DELCO REMY
HEAVY DUTY SYSTEMS
APPLICATIONS
MANUAL:

SECTION 2

Starter Applications Manual

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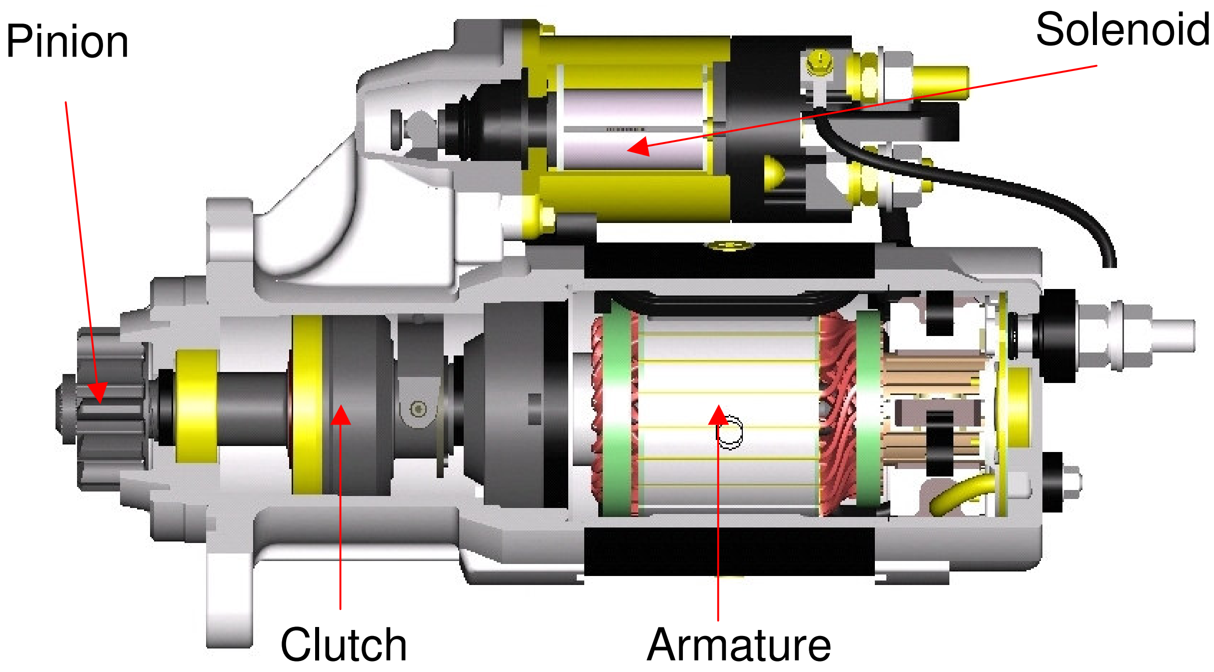
STARTING MOTOR OPERATING PRINCIPLES

The Delco Remy heavy duty starter is an intermittent duty motor that converts the chemical (electrical) energy of the vehicle batteries into mechanical energy to “start” the vehicle engine. The typical starting system consists of five main components: the ignition components, the start system cables, the starter solenoid, the starter motor and the vehicle batteries. All components are equally important for the proper starting of the vehicle. Refer to the diagram on the following page for a view of the internal starter components.

The starting process begins with the operator activating the vehicle ignition switch. When the ignition switch is turned to the start position, voltage is applied first to the magnetic switch, which closes and causes voltage from the batteries to be applied to the switch terminal on the starter solenoid. The purpose of the magnetic switch is to allow relatively small wiring to be used in the vehicle ignition circuit, while maximizing the voltage applied to the switch terminal.

Current then flows through the solenoid hold-in and pull-in coils, which are wired in parallel from the switch terminal. The pull-in coil assists with engaging the starter pinion into the engine ring gear, and is disabled during cranking. The hold-in coil allows the starter to continue to function while using less current than used by the pull-in coil. The current flowing through the solenoid coils creates a magnetic field that “pulls in” the solenoid plunger. The movement of the plunger moves the shift lever and engages the starter pinion into the engine ring gear. As the plunger is pulled in, the contact disc closes against the solenoid contacts, and current flows from the batteries to the solenoid battery terminal, across the contact disc, to the motor terminal, through the field coils, the positive brushes, the armature, and to ground through the negative brushes and ground terminal. Current flowing through the field coils and armature creates opposing magnetic fields between the pole shoes and armature windings that cause the armature to rotate.

When the starter turns the engine at a high enough speed for ignition to occur, the engine starts and accelerates to idle speed. The ring gear begins to drive the starter pinion faster than the starter armature. An over-running clutch in the starter allows the pinion to spin freely on the shaft, preventing the engine from driving the armature and over speeding it. When the vehicle start switch is released, current momentarily flows from the solenoid contacts through the hold-in and pull-in coils in series to ground. The current flow through the pull-in coil is opposite in direction to that in the hold-in coil. The opposing magnetic fields cancel, and the elimination of magnetic pull on the plunger releases it and the return spring pushes it to open the solenoid contacts. The spring force on the shift lever pulls the pinion out of engagement with the ring gear and the starter armature coasts to rest.



STARTING MOTOR TYPES

Delco Remy starters consist of two major types: straight-drive motors and planetary gear reduction motors. The straight-drive motor is the "traditional" motor in which the armature is connected to the starter pinion. The planetary gear (PG) motor, however, uses a planetary gear system between the armature and the pinion. This creates a lighter, more compact motor that can achieve torques similar to those of the straight-drive motor.

Starters can also be either case insulated or case grounded types. For the case insulated model, the starter has a ground terminal that must be connected to complete the starting circuit. For the case grounded starter, grounding is accomplished through the frame of the starter. The use of either type depends on the application and is discussed later in this section.

STARTING MOTOR SPECIFICATIONS

Many details are needed to specify the design characteristics of a starting motor. More information on these specifications and application criteria are included in the following pages, but the highlights are as follows:

Basic features:

- Voltage (12V, 24V or other)
- Case grounded or case insulated
- Rotation: either clock-wise or counter clock-wise
- Pinion and drive type
- Switch Position- the angular location in degrees to the center of the solenoid (switch) from the center mounting hole, which is usually directly opposite the pinion opening, as viewed from the drive end. Often called "clocking" position.
- Pinion opening location in degrees as described in switch position
- Engine mounting flange type—typically SAE #1 or #3
- Mounting bolt hole diameter
- Treatment: options include corrosion treatment, fungicidal, oil-sealed for wet flywheel housings, and water resistant treatment

- Special: there are numerous options available for special applications including drive dust seals, rotated housings, Jump-Start Protection, offset housings, heat shields, and others

Special features, which vary by starter model, include:

- Field terminal: a special terminal is added which has voltage only during cranking
- Ground Stud orientation: special locations such as rotated in the commutator end (CE) housing 180° or radial location
- Integral Magnetic Switch (IMS) included
- Dust shield in the lever housing: prevents ingress of dust past the starter drive, in open flywheel applications
- Provisions for Jump-Start Protection (JSP)
- Private branded
- Special housings, connectors, seals, and other features

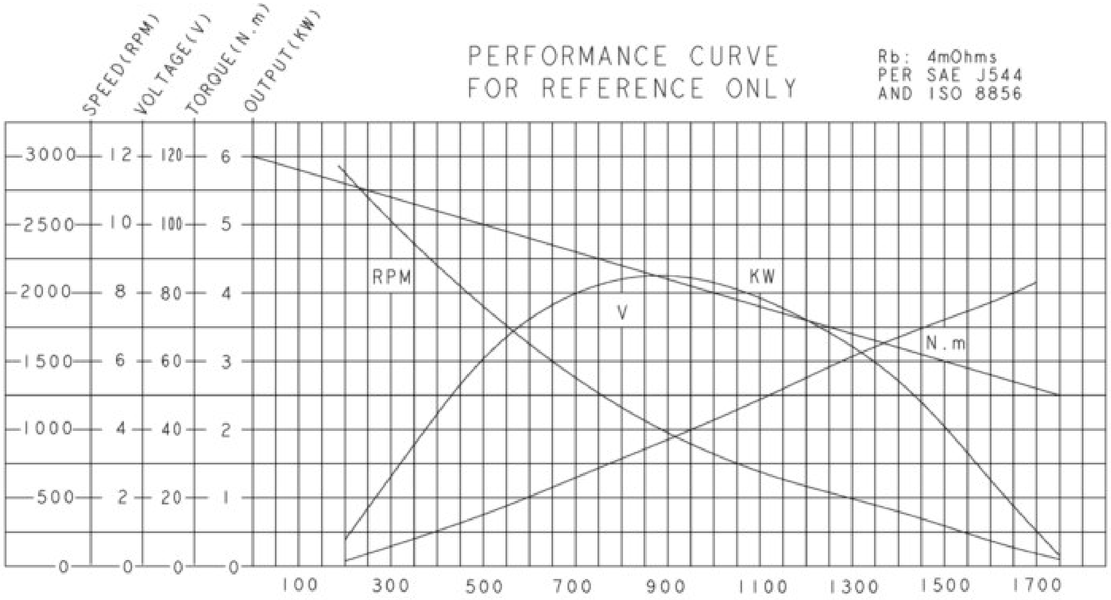
Completion of the Application Data Sheet in Section 6 allows Delco Remy to specify the appropriate motor for the particular application.

STARTER APPLICATION SPECIFICATIONS

Starter Output Ratings

Many starter, engine, and vehicle manufacturers refer to starters by the power rating at the peak point on the starter output performance curve. Thus a horsepower or kilowatt rating is given. However, this practice is not ideal and is an oversimplification, because the starter may be operating at any point on the performance curve, depending on system conditions and the load on the starter. Also, the power rating is only applicable for comparison to other starters when the voltage curve, which is also plotted on the performance curve, is identical. The battery internal resistance, which should be listed on the curve (as is standard Delco Remy practice), determines the voltage curve. Thus, do NOT compare starter ratings from curves using different battery internal resistances, or the comparison will be erroneous.

The Society of Automotive Engineers (SAE) J544, *Electric Starter Motor Test Procedure*, is the industry standard specification for rating starters. Below is a sample starter performance curve created according to SAE J544. Values are shown for starter speed, voltage, torque and output.



Ideally, comparison between different starters to judge performance differences should be made by a computerized cranking estimate, or by estimating the actual operating points on the performance curves, usually from recorded current data from cold start tests. Finally, the current rating and draw of the starter must always be reviewed. The current rating must not be exceeded for actual cranking. Thus, the starter should not operate at, or be given a power rating, which exceeds the current rating.

In summary, only compare performance curves with identical battery internal resistances, and avoid rating and comparing starters only by the peak power output, unless that is the actual operating point for a given application. This practice will avoid errors in estimating performance differences between different starters.

Selecting a Starter Model

Base guidelines are shown below for Delco Remy starter series by maximum recommended engine size. Reviewing the table on the next page should narrow the choice of starter series to no more than two possibilities. The recommended procedure for selecting a starter is to request computerized cranking estimates by submitting an Application Data Sheet or Request for Cranking Estimate form, which is included in Section 6. Actual cold room testing can make confirmation of these estimates. Historical data of starters used on similar engines and applications is also used to a great extent to simplify the application selection process.

Larger starters will typically provide slightly higher cranking performance. It should be noted, however, that the primary advantage of using a larger starter is to be able to utilize a larger battery pack without exceeding the current carrying capability of the starter. Thus, the starting system must be designed and applied as a complete system, not by considering the starter and batteries independently. Another important factor in selecting a starter is the starting requirements: how fast must the engine be cranked and at what temperature. The engine manufacturer must specify these parameters. Note that as temperature decreases starting becomes much more difficult. More information on starting is included in the section on Cold Cranking.

