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MAINTENANCE MANUAL

VOLUME 1 OF 3

COMMERCIAL OFF-THE-SHELF (COTS)

for

INTERNATIONAL

MINE RESISTANT VEHICLE

CATEGORY I
2355-01-553-4634
CATEGORY II
2355-01-553-4636

Manufactured by

International Military and Government, L.L.C.

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WARNING SUMMARY

Warning Summary

WARNINGS, CAUTIONS, AND NOTES

Read and observe all WARNING, CAUTION, and NOTE alert messages in this publication. They provide information that can help prevent serious personal injury, damage to components, or both.

This section clarifies the use of WARNINGS, CAUTIONS, **and** NOTES **as follows**:

WARNINGS **are presented in** BOLD **type and may result in serious injury or death to personnel.**

CAUTIONS **are presented in** BOLD **type, following** WARNINGS, **and may result in damage to equipment.**

NOTE

NOTES **are presented in NORMAL type, following** WARNINGS **and** CAUTIONS, **and are general statements**.

WARNING SUMMARY

A jack must never be used alone to support the vehicle while under chassis service is being performed. The jack may lower and serious personal injury could result. Always support the vehicle with floor stands.

A wheel and tire assembly is heavy. Request the assistance of another person to remove and install wheel and tire assembly. Failure to comply may result in serious injury or death to personnel.

Accidental or intentional introduction of liquid contaminants into the environment is in violation of state, federal, and military regulations. Refer to Army POL (para. 1-8) for information concerning storage, use, and disposal of these liquids. Failure to do so may result in injury or death.

Adhesives, solvents, and sealing compounds can burn easily, can give off harmful vapors, and are harmful to skin. Keep away from open fire and use in well-ventilated area. If adhesives, solvents, or sealing compounds get on skin or clothing, wash immediately with soap and water. Failure to comply may result in serious injury or death to personnel.

Allow heatshrink tubing to cool before handling. Failure to comply may result in serious injury to personnel.

Allow solder to cool before handling. Failure to comply may result in serious injury to personnel.

Alternator is extremely heavy and awkward. Use suitable lifting device and have Crewmember assist. Injury to personnel and/or equipment may result.

Always have two people when setting plunger: one person to steer the vehicle (with foot on the brake) and, one person to set and check adjustments.

Always pre-stretch wire rope and re-spool under load before use. Tightly wound wire rope reduces chances of "binding", which is wire rope working it's way down into a loosely wound wire rope layer and catching or damaging itself. Failure to comply may result in damage to equipment and may cause serious injury or death to personnel.

Always remove negative battery terminals first. When reconnecting, always connect negative terminals last to avoid arcing or sparks that could cause an explosion. DO NOT allow tools to contact battery box or other battery terminals when removing or installing terminals. Failure to comply may result in damage to equipment and or serious injury or death to personnel.

Always use a torque wrench to tighten the adjusting nuts to their correct adjusted torques. Always use the correct size socket wrench. Failure to comply may result in damage to equipment and or serious injury or death to personnel.

Always wear safety goggles and an approved respirator during all brake service procedures. Wear the respirator from removal of the wheels through assemble. Brake material dust may be potential health hazard. Handle ALL brake parts with care the brake dust covers all parts. Failure to comply may result in serious injury or death to personnel.

Anti-corrosion compound is toxic. Use only in well-ventilated area. Use approved respirator with dual organic vapor/mist and particulate cartridge. Do not get in eyes; wear chemical safety goggles and full-face shield when using. Avoid contact with skin and wear rubber or plastic, solvent-resistant gloves. In case of contact, remove contaminated clothing and immediately wash area with soap and water. If eyes are contacted, flush eyes with large amounts of water for at least 15 minutes and get immediate medical attention. If swallowed, DO NOT INDUCE VOMITING; contact a physician immediately. Failure to comply may result in serious injury or death to personnel.

Assure batteries are disconnected before removing ESC. Injury to personnel or damage to equipment may result.

Avoid contact with the hot fluid or the sump when draining transmission fluid. Direct contact with the hot fluid or the hot sump may result in bodily injury.

WARNING SUMMARY

Batteries can produce explosive gases. Batteries contain corrosive acid. Batteries supply a high enough electrical current level to cause burns. Wear protective eye goggles and face shield and long sleeves to protect your arms. Avoid leaning over or onto battery. DO NOT smoke or expose battery to open flames or sparks. Avoid contact with battery acid to eyes, skin or clothing. If contact is made to eyes or skin flush area with large amounts of water for 15 minutes and immediately contact medical care. If swallowed, DO NOT INDUCE VOMITING. Drink large amounts of water or milk. Follow with milk of magnesia, beaten egg, or vegetable oil. Seek immediate medical attention. Failure to comply may result in damage to equipment and or serious injury or death to personnel.

Be alert at all times for the smell of fuel. Hot engines and components can ignite fuel. If fuel smell is detected while operating vehicle, shut down vehicle immediately. Failure to comply may result in damage to equipment, injury, or death to personnel.

Be careful not to short out battery terminal. DO NOT smoke or use open flame near batteries. Batteries may explode from a spark. Failure to comply may result in serious injury or death to personnel.

Before beginning ANY work on the vehicle's air brake system, or any auxiliary pressurized systems, make sure to drain the air pressure from all reservoirs.

Before opening the hood, make sure that there is enough room in front of the vehicle for the hood to open completely without pinning or pinching yourself or an assistant between the hood and any other structure. Failure to comply may result in serious injury or death.

Before performing maintenance, be sure that parking brake is applied, transmission is in NEUTRAL (N) and wheels are chocked. Failure to comply may result in damage to equipment and or serious injury or death to personnel.

Before removal of any electrical component, disconnect negative ground cable from Batteries. Failure to comply may result in damage to equipment and/or serious injury or death to personnel.

Before removal, secure rear door/ramp using a suitable sling and lifting device.

Before removing ABS Control Module, disconnect Battery Disconnect Switch and disconnect batteries. Failure to comply may result in damage to equipment and/or serious injury or death to personnel.

Before removing the side A-pillar mounting bolts, you will need assistance with the remainder of the removal. The instrument panel is bulky and heavy. One person can not lift and remove it by themselves. Failure to comply may result in damage to equipment and or serious injury or death to personnel.

Before the removal of the belly armor, ensure that the floor area underneath and surrounding area of the vehicle is clear of all debris. Remove all rocks, extension cords, air hoses, tools, rags, dirt, etc. which could stop a transmission jack wheel from moving and knock it over. Failure to comply may result in damage to equipment and/or serious injury or death to personnel.

Before working on any electrical components, turn Battery Disconnect Switch to off position. Make sure you properly secure hood of vehicle after lifting to ensure that it does not fall while you are working in the engine compartment area. Failure to comply may result in damage to equipment and or serious injury or death to personnel.

Before working on the air system on the vehicle, make sure you have released the air pressure in the lines. Failure to comply may result in damage to equipment and/or serious injury or death to personnel.

Brake shoes and inside surface of brake drums may be coated with asbestos dust, wear required face shield and mask when performing this task. Breathing this dust may be harmful to your health. Do not use compressed air to clean brake drums. Use required brake cleaner spray to remove the dust residue from brake shoes and drums. Failure to comply may result in serious injury or death to personnel.

WARNING SUMMARY

Cabin emergency hatch is heavy. Make sure the hatch is secured so it will not move. Failure to do so may allow the hatch cover to move causing personal injury or death.

Cable is under tension when installed take care with personal protection. Have safety goggles and gloves. DO NOT have loose clothing, it can get caught up in cable as it is being wound round spool drum and pull personnel in and cause serious injury or possibly death.

Carbon monoxide is a colorless, odorless, and dangerous gas that is present in vehicle exhaust. When it is necessary to operate the engine during vehicle service in a confined area, always use the proper equipment to vent the exhaust gasses outside of the work area. Failure to comply may result in serious injury or death to personnel.

Check and verify extinguisher before installing into vehicle that the proper part number is being installed. There is no visible damage to the canister like dents, cracked plastic, chips or scratches where hoses connect. If damage is visible anywhere, DO NOT USE, contact your supervisor. Failure to comply may result in damage to equipment and/or serious injury or death to personnel.

Cleaning solvents may be toxic to skin, eyes, and respiratory tract. Skin and eye protection is required. Avoid repeated or prolonged contact. Ensure ventilation is adequate. Failure to comply could result in serious injury to personnel.

Connector lubricant is harmful to skin. Prolonged or repeated contact with skin or contact with eyes may cause irritation. If eyes are contacted, rinse thoroughly and contact physician if irritation persists. If skin is contacted, wash thoroughly with soap and water. Failure to comply may result in serious injury or death to personnel.

Connector lubricant is harmful to skin. Prolonged or repeated contact with skin or contact with eyes may cause irritation. If eyes are contacted, rinse thoroughly and contact a physician if irritation persists. If skin is contacted, wash thoroughly with soap and water.

Cooling system components become pressurized and extremely hot during normal operation. Use extreme care when working around hot components. DO NOT open hot radiator cap under pressure, hot coolant can/will spray out. Failure to comply may result in serious injury or death to personnel.

Diesel fuel is flammable. Keep all open flames, flammable materials, ignition sources, and sparks away from diesel fuel. Failure to comply may result in equipment damage and/or serious injury or death to personnel.

Discharging large quantities of dry chemical fire extinguisher in cab may result in temporary breathing difficulty during and immediately after the discharge event. If at all possible, discharge fire extinguisher from outside the cab. Ventilate and wash cab thoroughly prior to reentry. If respiratory irritation or distress occurs, remove victim to fresh air. Seek medical attention if irritation persists.

Dispose of used parts, rags, containers and engine fluids according to regulations. Failure to comply may result in equipment damage and/or serious injury or death to personnel.

Do not allow grease or oil to contact brake linings. Linings can absorb grease and oil, causing early glazing and very poor braking action. Failure to comply could cause serious injury or death to personnel.

Do not attempt to lift Wheel and Tire Assemblies by yourself. These assemblies are heavy and bulky and should not be lifted alone. Have another personnel assist with changing of a wheel/tire assembly. Failure to comply may result in damage to equipment or serious injury or death to personnel.

DO NOT attempt to remove winch from vehicle on your own. The winch is extremely heavy. Needs the aid of an assistant and a suitable lifting device to remove and install onto the front of vehicle. Wear safety goggles and work gloves while removing and installing. Failure to comply may result in damage to equipment and or serious injury or death to personnel.

WARNING SUMMARY

DO NOT attempt to restrict fan blade rotation during engine operation. DO NOT operate a vehicle with a drive or fan blades that are malfunctioning or are externally damaged. Improper use of application or modification of a viscous fan drive or fan that it carries can result in damage to the fan drive. Failure to comply may also result in equipment damage and or serious injury or death to personnel.

DO NOT back off the nut to locate the cotter pin hole! Always advance tightening to locate cotter pin hole. Failure to install and lock the cotter pin in the ball stud could result in a hazardous vehicle operating condition. Failure to comply will result in equipment damage and or serious injury or death to personnel.

DO NOT disconnect A/C lines from compressor. Release of refrigerant may cause injury to personnel, or damage to equipment and/or environment.

DO NOT disconnect any air line or fitting until system pressure has been relieved. Air under pressure can penetrate the skin. Failure to comply may result in serious injury or death to personnel.

DO NOT expose any refrigerant containers empty or full to open flames or temperatures above 125° F (51° C). DO NOT discard empty containers where they may be subject to heat of trash burner, they may explode. Containers must be stored, installed and disposed of in accordance with local regulations. Failure to comply may result in serious injury or death to personnel.

DO NOT expose pressurized refrigerant containers to open flame or to temperatures above 125°F (5C). Store, install, and dispose of containers in accordance with all state and local ordinances. Failure to comply may result in serious injury or death to personnel.

DO NOT HIT steel parts with a steel hammer. DO NOT PRY off the parts with sharp tools. To loosen the drive flange from the hub, hit with a soft mallet. This will avoid parts to break. Failure to comply will result in damage to equipment and or serious injury or death to personnel.

Do not hit the wheel studs with a steel hammer or remove the studs by twisting. Damage to the parts can occur and metal fragments can cause serious personal injury.

DO NOT hold onto cable when pulling in new one. Failure to comply may result in serious injury or death to personnel.

DO NOT install or remove air-conditioning testing or charging equipment while the engine is running. Failure to comply may result in serious injury or death to personnel.

DO NOT loosen fuel lines at filter housing to bleed fuel system. Periodic loosening of fittings will result in increased wear of threads. Failure to comply may result in damage to equipment and or serious injury or death to personnel.

DO NOT operate vehicle with air pressure system loss, this is extremely dangerous. Vehicle has reduced or no braking capability and may not stop. Failure to comply may result in damage to equipment and or serious injury or death to personnel.

Do not over tighten bolts for fuel pump or cross thread connections on fuel lines. This will interfere with sealing and operation of fuel pump. If seal is not complete, or lines leak due to cross threads, fuel pump will not operate properly and vehicle may not run. Starting vehicle with no fuel pressure in lines or pump will cause damage to equipment and/or serious injury or death to personnel.

Do not remove hot exhaust system from vehicle, bolts can stretch, crack and break easier when hot. Personnel should wear appropriate work gloves and long sleeves. Allow exhaust system to cool before loosening bolts on c-clamps, this will avoid any damage to any of the exhaust pipes. Failure to comply may result in damage to equipment and/or cause serious burns and/or injury or death to personnel.

WARNING SUMMARY

Do not replace sensors while engine is hot. Removing sensors while engine is hot may cause damage to the internal threads on engine block, cause sensor to break or crack in engine block, engine block could crack, or cause extremely hot coolant or oil to spill out. Failure to comply may result in damage to equipment or serious injury or death to personnel.

Do NOT service or maintain this system alone. This is a two person operation in case of Medical Emergency due to possible exposure to NBC Agents. This procedure must be performed by properly trained authorized personnel in suitable protective clothing. Make sure that batteries are disconnected, no open flames or smoking around vehicle, area is well ventilated, never operate system with cover or panel removed, have proper safety equipment and clothing. Failure to comply may result in serious injury or death to personnel.

Do not strike the round driving lugs on the flange of an axle shaft. Pieces can break off and cause serious personal injury.

DO NOT touch the exhaust system components with bare hands or with your body use protective work gloves and long sleeves. DO NOT use the exhaust tailpipe as a step. It will not hold weight and will collapse. Failure to comply may result in damage to equipment and or serious burns, injury, or death to personnel.

Do not use compressed air exceeding 30psi (207 kPa) for cleaning purposes. Use only with effective chip guarding and personal protective equipment, goggles, shield, and gloves. Failure to comply could result in serious injury or death to personnel.

DO NOT use heat on components to facilitate removal of arms. This may weaken other connecting parts. Use lubricating spray and a breaker bar to break loose after letting soak for a few minutes. Remember to use the proper socket wrench as not to damage bolt heads. Failure to comply will result in damage to equipment and or serious injury or death to personnel.

Do not use tank jack to lift vehicle, only used to support fuel tank while straps are removed to replace tank. Use suitable floor jack and jack stand to lift vehicle to a safe level. Do not work under vehicle or work alone with the fuel tank and cage while it is supported by tank jack. Failure to comply may result in damage to equipment and/or serious injury or death to personnel.

DO NOT wear any jewelry when servicing batteries, DO NOT smoke or use open flame. Batteries could explode from any spark. Failure to comply may result in serious injury or death to personnel.

Do not work on any component supported only by lift jacks or hoist. Always use blocks or proper stands to support the component prior to any work. Equipment may fall and cause injury or death to personnel.

Do not work on the system alone, there should always be at least two persons working on the system at all times for safety. Failure to comply may result in serious injury or death to personnel.

Drain all air from the air system before removing air lines or hose. Failure to do so could result in personal injury and/or death.

Drilling and grinding operations are hazardous to the eyes. Safety goggles or face shield protection is required. Failure to comply could result in serious injury to personnel.

Drycleaning solvent is flammable and will not be used near open flame. Keep fire extinguisher nearby. Use only in well-ventilated places. Failure to do so may result in injury to personnel.

During normal vehicle operation cooling system can become very hot. Allow cooling system to cool prior to servicing cooling system. Failure to comply may result in serious injury or death to personnel.

During normal vehicle operation the transfer case can become very hot. Allow transfer case to cool prior to servicing the hose. Failure to comply may result in serious injury to personnel.

WARNING SUMMARY

During normal vehicle operation the transfer case oil cooler can become very hot. Allow transfer case and oil cooler to cool prior to servicing the oil cooler. Failure to comply may result in serious injury to personnel.

Electrical shock hazard. Disconnect battery ground cable or power source prior to working on electrical components. Failure to heed warning could cause shock, injury or death. If electrical shock occurs, administer first aid and seek medical assistance immediately.

Engine components become extremely hot during normal operation. Always allow engine to cool completely prior to performing any task or procedures on it. Working in close quarters in engine compartment can be difficult moving around. Wear proper safety equipment; safety goggles, work gloves, long sleeves or shop coat. Failure to comply may result in serious burns, cuts, or injury or death to personnel.

Engine components become extremely hot during normal operation. Allow engine to cool completely prior to performing any task. DO NOT touch the exhaust system components with bare hands or with your body use protective work gloves and long sleeves. Failure to comply may result in damage to equipment and or serious burns, injury or death to personnel.

Engine components become extremely hot during normal operation. Always allow engine to cool completely prior to performing any task or procedures on it. Working in close quarters in engine compartment can be difficult moving around. Wear proper safety equipment; safety goggles, work gloves, long sleeves or shop coat. Failure to comply may result in serious burns, cuts, or injury or death to personnel.

ENGINE lamp will also be illuminated as long as the Diagnostic Trouble Code condition exists.

Ensure all personnel stay clear of radiator while engine is running. Air in radiator will be released which may cause hot coolant to spray out. Failure to comply may result in serious injury to personnel.

Ensure any excess oil is cleaned from lower armor plate. If not removed properly damage to equipment or injury may occur, due to fire.

Ensure that proper safety equipment is being used, protective eye wear and gloves. Failure to comply may result in serious injury or death to personnel.

Ensure that proper safety equipment is being used, protective eye wear and gloves. Failure to comply may result in serious injury or death to personnel.

Ensure that the gunners hatch is in the locked position before moving the vehicle. Use extreme caution when standing in gunner's hatch while vehicle is in motion; gunner should be holding onto the weapon or other suitable handle to maintain a stable posture at all times. Failure to comply may result in serious injury or death to personnel.

Ensure that the gunners hatch is in the locked position before moving the vehicle. Use extreme caution when standing in gunner's hatch while vehicle is in motion; gunner should be holding onto the weapon or other suitable handle to maintain a stable posture at all times. Failure to comply may result in serious injury or death to personnel.

Eyes: Flush with cold water for no less than 15 minutes and seek medical attention immediately.

First aid and fire control equipment should be available during all the operation and maintenance phases. People working with or near high voltages should be familiar with resuscitation methods. Failure to comply may result in serious injury or death to personnel.

Fuel is flammable and can explode. Keep fuel away from open flame and keep fire extinguisher within easy reach when working with fuel. DO NOT work on fuel system when engine is hot. Fuel can be ignited by hot engine. Smoking is prohibited while working with fuel. Never use gasoline to clean parts. Failure to comply may result in serious injury or death to personnel.

WARNING SUMMARY

Gunners hatch is extremely heavy, use caution when opening and closing it. Make sure that latch locks are secure into place in the open and or close positions before vehicle starts moving and personnel are set in place securely. Failure to comply may result in damage to equipment and or serious injury or death to personnel.

Hydraulic jacks are intended only for lifting the vehicle and not for supporting the vehicle while performing maintenance. DO NOT get under vehicle after vehicle is raised, unless it is properly supported with blocks or jack stands. Failure to comply may result in injury or death to personnel.

If NBC exposure is suspected, all filter media should be handled by personnel wearing protective equipment. Consult your unit NBC officer or NBC NCO for appropriate handling or disposal instructions.

If refrigerant comes in contact with your eyes, DO NOT rub them. Flush the eyes with cold water for at least 15 minutes to gradually get the temperature above the freezing point. See a doctor immediately. Failure to comply may result in serious injury or death to personnel.

If the measurement does not meet the acceptable minimum or maximum tolerance, the pitman arm and sector shaft must be replaced. Failure to take the measurement or replace worn parts could result in pitman arm looseness which could lead to an accident, personal injury or death.

If the pitman arm is not applied to the proper specifications, the pitman arm could work loose and loose its attachment and cause an accident. If the pitman arm is found loose, replace the pitman arm and sector shaft. Failure to comply may result in equipment damage and serious injury or death to personnel.

If the tabs and notches do not line up, tighten beyond the specified torque value until two tabs align. Never back off the retainer to align the retaining tabs. Failure to comply may result in damage to equipment and/or serious injury or death to personnel.

If there are any missing or damaged springs do not install new shoes until you replace them all with new spring hardware kit. Drums will have to be turned or replaced if there were any signs of overheating on the old brake shoes. Failure to comply may result in damage to equipment.

If there are any missing or damaged springs replace immediately. Replace brake shoes if there are any signs of overheating, if step on center wear tab of brake shoe lining is not visible, or if thickness on any part of brake shoe is ¼ inch (6mm) or less. Failure to comply may result in damage to equipment.

If there are any missing or damaged springs replace immediately. Drums will have to be turned or replaced if there are any signs of overheating on the brake shoes. Failure to comply may result in damage to equipment.

If transmission oil temperature is above 220°F (104°C), allow transmission oil to cool before removing dipstick.

Immediately have extinguisher replaced after use, even if only partly used. Failure to comply may result in damage to equipment and/or serious injury or death to personnel.

Increased effort may be required to turn steering wheel if there is a failure of power steering system or engine stops running. Stop vehicle as soon as road conditions permit. Operating vehicle with impaired steering can result in damage to equipment and or serious injury or death to personnel.

Inspection of emergency and service air lines and fittings will be accomplished over complete vehicles. Tighten, repair, and/or replace components of these compressed air systems as required. If maintenance is required at a higher level, records should reflect closest point of reference to ensure proper identification of components requiring service.

WARNING SUMMARY

Internal: If victim is conscious and alert, give two to three glasses of water to drink and DO NOT induce vomiting. DO NOT leave victim unattended. To prevent aspiration of swallowed product, lay victim on side with head lower than waist. If vomiting occurs and the victim is conscious, give water to further dilute the chemical. Seek medical attention immediately.

International® Mine Protected Vehicle (I-MPV) armor parts are heavy. Use care when removing or installing. DO NOT attempt to lift without the aid of an assistant and a suitable lifting device. Failure to comply may result in serious injury or death to personnel.

It is recommended that you DO NOT inhale the gas. In case of accidental inhalation exposure, go quickly to fresh air. In case of skin irritation, consult medical physician. If gets in eyes, flush with water for at least 15 minutes and contact medical physician. In case swallowed, DO NOT INDUCE VOMITING, contact medical physician. Failure to comply may result in serious injury or death to personnel.

Maintenance should only be performed on this system by properly trained and qualified personnel with proper safety suit. Failure to comply may result in serious injury or death to personnel.

Make absolutely certain that the gunners hatch is completely locked in the open position before moving the vehicle with a gunner in position. Use extreme caution when standing in gunner's hatch while vehicle is in motion, gunner should be holding on to the weapon or other suitable handle to maintain a stable posture at all times. Failure to comply may result in serious injury or death to personnel.

Make certain (by looking out one of the small rear windows) that no one is behind the vehicle when lowering the rear door/ramp. DO NOT operate the rear door/ramp when vehicle is in motion. Use extreme caution when using the emergency rear door/ramp release that no one can be struck by the door as it falls open. Keep arms and legs clear of rear door/ramp when closing it. Failure to comply may result in serious injury or death to personnel.

Make sure that before lifting vehicle off the ground that it is parked on a level surface and you have a suitable jack and rated jack stands for supporting vehicle axle. Set brake and chock wheels. Failure to comply may result in damage to equipment or serious injury or death to personnel.

Make sure that cable is free of kinks and binds or frayed wires before installing onto drum spool. Failure to comply may result in damage to equipment.

Make sure that engine is shut OFF, Master Powered or disconnect switch is turned OFF, wheels are chocked, transmission is in neutral/park, parking brake is set before starting service procedure on engine. Failure to comply may result in damage to equipment or serious injury or death to personnel.

Make sure that vehicle is parked on a flat level surface, with engine shut OFF, Master Power switch turn OFF and/or disconnected, wheels chocked and parking brake set. Keep all open flames, flammable materials, ignition sources, and sparks away from diesel fuel, it is flammable. Failure to comply may result in equipment damage and/or serious injury or death to personnel.

Make sure that vehicle is parked on level surface and apply parking brakes.

Make sure the vehicle engine has time to cool down before continuing with procedure. Use extreme caution – hot fuel can ignite easily. Wear safety goggles and have fire extinguisher on hand. Failure to comply may result in serious injury or death to personnel.

Make sure you have safety goggles/glasses and respiratory. Brake shoes may contact asbestos, which has been determined to be a cancer causing agent. Never clean the brake surface with compressed air. Avoid inhaling any dust from any brake surface. Only use authorized brake cleaning fluid. Failure to comply may result in damage to equipment or in serious injury to personnel.

WARNING SUMMARY

Never connect or disconnect air hoses containing pressure, it may whip. Never remove a component or plug unless you are certain all system pressure has been depleted. Failure to comply may result in serious injury or death to personnel.

Never let moving wire rope slide through hands, even when wearing gloves. A broken wire could cut through glove and cut hand.

NEVER tighten or loosen the adjusting nuts (11) and (12) by hitting them directly with a hammer or a drift or chisel placed against them with a hammer. This will damage the adjusting nuts (11) and (12) and prevent proper wheel bearing adjustment achievements. Failure to comply will result in damage to equipment and or serious injury or death to personnel.

NEVER use compressed air or dry brushing to clean brake parts or assemblies, carefully clean parts in a well ventilated or open air area. During disassembly, carefully place all parts on the floor to avoid getting dust into the air. Use an industrial vacuum cleaner with a HEPA filter system to clean dust from the brake drums, backing plates and other brake parts. After using the vacuum, remove any remaining dust with a rage soaked in water and wrung until nearly dry. DO NOT use compressed air to clean your clothing after working on brakes, use vacuum with HEPA filter system. Failure to comply may result in serious injury or death to personnel.

Never use gasoline to clean parts. Gasoline is highly flammable. Failure to comply may result in damage to equipment and/or serious injury or death to personnel.

Never use open flame to apply heat to heatshrink tubing. Failure to comply may result in serious injury to personnel.

No open flames or smoking allowed around diesel fuel. Diesel fuel is flammable and could cause an explosion or fire if exposed to flames, sparks or heat. Have fire extinguisher on hand when working with fuel systems. Failure to comply may result in damage to equipment and/or serious injury or death to personnel.

No smoking or open flames around diesel fuel, flammable and could cause explosion or fire if exposed. Have fire extinguisher on hand when working with fuel systems. Failure to comply may result in damage to equipment and serious injury or death to personnel.

Observe all warnings and cautions provided by the press manufacturer to avoid damage to components and serious personal injury.

Park the vehicle on a level surface. Block the wheels to prevent the vehicle from moving. Support the vehicle with safety stands. Do not work under a vehicle supported only by jacks. Jacks can slip and fall over. Serious personal injury can result.

Place jack stands under the frame rails. Never work under or near a vehicle supported only by a jack or lifting device. Failure to properly support the vehicle and components may result in death or serious injury.

Place the transmission in NEUTRAL (N), set the parking brake, and chock wheels before doing any diagnostic or service procedures on the engine or vehicle. Failure to comply may result in damage to equipment or serious injury or death to personnel.

Plate weighs approximately 100-120 lbs. If not properly secured before removal of final bolt, plate will slip or fall, resulting in personal injury or damage to equipment.

Prior to removing the leaf springs, park the vehicle on a flat surface. Place the transmission in the park position. Set the parking brake and set the wheel chocks in place.

Proper installation of the pitman is critical to the safe operation of the vehicle. Follow these procedures for the attachment. Correct torque values are very important! Use lubricant where indicated. Always use a new tab lock retainer. Failure to comply may result in damage to equipment and /or serious injury or death to personnel.

WARNING SUMMARY

Protective eye goggles or face shield needs to be worn. Air drain valves are under pressure. DO NOT place face in front of air drain valves while draining air reservoirs. Open air drain valves slowly to prevent sudden blast of air. Failure to comply may result in serious injury or death to personnel.

Pulling or pushing too fast may offset the transmission adapter plate and belly armor pan and cause it to become unstable and insecure. This may cause the transmission to jack to tip over and/or the belly armor pan to fall off. Failure to comply may result in damage to equipment and/or serious injury or death to personnel.

R-134a refrigerant must not be mixed with air and then pressurized. When mixed with large quantities of air and pressurized, R-134 becomes combustible.

Read all safety instructions in this manual before doing this procedure.

Rear cabin door is heavy. Make sure the door is secured so it will not move. Failure to do so may allow the door to move causing personal injury or death.

Refrigerant evaporates very quickly and may displace the oxygen surrounding the work area. If a leak should occur, avoid breathing the refrigerant and lubricant vapor. Thoroughly ventilate the area before continuing with service. Federal and state laws require that refrigerant be recovered and recycled.

Refrigerant must be recovered from the air-conditioning system with approved equipment before any components of the system are removed or replaced. Removing components while pressure is in the system will cause personal injury or death.

Refrigerant must be recovered from the system with authorized recommended equipment before any work can be preformed on the unit. Always use approved recycling equipment to prevent accidental discharge. Refrigerant evaporates very quickly and will take up all the oxygen in your work area, especially if a small or enclosed area. This can cause suffocation or brain damage for anyone in the work area. If a leak occurs avoid breathing the refrigerant vapor and thoroughly ventilate area before continuing service. If you do breathe in refrigerant vapors, contact emergency medical personnel right away. Failure to comply may result in serious injury or death to personnel.

Refrigerant will turn into a poisonous gas in the presence of heat. Do not smoke or allow any type of flame in immediate area while servicing the air conditioning system. Never weld, solder, steam clean, or use excessive heat on any part of the air conditioning system while charged/pressurized. Refrigerant must not be mixed with air and then pressurized. When mixed and then pressurized refrigerant becomes combustible. Failure to comply may result in damage to equipment and/or serious injury or death to personnel.

Remove all jewelry such as rings, dog tags, bracelets, etc. If jewelry contacts battery terminal, a direct short may result in instant heating of tools, damage to equipment, and injury or death to personnel.

Remove all jewelry such as rings, dog tags, bracelets, etc. If jewelry contacts battery terminal or positive electrical circuit, a direct short may result in instant heating of tools, damage to equipment, and injury or death to personnel.

Remove any rifles that may be stored in the rifle racks being worked on. Ensure rifles are not loaded and stored in a safe manner. Failure to follow this procedure may result in serious injury or death.

Remove or disconnect batteries in proper sequence and turn master Master Power switch off prior to performing maintenance in immediate area or working on electrical system. Such disconnects prevent electrical shock to personnel and equipment.

Roof hatches are heavy. Use caution when opening or closing the roof hatches. Ensure roof hatches are locked when in the open position. Failure to do so may result in injury to personnel.

WARNING SUMMARY

Safety goggles and full face shield should be worn while working with refrigerant. The temperature of liquid refrigerant I -20° F (-29° C). DO NOT rub eyes if refrigerant get in them. Splash with cold water to gradually increase temperature above freezing and seek immediate medical attention. Failure to comply may result in serious injury or death to personnel.

Safety goggles and full face shield should be worn while working with or around refrigerant. The temperature of liquid refrigerant is -20° F (-29° C). DO NOT rub eyes if refrigerant get in them. Splash with cold water to gradually increase temperature above freezing and seek immediate medical attention. Failure to comply may result in serious injury or death to personnel.

Safety goggles or other adequate eye protection must be worn when working with refrigerant. The temperature of liquid refrigerant is –20°F (–29C). Serious injury or blindness will result from refrigerant contacting the eyes.

Skin: Flush with large amounts of cold water until all acid is removed. Seek medical attention as required.

Solvent cleaners can be flammable, poisonous and cause burns. Examples of solvent cleaners are carbon tetrachloride, and emulsion-type and petroleum-base cleaners. Read the manufacturer's instructions before using a solvent cleaner, then carefully follow the instructions. Also follow the procedures below.

- **Wear safe eye protection.**
- **Wear clothing that protects your skin.**
- **Work in a well-ventilated area.**
- **Do not use gasoline or solvents that contain gasoline. Gasoline can explode.**
- **You must use hot solution tanks or alkaline solutions correctly. Read the manufacturer's instructions before using hot solution tanks and alkaline solutions. Then carefully follow the instructions.**

Solvents used with a spray gun must be used in a spray booth with filter. Face shield and mask must be used by personnel operating spray gun. Failure to comply could result in serious injury to personnel.

Some fire suppression systems have a safety pin to install before disconnecting lines. Check to see if this system uses a safety pin and install it before disconnecting lines. When disconnecting the extinguisher lines use extreme caution. DO NOT DISTURB the pyrotechnic actuator and pressure switch; this will cause the extinguisher to go off automatically. Failure to comply may result in damage to equipment and/or serious injury or death to personnel.

Springs are under extreme tension and can act as projectiles when being removed. Ensure all personnel wear protective goggles. Failure to comply may result in serious injury or death to personnel.

Steam cleaning creates hazardous noise levels and severe burn potential. Eye, skin, and ear protection are required. Failure to comply could result in serious injury to personnel.

Steering gear is heavy. Use care when removing or installing. DO NOT attempt to lift without the aid of an assistant, or a suitable lifting device. Failure to comply may result in serious injury or death of personnel.

Support the transfer case with a lifting strap before mounting the transfer case into the repair stand. A transfer case that is not supported correctly can fall. Serious personal injury and damage to components can result.

System components become extremely hot during normal operation. Use extreme care when working around hot components. Failure to comply may result in injury to personnel.

WARNING SUMMARY

Take care when you use Loctite® adhesive to avoid serious personal injury. Read the manufacturer's instructions before using this product. Follow the instructions carefully to prevent irritation to the eyes and skin. Apply a layer of Loctite® 680 sealant on the outside diameter of the bushing.

Take care when you use Loctite®adhesive to avoid serious personal injury. Read the manufacturer's instructions before using this product. Follow the instructions carefully to prevent irritation to the eyes and skin. If Loctite®adhesive material gets into your eyes, follow the manufacturer's emergency procedures. Have your eyes checked by a physician as soon as possible.

The gunners hatch must be secured before moving or lifting. Failure to comply may result in serious injury or death to personnel.

The gunner's sliding hatch can only be opened or closed when the vehicle is stationary and on a level surface. DO NOT attempt to open or close the hatch when the vehicle is in motion. Keep arms and hands clear of gunners hatch when closing it. Failure to comply may result in serious injury or death to personnel.

The I-MPV engine hood is extremely heavy, secure hood after raising it to ensure safety of personnel working in the engine compartment. Failure to comply may cause serious injury or death to personnel.

The NBC (nuclear/biological/chemical) LSS (Life Support System) regulates the fresh and re-circulated air within the vehicle in WAR TIME. The system may have been exposed to NBC AGENTS, USE EXTREME CARE WHEN REMOVING FILTER. Failure to comply may result in serious injury or death to personnel.

The pitman arm should be installed after the steering gear is mounted on the vehicle so proper torque can be applied to the pitman arm. Lack of proper torque will cause the looseness of the pitman arm. Failure to comply will result in damage to equipment and/or serious injury or death to personnel.

The pitman arm will be extremely tight. Do not pound on the pitman arm or apply any source of heat to the pitman arm or sector shaft. Never weld the pitman arm or the sector shaft. Failure to comply will result in damage to equipment and/or serious injury or death to personnel.

To avoid damage to engine and the possibility of personal injury, be sure to dispose of fuel in a proper container clearly stating diesel fuel.

To avoid personal injury or death from hot coolant or steam scalding, use the following procedure to remove the pressure cap from the cooling system. Allow the engine to cool. Wrap a thick cloth around the cap. Unscrew cap slowly, then pause to allow pressure to release.

To avoid personal injury or death use a jack stand or equivalent support under the prop shaft during the removal and installation procedure.

To avoid property damage, personal injury or death, park the vehicle on a level surface, set the parking brake, chock the wheels and turn the engine off. System components become extremely hot during normal operation. Use extreme care when working around hot components. Failure to comply may result in injury to personnel.

To avoid property damage, personal injury, or death, park the vehicle on a flat level surface, set the parking brake, turn the engine off, and chock the wheels.

To avoid property damage, personal injury, or death, park the vehicle on a flat Level surface, set the parking brake, turn the engine off, and chock the wheels.

To avoid serious personal injury or possible death, use heat protecting gloves to install heated vibration damper.

To avoid serious personal injury, possible death, and damage to vehicle or engine, do not rotate diesel engine when priming with oil. This may cause engine to accidentally start.

WARNING SUMMARY

To avoid serious personal injury, possible death, or damage to the engine or vehicle, read all safety instructions in the "Safety Information" section of this manual.

To avoid serious personal injury, possible death, or damage to the engine or vehicle, make sure the transmission is in neutral, parking brake is set, and wheels are blocked before doing diagnostic or service procedures on engine or vehicle.

To prevent arcing, DO NOT allow tools to contact batteries or other battery terminals. Failure to comply may result in serious injury or death to personnel.

To prevent serious eye injury, always wear safe eye protection when you perform vehicle maintenance or service.

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To prevent serious eye injury, always wear safe eye protection when you perform vehicle maintenance or service. Park the vehicle on a level surface. Block the wheels to prevent the vehicle from moving. Support the vehicle with safety stands. Do not work under a vehicle supported only by jacks. Jacks can slip and fall over. Serious personal injury can result.

To prevent serious eye injury, always wear safe eye protection when you perform vehicle maintenance or service.

To prevent serious eye injury, always wear safe eye protection when you perform vehicle maintenance or service. Use a brass or leather mallet for assembly and disassembly procedures. Do not hit steel parts with a steel hammer. Pieces of a part can break off and cause serious personal injury.

To prevent serious eye injury, always wear safe eye protection when you perform vehicle maintenance or service. Park the vehicle on a level surface. Block the wheels to prevent the vehicle from moving. Support the vehicle with safety stands. Do not work under a vehicle supported only by jacks. Jacks can slip and fall over. Serious personal injury can result.

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To prevent serious eye injury, always wear safe eye protection when you perform vehicle maintenance or service. Park the vehicle on a level surface. Block the wheels to prevent the vehicle from moving.

To prevent the adapters from blowing off during the test, increase air pressure slowly. After testing, relieve the pressure slowly through the bleed valve before removing the test equipment from the charge air cooler. Failure to comply may result in damage to equipment and or serious injury or death to personnel.

To prevent the possibility of the coupler blowing off the charge air cooler hose during the test, connect the safety chain before applying air pressure to the system. Failure to comply may result in damage to equipment and or serious injury or death to personnel.

Turn cap on surge tank one half turn and stop prior to removing cap completely. Pressure must be relieved from tank prior to removal of cap. Failure to comply may result in injury to personnel.

WARNING SUMMARY

Use a brass or leather mallet to loosen the drive flange from the hub during removal procedures. Do not use a sharp tool to pry the flange from the hub, which can damage mounting surfaces. Do not hit steel parts with a steel hammer. Pieces of a part can break off and cause serious personal injury and damage to components.

Use a brass or synthetic mallet for assembly and disassembly procedures. Do not hit steel parts with a steel hammer. Pieces of a part can break off. Serious personal injury and damage to components can result.

Use a brass or synthetic mallet for assembly and disassembly procedures. Do not hit steel parts with a steel hammer. Pieces of a part can break off. Serious personal injury and damage to components can result.

Use a torque wrench to tighten or loosen adjusting nuts. Do not use a hammer to directly hit adjusting nuts, or hit a chisel or drift placed against them. Damaged adjusting nuts can prevent you from obtaining correct wheel bearing end-play, which can affect vehicle operation and cause the wheel to separate from the vehicle and cause serious personal injury and damage to components.

Use all safety pre-cautions before, during and after this procedure. Wear protective safety goggles/face shield, compressed air is very dangerous. During this procedure the vehicle's engine needs to be running, use extreme caution. Make sure that there is no one behind vehicle, under vehicle, or in vehicle while you are working on the engine. Failure to comply may result in damage to equipment and/or serious injury or death to personnel.

Use appropriate safety goggles/glasses and respirator protection. Brake shoes may contact asbestos, which has been determined to be a cancer-causing agent. Never clean the brake surface with compressed air. Avoid inhaling any dust from any brake surface. Only use authorized brake cleaning fluid. Failure to comply may result in damage to equipment or in serious injury to personnel.

Use care when working around ether canister as ether canisters are pressurized and flammable. Keep away from flames, DO NOT incinerate or puncture canister, keep away from temperatures above 120°F (49°C). DO NOT store spare in cab. It contains hazardous materials and must be handled with care and disposed of in accordance with current directives. Avoid ether liquid to contact skin, eyes and breathing fumes. Use approved respirator with dual organic vapor/mist and particulate cartridge. If swallowed, DO NOT INDUCE VOMITING. Contact immediate medical attention. Failure to comply may result in serious injury or death to personnel.

Use care when working with hot transmission and fluid during maintenance procedures. Wear protective goggles, work gloves and long sleeves to avoid injury. Use caution when working under vehicle, make sure someone knows where you are located. Failure to comply may result to serious injury or death to personnel.

Use catch bag and catch bag retainer when firing a weapon from the machine gun mount. This is to prevent the links and spent hot brass cartridge casings from entering the crew compartment during firing. Failure to comply may result in damage to equipment or serious injury to personnel.

Use caution when inflating tires. Ensure tire is in a tire cage and properly seated on rim before inflating. An improperly seated tire can burst with explosive force. Failure to comply can cause death or serious injury to personnel.

Use extreme care when working under the hood of vehicle. Hood is extremely heavy, ensure it is braced properly. Wear protective eye goggles, work gloves and long sleeves when working and or removing engine parts. Make sure that vehicle engine has time to cool before working on it. Failure to comply may result in damage to equipment and or serious injury or death to personnel.

Use extreme caution when moving about the engine compartment with the hood in open position or under vehicle. Availability of space limited for maneuvering tools, arms, hands, and components can make procedures difficult. Failure to comply may result in serious injury or death to personnel.

Use extreme caution when working under vehicle. Make sure you have safety goggles on, fire extinguisher on hand and another personnel close by. Failure to comply may result in serious injury or death to personnel.

WARNING SUMMARY

Use plastic or leather mallet for disassembly and assembly procedures. DO NOT HIT steel parts with a steel hammer, parts can break off. Failure to comply will result in damage to equipment and or serious injury or death to personnel.

Use safety goggles and proper work gloves. Use assistance of other personnel when removing wheel and tire assembly. Failure to comply may result in serious injury or death to personnel.

Use suitable floor jack and jack stand to lift vehicle to a safe level. Do not work under vehicle or work alone with the fuel tank and cage while it is supported by tank jack. Failure to comply may result in damage to equipment and/or serious injury or death to personnel.

Use suitable jack and rated jack stand that can support the weight of the vehicle. Use safety goggles and proper work gloves. Use assistance of other personnel when removing wheel and tire assembly. Failure to comply may result in serious injury or death to personnel.

Vehicle must be parked on hard, level surface where jacks will have stable surface. Attempting to change assembly on non-level or soft surface may result in jack/jack stand and or vehicle falling. Failure to comply will result in equipment damage and or serious injury or death to personnel.

Vehicle must not be operated with the Emergency roof hatch open. Keep arms, hands and head clear of Emergency roof hatch when closing it. Failure to comply may result in serious injury or death to personnel.

Vehicle's engine must be off, brakes set and wheels chocked prior to performing this task. Failure to comply may result in serious injury or death to personnel.

Wear eye protection and non-porous gloves. If hydraulic fluid comes into contact with skin, remove contaminated clothing, including shoes. Wash immediately. If hydraulic fluid comes into contact with eyes, flush with water for 15 minutes. See a doctor immediately. Failure to do so could result in personal injury or death.

Wear gloves and goggles when lifting and lowering vehicle.

Wear non-porous gloves. If refrigerant comes into contact with skin, remove contaminated clothing, including shoes. Wash immediately. Treat the injury as though the skin had been frostbitten or frozen. See a doctor immediately. Failure to comply may result in serious injury or death to personnel.

Wear proper safety goggles and work gloves when fueling vehicle or working with fuel system. DO NOT use open flames or smoke, use caution around electrical components that you don't cause a spark which can explode fuel fumes. Failure to comply may result in damage to equipment and or serious burns, injury or death to personnel.

Wear protective eye wear while working with systems under pressure. Failure to comply may result in serious injury or death to personnel.

Wear protective eyewear while working with systems under pressure. Make sure that engine is shut off, Master Powered or disconnect switch is turned off, wheels are chocked, transmission is in neutral/park, parking brake is set before starting service procedure on engine. Failure to comply may result in damage to equipment or serious injury or death to personnel.

Wear protective eyewear while working with systems under pressure. Failure to comply may result in serious injury or death to personnel.

Wear protective goggles and work gloves when working on vehicle. Let engine cool before working on or around it. Have assistance when raising engine hood it is extremely heavy. Make sure there is enough room in front of the vehicle for the hood to open completely without pinning or pinching yourself or an assistant between the hood and any other structure. Failure to comply may result in serious injury or death.

WARNING SUMMARY

Wear protective goggles, work gloves, and long sleeves to avoid injury. Use caution when working under vehicle; make sure someone knows where you are at. Failure to comply may result in serious injury or death to personnel.

Wear protective rubberized gloves. Wear protective clothing while working with refrigerant. If refrigerant comes in contact with skin, remove all contaminated clothing. Treat skin as though it were frostbitten or frozen and seek immediate medical attention. Failure to comply may result in serious injury or death to personnel.

Wear safety glasses or goggles when checking batteries. Always check electrolyte level with engine stopped. Do not smoke or use exposed flame when checking batteries; explosive gases are present, and severe injury to personnel can result.

Wear safety goggles and gloves during gunners hatch removal and installation.

Wear safety goggles and gloves during vehicle wheel lifting and lowering.

Wear safety goggles and work gloves while working on vehicle. Mark and label all connections and reference areas before removal of parts. Failure to comply may result in damage to equipment and or serious injury or death to personnel.

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Wear safety goggles and work gloves while working on vehicle. Mark and label all connections and reference areas before removal of parts. Failure to comply may result in damage to equipment and or serious injury or death to personnel.

Wear safety goggles and work gloves. Working around engine components make sure that you allow the engine time to cool before working on it. Use caution when working under the hood of the vehicle in close quarters, there is little room to work around if engine is still on the hot side. Make sure that the vehicle hood is properly secure or propped so it will not fall on you while you are working. Failure to comply may result in vehicle equipment and or serious injury or death to personnel.

Wear safety goggles while working on interior of gunners hatch.

Wear safety goggles, work gloves and long sleeves when working on engine compartment. Use caution while working under the hood of the vehicle. Make sure it is secured properly. Do not smoke or have open flames around engine. Diesel fuel is flammable and can catch fire or explode. Failure to comply may result in damage to equipment and or serious injury or death to personnel.

Wear safety goggles, work gloves, and long sleeves while working around engine area. Make sure that hood of vehicle is secured so it will not fall while you are bending over engine compartment. Use extreme caution while working on engine that is still hot, it can burn you quickly. Watch for sharp edges on other engine components that can cut you. Failure to comply may result in damage to equipment and or serious injury or death to personnel.

Wear safety goggles, work gloves, long sleeves while working on vehicle engine. Allow engine to cool before disassembling, this will prevent damage to other components not being replaced. Secure hood of vehicle while working under it. No smoking or open flames while working on engine, diesel fuel is flammable and can catch fire with just a spark. Use caution when attaching lifting device that it is secured properly before lifting engine out of engine compartment. Lift slowly to ensure everything is disconnected. Failure to comply may result in damage to equipment and or serious injury or death to personnel.

WARNING SUMMARY

Wear safety goggles, work gloves, making sure vehicle has parking brake set, transmission and transfer case in neutral (N), wheels chocked. Transfer case and oil may be hot if vehicle has been driven, use extreme caution when opening drain valves and un-bolting bolts. Hot fluid and parts can burn through layers of skin quickly. Failure to comply may result in damage to equipment and or serious burns, injury or death to personnel.

Wheel and tire assembly is heavy. DO NOT attempt to lift or catch wheel and tire assembly without the aid of an assistant and a suitable lifting device. Failure to comply may result in serious injury or death to personnel.

When installing new cable, make sure you secure it to the spool drum with screws. Failure to comply may result in damage to equipment or serious injury or death to personnel.

When installing new cotter pin if slot is not visible, continue to tighten nut until slot appears and insert cotter pin. Never loosen a nut to install a cotter pin. Failure to comply may result in damage to equipment and or serious injury or death to personnel.

When lifting objects overhead with suitable lifting device use extreme caution while backing up. Make sure that direct path area is clear of personnel and object. Stop and lower load as soon as possible to avoid an accident. Failure to comply may result in damage to equipment and or serious injury or death to personnel.

When operating winch, ensure that there are no objects in the path of the cable or vehicle. Failure to comply may result in serious injury or death to personnel.

When removing adjusting nuts (11) and (12) with lock washer (13) from spindle (14), always make sure that the correct size socket wrench is used. NEVER tighten or loosen the adjusting nuts (11) and (12) by hitting them directly with a hammer or a drift or chisel placed against them with a hammer. This will damage the adjusting nuts (11) and (12) and prevent proper wheel bearing adjustment achievements. Failure to comply will result in damage to equipment and or serious injury or death to personnel.

When removing first hose fitting, break connection loose slowly and let any pressure release before removing connection. Failure to comply may result in serious injury.

When removing winch cable before the removal of winch from vehicle, also check cable for signs of damage. Make sure you have heavy work gloves on when handling the winch cable. Inspect for frayed wires, binds or kinks in the cable. If found replace cable. Failure to comply may result in damage to equipment and or serious injury or death to personnel.

When repositioning the tie rod clamps, check bolt clearance between the bolt and the axle I-beam at the maximum turn position, right and left turn. Interference may restrict proper steering linkage movement, and/or cause damage to clamp bolts.

When the tie rod, drag link or power steering linkage ends are replaced, they must be threaded into the tie rod sufficiently so that when the clamp is applied, the clamping action will be directly over the threads on the ball joint end. Be sure that the end is in far enough (past clamp) to provide adequate clamping.

When tie rod, drag link, or power steering linkage ends are replaced, they must be threaded into the tie rod or the drag link sufficiently to allow positioning of the clamp over the threads if not welded on the ball joint end. Position the clamp bolt so it crosses the slot in the rod end.

When working with compressed air, ensure that your safety goggles or full face shield are in place before using. Limit the air pressure to 30 psi (207 kPa) when using compressed air for cleaning to reduce the danger from flying debris. Failure to comply may result in serious injury or possible death to personnel.

When you apply some silicone gasket materials, a small amount of acid vapor is present. To prevent serious personal injury, ensure that the work area is well-ventilated. Read the manufacturer's instructions before using a silicone gasket material, then carefully follow the instructions. If a silicone gasket material gets into your eyes, follow the manufacturer's emergency procedures. Have your eyes checked by a physician as soon as possible.

WARNING SUMMARY

When you apply some silicone gasket materials, a small amount of acid vapor is present. To prevent serious personal injury, ensure that the work area is well-ventilated. Read the manufacturer's instructions before using a silicone gasket material, then carefully follow the instructions. If the silicone gasket material gets into your eyes, follow the manufacturer's emergency procedures. Have your eyes checked by a physician as soon as possible.

Whenever any component is serviced or removed from the air system, set the parking brake and chock the wheels to prevent it from moving while the service is being performed. Failure to do so could result in personal injury and/or death.

Whenever any component is serviced or removed from the air system, be sure to set the parking brake and chock the vehicle to prevent it from moving while the service is being

Wire rope can become frayed or contain broken wires. Wear heavy leather-palmed work gloves when handling wire rope. Frayed or broken wires can injure hands.

Wire rope can become frayed or contain broken wires. Wear heavy leather-palmed work gloves when handling wire rope. Frayed or broken wires can injure hands.

With all procedures, use safety regulations for all repairs being performed. Wear protective safety goggles. Have appropriate ventilation, do not smoke or have open flames. While underneath vehicle, make sure no one is inside or if they are, they know you are under the vehicle. Failure to comply may result in damage to equipment and/or serious injury or death to personnel.

You can not check the compressor oil level while the A/C system is charged with refrigerant. Never open the high side hand valve of the manifold gauge set while A/C system is operating. If hot, high pressure refrigerant is forced through the gauge to the refrigerant supply cylinder and it could rupture. Do not use parts other than those specified for the system being serviced. Failure in using improper parts may result in damage to equipment and/or serious injury or death to personnel.

TM 9-2355-106-23-1
HEADQUARTERS, DEPARTMENT OF THE ARMY
WASHINGTON D.C., 26 SEPTEMBER 2007

MAINTENANCE MANUAL

VOLUME 1 OF 3

COMMERCIAL OFF-THE-SHELF (COTS)

for

INTERNATIONAL

MINE RESISTANT VEHICLE

CATEGORY I

2355-01-553-4634

CATEGORY II

2355-01-553-4636

REPORTING ERRORS AND RECOMMENDING IMPROVEMENTS

You can help improve this manual. If you find any mistakes, or if you know of a way to improve procedures, please let us know. Mail comments directly to: PM-MRAP, AMSTA-LC-GMM, 6501 E. 11 Mile Road, Warren, MI 48397-5000.

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HOW TO USE THIS MANUAL

This manual:

Contains instructions for safe and efficient operation of the Mine Resistant Vehicle Category I and Category II, manufactured by International Military and Government, L.L.C. Protection, Inc.

This manual has five chapters that contain sections with alpha/numeric pages. Use the table of contents for reference and quick access.

There are three types of notations: Warnings- are posted in the summary and prior to text that cover any area that would present a situation that may result in injury or death, compliance is mandatory. Cautions- will be found on the same page and preceding the text covering any area that would present a situation that may result in damage to equipment. Notes - will precede text to alter normal procedures or point out areas of concern.

The manual consists of:

Front Matter - a cover page, copyright release, warning summary, how to use this manual, and recommended manual improvements.

Chapter 1 - provides General Information, Equipment Description, and Theory of Operation.

Chapter 2 - provides Troubleshooting Procedures.

Chapter 3 - contains Preventive Maintenance Checks and Services (PMCS) instructions.

Chapter 4 - provides Maintenance Instructions.

Chapter 5 - provides Supporting Information.

Chapter 1 - GENERAL INFORMATION, EQUIPMENT DESCRIPTION, AND THEORY OF OPERATION

1-1 General Information

SCOPE

This COTS manual contains instructions for the operation of Mine Resistant Vehicle, Preventative Maintenance Checks and Service (PMCS) associated with IMP MRAP, operator troubleshooting procedures and maintenance instructions.

MAINTENANCE FORMS AND PROCEDURES

Department of the Army forms and procedures used for equipment maintenance will be those prescribed by (as applicable) DA PAM 738-750, Functional Users Manual for The Army Maintenance Management System (TAMMS).

REPORTING EQUIPMENT IMPROVEMENT RECOMMENDATIONS (EIR)

If your vehicle needs improvement, let us know. Send us an EIR. You, the user, are the only one who can tell us what you don't like about your equipment. Let us know why you don't like the design or performance. Put it on an SF 368 (Product Quality Deficiency Report). Mail it to us at: Commander, U.S. Army Tank-Automotive and Armaments Command, ATTN: AMSTA-LC-GMM, Warren, MI 48397-5000. We'll send you a reply.

CORROSION PREVENTION AND CONTROL (CPC)

A corrosive environment includes exposure to high humidity, salt spray, road de-icing chemicals, gravel damage, and atmospheric contamination. No action beyond normal washing and repair of damaged areas is needed to control corrosion. To prevent moisture accumulation, drain holes are provided on structural and sheet metal areas where needed, and stowage boxes are provided with seals and baffled drains.

