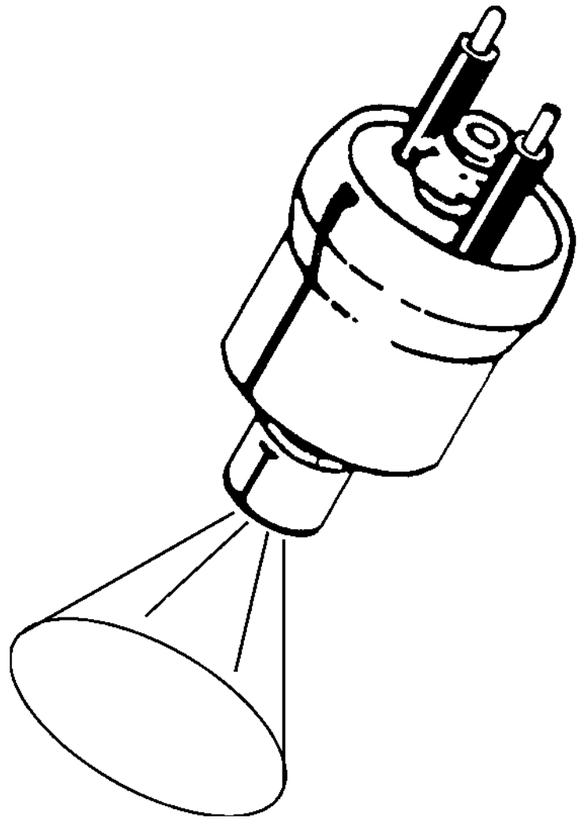
P/N 7788883-2
4-1996

Workshop Manual
"NC" Models

TBI Diagnostic (4.3 Gi, 5.7 Gi/GSi) - GM



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VOLVO PENTA
Volvo Penta of the Americas, Inc.
1300 Volvo Penta Drive
Chesapeake Virginia 23320
U.S.A.

VOLVO PENTA®

⚠ Safety Warning

This Workshop Manual will alert you to certain procedures that must be done very carefully. If you ignore this information, you could...

- **Injure yourself or people around you**
- **Injure the boat operator, boat passengers, or people around the boat**
- **Damage the Volvo Penta product or its systems**

Understand the following symbols before proceeding:

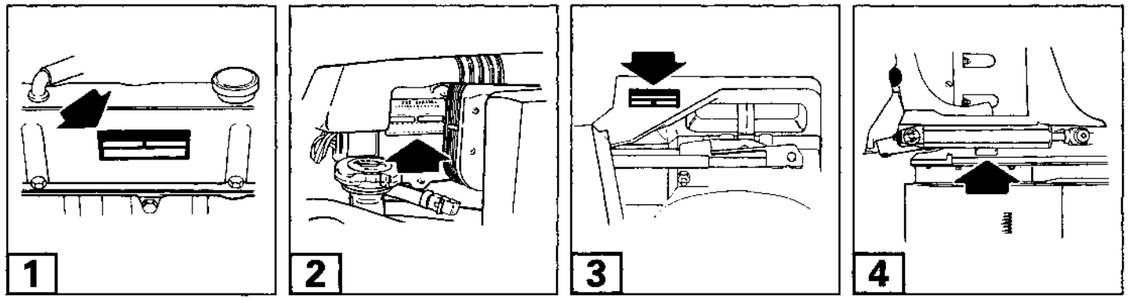
⚠ Safety Warning	Alerts you to the possibility of danger and identifies information that will help prevent injuries.
Note	Identifies information that will help prevent damage to machinery.
Important	Appears next to information that controls correct assembly and operation of the product.

This Workshop Manual is written for qualified, factory trained service technicians familiar with the use of Volvo Penta special tools.

This Workshop Manual tells you how to correctly maintain and service Volvo Penta products and systems. When correctly serviced, the Volvo Penta product will be reliable and safe to operate.

When Volvo Penta special tools are called for, use them. Where mentioned, the tools are required to perform the service procedure.

If you use service procedures or service tools that are not recommended in this manual, YOU ALONE must decided if your actions might injure people or damage the Volvo Penta product.



VOLVO PENTA MODEL IDENTIFICATION

Engine Model identification is located on the engine valve cover for four cylinder (in-line) models, on the inside of the port valve cover for V6 & V8 models, or on the Thick Film Ignition (TFI) module bracket for Ford fuel injection models. The identification numbers **must** correspond with the transom shield and drive unit numbers. See below.

1 Engine Model Number (GL, GS, and Gi Models)

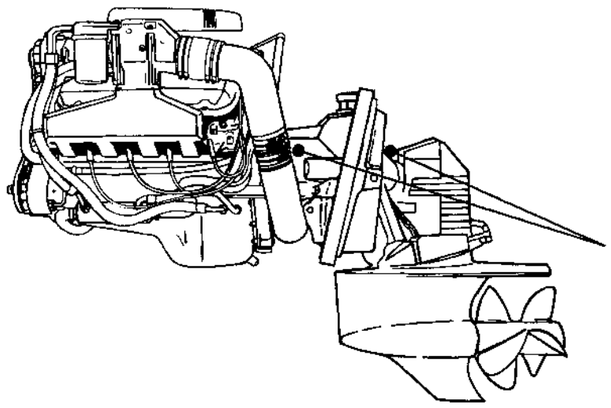
2 Engine Model Number (Fi Models)

SX MODELS:

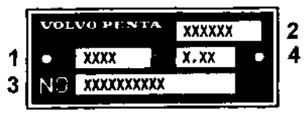
3 Transom Shield Model Number

4 Drive Unit Model Number

DP & DPX MODELS:



Nunber plate for drive unit and transom shield.
Only fields 2 and 3 are filled for transom shield.



1. Product Designation
2. Model Number
3. Serial Number
4. Reduction Ratio

MARINE ELECTRONIC FUEL INJECTION (MEFI) DIAGNOSTIC MANUAL

The Table of Contents on the following page indicates the sections covered in this manual. At the beginning of each individual section is a Table of Contents which gives the page number on which each subject begins.

When reference is made in this manual to a brand name, number, or specific tool, an equivalent product may be used in place of the recommended item.

All information, illustrations, and specifications contained in this manual are based on the latest product information available at the time of publication approval. The right is reserved to make changes at any time without notice.

NOTICE: When fasteners are removed, always reinstall them at the same location from which they were removed. If a fastener needs to be replaced, use the correct part number fastener for that application. If the correct part number fastener is not available, a fastener of equal size and strength (or stronger) may be used. Fasteners that are not reused, and those requiring thread locking compound will be called out. The correct torque value must be used when installing fasteners that require it. If the above conditions are not followed, parts or system damage could result.

⚠ Safety Warning

Before performing any tests or checks recommended in this manual, read the section called Safety located at the end of this manual.

This Workshop Manual is one of a set of nine that covers *Volvo Penta* sterndrive models. All nine books can be ordered as a set from *Volvo Penta Parts.* Order P/N 7788880-8.

Individual Workshop Manuals covering these models are also available. Order the following part numbers from *Volvo Penta Parts.*

- **P/N 7788881-6 *SX, DP-S Drive Unit and Transom Shield***
  Includes information on Transom Shield, Upper Gear Unit and Lower Gear Unit service; Drive Unit removal and installation; Propellers; and Trim/Tilt hydraulic operation.

- **P/N 7788882-4 *MFI Diagnostic (5.0 Fi, 5.8 Fi/FSi) - Ford***
  Includes step by step troubleshooting procedures for all MFI Ford related components and wiring.

- **P/N 7788883-2 *TBI Diagnostic (4.3 Gi, 5.7 Gi/GSi) - GM***
  Contains troubleshooting procedures for all TBI GM models and related components.

- **P/N 7788884-0 *MFI Diagnostic (7.4 Gi/GSi, 8.2 GSi) - GM***
  Includes step by step troubleshooting procedures for all MFI GM related components and wiring.

- **P/N 7788885-7 *SP-DP Drive Unit and Transom Shield***
  Includes information on Transom Shield, Upper Gear Unit, Lower Gear Unit service; Drive Unit removal and installation; Propellers; and Trim/Tilt hydraulic operation and servicing procedures.

- **P/N 7788886-5 *Engine Components***
  Includes information on Engine service and troubleshooting; Engine removal and installation; Steering systems; Throttle and Shift Control systems; and Cooling systems.

- **P/N 7788887-3 *Electrical & Ignition System***
  Includes service and troubleshooting information on Cranking systems; Charging systems; Trim/Tilt electrical systems; Ignition systems; and Engine and Instrument wiring diagrams.

- **P/N 7788888-1 *Fuel System***
  Includes service and troubleshooting information on all carburetor, MFI and TBI fuel systems and related components.

- **P/N 7788889-9 *DPX-Lower Unit and Xact™ Steering System***
  Includes specific information for repair and overhaul of the DPX Lower unit and Xact™ steering systems not covered in the SP and DP Workshop manual.

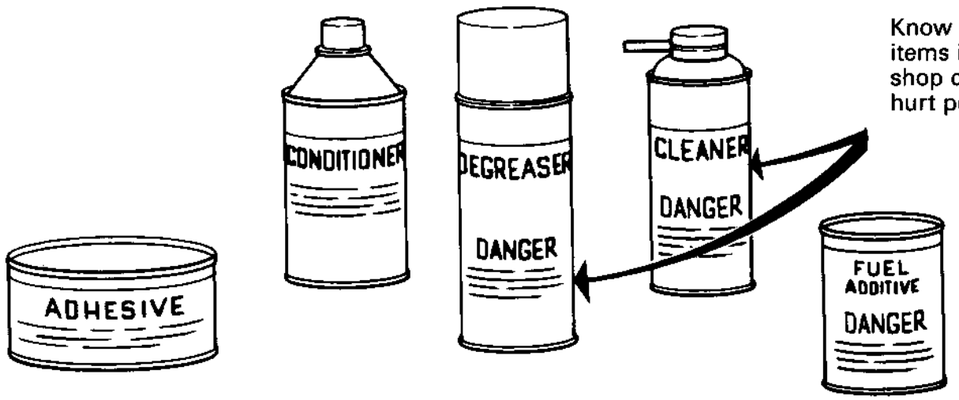
NOTES

- Know items in and around repair area which can ignite gasoline fumes . . . Control them if fumes are smelled.

