POWER WITH

INTELLIGENCE.

QSX15, QSK45, QSK60

GENERATOR DRIVE CONTROL SYSTEM

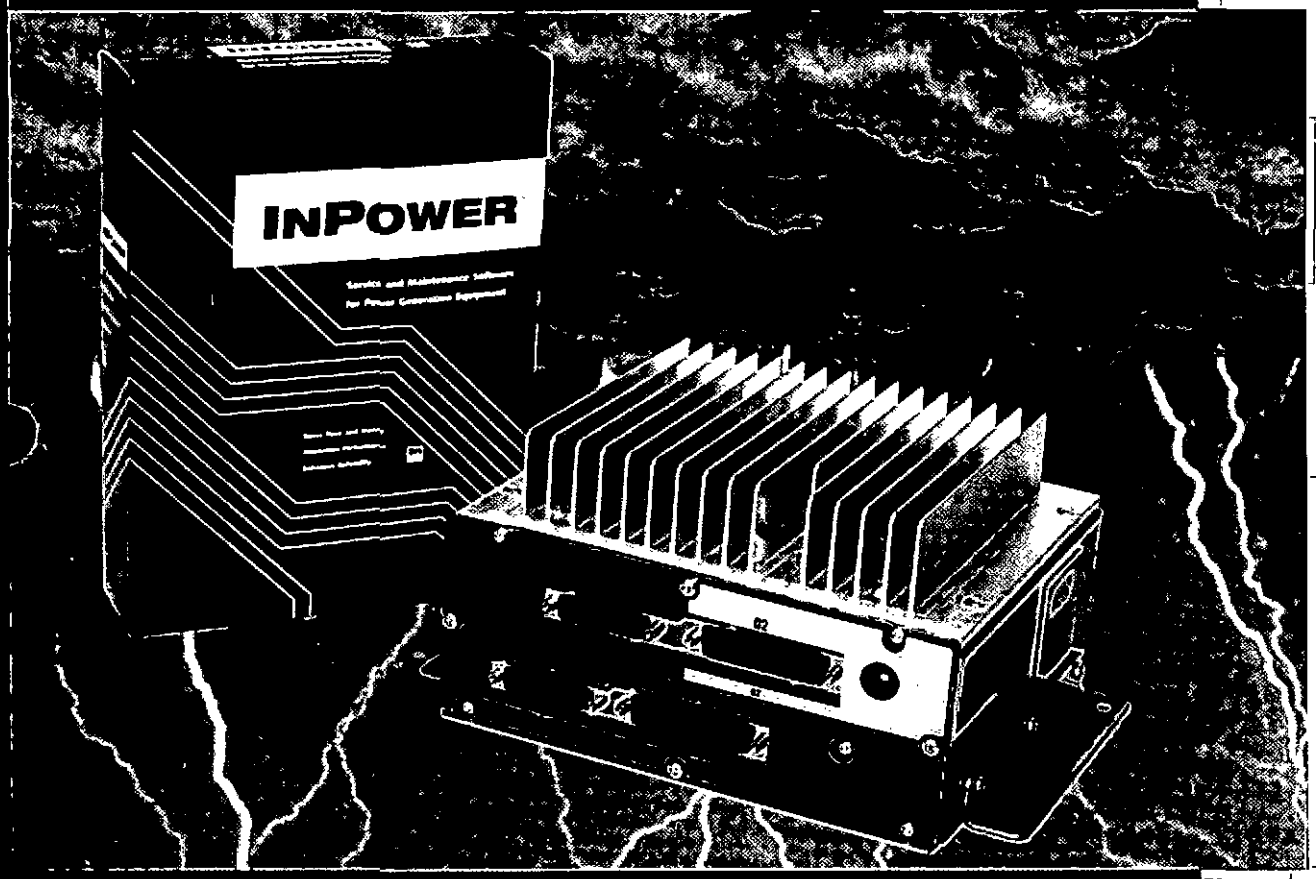


Table of Contents

Features List by Functional Grouping

About the Manual

This manual contains information needed to understand, correctly operate and maintain your Generator Drive Control System as recommended by Cummins Engine Company, Inc. Additional service literature (Operation and Maintenance, Shop Manual, Troubleshooting and Repair Manual, etc.) can be ordered by filling out and mailing the Literature Order Form located in the back of this manual.

This manual does **not** cover base engine maintenance procedures. Refer to the Operation and Maintenance Manual, Bulletin for the specific engine model for information.

This manual does **not** cover generator equipment maintenance or repair procedures. Consult the generator equipment manufacturer for specific maintenance and repair recommendations.

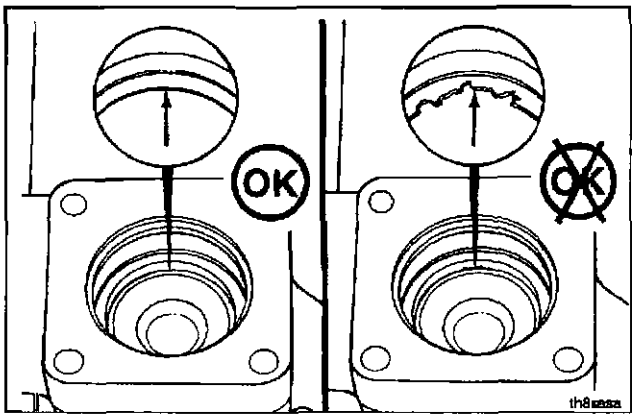
Both metric and U.S. customary values are listed in this manual. The metric value is listed first, followed by the U.S. customary in brackets.

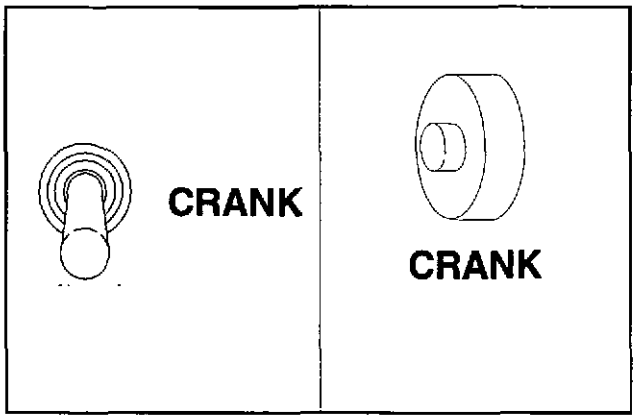
Illustrations

Some of the illustrations throughout this manual are generic and will **not** look exactly like the engine or parts used in your application. The illustrations can contain symbols to indicate an action required and an acceptable or **not** acceptable condition.

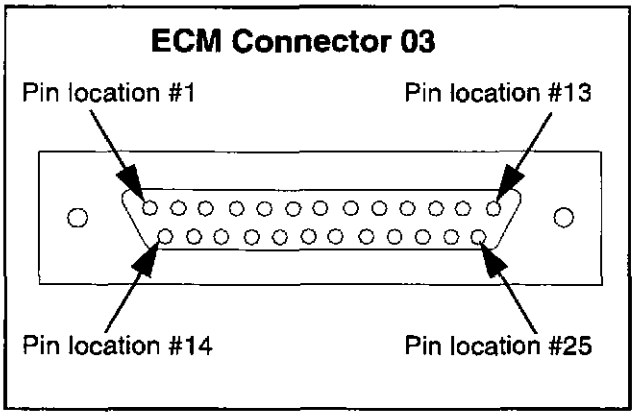
The illustrations included in this manual are intended to illustrate procedures performed or location of particular items.

The procedure performed or location of the item described will be the same even though the illustrations may vary.

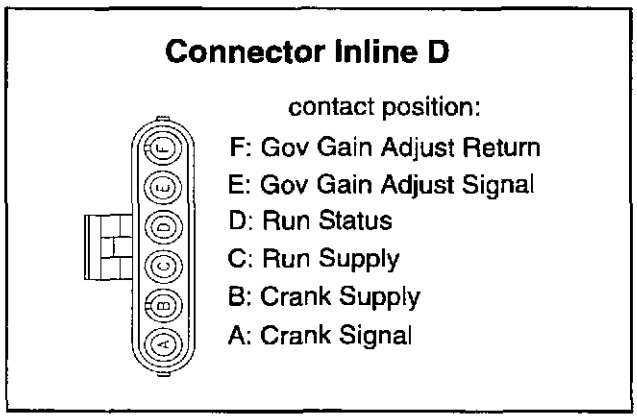




Illustrations showing connector contact positions for connections to the Electronic Control Module (ECM) are shown as viewed looking at the connector on the ECM, not the interfacing connector of the wiring harness.

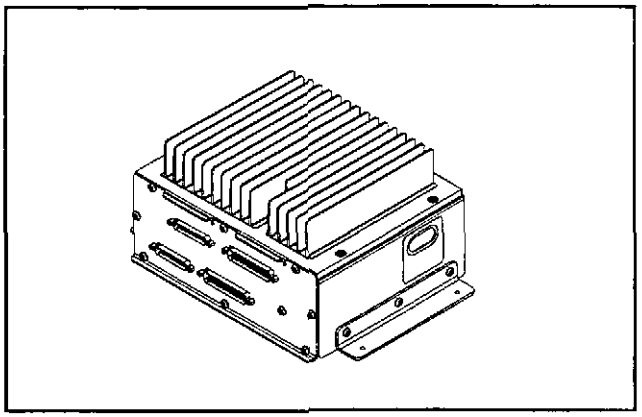


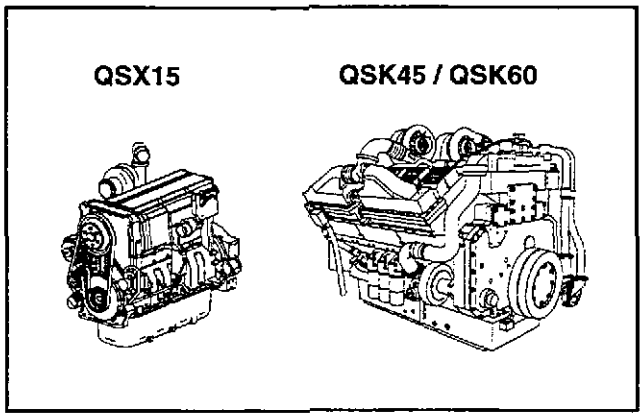
Illustrations showing connector contact positions for connections to the inline connectors of the wiring harnesses are viewed looking at the corresponding connector on the factory supplied engine or extension wiring harness, not the connector of the interfacing harness.



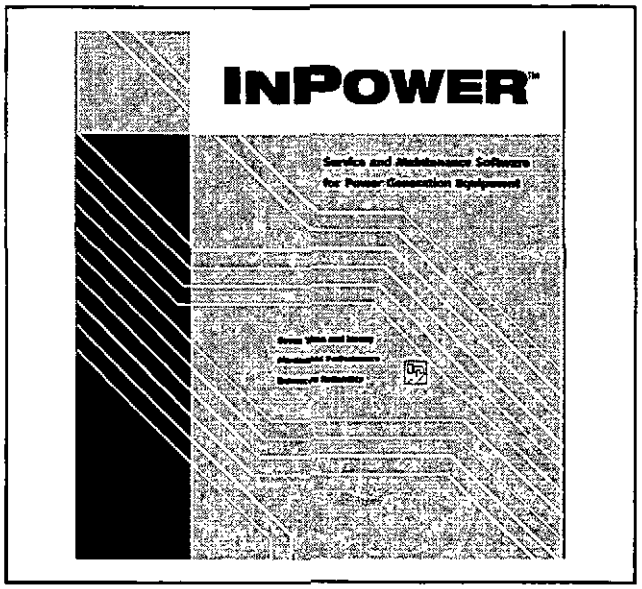
Acronyms and Abbreviations

A	Ampere
AC	Alternating Current
ABO	Area Business Organization
AEB	Application Engineering Bulletin
AMPS	Amperes
AWG	American Wire Gage
BIT	Built-In Test
B+	Battery Positive
°C	Degree Celsius
cSt	Centistokes
COM	Communication
CTS	Cooling Temperature Sensor
CW	Clockwise
CCW	Counterclockwise
DC	Direct Current
DSR	Data Set Ready
DTR	Data Terminal Ready
ECM	Electronic Control Module
EMC	Electro-Magnetic Compatibility
EMF	Electro-Motive Force
EMI	Electro-Magnetic Interference
EPA	Environment Protection Agency
EPROM	Erasable Programmable Read Only Memory
EPS	Engine Position Sensor
E-STOP	Emergency Stop
ESS	Engine Speed Sensor
°F	Degree Fahrenheit
FSOV	Fuel Shutoff Valve
ft (FT)	Foot
GCS	Generator-Drive Control System
GND	Ground
GOEM	G-Drive Original Equipment Manufacturer
H_2O	Water
HCT	High Coolant Temperature
Hg	Mercury
hp	Horsepower
HPI-PT	High Pressure Injection-Pressure/Time. Time is held constant while pressure is adjustable.
HPI-TP	High Pressure Injection-Time/Pressure. Pressure is held constant while time is adjustable.
Hz	Hertz
IEC	International Electrotechnical Commission
IP53	Ingress Protection - Dust-Protected & Spraying Water
IP54	Ingress Protection - Dust-Protected & Splashing Water
In	Inch
kg	Kilogram
kPa	Kilopascal
kW	Kilowatt
lb	Pound
LED	Light-Emitting Diode
LOP	Low Oil Pressure
mA	Milli-Ampere
mW	Milli-Watts
mm	Millimeter
N·m	Newton-meter
NEC	National Electric Code
NEMA	National Electric Manufacturers Association
O/M	Owner-Operator Manual
OEM	Original Equipment Manufacturer
OPS	Oil Pressure Sensor
OSS	Over Speed Sensor
PC	Personal Computer
p-p	Peak to Peak
P/N	Part Number
psi	Pounds Per Square Inch
PT	Potential Transformer
rpm(RPM)	Revolutions Per Minute
RTU	Remote Terminal Unit
RXD	Receive Data
PWM	Pulse Width Modulator
SCA	Supplemental Coolant Additive
TDC	Top Dead Center
TXD	Transmit Data
URL	Uniform Resource Locator
V	Volts
VAC	Volts-Alternating Current
VDC	Volts-Direct Current
WWW	World-Wide-Web





InPower™ Configurable Feature



Electronic Control Module

The Electronic Control Module (ECM) is the "brain" of the Generator-Drive Control System (GCS). The ECM is a state-of-the-art electronic digital control device. The primary function of the ECM is to govern the engine speed. The ECM hardware and software provides the following additional features:

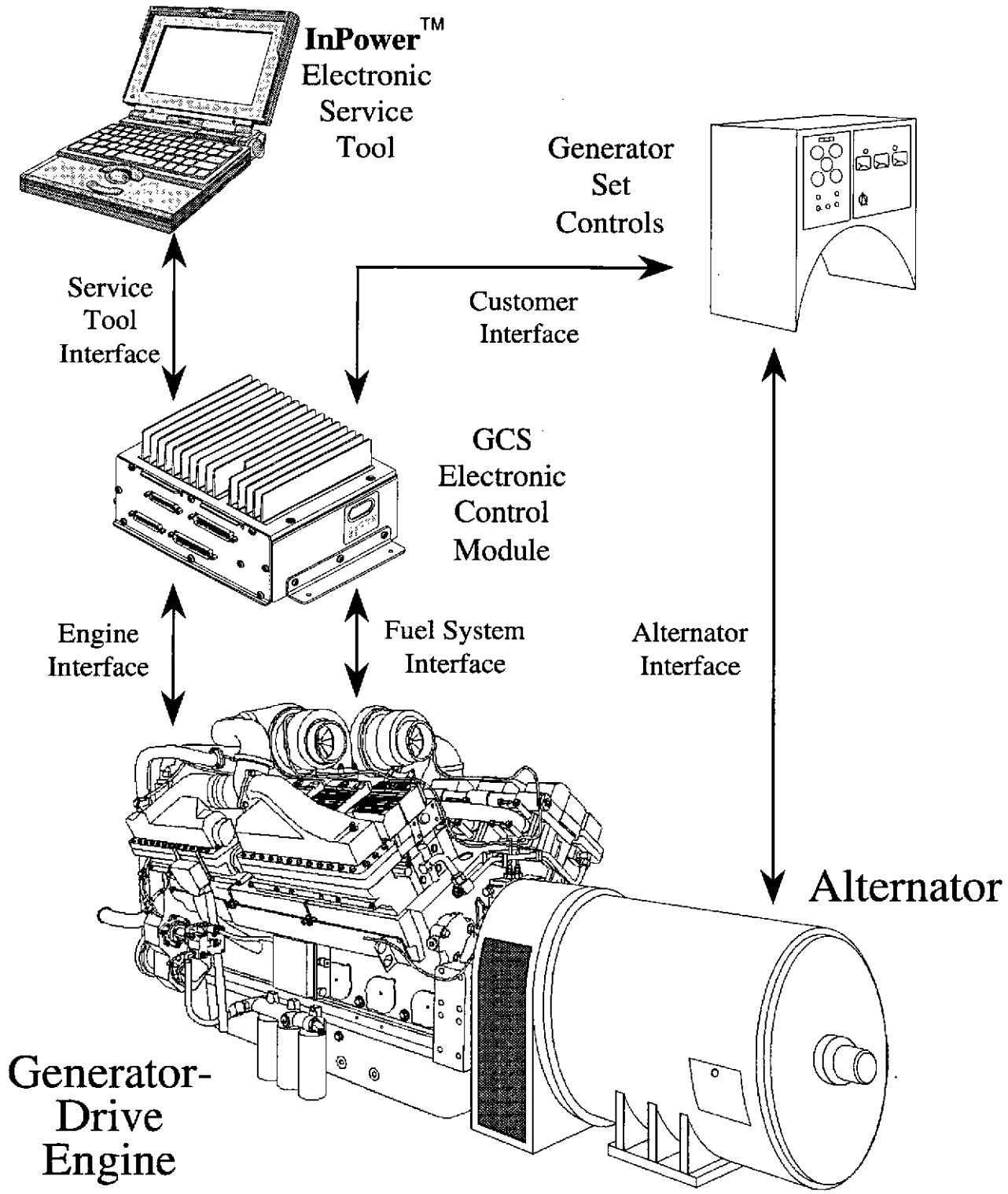
- Operator Controls Interface
- Engine Monitoring using:
  - MODBUS Serial Communications Datalink
  - Meter Drivers
  - InPower™ Electronic Service Tool
- Engine Protection
- System Fault Diagnostics
- System Check-Out / Test

NOTE: *Because the QSX15 uses the HPI-**TP** fuel system, and the QSK45 and QSK60 use the HPI-**PT** fuel system, there are two different ECM's. The user interfaces are the same for both types of ECM's, therefore, the differences are transparent to the operator. There are some engine wiring differences though. Throughout this manual, it can be assumed that no notation means the information applies to all engine models. If information is specific to one model, that text and/or graphic will be identified as referring to the applicable model(s).*

There are many features of the GCS that are configured using the InPower™ electronic service tool (Cummins Part No. 3886301). InPower™ is a packaged software application that installs on a compatible PC. The configurable features will be discussed in this manual, however, all functions of InPower™ are not covered. Refer to the InPower™ for Generator-Drive Control System Manual (Cummins Bulletin No. 3397100) for more detailed information about using InPower™. Note that the PC that has the InPower™ software installed requires a separate service cable (Cummins Part No. 3163156) to communicate with the ECM through the RS-232 service datalink connector on the Engine Harness.

NOTE: *All configurable features are disabled by default (the factory setting is "Disabled"). The customer must enable the features(s), using InPower™, in order to make the feature(s) operational. The steps required to enable specific configurable features are described in the respective sections of this manual.*

ECM Electronic Interfaces



ECM Hardwired Interconnections

The illustration on page 12 shows the features implemented via hardwired interconnections to the ECM, including the on-module Diagnostic LED's and the ECM mounting brackets.

This manual references the applicable ECM connectors and pins where each feature requiring a hardwired interface to the ECM is implemented. Refer to pages 27 through 41 for figures and schematics showing the external component wiring for each engine.

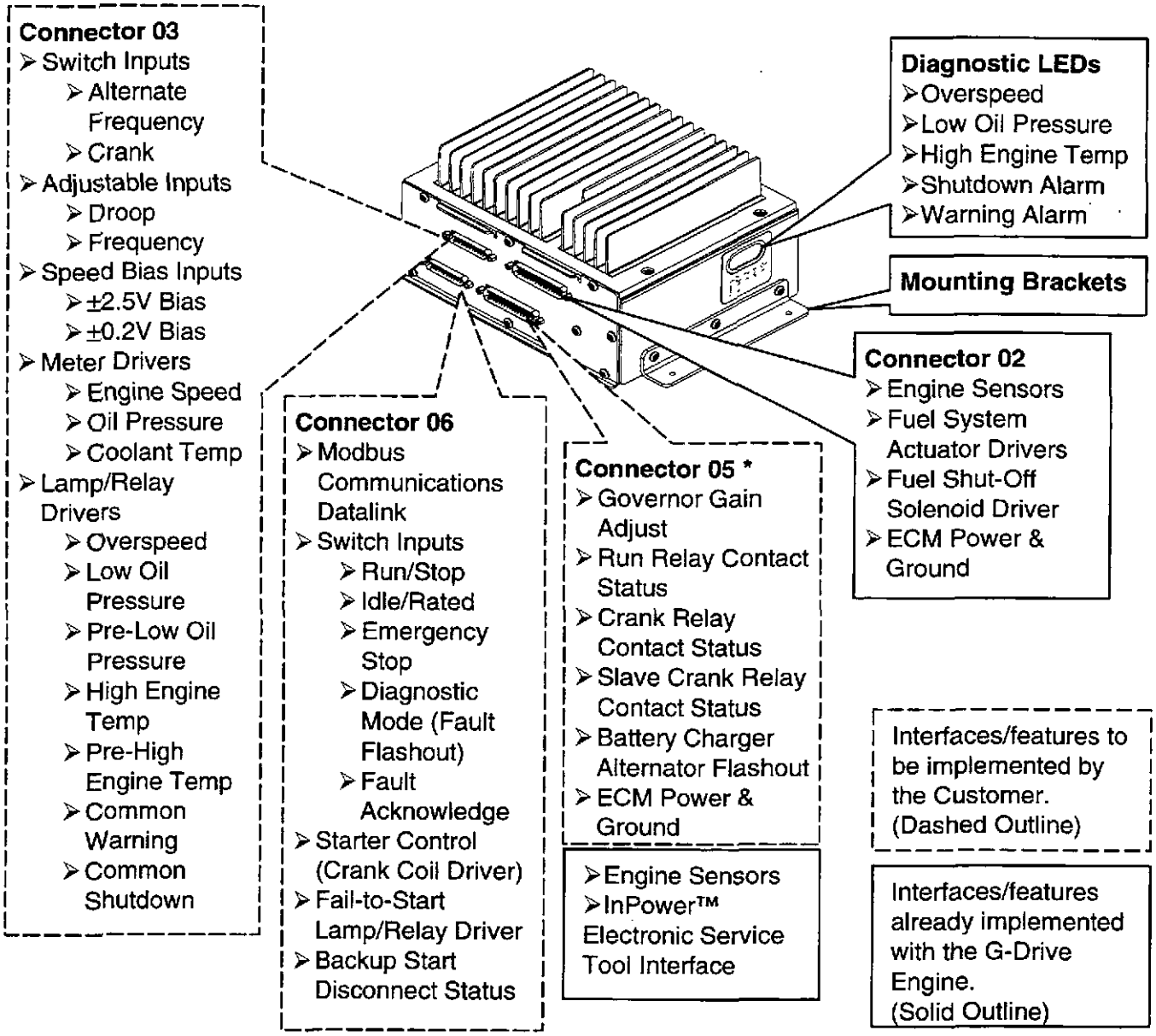
There are pins on the ECM connectors that provide an electrical ground (GND) for all hardwired interfaces requiring a ground reference or signal return path.

⚠ CAUTION ⚠

The use of the ECM ground (GND) pins is required when implementing the hardwired interfaces. The ground reference or signal path for these interfaces must not be connected directly to the battery posts or other grounding points, such as the engine block. Using the ECM GND pins is necessary to reduce the adverse effect of electrical noise on the proper operation of the electronic features.

The ***Electrical Interface Characteristics*** for the hardwired interfaces are specified in Appendix J. All customer connections to the ECM must comply with these interface specifications in order to ensure proper operation of the hardwired features.

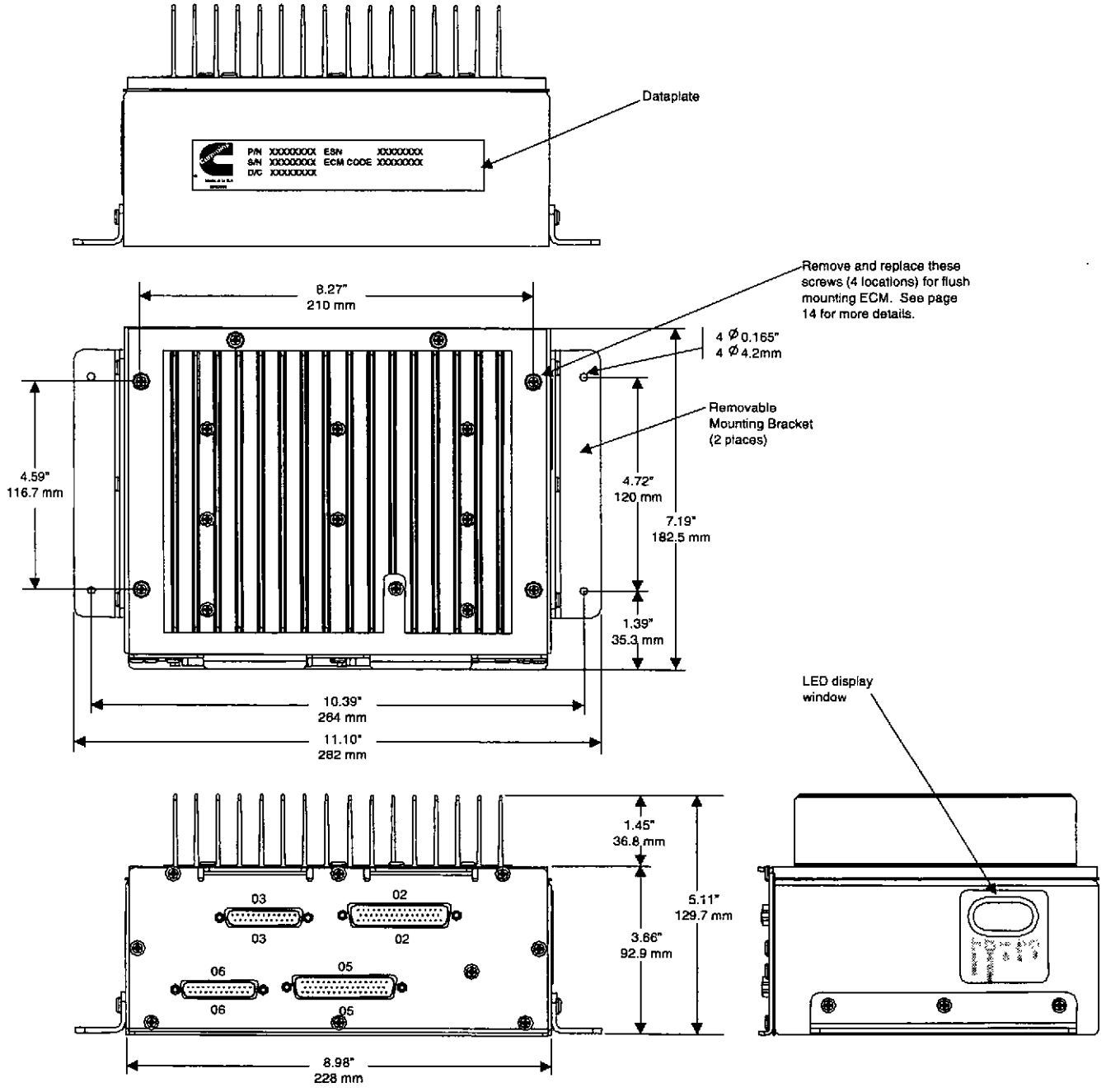
ECM Hardwired Interconnections



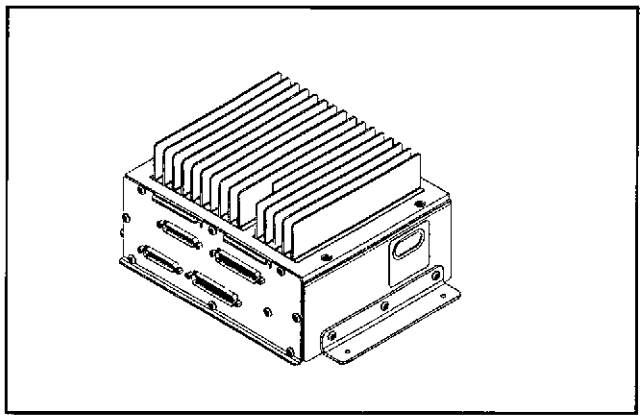
* The features of ECM Connector 05 are accessible to the customer by making the appropriate connections to Inline Connector D of the Extension Harness, Inline Connector E, and 1-Pin Weather-Pack Connector of the Engine Harness.

ECM Dimensions

The ECM measures 228.0 x 182.5 x 129.7mm [8.98 x 7.19 x 5.11 in.], including the heat-sink. Refer to the section "Installation" on page 14 for details and cautions before selecting a location for mounting the ECM.

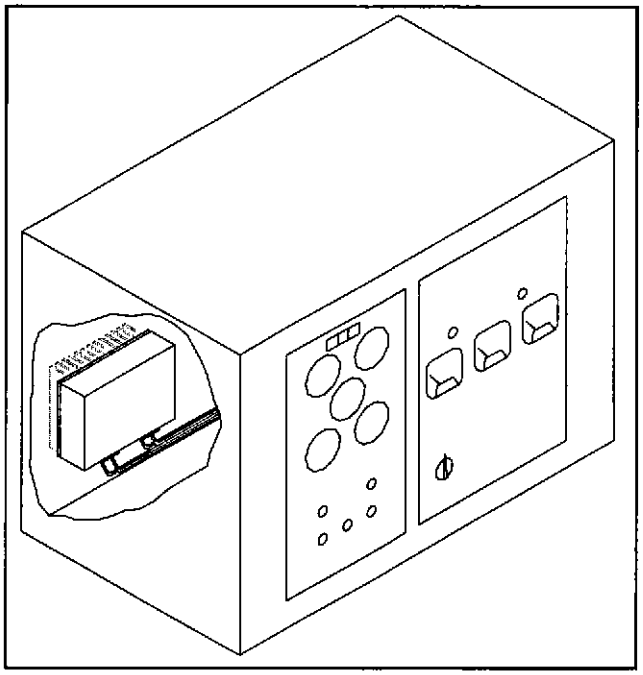


Installation



> **⚠ WARNING ⚠**
>
> *To avoid personal injury, or death, it is important that all electrical equipment be properly bonded or grounded. All metallic parts that could become energized under abnormal conditions must also be properly bonded or grounded.*

The chassis of the ECM must be properly bonded to provide protection against EMI and to conduct any fault current that may be imposed on the ECM. Typical requirements for bonding and grounding are given in the National Electrical Code. All connections, wire sizes, etc., must conform to the requirements of the electrical codes in effect at the installation site.

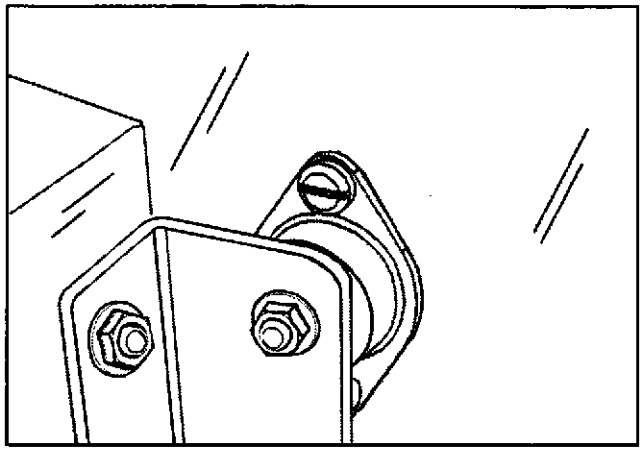


Where to Mount the ECM

The ECM is supplied by the factory, with each engine, as a kitted part and needs to be installed by the customer.

> **⚠ CAUTION ⚠**
>
> *The ECM must **NOT** be mounted directly to the engine. It is the customer's responsibility to provide proper mounting and ensure that the mounting method complies with all published environmental and application requirements. See Appendix J listing applicable operating and environmental specifications.*

The ECM includes brackets, already attached to the ECM, for installing the ECM with the backside flush to a mounting surface. See the figure on page 16 for details of the bracket mounting hole locations and dimensions.



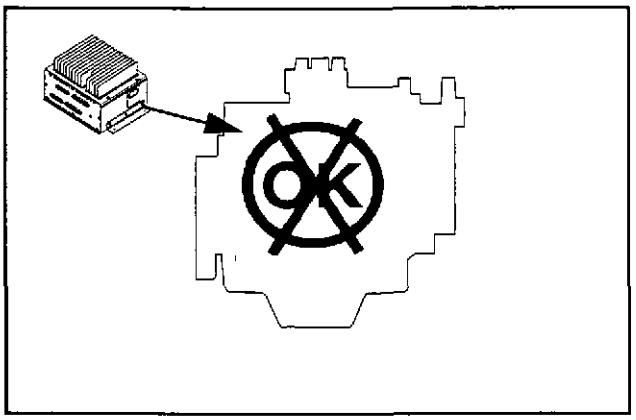
When the ECM mounting brackets are used to mount, the ECM to a panel or some other structure, the ECM must be adequately isolated to prevent damage due to vibration. If vibration isolators must be used to ensure compliance with the ECM vibration requirements, be sure to follow all manufacturer guidelines when selecting vibration isolators for use with the ECM installation.

> ***NOTE:** When vibration isolators are used, be sure that specified radial and axial load limits of the isolators are not exceeded. Be sure to provide adequate strain relief by installing clamps and allowing a sufficient bend radius on wiring harnesses.*

⚠ CAUTION ⚠

Close attention must be paid to the difference in the ambient cooling air requirements for the ECM and the heat-sink to prevent damage to the ECM. More importantly, pay attention to the maximum expected surface temperature of the heat-sink to avoid personal injury. See ***Appendix J*** *listing applicable operating and environmental specifications.*

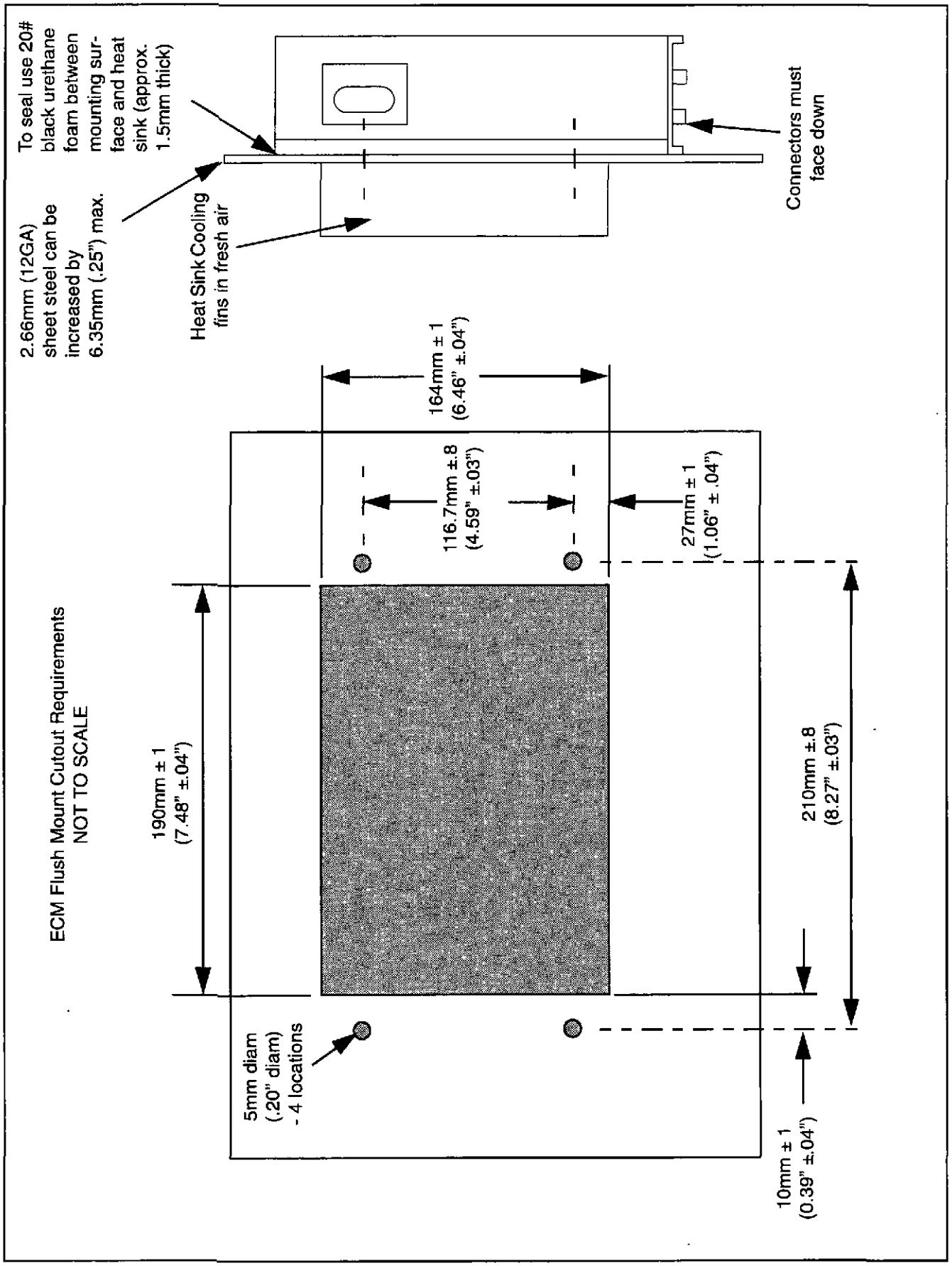
It is important that the location of the ECM allows adequate airflow to provide proper cooling to the ECM electronics. In some instances it may be necessary to have the cooling vanes of the ECM heat sink protrude through an opening in the control panel, exposing it to ambient air. When using this means to install the ECM, an opening must be cut in the mounting surface and attachment holes drilled per the template on the following page. Four (4) mounting screws must be removed, two (2) from either side of the heat-sink base, and replaced with screws of the same thread and size but longer by the thickness of the mounting surface. The replacement screws must have the appropriate head to accommodate the holes drilled in the mounting surface (i.e. countersunk or flat).



NOTE: *The mounting brackets are not used in this configuration and can be removed, however, the bracket attachment screws* ***MUST BE REPLACED*** *in the ECM case in order to ensure proper protection against the environment (i.e. dust and water ingress).*

Make sure there is no grease or dirt on the ECM mounting surfaces. Properly tighten the 4 mounting screws per the mounting screw size/grade torque recommendations to prevent mounting failures.

NOTE: *To comply with IP53 and NEMA-3R enclosure spray angle requirements, the ECM must be mounted with the connectors facing down. If the ECM is installed with the connectors facing sideways (heat-sink up), the customer must ensure that the installation complies with IP53 and NEMA-3R requirements. The ECM must* ***NEVER*** *be installed with the connectors facing up or with the heat-sink vanes oriented horizontally (level to the ground). The customer must also ensure that there is sufficient clearance for the wiring harnesses to be mounted to the ECM, and that the harnesses are properly supported to prevent undue stress or strain on both the harness and ECM connectors.*


To seal use 20# black urethane foam between mounting surface and heat sink (approx. 1.5mm thick)
2.66mm (12GA) sheet steel can be increased by 6.35mm (.25") max.
Heat Sink Cooling fins in fresh air
Connectors must face down
164mm ± 1 (6.46" ±.04")
116.7mm ±.8 (4.59" ±.03")
27mm ± 1 (1.06" ± .04")
190mm ± 1 (7.48" ±.04")
210mm ±.8 (8.27" ±.03")
5mm diam (.20" diam) - 4 locations
10mm ± 1 (0.39" ±.04")
ECM Flush Mount Cutout Requirements
NOT TO SCALE

The customer is responsible for supplying a wiring harness(es) that interfaces with the two 25-pin ECM connectors, labeled 03 and 06, and the customer connections at Inline connectors D & E. See the ***Wiring Harnesses and Interface Connectors*** section on page 19 for further details.