Corrosion Prevention and Control (CPC) of Army materiel is a continuing concern. It is important that any corrosion problems with the vehicle be reported so that the problem can be corrected and improvements made to prevent the problem in future items.

While corrosion is typically associated with rusting of metals, it can also include deterioration of other materials, such as rubber and plastic. Unusual cracking, softening, swelling, or breaking of these materials may be a corrosion problem.

If a corrosion problem is identified, it can be reported using form SF 368 (Product Quality Deficiency Report). Use of key words such as "corrosion", "rust", "deterioration", or "cracking" will ensure that the information is identified as a CPC problem.

The form should be submitted to the address specified: Commander, U.S. Army Tank-Automotive and Armaments Command, ATTN: AMSTA-LC-GMM, Warren, MI 48397-5000.

DESTRUCTION OF ARMY MATERIEL TO PREVENT ENEMY USE

Command decision, according to the tactical situation, will determine when the using organization is to destroy a vehicle. A destruction plan will be prepared by the using organization, unless one was prepared by a higher authority. For general vehicle destruction procedures, refer to TM 750-244-6, Procedures for Destruction of Tank-Automotive Equipment to Prevent Enemy Use (U.S. Army Tank-Automotive and Armaments Command).

1-2 Equipment Description

(a) Characteristics Category I and Category II Vehicles

The International® Mine Protected Vehicle (I-MPV) enhances the effectiveness of ground combat forces in stability operations against unconventional enemy forces. The vehicle provides its occupants with enhanced personnel protection when operating in this environment. The vehicles transportation capability allows ground combat forces to travel farther, carry more payloads, and remain engaged longer than was possible with previous vehicles.

The vehicle is designed to increase survivability. The primary mission of the vehicle is to provide ground mobility capable of operating in a threat environment involving ambushes employing the use of mines, Improvised Explosive Devices (IED), Rocket Propelled Grenades (RPG), and Small Arms Fire (SAF). The vehicle will operate in most weather and terrain conditions, including off-road operation and obstacles such as debris. The vehicle will be used for troop transport, ambulance, and combat engineering.

The major systems of the I-MPV include the cab, engine, transmission, drive train, electrical system, pneumatic system, suspension, steering, and winch. The vehicle additionally features a V-shaped hull, raised chassis, integral armor, blow-off wheels, and axles to provide increased survivability by improved mine and IED protection.

Each vehicle is capable of carrying a driver and five to nine troops. The vehicle is also capable of carrying a manned top-mounted machine gun. Firing ports and viewing ports with transparent armor are available for the remaining infantry troops to employ their individual weapons. The vehicle is equipped with an intercom (Interactive Communication System - ICS) and will normally carry radios for communications to higher, adjacent, and supporting units.

Category I:

The Category I vehicle is the smaller of the I-MVP vehicles, capable of carrying six persons including the driver. The vehicle is four-wheel drive with a curb weight of 21,000 to 32,000 lb and a GVW or 31,300 to 52,000 lb. The vehicle is designed for small unit combat operations in urban or confined areas including:

- Mounted patrols
- Convoy security
- Casualty evacuation
- Reconnaissance
- Communications
- Command and control
- Troop and cargo transport
- Direct interaction with civilian population

Category II:

The Category II vehicle is capable of carrying ten persons including the driver. The vehicle is four-wheel drive with a curb weight of 26,600 to 40,000 lb and a GVW of 31,300 to 52,000 lb. The vehicle is designed for ground logistic support operations such as:

- Convoy lead and escort
- Troop and cargo transport
- Ambulance
- Explosive Ordnance Disposal (EOD)
- Combat Engineering Operations

(b) Vehicle Capabilities for Category I and Category II

The vehicles have the capability of communicating with other vehicles to locate, prevent, and defend against the effects of mines and IED. The vehicles integrate communications equipment including:

- DOD tactical radios
- Satellite communication
- Jammers
- Intercom

The vehicle can contain situational awareness systems to assist in avoiding mines and IED by identification of friendly versus enemy forces and knowledge of location of potential hazards relative to the vehicle position.

- The vehicle is also capable of:
- Operating in temperatures ranging from -25 to +125ºF (-32 to +52ºC) without arctic kits.
- Water fording up to 36 in. (91.44 cm) deep.
- Climbing and descending 60 percent grades.

(c) Armor Capabilities

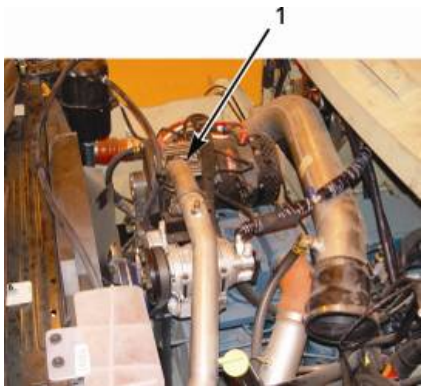
This vehicle provides integral protection for the crew from blast, shock, fragments, and effects of mine blast. It provides crew protection even when a mine is detonated under any wheel or directly under the crew compartment. The vehicle provides crew survivability against antitank mines, small arms fire, IED, and overhead airburst. Additional crew protection is provided by the four-point restrain system and shock absorbing seats. This vehicle has 360 degrees rollover protection.

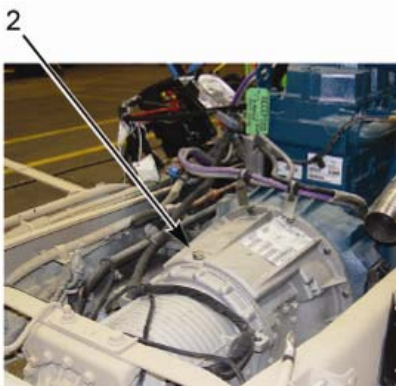
(d) Vehicle Features (as of 15 August 2007)

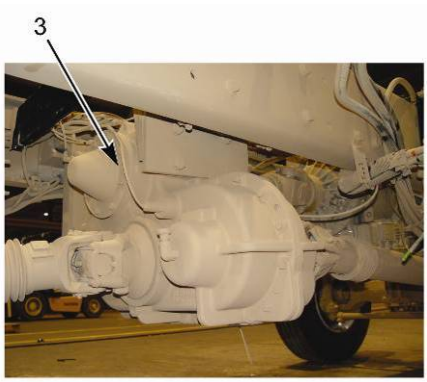
- Antilock Brake System (ABS)
- Air Conditioning (AC)
- Front and rear towing eyes
- Fire Suppression System (FSS)
- Run flat tires
- Four-point restraining seating system
- Intra-vehicle intercom system
- Blackout lighting and night vision capabilities
- NBC (Nuclear, Biological, or Chemical) overpressure system
- Electric winch
- Weapon mounting capability
- Remote controlled spotlight
- Remote controlled/heated mirrors
- Tilt steering wheel
- Two-speed with interval windshield wipers and washers

1-3 Location and Description of Major Components

(a) Drivetrain

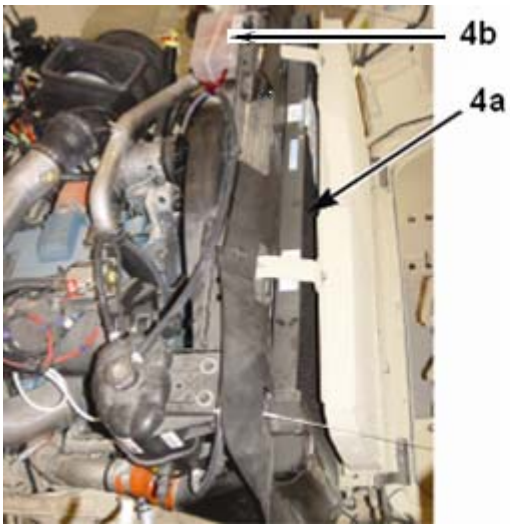






The I-MPV is powered by an International® DT 530, in-line six-cylinder, fuel-injected, diesel engine (1). The engine is coupled with a 3000SP, five-speed automatic transmission (2). The engine and transmission are coupled to a two-speed transfer case (3).

(b) Cooling System

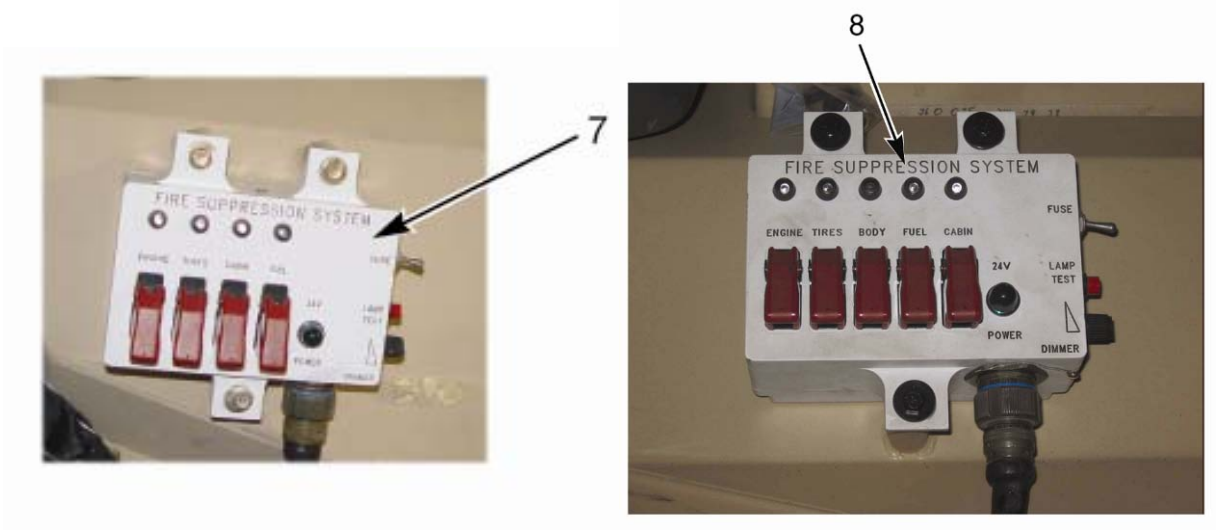


The cooling system consists of a radiator (4a), fill reservoir (4b) and surge tank (5). The cooling system keeps the engine from overheating and is located in front of the engine. The radiator cools the fluids that run through the engine and transmission to keep the vehicle running and moving. The coolant runs through separate passages in the engine to cool it down. The coolant is sent back to the radiator to cool it off before sending it back through the engine again. The transmission cooler attached to the radiator cools the transmission fluid. The coolant will heat the interior of the vehicle when the heater is turned ON. This will also pull heat away from the engine, cooling it off.

(c) Heating, Cooling, and Air Conditioning/Life Support System (HVAC/LSS)

The HVAC/LSS (6) regulates the fresh and re-circulated air within the cabin. It provides protection from outside extreme hot or cold temperatures. Fresh air is received into the vehicle's cabin through an inlet located on the vehicle's roof. The pre-treated air then moves through an evaporator and a heater, where fresh air is mixed with recycled air. A blower injects the treated air into the cabin. (In wartime configuration, the system provides protection from nuclear, biological, and chemical agents by a special filter.)

(d) Fire Suppression System (FSS)

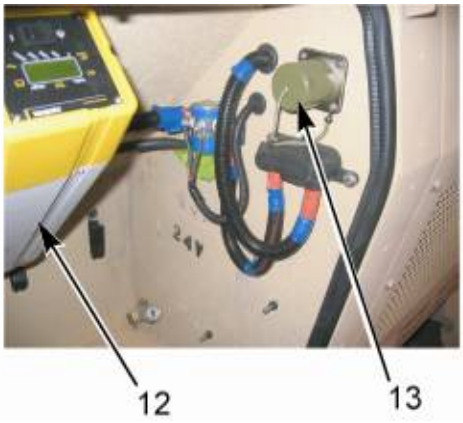


This vehicle is equipped with a fire suppression system Category I (7) or Category II (8). Control box is located between driver and passenger on the control console. The cabin, engine, tires, body, and fuel tank are protected with the fire suppression systems. Only the cabin and engine systems are automatic. All these systems can be operated manually by the driver of the vehicle in case of malfunction in automatic systems. There are different systems for different areas; water mist for cabin, HFC227ea Clean Agent for engine, Petrotech TM25 for tires, AFSS foam water spray for the body, and an AFSS system for fuel tank. The body system is not present on the Category l vehicles.

(e) Pneumatic (Air) System

This vehicle is equipped with air brakes, two air tanks (9), dash gauges and warning lights (10), and sounds to let you know if there is a problem with the air system. The air tanks can also provide a means of inflating the tires. The pneumatics (air) also assists in the opening and closing of cab doors.

(f) Electrical System



The electrical system on this vehicle is run by a 400 amp 24V alternator which runs the vehicle while the engine is operating and charges the four 12V batteries (11). This charging is accomplished through equalization. The batteries are hooked in series-parallel and are located under the right hand passenger front side of vehicle, in a box on top of the two air tanks. These batteries provide 12 or 24V power. The 110V (12) power inverter box is for assisted powering with auxiliary equipment. It is located next to the Slave receptacle (13) used to start a disabled vehicle; they are located in the right front exterior stowage box.

(g) Hydraulic System

There is a hydraulic system (14) located in the rear of the vehicle which is part of the rear troop door/ramp. A panel above the door contains a toggle switch to supply hydraulic power to operate the door/ramp. There are also controls in the driver area for the operation of the door/ramp. The door/ramp can also be raised manually using the hydraulic system.

1-4. Equipment Specifications

Refer to the following tables for specific equipment data.

Dimensions Table

Ground Clearance	Specification
Cross-Country	14 in. (35.56 cm)
Highway	16.7 in. (42.4 cm)

Capacities Table

Item	Specification
Engine Oil with Filter	30 qt (28.3L) 15W40 CI-4
Cooling System	88 qt Extended Life Coolant (ELC)
Transmission with Filter – Dry	29 qt TransSynd (TES-295)
Transmission with Filter – Drain and Refill	19 qt TransSynd (TES-295)
Axle - Front	18 qt (17 L) - (85W140)
Axle - Rear	19.5 qt (18.5 L) - (85W140)
Wheel Ends	1.6 qt (1.5 L)
Rear Door/Ramp Hydraulic Fluid	6.5 qt AW30
Power Steering Reservoir	5.5 qt - (15W-40)
Transfer Case w/o cooler	4.5 qt - SAE 50W (O-81)
Windshield Wiper Fluid	4 qt (3.7 L) Solvent
AC System	6.5 lb (R134A)

Cooling System Table

Item	Specification
Radiator Working Pressure	15 psi (103 kPa) low idle

Engine Configuration Table

Item	Specification
Make	International®
Model	DT 530 ST
Type	Four-stroke, In-line
Cylinders	Six
Bore	4.59 in. (116.5 mm)
Stroke	5.35 in. (135.9 mm)
Displacement	530 cu-in. (8.7 L)
Peak Torque	950 lb-ft @ 1200 rpm
Maximum Brake Horsepower (at 2,000 rpm)	330 hp
Maximum Governed Engine Speed	2,200 rpm

Oil Filter Table

Item	Specification
Type	Full flow, Spin-on
Quantity	1
Oil Pressure	40-70 psi (276-483 kPa)

Fuel System Configuration Table

Item	Specification
Type	Diesel Injection (electronically controlled)
Tank Quantity	70 gal. (265 L)
Air Cleaner	Dual Element
Fuel Type	Diesel or JP8
Fuel Pressure	45 psi (310 kPa)

Electrical System Table

Item	Specification
Alternator	Niehoff N/1602-1 24V
System amps	400
Rotation	Reversible

RPM Rated Output Table

Item	Specification
Recommended Speed	8,000 rpm
Over-speed	10,000 rpm
Drive Type	Pulley
RFI Suppression Ability	Yes
Batteries	650 CCA Exide
Quantity	4 each
Voltage, each	12V
Connection	Series-parallel

Transmission Table

Item	Specification
Make	Allison
Model	3000SP five-speed
Type	Automatic Electronic Control, WTEC III – Gen lV

Transmission Speeds Table

Item	Specification
Forward	Five
Reverse	One

Transfer Case Table

Item	Specification
Make	Meritor
Model	T-4210
Type	Two-speed with NEUTRAL (N)

Axles Table

Item	Specification
Front	MX-18-120 / 18,000 lb - Meritor
Rear (Category I)	RS-21-160 / 21,000 lb - Meritor
Rear (Category II)	RS-23-160 / 23,000 lb - Meritor

Brake System Table

Item	Specification
Actuation	Air
Number of Brake Chambers	2 per axle, rear also equipped with spring brakes
Type	S Cam
Front	Bendix Shoes - 16.5 x 7
Rear	Bendix Shoes - 16.5 x 7
Air Compressor	Bendix
Number of Cylinders	2; Bendix 922
Cylinder Configuration	In-line
Displacement	31.4 CFM
Air Dryer	Bendix Model # 3562656C91
Truck Air System	120-130 psi (827-896 kPa)
System Operating Pressure	70 Max Pressure

Wheels Table

Item	Specification
Type	Two-piece bolt together
Quantity	4
Rim Size	22.5 x 8.25
Stud Quantity per Wheel	10
Lug nut Torque	350-400 lb-ft (475-543 N•m)
Space Plate Torque	175-200 lb-ft

Tires Table

Item	Specification
Type	Tubeless
Quantity	4 per vehicle
Tire Model	XZL
Size	385 16 R20
Load Range	M
Tire Pressure	Category l 95 psi / Category ll 115 psi

Towing and Lifting Table

Item	Specification
Quantity	4 (2 front, 2 rear)
Maximum Load Capacity	N/A
Pintle Hook	49,000 lb
Front Tie Down Eyes	49,000 lb
Rear Tie Down Eyes	49,000 lb
Front Tow Eyes	61,500 lb
Forward Lifting Eyes	30,500 lb
Front Hook for towing	15,000 lb

Cab Table

Item	Specification
Windshield	Transparent Armor
Personnel Capacity	8 person Category I / 10 person Category II

Winch Table

Item	Specification
Make	Warn
Model	18 Series
Electric Winch powered by	Mega Fuse behind battery box

Wire Rope Table

Item	Specification
Diameter	5/8 in. (15.9 mm)
Length	70 ft (21.4 m)
Ultimate Strength	40,000 lb (18,144 kg)
Working Load	18,000 lb (8,172 kg)

Line Pull Ratings Table

Item	Specification
1st Layer (five wraps minimum)	22,000 lb (9,988 kg)
2nd Layer	19,800 lb (8,989 kg)

Filter Section Table

Item	Specification
Fresh Air Filter	3532800C1
Water Filter	3554348F91
Fuel/Water Filter	1618386C93
Oil Filter	1833121C1
Air Conditioner Filter	3542577C2
Secondary Air Filter	3532801C1
Fuel Filter	1677004C94
Power Steering Oil Filter	2503221C1
High Pressure Pump Filter	1825238C1
Air Cooler Cartridge Filter	2500518C91

1-5 Principles of Operation – System Overview

(a) Hydraulic System (Rear Door/Ramp)

Hydraulics are used to open and close the rear door/ramp of the vehicle. A dash-mounted toggle switch allows the driver to operate the door/ramp automatically. In the event of electrical failure or hydraulic failure or for an emergency exit the door can be lowered/raised using a manual release and a handle for the manual hydraulic pump. In a total failure, the rear ramp door, will free-fall.

(b) Electrical System

The vehicle has a dual electrical system that consists of a 24V alternator, starter, and four batteries that are configured in a series parallel configuration, which provides 12 or 24V power. The vehicle is equipped with a power inverter that supplies 110V AC, with a 110V outlet.

(c) Pneumatic (Air) System

The pneumatic system consists of air brakes and air assistance for the vehicle's doors.

Opening and closing of the vehicle's armor-enforced doors is assisted by pneumatic cylinders mounted inside each of the side doors.

There are two air brake chambers per axle. The rear axle also has spring-applied parking brakes. The system has two air supply tanks. One tank supplies air for the front (secondary) brake system. The other supplies air to the rear (primary) brakes. The air is supplied from an engine driven air compressor.

The air compressor compresses air to do the work of brake application. The driver operates a valve that controls air pressure to the brakes, and the pressure is determined by the driver's pedal stroke.

(d) Heating, Ventilation, and Air-Conditioning (HVAC)/Life Support System (LLS)

The vehicle's heating, ventilation, and air-conditioning (HVAC) system provides a comfortable cab environment by controlling temperature and humidity. It also features a special filtration system that protects the vehicle occupants from dust and chemical or biological contaminants.

The HVAC unit is inside the vehicle, on the cab's right side wall, behind the front passenger seat. The NBC filter is accessed externally.

Vehicle occupants can control the HVAC system functions with a mode selection panel, located directly behind the front seats. Controls consist of a group of switches.

(e) Fire Suppression System (FSS)

The vehicle is equipped with multiple sensor-operated and crew-activated fire suppression systems (FSS) that protect the cab and its occupants, the engine, the tires, the vehicle body, the outside of the vehicle, and the fuel tank.

The controls for the FSS are located between the driver's and front passenger's seats, and can also be accessed and activated by the crew. Occupants can easily activate any of the FSS switches by lifting the cover of the desired switch, and toggling the switch UP to activate the specific system.

There are five subsystems: cab protection, engine protection, tire protection, body protection, and fuel tank protection. The cab and engine protection systems can be operated automatically or manually. The other three systems only operate manually. The cab protection system is a water mist spray system without chemical additives, designed to protect occupants from extreme heat for a period of 3 minutes.

The Category I vehicle has only the engine, interior, fuel and tire protection system. The Category II vehicle has all five systems.

(f) Drivetrain

This vehicle is equipped with a DT530 in-line six-cylinder, fuel-injected, diesel engine, a five-speed automatic transmission, and a two-speed transfer case. These components move the vehicle forward, backward, and into LOW range in severe conditions. The output from the transfer case drives the rear differential when in two-wheel drive, and drives the front and rear differentials in four-wheel drive. The vehicle must be brought to a full stop to engage four-wheel drive or shift the transfer case from HIGH to LOW. The vehicle will not move if the transfer case is in NEUTRAL (N).

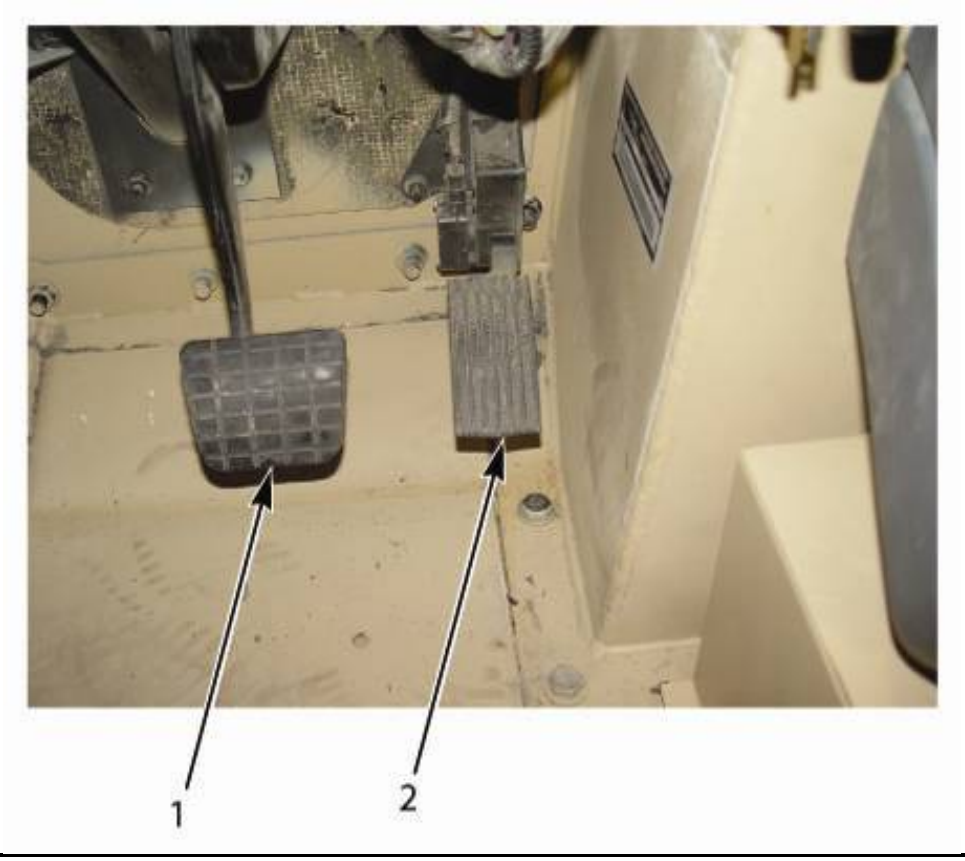
1-6 Location and Use of Features, Controls and Indicators

This section shows the locations and describes the use of controls and indicators used to operate the I-MPV.

Know the location and proper use of every control and indicator before operating the I-MPV. Use this section to learn about each control and indicator. Separate illustrations with keys are provided for each group of controls and indicators.

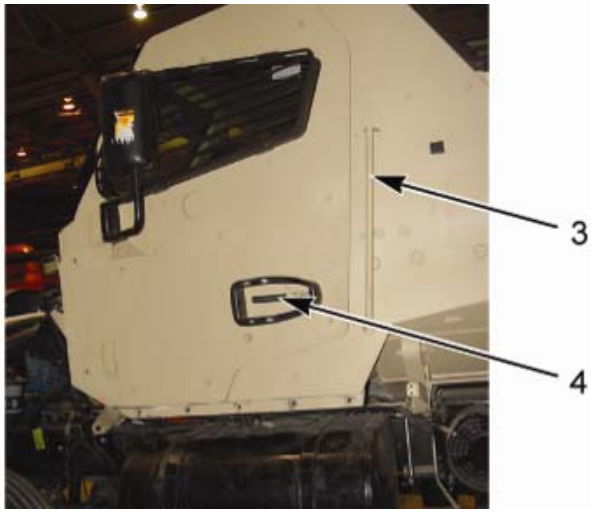
(a) Cabin Mounted Foot Controls

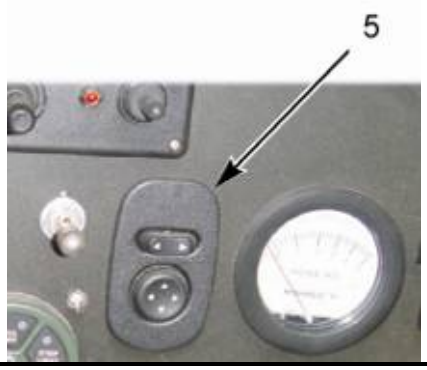
Key	Control or Indicator	Function
1	Service Brake Pedal	Applies service brakes. Apply pressure to stop.
2	Throttle Control	Controls engine speed. Apply pressure to go.



(b) Cabin Mounted Hand Controls

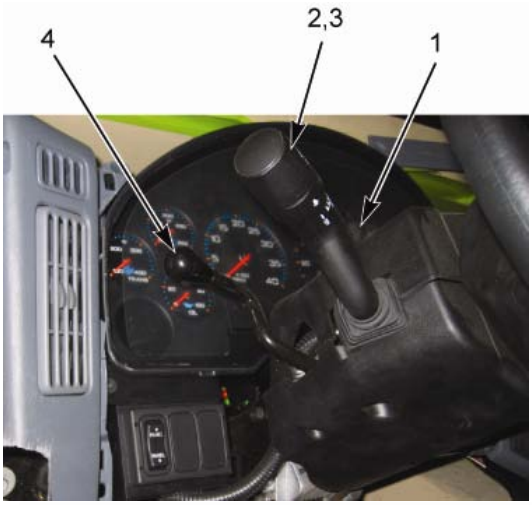
Key	Control or Indicator	Function
1	Cab Door Handle	Pull lever to open cab door from inside of cab.
2	Combat Lock	To secure door from being opened from outside.
3	Grab Handle	Used to assist in entry and exit of cab.
4	Cab Door Outside Handle	Pull to open cab door from outside of cab.
5	Mirror Controls	Allows driver to adjust both side mirrors.

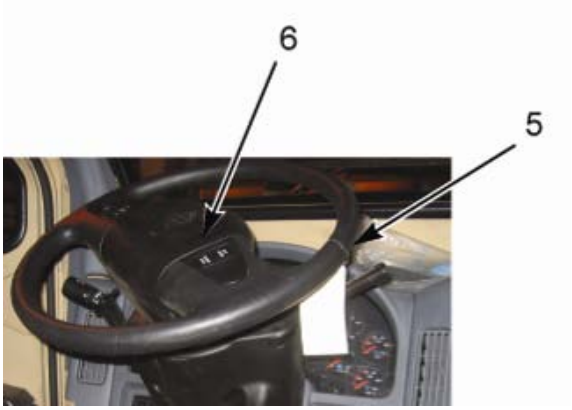




(c) Steering Column Mounted Controls

Key	Control or Indicator	Function
1	Emergency Flasher Control	To turn on hazard warning flashers, push button in. To turn off hazard warning flashers, pull button out.
2	Turn Signal Lever	Push up to signal right turn. Pull down to signal left turn. When turn is completed, lever will automatically return to off position.
3	Head Light Dimmer Lever	Pull directional lever to activate headlight beams. High beam indicator on dash will illuminate BLUE when high beams are on.
4	Steering Wheel Tilt Adjustment Lever	Pull lever forward to adjust steering wheel. Release lever when adjustment is complete.
5	Steering Wheel	Controls direction of vehicle.
6	Horn	Press the center of the steering wheel to sound the city horn.



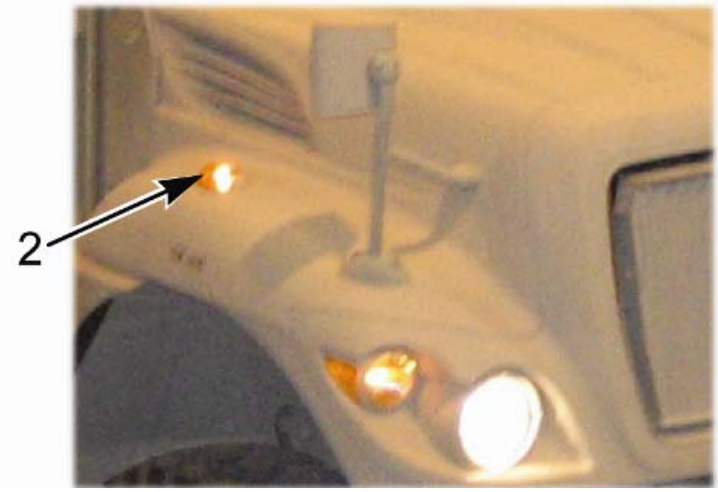


(d) Instrument Panel Controls and Indicators

The instrument cluster includes the instrument gauges, warning indicators, and an Integral Digital Display, that provides odometer and transmission gear indication. This instrument cluster displays the crucial operational functions of the vehicle.

(e) Master Vehicle Light Switch (MVLS)

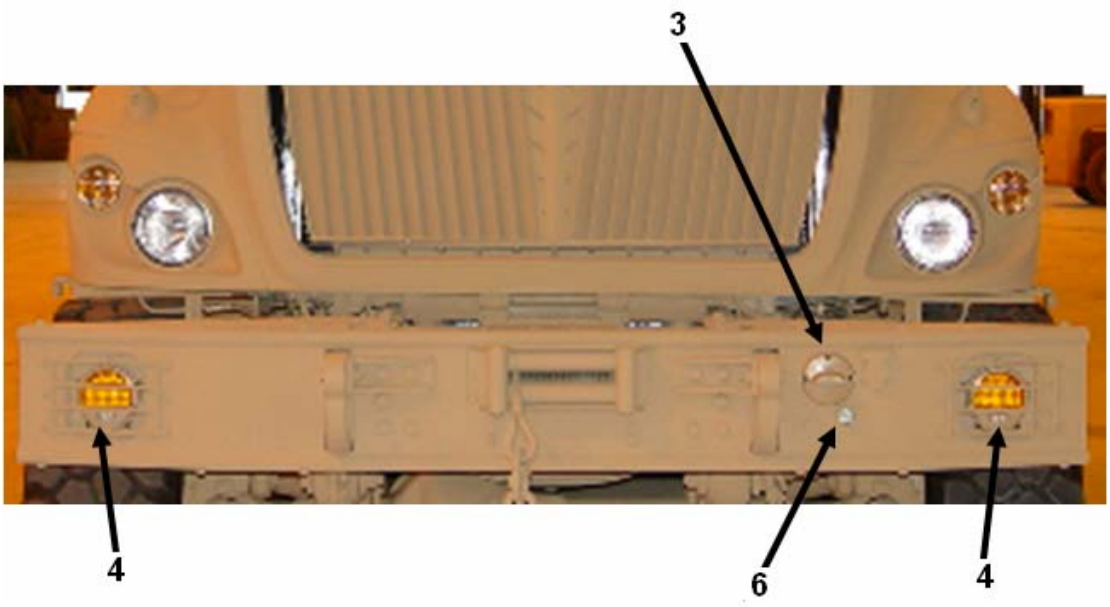
Vehicle lights are controlled by the Master Vehicle Light Switch (MVLS) (1) located on the center instrument panel. The MVLS controls the following lights.

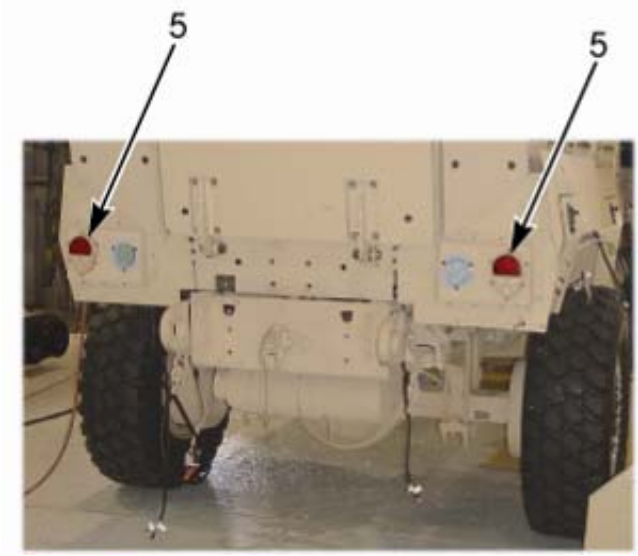


Marker lights (2) are located on the vehicle's fenders.

Blackout light (3) is located on the left front corner of front bumper. There are four blackout marker lights, two on front bumper (4) and two on the rear (5). They are located on the left and right edges of the vehicle's bumpers.

An I.R. lamp (6) is located on the left side of the front bumper.





1. Switch Key Board Function

B.O. DRIVE (1) – Normal Black Out night time driving mode. This will turn on the blackout headlights, clearance lights, marker lights, tail lights, turn signals, etc.

B.O. MARKER (2) – Same lights as B.O. Drive except B.O headlamps are off.

ALL OFF (3) – Turns OFF all vehicle lights.

STOP LIGHT (4) – Normal daytime operation of the vehicle lights. Still allows operation of the vehicle's stop lamps and turn signals.

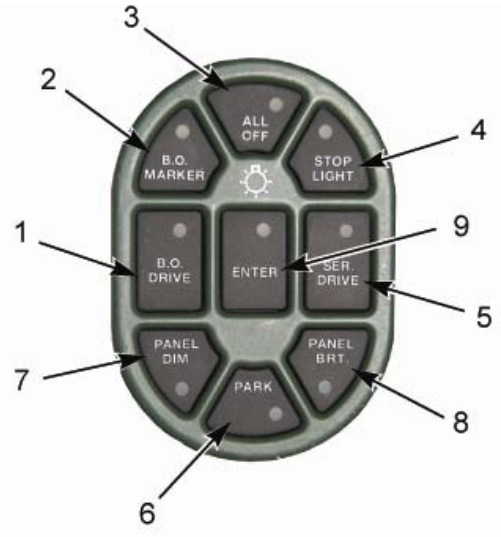
SERVICE DRIVE (5) – Normal night time driving mode of vehicle using headlamps.

PARK (6) – Normal twilight operation of the vehicle's lighting, using parking lights instead of headlamps.

PANEL DIM (7) – Dims the panel display.

PANEL BRT (8) – Brightens the panel display.

ENTER (9) – Inputs the mode selected.



2. Operation Instructions

INITIALIZE:

Press any key (lightning will flash once).

MODE SELECT:

Press desired mode/function (key will flash).

Press ENTER.

NOTE

If enter is not pressed within 5 seconds, switch will reset to previous mode. This prevents accidental switching.

OFF:

Press ALL OFF key.

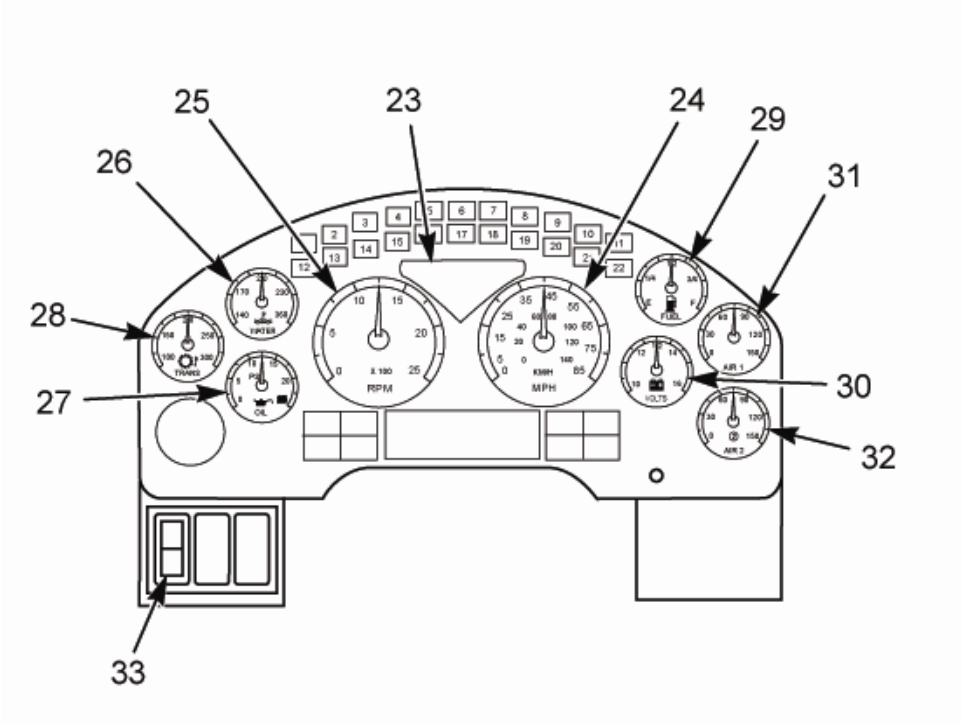
Press ENTER. (Switch will turn off after 20 seconds).

NOTE

If there are no blue indicators lighted, then no external vehicle lights are turned on. Amber backlight is for keypad illumination only.

(f) Warning Indicators

The gauge cluster may contain as many as 25 individual LED warning indicators. These indicators are used to alert the driver of vehicle conditions and functions and may indicate a WARNING or STOP condition. These warning indicators are driven by the software in the cluster. At ignition, the warning lights will illuminate for 8 to 10 seconds, as part of the vehicle power-up sequence.



NOTE

Callouts No. 1 thru 22, discussed in the Instrument Panel Controls and Indicators table, are not shown. Callouts No. 1 thru 22 are the small rectangles shown in the upper middle section of the dash. Callouts No. 1 thru 11 are in the top row of rectangles and are read left to right. Callouts No. 12 thru 22 are in the bottom row of rectangles and are read from left to right.

Instrument Panel Controls and Indicator Table

Callout	Item	Description
1	RANGE INHIBITED	Illuminates AMBER when the transmission is not engaged in the selected gear. The warning light goes out when the gearshift lever/button is adjusted to the appropriate gear.
2	PROTECT LAMP	Illuminates AMBER when coolant or engine oil levels are less than or equal to 80%. If turned on by another component, will be accompanied by a text message in the Integrated Digital Display.
4	AMBER ENGINE WARNING	Illuminates AMBER in conjunction with other warning lights.
5	RED ENGINE STOP	Illuminates RED in conjunction with other warning lights or General Text and Warning Messages to indicate a RED STOP alert.
7	PARK	Illuminates RED when the parking brake is applied. If the brake warning lamp does not illuminate, or if it stays on with the parking brake not engaged, seek service immediately.
21	**ABS** (Antilock Braking System)	Illuminates AMBER when an antilock brake system malfunction has been detected. If the ABS light stays illuminated or continues to flash, have the system serviced immediately.
23 **Triangle located on center of dash below LED indicators**	LEFT ARROW (On top left of center triangle)	Flashes GREEN when the left turn signal or the hazard lights are turned ON.
	HIGH BEAM (On bottom of center triangle)	Illuminates BLUE when the high beam head lamps are turned ON.
	RIGHT ARROW (On top right of center triangle)	Flashes GREEN when the right turn signal or the hazard lights are turned ON.

(g) Gauges and Dimmer Switch

There are nine gauges in the instrument cluster, hereafter called the Electronic Gauge Cluster (EGC). Most gauges have in-gauge warning lights which turn on if the gauge value goes above or below the warning indicator threshold. When the ignition switch is turned ON, the gauge pointer position will be initialized at the lowest pointer stop.

Gauge Table

Callout	Item	Description
24	SPEEDOMETER GAUGE	Indicates the vehicle speed in miles per hour.
25	TACHOMETER GAUGE	Indicates the engine speed in revolutions per minute.
26	COOLANT TEMP GAUGE	Indicates the engine coolant temperature. The warning light indicates the engine coolant temperature has exceeded 230°F (110°C) when equipped with a 10 psi surge tank, and 235°F (113°C) when equipped with a 15 psi surge tank. If the warning light is activated, stop the vehicle as soon as possible, turn the engine OFF and let it cool.
27	OIL PRESSURE GAUGE	Indicates engine oil pressure. If the needle falls below the normal range 20 to 65 psi (138 to 448 kPa) at normal operating temperature, stop the vehicle as soon as safely possible, and check the engine oil level. The gauge warning light indicates low engine oil.
28	TRANSMISSION OIL TEMP GAUGE	Indicates the transmission lubricant temperature in degrees Fahrenheit and Celsius.
29	FUEL GAUGE	Indicates the approximate fuel level in the fuel tank. If the vehicle is equipped with dual fuel tanks, the fuel gauge reads the fuel level only from the primary (draw) fuel tank. When the fuel level reaches approximately 1/8 full, the gauge warning light will illuminate and an audible alarm will sound (5 beeps). If equipped – Special Fuel Warning; the warning light will illuminate when the gauge falls below 1/3 of a tank and the alarm will continuously sound when gauge falls below 1/10 of a tank (close to “E”).
30	BATTERY VOLTAGE GAUGE 12V side only	Indicates the battery voltage when the switch is in the ON position and the engine is running. The warning light illuminates when the battery voltage is too high or low. This is for the 12V side only. There is a separate gauge for 24V.
31	AIR PRESSURE GAUGE #1	Provides indication of the air pressure available for the primary air brakes. The gauge warning light and under – limit audible alarm will indicate when the air pressure is less than 70 psi (483 kPa).
32	AIR PRESSURE GAUGE #2	Provides indication of the air pressure available for the secondary air brakes. The gauge warning light and under – limit audible alarm will indicate when the air pressure is less than 70 psi (483 kPa).
33	PANEL DIMMER SWITCH	Controls the brightness of the LCD (odometer) display.

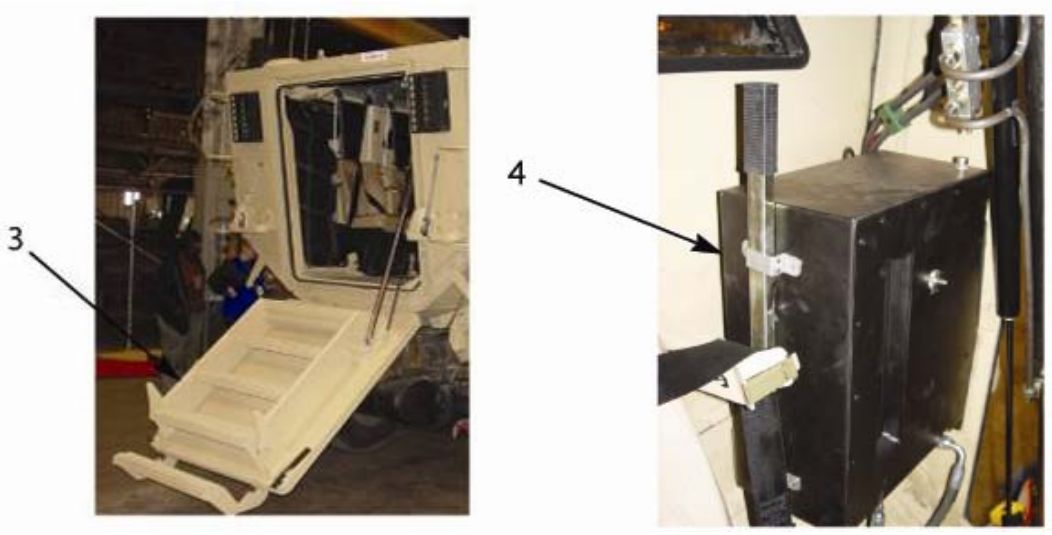
(h) Doors, Gun Ports and Hatches

1. Doors

Before attempting to open the door make sure the combat latch (1) is released by lifting the handle.

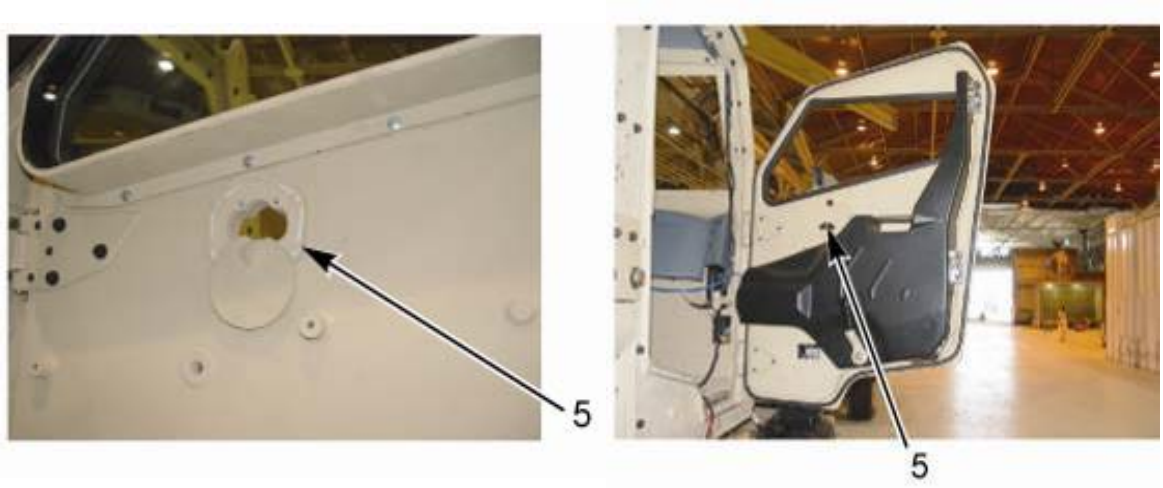
To open the door simply push the inside door handle (2) towards the outside and push open the door.

Vehicle armor and windows are fixed. No operator involvement is required. The armored windows on the vehicle are bolted on, fixed transparent material and do not open. Ventilation is provided by the HVAC/LSS.



The rear door/ramp (3) is operated by hydraulic pressure, or can be operated manually (4) in an emergency. The door/ramp is designed to allow fully equipped troops to easily exit and enter the vehicle.

2. Gun Ports



Category I vehicles features six gun ports (5) (three on each side of the vehicle) and Category II vehicles feature eight gun ports (four on each side of the vehicle).

The gun ports can be opened and sealed from inside the vehicle without the use of tools.

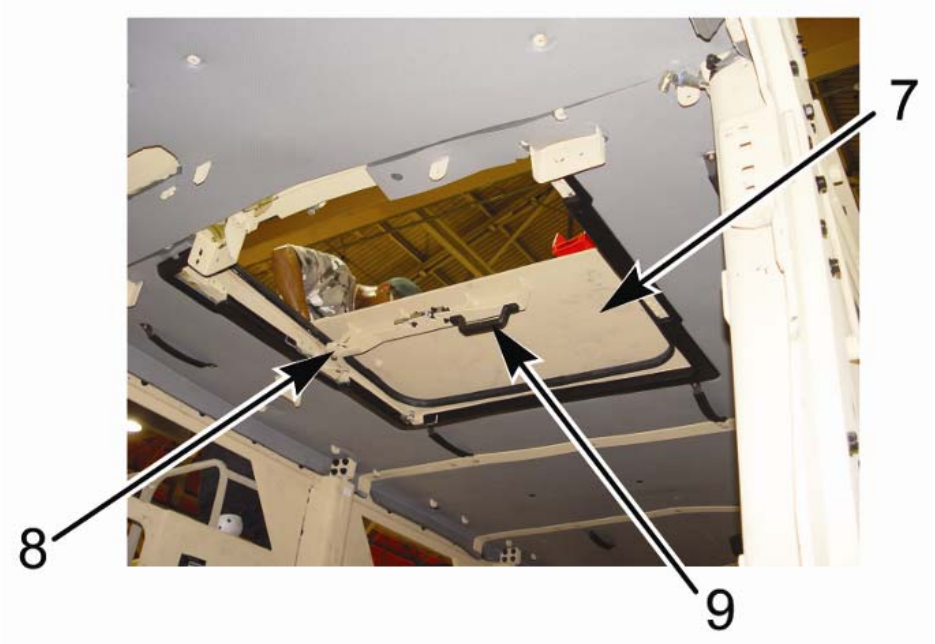
3. Hatches

Vehicle must not be operated with the Emergency roof hatch open. Keep arms, hands and head clear of Emergency roof hatch when closing it. Failure to comply may result in serious injury or death to personnel.

The emergency roof hatch (6) in the rear of the vehicle offers exit in the event of a rollover where the front driver or passenger doors, or rear door/ramp hatch are not available. The roof hatch is opened manually by a black handle, and closed with a clamp.

WARNING

Ensure that the gunners hatch is in the locked position before moving the vehicle. Use extreme caution when standing in gunner's hatch while vehicle is in motion; gunner should be holding onto the weapon or other suitable handle to maintain a stable posture at all times. Failure to comply may result in serious injury or death to personnel.



WARNING

The gunner's sliding hatch can only be opened or closed when the vehicle is stationary and on a level surface. DO NOT attempt to open or close the hatch when the vehicle is in motion. Keep arms and hands clear of gunners hatch when closing it. Failure to comply may result in serious injury or death to personnel.

Roof hatches are heavy. Use caution when opening or closing the roof hatches. Ensure roof hatches are locked when in the open position. Failure to do so may result in injury to personnel.

There is a sliding weapons hatch (7) in the forward roof behind the driver/operator. The gunner will open the hatch manually with a black handle and unhook the lock latch. Holding the black handle (9) and sliding the hatch backwards until it catches the rear latch and left side lock latch (8) to lock into place, (should hear it click as it locks). To close hatch, gunner will have to reach out on left hand side, grab hold of side lock latch (8) and lift to unlock. Holding the black handle slide the hatch closed until it locks into place with the inside lock latch, (should hear it click as it locks).

(i) Armor Protection

The vehicle provides integral protection for the crew from blast, shock, fragments, and effects of mine blast. It provides crew protection even when a mine is detonated under any wheel or directly under the crew compartment. The vehicle provides crew survivability against antitank mines and small arms fire. Additional protection is provided by the four-point restrain system and shock absorbing seats.

The base cab is constructed of metal-composite materials made of ceramic cylinders/based armor.

The armor system integrates an external armor module to the base armor equipped with internal high-performance liners.

The panel are bolted together and sealed.

The armored windows are bolted on, fixed transparent material and do not open.

CAUTION

Do not allow armor to come into contact with extreme heat such as welding equipment or a cutting torch. Extreme heat will degrade the capability of the armor. Failure to comply will result in damage to equipment.

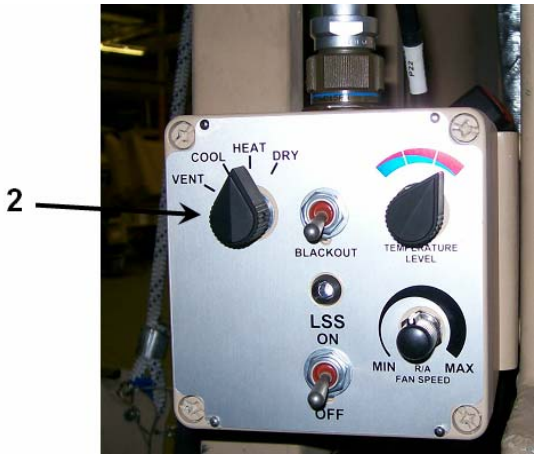
(j) I.R. System

The vehicle has night vision capabilities utilizing infrared (I.R.) technology (1). The I.R. light is located on the left front bumper of the vehicle. The toggle switch on the left will turn the I.R. system on (HIGH), off, and ADJ (adjust). The switch on the right Low and HIGH is for the intensity of the I.R. system. When the toggle switch is in the ADJ position, the control switch can be adjusted between HIGH or LOW intensity, located on the main instrument panel.

(k) Diesel Heater

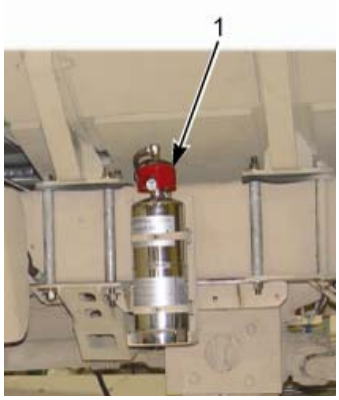
The vehicle is equipped with a diesel heater (1) located on the frame rail behind the passenger side rear stowage compartment. The diesel heater assists during cold weather starting by heating the engine coolant to 176°F and warming the fuel for the engine. Warm air is also provided for the interior of the vehicle.

(l) HVAC/Life Support System (LSS)



1. The Life Support System (LSS) (1) integrated within the vehicle's overpressure system provides a safe and comfortable indoor air supply for cabin occupants. The LSS unit has the following functions:
   - Cabin pressurization with fresh air
   - Nuclear, Biologic, and Chemical (NBC) protection
   - Space air-conditioning
   - Ventilation
   - Dust and particulate removal
2. The LSS control unit is mounted behind the front passenger seat. The controls (2) are accessible by the driver and by cabin occupants.

(m) Fire Suppression System (FSS)



1. The Category II vehicle has up to five separate dispersion locations on the Fire Suppression Systems (FSS) (1) that protects the engine, tires, body, fuel, and interior against fire. The CAT I vehicle has engine, tires, fuel and interior capabilities.