  - Matches, cigarettes, torches, welders
  - Electric motors (with unsealed cases)
  - Electric generators (with unsealed cases)
  - Light switches
  - Appliance pilot lights (furnace, dryer, water heater)
  - Loose wires on running engines
  - ????????

How many of these are in your area?

Hazardous Products



Know how items in the shop can hurt people . . .

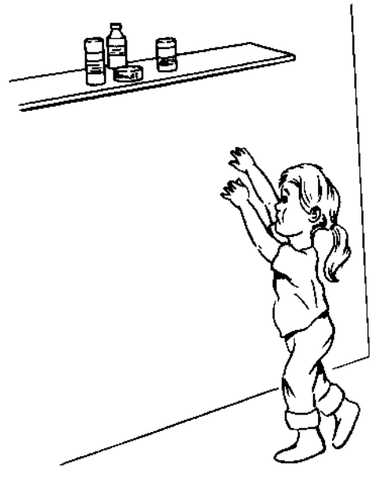
Read the container label. It tells you . . .

- "How, and where, to use,"
- "How to give First Aid," and have "recommended" first aid materials on hand- should an emergency arise
- "How to dispose of can,"

Remember: Little children are very curious and will try to taste everything, so . . .

. . . yummmmmmmm

▶ Keep containers away from children



CONTENTS

FOREWORD

This service manual includes general description, diagnosis, symptoms, and on-board service procedures for the fuel control and ignition systems used on GM equipped Marine Electronic Fuel Injection (MEFI) engines.

INTRODUCTION

The following manual has been prepared for effective diagnosis of the Marine Electronic Fuel Injection (MEFI) system

All information, illustrations and specifications contained in this manual are based on the latest product information available at the time of publication approval. The right is reserved to make changes at any time without notice.

This manual should be kept in a handy place for ready reference. If properly used, it will meet the needs of technicians and boat owners.

⚠ Safety Warning

Volvo Penta Workshop manuals are intended for use by professional, qualified technicians. Attempting repairs or service without the appropriate training, tools, and equipment could cause damage to the boat and could possibly result in personal injury to the operator and occupants.

CAUTION

To reduce the chance of personal injury and/or property damage, the following instructions must be carefully observed.

Proper service and repair are important to the safety of the service technician and the safe, reliable operation of all Marine Electronic Fuel Injection (MEFI) equipped engines. If part replacement is necessary, the part must be replaced with one of the same part number or with an equivalent part. Do not use a replacement part of lesser quality.

The service procedures recommended and described in this service manual are effective methods of performing service and repair. Some of these procedures require the use of tools specifically designed for the purpose.

Accordingly, anyone who intends to use a replacement part, service procedure, or tool which is not recommended by the boat manufacturer, must first determine that neither his safety nor the safe operation of the boat will be jeopardized by the replacement part, service procedure, or tool selected.

It is important to note that this manual contains various Cautions and Notices that must be carefully observed in order to reduce the risk of personal injury during service or repair, or the possibility that improper service or repair may damage the boat or render it unsafe. It is also important to understand that these 'Cautions' and 'Notices' are not exhaustive, because it is impossible to warn of all the possible hazardous consequences that might result from failure to follow these instructions.

Battery gas is explosive!
While charging or discharging, remember . . .

No Smoking
No Flames
No Sparks

Never yank cables off battery posts . . . it's a sure way to make lots of sparks . . . surrounded by battery gas.

Don't check battery condition by placing metal objects across posts.

You're sure to make sparks and serious burns are possible.

After Charging . . .

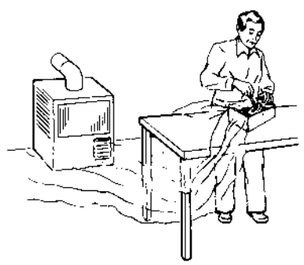
- Shut off charger
- Pull charger plug out of 110V outlet

Then . . .

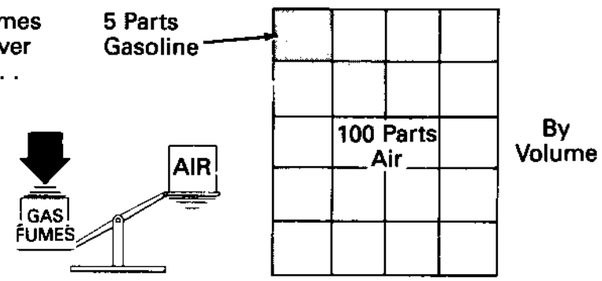
- Take charger cables off battery posts

Gasoline! Handle With Care

- When you smell any odor of gasoline, explosion is possible
- Gasoline fumes are heavy and will sink to the lowest point in the boat or room, and will stay there . . . waiting
- If the air around you is quiet . . . the pilot light in the heater may ignite the heavy fumes before your nose ever smells the fumes . . .



Gasoline explodes easily and violently when mixed as shown . . .



Store in sturdy, sealed gas can . . . and . . . keep outside

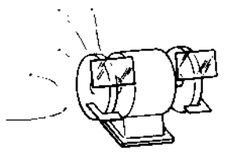
What Can You Do?

- Store properly . . .
- Fill portable tanks outside boat to prevent spillage in boat
- Use fuel for fuel . . . not for a cleaner, degreaser
- If fumes are smelled (in shop, basement, garage), immediately:
- Put out open flames, cigarettes, sparking devices
- Wipe up spill or leak; get towels, rags outside fast
- Check lowest area for fumes; open doors or windows

- Exhaust gases of running engines contain carbon monoxide . . . you can't see it . . . you can't smell it . . . you can't taste it . . . but it's there whenever an engine runs . . . and it's deadly!

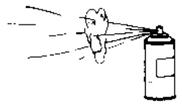
When you smell the other gases in the exhaust, you are inhaling carbon monoxide. Run engines only in well ventilated areas.

Eyes Need Help



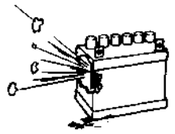
- Grinding

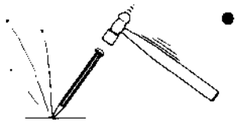
- Sprayed Cleaners, Paints



- Ends of Cables

- Acid

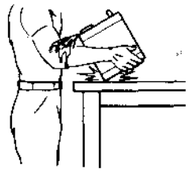




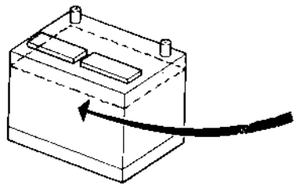
- Chiseling (steel on steel) (Tip: Use plastic or brass type hammers. They don't chip off as easily as steel hammers.)

Protect Eyes . . . Wear Safety Glasses

Handling Lead Acid Batteries



- If spilled or splashed on any part of body. .



Strong Acid Solution (Sulfuric Acid)

Wash with lots of water . . .

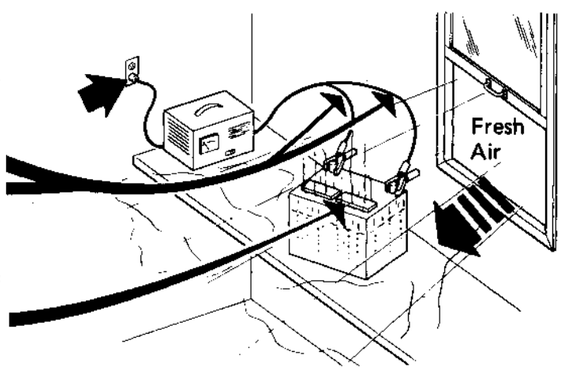
- If solution gets into eyes . . . Wash . . . and see a Doctor, fast!

Charging Lead Acid Batteries

1. Attach and remove these cables with charger **unplugged** from 110 volt wall socket. (Prevents shocks if the charger is defective.)

2. Observe correct polarity when connecting these charger leads.

3. Always charge in a well ventilated area. Charging causes acid solution to give off hydrogen gas through the vents in the caps . . . Make sure vents are open. If clogged, pressure inside may build . . . battery may explode.



MARINE ELECTRONIC FUEL INJECTION (MEFI)

SECTION 1

GENERAL INFORMATION

CONTENTS

VISUAL/PHYSICAL INSPECTION

A careful visual and physical inspection must be performed as part of any diagnostic procedure. This can often lead to fixing a problem without further steps. Inspect all vacuum hoses for correct routing, pinches, cuts, or disconnects. Be sure to inspect hoses that are difficult to see. Inspect all the wires in the engine compartment for proper connections, burned or chafed spots, pinched wires, or contact with sharp edges or hot exhaust manifolds. This visual/physical inspection is very important. It must be done carefully and thoroughly.

BASIC KNOWLEDGE AND TOOLS REQUIRED

To use this manual most effectively, a general understanding of basic electrical circuits and circuit testing tools is required. You should be familiar with wiring diagrams, the meaning of voltage, ohms, amps, the basic theories of electricity, and understand what happens in an open or shorted wire.

To perform system diagnosis, several special tools and equipment are required. Please become acquainted with the tools and their use before attempting to diagnose the system. Special tools which are required for system service are illustrated at the end of this section.

ELECTROSTATIC DISCHARGE DAMAGE

Electronic components used in control systems are often designed to carry very low voltage, and are very susceptible to damage caused by electrostatic discharge. It is possible for less than 100 volts of static electricity to cause damage to some electronic components. By comparison, it takes as much as 4,000 volts for a person to even feel the zap of a static discharge.

