-charge requirement. These are checked during the pretest.

Pretest

1. To prevent possible injury and to protect the vehicle from damage, perform a visual inspection of the battery(ies) and related components prior to a load test. Correct defects and/or replace battery(ies) and components as required. Look for the following conditions:
   - Proper battery(ies) for vehicle (meet minimum requirements)
   - Cracked case
   - Cracked cell cover
   - Sealing compound defect
   - Cell connector corrosion
   - Loose or overtightened battery hold-down
   - Dirt or acid
   - Loose or corroded terminals
   - Frayed or broken cables
   - Improper electrolyte level
   - Frozen electrolyte or resulting damage
2. Batteries must meet a minimum state-of-charge requirement before their condition can be accurately diagnosed by battery load testing. Batteries load tested that do not meet this minimum state-of-charge could test "bad" and be incorrectly condemned. A specific gravity or open circuit voltage test should be performed to determine a battery's state-of-charge.

   Note: A battery in an extremely discharged state, such as can be caused by parasitic drain (accessories that draw small current amounts continuously) over an extended period of time, may require many hours of charging. This is especially true for a maintenance-free battery. If charged long enough, it may return to a good usable state.

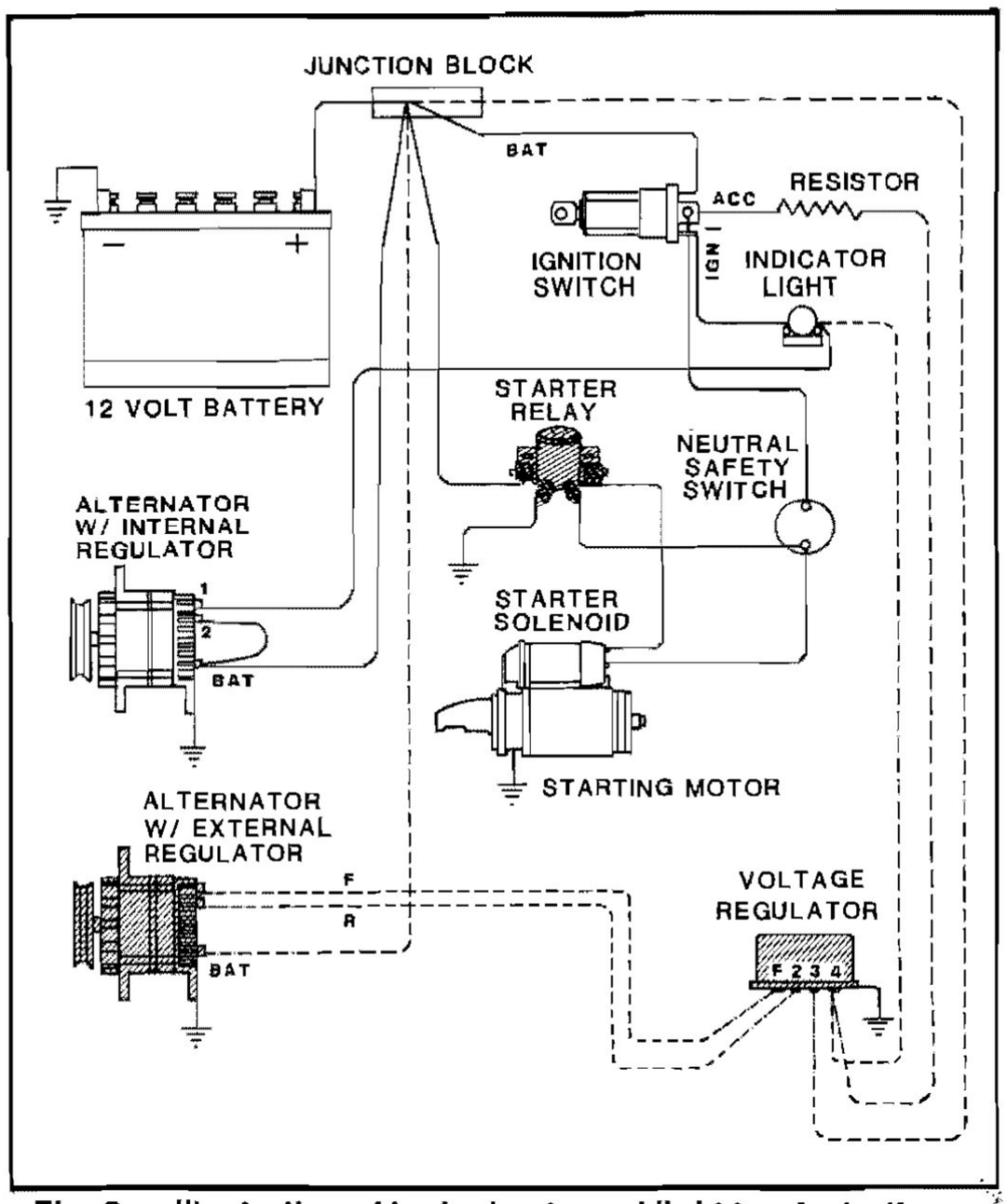

Fig. 2 — Illustration of typical auto and light truck starting and charging circuit. The shaded components and broken interconnecting wires show common variations, such as (1) a separate alternator and voltage regulator instead of an alternator with an integral regulator, and (2) a starter relay instead of a starter solenoid attached to the starter motor. Some starting systems use both the solenoid and the relay.

Specific Gravity - A hydrometer is used to test the specific gravity of electrolyte on batteries that allow access to the cells. The battery must test to a minimum of 1.225 (corrected for temperature) specific gravity, which indicates a 65% state-of-charge. If it does not, charge the battery and retest. If it still does not meet the minimum state-of-charge requirement, replace the battery. Also, replace any battery that has a fifty (0.050) point variation between the highest and lowest cell reading.

Note: The specific gravity of a fully charged battery should be at least 1.260 with the electrolyte at 80° F. The specific gravity reading is corrected for electrolyte temperature variations by adding four points (0.004) for each 10° above 80° F, and by subtracting four points for each 10° below 80° F.

Some maintenance-free batteries have a built-in hydrometer (color-coded state-of-charge indicator). Green indicates a specific gravity of 1.225 or higher, or that the state of charge is high enough for a load test. Yellow indicates that the battery is defective, should not be charged or load tested, and must be replaced. A dark color (any color other than green or yellow) indicates that the battery requires recharging.

Note: After battery charging, slight tipping or shaking of the battery may be necessary to make the indicator appear green.

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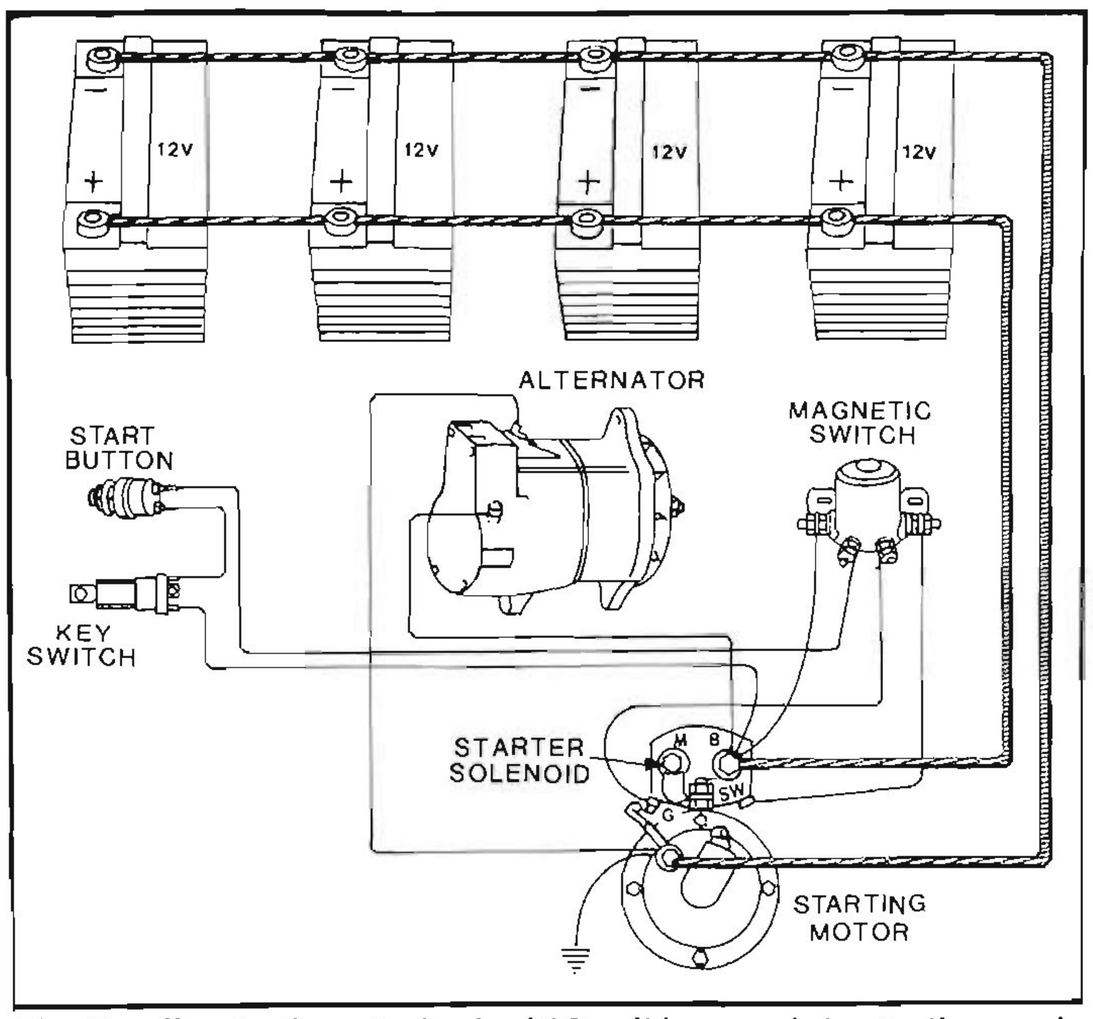

Fig. 3 — Illustration of a typical 12 volt heavy-duty starting and charging circuit with multiple batteries in a single-path parallel arrangement.

Refer to Medium & Heavy-Duty Vehicle Battery Arrangements on page 23 for illustrations and descriptions of other multiple battery systems.

Open Circuit Voltage (OCV) - The open circuit voltage test measures the terminal voltage of a battery to provide an indication of its state-of-charge. For 12 volt batteries, a voltage reading of 12.4 volts or higher indicates that the state-of-charge is at least 65%, and that the battery meets or exceeds the minimum requirement for load testing (6.2 volts for 6 volt battery).

For an open circuit voltage reading: (1) on vehicles with multiple batteries, disconnect interconnecting cable(s) as required to test batteries individually, (2) connect the MT1560 load leads to the battery terminals; red to positive and black to negative (tester will automatically be in BAT volts function when leads are connected) and (3) read the volts display. If a 12 volt battery tests to less than 12.4 volts (6 volt battery to less than 6.2 volts), charge the battery to at least this minimum level before load testing.

Note: Battery voltage must be stable for accurate test results. If the battery has been recently charged, it could take several hours for it to stabilize. To shorten the stabilization period, apply the proper test load to the battery for 15 seconds, and then allow a few minutes before taking a voltage reading. Also, a battery recently discharged by cranking must be allowed a few minutes to stabilize.

BATTERY LOAD TEST

1. Perform pretest (pg. 6).
2. With the load control off, connect load leads to the battery.
3. Determine the battery load test specification. The proper load to apply may be:

   - Stated on label by battery manufacturer
   - Specified by manufacturer of vehicle
   - One-half (1/2) of the battery's cold cranking amperage (CCA) rating (all battery voltages)
   - Three (3) times the amp-hour rating of 12 volt battery, and 2 times for 6-volt.

4. Zero AMPS display, if it does not read "0".
5. Clamp the current probe around the positive or negative load lead.
6. Turn the load knob to apply the proper test load to the battery. When the 15 seconds time indicator appears check the voltage reading, and then release the load knob.
7. Compare the voltage reading to the corrected-for-temperature minimum voltage requirements listed below. If the battery does not meet the minimum requirement, replace the battery.

Note: Estimate the battery temperature by touch and/or considering the temperature the battery has been exposed to during the preceding few hours, if an electrolyte thermometer is not available.

TEMPERATURE (°)								
Fahrenheit		70+	60	50	40	30	20	10	0
Celsius		21	16		104	-1	-7	-12	-18
MINIMUM	12V	9.6	9.5	9.4	9.3	9.1	8.9	8.7	8.5
VOLTAGE	8V	6.4	6.3	6.3	6.1	6.0	5.7	5.7	5.6
REQUIRED	6V	4.8	4.7	4.7	4.6	4.5	4.4	4.3	4.2

If the battery tests "good", but has performed unsatisfactorily in use, consider the following possible causes:

- *Accessories left on for an extended period of time.*
- *Vehicle has improper replacement battery.*

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- *Considerable slow driving with accessories on, or short driving periods with accessories left on.*
- *Defects in charging system; such as: slipping alt./gen. belt or other defective drive mechanism, high resistance, faulty alt./gen. or voltage regulator.*
- *Defects in electrical system, such as shorted or pinched wires.*
- *Previous improper battery charge.*
- *Poor battery cable to terminal connection.*
- *Loose or overtightened battery hold-down.*
- *Electrical demand exceeds charging system capacity, which can be caused by the addition of aftermarket accessories.*
- *Long periods of vehicle storage without disconnecting the battery (current drain from continuous draw accessories).*

The Electric Starting System

The function of a vehicle's starting system, put simply, is to rotate the engine's crankshaft so that the engine will begin to run under its own power. This system, also commonly referred to as the "cranking system", consists of several basic components, which include: (1) a battery(ies) and battery cables, (2) a starter motor, (3) an ignition or key switch, (4) a pushbutton start switch (some vehicles) (5) a starter relay and/or starter solenoid (may also include a series-parallel switch), and (6) a neutral safety switch (some vehicles).