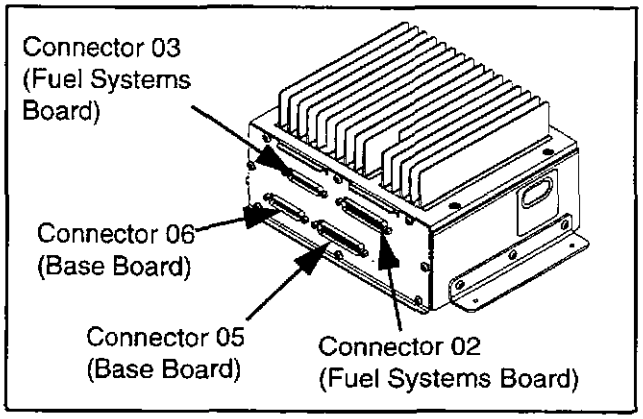
A "keying plate" is attached to the ECM on the side with the connectors. This keying plate has keyways, a polarizing feature, that mate with the backshells included with the keyed connector kits supplied by the factory with each engine. The keying feature of the 25-position connector assemblies built using the kits is designed to prevent improper connection of the customer supplied generator set interface harness to ECM connectors 03 and 06. See ***Appendix H*** for detailed instructions on how to assemble the keyed connector kit parts.

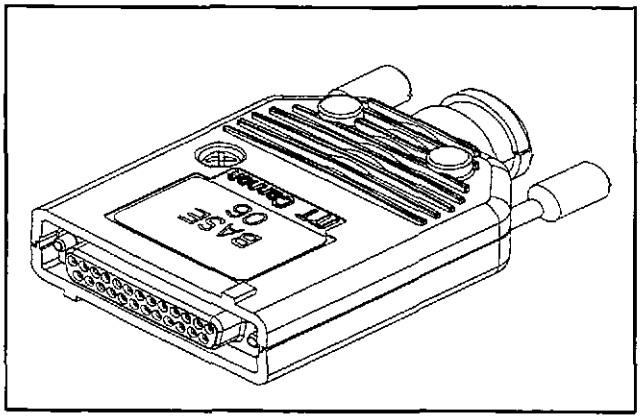
The following chart will assist in identifying the interfacing wiring harness connectors:

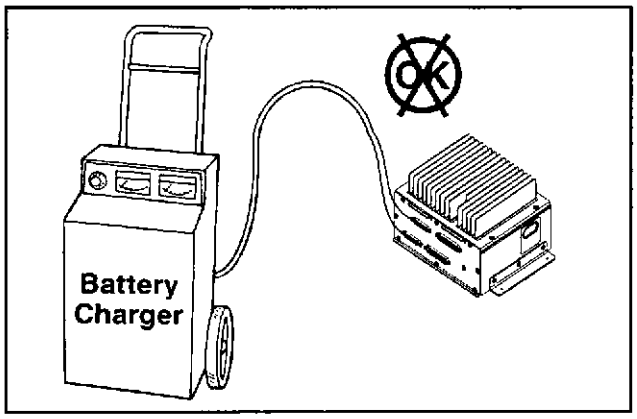
Connector Number	Keying Polarization	Label Color
06	Key A (25 position)	Green
03	Key B (25 position)	Brown
05	Key A (50 position)	Green
02 (QSK45/60)	Key B (50 position)	Brown
02 (QSX15)	Key C (50 position)	Yellow

NOTE: *When attaching the keyed connectors to the ECM, the thumbscrews should be torqued to 0.79 - 0.90 N m [7-8 in-lb].*

NOTE: *Because the connectors provided with the keyed connector kits are a high quality part using gold-plated terminals, the connectors* ***DO NOT*** *have to be coated or packed with any type of protective lubricant or anti-corrosion compound.*







Power Source

The ECM is designed to operate at a nominal 24 VDC. The ECM can operate normally within a range of 18 to 35 VDC continuous and as low as 10VDC during cranking.

⚠ CAUTION ⚠

Do not connect the ECM to a battery charger. Due to the circuitry and method of operation of the chargers, the governor will not function properly. Connect the battery charger to the battery.

⚠ CAUTION ⚠

To avoid damage to the ECM, disconnect all electrical connections to the ECM and remove the ECM from the generator set prior to using any type of welding equipment that requires electrical power to operate.

***NOTE:** To prevent loss of valuable diagnostic information, such as Fault Codes and Snapshot Data, power must be available to the ECM at all times during normal engine operation and for at least one minute following an engine shutdown.*

Positive / Isolated Grounding

When using a grounding method other than a negative ground system, where the electrical system ground reference is not connected to Battery (-), the following items must be taken into consideration to prevent damage to the GCS or to other electrical system components:

- Optical isolation devices are recommended for interfacing to the RS-485 Modbus Communications and the RS-232 InPower Electronic Service Tool datalinks.
- Any Load Sharing / Autosynchronization equipment interfacing to the GCS must use the same grounding method or be properly isolated electrically.
- The starter, battery charging alternator, and all wiring harnesses and components (i.e. protection diodes installed to prevent damage to relay contacts or relay drivers) must be designed to operate properly when connected using the grounding method being implemented.

Wiring Harnesses and Interface Connectors

The QSX15, QSK45, and QSK60 engines are shipped with a factory mounted Engine Harness and kit containing the ECM, Extension Harness, including the mate-with connectors, contacts, and connector accessories (keyed backshells and hardware) required for interfacing with ECM connectors 03 and 06. The Extension Harness is 3.3 m [10 ft.] in length. The customer is responsible for manufacturing the harness required for interfacing with ECM connectors 03 and 06.

A wiring harness that integrates the features of Inline Connector E, the 1-Pin Weather-Pack (as required), and other option components pre-installed and delivered with the engine (i.e. Crank Slave Relay, Starting Motor(s), and Battery Charging Alternator) is supplied, and factory installed, when certain options are purchased with the engine. If these options are not purchased with the engine, it is the customer's responsibility to manufacture and install the required wiring harness to interface with all required engine electrical components. All published application guidelines, requirements, and practices must be strictly followed.

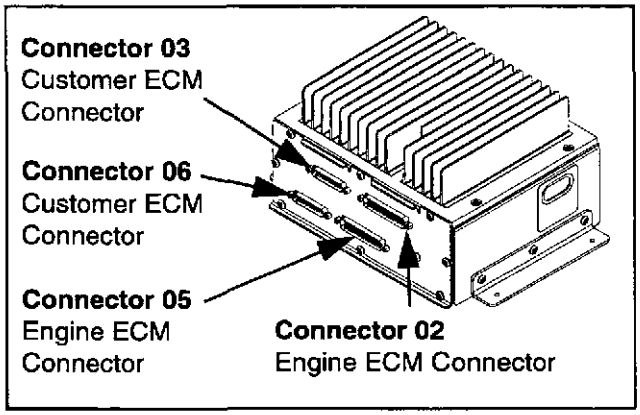
The ECM has four connectors, two 50-pin Engine ECM Connectors connectors (labeled 02 and 05), and two 25-pin Customer ECM Connectors (labeled 03 and 06). Connectors 02 & 05 are used primarily for engine control related features. Connectors 03 & 06 are used primarily for customer control related features.

The Engine ECM Connectors directly interface with the Extension Harness. In conjunction with the Extension Harness, Engine Harness, engine mounted sensors, and engine fuel system, these connectors are used to provide engine sensor information to the ECM and fueling control commands from the ECM to the engine fuel system.

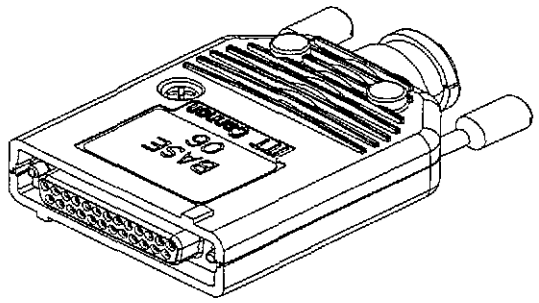
The Customer ECM connectors provide access to customer features of the ECM. It is the customer's responsibility to provide a harness that interfaces directly with these Customer ECM Connectors.

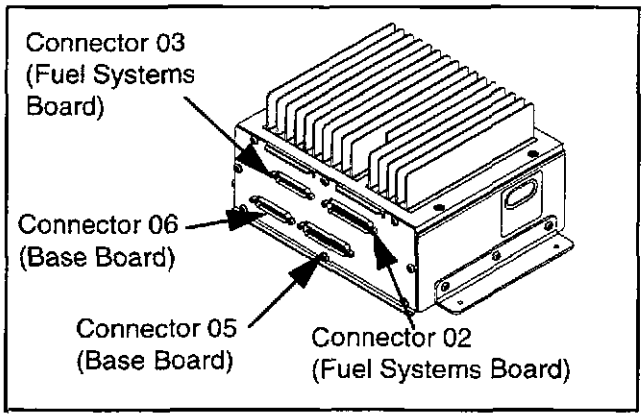
> ***NOTE:*** *The maximum length between the ECM and the location for customer feature terminations (i.e. control panel, switches, potentiometers, speed bias signals, etc.) is 15.24 m [50 ft.], with the exception of the Modbus RS-485 communications data bus.*

See the ***Modbus Communications Datalink*** section on page 97 for further details. The conductor size to be used for the customer generator set interface harness terminations to the Customer ECM Connectors is 0.5 mm^2 [20 Ga.].

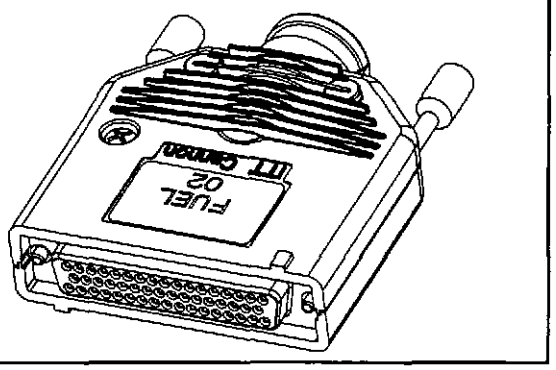


Customer ECM Connector 06





Engine ECM Connector 02



Keyed connector kits are included with each engine. The connector kits contain all of the necessary connector hardware required for the customer to interface with the two Customer ECM connectors. This includes the two 25-position mating connectors, a grommet for each connector, the necessary quantity of contacts, and the keyed connector backshells. The connector kits do not include the wires, or the hardware required to terminate the wires at the opposite end of the wiring harness (i.e. control panel terminations). See the ***Installation*** section on page 14 for further details about assembling the keyed connector kits and installing the customer supplied generator set interface harness.

The connector contacts provided in the keyed connector kits accept 0.5 mm^2 [20 Ga.] size conductor wire.

> ***NOTE:*** *The contacts included in the keyed connector kits are a non-standard part meeting high quality requirements. Substitute contacts* ***MUST NOT*** *be used.*

The connector backshells provided with the keyed connector kits have a polarized keying feature that, when properly installed on the customer generator set interface harness, prevents incorrect harness connections to the ECM.

> ***NOTE:*** *The customer is required to build the generator set interface harness using the hardware provided with the factory supplied keyed connector kits. Warranty claims related to the Customer ECM Connectors* ***WILL NOT*** *be honored unless the connector kit parts are used and assembled in accordance with the instructions supplied with the kits.*

Engine ECM Connectors

Connector 02

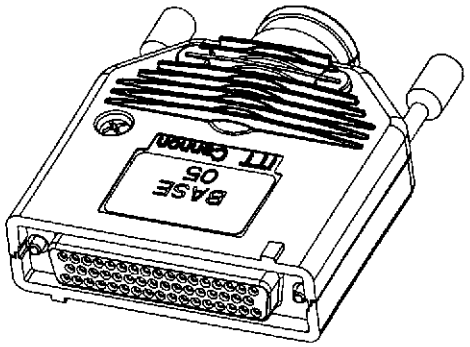
Engine ECM Connector 02 (Fuel System Board Connector) is a male 50-position D-subminiature plug with pins. The mate-with female connector on the Extension Harness is a 50-position D-subminiature receptacle with sockets.

Connector 05

Engine ECM Connector 05 (Base Board Connector) is a male 50-position D-subminiature plug with pins. The mate-with female connector on the Extension Harness is a 50-position D-subminiature receptacle with sockets.

> ***NOTE:*** *Both connectors 02 and 05, which are part of the factory supplied Engine Harness assembly, have a keying feature that prevents them from unintentionally being interchanged with one another.*

Engine ECM Connector 05



Customer ECM Connectors

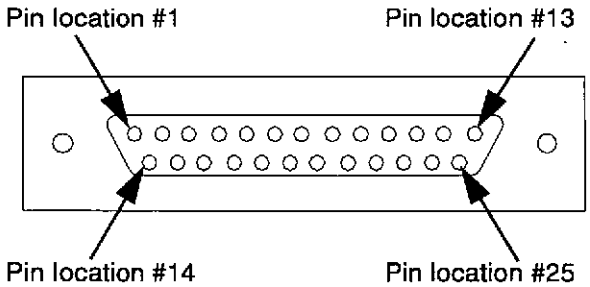
Connector 03

Customer ECM Connector 03 (Fuel System Board Connector) is a male 25-position D-subminiature plug with pins. The mate-with female connector on the customer supplied generator set interface harness is a 25-position D-subminiature receptacle with sockets.

The following customer features are accessible via hardwired interface to Connector 03:

- Alternate Frequency Switch
- Crank Switch
- Droop Adjust
- Frequency Adjust
- ±2.5V Speed Bias
- ±0.2V Speed Bias
- Engine Speed, Oil Pressure and Coolant Temperature Meter Drivers
- Overspeed (OS), Low Oil pressure (LOP) and High Engine Temp (HET) Shutdown Lamp/Relay Drivers
- Pre-LOP and Pre-HET Warning Lamp/Relay Drivers
- Common Warning Lamp/Relay Driver
- Common Shutdown Lamp/Relay Driver

ECM Connector 03



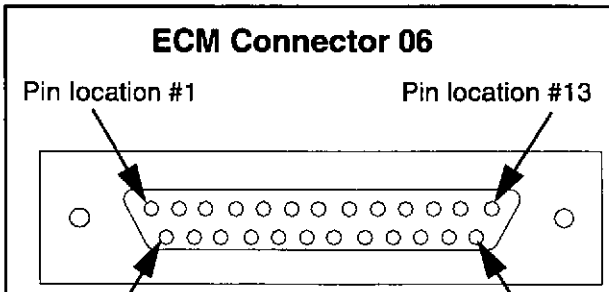
Connector 06

Customer ECM Connector 06 (Base Board Connector) is a male 25-position D-subminiature plug with pins. The mate-with female connector on the customer supplied generator set interface harness is a 25-position D-subminiature receptacle with sockets.

The following customer features are accessible via hardwired interface to Connector 06:

- Modbus RS-485 Communications Datalink
- Run/Stop Switch
- Idle/Rated Switch
- Emergency Stop Switch
- Diagnostic Mode Switch (Fault Flash Out Enable)

ECM Connector 06



- Fault Acknowledge Switch
- Starter Control (Crank Relay Coil Driver)
- Fail-to-Start Lamp / Relay Driver
- Backup Start Disconnect Status

NOTE: *As mentioned prior, the factory supplied connector kits for connectors 03 and 06 include backshells with a keying feature that, when properly installed on the customer generator set interface harness, prevents them from unintentionally being interchanged with one another.*

Extension Harness

The Extension Harness provides the means for mounting the ECM off of the engine, elsewhere on the generator set or some other remote location. This is accomplished by extending the circuits from the Engine Harness Inline connectors, located near the engine's flywheel housing, to ECM Connectors 02 and 05. The Inline Connectors comply with IP54/NEMA-4 specifications.

The Extension Harness allows access to the following customer features of ECM connector 05 via hardwired interfaces to Inline Connector D:

- Inline Connector D
  - Governor Gain Adjust
  - Run Relay Contact Status
  - Crank Relay Contact Status

Engine Harness

The factory supplied Engine Harness allows access to the following customer features of ECM connector 05 (including both connectors 02 and 05 for ECM Battery (+) and GND) via hardwired interfaces to Inline Connector E and the 1-Pin Weather-Pack connector:

- Inline Connector E
  - Crank Slave Relay Coil Supply Voltage
  - Crank Slave Relay Contact Status
  - ECM Power [Battery (+)]
  - ECM Ground [GND]
- 1-Pin Weather-Pack
  - Battery Charging Alternator Flashout

Further details discussing customer connections to each Inline Connector follow.

Inline Connectors

Inline Connector A, B and C

Inline Connectors A, B and C contain wiring for timing and fueling control actuators, the fuel shut-off solenoid driver, engine sensors, diagnostic mode enable, and service tool RS-232 communications datalink signals. Pre-wired by Cummins, OEM wiring is ***prohibited*** at these inline connectors.

⚠ CAUTION ⚠

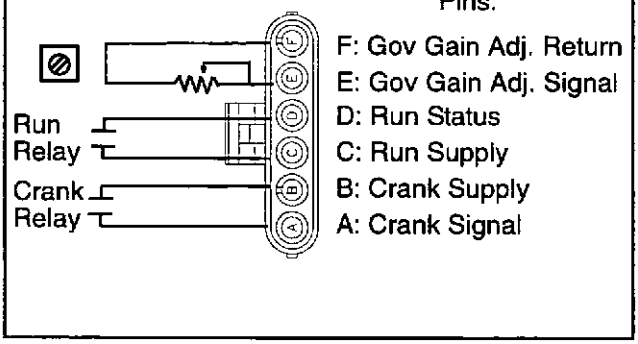
No attempt should be made to bypass existing engine sensors or actuators or to operate the engine using 3rd party governor control systems.

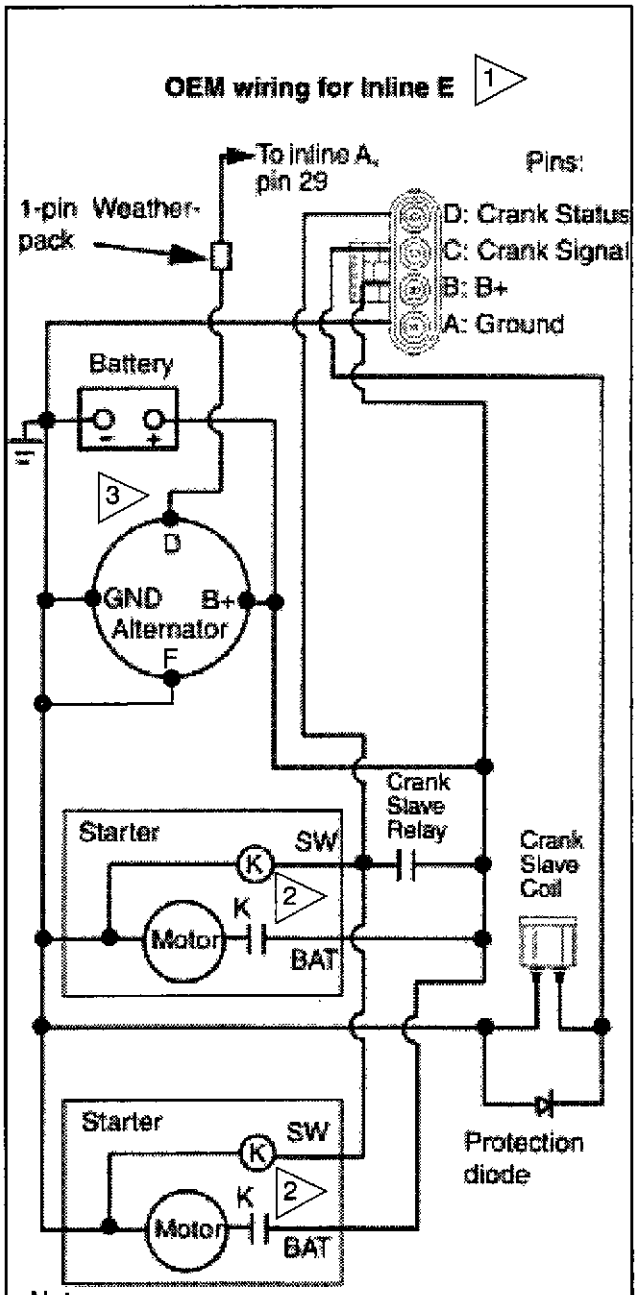
Inline Connector D

The inline connector D requires customer supplied wiring for Crank Relay contacts, Run Relay contacts, and the Governor Gain Adjust potentiometer.

NOTE: *The Run Relay contact connections are only used when the battery charging alternator requires additional energy to turn-on voltage regulation at low speeds. See the* ***Battery Charging Alternator Flashout*** *section on page 25 for further details.*

Customer Supplied Wiring for Inline D





Notes:

1. Cummins offers options for purchasing a battery charging alternator and / or starting motor(s) with the engine. If either option is purchased, the appropriate wiring harnesses are included. If the customer has not purchased either of these options and chooses to install their own electrical accessories, they must also provide the proper wiring harness that interfaces to Inline Connector E.
2. "K" indicates relay and associated contacts.
3. "D" indicates Charging Alternator Flashout Terminal

Inline Connector E

The QSX15, QSK45 and QSK60 utilize a 4 pin inline connector for crank signal and status, Battery (+) and Ground (GND) connections.

If either the optional battery charging alternator or optional starter(s) are not purchased with the engine, the customer must supply the required wiring harness that interfaces with Inline Connector E and the customer supplied device(s).

When using a customer supplied starter or alternator the following electrical system and controls related application items must be considered:

- Starter Motor(s)
  - Starting system voltage
  - Case grounded or case insulated
  - Magnetic switch mounting
  - Battery cranking capacity
  - Special requirements for cold cranking (i.e. additional battery capacity)
  - Wiring and connections
    - > Cable Routing
    - > Electrical grounding/bonding
    - > Cable size (voltage drops & circuit resistance)
    - > Diode protection of relays and relay drivers

⚠ WARNING! ⚠

Due to the high Pull-In and Hold-In current draw of the typical starter motor solenoid, a magnetic switch (also called Crank Slave Relay) is required. When using a magnetic switch, a primary Crank Relay must be used to power the magnetic switch (Crank Slave Relay). A protection diode, sometimes referred to as a free-wheeling or fly-back diode, must be installed in parallel with the magnetic switch coil to prevent back-EMF from the coil causing damage to the primary Crank Relay contacts.

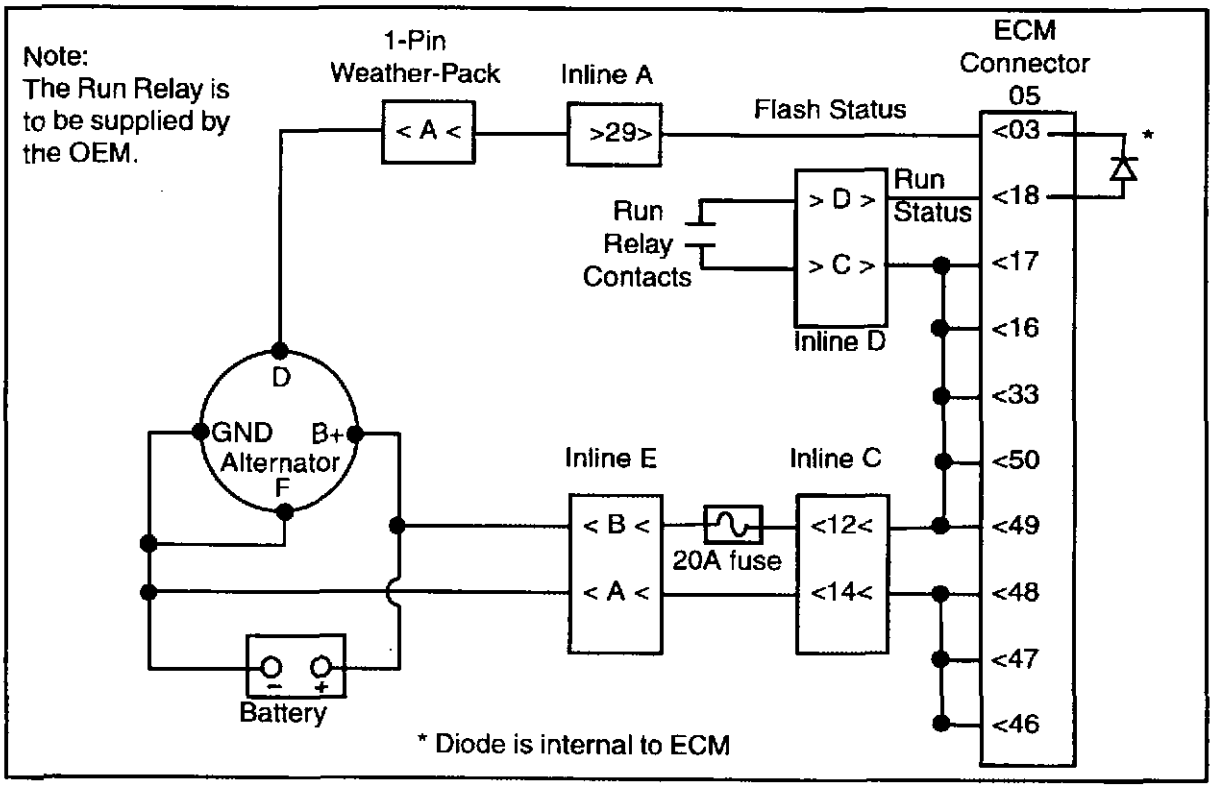
- Alternator
  - Cable Routing
  - Electrical grounding/bonding
  - Cable size (voltage drops & circuit resistance)

Battery Charging Alternator Flashout (1-Pin Weather-Pack)

The Alternator Flashout output provides battery power (supplied through the Run Status input on pin 18 of ECM connector 05) to the rotor windings of the battery charging alternator when the Run Relay contacts at connector Inline D (Pins C & D) are closed. The Flash Status output (Alternator Flashout output) is used on some battery charging alternators to provide the additional energy required to turn on the alternator voltage regulator at low speeds.

The customer can implement this feature by connecting the battery charging alternator flashout terminal to the 1-Pin Weather-Pack connector. The contacts of a Run relay must be connected to pins C & D of Inline Connector D to supply battery power, through the ECM, to the alternator flashout terminal when the Run Relay is energized.

> ***NOTE:*** *If the alternator flashout output is not used, the Run Relay contact connections to Inline Connector D* ***DO NOT*** *need to be made.*



Inline Connector D, E & 1-Pin Mating information		
Connector & Contact Position	Mate-With Part No. *	Description
Inline D	12010975	Packard Weather-Pack 6-position Shroud
A	12124587	3.0 mm^2 (12 AWG) Weather-Pack Male Terminal
B	12124587	3.0 mm^2 (12 AWG) Weather-Pack Male Terminal
C	12089040	0.5 mm^2 (20 AWG) Weather-Pack Male Terminal
D	12089040	0.5 mm^2 (20 AWG) Weather-Pack Male Terminal
E	12089040	0.5 mm^2 (20 AWG) Weather-Pack Male Terminal
F	12089040	0.5 mm^2 (20 AWG) Weather-Pack Male Terminal
Inline E	12015797	Packard Weather-Pack 4-position Tower
A	12124581	3.0 mm^2 (12 AWG) Weather-Pack Female Terminal
B	12124581	3.0 mm^2 (12 AWG) Weather-Pack Female Terminal
C	12124581	3.0 mm^2 (12 AWG) Weather-Pack Female Terminal
D	12010996	0.8 mm^2 (18 AWG) Weather-Pack Female Terminal
1-Pin	12010996	Packard Weather-Pack 1-position Shroud
A	12089040	0.8 mm^2 (18 AWG) Weather-Pack Male Terminal

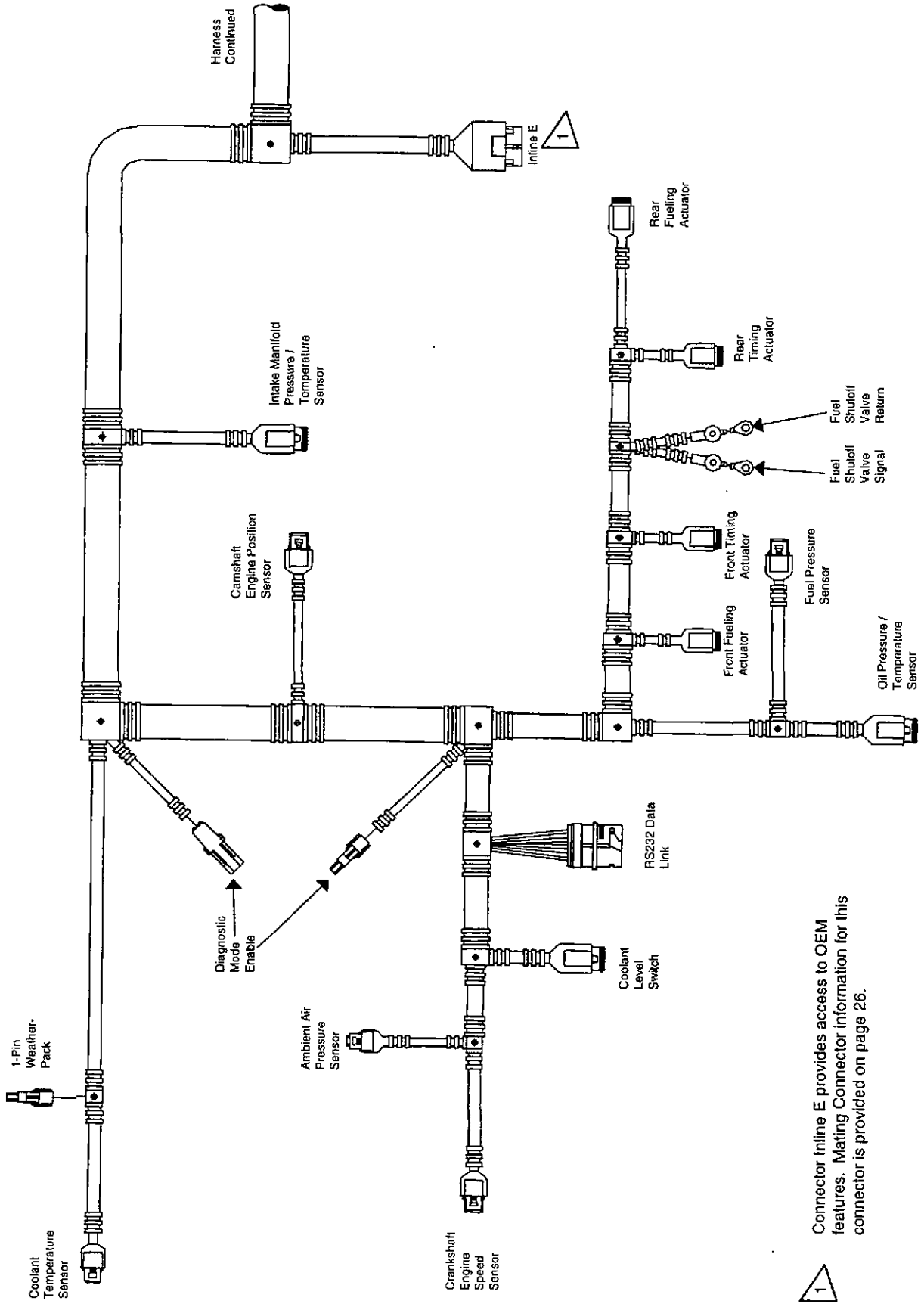
* All Part No.'s are Packard Weather-Pack. Use the cable seal specified on the corresponding drawing for each terminal.

Inline Connector Mate-With Information

Mating connector information for Inline connectors D & E and the 1-pin Weather-Pack are identified at the left. Each conductor of the mating connector should use the specified terminal size and the corresponding wire conductor size.

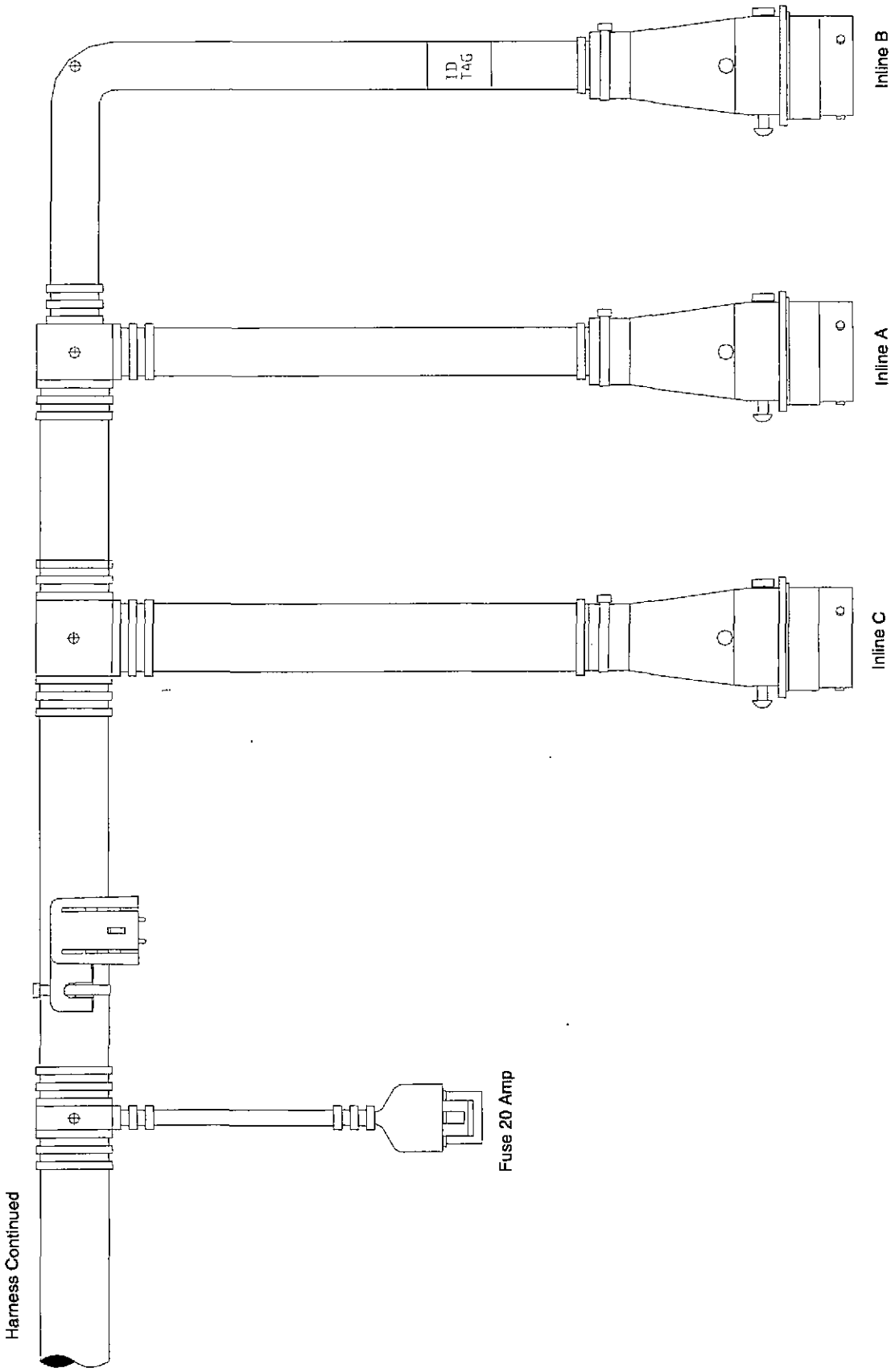
The following pages include figures showing the various sensor connection locations on the wiring harnesses. Also included are figures, and schematic diagrams, for the optional battery charging alternator and starter system options available for purchase and use with the respective engines.

QSX15 Engine Harness

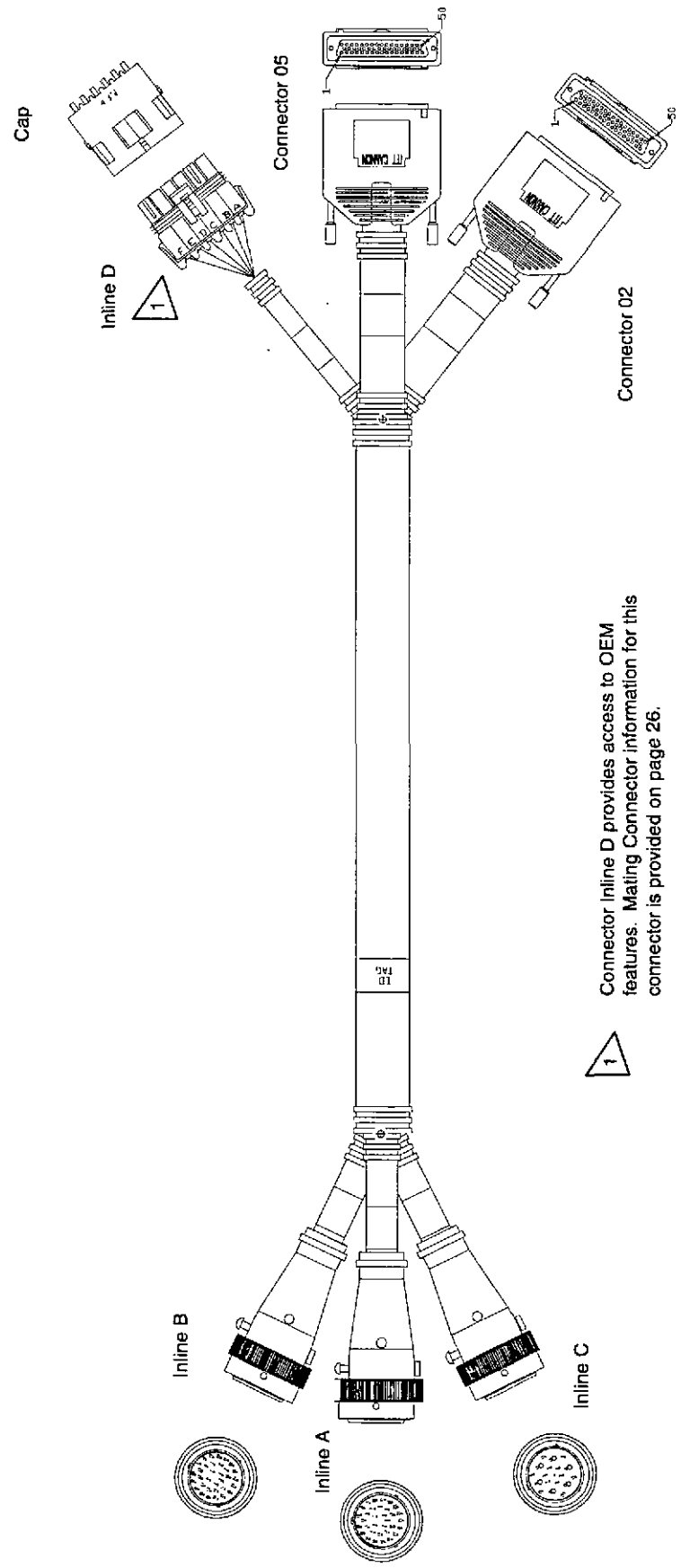


1 Connector Inline E provides access to OEM features. Mating Connector information for this connector is provided on page 26.