   The system includes:

   - heat detector for the engine
   - heat detector for the interior
   - dispersion system
   - fire suppression units
   - dispersion nozzles

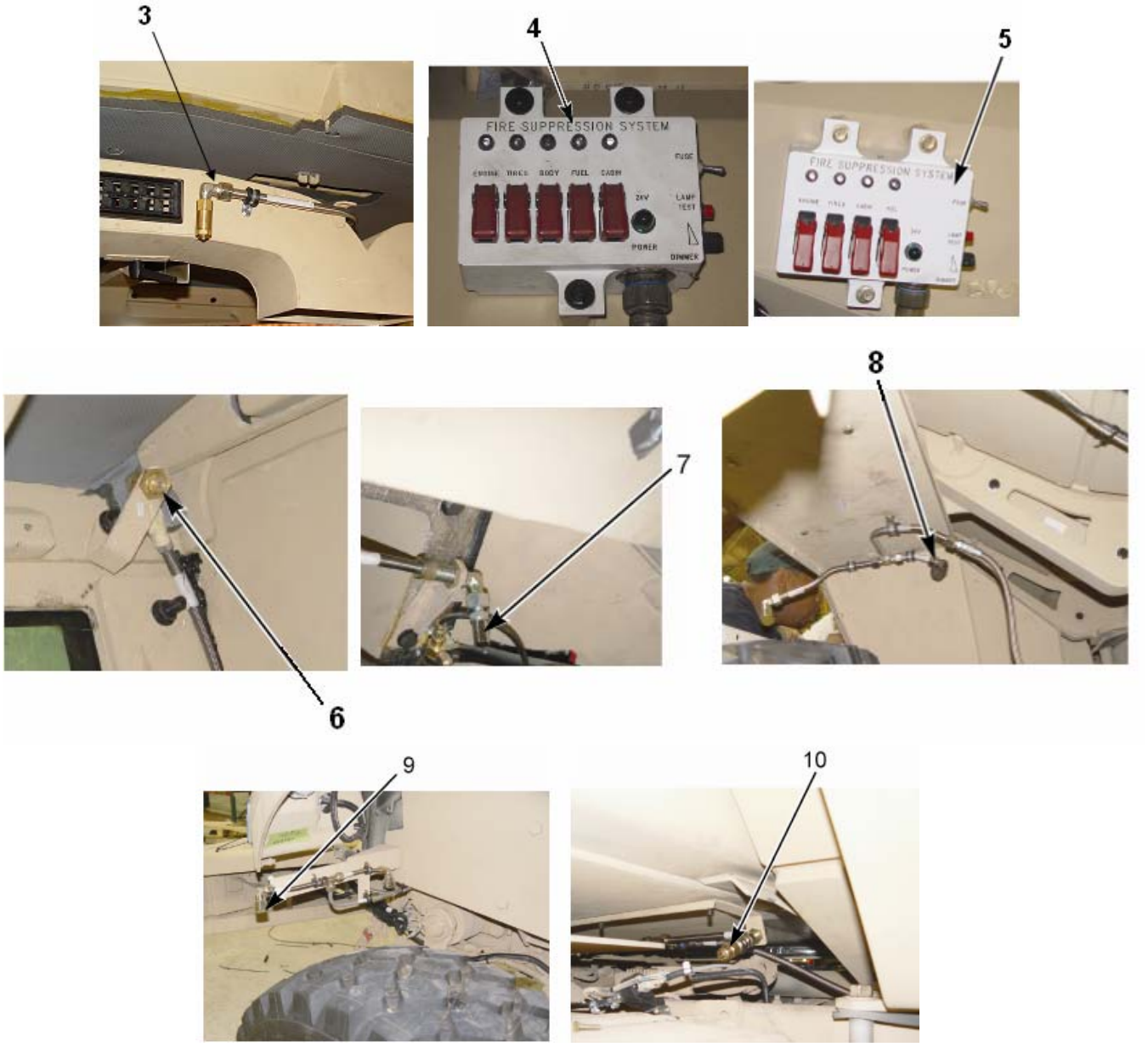
Discharging large quantities of dry chemical fire extinguisher in cab may result in temporary breathing difficulty during and immediately after the discharge event. If at all possible, discharge fire extinguisher from outside the cab. Ventilate and wash cab thoroughly prior to reentry. If respiratory irritation or distress occurs, remove victim to fresh air. Seek medical attention if irritation persists.

Eyes: Flush with cold water for no less than 15 minutes and seek medical attention immediately.

Skin: Flush with large amounts of cold water until all acid is removed. Seek medical attention as required.

Internal: If victim is conscious and alert, give two to three glasses of water to drink and DO NOT induce vomiting. DO NOT leave victim unattended. To prevent aspiration of swallowed product, lay victim on side with head lower than waist. If vomiting occurs and the victim is conscious, give water to further dilute the chemical. Seek medical attention immediately.

2. The engine system and the interior system include an automatic detector that will operate the fire suppression system when fire is detected by the detector.



3. When a fire is present in one of the protected areas : engine (7), front tires (8), rear tires (9), interior (3) and (6), body or fuel tank (10), lift up the cover of the switch and lift the toggle switch CAT I (5), and CAT II (4) up to operate the needed system (for example, if a fire has been detected in the engine, lift up the cover of the engine system switch, and lift the toggle switch up to operate the system).

The Fire Suppression Control Panel has several features:

- indication light for each one of the systems
- manual operation switches for each one of the systems
- automatic fuse
- lamp test
- dimmer
- power light (24V)

4. FSS Bottles

The Fire Suppression System protects personnel from fire.

The fire suppression unit for the crew cabin system is located under the HVAC/LSS.

The fire suppression unit for the engine is located on the right side of the vehicle behind the fans of the air conditioner.

The fire suppression unit for the body is located above the right rear wing of the right rear wheel.

The fire suppression unit for the fuel tank is located on the left side behind the fans of the air conditioner.

The fire suppression unit for the tires is located on the left rear wing of the left rear wheel.

(n) Spotlight

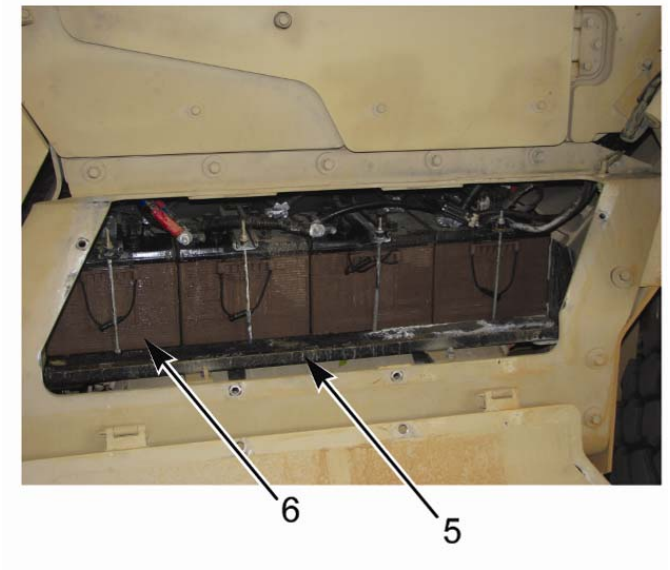
The vehicle is equipped with a remote controlled spotlight (1) mounted of the driver's side roof. The light is controlled by a wireless remote and/or a dash mounted control. This gives the operator a full 360^{o} horizontal rotation and a 135^{o} vertical tilt (2) with fingertip control.

1-7 Exterior Mounted Features

(a) Stowage Boxes

There are four main stowage compartments on this vehicle. Two located in rear (2) and (3) of the vehicle on both left and right sides near the rear wheels and two on front (1) and (4) of the vehicle on both left and right sides just behind the driver and passenger front doors. When you first receive the vehicle, the BII will be stored in the front passenger stowage box (4). Items for each stowage unit will be determined by local load plans.

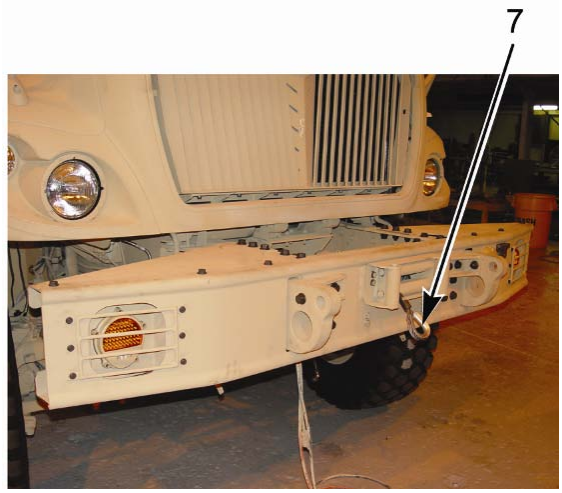
(b) Battery Box

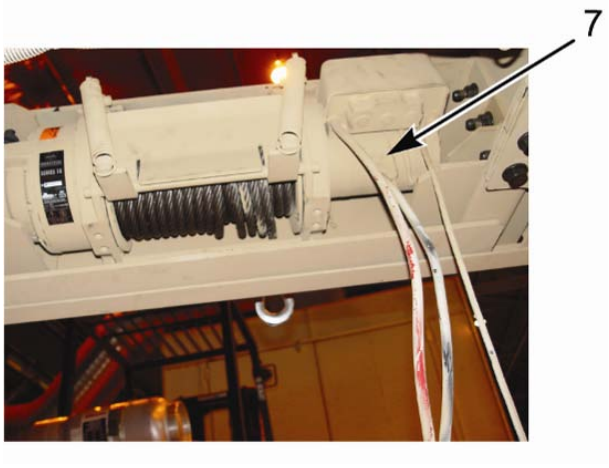


The battery box (5) is located under the passenger side of the cab and stores four 12V batteries (6) connected in series-parallel for 24V system.

(c) Winch System

The vehicle has a front-mounted, deployable self-recovery winch system (7) that is used for self-recovery operations.





The Winch Accessory Kit contains the following items:

Tow Hooks: Secure properly to your vehicle's frame. Tow hooks provide an attachment point for wire rope, straps, and chains.

Clevis/D-Shackles: The D-Shackle is a safe means for connecting the looped ends of cables, straps, and snatch blocks.

Snatch Block: Used properly, the multipurpose 24,000 lb (10,886 kg) snatch block allows you to increase your winch's pulling power and to change your pulling direction without damaging the wire rope.

Choker Chain: Can be used to hook-up to another vehicle or sharp objects for an anchor point.

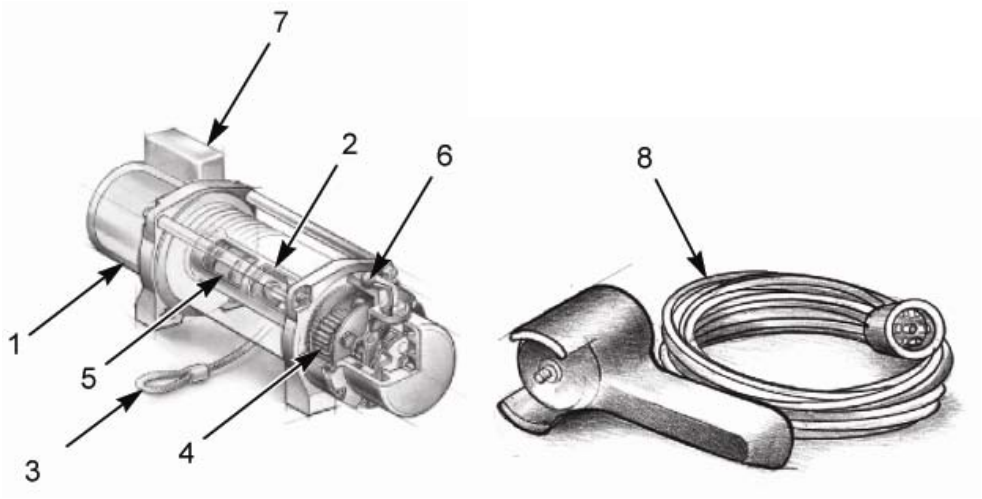
Gloves: Wire rope, through use, will develop "barbs" which can slice skin.

Recovery Straps: Used to "snatch" or pull out a stuck vehicle.

Tree Truck Protector: Use this with a clevis/d-shackle to secure the wire rope to an anchor.

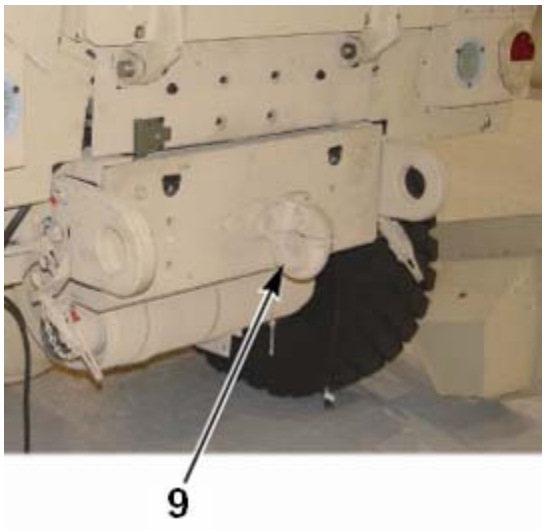
Cable/hook assembly: Wound on a spool motor.

Pulleys: To maintain proper alignment of the winch cable during pay-in and pay-out.



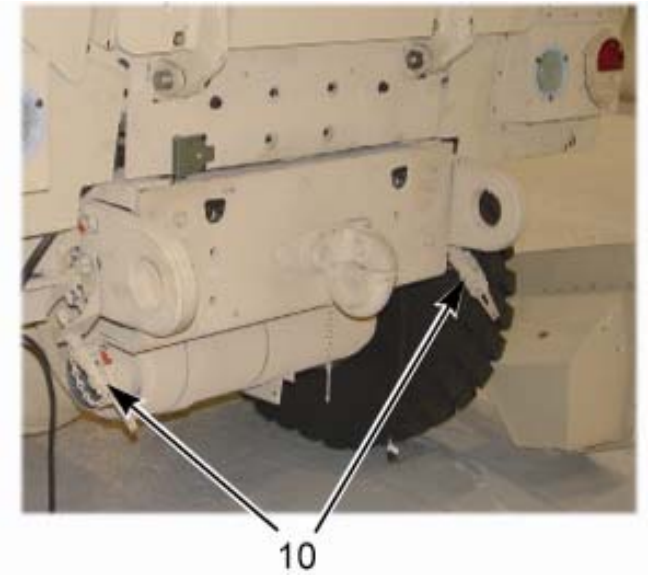
Description of Winch Components and their Functions		
Item #	Part	Description
1	Motor	**Typically the winch motor is powered by the vehicle's battery. The motor provides power to the gear mechanism, which turns the winch drum and winds the wire rope.**
2	Winch Drum	**The winch drum is the cylinder onto which the wire rope feeds. The drum is driven by the motor and drive train. Its direction can be changed using the remote control.**
3	Wire Rope	**Only use the wire rope assigned for this vehicle. The wire rope is looped at the end to accept the hook's clevis pin and wraps around the winch drum and fed through the fairlead.**
4	Gear Train	**The reduction gear converts the winch motor power into a larger pulling force. The gear train design makes it possible for the winch to be lighter and more compact.**
5	Braking System	**The brake is automatically applied to the winch drum when the winch motor is stopped and there is load on the wire rope. The brake prevents the winch from paying out line, which in turn holds the vehicle in place.**
6	Clutch	**The clutch allows the operator to manually disengage the spooling drum from the gear train, enabling the drum to rotate freely (known as "free-spooling"). Engaging the clutch "locks" the winch drum back onto the gear train.**
7	Control Box	**Using electrical power from the vehicle's battery, the control box solenoids switch power to the motor, enabling the operator to change the direction of the winch drum rotation.**
8	Remote Control	**The remote control plugs into the winch control box, allowing the operator to control the winch direction, as well as stand well clear of the wire rope while operating the winch.**

(d) Pintle



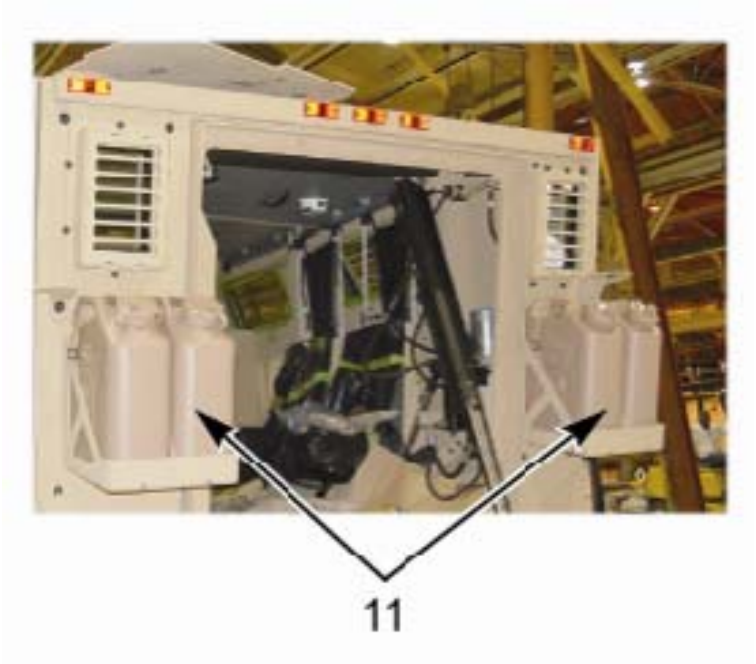
The vehicle is equipped with a rear mounted, swivel pintle (9). The pintle has the capacity to support recovered towing of a like vehicle at GVW. The pintle hooks are used for attaching trailers and tow bars.

(e) Glandhands



Air lines (10) are located on the front and rear crossmember. The two air lines are service brake and park air supplies.

(f) Water Cans and Fuel Cans



The vehicle has two brackets that hold two 5 gallon water or fuel cans (11) each. They are mounted on either side of the rear door/ramp exit. The words FUEL or WATER are molded into the can for identification.

(g) 110V Power Receptacle, NATO Slave Receptacle and Auxiliary Service Air

If the batteries on the vehicle run down and the vehicle will not start, you may want to use another vehicle to provide power to start the vehicle.

The NATO slave receptacle (12) is located in the right front stowage box.

The auxiliary service air fitting (13) is located in the right front stowage box.

There is a 110V receptacle (14) located in the right rear exterior stowage box for use with auxiliary equipment.

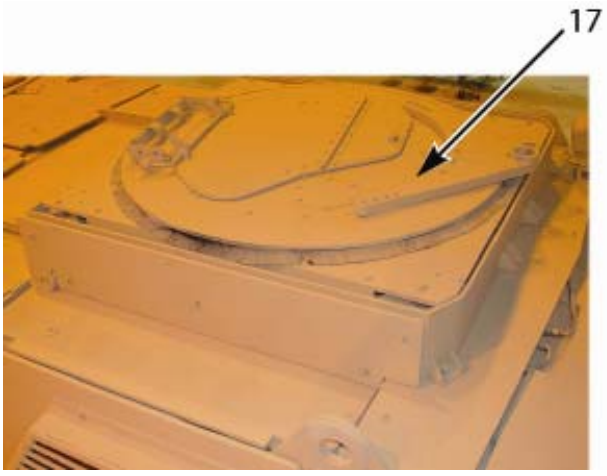
(h) Air Tank Drains

The air tanks (15) are located under the passenger side of the cab beneath the battery box. There are Primary (rear brake) and Secondary (front brake) air system storage tanks.

(i) Fuel Tank

The fuel tank (16) is located under the driver's door of the cab. It stores 70 gallons of fuel to operate vehicle.

(j) Weapons Mount



The weapons mount (17) is located over center of cab roof. The ring mount can rotate for a 360° field of fire.

(k) Engine Hood

The vehicle has a forward opening engine hood (18) with latches on both sides of the cowl.

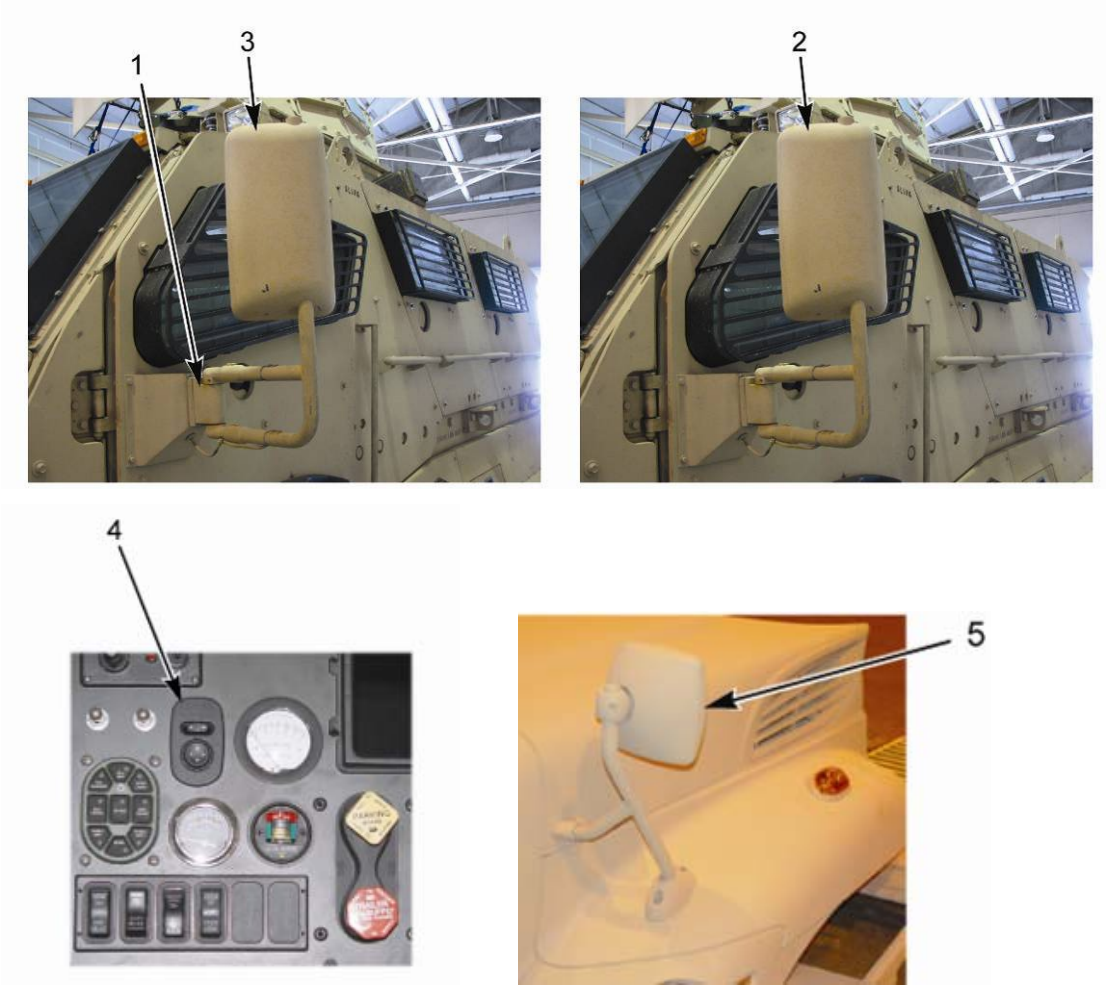
WARNING

Before opening the hood, make sure that there is enough room in front of the vehicle for the hood to open completely without pinning or pinching yourself or an assistant between the hood and any other structure. Failure to comply may result in serious injury or death.

(l) Mirrors

Exterior Mounted Controls and Indicators Table

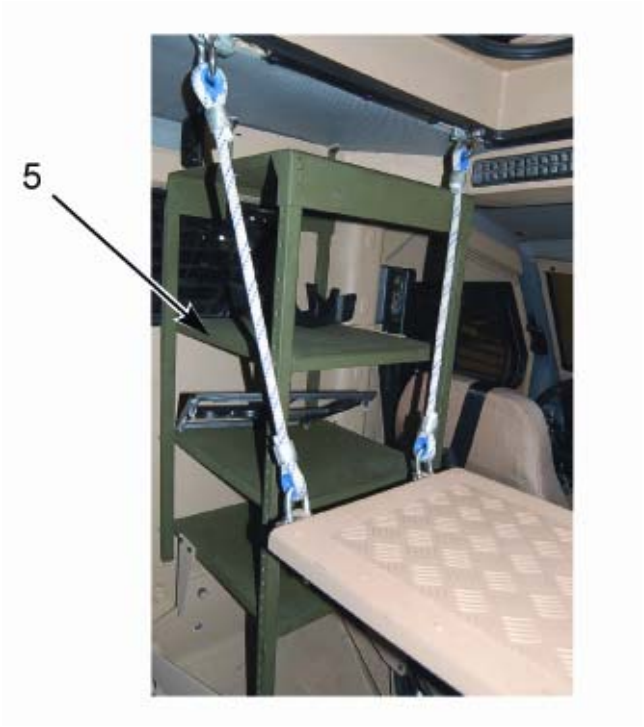
Key	Control or Indicator	Function
1	Mirror Mount (Both Sides)	Holds mirror in place.
2	Side View Mirror (Both Sides)	Remote controlled allowing operator full range of view of traffic and terrain to rear to vehicle.
3	Side View Spotter Mirror (Both Sides)	Allows viewing of blind spots along side and lower section of vehicle.
4	Mirror Controls	Allows driver to move side view mirrors for better viewing.
5	Fender Mounted Mirror	Allows the driver a wider view of blind spots along sides and rear of vehicle.



1-8 Transporting Cargo and Mounting Auxiliary Equipment

The vehicle provides areas for transporting cargo and mounting auxiliary equipment. Depending on what is to be transported, seats may have to be removed to provide the room. Notify Field Maintenance to remove seats.

There are four external stowage boxes located on the vehicle. Two located just in front of the rear wheels behind the cab doors (1) and (3), and two located just behind the rear wheels (2) and (4).



There is a communications rack (5) located behind the drivers seat. This rack may be used for mounting electronics or communications equipment.

There is a storage cargo bag (6) located behind the left rear crew seat.

Tie downs (7) and (8) in the crew compartment may also be used to secure larger cargo. Some seats may need to be removed to facilitate for the larger cargo.

Chapter 2 - TROUBLESHOOTING PROCEDURES

2-1 Troubleshooting Procedures

This section contains troubleshooting procedures to diagnose the most common malfunctions for the vehicle and its components. When performing troubleshooting, the tests, inspections, and corrective actions must be performed in the order listed.

If troubleshooting engine, transmission, ABS/ATC, or major component, it is recommended to refer to the symptom based troubleshooting table, included in this section, to help diagnose the problem.

If troubleshooting systems or components other than engine, transmission, or ABS/ATC, use symptom based troubleshooting table in this section to help resolve the problem.

This manual cannot list all malfunctions that occur. Nor can it list all tests, inspections, and corrective actions. If a malfunction is not listed, or if listed corrective actions are not adequate, notify your NCOIC.

a. Gather information by talking to the driver, if possible. Try to determine the exact symptoms by gathering relevant information:

1. What happened, and when?

2. Under what conditions?

3. When did the symptoms begin?

4. What else occurred at that time?

b. Perform the following preliminary steps:

5. Before beginning these test procedures, make sure the vehicle batteries are at 75% State of Charge (SOC) or higher. This represents an Open Circuit Voltage (OCV) of 12.4V. Batteries with an OCV of 12V or less are either completely discharged or have a dead cell.

6. Before beginning these test procedures, check any light or indicator lamp filaments that are suspected of being open (burned out). This is done to avoid unnecessary extensive circuit checks.

7. Before beginning these test procedures, inspect all connectors for loose or damaged pins, wires, etc.

8. When the Mechanic determines that a fuse is blown, while checking its condition, he is directed to locate the cause of the overload condition and to repair it. While no further instruction on this procedure is listed in the diagnostic tables, the common procedure is as follows: isolate sections of the circuit by disconnecting connectors, and measure the resistance to ground to find the circuit that is shorted to ground. Then locate the damaged spot in the wire or connector and repair.

9. Diagnostics for circuits that are malfunctioning by sticking in the ON position are generally not covered in detail. The Mechanic should check for a malfunctioning switch, relay, or solenoid.

2-2 Diagnostic Trouble Code Access Procedure

a. To display Electronic Control Module (ECM) Diagnostic Trouble Codes (DTC) using the Electronic Service Tool (EST) refer to Diagnostic Testing Section.
You can display ECM Diagnostic Trouble Codes when the EST is not available while out on a mission by using the following procedure:

1. When you have an AMBER or RED engine lamp on the gauge cluster, pull over as soon as safely possible.
2. Put transmission in NEUTRAL (N) and turn engine OFF.
3. Set parking brake, turn the ignition switch to the ON position.
4. Press and release the CRUISE ON and the RESUME/ACCEL buttons simultaneously, (at the same time). If no faults are present, the cluster odometer will display NO FAULTS. If codes are present, they will be flashed out using the RED and AMBER engine lamps on the gauge cluster.

b. To read the DTCs, you will need to count each time the AMBER engine lamp flashes, continue with the following sequence below. This sequence occurs each time the cruise control buttons are depressed together to access the DTCs.

1. The RED engine lamp will flash once to indicate the beginning of ACTIVE DTCs.
2. The AMBER engine lamp will flash repeatedly signaling the ACTIVE DTCs.

NOTE

All DTCs are three digits. Code 111 indicates no Diagnostic Trouble Codes have been detected.

3. Count the flashes in sequence. After each digit of the code a short pause will occur. Three flashes and a pause would indicate the number 3. Two flashes and a pause, three flashes and a pause, and two flashes and a pause would indicate the DTC 232. If there is more than one DTC, the RED engine lamp will flash once in-between to indicate the beginning of a new DTC.

c. After all active DTCs have flashed, the RED engine lamp will flash twice, two times, to indicate the start of the INACTIVE DTCs. Count the flashes of the AMBER engine lamp as before with the ACTIVE DTCs. If there is more than one inactive code, the RED engine lamp will flash once in-between each DTC found.

After all DTCs have been sent, the RED engine lamp will flash three times indicating END OF MESSAGE.

NOTE

If you need to repeat the DTC transmission, just repeat the above procedure by depressing both Cruise Control buttons at the same time again. The ECM will once again send all the stored DTCs.

2-3 Clearing Inactive Diagnostic Trouble Code Procedure

a. Set the parking brake (required for correct ESC signal to clear codes).

b. Turn Master Power Switch to the IGN/ON position.

c. Press and hold the CRUISE ON and RESUME/ACCEL buttons simultaneously, (at the same time).

d. Continue holding the Cruise Control buttons. Depress and release the accelerator (gas) pedal three times within a six second interval.

e. Release the cruise control buttons.

f. Inactive codes will now be cleared.Listed below is a Diagnostic Trouble Code chart. Listed in the chart are DTC numbers, Circuit Index, Condition/Description, Comments, and Probable Causes columns. These are to assist you in diagnosing any ECM problems that could occur with the vehicle.

DTC codes Table

DTC	Circuit Index	Condition / Description	Comments	Probable Causes
* Indicates AMBER engine lamp is ON an odometer message is displayed when Diagnostic Trouble Code is set ** DTC's only available in Engine Protection is enabled				
111	ECM	No errors detected - instrument panel flashing code only	No errors detected by the ECM	
112	ECM_PWR	Electrical system voltage B+ Out of Range HIGH	ECM voltage is continuously more than 18V	Charging system DTC
113	ECM_PWR	Electrical system voltage B+ Out of Range LOW	ECM voltage < 6.5 - cause of no start/misfire	Low battery, loose connections or resistance in circuit
114*	ECT	Engine coolant temp signal Out of Range LOW	Default 180°F (82°C), ECT sensor voltage below 0.127V	ECT signal circuit or sensor shorted to ground
115*	ECT	Engine coolant temp signal Out of Range HIGH	Default 180°F (82°C), ECT sensor voltage above 4.6V	ECT circuit or sensor open
121*	MAP	Intake manifold absolute pressure signal Out of Range HIGH	Default inferred map - low power, slow acceleration - map > 4.9V	MAP circuit shorted high, defective sensor
122*	MAP	Intake manifold absolute pressure signal Out of Range LOW	Default inferred map - low power, slow acceleration - map < 0.039V	MAP circuit short low or open
123*	MAP	Intake manifold absolute pressure in range DTC	Default inferred map - low power, slow acceleration	Hose to MAP sensor plugged
124*	ICP	ICP signal Out of Range LOW	Default open loop control - underrun at idle - ICP below 0.039V	Circuit short low, open, defective sensor
125*	ICP	ICP signal Out of Range HIGH	Default open loop control - underrun at idle - ICP above 4.897V	Circuit short high, defective sensor
131*	APS/IVS	Accelerator position signal Out of Range LOW	Signal voltage below 0.152V - engine idle only	Short to ground or open in circuit, defective sensor
132*	APS/IVS	Accelerator position signal Out of Range HIGH	Signal voltage above 4.55V - eng idle only	Short to V REF or 12 volt, defective sensor
133*	APS/IVS	Accelerator position signal in range DTC	APS/IVS conflict - limited to 0% APS	Failed APS signal
134*	APS/IVS	Accelerator position and idle validation disagree	APS/IVS conflict - limited to 0% APS	Both APS and IVS signal failure
135*	APS/IVS	Idle validation switch circuit DTC	APS/IVS conflict - limited to 50% APS	Failed IVS signal
141	VSS	Vehicle speed signal Out of Range LOW	VSS signal at 0 mph <0.048V -cruise/PTO disengaged -engine speed limited	VSS circuit open or shorted to ground
142	VSS	Vehicle speed signal Out of Range HIGH	VSS signal at 0 mph >4.492V- cruise/PTO disengaged -engine speed limited	VSS circuit shorted to V REF or 12 V

DTC	Circuit Index	Condition / Description	Comments	Probable Causes
* Indicates AMBER engine lamp is ON an odometer message is displayed when Diagnostic Trouble Code is set ** DTC's only available in Engine Protection is enabled				
143	CMP	Wrong number of CMP signal transitions per camshaft revolution	CMP signal intermittent	Poor connection, defective sensor
144	CMP	CMP signal noise detected	ECM detects electrical noise in circuit	Electrical noise, injector voltage shorted to ground
145*	CMP	CMP signal inactive while ICP has increased	No CMP signal while ICP signal increased	Short high, low or open, defective CMP sensor
151	BAP	BAP signal Out of Range HIGH	BAP signal voltage above 4.9V for 1.0 sec.- defaults to 14.7 psi	BAP circuit short high or open circuit
152	BAP	BAP signal Out of Range LOW	BAP signal voltage below 1.0V for 1.0 sec - defaults to 14.7 psi	BAP circuit short low
154	IAT	Intake air temp signal Out of Range LOW	IAT signal voltage low - defaults to 77°C IAT below 0.127V	IAT signal circuit or sensor shorted to ground
155	IAT	Intake air temp signal Out of Range HIGH	IAT signal voltage low - defaults to 77°C IAT above 4.6V	IAT circuit or sensor open
211*	EOP	Engine oil pressure signal Out of Range LOW	EOP signal voltage low, below 0.039V	EOP circuit short low
212*	EOP	Engine oil pressure signal Out of Range HIGH	EOP signal voltage high, above 4.9V EOP	EOP circuit short high or open
213	RPS	Remote throttle signal Out of Range LOW	RPS sensor signal voltage below 0.249V	Open RPS circuit
214	RPS	Remote throttle signal Out of Range HIGH	RPS sensor signal voltage above 4.5V	Shorted RPS circuit
215	VSS	Vehicle speed signal frequency Out of Range HIGH	Speedo, cruise, PTO disabled - engine speed limited -signal >4375 hz	Misadjusted / faulty speed sensor, electrical noise on circuit
216	EPG	Electronic pressure signal Out of Range LOW	EPS signal voltage below 0.039V	Circuit open, short to ground, defective sensor
225	EOP	EOP sensor signal in-range DTC	EOP signal above 40 psi w/engine-off key-on, disables engine protection	Wire harness/connector problem, faulty sensor
226	EPG	EPG sensor signal Out of Range HIGH	EPS signal above 4.9V	Circuit short high, defective sensor
231	ATA	ATA data communication link error	ATA link open or shorted, WTEC controller interference	ATA device grounded or overloaded
236	ECL	ECL switch circuit DTC	Engine coolant level switch circuit DTC	Open or short circuits
241	IPR	Injection control press regulator OCC self test failed	IPR-output circuit check - engine OFF test only	Short high or low or open
246	EFN	Engine fan - OCC self test failed	Fan relay - output circuit check - engine off test only	Open or short circuits
256	RSE	Radiator shutter enable OCC self test failed	Shutter relay - output circuit check - engine off test only	Open or short circuits
265	VRE	Vehicle retarder relay OCC DTC	Vehicle retarder relay-OCC check - engine off test only	Open or short circuits

DTC	Circuit Index	Condition / Description	Comments	Probable Causes
* Indicates AMBER engine lamp is ON an odometer message is displayed when Diagnostic Trouble Code is set ** DTC's only available in Engine Protection is enabled				
311*	EOT	Engine oil temp signal Out of Range LOW	Default 212°F (100°C), no fast idle, EOT above 4.8V	EOT signal circuit or sensor shorted to ground
312*	EOT	Engine oil temp signal Out of Range HIGH	Default 212°F (100°C), no fast idle, EOT below 0.2V	EOT circuit or sensor open
313	EOP**	Engine oil pressure below warning level	Engine monitor of low oil pressure, oil lamp on	No or low oil, sticking oil pressure regulator, pickup
314	EOP**	Engine oil pressure below critical level	Tube blocked or cracked, worn bearings or oil pump	Engine monitor of low oil pressure, shutdown (if equipped)
315*	CMP	Engine speed above warning level	ECM recorded excessive engine speed (above 3000 rpm)	Transmission improperly downshifted
316	ECT	Engine coolant temp unable to reach commanded set point	Enabled only when cold ambient protection enabled	Leaking thermostat, cooling system problems
321	ECT**	Engine coolant temp above warning level	Coolant temperature > 228°F (109°C)	Cooling system problem
322	ECT**	Engine coolant temp above critical level	Coolant temperature > 235°F (112.5°C)	-
323	ECL	Engine coolant below warning/critical level	ECM detects low coolant level	Check coolant level if low, check for leaks
324	IST	Idle shutdown timer enabled engine shutdown	Idle shutdown timer is on and idle time exceeded limit	Idle time limit exceeded
325	ECT	Power reduced, matched to cooling system performance	Engine power reduced, normal in certain conditions	High altitude or hot ambient temp
331*	IPR	Injection control pressure above system working range	ICP above 3675 psi (25 MPa)	Grounded IPR circuit, stuck IPR valve
332*	ICP	Injection control pressure above spec with engine off	ICP signal voltage higher than expected w/engine not running	Circuit shorted to voltage, defective sensor
333*	IPR_SYS	Injection control pressure above/below desired level	ICP desired does not = ICP signal (long period of time)	Air in oil, wrong oil, wrong or stuck IPR, leaking injector O-ring, rings, ICP sensor, high-pressure pump (see manual)
334	IPR_SYS	ICP unable to achieve set point in time (poor performance)	ICP desired does not = ICP signal (short period of time)	-
335	IPR_SYS	ICP unable to build pressure during cranking	< 725 psi ICP pressure after 10 seconds of cranking	Air in oil, injector pressure problem (see manual)
336	EPG	Hydraulic pressure unable to achieve commanded set point		Hydraulic pressure system leakage or problem
421-426	INJ	High side to low side open (Cyl. number indicated)	ECM detected a open circuit for injector circuit	Individual injector harness open

DTC	Circuit Index	Condition / Description	Comments	Probable Causes
* Indicates AMBER engine lamp is ON an odometer message is displayed when Diagnostic Trouble Code is set ** DTC's only available in Engine Protection is enabled				
431-436	INJ	High side shorted to low side (Cyl. number indicated)	ECM detected a short circuit for an injector	Injector or harness shorted low side to high side
451-456	INJ	High side shorted to ground or V BAT (Cyl. number indicated)	ECM detected injector low side shorted to ground -1 bank run	Injector harness shorted on low (control) circuit to ground
461-466	Perf. Diag.	Cylinder contribution test failed (Cyl. number indicated)	ECM finds cylinder contribution insufficient	See performance diagnostics
513*	INJ	Low side to bank 1 open	High voltage supply open - Cyl #1, #2, #3	Open circuit bank #1
514*	INJ	Low side to bank 2 open	High voltage supply open - Cyl #4, #5, #6	Open circuit bank #2
515*	INJ	Bank 1 low side short to ground or B+	Bank #1 side high voltage circuit shorted	Shorted circuit bank #1
521*	INJ	Bank 2 low side short to ground or B+	Bank #2 left side high voltage circuit shorted	Shorted circuit bank #2
525*	ECM	Injector driver circuit DTC	ECM cannot supply sufficient voltage to injectors	Engine harness, injector harness or ECM problem
612*	CMP	Incorrect ECM installed for CMP timing wheel	Mismatch between ECM and engine target wheel (I-6, V8)	Incorrect ECM or strategy for engine
614*	ECM	EFRC/ECM configuration mismatch	Programming problem	Components changed in the field not compatible
621*	ECM	Engine using mfg default rating program engine	Engine operates at 25 hp default	ECM not programmed but installed on truck
622*	ECM	Engine using field default rating	Programming problem, engine limited to 160 hp, options not available	ECM not programmed properly, internal ECM problem
623*	ECM	Invalid engine rating code; check ECM programming	Programming problem	ECM not programmed properly
624	ECM	Field defaults active	Programming problem / ECM problem	Programming problem, internal ECM problem
626	ECM_PWR	Unexpected reset DTC	ECM momentary lost power	See ECM_PWR circuit diagnostics
631*	ECM	ROM (read only memory) self test DTC	ECM failure	Internal ECM problem
632	ECM	RAM memory-CPU self test DTC	ECM failure	Internal ECM problem
655	ECM	Programmable parameter list level incompatible	Programming problem / ECM memory problem	Programming problem
661	ECM	RAM programmable parameter list corrupt	Programming problem / ECM memory problem	Programming problem, internal ECM problem
664	ECM	Calibration level incompatible	Programming problem	Programming problem, ECM not programmed
665	ECM	Programmable parameter memory content corrupt	ECM failure	Internal ECM problem

2-4. Wipers and Washers Diagnosis and Testing

a. Special Tools

The following special tools are required for diagnosing or testing the wiper/washer system:

Digital Multimeter (DMM)

Amp Clamp

b. Principles of Operation

The Power Distribution Center (PDC) wiper relay supplies power to the multifunction switch and the windshield wiper motor when the ignition is in the ON or ACCESSORY position. The multifunction switch contains an integrated module, which is not serviceable. The integrated module controls the INTERMITTENT SPEED and PARK modes.

1. High Speed Windshield Wipers

   The high speed output of the multifunction switch is hard wired directly to the windshield wiper motor. When the multifunction switch is set to the HIGH SPEED position, power is supplied to the windshield wiper motor high speed input. The windshield wiper motor will cycle in the HIGH SPEED mode until the multifunction switch is set to a different position. If the multifunction switch is turned to the OFF position while operating in the HIGH SPEED mode, the integrated module in the multifunction switch will cycle the wiper motor at low speed until the wiper motor reaches the PARK position and the park switch inside the wiper when it receives the ground signal from the park switch.

2. Low Speed Windshield Wipers

   The low speed output of the multifunction switch is hard-wired directly to the windshield wiper motor. When the multifunction switch is set to the LOW SPEED position, power is supplied to the windshield wiper motor low speed input. The windshield wiper motor will cycle in the LOW SPEED mode until the multifunction switch is set to a different position. If the multifunction switch is turned to the OFF position while operating in the LOW SPEED mode, the integrated module in the multifunction switch will cycle the wiper motor at low speed until the wiper motor reaches the PARK position, and the park switch inside the wiper motor provides a ground signal. The module will remove power from the wiper motor low speed input when it receives the ground signal from the park switch.

3. Intermittent Speed Windshield Wipers

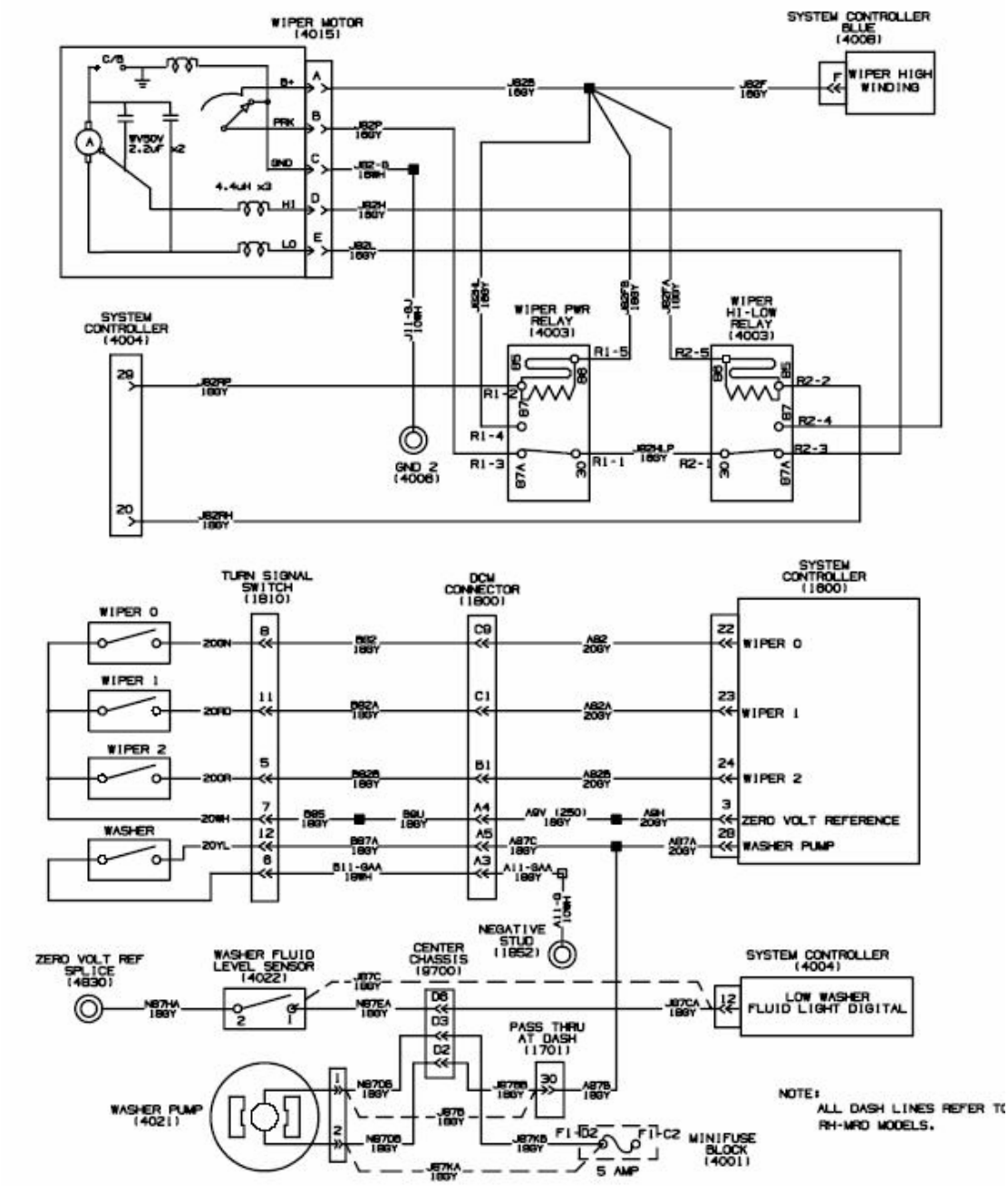
   The multifunction switch has three intermittent speed positions, which determine the length of time the wiper motor will dwell between each sweep. When the multifunction switch is set to one of the intermittent speed positions, the integral multifunction switch module will provide power to the low speed input, and the windshield wiper motor will cycle for one sweep, followed by a delay.

4. Washer System

The power feed for the washer pump motor is hard-wired to the multifunction switch. When the windshield washer portion of the multifunction switch is moved to the ON position, battery voltage is sent to the washer pump motor, which will operate until the windshield washer portion of the multifunction switch is moved to the OFF position.

c. Inspection and Verification

1. Verify the customer concern by operating the system.



WIPER AND WASHER MOTOR SCHEMATIC

WIPER AND WASHER MOTOR SCHEMATIC LEGEND

G - ABBREVIATIONS: COLOR, NOUN AND ENGINE

COLOR ABBREVIATION

AQ - AQUA
BK - BLACK
BL - BLUE
BN - BROWN
DK GN - DARK GREEN
GD - GOLD
GY - GRAY
GN - GREEN
LT BL - LIGHT BLUE
LT GN - LIGHT GREEN
OR - ORANGE
PK - PINK
PL - PURPLE
RD - RED
SIL - SILVER
TN - TAN
VT - VIOLET
WH - WHITE
YL - YELLOW

NOUN ABBREVIATION

A, ACC - ACCESSORY
AC - AIR CONDITIONER
AUX - AUXILIARY
AWG - AMERICAN WIRE GAUGE
B, BAT - BATTERY
CONN - CONNECTION OR CONNECTOR
DRL - DAYTIME RUNNING LIGHTS
ENG - ENGINE
FWD - FORWARD
GA - GAUGE
G, GND - GROUND
I, IGN - IGNITION
IND - INDICATOR
L - LEFT
LT - LIGHT
W/O - WITHOUT
OPT - OPTIONAL
R - RIGHT
S - START OR SENDER
THERMO - THERMOSTAT
W/ - WITH

PREFIX DESIGNATIONS

PREFIX	LOCATION
A	CAB-INSTRUMENT PANEL
B	CAB-DRIVER CONTROL MODULE
C	CAB-HEADER/CLEARANCE LIGHTS
D	CAB-ROOF/REAR PANEL
E	CAB-LEFT DOOR/DOORS
F	CAB-RIGHT DOOR/DOORS.
H	CAB-SLEEPER
J	CAB-DASH (OUTSIDE)
K	ENGINE/RADIATOR
L	TRANSMISSION
M	CHASSIS/FRONT END (CAB DASH PANEL FORWARD)
N	CHASSIS/CENTER SECTION (CAB DASH PANEL TO CAB RR XMBR)
P	CHASSIS/WHEEL BASE SECTION
R	CHASSIS/SUSPENSION/REAR AXLE/AXLES
S	CHASSIS/AF SECTION/STOP/TAIL/TURN LIGHTS

CIRCUIT NUMBER AND IDENTIFICATIONS

CIRCUIT NUMBER	COLOR	DESCRIPTION
1	LT BL	ALTERNATOR - FIELD
2	RD	ALTERNATOR - CHARGE
3	DK BL GY	1708 DATA LINK, SWITCH DATA LINK (+) 1708 DATA LINK, SWITCH DATA LINK (-)
4		SERIAL/DATA COMMUNICATION J1922
5	YL GN	DRIVE TRAIN J1939 DATA LINK (+) DRIVE TRAIN J1939 DATA LINK (-)
6	GY	LOW VOLTAGE ELECTRONIC FEED (9VOLTS)
7	RD	ALTERNATOR - RESISTANCE
8		

CIRCUIT NUMBER AND IDENTIFICATIONS (CONT.)

CIRCUIT NUMBER	COLOR	DESCRIPTION
9	GY	ZERO VOLT REFERENCE (ZVR)
10	WH	CHASSIS/ENGINE GROUND
11	WH	CAB/SLEEPER GROUND
12	LTBL	ACCESSORY FEED
13	PK BK	IGNITION FEED IGNITION FEED (BODY BUILDER CONNECTOR)
14	RD	BATTERY FEED
15	RD	KEY SWITCH FEED
16		
17	PK	STARTER CONTROL
18	PK	GLOW PLUG/PRE-HEATER
19	GY	ENGINE SHUTDOWN
20	LTGN	REMOTE POWER MODULE
21	TN	COLD START CONTROLS (ETHER)
22		
23	TN	ENGINE FAN/SHUTTERS
24	GY	ENGINE EXHAUST BRAKE
25	TN	PYROMETER
26	TN	AMMETER
27	TN	VOLTMETER
28	TN	INSTRUMENTS AND GAUGES
29	TN	ENGINE WATER TEMPERATURE
30	TN	ENGINE OIL TEMPERATURE
31	TN	TRANSMISSION OIL TEMPERATURE
32	TN	AXLE OIL TEMPERATURE

CIRCUIT NUMBER AND IDENTIFICATIONS (CONT.)

CIRCUIT NUMBER	COLOR	DESCRIPTION
33	TN	ENGINE OIL LEVEL
34	TN	COOLANT LEVEL
35	TN	ENGINE OIL PRESSURE
36	TN	FUEL LEVEL
37	TN	FUEL PUMP
38		
39	GY	AIR DRYER HEATER
40	GY	LOW AIR PRESSURE WARNING
41	TN	AIR TEMPERATURE
42	GY	FRONT AXLE ENGAGED
43	GY	POWER DIVIDER LOCK (PDL) WARNING
44	GY	PARK BRAKE WARNING
45	LTGN	ANTI - THEFT WARNING
46	GY	POWER TAKE - OFF WARNING
47	GY	SPEEDOMETER
48	GY	TACHOMETER
49	GY	DIFFERENTIAL LOCK WARNING
50	YL	LIGHT SWITCH FEED
51	YL	DIMMER SWITCH FEED
52	YL	HEADLIGHT HI - BEAM
53	YL	HEADLIGHT LO - BEAM
54	BN	PARKING/MARKER LIGHTS
55	OR	TURN SIGNAL - FEED
56	OR YL	TURN SIGNAL LIGHTS - LEFT TURN SIGNAL LIGHTS - LEFT (BODY BUILDER CONNECTION)
57	OR LT GN	TURN SIGNAL LIGHTS - RIGHT TURN SIGNAL LIGHTS - RIGHT (BODY BUILDER CONNECTION)

CIRCUIT NUMBER AND IDENTIFICATIONS (CONT.)

CIRCUIT NUMBER	COLOR	DESCRIPTION
58	BN	CLEARANCE/IDENTIFICATION LIGHTS
59	GY	SOLENOID
60	OR	HAZARD LIGHTS
61	GY	AIR SUSPENSION
62	DKBL	PANEL LIGHTS
63	DKBL	COURTESY/DOME LIGHTS
64	YL	FOG/DRIVING LIGHTS
65	OR	CAB REAR FLOOD LIGHT
66	YL	DAYTIME RUNNING LIGHTS
67		
68	BN	TAIL LIGHTS
69	BN	LICENSE PLATE LIGHT
70	OR RD	STOP LIGHTS STOP LIGHTS (BODY BUILDER CONNECTION)
71	OR LTBL	BACK - UP LIGHTS BACK - UP LIGHTS (BODY BUILDER CONNECTION)
72	OR	TRAILER AUXILIARY FEED - BATTERY
73	LTGN	PWM
74	LTGN	HEATER RECIRC MOTOR
75	LTGN	HEATER BLOWER MOTOR
76	LTGN	AUXILIARY FAN
77	LTGN	AIR CONDITIONER
78	LTGN	MIRRORS - HEATED; MOTORIZED
79	GY	SEAT BELTS
80	BK	SLEEPER BOX RELAY - FEED
81	LTGN	POWER DOOR LOCKS

CIRCUIT NUMBER AND IDENTIFICATIONS (CONT.)

CIRCUIT NUMBER	COLOR	DESCRIPTION
82	GY	WINDSHIELD WIPER
83	LTGN	POWER WINDOWS
84	LTGN	CIGAR LIGHTER
85	GY	HORN
86	LTGN	RADIO - ENTERTAINMENT/CLOCK
87	GY	WINDSHIELD WASHER
88	LTGN	CLOCK/HOURMETER
89	VT	AIR BAG
90	GY	HYDRAULIC BRAKE PUMP
91	VT	INTERCOMMUNICATIONS
92	TN	TRANSMISSION CONTROLS - ELECTRONIC
93	TN	AXLE SHIFT CONTROL
94	GY	ANTILOCK BRAKE SYSTEM
95	TN	EXHAUST EMISSION
96	YL	SNOW PLOW LIGHTS/CRUISE CONTROL
97	VT	ENGINE CONTROLS - ELECTRONIC
98	BK	DATALINK AND DIAGNOSTICS
99	VT	ACCELERATOR POSITION SENSOR (APS)
100	GY	AIR HORN (ELECTRIC SOLENOID ACTUATED)
101	TN	BRAKE APPLICATION AIR
102	YL	FLASH TO PASS
103	LTGN	BODY BUILDER AUX. FEED
104	DKBL	REMOTE START/STOP
105	LTGN	HEATED SEATS

2-5 Diagnostics

Faults with the wiper and washer systems are apparent when the wiper or washers do not operate correctly. The ESC will also log diagnostic trouble codes for some types of failures.

There is no shortcut available to identify if a problem is caused by failures with inputs to the ESC or failures in circuits out of the ESC. The "INTUNE" software can identify if switch inputs are reaching the ESC. It can also override switch inputs to test outputs from the ESC. Using the software will allow you to quickly identify if the problem is with an input to the ESC or an output from the ESC. If the software is not available check output circuits, then check switch input circuits to the ESC.