Providing the cranking power for reliable engine starts requires all starting system components to be in good working order. Testing the starting system with the MT1560 can confirm that it is functioning properly, or provide valuable diagnostic information to isolate a problem in the system.

The Starting System Test measures starter current draw and cranking voltage. If the engine cranks good, and the starter current draw amperage and cranking voltage readings are within specifications, you can generally conclude that the starting system is functioning properly. But, if the starter does not crank, cranks too slowly, or the amps and/or volts reading are not within specifications, further testing will be required.

Before performing the Starting System Test, the starting system should be visually inspected for physical defects, and some preliminary checks should be performed that will aid you in diagnosing a starting system problem. These are done during the pretest.

Pretest

1. To prevent possible personal injury and protect the vehicle from damage, inspect the starting system for defects. Repair and/or replace any defective components. Check for the following:

   - Battery defects (see THE BATTERY - Pretest 1)
   - Frayed or broken electrical wiring
   - Corroded or loose connections
   - Loosely mounted starter motor, series-parallel switch, magnetic switch, solenoid, starter relay, etc.

2. Check state-of-charge of battery(ies). For dependable starter current draw test results, the batteries must be fully charged.

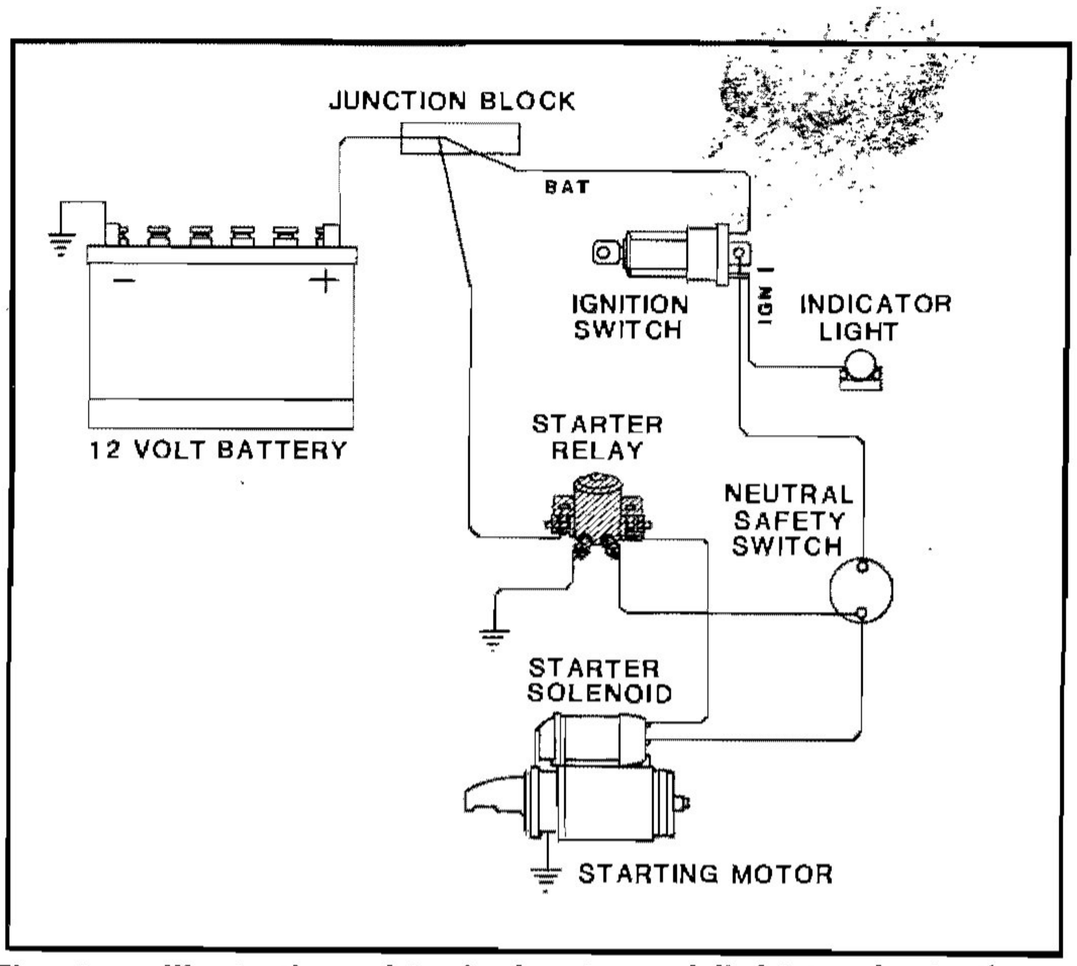

Fig. 4 — Illustration of typical auto and light truck starting system. A system may have either a starter solenoid or starter relay (shaded). Some systems are equipped with both.

3. Analyze and check symptoms of known starting system problems. Correct problems. Examples:

   - Battery(ies) fully charged, but starter will not crank engine or cranks slowly - Check for excessive resistance in starting system that is preventing full current from reaching the starter motor. See Troubleshooting Starting Systems (pg. 15).

     Keep in mind the non-starting system related problems that can prevent the starter from cranking or cause slow cranking, such as: internal engine defects (tight bearings, etc.), overheated engine, liquid in cylinders (hydrostatic lock), extremely cold temperatures, oil viscosity very high or very low, carbon deposits (higher compression), incorrect ignition or diesel injection timing, etc.

   - Starter spins, but does not crank engine - Remove starter and check starter drive and flywheel for excessive wear. Check for improper starter drive pinion clearance.

   - Starter cranking is noisy - Check for loose, worn, and misaligned starter components. Also check flywheel. On starters with adjustable pinion clearance, check and adjust pinion clearance, if necessary.

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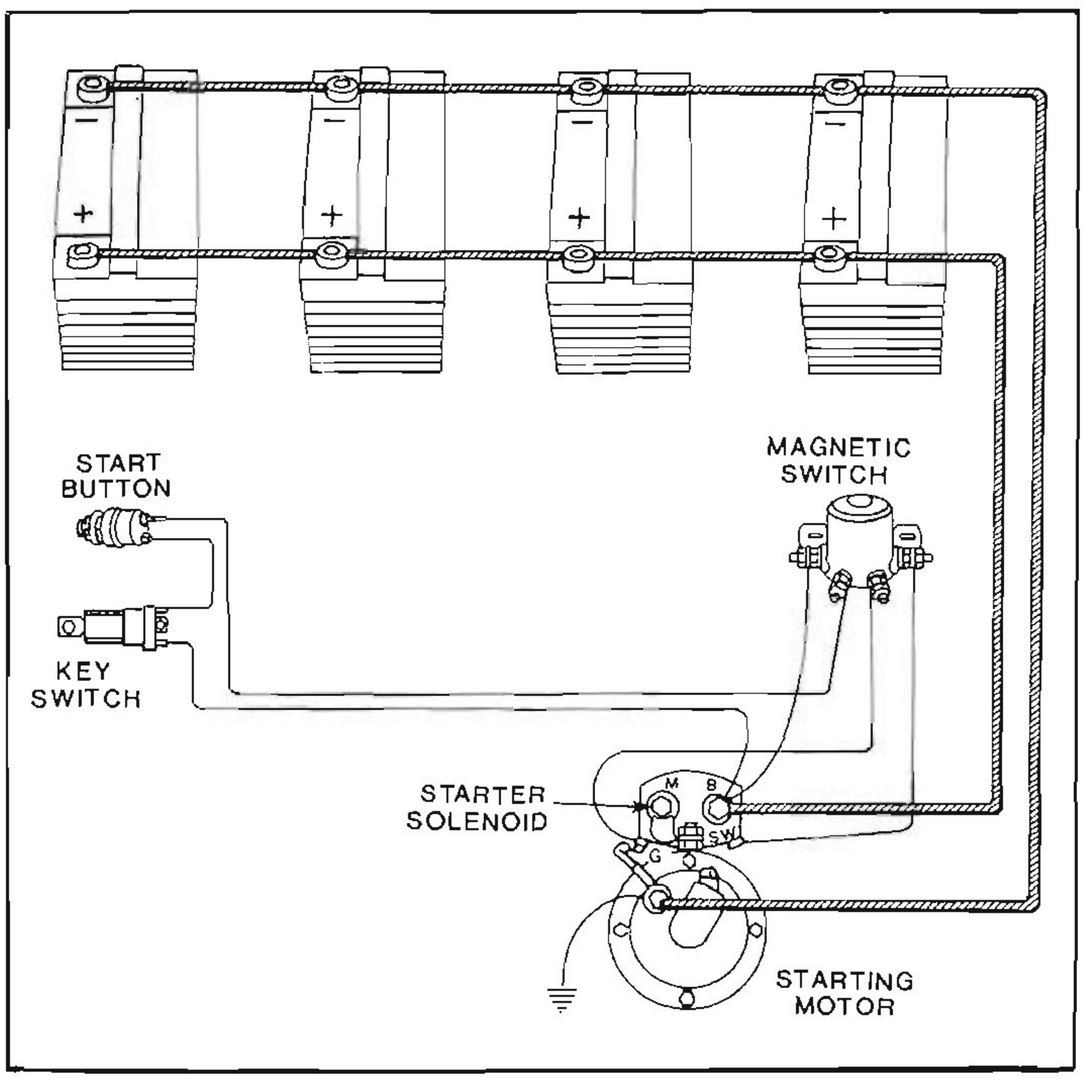

Fig. 5 — Illustration of a typical heavy-duty 12 volt starting system with batteries connected in parallel.

STARTING SYSTEM TEST

The following test procedure is intended for use on automotive and light truck starting systems primarily, because starter current draw and cranking voltage specifications are rarely given by manufacturers for medium and heavy-duty starting systems. The procedure can be used to test these systems if the specifications are known.

Manufacturers of medium and heavy-duty vehicles usually recommend that all other starting system components be checked first, by performing voltage available and voltage drop tests. If all of the components test good, their procedure is to remove the starter, "no load" bench test it, and compare current requirement and armature speed to specifications.

To test medium and heavy-duty starting systems when manufacturer does not provide starter current draw and cranking voltage specifications, refer to Troubleshooting Starting Systems - Medium and Heavy-Duty Starting Systems on page 16.

1. Perform pretest (pg. 8).

2. Turn off all of the vehicle's electrical accessories. Battery(ies) should be fully charged and vehicle should be at shop temperature.

3. Disable the ignition system (gasoline engine) or fuel system (diesel engine) to prevent engine from starting during test.

   Ignition system with remote ignition coil(s) - disconnect coil wire from distributor cap and ground the wire(s).

   Ignition system with integral coil ignition system - disconnect BAT wire from distributor.

   Diesel fuel systems - As required, (1) disconnect fuel solenoid wire and insulate it from ground, or (2) move fuel control lever or shut-off device to "off" position.

4. With load control in the off position, connect load leads as follows:

   12 volt system - across the battery (any battery on a multiple battery system)

   24 volt system - across one 12 volt battery, or two 6 volt batteries that are connected in series (12 volt connection can be verified by reading voltage display with tester in BAT volts function). Then, connect EXT leads across the the battery connections that provide 24 volts (24 volt connection can be verified by reading voltage display with tester in EXT Volts function).

5. Zero AMPS display if it does not read zero (0).

6. Make sure tester is in BAT volts function (EXT volts function for 24 volt system).

7. Connect the current probe as follows:

   Auto & light truck - around starter cable.

(Cont'd)

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Medium & heavy-duty systems - around either the positive or negative starter cable.

For dual path circuits (Pg. 24, Fig. 15) - around both positive or negative starter cables. If this can not be done, test each side individually and add the amps readings for total current draw.

8. Crank engine and observe amps and volts readings (after readings have leveled off - not peak readings). Compare readings to vehicle specifications.

CAUTION: To prevent starter damage, do not crank engine for more than 15 seconds. Allow two minutes for cooling between cranking tests.

If starter current draw is too high, or voltage is below minimum specification, or the engine cranks slowly or not at all, refer to Troubleshooting Starter Systems.

Starter current draw specifications vary considerably, depending on engine size, type (gas or diesel), compression ratio, etc. The following auto and light truck current draw information is to be considered as a general guideline, as it is normal for some starting systems to draw more amperage.

4 cyl. gas engine - typically draws 120 to 200 amps for direct drive starters and 150 to 250 for reduction gear starters.

4 cyl. diesel - typically draws up to 350 amps.

6 cyl. gas engine - typically draws up to 250 amps (less with larger diameter starter).

6 cyl. diesel - typically draws up to 450 amps.

8 cyl. gas - typically draws up to 250 amps.

8 cyl. diesel - typically draws up to 650 amps.