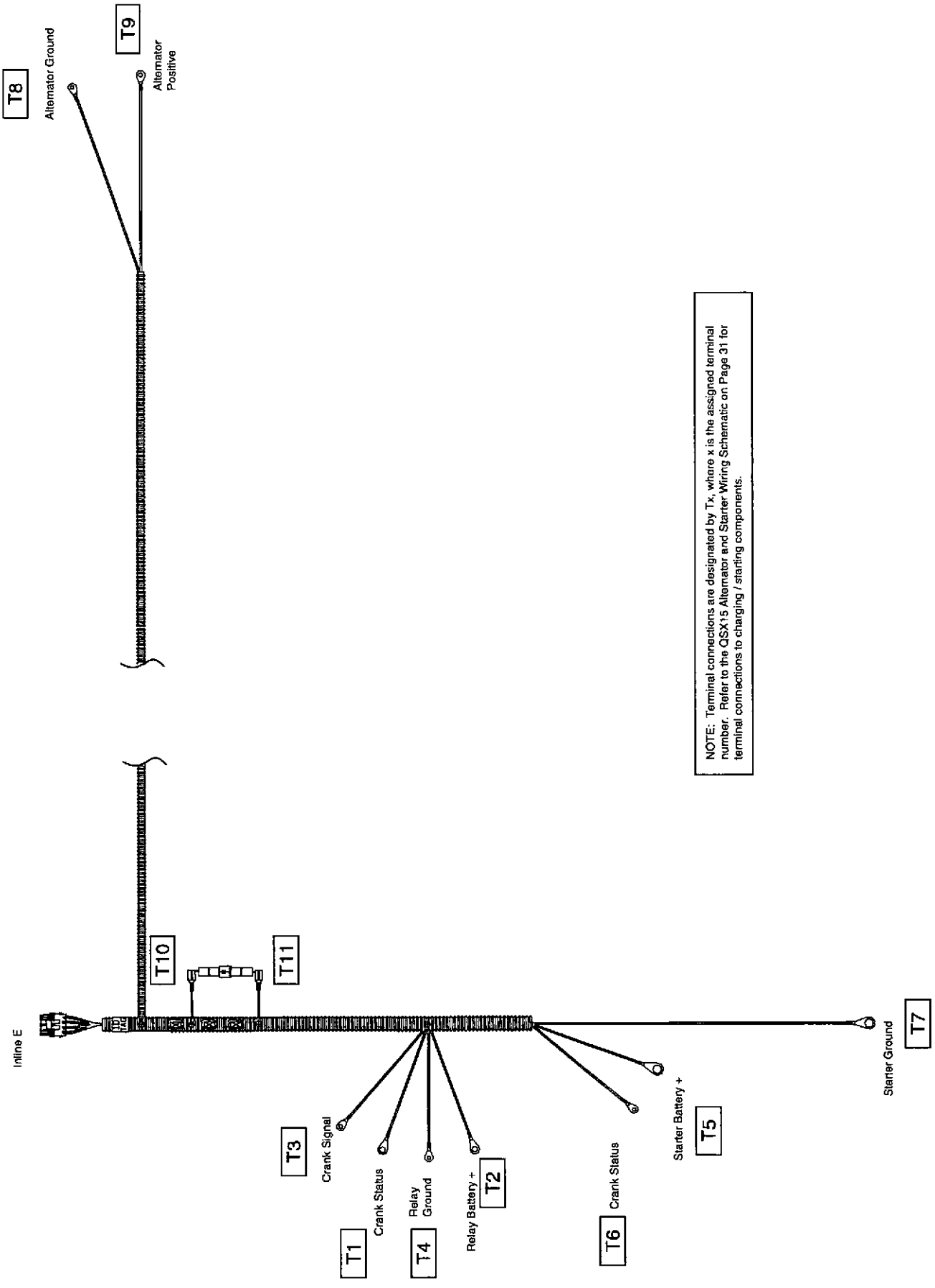
QSX15 Engine Harness (Continued)



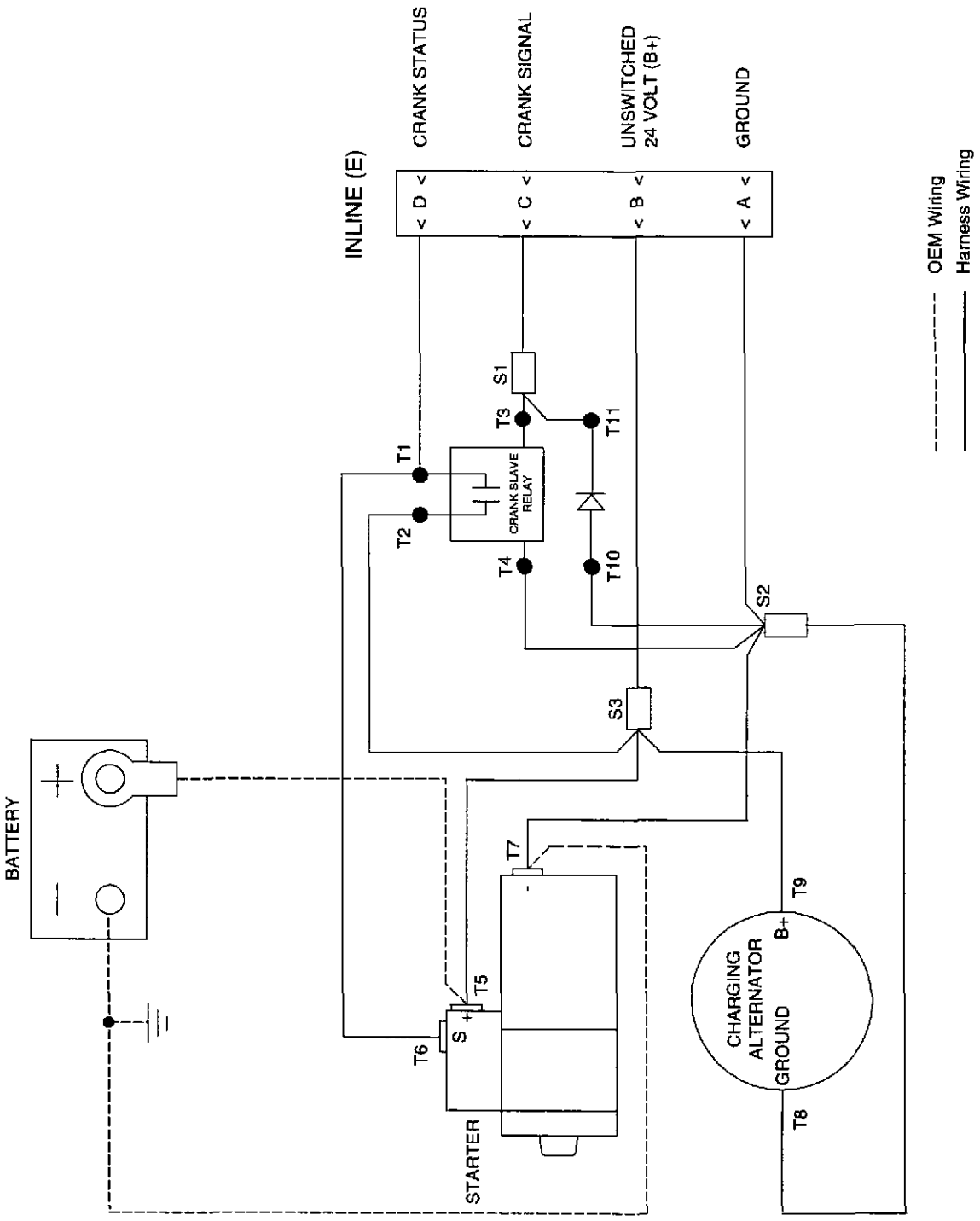
QSX15 Extension Harness



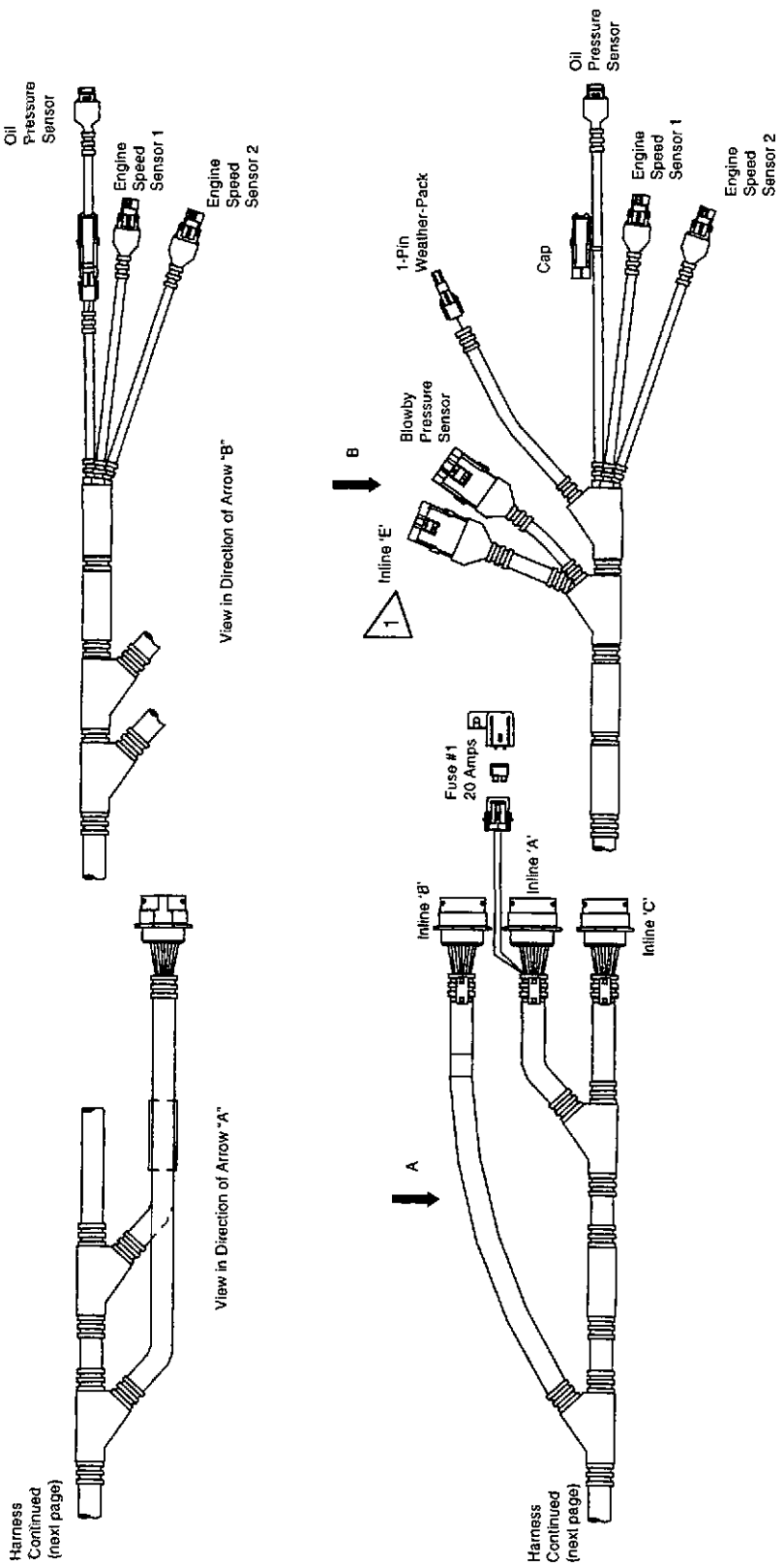
QSX15 Alternator and Starter Harness



QSX15 Alternator and Starter Wiring Schematic

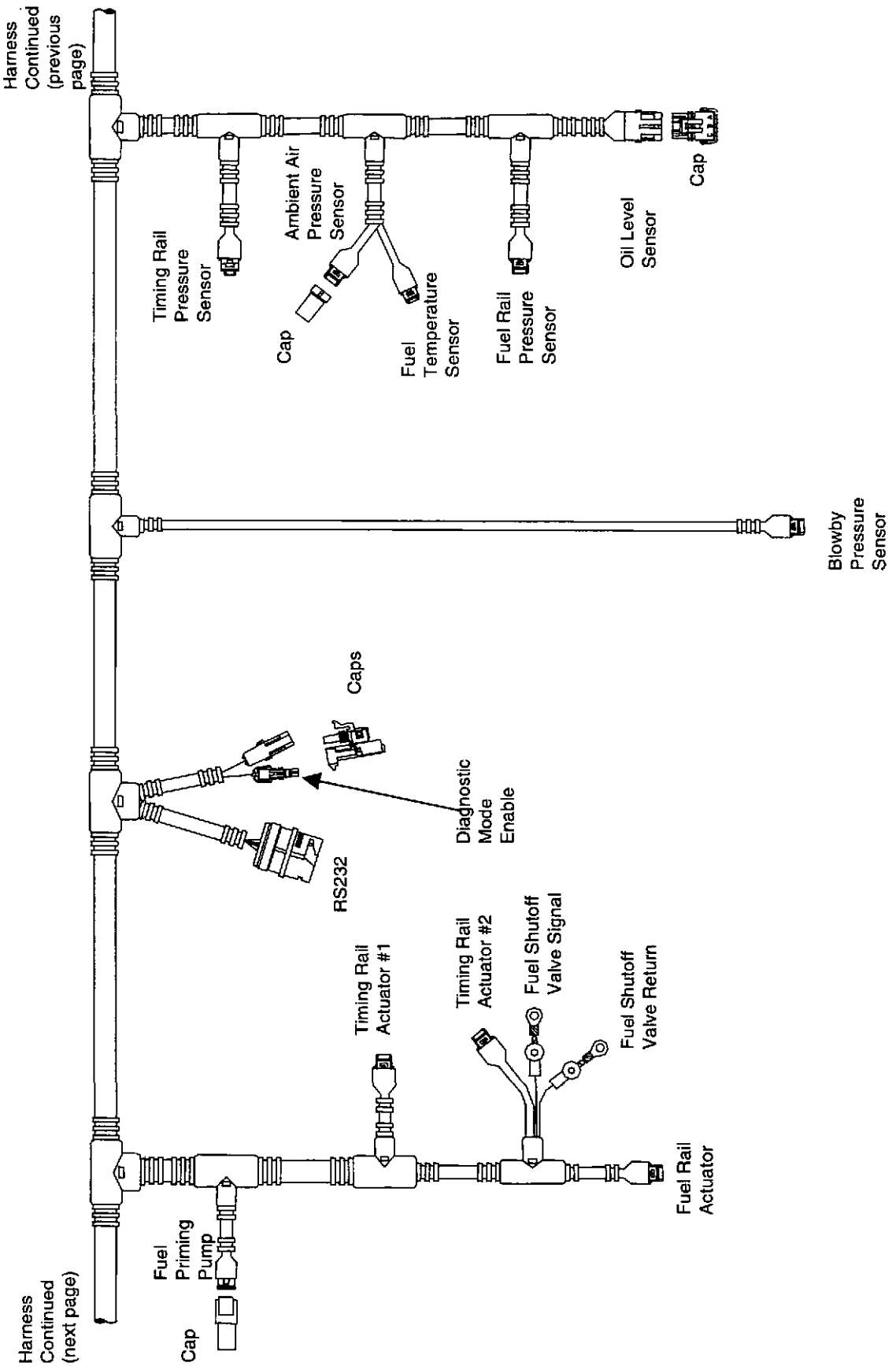


QSK45 / QSK60 Engine Harness

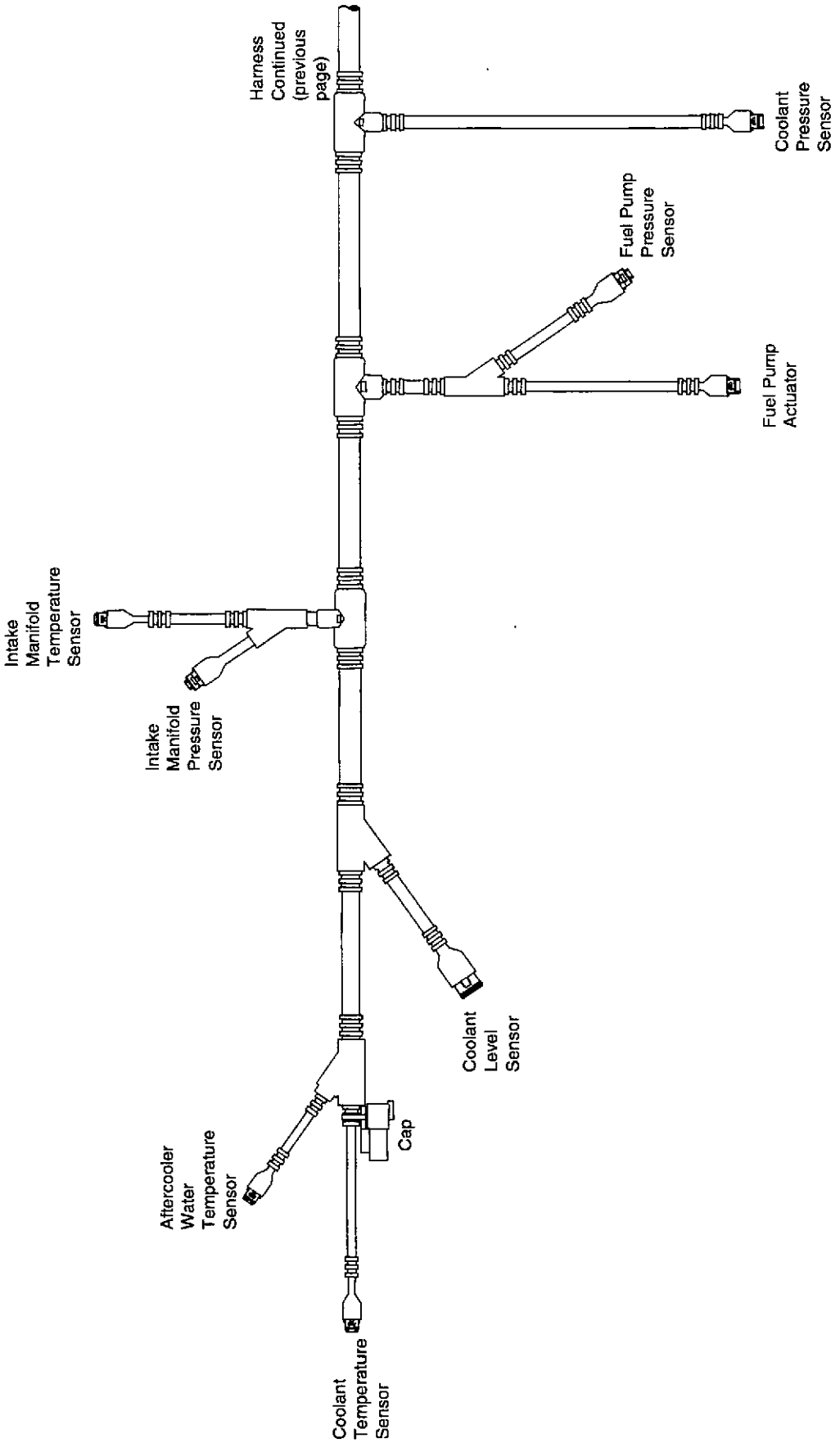


1 Connector Inline **E** provides access to OEM features. Mating Connector information for this connector is provided on page 26.

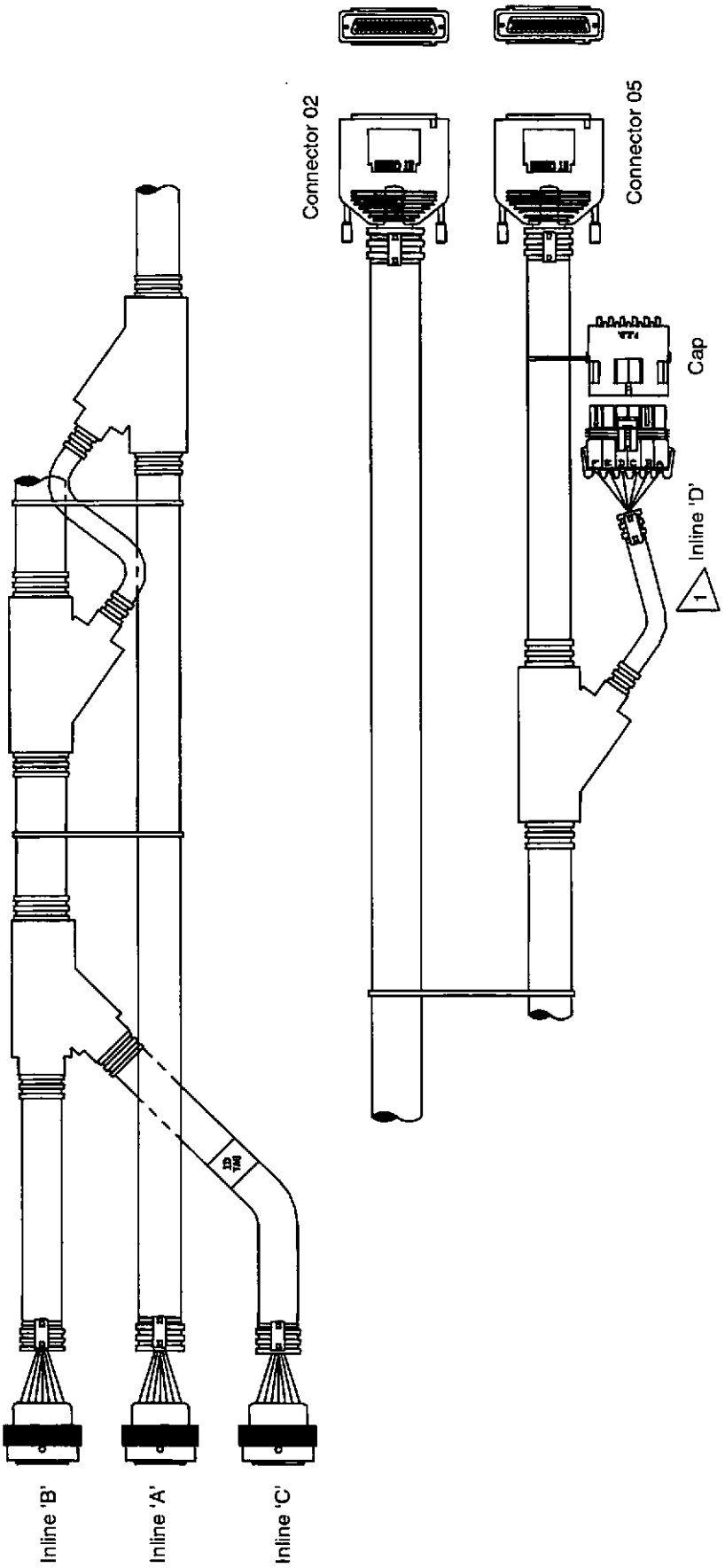
QSK45 / QSK60 Engine Harness (Continued)



QSK45 / QSK60 Engine Harness (Continued)

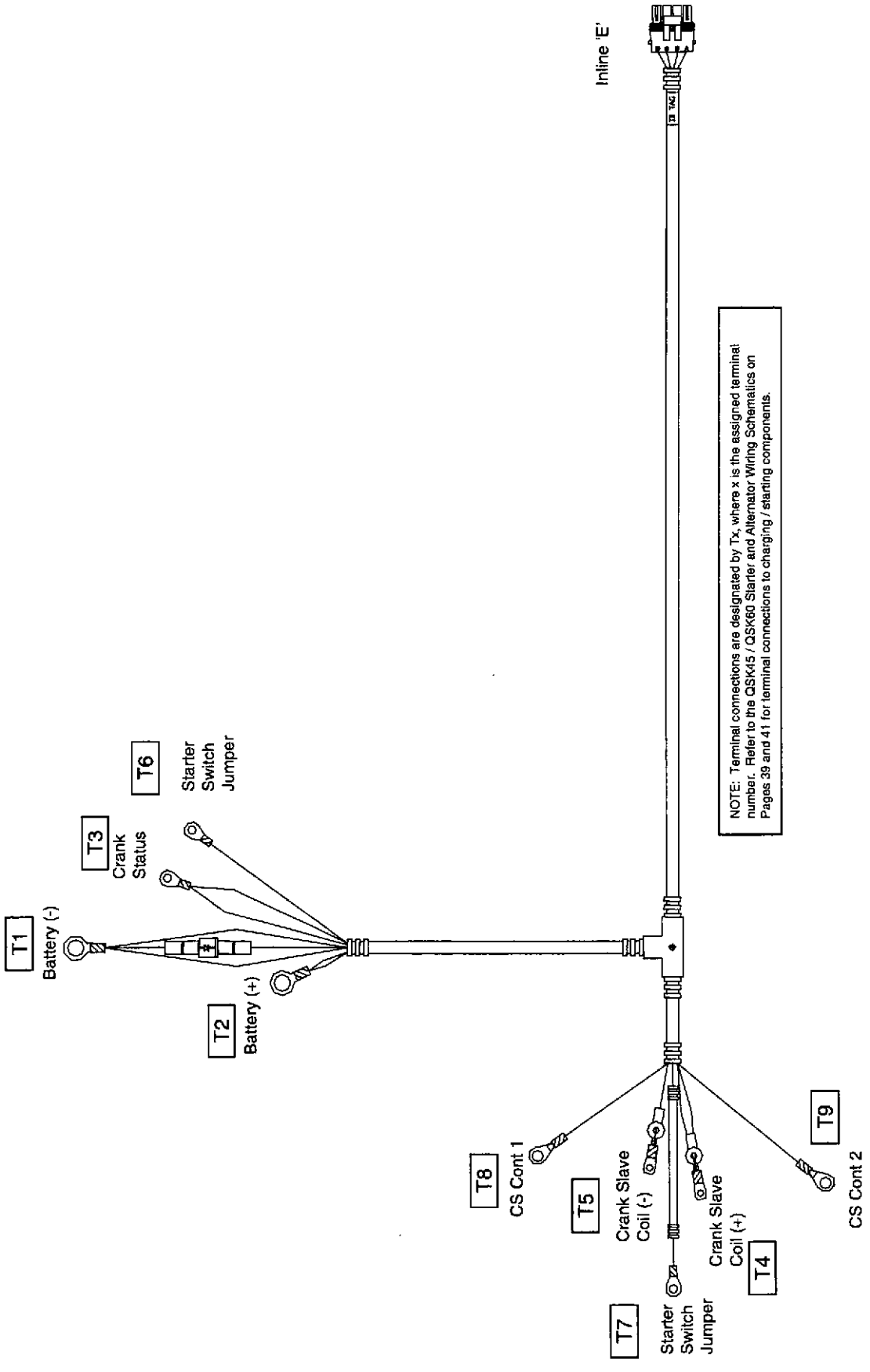


QSK45 / QSK60 Extension Harness

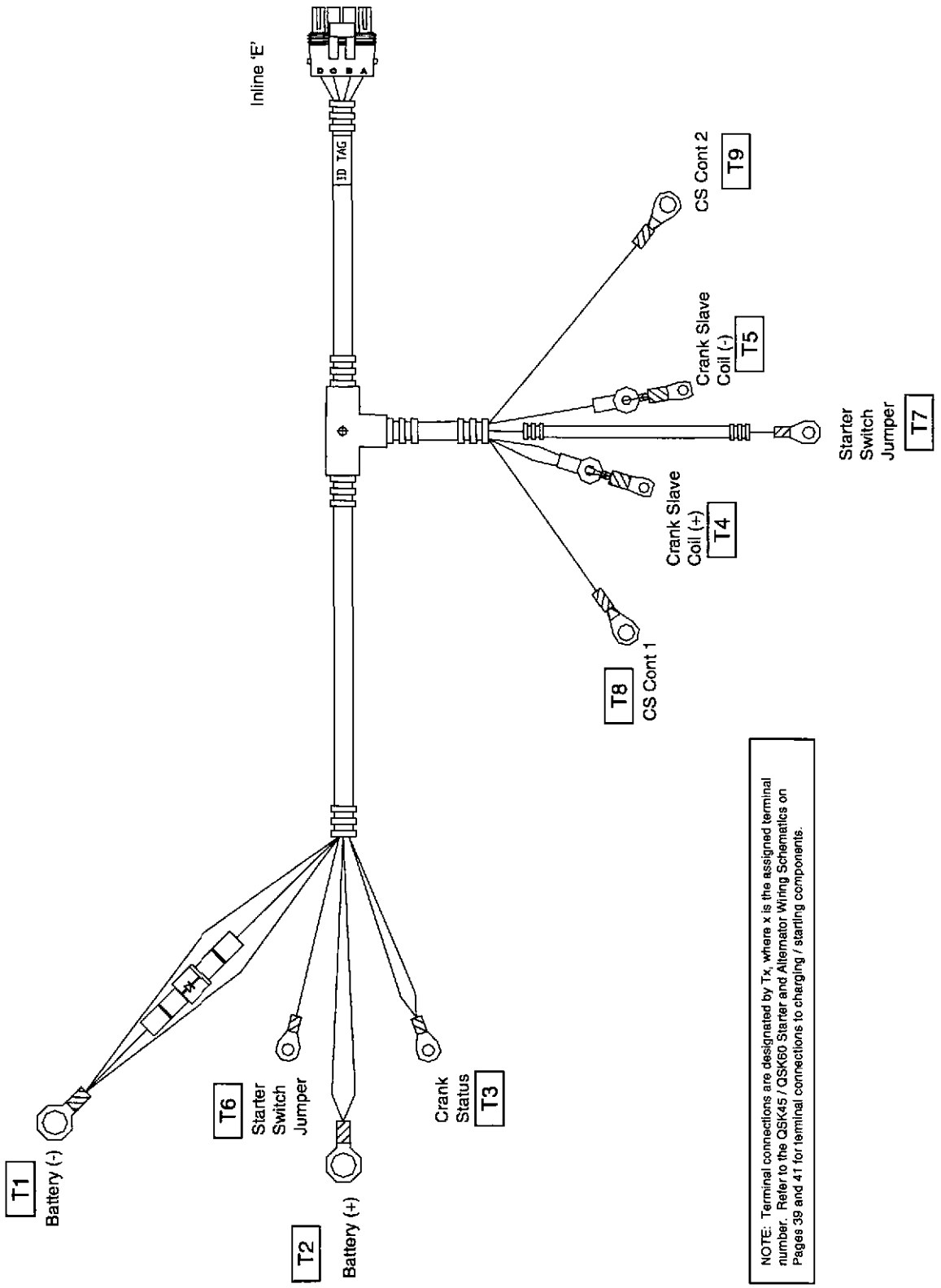


1 Connector Inline D provides access to OEM features. Mating Connector information for this connector is provided on page 26.

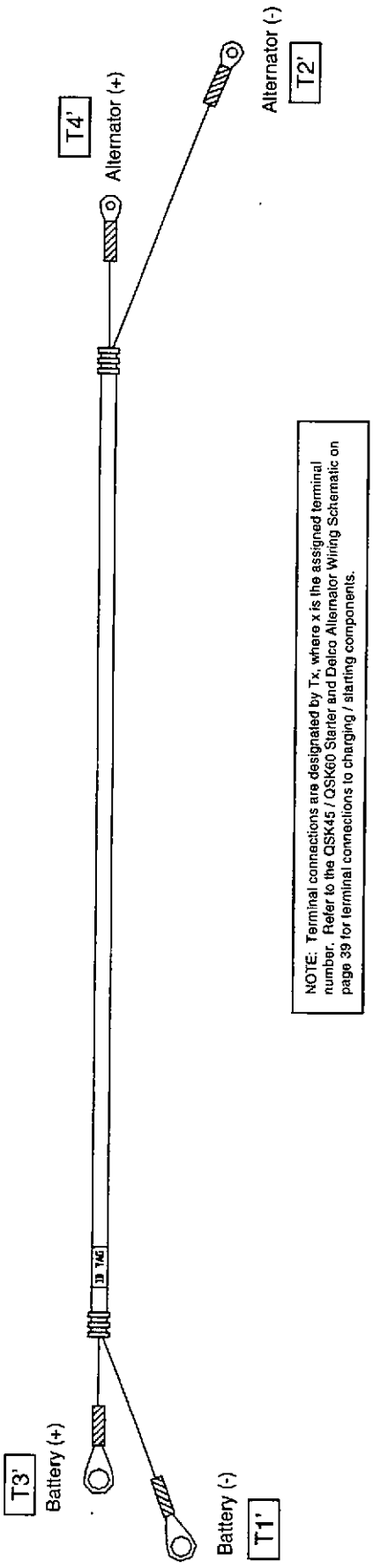
QSK45 / QSK60 Starter Harness, Right Bank



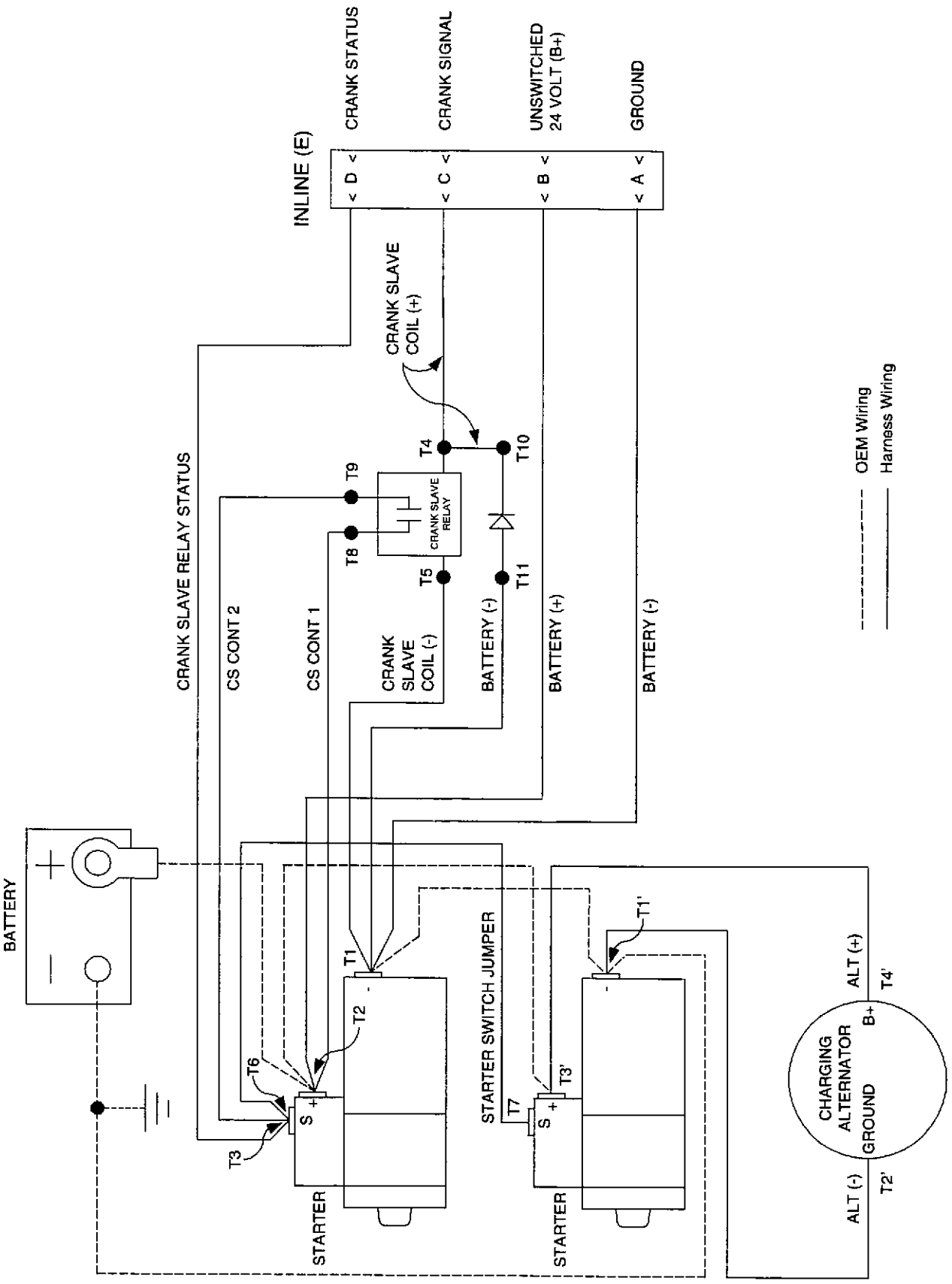
QSK45 / QSK60 Starter Harness, Left Bank



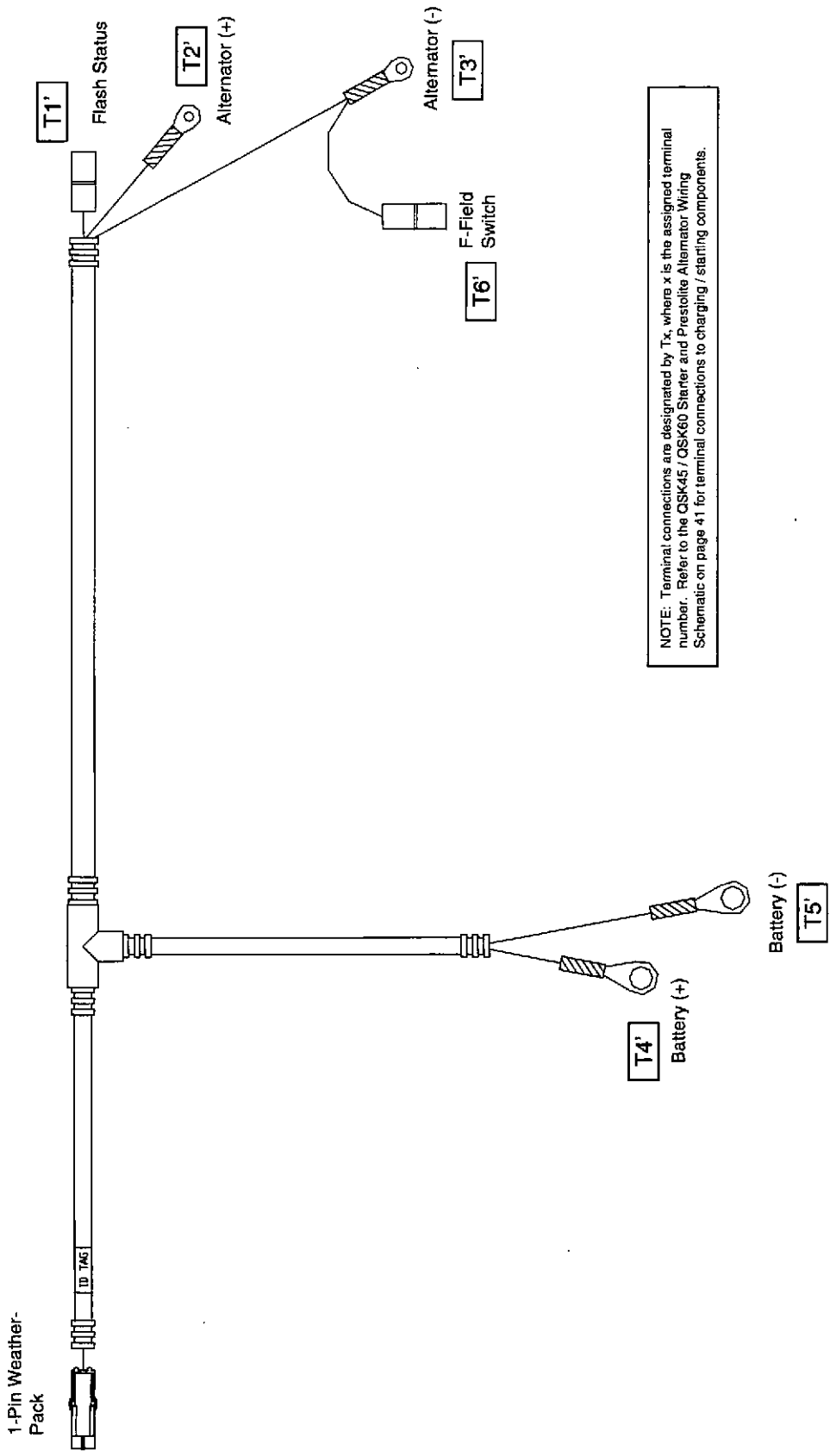
QSK45 / QSK60 Delco Alternator to Starter Harness, Left & Right Bank



QSK45 / QSK60 Starter and Delco Alternator Wiring Schematic

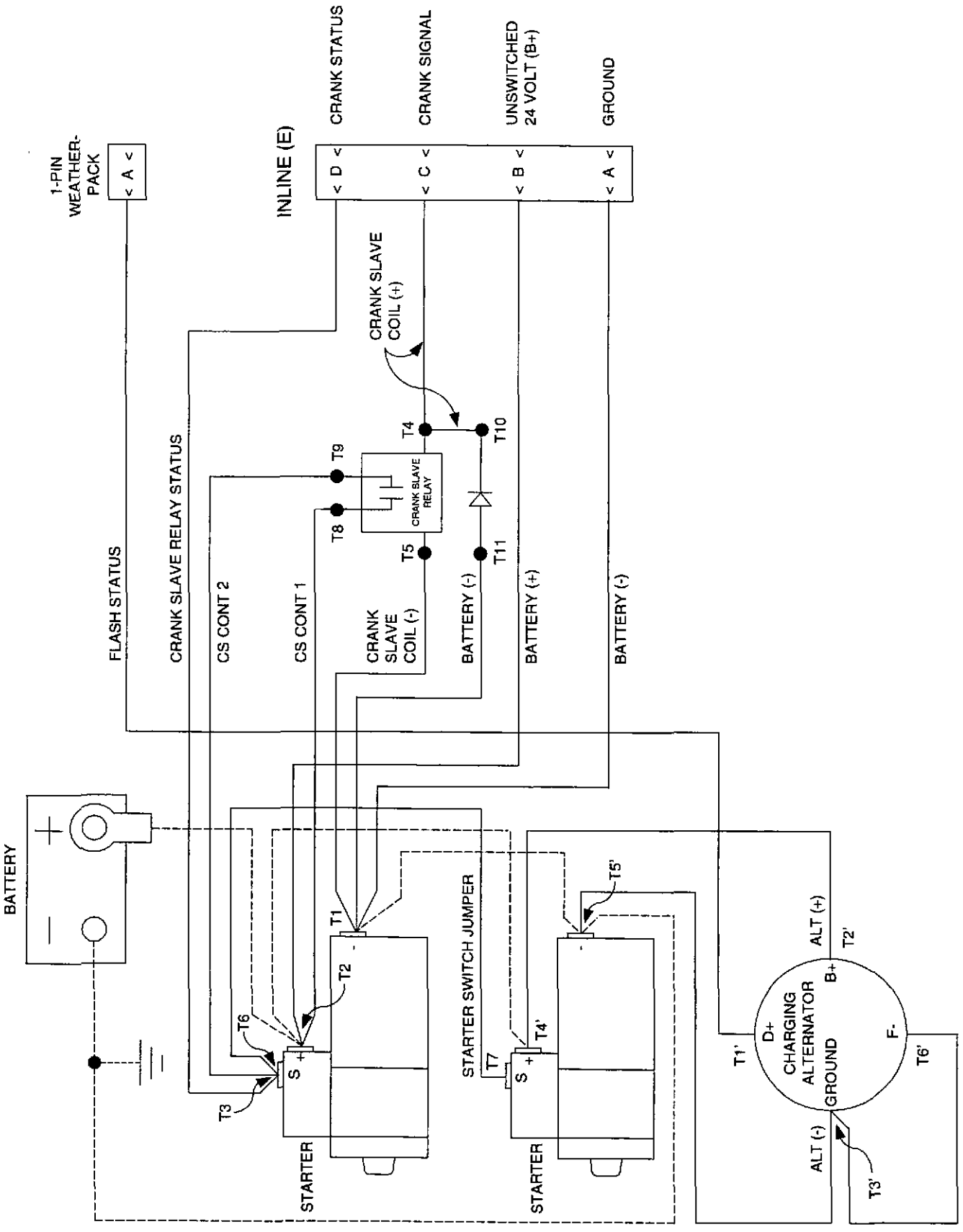


QSK45 / QSK60 Prestolite Alternator to Starter Harness, Left & Right Bank



NOTE: Terminal connections are designated by Tx, where x is the assigned terminal number. Refer to the QSK45 / QSK60 Starter and Prestolite Alternator Wiring Schematic on page 41 for terminal connections to charging / starting components.