A problem with wiper operation could be attributed to an open or short in the wiper switch, missing power or ground to the wiper motor, open or shorted wires, a failed relay, a bad wiper motor or an internal problem in the ESC.

A problem with washer operation could be attributed to an open or short in the washer switch, missing power or ground to the washer pump motor, open or shorted wires, or a bad washer pump motor.

An electronic service tool, running the "INTUNE" diagnostic software, can be used to request operation of the wiper motor and monitor activation of the wiper switches. See the diagnostic software manual for details on using the software.

a. Wiper and Washer Preliminary Check

Wiper and Washer Preliminary Check

STEP	KEY	ACTION	TEST POINTS	SPEC.	YES - IN SPEC.	NO - OUT OF SPEC.
1.	On	Verify washer or wipers are not operating incorrectly.	Attempt to operate washer and wipers.	Washer or wipers are **not** operating correctly.	Go to next step.	Washer and wipers are operating correctly. Problem does not exist or is intermittent. (Check for previously active diagnostic trouble codes.)
2.	On	Determine if any other features are malfunctioning that may have common circuits. (Example:	Visually check for other malfunctioning features.	No other features are malfunctioning.	Go to next step.	Identify and repair condition causing several features to be inoperative.

Wiper and Washer Preliminary Check

		Missing power or ground common to several features.)				
3.	On	Check if washer is operating correctly.	Attempt to operate washer.	Washer is operating correctly.	Go to next step.	Go to washer circuits.
4.	On	Are wipers working correctly except for wiper parking?	Visually check if wipers work correctly except for wiper parking.	Wipers work correctly except for wiper parking.	Go to wiper park circuits.	Go to next step.
5.	On	Check for diagnostic trouble codes.	Read display on odometer.	No wiper diagnostic trouble codes are active.	Go to next step.	Go to Wiper Motor Circuits.

6. There is no shortcut available to identify if a problem is caused by failures with switch inputs to the ESC or failures in circuits out of the ESC. The "INTUNE" software can identify if switch inputs are reaching the ESC. It can also override switch inputs to test outputs from the ESC. Using the software will allow you to quickly identify if the problem is with an input to the ESC or an output from the ESC. If the software is not available check output circuits, then check switch input circuits to the ESC.

   Go to Wiper Motor Circuits.

   Go to Wiper Input Circuits to the ESC.

b. Diagnostic Trouble Codes (DTC)

To display diagnostic codes, put the vehicle in diagnostic mode. Set the parking brake and turn the Ignition key "ON". Then press the Cruise "ON" switch and the Cruise "Resume" switch. If no diagnostic trouble codes are present, the cluster odometer will display "NO FAULT". If diagnostic trouble codes are present the gauge cluster will display the total number of faults and cycle to the next diagnostic trouble code after 10 seconds. To manually cycle through the diagnostic trouble code list, press the cluster display select/reset button. The last character of the diagnostic trouble code will end in "A" for active diagnostic trouble codes or "P" for previously active diagnostic trouble codes. Turning the ignition key off or releasing the park brake will take the ESC and the gauge cluster out of the diagnostic mode.

The previously active diagnostic trouble codes may be cleared, while in the diagnostic mode, by turning on the left turn signal and pressing the cruise on and set switches simultaneously.

Wiper Diagnostic Trouble Codes	
DIAGNOSTIC TROUBLE CODE	**FAULT DESCRIPTION**
611 14 6 1	Wiper power under current. 4008 pin F. Refer to Wiper Motor Circuits.
611 14 6 2	**NOTE** The virtual fuse in the ESC will trip during a short. To reset the fuse, the key switch must be cycled. Wiper power over current. 4008 pin F. Refer to Wiper Motor Circuits.
611 14 6 3	Wiper power, less than normal low current but more than open circuit
611 14 6 4	Wiper power, greater than normal high current and less than fusing current
611 14 6 6	Wiper power has current flow when output commanded off
2033 14 8 1	Wiper high-low relay circuit overloaded. Connector 4004 pin 20 current overload. Refer to Wiper Motor Circuits.
2033 14 8 2	Wiper high-low relay circuit open circuit. Connector 4004 Pin 20 open. Refer to Wiper Motor Circuits.
2033 14 8 3	Wiper high-low relay circuit shorted to ground. Connector 4004 Pin 20 shorted to ground. Shorted to ground or defective relay. Refer to Wiper Motor Circuits.
2033 14 14 1	Wiper on relay circuit overloaded. Connector 4004 pin 29 current overload. Refer to Wiper Motor Circuits.
2033 14 14 2	Wiper on relay circuit open circuit. Connector 4004 Pin 29 open. Refer to Wiper Motor Circuits.
2033 14 14 3	Wiper on relay circuit shorted to ground. Connector 4004 Pin 29 shorted to ground. Shorted to ground or defective relay. Refer to Wiper Motor Circuits.

2-6 Washer Circuits

Fault Detection Management

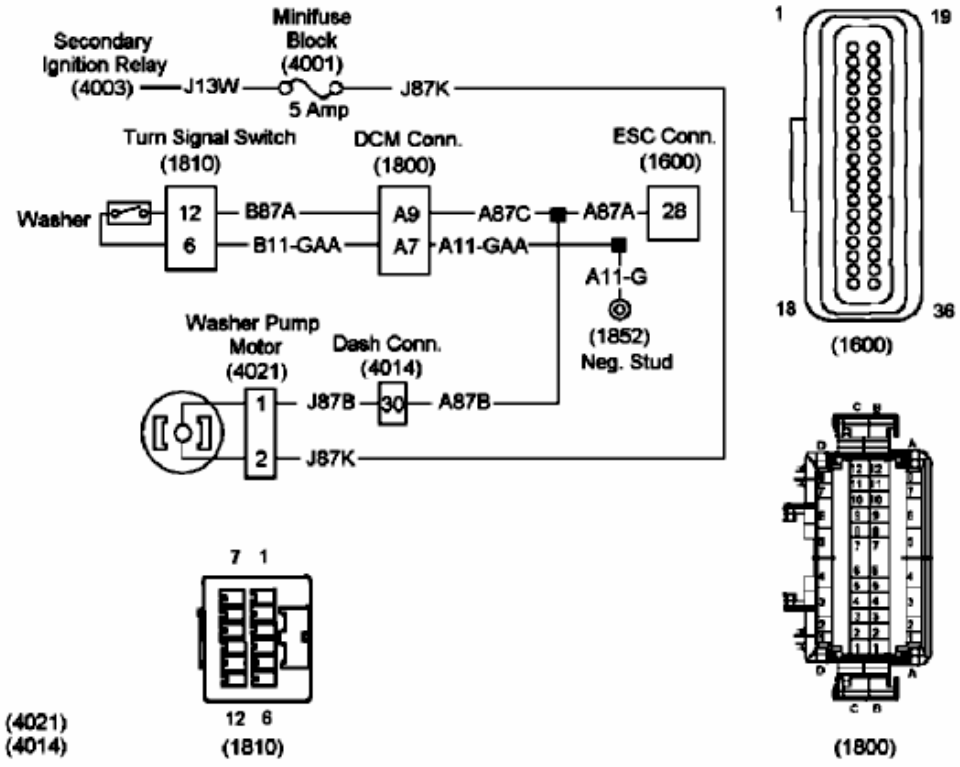
NOTE

The testing method for troubleshooting the electrical systems portrayed in this manual is a basic voltage test. An alternative method of checking for voltage drops within a given circuit may be a quicker method of identifying an exact problem.

A fault in the washer system will be apparent when the washers do not operate correctly. There are no diagnostic trouble codes associated with the washer circuits.

A problem with washer operation could be attributed to an open or short in the washer switch, missing power to the washer pump motor, open or shorted wires or a failed washer pump motor.

Refer to washer pump circuits .



Washer Pump Circuits (Connectors Viewed From Mating End)

J13W TO SECONDARY IGNITION RELAY
(1600) 36-WAY SYSTEM CONTROLLER CONNECTOR
(1800) CAB HARNESS/DCM CONNECTOR
(1810) TURN SIGNAL SWITCH CONNECTOR
(1852) NEGATIVE STUD
(4001) MINIFUSE BLOCK
(4003) SECONDARY IGNITION RELAY
(4014) DASH PASS THROUGH CONNECTOR
(4021) WASHER PUMP CONNECTOR (ON WASHER BOTTLE)

Washer Connector Tests

Washer Pump Connector (4021) Voltage Checks

Check with ignition on and pump connector (4021) removed.

NOTE
Always check connectors for damage and pushed-out terminals.

Test Points	Spec.	Comments
Pump harness connector (4021) cavity 2 to ground	12 ± 1.5 volts	If voltage is missing, check for blown fuse or open or short in circuit J87KA to mini fuse block.
Without washer switch activated, pump harness connector (4021) cavity 1 to ground		Tests circuit between ESC and pump motor.
		If voltage is missing, check for open or short in circuit J87B, A87B, A87A or A87C. Also check for incorrect voltage from ESC.
	12 ± 1.5 volts	**NOTE** Always use breakout box ZTSE 4477 to take measurements on ESC connectors.
		A short to ground would cause the washer to operate continuously.
With washer switch activated, Pump harness connector (4021) cavity 1 to cavity 2.		Tests circuits from ground through washer switch to washer pump motor.
	12 ± 1.5 volts	If voltage is incorrect check for open circuits from (4021) cavity 1, through closed washer switch, to ground. Disconnect (1810) and jumper pins 12 to 6, if voltage is correct, replace washer switch. Repair circuits.
		If voltage is correct and washers are inoperative, replace washer pump motor.

Extended Description

The washer pump motor is wired directly to the washer switch, in the turn signal switch assembly. 12 volts to the washer pump motor is provided from a 5 amp fuse in the mini fuse block, within the engine compartment power distribution panel. When the washer switch is depressed, a ground will be supplied to the washer pump motor. This will cause the pump to run until the washer switch is released. The ground from the washer switch is also applied to ESC connector (1600) terminal 28. This will signal the ESC that the washer has been activated. The ESC will activate the low speed wipers for several wipes.

2-7 Wiper Circuit Inputs to ESC

Fault Detection Management

NOTE

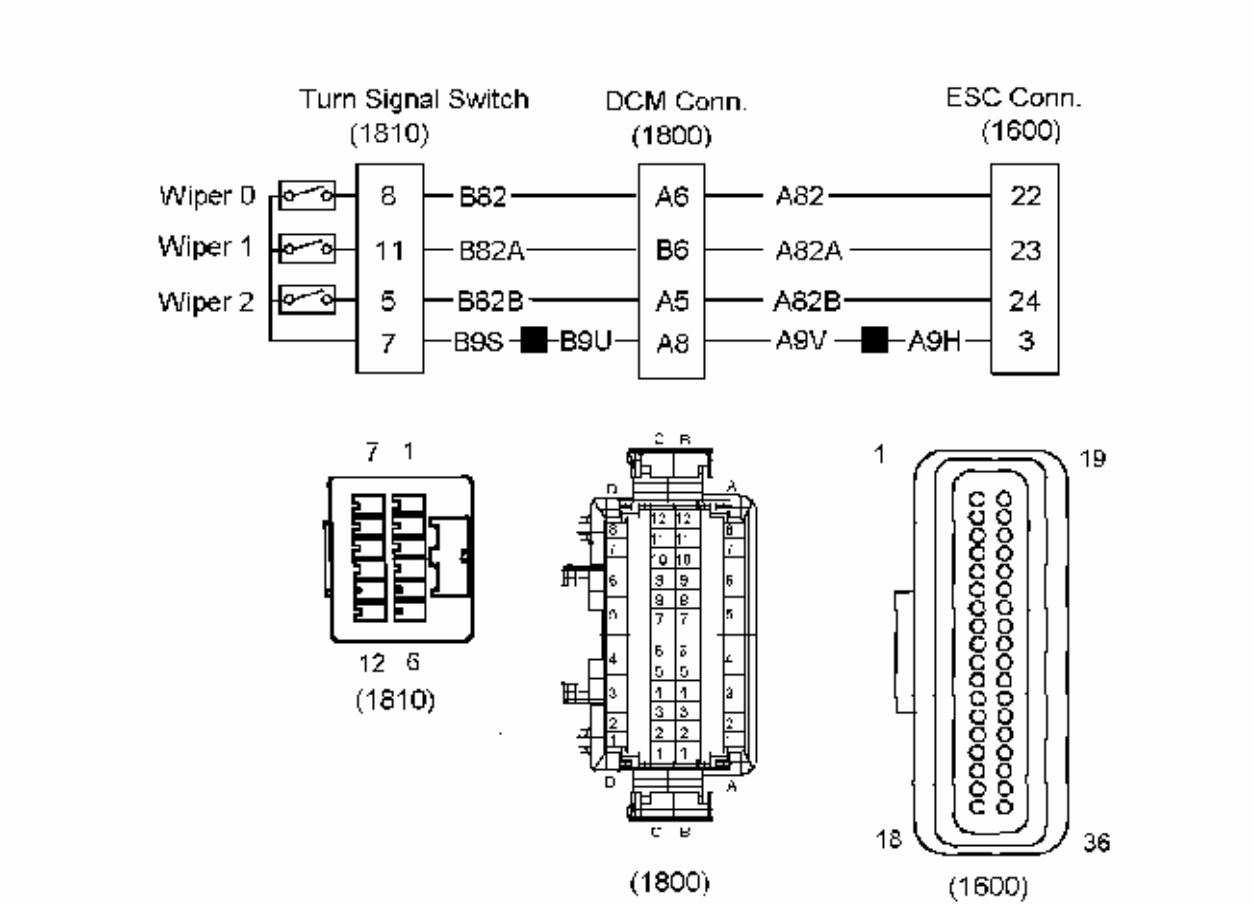
The testing method for troubleshooting the electrical systems portrayed in this manual is a basic voltage test. An alternative method of checking for voltage drops within a given circuit may be a quicker method of identifying an exact problem.

A fault in the wiper circuit inputs to the ESC will be apparent when the wipers don't operate correctly and there are no active wiper diagnostic trouble codes. Problems in the wiper input circuits could be attributed to short circuits, open circuits, a faulty switch or a problem in the ESC.

NOTE

Open circuits or failed switches may cause high speed wipers to operate when they haven't been selected.

Refer to wiper switch input circuits.



Wiper Switch Input Circuits (Connectors Viewed From Mating End)

(1600) 36-WAY SYSTEM CONTROLLER CONNECTOR
(1800) DCM CONNECTOR-DRIVER CONTROL MODULE HARNESS SHOWN
(1810) TURN SIGNAL SWITCH CONNECTOR

Wiper Switch Input Tests

Turn signal switch Harness Connector (1810) Voltage Checks

Check with ignition key on and connector (1810) removed.

NOTE
Voltage to the switch will be approximately 5 volts with the key off.

NOTE
The high speed wipers and head lights should come on when connector (1810) is disconnected. Disconnect wiper motor connector (4015) to disable wiper during checks.

NOTE
Always check connectors for damage and pushed-out terminals**.**

Test Points	Spec.	Comments
(1810) harness connector, pin 8 to ground		If voltage is missing, check for open in circuits B82 or A82.
	11 ± 1.5 volts	If circuits check good and problem is still present, verify voltage out of ESC. **NOTE** Always use breakout box ZTSE 4477 to take measurements on ESC connectors.
(1810) harness connector, pin 11 to ground		If voltage is missing, check for open in circuits B82A or A82A.
	11 ± 1.5 volts	If circuits check good and problem is still present, verify voltage out of ESC. **NOTE** Always use breakout box ZTSE 4477 to take measurements on ESC connectors.
(1810) harness connector, pin 5 to ground		If voltage is missing, check for open in circuits B82B or A82B.
	11 ± 1.5 volts	If circuits check good and problem is still present, verify voltage out of ESC. **NOTE** Always use breakout box ZTSE 4477 to take measurements on ESC connectors.

Wiper Switch Input Tests

(1810) harness connector, pin 7 to ground	<2 Volts	Zero volt reference level. No voltage expected. If voltage is incorrect, check for shorts to voltage or incorrect output from ESC.

Reconnect wiper motor connector (4015).
Reconnect turn signal switch harness connector (1810) and wiper stops operating.
Ignition key off and on, ESC turns off headlights.
Operate wiper speed control in the turn signal switch through all eight speeds, if wiper fails to operate and no diagnostic trouble codes are generated, replace switch.

Wiper Speed Control Switch in the Turn Signal Switch Connector (1810) Resistance Checks

Check with ignition key off and turn signal connector (1810) removed.

NOTE

Always check connectors for damage and pushed-out terminals.

Test Points	Spec.	Comments
Operate wiper speed control to the OFF position, check for continuity between pin 7 and pins 5, 8, and 11.	<1 ohm	If there is no continuity, replace turn signal switch.
Operate wiper speed control to the HI position, check for continuity between pin 7 and pins 5, 8, and 11.	>100K ohms	If there is continuity, replace turn signal switch.

Extended Description

The three wiper switches, in the turn signal assembly, are wired directly to the ESC. When the three wiper switches are turned on, 0 volt reference on pin 3 from the ESC will pass through the wiper switch 0 to pin 22 in the ESC, the wiper switch 1 to pin 23 in the ESC and the wiper switch 2 to pin 24 in the ESC. This will cause the ESC to send 12 volts to the windshield wipers and operate eight speeds (off, high, low, and five different intermittent speeds).

2-8 Wiper Motor Circuits

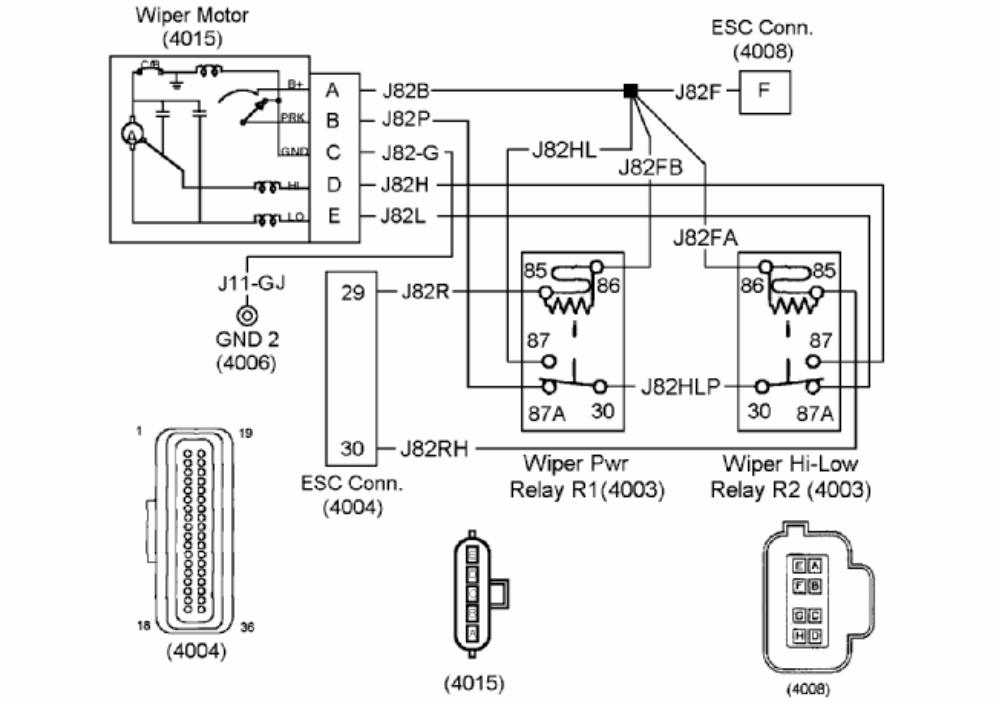
Fault Detection Management

NOTE

The testing method for troubleshooting the electrical systems portrayed in this manual is a basic voltage test. An alternative method of checking for voltage drops within a given circuit may be a quicker method of identifying an exact problem.

A fault in the wiper motor circuits will be apparent when the high or low speed wipers don't work. The ESC will log an active diagnostic trouble code when there is a short or open in the wiper power relay R1 circuits or the wiper high-low relay circuits. Problems in the wiper circuits could be attributed to a failed relay, a failed motor, a tripped wiper motor circuit breaker, a short, an open or a problem in the ESC.

Refer to wiper circuits .



Wiper Circuits (Connectors Viewed From Mating End)

R1 (4003) WIPER POWER RELAY
LOCATED IN ENGINE POWER DISTRIBUTION CENTER
R2 (4003) WIPER HIGH-LOW RELAY
LOCATED IN ENGINE POWER DISTRIBUTION CENTER
(4004) 36-WAY SYSTEM CONTROLLER CONNECTOR
(4008) 8-WAY BLUE SYSTEM CONTROLLER CONNECTOR
(4006) GROUND STUD
(4015) WIPER MOTOR CONNECTOR

Wiper Motor Diagnostic Trouble Codes

611 14 6 3	Wiper power, less than normal low current but more than open circuit
611 14 6 4	Wiper power, greater than normal high current and less than fusing current
611 14 6 6	Wiper power has current flow when output commanded off
611 14 6 2	Wiper power over current

This diagnostic trouble code is logged when there is a short to ground or an excessive load in a circuit connected to the wiper power output of ESC connector (4008) pin F.

NOTE

The virtual fuse in the ESC will trip during a short. To reset the fuse, the key switch must be cycled.

Disconnecting connectors will cause new open circuit diagnostic trouble codes to be logged. Clear all diagnostic trouble codes after connections have been restored.

Turn off wipers and disconnect wiper motor connector (4015). Cycle key switch and clear diagnostic trouble code codes. Turn on the high speed wipers. If the diagnostic trouble code doesn't reoccur, there is a short or an overload in the wiper motor. If the diagnostic trouble code reoccurs, there is a short in the circuits to the wiper relays or between the ESC and the wiper motor, or in the ESC.

Disconnect blue ESC connector (4008). Cycle key switch and clear diagnostic trouble code codes. Turn on the high speed wiper and check for diagnostic trouble codes. If the diagnostic trouble code doesn't reoccur, there is a short in the circuits between the ESC and the wiper motor. If the diagnostic trouble code reoccurs, there is a short inside the ESC. Check high speed wiper voltage between harness connector (4015) pin D and C.

Wiper Motor Diagnostic Trouble Codes

611 14 6 1 Wiper power under current

This diagnostic trouble code is logged when the wipers are turned on and there is an open in circuits between the high speed wiper motor output of the ESC, through the motor, and ground.

Check for open circuits or tripped wiper motor circuit breaker.

Check high speed wiper voltage between harness connector (4015) pin D and C with high speed wiper switch on.

2033 14 14 1 Wiper on relay driver overloaded. Connector 4004 pin 29 current overload. To much load attached or defective relay.

This diagnostic trouble code is logged when there is an overload in the circuits between wiper power relay R1 and the ESC, an excessive load on the circuit or a high resistance in the relay coil.

NOTE

Disconnecting connectors will cause new open circuit diagnostic trouble codes to be logged. Clear all diagnostic trouble codes after connections have been restored.

Remove wiper power relay R1. Clear diagnostic trouble code codes and turn on the high speed wipers. If the diagnostic trouble code doesn't reoccur, there is a short or an overload in the relay. If the diagnostic trouble code reoccurs, there is a short in the circuits between the relay socket and the ESC, or in the ESC.

Disconnect ESC connector (4004), and clear diagnostic trouble codes. Turn on the high speed wiper and check for diagnostic trouble codes. If the diagnostic trouble code doesn't reoccur, there is an overload in the circuits between the ESC and the relay. If the diagnostic trouble code reoccurs, there is an overload inside the ESC.

2033 14 14 2 Wiper on relay driver circuit open circuit.

Connector 4004 Pin 29 open. Open circuit or defective relay.

This diagnostic trouble code is logged when wipers are turned on and there is an open in circuits between ESC connector (4004) pin 29, through the wiper power relay, and ground.

Check for open circuits or open relay coil.

Wiper Motor Diagnostic Trouble Codes

2033 14 14 3	Wiper on relay driver circuit shorted. Connector 4004 pin 29 shorted to ground, short circuit or defective relay.

This diagnostic trouble code is logged when there is a short in the circuits between wiper power relay R1 and the ESC, an excessive load on the circuit or a short in the relay coil.

NOTE

Disconnecting connectors will cause new open circuit diagnostic trouble codes to be logged. Clear all diagnostic trouble codes after connections have been restored.

Remove wiper power Relay R1. Clear diagnostic trouble code codes and turn on the high speed wipers. If the diagnostic trouble code doesn't reoccur, there is a short or an overload in the relay. If the diagnostic trouble code reoccurs, there is a short in the circuits between the relay socket and the ESC, or in the ESC.

Disconnect ESC connector (4004), and clear diagnostic trouble codes. Turn on the high speed wiper and check for diagnostic trouble codes. If the diagnostic trouble code doesn't reoccur, there is a short in the circuits between the ESC and the relay. If the diagnostic trouble code reoccurs, there is a short inside the ESC.

2033 14 8 1	Wiper high-low relay driver overloaded. Connector 4004 pin 20 current overloaded. Too much load attached or defective relay.

This diagnostic trouble code is logged when there is an overload in the circuits between wiper power relay R2 and the ESC, an excessive load on the circuit or a high resistance in the relay coil.

NOTE

Disconnecting connectors will cause new open circuit diagnostic trouble codes to be logged. Clear all diagnostic trouble codes after connections have been restored.

Remove high-low relay R2. Clear diagnostic trouble code codes and turn on the high speed wipers. If the diagnostic trouble code doesn't reoccur, there is a short or an overload in the relay. If the diagnostic trouble code reoccurs, there is a short in the circuits between the relay socket and the ESC, or in the ESC.

Disconnect ESC connector (4004), and clear diagnostic trouble codes. Turn on the high speed wiper and check for diagnostic trouble codes. If the diagnostic trouble code doesn't reoccur, there is an overload in the circuits between the ESC and the relay. If the diagnostic trouble code reoccurs, there is an overload inside the ESC.

Wiper Motor Diagnostic Trouble Codes

2033 14 8 2 Wiper high-low relay driver circuit open circuit.

Connector 4004 Pin 20 open. Open circuit or defective relay.

This diagnostic trouble code is logged when high wipers are turned on and there is an open in circuits between ESC connector (4004) pin 20, through the wiper power relay, and ground.

Check for open circuits or open relay coil.

2033 14 8 3 Wiper high-low relay driver circuit shorted. Connector 4004 pin 20 shorted to ground, short circuit or defective relay.

This diagnostic trouble code is logged when there is a short in the circuits between wiper high-low relay R2 and the ESC, an excessive load on the circuit or a short in the relay coil.

NOTE

Disconnecting connectors will cause new open circuit diagnostic trouble codes to be logged. Clear all diagnostic trouble codes after connections have been restored.

Remove wiper high-low relay R2. Clear diagnostic trouble code codes and turn on the high speed wipers. If the diagnostic trouble code doesn't reoccur, there is a short or an overload in the relay. If the diagnostic trouble code reoccurs, there is a short in the circuits between the relay socket and the ESC, or in the ESC.

Disconnect ESC connector (4004), and clear diagnostic trouble codes. Turn on the high speed wiper and check for diagnostic trouble codes. If the diagnostic trouble code doesn't reoccur, there is a short in the circuits between the ESC and the relay. If the diagnostic trouble code reoccurs, there is a short inside the ESC.

Wiper Motor Voltage Checks

Wiper Motor Harness Connector (4015) Voltage Checks

Check with ignition on and (4015) disconnected.

NOTE

Always use breakout box ZTSE 4477 to take measurements on ESC connectors.

Test Points	Spec.	Comments
(4015) Harness connector, pin A to ground	**NOTE** A load device, such as a test light, must be used in parallel with voltmeter probes to read an accurate voltage. 12 ± 1.5 volts	If voltage is missing, check for short or open in circuit J82B or J82F. If circuits check good check for voltage from ESC connector (4008) pin F. **NOTE** A load device, such as a test light, must be used in parallel with voltmeter probes to read an accurate voltage from pin F. If voltage is missing consider replacing ESC. Refer to ESC Replacement in this manual.
(4015) Harness connector, pin A to pin C.	12 ± 1.5 volts	If voltage is missing, check for open in circuits J82-G or J11-GJ to ground.
With wiper switch in low selection (4015) Harness connector, pin E to ground	With low speed wiper switch on, 12 ± 1.5 volts. With low speed wiper switch off and wipers parked, 0 volts.	If voltage is incorrect, check for open or short in circuit J82L and perform wiper relay R1 and R2 circuit checks. If circuit and relays check good, verify voltage out of ESC.
(4015) Harness connector, pin D to ground	With high speed wiper switch on, 12 ± 1.5 volts With low speed wiper switch off, 0 volts	If voltage is incorrect, check for open or short in circuit J82H and perform wiper relay R1 and R2 circuit checks. If circuit and relays check good, verify voltage out of ESC.

Extended Description

When the key is on the ESC will supply battery voltage to blue connector (4008) pin F. This voltage is applied to wiper motor connector (4015) cavity A, wiper power relay R1 pins 4 and 5, and wiper high-low relay R2.

When high or low wipers are selected the ESC will supply a ground from system controller connector (4004) terminal 29 to wiper power relay 94003) R1 terminal 2. This will energize the wiper power relay and apply 12 volts to the common contact of wiper high-low relay (4003) R2.

When low speed wipers are selected the wiper high-low relay will remain de-energized and the voltage at the common contact will pass through the normally closed contact to the low speed wiper motor windings.

When high speed wipers are selected the wiper high-low relay will energize and the voltage at the common contact will pass through the normally open contact to the high speed wiper motor windings.

Ground for the wiper motor is supplied from ground stud 2 (4006) to wiper motor connector (4015) terminal C.

2-9 Wiper Park Circuits

Fault Detection Management

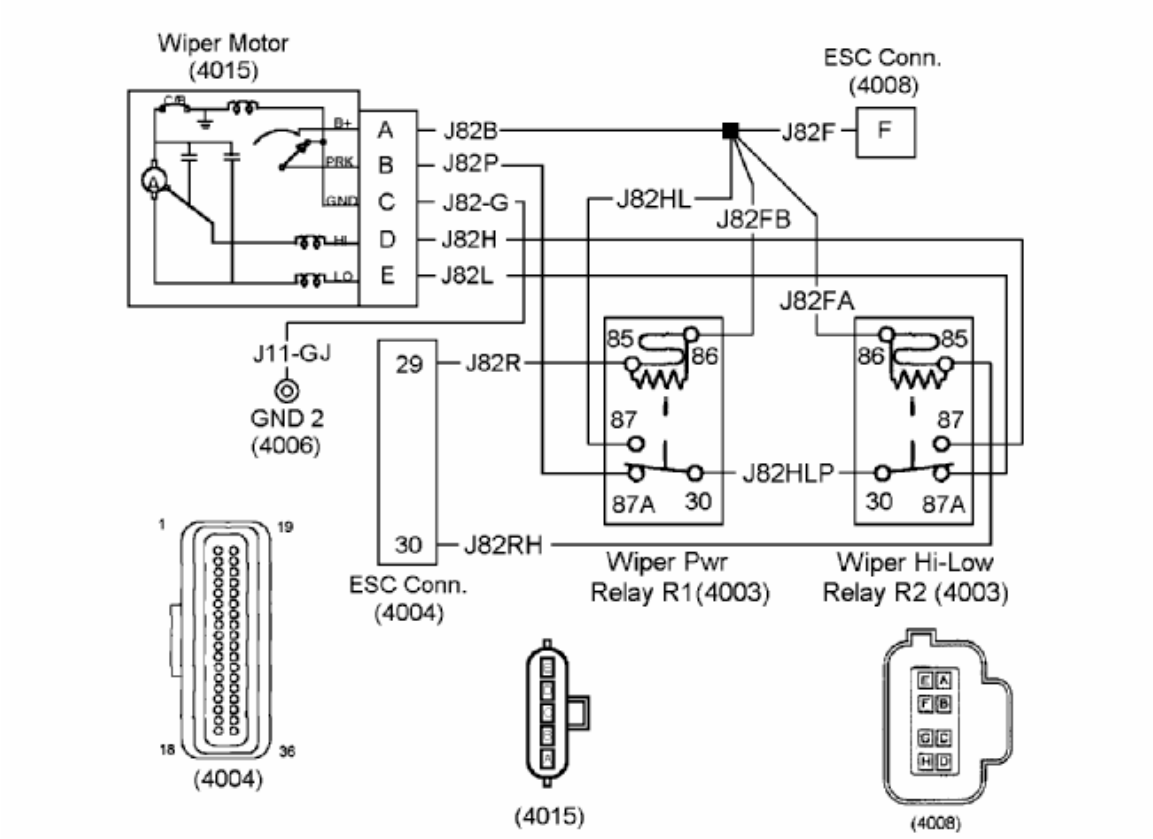
NOTE

The testing method for troubleshooting the electrical systems portrayed in this manual is a basic voltage test. An alternative method of checking for voltage drops within a given circuit may be a quicker method of identifying an exact problem.

When the high and low speed wipers are turned off and the ignition is on, the wipers should return to the parked position.

A fault in the wiper park circuits will be apparent when the wipers don't park, after they are turned turn off and the intermittent wipers are inoperative (low wipers should still operate when selected). There are no diagnostic trouble codes associated with the wiper parking circuits. Problems in the wiper parking circuits could be attributed to, a short to ground, an open, faulty circuits in the motor or a problem in the ESC.

Refer to Wiper Park Circuits.



Wiper Park Circuits (Connectors Viewed From Mating End)

R1 (4003) WIPER POWER RELAY
LOCATED IN ENGINE POWER DISTRIBUTION CENTER
R2 (4003) WIPER HIGH-LOW RELAY
LOCATED IN ENGINE POWER DISTRIBUTION CENTER
(4004) 36-WAY SYSTEM CONTROLLER CONNECTOR
(4008) 8-WAY BLUE SYSTEM CONTROLLER CONNECTOR
(4006) GROUND STUD
(4015) WIPER MOTOR CONNECTOR

Park Circuits Tests

Diagnostic Trouble Codes

There are no specific diagnostic trouble codes associated with the wiper park circuits.

Wiper Motor Harness Connector (4015) Park Circuit Voltage Checks

Check with ignition on and (4015) disconnected.

NOTE

Always use breakout box ZTSE 4477 to take measurements on ESC connectors.

Test Points	Spec.	Comments
(4015) Harness connector, pin A to ground.	**NOTE** A load device, such as a test light, must be used in parallel with voltmeter probes to read an accurate voltage. 12 ± 1.5 volts	If voltage is missing, check for short or open in circuit J82B or J82F. If circuits check good check for voltage from ESC.

Wiper Motor Harness Connector (4015) Park Circuit Resistance Checks

Check with ignition off and (4015) disconnected.

(4015) Harness connector, pin B to pin E.	< 1 ohm	If resistance is high check for open in circuits J82P, J82HLP and J82L. Also check for failed normally closed contacts of wiper power relay R1 and wiper high low relay R2.

If voltages and resistances check good, consider replacing wiper motor.

Extended Description

When the high and low speed wipers are turned off and the ignition is on, the wipers should return to the parked position.

When the key is on the ESC will supply battery voltage to blue connector (4008) pin F. This voltage is applied to wiper motor connector (4015) cavity A, wiper power relay R1 pins 4 and 5, and wiper high-low relay R2.

When the wipers are off and the wipers are not parked, the voltage at (4015) pin A will pass through the wiper motor park contact to (4015) pin B and the normally closed contact of wiper power relay. This voltage will also be applied to the wiper power relay common contact, wiper high-low relay normally closed contact, and the wiper motor low speed winding.

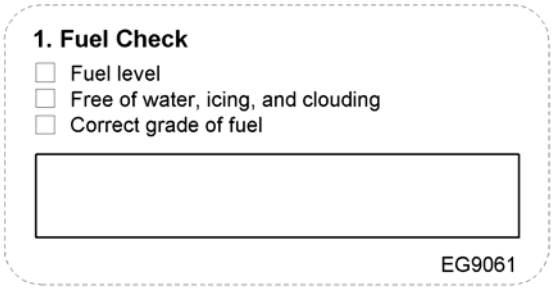
When the wipers reach the park position a ground will replace the voltage causing the wipers to stop at the parked position.

2-10 Engine Start/No Start Diagnostics

NOTE

If a NO-START condition is encountered, check the condition of fuses located in wiring connectors just above batteries.

a. Fuel Check



Purpose

To determine if the engine has clean fuel for efficient engine operation.

Possible Causes

- No fuel in tank.
- The in-line fuel valve (if equipped) could be shut OFF.
- Fuel supply line could be broken or crimped.
- The tank pickup tube could be clogged or cracked.
- Supplemental filters or water separators may be plugged or leaking, allowing air to enter the fuel system.
- Water or contaminants in fuel tank.
- Ice in fuel lines.
- Fuel grade may not be suitable for cold temperatures.
- Fuel could be waxed or jelled (usually Grade 2-D).

Tools Required

- Clear container (approximately 1 Quart or 1 Liter)

Test Procedure

Read all safety instructions in this manual before doing this procedure.

1. Take fuel sample from fuel tank. Fuel must be the correct grade, clean, and undiluted.
2. Check for air in fuel. If air is suspected, check for air leaks in the supply line to the fuel transfer pump. Install a piece of clear plastic between the filter and the transfer pump inlet. Crank the engine and check for air bubbles.

NOTE

Cold weather can cause fuel waxing in some grades of diesel fuel. Waxing will restrict or stop fuel flow through the fuel filter.

3. Check for gasoline or kerosene in the diesel fuel. If present fuel will be brownish or dark colored.
4. If engine oil is in the fuel, injector O-ring leaks and lower injection control pressure are likely. If these conditions are suspected, do the following:

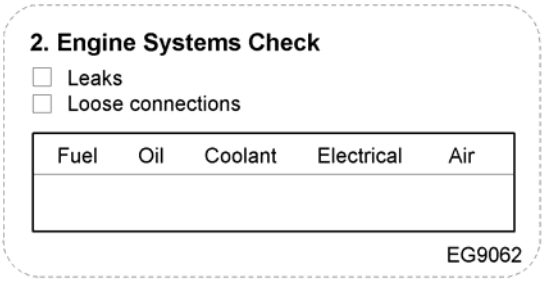
   a. Drain some fuel from the fuel filter and check fuel color. If fuel sample is dark, compare the sample to the correct grade of uncontaminated fuel.

   b. If the comparison is inconclusive, remove the fuel filter. If the element is black, oil may have entered the fuel system past injector O-rings.

NOTE

If fuel quality is good, but the engine will not start, depress priming valve plunger. If the plunger has no resistance, the fuel system is out of fuel. Do Fuel Pump Pressure Test (Test 14) to check fuel pressure.

b. Engine Systems Check



Purpose

To check engine systems for hard or no start conditions.

Tools Required

- Inspection Lamp
- Air Pressure Regulator

Test Procedure

WARNING

Read all safety instructions in this manual before doing this procedure.

1. Inspect fuel tank and lines for damage and leaks.
2. Check oil line from high-pressure pump to oil supply manifold for oil leaks.
3. Inspect entire cooling system for leaks.
4. Check air induction system for leaks. See Air Induction System Inspection below.
5. Inspect engine wiring harness for correct routing and protection against rubbing or chaffing.

NOTE

The engine will not start with the Injection Pressure Regulator (IPR) or Camshaft Position Sensor (CMP) disconnected.

6. Check sensor, relay, and control module connections. All connections must be seated, in good condition, and free of damage or corrosion.
7. Inspect battery cable and fuse connections for corrosion. All connections must be seated, in good condition, and free of damage or corrosion.

NOTE

The ECM harness connections torque specification is 35 lb-in. (4 N•m).

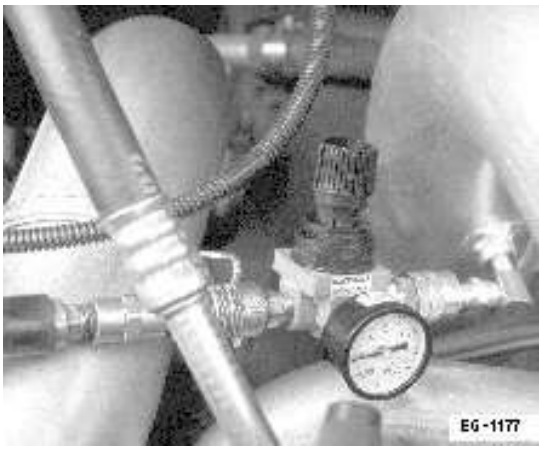
Air Induction System Inspection

1. Inspect air cleaner housing for damage or distortion that could allow unfiltered air into the engine.
2. Inspect for end seal movement inside the housing. End seal movement is indicated if the seal contact area is polished. A polished contact area indicates that unfiltered air has passed by the filter element and into the engine.
3. Inspect air cleaner element for end cap dents, holes, damaged seals, and soot.
4. Inspect air intake hoses and clamps for tightness and positioning over sealing beads.
5. Inspect the chassis mounted charge air cooler and piping.

Air Induction System Pressure Test

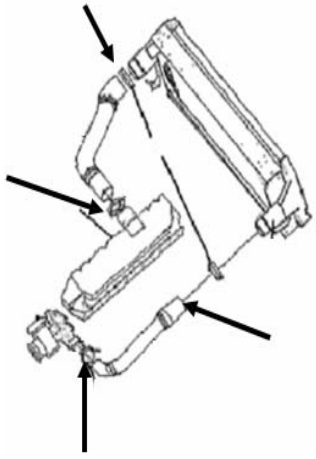
1. Mask the outer diameter of air cleaner element air inlet with duct tape and plug air cleaner canister drain.

2. Remove the air cleaner restriction indicator or tubing to the air cleaner. Install a plug to seal opening.
3. Find cold air discharge pipe containing a plug. Remove plug and connect a manually regulated air supply with pressure gauge.



Regulated Air Supply

4. Apply 5 to 8 psi of air pressure to the air induction system. A constant air supply is needed to replace air lost through opened intake valves.
5. Coat all clamped hoses and gasket connections between air cleaner outlet and intake manifold as well as fittings, gasket, and piping to the charge air cooler with a soap solution and check for leaks. (Areas are indicated by arrows).



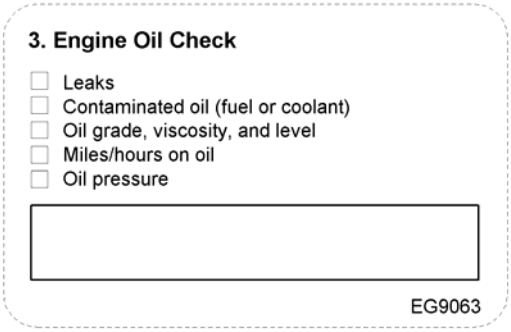
Checking for Leakage

6. Leakage is not permitted between air cleaner and turbocharger (suction side). If leaks are found, tighten hose clamps. If leaks continue, replace necessary parts. Retest corrected area.

NOTE

Air induction leaks can indicate dirt in the engine. Dirt can cause piston rings to wear or break causing high oil consumption and excessive blue smoke and pitting or erosion of the turbocharger compressor wheel. If leaks are found, test crankcase pressure.

c. Engine Oil Check



Purpose

To check engine oil level, quality, and pressure.

Possible Causes

- Low oil level - Oil leak, oil consumption, or incorrect servicing.
- High oil level - Incorrect servicing, fuel dilution from lift pump.
- Oil contamination with coolant - Oil cooler, head gasket leakage, (accessories i.e., water cooled air compressors).
- Slow engine cranking.
- Incorrect viscosity for ambient operating temperature.

Tools Required

- None

Test Procedure

Read all safety instructions in this manual before doing this procedure.

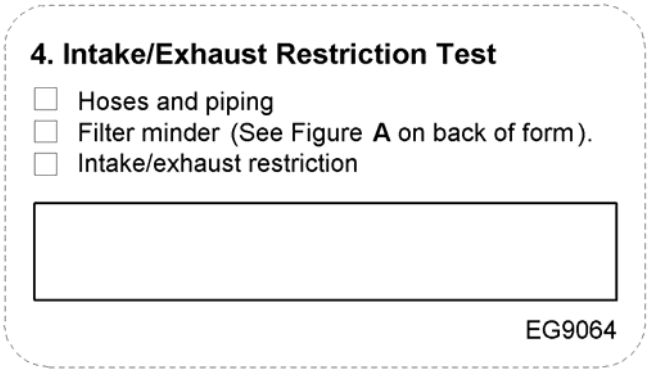
1. Park vehicle on level ground.
2. Check oil level with dipstick.

NOTE

If the oil level is not at full, the fuel injectors will not work correctly. If the oil level is above full, the engine has been incorrectly serviced, or fuel is diluting the oil. Check for fuel odor in oil.

3. Inspect oil for color and odor. Milky white oil and an ethylene glycol odor will indicate coolant contamination.
4. Check engine service records for correct oil grade and viscosity for ambient operating temperatures. Do not use 15W-40 oil below 20°F (-6.7°C). Long oil drain intervals can decrease oil viscosity; thicker oil will make engine cranking and starting more difficult below freezing temperatures. See lube oil chart in the operator's manual for the correct grade of oil for vehicle operation in various temperature ranges.

d. Intake/Exhaust Restriction Check



Purpose

To determine if intake or exhaust restriction is causing hard or no start conditions.

NOTE

High intake or exhaust restriction can cause a large amount of black or blue smoke when starting the engine.

Possible Causes

- Snow, plastic bags, or other foreign material can restrict air flow in the air cleaner inlet. On engines recently repaired, rags or cap plugs may have been left in the intake system.
- Tailpipe or muffler may be damaged or collapsed.
- Retarder could be stuck closed.

Tools Required

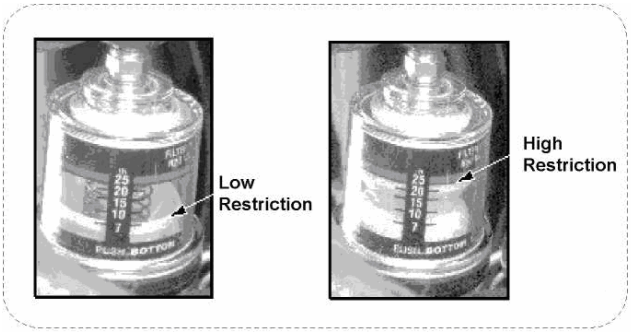
- None

Inspection

Read all safety instructions in this manual before doing this procedure.

Inspect the following parts for restriction, damage, or incorrect installation:

1. Air cleaner inlet and ducting.
2. Air cleaner housing, filter element, and gaskets.



Air Restriction Gage

NOTE

Intake restriction should be below 25 in. H20. When the filter element reaches maximum allowable restriction, the yellow indicator will reach the top of window and automatically lock in this position.

3. Exhaust system piping.

e. Electronic Service Tool (EST) Diagnostic Trouble Codes (DTC)

5. EST Diagnostic Trouble Codes (DTC's)

☐ Install Electronic Service Tool (EST). (See Figure **B** on back of form).
☐ Do **Test 8** if EST is not available.

Active DTC's
Inactive DTC's

EG9065

Purpose

To determine if the Electronic Control Module (ECM) has detected Diagnostic Trouble Codes (DTC) that could cause hard start or no start conditions.

Test Procedure

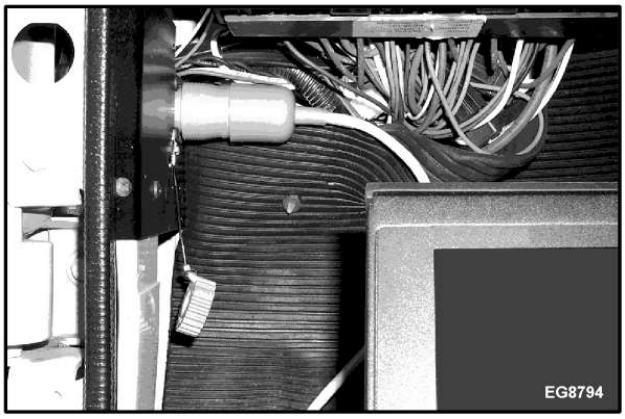
WARNING

Read all safety instructions in this manual before doing this procedure.

NOTE

Use Diagnostic Code Access Procedure if the Electronic Service Tool (EST) is not available.

1. Turn all accessories and ignition OFF.



ATA Connector

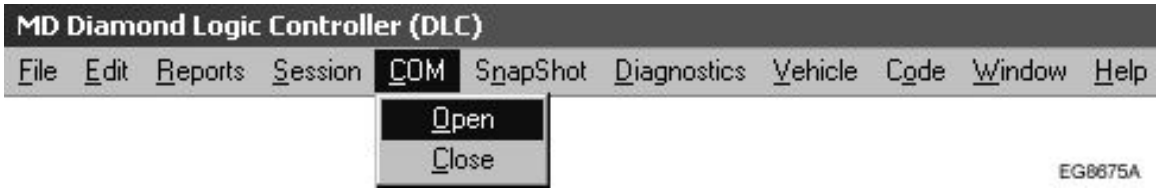
2. Connect EST to the American Trucking Association (ATA) diagnostic connector.

NOTE

The ATA connector is on the lower left kick panel or underneath the left side dashboard.

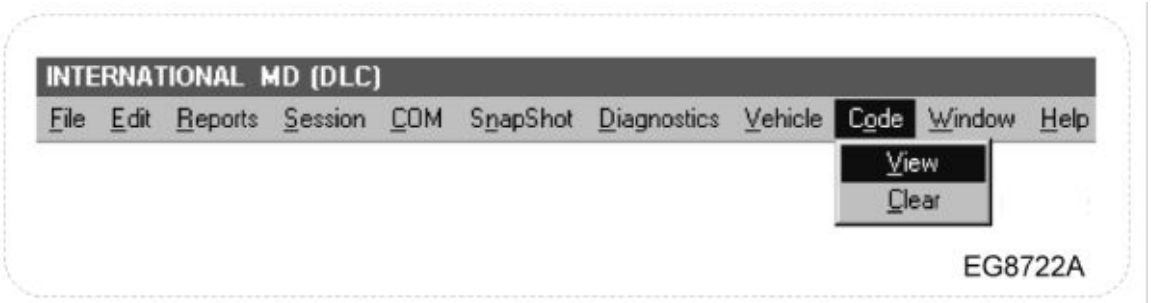
International® Truck Interface Cable

3. Connect one end of the International® Truck interface cable to the EST and the other end to the ATA connector.
4. Boot up EST.
5. Turn ignition ON.
6. Launch Master Diagnostic (MSD).



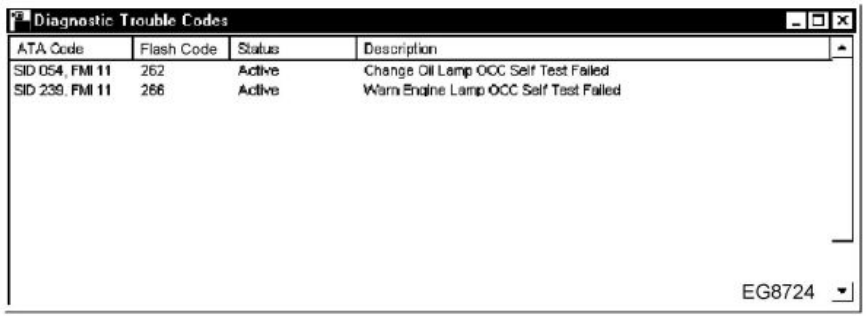
Menu Bar Com/Open

7. Select COM from the menu bar in the main window, then Open.



Menu Bar Code/View

8. Select Code from the menu bar, then View for the Diagnostic Trouble Codes window.



Diagnostics Trouble Code Window

Diagnostics Trouble Code Window

- **ATA Code:** The ATA Code column displays codes associated with a sub-system (SID), parameter (PID), and failure mode indicator (FMI).
- **Flash Code:** The Flash Code column displays Diagnostic Trouble Code (DTC) numbers.
- **Status:** The Status column indicates Active, Inactive, or Active/Inactive DTCs.
- **Active:** With the ignition key ON, Active indicates a DTC for a condition currently in the system. When the key is turned OFF, an Active DTC becomes Inactive.
- **Inactive:** With the ignition key ON, Inactive indicates a DTC for a condition no longer in the system. When the ignition key is turned OFF. Inactive DTCs from previous ignition key ON cycles are stored in the ECM memory.
- **Active/Inactive:** With the ignition key ON, Active/Inactive indicates a DTC for an intermittent condition currently in the system.
- **Description:** The Description column defines each DTC.

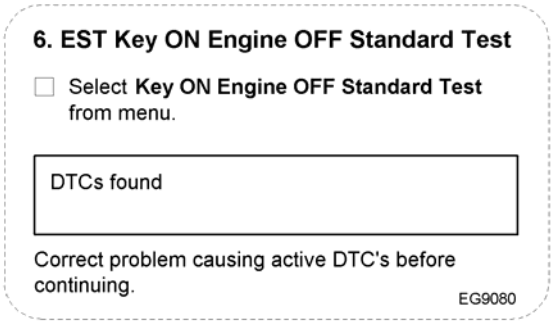
See Electronic Control System Diagnostics form EGED-185-2 for a complete list of Diagnostic Trouble Codes.

9. Record all Diagnostic Trouble Codes on Mechanical Diagnostics form EGED-180-2.

Tools Required

Electronic Service Tool (EST) with Master Diagnostics software

f. EST Key ON Engine OFF Standard Test



Purpose

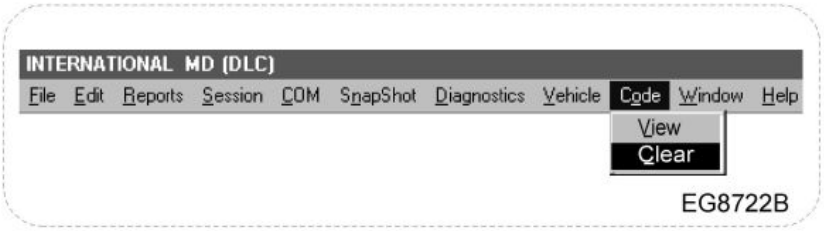
To identify electrical malfunctions detected by the Electronic Control Module (ECM) self test.

Test Procedure

WARNING

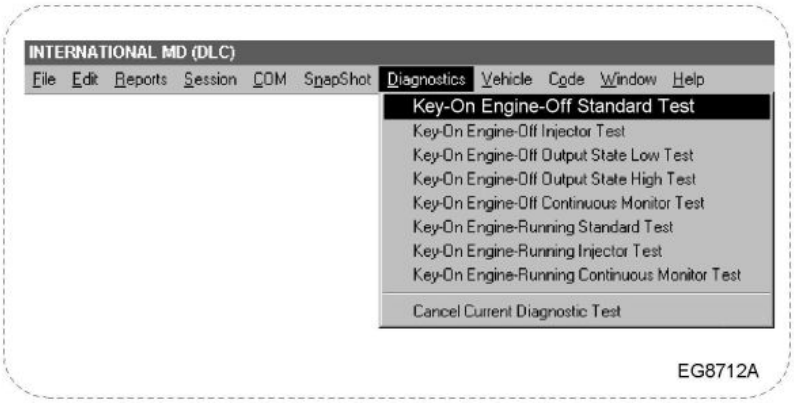
Read all safety instructions in this manual before doing this procedure.

1. Set parking brake.
2. Turn ignition switch ON.



Menu Bar Code/Clear

3. Select Code from the menu bar, then Clear to clear all Diagnostic Trouble Codes.



Key-ON Engine-Off Standard Test

4. Select Key-ON Engine-OFF Standard Test from the Diagnostic drop-down menu.
5. The ECM will complete an internal self-test and an Output Circuit Check (OCC). When the OCC test is over, the Diagnostic Trouble Code screen will show DTCs. Scroll down to find additional Diagnostic Trouble Codes, if they appear to be off the screen.
6. For a complete listing of Diagnostic Trouble Codes, see DTC column on Electronic Control System Diagnostics form EGED1852.
7. Record all Diagnostic Trouble Codes on Mechanical Diagnostics form EGED-180-2.

NOTE

To repeat this test select, the Diagnostic drop-down menu and click on Key-ON Engine-OFF Standard Test.