There are several ways for a person to become statically charged. The most common methods of charging are by friction and by induction. An example of charging by friction is a person sliding across a seat, in which a charge of as much as 25,000 volts can build up. Charging by induction occurs when a person with well insulated shoes stands near a highly charged object and momentarily touches ground. Charges of the same polarity are drained off, leaving the person highly charged with the opposite polarity. Static charges of either type can cause damage, therefore, it is important to use care when handling and testing electronic components.

DIAGNOSTIC INFORMATION

The diagnostic charts and functional checks in this manual are designed to locate a faulty circuit or component through logic based on the process of elimination.

The charts are prepared with the requirement that the system functioned correctly at the time of assembly and that there are no multiple failures.

Engine control circuits contain many special design features not found in standard vehicle wiring. Environmental protection is used extensively to protect electrical contacts and proper splicing methods must be used when necessary.

The proper operation of low amperage input/output circuits depend upon good continuity between circuit connectors. It is important before component replacement and/or during normal troubleshooting procedures that a visual inspection of any questionable mating connector is performed. Mating surfaces should be properly formed, clean and likely to make proper contact. Some typical causes of connector problems are listed below.

1. Improperly formed contacts and/or connector housing.
2. Damaged contacts or housing due to improper engagement.
3. Corrosion, sealer or other contaminants on the contact mating surfaces.
4. Incomplete mating of the connector halves during initial assembly or during subsequent troubleshooting procedures.
5. Tendency for connectors to come apart due to vibration and/or temperature cycling.
6. Terminals not fully seated in the connector body.
7. Inadequate terminal crimps to the wire.

WIRING HARNESS SERVICE

Wire harnesses should be replaced with proper part number harnesses. When signal wires are spliced into a harness, use the same gage wire with high temperature insulation only.

With the low current and voltage levels found in the system, it is important that the best possible bond be made at all wire splices by soldering the splices as shown in Figure 1.

Use care when probing a connector or replacing connector terminals. It is possible to short between opposite terminals. If this happens, certain components can be damaged. Always use jumper wires with the corresponding mating terminals between connectors for circuit checking. **NEVER** probe through connector seals, wire insulation, secondary ignition wires, boots, nipples or covers. Microscopic damage or holes may result in eventual water intrusion, corrosion and/or component or circuit failure.

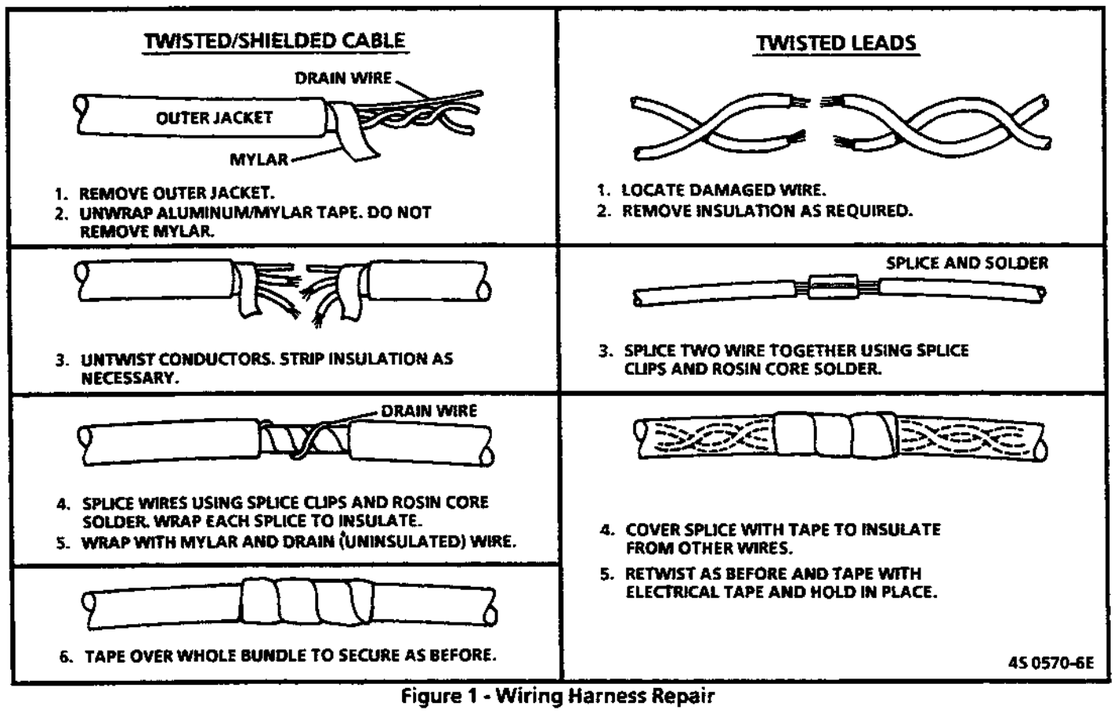


Figure 1 - Wiring Harness Repair

Part B - Marine Products and Safety of People* Who Fix Them

Part A talked about safe boating and how you, the mechanic, can help keep it safe for the boater. But what about you? Mechanics can be hurt while . . .

- Servicing boats
- Servicing stern drives
- Troubleshooting problems
- Testing their work

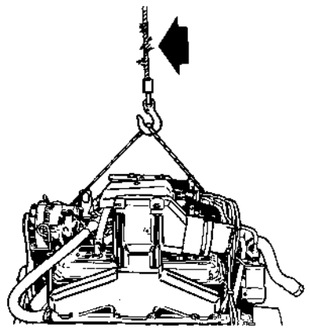
Some items you'll know . . . others you may not.

Handling Engines

When Lifting Engines

- Engine may drop suddenly

If hoist is in poor shape . . . or too small for the job



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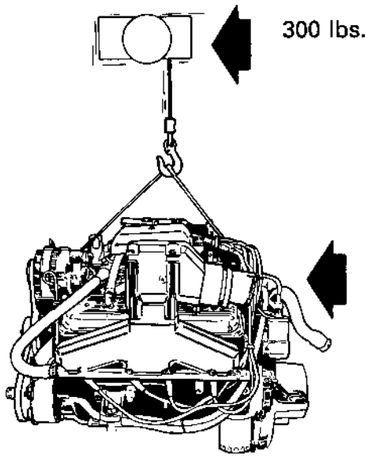


DR3469

- Make sure shop aids have extra capacity . . . . . and keep them in good repair!

When Running Engine with Engine Compartment Cover Removed

Engine compartment cover is a guard. When you remove cover/guard to work on the engine remember . . .

- Loose clothing (open shirt sleeves, neckties)
- Long hair
- Jewelry (rings, watches, bracelets)
- Hands, arms, belts . . . can be caught by moving belts or spinning pulleys.
- Handle high voltage ignition components carefully. They can shock you and may cause you to recoil into moving parts

Two people working together on running engine must look out for each other . . . Never, ever, hit the key to start engine before signaling your partner. (He may be leaning over the engine with hands on a belt . . . or a "hot" electrical part . . . near the propeller . . . or ? ? ?)

*Mechanics, technicians, backyard do-it-yourselfers.

Summing Up

Now you know some things that can take the joy out of enjoyable boating.

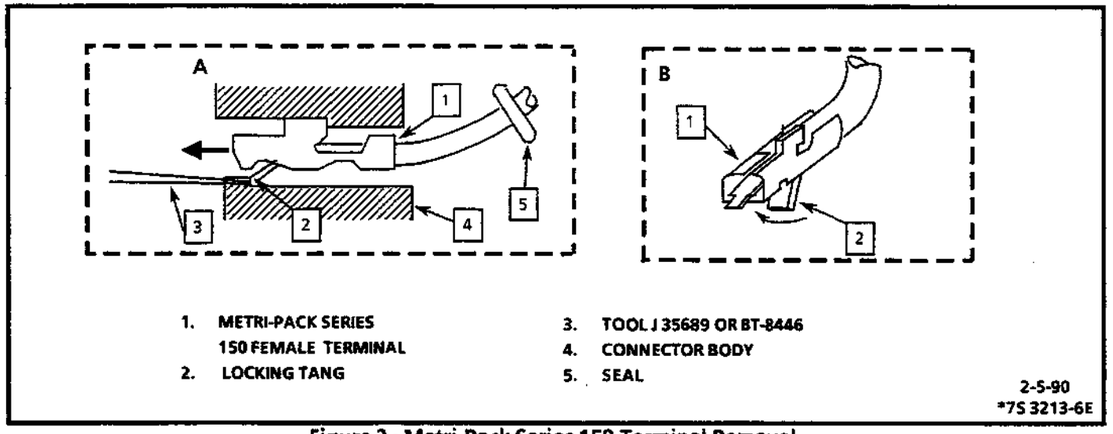
No doubt about . . . it takes time!

- Reading and understanding instructions.
- Re-reading warnings marked with this symbol ⚠ . . .
- Putting parts together right . . .
- Making adjustments right . . .
- Testing your work.

and making sure

- Worn or damaged parts are replaced,
- Replaced parts are like originals . . . in every way.
- Customer is told of things which need attention . . .

But, Do You Really Want the Alternative?



1. METRI-PACK SERIES 150 FEMALE TERMINAL
2. LOCKING TANG
3. TOOL J 35689 OR BT-8446
4. CONNECTOR BODY
5. SEAL

2-5-90
*7S 3213-6E

Figure 2 - Metri-Pack Series 150 Terminal Removal

WIRING CONNECTOR SERVICE

Most connectors in the engine compartment are protected against moisture and dirt which could create oxidation and deposits on the terminals. This protection is important because of the very low voltage and current levels found in the electronic system. The connectors have a lock which secures the male and female terminals together. A secondary lock holds the seal and terminal into the connector.

When diagnosing, open circuits are often difficult to locate by sight because oxidation or terminal misalignment are hidden by the connectors. Merely wiggling a connector on a sensor or in the wiring harness may locate the open circuit condition. This should always be considered when an open circuit or failed sensor is indicated. Intermittent problems may also be caused by oxidized or loose connections.