Starter Series Specification

	Voltage	Rating	Max Disp.	Weight	Frame Diameter	Drive			Housing		Wet Housing Option	Available Features			Mounting	
PRODUCT SERIES	(V)	kW	(L)	Lbs.	(mm)	SD	PG	OG	Nose	Nose-less		IMS	OCP	JSP	SAE #1	SAE #3
28MT	12		6.5	18.5	90			X	X		X				X*	
	24		6.5					X	X		X				X*	
29MT	12	3.3	6.6	17.5	90		X			X	X				X	
	24	4.0	8.0				X			X	X	X			X	
37MT	12	4.5	8.3	50	130	X			X				X		X	X
	24	7.5	8.3			X			X				X	X	X	X
38MT	12	4.6	10	28	100		X			X	X	X			X	X
	24	7.5	11				X			X	X	X			X	X
39MT	12	7.2	15	31	115		X			X	X	X	X	X		X
	24	8.3	16				X			X	X	X	X	X		X
41MT	12	4.5	10	50	130	X			X		X		X	X	X	X
	24	7.5	10			X			X		X		X	X	X	X
42MT	12	7.8	15	58	130	X			X		X	X	X	X		X
	24	7.8	15			X			X		X	X	X	X		X
50MT	12	8.5	30	79	142	X			X		X			X		X
	24	9.0	30			X			X		X			X		X
	32	10.5	30			X			X		X			X		X
	64		30			X			X		X			X		X

SD = Straight Drive
PG = Planetary Gear
OG = Offset Gear

IMS = Integrated Magnetic Switch
OCP = OverCrank Protection
JSP = Jump Start Protection

*28MT also available in SAE #4 and Pad Mount

Two or more starters may also be coupled together for starting extremely large displacement engines. The above specifications are general guidelines, and exact specifications depend on the starting speed, temperature requirements, oil viscosity, and other variables of the engine application. These ratings include the base engine only and do NOT include any auxiliary equipment (also called parasitic loads) that may significantly add to the starting torque requirement of the engine. Examples of such equipment are hydraulic pumps (the most common parasitic starting load, especially in agricultural and construction equipment) and automatic or hydrostatic transmissions.

12V versus 24V System Selection

One of the most frequently asked questions in specifying a starting motor concerns the advantages and disadvantages of using a 12-volt versus a 24-volt starting system. In North American on-highway applications, 12-volt systems are standard, while construction equipment, buses, and larger displacement engines, as well as most of Europe, South America, and Asia-Pacific employ 24-volt systems. A thorough discussion of the advantages and disadvantages of each are beyond the scope of this manual, but all Delco Remy medium and heavy duty starters are available in either 12 or 24 volt (the 50MT is also available in 32 and 64 volts).

While every application is unique because of oil viscosity, engine displacement, cranking ratio, etc., in general a 24-volt starter will crank a given engine up to 10-12% faster at the same ambient temperature than will a 12-volt starter, but the difference can be less than 5%. While this may be insignificant much of the time, at cold temperatures that result in marginal starting conditions, this could be the difference between a running engine and a no-start condition. A higher voltage starter can also use smaller cables because the starter draws less current. Due to the reduced current and higher allowable voltage drops, smaller cables can also be used in the charging circuit of a 24-volt system. Larger cables, however, allow longer cables to be utilized while maintaining voltage drop recommendations. Less current flows in a 24-volt system so heat build-up in the cables is reduced for a given cable size (although this is generally insignificant). Also note 24-volt switches tend to be more expensive than 12-volt switches.

There are two primary advantages of 12-volt starting versus a comparable 24-volt system. The first is usually lower cost because smaller diameter cables can be used for 24-volt systems. Second, greatly simplified system wiring can be used, compared to a split 12/24 volt system. If the entire vehicle is 24-volt, then wiring is essentially the same as 12-volt. A system using 24-volt starting and 12-volt loads requires a series-parallel switch, a transformer-rectified alternator, or other complex components.

There are other considerations regarding system voltage for different vehicle components, such as lighting and wiring. However, to summarize, 12-volt versus 24-volt starting systems, like so many other items, is generally a trade-off between lower cost versus increased performance and system complexity.

MOTOR MOUNTING RECOMMENDATIONS

Environmental Factors and Temperatures

The starting motor and solenoid are designed to withstand normal engine compartment temperatures. The operating temperature range is -25°C to 121°C (-13°F to 250°F). Military application starters have an operating range from -54°C to 121°C (-65°F to 250°F). Locating the motor close to the exhaust manifold or other heat source may result in reduced motor performance, deterioration of insulation and rubber components, or both. A minimum 2-inch clearance is recommended. Where relocation or rotation is not possible, metal shielding can often be used to protect the starter from radiated heat. Excessive heat will increase solenoid coil resistance and may prevent starter engagement under some conditions.

WARNING: The starter (and alternator), and any wiring and connections, should not be mounted in close proximity to fuel system lines, hoses, filters, or any other devices that may be adversely affected by heat. Both the starter and alternator, and the associated wiring, generate heat during normal operation and surfaces may become warm. Also, certain failure modes of electrical components and wiring may result in extreme current draw, and thus high temperature.

The starter (and alternator) should not be exposed to water drains or road splash. These conditions will shorten the service life of electrical products. Similarly, steam cleaning or pressure washing is not recommended.

Mounting Specifications

The most common mountings used on heavy-duty starters are the SAE #1 and #3 mountings- reference SAE specification J542, *Starter Motor Mountings* for more detail. The list of available nose housings is shown in the following table.

Available Starting Motor Mounting Types

Remy Model	Flange Type (SAE J542)
28MT	SAE #1
	SAE #4
	Pad Mount
29MT	SAE #1
37MT, 38MT, 41MT	SAE #1
	SAE #3
39MT	SAE #3
42MT	SAE #1
	SAE #3
50MT	SAE #3

SAE #1
(Holes x 90° and holes at 180°)

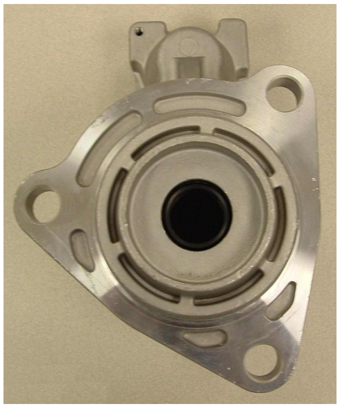
Nose starters

SAE #3
(3 holes x 120°)

SAE #1
(Holes x 90° and holes at 180°)

SAE #3
(3 holes x 120°)

Noseless starters

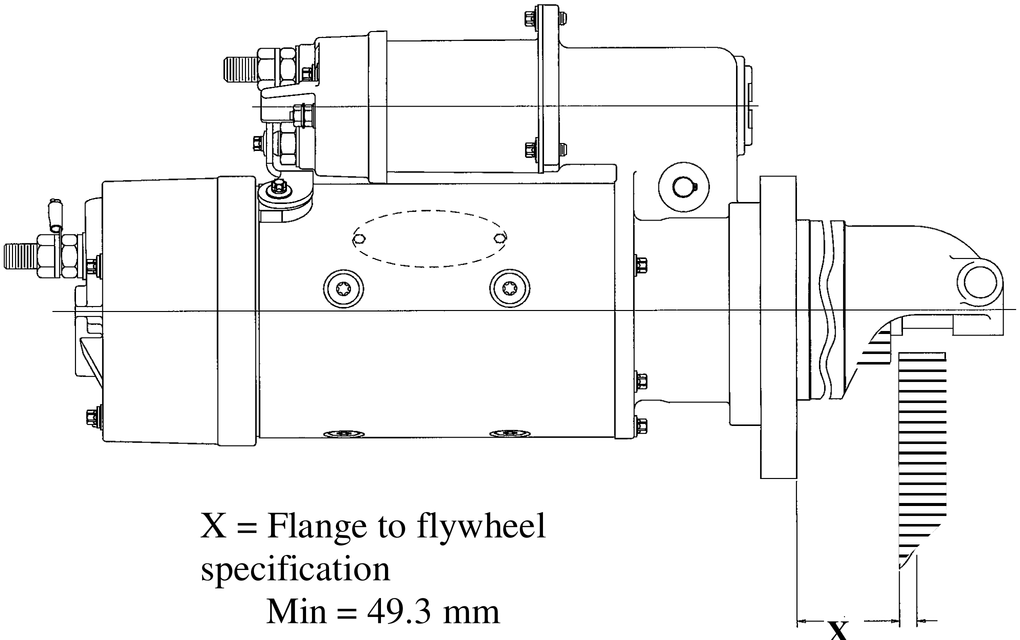


Nose starter

Noseless starter

Flange to Flywheel Specifications

In almost all applications, the flange-to-flywheel distance on the engine from the starting motor mounting surface to the ring gear face is 49.3 to 52.3 mm. This dimension must include spacers or gaskets used on the engine. The starting motor is designed to function within this dimension, and if it is altered, failure to engage or pinion and ring gear damage may occur.



X = Flange to flywheel specification
Min = 49.3 mm
Max = 52.3 mm

Modified nose housings, including offsets, are available by customer request. On straight drive motors the pinion opening on the nose housing is normally 180°, but others are also available by customer request. Standard starting motor mounting hole diameter sizes are defined in SAE J542.

Surfaces between the starting motor and interface to the engine should be flat and free of paint, oils, or any insulating films. In the case of an insulated motor or one with an external ground stud connection, the oil, insulating film, or a gasket is not a problem for electrical purposes, however, these surfaces must not interfere with proper flange-to-flywheel distance.

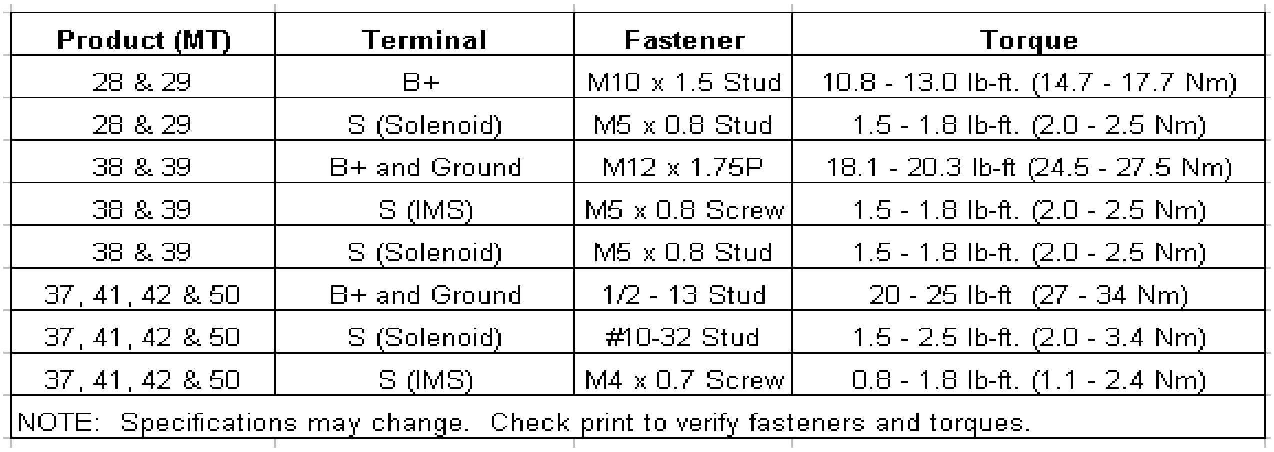
Flywheel Housings

"Dry" Flywheel housings should be vented and drained to prevent water buildup and contamination of the starter. Not all starters are designed for "wet" (lubricated) flywheel housings.

Mounting Hardware Recommendations

Delco Remy does not make recommendations on starting motor mounting bolt torque, because the flywheel housing material and thread engagement length vary by application. We recommend the use of 12-point, flanged head bolts. The torque specified should be appropriate for the mounting configuration. No lock washers, star washers, soft washers, or copper electrical connections, should be used. Star washers do not have a rectangular cross-section, and lock washers could result in a gradual loss of clamp force on the mounting bolts. The yield strength of soft washers or copper connections could be exceeded with the mounting bolts torqued. Both scenarios may result in a loose starter mounting.