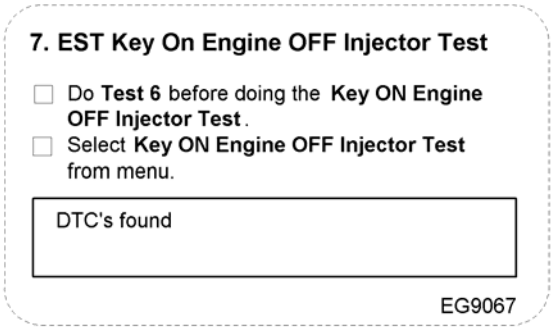
Possible Causes

- Defective electrical components or circuitry.
- Output circuit check fault for Injection Pressure Regulator (IPR).

Tools Required

- Electronic Service Tool (EST) with Master Diagnostics software

g. EST Key ON Engine OFF Injector Test



Purpose

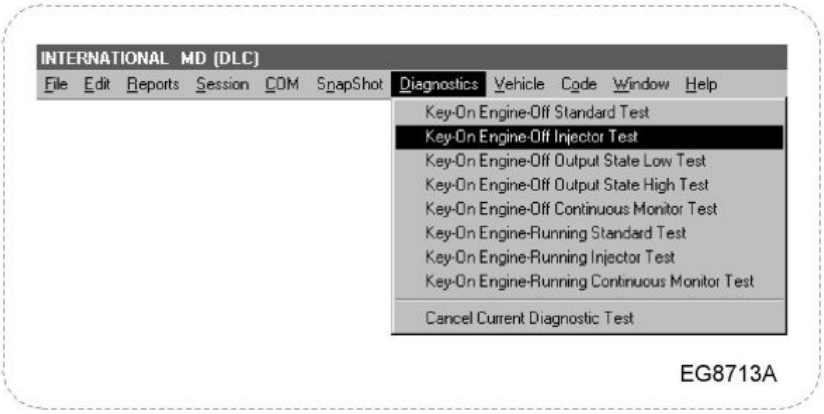
To determine if the fuel injectors are working (electronically) by energizing the injectors in a programmed sequence. The Electronic Control Module (ECM) monitors this test and transmits Diagnostic Trouble Codes, if injectors are not working correctly.

Test Procedure

Read all safety instructions in this manual before doing this procedure.

NOTE

Do Engine-OFF Standard Test (Test 6) before doing the Key-ON Engine-OFF Injector Test.



Key-ON Engine-OFF Injector Test

1. Select Diagnostics drop-down menu in Master Diagnostics (MD).
2. Select Key-ON Engine-OFF Injector Test.

NOTE

During this test, injector solenoids should click when actuated. If a series of rapid clicks are not heard for each injector, one or more injectors are not activating.

After the Key-ON Engine-OFF Injector Test, detected Diagnostic Trouble Codes will be displayed. More Diagnostic Trouble Codes can be found by scrolling down the Diagnostic Trouble Code screen.

Possible Causes

- Bad wiring harness connection on injector solenoid
- Open or shorted engine wiring harness to injectors
- Defective injector solenoid
- Defective ECM

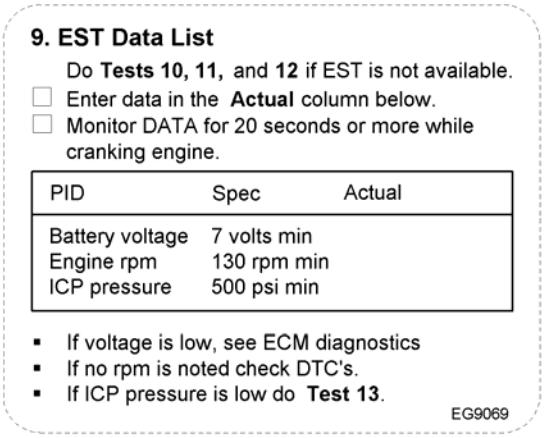
Tools Required

- Electronic Service Tool (EST) with Master Diagnostic's software
- **Diagnostic Trouble Code Access**

To read DTC's detected by the Electronic Control Module (ECM) if the Electronic Service Tool (EST) is not available, or if the EST will not communicate with the ECM.

The Cruise Control buttons on the steering wheel act as an interface between the Operator and the ECM. The resulting flashes of the amber ENGINE lamp indicate the ECM is performing a series of electronic tests.

h. EST Data List



9. EST Data List

Do **Tests 10, 11,** and **12** if EST is not available.

☐ Enter data in the **Actual** column below.

☐ Monitor DATA for 20 seconds or more while cranking engine.

PID	Spec	Actual
Battery voltage	7 volts min	
Engine rpm	130 rpm min	
ICP pressure	500 psi min	

- If voltage is low, see ECM diagnostics
- If no rpm is noted check DTC's.
- If ICP pressure is low do **Test 13**.

EG9069

Purpose

To determine if starting components meet operating specifications.

Test Procedure

WARNING

Read all safety instructions in this manual before doing this procedure.

NOTE

Make sure batteries are fully charged before doing this test.

1. Set parking brake.
2. Turn accessories and ignition OFF.
3. Connect the EST tool to the American Trucking Association (ATA) diagnostic connector.

NOTE

If an EST is not available, use a Digital Volt Ohm Meter (DMM) to do the following tests:

a. ECM Voltage Test (Test 10)

b. Engine Cranking Test (Test 11)

c. Injection Control Pressure Test (Test 12)

4. Turn ignition switch ON. DO NOT start the engine.

5. Crank engine and read Electronic Service Tool (EST) to measure battery voltage, engine cranking rpm, and Injection Control Pressure (ICP).

    a. The battery voltage must be 7 or more volts. If voltage to the Electronic Control Module (ECM) drops below 7 volts, the ECM will not remain powered up. If the ECM does not get power through the ECM relay, the engine will not start.

    b. Engine cranking speed must generate the required ICP to operate the fuel injectors and create required compression to ignite the fuel. If the EST shows 0 rpm during engine cranking, the ECM may not be receiving a signal from the Camshaft Position (CMP) sensor. If the CMP sensor is not functioning, it must be replaced. The ECM will not allow the Injection Pressure Regulator (IPR) valve to fully activate without a CMP signal. See CMP sensor diagnostics in Electronic Control System Diagnostics.

    c. If the EST indicates low or no injection control pressure, check oil in oil reservoir (on front cover) as follows:

        1. Remove the engine harness connector from the Engine Oil Temperature (EOT) sensor.

        2. Remove the EOT sensor from the front cover. Oil should drain from the internal reservoir.

        3. Refill the reservoir and reinstall EOT sensor and harness connector.

NOTE

If the oil reservoir level continues to fall, the primary lube oil pump may no be supplying adequate oil to the OIL reservoir.

Possible Causes

- Low battery voltage - Failed batteries, high resistance at battery cable connections or in wiring to the ECM.
- Defective ECM power relay.
- Blown 40A in-line fuse (in battery box) which supplies voltage to the ECM.
- Low cranking rpm - Electrical system malfunctions, incorrect oil, or long oil change intervals in cold ambient temperatures.
- No rpm indication on the EST while cranking the engine - Faulty CMP sensor or circuitry to the ECM. Recheck Diagnostic Trouble Codes after cranking engine. See EST, Diagnostic Trouble Codes or STI Diagnostic Trouble Codes.
- Low ICP Pressure - A leak in the high-pressure oil system or a defective ICP sensor.
- Defective high-pressure oil pump, or pump drive.
- Defective Injection Pressure Regulator (IPR) or electronic controls for the regulator.

Tools Required

- Electronic Service Tool (EST) with Master Diagnostic software

Supplemental Diagnostics

- Low voltage at ECM: See ECM PWR, Electronic Control Module Power Circuit in, Electronic Control System Diagnostics.
- No Engine rpm indication during engine cranking: See CMP sensor diagnostics in Electronic Control System Diagnostics.
- No Injection Control Pressure: See Injection Control Pressure (ICP) sensor and IPR valve diagnostics in Electronic Control System Diagnostics.
- No or low injection control pressure and no electronic Diagnostic Trouble Codes: See ECM Voltage Test (Test 10).

i. ECM Voltage Test

10. ECM Voltage Test

Use a DMM to measure ICP voltage while cranking engine [min 130 rpm (26 Hz)] for 20 seconds: For procedure 1 or 2 below.
1. Connect breakout tee **ZTSE4484** between IPR valve and IPR harness connector. Check voltage between connector pin **A** and **ground**. See Figure **D** on back of form.
2. Connect breakout box to vehicle harness connector on ECM. Check voltage at breakout box pins (21+ & 1-) (22+ & 2-) (24 + & 23-). See Figure **E** on back of form.

Instrument	Spec	Actual
DMM	7 Volts (min each pin)	

If voltage is low see ECM diagnostics. EG9070

Purpose

To determine correct voltage and current to operate the Electronic Control Module (ECM). The ECM requires 7 volts minimum to operate and drive the fuel injectors. Do the following test if the Electronic Service Tool (EST) is unavailable or fails to function correctly. Low battery power or an electronic failure may inhibit the EST from receiving diagnostic data.

Test Procedure

Read all safety instructions in this manual before doing this procedure.

NOTE

Batteries must be fully charged before doing this test.

Measuring ECM Voltage Using IPR Breakout Tee

Battery Voltage Measurement

1. Set parking brake.
2. Turn accessories OFF and connect a Digital Volt Ohm Meter (DMM) across the battery terminals.
3. Crank the engine.
4. Record the lowest voltage. If the voltage is below 7 volts, the ECM power relay may be resetting, resulting from low voltage and current from the batteries or problems in the starting system.
5. If voltage is within specification, check Voltage Measurement at ECM with Breakout Box.

j. Engine Cranking Test

11. Engine Cranking Test

Use a DMM to measure engine cranking speed for 20 seconds: For procedure 1 or 2 below.
1. Connect breakout tee **ZTSE4486** between CMP sensor and CMP harness connector. Check rpm or Hz between connector pin **C** and ground. See Figure **F** on back of form.
2. Connect breakout box to engine harness connector on ECM. Check voltage at breakout box pins (51+ & 19-). See Figure **E** on back of form.

Instrument	Spec	Actual
DMM 51+ & 19 -	130 rpm (26 Hz) min	

If rpm is not shown, recheck DTC's and do CMP diagnostics.

EG9071

Purpose

To determine correct engine cranking speed to start the engine. Do the following test if the Electronic Service Tool (EST) is unavailable or fails to function correctly. Low battery power or an electronic failure may inhibit the EST from receiving diagnostic data.

Test Procedure

WARNING

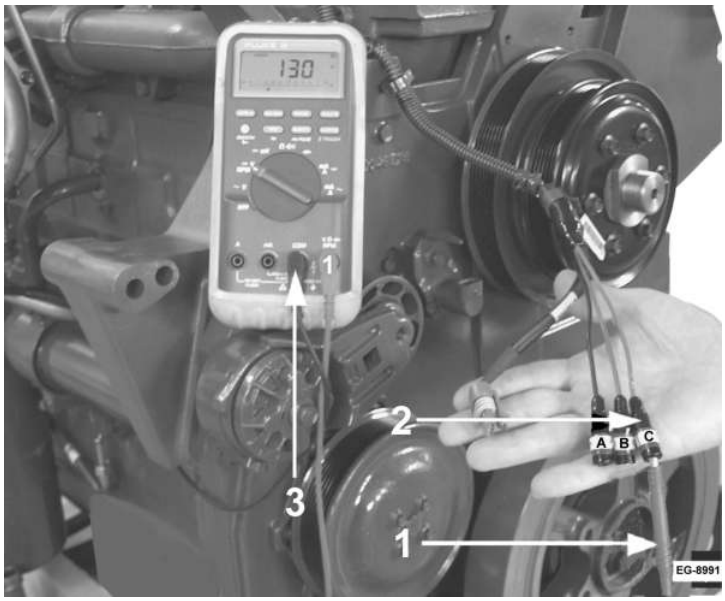
Read all safety instructions in this manual before doing this procedure.

NOTE

Make sure batteries are fully charged before doing this test.

Engine cranking rpm must generate the required ICP to operate the fuel injectors and create enough compression to ignite the fuel.

Measuring Cranking rpm with CMP Breakout Tee



1. Connect Breakout Tee (ZTSE4486) between CMP sensor and CMP sensor harness.
2. Ground black DMM negative probe to the engine.
3. Set DMM knob to V/RPM and toggle to rpm or Hz.
4. Crank engine for 20 seconds (minimum) and measure cranking rpm (Hz) at CMP signal green connector (C).

NOTE

When using a DMM in the 4-cycle rpm mode, the meter reading must be divided by 12 to equal the actual rpm of the engine. When reading Hertz (Hz), the meter reading is 1/5 the actual rpm. (26Hz = 130 rpm).

5. Record engine cranking speed on Mechanical Diagnostics form EGED-180-2.

k. Injection Control Pressure (ICP) Test

12. Injection Control Pressure Test

Use a DMM to measure ICP voltage while cranking engine [min 130 rpm (26 Hz)] for 20 seconds: For procedure 1 or 2 below.
1. Connect breakout tee **ZTSE4347** between ICP sensor and ICP harness connector. Check voltage between connector pin **C** and ground. See Figure **G** on back of form.
2. Connect breakout box to engine harness connector on ECM. Check voltage at breakout box pins (16+ & 19-). See Figure **E** on back of form.

Instrument	Spec	Actual
DMM 16+ & 19 -	1 Volt min	

If ICP pressure is low do **Test 13**.

EG9072

Purpose

To determine injection control pressure during engine cranking.

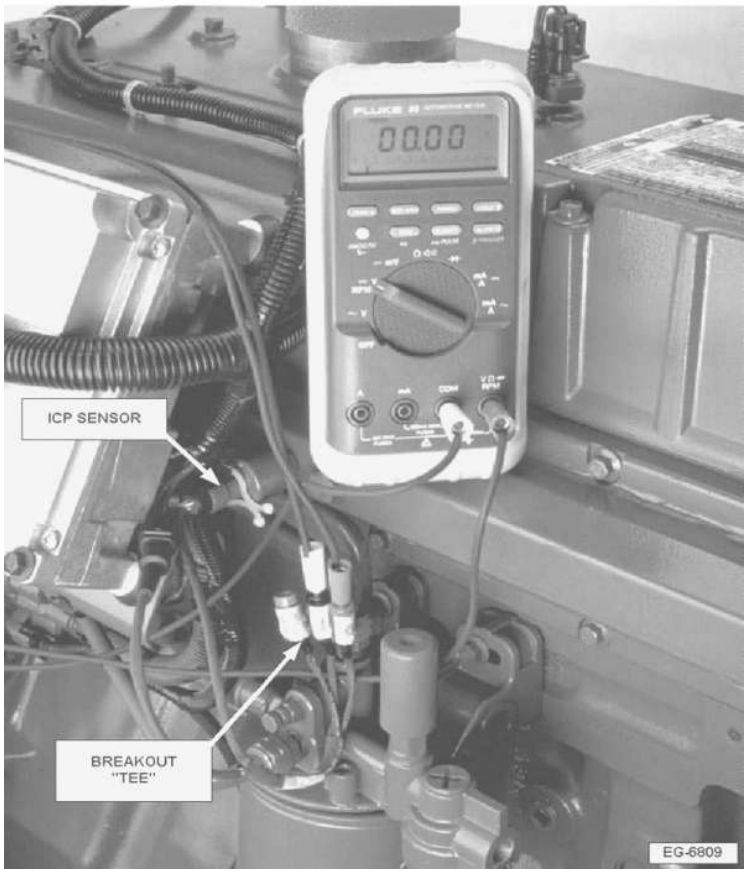
NOTE

Two procedures can be used if the Electronic Service Tool (EST) is unavailable or fails to function. Low battery voltage or electronic failures will inhibit the EST from receiving diagnostic data.

Measuring Injection Control Pressure Using a Breakout Tee

Read all safety instructions in this manual before doing this procedure.

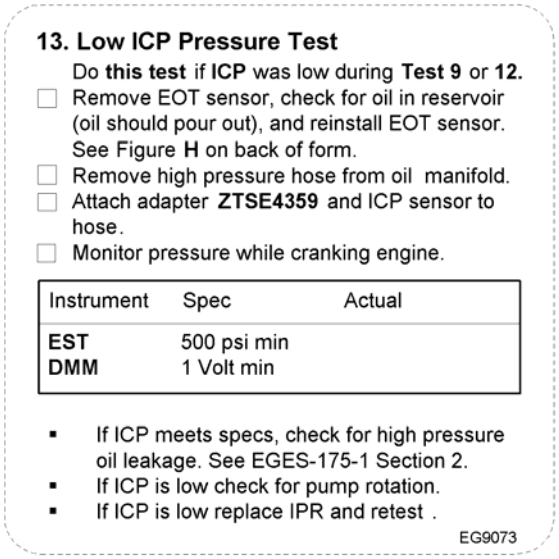
1. Set parking brake.
2. Remove engine harness connector at ICP sensor.



DMM and Breakout Tee

3. Connect the ICP breakout tee between the engine harness connector and the ICP sensor.
4. Connect Digital Volt Ohm Meter (DMM) leads (+ Red, - Black) to the breakout tee (+ Green, - Black) as shown above.
5. Crank engine and check DMM voltage reading. Record reading on Mechanical Diagnostic form EGED1802.
6. If voltage is low, recheck oil level in reservoir (at EOT sensor) for correct oil level required to operate the fuel injectors.
7. If oil level is correct, go to Low ICP Pressure Test (Test 13).

I. Low ICP Pressure Test



13. Low ICP Pressure Test

Do **this test** if **ICP** was low during **Test 9** or **12.**

- ☐ Remove EOT sensor, check for oil in reservoir (oil should pour out), and reinstall EOT sensor. See Figure **H** on back of form.
- ☐ Remove high pressure hose from oil manifold.
- ☐ Attach adapter **ZTSE4359** and ICP sensor to hose.
- ☐ Monitor pressure while cranking engine.

Instrument	Spec	Actual
EST	500 psi min	
DMM	1 Volt min	

- If ICP meets specs, check for high pressure oil leakage. See EGES-175-1 Section 2.
- If ICP is low check for pump rotation.
- If ICP is low replace IPR and retest .

EG9073

Purpose

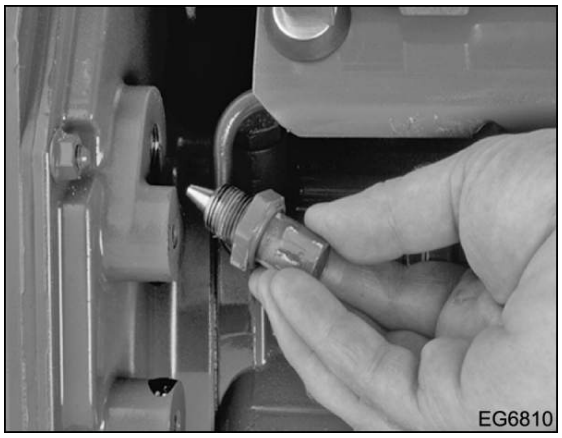
To find the cause of low ICP pressure that prevents engine starting.

Test Procedure

Read all safety instructions in this manual before doing this procedure.

If Diagnostic Trouble Codes were detected, correct the problems causing the DTCs before doing this test.

1. Set parking brake.
2. Remove engine harness connector from Engine Oil Temperature (EOT) sensor.

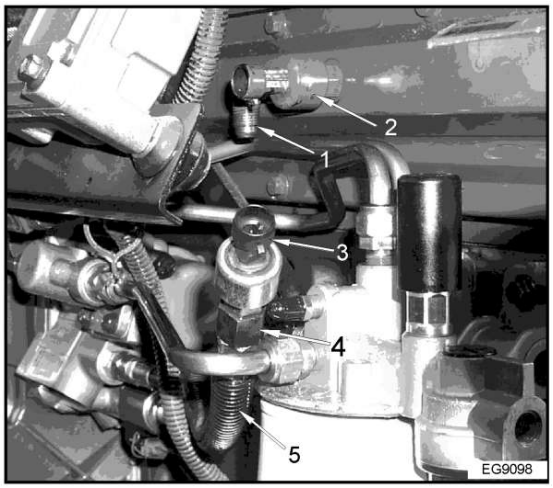


3. Remove EOT sensor to allow oil to pour out.
4. If oil pours out, reinstall EOT sensor and harness connector.

NOTE

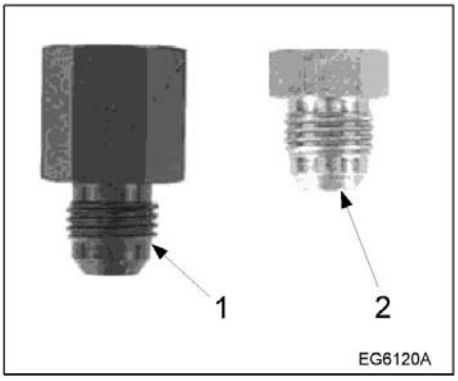
If oil does not pour out, the lubrication system may not be supplying enough oil to the oil reservoir. Correct the problem and reinstall EOT sensor and engine harness connector.

5. Crank engine. If engine does not start, continue with Step 6.



(1) Elbow Fitting in High-Pressure Oil Manifold
(2) ICP Sensor in High-Pressure Oil Manifold
(3) Extra ICP Sensor
(4) ICP Adapter
(5) High-Pressure Oil Hose
(6) Disconnect High-Pressure Oil Hose from the Elbow Fitting in High-Pressure Oil Manifold
(7) Disconnect ICP Engine Harness Connector from the ICP Senor in the High-Pressure Oil Manifold
(8) Leave ICP Sensor In High-Pressure Oil Manifold

High-Pressure Oil Hose, ICP Adapter, and ICP Sensor



(1) ICP Adapter
(2) Plug

ICP Adapter/Plug Kit (ZTSE4359)

6. Install the ICP Adapter from the ICP Adapter/Plug Kit into the end of the high-pressure hose.
7. Install extra ICP sensor into ICP Adapter. (Check for correct part number.)

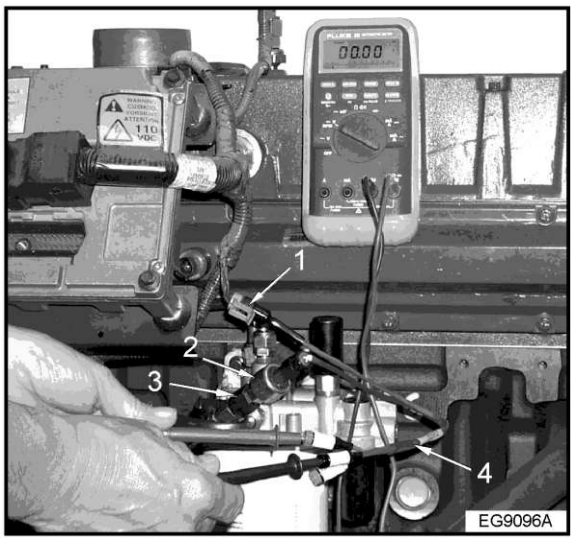
NOTE

If the EST is used for measuring ICP pressure, reconnect ICP engine harness connector to ICP sensor.

If EST is not available do a. and b.:

a. Install breakout tee between ICP sensor and the ICP connector on the engine harness.

b. Connect (+) lead of DMM to the green terminal and the (-) lead to the black terminal of the breakout tee.



(1) Engine Harness Connector
(2) ICP Sensor
(3) ICP Adapter
(4) ICP Breakout Tee

ICP Breakout Tee

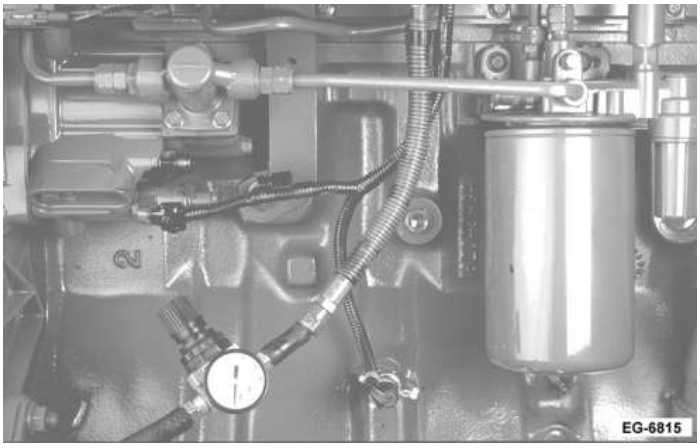
8. Crank engine and record the reading for ICP on Mechanical Diagnostics form EGED1802.

NOTE

If the EST reading for ICP is more than 500 psi, or the DMM reading is more than 1 volt do the following ICP Leakage Test:

ICP Leakage Test

1. Remove intake manifold/valve cover.
2. Remove ICP sensor and adapter plug from high-pressure hose.
3. Reattach hose to oil manifold.



Air Pressure Regulator

4. Remove the other end of the hose from the high-pressure pump and connect an air pressure regulator to the hose.
5. Apply 100 psi to the oil manifold.
6. Inspect for leakage around the base of each fuel injector.

NOTE

Some leakage from the top of the injector is normal.

7. If an injector leaks, remove and inspect injector for damage or worn o-rings.
8. If injectors do not leak, do Key-ON Engine-OFF Injector Test (Test 7) with air pressure still applied.
9. Check oil discharge from each injector. Oil discharge should be equal. Excess oil leakage indicates defective fuel injectors.
10. To find injector leaks, remove air supply and regulator from the high-pressure hose and follow the procedure below.
    a. Connect an automotive cylinder leak tester to the high-pressure hose and apply air pressure from the cylinder leak tester.
    b. Do an Injector Key-ON Engine-OFF Injector Test (Test 7) to determine the percent of cylinder leakage for each actuated injector. Remove and inspect injectors showing the most leakage.

c. If none of the injectors have excessive leakage, remove all injectors. Inspect all o-rings for wear and damage. Replace faulty o-rings.

NOTE

If oil entered the fuel system, drain contaminated fuel from tank.

d. Crank engine and record ICP reading.

NOTE

If ICP pressure remains low, do the following:

11. Remove fuel transfer pump from the high-pressure pump housing.
12. Crank the engine and check for rotation of the fuel transfer pump camshaft inside the housing.
13. If the camshaft is not rotating, remove high-pressure pump and tighten drive gear.
14. Reinstall high-pressure pump and recheck ICP pressure, while cranking engine.
15. If pressure is low, replace IPR valve and recheck ICP pressure.
16. If pressure is still low, replace high-pressure oil pump.

Possible Causes

- No oil in engine
- Oil reservoir leak (possibly through check valve for the high-pressure pump)
- Cracked or porous cylinder head
- Cracked or porous fuel/oil manifold
- Defective high-pressure pump
- Injector o-ring leak
- Injector body leak
- Internal leakage of HEUI injector
- IPR valve stuck open
- Pump drive gear loose or damaged
- Faulty lube oil pump unable to fill reservoir
- Faulty IPR wiring

Tools Required

- Maintenance Support Device (MSD) with Master Diagnostics software
- ICP adapter fitting from Hydraulic Fitting Kit (ZTSE4359)
- DMM (ZTSE4357) (optional)
- ICP sensor breakout tee (ZTSE4347) (optional)

Supplemental Diagnostics

- See Camshaft Position (CMP) sensor diagnostics in Electronic Control System Diagnostics.

m. Fuel Pump Pressure Test

14. Fuel Pump Presssure Test

See Figure J on back of form.
☐ Measure pressure at bleeder valve on filter header.
☐ Minimum 130 rpm cranking speed for 20 seconds

Instrument	Spec	Actual
0-160 psi gauge	35 psi	

- If fuel pressure is low replace fuel filter, clean strainer, and retest.
- If fuel pressure is still low, do **Performance Diagnostics Test 3**.

EG9074

Purpose

To determine correct fuel pressure to start and run the engine.

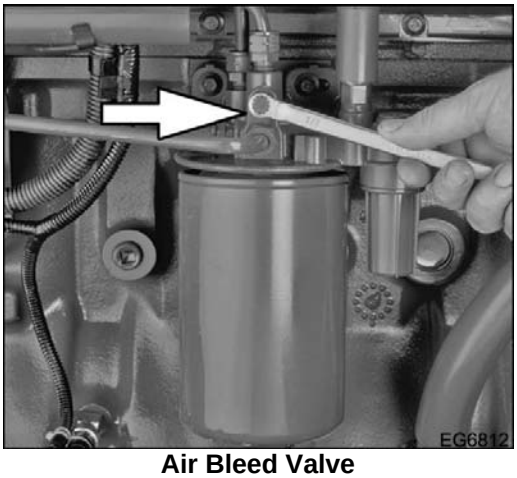
NOTE

If vehicle has an optional fuel/water separator and a water-in-fuel probe, check with the driver to determine if the water-in-fuel lamp was lit during vehicle operation.

Test Procedure

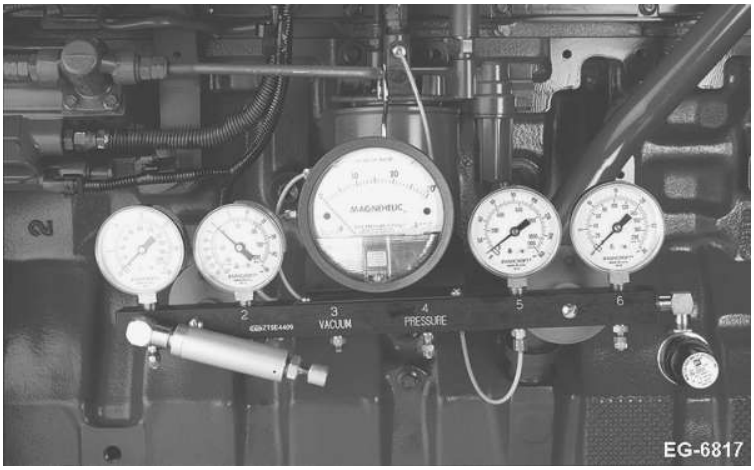
WARNING

Read all safety instructions in this manual before doing this procedure.



Air Bleed Valve

1. Remove air bleed valve from the fuel filter header.
2. Install 1/8 in. (3 mm) pipe fitting.



Gauge Bar

3. Connect a line from the fitting to Gauge Bar.
4. Cranking engine for 20 seconds and record maximum pressure and compare to specifications. If fuel pressure is low, replace fuel filter, clean fuel strainer, and retest.
5. If pressure is low do the following:
   a. Remove fuel return line and install plug into fuel return opening.
   b. Crank engine and check fuel pressure gauge.
   c. If pressure rises, replace fuel return valve and recheck fuel pressure.
   d. If pressure does not increase, see Transfer Pump Restriction Test (Test 3).

NOTE

Several crank cycles may be required to purge air from fuel system.

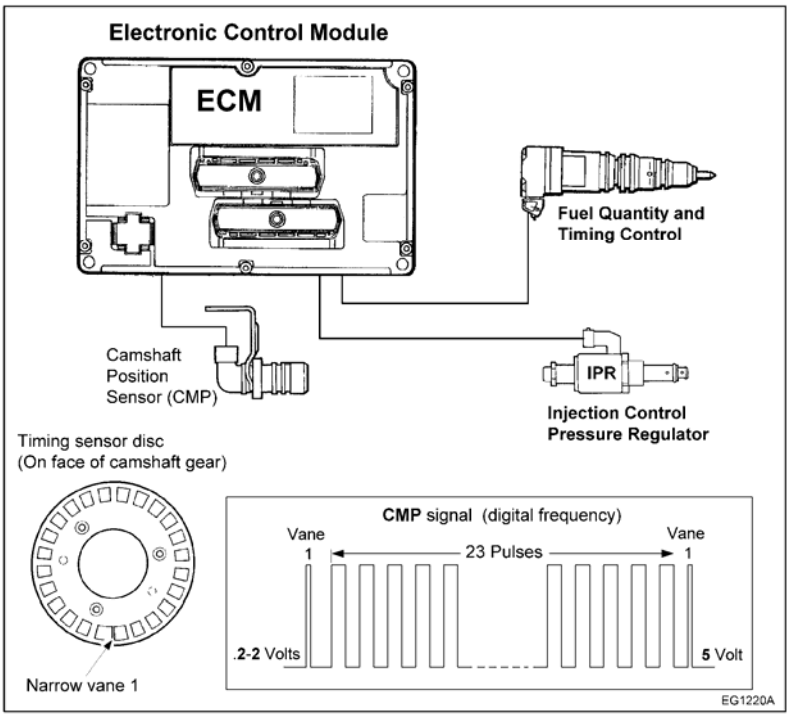
Possible Causes

- No fuel in tank.
- Dirt or fuel jelling in cold ambient temperatures.
- Debris in the fuel regulator valve.
- A kinked or severely bent fuel supply line or blockage at the pickup tube.
- A loose fuel line on the suction side of the fuel system could allow air into the system.
- Defective fuel transfer pump.

Tools Required

- Gauge Bar (PS94-831-3) or fuel pressure gauge, appropriate line with 1/8 in. (3 mm) NPT fitting.

2-11 Camshaft Position Sensor (CMP)



Signal Function Diagram for Camshaft Position Sensor

The Camshaft Position (CMP) sensor is a Hall Effect sensor that generates a digital frequency as windows on the timing disk pass through its magnetic field. The frequency of the windows passing by the sensor as well as the width of selected windows allows the ECM to detect engine speed and position.

Engine Speed - Engine speed is determined by counting 24 windows on the timing sensor disk each camshaft revolution.

Fuel Timing Control - The position of cylinder 1 is determined by distinguishing a narrow vane on the camshaft timing sensor disk.

Engine Mode Selection - Allows the ECM to discern when the engine is in the off, crank or run mode.

Injection Control Pressure - Engine speed is one of the controlling variables in the calculation of desired injection control pressure.

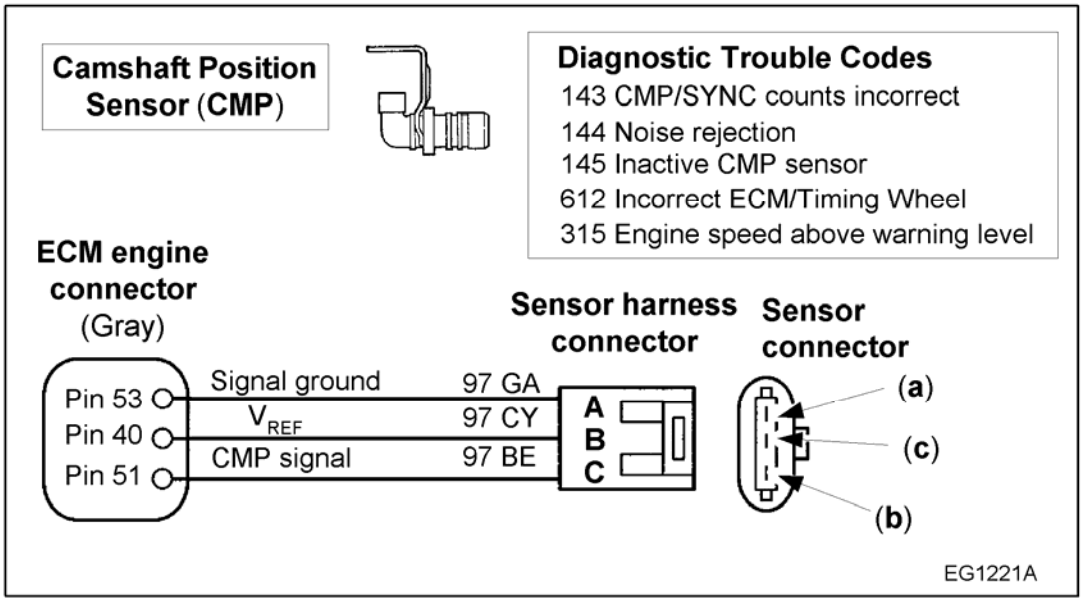
Fuel Quantity Control / Torque Limiting - Engine torque and fuel is controlled and is dependent on engine speed. Fuel quantity is determined by engine speed.

Fault Detection / Management

An inactive CMP signal during cranking is detectable by the ECM. An inactive CMP signal will cause a no start condition. Electrical noise can also be detected by the ECM. If the noise level affects engine operation, a corresponding Diagnostic Trouble Code will be set.

NOTE

The engine will not operate without a functioning CMP.



Circuit Diagram for Camshaft Position Sensor

NOTE

After removing connectors always check for damaged pins, corrosion, loose terminals, and intermittent connections.

Camshaft Position Sensor and Circuit Diagnostics

Connector Voltage Checks (Check with sensor connector disconnected, ignition key ON, all accessories off.)		
Test Points	**Spec.**	**Comments**
A to gnd	0V	No voltage expected
B to gnd	5V ± 0.5	VREF, check key ON, VREF not present check open/short to ground Pin 40 to B, see VREF circuit
C to gnd	5V ± 0.5	If < than 4.5V check for poor connection, if 0V check for open/short to ground circuit
Connector Checks to Chassis Ground (Check with sensor connector (406) disconnected, positive battery cable disconnected and ignition key OFF.)		
Test Points	**Spec.**	**Comments**
A to gnd	<5 Ω	Resistance to chassis ground, check with key off, > than 5 Ω the harness is open
B to gnd	>1000 Ω	Resistance less than 1000 Ω indicates a short to ground
C to gnd	>1000 Ω	Resistance less than 1000 Ω indicates a short to ground
Harness Resistance Checks (Check with breakout box installed on engine harness only with ignition key Off.)		
Test Points	**Spec.**	**Comments**
53 to A	<5 Ω	Resistance from harness connector to 60 pin connector - Signal ground (CMP) has dedicated ground circuit
40 to B	<5 Ω	Resistance from harness connector to 60 pin connector - VREF
51 to C	<5 Ω	Resistance from harness connector to 60 pin connector - CMP signal
Test Points (+) No.51 to () No.53		**Operational Voltage Checks (Check with breakout box installed in line with the ECM and ignition key ON.)**
Voltage	**Position**	**Comments**
5V ± 0.5	Vane	With the breakout box installed, the CMP sensor and ECM connected, bar engine by hand
0.2V to 2V	Window	The CMP signal voltage should change voltage state as the timing wheel and cam are rotated
Diagnostic Trouble Code Reference		
612 = ECM / target disk mismatch detected (wrong ECM Programming Installed). 315 = Engine rpm exceeded 3000 rpm. 143 = Incorrect number of sync to transition counts detected, possible intermittent CMP sensor/circuit. 144 = Electrical noise detected, check wire routing and grounds. 145 = Inactive CMP signal detected during engine cranking when ICP pressure was sufficient for starting.		

Extended Description

Function

The International engine control system includes a Camshaft Position Sensor (CMP). The CMP sensor provides the Electronic Control Module (ECM) with a signal that indicates camshaft position and engine speed.

The CMP sensor signal is used by the ECM to synchronize piston position to injector firing sequence. The injection sequence begins when the ECM detects the narrow vane on the timing disk indicating cylinder 1. The piston position for each cylinder is then continuously calculated as each vane on the timing disk passes by the CMP sensor. This information is processed by the ECM and used for injection timing and fuel delivery control.

Operation

The Camshaft Position Sensor is a Hall Effect type sensor that generates a digital frequency as windows on the timing disk pass through its magnetic field. The frequency of the windows passing by the sensor as well as the width of selected windows allows the ECM to detect engine speed and position. When the narrow vane passes the CMP sensor, the signal on time is less than when the other vanes pass the sensor. This produces a signal that the ECM uses to indicate engine position.

Engine speed is detected by the ECM by counting the frequency of the 24 signal pulses for each camshaft revolution.

ECM Diagnostics

Once the ECM has recognized the narrow vane (wide window) it will synchronize the engine firing order to the timing of the CMP signal. Every two crankshaft revolutions it will verify that synchronization. If the ECM receives too many or too few pulses for the number of engine revolutions, it will set a Diagnostic Trouble Code.

The engine will not operate without a functioning CMP signal. However, the ECM will attempt to determine the cause of an invalid signal and identify it with a Diagnostic Trouble Code.

CMP codes that are set will become inactive codes if the key is turned off. These codes can be retrieved using the Self Test Input (STI) switch (Engine DIAGNOSTICS switch) on the vehicle dashboard or the Electronic Service Tool (EST).

Diagnostic Trouble Code 143
ATA Code SID 21 FMI 2
Incorrect Number of CMP Signal Transitions per Cam Revolution

Diagnostic Trouble Code 143 indicates the ECM has received CMP signals with the wrong number of transitions. This indicates that the ECM has counted the voltage transitions and found less than the specified number of pulses from the sensor. When this problem is continuous, the engine will stop running and the ECM will log an active Diagnostic Trouble Code. If the ignition is shut off, the active Diagnostic Trouble Code becomes an inactive Diagnostic Trouble Code.

Diagnostic Trouble Code 143 will not turn the warning light on.

Possible causes for Diagnostic Trouble Code 143: Intermittent CMP signal caused by an intermittent circuit, defective Camshaft Position Sensor, or incorrect CMP sensor to timing disk clearance.

Diagnostic Trouble Code 144
ATA Code SID 21 FMI 2
CMP Signal Noise Detected

Diagnostic Trouble Code 144 indicates that the ECM has detected voltage spikes or transitions other than the CMP signal. If this problem is continuous, the engine could stop running and the ECM will log an active Diagnostic Trouble Code. If the key is shut off, the active Diagnostic Trouble Code 144 will become inactive. Diagnostic Trouble Code 144 will not cause the warning light to illuminate.

Diagnostic Trouble Code 144 may be caused by:
(1) Poor ground connections for the CMP or other electronic components
(2) Wire harness shielding missing or incorrectly installed on the engine harness
(3) Outside components that could induce voltage signals

Diagnostic Trouble Code 145
ATA Code SID 21 FMI 12
CMP Signal Inactive while ICP has Increased

Diagnostic Trouble Code 145 indicates that the ECM does not detect a CMP signal. Diagnostic Trouble Code 145 would be set if the engine was rotating and the ECM detected a rise in ICP pressure, but did not detect a CMP signal. To set Diagnostic Trouble Code 145 the engine must be rotated long enough for the ICP pressure to increase. When Diagnostic Trouble Code 145 is set, the engine will not operate. Diagnostic Trouble Code 145 will not cause the engine warning light to illuminate.

Possible causes for Diagnostic Trouble Code 145: Defective CMP sensor, faulty sensor circuitry or improper air gap between sensor and camshaft timing disk.

Diagnostic Trouble Code 612
ATA Code SID 21 FMI 7
Incorrect ECM Installed for CMP Timing Disk

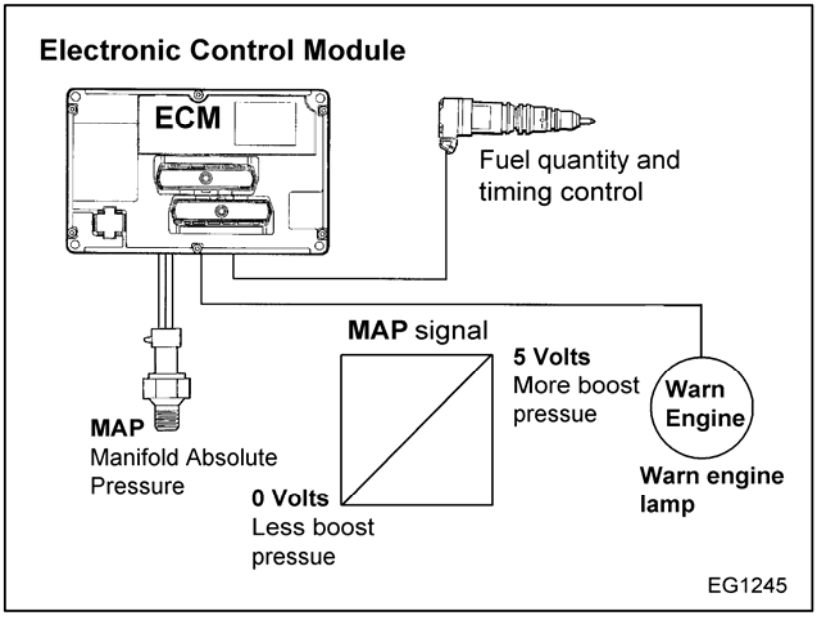
Diagnostic Trouble Code 612 indicates that the ECM has monitored the CMP signal and the signal is incorrect for the programming in the ECM. This means that the ECM does not recognize the signal generated from the timing disk and CMP sensor.

Possible causes for Diagnostic Trouble Code 612: ECM has been replaced with an incorrect ECM for the particular engine application. For example, the timing disk for the I-6 and V-8 (T 444E) are different and generate a different signal, and the ECM from the V-8 (T 444E) engine will not run an I-6 engine. Incorrect signal due to a defective CMP sensor or incorrect air gap between the CMP sensor and the timing disk.

Diagnostic Trouble Code 315
ATA Code PID 190 FMI 0
Engine Speed Above Warning Level

Diagnostic Trouble Code 315 indicates that the ECM has detected engine speed above 3000 rpm. The most likely cause of the excessive engine speed is an unintended down shift, steep acceleration down a hill without correct brake application, or an external fuel source being ingested into the air intake system. Engine hours and miles for the last two over speed occurrences will be recorded in the Engine Event Log. Diagnostic Trouble Code 315 will cause the WARN ENGINE lamp to illuminate.

2-12 Manifold Absolute Pressure (MAP) Sensor Test



Signal Function Diagram for Manifold Absolute Pressure Sensor

The Manifold Absolute Pressure (MAP) sensor is a variable capacitance sensor that operates on a 5V reference signal from the ECM to produce a linear analog voltage signal that indicates pressure.

Smoke Control
The MAP signal is used to control smoke by limiting fuel quantity during acceleration until a specified boost pressure is obtained.

Dynamic Injection Timing
The ECM optimizes injection timing for boost pressure measured.

Fault Detection / Management

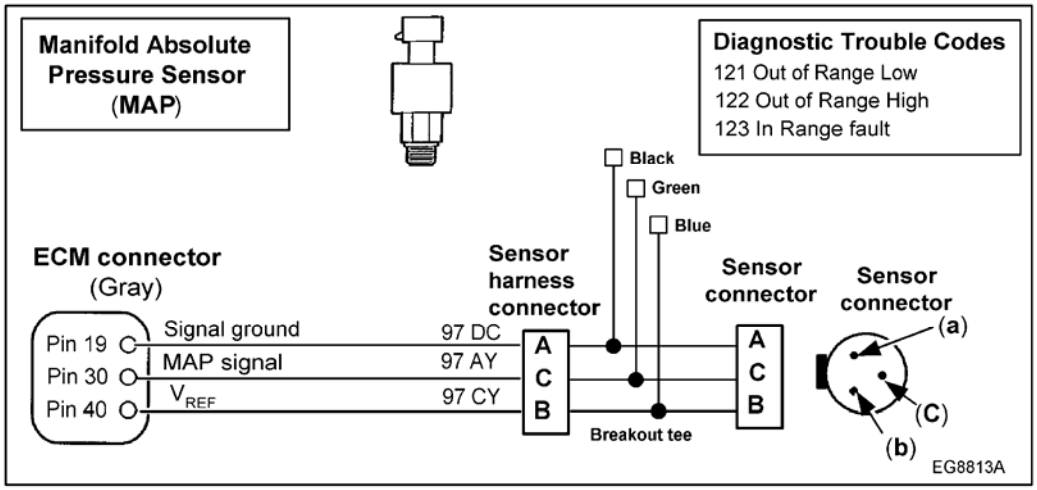
A MAP signal that is detected by the ECM to be out of range or an incorrect value for specific conditions will cause the ECM to ignore the MAP signal and continue to operate the engine with the values from estimated MAP (Operate from a calculated boost pressure signal.)

To troubleshoot MAP sensor and circuitry see:

Manifold Absolute Pressure Sensor Circuit Diagram

Manifold Absolute Pressure Sensor and Circuit Diagnostic

Sensor Circuit Diagnostics Using an EST



Circuit Diagram for Manifold Absolute Pressure Sensor

SENSOR TESTS

If multiple active sensor codes exist, measure V-ref voltage and sensor ground circuit resistance using a DMM before doing the Sensor Tests

MAP Sensor Voltage Tests Using Master Diagnostics

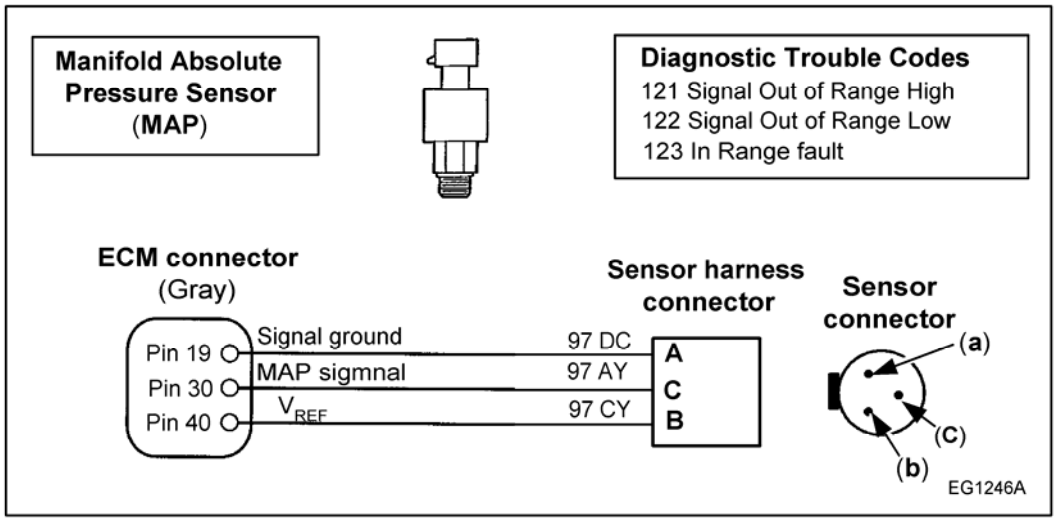
Manifold Absolute Pressure (MAP) Sensor Voltage Checks (check with key-ON engine-OFF)		
Install the 3 wire breakout tee between the MAP sensor and harness connector. View MAP VOLTAGE using the Continuous Monitor session and the Continuous Monitor test found under the diagnostics menu in MASTER DIAGNOSTICS. If the circuit has an active fault according to the voltage level (Code 121 >4.9V, Code 122 <0.039V, Code 123 >1.0 V), complete the following steps. Tests must be performed in order.		
Test Condition	**Voltage**	**Comments**
Sensor Disconnected	0V	If voltage >0.039V, check signal circuit for short to VREF or B+.
Measure voltage from PIN B to gnd using a DMM.	5V ± 0.5	If voltage is >5.5V, check VREF for short to B+. If voltage is <4.5V check VREF circuit for open or short to ground.
0.5 kΩ jumper installed between the GREEN and BLUE pins of the breakout tee.	5V	If voltage is <4.9V, check signal circuit for open circuit or short to ground. Remove positive battery cable. Measure resistance from PIN C to Ground (spec >500) and from PIN C to PIN 30 (spec <5) using a breakout box to determine if short to ground or open is in the harness.

MAP Sensor Voltage Tests Using Master Diagnostics - Continued			
Standard jumper installed between the BLUE, GREEN, and BLACK pins of the breakout tee.	0V	If voltage is >0.039V, check ground circuit for resistance >5Ω. Measure resistance between PIN A and PIN 19 (spec < 5Ω) using a breakout box to determine if resistance is in the harness.	
Replace the sensor if the code is active and the expected results are obtained with all the sensor tests. The sensor is not at fault if one or more of the sensor tests does not produce the expected results. See MAP Sensor Troubleshooting Flowchart .			
MD Voltage: (+)30 to (-)19		Operational Voltage Checks (check with breakout tee installed in-line with the sensor)	
Voltage	**psi**	**kPa**	**Comments**
0.039V	N/A	N/A	Out of range LOW limit.
0.92V	0	0	Voltage with key ON engine OFF. Atmospheric pressure dependent on altitude and BAP pressure.
1.73V	8.0	55	
2.72V	18.0	124	
Diagnostic Trouble Code Description			
121 = Signal voltage was >4.9 volts for more than .1 sec.			
122 = Signal voltage was <0.039 volts for more than .1 sec.			
123 = Detected boost signal >2.0 psi (13.8 kPa) at low idle.			

Alternate Testing Procedure

NOTE

Use this procedure if no EST is available.



Circuit Diagram for Manifold Absolute Pressure Sensor

NOTE

After removing connector always check for damaged pins, corrosion, and loose terminals.

Manifold Absolute Pressure Sensor and Circuit Diagnostics

Connector Voltage Checks (Check voltage with sensor connector disconnected and ignition key ON.)			
Test Points	**Spec.**	**Comments**	
A to gnd	0 to 0.25V	If greater than 0.25V, signal ground is shorted to VREF or battery.	
B to gnd	5V ± 0.5	VREF check with key ON, if voltage not in spec. See VREF circuit.	
C to gnd	0 to 0.25V	If greater than 0.25V, signal ground is shorted to VREF or battery.	
Connector Checks To Chassis Ground (Check with sensor connector disconnected, positive battery cable disconnected and ignition key OFF.)			
Test Points	**Spec.**	**Comments**	
A to gnd	<5 Ω	Resistance to chassis ground, check with key OFF, if > than 5 the harness is open.	
B to gnd	>500 Ω	Resistance less than 1000 Ω indicates a short to ground.	
C to gnd	>1000 Ω	Resistance less than 1000 Ω indicates a short to ground.	
Harness Resistance Checks (Check with breakout box installed on engine harness only.)			
Test Points	**Spec.**	**Comments**	
19 to A	<5 Ω	Resistance from sensor connector to 60 pin connector - Signal ground.	
40 to B	<5 Ω	Resistance from sensor connector to 60 pin connector - VREF.	
30 to C	<5 Ω	Resistance from sensor connector to 60 pin connector - MAP signal.	
Test Points: (+)30 to (-)19		Operational Voltage Checks (Check voltage with breakout box installed in-line with the ECM.)	
Voltage	**psi**	**kPa**	**Comments**
0.039V	N/A	N/A	Out of range low limit.
0.92V	0	0	Voltage with key on engine OFF. Atmospheric pressure dependent on altitude and BAP pressure.
1.73V	8.0	55	
2.72V	18.0	124	
Diagnostic Trouble Code Reference			
121 = Signal voltage was less than 0.039V for more than 0.1 second.			
122 = Signal voltage was greater than 4.9V for more than 0.1 second.			
123 = Detected boost signal (above 16.7 psi / 115 kPa) at low idle.			

Extended Description

Function

The International engine control system includes a Manifold Absolute Pressure (MAP) sensor. The Electronic Control Module (ECM) measures the signal from the MAP sensor to determine intake manifold (boost) pressure. From this information, the ECM can control fuel efficiency and injection timing for all engine operating conditions.

Operation

The MAP sensor is a variable capacitance sensor that produces a linear analog voltage signal. The MAP sensor, on the intake manifold, is supplied 5V from ECM pin 40 to terminal B of the sensor. A return circuit (ground) is supplied from ECM pin 19 to terminal A of the sensor. Pressure applied to the MAP sensor changes the capacitance of the sensor which varies the signal voltage sent to the ECM. As boost pressure increases, the voltage signal increases.

ECM Diagnostics
The ECM monitors the MAP sensor signal for expected values. If the ECM detects the MAP signal more or less than the desired value, the ECM will set a Diagnostic Trouble Code.

If an active Diagnostic Trouble Code for the MAP sensor is set, the ECM will ignore the MAP sensor signal and operate the engine using programmed default values. Active Diagnostic Trouble Codes for the MAP sensor will cause the ECM to illuminate the engine warning light. Active Diagnostic Trouble Codes can be retrieved using the diagnostic switch (on the dashboard) for the self test, or the Electronic Service Tool (EST). If the ignition key is turned OFF, the Diagnostic Trouble Code will be stored as inactive.

Diagnostic Trouble Code 121
ATA Code PID 102 FMI 8
Map Signal Out of Range High
Diagnostic trouble Code 121 is set when the ECM detects a MAP signal voltage greater than 4.9V for more than 0.1 second.