Before making a connector repair, be certain of the type of connector. Some connectors look similar but are serviced differently. Replacement connectors and terminals are listed in the parts catalog.

Metri-Pack Series 150 Terminals

Some ECM harness connectors contain terminals called Metri-Pack (Figure 2). These are used at some of the sensors and the distributor connector.

Metri-Pack terminals are also called "Pull-To-Seat" terminals because to install a terminal on a wire, the wire is first inserted through the seal (5) and connector (4). The terminal is then crimped on the wire, and the terminal pulled back into the connector to seat it in place.

To remove a terminal:

1. Slide the seal back on the wire.
2. Insert tool (3) BT-8518, J 35689, or equivalent as shown in insert "A" and "B" to release the terminal locking tang (2).
3. Push the wire and terminal out through the connector.
   If the terminal is being reused, reshape the locking tang (2).

Weather-Pack Connectors

Figure 3 shows a Weather-Pack connector and the tool (J 28742, BT-8234-A or equivalent) required to service it. This tool is used to remove the pin and sleeve terminals. If terminal removal is attempted without using the special tool required, there is a good chance that the terminal will be bent or deformed, and unlike standard blade type terminals, these terminals cannot be straightened once they are bent.

Make certain that the connectors are properly seated and all of the sealing rings in place when connecting leads. The hinge-type flap provides a secondary locking feature for the connector. It improves the connector reliability by retaining the terminals if the small terminal lock tangs are not positioned properly.

Weather-Pack connections cannot be replaced with standard connections. Instructions are provided with Weather-Pack connector and terminal packages.

ENGINE CONTROL MODULE (ECM) SELF-DIAGNOSTICS

The Engine Control Module (ECM) performs a continual self-diagnosis on certain control functions. This diagnostic capability is complemented by the diagnostic procedures contained in this manual. The ECM's language for communicating the source of a malfunction is a system of Diagnostic Trouble Codes (DTCs). The DTCs are two digit numbers that can range from 12 to 51. When a malfunction is detected by the ECM, a DTC is set and the malfunction indicator lamp is illuminated.

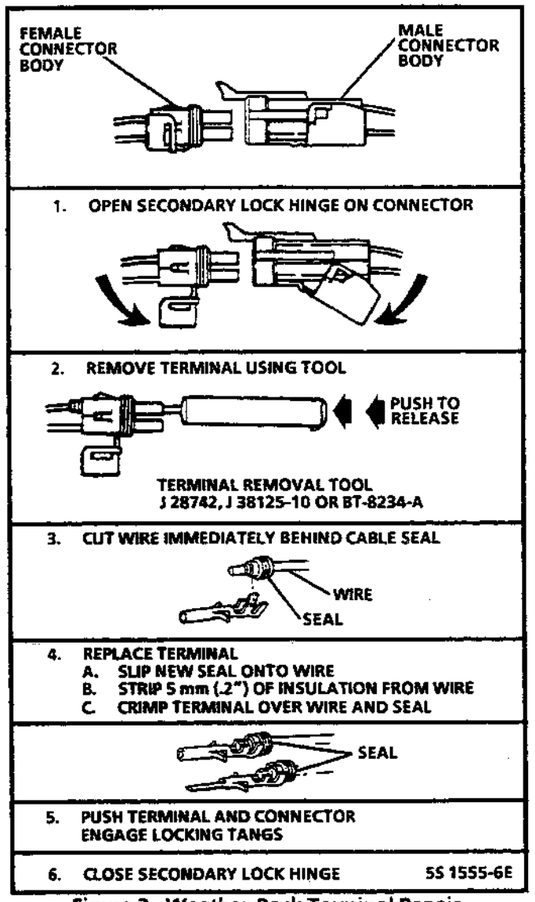


Figure 3 - Weather-Pack Terminal Repair

MALFUNCTION INDICATOR LAMP (MIL)

The malfunction indicator lamp is part of the Marine Diagnostic Trouble Code (MDTC) tool (TA-06075), or it can be a dash mounted warning light on some boat models.

- If present it informs the operator that a problem has occurred and that the boat should be taken for service as soon as reasonably possible.
- It displays DTCs stored by the ECM which help the technician diagnose system problems.

As a bulb and system check, the light will come "ON" with the key "ON" and the engine not running. When the engine is started, the light will turn "OFF." If the light remains "ON," the self-diagnostic system has detected a problem. If the problem goes away, the light will go out in most cases after 10 seconds, but a DTC will remain stored in the ECM.

When the light remains "ON" while the engine is running, or when a malfunction is suspected due to a driveability problem, **"MEFI On-Board Diagnostic**

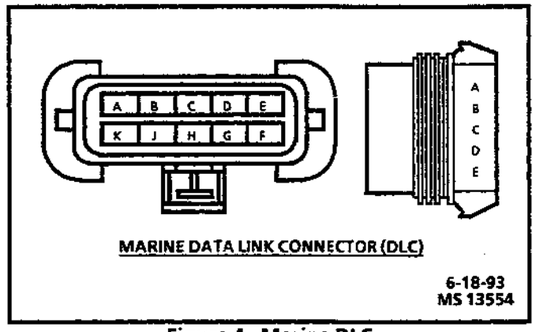


Figure 4 - Marine DLC

(OBD) System Check" must be performed. These checks will expose malfunctions which may not be detected if other diagnostics are performed prematurely.

Intermittent Malfunction Indicator Lamp (MIL)

In the case of an "intermittent" problem, the malfunction indicator lamp will light for ten (10) seconds and then will go out. However, the corresponding Diagnostic Trouble Code (DTC) will be stored in the memory of the ECM. When DTCs are set by an intermittent malfunction they could be helpful in diagnosing the system.

An intermittent DTC if cleared may or may not reset. If it is an intermittent failure, consult the "Diagnostic Aids" on the page facing the DTC chart corresponding to the intermittent DTC. "Symptoms" also covers the topic of "Intermittents." A physical inspection of the applicable sub-system most often will resolve the problem.

Reading Diagnostic Trouble Codes (DTCs)

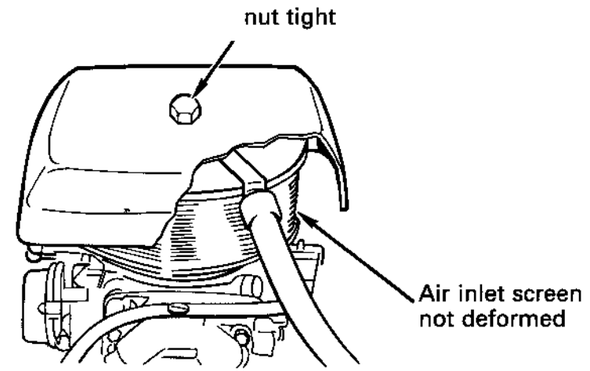
The provision for communicating with the ECM is the Data Link Connector (DLC) (See Figure 4). It is part of the MEFI engine wiring harness, and is a 10 pin connector, which is electrically connected to the ECM. It is used in the assembly plant to receive information in checking that the engine is operating properly before it leaves the plant. The DTC(s) stored in the ECM's memory can be read either through scan tool, a hand-held diagnostic scanner plugged into the DLC or by counting the number of flashes of the MIL when the marine diagnostic trouble code tool is installed and "Service" mode is selected.

Once the marine diagnostic trouble code tool has been connected, the ignition switch must be moved to the "ON" position, with the engine not running. At this point, the MIL should flash DTC 12 three times consecutively.

- Follow "Starting Procedures" outlined in the operator's manual.

  Always make sure there are no gasoline fumes in the engine compartment before starting the engine. Open the compartment and use your nose. Don't gamble.

- **Backfire flame arrestor** must be in place and securely attached to carburetor.

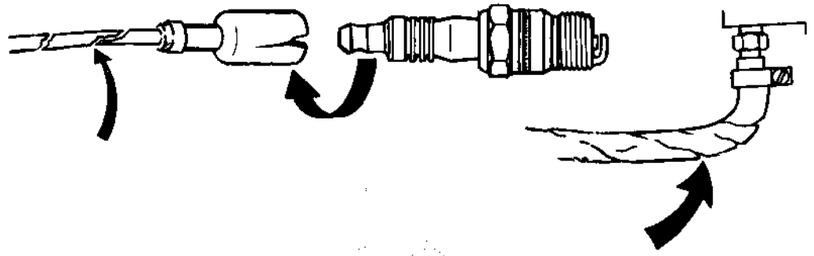


Do not alter the backfire flame arrestor.

If loose, damaged, or altered, an engine "backfire" may pass through the flame arrestor assembly into the engine compartment. If fumes are present in compartment, fire and explosion could result.

- Always use replacement parts specified by the manufacturer. They meet the Coast Guard requirements. Most automotive parts do not, especially electrical components that must meet ignition protection requirements of Coast Guard regulations.

- When non-metallic parts look to be in poor shape . . . replace them!



DR3478

wires cracked boots torn flexible fuel lines cracked

Using parts which meet Coast Guard requirements is only half the job. The other half is your job . . .

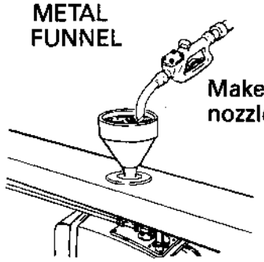
It's time for replacement BEFORE sparks and/or fuel leaks occur.

- Replace parts carefully. Make sure nuts and bolts are tight especially where they anchor electrical wires (to prevent sparking). If lockwashers are specified - use them. No short cuts or missing parts with either of these CRITICAL safety related systems.

- When refueling, always ground fuel nozzle to the inlet fitting on the boat to prevent the build-up of electrostatic sparks. If you use a funnel, make sure it's metal and ground the fuel nozzle to the funnel.