QSK45 / QSK60 Starter and Prestolite Alternator Wiring Schematic



Magnetic Pickup Adjustment

QSX 15 Only:

The QSX15 engine model uses a hall effect type sensors for detecting engine speed and cam position. This type of sensor does not require any adjustment.

QSK45 and QSK60 Only:

The QSK45 and QSK60 engine models us a magnetic pickup type sensor, an electromagnetic device, mounted in the flywheel housing for detecting engine speed. The flywheel housing is set up with two magnetic pickup hole locations. One of these two hole locations is used for the GCS speed sensor.

The GCS speed sensor is a dual-coil magnetic pickup design that has two connectors, one for each coil. Both coils must be connected to the engine harness to provide backup speed detection in the event that one of the two coils fails.

To adjust the speed sensor, ensure that a ring gear tooth is centered under the magnetic pickup hole. Rotate the flywheel if necessary.

Screw the magnetic pickup in until it contacts the targeted gear tooth. The magnetic pickup will screw in very easily; do not use excessive pressure.

> ***NOTE:*** *If the magnetic pickup does not turn with finger pressure, check the hole and magnetic pickup threads. Chase threads with a tap if necessary. Using a magnet, remove any chips created by the tap.*

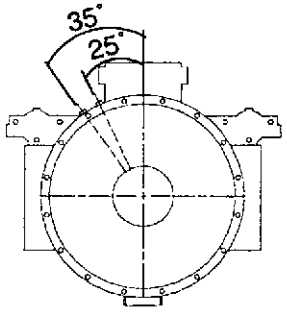
Back the magnetic pickup out (counterclockwise) 1/2 to 3/4 turn.

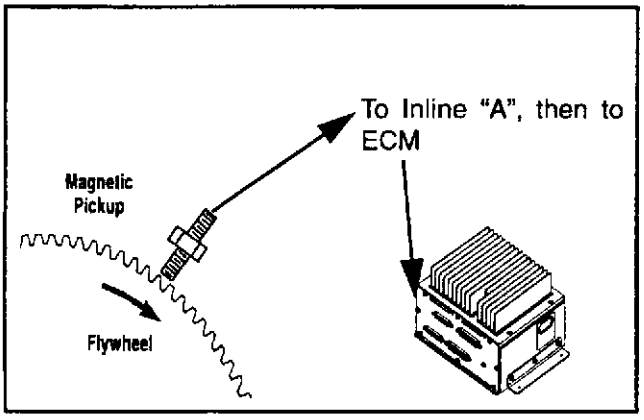
If a feeler gauge can be inserted between the magnetic pickup and the flywheel ring gear tooth, back the magnetic pickup out 0.71 to 1.07 mm [0.028 to 0.042 in.] from the gear tooth.

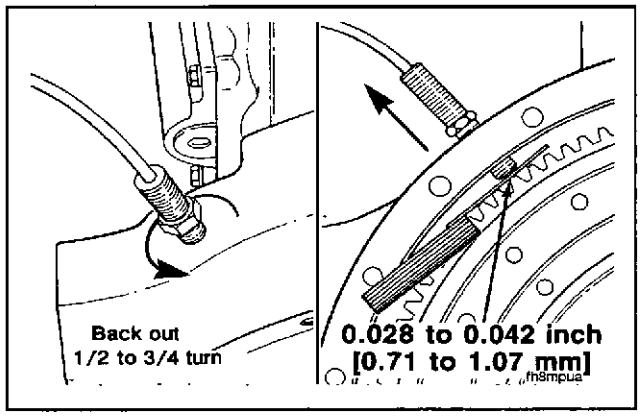
Tighten the jam nut on the flywheel housing. While holding the magnetic pickup, torque the jam nut to 34-47 N·m [25-35 ft-lb].

> **⚠ CAUTION ⚠**
>
> *Jam nut over-torque will damage the magnetic pickup.*

Flywheel Housing, Magnetic Pickup Locations - QSK45 and QSK60 Only





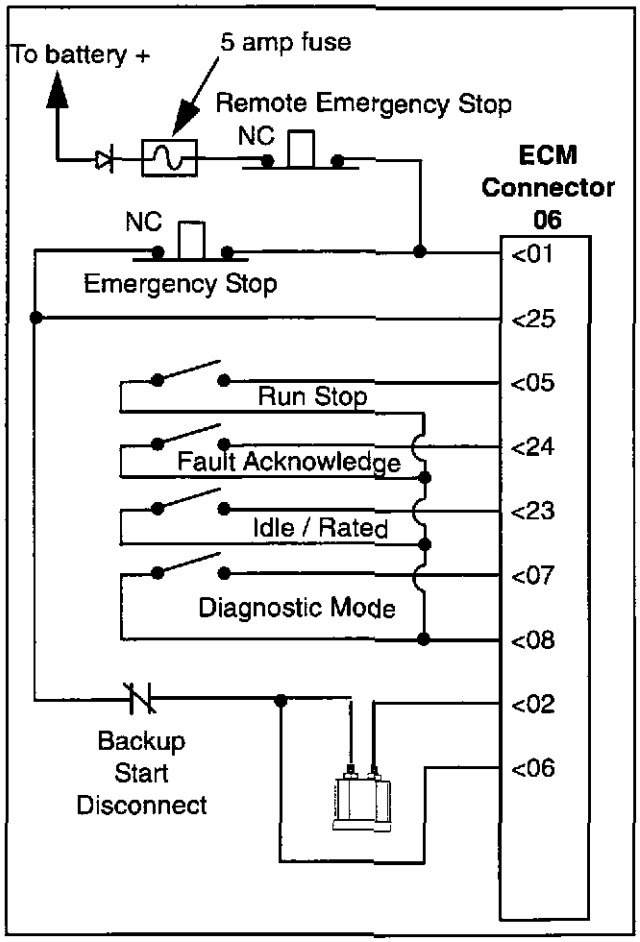


When a ring gear tooth passes the magnetic pickup, an AC voltage is induced producing the speed signal for the ECM. One cycle is induced for each gear tooth.

The speed sensor is connected to the ECM speed sensor signal and return pins via extension harness Inline connector A. The voltage generated by the speed sensor should be between 2.5 to 50 V_{p-p} under any running condition (cranking or run speeds).

If the magnetic pickup signal is less than 2.5 V_{p-p} when cranking the engine, screw the pickup in (clockwise) 1/8 to 1/4 turn.

NOTE: *One of the two magnetic pickup connectors can be disconnected in order to measure the speed sensor voltage at the sensor. Be sure to re-connect the magnetic pickup connector once all measurements have been completed.*



Run/Stop Controls

The information in this section pertains to running or stopping the engine.

Run/Stop

A Run/Stop input is provided to enable starting, running, and stopping the engine.

When used in conjunction with the Crank switch input, when the Run/Stop input is in the "Run" state, the ECM will enable the Starter Control and fueling control for starting and running the engine. See the ***Crank*** feature description on page 47 for further details.

In "Stop" state, the ECM will command the engine to stop running and inhibit starting once the engine has stopped.

To implement this feature, the customer supplies a bi-state signal, to pin 5 of ECM connector 06. Pin 8 of ECM connector 06 is used to supply an electrical signal path to GND through the ECM.

When the switch is set in the position that connects GND to the Run/Stop input, the ECM will enter the "Run" mode (GND = Run). When the switch input is set in the position that opens the circuit connection, disconnecting GND from the Run/Stop input, the ECM enters the "Stop" mode (Open = Stop).

Local Emergency Stop

The Local Emergency Stop, or Local E-Stop, feature is implemented by providing a normally-closed momentary bi-state signal, or switch, connected bewteen pins 1 and 25 of ECM connector 06. This feature provides a means to immediately shutdown the engine during an emergency condition by opening the Local E-Stop switch located at the operator panel, interrupting power to the Fuel Shut-Off Valve and fuel system actuator driver circuits of the ECM through pin 25 of ECM connector 06 (Open = E-Stop).

> ***NOTE: DO NOT** use the Emergency Stop for normal or routine shutdowns. This switch is for emergency stopping only.*

The engine Run/Stop state can also be controlled electronically using InPower™. This is accomplished by setting the *Run/Stop Command* parameter to the desired state.

NOTE: *The Run/Stop electronic trim setting and switch input are both used by the ECM to determine the operating state of the engine. The electronic trim and switch input must both be set to "Run" in order for the engine to be able to start and run. If either the electronic trim or the switch input, or both, are set to "Stop" the engine will not start or run.*

If the customer prefers using the switch input as the sole means of controlling the engine operating speed, the Run/Stop Command *parameter must be set to "Run" at all times. The* Run/Stop Command *parameter defaults to "Run" on ECM power-up.*

InPower™ Configurable Feature

Run/Stop Control

InPower™ Location:

Monitor

Control

Starting / Stopping

Run/Stop Command

Remote Emergency Stop

Similar to the Local E-Stop switch, the Remote E-Stop feature is implemented by providing a normally-closed momentary bi-state signal, or switch, to pin 1 of ECM connector 06. This feature provides a means to immediately shutdown the engine during an emergency condition by opening the Remote E-Stop switch located at a location remote from the operator panel, interrupting power to the Fuel Shut-Off Valve and fuel system actuator driver circuits of the ECM through pin 25 of ECM connector 06 (Open = E-Stop).

The engine can also be electronically shutdown using the InPower™ service tool. This is accomplished by setting the *Remote E-Stop Command* parameter to "Stop".

Remote Emergency Stop

InPower™ Location:

Monitor

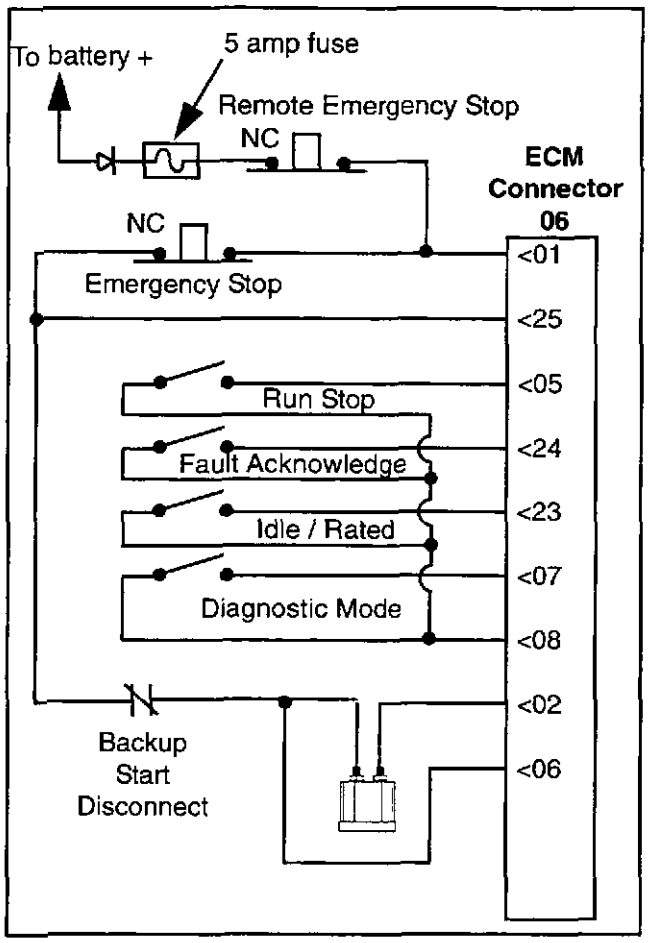
Control

Starting / Stopping

Remote E-Stop Command

⚠ WARNING ⚠

The electronic shutdown Remote E-Stop Command does not cause battery power to be physically disconnected from the ECM Fuel Shut-Off Valve and fuel system actuator driver circuits. If application requirements for the generator set dictate that emergency stopping of the engine must absolutely prevent operation of such fueling control circuits, the hard-wired Emergency Stop inputs must be used.



Starter Control

The Starter Control feature provides the means to control the engine starter solenoid and the cranking routine during engine start-up. The Starter Control cranking routine is initated based on the state of the Crank and Run/Stop switch inputs. See pages 44 and 47 describing the ***Run/Stop*** and ***Crank*** features for further details.

Following is an operational description of the GCS Starter Control feature. This description assumes that the starting circuit is connected as shown in the respective wiring schematics on pages 31, 39 and 41, and that the Emergency Stop inputs and Backup Start Disconnect are connected as shown at the left.

The Run/Stop switch must be placed in the "Run" state and the Crank Relay coil high side must be connected to Battery (+) (i.e. the Local E-Stop, Remote E-Stop and Backup Start Disconnect switches are all closed).

Engine cranking is initiated by holding the Crank switch in the "Crank" state. The Crank Coil relay driver will immediately activate the Crank Relay driver output at pin 2 of ECM connector 06, providing a signal path to GND, which energizes the Crank Relay coil. The Crank Relay will then provide power to the Crank Slave Relay (or magnetic switch) coil closing the Crank Slave Relay contacts, which in turn will supply power to the starter motor switch, causing the starter motor to engage and to begin cranking the engine.

Once the engine speed has reached a pre-programmed starter disconnect speed, the Crank Relay coil driver will open, de-energizing the Crank Relay. In turn, the Crank Slave Relay will de-energize and the starter will disengage as the engine speed continues to ramp-up to either the idle or rated speed depending upon the state of the Idle/Rated switch input. See the ***Idle/Rated Speed*** feature description on page 49 for further details.

> ***NOTE:*** *Use of the GCS Starter Control feature is not required in order to start and run the engine. If a customer supplied starting system is used, the Run/Stop switch must still be placed in the "Run" state in order to start and run the engine.*

Crank

A Crank switch input is provided to command the ECM to initiate the crank sequence to start the engine, as explained in the previous section.

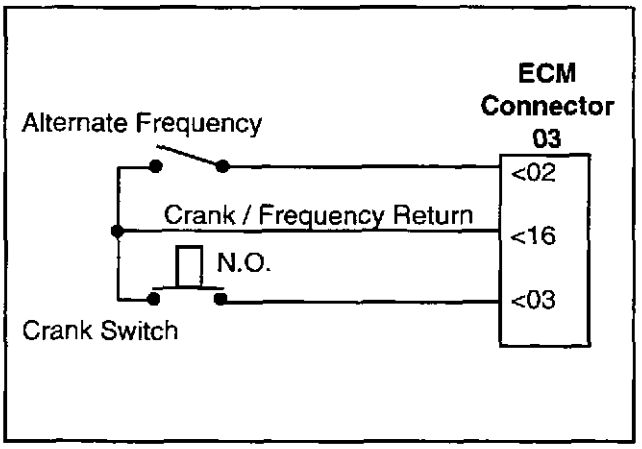
To implement this feature, the customer supplies a bi-state (normally open) signal, or switch, to pin 3 of ECM connector 03. Pin 16 of ECM connector 03 is used to provide an electrical signal path to GND through the ECM. The Crank swich input must be enabled, using InPower™, to make this feature operational. This is accomplished by setting the *Crank Switch Enable* parameter to "Enabled".

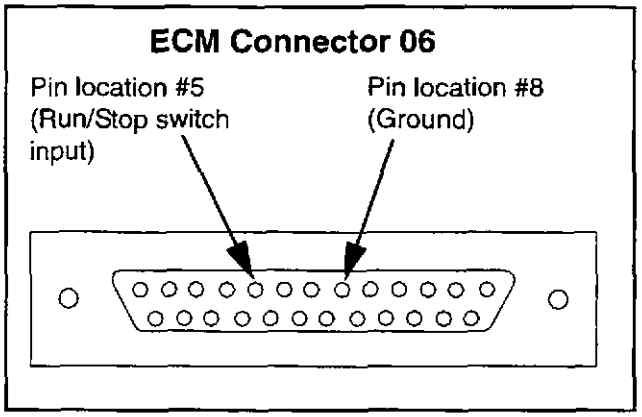
When the switch is set in the position that connects GND to the Crank input, the input is in the "Crank" state (GND = Crank).

When the switch is set in the position that opens the circuit connection, disconnecting GND from the Crank input, the input is in the "Not Crank" state (Open = Not Crank).

When the Crank switch input transitions from the "Not Crank" state to the "Crank" state while the engine is not yet running, and the Run/Stop switch is in the "Run" state, the ECM will initiate the cycle/continuous crank sequence. See the ***Cycle/Continuous Cranking*** section following for further details.

There is no effect on engine operation when the Crank switch input transitions from the "Crank" state to the "Not Crank" state once the engine has already started. If this switch transition occurs prior to the engine starting after the crank sequence has been initiated the crank sequence will cease immediately.





InPower™
Configurable Feature

Cycle/Continuous Cranking

The Starter Control feature allows the use of either cycle or continuous cranking routines which are set-up and selected using the InPower™ service tool.

The **Continuous Cranking** routine provides the capability to engage the starter only once for a configurable length of time. The *Continuous Crank Engage Time* parameter allows the user to define how long the starter will crank in an attempt to start the engine.

The **Cycle Cranking** routine provides the capability to perform a maximum of seven starting attempts with configurable starter engage and rest times. The *Cycle Crank Attempts* parameter allows the user to determine how many times the starter will attempt to start the engine. The *Cycle Crank Engage Time* parameter allows the user to define how long the starter will crank during each start attempt. The *Cycle Crank Rest Time* parameter defines how long the starter will wait, or rest, between starting attempts.

Starting Control

InPower™ Location:

Adjustments

Starting

Crank Switch Enable

Cycle / Continuous Crank Select

Continuous Crank Engage Time

Cycle Crank Attempts

Cycle Crank Engage Time

Cycle Crank Rest Time

Speed Ramping

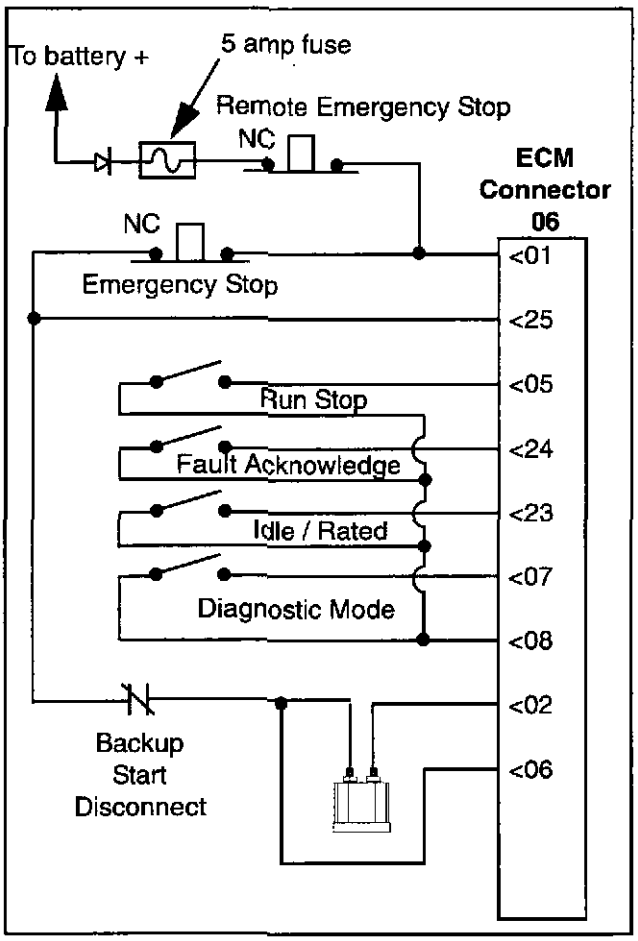
InPower™ Location:

Adjustments

Governor

Idle and Ramping

Starting to Rated Ramp Time



Starting-to-Rated Speed Ramp

During starting with the Idle/Rated Switch Input set to "Rated", the engine will ramp-up (accelerate) to rated speed at the Starting-to-Rated Speed Ramp rate.

If the ramp rate is set at or near 0 seconds, the engine speed will accelerate to achieve rated speed as quickly as possible based on the governor gain settings and the generator set performance. The user can increase or decrease the governor gain using the ***Governor Gain Adjust*** feature described on page 51.

Backup Start Disconnect

The Backup Start Disconnect is implemented by providing a bi-state switched signal, or switch, between pin 25 of ECM connector 06 and the high-side of the Crank Relay coil.

This feature provides a means to manually disengage the starter by removing power to the Crank Relay coil when the Backup Start Disconnect switch located on the operator panel is "open" (Open = Inhibit/Disengage Starter).

This feature is intended to save the starter from damage in case the Starter Control feature does not automatically disengage the starter when the engine reaches the required start disconnect speed. See the ***Starter Control*** feature description on page 46 for further details.

Backup Starting Systems

The GCS Starter Control feature can be implemented for use as either the primary or secondary starting system where backup starting control is required.

> ***NOTE:*** *If the GCS Starter Control feature is used as part of a backup starting system, it is the customer's responsibility to ensure that the GCS Starter Control feature is set-up in the correct manner to avoid interference with the proper function of either of the starting systems.*

Idle/Rated Speed

An Idle/Rated speed input is provided to allow control of the engine speed.

To implement this feature, the customer supplies a bi-state signal, or switch, to pin 23 of ECM connector 06. Pin 8 of ECM connector 06 is used to provide an electrical signal path to GND through the ECM.

When the switch is in the position that connects GND to the Idle/Rated input, the ECM enters the "Idle" speed mode (GND = Idle). Upon transition to the Idle speed mode, the generator set speed will ramp from the current speed to the idle speed. See the ***Rated-to-Idle Speed Ramp*** feature description on page 50 for further details regarding transitions from rated to idle speed.

When the switch input is set in the position that opens the circuit connection, disconnecting GND from the Idle/Rated input, the ECM enters the "Rated" speed mode (Open = Rated). Upon transition to the Rated speed mode, the generator set speed will ramp from the current speed up to the rated speed. See the ***Idle-to-Rated Speed Ramp*** feature description on page 50 for further details regarding transitions from idle to rated speed.

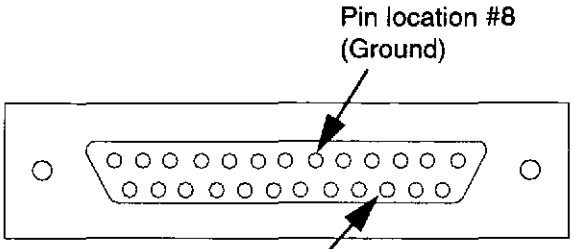
If the Idle/Rated switch input is set to "Rated" prior to starting the engine, the rate at which the engine will ramp-up to rated speed is determined based on the Starting-to-Rated Speed Ramp setting. See the ***Starting-to-Rated Speed Ramp*** feature description on page 48 for further details.

The Idle/Rated speed can also be controlled electronically using InPower™. This is accomplished by setting the *Idle / Rated Command* parameter to the desired state.

NOTE: *The Idle/Rated electronic trim setting and switch input are both used by the ECM to determine the operating speed of the engine. The electronic trim and switch input must both be set to "Rated" in order for the engine to operate at rated speed. If either the electronic trim or the switch input, or both, are set to "Idle" the engine will operate at idle speed.*

If the customer prefers using the switch input as the sole means of controlling the engine operating speed, the Idle / Rated Command *parameter must be set to "Rated" at all times. The* Idle / Rated Command *parameter defaults to "Rated" on ECM power-up.*

ECM Connector 06



**InPower™
Configurable Feature**

Idle/Rated Speed

InPower™ Location:

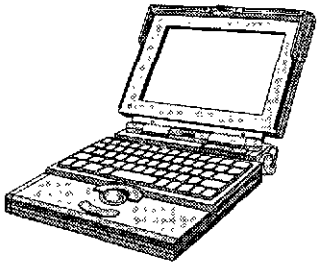
Monitor

Control

Starting / Stopping

Idle / Rated Command

InPower™ Configurable Feature



Idle Speed Adjust

InPower™ Location:

Adjustments

Governor

Idle and Ramping

Engine Idle Speed

Idle to Rated Ramp Time

Rated to Idle Ramp Time

Idle Speed Adjust

The engine idle speed can be set between a minimum and maximum limit pre-programmed in the ECM. This is accomplished by setting the *Engine Idle Speed* parameter to the desired idle speed using InPower™.

Idle-to-Rated Speed Ramp

When the engine is at idle speed and the Idle/Rated switch Input state transitions from "Idle" to "Rated", the engine speed will ramp-up (accelerate) to rated speed at the Idle-to-Rated Speed Ramp rate.

If the ramp rate is set at or near 0 seconds, the engine speed will accelerate to achieve rated speed as quickly as possible based on the governor gain settings and the generator set performance. The customer can increase or decrease the governor gain using the ***Governor Gain Adjust*** *feature described on page* 51.

Rated-to-Idle Speed Ramp

When the engine is at rated speed and the Idle/Rated Switch Input state transitions from "Rated" to "Idle", the engine speed will ramp-down (decelerate) to idle speed at the Rated-to-Idle Speed Ramp rate.

If the ramp rate is set at or near 0 seconds, the engine speed will decelerate to achieve idle speed as quickly as possible based upon the governor gain settings and the generator set performance. The customer can increase or decrease the governor gain using the ***Governor Gain Adjust*** feature described on page 51.

Performance, Frequency and Droop Controls

Governor Gain Adjust

An adjustable signal input is provided to adjust the governor gain. The governor gain is adjustable from 0.05 (least amount of gain) to 10.00 (highest amount of gain).

The customer can implement the Governor Gain Adjust feature by connecting one side of a 5kΩ potentiometer to the analog ground at pin F of the Inline D connector, the other side is connected to pin E of the Inline D connector, and the wiper is also connected to pin E of the Inline D connector.

A potentiometer with a smaller resistance can be used to improve the adjustment sensitivity. Using a smaller resistance potentiometer will also decrease the adjustment range.

This feature can also be implemented by supplying a 0 to 3.177 VDC variable voltage to pin E of the Inline D connector, using pin F of the Inline D connector as a GND reference.

⚠ CAUTION ⚠

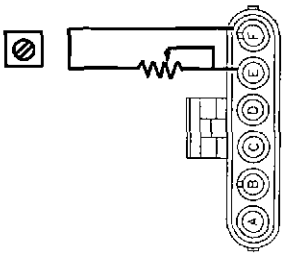
When using a variable voltage input, the voltage must not exceed 5 VDC.

The governor gain setting is directly proportional to the potentiometer resistance, or input voltage. As the resistance increases, the gain increases. The amount of gain can be calculated using the formulas shown at the right.

The Inline D connector is located on the Extension Harness. See the ***Wiring Harnesses and Interface Connectors*** section on page 19 for further details about the Extension Harness.

Governor Gain Adjust - Inline D

Pins:



F: Gov Gain Adjust Return
E: Gov Gain Adjust Signal

When using a 5kΩ potentiometer:

$$\text{Gain} = \left[\frac{R_{pot}}{5000\ \Omega} \times 9.95\right] + 0.05$$

OR

When using a potentiometer less than 5kΩ:

$$\text{Gain} = \left[\frac{R_{pot}}{(R_{pot} + 2870\ \Omega)} \times 15.6613\right] + 0.05$$

OR

When using a variable voltage:

$$\text{Gain} = \left[\frac{V_{in}}{3.17662\ V} \times 9.95\right] + 0.05$$

Where:

R_{pot} = Potentiometer Resistance (Ω)
V_{in} = Signal Input Voltage (V)

Examples:

R_{pot} = 2500 Ω (Using a 5kΩ potentiometer)

$$\text{Gain} = \left[\frac{2500\ \Omega}{5000\ \Omega} \times 9.95\right] + 0.05 = 5.025$$

R_{pot} = 1336 Ω (Using a 2kΩ potentiometer)

$$\text{Gain} = \left[\frac{1336\ \Omega}{1336\ \Omega + 2870\ \Omega} \times 15.6613\right] + 0.05 = 5.025$$

V_{in} = 1.58831 V

$$\text{Gain} = \left[\frac{1.58831\ V}{3.17662\ V} \times 9.95\right] + 0.05 = 5.025$$

InPower™
Configurable Feature

The governor gain can also be set by changing a trim value electronically using InPower™. Either the potentiometer or the electronic trim may be used to determine the governor gain, but not both simultaneously.

Governor Gain Adjust

InPower™ Location:

Adjustments
Governor
Gain and Droop
Governor Gain Adjust
Governor Gain Adjust Select

NOTE: *A selection must be set to either "Pot" or "Trim", using InPower™, to tell the ECM whether a potentiometer is being used for this feature, or if the electronic trim governor gain setting is to be used.*

If a potentiometer is used the signal input must also be enabled, using InPower™, after the "Pot" selection is set-up.

Governor Gain Adjust

InPower™ Location:

Adjustments
Features
Inputs
Governor Gain Adjust Pot Enable

⚠ CAUTION ⚠

Improper configuration or adjustment of the Governor Gain feature can cause unstable engine operation. The customer is responsible for performing any necessary system and generator set tests to ensure that this feature has been properly set-up.

Droop Adjust

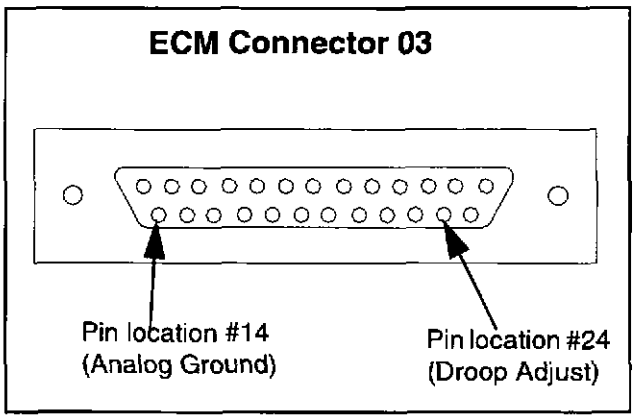
An adjustable signal input is provided to control the governor speed droop. The speed droop is adjustable from 0 to 10%.

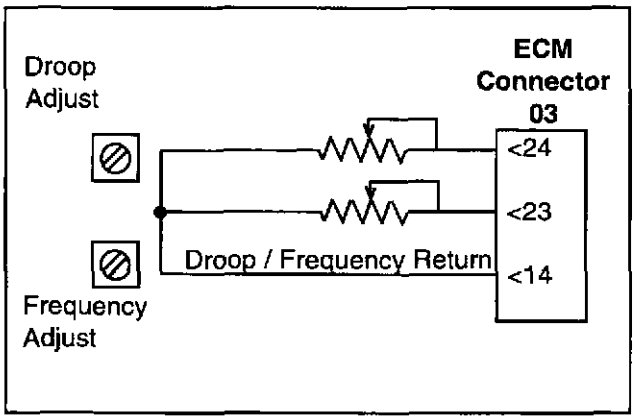
The customer can implement the Droop Adjust feature by connecting one side of a 5kΩ potentiometer to the analog ground at pin 14 of connector 03, the other side connected to pin 24 of connector 03, and the wiper also connected to pin 24 of connector 03.

This feature can also be implemented by supplying a 0 to 3.177 VDC variable voltage to pin 24 of ECM connector 03, using pin 14 of ECM connector 03 as a GND reference.

⚠ CAUTION ⚠

When using a variable voltage input, the voltage must not exceed 5 VDC.





The droop adjust setting is directly proportional to the potentiometer resistance, or input voltage. As the resistance increases, the droop increases. The amount of droop can be calculated using the formula shown at the right.

$$\% \text{ Droop} = \frac{R_{pot}}{5000\ \Omega} \times 10.00\%$$

OR

$$\% \text{ Droop} = \frac{V_{in}}{3.17662\ V} \times 10.00\%$$

Where:

R_{pot} = Potentiometer Resistance (Ω)
V_{in} = Signal Input Voltage (V)

Examples:

$R_{pot} = 2500\ \Omega$

$$\% \text{ Droop} = \frac{2500\ \Omega}{5000\ \Omega} \times 10.00\% = 5.00\%$$

$V_{in} = 1.58831\ V$

$$\% \text{ Droop} = \frac{1.58831\ V}{3.17662\ V} \times 10.00\% = 5.00\%$$

InPower™
Configurable Feature

Droop Adjust

InPower™ Location:

Adjustments

Governor

Gain and Droop

Droop Adjust

Droop Adjust Select

Droop Adjust

InPower™ Location:

Adjustments

Features

Inputs

Droop Adjust Pot Enable

The speed droop can also be set by changing a trim value electronically using InPower™. Either the potentiometer or the electronic trim may be used to determine the speed droop, but not both simultaneously.

NOTE: *A selection must be set to either "Pot" or "Trim", using InPower™, to tell the ECM whether a potentiometer is being used for this feature, or if the electronic trim droop setting is to be used.*

If a potentiometer is used, the signal input must also be enabled, using InPower™, after the "Pot" selection is set-up.

⚠ CAUTION ⚠

Improper configuration or adjustment of the Droop feature can cause undesireable engine speed variation. The customer is responsible for performing any necessary system and generator set tests to ensure that this feature has been properly set-up.

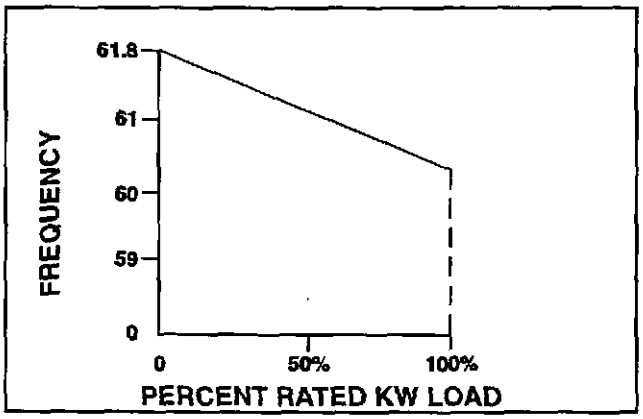
Droop engine-generator sets which are to operate at 60Hz full-load, must have the engine no-load governed speed adjusted to:

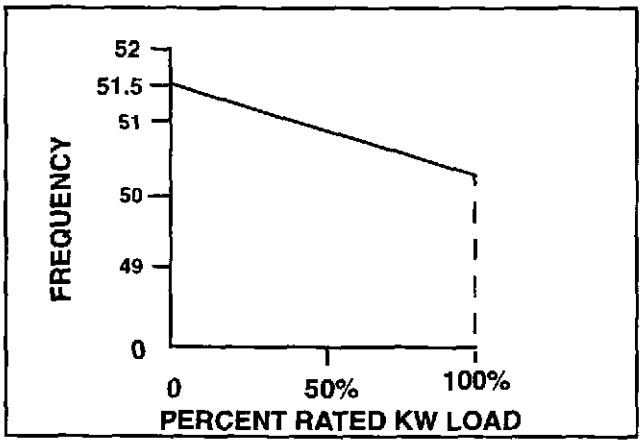
- 61.8 Hz (1854 RPM) for 3% Speed Droop
- 63.0 Hz (1890 RPM) for 5% Speed Droop

Droop engine-generator sets which are to operate at 50Hz full-load, must have the engine no-load governed speed adjusted to:

- 51.5 Hz (1545 RPM) for 3% Speed Droop
- 52.5 Hz (1575 RPM) for 5% Speed Droop

NOTE: *Speed adjustments to obtain desired no-load rated speeds must be made using the* Frequency Adjust *feature (see the Frequency Adjust section on page 56).*





Percent Speed Droop on the engine-generator set can be verified by noting no-load and full-load speeds and using the Speed Droop formula found at right.

When full-load kW is not available, to calculate what the Droop Governed speed should be under the available load, use this formula.

$$S_{al} = S_{nl} - \left(\left(\frac{\text{Available kW Load}}{\text{Rated kW}}\right) \times (S_{nl}-S_{fl})\right)$$

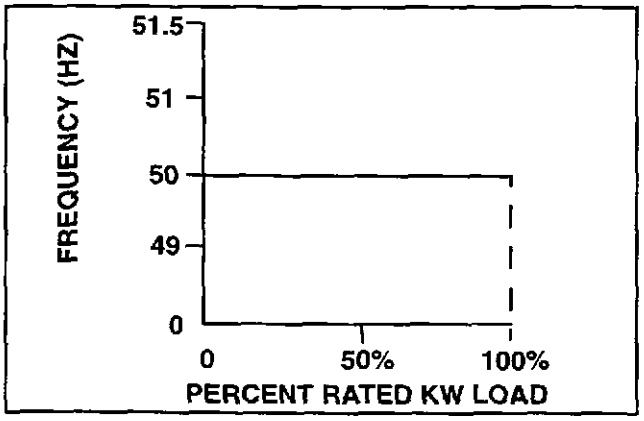
Where:
S_{al} = Speed at Available kW Load
S_{fl} = Speed at Full kW Load
S_{nl} = Speed at No Load

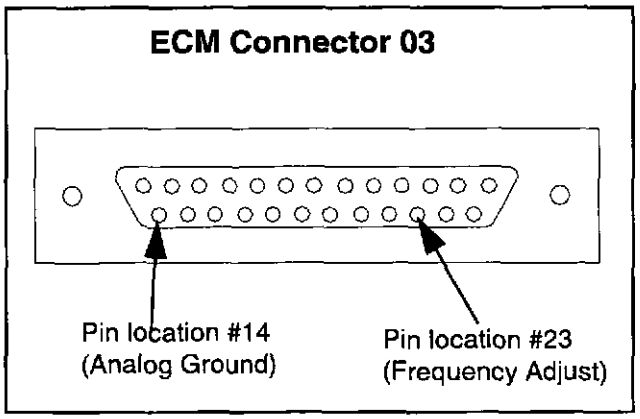
Example:
Available kW Load = 400
Rated kW = 500
Speed at Full kW Load = 1800
Speed at No Load = 1854
$S_{al} = 1854 - \left(\left(\frac{400}{500}\right) \times (1854-1800)\right)$
S_{al} = 1811 RPM

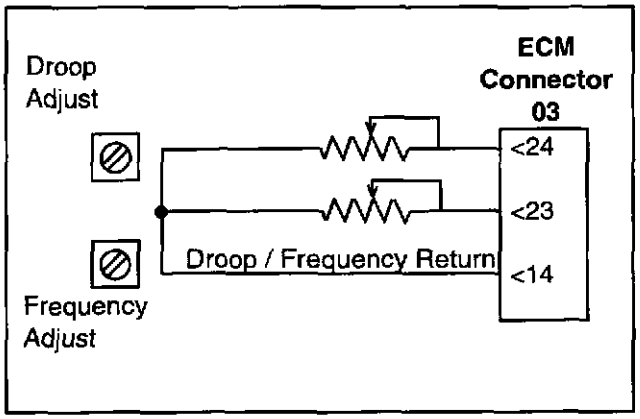
Isochronous Mode

For Isochronous Speed operation, the Droop setting needs to be set at 0%.

The Droop setting can be adjusted using the InPower™ electronic service tool, or a variable analog signal as described in the ***Droop Adjust*** section on page 53.







$$\Delta \text{ Frequency} = \left[\frac{R_{pot}}{5000\ \Omega} \times 6\text{Hz}\right] - 3\text{Hz}$$

OR

$$\Delta \text{ Frequency} = \left[\frac{V_{in}}{3.17662\ \text{V}} \times 6\text{Hz}\right] - 3\text{Hz}$$

Where:

R_{pot} = Potentiometer Resistance (Ω)
V_{in} = Signal Input Voltage (V)

Examples:

R_{pot} = 1667 Ω

$$\Delta \text{ Frequency} = \left[\frac{1667\ \Omega}{5000\ \Omega} \times 6\text{Hz}\right] - 3\text{Hz} = -1\text{Hz}$$

V_{in} = 1.05887 V

$$\Delta \text{ Frequency} = \left[\frac{1.05887\ \text{V}}{3.17662\ \text{V}} \times 6\text{Hz}\right] - 3\text{Hz} = -1\text{Hz}$$

Frequency Adjust

An adjustable signal input is provided to adjust the generator set frequency. The frequency is adjustable within ±9Hz of the rated operating frequency.