The Charging System

The primary functions of the charging system are to provide the proper amount of energy to operate the vehicle's electrical systems while the vehicle is running, and replace the battery energy expended during engine starts and while supplementing the charging system when electrical demand exceeds output.

Today's charging systems most commonly consist of an (1) alternator - converts mechanical energy into alternating electrical current (AC), and rectifies the AC into direct current (DC), (2) voltage regulator - controls the electrical output of the alternator, (3) key or ignition switch - activates the voltage regulator, (4) dashboard mounted indicator light or gauge - alerts driver to problems in the charging system, (5) battery(ies) - (refer to THE BATTERY, pg. 6), and (6) the interconnecting cables and wires.

The charging system check consists of several tests. The basic test is the current output test, which measures the total current output of the alternator to determine if it is capable of supplying its rated output. Next, the quality of the alternator output is tested (alternator diode test). And then, the regulated voltage level to the battery(ies) and accessories is tested to make sure it is within manufacturer's specifications - too low will allow the battery(ies) to discharge, and too high can damage the battery(ies) and other electrical system components. The charging system troubleshooting section provides other tests for identifying faulty components and checking wiring and connections.

Before performing charging system tests, the system should be visually inspected for physical defects, and some preliminary checks should be performed that will aid in diagnosing a charging system problem. These are done during the pretest.

Pretest

1. Check the battery(ies) for physical defects and make sure that it is fully charged (see THE BATTERY - Pretest and BATTERY LOAD TEST).
2. Visually inspect charging system components. Repair or replace defective components as required. Check for the following:

   - Loose, overtightened, frayed, stretched, glazed, oily, or improper belt (defective heavy-duty alternator drive mechanism)
   - Loose mounting bolts
   - Loose drive pulley
   - Damaged external alternator or generator fan
   - Frayed or broken wiring
   - Corroded or loose electrical connections
   - Improperly grounded voltage regulator

3. Run engine and listen for any abnormal sounds, such as could be caused by internal alternator problems, belt problems, damaged alternator fan, misaligned pulley, etc. Repair or replace malfunctioning components as required.

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output with both alternator and internal

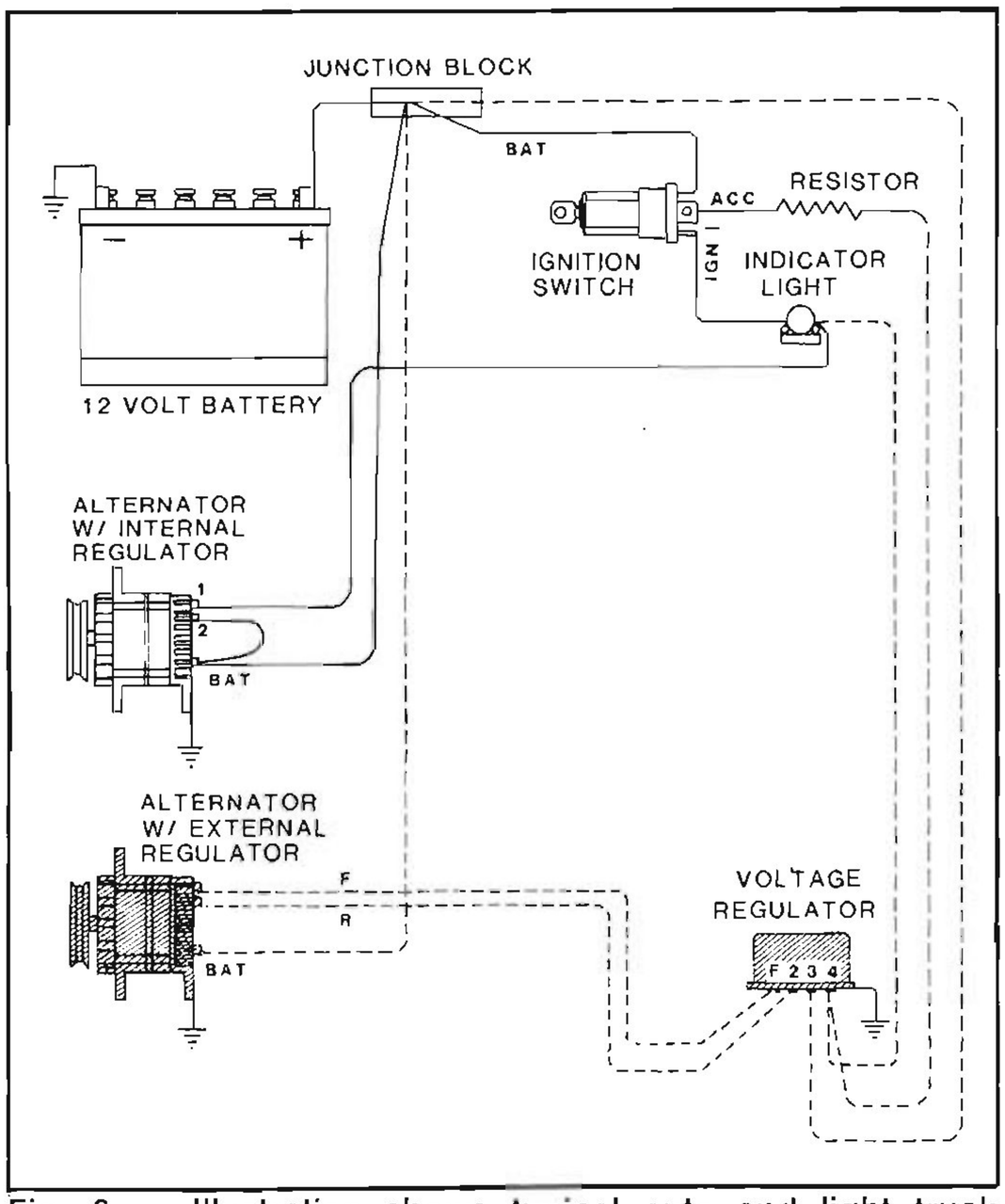

Fig. 6 — Illustration shows typical auto and light truck charging systems. A system may be equipped with either an alternator with an internal regulator, or a separate alternator and regulator (shown shaded with wiring represented by broken lines).

Refer to illustration of heavy-duty starting and charging systems on page 7 for example of heavy-duty charging system. The starting motor and starter solenoid are included in the charging system illustration because the alternator's output and ground wires connect to them.

4. If vehicle is equipped with an ammeter or voltmeter, check meter for indication of charging system malfunction.

5. If vehicle is equipped with an instrument panel indicator light, observe light for abnormal operation. Proper operation is as follows:

Ignition Switch	Indicator Lamp	Engine
off	off	stopped
on	on	stopped
on	off	running

Check abnormal operating conditions as follows:

Off/on/stopped - Remove field current supply to field terminal (terminal R or #1). If light stays on, there is a short in this wire. If light goes out, the rectifier bridge is faulty.

On/off/stopped - Check for blown fuse, bad bulb, defective socket, or an open in the field current supply wire.

On/on/running - Check fuse and proceed to charging system tests. Check alternator, regulator, wires, connections, belt tension, etc.

CHARGING SYSTEM TESTS

Alternator Current Output Tests

Auto & light truck, and medium & heavy-duty alternators not equipped with 24 volt transformer-rectifier (TR)

If heavy-duty vehicle is equipped with two alternators connected in parallel, test each separately.

NOTE: The following procedure can be used to test current output on DC generators.

1. Perform charging system pretest (pg. 10).

2. Turn off all of the vehicle's electrical accessories. Battery(ies) should be fully charged and vehicle should be at shop temperature.

3. With load control in the off position, connect load leads as follows:

   12 volt system - across the battery (any battery on a multiple battery system).

   24 volt system - across one 12 volt battery, or two 6 volt batteries that are connected in series. 12 volt connection can be verified by reading voltage display with tester in BAT volts function. Connect EXT leads across the battery connections that provide 24 volts. 24 volt connection can be verified by reading voltage display with tester in EXT volts function.

4. Zero AMPS display, if it does not read zero (0).

5. Make sure tester is in BAT volts function (EXT volts function for 24 volt system) and that ALTERNATOR DIODE TEST function is on.

6. Clamp current probe around the alternator output wire (at least 6" from alternator) - on the alternator output wire alone if it goes

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directly to the battery(ies), or on alternator output wire between alternator and where a feed wire splices off to operate an accessory (heater blower fan, etc.).

On automotive and light trucks, if neither of the above current probe connections can be made, clamp current probe around all cables going to negative battery terminal. Turn ignition switch to "ON" (do not start engine) and note the current draw. Add current draw to the charging output reading when comparing to manufacturer's specification in Step 8.

7. Operate engine at moderate speed as required and adjust the load control knob to obtain the highest AMPS reading (remember reading). Then, reduce the load to half of the alternator's rated output and observe the alternator diode test display. Return carbon pile to off position, and turn off diode test function and engine.

8. Compare AMPS reading to manufacturer's rated output, which is usually stamped on the alternator case or on attached tag.

If current output is within 10% of alternator's rated amperage, the alternator tests good. Proceed to Voltage Regulator Test on page 14.

If current output is not within 10% of alternator's rated amperage, refer to Charging System Troubleshooting - Bypassing the Voltage Regulator to determine if the alternator is faulty (pg. 21).

Interpret alternator diode test indication by referring to ALTERNATOR DIODE TEST FUNCTION.

ALTERNATOR DIODE TEST FUNCTION

The alternator diode test provides an indication of the condition of the alternator's diodes and stator by monitoring the quality of the alternator output current. It tests for unwanted alternating current (AC), relative to the direct current (DC), flowing through the alternator output wire.

The alternator diode test display indicates the condition of the diodes and stator as follows:

GOOD	Indicates acceptable quality of alternator output current.
MARGINAL	Indicates questionable quality of alternator output current. If the alternator diode indicator display flashes alternately between two conditions, interpret towards the better condition. Marginal is usually an early indication of a problem that may get progressively worse. Bench testing may be recommended. However, judgement to proceed with further tests or repairs should depend on whether the alternator output is unsatisfactory or if there is a driver complaint regarding the charging or starting system.
BAD	Indicates unacceptable quality of output current. Remove unit for testing. Repair or replace as necessary.

The alternator diode test indicator should be turned off when not in use. Disregard the indicator if it is left on during other testing.

Note: Some vehicles have accessories that operate on AC voltage. Watch for these systems when testing, because special conditions and/or procedures may be required. See manufacturer's recommendations.

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Transformer-Rectifier (TR) Equipped Alternators

TR equipped alternators will have two separate output wires carrying different output voltages and current amounts. Typically, the TR unit's voltage output will be double that of the alternator's, but at at a greatly reduced amperage. The TR unit's output is used only for the purpose of charging the C (cranking) battery, and the alternator's output is used for charging the other S (system) battery(ies) and operating vehicle accessories. These systems have several operating characteristics:

As C battery charge increases, TR unit output will decline and alternator output may increase (depending on state of charge of S battery(ies).

Under normal operating conditions, the TR will have the C battery recharged in about 15 minutes after starting.

TR units have no voltage adjustments, yet they are controlled indirectly by the voltage level of the alternator's output.

The two sources of current output of a TR equipped alternator are tested separately. The sum of the alternator's output and the TR's output should equal the alternator's rated output.

Measuring Current at Alternator 12 Volt Output Terminal

For accurate test results, S and C batteries must be fully charged.

1. Connect load leads across S battery(ies).

   To identify "S" and "C" battery(ies) on negative ground systems: (1) connect load leads to any battery (2) press EXT volts (3) attach negative EXT lead to a good frame or engine ground (not to battery) (4) start engine, accelerate momentarily and allow to idle (5) touch positive EXT lead to positive terminal of each battery. A "C" battery is indicated by about a 26 - 30 volt reading. An "S" battery is indicated by about a 13 - 15 volt reading. Note: On positive ground systems, reverse EXT lead connections.