When Diagnostic trouble Code 121 is active, the ECM will ignore the MAP signal and operate the engine using programmed default values. The ECM will illuminate the engine warning light when this code is active.

Diagnostic Trouble Code 122
ATA Code PID 102 FMI 11
Map Signal is Out of Range Low
Diagnostic Trouble Code 122 is set when the ECM detects a MAP signal voltage less than 0.039V for more than 0.1 second.

When Diagnostic Trouble Code 122 is active, the ECM will ignore the MAP signal and operate the engine using programmed default values. The ECM will illuminate the engine warning light when this code is active.

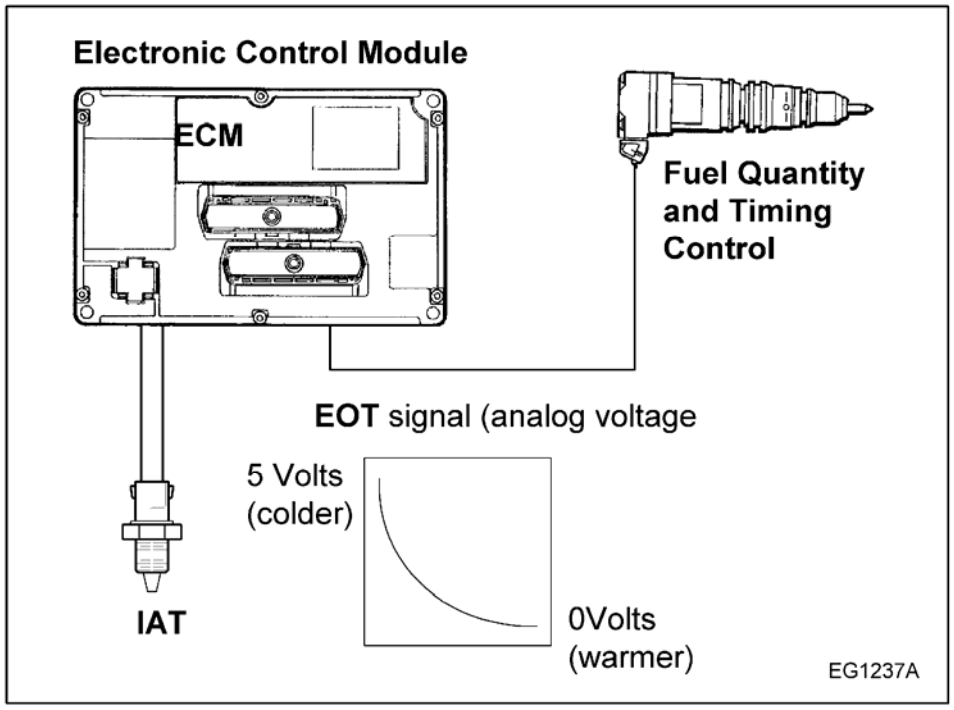
Possible causes: A defective MAP sensor or MAP sensor signal circuit may be open or shorted to ground.

Diagnostic Trouble Code 123
ATA Code PID 102 FMI 2
Map Signal above Specified Level at Low Idle
Diagnostic Trouble Code 123 is set when the MAP signal is greater than 16.7 psi (115 kPa) Absolute at low idle.

When Diagnostic Trouble Code 123 is active, the ECM will ignore the MAP signal and operate the engine using programmed default values. The ECM will illuminate the Engine Warning light when this code is active.

Possible Causes: Restricted or plugged sensor inlet or a defective MAP sensor.

2-13 Intake Air Temperature (IAT) Sensor Test



Signal Function Diagram for Intake Air Temperature Sensor

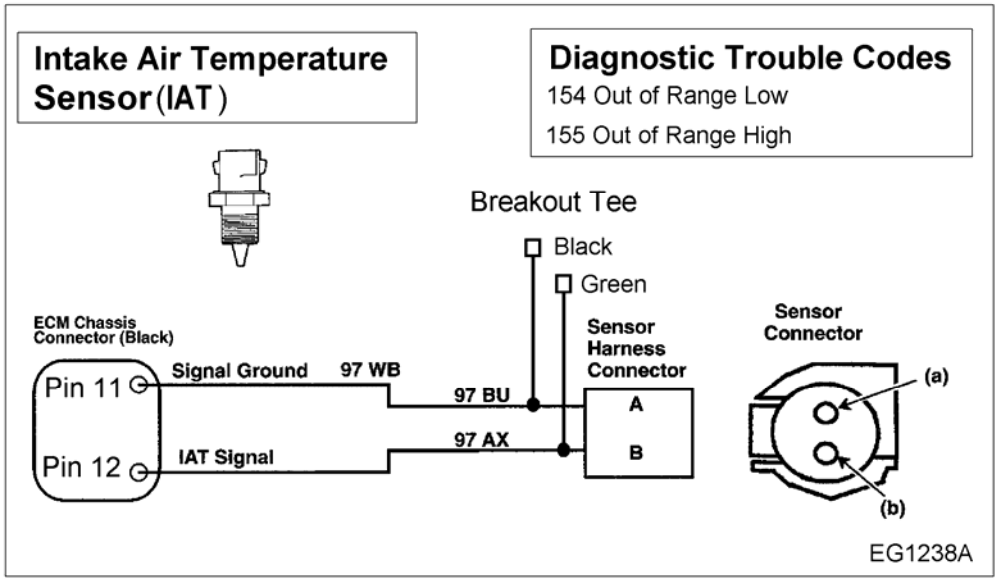
The Intake Air Temperature (IAT) sensor is a thermistor sensor that changes resistance when exposed to different temperatures. When interfaced with the ECM it produces a 0-5V analog signal that will indicate intake air temperature.

Timing and Fuel Rate - The primary function of the IAT sensor is to measure intake air temperature, to control timing and fuel rate, and to limit smoke emissions while starting the engine in cold weather.

Fault Detection / Management

An IAT signal detected out of range high or low by the ECM will cause the engine to ignore the IAT signal and assume an ambient temperature of 77F (25C).

Sensor Circuit Diagnostics Using an EST



Circuit Diagram for Intake Air Temperature Sensor using a Breakout Tee

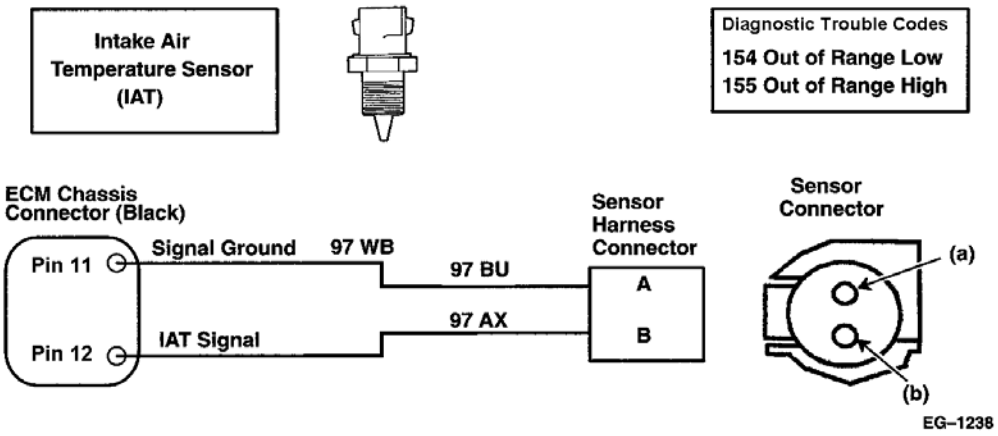
IAT Sensor Tests Using Master Diagnostics

Intake Air Temperature Sensor (IAT) Voltage Checks (Check with key-on engine-OFF.)		
Install the 2 wire breakout tee between the IAT sensor and harness connector. View IAT VOLTAGE using the Continuous Monitor session and the Continuous Monitor test found under the diagnostics menu in MASTER DIAGNOSTICS. If the circuit has an active fault according to the voltage level (Code 154 = < 0.127V, Code 155 =>4.6V), complete the following steps.		
Test Condition	Voltage (expected)	Comments
Sensor Disconnected	> 4.6 V	Voltage < 4.6V, inspect the signal circuit for short to ground.
Standard jumper installed between the GREEN and BLACK pins of the breakout tee	0 volts	If voltage is > 0.127V, check ground circuit for open or high resistance. Measure resistance from PIN A to PIN 11 (spec. =<5) using a breakout box to determine if the resistance is in the harness.
Replace the sensor if the code is active and the expected results are obtained with all the sensor tests. The sensor is not at fault if one or more of the sensor tests does not produce the expected results. If the expected results are not obtained, check the signal and ground circuits using the procedure on the next page.		
Diagnostic Trouble Code Descriptions:		
154 = Intake Air Temperature signal voltage was less than 0.127 volts for more than 0.2 sec		
155 = Intake Air Temperature signal voltage was more than 4.6 volts for more than 0.2 sec		

Alternate Testing Procedure

NOTE

Use this procedure if no EST is available.



Circuit Diagram for Intake Air Temperature Sensor

NOTE

After removing connectors check for damaged pins, corrosion, and loose terminals.

Circuit Diagnostics for Intake Air Temperature Sensor

Connector Voltage Checks (Check with sensor connector disconnected and ignition key ON.)					
Test Points	Spec.	Comments			
A to gnd	0 to 0.25V	If greater than 0.25V, signal wire is shorted to VREF or battery			
B to gnd	4.6 to 5.0V	Pull up voltage, if no voltage, circuit has open or high resistance or short to ground			
Connector Checks to Chassis Ground (Check with sensor connector disconnected, positive battery cable disconnected, and ignition key OFF.)					
Test Points	Spec.	Comments			
A to gnd	<5 Ω	Resistance to chassis ground. Check with key off, if >5 Ω the harness is open.			
B to gnd	>1000 Ω	Resistance less than 1000 Ω indicates a short to ground			
Harness Resistance Checks (Check with breakout box installed on chassis harness only.)					
Test Points	Spec.	Comments			
11 to A	<5 Ω	Resistance from sensor connector to 60 pin connector - Signal ground			
12 to B	<5 Ω	Resistance from sensor connector to 60 pin connector - IAT Signal			
Test Points: (+)12 to (-)11		Operational Signal Checks (Check with breakout box installed in-line with the ECM.)			
Temp F	Temp C	Min.Resistance	Max. Resistance	Volts@ Min. k	Volts@ Max. k
32	0	91.1 k	100.6 k	3.846V	3.909V
68	20	35.5 k	39.2 k	3.041V	3.144V
212	100	2.0 k	2.1 k	0.446V	0.488V
Resistance checks must be taken across sensor only with the Master Powered.					
Diagnostic Trouble Code Reference					
154 = Signal voltage was less than 0.127V for more than 0.2 sec					
155 = Signal voltage was greater than 4.6V for more than 0.2 sec					

Extended Description

Function

The International engine control system includes an Intake Air Temperature sensor (IAT). The ECM measures the signal from the IAT sensor to determine the temperature of the intake air. The ECM uses this data to adjust timing and fuel rate for starting in cold weather to limit smoke emissions.

Operation

The Intake Air Temperature sensor is a thermistor sensor that changes resistance when exposed to different air temperatures.

When the temperature of the intake air decreases, the resistance of thermistor increases which causes the signal voltage to increase. When the air temperature increases, the resistance of the thermistor decreases causing the signal voltage to decrease.

The IAT sensor is supplied a regulated 5V reference signal at terminal B from the ECM. A return circuit (ground) is supplied at terminal A from the ECM. As the air temperature increases or decreases, the sensor changes resistance and provides the ECM with the air temperature signal voltage reading.

ECM Diagnostics
With the ignition key ON, the ECM continuously monitors the IAT signal to determine if the temperature is within expected values. If the signal voltage is above or below the expected levels, the ECM will set a Diagnostic Trouble Code.

If the IAT sensor is not sending a correct signal, the ECM will default to 77F (25 C).
IAT Diagnostic Trouble Codes can be retrieved using the Electronic Service Tool (EST) or by reading the Diagnostic Trouble Codes from the warning light, using the Engine Diagnostic Switch. If the ignition key is turned OFF, the Diagnostic Trouble Codes will become inactive. IAT Diagnostic Trouble Codes will cause the Engine Warning light to be illuminated.

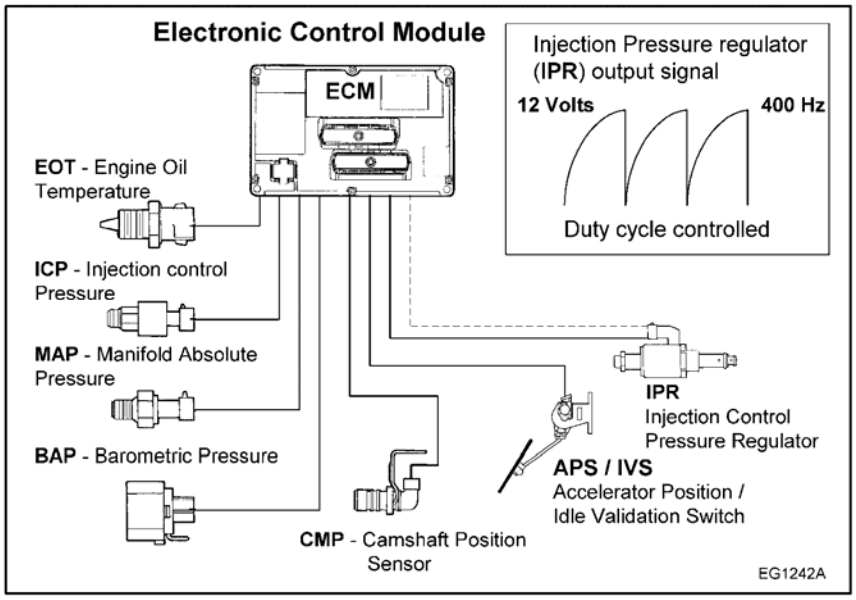
Diagnostic Trouble Code 154
ATA Code PID 171 FMI 4
Intake Air Temp signal Out of Range Low
Diagnostic Trouble Code 154 will be set if the ECM detects the signal voltage to be less than 0.127V for more than 0.2 seconds. If Diagnostic Trouble Code 154 is active, the ECM will default to a value of 77F (25C) for starting.

Diagnostic Trouble Code 154 may be set due to a short to ground in the signal circuit or a defective sensor.

Diagnostic Trouble Code 155
ATA Code PID 171 FMI 3
Intake Air Temp signal Out of Range High
Diagnostic Trouble Code 155 will be set if the ECM detects the signal voltage to be more than 4.6V for more than 0.2 seconds. If Diagnostic Trouble Code 155 is active, the ECM will default to a value of 77F (25C) for starting.

Diagnostic Trouble Code 155 may be set due to an open signal circuit between the ECM and the sensor, an open signal ground, or a short to a voltage source. A defective sensor may also cause code 155 to be set.

2-14 Injection Pressure Regulator (IPR) Sensor Test



Output Function Diagram for Injection Pressure Regulator

Injection Pressure Regulator (IPR)
The Injection Pressure Regulator is a variable position valve that controls injection control pressure. The ECM uses many input variables to determine the desired injection control pressure.

Battery voltage is supplied to the IPR when the ignition key is ON. Valve position is controlled by switching the output signal circuit to ground inside the Electronic Control Module (ECM). On / off time is modulated from 0-60% depending on the desired injection control pressure.

Fault Detection / Management

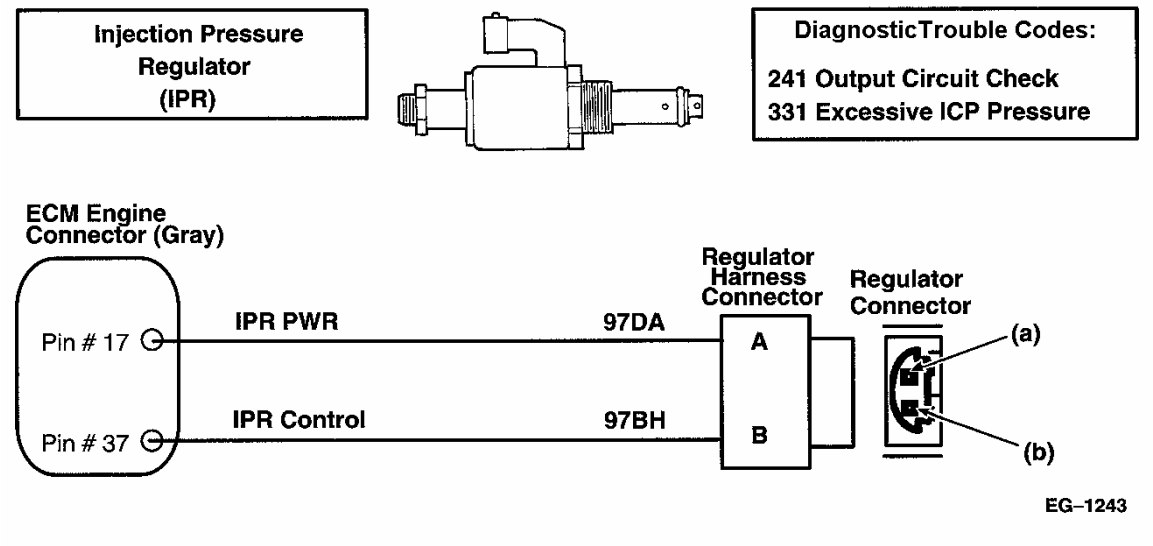
An open or short to ground control in the circuit can be detected by an on demand output circuit check performed during the engine off test.

While the engine is running, the ECM is capable of detecting, if desired injection control pressure is equal to measured injection control pressure. If the measured injection control pressure does not reasonably compare to the desired injection control pressure, the ECM ignores the measured ICP signal and attempts to control the engine with the desired value. If the suspect problem was in the sensor circuit, this strategy causes little performance deterioration. If the problem is in the control circuit, engine performance will probably still be unsatisfactory.

A faulty IPR or problem with the high pressure oil system can be detected by the engine running test during the injection control pressure step test. During this test, the ECM commands and measures two specific preprogrammed pressures. A Diagnostic Trouble Code is set, if the pressures cannot be maintained.

NOTE

The engine will not operate with an IPR circuit that is not functioning.



Circuit Diagram for Injection Pressure Regulator

NOTE

After removing connectors always check for damaged pins, corrosion, and loose terminals.

Injection Pressure Regulator and Circuit Diagnostics

IPR Voltage Check (Check with regulator connector disconnected and ignition key ON.)		
Test Points	**Spec.**	**Comments**
A to gnd	B+	IPR power voltage from ECM
B to gnd	0 to 0.25V	If greater than 0.25V, signal wire is shorted to VREF or battery
Connector Checks to Ground (B-) (Check with IPR connector disconnected, ignition key OFF, and positive battery cable disconnected.)		
Test Points	**Spec.**	**Comments**
A to gnd	>1000 Ω	Resistance to chassis ground. If less than 1000 Ω, check for short to ground in circuit
B to gnd	>1000 Ω	Remove fuse F5 in fuse box prior to measuring resistance
Harness Resistance Checks (Check with breakout box installed on engine harness only.)		
Test Points	**Spec.**	**Comments**
17 to 37	5 to 20 Ω	Resistance through entire IPR circuit including regulator coil. Check with regulator connector connected to IPR.
17 to A	<5 Ω	Resistance from 60 pin connector to regulator connector
37 to B	<5 Ω	Resistance from 60 pin connector to regulator connector
Diagnostic Trouble Code Reference		
241 = Output Circuit Check detected during Standard Test, indicates high or low resistance in circuit		
331 = ICP pressure was greater than 3675 psi (25 MPa) for 1.5 sec. Possible grounded IPR control circuit. See ICP diagnostics if there is not an electronic diagnostic trouble code.		

Extended Description

Function

The International engine control system includes an Injection Pressure Regulator (IPR) valve that controls oil pressure in the high pressure injection control system which is used to actuate the injectors. The IPR valve consists of a solenoid, poppet and spool valve assembly. It is mounted in the high pressure oil pump. The ECM regulates injection control pressure by controlling the duty cycle (or on/off time) of the injection control pressure solenoid. This increase or decrease of (on/off) time positions a poppet valve and spool valve inside the IPR, which in turn either maintains pressure in the injection control pressure system or vents pressure to the oil sump via the front cover. See Section, Engine Control system Overview, in this manual for a more complete description of the IPR operation and function.

Operation

The IPR valve is supplied with voltage at terminal A of the IPR connector from the ECM when the ignition key is turned on. Control of the injection control system is accomplished by the ECM grounding the IPR circuit from terminal B of the IPR valve through pin 37 of the ECM. Precise control is accomplished by varying the pulse width or percentage of on/off time of the IPR solenoid. The frequency of the pulse width to the IPR is 400 Hz, normal on/off times vary from 8% to 60%. A high duty cycle indicates a high amount of injection control pressure being commanded, a low duty cycle is an indication of less pressure being commanded.

ECM Diagnostics
The ECM monitors the Injection Control Pressure while the engine is operating. If the actual pressure is more or less than the desired pressure, the ECM will set a Diagnostic Trouble Code. When this occurs, the ECM will ignore the ICP sensor and control the engine using preprogrammed values for the IPR.

The Electronic Service Tool (EST) requests the Engine Running Standard Test that enables the ECM to vary the command signal to the IPR and monitor the performance of the Injection Control Pressure system. If the system does not respond within the specified parameters, the ECM will set a Diagnostic Trouble Code.

Diagnostic Trouble Codes can be retrieved using the Electronic Service Tool (EST), or the Engine Diagnostic Switch (STI). If the ignition key is turned OFF, the code will be stored as inactive.

Diagnostic Trouble Code 241
ATA Code SID 42 FMI 11
Injection Control Pressure Regulator OCC Self Test Failed

Diagnostic Trouble Code 241 is set only during the Engine Off Standard Output Circuit Check. This test indicates the ECM has performed an output circuit test, measured voltage drop across the IPR circuit and determined it is below or above specification.

If Diagnostic Trouble Code 241 is active, the engine will not run. The ECM will not illuminate the Engine Warning light if Diagnostic Trouble Code 241 is active; however, Diagnostic Trouble Code 241 will be sent after Output Circuit Check, using the Electronic Service Tool (EST) or Engine Diagnostic Switch (STI).

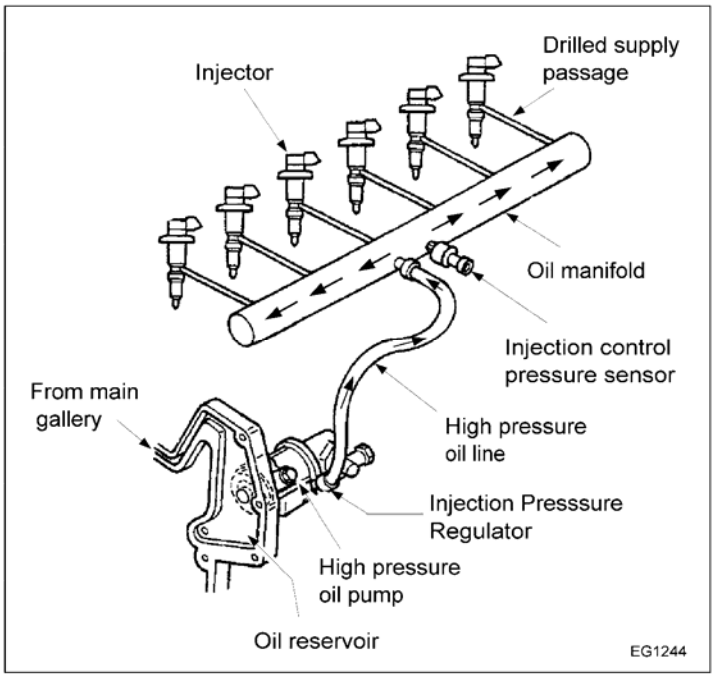
Diagnostic Trouble Code 331
ATA Code PID 164 FMI 0
Injection Control Pressure above System Working Range

Diagnostic Trouble Code 331 indicates the ECM has detected injection control pressure greater than 3675 psi (25 MPa) which is greater than the maximum allowable working pressure.

When Diagnostic Trouble Code 331 is active, the ECM will illuminate the Engine Warning Light.

Possible causes: Incorrect ICP signal due to faulty circuits or sensor, incorrect sensor, grounded IPR signal circuit, a malfunction in the injection control pressure system or a sticking, or blocked IPR valve.

Injection Pressure Regulation System (IPR_SYS) Test



Functions Injection Pressure Regulation System

The Injection Control Pressure System consists of the low pressure oil lubrication system, passages in the front cover and reservoir, high pressure oil pump, high pressure oil line as well as the high pressure oil rail mounted on the side of the cylinder head. The injection control pressure system also includes the injectors (and their respective sealing O-rings), the IPR valve (injection pressure regulator) and the ICP (injection control pressure) sensor and associated wiring.

The function of this system is to develop, maintain, and control the injection control pressure to provide the force to actuate the injectors and provide fuel to the engine.

Fault Detection / Management

The Diagnostic Trouble Codes associated with this system may indicate an electrical or electronic control system failure, but most likely will indicate a mechanical or hydraulic problem with the injection control pressure system.

The ECM constantly monitors the injection control pressure to assure the control system is providing the correct pressure at all times. If the oil pressure feedback provided by the ICP sensor does not meet the ECM's programmed desired values, the ECM will set a Diagnostic Trouble Code, illuminate the WARN ENGINE lamp and control the operation of the injection control system by calculating the correct oil pressure for all engine operating conditions until the system is diagnosed and repaired.

The ECM also monitors the injection control pressure developed while cranking the engine. If pressure does not develop within the ECM's expected time limit, it will set an appropriate Diagnostic Trouble Code which will aid the technician in diagnosing the no start or hard start condition.

The Electronic Service Tool (EST) may be used by the technician to command the ECM to perform an engine running test on the Injection Control Pressure system. The ECM controls the pressure regulator in a programmed sequence to evaluate system performance. At the end of the test, the ECM will transmit any Diagnostic Trouble Code if system performance is unsatisfactory.

ECM Diagnostics
Diagnostic Trouble Code 333
ATA Code PID 164 FMI 10
Injection Control Pressure above/below Desired Level

Diagnostic Trouble Code 333 is set during normal engine operation through the continuous monitor function or during the Engine Running Standard Test. Diagnostic Trouble Code 333 indicates that the measured pressure does not match the pressure value the ECM expects.

Diagnostic Trouble Code 333 will be set if the measured value is less than or greater than 362 psi (2.5 MPa) of desired injection control pressure for more than 7 seconds. When Diagnostic Trouble Code 333 is active, the ECM will ignore feedback from the ICP sensor and control the IPR valve from pre-programmed default values. When this occurs it will illuminate the WARN ENGINE lamp to notify the driver.

Diagnostic trouble code 333 usually indicates poor engine performance. Symptoms include slow acceleration time, low power at full load and possible engine under run.

Possible Causes:

- Low oil level, contaminated or aerated engine oil.
- Trapped air in the ICP system (particularly after an injector or high pressure pump replacement).
- Defective or stuck injection pressure regulator.
- Intermittent IPR valve wiring connection. Spread IPR harness terminals at valve, poorly crimped terminals or pulled back pins.
- Leaky injector O rings.
- Problem with ICP sensor and sensor circuit, system biased high or low. Incorrect sensor
- High pressure pump.

See Diagnostic Trouble Code 333 Recommended Actions.

Diagnostic Trouble Code 333 Recommended Actions

Recommended Actions:	
Test	**Comments**
Check repair history - (Determine if air entrapment could be caused by ICP system disassembly.)	If system was disassembled assure vehicle is operated 15 to 20 miles after injection control system has been serviced
Check oil level and quality	Check oil level and for contamination and correct API classification
Check active and inactive diagnostic trouble codes	Repair any ICP sensor codes first
Perform a Key-ON Engine-OFF Standard Test	Test will verify IPR circuit continuity
Perform a Key-ON Engine-Running test	ICP step test will verify a gross ICP system failure
Perform Engine Running / Wiggle Test intermittent diagnostic trouble code detection test	When running the Engine Running / Wiggle Test, pull / wiggle wires on ICP sensor and IPR valve as well as all pass through connectors. If a diagnostic trouble code is set or the engine dies, inspect wires at point of connection, check codes.
Perform ICP Pressure test - Performance Diagnostic Form (Oil aeration)	Will verify if oil is aerated at high idle. See Test 12 in Performance Diagnostics on form EGED 1802.
Test high pressure (injection control pressure system) for leaks	See ICP Leakage tests in Section 2

DIAGNOSTIC TROUBLE CODE 334
ATA Code PID 164 FMI 7
Injection Control Pressure (ICP) Unable to Reach Set Point - Poor Performance

The purpose of Diagnostic Trouble Code 334 is to determine if a rapid increase in injection control pressure can be developed when commanded by the operator while the engine is running. Diagnostic Trouble Code 334 is an ICP system response time Diagnostic Trouble Code that compares measured injection control pressure to desired injection control pressure and looks for a large pressure difference, 1300 psi (9 MPa) for a short period of time (3 seconds). Its primary function is to detect injection control pressure system Diagnostic Trouble Codes. When this code is active, the Engine Warning Lamp will be illuminated and the ECM will ignore the ICP sensor and control IPR valve operation from pre-programmed default values.

An active code 334 is usually associated with poor engine performance conditions including slow acceleration times and low power concerns.

Possible Causes:

- Low oil level, contaminated or aerated engine oil.
- Trapped air in the ICP system particularly after an injector or high pressure pump replacement.
- Defective or stuck injection pressure regulator.
- Intermittent IPR valve wiring connection. Spread IPR harness terminals at valve, poorly crimped terminals or pulled back pins.
- Leaky injector O rings.
- Problem with ICP sensor and/or sensor circuit, system biased high or low. (Incorrect sensor).

See Diagnostic Trouble Code 334 Recommended Actions.

Diagnostic Trouble Code 334 Recommended Actions

Recommended Actions:	
Test	**Comments**
Check repair history - (Determine if air entrapment could be caused by ICP system disassembly.)	If system was disassembled assure vehicle is operated 15 to 20 miles after injection control system has been serviced
Check oil level and quality	Check oil level and for contamination and correct API classification
Check active and inactive diagnostic trouble codes	Repair any ICP sensor codes first
Perform a Key ON Engine OFF Standard Test	Test will verify IPR valve circuit continuity
Perform a Key ON Engine Running test	ICP step test will verify a gross ICP system failure
Perform Engine Running Wiggle Test Intermittent diagnostic trouble code detection test	When engine is running enable test, pull/wiggle wires on ICP sensor and IPR valve as well as all pass through connectors. If a diagnostic trouble code is set or engine dies, inspect wires at point of connection, check codes.
Perform ICP Pressure test - Performance Diagnostic form (Oil aeration)	Will verify if oil is aerated at high idle. See Test 12 in Performance Diagnostics on form EGED 1802.
Test high pressure (injection control pressure system) for leaks	See ICP Leakage Tests in Section 2

Diagnostic Trouble Code 331
ATA Code PID 164 FMI 0
ICP (Injection Control Pressure) above Working System Range

Diagnostic Trouble Code 331 indicates injection control pressure above normal working range 3675 psi (25 MPa). When Diagnostic Trouble Code 331 is set the Engine Warning Lamp is illuminated, the ECM ignores the ICP sensor signal and uses estimated ICP values to operate the engine.

Diagnostic Trouble Code 331 may indicate a mechanical injection control pressure system problem, a wiring or ICP sensor problem.

NOTE

If the engine still performs well when Diagnostic Trouble Code 331 is set, the problem is more likely in the ICP sensor circuit.

Possible Causes:

- Contaminated or incorrect grade of engine oil
- Defective or stuck injection pressure regulator (IPR) valve
- Improperly matched parts (IPR valve, high pressure pump, ICP sensor)
- Grounded IPR control wire
- Problems with the ICP sensor or circuit causing signal to be biased high

Diagnostic Trouble Code 335
ATA Code PID 164 FMI 1
ICP (Injection Control Pressure) Unable to Build Pressure During Cranking

Diagnostic Trouble Code 335 determines if injection control pressure is being developed during engine cranking. It is an ICP system check and will be set after 8 to 10 seconds of engine cranking time with less than 725 psi (5 MPa) of detected injection control pressure. Engine cranking time before Diagnostic Trouble Code 335 is set varies with engine temperature. Engine cranking speed must be more than 130 rpm before Diagnostic Trouble Code 335 detection can begin.

An active Diagnostic Trouble Code 335 is normally associated with long start or no start conditions.

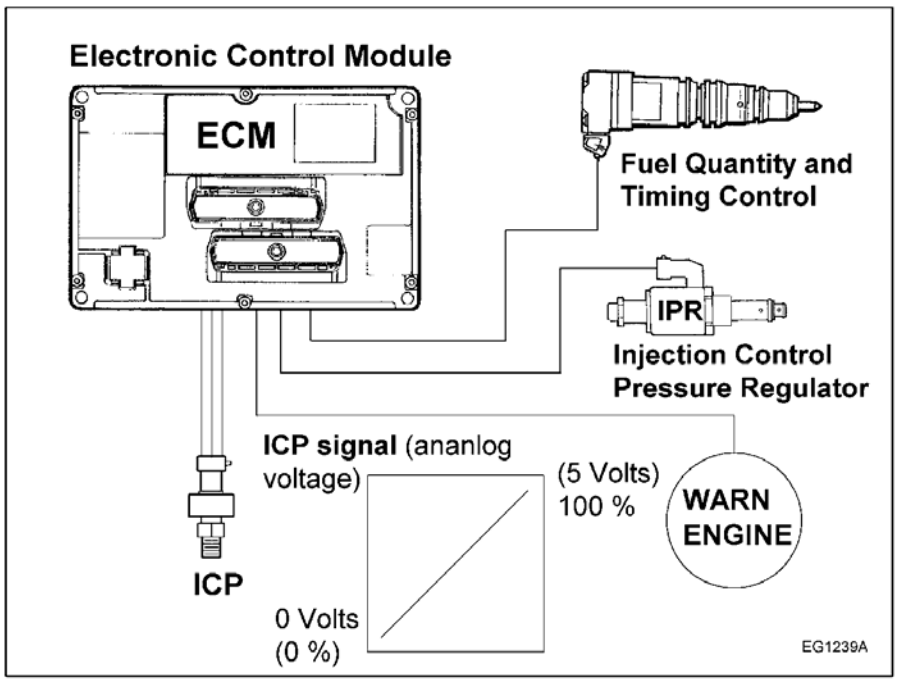
Possible Causes

- Lack of or insufficient quantity of engine oil in the crankcase.
- Air in the injection control pressure system, particularly after an injector or high pressure pump replacement
- Defective or stuck injection pressure regulator.
- Leaky injector O-rings
- Loose high pressure pump gear
- Defective high pressure pump

Diagnostic Trouble Code 335 Recommended Actions

Recommended Actions:	
Test	**Comments**
Visual Inspection	Check to see if IPR regulator and ICP sensor wiring is connected. Check for oil leaks, and see if injection control system has recently been disassembled (air entrapment). Ensure that the vehicle is operated a minimum of 15 to 20 miles if the symptom is hard starting with evidence of recent ICP system disassembly.
Check oil level and pressure.	Check oil level and for contamination. Remove EOT and check for oil in the oil reservoir. Verify lube oil pressure during engine cranking.
Check active and inactive diagnostic trouble codes.	Repair any ICP and CMP sensor codes first.
Perform a Key ON Engine OFF Standard Test.	Test will verify IPR valve circuit continuity.
Perform Engine Running / Wiggle Test, Intermittent diagnostic trouble code detection only.	When engine is running enable test, pull / wiggle wires on ICP sensor and IPR valve as well as all pass through connectors. If a diagnostic trouble code is set or engine dies inspect wires at point of connection, check for codes.
Perform ICP Pressure test - Hard Start/No Start Diagnostic form.	Will verify if oil is aerated at high idle Test 12 on the Performance form.
Test high pressure (injection control pressure system) for leaks.	See ICP Leakage tests in Section 2

2-15 Injection Control Pressure (ICP) Sensor Test



Signal Function Diagram for Injection Control Pressure Sensor

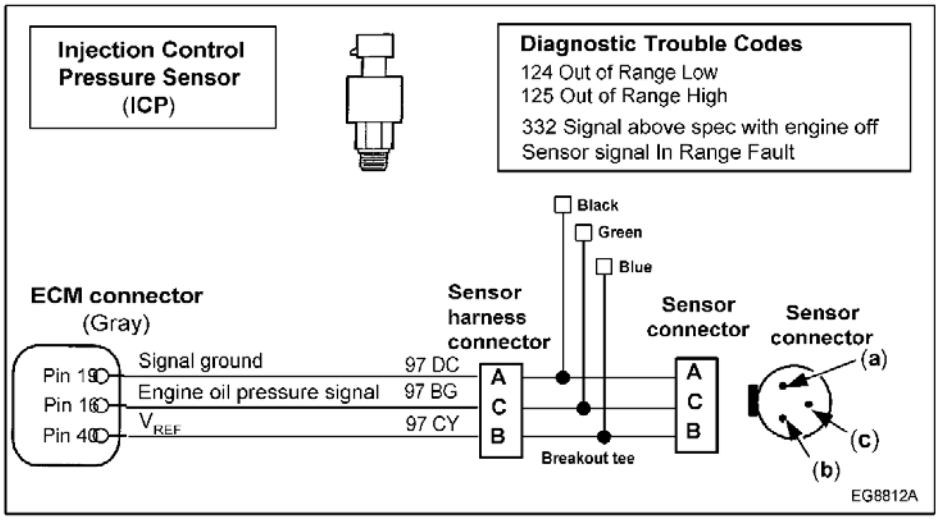
The Injection Control Pressure (ICP) sensor is a variable capacitance sensor that when supplied with a 5V reference signal from the ECM produces a linear analog voltage signal that indicates pressure.

The ICP sensor's primary function is to provide a feedback signal to indicate injection control pressure. This enables the ECM to command the correct injector timing and pulse width and the correct injection control pressure for proper fuel delivery at all speed and load conditions.

Fault Detection / Management

If the ECM detects a malfunctioning ICP sensor or a problem in the ICP sensor circuit, the WARN ENGINE lamp will illuminate. The ECM will go to open loop control of injection control pressure (operate from an estimated ICP pressure).

Sensor Circuit Diagnostics Using an EST



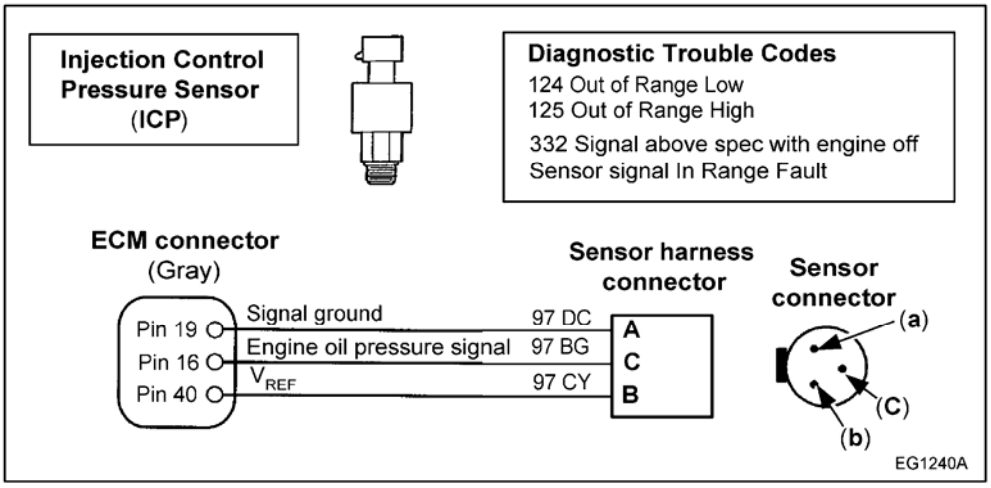
ICP Sensor Tests Using Master Diagnostics

Injection Control Pressure (ICP) Sensor Voltage Checks (Check with key-ON engine-OFF.)		
Install the 3 wire breakout tee between the ICP sensor and harness connector. View ICP VOLTAGE using the Continuous Monitor session and the Continuous Monitor test found under the diagnostics menu in MASTER DIAGNOSTICS. If the circuit has an active fault according to the voltage level (Code124 <0.039V, Code 125 >4.9V, Code 332 >1.625V), complete the following steps. Tests must be performed in order.		
Test Condition	**Expected Voltage**	**Comments**
Sensor Disconnected	0V	If voltage >0.039V, check signal circuit for short to VREF or B+.
Measure voltage from PIN B to gnd using a DMM.	5V ± 0.5	If voltage is >5.5V, check VREF for short to B+. If voltage is <4.5V, check VREF for open or short to Ground.
0.5 k jumper installed between the GREEN and BLUE pins of the breakout tee.	5V	If voltage is <4.9V, check signal circuit for open circuit or short to ground. Remove positive battery cable. Measure resistance from PIN C to Ground (spec >500) and from PIN C to PIN 16 (spec <5) using a breakout box to determine if short to ground or open is in the harness.
Standard jumper installed between the BLUE, GREEN, and BLACK pins of the breakout tee.	0V	If voltage is >0.039V, check ground circuit for resistance. Measure resistance between PIN A and PIN 19 (spec <5) using a breakout box to determine if resistance is in the harness.
Replace the sensor if the code is active and the expected results are obtained with all the sensor tests. The sensor is not at fault if one or more of the sensor tests does not produce the expected results. See ICP Sensor Troubleshooting Flowchart on next page.		

Alternate Testing Procedure

NOTE

Use this procedure if no EST is available.



Circuit Diagram for Injection Control Pressure Sensor

NOTE

After removing connector check for damaged pins, corrosion, and loose terminals.

ICP Sensor Circuit Specifications

CONNECTOR VOLTAGE CHECKS (Check with sensor disconnected from harness and key ON.)		
Test Points	**Spec.**	**Comments**
A to gnd	0V	Signal ground, no voltage expected
B to gnd	5±0.5V	If voltage not in spec., Vref circuit shorted to gnd or B+
C to gnd	<0.25V	If voltage > spec., wire shorted to Vref or B+
CONNECTOR CHECKS TO CHASSIS GROUND (Check with sensor connector disconnected, positive battery cable disconnected, and key OFF.)		
Test Points	**Spec.**	**Comments**
A to gnd	< 5 Ω	> 5Ω, indicates circuit is open
B to gnd	> 500 Ω	< 500Ω, indicates short to ground
C to gnd	> 1kΩ	< 1kΩ, indicates short to ground
HARNESS RESISTANCE CHECKS (Check with breakout box installed on chassis side only.)		
Test Points	**Spec.**	**Comments**
19 to A	<5 Ω	If >5Ω indicates ground wire open
40 to B	<5 Ω	If >5Ω indicates VREF wire open
16 to C	<5 Ω	If >5Ω indicates signal wire open

Extended Description

Function

The International engine control system includes an Injection Control Pressure (ICP) sensor. The ECM measures the signal from the ICP sensor to determine the injection control pressure as the engine is running to modulate the Injection Control Pressure Regulator. This is a closed loop function which means the ECM continuously monitors and adjusts for ideal Injection Control Pressure determined by operating conditions such as load, speed, and temperature.

The ECM monitors the ICP signal to determine if the performance of the hydraulic system is satisfactory. During engine operation, if the ECM recognizes that the pressure reading is lower or higher than the value that was commanded; the ECM will set a Diagnostic Trouble Code. This strategy is also used during the On Demand tests, commanded by the Electronic Service Tool (EST), and referred to as the Engine Running tests.

Operation

The Injection Control Pressure (ICP) sensor is a variable capacitance sensor supplied with a 5V reference voltage at terminal B by the ECM from terminal 40. The ICP sensor is also supplied with a return circuit (ground) at terminal A from ECM terminal 19. The ICP sensor sends a signal from terminal C of the sensor to ECM terminal 16.

The ICP signal voltage increases or decreases equally in proportion to an increase or decrease in injection control pressure.

ECM Diagnostics

The ECM continuously monitors the signal of the ICP sensor to determine if the signal is within an expected range. If the signal voltage is higher or lower than expected, the ECM will set a Diagnostic Trouble Code. The ECM will then ignore the ICP sensor signal and use a preset value determined by engine operating conditions. If the ignition key is turned OFF, the Diagnostic Trouble Code will become inactive.

ICP Diagnostic Trouble Codes can be retrieved using the Electronic Service Tool (EST) or by reading the Diagnostic Trouble Codes from the warning light, using the Engine Diagnostic Switch.

If the ignition key is turned OFF, the Diagnostic Trouble Code becomes inactive. An ICP Diagnostic Trouble Code will cause the Engine Warning light to be illuminated.

Diagnostic Trouble Code 124
ATA Code PID 164 FMI 4
ICP signal Out of Range Low

Diagnostic Trouble Code 124 will be set by the ECM if the signal voltage is less than 0.039V for more than 1.0 seconds.

Diagnostic Trouble Code 124 may be set due to an open or short to ground on the signal circuit, a defective sensor or an open VREF circuit.

Diagnostic Trouble Code 125
ATA Code PID 164 FMI 3
ICP Signal Out Of Range High

Diagnostic trouble code 125 will be set by the ECM if the signal voltage is greater than 4.9V for more than 1.0 seconds.

Diagnostic trouble code 125 may be set by an open signal ground circuit, short to a voltage source on the ICP signal circuit or a defective sensor.

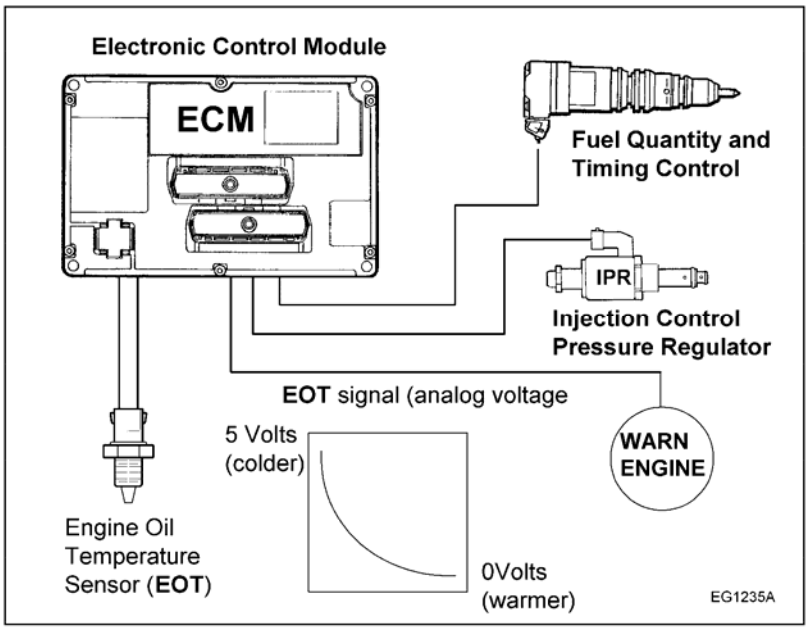
Diagnostic Trouble Code 332
ATA Code PID 164 FMI 13
Injection Control Pressure above Specification with Engine Off

Diagnostic Trouble Code 332 will be set by the ECM, if the signal from the ICP sensor is higher than expected with the engine not running. If the ECM detects this diagnostic trouble code, the ECM will ignore the ICP signal and will operate the IPR with fixed values determined from engine operating conditions.

Diagnostic Trouble Code 332 may be caused by a defective sensor or a biased circuit.

Momentary loss of the CMP signal can also cause this code.

2-16 Engine Oil Temperature Sensor (EOT)



Signal Function Diagram for Engine Oil Temperature Sensor

The Engine Oil Temperature (EOT) sensor is a thermistor type sensor that has a variable resistance that changes when exposed to different temperatures. When interfaced with the ECM, it produces a 0 to 5V analog signal that indicates temperature.

Cranking Fuel Timing and Quantity Control - The EOT signal determines the timing and quantity of fuel required for efficient engine starting during all temperature conditions.
Temperature Compensation - Fuel timing and quantity is controlled throughout the total operating range to compensate for oil viscosity changes during temperature variations, and to ensure that adequate torque and power is available.

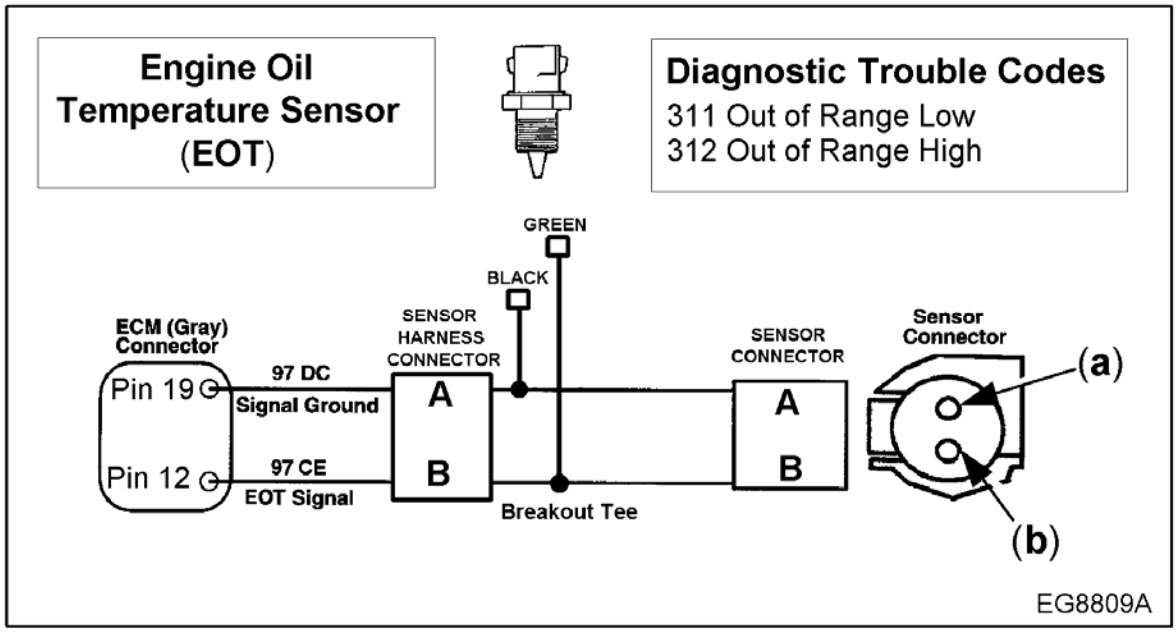
Fault Detection / Management

An EOT signal that is detected Out of Range High or Out of Range Low by the ECM will cause the ECM to ignore the EOT signal and default to the engine coolant temperature (ECT) sensor. The WARN ENGINE lamp will also be illuminated as long as the Diagnostic Trouble Code condition exists. If both the EOT and ECT sensors are not functioning, the ECM will assume a 212F (100C) value for engine oil temperature.

To troubleshoot the EOT sensor and circuit see:

(a) Engine Oil Temperature Sensor Circuit Diagram
(b) Engine Oil Temperature Sensor and Circuit Diagnostics

Sensor Circuit Diagnostics Using an EST



Circuit Diagram for Engine Oil Temperature Sensor using Breakout Tee

NOTE

The following EOT Sensor tests are for 2001 MY vehicles with serial No. 1287935-up.

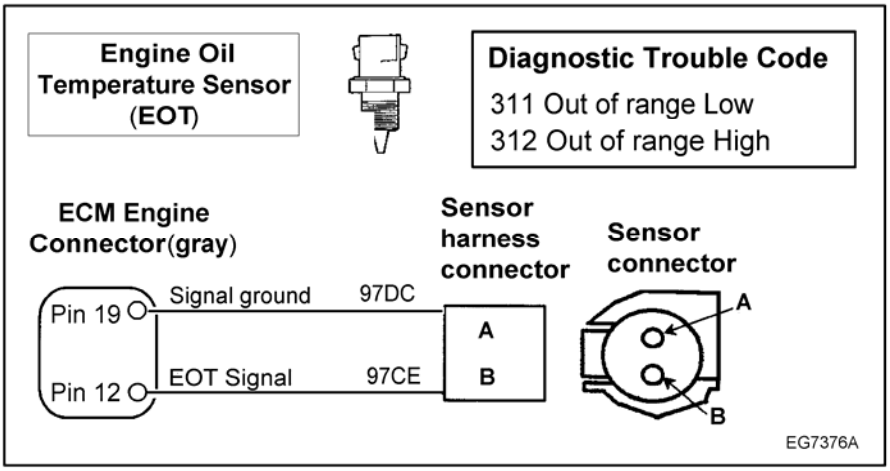
Engine Oil Temperature Sensor Tests Using Master Diagnostics

Engine Oil Temperature (EOT) Sensor Voltage Checks (Check with key-on engine-OFF.)		
Install the 2 wire breakout tee between the EOT sensor and harness connector. View EOT VOLTAGE using the sensor voltage test found under the diagnostics menu in MASTER DIAGNOSTICS. If the circuit has an active fault according to the voltage level (Code 311= < 0.2V, Code 312 =>4.78V), complete the following steps.		
Test Condition	**Voltage (expected)**	**Comments**
Sensor Disconnected	> 4.78 V	Voltage < 4.78V, inspect the signal circuit for short to ground.
Standard jumper installed between the GREEN and BLACK pins of the breakout tee	0 volts	If voltage is > 0.2Vcheck ground circuit for open or high resistance. Measure resistance from PIN A to PIN 19 (spec. =<5Ω) using a breakout box to determine if the resistance is in the harness.
Replace the sensor if the code is active and the expected results are obtained with all the sensor tests. The sensor is not at fault if one or more of the sensor tests does not produce the expected results. If the expected results are not obtained, check the signal and ground circuits using the procedure on next page.		
Diagnostic Trouble Code Descriptions		
311 = Signal voltage was less than 0.2 volts for more than 0.1 sec		
312 = Signal voltage was more than 4.78 volts for more than 0.1 sec		

Alternate Testing Procedure

NOTE

Use this procedure if no EST is available.



Circuit Diagram for Engine Oil Temperature Sensor

NOTE

After removing connectors always check for damaged pins, corrosion, and loose terminals.

Engine Oil Temperature Sensor Diagnostics

Connector Voltage Checks (Check with sensor connector disconnected and ignition key ON.)					
Test Points	**Spec.**	**Comments**			
B to gnd	> 4.8V to 5.0V	Pull up voltage, if low or no voltage, circuit has open or high resistance or short to ground			
A to gnd	0V to 0.25V	If greater than 0.25V, signal ground wire is shorted to VREF or battery			
Connector Checks to Chassis Ground (Check with sensor connector disconnected, ignition key OFF, and positive battery cable disconnected.)					
Test Points	**Spec.**	**Comments**			
A to gnd	<5 Ω	Resistance to chassis ground, check with key OFF, if > than 5 Ω the harness is open			
B to gnd	>1000 Ω	Resistance less than 1000 Ω indicates a short to ground			
Harness Resistance Checks (Check with breakout box installed on engine harness only.)					
Test Points	**Spec.**	**Comments**			
19 to A	<5 Ω	Resistance from sensor connector to 60 pin connector - Signal ground			
12 to B	<5 Ω	Resistance from sensor connector to 60 pin connector - EOT Signal			
Test Points: (+) No.12 to (-) No.19		**Operational Signal Checks (Check with breakout box installed in-line with the ECM.)**			
Temp F	Temp C	Min. Resistance	Max. Resistance	Volts @ Min. Resistance	Volts @ Max. Resistance
32	0	91.1k	100.6 k	4.348V	4.388V
68	20	35.5 k	39.2 k	3.782V	3.861V
212	100	2.0 k	2.1k	0.819V	0.890V
Diagnostic Trouble Code Reference					
311 = Signal was less than 0.2V more than 0.1 sec					
312 = Signal voltage was greater than 4.78V for more than 0.1 sec					

Extended Description

Function

The International engine control system includes an Engine Oil Temperature (EOT) sensor. The ECM monitors signals for engine oil temperature sensor to control fuel quantity and timing for the operating range of the engine. The EOT signal allows the ECM to compensate for oil viscosity variations due to temperature changes in the operating environment. This ensures that adequate power and torque are available.