The customer can implement the Frequency Adjust feature by connecting one side of a 5 kΩ potentiometer to the analog ground at pin 14 of connector 03, the other side connected to pin 23 of connector 03, and the wiper also connected to pin 23 of connector 03.

This feature can also be implemented by supplying a 0 to 3.177 VDC variable voltage to pin 23 of ECM connector 03, using pin 14 of ECM connector 03 as a GND reference.

⚠ CAUTION ⚠

NOTE: *When using a variable voltage input, the voltage must not exceed 5 VDC.*

The frequency adjust setting is directly proportional to the potentiometer resistance, or input voltage. As the resistance increases, the frequency increases. The amount of frequency change can be calculated using the formula shown at the left.

The governor frequency is adjustable by ±9Hz using a combination of both a remote mounted potentiometer and the frequency adjustment trim which can be set using InPower™.

The potentiometer allows an adjustment range of ±3Hz, while the frequency adjustment trim allows an additional adjustment range of ±6Hz.

NOTE: *The Frequency Adjust feature is different from the Droop Adjust and Governor Gain Adjust features in that both the potentiometer and the electronic trim can be used simultaneously. The effect of the potentiometer setting and the electronic trim setting is additive.*

For example, if the potentiometer were set to provide a +3Hz adjustment and the electronic trim where set to +4Hz, the overall frequency adjustment would be equal to +7Hz. Using another example, if the potentiometer where set to provide a -1Hz adjustment and the electronic trim where set to +6Hz, the overall frequency adjustment would be equal to +5Hz.

If a potentiometer is used, the signal input must be enabled, using InPower™. This is accomplished by setting the Frequency Adjust Pot Enable parameter to "Enabled".

⚠ CAUTION ⚠

Improper configuration or adjustment of the frequency adjust feature can cause the engine to operate at the incorrect speed. The customer is responsible for performing any necessary system and generator set tests to ensure that this feature has been properly set-up.

InPower™ Configurable Feature

Frequency Adjust

InPower™ Location:

Adjustments

Governor

Frequency

Frequency Adjust

Frequency Adjust

InPower™ Location:

Adjustments

Features

Inputs

Frequency Adjust Pot Enable

Alternate Frequency

An Alternate Frequency input is provided to allow selecting between one of two generator set frequency settings.

To implement this feature, the customer supplies a bi-state signal, or switch, to pin 2 of ECM connector 03. Pin 16 of ECM connector 03 is used to provide an electrical signal path to GND through the ECM.

> ***NOTE:*** *The alternate frequency selection feature is only enabled for engines that have been rated for dual speed operation. For engines rated for a single operating speed, the Alternate Frequency input is non-operational and no connection needs to be made to this input.*

When the switch is set in the position that opens the circuit connection, disconnecting GND from the Alternate Frequency input, and the engine is not running, the ECM will transition to the "Primary" (or "Normal") frequency setting (Open = Primary/Normal). Upon engine start-up, and after being commanded to run at "rated" speed, the engine speed will ramp-up to the speed specified for the Primary frequency setting.

When the switch is set in the position that connects GND to the Alternate Frequency input, and the engine is not running, the ECM will transition to the "Secondary" (or "Alternate") frequency setting (GND = Secondary/Alternate). Upon engine start-up, and after being commanded to run at "rated" speed, the engine speed will ramp-up to the speed specified for the Secondary frequency setting.

> ***NOTE:*** *If the frequency selection using the Alternate Frequency input changes while the engine is running, the selected frequency setting will not take effect until after the engine is shut down and re-started.*

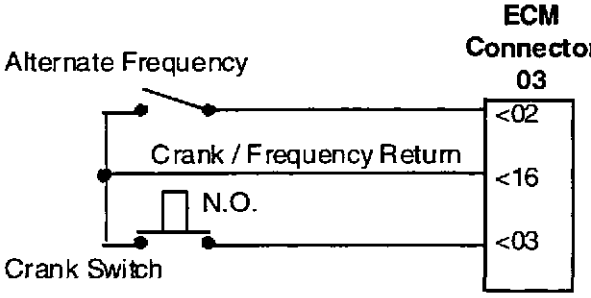
The frequency settings for the Primary/Secondary states of the Alternate Frequency input can be reversed (e.g. Primary = 50Hz / Secondary = 60Hz changed to Primary = 60Hz / Secondary = 50Hz) using InPower™. This is accomplished by setting the *Alternate Frequency Select* parameter to either "60Hz Primary" or "50Hz Primary".

The Alternate Frequency setting can also be controlled electronically using InPower™. This is accomplished by setting the *Alternate Frequency Select* parameter to either "60Hz Only" or "50Hz Only". These settings effectively disable the Alternate Frequency switch input, by overriding the switch setting.

Alternate Frequency Switch

Primary

Secondary



**InPower™
Configurable Feature**

Alternate Frequency

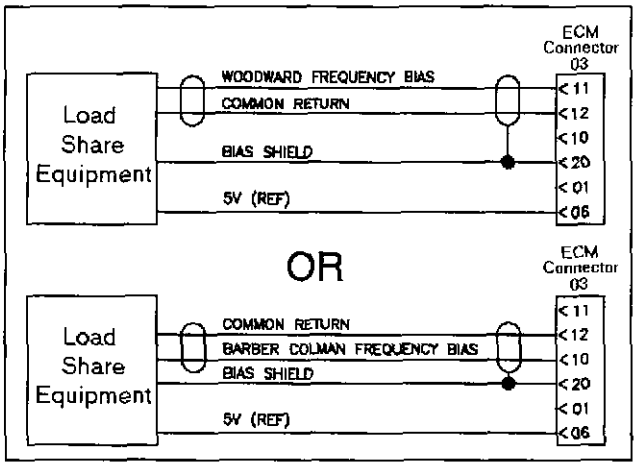
InPower™ Location:

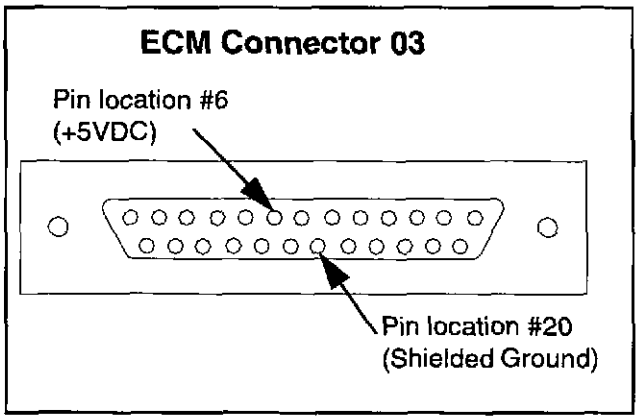
Adjustments

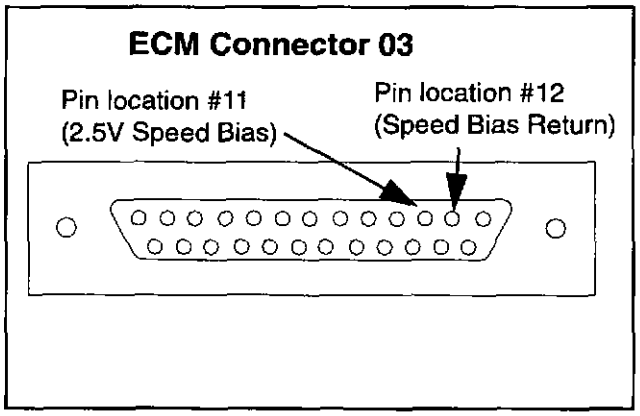
Governor

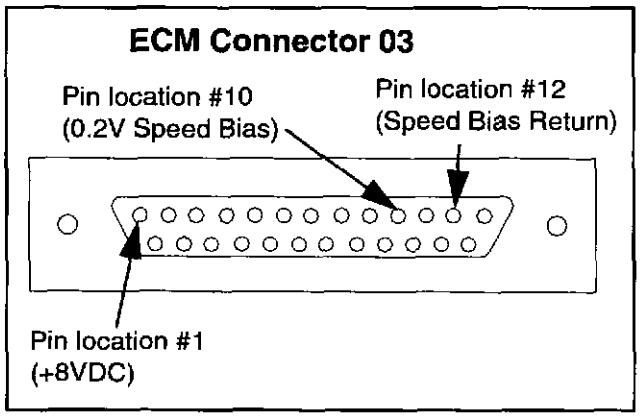
Frequency

Alternate Frequency Select









Load Sharing / Autosynchronization

The ECM provides two types of speed bias inputs making it compatible for use with off-the-shelf isochronous load share and synchronizing equipment (i.e. Woodward and Barber-Colman speed governing and load sharing controls).

NOTE: *The speed bias signal and the signal return conductors must be protected from EMI by a common shield. One end of the shield must be attached to GND and the other end must be left open-ended (not attached to GND). The open-end of the shield must terminate as close as possible to the connector of the interfacing device. To accommodate grounding the shield at the ECM end of the interface a shield ground is provided at ECM connector 03, pin 20. It is highly recommended that the shield be terminated at the ECM, which provides a common low impedance shield ground point.*

The ECM provides a +5VDC (±2%) supply voltage at pin 6 of connector 03. This supply voltage is to be used as the signal reference for both the ±2.5V and ±0.2V speed bias signals. The supply is rated to provide the specified voltage at $50mV_{p-p}$ max. ripple voltage, and 25mA max. current.

±2.5V Speed Bias

A ±2.5V speed bias signal input is provided for interfacing with Woodward and Woodward compatible speed governing and load share controls. The ±2.5V speed bias signal represents a full scale speed bias control range of ±3Hz.

The customer can implement this feature by supplying a speed bias signal to pin 11 of connector 03. Pin 12 of connector 03 is to be used as the speed bias signal return.

±0.2V Speed Bias

A ±0.2V signal input is provided for interfacing with Barber-Colman and Barber-Colman compatible speed governing and load share controls. The ±0.2V speed bias signal represents a full scale speed bias control range of ±7.38Hz.

The customer can implement this feature by supplying a speed bias signal to pin 10 of connector 03. Pin 12 of connector 03 is to be used as the speed bias signal return.

In addition to the +5VDC reference supply voltage, the ECM also provides a +8VDC (±5%) power supply at pin 1 of connector 03. This supply voltage is provided as a means to power the electronic circuits on analog load share equipment. The supply is rated to provide the specified voltage at $50mV_{p-p}$ max. ripple voltage, and 15 mA max. current.

Speed Bias Input Type

The type of speed bias input to be used is selected, using InPower™. This is accomplished by setting the *Frequency Bias Select* parameter to either "Barber Colman" or "Woodward", depending on which speed bias input is being used.

Once the type of speed bias input to be used is selected the speed bias input must be enabled, using InPower™, to make this feature operational. This is accomplished by setting either the *Barber Colman Frequency Bias Enable* parameter or *Woodward Frequency Bias Enable* parameter to "Enabled", depending on which speed bias input is being used.

> ***NOTE:*** *The Load Sharing / Autosynchronization feature will not operate unless the corresponding speed bias input is enabled, and the type of speed bias selected is the same as the speed bias input being used.*
>
> *If the speed bias input is not used, the* Frequency Bias Select *parameter should be set to "None".*

InPower™
Configurable Feature

Load Sharing / Autosynchronization

InPower™ Location:

Adjustments

Features

Inputs

Frequency Bias Select

Barber Colman Frequency Bias Enable

Woodward Frequency Bias Enable

Engine-Generator Sets in Parallel

Make necessary point-to-point connections as schematically shown in the Woodward and Barber-Colman wiring diagrams shown on the following pages.

Change the Speed Bias Input Type to the correct setting using InPower™. Refer to the ***Speed Bias Input Type*** section on page 60 for details about selecting the correct Speed Bias input type.

Barber-Colman DYNA II Analog ILS Generator Sets

(Refer to Barber-Colman Analog diagram on page 65)

DYNA II Auto-Synchronizer

The DYNA II Auto-Synchronizer (P/N DYN2 90200) can be used with the Cummins GCS and DYNA II Analog Isochronous Load Sharing Control to automatically synchronize one generator with another or with a bus. The Auto-Synchronizer eliminates the risk of operator error inherent with manual synchronizing.

The figure illustrates the wiring of two engine generator sets having Cummins GCS, DYNA II Analog Isochronous Load Sharing controls and DYNA II Auto-Synchronizers. Additional engine generator sets can be paralleled by wiring them at the point designated, PARALLELING LINES TO OTHER SYSTEMS.

NOTE: The Cummins GCS provides independent overspeed protection for each individual engine control system.

Note For Auto-Synchronizer

1. a. Closing a contact between 12 and 13 allows the Auto-Synchronizer to perform as a speed matching unit. The speed and phase of the incoming generator are controlled and a contact is closed to drive a circuit breaker. Once the circuit breaker is closed the contact between 12 and 13 should be opened. Another method would be to use the "Output Hold" dip switch, SW1, on the front of the unit.

   b. Open contacts or no jumper between 12 and 13 allows the Auto-Synchronizer to still sense any error, but it does not provide any control or contact closure.

2. Phasing of voltage potential to the Auto-Synchronizer is necessary to keep each signal in its correct phase relationship. If the generator voltage is not the same as the voltage rating of the Auto-Synchronizer, step-down transformers are required. The step-down transformers require a nominal 7 VA/PHASE for the Generator input and 2 VA/PHASE for the Bus input.

3. Connections to terminals 1-3 or 2-3 and 4-6 or 5-6 of the Auto Synchronizer must be the same voltage potential. Applying generator voltage without applying bus voltage may cause the engine to run faster or slower than the desired speed. However, when bus voltage is applied, the Auto-Synchronizer will change engine speed to quickly match the generator to the bus frequency.

Notes for Isochronous Load Sharing Module

4. Select the ILS current transformers to provide 2.5 to 5.0 amperes at full rated load. Current transformers require nominal 12.5 VA/PHASE at 5.0 amperes.

5. Step-down potential transformers require a nominal 6 VA/PHASE for the ILS.

6. Observe current and potential transformer markings when wiring system because it is necessary to keep each signal in its correct phase relationship to each other.

7. If the "load pulse" function is not being used, set the "load pulse" potentiometer fully counterclockwise.

8. The Droop-isochronous switch is not required if the system is always operated in the isochronous mode.

9. The GCS ECM has a built in adjustable ramp. **DO NOT** use the ramp built in the analog ILS.

10. When neither terminal 17 or 18 are wired externally, jumper terminal 18 to ILS terminal 15.

General System Notes

11. Run/Stop switch rating: 100 mA @ 24VDC.

12. System battery supply. If more than one engine is started using the same battery supply, use a separate battery supply for the governor system.

13. If each generator has a separate power supply, connect the negative of all power supplies together for a common reference.

14. Use shielded and twisted leads as shown.

15. Customer supplied ground/open signal for Run/Stop input is at ECM Connector 06, pin 5. The ground signal return for this input is at ECM Connector 06, pin 8.

16. To help avoid possible noise induced instabilities, it is recommended the customer use the customer supplied GCS ECM remote speed adjust pot feature and avoid utilizing a DYNA II Analog ILS remote speed selector rheostat.

17. Battery voltage B+ is applied to the ECM via the Cummins supplied connector Inline E, pin B. Battery ground is terminated at the ECM via the Cummins supplied connector Inline E, pin A.

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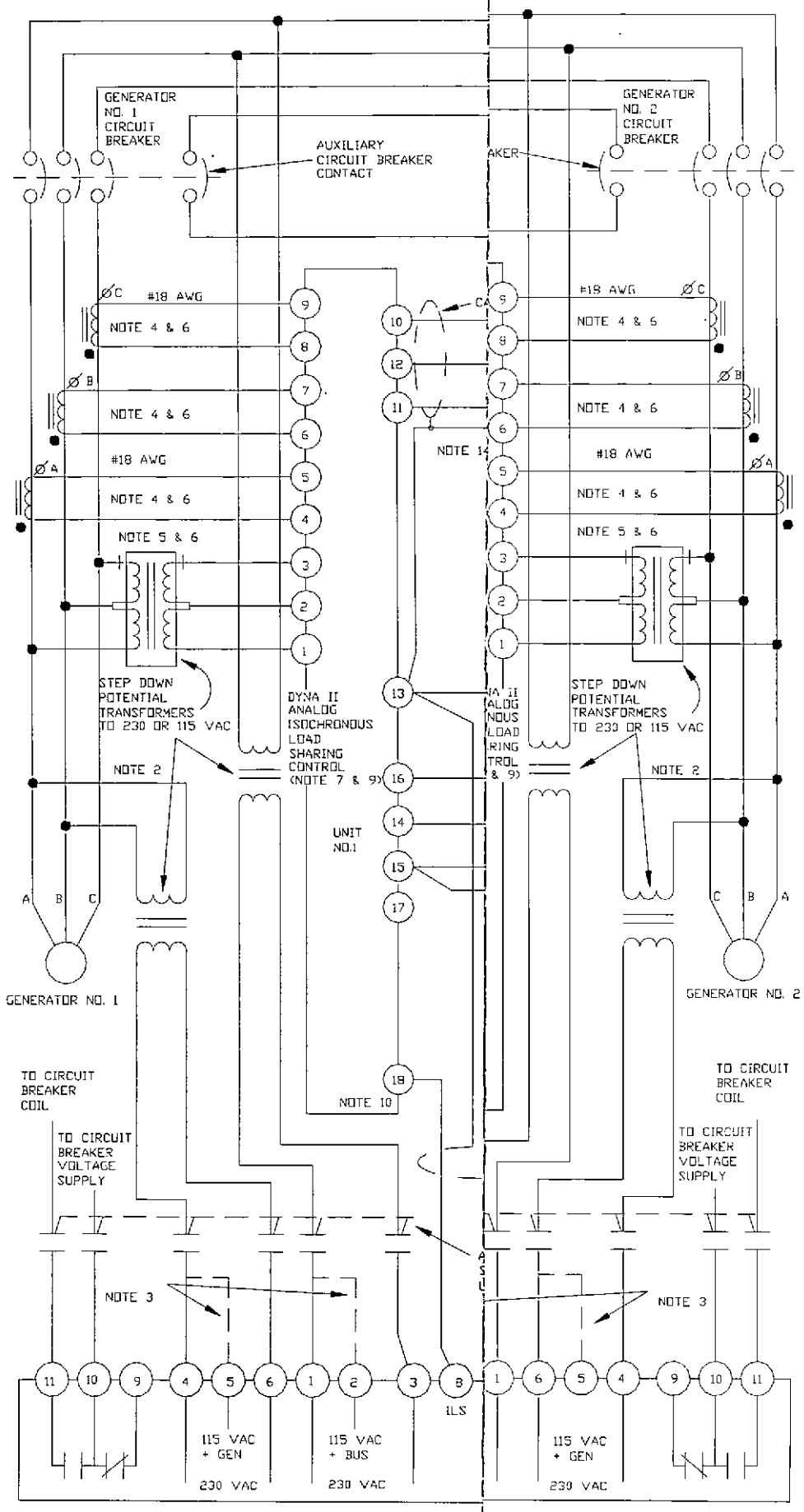

Barber-Colman Analog Wiring Diagram.

QSX15, QSK45, QSK 60 Generator Drive Control System

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Barber-Colman DYNA II Digital ILS Generator Sets

(Refer to Barber-Colman Digital Diagram on page 69)

DYNA II Auto-Synchronizer

The DYNA II Auto-Synchronizer (P/N DYN2 90200) can be used with the Cummins GCS and DYNA II Digital Isochronous Load Sharing Control to automatically synchronize one generator with another or with a bus. The Auto-Synchronizer eliminates the risk of operator error inherent with manual synchronizing.

The figure illustrates the wiring of two engine generator sets having Cummins GCS, DYNA II Digital Isochronous Load Sharing Controls, and DYNA II Auto-Synchronizers. Additional engine generator sets can be paralleled by wiring them at the point designated, PARALLELING LINES TO OTHER SYSTEMS.

NOTE: The Cummins GCS provides independent overspeed protection for each individual engine control system.

Notes For Auto-Synchronizer

1. a. Closing a contact between 12 and 13 allows the Auto-Synchronizer to perform as a speed matching unit. The speed and phase of the incoming generator are controlled and a contact is closed to drive a circuit breaker. Once the circuit breaker is closed the contact between 12 and 13 should be opened. Another method would be to use the "Output Hold" dip switch, SW1, on the front of the unit.

   b. Open contacts or no jumper between 12 and 13 allows the Auto-Synchronizer to still sense any error, but it does not provide any control or contact closure.

2. Phasing of voltage potential to the Auto-Synchronizer is necessary to keep each signal in its correct phase relationship. If the generator voltage is not the same as the voltage rating of the Auto-Synchronizer, step-down transformers are required. The step-down transformers require a nominal 7 VA/PHASE for the Generator input and 2 VA/PHASE for the Bus input.

3. Connections to terminals 1-3 or 2-3 and 4-6 or 5-6 of the Auto-Synchronizer must be the same voltage potential. Applying generator voltage without applying bus voltage may cause the engine to run faster or slower than the desired speed. However, when bus voltage is applied, the Auto-synchronizer will change engine speed to quickly match the generator to the bus frequency.

Notes For Isochronous Load Sharing Module

4. Select the ILS current transformers to provide 2.5 to 5.0 amperes at full rated load. Current transformers require nominal 12.5 VA/PHASE at 5.0 amperes.

5. Step-down potential transformers require a nominal 1 VA/PHASE for the ILS.

6. Observe current and potential transformer markings when wiring system because it is necessary to keep each signal in its correct phase relationship to each other.

7. If the "load pulse" function is not being used, set the "load pulse" potentiometer fully counterclockwise.

8. *Droop-isochronous switch is not required if the system is always operated in the isochronous mode.*

9. The GCS ECM has a built in adjustable ramp. **DO NOT** use the ramp built in the digital ILS.

10. When neither terminal 17 or 18 are wired externally, wire terminal 18 to ILS terminal 15.

General System Notes

11. Run/Stop switch rating: 100mA @ 24VDC.

12. System battery supply. If more than one engine is started using the same battery supply, use a separate battery supply for the governor system.

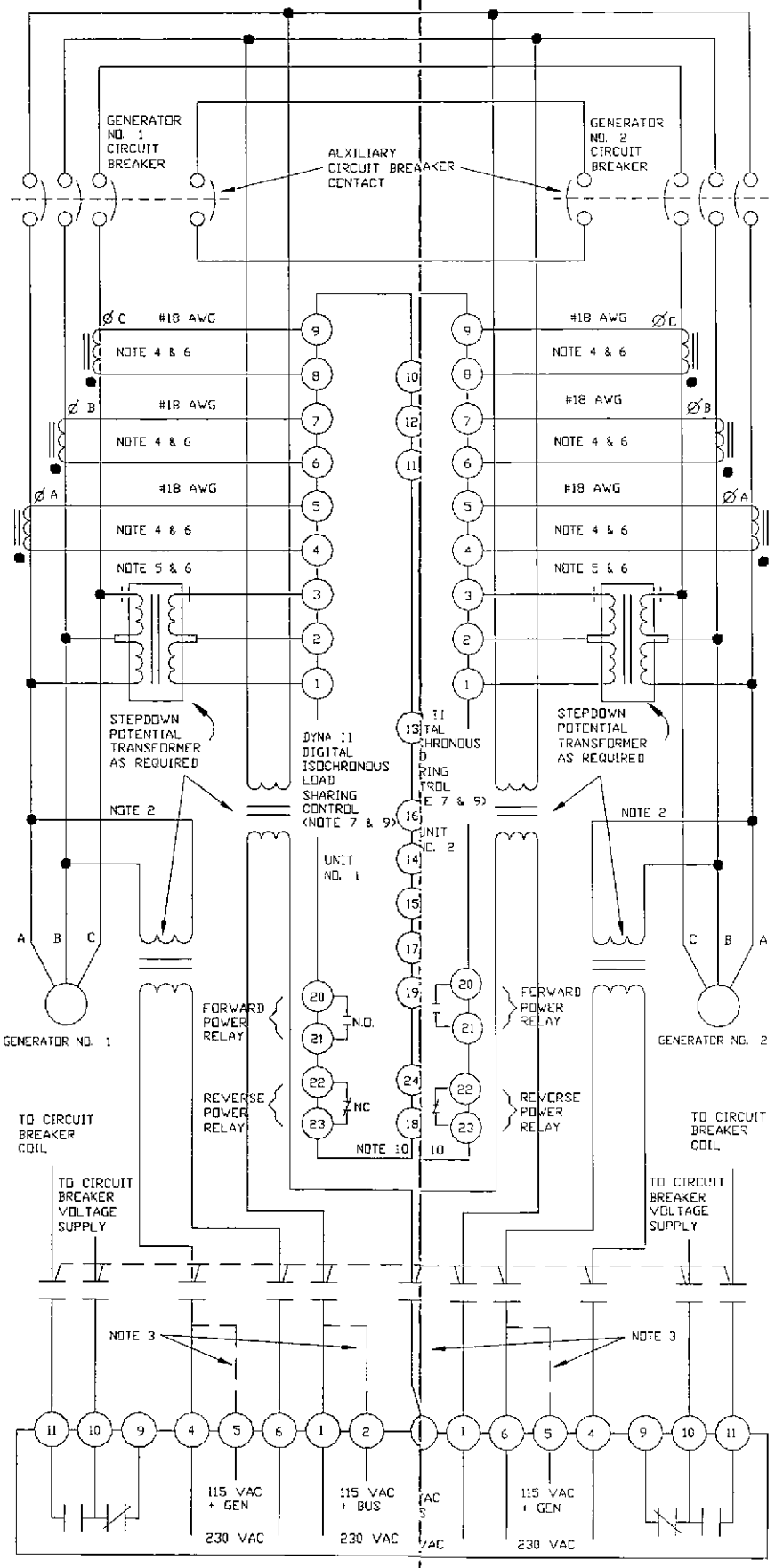
13. If each generator has a separate power supply, connect the negative of all power supplies together for a common reference.

14. Use shielded and twisted leads as shown.

15. Customer supplied ground/open signal for Run/Stop input is at ECM Connector 06, pin 5. The ground signal return for this input is at ECM Connector 06, pin 8.

16. To help avoid possible noise induced instabilities, it is recommended the customer use the customer supplied GCS ECM remote speed adjust pot feature and avoid utilizing a DYNA II Digital ILS remote speed selector rheostat.

17. Battery voltage B+ is applied to the ECM via the Cummins supplied connector Inline E, pin B. Battery ground is terminated at the ECM via the Cummins supplied connector Inline E, pin A.



Barber-Colman Digital Wiring Diagram.

QSX15, QSK45, QSK 60 Generator Drive Control System

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Woodward Analog SPM-A and AGLC Generator Sets

(Refer to Woodward Analog Diagram on page 73)

SPM-A Auto-Synchronizer

The SPM-A Auto-Synchronizer (P/N 9905-01) can be used with the Cummins GCS and the Analog Woodward Load Sensor Control to automatically synchronize one generator with another or with a bus. The SPM-A Synchronizer eliminates the risk of operator error inherent with manual synchronizing.

The figure illustrates the wiring of two engine generator sets having Cummins GCS, Load Sensor and AGLC load sharing controls and SPM-A auto-synchronizers. Additional engine generator sets can be paralleled by wiring them at the point designated, OTHER SYSTEM LOAD
SHARING LINES.

NOTE: The Cummins GCS provides independent overspeed protection for each individual engine control system.

Notes for SPM-A Auto-Synchronizer

1. If the generator or bus voltages are not the same as the rating of the bus or generator sensing inputs, step-down transformers are required.

   Bus sensing step-down transformers (input terminals 6 thruogh 9) must be rated at a minimum of 0.1 VA and generator sensing step-down transformers (input terminals 2 through 5) must be rated at a minimum of 16.3VA/PHASE.

   Jumpers shown are for 115 VAC input. Consult Woodward for 190 to 260 VAC operation.

   Applying generator voltage without applying bus voltage may cause the engine to run faster or slower than the desired speed. However, when bus voltage is applied, the SPM-A will change engine speed to quickly match the generator to the bus frequency.

   NOTE: Minimum generator sensing PT rating allows for power draw of SPM-A, AGLC and Generator Load Sensor.

2. Proper phasing of voltage potential to the bus and generator PT's and SPM-A bus and generator inputs is necessary to keep each signal in its correct phase relationship. Failure to ensure proper phasing could potentially result in out-of-synch paralleling and subsequent hardware damage.

3. Breaker close relay contacts rated at 10 amps resistive and 6 amps inductive at 28 VDC, 3 Amps resistive and 2 amps inductive at 115 VAC, and 1.5 amps resistive and 1.0 amps inductive at 230 VAC.

Notes for Load Sensor and Automatic Load Control (AGLC)

4. Select current transformers to produce 5.0 amperes secondary current at full rated load. Current transformers require at least 0.1VA/PHASE at 5.0 amperes.

5. Observe current transformer markings as it is necessary to keep each signal in its correct phase relationship to each other.

6. Jumper 17 to 18 and 19 to 20 on Load Sensor when potential input terminals 1 through 3 is 95 to 130 VAC phase-to-phase (50 - 400 Hz.). Consult Woodward for 190 to 260 VAC option.

7. Terminals 15 and 16 on Load Sensor shown with jumper for isochronous load sharing. Open terminals 15 and 16 for droop load sharing.

Notes for Load Sensor and Automatic Load Control (AGLC) (Continued)

8. Internal relay de-energizes to state shown when Unload Trip Level is reached on Unload to issue breaker open command. Breaker open relay contact ratings:

	Resistive	Inductive	Motor	Lamp
28VDC	10 Amp	6.0	3.0	1.0
115V, 400 Hz	5 Amp	2.5	3.0	0.8
115V, 60 Hz	3 Amp	2.0	1.5	0.5

9. Jumper 1 to 2 and 3 to 4 on AGLC for potential inputs of 105 to 132 VAC phase-to-phase. Consult Woodward for 210 to 264 VAC option.

General System Notes

10. Run/Stop switch rating: 100mA @ 24VDC.

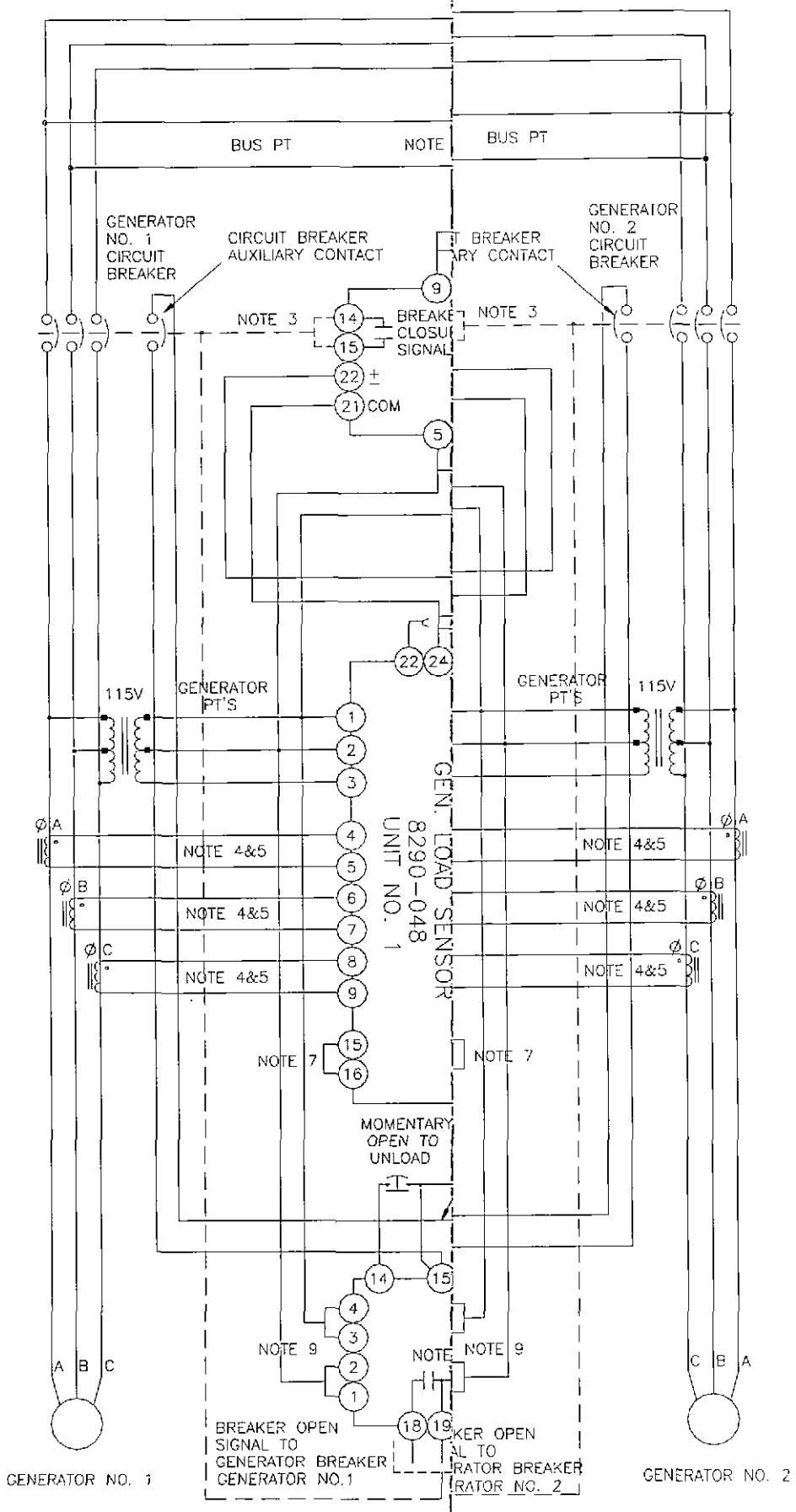
11. System battery supply. If more than one engine is started using the same battery supply, use a separate battery supply for the governor system.

12. If each generator has a separate power supply, connect the negative of all power supplies together for a common reference.

13. Use shielded and twisted leads as shown.

14. Customer supplied ground/open signal for Run/Stop input is at ECM Connector 06, pin 5. The ground signal return for this input is at ECM Connector 06, pin 8.

15. Battery voltage B+ is applied to the ECM via the Cummins supplied connector Inline E, pin B. Battery ground is terminated at the ECM via the Cummins supplied connector Inline E, pin A.



Woodward Analog Wiring Diagram.

QSX15, QSK45, QSK 60 Generator Drive Control System

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Woodward Digital DSLC Generator Sets

(Refer to Woodward Digital Diagram on page 77)

DSLC (Digital Synchronizer and Load Control)

The Woodward DSLC Synchronizer and Load Controller can be used with the Cummins GCS to automatically synchronize one generator with another or with a bus. The DSLC eliminates the risk of operator error inherent with manual synchronizing. In addition to synchronizing, the DSLC provides load sensing, automatic generator loading / unloading along with isochronous load sharing.

The figure illustrates the wiring of two engine generator sets having Cummins GCS and DSLC Synchronizer and Load Controllers. Additional engine generator sets can be paralleled by wiring them at the point designated, LONWORKS NETWORK TO ALL DIGITAL GENERATOR CONTROLS. The diagram as drawn shows a 120 VAC Wye configuration. Other potential configurations are 240 VAC Wye, 120 VAC and 240 VAC Open Delta configurations. You should consult pertinent Woodward technical manuals for the proper wiring in the case of these other configurations.

NOTE: The Cummins GCS provides independent overspeed protection for each individual engine control system.

Notes for DSLC

1. If the generator voltage is not the same as the rating of the bus or generator voltage sensing inputs (65 - 150 VAC, 45 - 66 Hz.), step-down transformers are required. Bus or generator step-down transformers require at least 0.1 VA/PHASE. Applying generator voltage without applying bus voltage may cause the engine to run faster or slower than the desired speed. However, when bus voltage is applied, the DSLC will change engine speed to quickly match the generator to the bus frequency.

2. Proper phasing of voltage potential to the bus and generator PT's and DSLC bus and generator inputs is necessary to keep each signal in its correct phase relationship. Failure to ensure proper phasing could potentially result in out-of-synch paralleling and subsequent hardware damage.

3. Select current transformers to produce 5.0 amperes secondary current at full rated load. Current transformers require at least .01 VA/PHASE at 5.0 amperes.

4. Observe current transformer markings as it is necessary to keep each signal in its correct phase relationship to each other.

5. Breaker close and open functions may require customer supplied relay. DSLC relay drivers are rated at 18-40 VDC, 200 mA.

6. Required DSLC power supply input is 18 to 40 VDC continuous.

7. Termination jumpers (terminals 41 and 42) are required on units located on each end of LonWorks network.

8. Properly ground the DSLC chassis for proper safety and shielding (Woodward DSLC chassis provides for case grounding stud).

General System Notes

9. Run/Stop switch rating: 100mA @ 24VDC.

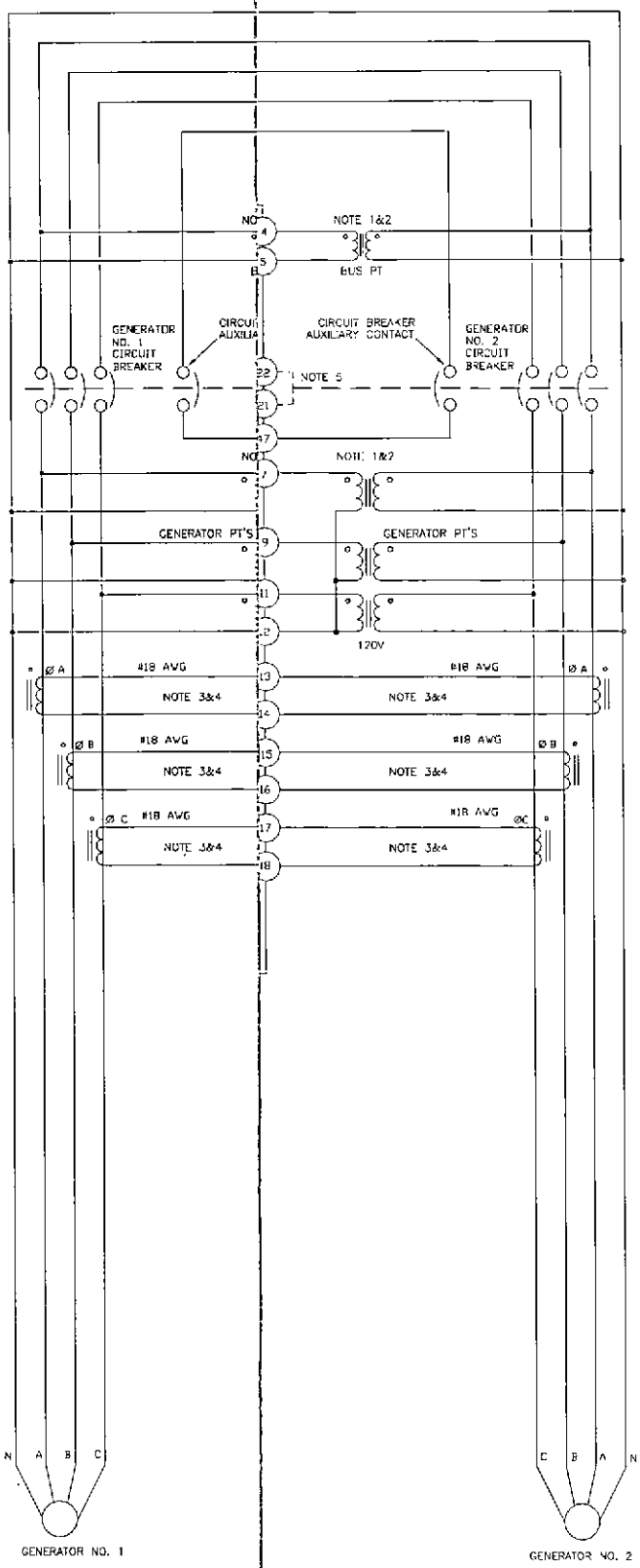
10. System battery supply. If more than one engine is started using the same battery supply, use a separate battery supply for the governor system.

11. If each generator has a separate power supply, connect the negative of all power supplies together for a common reference.

12. Use shielded and twisted leads as shown.

13. Customer supplied ground/open signal for Run/Stop input is at ECM Connector 06, pin 5. The ground signal return for this input is at ECM Connector 06, pin 8.

14. Battery voltage B+ is applied to the ECM via the Cummins supplied connector Inline E, pin B. Battery ground is terminated at the ECM via the Cummins supplied connector Inline E, pin A.



Woodward Digital Wiring Diagram.