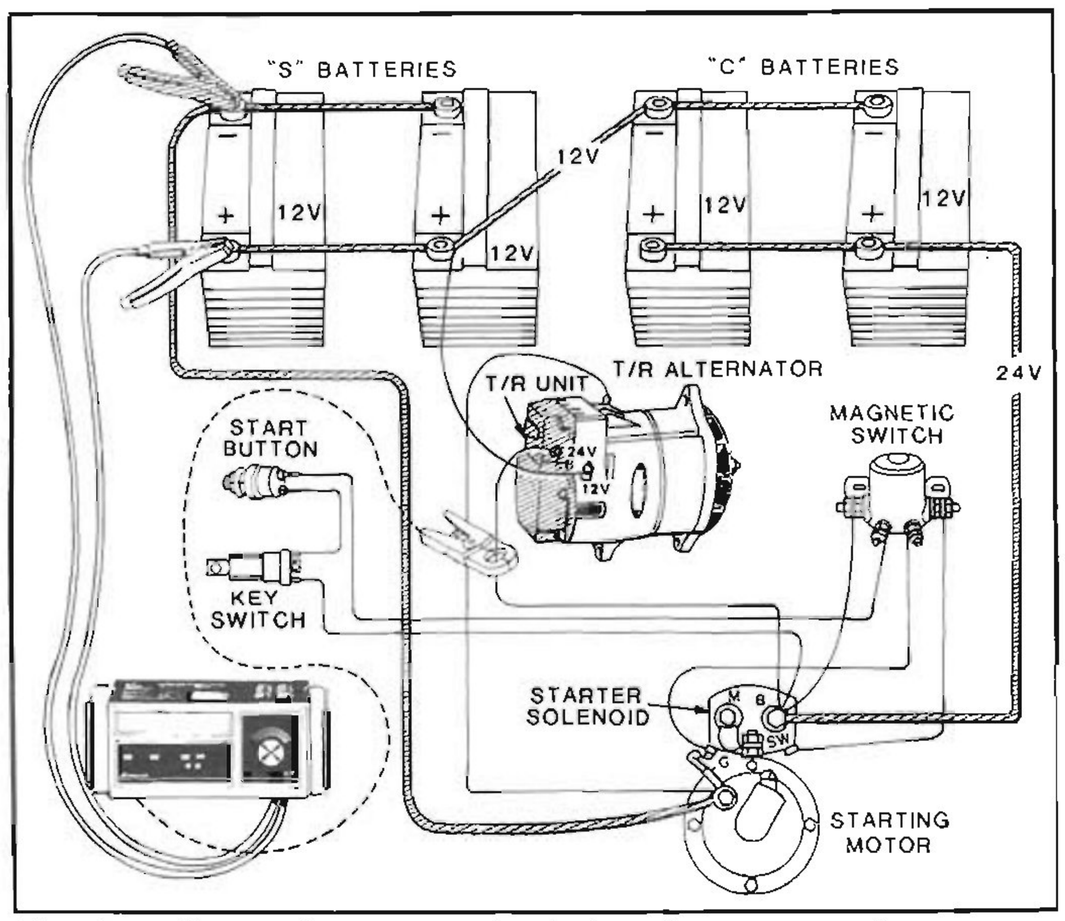

Fig. 7 — Illustration of a typical charging system that uses an alternator equipped with a transformer rectifier. Current probe connections for testing T/R unit's 24 volt output current is shown.

2. Perform Steps 4 - 8 of preceeding Alternator Current Output Tests.

   If alternator passes current output and alternator diode tests, continue with the following transformer-rectifier test.

   If current output is low, remove TR unit from alternator and retest the alternator, as a faulty TR unit can reduce the alternator's current output. If alternator then tests bad, refer to Medium and Heavy-Duty Charging Circuit Resistance Tests (pg. 22) Repair or replace any defective circuit components or connections. If charging circuit is OK and alternator still tests bad, remove the alternator and bench test it per manufacturer's procedure. Repair or replace alternator as required, and retest. If it tests good, reinstall TR unit and continue testing.

Measuring Current at Transformer-Rectifier 24 Volt Output Terminal

3. Connect load leads to the C battery(ies).

4. Zero AMPS display, if it does not read "0".

5. Make sure tester is in BAT volts function and that ALTERNATOR DIODE TEST function is on.

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6. Connect current probe to either load lead.

7. With engine off and key switch in off position, apply load to cranking "C" battery for 15 seconds - the same load that would be used for battery load test. The proper load may be:

   - Stated on label by battery manufacturer
   - Specified by manufacturer of vehicle
   - One-half (1/2) of the battery's cold cranking amperage (CCA) rating
   - Three (3) times the amp-hour rating

8. Connect current probe to the TR output wire (at least 6" away from the alternator/TR).

9. Start the engine, run at moderate speed, and note AMPS reading and the alternator diode test display.

10. Current output should be at least 5 amps. If it is less than 5 amps, remove TR unit and bench test per manufacturer's procedure.

    Interpret alternator diode test indication by referring to ALTERNATOR DIODE TEST FUNCTION on pg. 12.

Voltage Regulator Test

If heavy-duty vehicle is equipped with two alternators connected in parallel, test each alternator's voltage regulator separately.

1. Perform Steps 1 - 6 of Alternator Current Output Tests for auto & light truck, and medium & heavy-duty alternators not equipped with transformer-rectifiers (pg. 11).

2. Operate engine at moderate speed as required with all accessories off. Allow some running time for charging system to stabilize (charging system should be at normal operating temperature).

3. Observe VOLTS and AMPS readings and compare to manufacturer's specification(s).

Note: Normally, for 12 volt systems, a voltage reading of 13.0 to 15.0, and an amperage reading between 0 and 10 indicate that the voltage regulation system is good (24 volt system: 26.0 - 30.0V with 0 - 10A).

Less than 13.0V with 0-10A, and the alternator passes the current output test, the problem is the regulator (24 volt system: less than 26.0V with 0 - 10A).

Less than 13.0V and more than 10A, indicates an undercharged battery (24 volt system: less than 26.0V and more than 10A).

If 13.0V to 15.0V and 10A or higher (24 volt system: 26.0 - 30.0V and 10A or higher), run engine at a fast idle for about 15 minutes (or charge battery) and retest. If amperage is still too high, test battery. If amperage is OK (0 -10A), but voltage is less than 13.0, a regulator problem is indicated (24 volt system: less than 26.0V).

If 15V or higher (24 volt system: 30V), regardless of amperage reading, disable field circuit (external regulator only) per manufacturer's procedure. A drop in voltage indicates a regulator problem. Voltage remaining high indicates an alternator problem. If this condition is encountered on an alternator with an integral regulator, remove the alternator and bench test it per manufacturer's procedure.

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Troubleshooting Starting & Charging Systems

Troubleshooting tests are performed to determine if there is a problem in the circuit being tested, and to isolate the defective component(s) if a problem exists. The tests measure current (amps), voltage available at different points in the circuit, or voltage drop between points in the circuit. Amps and volts test data provides valuable information on the condition of a starting or charging system.

Amps measurements enable you to determine if starter current draw is normal or excessive, and if alternator current output is good, too high or low. If amps testing indicates that there is a problem, voltage available and voltage drop testing is done to determine the cause(s) of the problem.

Voltage available tests are performed to determine if voltage is present in the circuit and/or for a voltage measurement to compare against a specification. Although voltage available can be measured with the tester in the battery volts function using the load leads, the external volts function is more commonly used for troubleshooting tests. To test voltage available, the negative lead must be connected to the negative side of the test circuit and the positive lead to the positive side of the circuit.

Voltage drop tests measure the amount of voltage (pressure) expended in overcoming resistance (opposition to current flow); the lower the voltage drop reading, the less resistance there is in the portion of the circuit being tested. A "0" (zero) reading indicates that the amount of resistance is very low; too small for measurement with this instrument. To measure voltage drop, the load leads must be connected to power the tester, current must be flowing in the circuit, and both EXT leads must be connected on the same side of the circuit. If EXT leads are connected with one on each side of the circuit, the tester will display voltage available.

Voltage drop can also be determined from available voltage readings, by subtracting each successive reading from the previous reading.

TROUBLESHOOTING STARTING SYSTEMS

Starting system troubleshooting tests are divided into two sections - Auto & Light Truck Starting Systems and Medium & Heavy-Duty Starting Systems. Manufacturers of automobiles and light trucks generally specify procedures that require operation of the starter. Medium and heavy-duty starter system procedures usually specify that tests be done using a carbon pile to apply a load.

Auto & Light Truck Starting Systems

VOLTAGE AVAILABLE TESTS FOR ISOLATING PROBLEM AREAS

If the cranking amps test reading was too high, the voltage reading too low, or the engine cranked too slowly or not at all (Starter System Test - Step 8), check for available voltages while cranking as follows:

1. With load leads connected and tester in the EXT volts function, connect the negative EXT lead to the negative battery terminal.

2. Connect positive EXT lead to the positive battery terminal. If voltage reading is 9.6 volts or more and the starter does not crank or cranks slowly, perform insulated circuit and ground circuit voltage drop tests.

3. Move positive EXT lead to the starter solenoid battery (B) terminal - If voltage reading is 9.0 volts or more and the starter does not crank, perform starter control circuit voltage drop test. If the voltage reading is 9.0 volts or more and the starter cranks slowly, repair or replace starter if the problem is in not the vehicle's engine.

4. Move positive EXT lead to the starter solenoid starter (S) terminal - If voltage reading is 7.0 volts or more and starter does not crank, repair or replace starter or solenoid if the problem is not in the vehicle's engine. If the voltage reading is less than 7.0 volts, perform starter control circuit voltage drop test.

VOLTAGE DROP TESTS FOR DETERMINING DEFECTIVE COMPONENT(S)

CAUTION: Do not use the allowable voltage drop values, provided in the following test procedures, when testing circuits that use aluminum cables. Refer to manufacturer's specifications.

Insulated Circuit Voltage Drop Test

1. Connect load leads to battery (battery should be fully charged).

2. Connect EXT positive lead to positive battery terminal.

3. Connect EXT negative lead to starter motor battery terminal.

4. Crank engine (engine disabled to prevent it from starting) and read voltage.

5. Refer to manufacturer's specification for voltage drop. If specification is not available, refer to the following

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list to determine the insulated circuit's maximum allowable voltage drop. The maximum allowable voltage drop is the total of the allowable voltage drop values for all of the components and connections in a series circuit.

	Allowable Voltage Drop
Cables up to 3 ft.	0.1V
Cables over 3 ft.	0.2V
Magnetic switches	0.3V
Solenoid switches	0.2V
Mechanical switches	0.1V
Connections	0.0V

If the voltage reading is within allowable maximum voltage drop specification, the insulated circuit is in good operating condition.

If voltage reading at the starter terminal exceeds the maximum allowable voltage drop, the point of excessive resistance can be located by checking the voltage reading at each connection and cable end, working your way back from the starter motor battery terminal towards the battery. Do this by disconnecting the black lead from the starter motor battery terminal and using it to probe at each of these points. When a sharp decrease in voltage drop is observed, the cause of the excessive resistance will be located between that test point and the previous test point.

Ground Circuit Voltage Drop Test

1. Connect load leads to battery (battery should be fully charged).

2. Connect EXT negative lead to negative battery terminal.

3. Connect EXT positive lead to starter drive housing frame.

4. Crank engine (engine disabled to prevent it from starting) and read voltage. Normally it should not exceed 0.3 volts. Refer to manufacturer's specification, as some specify a 0.2V or 0.1V maximum.

5. If voltage drop reading exceeds specification, connect EXT positive lead at the following points and crank engine. Compare the readings to the typical maximum allowable voltage drops listed below (12 volt system only).

Negative battery cable at engine	
cable length up to 3 ft.	0.1V
cable length over 3 ft.	0.2V
Negative battery cable connector	0.0V

Starter Control Circuit Voltage Drop Test

1. Connect load leads to battery (battery should be fully charged).

2. Connect EXT positive lead to positive battery terminal.

3. Connect EXT negative lead to switch (S) terminal at the starter relay or solenoid.

4. Crank engine (engine disabled to prevent it from starting) and compare reading to specification (typically 2.0V to 2.5V).

   If voltage drop reading is more than specification, excessive resistance in the control circuit is indicated. Use the EXT negative lead to check voltage at the following points to isolate the defective component: neutral safety switch (or clutch switch), ignition switch, and any junctions or connections back to and including the battery terminals.

   If voltage drop reading is within specification and the solenoid switch does not pull-in or close, the solenoid switch is at fault.

Medium & Heavy-Duty Starting Systems

The following medium and heavy-duty starter system general testing procedure is intended for use when the vehicle manufacturer does not provide or specify a starter cranking test procedure and/or starter system test specifications.

This testing procedure will assist you in locating the cause(s) of poor cranking performance — engine cranks slow, erratic, rhythmically uneven, or not at all.

CAUTION: Do not use the following test procedures if the system being tested is a combination 12/24 volt system using a series-parallel switch or transformer-rectifier (T/R) type alternator. Refer to manufacturer's procedures and specifications.

CRANKING VOLTAGE AVAILABLE AT THE STARTER

If engine cranking performance is poor and the vehicle's battery(ies) test good (see Battery Load Test), perform the following starter cranking voltage test.

1. Disable the ignition system (gasoline engine) or fuel system (diesel engine) to prevent engine from starting during test.

   Ignition system with remote ignition coil(s) - disconnect coil wire from distributor cap and ground the wire(s).

   Integral coil ignition system - disconnect battery wire from distributor.

   Diesel fuel systems - As required, (1) disconnect fuel solenoid wire shut-off wire and insulate it from touching ground, or (2) move fuel control lever or shut-off device to "off" position.

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2. With the load control in the off position, connect the positive load lead to the starter solenoid battery (BAT or B) terminal and the negative load lead to the starter ground terminal. Reverse these lead connections for positive ground systems.

3. With tester in BAT volts function, crank engine and observe starter cranking voltage reading and cranking performance.

   CAUTION: To prevent starter damage, do not crank engine for more than 15 seconds. Allow two minutes for cooling between cranking tests.

   The minimum voltage reading for a 12 volt cranking system is usually 9.0 volts; 18 volts for a 24 volt system.

4. Compare the results of the test to the voltage and cranking performance conditions listed on the chart and refer to the recommended troubleshooting sequence. The letters A - I identify the troubleshooting procedures that follow. When a defective component is found, repair or replace it, and repeat this test.

Voltage	Cranking Performance	Troubleshooting Sequence
Good	Slow	HIJ
Good	Does not crank	DEFHIJ
Good	Erratic*	DEFGHI
Good	Rhythmically uneven**	J
Low	Slow or does not crank	ABCIJ
Low	Erratic*	ABCHJ
Low	Fair	ABCHIJ

* Refers to erratic starter operation.
** Refers to engine cranking speed.

Note: When performing troubleshooting tests A & B on multiple battery installations using dual path circuitry (2 sets of cables), test each side separately. Disconnect the batteries on the side not being tested.

