SURFACE VEHICLE RECOMMENDED PRACTICE	J3053™	MAR2024
	Issued 2015-07 Revised 2024-03 Superseding J3053 JAN2019	

Heavy Duty Truck and Bus Electrical Circuit Performance Requirement for 12/24-Volt Electric Starter Motors

RATIONALE

The scope of this document has been modified to define the battery technologies used in its development.

1. SCOPE

The recommended practice describes a design standard that defines the maximum recommended voltage drop of the starting motor main circuits, as well as control system circuits, for 12/24-V starter systems.

The battery technologies used in developing this document include the flooded lead acid, gel cell, and AGM. Starting systems supported by NiCd, Lithium Ion, NiZn, etc., or Ultracaps are not included in this document.

This document is not intended to be updated or modified to include starter motors rated at voltages above the nominal 24-V electrical system. The starter is basically an electrical-to-mechanical power converter. If you double the available battery power in, you double the peak mechanical power out and double the heat losses. This means that we have to pay special attention to how battery power changes when we change the battery voltage and the effects it may have in overpowering the cranking system. A new stand-alone document would need to be developed to address electrical circuit performance for starter motor systems with ratings above the nominal 24-V system.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J544 Electric Starting Motor Test Procedure

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: **http://www.sae.org**

For more information on this standard, visit
https://www.sae.org/standards/content/J3053_202403/

2.1.2 ISO Publications

Available from International Organization for Standardization, ISO Central Secretariat, 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, Tel: +41 22 749 01 11, www.iso.org.

ISO 8856 Road vehicles - Electrical performance of starter motors - Test methods and general requirements

3. DESCRIPTION

The electrical cranking system components in a heavy duty truck and bus include batteries, cabling, master disconnects, switches, control switches, relays, terminations, and cranking motor. The starting system shall be designed in a fashion to provide the necessary engine rpm to start an engine under the most severe climatic conditions for which the system is intended. This SAE Recommended Practice is focused on the starter motor electrical circuit and its corresponding circuit components (see Figure 6), but engine cranking has many other variables, as shown in Figure 1, that will also influence engine cranking and starting performance.

3.1 Engine manufacturers may have minimum electrical system design guidelines defined to meet their engine starting requirements. These engine manufacture guidelines shall be considered by the truck and bus OEM when designing the electrical cranking system.

3.2 Truck and bus OEMs may also incorporate a holistic electrical cranking system design. For example, by reviewing the minimum operating temperature, minimum required engine cranking speed, circuit components, starting aids, and recommended oil type, the OEM may choose to deviate from recommended circuit voltage drops:

- Battery internal resistance (Rbatt) may be reduced by applying a battery pack with a lower internal resistance, or by using ultracapacitors, or other alternative power sources (see Section 6).

- A starting aid such as a block heater may allow the engine to crank at an internal temperature that greatly exceeds cold climate ambient temperatures.

- Temperature aids such as an air preheater and low-viscosity oil may be used.

3.3 If a truck or bus OEM’s electrical cranking system design deviates from the defined component “voltage drops found in the table” shown in Section 6, explicit service literature shall be provided by the truck or bus OEM defining the proper electrical crank system test procedure and a list of any specialized components and their voltage drop values.