QSX15, QSK45, QSK 60 Generator Drive Control System

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InPower™ Configurable Feature

Engine Protection

InPower™ Location:

Adjustments

Engine Protection Adjustments

- ***Engine Cold Warning Threshold***
- ***LOP Warning Threshold Table***
- ***LOP Shutdown Threshold Table***
- ***HOT Warning Threshold ****
- ***HOT Shutdown Threshold ****
- ***LCL Warning Threshold***
- ***LCL Shutdown Threshold***
- ***LCP Warning Threshold Table *****
- ***LCP Shutdown Threshold Table *****
- ***LCT Warning Threshold***
- ***HCT Shutdown Threshold***
- ***HCT Shutdown Threshold***
- ***HBF Warning Threshold Table *****
- ***HBF Shutdown Threshold Table *****
- ***HFT Warning Threshold *****
- ***HFT Shutdown Threshold *****
- ***HAT Warning Threshold *****
- ***HAT Shutdown Threshold *****
- ***IMT Warning Threshold***
- ***IMT Shutdown Threshold***
- ***Overspeed Shutdown Threshold***

Engine Protection

The engine protections shown to the left are user configurable, within pre-programmed limits, using InPower™. The InPower™ software will not allow settings outside the *minimum* and *maximum* ranges established for your engine.

QSX15 Only:

The engine protections designated with a single asterisk (*) are only available on the QSX15 model engines.

QSK45 and QSK60 Only:

The engine protections designated with a double asterisk (**) are only available on the QSK45 and QSK60 model engines.

Abbreviations:

LOP	**Low Oil Pressure**
HOT*	**High Oil Temperature**
LCL	**Low Coolant Level**
LCP**	**Low Coolant Pressure**
LCT	**Low Coolant Temperature**
HCT	**High Coolant Temperature**
HBF**	**High Blowby FLow**
HFT**	**High Fuel Temperature**
HAT**	**High Aftercooler Water Temperature**
LCT	**Low Coolant Temperature**
IMT	**Intake Manifold Temperature**

NOTE: *When the engine coolant temperature is less than the LCT Warning Threshold* ***when the engine is running****, a Common Warning will be activated to signal that a Low Coolant Temperature condition exists.*

The Engine Cold Warning Threshold is intended for use when block heaters are installed. When the engine coolant temperature is less than the Engine Cold Warning Threshold ***prior to starting the engine****, a Common Warning will be activated to signal that an Engine Cold Warning condition exists.*

Setting the Engine Cold Warning Threshold at too high a level can cause nuisance Engine Cold Warning faults. The customer is responsible for properly setting the Engine Cold Warning Threshold at the proper level, dependent upon whether block heaters are being used, or are not used.

The switch for the Low Coolant Level (LCL) engine protection is mandatory and must be installed. A customer option for this switch is available from Cummins for use with these engines. See the Cummins G-Drive Sales Handbook or contact your local Cummins distributor for further details and ordering information. Also, see the ***Miscellaneous Application Requirements and Information*** section on page 101 for further details about the Coolant Level switch.

InPower™ Configurable Feature

Shutdown Override

The ECM can be configured to allow continued engine operation while most shutdown faults are active. Even when enabled, the Shutdown Override feature does not allow engine operation while overspeed or loss of engine speed faults are active, or while the ECM detects that the Local E-Stop, Remote E-Stop, or Backup Start Disconnect switches are in an "open" state. All other shutdown faults are overridden when this feature is enabled.

The Shutdown Override feature is enabled using the Cummins InPower™ electronic service tool. This is accomplished by setting the *Shutdown Override Enable* parameter to "Enabled".

Shutdown Override

InPower™ Location:

Adjustments

Features

Shutdown Override

Shutdown Override Enable

⚠ WARNING ⚠

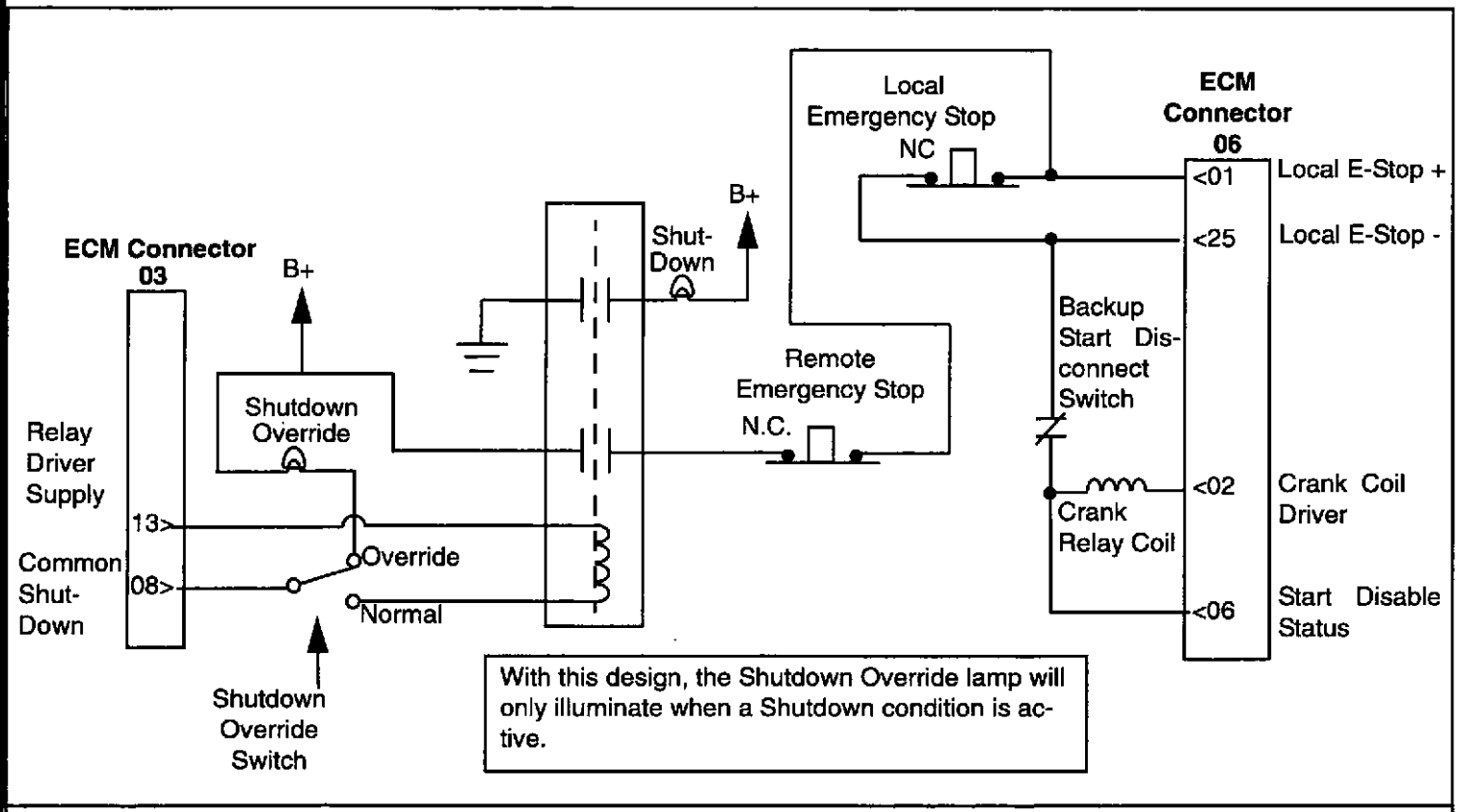
The Shutdown Override feature prevents the ECM from shutting down the engine, even when engine-damaging conditions are present. Damage done to the engine or the GCS while in Shutdown Override mode is ***NOT*** *covered by the engine warranty.*

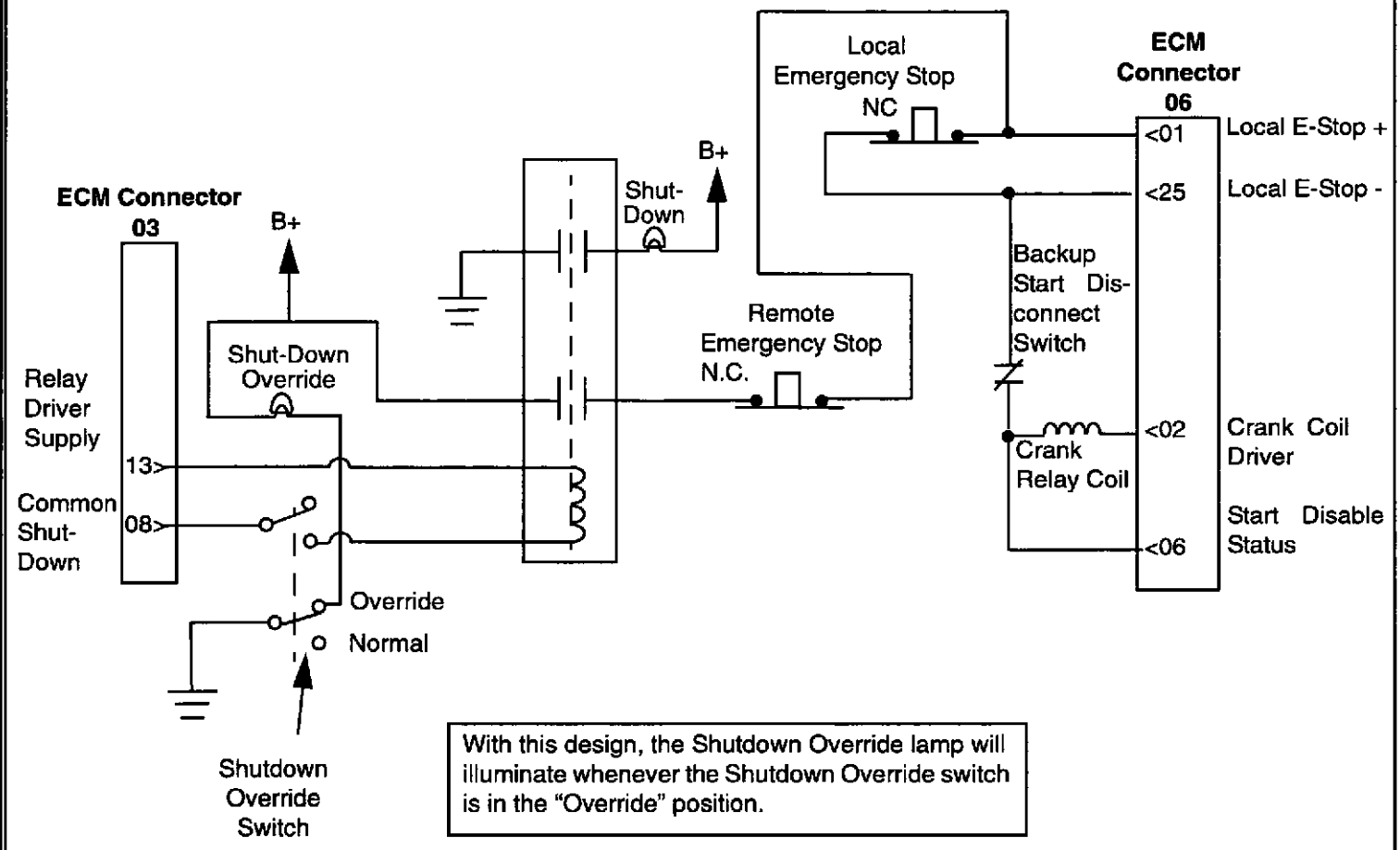
This feature should only be used in applications where engine damage is an acceptable trade-off for keeping the engine running.

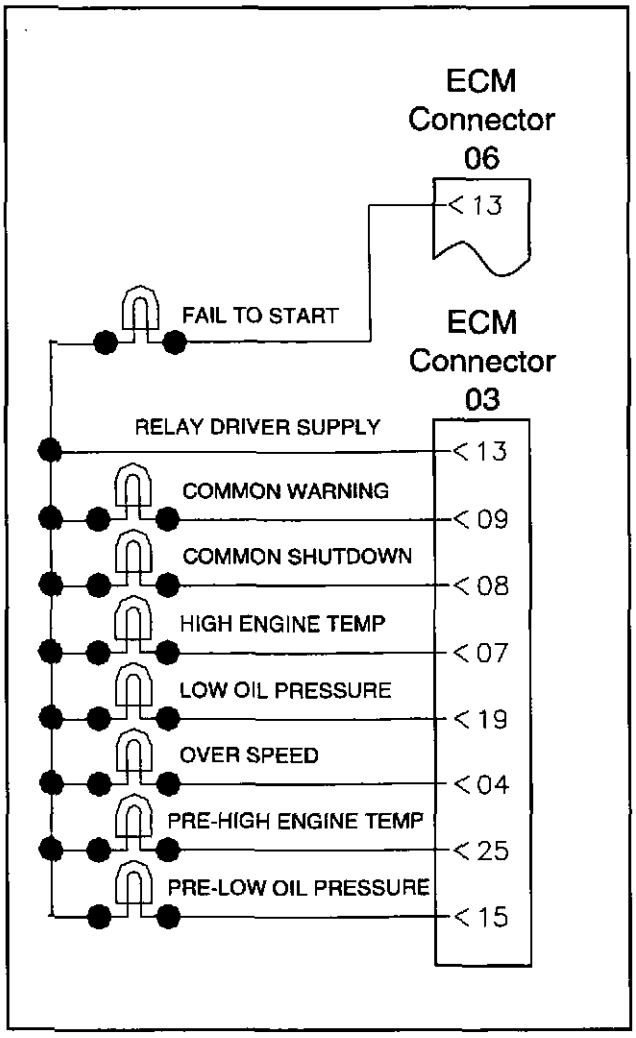
NEVER *use this feature to disable "nuisance" alarms. All alarms are to be treated as real until the root-cause is determined.*

An external switch can also be used to implement the shutdown override feature. The schematic diagrams on page 82 describe two different means to implement the external shutdown override control.

NOTE: *In order for the external Shutdown Override to operate, the Shutdown Override Enable parameter must be set to "Enabled" using InPower™.*


Local
Emergency Stop
NC
ECM
Connector
06
<01
Local E-Stop +
<25
Local E-Stop -
B+
ECM Connector
03
B+
Shut-
Down
Backup
Start Dis-
connect
Switch
Remote
Emergency Stop
N.C.
Shutdown
Override
Relay
Driver
Supply
13>
<02
Crank Coil
Driver
Crank
Relay Coil
Common
Shut-
Down
08>
Override
<06
Start Disable
Status
Normal
Shutdown
Override
Switch
With this design, the Shutdown Override lamp will only illuminate when a Shutdown condition is active.


Local
Emergency Stop
NC
ECM
Connector
06
<01
Local E-Stop +
<25
Local E-Stop -
B+
ECM Connector
03
B+
Shut-
Down
Backup
Start Dis-
connect
Switch
Remote
Emergency Stop
N.C.
Shut-Down
Override
Relay
Driver
Supply
13>
<02
Crank Coil
Driver
Crank
Relay Coil
Common
Shut-
Down
08>
Start Disable
Status
<06
Override
Normal
Shutdown
Override
Switch
With this design, the Shutdown Override lamp will illuminate whenever the Shutdown Override switch is in the "Override" position.



Alarm Lamp/Relay Drivers

Eight (8) output drivers are provided to annunciate that specific engine protection alarm conditions have occurred. Each output can be used to drive either a lamp or a relay. The following alarm drivers are provided:

Engine Shutdown Alarms

Drivers are provided for annunciating three Engine Shutdown Alarms for the following conditions:

- High Engine Temperature (HET)
- Low Oil Pressure (LOP)
- Overspeed (OS)

A condition that causes an HET, LOP or OS Engine Shutdown Alarm will activate the relay or lamp connected to the respective lamp/relay driver output.

Common Shutdown Alarm

A driver is provided for annunciating a Common Shutdown Alarm. The Common Shutdown Alarm activates when:

- Any Engine Shutdown Alarm condition is active
- The Local or Remote Emergency Stop Input is activated (either or both of these switches is "open")

Engine Warning Alarms

Drivers are provided for annunciating three Engine Shutdown Alarms for the following conditions:

- Pre-High Engine Temperature (HET)
- Pre-Low Oil Pressure (LOP)
- Fail-to-Start

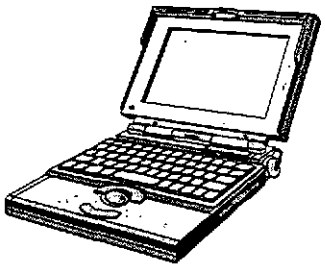
A condition that causes a Pre-HET or Pre-LOP Engine Warning Alarm will activate the relay or lamp connected to the respective lamp/relay driver output. The Fail-to-Start output activates when the engine fails to start after the number of start attempts configured using the Cycle/Continuous Cranking feature have expired without successfully starting the engine. See the ***Cycle/Continuous Cranking*** section on page 47 for further details.

Common Warning Alarm

A driver is provided for annunciating a Common Warning Alarm. The Common Warning Alarm activates when any Engine Warning Alarm condition is active.

Each lamp/relay driver is rated to handle a maximum continuous voltage equivalent to Battery (+) and 200mA maximum continuous sink current.

InPower™
User Configurable Feature



Alarm Lamp/Relay Driver Diagnostics

InPower™ Location:

Adjustments

Features

Relay Drivers

Relay Driver Supply Diagnostic Enable

Fail to Start Driver Diagnostic Enable

Common Warning Driver Diagnostic Enable

Common Shutdown Driver Diagnostic Enable

HET Driver Diagnostic Enable

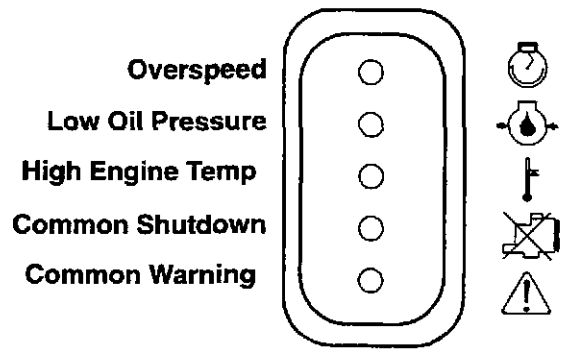
LOP Driver Diagnostic Enable

Overspeed Driver Diagnostic Enable

Pre-HET Driver Diagnostic Enable

Pre-LOP Driver Diagnostic Enable

Diagnostic LED Display Window
(located on the side of the ECM)



The lamp/relay driver outputs are implemented by making the appropriate connections to ECM connector 03, except for the Fail-to-Start driver output, which is at ECM connector 06.

The Relay Driver Supply voltage is supplied by the ECM at pin 13 of ECM connector 03.

The lamp/relay drivers and driver supply voltage diagnostics must be enabled in order for the ECM to properly diagnose and report any lamp/relay driver faults. This is accomplished by setting the corresponding driver, or the driver supply, diagnostic parameters to "Enabled" using InPower™.

NOTE: *The ECM lamp/relay driver diagnostics are capable of detecting an open or short circuit condition. In order for the open circuit diagnostic to properly function, the lamp/relay load must draw between 2 to 200 mA current at +24 VDC. A load drawing less than 2mA will be diagnosed and reported as a driver open circuit fault. If any lamp or relay driver load draws less than 2mA, the respective driver diagnostic should be disabled to prevent nuisance open circuit faults from being reported.*

Fault Diagnostics

The following information is not intended to take the place of similar information provided in the engine Troubleshooting and Repair Manual (Cummins Bulletin No. 3666393). If there are discrepancies between the information in this manual and the information in the Troubleshooting and Repair Manual, the Troubleshooting and Repair Manual takes precedence.

Diagnostic LEDs

There are five diagnostic LEDs located on the side of the ECM that are visible through the display window. Following is a description of the condition being reported when the respective LED is illuminated:

Overspeed - this red LED indicates that an overspeed shutdown fault has occurred.

Low Oil Pressure - this red LED indicates that an engine Low Oil Pressure shutdown fault has occurred.

High Engine Temperature - this red LED indicates that a High Coolant Temperature or a High Intake Manifold Temperature shutdown fault has occurred.

Common Shutdown - this red LED indicates that a shutdown fault, other than those identified above, has occurred.

Common Warning - This yellow LED indicates that a warning fault has occurred.

Service Tool Interface

A 9-pin circular connector is accessible on the Engine Harness to provide a means of connecting the PC to the ECM so that the InPower™ electronic service tool can be used. Refer to the QSX15, QSK45, QSK60 Generator-Drive Control System Troubleshooting and Repair Manual (Cummins Bulletin No. 3666393) for further details.

Fault Codes

The ECM can record and report certain detectable diagnostic conditions. These conditions are recorded as fault codes, which can be used to assist in troubleshooting engine and control system failures. Refer to the QSX15, QSK45, QSK60 Generator-Drive Control System Troubleshooting and Repair Manual (Cummins Bulletin No. 3666393) for further details.

Fault codes recorded in the ECM memory can be accessed in three different ways:

- Diagnostic Mode (Fault Flash Out)
- Cummins InPower™ Electronic Service Tool
- Modbus Communications Datalink

Diagnostic Mode

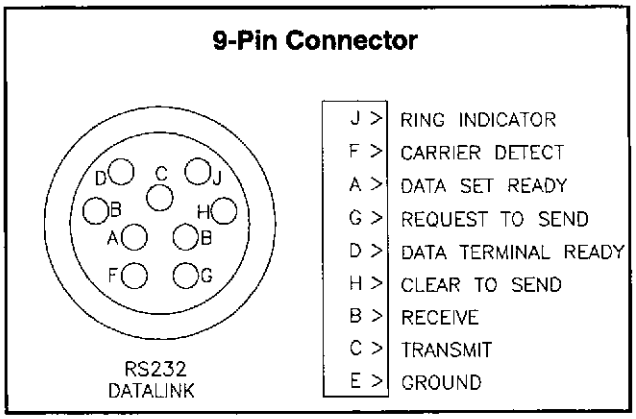
A Diagnostic Mode input is provided to allow a means of placing the ECM into the diagnostic mode. When the ECM is in the diagnostic mode, fault codes are visually displayed, or "flashed out", using the Common Warning and Common Shutdown LEDs on the ECM. See the ***Fault Flash Out*** section on page 87 for further details.

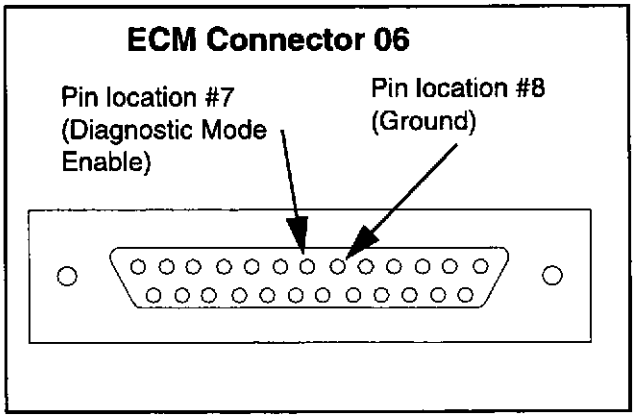
To implement this feature, the customer supplies a bi-state signal, or switch, to pin 7 of ECM connector 06. Pin 8 of ECM connector 06 is used to provide an electrical signal path to GND through the ECM.

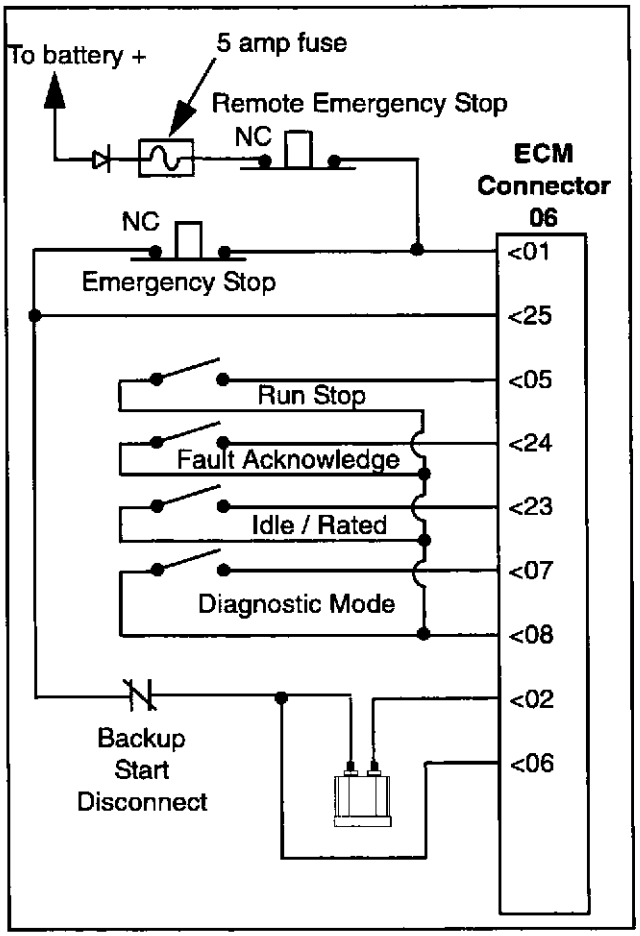
When the switch is set in the position that connects GND to the Diagnostic Mode input, the input is in the "Fault Flash Out Enabled" state (GND = Fault Flash Out Enabled).

When the switch is set in the position that opens the circuit connection, disconnecting GND from the Diagnostic Mode input, the input is in the "Fault Flash Out Inhibited" state (Open = Fault Flash Out Inhibited).

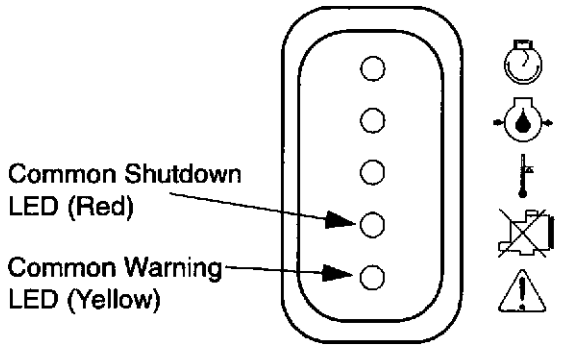
The diagnostic mode can also be enabled by removing the protective covers from the Diagnostic Mode Enable connectors on the Engine Harness, and plugging the two connectors together (the Diagnostic Mode Enable connectors are opposite genders).







Diagnostic LED Display Window
(located on the side of the ECM)



Once the diagnostic mode has been enabled, the Common Warning LED will flash once signifying the start of a new fault code, and then the fault code will flash out on the Common Shutdown LED. See the ***Fault Flash Out*** section on page 87 for further details.

> ***NOTE:*** *The Run/Stop input must be set to the "Stop" state in order to enter the Diagnostic Mode. If the Run/Stop input state changes to "Run" while the ECM is in the Diagnostic Mode, the ECM will immediately exit Diagnostic Mode and any fault flash out in process will terminate.*

InPower™
User Configurable Feature

The Cummins InPower™ electronic service tool can also be used to read the fault codes. Refer to the InPower™ for Generator-Drive Control System Manual (Cummins Bulletin No. 3397100) for detailed instructions on how to use InPower™ to read fault codes.

A third means of reading the fault codes is available via the Modbus communications datalink. See the ***Modbus Communications Datalink*** section on page 97 for further details.

GCS Faults

InPower™ Location:

Faults

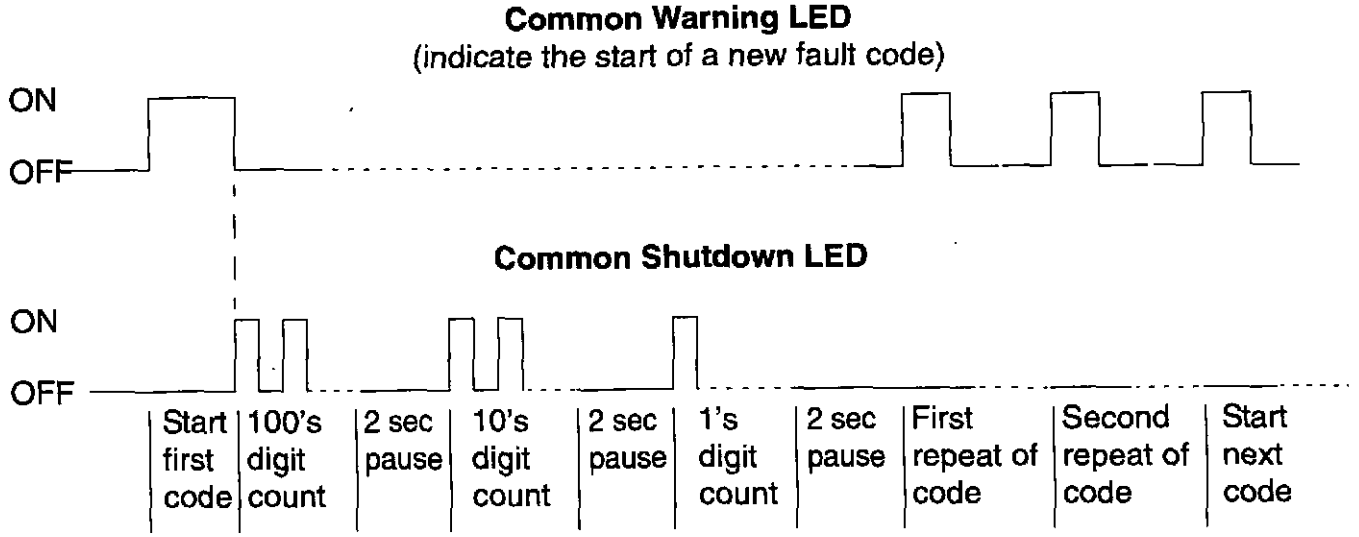
Fault Flash Out

When the ECM is in Diagnostic Mode, the Common Shutdown and Common Warning LEDs are used to display the fault codes of the currently active shutdown and warning faults.

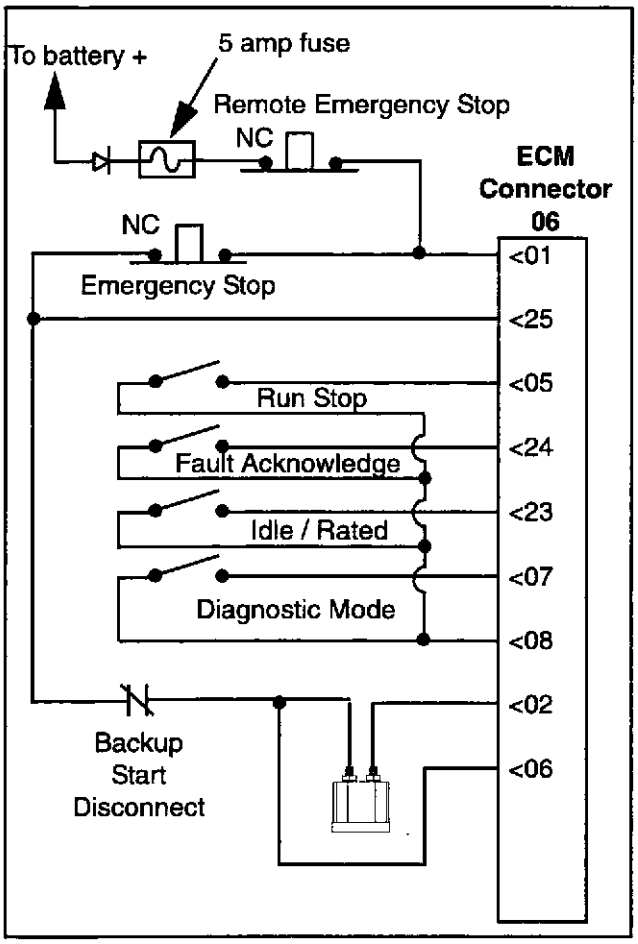
These active fault codes are flashed out in the following method:

1. The first active fault code is flashed out 3 times consecutively.
2. If there is more than one active fault code, the process advances to the next fault and flashes out its code 3 times and so forth until all of the active faults have been displayed.
3. If the Fault Flashout mode is still active after all faults have been displayed, the process starts over again with the first active fault.
4. This cyclical display of active faults continues while Diagnostic Mode is active.

Following is a graphic depiction of the fault code flash out sequence for a 3-digit fault code:



The above example shows the LED flash-out sequence for reporting fault code 221.



InPower™
User Configurable Feature

Fault Acknowledge

InPower™ Location:

Monitor

Control

Starting / Stopping

Fault Acknowledge Command

Fault Acknowledge

A Fault Acknowledge input is provided to allow a means of acknowledging the Common Warning and Common Shutdown lamp/relay driver outputs and Common Warning and Common Shutdown Diagnostic LED's that activate due to a fault condition. This feature is also used to acknowledge a shutdown condition and allow a re-start of the engine after it has shutdown due to an Emergency Shutdown condition.

To implement this feature, the customer supplies a normally open momentary bi-state signal, or switch, connection to pin 24 of ECM connector 06. Pin 8 of ECM connector 06 is used to supply an electrical signal path to GND through the ECM.

When the switch is actuated, momentarily connecting GND to the Fault Acknowledge input, the ECM will extinguish the indication of warning and shutdown conditions being displayed by the lamp/relay drivers and the diagnostic LED's (GND = Acknowledge, Open = Not Acknowledge).

> ***NOTE:*** *The Warning (Pre-Alarm) indications can be acknowledged when the engine is stopped or while the engine is still running. The Shutdown (Alarm) indications can only be acknowledged when the engine is stopped and the Run/Stop switch is in the "Stop" state.*
>
> *When a shutdown alarm condition is recognized by the ECM, the user must acknowledge this alarm before the engine can be re-started.*
>
> *Activation of the Fault Acknowledge input does not clear fault codes. The Cummins InPower™ Electronic Service Tool must be used to clear fault codes. Refer to the QSX15, QSK45, QSK60 Generator-Drive Control System Troubleshooting and Repair Manual (Cummins Bulletin No. 3666393) for details.*

The Fault Acknowledge feature can also be activated electronically using InPower™. This is accomplished by setting the *Fault Acknowledge Command* parameter to "Acknowledge". The ECM will automatically reset this parameter to "Not Acknowledge" after it has been activated.

NOTE: *Either the electronic trim, the switch input, or the MODBUS Fault Acknowledge bit can be used to acknowledge fault conditions. See the Modbus Communications Datalink section on page 97 for further information about the MODBUS communications datalink and the MODBUS Fault Acknowledge bit parameter.*

The Fault Acknowledge Command *parameter defaults to "Not Acknowledge" on ECM power-up.*

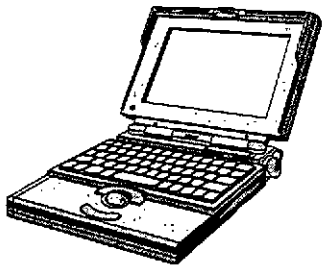
Snapshot Data

Snapshot data allows the relationship between the fault condition and the state of the ECM inputs and outputs, at the time the condition occurred, to be captured and viewed to assist in troubleshooting. When a fault code is recorded in the ECM, a "snapshot" of data is also recorded by the ECM.

The snapshot data is read using the Cummins InPower™ electronic service tool. Refer to the InPower™ for Generator-Drive Control System Manual (Cummins Bulletin No. 3397100) for detailed instructions on how to use InPower™ to read snapshot data.

NOTE: *To prevent loss of valuable diagnostic information, such as Fault Codes and Snapshot Data, power must be available to the ECM at all times during normal engine operation and for at least one minute following an engine shutdown.*

InPower™
Configurable Feature



Built-In Test

InPower™ Location:

Test

Self Test

Built In Test Command

System Check-Out / Test

Built-In Test

The following Built-In Tests are provided for the purpose of checking specific ECM electronic features:

- Lamp/Relay Driver Start-Up Test
- Stationary Test
- Cranking Test

The Lamp/Relay Driver Start-Up Test is automatically performed whenever the engine is started. It is also the first test conducted in the sequence of tests performed during the Stationary and Cranking Tests. The Stationary and Cranking Tests are initiated using InPower™ . This is accomplished by setting the *Built In Test Command* toggle parameter to the desired state, either "Test-Stationary" or "Test-Cranking".

When the Stationary Test is initiated the Outputs Test and Fuel Shut-Off Test, as described on page 91, will be performed sequentially.

When the Cranking Test is initiated the Outputs Test, Fuel Shut-Off Test, and Starter Test, as described on page 91, will be performed sequentially.

The Stationary or Cranking Tests can be aborted at any moment when commanded to do so using the Cummins InPower™ electronic service tool. This is accomplished by setting the *Built In Test Command* toggle parameter to "Test-Abort". The *Built In Test Command* toggle parameter will automatically reset to "Test-Abort" once the Stationary or Cranking Test is completed.

While conducting each test, the standard ECM diagnostic routines are performed. If any faults are detected during this time, the faults are recorded and reported using the means described in the ***Fault Diagnostics*** section on page 84.

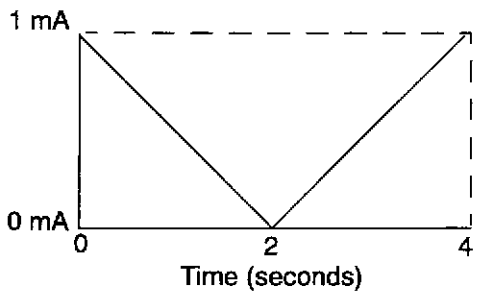
Lamp/Relay Driver Start-Up Test

The Lamp/Relay Driver supply voltage at connector 03 is normally on when the ECM is powered. During engine start-up the ECM will turn this supply voltage off for a 1.5 second interval as a means of testing the lamps/relays driven by the supply. Any Lamp/Relay Driver output that is active during this test will extinguish/de-energize during the 1.5 second test duration.

Outputs Test

During the Outputs test all meter drivers, lamp/relay drivers and diagnostic LEDs will be exercised. The meter driver output test will respond according to the Analog Output Test Profile shown to the right. The Lamp/Relay drivers and LEDs will respond according to the Discrete Output Test Profile shown to the right. Note that the Outputs Test for the lamps/relay drivers and the LEDs are performed first, followed by the meter drivers test.

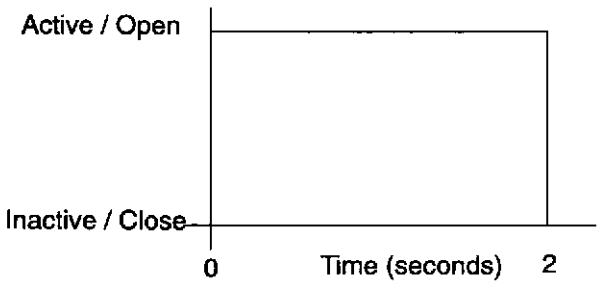
Analog Output Test Profile



Fuel Shut-Off Test

Immediately following the Output Tests, the Fuel Shut-Off Test will be initiated. During this test, the FSO driver will respond according to the Discrete Output Test Profile shown to the right. Also, the fueling actuators are de-energized while this test is being conducted.

Discrete Output Test Profile



Starter Test

The Starter Test will be performed immediately following the Fuel Shut-Off Test, only when the Cranking Test is being performed. For this test, the Crank Relay driver output will respond to the Discrete Output Test Profile shown to the right.

⚠ WARNING ⚠

The Starter Test will cause the engine to crank for 2 seconds, although the engine will not start. All barring devices should be removed from the engine and personnel should be a safe distance away from the engine prior to initiating the Starter Test.

InPower™ Configurable Feature

Additional Test Capabilities

The GCS provides the following additional test capabilities. These test functions are set-up using InPower™.

> ***NOTE:*** *These tests require that the normal input/output signal levels be manually overriden by the user.*
>
> *Once testing is complete, be certain that all override enables are set back to "Disabled" to ensure that the ECM is using the actual engine sensor signals and controlling the meter and lamp/relay drivers to the actual output level/ state.*
>
> *Override enables will default back to "Disabled" when the ECM is powered off and back on.*

Meter Drivers Test

InPower™ Location:

Test
- Outputs
  - Meter Drivers
    - Coolant Temp
      - ***Coolant Temp Meter Override***
      - ***Coolant Temp Meter Override Enable***
    - Engine Speed
      - ***Engine Speed Meter Override***
      - ***Engine Speed Meter Override Enable***
    - Oil Pressure
      - ***Oil Pressure Meter Override***
      - ***Oil Pressure Meter Override Enable***

Meter Drivers

The normal analog meter driver outputs can be overriden to command a specified test output level. This is accomplished by setting the respective meter override enable command to "Enabled" and setting the override value to the desired meter output driver current.

Lamp/Relay Drivers

The state of each Alarm Lamp/Relay Driver output can be overriden individually. This is accomplished by setting the respective driver override enable command to "Enabled" and setting the override value to the desired driver output state.