If manufacturer does not provide test specifications, refer to the following chart of typical individual allowable voltage drop values. The maximum allowable resistance is the total of the individual allowable voltage drop values for all of the components and connections within that portion of the circuit being tested.

Cables up to 3 ft.	0.1V
Cables over 3 ft.	0.2V
Magnetic switches	0.3V
Solenoid switches	0.2V
Mechanical switches	0.1V
Connections	0.0V

CAUTION: When using the carbon pile to apply load, the starting system troubleshooting tests must be performed with 12 volts in the circuit being tested. 6 volt and 24 volt systems must be temporarily reconnected to provide 12 volts. When testing is completed, reconnect batteries to restore system to normal operating voltage.

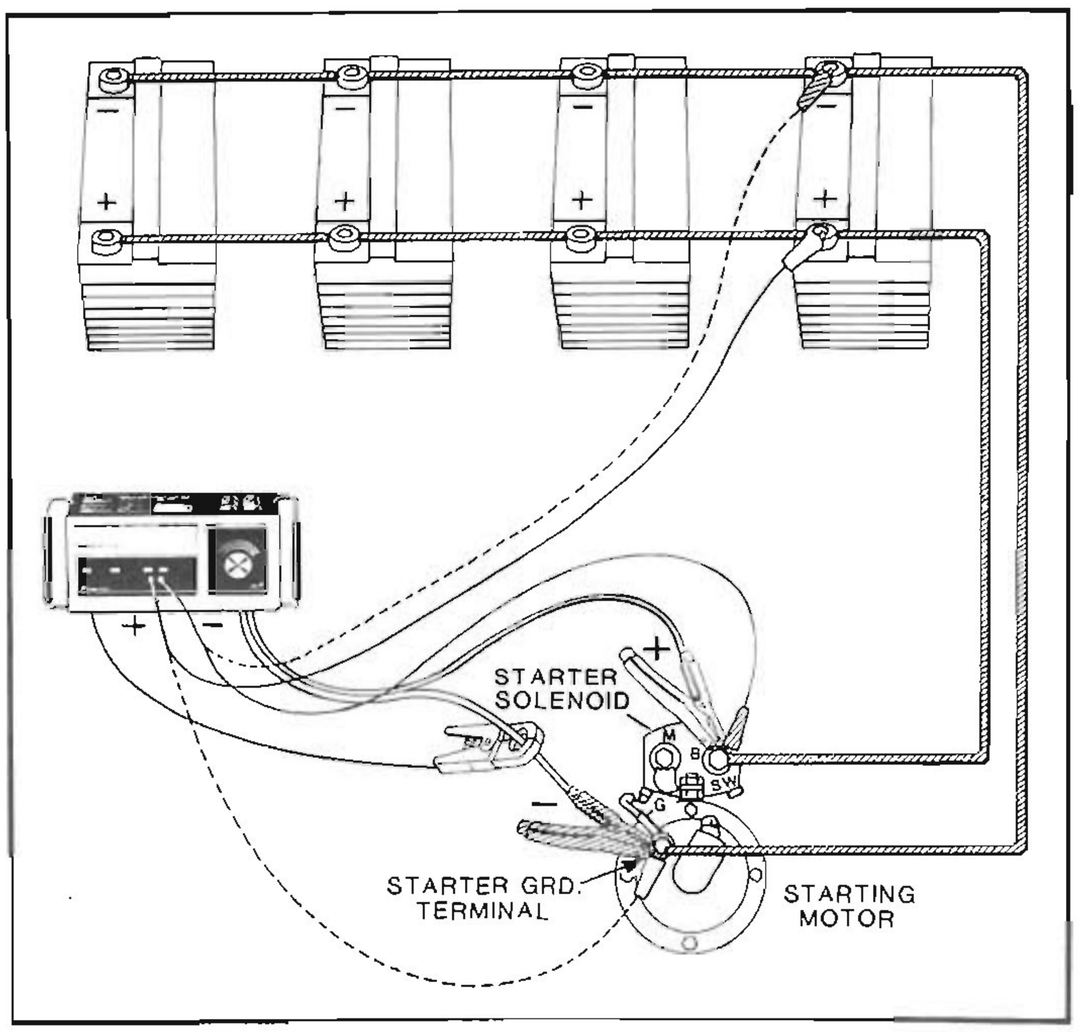

Fig. 8 — Illustration of typical lead connections for troubleshooting procedures B and C. The load leads and current probe connections are the same for both tests. The broken lines are used to indicate the EXT lead connections for C.

A Interconnecting Battery Cables for Parallel Battery Arrangements (if so equipped)

1. Lead connections:

   Load leads - positive to solenoid BAT terminal and negative to the starter ground terminal.

   Current probe - not required.

   EXT leads - see step 2.

2. Quickly measure each battery's voltage by touching the EXT leads to their positive and negative posts (stud nuts) while cranking the engine.

   The terminal voltage between any two interconnected batteries should not vary by more than 0.5 volts. Repair or replace any interconnecting cable that exceeds this, or feels warm to the touch.

   Note: On series battery arrangements, quickly measure the voltage at each battery's posts or stud nuts and then at the terminal clamps that connect to the posts or stud nuts. The difference between these two readings will be the total voltage drop between the posts (or stud nuts) and the terminal clamps.

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B Insulated Circuit Battery Cable(s) from Battery(ies) to Starter

1. Lead connections (Fig. 8):

   Load leads - positive to the starter solenoid battery (BAT or B) terminal and the negative load lead to the starter ground terminal. Reverse these lead connections for positive ground systems.

   Current probe - Zero AMPS reading, and then connect probe to either load lead.

   EXT leads - positive to battery positive terminal and negative to solenoid battery (BAT, B) terminal, not load lead clamp.

2. With tester in EXT volts function, apply a 500 amp load with load control. Quickly measure voltage. Release load and record voltage.

   If voltage drop is excessive, check connections, and repair or replace defective components as necessary.

   If cable has a magnetic, master/battery disconnect switch, etc., check for excessive voltage drop across switch.

C Ground Circuit Battery Cable(s) from Battery(ies) to Starter

1. Use same load lead and current probe connections as used for test B.
2. Connect positive EXT lead to starter ground terminal and negative EXT lead to negative battery post (Fig. 8).
3. With tester in EXT volts function, apply a 500 amp load with load control.

   If voltage drop is excessive, check connections, and repair or replace defective components as necessary.

D Magnetic Switch (Solenoid) Circuit

1. Disconnect the wire to the SW (S) terminal at the solenoid.
2. Lead connections (Fig. 9):

   Load leads - positive to end of disconnected SW wire (alligator clip or jumper wire may make connection easier) and negative to the starter ground terminal.

   Current probe - See step 3.

   EXT leads - positive to solenoid battery terminal and negative to the side of the magnetic switch that the solenoid's BAT (B) cable connects to.

3. Activate the magnetic switch (using key switch, starter button or remote switch). Zero AMPS reading, and then connect probe to either load lead. Press EXT volts and adjust carbon pile to 80 amps load (45 amps for 24 volt system) and observe voltage reading. Return load control to off position and record voltage reading.
4. Reconnect EXT leads; positive to the other large terminal of magnetic switch and negative to end of wire disconnected from SW terminal of solenoid. Disconnect current probe and repeat Step #3.

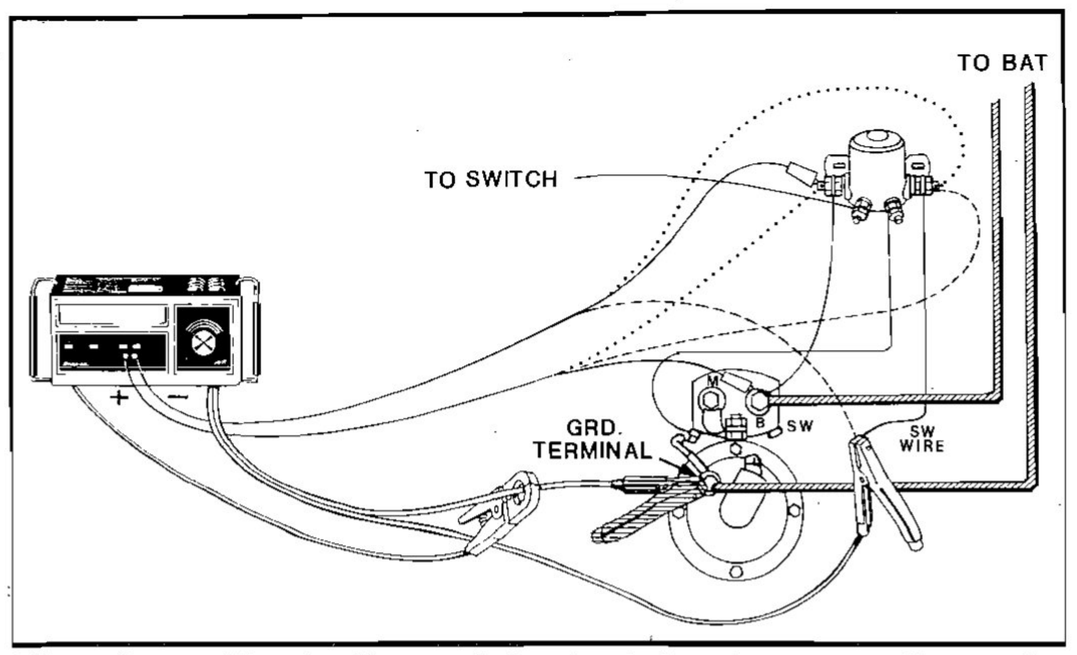

Fig. 9 — Illustration of typical lead connections for troubleshooting procedure D. The EXT lead connections shown with a solid line are used in step 2 of the procedure, the broken line (dashes) in step 4, and the dotted line in step 5. Load leads and current probe connections remain the same throughout the procedure.

5. Move positive EXT lead to the BAT side of the magnetic switch and the negative EXT lead to the solenoid side of the magnetic switch. Disconnect current probe and repeat Step 3.

6. Compare the three voltage readings to specifications. If none are available, refer to list of allowable voltage drops on page . Repair or replace defective wires or switch as necessary.

   Note: On 24 volt systems, the temporary 12 volts may not be enough to close the magnetic switch. Bypass the switch when performing Steps 3 & 4, by placing a jumper cable across the two large switch terminals. To check voltage drop across the switch, reconnect batteries to 24 volts, connect EXT leads across the magnetic switch, crank engine (disabled), and note the reading.

E Magnetic Switch Control Circuit - Insulated Side

Note: Some heavy-duty starting systems use special circuits (ADLO - automatic disengagement & lock-out, OCP - overcrank protection, etc.) to prevent accidental or prolonged starter operation. These may be located in the insulated or ground side of the control circuit. Refer to manufacturer's procedures for testing these circuits.

1. If system voltage has been changed to 12 volts for other testing, restore system to normal voltage.

2. Disconnect wire from SW (S) terminal of solenoid and insulate it to prevent it from grounding.

3. Lead connections:

   Load leads - positive to battery terminal at starter solenoid and negative to starter ground terminal.
   Current probe - not required.

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EXT leads - positive to starter solenoid BAT (B) terminal (not load lead clamp) and negative to ignition switch BAT terminal.

4. With tester in EXT volts function, turn key to "on" position (start position if no starter button), press start button (magnetic switch should close), and record voltage reading.

5. The remainder of the components of the insulated side of the control circuit are tested in the same manner by progressively moving the EXT leads across each component and taking a voltage drop reading with the magnetic switch closed.

6. Check voltage drop readings against specifications. If none are available, refer to list of allowable voltage drops on pg. 17.

7. Repair or replace defective components.

F Magnetic Switch Ground Circuit

Refer to note at beginning of test section E.

1. If system voltage has been changed to 12 volts for other testing, restore system to normal voltage.

2. Disconnect wire from SW (S) terminal of solenoid and insulate it to prevent it from grounding.

3. Lead connections:

   Load leads - positive to BAT (B) terminal at starter solenoid and negative to starter ground terminal.

   Current probe - not required.

   EXT leads - positive to magnetic switch ground terminal and negative to starter ground terminal (not load lead clamp).

4. With tester in EXT volts function, turn key to on position (start position if no starter button), press start button (magnetic switch should close), and record voltage reading.

5. The remainder of the components (if any) on the ground side of the magnetic switch circuit are tested in the same manner by progressively moving the EXT leads across each component and taking a voltage drop reading with the magnetic switch closed.

6. Check voltage drop readings against specifications. If none are available, refer to list of allowable voltage drops on pg. 17.

7. Repair or replace defective components.

G Solenoid-to-Starter Ground Cable

1. Reconnect SW wire to starter solenoid if disconnected.

2. Lead connections:

   Load leads - positive to BAT (B) terminal at starter solenoid and negative to starter ground terminal.

   Current probe - not required.

   EXT leads - positive to starter solenoid ground (G) terminal and negative to starter ground terminal (not load lead clamp).

3. With tester in EXT volts function, crank engine (disabled), and read voltage drop.
   If voltage drop is over 0.1 volt, repair or replace solenoid-to-starter ground cable.

H Starter Mounting Bolts

A loose starter may cause an erratic cranking condition due to improper starter drive engagement.