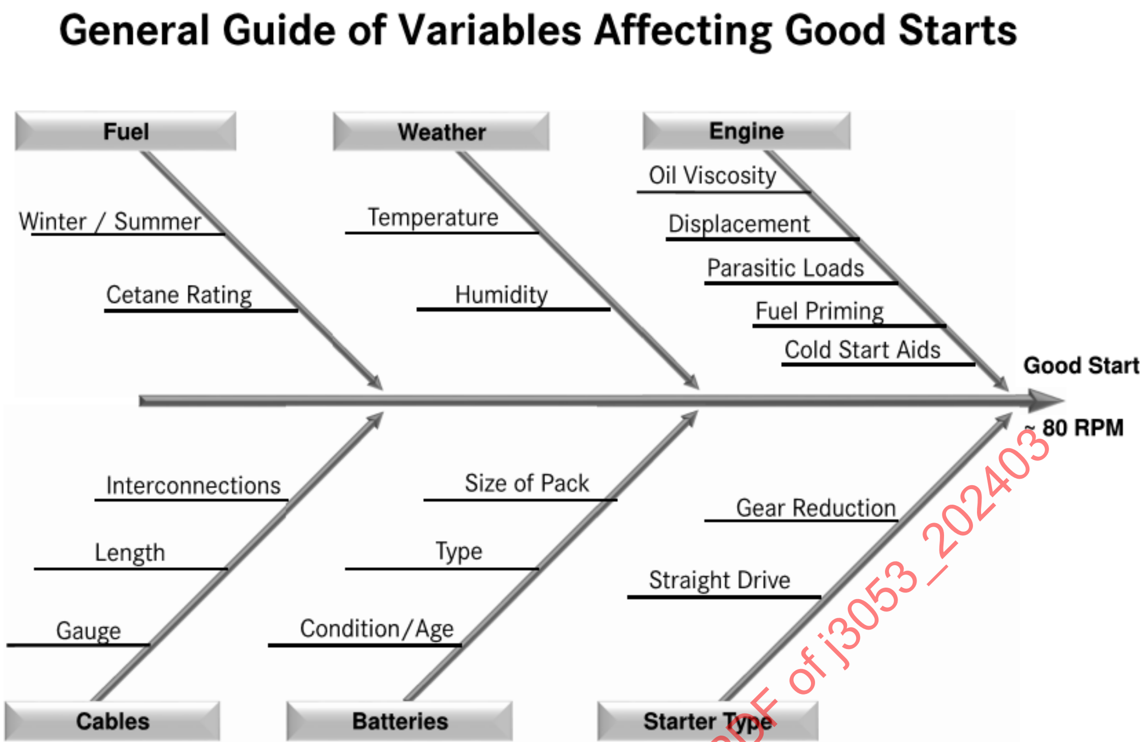


Figure 1 - Fishbone diagram

4. COMPONENT - STARTER MOTOR - STRAIGHT DRIVE VERSUS GEAR REDUCTION AND STARTER EFFICIENCY

- Torque per amp - The gear reduction starters have the advantage of producing more torque for a given amount of current (see Figure 2). So, in this regard, gear reduction is "more efficient."

- Efficiency - True efficiency is defined as power out/power in. Gear reduction starters are more efficient than straight drive starters in the desired working range of the starter (see Figure 3).

- Speed versus voltage - For a given steady state current, speed is proportional to voltage. Both straight drive and gear reduction motors are affected nearly equally in this regard. As shown in Figure 4, the slope is basically the same for straight drive and gear reduction.

Figures 2 through 4 were created from starter performance test data. The test method used to generate this data conforms to SAE J544 and ISO 8856. (All data shown is relative to a 12-V electrical system.)