Recommended Terminal Torques



Product (MT)	**Terminal**	**Fastener**	**Torque**
28 & 29	B+	M10 x 1.5 Stud	10.8 - 13.0 lb-ft. (14.7 - 17.7 Nm)
28 & 29	S (Solenoid)	M5 x 0.8 Stud	1.5 - 1.8 lb-ft. (2.0 - 2.5 Nm)
38 & 39	B+ and Ground	M12 x 1.75P	18.1 - 20.3 lb-ft (24.5 - 27.5 Nm)
38 & 39	S (IMS)	M5 x 0.8 Screw	1.5 - 1.8 lb-ft. (2.0 - 2.5 Nm)
38 & 39	S (Solenoid)	M5 x 0.8 Stud	1.5 - 1.8 lb-ft. (2.0 - 2.5 Nm)
37, 41, 42 & 50	B+ and Ground	1/2 - 13 Stud	20 - 25 lb-ft (27 - 34 Nm)
37, 41, 42 & 50	S (Solenoid)	#10-32 Stud	1.5 - 2.5 lb-ft. (2.0 - 3.4 Nm)
37, 41, 42 & 50	S (IMS)	M4 x 0.7 Screw	0.8 - 1.8 lb-ft. (1.1 - 2.4 Nm)
NOTE: Specifications may change. Check print to verify fasteners and torques.			

NOTE: Refer to the outline drawing for specific model specifications since torques may vary from these due to special requirements on unique models.

Marine Suitability

Delco Remy straight-drive starters are tested to and meet the requirements of SAE J1171, *External Ignition Protection of Marine Electrical Devices*, for usage in marine environments. Delco Remy does NOT certify starters to any other industry or government specifications for explosive environments.

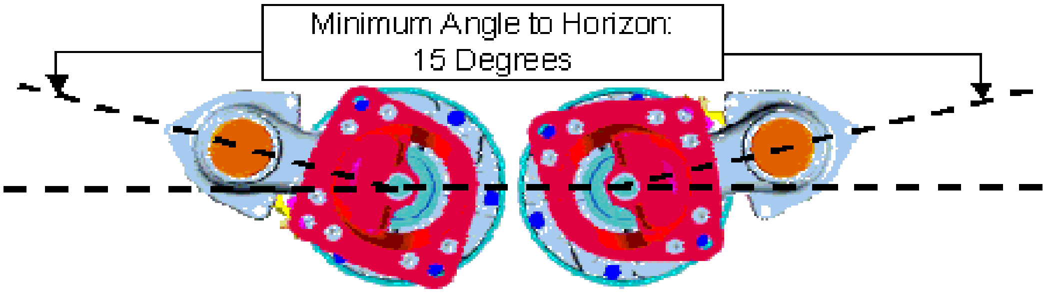
Jump-Start Protection

Most starter models are available with solenoid terminal shields that meet SAE J1493 requirements for jump-start protection (JSP). J1493 states " . . . *the requirements to prevent inadvertent and to discourage deliberate electrical at the starter motor solenoid or starter relay, which may result in the starter pinion engaging the ring gear*." This provision "*applies to off-road, self-propelled work machines as identified in SAE J1116, which have the potential of powered movement as a direct result of the starter pinion engaging the ring gear*." It is extremely important that this specification be adhered to for off-road machines.

Solenoid Orientation

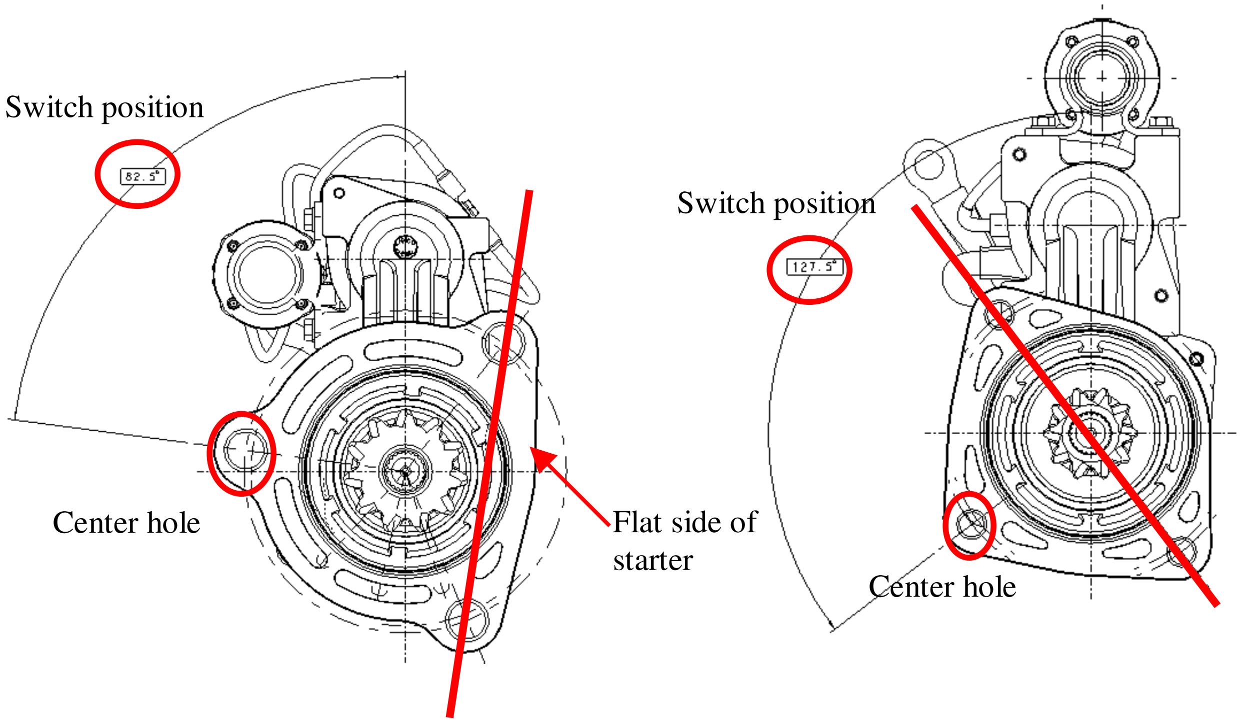
When positioning the motor at the mounting locations, it is important to place the solenoid above the centerline of the motor, with a minimum position of 15° above horizontal, as shown in the sketch on the next page. This will prevent the potential accumulation of foreign material or moisture that can restrict operation in the tower portion of the shift lever housing, and the potential for contamination ingress into the solenoid. It also reduces the possibility of road debris striking and breaking the solenoid cap. This recommendation is also contained in SAE J1375, *Starting Motor Application Considerations.*

Installation Orientation Guideline for Straight-Drive Starters



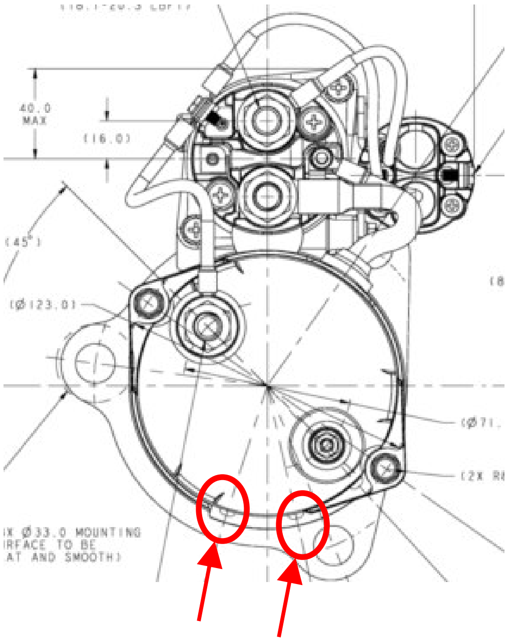
Switch Position (Clocking)

The switch position gives the angular location in degrees to the center of the solenoid measured clockwise from the center mounting hole viewed from the drive end of the motor. The following drawings show some example switch positions.



Installation Orientation Guideline for Planetary Gear Starters

A drain hole or a notch must be within 30° of vertical.



Drain holes

Magnetic Switch Mounting

An Integral Magnetic Switch (IMS) is an option on most Delco Remy starter motors. The IMS provides an alternative to the end-user process of selecting a suitable magnetic switch and designing the associated solenoid control circuit. Delco Remy starters with IMS have a specifically engineered magnetic switch installed directly on the starter motor at our factory. The magnetic switch on these motors has been tested to withstand shock forces in all available factory mounting positions. An IMS starter can take the start signal directly from the driver's starter switch or from a small relay which would otherwise be too small to supply current to the solenoid. The advantages of the IMS motor are:

1. A reduction in wiring, and thus voltage drop, as compared to a remotely mounted magnetic switch,
2. A correctly-sized switch selected and tested by Delco Remy,
3. The saving of the cost and labor to install the additional wiring,
4. Environmental sealing which offers greater resistance to environmental factors such as corrosion and,
5. A single connection, which reduces the amount of hardware and labor necessary for installation.

The tightening torques for the IMS connections to the solenoid do not change from standard recommendations. The connection to the vehicle start switch is a threaded terminal. IMS models are available in 12 and 24-volts. The IMS starter can be selected for vehicles with light duty relays or control circuits that have not been designed for electrical soft-start engagement systems. For this reason it is a great choice as a service part replacement in older vehicles known to have marginal or troublesome control circuits.

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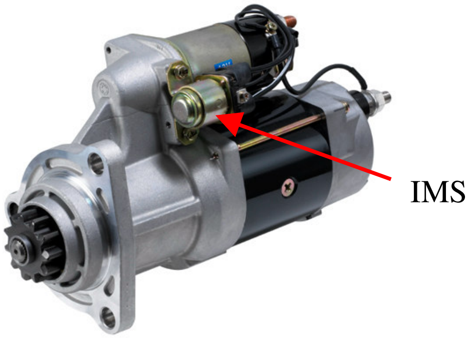
Example of an IMS on a 39MT Starter



When using a customer installed magnetic switch instead of Remy's IMS the following guidelines should be observed. When mounting a magnetic ("mag") switch on a vehicle, the axis of the plunger should be horizontal with respect to the ground and perpendicular to the axis of travel of the vehicle. If this mounting is not possible, the switch should be tested to ensure the motion of the vehicle does not activate the switch. The switch should not be mounted on the engine or any metal that could resonate as the result of road or engine vibration. If a magnetic switch is not used, the vehicle manufacturer must be certain that the start switch can handle the solenoid pull-in and hold-in currents which can be in short-term excess of 300 amps

Maximum Battery Size Recommendations

Limitations on maximum battery CCA (Cold Cranking Amps) exist to limit potential heat damage to the starter. Heat damage can occur if the starter operates, either while cranking or running disengaged ("free speed"), for an excessive period of time. Delco Remy Product Engineering may approve battery packs larger than those recommended in the table on the basis of engine or vehicle test results.

MAXIMUM BATTERY CCA RECOMMENDATIONS				
STARTER SERIES	TYPE	BTY QTY	CCA (EACH)	TOTAL CCA
28MT	12	2	550	1100
	24	2	900	900
29MT	12	2	550	1100
	24	2	900	900
37MT	12	3	625	1875
	24	2	900	900
38MT	12	3	700	2100
	24	2	900	900
39MT	12	4	700	2800
	24	4	700	1400
41MT	12	3	700	2100
	24	2	900	900
42MT	12	4	700	2800
	24	4	700	1400
50MT	12	4	900	3600
	24	4	900	1800

Over-Crank Protection (OCP)

Delco Remy offers a feature called Over-Crank Protection (OCP). This optional feature uses an internal temperature-sensitive switch to sense excessive heat build-up in the starter and will automatically discontinue cranking when the temperature reaches a damaging level. This prevents heat related damage to the starter due to excessive cranking. When the starter cools to a safe temperature, the temperature switch resets to allow cranking again. Even with the OCP feature, the following guidelines should be followed to maximize starter life.