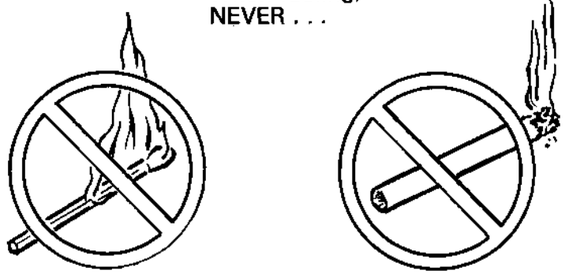
METAL FUNNEL

Make sure nozzle touches!



DR3110

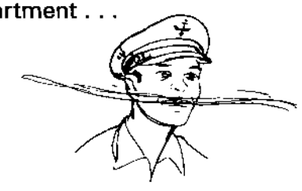
When fueling, NEVER . . .



DR3118

DR3111

- If you smell gasoline in the engine compartment . . . find its source and stop the leakage.



DR3117

This would be the following flash sequence: "flash, pause, flash-flash, long pause, flash, pause, flash-flash, long pause, flash, pause, flash-flash." DTC 12 indicates that the ECM's diagnostic system is operating. If DTC 12 is not indicated, a problem is present within the diagnostic system itself, and should be addressed by consulting the appropriate diagnostic chart in the "Diagnosis" section.

Following the output of DTC 12, the MIL will indicate a DTC three times if a DTC is present, or it will simply continue to output DTC 12. If more than one DTC has been stored in the ECM's memory, the DTCs will be output from the lowest to the highest, with each DTC being displayed three times.

Service Mode

When the marine diagnostic trouble code tool is installed at the DLC and the switch is selected to "Service," the system will enter what is called the Service Mode. In this mode the ECM will:

1. Display a DTC 12 by flashing the MIL (indicating the system is operating correctly).
2. Display any stored DTCs by flashing the MIL. Each DTC will be flashed three times, then DTC 12 will be flashed again.
3. The ignition timing is controlled to a fixed timing degree programmed in the ECM. This will allow base timing to be adjusted on distributor ignition engines.
4. The IAC valve moves to its fully extended position on most models, blocking the idle air passage. This is important to remember, as an attempt to run the boat while in "Service" mode will most likely result in an abnormally low idle speed.

Normal Mode

The normal mode will have no effect on engine operation.

DLC SCAN TOOLS

The ECM can communicate a variety of information through the DLC. This data is transmitted at a high frequency which requires a scan tool for interpretation.

With an understanding of the data which the scan tool displays, and knowledge of the circuits involved, the scan tool can be very useful in obtaining information which would be more difficult or impossible to obtain with other equipment.

A scan tool does not make the use of diagnostic charts unnecessary, nor can they indicate exactly where a problem is in a particular circuit. Tree charts incorporate diagnosis procedures using a scan tool where possible or a marine diagnostic trouble code tool (non-scan) if a scan tool is unavailable.

MEFI ON-BOARD DIAGNOSTIC (OBD) SYSTEM CHECK

After the visual/physical inspection, the "On-Board Diagnostic System Check" is the starting point for all diagnostic procedures. Refer to "Diagnosis" section.

The correct procedure to diagnose a problem is to follow two basic steps.

1. Are the on-board diagnostics working? This is determined by performing the "On-Board Diagnostic (OBD) System Check." Since this is the starting point for the diagnostic procedures, always begin here. If the on-board diagnostics aren't working, the OBD system check will lead to a diagnostic chart in "Diagnosis" section to correct the problem. If the on-board diagnostics are working correctly, the next step is:
2. Is there a DTC stored? If a DTC is stored, go directly to the numbered DTC chart in "Diagnosis" section. This will determine if the fault is still present.

SCAN TOOL USE WITH INTERMITTENTS

The scan tool provides the ability to check, (wiggle test) of wiring harnesses or components with the engine not running, while observing the scan tool readout.

The scan tool can be plugged in and observed while driving the boat under the condition when the MIL turns "ON" momentarily or when the engine driveability is momentarily poor. If the problem seems to be related to certain parameters that can be checked on the scan tool, they should be checked while driving the boat. If there does not seem to be any correlation between the problem and any specific circuit, the scan tool can be checked on each position, watching for a period of time to see if there is any change in the readings that indicates intermittent operation.

The scan tool is also an easy way to compare the operating parameters of a poorly operating engine with those of a known good one. For example, a sensor may shift in value but not set a diagnostic trouble code. Comparing the sensor's readings, with those of the typical scan tool data readings, may uncover the problem.

The scan tool has the ability to save time in diagnosis and prevent the replacement of good parts. The key to using the scan tool successfully for diagnosis lies in the technician's ability to understand the system he is trying to diagnose as well as an understanding of the scan tool operation and limitations.

The technician should read the tool manufacturer's operating manual to become familiar with the tool's operation.

HOW DIAGNOSTIC TROUBLE CODES ARE SET

The ECM is programmed to receive calibrated voltage signals from the sensors. The voltage signal from the sensor may range from as low as .1 volt to as high as 4.9 volts. The sensor voltage signal is calibrated for engine application. This would be the sensor's working parameter or "window." The ECM and sensors will be discussed further in the "ECM and Sensor" section.

If a sensor is within its working or acceptable parameters (Figure 5), the ECM does not detect a problem. When a sensor voltage signal falls out of this "window," or an open or short occurs in the wiring to the sensor, the ECM would not receive the "window" voltage for that sensor. When the ECM does not receive the "window" voltage for a programmed length of time a DTC will be stored. The MIL will be illuminated and a known default value will replace the sensed value to restore engine performance.

CLEARING DIAGNOSTIC TROUBLE CODES (NON-SCAN)

1. Install Marine Diagnostic Trouble Code (MDTC) tool.
2. Turn ignition switch to "ON," engine not running.
3. Select "Service" mode on MDTC tool.
4. Move the throttle from 0% (idle) to 100% (WOT) and back to 0%.
5. Select "Normal" mode on MDTC tool. (If this step is not performed, the engine may not start and run.)
6. Start engine and run for at least 20 seconds.
7. Turn ignition switch to "OFF" for at least 20 seconds.
8. Turn ignition switch to "ON." Engine not running.
9. Select "Service" mode on the MDTC tool and verify DTC 12 only. Remove MDTC tool.
10. If original DTCs are still present, check "Notice" below and repeat the DTC clearing procedure.
11. If new DTCs are displayed, perform On-Board Diagnostic (OBD) system check.

NOTICE: When clearing DTCs without the use of a scan tool, the battery must be fully charged and cranking speed must be at least 200 RPM. The ability to clear DTCs is directly dependent on battery being fully charged and able to crank engine with adequate cranking RPM.

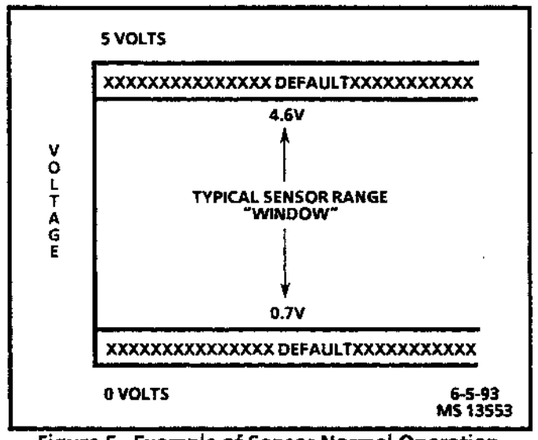


Figure 5 - Example of Sensor Normal Operation

CLEARING DIAGNOSTIC TROUBLE CODES (SCAN)

1. Install scan tool.
2. Start engine.
3. Select clear DTCs function.
4. Clear DTCs.
5. Turn ignition "OFF" for 20 seconds.
6. Turn ignition "ON" and read DTCs. If DTCs are still present, check "Notice" below and repeat following from Step 2.

NOTICE: When clearing DTCs with the use of a scan tool, the battery must be fully charged and cranking speed must be at least 200 RPM. The ability to clear DTCs is directly dependent on battery being fully charged and able to start engine with adequate cranking RPM.

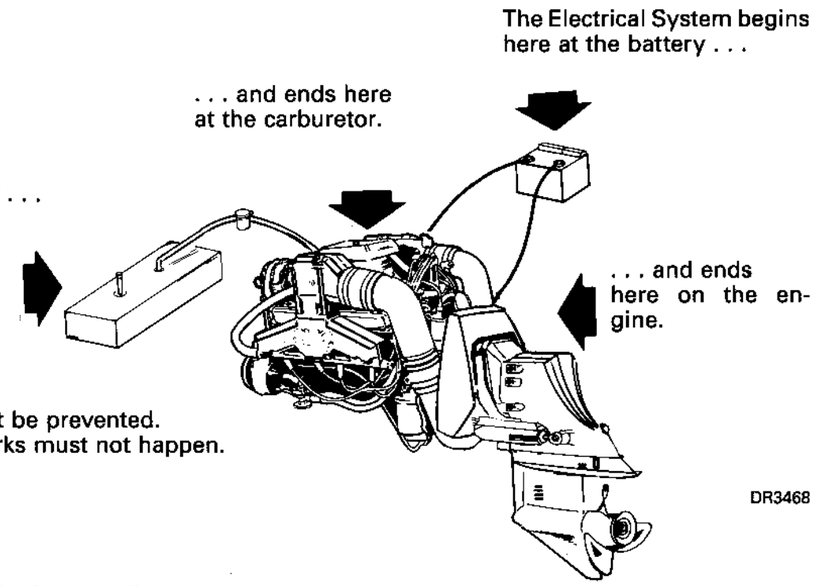
A poorly charged battery or engine cranking problem may result in an ECM "reset" and may not allow stored DTCs to be cleared from EEPROM memory.

If this condition exists, be sure battery is fully charged and repair charging/starting system before attempting to clear DTCs from memory.

NON-SCAN DIAGNOSIS OF DRIVEABILITY CONCERNS (WITH NO DTCs SET)

If a driveability concern still exists after following the diagnostic circuit check and reviewing the "Symptoms" section, an out of range sensor may be suspected. Because of the unique design of the MEFI system, fail safes have been programmed into the ECM to replace a sensed value with a default value in the case of a sensor malfunction or sensor wiring concern. By allowing this to occur, limited engine performance is restored until the vehicle is repaired.