I No-Load Bench Test

The no-load bench test requires:

a set of jumper cables with heavy-duty cable clamps

tachometer - a light emitting type (Snap-on MT137A) or a mechanical type

remote starter switch (Snap-on MT302), if testing solenoid equipped starter

WARNING: MAKE SURE REMOTE STARTER SWITCH IS IN THE OPEN (BUTTON RELEASED) POSITION PRIOR TO CONNECTING OR DISCONNECTING TEST LEADS.

CAUTION: DO NOT test at voltages above the specified level. Voltage levels above specification may cause excessive armature speeds, resulting in thrown windings.

SOLENOID EQUIPPED STARTERS
(Refer to test circuit diagram Fig. 10)

1. Secure starter to bench to prevent its movement when operating starter.

2. Connect one jumper cable to the positive battery post and the BAT (B) terminal on the solenoid.

3. Connect another jumper cable to the negative battery post and the starter motor case or starter ground terminal.
   Some starters may also require a jumper wire between the starter solenoid ground terminal and starter ground terminal or case.

4. Lead connections:

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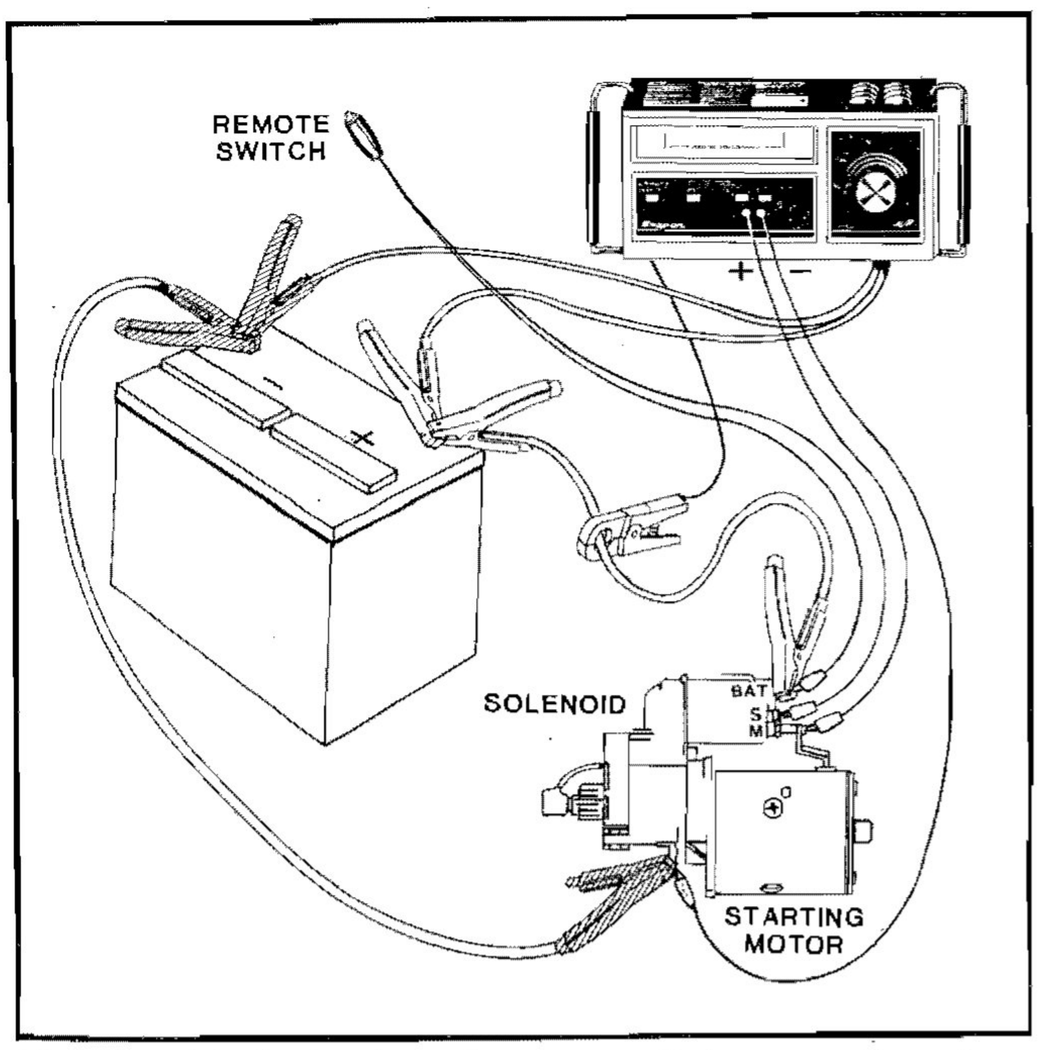

Fig. 10 — Tester leads and remote switch connections for no-load bench testing typical solenoid equipped starters.

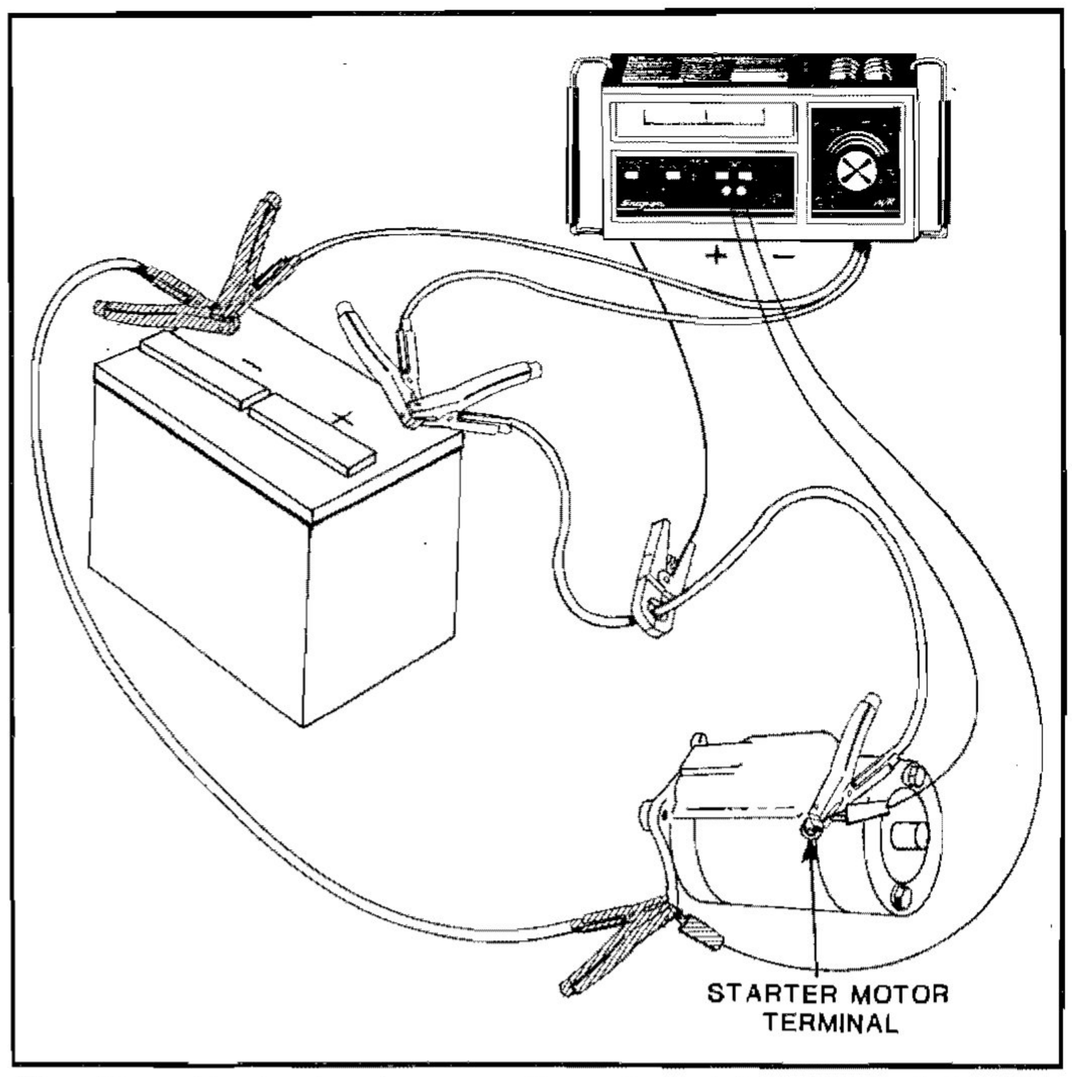

Fig. 11 — Tester lead connections for no-load bench testing typical non-solenoid equipped starters.

Load leads - with load control off, connect load leads to fully charged test battery(ies) of the proper voltage.

Current probe - to either jumper cable, near the battery(ies).

Connecting probe near starter may cause false readings due to strong magnetic fields surrounding the starter during operation.

EXT leads - positive to M (motor) terminal of solenoid and negative to starter motor case or ground terminal.

5. With the remote starter switch in the open position, connect its leads to the solenoid's BAT (B) and SW (S) terminals.

6. With the tester in the EXT volts function, close remote starter switch (starter should operate) and apply load with carbon pile to obtain specified test voltage. DO NOT test at voltages above specifications.

   Quickly observe starter amps reading and armature speed. Operate starter only as long as needed to obtain readings.

7. Compare readings against specifications. If repairs are necessary, follow manufacturer's procedures.

NON-SOLENOID EQUIPPED STARTERS
(Refer to test circuit diagram Fig. 11)

This procedure does not use the remote starter switch, as it does not have sufficient current carrying capabililty for this test.

1. Secure starter to bench to prevent its movement when testing.

2. Connect one jumper cable to the positive battery post and the starter motor's stud terminal.

3. Lead connections:

   Load leads - with load control off, connect load leads to fully charged test battery(ies) of the proper voltage.

   Current probe - to the jumper cable, near the battery(ies).

   Connecting probe near starter may cause false readings due to strong magnetic fields surrounding the starter during operation.

   EXT leads - positive to starter motor's stud terminal and negative to starter motor case or ground terminal.

4. With the tester in the EXT volts function, connect another jumper cable; first to the negative battery post and then to the starter motor case (starter should operate). Apply load with carbon pile to obtain specified test voltage. DO NOT test at voltages above specifications.

   Quickly observe starter amps reading and armature speed. Operate starter only as long as needed to obtain readings, and disconnect jumper cable from starter motor case.

5. Compare readings against specifications. If repairs are necessary, follow manufacturer's procedures.

J Engine Defects

Check the engine for defects such as excessive internal friction, compression problems, damaged flywheel ring gear and/or starter drive, etc.

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TROUBLESHOOTING CHARGING SYSTEMS

Bypassing the Voltage Regulator

Note: Some alternators with integral (built-in) regulators, such as Delco-Remy heavy-duty SI series, Delco-Remy CS series, Ducellier, Hitachi with IC (integrated circuit), etc., have no means for bypassing the voltage regulator. If a charging problem is encountered on charging systems with these types of alternators, the interconnecting circuitry must be checked first. Then, if the circuitry tests good, or repairs to the circuitry have been made and a charging problem is still experienced, the alternator must be bench tested.

The voltage regulator is bypassed to determine if the alternator or voltage regulator is at fault when the alternator fails to pass the current output test.

This test is usually performed by disconnecting the field wire from the alternator and then connecting a jumper wire between the alternator's field and battery (BAT) terminals.

Some alternators (Chrysler) have two field terminals. In this case, disconnect the green (regulator) field wire at the alternator and connect a jumper wire from that alternator field terminal to ground.

Some alternators (Ford) are most easily bypassed by disconnecting the regulator wiring connector at the regulator and placing a jumper wire between the connector's F and A terminals.

Some alternators (GM and Mitsubishi) have a test hole in the rectifier end frame. This hole allows a grounding tap to be touched with a screwdriver tip while the screwdriver shaft is grounded against the alternator case.

Some alternators (Leece-Neville) have a test hole in the brush holder housing. A short piece of stiff wire, such as a paper clip, may be inserted to contact the outer brush terminal. A short jumper wire is then connected to the negative generator output terminal and the paper clip.

Procedure:

With ignition or key switch in the off position, and the engine stopped, perform bypass connection(s) per manufacturer's procedure that applies to the type of unit being tested. Then retest the alternator current output.

If within 10% of rated output:

External regulator - check wiring between regulator and alternator. If wiring is OK, replace regulator and retest.

Integral regulator - replace regulator.

If not within 10% of rated output:

External regulator - check wiring between regulator and alternator. If wiring is OK, perform charging circuit resistance troubleshooting tests. If charging circuit tests good, and output is still not within 10%, bench test alternator.

Integral regulator - perform charging circuit resistance troubleshooting tests. If charging circuit tests good, and output is still not within 10%, bench test alternator.

Auto & Light Truck Charging Circuit Resistance Tests

The following circuit resistance tests are performed to check for areas of high resistance in the charging system's wiring and connectors - resistance that can reduce the amount of current available for operating electrical components and charging the battery. These tests measure voltage drop to locate high resistance.

1. Turn off all of the vehicle's electrical accessories. Battery(ies) should be fully charged and vehicle should be at shop temperature.

2. With engine off and load control in the off position, connect load leads to battery.

3. Connect EXT leads; positive to alternator's output (BAT) terminal, and negative lead to positive battery terminal.

4. Clamp current probe around the alternator output wire (at least 6" from alternator) - on the alternator output wire alone if it goes directly to the battery(ies), or on alternator output wire between alternator and where a feed wire splices off to operate an accessory (heater blower fan, etc.).