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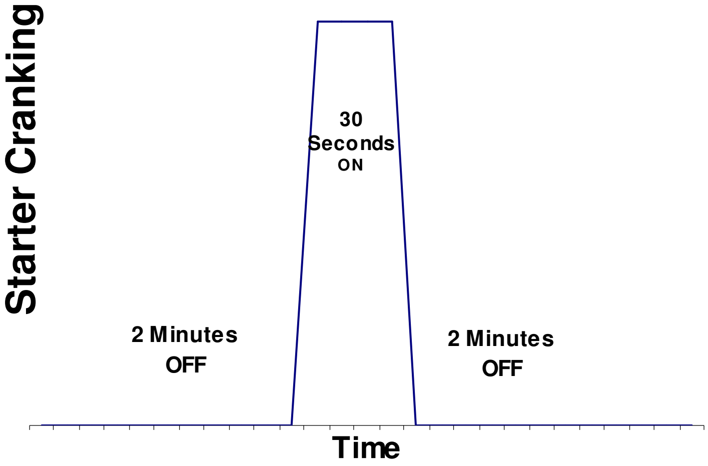
Operating Guidelines For Starting Motor Operation

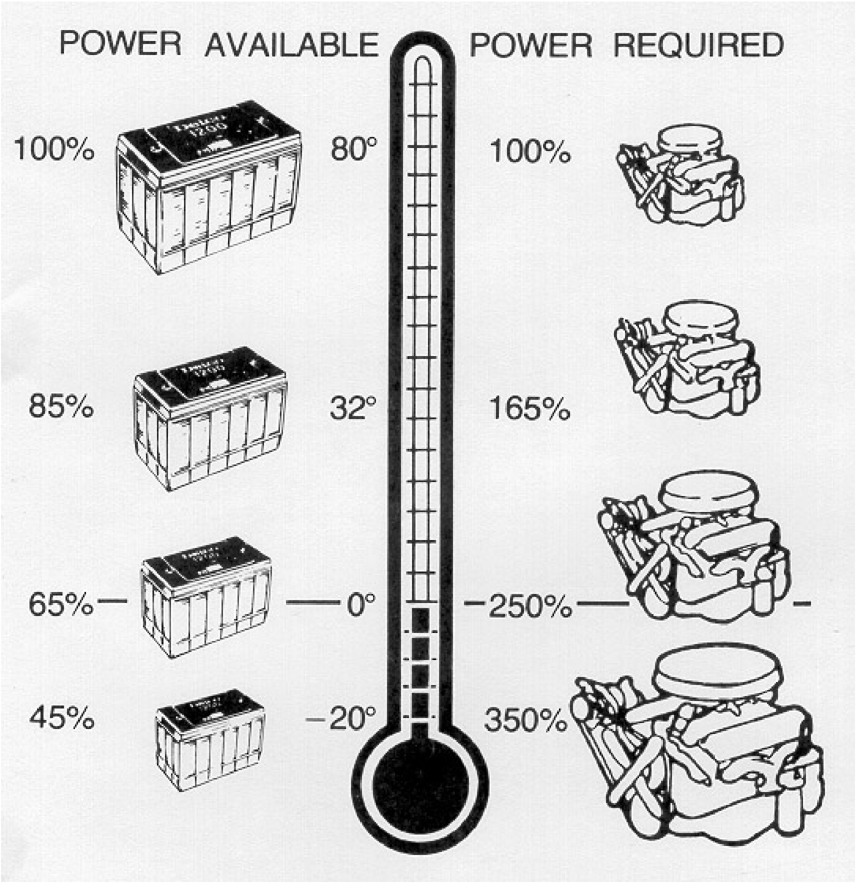
To prevent any undue stress or severe internal heat build-up, the starting motor should not be operated for more than 30 seconds continuously. A minimum of a 2-minute cooling period should be used between extended cranking cycles. An over-crank protected motor will also help prevent heat related damage, but the 30 second crank: 2 minute cool cycle should be used on any motor, whether equipped with OCP or not.



If the engine does not start and must be re-cranked, always wait five seconds, to allow the pinion and ring gear to stop. If the starter is re-engaged before the pinion or ring gear has stopped, they can be milled or the armature could be twisted. The starter should NOT be used to “bump” the engine to move the vehicle or otherwise be used in a manner other than normally cranking the engine.

Cold Cranking

The cranking system, including the starting motor, batteries, and cables, must be capable of providing a minimum engine speed for a specified time. When cold, especially below 0°C (32°F), the engine torque requirement from the starting motor increases due to lower lubricating oil viscosity. Simultaneously, the battery is able to offer fewer amp-hours at low temperatures. The following diagram shows this relationship.



Under these adverse conditions, it is also important to limit the cranking current to the maximum current rating of the starting motor.

Some of the ways to increase the chances of the engine starting are:

1. Reduce Cranking Load
    a. Engine block heaters (oil or coolant)
    b. Lower oil viscosity*
    c. Reduce parasitic loads, such as hydraulic pumps, etc

2. Quicker Fuel Ignition
    a. Manifold heater
    b. Ether
    c. Glow plugs

**The engine manufacturer's oil recommendations should always be followed for the applicable operating ambient temperature range of the engine.*

Controlled cold cranking tests, using design intent hardware, can and should be performed on the applicable fully dressed engine (with transmission and hydraulic pump if applicable), in order to verify that the cranking speed requirements will be met. The engine manufacturer must specify the cranking speed goal for startability. SAE J1253, *Low Temperature Cranking Load Requirements of an Engine*, provides more information on this subject.

Computer generated cranking estimates can be performed to simulate various engine operating conditions. The Delco Remy applications engineer can run these simulations, using the information provided on the “Starting Motor Application Data Sheet” (found in Section 6).

GEARING - RING GEARS AND PINIONS

Ring Gear Requirements

Concerning gears and pinions, it is highly recommended that SAE specification J543, *Starting Motor Pinions and Ring Gears*, be followed. Note that this specification requires ring gears coarser than 12/14 pitch to have a chamfer and that the edge of the chamfer be in the center of the tooth face and be perpendicular to the ring gear OD.

The ring gear should be hardened as follows:

8/10 pitch and coarser	Rockwell ‘C’ 45-52
10/12 pitch and finer	Rockwell ‘C’ 48-55

The distance between the center of the ring gear and the center of the mating pinion is the ***center distance***. In mating the ring gear and pinion together, SAE recommends a center distance clearance of 0.030-inch (0.76mm) ± 0.010 inch (0.25mm) for the center distance for proper gear action. This dimension is referred to as “spread of centers” and is explained in more detail in the following section.

Gears and Pinions- Standard System

An understanding of the nomenclature used for gears and pinions is important for proper application. Below follows an explanation of the gear system used on Delco Remy starting motors, and the basic theory necessary to correctly specify different pinions. In addition to the following system, Delco Remy now also offers metric pinions and gears. Nomenclature for the metric system follows this section.

Ring gears are much larger than starter pinions (approximately 10 inches (250mm) to 30 inches (750mm) of diameter versus 2 to 3 inches for pinions). The ring gear is attached to the flywheel and is housed in the bell or flywheel housing of the engine. The starting motor is bolted to the bell housing, and the starter pinion engages the ring gear to turn the engine by driving the ring gear (a more precise explanation is covered in "Engagement Feature Types".) Every engine has a given cranking torque at specific conditions based on engine size, oil temperature, etc., and it must turn at a specific speed in order to start the engine (both conditions are determined by the engine manufacturer). The ring gear-to-pinion ratio, which is referred to as the ***cranking ratio***, and ideally is designed to optimize the cranking system. However, since there is a limit to the number of teeth of a particular size that can be cut on a given ring gear or pinion, the number of teeth on the two gears is also controlled by space limitations and strength requirements.

The size of the teeth is specified by the ***pitch***, which is the number of teeth per inch of gear diameter. The more precise term is actually diametral pitch. Thus, a gear with a pitch of 8 has 8 teeth per inch of diameter. The diameter of a gear is the diameter of a wheel or flat pulley that would take its place, and is called the ***pitch diameter.***

Starting with the pitch diameter, a portion of the tooth, called the addendum, is built out to engage with a mating gear, and a portion is indented, called the dedendum, to provide a space into which the mating gear engages. In a standard gear system, the addendum is equal to the reciprocal of the diametral pitch and the dedendum is equal to the addendum, plus a clearance. Therefore, the total height of a tooth is equal to twice the addendum plus clearance.

Delco Remy uses the Stub Tooth Gear System, in which the teeth are shorter than the standard gear system. In this system, two numbers are used to specify the pitch, such as 8/10. In this case, 8 is the diametral pitch and indicates of the thickness of the tooth measured on the circumference of the gear, and 10 indicates the height measured radially. In this system, the addendum is not equal to the reciprocal of the diametral pitch but is equal to the reciprocal of the second number (or 1/10 inch). Therefore, the tooth height (2 x 1/10 inch + clearance) is less in the Fellows Stub Gear System than in the standard system where the tooth height would be (2 x 1/8 inch + clearance). The result is that the shorter tooth is stronger than the standard system. This tooth strength is the main incentive for using the Fellows System.

There are different reasons why one pitch is preferable to another. Tooth strength is one. For example, for a 20" diameter ring gear, comparing a pitch of 8/10 vs. 12/14, there would be 160 teeth versus 240 teeth on the ring gear. Given the same diameter (and circumference), the160 teeth (of 8/10 pitch) would obviously be larger and stronger. Different cranking ratios are another reason for specifying different pitch. For example, consider, again, a 20-inch diameter ring gear. Different pitches would yield different numbers of teeth: 8/10 (160 teeth), 10/12 pitch (200 teeth), and 12/14 pitch (240 teeth). For a given ten-tooth pinion, the different cranking ratios would be 16:1 (for 8/10 pitch- 160/10), 20:1 (for 10/12 pitch- 200/10), and 24:1 (for 12/14 pitch- 240/10). Available pitches on Delco Remy starters are listed following this section.

To provide for optimum cranking, it is usually recommended that the smallest teeth be used that will yield acceptable tooth strength (8/10 is preferred to 6/8, 12/14 is preferred to 10/12, etc.) This practice allows for the highest possible cranking ratio for a given ring gear size.

Regarding pinion specification, the nomenclature 10-11, 12-13, etc. is used, meaning 10 teeth on an 11 tooth blank, 12 teeth on a 13 tooth blank. This simply indicates that for the given pinion, 10 teeth are cut into the area that could accommodate 11 teeth, 12 teeth in an area for 13 teeth, etc. There are two reasons for this practice:

1. The major advantage of cutting fewer teeth into a given pinion is to increase tooth strength. Using the example above, the 10 teeth cut into the area for 11 teeth would obviously give stronger teeth. Available pinion teeth for various pitches are listed in the following section.

2. Another advantage of cutting fewer teeth into a given pinion is increased cranking ratio (and thus increased mechanical advantage). Take the 20-inch ring gear above, with 8/10 pitch and 160 teeth. If an 11-tooth pinion is used, the cranking ratio is 14.5:1 (160/11). But, if 10 teeth are cut into the same area as the 11 tooth pinion, the cranking ratio is 16:1 (160/10); an increase of about 10% (this changes the operating point on the starter performance curve, but does NOT mean that starter performance will increase). The significance of this change is that other options to increase cranking speed are all expensive and difficult. These include: increased battery size, a larger starter,

increased number of ring gear teeth (except pitch is fixed and diameter is limited by the bell housing), or a decreased number of pinion teeth with a smaller pinion (but the starter would have to move closer to the center of the engine, which requires a new mounting arrangement and the smaller pinion may not be as strong.)

The center distance dimension mentioned in the previous section is critical in mounting a starting motor and is controlled by the location of the motor mounting holes in the bell housing. The approximate method of determining center distance is shown below and discussed in SAE J543. For mountings that may be marginal with respect to actual center distance, if mounting data is furnished, Delco Remy will make a determination of the allowable center distance measurements.

$$\text{Center Distance} = \frac{(\text{\# of teeth in ring gear}) + (\text{\# of teeth in pinion blank})}{2 \times (\text{Diametral Pitch})} + \text{clearance}$$

Recall from the previous section that SAE recommends a clearance of 0.030 inch in order to provide meshing clearance for the teeth (also called backlash). This method provides for standardized ring gears and starter pinions, but is not necessarily the best method for gear action.