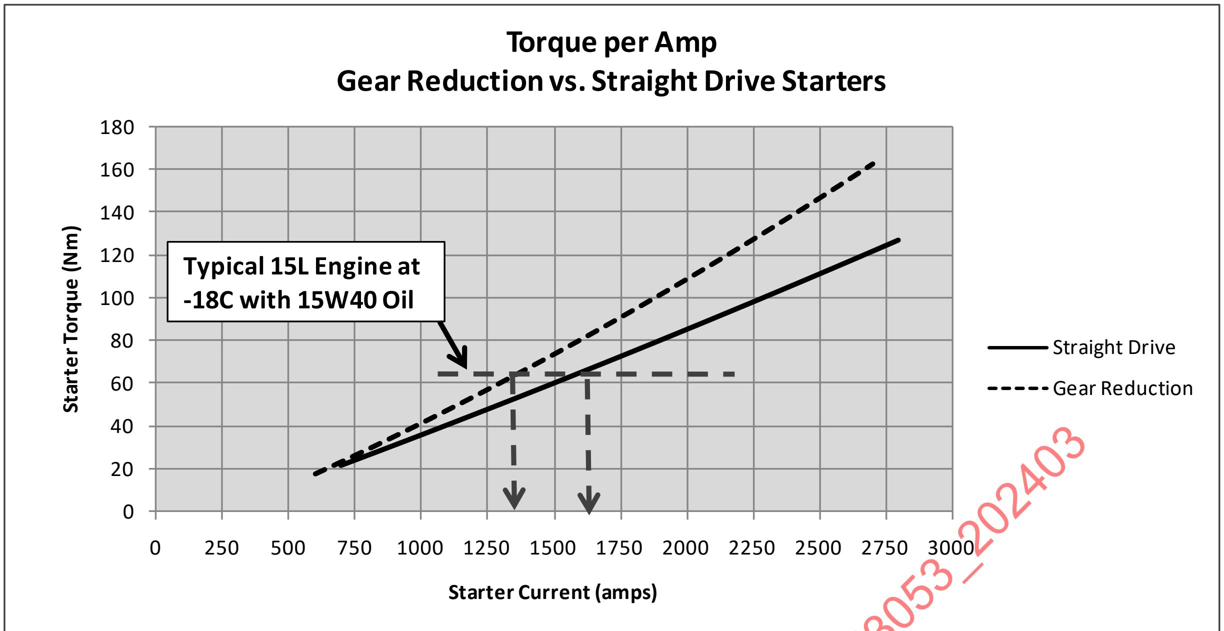


Figure 2 - Chart of starter torque versus current

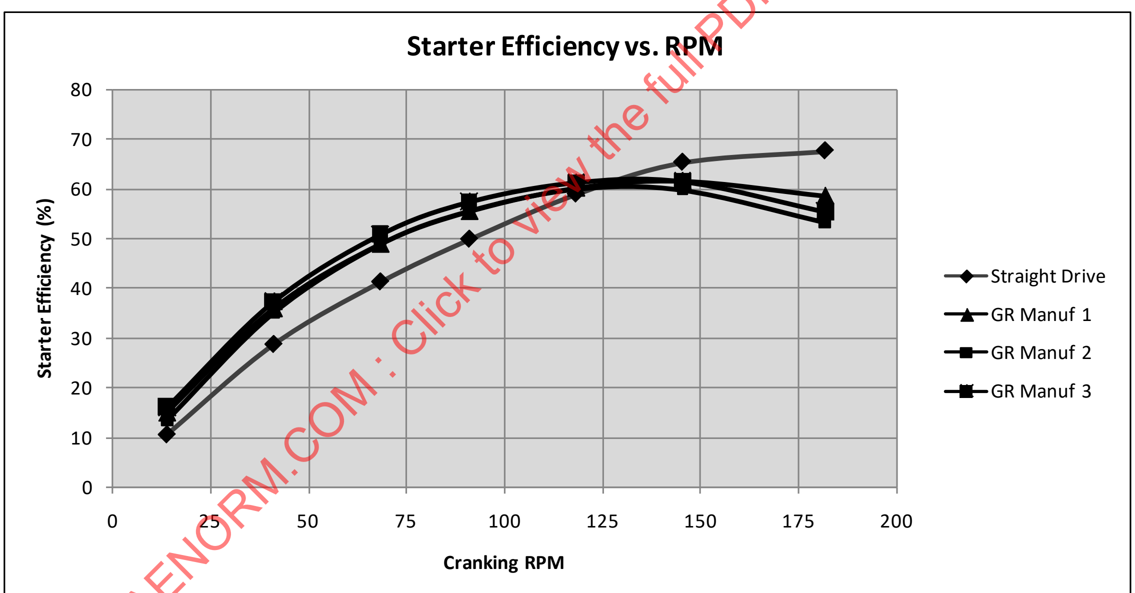


Figure 3 - Chart of starter efficiency versus cranking rpm

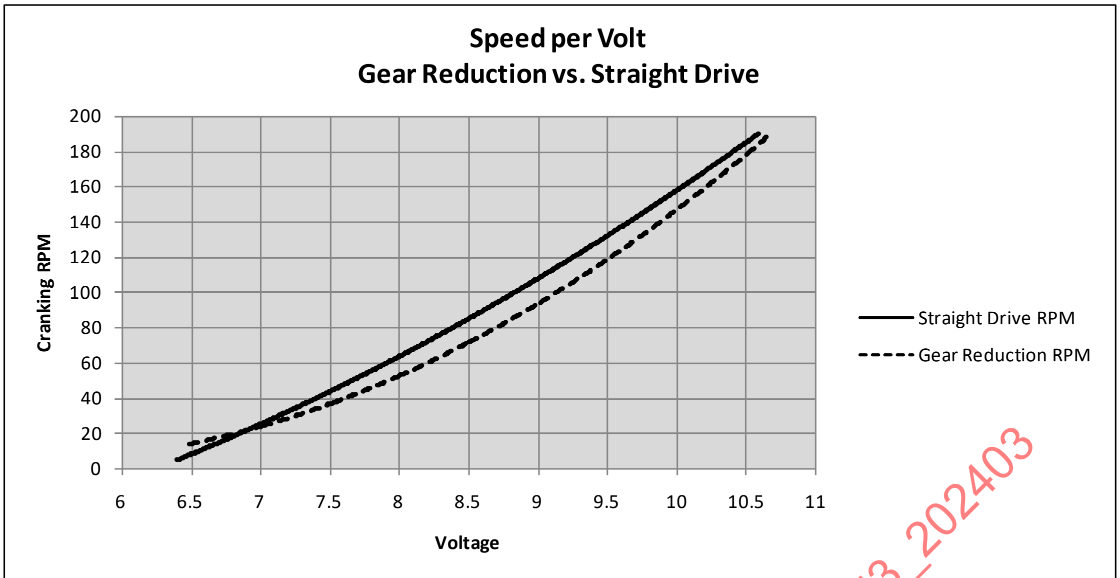


Figure 4 - Chart of cranking speed versus voltage

5. COLD CRANKING - ENGINE RPM/VOLTAGE/CURRENT

The bar charts in Figure 5 are based on actual data from a cold crank test of a 13-L engine with 15W40 oil at -18 °C fitted with a gear reduction starter motor. The crank data is based on 20-second continuous crank events. Fuel was disabled to prevent engine starting. Four different lead-acid battery packs were tested, and all were conditioned to 70% state of charge. Since temperature and oil weight were held constant for all tests, the cranking torque demanded by the engine was also constant for each test. This cold crank data clearly demonstrates that:

a. Cranking speed is proportional to voltage. Voltage is relative to battery chemistry (battery internal resistance, Rbatt), but not necessarily a direct correlation to cold cranking amps (CCA). As battery internal resistance increases, starter rpm will decrease as a result of lower available voltage at the starter. (See Charts 5A and 5B in Figure 5.)

b. Current is proportional to torque. Required cranking torque was constant for each test; therefore, the current remained constant, despite the different battery packs and resulting voltages during cranking, because all four battery packs had enough excess CCAs to provide all the current demanded by the starter. (See Chart 5C in Figure 5.)