Stern Drive Fuel and Electrical Systems



What's Important?

- Fuel leakage must be prevented.
- Stray electric sparks must not happen.

What Could Happen?

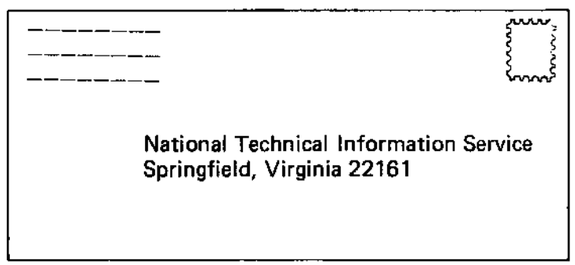
Gasoline can explode and/or burn easily:

- When boating, fuel leaking in the engine compartment could be ignited by a spark from a loose wire connection, or a damaged or deteriorated electrical component.

How Can Fire and Explosion Be Minimized?

- Read, understand, and follow manufacturers instructions.
- Closely follow the warnings marked with this symbol ⚠ . . .
- Do not substitute fuel or electrical parts with other parts which may look the same. These parts are designed and manufactured to meet special U.S. Coast Guard safety regulation requirements to prevent fire and explosion.

If you work on stern drive engines, you must understand these Coast Guard requirements. If you don't have them, write to . . .



. . . and ask for copies of:

(1) Electrical System Compliance Guideline (AD/A-049-638)
(2) Fuel System Compliance Guideline (AD/A-047-767)

These are concise guidelines - easy to read and understand. They explain what must be done to prevent fire and explosions.

How Can Loss of Steering Control be Minimized?

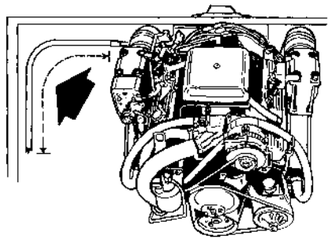
In pre-delivery inspection and when servicing

- Use steering components which meets marine industry (ABYC) standards . .
- Read, understand, and follow manufacturer's instructions.
- Assemble parts and make adjustments carefully . . .
- Closely follow the warnings marked with this symbol, ⚠ . . .
- Keep parts moving freely . . . lubricate parts as shown in manuals
- Use the bolts, nuts, and washers supplied with steering attachment kits . . . they're a special locking type that won't loosen, rust, or weaken.

When power assisted or mechanical steering systems are used, check to uncover possible trouble!

- Cable housing in this area must not be restricted

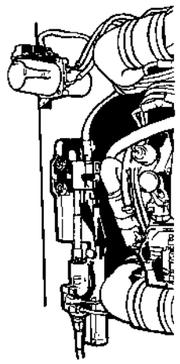
Why? Unit may go to full turn without turning steering wheel (power steering models)



DR3475

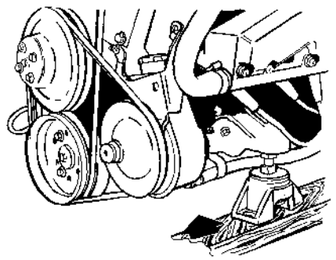
- Steering components must not bind

Why? Possible jamming of steering system



Power steering parts and push/pull cable must be free to move in order to actuate power steering valve when operator turns steering wheel

DR3470

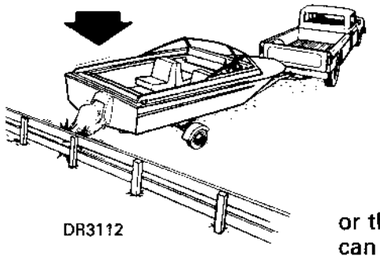


Engine stringer must not interfere with power steering pump and pulley

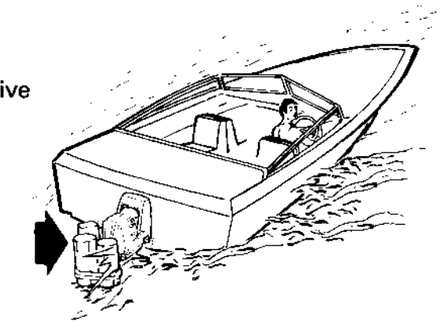
Maintain proper belt tension

DR3472

- Check for damaged parts . . . impacts to the vertical drive like this . . .



DR3112



DR3128

or this . . . or ? ? ?
can put stress on steering components. Look for . . .

- Cracked parts
- Bent parts
- Loose fasteners

Replace damaged parts. If weakened, parts could fail later . . . on the water . . . when least expected.

A basic understanding of sensor operation is necessary to be able to diagnose an out of range sensor.

If the sensor is out of range, but still within the operating "Window" of the ECM, the problem will go undetected by the ECM and may result in a driveability concern.

A good example of this would be if the coolant sensor was reading incorrectly and indicating to the ECM that coolant temperature was at 50°F, but actual coolant temperature was 150°F (Figure 6). This would cause the ECM to deliver more fuel than was actually needed and result in an overly rich, rough running condition. This condition would not have caused a DTC to set as the ECM interprets this as within it's "Range."

To identify a sensor which is out of range, you may unplug it while running the engine. After approximately 2 minutes, the DTC for that sensor will set, illuminate the MIL, and replace the sensed value with a default value. If at that point a noticeable performance increase is observed, the non-scan DTC chart for that particular sensor should be followed to correct the problem.

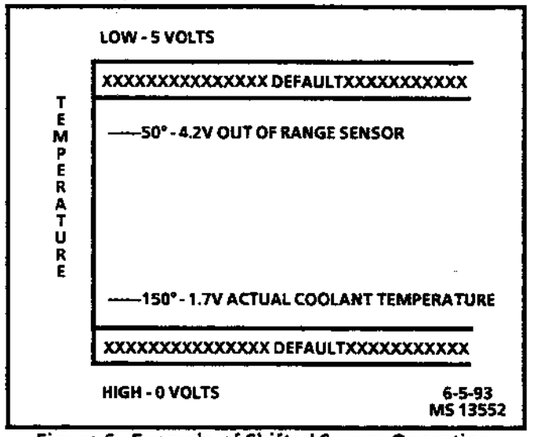


Figure 6 - Example of Shifted Sensor Operation

NOTICE: Be sure to clear each DTC after disconnecting and reconnecting each sensor. Failure to do so may result in a mis-diagnosis of the driveability concern.

TOOLS NEEDED TO SERVICE THE SYSTEM

The system requires a scan tool or Marine Diagnostic Trouble Code (MDTC) tool, inductive pick-up timing light, fuel pressure test gauge, tachometer, test light, digital volt ohmmeter with a minimum of 10 megohms impedance (J 34029-A or equivalent), vacuum pump with gage and jumper wires for diagnosis. A test light or DVOM must be used when specified in the procedures. See the end of this section for special tools needed to diagnose or repair a system. For more complete information on the operation of these tools, consult the tool manufacturer's instructions.

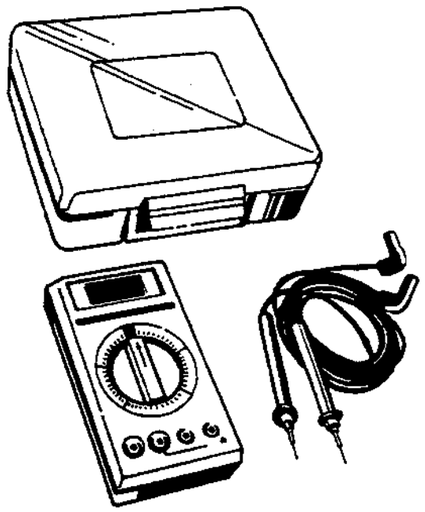
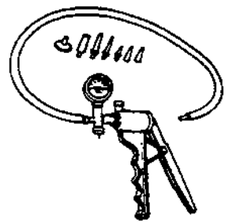
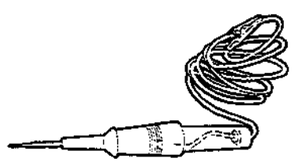
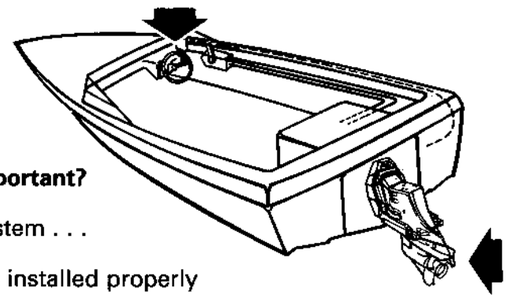
 HIGH IMPEDANCE MULTIMETER (DIGITAL VOLT-OHMMETER-DVOM) J 34029-A	**VOLTMETER** - Voltage position measures magnitude of voltage when connected in parallel to an existing circuit. A digital voltmeter with a 10 megohm input impedance is used because this type of meter will not load down the circuit and result in faulty readings. Some circuits require accurate low voltage readings because they have a very high resistance. **AMMETER** - When used as an ammeter, this meter accurately measures extremely low current flow. Refer to meter instructions for more information. • Selector must be set properly for both function and range. DC is used for most measurements. **OHMMETER** - Measures resistance of circuit directly in ohms. Refer to meter instructions for more information. • OL display in all ranges indicates open circuit. • Zero display in all ranges indicates a short circuit. • An intermittent connection in a circuit may be indicated by a digital reading that will not stabilize on the circuit. • Range Switch - Automatic and Manual. 200Ω – Reads ohms directly 2K, 20K, 200KΩ – Reads ohms in thousands 2M, 20MΩ, 200MΩ - Reads ohms in millions
 J 23738-A	**VACUUM PUMP WITH GAGE (20 IN. HG. MINIMUM)** Use the gage to monitor manifold engine vacuum and use the hand pump to check vacuum sensors, solenoids and valves.
 J 34142-B	**UNPOWERED TEST LIGHT** Used for checking wiring for complete circuit, short to ground, or voltage.
	**TACHOMETER** Must have inductive trigger signal pick-up. 4-14-92 NS 14574

Figure 7 - Special Tools (1 of 3)

Stern Drive Steering System

The Steering System starts here at the steering wheel . . .