Operation

The Engine Oil Temperature Sensor is a thermistor type sensor that changes resistance when exposed to a variety of oil operating temperatures.

When oil temperature decreases, the resistance of the thermistor increases which causes the signal voltage to increase. As oil temperature increases, the resistance of the thermistor decreases, causing the signal voltage to decrease.

The EOT sensor is supplied a regulated 5V reference signal at terminal B from the ECM. A return circuit (ground) is supplied at terminal A from the ECM. As the oil temperature increases or decreases, the sensor changes resistance and provides the ECM with the oil temperature signal voltage. This signal voltage is read by the ECM to determine the temperature of the oil.

ECM Diagnostics

With the ignition key ON, the ECM continuously monitors the EOT signal to determine if it is within expected values. If the signal voltage is above or below the expected levels, the ECM will set a Diagnostic Trouble Code.

If the ECM detects a Diagnostic Trouble Code, it will use the value of the Engine Coolant Temperature signal, in place of the EOT signal. If the ECT sensor is not sending a correct signal, the ECM will default to 29°F (-1.7°C) for starting or 212°F (100°C) for engine running operation.

EOT sensor Diagnostic Trouble Codes can be retrieved using the Electronic Service Tool (EST) or by reading the Diagnostic Trouble Codes from the warning light using the Engine Diagnostic Switch located on the vehicle dash. If the ignition key is shut off, the Diagnostic Trouble Code will become inactive. EOT codes will cause the Engine Warning light to be illuminated.

Diagnostic Trouble Code 311
ATA Code PID 175 FMI 4
Engine Oil Temperature signal Out of Range Low

Diagnostic Trouble Code 311 Out of Range Low, will be set if the signal voltage was less than 0.2V for more than 0.1 seconds. If Diagnostic Trouble Code 311 is set, the ECM will default to ECT temperature or a default value of -4°F (-20°C) for starting or 212°F (100°C) for engine running operation. Diagnostic Trouble Code 311 will cause the ECM to illuminate the Engine Warning light.

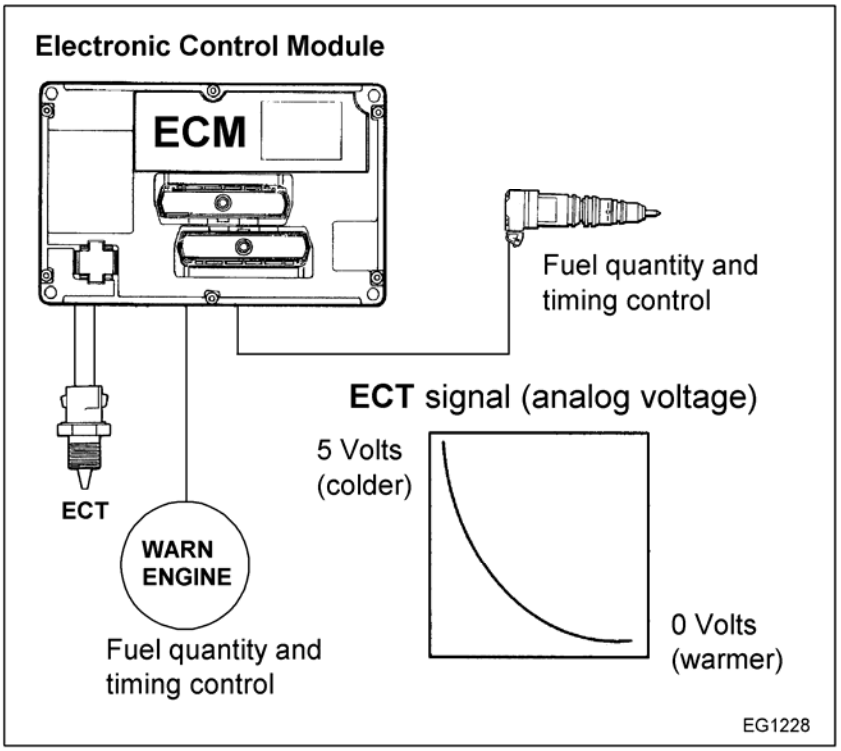
Diagnostic Trouble Code 311 may be set due to a short to ground in the signal circuit or a defective sensor.

Diagnostic Trouble Code 312
ATA PID 175 FMI 3
Engine Oil Temperature signal Out of Range High

Diagnostic Trouble Code 312 out of range high, will be set if the signal voltage is more than 4.8V for more than 0.1 seconds. If this code is set, the ECM will default to ECT temperature or a default value of -4°F (-20°C) for starting or 212°F (100°C) for engine running operation. This code will cause the ECM to illuminate the Engine Warning light.

Diagnostic Trouble Code 312 can be set due to an open signal circuit between the ECM and the sensor or a short to a voltage source. A defective sensor may also cause code 312 to be set.

2-17 Engine Coolant Temperature Sensor (ECT)



Signal Function Diagram for Engine Coolant Sensor

The Engine Coolant Temperature (ECT) sensor is a thermistor type sensor that changes resistance when exposed to changes in coolant temperature. When interfaced with the ECM it produces a 0 to 5V analog signal that indicates temperature.

Coolant Temperature Compensation- At coolant temperatures greater than 214°F (101°C) full load fuel quantity is reduced by approximately 6% for each degree of temperature (C), until engine temperature reaches 218°F (103°C). Above 218°F (103°C) fuel is reduced by 3% for each C increase in temperature.

Idle Speed- At temperatures below 158°F, (70°C) low idle is incrementally increased to a maximum of 875 rpm.

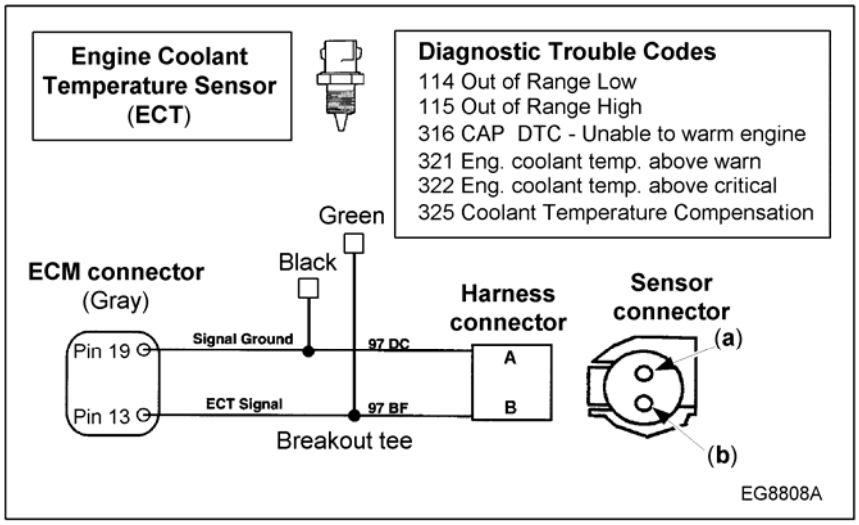
Fault Detection / Management

An ECT signal detected Out of Range High or Out of Range Low by the ECM will cause the ECM to ignore the ECT signal and assume an engine coolant temperature of -29°F (-20°C) for starting and a temperature of 180°F (82°C) for engine running conditions.

Sensor Circuit Diagnostics Using an EST

WARNING

ENGINE lamp will also be illuminated as long as the Diagnostic Trouble Code condition exists.



Circuit Diagram for Engine Coolant Temperature Sensor (with two wire breakout tee)

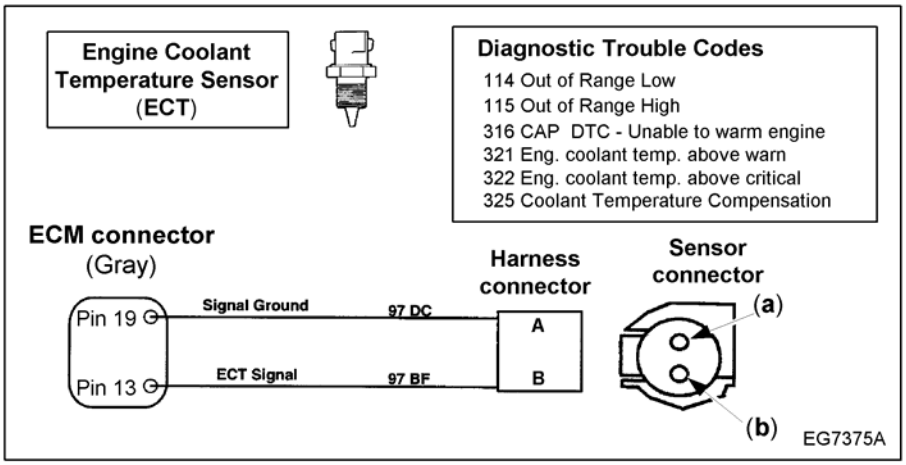
ECT Sensor Tests Using Master Diagnostics

Engine Coolant Temperature (ECT) Sensor Voltage Checks (Check with key-ON engine-OFF.)		
Install the 2 wire breakout tee between the ECT sensor and harness connector. View ECT VOLTAGE using the Continuous Monitor test found under the diagnostics menu in MASTER DIAGNOSTICS. If the circuit has an active fault according to the voltage level (Code 114 <0.127V, Code 115 >4.6V), complete the following steps.		
Test Condition	**Expected Voltage**	**Comments**
Sensor Disconnected	>4.6 V	Voltage <4.6, inspect the signal circuit for short to ground.
Standard jumper installed between the GREEN and BLACK pins of the breakout tee	0V	If voltage is >0.127, check ground and signal circuits for an open or high resistance. Measure resistance from PIN A to PIN 19, and from PIN B to PIN 13 (spec. <5Ω) using a breakout box to determine if the resistance is in the harness.
0.5 kΩ jumper installed between the GREEN and BLACK pins of the breakout tee	<1.0V	If voltage is >1.0V, check signal circuit for a short to VREF, B+, or another sensor's signal voltage.
Replace the sensor if the code is active and the expected results are obtained with all the sensor tests. The sensor is not at fault if one or more of the sensor tests does not produce the expected results.		

Alternate Testing Procedure

NOTE

Use this procedure if no EST is available.



Circuit Diagram for Engine Coolant Temperature Sensor

NOTE

After removing connectors always check for damaged pins, corrosion, and loose terminals.

Engine Coolant Temperature Sensor Diagnostics

Connector Voltage Checks (Check with sensor disconnected from harness and ignition key ON.)			
Test Points	**Spec.**	**Comments**	
B to Gnd	4.6 - 5.0V	Pull up voltage, if no voltage or low voltage, circuit is open or has high resistance or short to ground.	
A to Gnd	0 - 0.25V	Voltage > 0.25V, wire shorted to Vref or B+	
Connector Checks To Chassis Ground (Check with sensor connector disconnected, positive battery cable disconnected, and key OFF.)			
Test Points	**Spec.**	**Comments**	
A to Gnd	< 5 Ω	More than 5 Ω indicates harness is open	
B to Gnd	> 1000 Ω	If < 1000 Ω indicates a short to ground	
Operational Voltage Checks			
Test Points: (+) No. 13 to () No.19	Spec.		(Check with breakout tee installed and key-ON.)
Voltage	**Temp F**	**Temp C**	**Sensor Resistance**
0.356V	230	110	1.19 kΩ
3.87V	32	0	69.2 kΩ
4.33V	5	20	131 kΩ
Harness Resistance Checks (Check with breakout box installed on Engine side only.)			
Test Points:	**Spec.**	**Comments**	
19 to A	< 5 Ω	Ground wire open	
13 to B	< 5 Ω	Signal wire open	
114 = Engine coolant temperature signal voltage < 0.127V for more than 0.1 second			
Harness Resistance Checks (Check with breakout box installed on Engine side only.)			
Diagnostic Trouble Code Reference			
115 = Engine coolant temperature signal voltage > 4.6V for more than 0.1 second			
316 = CAP temperature specifications not met after 120 minutes of operation			
321 = Engine coolant temperature above WARN level, 228F (109C)			
322 = Engine coolant temperature above critical level, 234F (112C)			
325 = Engine coolant temperature compensation enabled			

Extended Description

Function

The International engine control system includes an Engine Coolant Temperature sensor (ECT). The ECM measures the Engine Coolant Temperature signal and uses this information for Coolant Temperature Compensation and optional high temperature warning and shut down systems.

Coolant Temperature Compensation is used to protect the engine if the coolant temperature is too high. The ECM monitors the ECT signal to determine coolant temperature. If the coolant reaches 214°F (101°C), the ECM will reduce the fuel delivery by 6% for each degree (in Celsius) of temperature increase. If the coolant temperature increases to 218°F (104°C), fuel quantity will be reduced 3% for each degree (in Celsius) of temperature increase. Coolant Temperature Compensation can be programmed to be inoperative in certain applications where full engine performance is required over the protection of the engine.

For engines equipped with an engine warning system, the ECM will activate the audible warning alarm and illuminate the red Oil/Water warning light when the engine coolant temperature reaches 225°F (107°C).

Operation

The Engine Coolant temperature sensor is a thermistor type sensor that changes resistance when exposed to different temperatures.

When the temperature of the coolant is decreased, the resistance of the thermistor increases which causes the signal voltage to increase. As the temperature of the coolant is increased the resistance of the thermistor decreases, which causes the signal voltage to decrease.

The ECT sensor is supplied a regulated 5V reference voltage from the ECM. The sensor is grounded at terminal A through the signal return terminal at the ECM. As the coolant temperature increases or decreases, the sensor changes resistance and provides the ECM with the coolant temperature signal voltage. This signal voltage is then read by the ECM to determine the temperature of the coolant.

ECM Diagnostics

With the ignition key ON, the ECM continuously monitors the ECT circuit for expected voltages. If the signal voltage is more or less than the expected value the ECM will set a Diagnostic Trouble Code.

If the ECM detects a Diagnostic Trouble Code in the ECT signal, the ECM will disregard the signal and default to a temperature of 180°F (82°C) for engine running operation and -29°F (-33.9°C) for starting the engine. If the Diagnostic Trouble Code is no longer present, the ECM will return to normal operation using the ECT signal for processing.

Diagnostic Trouble Codes in the ECT signal can be retrieved using the Engine Diagnostic Switch or the Electronic Service Tool (EST). If the Diagnostic Trouble Code is no longer present, it will be stored as an Inactive Code.

Diagnostic Trouble Code 114
ATA PID 110 FMI 4
ECT Out of Range Low
An Out of Range Low Diagnostic Trouble Code 114 will be set if the ECM detects voltage less than 0.127V for more than 0.1 seconds. If code 114 is active, the ECM will use the default value of 180°F (82°C) for engine operation.

Diagnostic trouble code 114 may be caused by a short to ground or a shorted or biased sensor.

Diagnostic Trouble Code 115
ATA Code PID 110 FMI 3
ECT Out of Range High
An Out of Range High Diagnostic Trouble Code 115 will be set if the ECM detects voltage greater than 4.6V for more than 0.1 seconds. If Code 115 is active, the ECM will use the default value of 180°F (82°C) for engine operation.

Diagnostic Trouble Code 115 may be caused by an open circuit, an open sensor, or a short to another voltage source.

Diagnostic Trouble Code 321
ATA Code PID 110 FMI 0
Engine Coolant Temperature Above Warning Level

Diagnostic Trouble Code 321 will be set if the ECM detects engine coolant temperature above 225°F (107°C). When this occurs, the ECM illuminates the OIL/WATER warning light and sounds the audible alarm (if equipped), alerting the operator.

If the temperature drops below 225°F (107°C), code 321 will become inactive and the ECM will return to normal operation.

Diagnostic Trouble Code 322
ATA Code PID 110 FMI 7
Engine Coolant Temperature Above Critical Level

Diagnostic trouble code 322 will be set if the ECM detects engine coolant temperature above 235°F (112.5°C). When this occurs, the OIL/WATER warning light illuminates and the audible alarm sounds (if equipped) alerting the operator that the temperature is increasing (having set code 321) indicating a potential for engine damage.

Diagnostic Trouble Code 325
ATA Code PID 110 FMI 14
Power reduced or matched to cooling system performance

Diagnostic Trouble Code 325 will be set if the cooling system temperature exceeds 214°F (101°C). At this temperature the ECM will reduce the fuel delivered to the engine. For each Celsius degree of temperature above 1% the fuel will be reduced 6%. This reduces the heat produced by the engine and reduces the burden on the engine cooling system. Reduced fuel to the engine will also slow the vehicle, encouraging the operator to downshift, increasing the efficiency of the cooling system.

As the temperature is reduced the compensation level is reduced until the temperature drops below 214°F (101°C) at which normal operation is resumed.

Diagnostic Trouble Code 316
ATA Code PID 110 FMI 1
CAP diagnostic trouble code - Unable to warm engine

Diagnostic Trouble Code 316 will only be set with engines that have CAP (Cold Ambient Protection) strategy enabled. Code 316 is set after the engine has run for more than 120 minutes and has not exceeded the following specifications for engine coolant temperature. This code can be cleared with the Electronic Service Tool (EST).

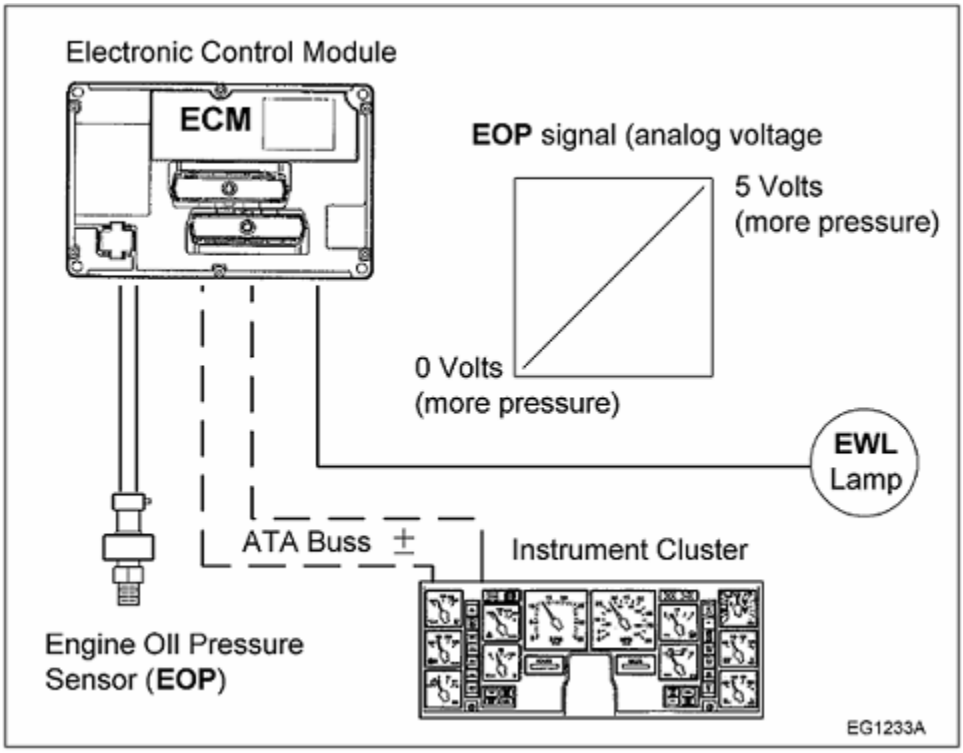
NOTE

This code only indicates that the engine has not reached operating temperature. It does not indicate an electrical problem.

Possible System Faults:

(a) Extended idle time
(b) Cold ambient temperatures (may require winter front)
(c) Thermostat stuck in open position
(d) Incorrect coolant hose routing (thermostat bypassed)
(e) Fan clutch locked on

2-18 Engine Oil Pressure Sensor (EOP)



Signal Engine Oil Pressure Sensor Function Diagram

The Engine Oil Pressure (EOP) sensor is a variable capacitance sensor. As the ECM applies a 5V reference signal to this sensor, the sensor produces a linear analog voltage signal that indicates engine oil pressure.

Engine Warning and Protection - An optional feature which, when enabled, will warn the driver of low engine oil pressure and can be programmed to shut the engine down.

Instrument Cluster Display - The ECM transmits sensed engine oil pressure information on the ATA data link which is displayed on the instrument cluster.

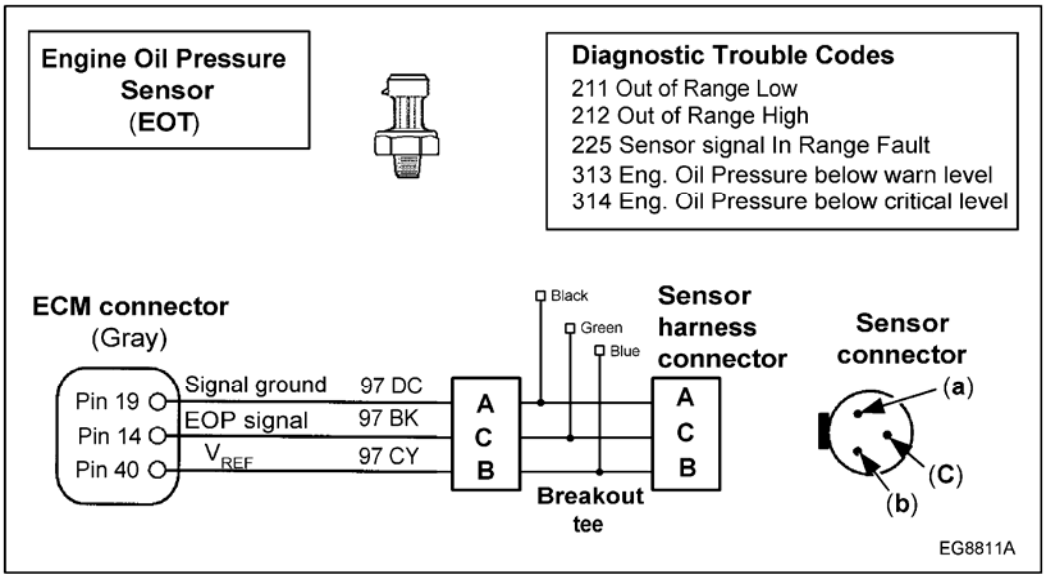
Fault Detection / Management

An EOP signal detected Out of Range High or Out of Range Low by the ECM will cause the engine to ignore the EOP signal and disable Engine Warning and Protection.

To troubleshoot the EOP sensor and circuit see:

(a) Engine Oil Pressure Sensor Circuit Diagram.
(b) Engine Oil Pressure Sensor and Circuit Diagnostics

Sensor Circuit Diagnostics Using an EST



Circuit Diagram for Engine Oil Pressure (EOP) sensor using a breakout tee

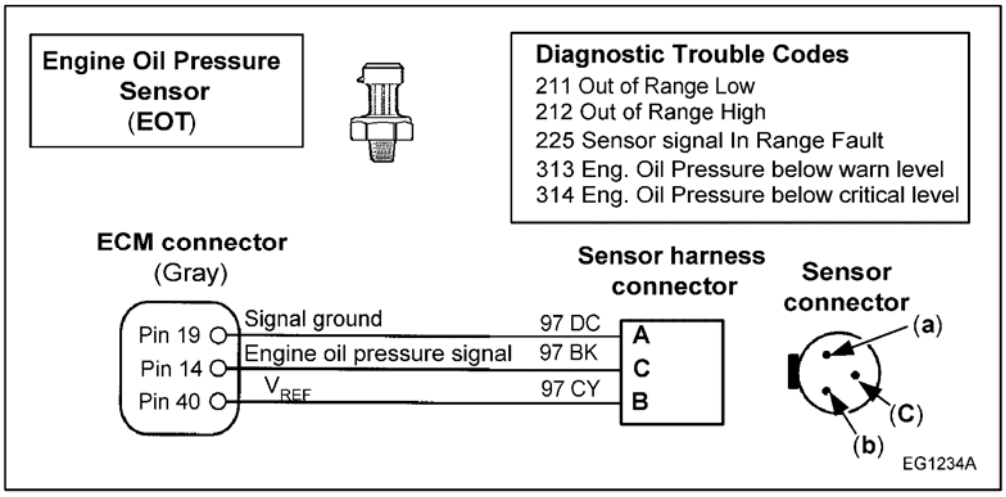
Engine Oil Pressure Sensor Tests Using Master Diagnostics

Engine Oil Pressure (EOP) Sensor Voltage Checks (check with key-ON engine-OFF)		
Install the 3 wire breakout tee between the EOP sensor and harness connector. View EOP VOLTAGE using the Continuous Monitor Session and the Continuous Monitor test found under the diagnostics menu in MASTER DIAGNOSTICS. If the circuit has an active fault according to the voltage level (Code 211 < 0.039V, Code 212 >4.9V, Code 225 >1.49V), complete the following steps.		
Test Condition	**Expected Voltage**	**Comments**
Sensor Disconnected	0V	If voltage is > 0.039V, inspect the signal circuit for short to VREF or B+.
Measure voltage from PIN B to gnd using a DMM.	5V ± 0.5	If voltage is > 5.5V, check VREF for short to B+. If voltage is < 4.5V, check VREF circuit for open or short to ground.
500Ω jumper installed between the GREEN and BLUE pins of the breakout tee.	5V	If voltage is < 4.9V, check signal circuit for open or short to ground. Remove positive battery cable. Measure resistance from PIN C to Ground (spec >1 k) and from PIN C to PIN 14 (spec < 5) using a breakout box to determine if short to ground or open is in the harness.
3 way jumper installed between the BLUE, GREEN, and BLACK pins of the breakout tee.	0V	If voltage is > 0.039V, check ground circuit for resistance. Measure resistance between PIN A and PIN 19 (spec < 5) using a breakout box to determine if resistance is in the harness.
Replace the sensor if the code is active and the expected results are obtained with all the sensor tests. The sensor is not at fault if one or more of the sensor tests does not produce the expected results.		

Alternate Testing Procedure

NOTE

Use this procedure if no EST is available.



Circuit Diagram for Engine Oil Pressure Sensor

NOTE

After removing connectors, always check for damaged pins, corrosion, and loose terminals.

Engine Oil Pressure Sensor and Circuit Diagnostics

Connector Voltage Checks (Check with sensor connector disconnected and ignition key ON.)		
Test Points	**Spec.**	**Comments**
A to gnd	0V	Signal ground no voltage expected
B to gnd	5V ± 0.5	Check VREF with key ON. If voltage not within spec., see VREF circuit
C to gnd	<0.75V	If greater then 0.75V, signal ground wire is shorted to VREF or battery
Connector Checks to Chassis Ground (Check with sensor connector disconnected, positive battery cable disconnected, and ignition key OFF.)		
Test Points	**Spec.**	**Comments**
A to gnd	<5 Ω	Resistance to chassis ground, check with key off, if > than 5 the harness is open
B to gnd	>500 Ω	Resistance less than 500 Ω indicates a short to ground
C to gnd	>1000 Ω	Resistance less than 1000 Ω indicates a short to ground
Harness Resistance Checks (Check with breakout box installed on engine harness only.)		
Test Points	**Spec.**	**Comments**
19 to A	<5 Ω	Resistance from sensor connector to 60 pin connector - Signal ground
40 to B	<5 Ω	Resistance from sensor connector to 60 pin connector - VREF
14 to C	<5 Ω	Resistance from sensor connector to 60 pin connector - EOP signal
Test Points: (+) 14 to (-) 19		**Operational Signal Checks (Check with breakout box installed in line with the ECM.)**
Diagnostic Trouble Code Reference		
211 = Signal was less than 0.039V for more than 0.1 second 212 = Signal voltage was greater than 4.9V for more than 0.1 second 225 = Engine oil pressure was sensed greater than 40 psi with the ignition key ON engine OFF 313 = Engine oil pressure < 5 psi (34 kPa) @ 700 rpm or 10 psi (69 kPa) @ 1400 rpm or 20 psi (138 kPa) @ 2000 rpm 314 = Engine oil pressure < 2 psi (14 kPa) @ 700 rpm or 5 psi (34 kPa) @ 1400 rpm or 12 psi (152 kPa) @ 2000 rpm		

Extended Description

Function

The Engine Oil Pressure sensor (EOP) is standard in the International engine control system.

The ECM measures the EOP signal to monitor the oil pressure. If the oil pressure drops below 5.0 psi (34 kPa) @ 700 rpm or 10.0 psi (69 kPa) @ 1400 rpm or 20.0 psi (138 kPa) @ 2000 rpm, the ECM will illuminate the OIL/WATER (OWL) light and sound the warning alarm.

Operation

The Engine Oil Pressure sensor is a variable capacitance sensor. When pressure is applied to the sensor the capacitance changes in relation to the pressure.

The ECM supplies a regulated 5V signal to terminal B of the EOP sensor from terminal 40 of the ECM. The EOP sensor is supplied a signal return (ground) at terminal A to terminal 19 of the ECM.

During engine operation, oil pressure changes sensor capacitance; the incoming 5V reference signal changes in relation to pressure. The oil pressure signal from the sensor at terminal C is sent to terminal 14 of the ECM. This signal increases equally in proportion to an increase in pressure up to a maximum of 85.3 psi (588 kPa).

ECM Diagnostics

The ECM continuously monitors the signal from the EOP sensor to ensure the signal is in the correct operating range. If the signal is lower or higher than required, the ECM will set a Diagnostic Trouble Code. The Diagnostic Trouble Code is retrieved using the Electronic Service Tool (EST) or by reading the Diagnostic Trouble Code, using the Engine Diagnostic Switch. If the ignition key is turned OFF, the Diagnostic Trouble Code will be stored as inactive.

During engine operation, the ECM monitors the engine speed signal. The ECM compares the expected oil pressure to engine speed. If the ECM detects low oil pressure for a given engine speed, the ECM will set a Diagnostic Trouble Code. If the oil pressure is lower than the critical level, the ECM will record a Diagnostic Trouble Code. The ECM automatically records this as a low oil pressure event that cannot be erased using the EST. This becomes a record of engine operation.

Diagnostic Trouble Code 211
ATA Code PID 100 FMI 4
Engine Oil Press signal Out of Range Low

An Out of Range Low Diagnostic Trouble Code 211 code will be set if the ECM detects voltage less than 0.039V for more than 0.1 second. If Diagnostic Trouble Code 211 is set the ECM will ignore the EOP signal and continue to operate normally. If Diagnostic Trouble Code 211 is active, the ECM will turn on the Engine Warning light.

Diagnostic Trouble Code 211 may be caused by an open VREF feed, open signal circuit, or a defective sensor.

Diagnostic Trouble Code 212
ATA Code PID 100 FMI 3
Engine Oil Pressure signal Out of Range High

An Out of Range High Diagnostic Trouble Code 212 will be set if the ECM detects a voltage more than 4.9V for more than 0.1 seconds. If Diagnostic Trouble Code 212 is set, the ECM will ignore the EOP signal and continue to operate normally. If Diagnostic Trouble Code 212 is active, the ECM will illuminate the Engine Warning light.

Diagnostic Trouble Code 212 can be caused by an open signal ground circuit, a short to a voltage source, or a defective sensor.

Diagnostic Trouble Code 225
ATA Code PID 100 FMI 0
Engine Oil Pressure sensor signal In Range Diagnostic Trouble Code

Diagnostic Trouble Code 225 will be set by the ECM, if the signal from the EOP sensor is higher than expected with the key on and the engine off (a signal that indicates 40 psi). If the ECM detects Diagnostic Trouble Code 225, the ECM will ignore the EOP signal and illuminate the Engine Warning Lamp. Diagnostic Trouble Code 225 is usually caused by a defective EOP sensor, a biased circuit, or the incorrect EOP sensor.

Diagnostic Trouble Code 313
ATA Code PID 100 FMI 1
Engine Oil Pressure Below Warning Level

Diagnostic Trouble Code 313 indicates that the oil pressure has dropped below the warning level. The warning level is 5.0 psi (34 kPa) @ 700 rpm or 10.0 psi (69 kPa) @ 1400 rpm or 20.0 psi (138 kPa) @ 2000 rpm.

Diagnostic Trouble Code 313 can be caused by a defective or incorrect sensor sending an incorrect signal. To confirm this, compare actual oil pressure (with a mechanical gauge) to the reading on the data list of the EST. Low oil pressure due to defective mechanical components will also set this code.

NOTE

It may be possible to set this code at start-up, especially if the oil was just changed, or after a rebuild until the oil system is primed.

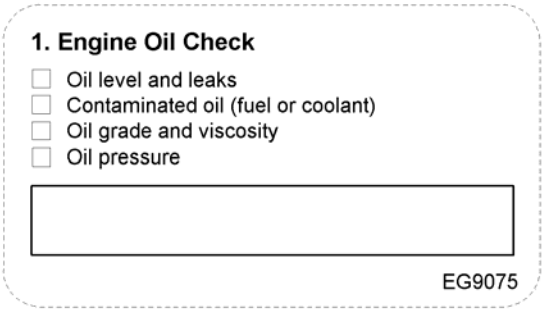
Diagnostic Trouble Code 314
ATA Code 100 FMI 7
Engine Oil Pressure Below Critical Level

If Diagnostic Trouble Code 314 is set, this indicates that the oil pressure has dropped below the critical level. The critical level is 2.0 psi (14 kPa) @ 700 rpm or 5.0 psi (34 kPa) @ 1400 rpm or 12.0 psi (83 kPa) @ 2000 rpm.

Diagnostic Trouble Code 314 may be caused by a defective or incorrect sensor sending an incorrect signal. To confirm this, compare actual oil pressure (with a mechanical gauge installed) to the reading on the data list of the EST. Low oil pressure due to defective mechanical components will also set this code.

2-19 Performance Diagnostics

a. Engine Oil Check



Purpose

To check engine oil level and quality and determine if oil pressure is correct for the injection control pressure system.

Test Procedure

Read all safety instructions in this manual before doing this procedure.

1. Park vehicle on level ground.
2. Check oil level with oil level gauge. If the oil level is not at full, the fuel injectors will not work correctly.

NOTE

If the oil level is above full, the engine has been incorrectly serviced, or fuel is diluting the oil. Check oil for fuel odor.

3. Inspect oil for color and odor. Milky white oil and an ethylene glycol odor indicate coolant contamination.
4. Check engine service records for correct oil grade and viscosity for ambient operating temperatures. See lube oil chart in the engine operator's manual for the correct grade of oil for vehicle operation in various temperature ranges.

NOTE

Do not use 15W-40 motor oil below 20°F (-6.7°C). Long oil drain intervals can cause increased oil viscosity; thicker oil will make engine cranking and starting more difficult below freezing temperatures.

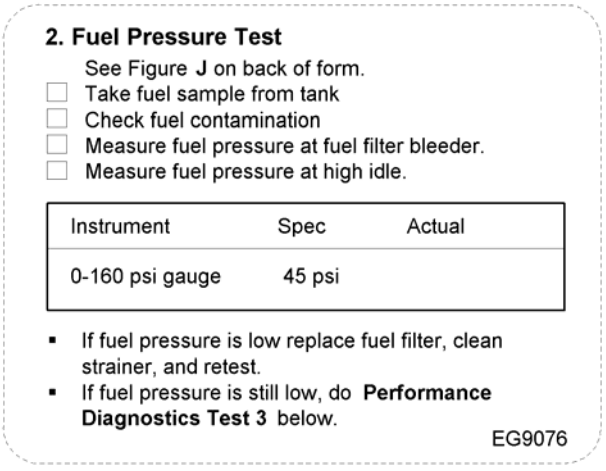
Possible Causes

- Oil level low: Oil leak, oil consumption, incorrect servicing.
- Oil level high: Incorrect servicing, fuel dilution from lift pump.
- Oil contamination with coolant: Oil cooler, head gasket, porosity, (accessories i.e., water cooled air compressors.)
- Oil viscosity

Tools Required

- None

b.Fuel Pressure Test



Purpose

To determine if fuel system has clean fuel and correct pressure to start and run the engine.

Test Procedure

Read all safety instructions in this manual before doing this procedure.

1. Take fuel sample from tank.
2. Inspect fuel. Fuel must be clean, free of air, contaminants, water, icing, or clouding. Fuel should be straw colored. Dyed fuel (red or blue) indicates designation for off-highway use.
3. Check for gasoline or kerosene odors.

NOTE

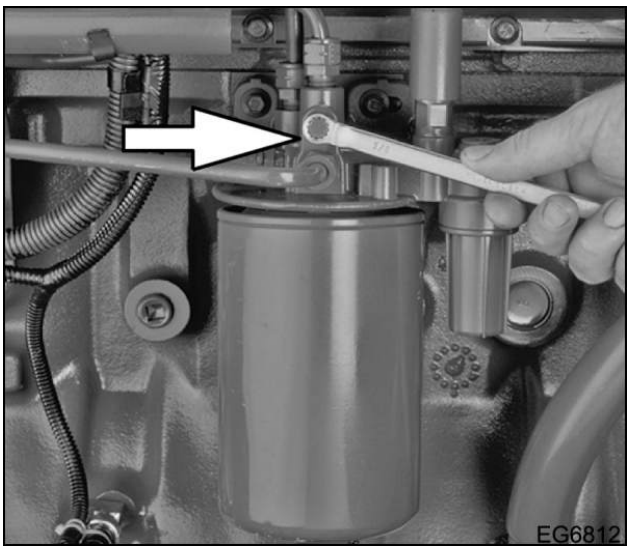
Engine oil in the fuel may indicate an injector O-ring leak and loss of injection control pressure. To determine the cause of oil in the fuel, see Low ICP Pressure Test (Test13), including ICP Leakage Test in Hard Start/No Start Diagnostics in this section.

4. If gasoline or kerosene is found in tank, drain and refill tank.
5. Properly dispose of contaminated fuel.

Fuel Pressure Test

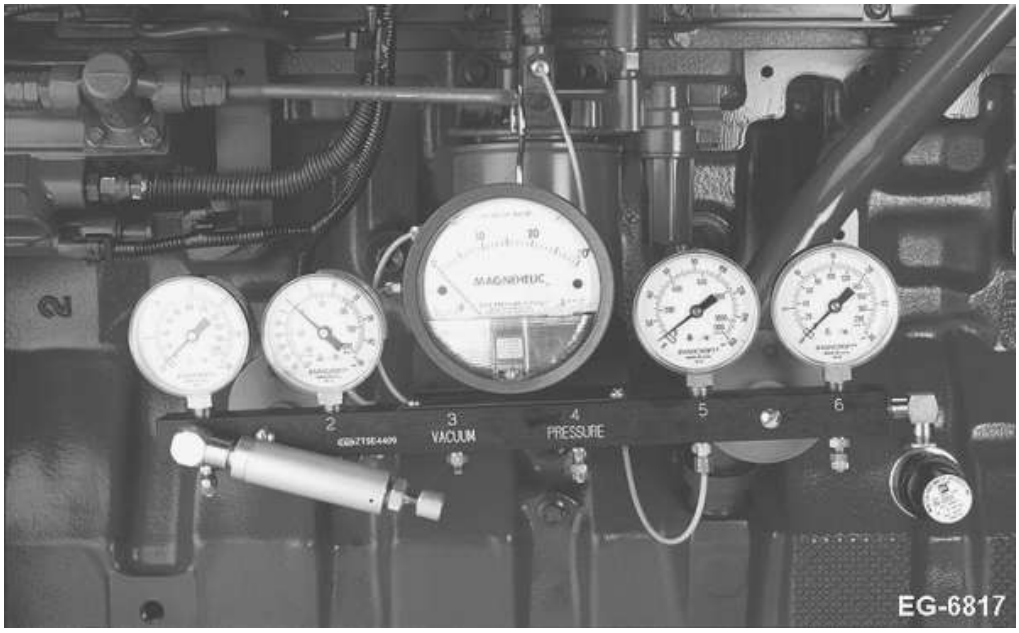
WARNING

Read all safety instructions in this manual before doing this procedure.



Air Bleeder Valve

1. Remove air bleed valve on fuel filter header.
2. Install a 1/8 in. (3 mm) pipe fitting in place of the bleed valve.



Gauge Bar (PS948313)

3. Connect a line from the fitting to Gauge Bar.
4. Measure fuel pressure at high idle. Record pressures on Mechanical Diagnostics form EGED1802 and compare to specifications.
5. If fuel pressure is low after replacing the fuel filter, do the following:
    a. Remove fuel return line and install plug (to prevent fuel from exiting) into fuel return opening.
    b. Crank engine and check fuel pressure gauge. If fuel pressure rises, replace fuel return valve and recheck fuel pressure. If fuel pressure does not increase, do Transfer Pump Restriction Test (Test 3).

NOTE

Do Fuel Pressure Test (Test 11), before removing pressure test equipment.

Possible Causes

- No fuel in tank
- In-line fuel valve shut off (if equipped)
- Fuel supply line from tank broken, crimped or kinked.
- Incorrect fuel grade for cold temperatures. Fuel waxed or jelled (most likely grade 2 fuel). Pickup tube in tank could be clogged or cracked.
- Water, ice, or contaminants in the tank and fuel system stopping fuel flow.
- Plugged supplemental filters or water separators causing the fuel system to draw air.

Tools Required

- Clear container (approximately 1 Quart or 1 Liter)
- Gauge Bar (PS94-831-3) and appropriate line with 1/8 in (3 mm) NPT fitting

c. Transfer Pump Restriction Test

3. Transfer Pump Restriction Test

Do **this test** only if fuel pressure is low. See Figure **K** on back of form.

☐ Measure restriction at fuel filter inlet at high idle.

Instrument	Spec	Actual
0-30 in Hg Vacuum gauge	< 8 in Hg	

- If restriction is more than 8 in Hg , check for blockage between fuel pump and tank.
- If restriction is less than 8 in Hg, see EGES-175-1 Section 2.

EG9077

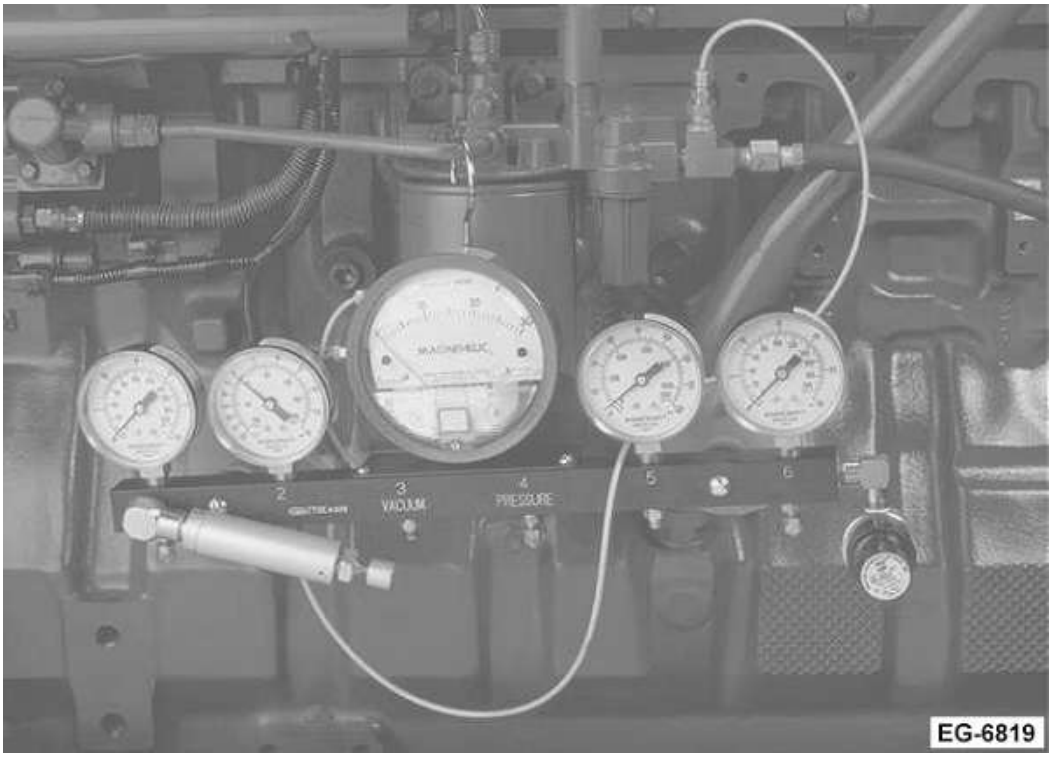
Purpose

To determine if low fuel pressure is caused by excessive restriction in the fuel supply line from the fuel tank to the transfer pump inlet.

Test Procedure

WARNING

Read all safety instructions in this manual before doing this procedure.



Measuring Transfer Pump Restriction with Gauge Bar

1. Connect a tee between the fuel filter inlet and fuel supply line.
2. Connect a line from the tee to a 0-30 in. Hg vacuum gauge on Gauge Bar.
3. Measure fuel inlet restriction at high idle and record the reading on the diagnostic form.
4. If restriction exceeds 8 in Hg, find the restriction on the suction side of the fuel system and correct. If restriction is within specifications or very low, check for restriction between fuel inlet and the transfer pump inlet. If no restriction is found do the following:
   a. Remove fuel supply line. Connect a clear plastic line to the fuel inlet fitting and connect the fuel supply line to clear plastic line.
   b. Check for air bubbles in the clear plastic line while engine is running at high idle. If air bubbles are seen, inspect fuel system for suction leaks. Repair system, if necessary. If air bubbles were not present, remove clear plastic line.
   c. Install plug to seal off the fuel inlet.
   d. Start engine and run at high idle. Vacuum reading should be greater than 22 in Hg. If less, check for air ingestion from the vacuum gauge to the transfer pump. If no leak is found, replace transfer pump.

NOTE

If no leaks are found on the inlet side of the fuel system, while the transfer pump is providing > 22 in Hg. vacuum, replace fuel return valve. Recheck fuel pressure to verify the valve was defective.

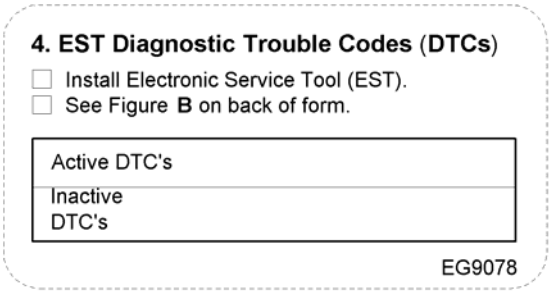
Possible Causes

- A fuel filter could cause high restriction and low fuel pressure from dirt or fuel jelling in cold ambient temperatures.
- Primary fuel filter or fuel/water separator clogged.
- A kinked or severely bent fuel supply line or blockage at the pickup tube could cause restriction and low fuel pressure.
- A loose fuel line on the suction side of the fuel system could allow air into the system causing low fuel pressure.
- Primary fuel filter or fuel/water separator may be ingesting air into fuel system through loose connections etc.
- Fuel return valve defective or stuck open due to debris.
- Defective fuel transfer pump.

Tools Required

- Gauge Bar (PS94-831-3)
- Tee or reworked hollow screw fitting
- NPT pipe adapter and appropriate fuel lines

d. EST Diagnostic Trouble Codes (DTC)

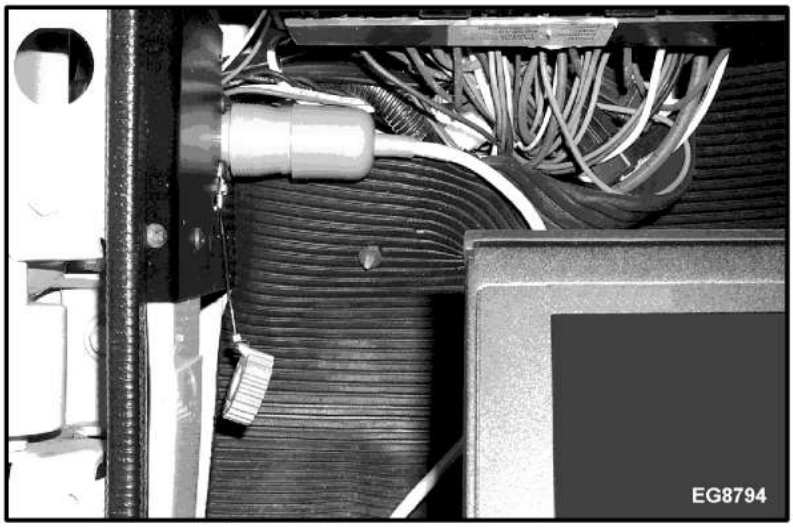


Test Procedure

WARNING

Read all safety instructions in this manual before doing this procedure.

1. Set parking brake.
2. Turn all accessories and ignition OFF.



ATA Connector

3. Connect EST to the American Trucking Association (ATA) diagnostic connector.

NOTE

The ATA connector is on the lower left kick panel or underneath the left side dashboard.

International® Truck Interface Cable

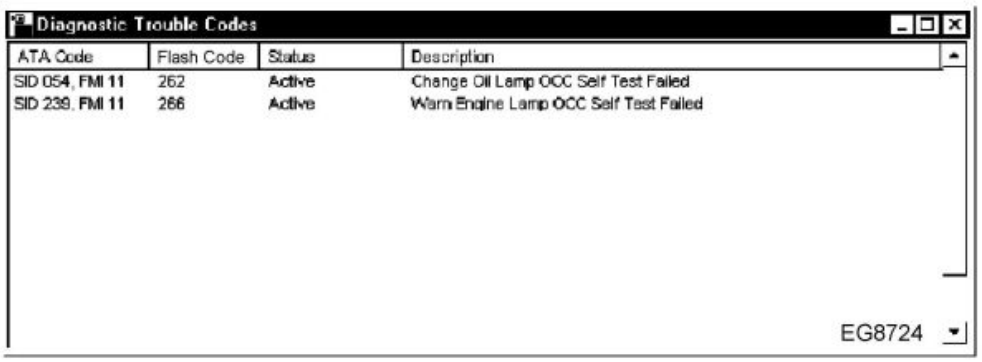
4. Connect one end of the International® truck interface cable to the EST and the other end to the ATA connector.
5. Boot up EST.

Menu Bar 1. Com/Open

6. Select COM from the menu bar in the main window, then Open.

Menu Bar 1. Code/View

7. Select Code from the menu bar, then View for the Diagnostic Trouble Code window.



Diagnostics Trouble Code Window

Diagnostics Trouble Code Window

- **ATA Code:** The ATA Code column displays codes associated with a sub-system (SID), parameter (PID), and failure mode indicator (FMI).
- **Flash Code:** The Flash Code column displays Diagnostic Trouble Code (DTC) numbers.
- **Status:** The Status column indicates Active, Inactive, or Active/Inactive DTCs.
- **Active:** With the ignition key ON, Active indicates a DTC for a condition currently in the system. When the key is turned OFF, an Active DTC becomes Inactive.
- **Inactive:** With the ignition key ON, Inactive indicates a DTC for a condition no longer in the system. When the ignition key is turned OFF, inactive DTCs from previous ignition Key ON cycles are stored in the ECM memory.
- **Active/Inactive:** Indicates a DTC for an intermittent condition currently in the system.
- **Description:** The Description column defines each DTC.

8. If Active DTCs are set, see DTC column on Electronics Control System Diagnostics form EGED1852 for a complete list of Diagnostic Trouble Codes.

NOTE

Active DTCs identify conditions or problems that must be corrected before starting the remaining performance tests.

9. Record DTCs on Mechanical Diagnostics form EGED1802.

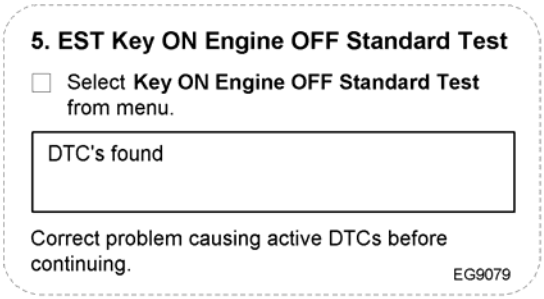
Possible Causes

- Electronic malfunctions detected continuously by the ECM.

Tools Required

- Electronic Service Tool (EST) with Master Diagnostic's software

e. EST Engine OFF Standard Test



Purpose

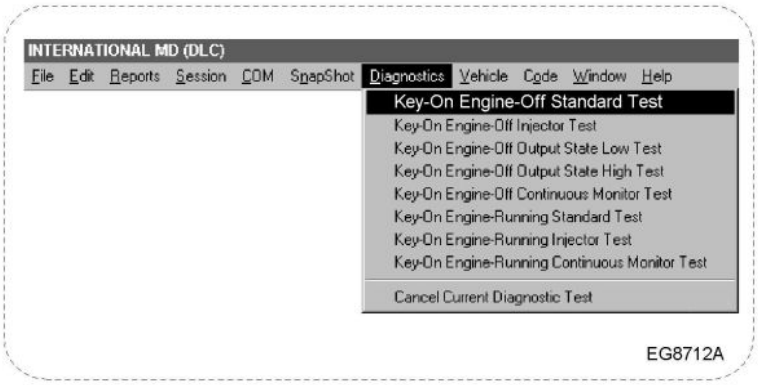
To determine electrical malfunctions detected by the Electronic Control Module (ECM). This requires an Output Circuit Check self test.

Test Procedure

WARNING

Read all safety instructions in this manual before doing this procedure.

1. Set parking brake.
2. Turn ignition key ON.



Key-ON Engine-OFF Standard Test

3. Select Key-ON Engine-OFF Standard Test from the Diagnostics Drop-Down Menu.
4. The ECM will complete an internal self-test and an Output Circuit Check (OCC). When the OCC test is over, the Diagnostic Trouble Code screen will show DTCs. Scroll down to find additional Diagnostic Trouble Codes, if they appear to be off the screen.

5. For a complete listing of Diagnostic Trouble Codes, see DTC column on Electronic Control System Diagnostics form EGED-185-2.
6. Record all Diagnostic Trouble Codes on Mechanical Diagnostics form EGED-180-2.

NOTE

To repeat this test, select the Diagnostic Drop-Down Menu and click on Key-ON Engine-OFF Standard Test.

Possible Causes

- Defective electrical components or circuitry.

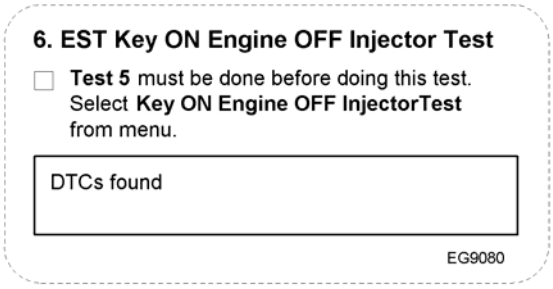
Tools Required

- Electronic Service Tool (EST) with Master Diagnostic's software

Supplemental Diagnostics

- If DTCs are set, see DTC column on Electronic Control System Diagnostics form EGED-185-2.

f. EST Engine OFF Injector Test



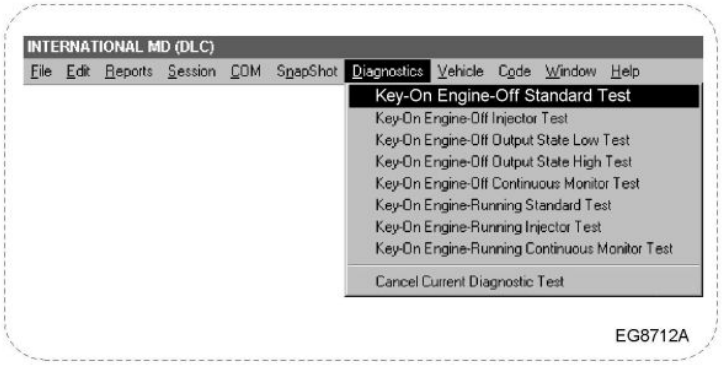
Purpose

To determine if fuel injector electronics are working correctly, by energizing each injector in a programmed sequence. The Electronic Control Module (ECM) will monitor the Key-ON Engine-OFF Injector Test and transmit DTCs if injectors or related electrical circuits are not working correctly.