   If neither of the above current probe connections can be made, clamp current probe around all cables going to negative battery terminal.

5. Press EXT volts switch, and zero AMPS display.

6. Start engine and momentarily increase engine speed to about 1500 rpm. Then let engine idle at normal speed.

7. Adjust load control until meter reads about 20 amps of charging current, observe the volts reading, and return load control to off position.

   Typically, 0.3V or less - insulated circuit OK.

   Over 0.3V - repair or replace any loose, corroded or damaged wiring or connectors.

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8. Reconnect EXT leads; positive lead to negative battery terminal, and negative lead to alternator's ground wire or case. Apply 20 amp test load.

   0.3V or less - indicates ground circuit is OK.

   Over 0.3V - repair or replace any loose, corroded or damaged wiring and/or connectors.

9. While applying 20 amp test load, touch EXT positive lead to chassis or body ground to determine if high resistance exists between charging system ground and body.

   0.1V or less - ground circuit is OK.

   Over 0.1V - repair or replace any loose, corroded or damaged wiring, connectors, or mounting brackets.

GM Delcotron SI Series alternators specify an available voltage test be made at the alternator terminals. Test with ignition switch in "ON" position, and the alternator terminal connectors attached. Connect EXT negative lead to ground. Use EXT positive lead to probe the alternator's BAT, #1, and #2 terminals and note voltage readings. Results: Any zero (0) voltage reading indicates an open between that terminal connection and the battery. Repair as required.

Medium and Heavy-Duty Charging Circuit Resistance Tests

INSULATED CIRCUIT VOLTAGE DROP

1. With key switch off and engine stopped, reconnect batteries to provide a 12 volt system, if necessary.

2. Connect positive load lead to alternator output (battery) terminal and negative to alternator case (ground).

3. Zero amps reading, and connect current probe to either load lead.

4. Press EXT volts and connect positive EXT lead to positive battery post and negative EXT lead to alternator output terminal (not load lead clamp).

5. Determine alternator's rated output (usually stamped on alternator case or attached tag).

6. Adjust load control until the indicated load is the same as the alternator's rated output and note voltage. Return load control to off position. (Continue with ground circuit voltage drop - step 7.)

GROUND CIRCUIT VOLTAGE DROP

7. Reconnect EXT leads; positive to alternator case or ground screw (not load lead clamp) and negative to the negative battery post.

8. Repeat Step 6. The reading indicated is the ground circuit voltage drop.

9. A voltage drop in excess of 0.3 volts on the insulated and 0.2 volts on the ground side of the circuit usually indicates a circuit problem. If voltage drop is excessive, locate cause(s) by testing components and connections in that side of the circuit with the EXT leads while applying load as in Step 6.

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Medium & Heavy-Duty Vehicle Battery Arrangements

Medium and heavy-duty vehicle battery arrangements vary in the number of batteries used, the voltage of the batteries, and how the batteries are interconnected (the circuitry). Each type of circuit has its own characteristics. Following are some examples of different battery/circuit arrangements and a brief description of their advantages.

Series Arrangement (Fig. 12) - When batteries are connected in series, the system voltage will equal the total of the voltages of all batteries, while current available will be the same as that from just one battery. This voltage increase is used to provide faster engine cranking speed.

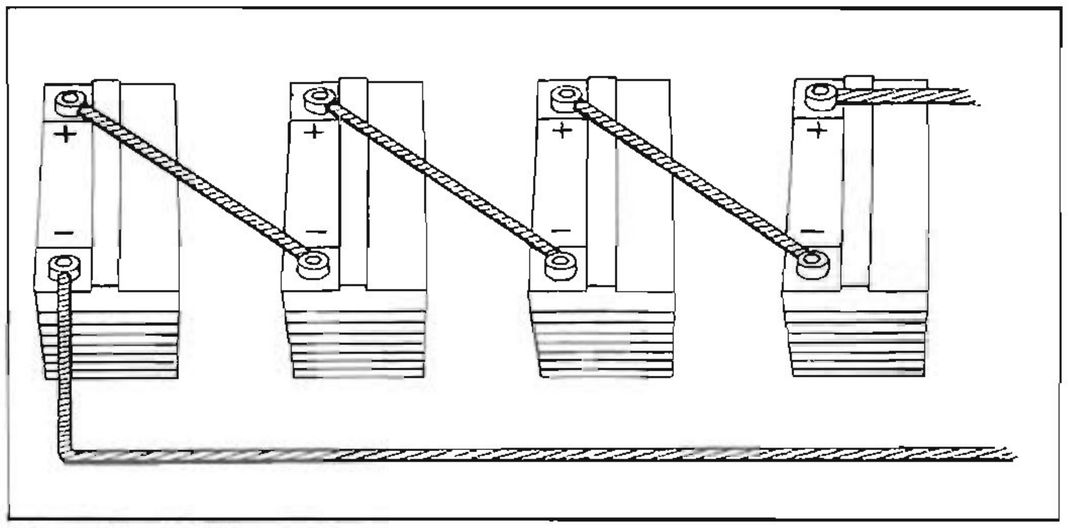

Fig. 12 — Illustration of 4 batteries connected in series. If batteries are 6 volt, this arrangement will provide 24 volts.

Parallel Arrangement (Fig. 13) - When batteries are connected in parallel, the voltage available is the same as one battery, while current available is the total available from all batteries. More current available provides the reserve for extended electrical system operation.

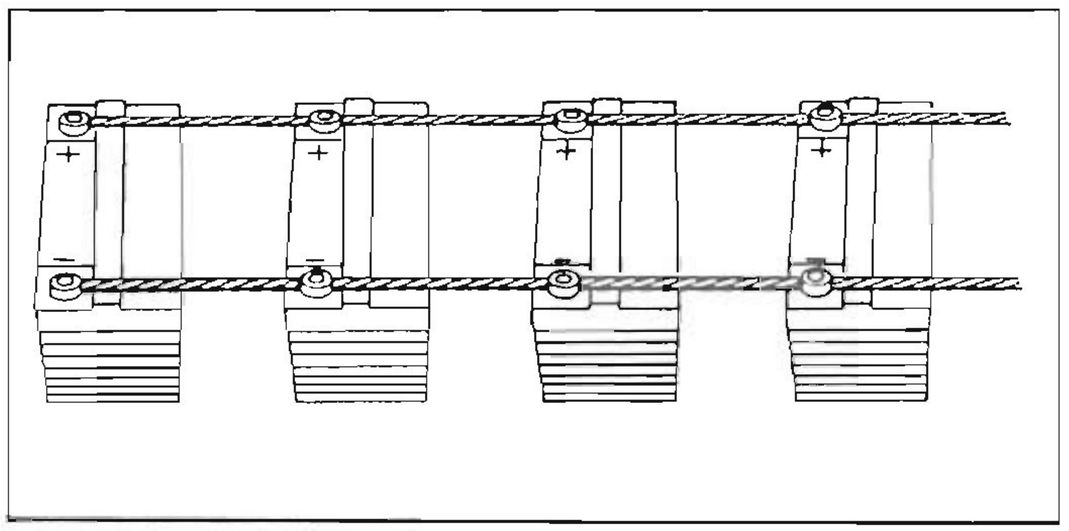

Fig. 13 — Illustration of 4 batteries connected parallel. If the batteries are 6 volt, this arrangement will provide 6 volts; if 12 volt batteries, 12 volts, etc.

Combination Circuits - Batteries may be arranged in combinations of series and parallel circuits using either single (Fig. 14) or dual (Fig. 15) paths. These may be used in conjunction with a switch to alternate circuits. These arrangements provide the advantages of both types of circuits.

Series-Parallel Switches - These switches are usually used to connect two 12 volt batteries, (or two groups of 6 volt batteries) in series for 24 volt cranking and to connect the same batteries in parallel for 12 volt charging and electrical system operation. Electrical systems using series-parallel switches are gradually being replaced by electrical systems using alternators equipped with T/R (transformer-rectifier) units.

The following illustrations of series-parallel circuits (Figs. 16, 17 & 18) are provided only to enable identification of series-parallel circuits. Refer to manufacturer's shop manuals for test procedures.

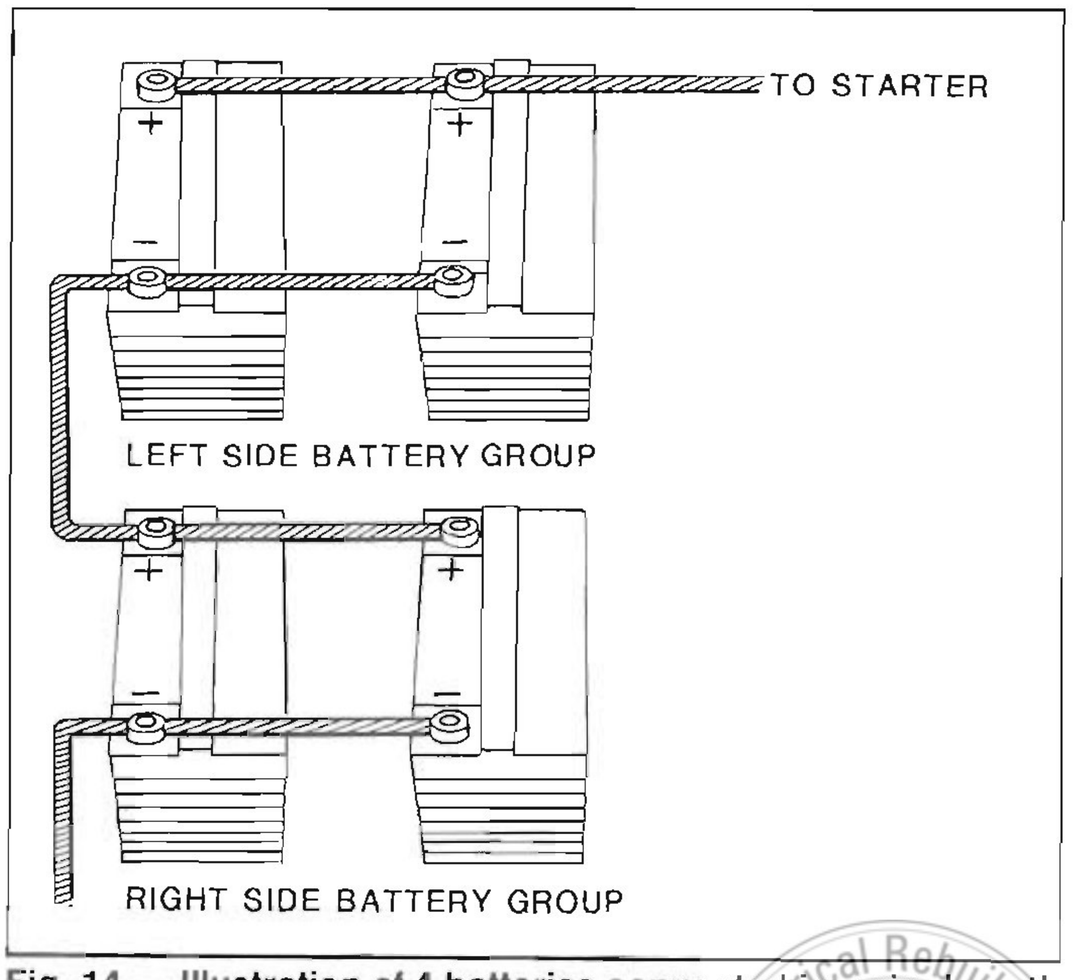

Fig. 14 — Illustration of 4 batteries connected in a single path parallel-series arrangement.

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KENOSHA, WI 53141-1410

Form ZMT1560
5M-BP

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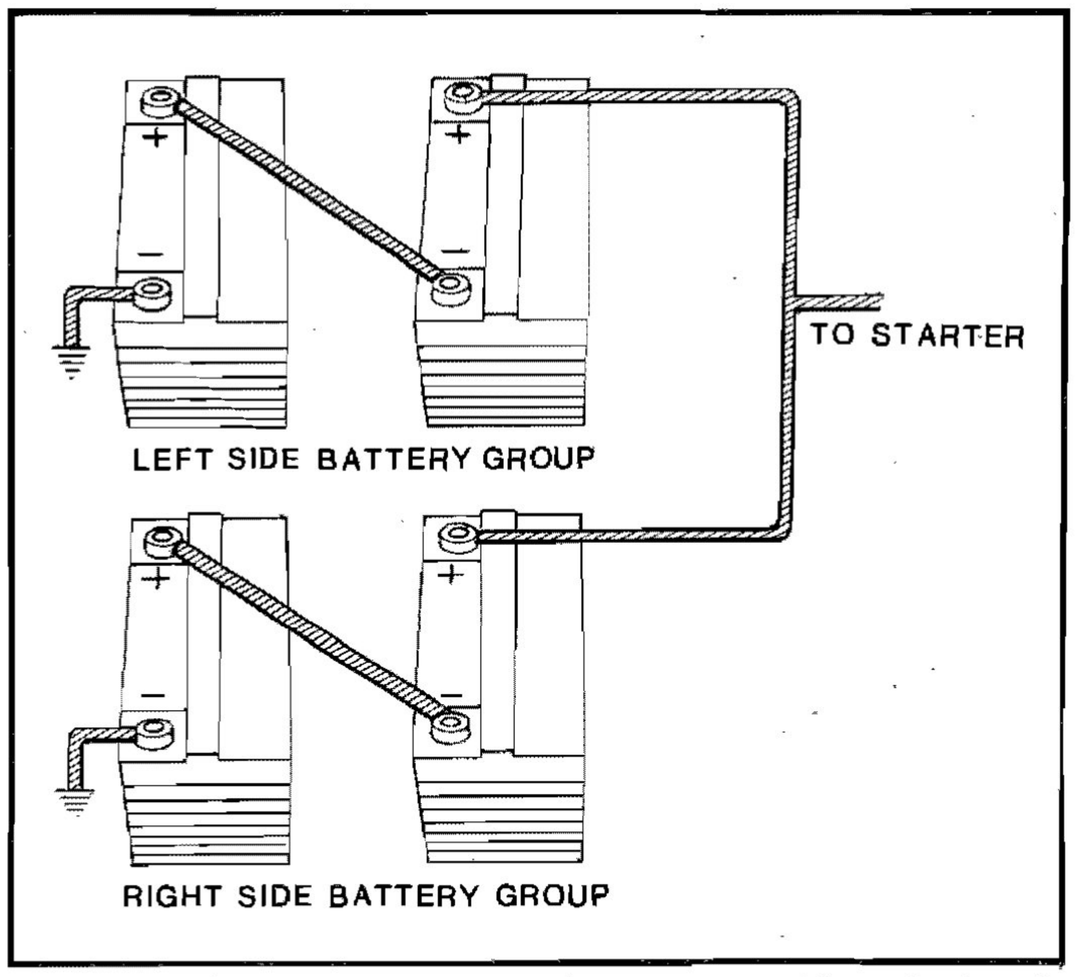

Fig. 15 — Illustration of 4 batteries connected in a dual path series-parallel arrangement.