While the above information can be used to specify standard pinion-ring gear combinations, there are situations where different cranking ratios or different pitch ring gears are required. It then may be necessary to offset the motor mounting to move the pinion closer to or further away from the center of the ring gear to allow for decreased or increased center distance. However, these types of non-standard mountings generally have significant cost penalties. Each individual application must be analyzed in order to evaluate the best options for starter mounting and performance.

Gears and Pinions- Metric System

In the metric system, the pitch (**P**) is analogous (but not equivalent) to the ***module*** (**m** in mm) and is related by the equation:

$$\mathbf{m = 25.4/P}$$

Stub gears are not used in the metric system. Delco Remy currently manufactures pinions in sizes of Mod. 3 and Mod. 3.5 (see following section). Occasionally, metric gears will be specified in sizes identical to the standard system (e.g. Mod. 3.175 which, by the above equation, is the same as diametral pitch 8).

Available Starting Motor Pinions

28MT	8/10 pitch	10-11 teeth
	8/10 pitch	12-13 teeth
	10/12 pitch	10-11 teeth
	10/12 pitch	12-13 teeth
	Mod. 3	9-10 teeth
29MT	8/10 pitch	10-11 teeth
	10/12 pitch	10-11 teeth
	Mod. 3	9-10 teeth
	Mod. 3	11-12 teeth
37MT	8/10 pitch	10-11 teeth
	8/10 pitch	12-13 teeth
	Mod. 3	11-12 teeth
38MT	6/8 pitch	11 teeth
	8/10 pitch	10-12 teeth
	Mod 3	11-12 teeth
39MT	6/8 pitch	11 teeth
	8/10 pitch	12 teeth
	Mod 3	12 teeth
41MT	8/10 pitch	12-13 teeth
	6/8 pitch	11-12 teeth
42MT	8/10 pitch	12-13 teeth
	8/10 pitch	13-14 teeth
	6/8 pitch	11-12 teeth
50MT	8/10 pitch	12-13 teeth
	6/8 pitch	11-12 teeth
	Mod. 3.5	13-14 teeth

Engagement Feature Types

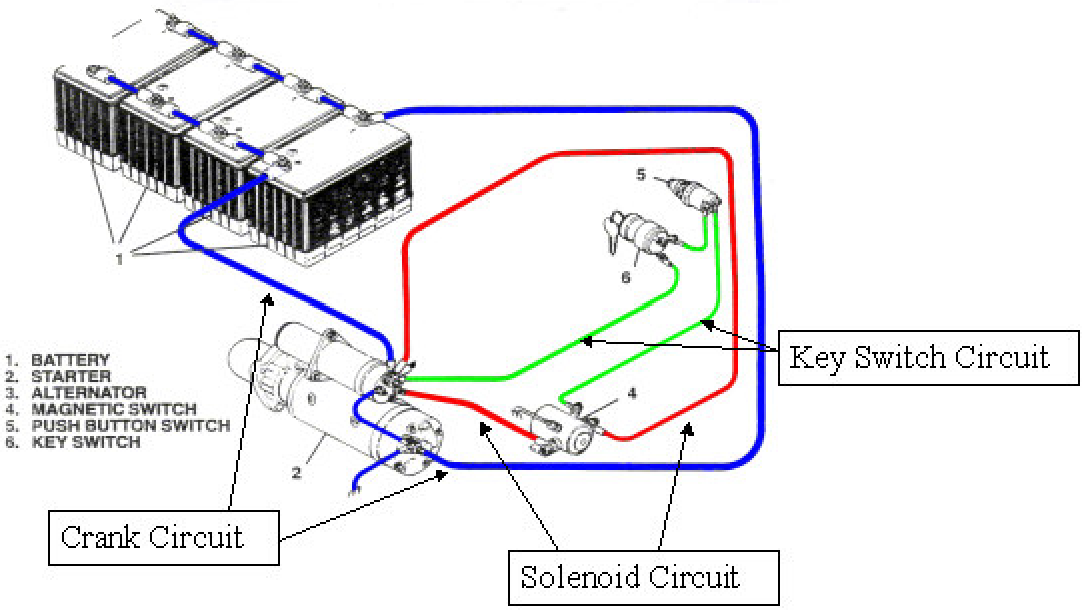
Delco Remy starting motors have one of two types of engagement features. These are the ***positive engagement*** and ***positive shift engagement types***. A brief description of their operation follows.

On starters with positive shift engagement, the pinion may not engage the ring gear before the motor armature begins to rotate. If a tooth abutment (when the pinion and ring gear teeth line up axially and do not allow engagement of the pinion into the ring gear) occurs, the pinion must be rotated in order to clear the abutment. This is accomplished by shifting the pinion down spiral splines until the pinion hits the ring gear. While the drive stops moving, the solenoid continues to compress a spring attached to the rear of the drive. Then, the contact disc closes against the terminals and the motor begins to turn. As soon as the tooth abutment is cleared, the spring forces the drive into mesh with the ring gear and engine cranking commences. Some starters, generally gear reduction, have a different type of positive engagement than other starters. The shaft and drive assembly both have helical splines. If tooth abutment occurs, the relatively low current with only the pull-in coil energized causes the pinion to rotate slowly to clear the tooth abutment and mesh with the ring gear.

On starters with positive engagement, the pinion meshes with the ring gear before the motor armature begins to rotate. If a tooth abutment occurs, the pinion is indexed without the motor rotating. This is accomplished by shifting the drive down the armature straight splines until the pinion contacts the ring gear. The drive has an internal spiral spline and, as the solenoid continues to push the drive toward the ring gear, the internal spline rotates the pinion off the tooth abutment. As the pinion is indexed, the internal drive meshing spring is compressed, which forces the pinion into the ring gear. The drive then moves forward, permitting the solenoid contact disc to close against the terminals and allow the motor to turn.

Twelve volt 28MT, 29MT and all 37MT motors have positive shift engagement drives, while 24-volt 28MT and all 38MT, 39MT, 41MT, 42MT, and 50MT motors have positive engagement drives.

WIRING AND CONNECTIONS



Delco Remy starter motors are designed to be reliable for a very wide range of applications and operating conditions. The starter is part of the vehicle's cranking system, and certain electrical and mechanical system requirements must be met. Cables and connections provide the vital electrical link between the power source (batteries) and power user (starter) in the starting system. The cables and connections are just as important to specify for satisfactory performance, as are the starting motor and batteries. The most widely used example of similarity is the garden hose and its ability to deliver sufficient water pressure (voltage in the electrical system) and volume (current in the electrical system) for the job at hand. If the hose diameter is too small or if the connections are leaky, the result is a dribble of water that will not do the job.

In a like manner, the size of cables and condition of connections determines the delivery of voltage and current from the battery to the starting motor. Any restrictions will cause resistance in flow and volume. Factors controlling resistance, insulation, and adequate clamps, along with proper routing should be carefully specified when designing, redesigning, or modifying an electrical system. Consideration should be given to all control circuit wiring as well as cables between the starting motor and battery.

Development of a wiring system begins with establishing system characteristics:

- Actual vehicle, chassis, or engine
- System voltage
- Starting motor type
- Batteries used and location

With the requirements set by this information, development of the wiring system can progress through the following steps:

1. Cable Routing
    - Establish proper routing and determine cable lengths.
    - Avoid routing taut cables between connections
    - When routing battery cables from the frame rails to the starting motor, anchor the cables to the engine, transmission, or starting motor prior to attachment to the starting motor, to allow for relative movement between the engine and the frame.
2. Determine cable sizes in order to meet circuit resistance and voltage drop recommendations.
3. It is highly recommended that a copper ground return is utilized, and the frame is ***not*** relied upon for the ground return in the starting circuit, to ensure that corrosion does not create excessive voltage drops. Often, engine manufacturers require an isolated starter to prevent voltage transients from damaging the engine control module. Using a copper ground cable is especially critical in applications utilizing wet flywheel housing, where reliance on frame grounding can create a current path through the crankshaft and main bearings.
4. Do ***not*** use star washers or toothed lock washers in any electrical connection. These washers can result in a high resistance connection. Also refer to SAE J1908, "*Electrical Grounding Practices*".
5. Select insulation to meet environmental and routing requirements.
6. Choose proper terminals for all cables.
7. Specify wiring covers and protection such as clamps, loom, conduit, terminal boots, and sleeves to protect against abrasion and exposure.
8. Use suitable protection from environmental contamination, such as anti-corrosion lubricant, where necessary, such as on battery cable connections. Note that starting motors can withstand occasional road splash, but are not designed for continuous exposure to high-pressure water spray.
9. Keep the number of cables attached to the battery terminal of the solenoid to a minimum, preferably no more than three. Each terminal on the battery post adds some resistance to the stack-up and increases the risk of looseness at the post
10. Do not install a bus bar bracket or de-population stud on the B+ starter terminals as these apply excess mechanical loads and create a safety hazard.

11. For more information, refer to the industry standards listed on the following page.

Grounding

Providing a proper ground for the starter is extremely important and often overlooked. Always follow the recommendations in the section above when designing a starter ground circuit.

Starters may be available in either case insulated or case grounded versions. For case insulated models, there must be a connection to the ground terminal on the starter to complete the starting circuit. For case-grounded models, grounding is accomplished through the frame of the starter. However, as discussed above, to ensure minimal voltage drops over the life of the vehicle, we recommend a full copper return to the batteries. On a case grounded starter, this becomes a redundant ground path. Some manufacturers also ground the starter to the engine and/or frame of the vehicle, in addition to providing the copper return path to the batteries, to ensure good ground connections.

Industry Standards- Wiring and Cabling

There are many industry references relating to wiring. These include:

- SAE J1127, *Battery Cable*
- TMC RP105, *Battery Cable Assemblies*
- TMC RP110, *Low Tension Cable for Heavy-Duty Truck-Tractor Wiring Systems*
- TMC RP111, *Circuit Protection*
- TMC RP114, *Wiring Harness Protection*