Lamp/Relay Drivers Test

InPower™ Location:

Test
- Outputs
  - Relay Drivers
    - Common Shutdown
      - ***Common Shutdown Driver Override Command***
      - ***Common Shutdown Driver Override Enable***
    - Common Warning
      - ***Common Warning Driver Override Command***
      - ***Common Warning Driver Override Enable***
    - Fail to Start
      - ***Fail to Start Driver Override Command***
      - ***Fail to Start Driver Override Enable***
    - HET Shutdown
      - ***HET Driver/LED Override Command***
      - ***HET Driver/LED Override Enable***
    - LOP Shutdown
      - ***LOP Driver /LED Override Command***
      - ***LOP Driver/LED Override Enable***
    - Overspeed
      - ***Overspeed Driver/LED Override Command***
      - ***Overspeed Driver/LED Override Enable***
    - Pre-HET Warning
      - ***Pre-HET Driver Override Command***
      - ***Pre-HET Driver Override Enable***
    - Pre-LOP Warning
      - ***Pre-LOP Driver Override Command***
      - ***Pre-LOP Driver Override Enable***

Engine Protection Verification Test

InPower™ Location:

Test

Fault Simulation

Engine Protection Tests

Aftercooler Water Temp**

Aftercooler Water Temp Override Command

Aftercooler Water Temp Override Enable

Blowby Flow**

Blowby Flow Override Command

Blowby Flow Override Enable

Coolant Pressure**

Coolant Pressure Override Command

Coolant Pressure Override Enable

Coolant Temp

Coolant Temp Override Command

Coolant Temp Override Enable

Fuel Temp**

Fuel Temp Override Command

Fuel Temp Override Enable

Intake Manifold Temp

Intake Manifold Temp Override Command

Intake Manifold Temp Override Enable

Oil Pressure

Oil Pressure Override Command

Oil Pressure Override Enable

Oil Temp*

Oil Temp Override Command

Oil Temp Override Enable

Overspeeding

Overspeed Shutdown Threshold

Engine Speed Reference Override Command

Engine Speed Reference Override Enable

Accel Ramp for Engine Speed Override

Decel Ramp for Engine Speed Override

Engine Protection Verification

The normal sensor values used by the ECM to perform engine protection can be overriden to simulate a specified test signal level. This is accomplished by setting the respective engine sensor override enable command to "Enabled" and setting the override value to the desired sensor input level.

QSX 15 Only:

The engine protection verification test parameters designated with a single asterisk (*) are only available on the QSX15 model engines.

QSK45 and 60 Only:

The engine protection verification test parameters designated with a double asterisk (**) are only available on the QSK45 and QSK60 model engines.

Miscellaneous Outputs / Capabilities

Reset Fuel Consumption

The ECM stores the total cumulative amount of fuel used by the engine in non-volatile memory. There is also a second fuel consumption counter, called *Fuel Consumption Since Reset*, that stores the amount of fuel consumed since this counter was last reset. The *Fuel Consumption Since Reset* counter can be reset to zero using InPower™. This is accomplished by selecting the *Reset Fuel Consumption* toggle parameter.

Power Limiter

The Power Limiter feature provides the capability to select a power limit best suited for the specific application in which the engine is being used (i.e. standy, prime, or continuous power applications). This is accomplished by setting the *Power Limiter State* parameter to the desired selection (Standy, Limited Time Prime, Unlimited Time Prime, or Continuous) using InPower™.

The Power Limiter feature must be enabled in order make the feature operational. This is accomplished by setting the *Power Limiter Enable* parameter to "Enabled" using InPower™. Once enabled, the engine power is limited by the maximum fueling that the fuel system is commanded to deliver to the engine based on limits pre-programmed in the ECM.

When the Power Limiter State is set to "Continuous" the *Continuous Scale Factor* parameter can be used to control the maximum amount of continuous power that the engine is capable of providing. This is accomplished by setting the *Continuous Scale Factor* to a value between 0 and 1, representing the percentage (between 0 and 100%) of the total engine continuous rated power capability.

> ***NOTE:*** *There is only a scale factor for use with continuous power applications. For engines used in standby or prime-time applications, the Power Limiter feature uses pre-programmed fueling limits and the Continuous Scale Factor parameter setting has no effect.*

InPower™ Configurable Feature

Reset Fuel Consumption

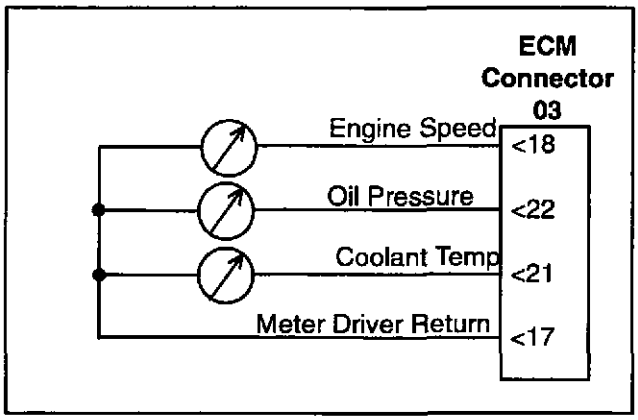
InPower™ Location:

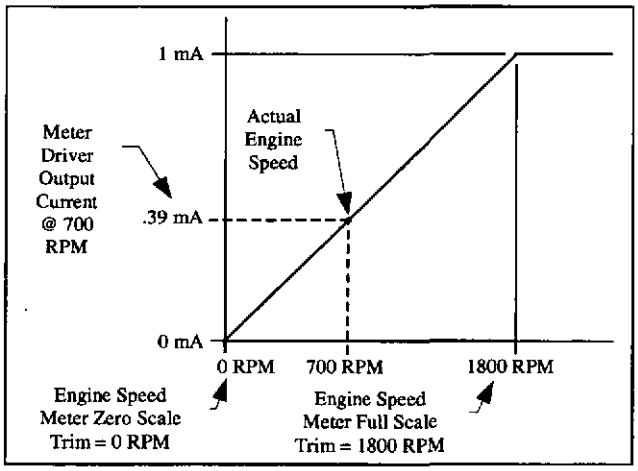
Adjustments
Reset History Counters
Fuel
Reset Fuel Consumption

Power Limiter

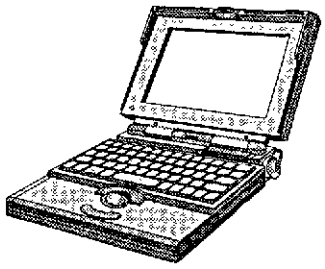
InPower™ Location:

Adjustments
Features
Power Limiter
Power Limiter State
Power Limiter Enable
Continuous Scale Factor





InPower™
Configurable Feature



Analog Meter Drivers

InPower™ Location:

Adjustments

Features

Meter Drivers

Engine Speed Meter Zero Scale

Engine Speed Meter Full Scale

Oil Pressure Meter Zero Scale

Oil Pressure Meter Full Scale

Coolant Temp Meter Zero Scale

Coolant Temp Meter Full Scale

Engine Monitoring

Analog Meter Drivers

Drivers are provided for driving analog meters to monitor the following three engine parameters:

- Engine Speed
- Oil Pressure
- Coolant Temperature

These parameters can be monitored by interfacing with the respective meter driver outputs and meter driver return input of ECM connector 03.

> ***NOTE:*** *The type of meter selected for use with this feature must have a 0 to 1 mA meter movement, with an impedance not greater than 100 ohms. The lower the impedance, the higher the accuracy of the indication will be. A meter with a 50 ohm impedance will provide an accuracy of approximately 1.2%.*

The meter drivers are configured using InPower™ to set the parameter trim values for the lower and upper parameter limits corresponding to 0 and 1 mA driver current levels. For example, the figure at the left is a graph depicting the driver response when configured to monitor the Engine Speed, using 0 and 1800 RPM as the trim values.

Modbus Communications Datalink

The ECM contains data that can be read using a remote device communicating with the ECM via Modbus protocol on a two-wire half-duplex RS-485 serial communications bus. In this arrangement, the remote device is the master, and the ECM is a slave, supplying data to the master when requested. For further details refer to the Modbus master-slave technique described in the Modbus Protocol Reference Guide (Modicon Document No. PI-MBUS-300). The Modbus Protocol Reference Guide can be found on the World-Wide-Web (WWW) at the Schneider Automation Inc. web-site. The document is accessible on-line using Universal Resource Locator (URL):

http://www.modicon.com/techpubs/techpubnew/pi_mbus_300.pdf

The following engine and ECM information can be monitored using the Modbus datalink:

QSX 15 Only:

The Modbus data designated with a single asterisk (*) are only available on the QSX15 model engines.

QSK45 and QSK60 Only:

The Modbus data designated with a double asterisk (**) are only available on the QSK45 and QSK60 model engines.

Engine Sensor Parameters
- Engine Speed
- Coolant Temperature
- Oil Pressure
- Ambient Air Pressure
- Intake Manifold Pressure
- Intake Manifold Temperature
- Aftercooler Water Inlet Temperature**
- Blowby Flow**
- Coolant Pressure**
- Fuel Pump Pressure**
- Fuel Rail Pressure**
- Fuel Outlet Pressure*
- Oil Temperature*
- Fuel Inlet Temperature**
- Timing Rail Pressure**
- Coolant Level

Switch Input States
- Idle/Rated
- Run/Stop
- Remote Emergency Stop

Adjustable Input Settings
- Frequency Adjust Pot
- Droop Adjust Pot
- Governor Gain Adjust Pot

Speed Bias Inputs
- ±0.2V Speed Bias Signal
- ±2.5V Speed Bias Signal

Lamp/Relay Driver States
- Common Shutdown
- Common Warning

Actuator Driver States
- Fuel Shut-Off Solenoid

Fault/Diagnostic Data
- Active Warning Fault Events
- Active Shutdown Fault Events
- Most Recent Fault Events

Other GCS/ECM Data
- Battery Voltage
- Operator Interface Mode
- Engine Running Time
- ECM On-Time
- Base Frequency
- Base Speed
- Final Speed Reference
- Estimated Torque
- Load Profile Monitor
- Fuel Consumption Rate
- Cumulative Fuel Consumption

The customer can implement the RS-485 physical interface by connecting the shielded twisted-pair serial communications bus wires RS485+ and RS485- (pins 21 and 18 respectively) and the bus shield (pin 20) of ECM connector 06.

The Modbus operates at a communications rate of 9600 baud. At this data rate, the maximum specified bus length of 4000 ft. [1219m] can be achieved. If the ECM is connected at either end of the communications bus, Term 1 and Term 2 (pins 22 and 19 respectively) of ECM connector 06 are to be jumpered by shorting these two pins together. If the ECM is not connected at either end of the bus, Term 1 and Term 2 should be left unconnected.

For further details regarding RS-485 implementation and applications, refer to Electronic Industries Association Standard EIA-485, "Electrical Characteristics of Generators and Receivers for use in Balanced Digital Multi-Point Systems". Additional information can be found on the WWW at the B&B Electronics Manufacturing Company website. Refer to the "RS-422 and RS-485 Application Note" accessible on-line using URL:

http://www.bb-elec.com/bb-elec/literature/tech/485appnote.pdf

The information following provides specific details required to implement the digital portion of the Modbus Interface. Please refer to Modicon's Modbus Protocol Reference Guide for further details not inlcuded in this manual

The Modbus interface supports the Remote Terminal Unit (RTU) mode message framing only. The communications parameters are set at 1 start bit, 8 data bits, no parity and 2 stop bits. The ECM slave device address is 1.

Modbus register data available for all engine models is defined in Appendix A. Appendix B defines the register data available for only the QSX15 model engine. Appendix C defines the register data available for only the QSK45 and QSK60 model engines. Modbus register parameters are identified as either Signed (S) or Unsigned (U) in the Type column of the respective tables. Where signed values are used, the value is a 16-bit 2's complement number. The maximum amount of register data the ECM can return in a slave response is 16 registers. The maximum length of the entire message must not exceed 256 bytes.

Appendix D defines the bit data available via the Modbus for all engine models. The maximum amount of bit data the ECM can return in a slave response is 32 bits (specified as "inputs", per the Modbus Protocol Reference Guide). The maximum length of the entire message must not exceed 256 bytes.

Supported Modbus exception codes are defined in Appendix E, and supported diagnostic sub-functions are defined in Appendix F.

First Time Engine Start

Prior to starting the engine for the first time the following Engine Check and Functional Test procedures should be performed.

Engine Check

Perform the following checks:

- Verify nominal battery voltage
- Verify there are no active faults
- Using InPower™, verify the following critical sensors are indicating a normal value (with engine not running)
  - Boost Pressure
  - Fuel Rail Pressure
  - Fuel Pump Pressure
  - Oil Pressure
  - Coolant Temperature
- Manually check that the Oil Level is normal
- Manually check that the Coolant level is normal

If any problems or abnormal conditions are observed, perform any necessary troubleshooting and repairs prior to performing the following functional test.

Control System Functional Test

Perform the following control system tests in the sequence shown. Verify by observation that the expected system/engine response occurs during each test. These tests are described in detail in the ***Built-In Test*** section on page 90 of this manual.

- Stationary Test
- Cranking Test

If any test fails to produce the expected result, perform any necessary troubleshooting and repairs prior to attempting to start the engine for the first time.

Engine Starting

Prior to starting the engine for the first time, the ***Engine Check*** and ***Control System Functional Test*** procedures described on page 99 should be performed.

To start the engine, the Run/Stop input must be set to the "Run" state first. Then to engage the starter and crank the engine, the Crank input must be held in the "Crank" state until the engine starts and is running on its own power. The control system will automatically disengage the starter once the engine speed has increased above a pre-programmed starter disconnect speed. If the starter fails to automatically disengage, the Backup Start Disconnect switch should be used to disengage the starter. See the ***Backup Start Disconnect*** section on page 48 for details.

The control system is designed so that it can be programmed by the customer to prevent damage to the starter due to over-cranking. The maximum cranking time can be programmed using InPower. See the ***Cycle/Continuous Cranking*** section on page 47 for details. When the specified crank engage time has been achieved, the control system will automatically disengage the starter.

Miscellaneous Application Requirements and Information

Customer Supplied Redundant Fuel Shut-Off Devices (QSK45 and QSK60 Only)

On the QSK45 and QSK60 engines, timing rail pressure must be maintained for a minimum of 27 seconds immediately following a commanded engine shutdown. This is necessary in order to prevent hard starting on the next start-up following the shutdown. To comply with this requirement, a customer supplied Fuel Shut-Off (FSO) device must be delayed from shutting off the supply of fuel until after the minimum time interval has expired. A time delay relay driven by the customer supplied run relay can be used to implement the required time delay.

Customer Supplied Coolant Level Switch

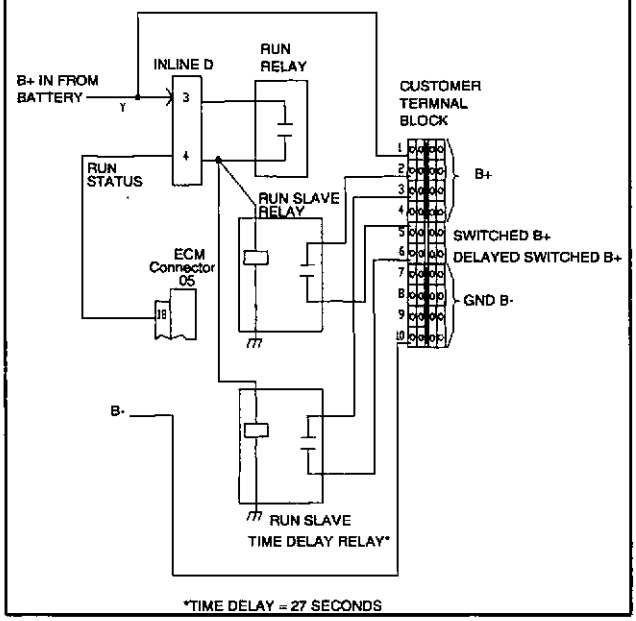
The Engine Harness has a provision for installing a customer supplied Coolant Level Switch. The Coolant Level Switch interface connector on the harness is a Deutsch 4-position connector (Deutsch P/N DT06-4S with a P/N W4S wedge insert) using 0.969 - 1.442 mm^2 sockets (16-18 AWG; Deutsch P/N 1062-16-0122).

A Coolant Level Switch that is compatible for use with the engine can be purchased from Cummins. See the Cummins G-Drive Sales Handbook or contact your local Cummins distributor for further details and ordering information.

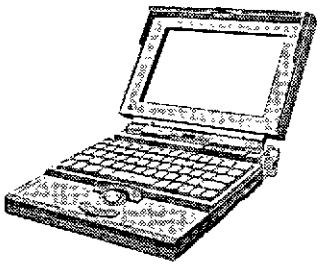
The control system must be set-up to read the Coolant Level Switch signal. This is accomplished by setting the *Coolant Level Switch Enable* parameter to "Enabled" using InPower™. This is necessary to ensure that a low coolant level condition can be detected and reported by the control system engine protection feature.

> ***NOTE:*** *Use of the Coolant Level Switch is mandatory and must be installed. The customer is responsible for performing a test to ensure that this feature is set-up correctly and that a low coolant level is being properly detected and reported.*

Double Slave Relay
Configuration with Time Delay



InPower™ Configurable Feature



Coolant Level Switch Enable

InPower™ Location:

Adjustments

Engine Protection Adjustments

Coolant Level Switch Enable

Appendix A: Modbus Register Data[1]

Parameter	Function Code	Register Address (Decimal)	Total number of bytes	Read/ Write	Scaling	Type	Eng Units	Range
Engine Speed	04	30001	2	Read Only	8	S	rpm	≥ 0
Coolant Temperature	04	30002	2	Read Only	64	S	°F	-40 to 302
Oil Pressure	04	30003	2	Read Only	64	S	*psig* psia	*0 to 100* (QSK45/60) 6.5 to 75 (QSX15)
Battery Voltage	04	30004	2	Read Only	64	S	volts	0 to 40
Frequency Adjust Pot	04	30005	2	Read Only	80	S	Hz	-3 to 3
Droop Adjust Pot	04	30006	2	Read Only	256	S	%	0 to 10
Ambient Air Absolute Pressure	04	30007	2	Read Only	64	S	In. Hg	10.2 to 30.5 (QSK45/60) 13.2 to 32.6 (QSX15)
Engine Running Time	04	30008-30009	4	Read Only	10	U	sec	0 to 200,000,000
ECM On Time	04	30010-30011	4	Read Only	1	U	sec	0 to 789,000,000
Base Frequency	04	30012	2	Read Only	80	U	Hz	50 to 60
Base Speed	04	30013	2	Read Only	8	U	rpm	1000 to 3600
Final Speed Reference	04	30014	2	Read Only	8	U	rpm	≥ 0
Estimated Torque	04	30015	2	Read Only	1	S	lb.-ft.	0 to 11,952
±0.2V Speed Bias	04	30016	2	Read Only	80	S	Hz	± 7.38
±2.5V Speed Bias	04	30017	2	Read Only	80	S	Hz	± 3
Fuel Consumption Rate	04	30018	2	Read Only	100	U	Gal./Hr.	0 to 600
Cumulative Fuel Consumption	04	30019 to 30020	4	Read Only	100	U	Gal.	0 to 10,000,000
Governor Gain Adjust Pot	04	30021	2	Read Only	256	U	N/A	0.05 to 10.0

1. The maximum amount of data the ECM can return in response to a Read Input Registers request (Function Code 04) is 16 registers. The maximum length of an entire message must not exceed 256 bytes.

Parameter	Function Code	Register Address (Decimal)	Total number of bytes	Read/ Write	Scaling	Type	Eng Units	Range
Active Warning Fault Events List[a]	04	30033-30048	32 (total)	Read Only				
Fault Code			*2 each*		*1*	*U*	*N/A*	*0 to 9999*
Active Shutdown Fault Events List[a]	04	30049-30064	32	Read Only				
Fault Code			*2 each*		*1*	*U*	*N/A*	*0 to 9999*
Most Recent Fault Events List[b]	04	30065-30316	504 (total)	Read Only				
Fault Code			*2 each*		*1*	*U*	*N/A*	*0 to 9999*
Fault Count			*2 each*		*1*	*U*	*N/A*	*0 to 65535*
Time Stamp (last occurrence, ECM on time)			*4 each*		*1*	*U*	*sec*	*0 to 789,000,000*
Time Stamp (last occurrence, engine running time)			*4 each*		*10*	*U*	*sec*	*0 to 200,000,000*

a. The Active Warning and Active Shutdown Fault Events Lists each consist of 16 Fault Codes.

b. The Most Recent Fault Events List consists of 42 records of fault data. Each record consists of 12 bytes containing data for the Fault Code. Fault Code, Fault Count, ECM On-Time Time Stamp, and Engine Running Time Stamp. The Fault Count is the number of occurences for the respective Fault Codes.

Parameter	Function Code	Register Address (Decimal)	Total number of bytes	Read/ Write	Scaling	Type	Eng Units	Range
Load Profile Monitor[a] (50Hz Log)	04	30317-30336	40 (Total)	Read Only				
Range #1 (0% to 10% load)	*04*	*30317-30318*	*4 each*		*10*	*U*	*min*	*0 to 200,000,000*
Range #2 (> 10% to 20% load)	*04*	*30319-30320*	*4 each*		*10*	*U*	*min*	*0 to 200,000,000*
Range #3 (>20% to 30% load)	*04*	*30321-30322*	*4 each*		*10*	*U*	*min*	*0 to 200,000,000*
Range #4 (> 30% to 40% load)	*04*	*30323-30324*	*4 each*		*10*	*U*	*min*	*0 to 200,000,000*
Range #5 (> 40% to 50% load)	*04*	*30325-30326*	*4 each*		*10*	*U*	*min*	*0 to 200,000,000*
Range #6 (> 50% to 60% load)	*04*	*30327-30328*	*4 each*		*10*	*U*	*min*	*0 to 200,000,000*
Range #7 (> 60% to 70% load)	*04*	*30329-30330*	*4 each*		*10*	*U*	*min*	*0 to 200,000,000*
Range #8 (> 70% to 80% load)	*04*	*30331-30332*	*4 each*		*10*	*U*	*min*	*0 to 200,000,000*
Range #9 (> 80% to 90% load)	*04*	*30333-30334*	*4 each*		*10*	*U*	*min*	*0 to 200,000,000*
Range #10 (> 90% to 100% load)	*04*	*30335-30336*	*4 each*		*10*	*U*	*min*	*0 to 200,000,000*

a. The Load Profile Monitor is a record consisting of percentile Ranges #1 through #10. Each range consists of 4 bytes designating the amount of time (in minutes) that the engine has been operating in the respective load range.

Parameter	Function Code	Register Address (Decimal)	Total number of bytes	Read/ Write	Scaling	Type	Eng Units	Range
Load Profile Monitor[a] (60Hz Log)	04	30337-30356	40 (Total)	Read Only				
Range #1 (0% to 10% load)	*04*	*30337-30338*	*4 each*		*10*	*U*	*min*	*0 to 200,000,000*
Range #2 (> 10% to 20% load)	*04*	*30339-30340*	*4 each*		*10*	*U*	*min*	*0 to 200,000,000*
Range #3 (>20% to 30% load)	*04*	*30341-30342*	*4 each*		*10*	*U*	*min*	*0 to 200,000,000*
Range #4 (> 30% to 40% load)	*04*	*30343-30344*	*4 each*		*10*	*U*	*min*	*0 to 200,000,000*
Range #5 (> 40% to 50% load)	*04*	*30345-30346*	*4 each*		*10*	*U*	*min*	*0 to 200,000,000*
Range #6 (> 50% to 60% load)	*04*	*30347-30348*	*4 each*		*10*	*U*	*min*	*0 to 200,000,000*
Range #7 (> 60% to 70% load)	*04*	*30349-30350*	*4 each*		*10*	*U*	*min*	*0 to 200,000,000*
Range #8 (> 70% to 80% load)	*04*	*30351-30352*	*4 each*		*10*	*U*	*min*	*0 to 200,000,000*
Range #9 (> 80% to 90% load)	*04*	*30353-30354*	*4 each*		*10*	*U*	*min*	*0 to 200,000,000*
Range #10 (> 90% to 100% load)	*04*	*30355-30356*	*4 each*		*10*	*U*	*min*	*0 to 200,000,000*

a. The Load Profile Monitor is a record consisting of percentile Ranges #1 through #10. Each range consists of 4 bytes designating the amount of time (in minutes) that the engine has been operating in the respective load range.

Appendix B: Modbus Register Data[1] - QSX15 Only

Parameter	Function Code	Register Address (Decimal)	Total number of bytes	Read/ Write	Scaling	Type	Eng Units	Range
Intake Manifold Absolute Pressure	04	30513	2	Read Only	64	S	In. Hg	13.2 to 132.3
Intake Manifold Temperature	04	30514	2	Read Only	64	S	°F	-40 to 302
Fuel Outlet Absolute Pressure	04	30515	2	Read Only	64	S	psia	0 to 315
Oil Temperature	04	30516	2	Read Only	64	S	°F	-40-302

Appendix C: Modbus Register Data[1] - QSK45 and QSK60 Only

Parameter	Function Code	Register Address (Decimal)	Total number of bytes	Read/ Write	Scaling	Type	Eng Units	Range
Blowby Flow	04	30529	2	Read Only	128	S	cfm	0 to 17.95
Intake Manifold Absolute Pressure	04	30530	2	Read Only	64	S	In. Hg	0 to 152.7
Intake Manifold Temperature	04	30531	2	Read Only	64	S	°F	-40 to 302
Coolant Absolute Pressure	04	30532	2	Read Only	64	S	psia	0 to 75
Fuel Pump Absolute Pressure	04	30533	2	Read Only	64	S	psia	0 to 375
Fuel Rail Absolute Pressure	04	30534	2	Read Only	64	S	psia	15 to 250
Fuel Inlet Temperature	04	30535	2	Read Only	64	S	°F	-40 to 302
Timing Rail Absolute Pressure	04	30536	2	Read Only	64	S	psia	0 to 375
Aftercooler Water Inlet Temperature	04	30537	2	Read Only	64	S	°F	-40 to 302

1. *The maximum amount of data the ECM can return in response to a Read Input Registers request (Function Code 04) is 16* registers. The maximum length of an entire message must not exceed 256 bytes.

Appendix D - Modbus Bit Data[1]

Switch Name	Function Code	Coil/Input Address (Decimal)	Total number of bits	Read/Write	States
Shutdown Override	01 (Read) 05 (Write)	00001	1	Read / Write	Enabled = 1 Disabled = 0
Fault Acknowledge[a]	01 (Read) 05 (Write)	00002	1	Read / Write	Acknowledge = 1 Not Acknowledge = 0
Idle/Rated Switch State	02	10001	1	Read Only	Rated =1, Idle = 0
Run/Stop Switch State	02	10002	1	Read Only	Run =1, Stop = 0
Remote Emergency-Stop Input	02	10003	1	Read Only	Stop =1, Not Stop =0
Coolant Level Switch State[b]	02	10004	1	Read Only	Low =1, Normal =0
Common Shutdown Lamp/Relay Driver Command	02	10005	1	Read Only	Driver On =1 Driver Off =0
Common Warning Lamp/Relay Driver Command	02	10006	1	Read Only	Driver On =1 Driver Off =0
Fuel Shut-off Valve Driver State	02	10007	1	Read Only	Driver On =1 Driver Off =0
Operator Interface Mode	02	10008 - 10011	4	Read Only	See Table Below

a. The Fault Acknowledge command is a momentary signal and should be held in the "acknowledge" state for no longer than 0.5 seconds when acknowledging a fault condition.

b. The Coolant Level Switch is to be supplied by the customer. The control system must be set -up to read the Coolant Level Switch signal. See the ***Customer Supplied Coolant Level Switch*** section on page 101 for further details.

Bit No.	B	A	9	8
Off	0	0	0	0
Ready	0	0	0	1
Fault Flashout	0	0	1	0
Non-Running Test	0	0	1	1
Starting	0	1	0	0
Idle	0	1	0	1
Rated	0	1	1	0
Normal Stop	0	1	1	1
Emergency Stop	1	0	0	0
Watchdog Test	1	0	0	1

1. The maximum amount of data the ECM can return in response to: i) a Read Coil Status request (Function Code 01) is 32 coils, ii) a Force Single Coil request (Function Code 05) is 1 coil, or iii) a Read Input Status request (Function Code 02) is 32 inputs. The maximum length of an entire message must not exceed 256 bytes.

Appendix E - Supported Modbus Exception Codes

Code	Name	Description
01	Illegal Function	The function code received is not valid
02	Illegal Data Address	The data address received in the query is not a valid address
03	Illegal Data Value	A value contained in the query data field is not a valid value for the slave

Appendix F - Supported Modbus Diagnostics

Sub-Function Code	Name	Description
00	Return Query Data	The data passed in the query data field is to be returned (looped back) in the response. The entire response message should be identical to the query.
01	Restart Communications Option	The slave's peripheral port is to be initialized and restarted, and all of its communications event counters are to be cleared. If the port is currently in Listen Only Mode, no response is returned. If the port is not currently in Listen Only Mode, a normal response is returned.
04	Force Listen Only Mode	Forces the ECM into Listen Only Mode. This isolates it from the other devices on the network, allowing them to continue communicating without interruption from the addressed slave. No response is returned. The only function that will be processed after this mode is entered will be the Restart Communications Option function (function code 08, subfunction 01)
10	Clear Counters and Diagnostic Register	Clears all counters and the diagnostic register.
11	Return Bus Message Count	The response data field returns the quantity of messages that the slave has detected on the communications system, since its last restart, clear counters operation, or power up.
12	Return Bus Communication Error Count	The response data field returns the quantity of CRC errors encountered by the ECM since the its last restart, clear counters operation, or power-up.
13	Return Bus Exception Error Count	The response data field returns the quantity of Modbus exception responses returned by the ECM since the its last restart, clear counters operation, or power-up.
14	Return Slave Message Count	The response data field returns the quantity of messages addressed to the ECM, or broadcast, that the ECM has processed since its last restart, clear counters operation, or power-up.
15	Return Slave No Response Count	The response data field returns the quantity of messages addressed to the ECM for which it did not return a response (neither a normal response nor an exception response), since its last restart, clear counters operation, or power-up

Appendix G - Electronic Device Usage

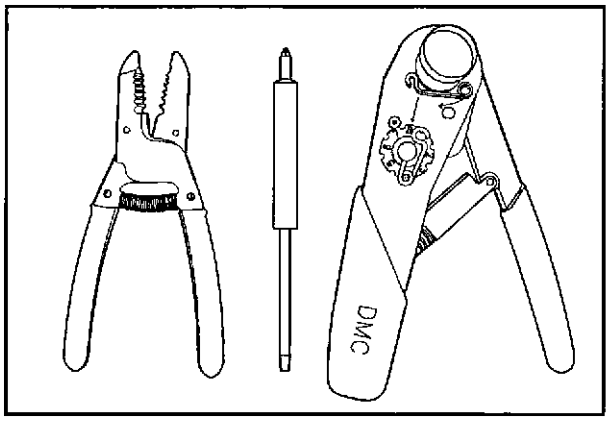
Device Type/Description	QSK45/60	QSX15	Comments
Sensors			
Aftercooler Water Inlet Temperature	X		Provisions in ECM H/W for the QSX15
Ambient Air Pressure	X	X	
Blowby flow	X		
Coolant Level	X	X	***INSTALLATION OF THE COOLANT LEVEL SENSOR IS MANDATORY.*** Provisions are in QSX15 and QSK45/60 wiring harnesses to connect customer supplied sensor.
Coolant Pressure	X		
Coolant Temperature	X	X	
Engine Speed Sensor (ESS)/ Engine Position Sensor (EPS)			
Crankshaft ESS		X	
Camshaft EPS		X	
Flywheel (Ring Gear) ESS	X		Sensor has redundant main/backup coils (both are wired to the ECM)
Fuel/Timing Pressure			
Fuel Outlet Pressure		X	
Fuel Pump Pressure	X		
Fuel Rail Pressure	X		
Timing Rail Pressure	X		
Fuel Temperature	X		
Intake Manifold Pressure	X	X	QSX15 uses combination pressure/temp sensor
Intake Manifold Temperature	X	X	QSX15 uses combination pressure/temp sensor
Oil Pressure	X	X	QSX15 uses combination pressure/temp sensor
Oil Temperature		X	QSX15 uses combination pressure/temp sensor
Switch Inputs			
Run/Stop	X	X	
Idle/Rated	X	X	
Crank	X	X	
Alternate Frequency	X	X	
Diagnostic Mode	X	X	
Fault Acknowledge	X	X	
Control/Service/Safety Discrete Inputs			
Emergency Stop (Local & Remote)	X	X	
Run Relay Contact Status	X	X	
Crank (Slave) Relay Contact Status	X	X	
Backup Start Disconnect Status	X	X	
Diagnostic Mode Enable	X	X	Two one-pin connectors (opposite gender) are plugged together to enable Diagnostic Mode

Device Type/Description	QSK45/60	QSX15	Comments
Adjustable Inputs			
Governor Gain	X	X	
Speed Droop	X	X	
Frequency	X	X	
Speed Bias/Synchronizing Inputs			
+/- 0.2V Signal	X	X	For use with Barber-Colman compatible governing and load share equipment
+/- 2.5V Signal	X	X	For use with Woodward compatible governing and load share equipment
Drivers			
Lamp/Relay Drivers			
Common Warning	X	X	
Common Shutdown	X	X	
High Engine Temperature	X	X	
Low Oil Pressure	X	X	
Overspeed	X	X	
Pre-High Engine Temperature	X	X	
Pre-Low Oil Pressure	X	X	
Fail-to-Start	X	X	
Meter Drivers			
Engine Speed	X	X	
Oil Pressure	X	X	
Coolant Temperature	X	X	
Actuator Drivers			
HPI-TP Fuel System			
Fueling Actuator #1 (Front)		X	
Fueling Actuator #2 (Rear)		X	
Timing Actuator #1 (Front)		X	
Timing Actuator #2 (Rear)		X	
HPI-PT Fuel System			
Fuel Rail Actuator	X		
Fuel Pump Actuator	X		
Timing Rail Actuator (1)	X		
Timing Rail Actuator (2)	X		
Fuel Shut-Off Valve Solenoid	X	X	
Starter Control (Crank Coil Relay)	X	X	
Miscellaneous Outputs			
Battery Charging Alternator Field Flash Out	X	X	
Serial Communications Datalinks			
RS-232 Datalink (Service Tool Interface)	X	X	
MODBUS RS-485 Datalink (Customer Interface)	X	X	

Appendix H - Keyed Connector Backshell Assembly Instructions

Each keyed connector kit includes the following parts:

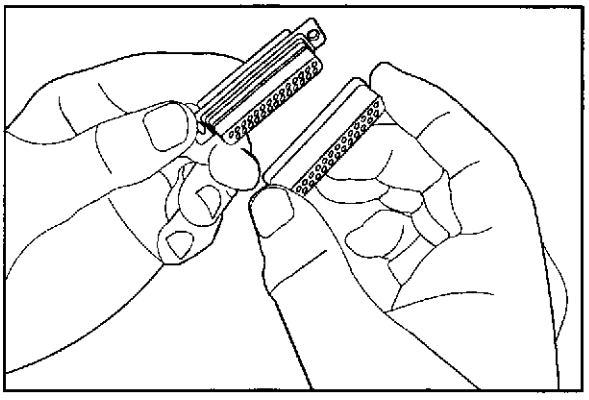
- Keyed Backshell
  (2 halves – includes color-coded connector identification label on each half)
- Backshell Fastening Screws (Qty. 2)
- Thumbscrews (Qty. 2)
- Wiring Harness Strain Relief Clamp (Qty. 1)
- Strain Relief Clamp Fastening Screws (Qty. 2)
- Connector Grommet Seal (Qty. 1)
- Connector Terminals (Qty. 30)
- Sealing Plugs (Qty. 30)
- Terminal Insertion/Extraction Tool (Qty. 1)



Required tools (not included in kit):

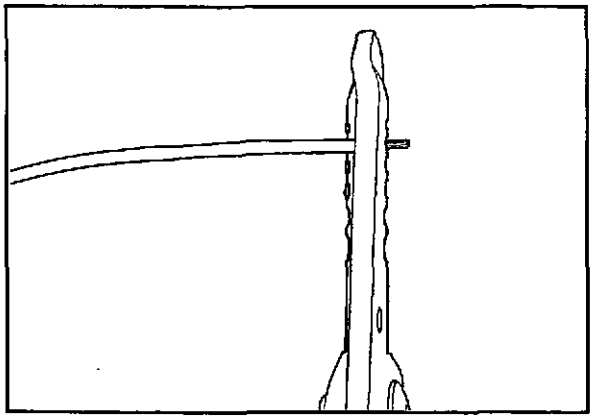
- Wire Strippers
- Standard Screwdriver
- Terminal Crimp Tool (and required accessories, i.e. positioner)

Following are the instructions explaining how to assemble the 25-position connector together with the wiring harness and the keyed connector backshell.

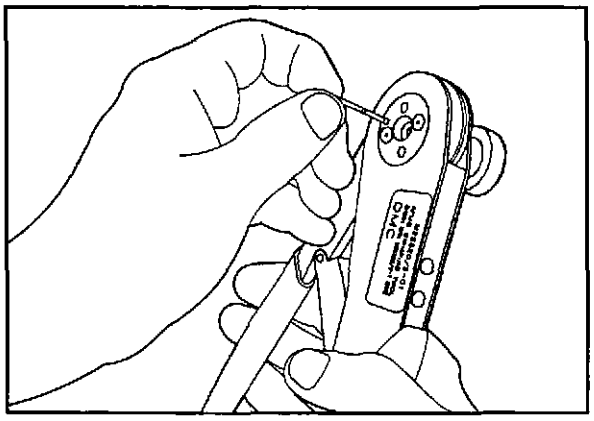


1. Position the connector grommet seal on the backside of the connector (the side that the harness conductors will be terminated to at the connector).

2. Strip 4.3 to 5.1 millimeters (0.17 to 0.20 inches) of insulation from the ends of the wire harness conductors.

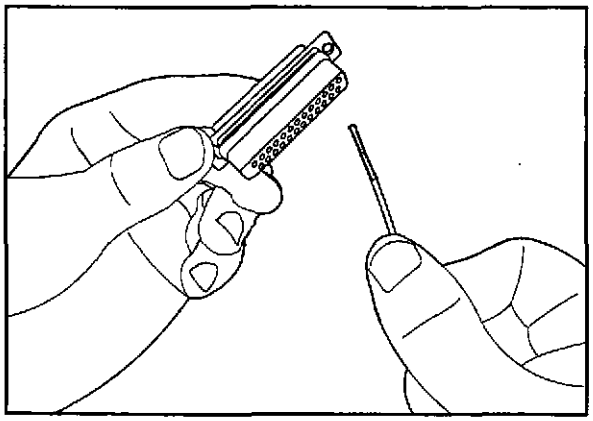


3. Using the appropriate terminal crimping apparatus, crimp the connector terminals onto the stripped, bare ends of the wire harness conductors. Use a crimp tool with frame style M22520/2-01 per MIL-C-22520, or equivalent. A hand-held or pneumatic crimp tool can be purchased from Daniels Manufacturing Corporation (P/N AFM8 for hand-held, P/N WA27F for pneumatic) along with the terminal positioner (Part No. K13-1 for use with 0.5 mm^2 [20 AWG] terminals).



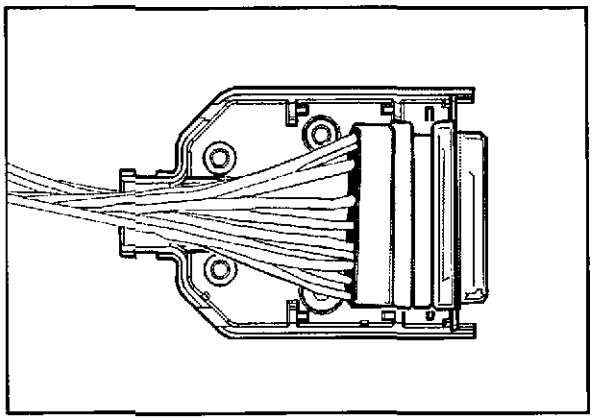
> ***NOTE:*** *Carefully read and follow all of the manufacturer's instructions for the specific crimp tool being used for this procedure. The AFM8 crimp tool from Daniels Manufacturing Corporation requires that the correct positioner be used and that the crimp tool selector knob is adjusted to the correct setting for the terminal size being used.*

4. Once all conductors to be used are crimped onto connector terminals, insert each terminal into the correct cavity of the connector. Because the grommet seal is covering the connector, each terminal will first have to be inserted through the corresponding cavity of the grommet seal. The terminal can be installed by using a small amount of pressure to push the terminal into the connector cavity. There will be a quiet "click" or "snap" sound when the detents in the connector cavity engage, indicating that the terminal is properly seated in the connector cavity.