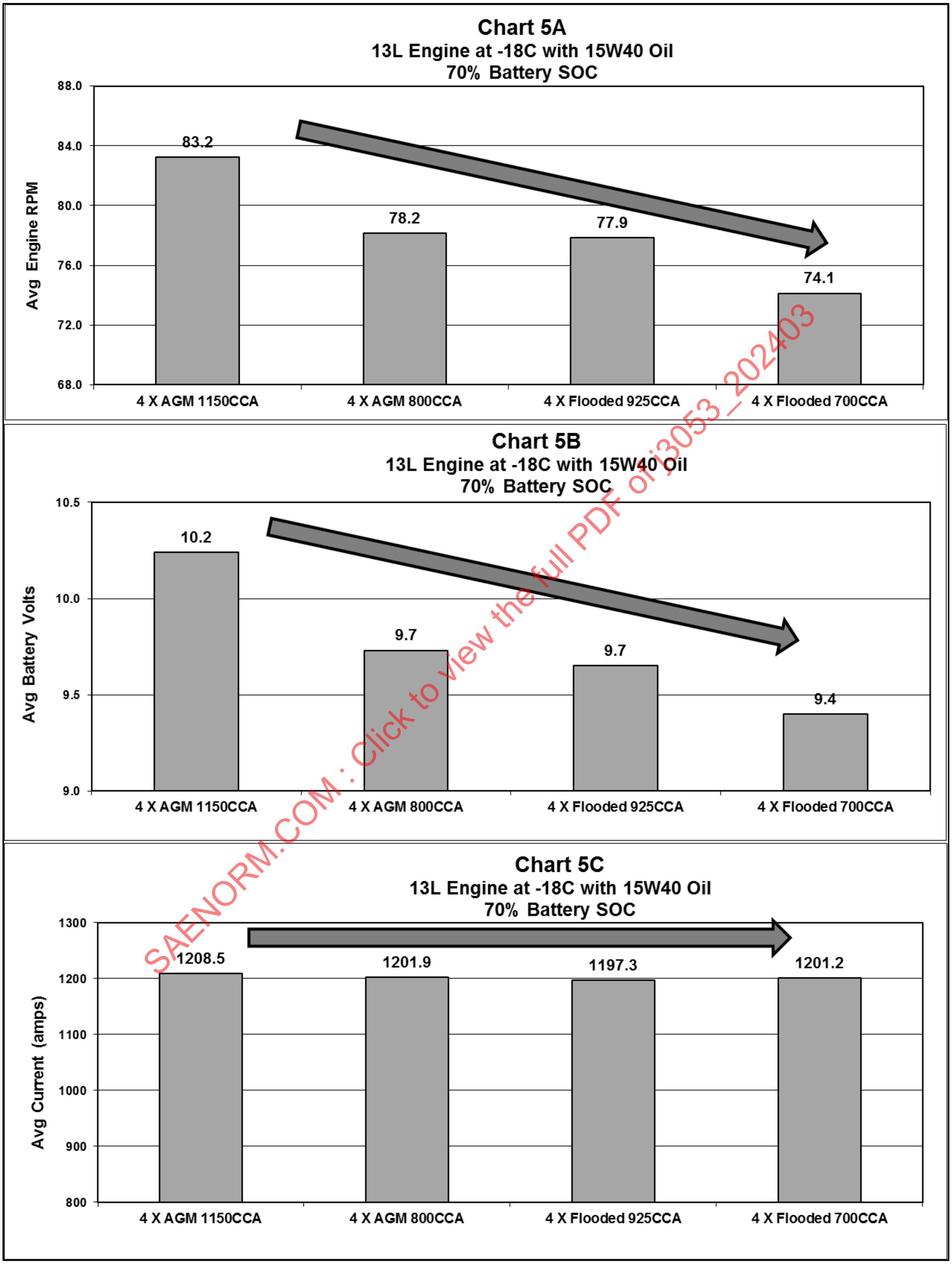


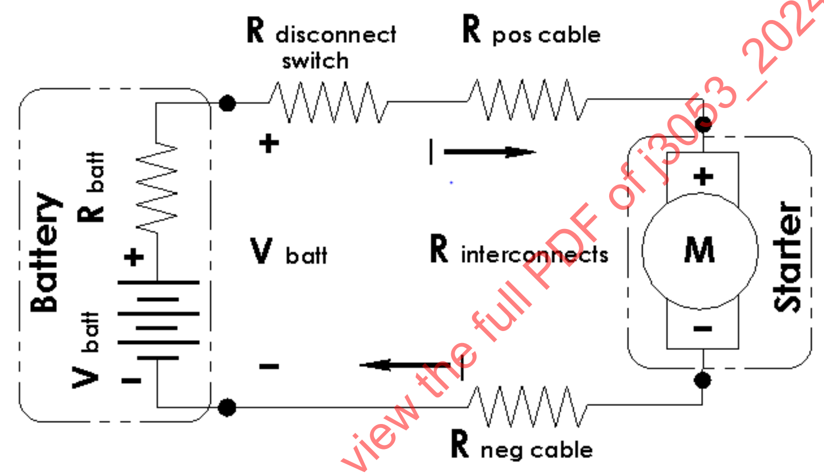
Figure 5 - Charts of cold crank data

6. STARTER ELECTRICAL CIRCUIT - MAIN CRANKING CIRCUIT

The main cranking circuit consists of the positive and negative cables, master disconnect switch, and all circuit terminations (see Figure 6).