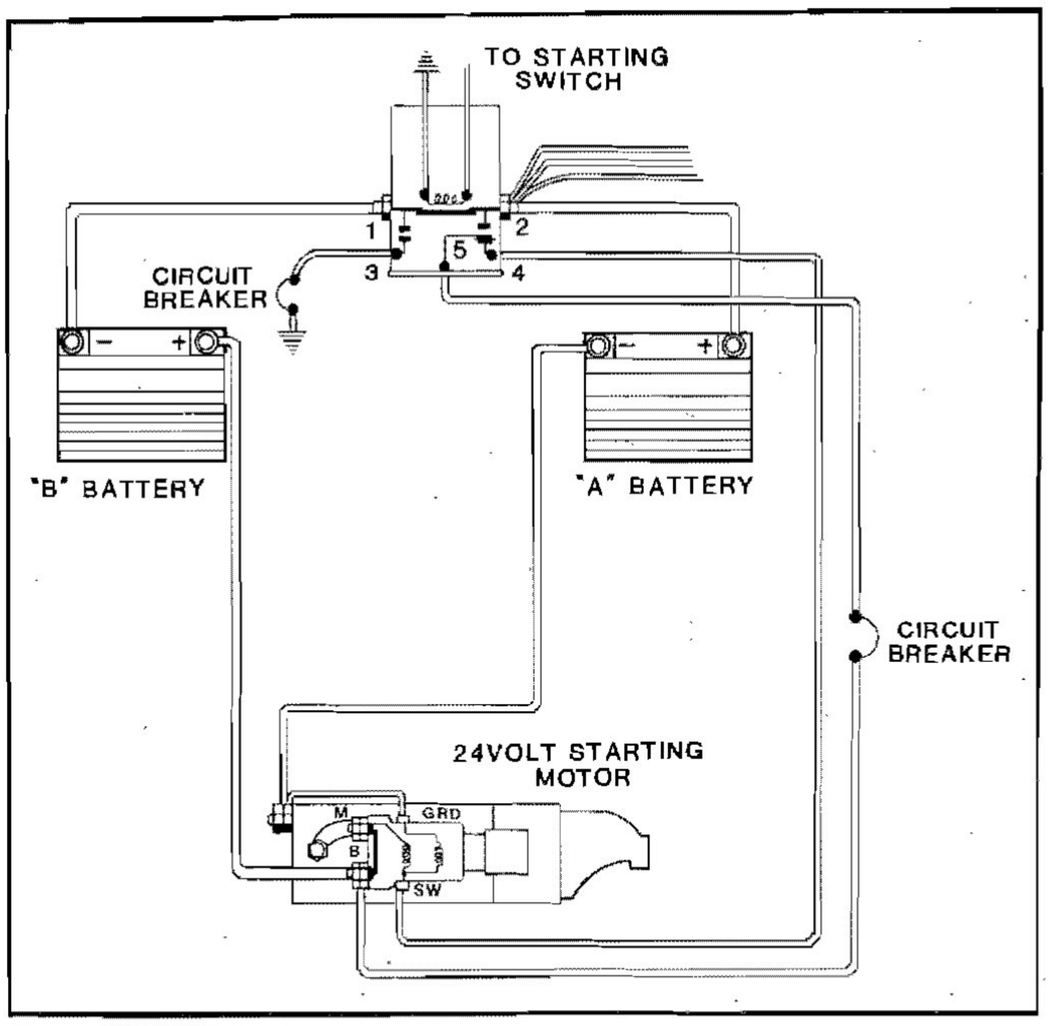

Fig. 17 - "B" circuit

IDENTIFYING CHARACTERISTICS:

2 large terminals on switch

additional accessories connected to #2 terminal

#2 terminal is connected to positive terminal of "A" battery

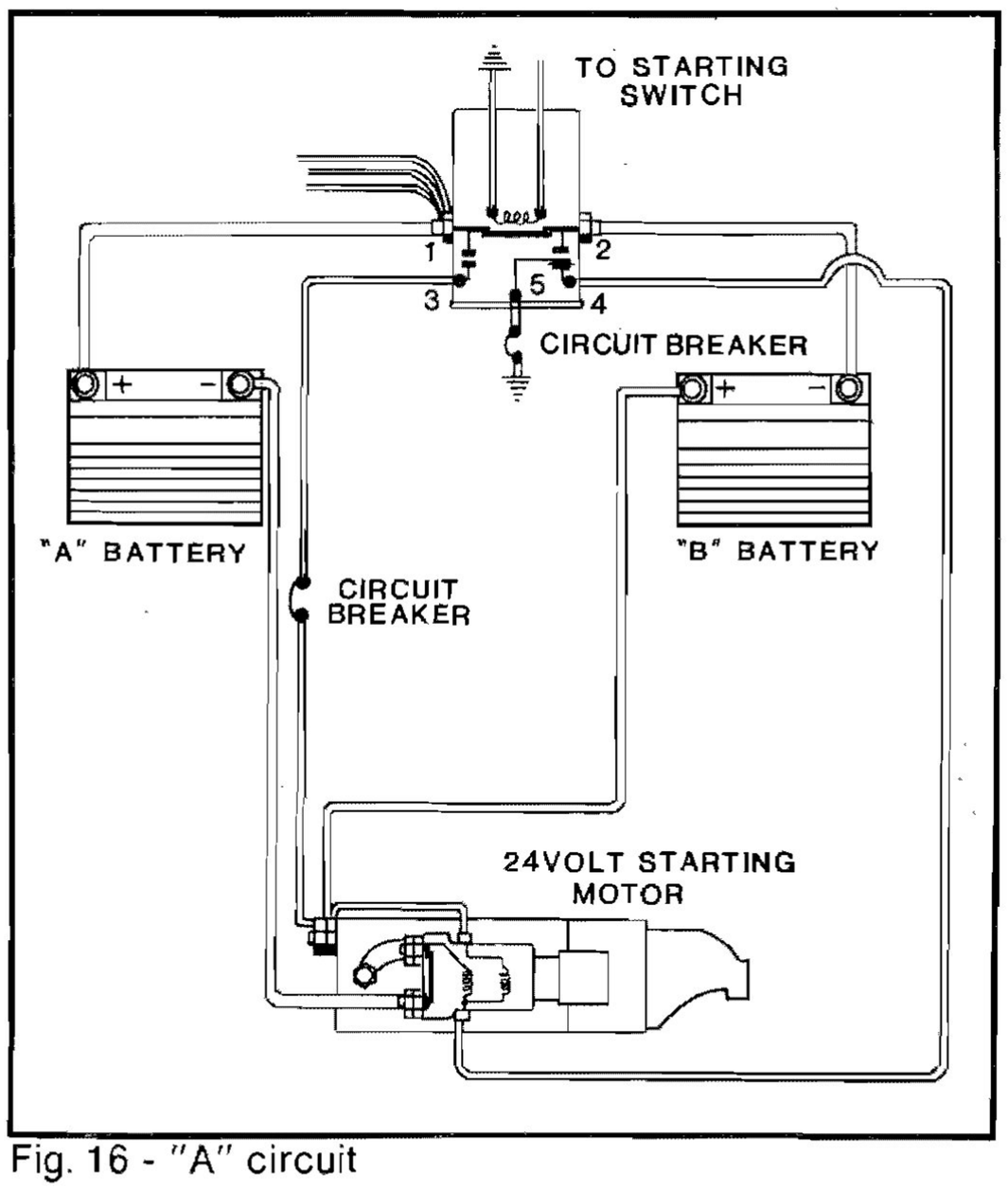

Fig. 16 - "A" circuit

IDENTIFYING CHARACTERISTICS:

2 large terminals on switch

additional accessories connected to #1 terminal

#1 terminal is connected to positive of "A" (accessory) battery

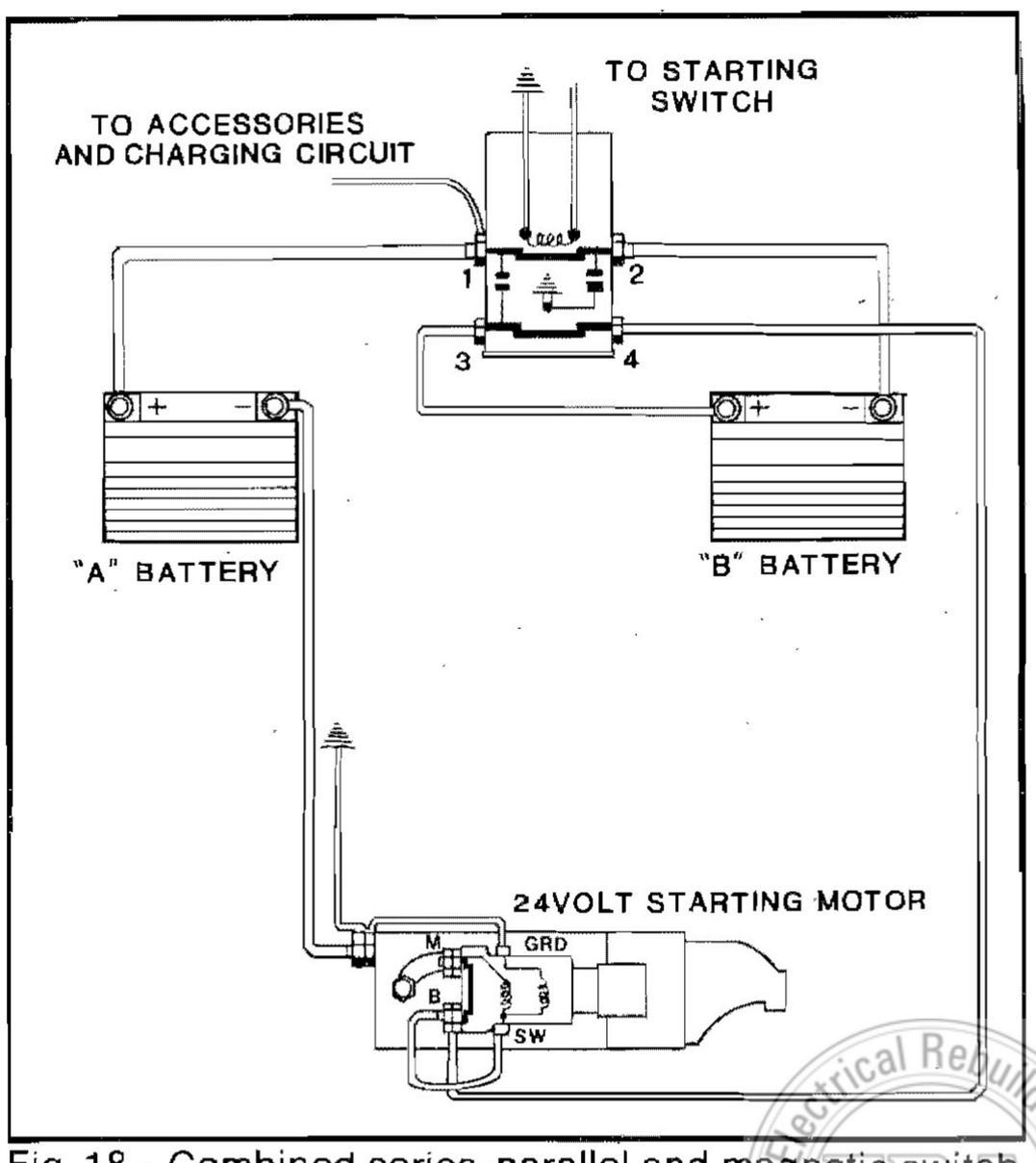

Fig. 18 - Combined series-parallel and magnetic switch circuit

IDENTIFYING CHARACTERISTIC:

4 large terminals on switch

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