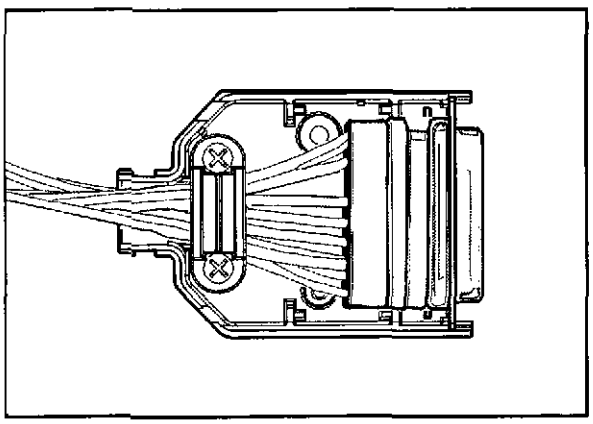


> ***NOTE:*** *If for any reason a terminal must be extracted from a connector cavity after it has already been installed, use the extraction tool provided in the kit to do so. The terminals are a rear-side removal type.*

5. The grommet seal must have a sealing plug inserted in the unpopulated cavity positions in order to provide adequate protection against debris and water intrusion. Insert a sealing plug into each open cavity position on the back (exposed) side of the grommet.
6. Ensure that all terminals are properly seated into each of the connector cavities. Applying a small amount of force to try and pull the harness conductor attached to the terminal out of the connector cavity can check this. If the terminal is improperly seated, it should easily pullout of the connector cavity. If the terminal is properly seated, there should be resistance when pulling on the conductor and the terminal will remain seated in the connector cavity.

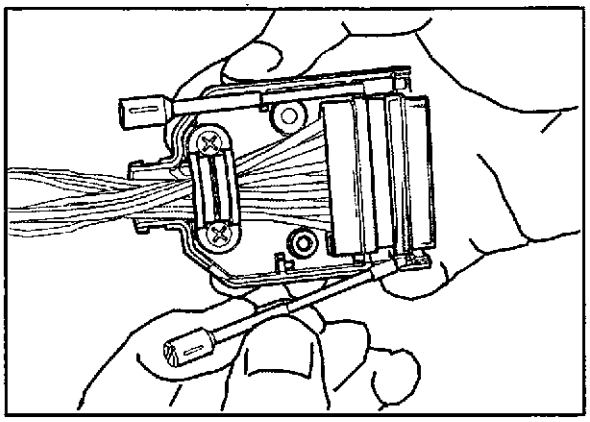


7. When all harness conductors have been inserted into the connector and properly seated, place the connector into one half of the keyed backshell, laying the harness bundle as shown in the diagram.

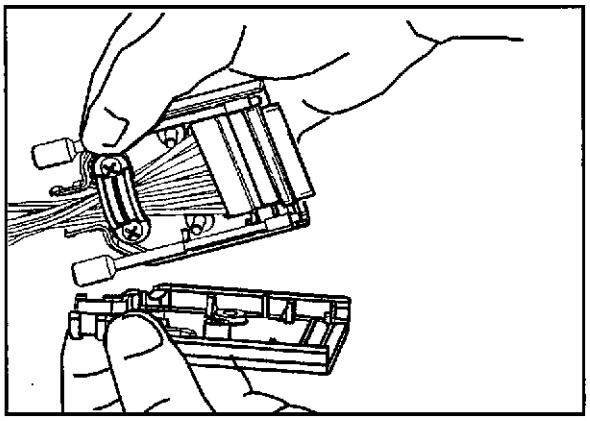


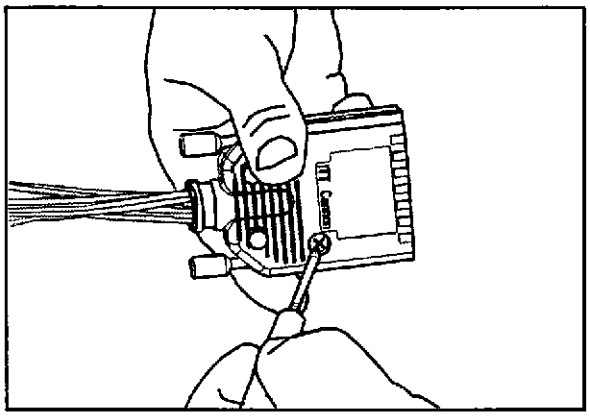
8. Place the strain relief clamp over the harness bundle and attach it to the backshell half using the two strain relief clamp screws provided.

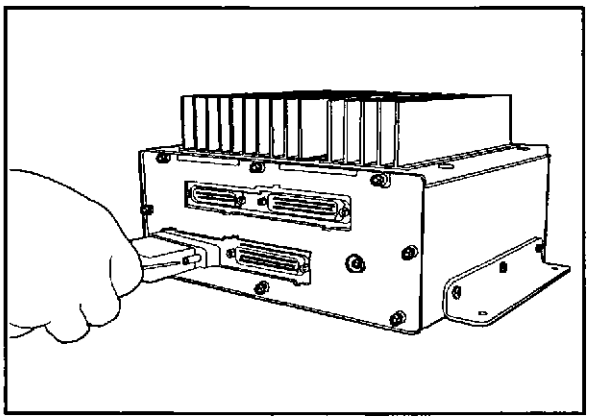
9. Place the two thumbscrews into the proper locations of the backshell half.



10. Finally, place the second half of the backshell in place, fitting it to the first half of the backshell to cover the exposed grommet seal and harness strain relief clamp and fasten the two backshell halves together using the two backshell fastening screws provided.







NOTE: *When attaching the keyed connectors to the ECM, the thumbscrews should be torqued to 0.79 - 0.90 N m (7-8 in.-lbs.).*

Appendix I - Component Manufacturers' Addresses

NOTE: The following list contains addresses and telephone numbers of suppliers of accessories used on Cummins engines. Suppliers can be contacted directly for any specifications **not** covered in this manual.

Alternators

Robert Bosch Ltd.
P.O. Box 98
Broadwater Park
North Orbital Road
Denham
Uxbridge
Middlesex UD9 5HG
England
Telephone: 01895-833633

Butec Electrics
Cleveland Road
Leyland
PR5 1XB
England
Telephone: 01744-21663

C.A.V. Electrical Equipment
P.O. Box 36
Warple Way
London
W3 7SS
England
Telephone: 01-743-3111

A.C. Delco Components Group
Civic Offices
Central Milton Keynes
MK9 3EL
England
Telephone: 01908-66001

C.E. Niehoff & Co.
2021 Lee Street
Evanston, Il 60202
Telephone: (708) 866-6030

Delco-Remy America
2401 Columbus Avenue
Anderson, In 46018
Telephone: (317) 646-3528

Leece-Neville Corp.
400 Main Street
Arcade, NY 14009
Telephone: (716) 482-1700

Coolant Level Switches

Robertshaw Controls Company
P.O. Box 400
Knoxville, TN 37901
Telephone: (216) 885-1773

Connnector Contact Crimp Tools & Accessories

Daniels Manufacturing Corp.
526 Thorpe Rd.
Orlando, FL 32824
Telephone: (407) 855-6161

Connnector Contact Insertion & Removal Tools

Aiconics, Inc.
13100 Kirkham Way #206
Poway, CA 92064
Telephone: (858) 513-2115

Electric Starting Motors

Butec Electrics
Cleveland Road
Leyland
PR5 1XB
England
Telephone: 01744-21663

C.A.V. Electrical Equipment
P.O. Box 36
Warple Way
London
W3 7SS
England
Telephone: 01-743-3111

A.C. Delco Components Group
Civic Offices
Central Milton Keynes
MK9 3EL
England
Telephone: 01908-66001

Delco-Remy America
2401 Columbus Avenue
Anderson, IN 46018
Telephone: (317) 646-3528

Leece-Neville Corp.
400 Main Street
Arcade, NY 14009
Telephone: (716) 482-1700

Nippondenso Inc.
2477 Denso Drive
P.O. Box 5133
Southfield, MI 48086
Telephone: (313) 350-7500

Electronic Switches

Cutler-Hammer Products
Eaton Corporation
4201 N. 27th Street
Milwaukee, WI 53216
Telephone: (414) 449-6600

Electronic Switches (continued)

Cutler-Hammer Products
Eaton Corporation
4201 N. 27th Street
Milwaukee, WI 53216
Telephone: (414) 449-6600

Gauges

A.I.S.
Dyffon Industrial Estate
Ystrad Mynach
Hengoed
Mid Glamorgam
CF8 7XD
Telephone: 01443-812791

Yokogawa Electric Corporation
9-32
Nakacho 2-chome Musashino-shi
Tokyo, 180-8750
Japan
Telephone: 81-422-52-5535

Grasslin U.K. Ltd.
Vale Rise
Tonbridge
Kent
TN9 1TB
England
Telephone: 01732-359888

Icknield Instruments Ltd.
Jubilee Road
Letchworth
Herts
England
Telephone: 04626-5551

Superb Tool and Gauge Co.
21 Princip Street
Birmingham
B4 61E
England
Telephone: 021-359-4876

Gauges (continued)

Kabi Electrical and Plastics
Cranborne Road
Potters Bar
Herts
EN6 3JP
England
Telephone: 01707-52444

Datcom Instruments
P.O. Box 128
East Petersburg, PA 17520
Telephone: (717) 569-5713

Rochester Gauges, Inc.
11616 Harry Hines Blvd.
P.O. Box 29242
Dallas, TX 75229

Crompton Instruments Ltd.
Freebournes Road
Withan Essex
CM8 3AH
England
Telephone: 44(0) 1376 512601

In-Line Connectors

Pioneer-Standard Electronics, Inc.
5440 Neiman Parkway
Solon, OH 44139
Telephone: (216) 349-1300

Deutsch
Industrial Products Division
37140 Industrial Avenue
Hemet, CA 92343
Telephone: (714) 929-1200

Ladd Industries, Inc.
4849 Hempstead Station Drive
Kettering, OH 45429
Telephone: (937) 438-2646
(800)223-1236

Load Share/ Synchronizing Controls

Woodward Governors Ltd.
P.O. Box 15
663 / 664 Ajax Avenue
Slough
Bucks
SL1 4DD
England
Telephone: 01753-26835

Load Share/ Synchronizing Controls (continued)

Woodward Governor Co.
P.O. Box 1519
Fort Collins, CO 80522
Telephone: (303) 482-5811
(800) 523-2831

Barber Colman Co.
1354 Clifford Avenue
Loves Park, IL 61132
Telephone: (815) 637-3000

United Technologies
Diesel Systems
1000 Jorie Blvd.
Suite 111
Oak Brook, IL 69521
Telephone: (312) 325-2020

Appendix J - Operating, Electrical & Environmental Specifications

Operation

Governor Mode	Isochronous to 10% Droop
Governor Gain Adjust	0.05 to 10.00
Frequency Adjust Range	±9Hz (±3Hz Using External Pot, ±6Hz Using InPower™)
Speed Bias Reference Voltage	+5VDC (±2%); 50mV$_{(p-p)}$ Max. Ripple
±2.5V Speed Bias Signal	5.0V ± 2.5V (±3Hz full scale)
±0.2V Speed Bias Signal	5.0V ± 0.2V (±7.38Hz full scale)
Minimum Mag Pickup Speed Signal Input	1.5V$_{p-p}$ @ 200 rpm, 6.5V$_{p-p}$ @ 1800 rpm

Power

Nominal Operating Voltage	+24VDC
Operating Voltage Range	+18 to +35VDC (+10VDC Minimum during engine starting)
Maximum Continuous Voltage	+35VDC
Ground Polarity	Negative Ground (Convertible to Positive or Isolated Ground; See the ***Positive/Isolated Grounding*** section on page 18 for further details)
Nominal Operating Current	3.5A @ +24VDC (HPI-PT ECM); 5.8A @ +24VDC (HPI-TP ECM)
Maximum Operating Current	6.0A @ +24VDC (HPI-PT ECM); 7.2A @ +18VDC (HPI-TP ECM)
Sleep Mode Operating Current	60mA (nominal)
Ready Mode Operating Current [ECM On & Engine Not Running]	350mA (nominal)

Environmental

Ambient ECM Housing Operating Temp.	-40° to158°F [-40° to 70°C]
Ambient ECM Heat Sink Operating Temp.	-40° to 140°F [-40° to 60°C]
Maximum ECM Heat Sink Surface Temperature	167°F [75°C] @ 140° F [60°C] ambient air temperature
Storage Temperature	-67° to 176°F [-55° to 80°C]
Vibration Limits	20-100Hz, 93.6mm/sec; 100-200Hz, 6g
Relative Humidity	0-95% Non-Condensing
Salt Fog Resistant	150 Hours, 5% salt @ 95°F
Radiated Immunity	per ENV50140, 10V/m
Conducted Susceptibility	per ENV 50141, 10V/m
Radiated Emissions	per EN55011
Electrical Fast Transient (EFT)	per EN61000-4-4 (Level 3)
Mounting (Off engine)	IP53/NEMA-3R (with connectors facing down)

Physical

Dimensions (Including Heat Sink;	228.0 mm X 182.5 mm X 129.7 mm
excluding mounting brackets)	(8.98 in. X 7.19 in. X 5.11 in.)
Weight	4.15 kg [9.16 lbs.]
Housing Metal	Sheet Steel
Heat Sink Metal	Aluminum

Protection

Voltage Surge Protection	per EN61000-4-5 and +63 V DC supply surge voltage
Reverse Polarity Protection	+28VDC Maximum
High Voltage Protection	+35VDC Maximum Continuous
Electrostatic Discharge (ESD)	per EN61000-4-2 (8kV direct contact, 15kV air discharge)

Standards Compliance

CE	Low Voltage Directive (73/23/EEC), EN50081-2, EN50082-2
NEMA	3R (ECM Housing)
IEC	IP53 (ECM Housing), IP54 (Harness Inline Connectors)
CSA[1]	C282-M (1989)
NFPA[1]	76A

Electrical Interface Characteristics

Lamp/Relay Driver Supply

Supply Voltage	+24VDC Nominal, +35VDC Maximum
Maximum Supply Current	1.5A
Maximum Supply Impedance	0.5Ω

Lamp/Relay Drivers

Driver Type	Low-Side (switched GND/Open)
Driver Voltage Rating	+24VDC Nominal, +35VDC Maximum
Maximum Sink Current (Driver On)	200mA
Maximum Driver Impedance (Driver On)	1Ω
Open Circuit Fault Current (Driver On)	< 2mA (See ***Alarm Lamp/Relay Drivers*** section on page 83 for further details.)

1. The Generator-Drive Control System is suitable for use with generator products intended to comply with the specified standards.

Electrical Interface Characteristics (Continued)

Analog Meter Drivers

Output Current ..... 0 to 1 mA
Maximum Meter Load Impedance 100Ω
Output Accuracy (@ 100Ω meter load)..... < ±0.5% of Full Scale
Output Resolution (@ 100Ω meter load) ..... < 0.5% of Full Scale

Analog (Adjustable) Inputs

Nominal Input Voltage Adjustment Range ..... 0 to 3.177VDC
Maximum Input Voltage 5VDC
Maximum Potentiometer Resistance ..... 5KΩ ± 5%

Remote Potentiometer Specifications (Recommended)

Resistance ..... 5KΩ ± 5%
Linearity 0.25%
Travel ..... 360° x 10
Power Rating ..... 2.5mW minimum @ 70 °C [158 °F]
Insulation Rating ..... 1000MΩ @ 500VDC
Dielectric Strength..... 100V RMS
Operating Temperature ..... -55° to 105°C [-67° to 221 °F]

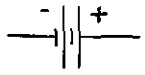
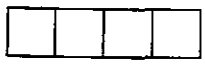
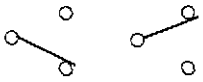
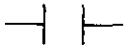
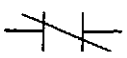
Speed (Frequency) Bias Reference & Voltage Supply

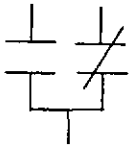
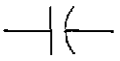
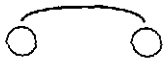
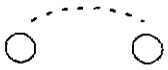
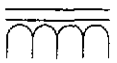
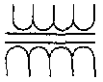
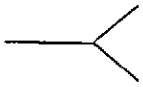
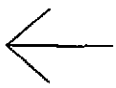
5VDC Reference Voltage..... +5VDC ± 2%; 50mV$_{p-p}$ Maximum ripple voltage; 25mA Maximum Current
8VDC Supply Voltage ..... +8VDC ± 5%; 50mV$_{p-p}$ Maximum ripple voltage; 15mA Maximum Current

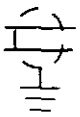
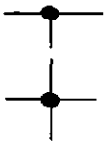
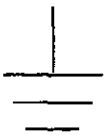
Switch Inputs

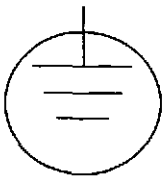
Maximum Source Current..... 100mA (when input is connected to signal GND return)
Input Voltage(measured @ signal input)..... +5VDC when ECM is in Sleep Mode or B+ (approx. 24VDC) when ECM is not in Sleep Mode
Switching Threshold..... +2.5VDC

Appendix K - Electrical Symbols

Name		Symbol
Battery		
Alternator (Frequency Source)		
Resistor		
Variable Resistor (Potentiometer)	3 Terminal Device	
	2 Terminal Device	
Terminal Strip		
Switches:		
(N.O.) Normally Open		
(N.C.) Normally Closed		
Transfer		
Transfer 3 position		
Relay Contact:		
(N.O.) Normally Open		
(N.C.) Normally Closed		

Name	Symbol
Transfer	
Capacitor	
Fuse	
Circuit Breaker	
Jumper Wire	
Coil	
Magnetic Core	
Transformer	
Variable Reluctance Magnetic Pickup	
Female Contact	
Male Contact	

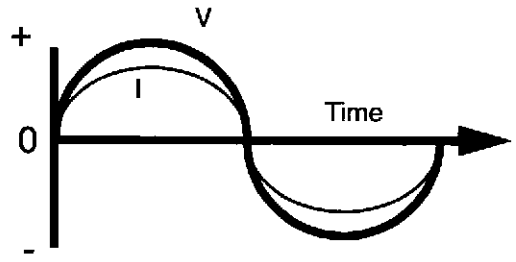
Name	**Symbol**
Shields:	
Shielded Wire	
Shielded Pair	
Crossing of Conductors (wires) not Connected	
Junction of Connected Conductors (wires)	
Grounded Chassis or Frame Connection Conducting connection to a chassis or frame, of equivalent chassis connection of a printed wiring board. The chassis or frame (or equivalent chassis connection of a printed wiring board) *may be at a different potential* than the earth or structure in which this chassis or frame (or printed wiring board) is mounted.	
Direct Conducting Connection to Circuit Return Conducting connection to a structure that services a function similar to that of an earth ground (that is, a structure such as a frame of an air, space or land vehicle that is not conductively connected to earth.)	

Name	**Symbol**
Earth Safety Ground ** This symbol may be used in place of symbol for direct conducting connection to circuit return to indicate a ground connection having a specified protective function (e.g., for protection against electrical shock in case of a fault). ** Ref. Electrical and Electronics Graphic Symbols and abbreviated name.	

Glossary of Power Terms

A.C. -- See Alternating Current.

Alternating Current -- Electrical current which repeatedly varies from zero to a positive maximum value to zero to a negative maximum value and back to zero at a periodic rate. Since the applied voltage continually reverses polarity, the resultant current flow alternates in direction within the circuit.



Alternating Current = I
Applied Voltage = V

AMP – An abbreviation for the term Ampere.

Ampere – The unit of measure of electrical current flow. One ampere of current will flow when one volt of electrical potential is applied across one ohm of resistance.

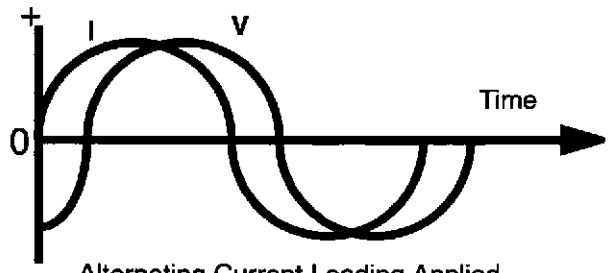
Auto-Transformer -- A transformer of single coil construction in which both the primary and secondary connections are made on the same coil but use different taps.

Bi-State – Refers to the type of eletrical device, or the signal supplied by such a device, that has two discrete and mutually exclusive states. For example, a two-position toggle switch is a bi-state switching device that is either 'open' or 'closed'.

B- -- Symbol used to designate the negative polarity of a D.C. voltage supply.

B+ – Symbol used to designate the positive polarity of a D.C. voltage supply.

Capacitance -- The property of a device which resists changes in voltage. In an A.C. circuit, a capacitive load will cause the voltage to lag behind the current flow. Stated more conventionally, the current leads the applied voltage. A capacitive load is, therefore, a leading power factor load (see Power Factor).



Alternating Current Leading Applied Voltage Caused by Capacitive Load

Capacitor -- A device possessing the property of capacitance. A typical capacitor consists of two conducting surfaces separated by an insulating material. A capacitor stores electrical energy, blocks the flow of D.C. and permits the flow of A.C. to a degree largely dependent on the capacitance and the frequency of the applied A.C.

Circuit -- An electrical path through which an electric current may flow from a voltage supply to a load and return. A closed or complete circuit is one where current is flowing. An open circuit is where the path has been disrupted, such as an open switch or circuit breaker, thus stopping current flow.

Circuit Breaker -- A protective device for opening a circuit where current flow exceeds a predetermined value.

Circulating Current -- Also called Cross Current. Current which flows between paralleled generators, most apparent with no external load on the paralleled generators. Circulating current is caused (1) by unequal excitation of the generators (reactive current, which may be reduced by changing the voltage regulator adjustment or connections); and (2) by unequal power from the engines that are driving the generators real current (and power) which can be eliminated by governor adjustments.

Conductor – A wire cable, bus, or other device intended to distribute current from the supply to the load. Technically, a conductor is any device which will permit the flow of current.

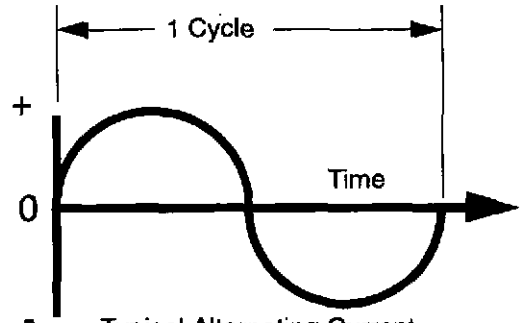
Contactor – A device for opening and closing an electric circuit. Contactors are normally used in motor circuits where large amounts of current are controlled.

Cross Current – See Circulating Current.

Cross Current Compensation -- A term, no longer approved, for a circuit arrangement that made paralleled generators share the reactive component of load current in proportion to the generator ratings. The circuit arrangement could also essentially eliminate the reactive component of circulating current flowing between paralleled generators (See Reactive Differential (Cross Current) Compensation and Reactive Droop Compensation).

Current (Electrical, Symbol I) -- The rate of transfer of electricity from one point to another. Current is usually a movement of electrons, but may also be a movement of positive ions, negative ions, or holes. Current is usually measured in amperes.

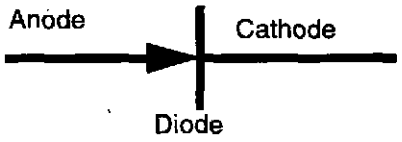
Cycle 00 -- A complete set of events before repetition occurs. In alternating current or voltage, a cycle starts at zero, continues to a maximum positive value returns to zero, continues to a maximum negative value, and is completed at zero.



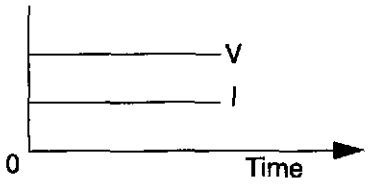
Typical Alternating Current or Voltage Cycle

D.C. -- See Direct Current.

Diode -- A two terminal solid-state device which permits current to flow in one direction, but not in the other. In alternating current circuits, a diode will permit one half cycle to flow but will resist the flow of the opposite half cycle of current. Thus, alternating current is converted to direct current by a diode.



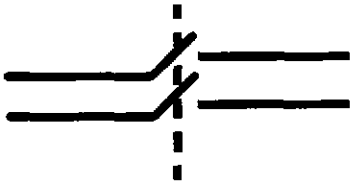
Direct Current (D.C.) -- An electric current that flows in one direction only. Conventional direct current is defined as flowing from positive to negative in the circuit outside the source (example: a battery or combination of diodes). Conventional current flows in the direction of the arrow through a diode. Electron flow and U.S. Navy designated current flow in the opposite direction.



Direct Current I
Applied Voltage V

Distribution Panel -- A control panel containing circuit breakers, transfer switches, and other control devices which distribute the electrical power, such as from a generator set to the loads.

Double Pole Switch -- A switch which has two sets of contacts which operate on two independent circuits at the same time.



Typical Double Pole Switch Shown as a Single Throw Type in the "Off" Position

E -- Symbol used to represent electrical potential (voltage).

Earth Ground -- An intentional connection made between the earth and the metallic frame of electrical equipment as a means to eliminate possible voltage hazards to personnel. Earth Ground also serves, in some cases, to reduce electrical interference in sensitive circuits such as television and radio equipment.

EMI -- An abbreviation for the term electromagnetic interference which is sometimes caused by SCR type devices and evident in radio and television operation.

Energy -- The capability of performing work.

Frequency -- The number of complete cycles of alternation current per unit of time. Typically, frequency is expressed in cycles per second or Hertz (HZ).

Frequency Droop -- A decrease in steady state frequency output of a generator caused by an increase in load. This decrease in frequency from the no load frequency is expressed as a percentage of the full load frequency or:

$$\%F_{Droop} = \frac{(F_{NL} - F_{FL}) \times 100}{F_{FL}}$$

Where: $\%F_{Droop}$ = *Percent Frequency Droop*
F_{NL} = *No Load Frequency*
F_{FL} = *Full Load Frequency*

A three percent frequency droop may be used to provide governor stability and for load sharing between paralleled generator sets.

Frequency Meter -- An instrument deigned to measure the frequency of an alternation current system.

Gain -- The increase in signal power that is produced by an amplifier, usually given as the ratio of output to input voltage, current, or power. In generator set systems, a low gain setting on the electric governor or voltage regulator provides a relatively small signal to correct variations of frequency or voltage. The frequency and/or voltage may wander or be slow in recovering to stable conditions after a load change. A high gain setting provides a relatively large signal to correct variations of frequency and/or voltage. If the gain is set too high, the electric governor or voltage regulator may over-correct. This may produce unacceptable hunting of the frequency and/or voltage.

Gate -- The third terminal of an SCR to which a voltage must be applied before the SCR will conduct.

Governor -- A device which controls engine speed and thus the generator output frequency.

Ground -- A connection, either accidental or intentional, between an electrical potential and the earth or some conducting body serving in place of the earth.

Heat Sink -- A device which absorbs heat from electrical devices such as diodes and SCR's and dissipates the heat to the surrounding air.

Hertz -- A term equivalent to cycles per second (See Frequency).

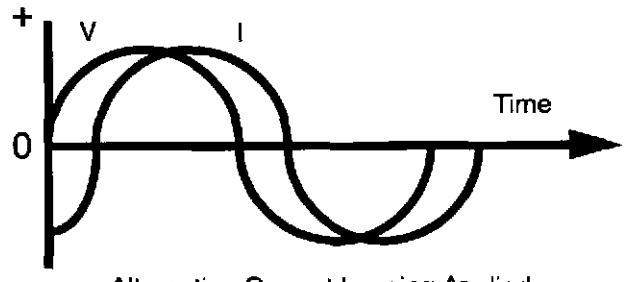
Hunting -- Oscillation in frequency or in voltage where steady state conditions are not reached, particularly after a load transient change.

I -- Symbol used to represent current.

Impedance -- The opposition to the flow of alternating current.

Induced Voltage -- The voltage which is produced by relative motion between a wire and a magnetic field.

Inductance -- The property of a device which resists changes in current. In an A.C. circuit, an inductive load will cause the current to lag behind the applied voltage. Stated more conventionally, the current lags the applied voltage. An inductive load is therefore a lagging power factor load (see Power Factor).



Alternating Current Lagging Applied Voltage Caused by Inductive Load

Inductor – A device possessing the property of inductance. An inductor stores electrical energy, passes D.C., and opposes the flow of A.C. to a degree largely dependent on the inductance and the frequency of the applied A.C. A typical inductor consists of a coil of wire.

In Phase – Alternating currents or voltages are in phase with respect to each other if they cross through zero and reach their positive and negative maximum values together.

Insulation – A non-conductive material such as rubber or plastic intended to prevent current from flowing. Technically, insulation is any material which stops the flow of current.

Isochronous – As it applies to engine governors, maintaining constant steady state speed regardless of the load within the rating of the engine. Thus, a generator set is said to be isochronous if the frequency remains the same regardless of load.

Normally Closed (Symbol N.C.) – As applied to a magnetically operated device such as a valve or the contacts of a relay, Normally Closed indicates that the valve or the relay contacts are closed when no power is supplied to the operating magnet.

Normally Open (Symbol N.O.) – As applied to a magnetically operated device such as a valve or the contacts of a relay, Normally Open indicates that the valve or the relay contacts are open when no power is supplied to the operating magnet.

Ohm – The unit of measure of electrical resistance. One ohm of resistance will allow a current of one ampere to flow with an applied potential of one volt.

Ohmmeter – An instrument for measuring electrical resistance.

Ohm's Law – A fundamental law expressing the relationship between voltage, current, and resistance in electrical circuits. The law states that E = IR or voltage is equal to current times resistance.

Open Circuit – 1) A circuit that does not provide a complete path for the flow of current. 2.) A condition of an electrical circuit caused by the breaking of continuity of one or more conductors of the circuit; often an undesired condition. 3) An arrangement of conductors and equipment that depends upon lack of continuity for operation, as open-circuit telegraphy; a circuit in which continuity is incomplete or interrupted.

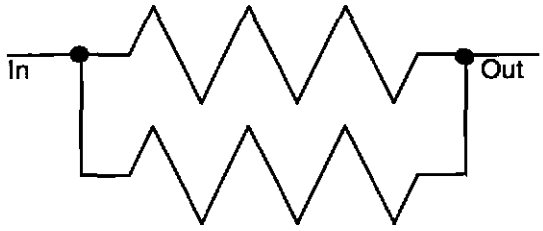
Oscillogram – The permanent record produced by an oscillograph, or a photograph of the trace produced by an oscilloscope.

Oscillograph – A measurement device for determining waveform by recording the instantaneous values of a quantity such as voltage as a function of time.

Oscilloscope – An instrument primarily for making visible the instantaneous value of one or more rapidly varying electrical quantities as a function of time or of another electrical or mechanical quantity.

Oscilloscope Dual Beam – An oscilloscope in which the cathode-ray tube produces two separate electron beams that may be individually or jointly controlled.

Parallel Connection – An electrical connection in which the input of one element is connected to the input of another element. The output connections are similarly connected together thus providing two or more paths for current to flow.



Parallel Connection

Parallel Operation – The method by which two or more generators having the same voltage and frequency characteristics are connected to a common load.

Permanent Magnet Generator – A generator which uses permanent magnets to create a magnetic field. As applied to Cummins Generators; a permanent magnet generator, within the main generator, supplies the power to the voltage regulator which in turn supplies the power to the exciter field. The permanent magnet generator still supplies power during a short circuit of the main generator. This permits the main generator to sustain high short circuit currents. The output of the permanent magnet generator is electrically isolated from the main generator output and is not adversely affected by main generator output waveform distortion such as from SCR type loads.

PMG – See Permanent Magnet Generator.

Polarity -- An electrical term which indicates the direction in which current flows in a conductor. In a direct current system, current flows in the same direction. In an alternating current system, current changes direction as the polarity of the A.C. voltage source changes.

Potential – Another term to indicate voltage.

Potential Difference – The difference in voltage between two points in a circuit.

Power – Defined as the rate of performing work. Mechanical power is measured in horsepower or kilowatts. Electrical power is measured in kilowatts.

Power Factor – The ratio of the true power (KW) requirements of a load to the apparent power (KVA) requirements of a load. The combined loads applied to a power source may have a resistive, capacitive, or inductive effect.

Resistive loads such as incandescent lighting or resistive heating elements cause no shift in the voltage/current wave forms and are, therefore, unity (1.0) power factor loads.

Inductive and capacitive loads, however, cause the voltage and current waveforms to shift with respect to one another. These types of loads are commonly called power factor loads (i.e., the power factor is less than 1.0).

See INDUCTANCE and CAPACITANCE for more information.

Power factor is frequently multiplied by 100 and expressed as a percentage.
The formula for power factor is:

$$Power\ Factor = \frac{True\ Power\ (KW)}{Apparent\ power\ (KVA)}$$

R -- Symbol used to represent resistance.

Reactive Differential (Cross Current) Compensation -- A circuit arrangement for operating generators in parallel with no generator voltage droop. Reactive Differential Compensation is accomplished by a differential interconnection of the secondaries of the generator current transformers used for Reactive Droop Compensation. This arrangement is not often used and is very difficult to set up when paralleling generators of different capacities.

Reactive Droop Compensation -- A circuit arrangement that creates a droop in generator output voltage that is proportional to the reactive load current. This circuit arrangement makes the paralleled generators share the reactive component of the load current in proportion to the generator ratings. It also can essentially eliminate the reactive component of circulating current which may flow between paralleled generators. The Reactive Droop Compensation arrangement is commonly called the Generator Paralleling Module.

Relay -- An electromechanical device having a magnetic coil which, when energized, opens or closes several sets of contacts.

Resistance -- Opposition to the flow of current.

Resistor (Symbol R) – A device or component designed to have a definite amount of resistance. Resistors are used in circuits to limit current flow or to provide a voltage drop.

Resistor, Fixed – A component which is used to control voltage and current by introducing a constant resistance of known value into the circuit.

Resistor, Variable – Similar to a fixed resistor except the resistance value can be adjusted. The voltage adjust rheostat is a variable resistor.

Rheostat -- A variable resistor.

Series Connection -- An electrical connection in which the input of one element is connected to the output of another element providing only one path for current to flow.

Series Connection

Short Circuit – An abnormal connection (including an arc) of relatively low resistance, whether made accidentally, or intentionally, between two points of different potential in a circuit. Equipment, not protected by fuse or circuit breakers, may be damaged by a short circuit.

Shunt Trip – An electromechanical device which, when energized, trips the main line circuit breaker.

Single Pole Switch -- A switch which has only one set of contacts.

Typical Single Pole Switch Shown as a Single Throw Type in the "Off" Position

Single Throw Switch -- A switch which opens a set of contacts in one switch position and closes the contacts in the other position.

Typical Single Throw Switch Shown as a Single Pole Type in the "Off" Position

Speed Droop -- A decrease in steady state speed of an engine due to an increase in applied load. This decrease in speed from the no load speed is expressed as a percentage of full load speed or:

$$\%S_{Droop} = \frac{(S_{NL} - S_{FL}) \times 100}{S_{FL}}$$

Where: $\%S_{Droop}$ = *Percent Speed Droop*
S_{FL} = *Full Load Speed*
S_{NL} = *No Load Speed*

Solenoid -- An electromechanical device which when energized, acts on a movable core or plunger in the center of the energizing coil to perform mechanical work.

Solid-State -- A term which applies to electronic devices which are constructed using semiconductor material. Such devices include transistors, SCR's, and diodes.

Stability -- Freedom from undesired variations or oscillation. In generator set systems, the generator set is stable if it can maintain or quickly re-establish steady state conditions of voltage and frequency after a sudden load change.

Surge Suppressor -- A device capable of conducting current in either direction in the presence of high transient voltages thus protecting devices that could otherwise be damaged.

Synchronism -- The condition where two or more generators are operating at the same frequency and output voltage and are in phase with one another.

Synchronizing -- The procedure of matching the frequency, phase rotation, voltage, and phase relationship of one generator to another for purposes of paralleling the units onto a common bus.

Synchronous -- A generator whose output frequency is directly related (proportional) to the speed of the engine driving the generator.

Tachometer -- An instrument for measuring the rate of rotation expressed in revolutions per minute.

Temperature Drift -- A change in the value of a component caused by changes in operating temperature.

Terminal -- A mechanical device for making electrical connections.

Thyristor (SCR) -- A Silicon-Controlled Rectifier is a structure with an external connection (gate) to one of the inter layer. With no gate current, the SCR characteristic is that of a four-level diode.

Transformer -- Frequently, a device using a laminated iron core with a primary and secondary winding. A transformer changes some level of input (primary) voltage or current to a proportional output (secondary) voltage or current (see *Current Transformer* and *Potential Transformer*).

Transient -- A temporary change from the steady state conditions.

V -- Symbol used to represent voltage.

Volt -- The unit of measure of electrical potential (voltage). One volt of electrical potential will force a current of one ampere to flow through a resistance of one ohm.

Voltage -- Electrical potential or pressure which forces current to flow through a circuit.

Voltage Dip -- A temporary reduction in voltage generally resulting from an increase in load.

Voltage Droop -- A decrease in steady state voltage of a generator due to an increase in load applied. This decrease in voltage from the no load voltage is expressed as a percentage of the full load voltage or

$$\%V_{Droop} = \frac{(V_{NL} - V_{FL}) \times 100}{V_{FL}}$$

Where: $\%V_{Droop}$ = *Percent Voltage Droop*
V_{NL} = *No Load Voltage*
V_{FL} = *Full Load Voltage*

Voltage Droop Compensation -- A system which permits paralleled generators to share the currents of a load in proportion to the generator set ratings.

Voltage Regulator -- A device which controls the voltage output of a generator at a preset value regardless of the amount of load applied.

Voltmeter -- An instrument designed to measure electrical potential or voltage.

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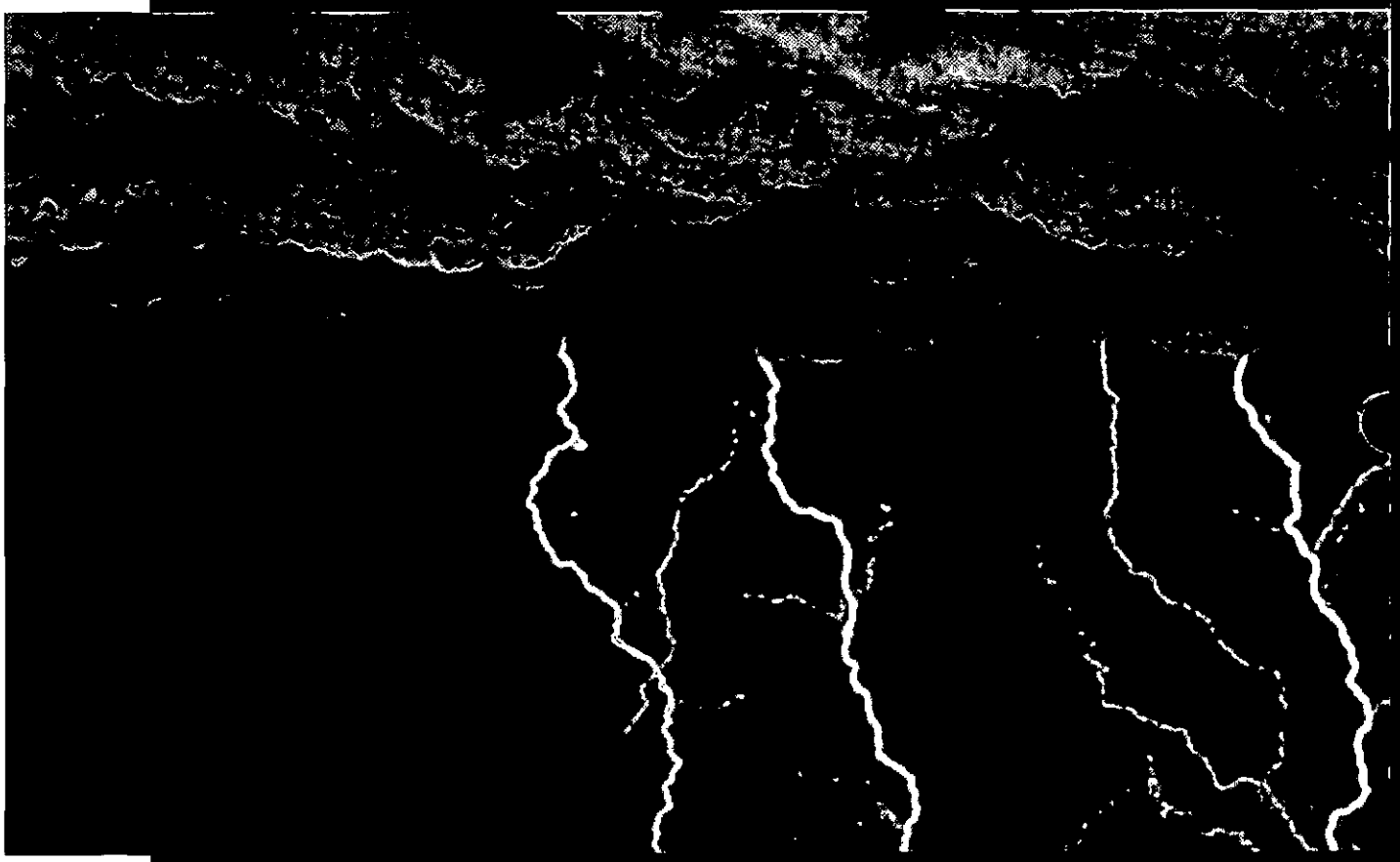

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