CIRCUIT SPECIFICATIONS

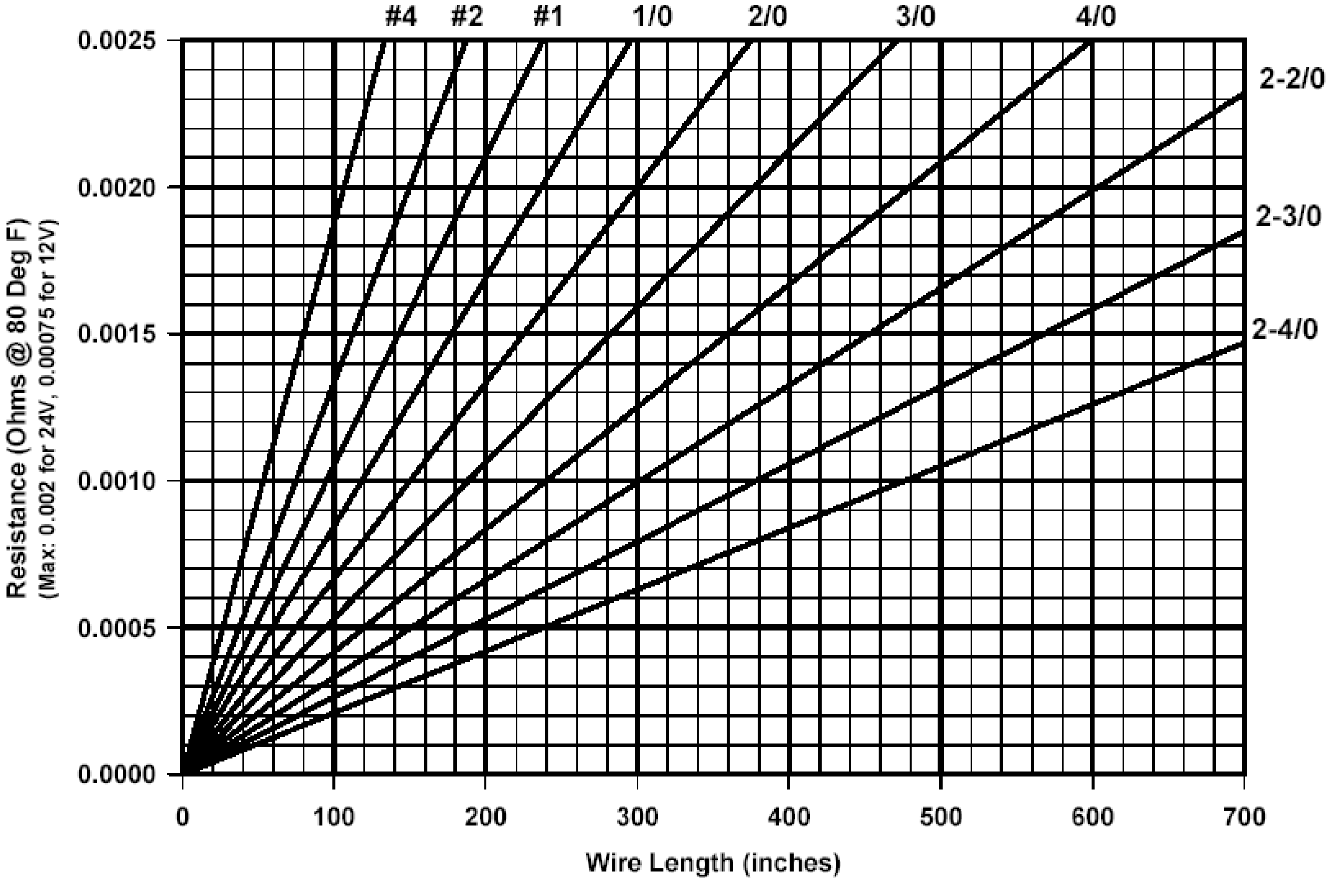
Both the cranking and solenoid control circuits for the starting motor are considered to originate and end at the positive and negative terminals of the batteries. The maximum voltage drops and circuit resistances are specified below for both circuits:

Cranking Circuit Requirements and Specifications

All Models	12-volt system	0.001 Ω *(maximum) in-service vehicle*
		0.00075 Ω *(maximum) new vehicle*
	24, 32 & 64 volt systems	0.002 Ω *(maximum) in-service vehicle*
		0.0015 Ω *(maximum) new vehicle*

For an optimum system, include all interconnecting battery cables in the resistance calculation. Note that the values specified above for Delco Remy starting motors are slightly different from SAE specifications, but are consistent with TMC RP-129. TMC recommends crank circuit testing at 500 amps, so the above values correspond to voltage drops of 0.5 V on a vehicle in-service and 0.375 V on a new vehicle with a 12-volt system.

Cranking Circuit Resistance vs Length



Solenoid Circuit Requirements and Specifications

CAUTION: Additional circuits and relays such as fuel-control or intake-air-heater solenoids must NOT be wired to the starter solenoid switch terminal nor to the output of the magnetic switch (which is nearly the same point of the circuit as the switch terminal). These may become an alternate path for current flow upon release of energy stored in the solenoid coils. Other devices wired in the solenoid control circuit, such as intake air heater controls, can also create an imbalance of current through the solenoid windings. Such a current imbalance may prevent the solenoid from disengaging, which causes the starter to continue to run and eventually fail due to overheating. See the Operating Principles section for the description of operation of the solenoid.

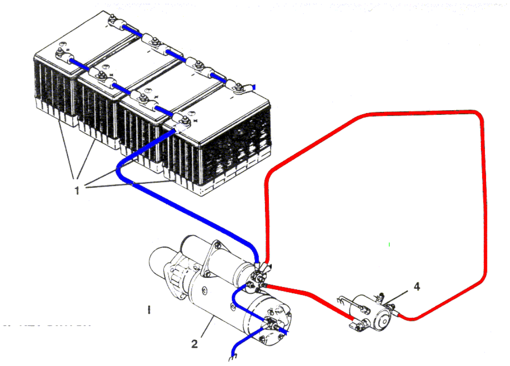
The solenoid coils use electromagnetic force to pull and hold a plunger to engage the pinion and close the contactor that energizes the motor. **This circuit can see current as high as 225 amps on a 12V 39MT and 300 amps on a 12V -** the level is a function of the engagement system.

Maximum Control Circuit Current for Heavy Duty Starter Motors

Product Series	12V Motor, amps	24V Motor, amps
28MT	70	120
29MT	80	175
37MT	70	40
38MT & 39MT	300	225
41MT & 42MT	80	60
50MT	90	50

The values listed above are average at 20°C (68°F) and will vary based on many factors including temperature, battery state-of-charge, wiring condition, and variation in circuit resistances. For these reasons, circuits should be designed using wiring and accessory components, such as magnetic switches, that will carry instantaneous and short-term (up to 30 seconds) currents at least 20% higher than these values.

A properly applied mag switch, together with a compliant control circuit, provides the necessary voltage and current to the solenoid for reliable starter operation. The most common problem with solenoid control circuits is voltage drop in the wiring, connections, and the relay or mag switch. From the maximum current ratings above, note that electrical soft-start motors (all 38MT and 39MT, as well as 29MT and 24V 28MT) require approximately 200% to 400% (depending on the units being compared) lower resistance components and wiring than the components and wiring used on conventional (12V 28MT, 12V & 24V 37MT, 41MT, and 42MT) starter motors. Wiring that is too long or too small, and inadequate connections on positive and negative sections of the circuit, cause loss of voltage supplied to the starter solenoid. Inadequate wiring and switches can lead to malfunctioning of the starting system. Voltage drop exceeding specifications produces unreliable cranking conditions that can be amplified by other factors, such as low battery, extreme ambient temperatures, and gear-tooth abutment or jamming and can ultimately cause premature starter failure.



Solenoid Control Circuit Specifications at Maximum Current

Battery System	Maximum Voltage Drop at Product-Specific, Maximum Current
12 V	1.0
24 V	2.0
32 V	2.0

Since the voltage drop is a function of current, you must measure or calculate the drop at the corresponding maximum solenoid current rating. To simplify the process of measuring voltage drop in a control circuit (and other electrical system tests), Delco Remy has developed the Intellicheck diagnostic test system.

Starter Total Current Draw

The average or "typical" current draw of a starter depends on so many variables that it is not possible to predict. The 42MT 12-volt starter will normally draw from less than 300 amps to more than 1600 amps depending on torque required, available battery power and capacity, and wiring sizes and condition. In-rush current, the momentary current spike at zero rpm (engine off) as the starter engages, is even higher, and can be 2,000 – 3,000 amps, depending on temperatures, starter, and batteries. Required torque depends on engine displacement, number of cylinders, engine temperature, oil viscosity (varies with temperature), accessory loads, and the condition of all the system components among others.

APPENDIX A:

CHECKING SOLENOID CONTROL CIRCUIT VOLTAGE DROP

I. Basic Method

1. Disconnect the battery.

2. Remove ***all*** cables and connections from the battery terminal of the starting motor.

3. Clamp all of these cables and connections together (a ½ inch bolt and nut works well). Wrap a heavy rag or tape around this connection to be certain that it does not touch any metal.

4. Reconnect the battery (ies).

5. Connect a voltmeter between battery positive and the ‘S’ terminal. The voltmeter should show battery open circuit voltage, about 12.5 – 12.6 volts or 25.0 – 25.2 volts (for 12V and 24V systems, respectively).

6. Close the vehicle start switch, observe the very first reading, and immediately release the start switch. The first reading is the voltage drop. (If you wait, the voltage reading will drop rapidly as the solenoid heats up and raises the solenoid resistance.) Again, be certain to record the very first reading. (The motor will not crank, as there is no voltage supplied to the motor.)

7. Repeat Step 6 with the voltmeter connected between the battery negative and motor negative. Add the voltages from Steps 6 and 7 to get the control circuit voltage drop.

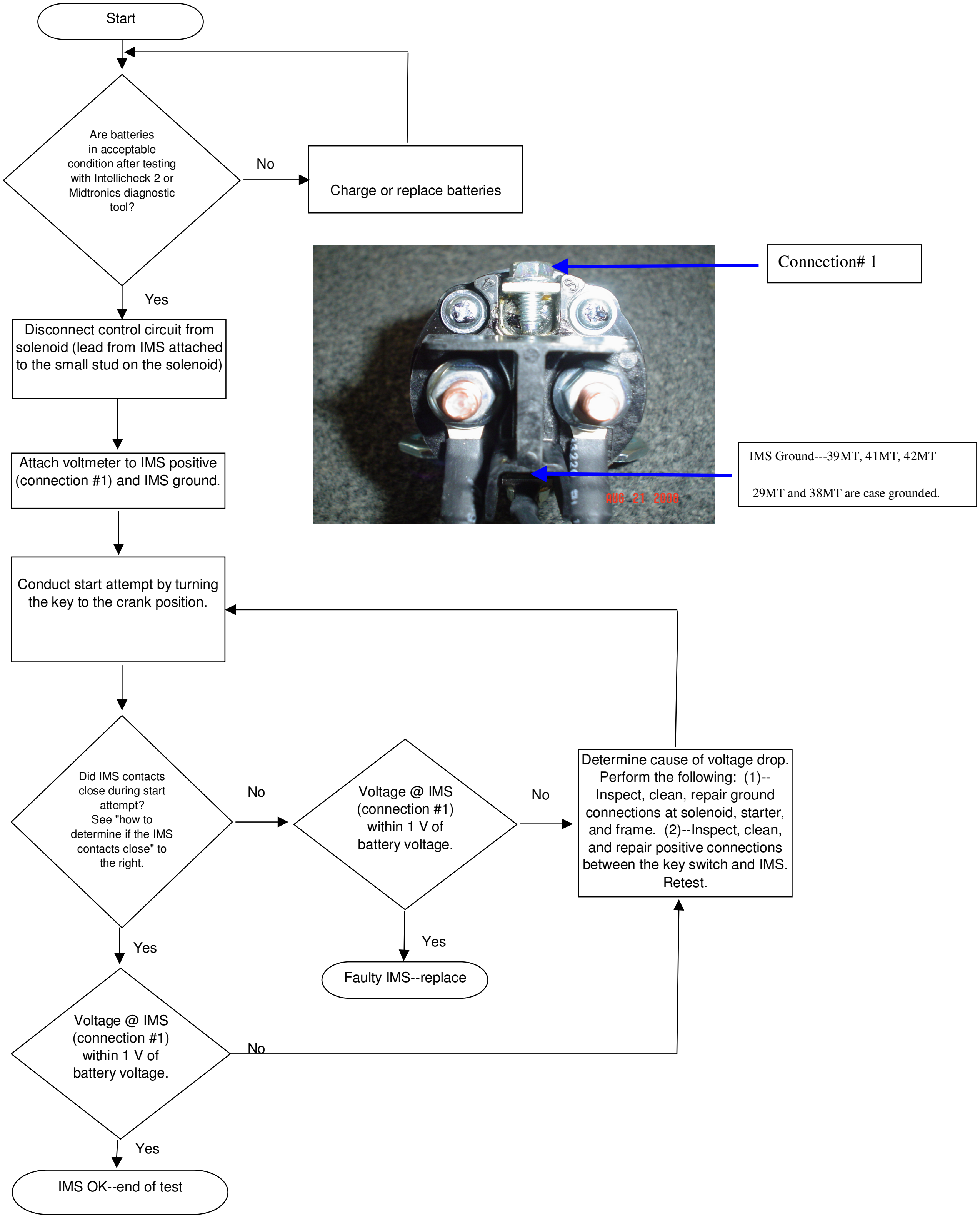
8. Disconnect the battery.

9. Replace all the connections to the battery terminal of the motor and then reconnect the battery.

II. Automated Circuit Test Using Intellicheck2 Test System
(Remy part number 10503560)

This portable tester is designed to replace a carbon pile load box and multi-meter. Programmed with logic that guides the user through every connection, the unit conducts a semi-automated test.