. . . and ends here at the propeller on the vertical drive.

DR3114

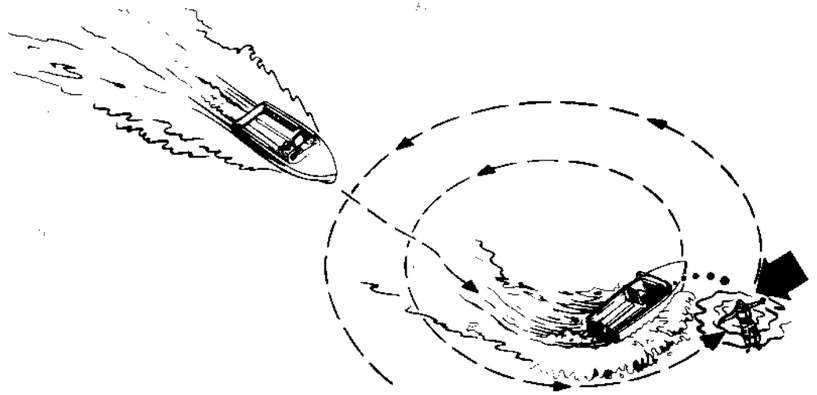
What's Most Important?

The Steering System . . .

- must be installed properly
- must be adjusted properly
- must be lubricated

What Could Happen?

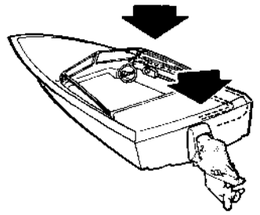
- . . . if steering system comes apart, boat would turn suddenly and circle . . . persons thrown into water could be hit.



- . . . if steering jams, operator may not be able to avoid obstacles. Operator could panic.
- . . . if steering is loose, operator may not be able to maintain a true course, and could result in loss of boat control.

Stern Drive Throttle Control System

The Throttle Control System starts here at the remote control lever . . .

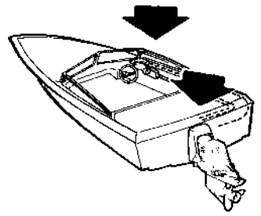


DR3114

. . . and ends here on the engine.

What's Most Important?

When control lever is moved from Forward (or Reverse) to Neutral . . .



DR3114

. . . engine speed must slow to idle RPM and allow operator to shift into Neutral.

Operator must be able to stop propeller.

What Could Happen?

If operator cannot slow the engine to idle RPM and shift into Neutral, (stop propeller), operator could panic and lose control of boat.

How Can Loss of Throttle Control be Minimized? In pre-delivery inspection and when servicing . . .

- Read, understand, and follow manufacturers instructions.
- Closely follow the warnings marked with this symbol, ⚠ . . .
- Assemble parts and make adjustments carefully . . .
- Test your work. Don't guess. Make sure engine throttle response is smooth.
- Make sure full throttle operating RPM can be obtained so operator won't overload engine.

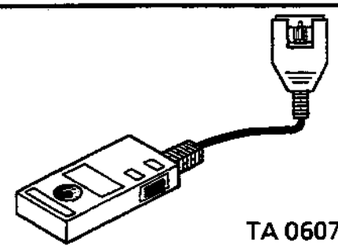
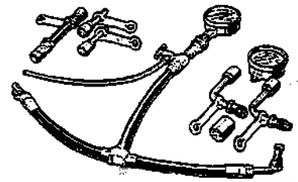
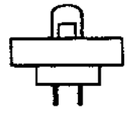
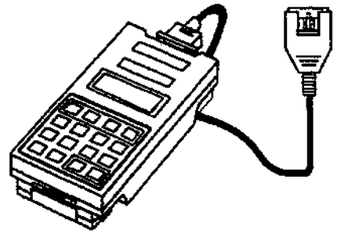
 J 35689	**METRI-PACK TERMINAL REMOVER** Used for removing 150 series Metri-Pack "pull-to-seat" terminals from connectors. Refer to wiring harness service in MEFI General Information Section for removal procedure.
 J 28742-A/BT-8234-A	**WEATHER PACK TERMINAL REMOVER** Used for removing terminals from Weather Pack connectors. Refer to wiring harness service in MEFI General Information Section for removal procedure.
 TA 06075	**MARINE DIAGNOSTIC TROUBLE CODE (MDTC) TOOL** A hand held diagnostic tool that is used to diagnose fuel and emission systems. It will flash a code when a problem is detected.
 J 29658-D	**FUEL PRESSURE GAUGE** Used for checking fuel system pressure on TBI engines.
 J 34730-1A	**FUEL PRESSURE GAUGE** Used for checking fuel pump pressure on MFI engines.
 J34730-2C & J 34730-350/BT 8329	**INJECTOR HARNESS TEST LIGHT** A specially designed light used to visually indicate injector electrical impulses from the ECM.
 TK 00450	**TECH 1 SCAN TOOL (Optional)** A hand held diagnostic tool that is used to diagnose fuel and emission systems. It will display various parameters. (A cartridge is required: TK 01940.) 7-6-93 NS 15871

Figure 8 - Special Tools (2 of 3)

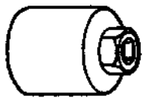
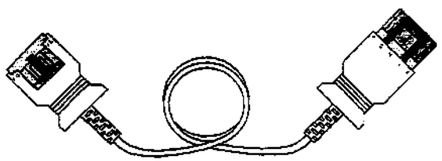
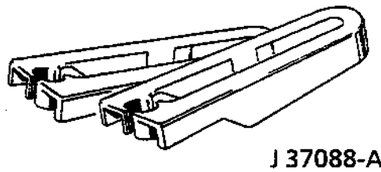
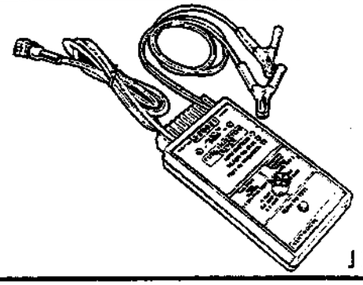
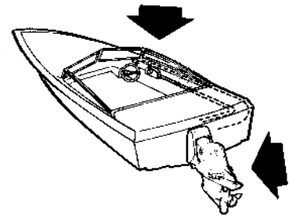
 J 33031	**IDLE AIR CONTROL (IAC) WRENCH** Used for removing and installing the thread mounted IAC valve on the throttle body.
 J 35632/BT-8514A	**IDLE AIR CONTROL REMOVER** Used to remove idle air control assembly on port fuel injection engine.
 J 35616	**HARNESS TEST ADAPTER KIT** Used to make electrical test connections in current Weather Pack, Metri-Pack, and Micro-Pack style terminals.
 TA 06076	**20' DIAGNOSTIC CONNECTOR EXTENSION CABLE** Extension cable to go between the "Tech 1" and the DLC on the engine harness.
 J 37088-A/BT-9171	**FUEL LINE QUICK-CONNECT SEPARATOR** Used to release fuel line quick-connect fittings.
 J 39021	**INJECTOR TESTER** Separately energized each injector to compare for equal impulses over a constant time interval.
	TIMING LIGHT Must have inductive signal pickup. 7-6-93 MS 13617

Figure 9 - Special Tools (3 of 3)

Stern Drive Shift System

The Shift System starts here at the remote control lever . . .

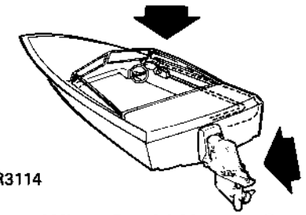


. . . and ends here at the propeller.

DR3114

What's Most Important?

When control lever is in Forward, Neutral or Reverse "position" . . .

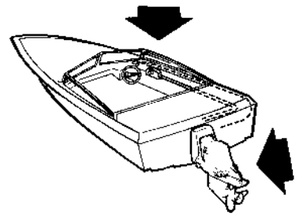


DR3114

. . . Shift mechanism must match control lever "position".

What Could Happen?

- If . . . Neutral

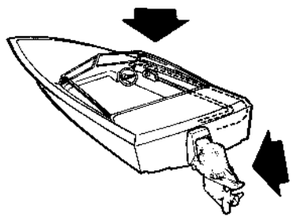


Forward or Reverse

DR3114

. . . propeller is still powered (turning) unknown to operator, or engine will start in gear, boat will move unexpectedly.

- If . . . Forward



Reverse

DR3114

. . . boat will move opposite to direction intended by operator.

How Can Loss of Shift Control be Minimized? In pre-delivery inspection and when servicing . . .

- Read, understand, and follow manufacturers instructions.
- Closely follow the warnings marked with this symbol, ⚠ . . .
- Assemble parts and make adjustments carefully . . .
- Test your work. Don't guess. Make sure propeller does just what the operator wants and nothing else.
- Do not shift gears when engine is stopped. Adjustments can be lost, and parts weakened.

Part A - Marine Products and Safety of People Who Use Them

Enjoyable boating is the goal of people who design and build marine products. To reach this goal, manufacturers are careful to make sure . . .

- Product user is informed . . .
- Products are safe and reliable . . .

It's up to you, the people who . . .

- Install accessories . . .
- Service and maintain the boat . . .
- Service and maintain the stern drive . . .

. . .to keep the products safe and reliable.

This section talks about safe boating and how you can help keep it safe. Some things you may know . . . but others you may not.

First!

A word about fasteners . . . plain . . . special . . . all screws, nuts, washers and bolts.

Do Not Substitute Fasteners

DR3113

They look the same, but . . . are they?

The Same Size?
The Same Strength?
The Same Material?
The Same Type?
Standard or Metric Thread?