- Voltage drop measurement shall be performed by applying the highest reasonable stable current load to the circuit to maximize the signal to noise ratio. Measurements should be performed quickly to minimize changes in circuit resistance due to I^2 X R self-heating effects. The minimum recommended current to be applied for measurement purposes is 120 A. Figure 7 provides recommended values for V-drop/120 A, V-drop/500 A, as well as the equivalent resistance in ohms.

- The starting motor circuits in motor vehicles shall be designed so that the difference between the voltage at the battery terminals and the starting motor terminals (including connections and disconnect switch) shall not exceed those values shown in Figure 7. The voltage drop values are defined with a normal circuit temperature of 20 °C (68 °F).



$$V_{starter} \sim V_{batt} - I * (R_{batt} + R_{disconnect\ switch} + R_{cables} + R_{interconnects})$$

Figure 6 - Crank circuit diagram, main cables

Main Cranking Circuit Recommended Maximum Voltage Drop						
System Voltage	***Use***	***Total Circuit Resistance***	***V-Drop/500 A***	***V-Drop/120 A***	***Starter Output Range***	***Max Engine Displacement***
12 V	Light Duty	0.003-0.004 Ω	--	0.36-0.48 V	0.9-2.5 kW	8 L gas 3.5 L diesel
12 V	Light/Medium Duty (LHDD)	0.002 Ω	1.0 V	0.24 V	2.2-3.3 kW	6 L
12 V	Medium Duty (MHDD)	0.0012 Ω	0.6 V	0.14 V	2.7-6.8 kW	9 L
24 V	Medium Duty (MHDD)	0.002 Ω	1.0 V	0.24 V	4.5-7.3 kW	13 L
12 V	Heavy Duty (HHDD)	0.001 Ω	0.5 V	0.12 V	6.8-8.5 kW	16 L
24 V	Heavy Duty (HHDD)	0.002 Ω	1.0 V	0.24 V	7.0-13 kW	30 L

NOTE: All exceptions to this requirement shall be defined in Section 3.

Figure 7 - Table of main cranking circuit recommended maximum voltage drop

6.1 Starter Electrical Circuit - Control Circuit

Starter solenoid current draw varies widely based on the type of starter engagement system. Robust control circuit design is critical to the starter engagement reliability and solenoid life. Although still important, the control circuit design for starters equipped with integrated magnetic switch (IMS) is less sensitive to voltage drop based on the relatively low-current draw of the IMS coil (approximately 2 to 4 A). For starters, without IMS, the control circuit consists of the wiring from the battery power source to the magnetic switch, the magnetic switch contacts, and the wiring from the magnetic switch to the starter solenoid (see Figures 8 and 9). Vehicles with electronically managed starter controls shall consider protection for inductive voltage spikes resulting from de-energizing the starter solenoid. Likewise, the system design should ensure that (if) a control relay exists on the starter, that suppression is present on the coil of the relay, which will ensure ample protection exists at the source where such inductive voltage spikes would be generated.

- Voltage drop measurement shall be performed by applying a current suitable to the operating current level of the starter solenoid or IMS during the initial engagement phase.

- Magnetic switch shall be energized to perform total circuit voltage drop measurement. (Disconnect circuit from starter motor prior to performing measurement.)

- Measurements should be performed quickly to minimize changes in circuit resistance due to I^2 X R heating effects. Figure 10 describes several different engagement system types and provides recommended values for V-drop/100 A, as well as the equivalent resistance in ohms.

- The starting motor control circuits in motor vehicles shall be designed so that the difference between the voltage at the battery terminals and the starting motor control circuit terminals (including connections) shall not exceed those values shown in Figure 10. The voltage drop values are defined with a normal circuit temperature of 20 °C (68 °F).