APPENDIX B: INTEGRAL MAG SWITCH TROUBLESHOOTING



Start

Are batteries in acceptable condition after testing with Intellicheck 2 or Midtronics diagnostic tool?

No: Charge or replace batteries

Yes: Disconnect control circuit from solenoid (lead from IMS attached to the small stud on the solenoid)

Attach voltmeter to IMS positive (connection #1) and IMS ground.

Conduct start attempt by turning the key to the crank position.

Did IMS contacts close during start attempt? See "how to determine if the IMS contacts close" to the right.

No: Voltage @ IMS (connection #1) within 1 V of battery voltage.

Yes: Faulty IMS--replace

No: Determine cause of voltage drop. Perform the following: (1)--Inspect, clean, repair ground connections at solenoid, starter, and frame. (2)--Inspect, clean, and repair positive connections between the key switch and IMS. Retest.

Yes: Voltage @ IMS (connection #1) within 1 V of battery voltage.

No

Yes: IMS OK--end of test

Connection# 1

IMS Ground---39MT, 41MT, 42MT

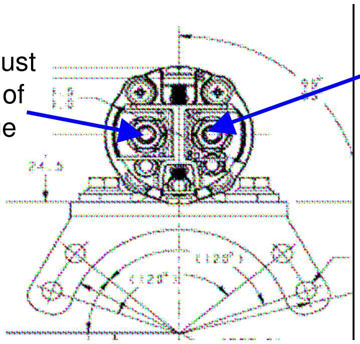
29MT and 38MT are case grounded.

How to determine if the IMS contacts close?

This can by determined by monitoring voltage on the 2 large IMS studs. If voltage is present at the IMS terminal that sends the signal to the solenoid, the contacts are closed. See explanations below.

Depending on the noise level in the test environment, an audible click may be heard when the contacts close.

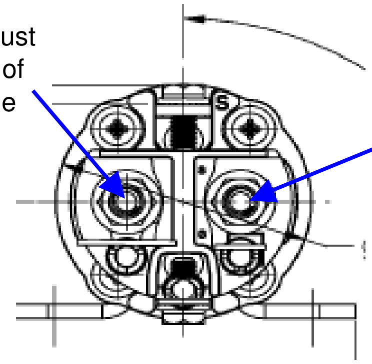
41MT & 42 MT starter models



Lead from starter B+--must be within 1 V of battery voltage

Monitor this terminal during a crank attempt. If voltage is present, the contacts are closed.

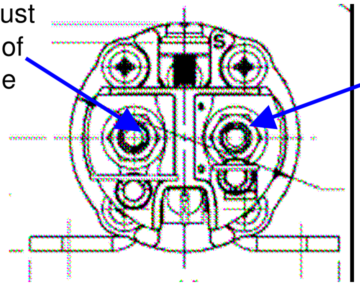
39 MT starter models



Lead from starter B+--must be within 1 V of battery voltage

Monitor this terminal during a crank attempt. If voltage is present, the contacts are closed.

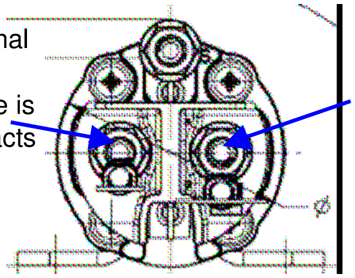
38MT starter models



Lead from starter B+--must be within 1 V of battery voltage

Monitor this terminal during a crank attempt. If voltage is present, the contacts are closed.

29MT starter models



Monitor this terminal during a crank attempt. If voltage is present, the contacts are closed.

Lead from starter B+--must be within 1 V of battery voltage

APPENDIX C: WIRING SIZE VS. LENGTH

Solenoid Control Circuit
Wire Length Limits Estimator

NOTE: TERMINAL and CONNECTOR RESISTANCE MUST ALSO BE CONSIDERED

12V 38MT & 39MT	Assuming Mag Switch & Connection Voltage Drop =	0.3
Max Voltage Drop = 1V	Assuming Max Solenoid Load (HI & PI Coils Energized)	
Max Wire Length in Circuit, Inches	Recommended Minimum Gauge of Wire, AWG	Ohms/1000ft
7	16	4.125
11	14	2.586
17	12	1.632
27	10	1.025
43	8	0.645
69	6	0.406
110	4	0.255
175	2	0.16

24V 38MT & 39MT	Assuming Mag Switch & Connection Voltage Drop =	0.3
Max Voltage Drop = 2V	Assuming Max Solenoid Load (HI & PI Coils Energized)	
Max Wire Length in Circuit, Inches	Recommended Minimum Gauge of Wire, AWG	Ohms/1000ft
25	16	4.125
39	14	2.586
63	12	1.632
100	10	1.025
158	8	0.645
251	6	0.406
400	4	0.255
638	2	0.16

12V 28MT, 29MT, 37MT, 41MT, & 42MT	Assuming Mag Switch & Connection Voltage Drop =	0.3
Max Voltage Drop = 1V	Assuming Max Solenoid Load (HI & PI Coils Energized)	
Max Wire Length in Circuit, Inches	Recommended Minimum Gauge of Wire, AWG	Ohms/1000ft
25	16	4.125
41	14	2.586
64	12	1.632
102	10	1.025
163	8	0.645
259	6	0.406
412	4	0.255
656	2	0.16

24V 28MT, 29MT, 37MT, 41MT, & 42MT	Assuming Mag Switch & Connection Voltage Drop =	0.3
Max Voltage Drop = 2V	Assuming Max Solenoid Load (HI & PI Coils Energized)	

Max Wire Length in Circuit, Inches	Recommended Minimum Gauge of Wire, AWG	Ohms/1000ft
124	16	4.125
197	14	2.586
313	12	1.632
498	10	1.025
791	8	0.645
1256	6	0.406
2000	4	0.255
3188	2	0.16

APPENDIX D: MOTOR OVER-HEAT FROM DISCHARGED BATTERIES

While common sense would seem to say that motor over-heat would be more likely with highly charged batteries, there are cases where the opposite is true. To understand the reasons requires some explanation. In a cranking system, the starting motor converts the electrical energy of the battery (which itself converts chemical energy to electrical energy) to mechanical energy to crank the engine. The motor is almost always a series motor, which has the distinct feature that torque is proportional to current and speed is proportional to voltage.

The engine is the load on the starting motor that is driven up to a particular speed where it will start and run on its own. A certain amount of power is required to crank the engine at various speeds. This power requirement can be expressed on a graph as power vs. speed or as torque vs. speed, using the relationship below and shown in Figure 1:

$$HP = \frac{T \text{ x } S}{5250} \qquad KW = \frac{T \text{ x } S}{9550}$$

Where T is torque in lb-ft	T is torque in N-m
S is speed in rpm	S is speed in rpm
HP is power in hp	KW is power in kW

Starting motor performance can be shown on a graph in the same manner, in a torque-speed relationship, as shown in Figure 2. The solid line in Figure 2 represents the torque-speed relationship with a given power supply (e.g. batteries). If the power supply is increased, the dotted line is the new torque-speed relationship; if it is decreased, as with discharged batteries, then the torque-speed relationship is represented by the dashed line. Recall that torque is proportional to current, so the torque scale is also a current scale.

Power required to crank an engine

(Power = Torque x speed)

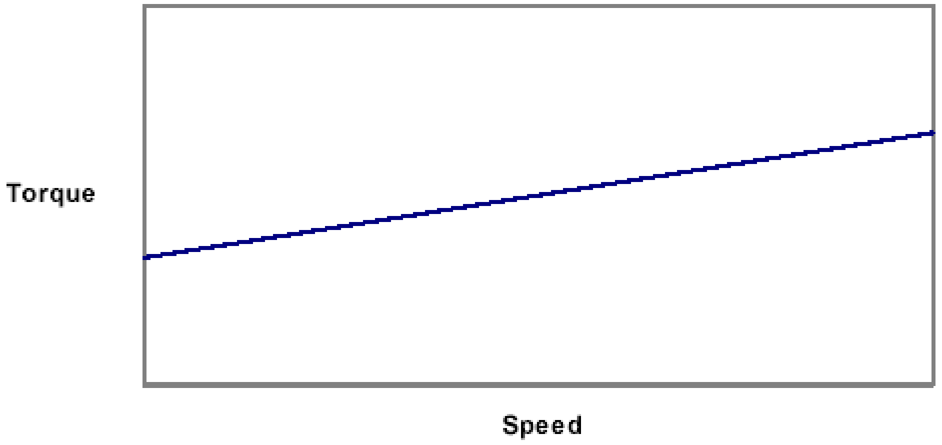


Figure 1

Battery effect on starter motor performance

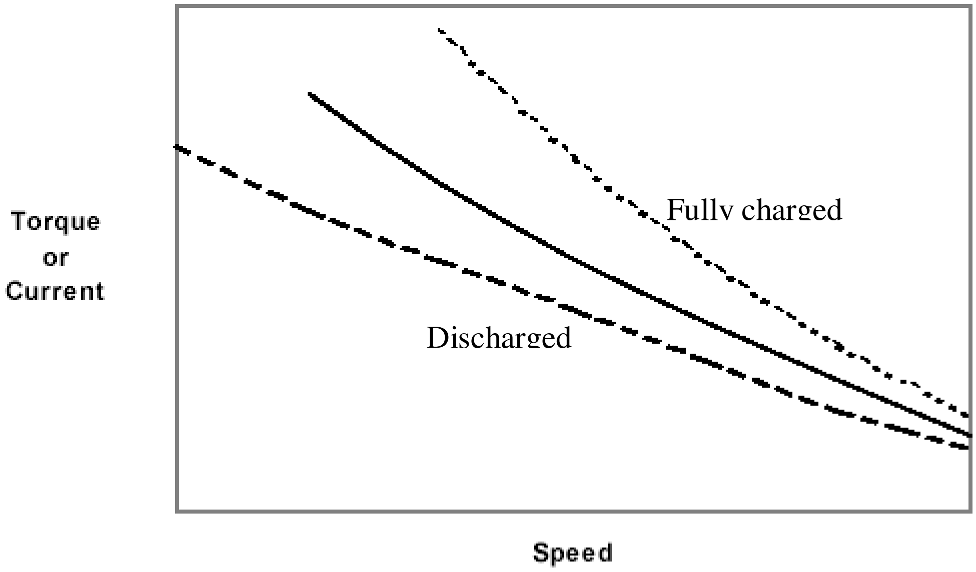


Figure 2

When the two graphs are combined in Figure 3, the motor-battery curves intersect the engine requirements curve. The point of intersection is the cranking performance of the system. Point B represents where the standard system would crank the engine, Point A is where a larger battery would crank, and Point C is where the smaller or discharged battery would crank. Point B represents a higher cranking speed at higher current (because torque is higher) and Point C represents a lower cranking speed at lower current (because torque is lower). Current is directly related to engine torque at the speed being cranked.

Starter motor performance combined with engine power requirements (Figure 1 combined with figure 2)

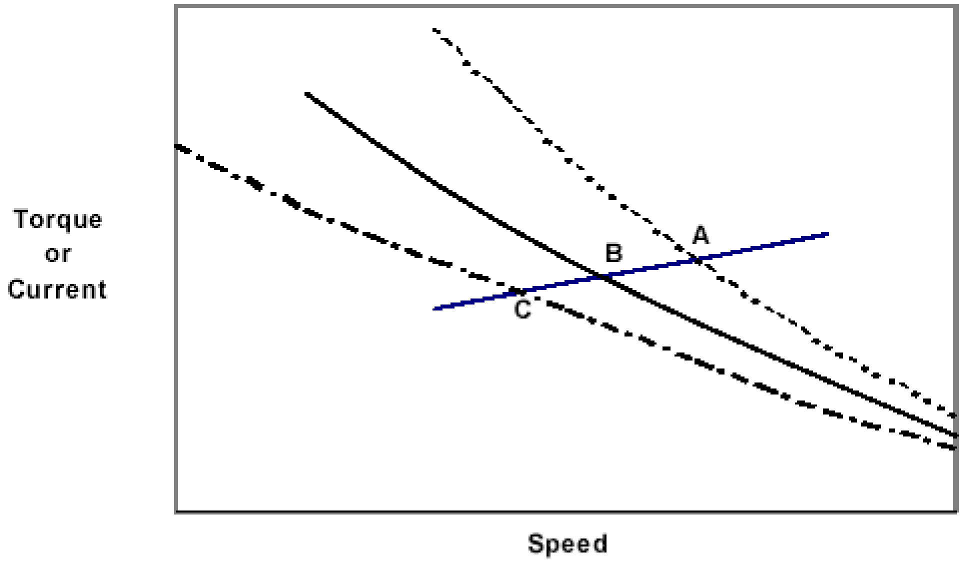


Figure 3

Some engines have a torque characteristic that rises sharply at lower speeds, due to temperature, oil, fit of parts, etc. (see Figure 4).