Don't substitute unless you know they are the same in all characteristics.

Second!

- Special locking screws and nuts are often used to attach steering, and remote control components to the stern drive.
- When you remove any part from the stern drive, keep track of special screws and nuts. Don't mix with other parts.
- When reassembling the stern drive, use only the special screws and nuts intended to hold steering, and control cables, plus related parts.
- Service with parts of known quality that meet Marine Industry (BIA/ABYC) Standard.

ABBREVIATIONS

BARO	-	BAROMETRIC PRESSURE
BAT	-	BATTERY, BATTERY POSITIVE TERMINAL, BATTERY OR SYSTEM VOLTAGE
B+	-	BATTERY POSITIVE
CKP	-	CRANKSHAFT POSITION SENSOR
CKT	-	CIRCUIT
CMFI	-	CENTRAL MULTIPORT FUEL INJECTION
CONN	-	CONNECTOR
CYL	-	CYLINDER
DEG	-	DEGREES
DI	-	DISTRIBUTOR IGNITION
DIAG	-	DIAGNOSTIC
DIST	-	DISTRIBUTOR
DLC	-	DATA LINK CONNECTOR
DTC	-	DIAGNOSTIC TROUBLE CODE
DVOM	-	DIGITAL VOLT OHMMETER
ECM	-	ENGINE CONTROL MODULE
ECT	-	ENGINE COOLANT TEMPERATURE SENSOR
EEPROM	-	ELECTRONIC ERASABLE PROGRAMMABLE READ ONLY MEMORY
EI	-	ELECTRONIC IGNITION
EMI	-	ELECTROMAGNETIC INTERFERENCE
ENG	-	ENGINE
E-STOP	-	EMERGENCY STOP
GND	-	GROUND
GPH	-	GALLONS PER HOUR
IAC	-	IDLE AIR CONTROL
IAT	-	INTAKE AIR TEMPERATURE
IC	-	IGNITION CONTROL
IGN	-	IGNITION
INJ	-	INJECTOR
I/O	-	INPUT/OUTPUT
kPa	-	KILOPASCAL
KS	-	KNOCK SENSOR SYSTEM
KV	-	KILOVOLTS
MAP	-	MANIFOLD ABSOLUTE PRESSURE
MDTC	-	MARINE DIAGNOSTIC TROUBLE CODE TOOL
MEFI	-	MARINE ELECTRONIC FUEL INJECTION
MFI	-	MULTIPORT FUEL INJECTION
MIL	-	MALFUNCTION INDICATOR LAMP
MSEC	-	MILLSECOND
N/C	-	NORMALLY CLOSED
N/O	-	NORMALLY OPEN
OBD	-	ON-BOARD DIAGNOSTIC SYSTEM CHECK
OPT	-	OPTIONAL
PROM	-	PROGRAMMABLE READ ONLY MEMORY
PWM	-	PULSE WIDTH MODULATION
RAM	-	RANDOM ACESS MEMORY
REF HI	-	REFERENCE HIGH
REF LO	-	REFERENCE LOW
ROM	-	READ ONLY MEMORY
SLV	-	SLAVE

ABBREVIATIONS (CONT)

SW	-	SWITCH
TACH	-	TACHOMETER
TBI	-	THROTTLE BODY INJECTION
TERM	-	TERMINAL
TP	-	THROTTLE POSITION SENSOR
V	-	VOLTS
VAC	-	VACUUM
WOT	-	WIDE OPEN THROTTLE
"HG	-	INCHES OF MERCURY

⚠ Safety Section

S

NOTES

MARINE ELECTRONIC FUEL INJECTION (MEFI)

SECTION 2

ENGINE CONTROL MODULE (ECM) AND SENSORS

CONTENTS

GENERAL DESCRIPTION

The Marine Electronic Fuel Injection (MEFI) system is equipped with a computer that provides the operator with state-of-the-art control of fuel and spark delivery. Before we discuss the computers on the Marine applications, let's discuss how computers use voltage to send and receive information.

COMPUTERS AND VOLTAGE SIGNALS

Voltage is electrical pressure. Voltage does not flow thru circuits. Instead, voltage causes current. Current does the real work in electrical circuits. It is current, the flow of electrically charged particles, that energizes solenoids, closes relays and lights lamps.

Besides causing currents in circuits, voltage can be used as a signal. Voltage signals can send information by changing levels, changing waveform (shape), or changing the speed at which the signal switches from one level to another. Computers use voltage signals to communicate with one another. The different sections inside computers also use voltage signals to talk to each other.

There are two kinds of voltage signals, analog and digital. Both of these are used in computer systems. It's important to understand the difference between them and the different ways they are used.

ANALOG SIGNALS

An analog signal is continuously variable. This means that the signal can be any voltage within a certain range.

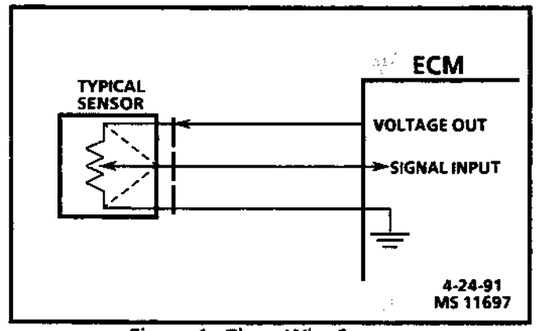


Figure 1 - Three Wire Sensors

An analog signal usually gives information about a condition that changes continuously over a certain range. For example, in a Marine engine, temperature is usually provided by an analog signal. There are two general types of sensors that produce analog signals; the 3-wire and the 2-wire sensor.

Three-Wire Sensors

Figure 1 shows a schematic representation of a 3-wire sensor. All 3-wire sensors have a reference voltage, a ground and a variable "wiper." The lead coming off of the "wiper" will be the signal to the Engine Control Module (ECM). As this wiper position changes, the signal voltage returned to the computer also changes.

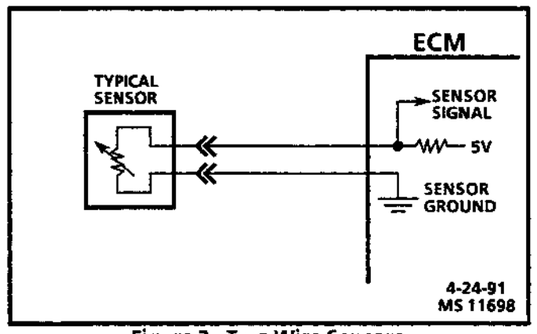


Figure 2 - Two Wire Sensors

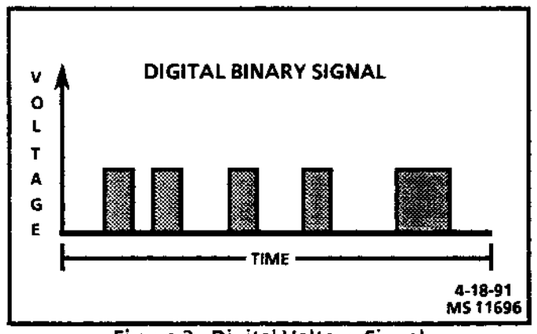


Figure 3 - Digital Voltage Signal

Two-Wire Sensors

Figure 2 is the schematic of a 2-wire type sensor. This sensor is basically a variable resistor in series with a fixed-known resistor within the computer. By knowing the values of the input voltage and the voltage drop across the known resistor, the value of the variable resistor can be determined. The variable resistors that are commonly used are called thermistors. A thermistor's resistance varies with temperature.

DIGITAL SIGNALS

Digital signals are also variable, but not continuously. They can only be represented by distinct voltages within a range. For example, 1V, 2V or 3V would be allowed, but 1.27V or 2.65V would not. Digital signals are especially useful when the information can only refer to two conditions - "YES" and "NO," "ON" and "OFF," or "High" and "Low." This would be called a digital binary signal. A digital binary signal is limited to two voltage levels. One level is a positive voltage, the other is no voltage (zero volts). As you can see in Figure 3, a digital binary signal is a square wave.

The computer uses digital signals in a code that contains only ones and zeros. The high voltage of the digital signal represents a one (1), and no voltage represents a zero (0). Each zero and each one is called a bit of information, or just a "bit." Eight bits together are called a "word." A word, therefore, contains some combination of eight binary code bits: eight ones, eight zeros, five ones and three zeros, and so on.

Binary code is used inside a computer and between a computer and any electronic device that understands the code. Buy stringing together thousands of bits, computers can communicate and store an infinite variety of information. To a computer that understands binary, 11001011 might mean that it should turn an output device "ON" at a slow speed. Although the computer uses 8-bit digital codes internally and when talking to another computer, each bit can have a meaning.

Switch Types

Switched inputs (also known as discretes) to the computer can cause one bit to change, resulting in information being communicated to the computer. Switched inputs can come in two types; they are "pull-up" and "pull-down" types. Both types will be discussed.

With a "pull-up" type switch, the ECM will sense a voltage when the switch is CLOSED. In the case of the "pull-down," the ECM "sees" the voltage when the switch is OPEN.

Pulse Counters

For the computer to determine frequency information from a switched input, the computer must measure the time between voltage pulses. As a number of pulses are recorded in a set amount of time, the computer can calculate the frequency. The meaning of the frequency number can have any number of meanings to the computer.

An example of a pulse counter type of input is the distributor reference pulse input. The computer can count a train of pulses, a given number of pulses per engine revolution. In this way, the computer can determine the RPM of the engine.

ENGINE CONTROL MODULE (ECM)

The Engine Control Module (ECM) (Figure 4) is the control center of the fuel injection system. It constantly monitors information from various sensors, and controls the systems that affect vehicle performance.

The ECM also performs a diagnostic function check of the system. It can recognize operational problems and store a Diagnostic Trouble Code(s) which identify the problem areas to aid the technician in making repairs.

ECM Function

The ECM supplies 5 or 12 volts to power various sensors or switches.

NOTES