Sample engine crank requirements

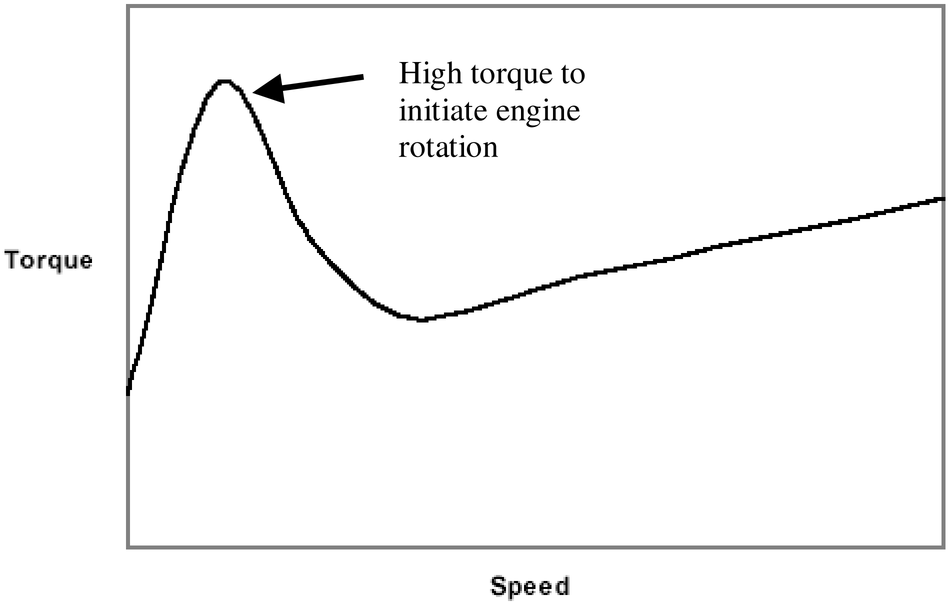


Figure 4

If this engine requirement is shown on the motor performance of Figure 2, it is readily seen how discharged batteries can cause slow cranking at high current (see Figure 5). The high current is not due to slow cranking, but rather to the increase in torque of the engine. Point A is the performance of a standard system, while Point C represents the performance of a system with discharged batteries. From this graph, it is readily apparent how cranking with low batteries can cause an increase in cranking current. If, due to the slow cranking speed and inability to start the engine, the operator continues to crank, the motor will stall or over-heat due to the increase in current.

Engine requirements combined with starter performance
(Figure 2 combined with figure 4)

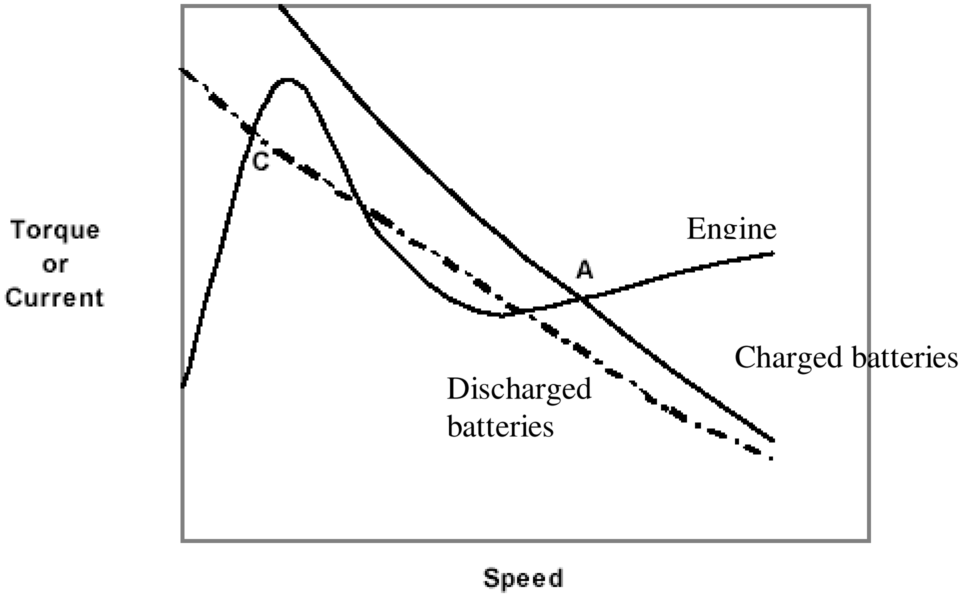


Figure 5

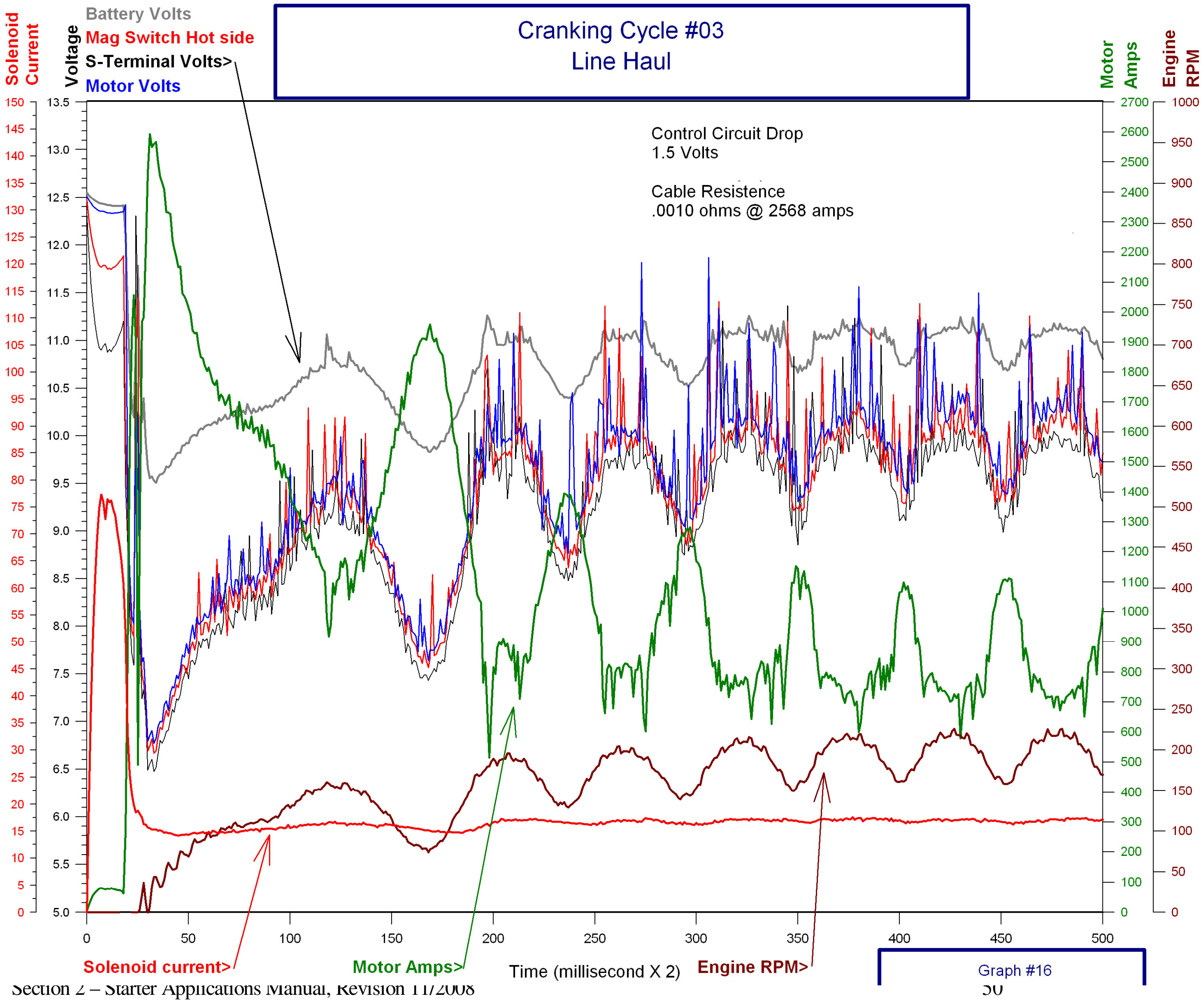
It is frequently misunderstood how motor over-heat can occur as a result of discharged batteries, since discharged batteries obviously have a lower maximum current available than fully charged batteries. However, the comparison being made is improper. As seen in the graphs above, current increases slightly with greater battery size, but with discharged batteries, current increases significantly <u>due to the higher torque requirement</u>. The load dictates the current in a series motor as long as the armature is rotating. When the motor stalls, current is dictated by the total circuit resistance and applied voltage.

APPENDIX E (see Alternator section for additional MODAC discussion):

MODAC can provide the following starter information:

1. Starter solenoid current
2. Starter current
3. Battery voltage (2 millisecond data)
4. Starter solenoid voltage (2 millisecond data)
5. Starter solenoid voltage across the contacts (2 millisecond data)
6. Starter S-Terminal voltage (2 millisecond data)
7. Starter Mag switch voltage – hot side (2 millisecond data)
8. Starter Mag switch voltage – across the contacts (2 millisecond data)
9. Starter voltage (2 millisecond data)
10. Engine speed during crank (2 millisecond data)
11. Number of cranks during the testing

SAMPLE STARTER CRANK CYCLE (MODAC)



APPENDIX E:

FAQ ABOUT STARTERS

1. How much current will a starter draw during normal operation?

This question is impossible to answer for a given starter given no other information. Current draw depends on many variables including load, which is effected by engine size, parasitic engine loads, oil viscosity, as well as the batteries used, temperature, and state-of-charge of the batteries. But in-rush current can briefly exceed 2000 amps (See MODAC chart in Appendix D). Delco Remy can estimate current draw for a given set of conditions by performing a cranking system computerized estimate, but cannot estimate current draw without other information.

2. Can too large of a battery pack size damage a starter?

Yes. See the recommendations listed in this guide. Too large of a battery pack can result in excessive current draw by the starter, which can cause starter damage.

3. What is the minimum battery pack size?

Starters and batteries must be specified concurrently. The size of the battery pack required depends on the engine starting requirements and any "key-off" accessory loads that are present when the engine is not running. The battery pack must provide sufficient amperage for the starter during cranking and also have sufficient reserve capacity for key-off loads. Thus, the minimum battery pack size depends upon the application, the starter, the cold weather starting requirements, and other factors.

4. How are the "Maximum engine size" recommendations (table) determined?

The engine sizes shown in the table are the largest size for which Delco Remy has either tested, or reviewed test data, and approved a starter application for an engine of the specified size. These application approvals are based upon engine manufacturers' temperature and cranking speed requirements. Most requirements are usually 0°C to -20°C, with a cranking speeds of about 100rpm. The engine sizes do NOT represent the maximum possible engine size for each starter, but are guidelines to determine when a larger starter will likely be the most suitable choice. The allowable engine size will increase with certain conditions (ambient temperature well above freezing, starting aids, etc.), or decrease at other conditions (temperatures well below freezing, high parasitic loads, high viscosity oil, etc.)

Application manual change dates:
March 2005: Original copy
November 2008: updated copy