Test Procedure

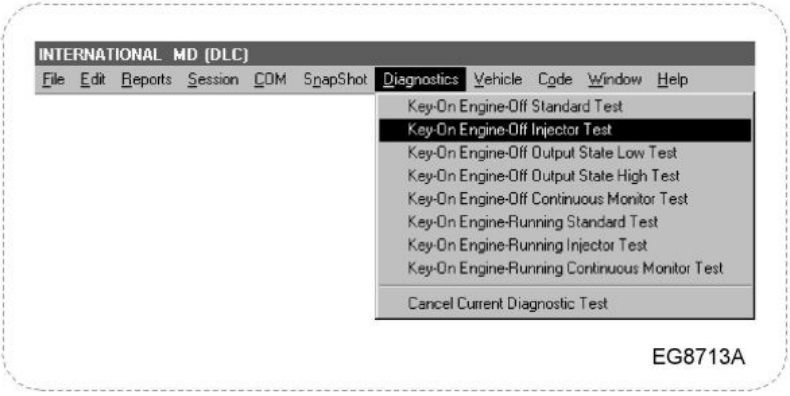
Read all safety instructions in this manual before doing this procedure.

1. Set parking brake.
2. Turn ignition switch ON.



Key-ON Engine OFF Standard Test

3. Select Key-ON Engine-OFF Standard Test from the Diagnostics drop-down menu.



Diagnostics Drop Down Menu

4. When the Engine OFF Standard Test is over, select the Diagnostics drop down menu and click on Engine OFF Injector Test.
5. During the Engine OFF Injector Test, injector solenoids should rapidly click or buzz when actuated. If clicks are not heard, the injectors are not working.
6. When the Engine OFF Injector Test is over, detected DTCs will be displayed. More DTCs can be found by scrolling down.
7. Record DTCs found and see Electronic Control System Diagnostics.

Possible Causes

- Bad wiring harness connection at injector solenoid.
- Open or shorted engine wiring harness to injectors.
- Defective injector solenoids.
- Defective ECM.

Tools Required

- Electronic Service Tool (EST) with Master Diagnostic's software

Supplemental Diagnostics

- If DTCs are set, see DTC column on Electronic Control System Diagnostics form EGED-185-2.

g. Diagnostic Trouble Code Access

To read DTC's detected by the Electronic Control Module (ECM) if the Electronic Service Tool (EST) is not available, or if the EST will not communicate with the ECM.

The Cruise Control buttons on the steering wheel act as an interface between the Operator and the ECM. The resulting flashes of the amber ENGINE lamp indicates the ECM is performing a series of electronic tests.

h. Intake Restriction Test

8. Intake Restriction Test

See Figure **L** on back of form.

☐ Measure restriction at high idle and no load.

Instrument	Spec	Actual
Manometer or Magnehelic gauge	12.5 in H_20	

EG9082

Purpose

To determine if the air cleaner is restricted.

NOTE

High restriction will cause low power, poor fuel economy, and may cause excessive black or blue smoke when starting the engine. Also, high air cleaner restriction can cause turbocharger seals to unseat, allowing oil to be drawn in around seals and into the engine.

See Operation Manual, for details about the air intake system and air cleaner restriction indicators.

Read all safety instructions in the front of this manual before doing the following procedures.

Inspect Air Intake System

1. Inspect inlet piping for debris.
2. Check for loose hoses and clamps.

Leaks (unfiltered air) between the air cleaner and suction side of the turbocharger can cause damage to the turbocharger and engine parts.

3. Check air cleaner housing for cracks.
4. Check Air-to-Air Cooler for holes and damage.
5. Check air cleaner elements for damaged gaskets or dents.
6. Check air cleaner restriction indicator or gauge.

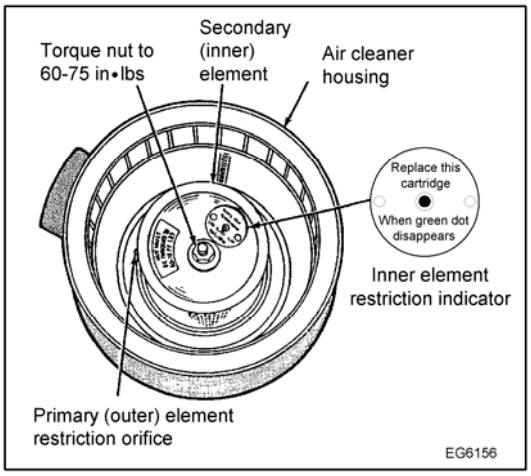
Dual Element Cleaner

The dual element air cleaner has a large primary (outer) filter element and an optional small secondary (inner) filter element. The secondary element is used in dusty environments.

The restriction connection for the dual element air cleaner is between the primary and the secondary element at the bottom of the air cleaner housing. This allows only the primary (outer) element to be sensed by the restriction indicator or dash mounted vacuum gauge. Restriction for the inner element is not recorded on the restriction indicator or dash mounted vacuum gauge.

NOTE

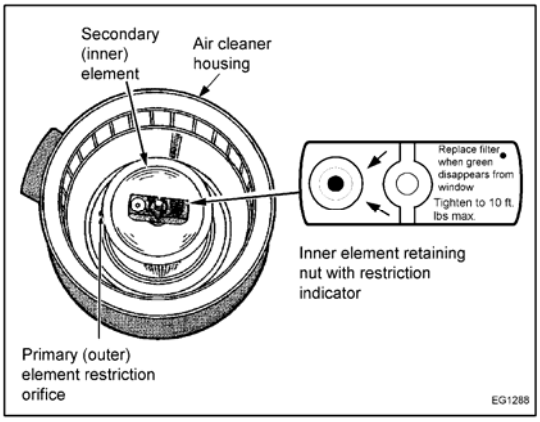
Dual element air cleaners use one of the following restriction indicators:



Dual element air cleaner with indicator in end cap. Tighten retaining nut to 60 to75 lb-in. (6.8 to 8.5 N•m).

NOTE

Replace the element when the green dot disappears from the element end cap.

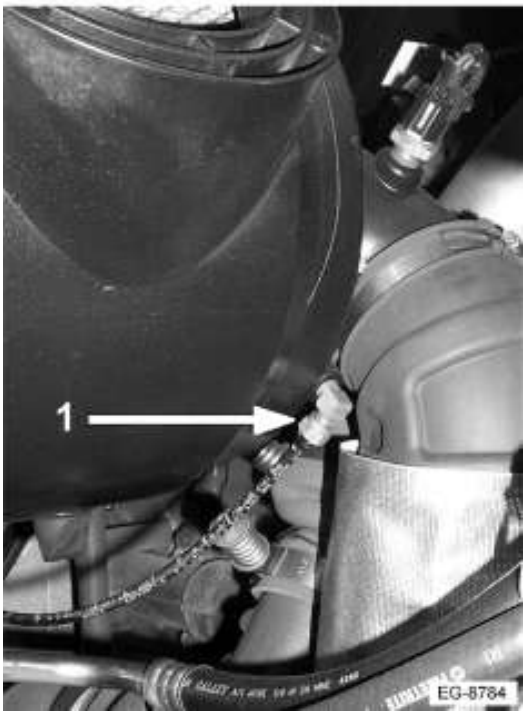


Dual-element air cleaner retaining-nut indicator. Tighten retaining nut to 120 lb-in. (13.6 N•m).

NOTE

Replace the element when the green dot disappears from the window in the retaining nut.

Procedure to Measure Intake Air Restriction



Tap for Restriction Test

1. Attach a restriction test tool to the air cleaner housing tap.
2. Run engine at high idle rpm (no load).
3. Replace the air cleaner element when the test gauge shows a restriction greater than 12.5 in. H2O (3.13 kPa).

NOTE

Equivalent Test using the dash mounted restriction gauge: The true maximum air cleaner restriction 25 in. H2O (6.22 kPa) can only be obtained when operating the engine at full load and rated horsepower.

Possible Causes

- Dirty air cleaner element.
- Snow, plastic bags, or foreign material may restrict air flow in the air cleaner inlet. Repaired engines may have rags or cap plugs in the intake system.

Tools Required

- Model D-200 Pressure Test Kit (ZTSE-2239)
- Gauge Bar (PS94-831-3)
- Magnehelic Gauge or Water Manometer

i. EST Engine Running Standard Test

9. EST Key ON Engine Running Standard Test

Note: Engine must be above 160 °F.

☐ Select **Key ON Engine Running StandardTest** from menu.

DTC's found

EG9083

Purpose

To verify correct operation and specification ranges for engine actuators and electronic sensors. The Electronic Service Tool (EST) signals the Electronic Control Module (ECM) to perform the Key-ON Engine-Running Standard Test. The ECM will activate the actuators, monitor sensor feedback signals, and send fault codes for actuators or sensors to the EST.

Test Procedure

WARNING

Read all safety instructions in this manual before doing this procedure.

NOTE

Before running the Key-ON Engine-Running Standard Test, set parking brake and make sure the transmission is in neutral (N).

1. Set parking brake.
2. Start and run engine until it reaches 160°F (71°C) minimum.

NOTE

Engine coolant temperature must reach 160°F (71°C) minimum for the ECM to accurately test engine actuators and sensors. If engine coolant temperature is below self test range, the EST tool will show ECT Out of Self Test Range.

Key-ON Engine Running Standard Test

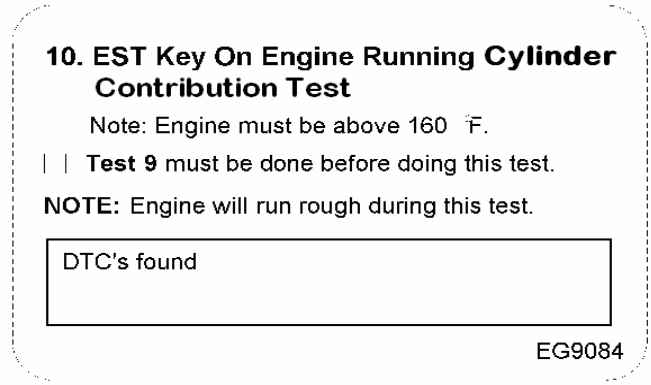
3. Select the Key-ON Engine-Running All Other Products Test from the Diagnostics drop-down menu.
4. Select standard Test and click run.

The ECM will start the Key-ON Engine-Running Standard Test and command the engine to accelerate to a predetermined engine rpm and operate the Injection Pressure Regulator (IPR) valve.

Possible Causes

- Defective or inoperative ICP sensor or IPR valve
- Oil leakage in high-pressure Injection Control System
- Defective high-pressure pump
- Open or shorted wiring harness to ICP or IPR
- Loose or corroded engine wiring harness for ICP or IPR

j. EST Engine Running Injector Test



Purpose

To verify that all power cylinders are contributing equally.

Test Procedure

WARNING

Read all safety instructions in this manual before doing this procedure.

NOTE

The Key-ON Engine Running Standard Test must be done first to access the injector test.

The Key-ON Engine Running Standard Test

1. Select Key-ON Engine Running All Other Products Test from the Diagnostics drop-down menu.
2. Select The Standard Test and click Run.

Key-ON Engine Running Injector Test

3. Select the Cylinder Contribution Test from the Diagnostic box and click Run.
4. Select Engine Running Injector Test from the Diagnostics drop-down menu.

NOTE

The engine will run rough during the Key-ON Engine Running Injector Test.

The Electronic Service Tool (EST) will signal the Electronic Control Module (ECM) to actuate each injector in a programmed sequence and then measure power cylinder performance.

Record the Diagnostic Trouble Codes on Mechanical Diagnostics form EGED180-2.

Possible Causes

- Broken compression rings, leaking or bent valves, bent push rods or connecting rods
- Open or shorted engine wiring harness to injectors
- Defective injectors or solenoids

Tools Required

- Electronic Service Tool (EST) with Master Diagnostics software

Supplemental Diagnostics

- If Diagnostic Trouble Codes are set, see DTC column on Electronic Control System Diagnostics form EGED-185-2.

k. Fuel Pressure Test (Full Load)

11. Fuel Pressure Test (Full Load)

See Figure J on back of form.

☐ Measure fuel pressure at fuel filter bleeder.

☐ Check fuel pressure at full load and rated speed.

Instrument	Spec	Actual
0-160 psi gauge	45 psi	

- If fuel pressure is low, replace fuel filter, clean fuel strainer, and retest.
- If pressure is still low do **Test 3**.

EG9085

Purpose

To determine if the fuel system is supplying the engine with the proper fuel quantity and pressure at full load conditions.

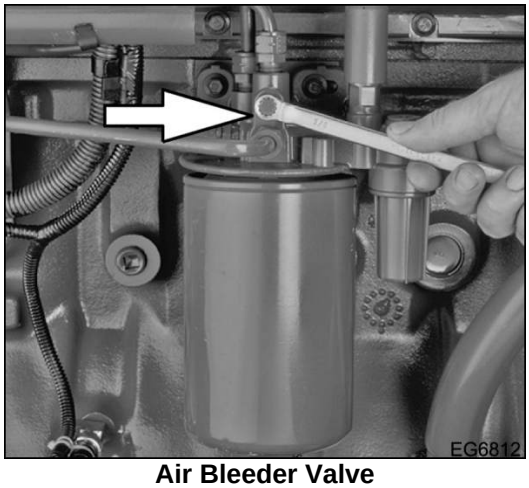
Test Procedure

WARNING

Read all safety instructions in this manual before doing this procedure.

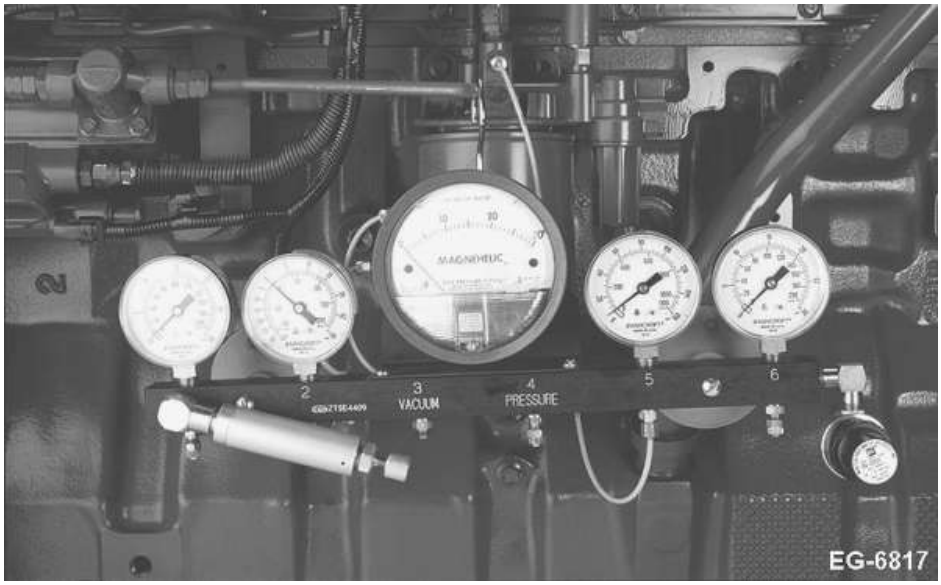
NOTE

If the fuel filter has a water-in-fuel probe, ask the vehicle operator if the water-in-fuel lamp is illuminated during vehicle operation.



Air Bleeder Valve

1. If pressure gauge is not connected to fuel system in Test 2, remove air bleed valve on fuel filter header.
2. Install 1/8 in. (3 mm) pipe fitting in place of the bleed valve.



Gauge Bar (PS948313)

3. Connect a line from the fitting to the 0-160 psi gauge of the Gauge Bar.
4. Start engine and run at low idle to check for fuel leaks in-line to pressure gauge.

NOTE

Bleed air from the fuel line to ensure an accurate reading.

5. Drive vehicle on road until engine reaches operating temperature. Find an open section of road and select a suitable gear. Depress the accelerator pedal (full depression) to the floor and accelerate to rated speed and 100 percent load.

NOTE

Drive the vehicle uphill or fully loaded to reach the correct engine loading at rated engine speed.

6. Measure fuel pressure and record on Mechanical Diagnostics form EGED1802. If pressure is not within specifications, replace fuel filter, clean fuel strainer, and recheck fuel pressure.

NOTE

Several crank cycles may be required to purge the air from the fuel system after replacing the fuel filter.

If fuel pressure remains low after replacing the filter, do Transfer Pump Restriction Test (Test 3).

Possible Causes

- A clogged fuel filter or fuel strainer could cause high restriction and low fuel pressure. Replace fuel filter, clean strainer, and retest.
- Debris in the fuel regulator valve will cause low fuel pressure.
- A kinked or severely bent fuel supply line, or blockage at the pickup tube.
- A loose fuel line on the suction side of the fuel system.
- The fuel pump could have internal damage; for example, a seized plunger or leaking check valves.
- A restriction between the transfer pump inlet and fuel tank.
- Restriction between the fuel line inlet fitting, strainer, and transfer pump.

Tools Required

- Gauge Bar (PS94-831-3) and an appropriate line with 1/8 in. NPT fitting

I. ICP Pressure Test

12. ICP Pressure Test

- ☐ Monitor ICP and engine rpm. Use EST data list or breakout tee and DMM. See figure **G** on back of form.
- ☐ See EGES-175-1 for specifications.

PID	Spec	Actual
Low idle	psi/volts	
High idle	psi/volts	
Full load	psi/volts	

- If ICP is low or unstable, disconnect ICP sensor and retest.
- If problem is solved see ICP diagnostics.
- If still slow or unstable replace IPR and retest.

EG9086

Purpose

To determine if the high-pressure lube oil system is providing sufficient hydraulic pressure to operate the injectors.

Test Procedure

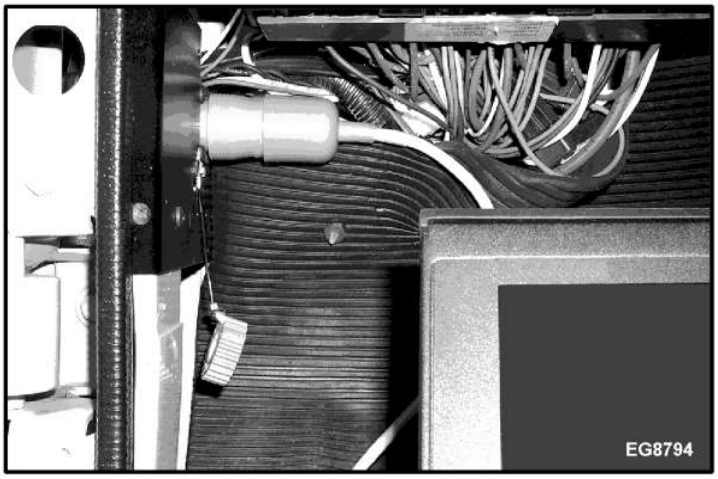
WARNING

Read all safety instructions in this manual before doing this procedure.

Do this procedure at full load in conjunction with Fuel Pressure Test (Test 11) and Boost Pressure Test (Test 13).

NOTE

Turn all accessories and the ignition OFF, before connecting Electronic Service Tool (EST) tool to American Trucking Association (ATA) diagnostic connector.



ATA Connector

1. Connect the EST to the ATA data link connector.
2. Start Master Diagnostics and select the Road Performance session. Drive the vehicle on the road until the engine reaches operating temperature. Find an open section of road and select a suitable gear. Depress the accelerator pedal (full depression) to the floor and accelerate to rated speed and 100 percent load.

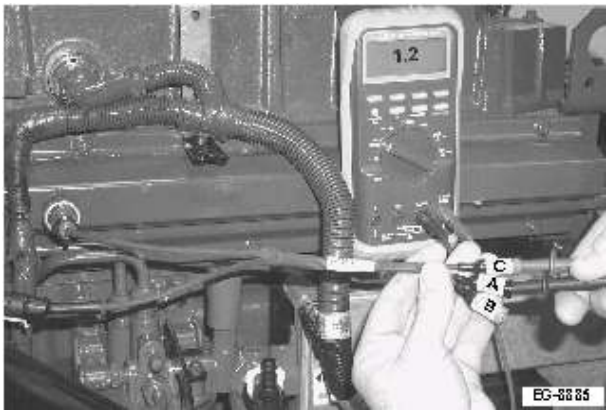
NOTE

Drive the vehicle uphill or fully loaded to reach the correct engine loading at rated engine speed.

3. Read minimum and maximum voltages for ICP pressure and record on Mechanical Diagnostic form EGED-180-2.
4. Stop the vehicle, read voltages for low and high idle ICP pressures, and record on Mechanical Diagnostic form EGED-180-2.

Alternate Method for Measuring ICP using Breakout Tee

1. Remove engine harness connector from ICP sensor.
2. Connect ICP breakout tee to the removed engine harness connector and the ICP sensor.



DMM (ZTSE4357) and ICP Breakout Tee (ZTSE4347)

3. Use a DMM and connect a long set of leads (+ Green, - Black) to breakout tee (ZTSE4347), as shown above.
4. Drive vehicle on road until the engine reaches operating temperature. Find an open section of road and select a suitable gear. Depress the accelerator pedal (full depression) to the floor and accelerate to rated speed and 100 percent load.

NOTE

Drive the vehicle uphill or fully loaded to reach the correct engine loading at rated engine speed.

Possible Causes

Low voltage for injection pressure indicates insufficient oil pressure to operate the fuel injectors. Insufficient oil pressure can be caused by:

- A defective IPR valve,
- A defective High-Pressure Pump,
- Injection Control Pressure system leakage, or the ECM commanding the IPR valve to reduce injection control pressure due to:
    a. Low Boost pressure
    b. Incorrect feedback signal from Accelerator Position Sensor (APS)
    c. Incorrect feedback signal from ICP sensor (check part number)

To check for insufficient oil pressure, do ICP Boost Pressure Test (Test 13).

Tools Required

- Electronic Service Tool (EST) with Master Diagnostics software
- DMM (ZTSE4357) (optional)
- ICP breakout tee (ZTSE4347) (optional)

m. Boost Pressure Test

13. Boost Pressure Test (Full Load)

- ☐ Monitor boost pressure and engine rpm with EST in data list. See Figure M on back of form.
- ☐ Use dash tach, 0-30 psi gauge, breakout tee, and DMM if EST is not available.
- ☐ See EGES-175-1 for specifications.

Test	Spec psi @ rpm	Actual
Peak HP		
Peak Torque		

EG9087

Purpose

To determine if the engine can develop necessary boost pressure for required power.

Test Procedure

WARNING

Read all safety instructions in this manual before doing this procedure.

Test should be performed at full load in conjunction with Fuel Pressure Test (Test 11) and ICP Pressure Test (Test 12).

NOTE

Turn accessories and ignition OFF, before connecting Electronic Service Tool (EST) to the American Trucking Association (ATA) diagnostic connector.

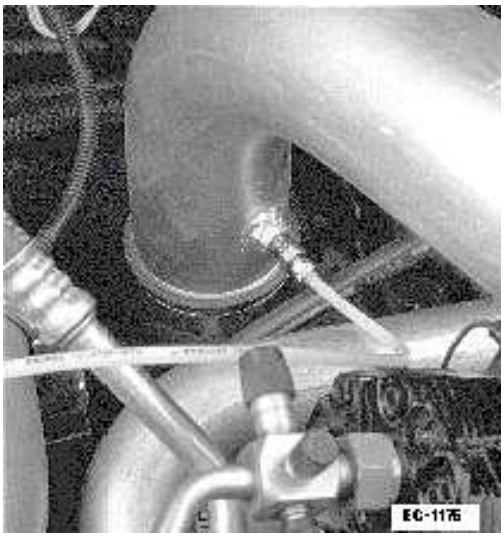
1. Connect the EST to the ATA connector.
2. Turn the ignition switch ON.
3. Start Master Diagnostics and select the preconfigured session entitled Road Performance.
4. Boost psi is shown in the text window.
5. Drive the vehicle on the road until the engine reaches operating temperature. Find an open section of road and select a suitable gear. Depress the accelerator pedal (full depression) to the floor and accelerate to rated speed and 100% load.

NOTE

Drive the vehicle uphill or fully loaded to reach the correct engine loading at rated engine speed and peak torque speed.

6. Record intake manifold boost at full load rated engine speed.

Alternate Test Procedure



Boost Pressure Tap

1. Remove plug from boost pipe, install adapter fitting, and connect a test line as shown above. (See Step 4.)
2. If no plug is on the boost pipe, remove the Manifold Absolute Pressure sensor at intake manifold/valve cover.
3. Install a tee fitting, and reinstall MAP sensor, and connect a test line to the tee. (See form EGED1802 Figure M).
4. Route the line from the engine compartment into the cab.

NOTE

Do not crimp the line or let the line touch hot engine surfaces.
MAP sensor must be connected during boost pressure test.

5. Temporarily install the Gauge Bar in the cab of the vehicle. Connect the line routed from the boost pipe or tee at MAP sensor to the appropriate pressure gauge.
6. Drive the vehicle on the road until the engine reaches operating temperature. Find an open section of road and select a suitable gear. Depress the accelerator pedal (full depression) to the floor and accelerate to rated speed and 100 percent load.

NOTE

Drive the vehicle uphill or fully loaded to reach the correct engine loading at rated engine speed.

7. Record intake manifold boost pressure at full load rated engine speed and peak torque speed.

NOTE

If boost pressure is within specifications, the engine is functioning correctly. Chassis or application problems are possible.

Possible Causes

- Restricted intake or exhaust
- Low fuel pressure
- Low injection control pressure
- Control system DTCs
- Defective injectors
- Defective turbocharger
- Base engine failure

Tools Required

- Electronic Service Tool (EST) with Master Diagnostics software
- Gauge Bar (PS94-831-3) and a tee fitting (optional)

n. Crankcase Pressure Test

14. Crankcase Pressure Test

☐ Measure pressure at road draft tube with restriction tool **ZTSE4039.** See Figure **N** on back of form.
☐ Measure at high idle, **NO LOAD**.

Instrument	Spec	Actual
Manometer or Magnehelic gauge	< 6 in H_20	

EG9088

Crankcase Pressure Test

Purpose

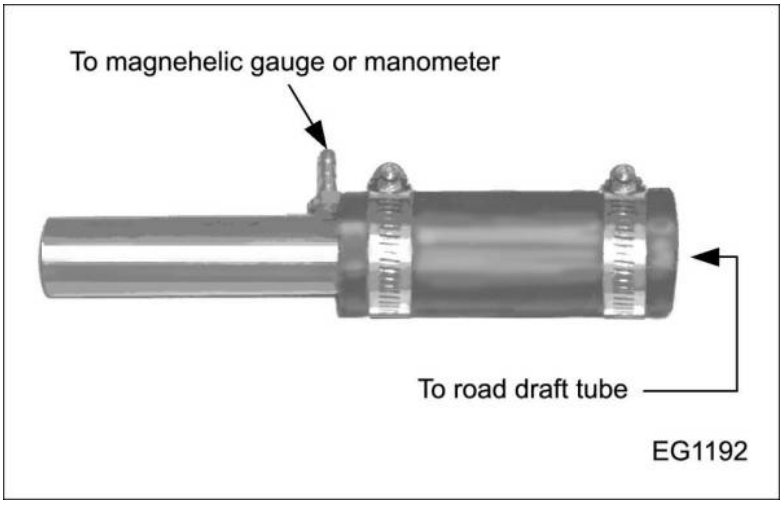
To measure the condition of the power cylinders.

Test Procedure

WARNING

Read all safety instructions in this manual before doing this procedure.

1. Park vehicle on level ground.
2. Make sure breather tube is clean and the valve intake manifold is tight.
3. Make sure the engine oil level is not above full mark and the oil level gauge is secured.

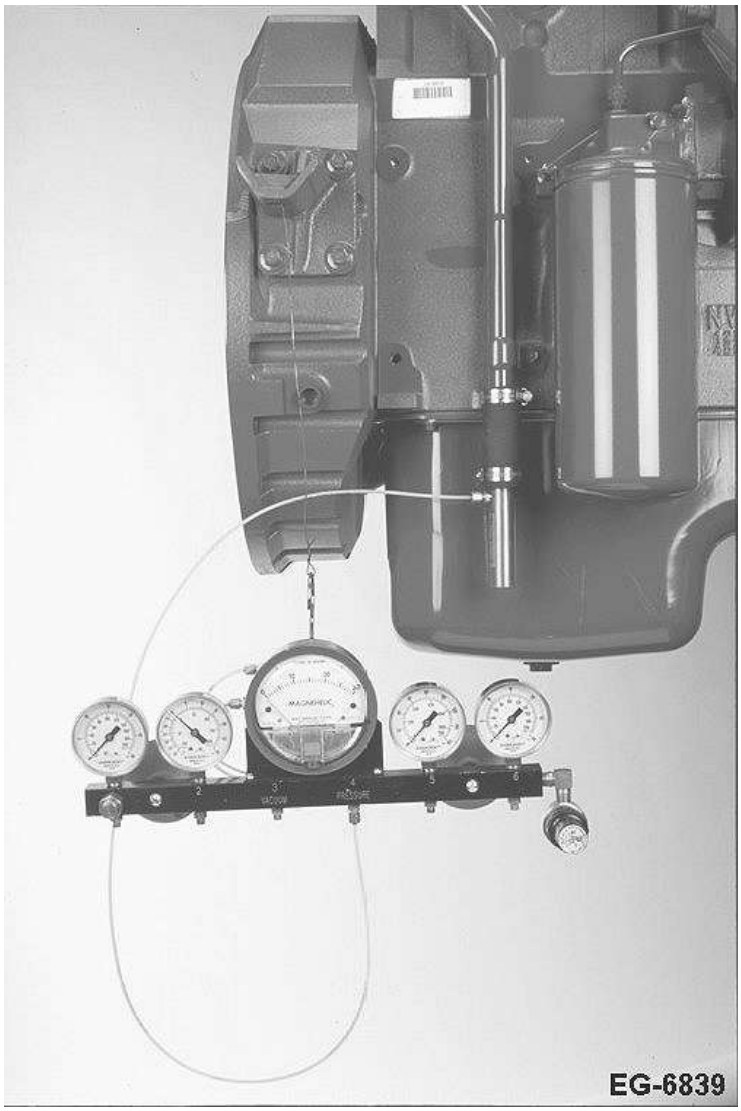


Crankcase Breather Tool (ZTSE4039)

4. Install Crankcase Breather Tool.

NOTE

If the engine has a breather extension tube, the extension tube must be removed before testing.



Crankcase Breather Tool (ZTSE4039) and Gauge Bar (PS948313)

5. Connect a line from the crankcase breather tool to a water manometer gauge or magnehelic gauge on the gauge bar.
6. Run engine to reach normal engine operating temperature before measuring crankcase pressure.
7. Run engine at high idle (no load) rpm. Allow the gauge reading to stabilize before taking the pressure reading.
8. Record crankcase pressure on Mechanical Diagnostic form EGED1802.

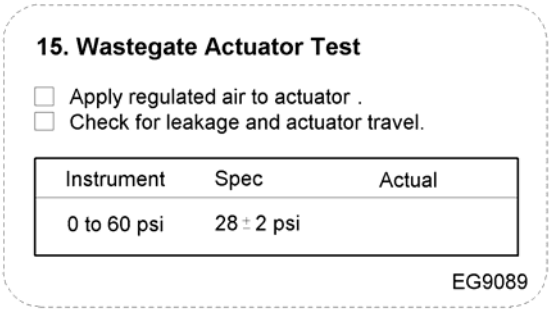
Possible Causes

1. Excessive crankcase pressure with high oil consumption indicates:
   - Dirt in air induction system. Do Air Induction System Pressure Test.
   - Badly worn or broken rings
   - Badly worn or scored cylinder sleeves
   - Leaking valve seals or worn valve guides
   - A restricted orifice in Crankcase Breather Tool
2. Excessive crankcase pressure without high oil consumption indicates
   1. Leaking intake manifold gasket
   2. Air compressor effecting crankcase pressure. Remove compressor discharge line to remove its influence.

Tools Required

- Magnehelic gauge on Gauge Bar (PS94-831-3)
- Crankcase Breather Tool (ZTSE4039)

o. Wastegate Actuator Test



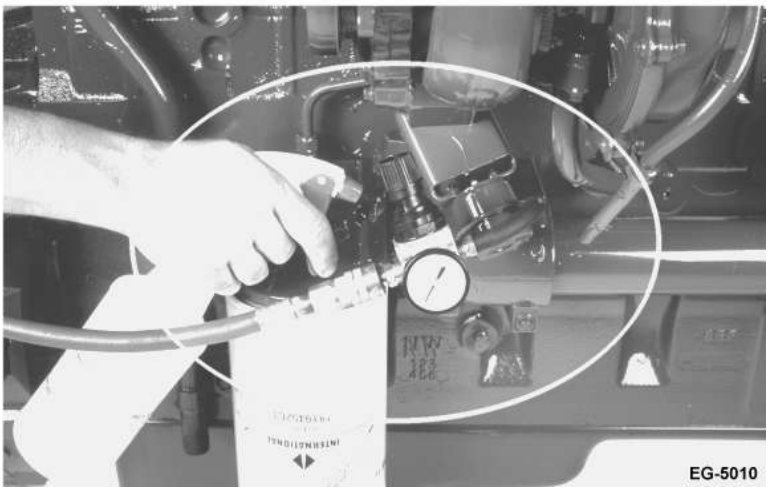
Purpose

To determine if the wastegate actuator works correctly.

Test Procedure

Read all safety instructions in this manual before doing this procedure.

1. Remove actuator boost line from turbo compressor housing.



Air Regulator with 060 psi Gauge

2. Connect an air regulator with a 0-60 psi gauge to the actuator boost line.
3. Mark actuator shaft with paint pen. Spray leak detector or soap solution around the actuator housing.
4. Slowly apply air pressure to the actuator. Movement of the actuator shaft (indicated by position of paint mark) should start between 26 and 30 psi.

   If the actuator shaft moves 0.015 in. (0.369 mm) or more and the housing does not leak air, the actuator is good. If the actuator shaft moves less than 0.015 in. (0.369 mm) or the housing leaks air, the actuator must be replaced. Before replacing the actuator, remove the turbocharger.

Possible Causes

- Sticky flapper valve
- Ruptured actuator diaphragm
- Leaky canister
- Leaky hose to actuator

Tools Required

- Air Pressure Regulator, 0-60 psi gauge, and paint marker.

p. Exhaust Restriction Test

16. Exhaust Restriction Test

- ☐ Inspect exhaust system.
- ☐ Check restriction (3-6 in) after turbocharger.
- ☐ Measure restriction at full load and rated speed.

Instrument	Spec	Actual
Manometer or Magnehelic gauge	0-33 in H_20	

EG9090

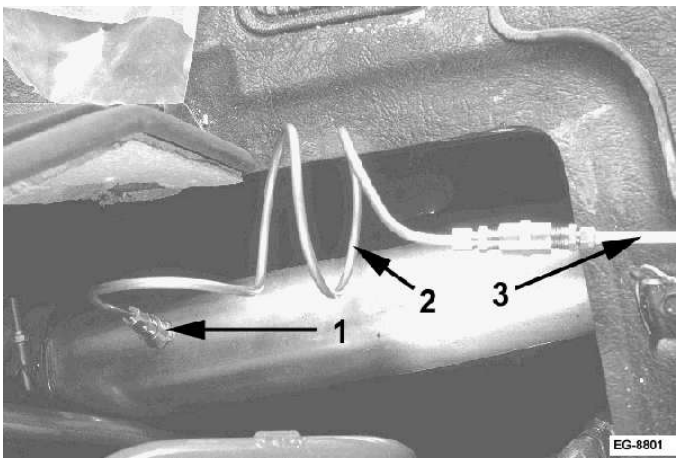
Purpose

To check for restrictions in the exhaust system likely to cause engine performance problems.

Test Procedure

WARNING

Read all safety instructions in this manual before doing this procedure.



(1) 1/8 NPT Male Connector
(2) Cooper Tubing (coiled)
12 in. (31 cm) minimum
(3) Plastic Tubing

Measuring Exhaust Restriction

1. Drill and braze on an 1/8 in. NPT male connector in a straight section of exhaust pipe approximately 3 to 6 in. after the bend in the exhaust pipe.
2. Connect coiled copper tubing (min 1 ft) to the connector before attaching the plastic tubing from Gauge Bar.

NOTE

The coiled copper tubing prevents the plastic tubing from melting.

3. Connect the other end of the plastic tubing to a water manometer or magnehelic gauge on the Gauge Bar.
4. Obtain the data at rated speed on a chassis dynamometer or fully loaded on the highway. The engine must be at normal operating temperature.
5. Exhaust pressures over specification indicate exhaust system restriction and reduced engine power. Replace the muffler or exhaust piping as necessary.

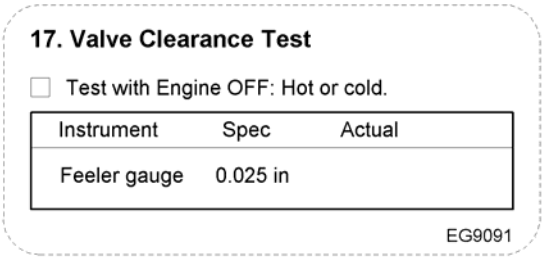
Possible Causes

- Collapsed exhaust piping
- Restricted exhaust piping
- Damaged muffler
- Malfunctioning retarder

Tools Required

- Gauge Bar (PS94-831-3) or Water Manometer

q. Valve Clearance Test



Purpose

To determine correct valve clearance.

Test Procedure

Read all safety instructions in this manual before doing this procedure.

1. Remove the valve intake manifold.
2. Rotate the crankshaft until piston No.1 is on the compression stroke and the timing mark on the damper pulley is aligned with the Top Dead Center (TDC) mark on the front cover.

NOTE

To check for compression stroke, turn both push rods; if both rods are loose and easily turned both valves are closed and No. 1 piston is on the compression stroke.

Valve Lash Adjustment

Valve Lash Adjustment		
Engines	**Intake (mm)**	**Exhaust (mm)**
DT 466E	0.025 (0.635)	0.025 (0.635)
International® 530E		EG9094

Valve Lash Specifications

3. Check valve lash by inserting a feeler gauge between the rocker arm and valve stem tip. If adjustment is required, loosen the locknut and turn the valve adjustment screw until the valve lever can support the feeler gauge.
4. Tighten the locknut once the adjustment is set and remove the feeler gauge.

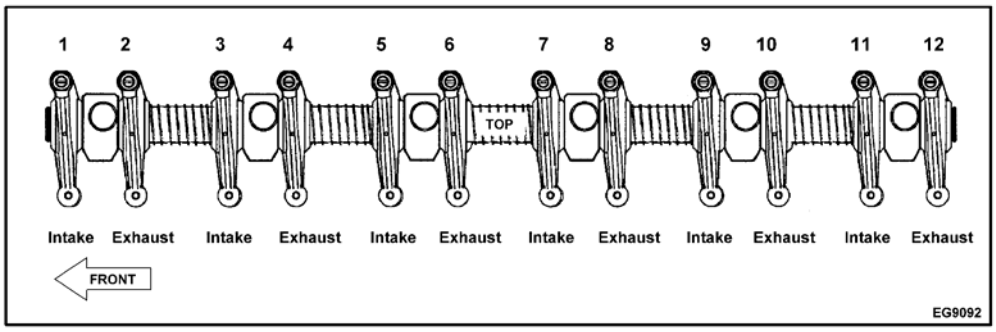
Valve Adjustments with No. 1 Piston and No. 6 Piston at TDC												
Piston Position	**Cylinder 1**		**Cylinder 2**		**Cylinder 3**		**Cylinder 4**		**Cylinder 5**		**Cylinder 6**	
No. 1 Piston (TDC compression)	Intake valve 1	Exhaust valve 2	Intake valve 3			Exhaust valve 6	Intake valve 7			Exhaust valve 10		
No. 6 Piston (TDC compression)				Exhaust valve 4	Intake valve 5			Exhaust valve 8	Intake valve 9		Intake valve 11	Exhaust valve 12

EG9093

Valve Adjustment with No. 1 Piston and No. 6 Piston at TDC

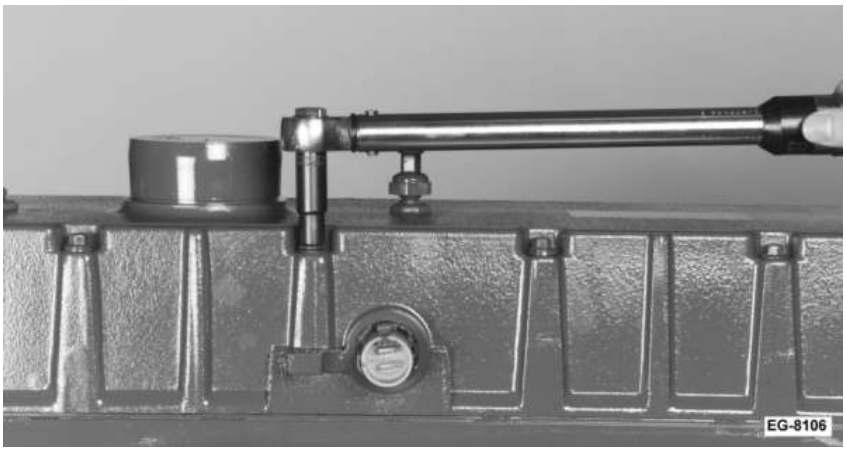
NOTE

Six valves are adjusted with the No. 1 piston at TDC (compression stroke). The remaining six are adjusted with the No. 6 piston at TDC (compression stroke).



Valve Lash Adjustment Sequence

5. Continue checking and adjusting valves (if necessary) following the valve sequence as shown above. Identify valve numbers on the rocker arm.



Valve Cover/Intake Manifold

6. Install the valve cover/intake manifold. Tighten mounting bolts to 13 ft-lb (17.6 N•m).

Possible Causes

- Worn valve train
- Valve seat or face wear

Tools Required

- Feeler Gauge
- Torque Wrench

2-20 ABS Sensor Test

WARNING

Hydraulic jacks are intended only for lifting the vehicle and not for supporting the vehicle while performing maintenance. DO NOT get under vehicle after vehicle is raised, unless it is properly supported with blocks or jack stands. Failure to comply may result in injury or death to personnel.

Do not attempt to lift Wheel and Tire Assemblies by yourself. These assemblies are heavy and bulky and should not be lifted alone. Have another personnel assist with changing of a wheel/tire assembly. Failure to comply may result in damage to equipment or serious injury or death to personnel.

Before beginning ANY work on the vehicle's air brake system, or any auxiliary pressurized systems, make sure to drain the air pressure from all reservoirs.

Wear safety goggles and gloves during vehicle wheel lifting and lowering.

The WS-24™ wheel speed sensor is an electromagnetic device used to collect vehicle speed information for an antilock controller. When the wheel rotates, the sensor and an exciter ring (also called a "rotor" or "tone wheel") generate a simple signal. The signal is sent to the controller, which analyzes the data. The controller commands the antilock system based on the data.

Location	Measurement
Sensor	**1500 - 2000 Ohms - Normal resistance**
Sensor to voltage or ground	**Open Circuit (no continuity)**
Sensor output voltage	**>0.25 of VAC sensor output at ~ 0.5 revs/sec.**

1. Electrical Test Procedures Operational Test (a) and (b)

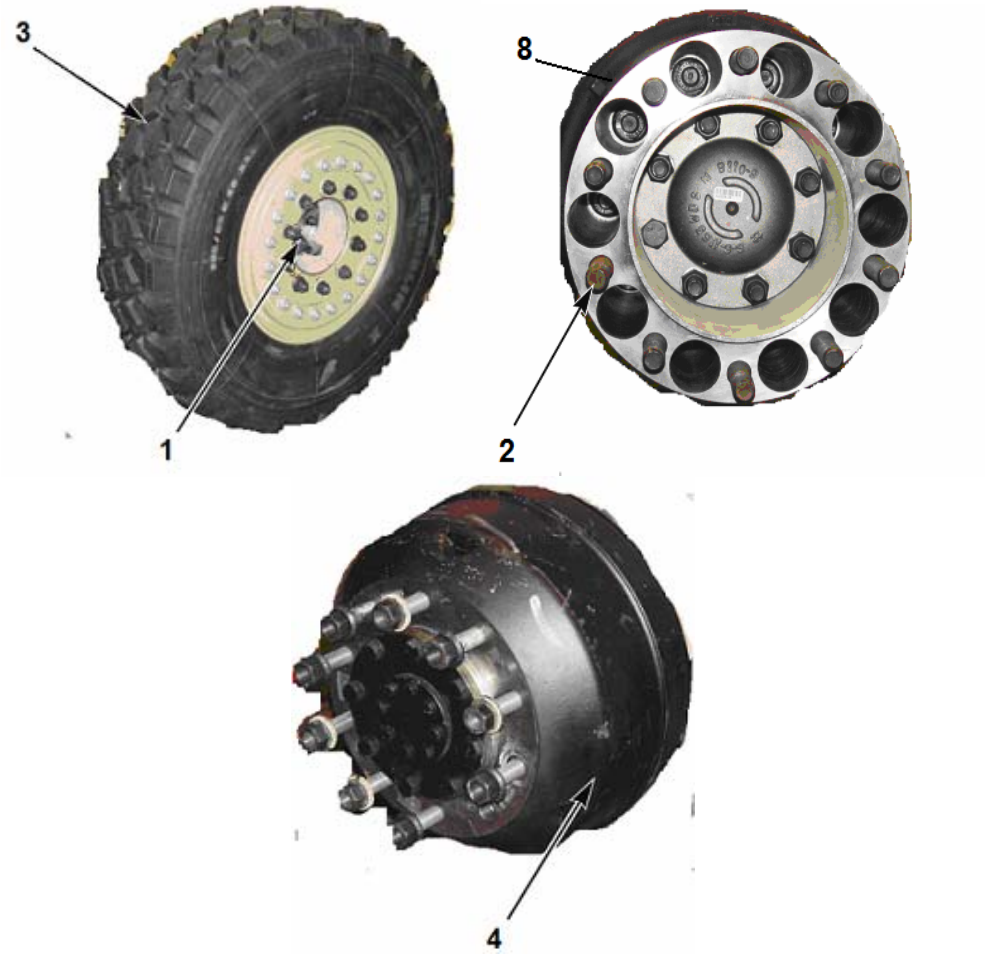
To test sensor operation, perform either one of the following two tests:

a. <u>Test A.</u>

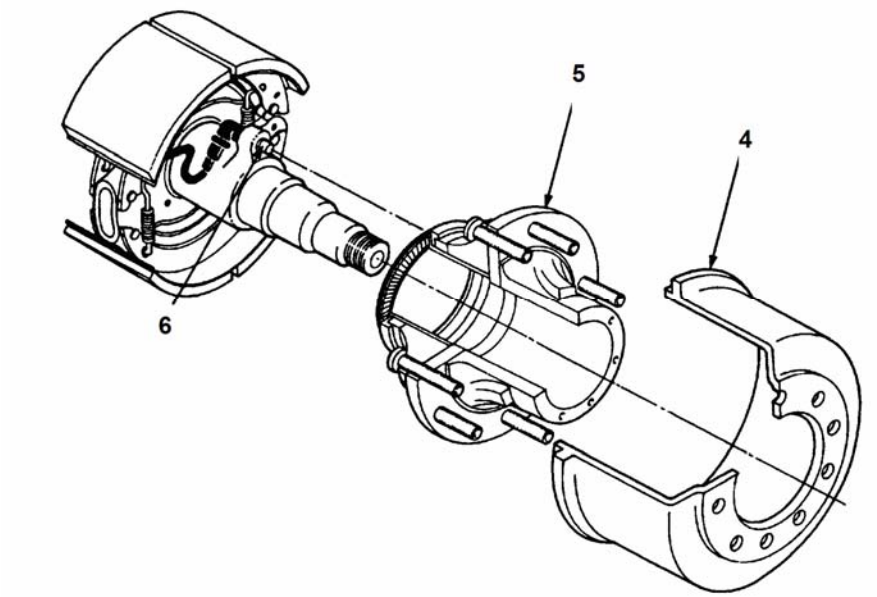
1. Drive the vehicle into a safe area at a minimum speed of 15 mph.
2. Apply the brakes several times.
3. Stop the vehicle and check the LED display on the Bendix controller.
4. If the dash light is out and the sensor LED(s) are not illuminated, the sensor is correctly installed.

b. Test B.

Tire Removal



1. Drain air tanks and reservoirs.
2. Using a suitable lifting device with a suitable rated jack, raise the wheel so the wheel easily rotates.
3. Loosen and remove ten lug nuts (1) from studs (2) for wheel and tire assembly (3).
4. With assistance and care, remove wheel and tire assembly (3) from drum assembly (4) and set on ground.
5. Remove 5 inch spacer (8), on rear wheels only.
6. Remove the brake drum (4) from the wheel hub (5).



7. Disconnect the connector from the sensor's socket (6) or from the attached lead on backside of the wheel assembly plate.
8. Connect the DVOM (set to read Volts AC) to the pins on the sensor or lead.
9. Spin the wheel. If the wheel spin is at ½ revolution per second, the reading should be greater than 0.250 VAC.
10. If the sensor fails to operate as described, do the following checks:
    - Check sensor's wiring connector
    - Check the wiring from the controller to the sensor
    - Make sure all connectors are correctly and tightly installed
    - Check for frayed or damaged wires
    - Check and/or reset the sensor air gap (distance from sensor tip to exciter ring) as described in the manual

    If the ABS Sensor continues to malfunction, perform the next test.

2) Electrical Test Procedure (A).

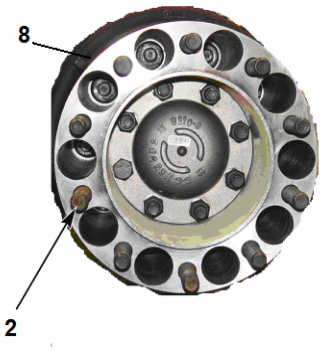
a. Test A.

1. Re-drain the air pressure from the air tanks and reservoirs.
2. Before testing the speed sensor, find the sensor located on the backside of wheel assembly plate.
3. Using a suitable lifting device with a suitable rated jack, raise the wheel so the wheel easily rotates.
4. Loosen and remove ten lug nuts (1) from studs (2) for wheel and tire assembly (3).
5. With assistance and care, remove wheel and tire assembly (3) from drum assembly (4) and set on ground.
6. Remove 5 inch spacer (8), on rear wheels only.
7. Remove the brake drum (4) from the wheel hub (5).
8. Inspect sensor's wiring connector.
9. Test the resistance between the pins ON THE SENSOR.
   - Normal resistance range across pins at room temperature should be 1500 - 2000 Ohms.
   - Test the resistance of each pin to vehicle ground and note if there is NO CONTINUITY.

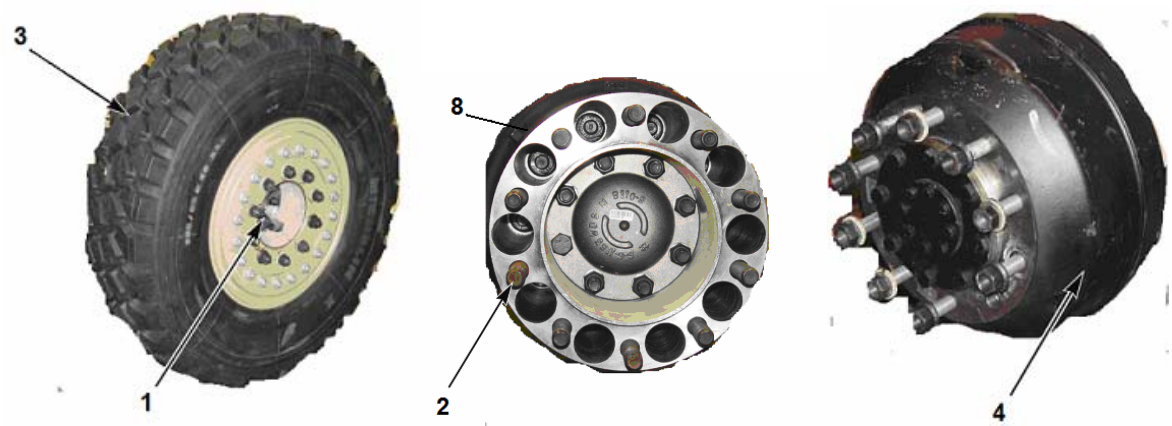
   If the resistance readings are as shown, the wire harness leading to the modulator may need repair or replacement. Before repairing or replacing the wire harness, see the test procedures used for the vehicle's antilock controller. More testing may be needed to verify the wire harness problem.

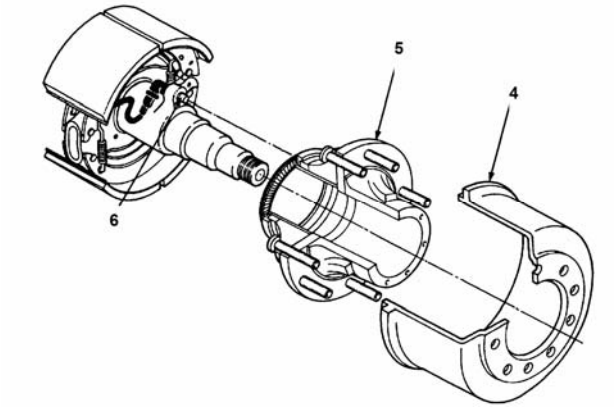
   Resistance could be as low as 1100 Ohms or as high as 3300 Ohms if the wheel end has been recently exposed to extreme temperature.

   If the resistance values show NOT AS STATED, replace the sensor.



Tire Installation



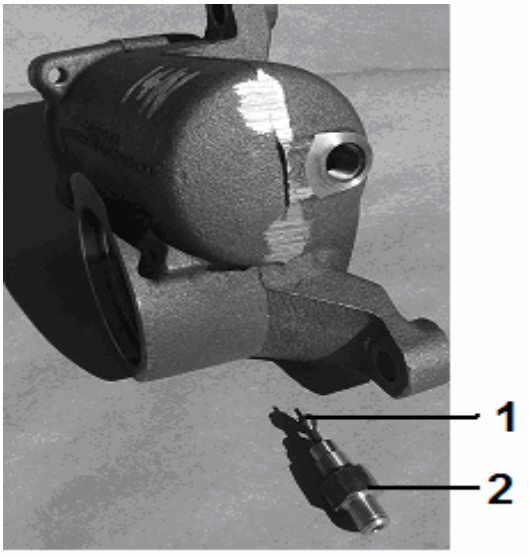


b. Test B.

1. Disconnect the DVOM.
2. Reconnect the connector.
3. Install the brake drum (4) onto the wheel hub (5).
4. Install the 5 inch spacer (8), on rear wheel only.
5. With assistance, lift the wheel and tire assembly (3) onto drum assembly (4).
6. Install lug nuts (1) and studs (2).
7. Tighten in proper sequence and torque to specification.
8. Remove suitable jack stand and lower floor jack, and remove.
9. Pressurize air tanks and reservoirs to specification.
10. Verify operation of braking system.

11. Verify operation of sensor.
12. Test drive vehicle.
13. Shut engine OFF.
14. Master Power Switch OFF.
15. Set parking brake.
16. Wheels chocked.

3. Sheppard Steering Relief Plunger (Valve) Test



Relief plungers (1) prevent reduce system temperature and excessive stress on the Mechanical components of the steering system. The plungers prevent the axle stops from contacting the axle under full pump pressure. Any time tire size or steering gears are changed; the relief plungers must be adjusted. A relief plunger is located in each end cap of the steering gear. One plunger is located in a small hole in the bearing cap cover next to the input shaft. The other plunger is on the opposite end of the steering gear in a cartridge (2) screwed into the housing. One plunger for right turn; one plunger for left turn.

International® Mine Protected Vehicle (I-MPV) armor parts are heavy. Use care when removing or installing. DO NOT attempt to lift without the aid of an assistant and a suitable lifting device. Failure to comply may result in serious injury or death to personnel.

Hydraulic jacks are intended only for lifting the vehicle and not for supporting the vehicle while performing maintenance. DO NOT get under vehicle after vehicle is raised, unless it is properly supported with blocks or jack stands. Failure to comply may result in injury or death to personnel.

Always have two people when setting plunger: one person to steer the vehicle (with foot on the brake) and, one person to set and check adjustments.

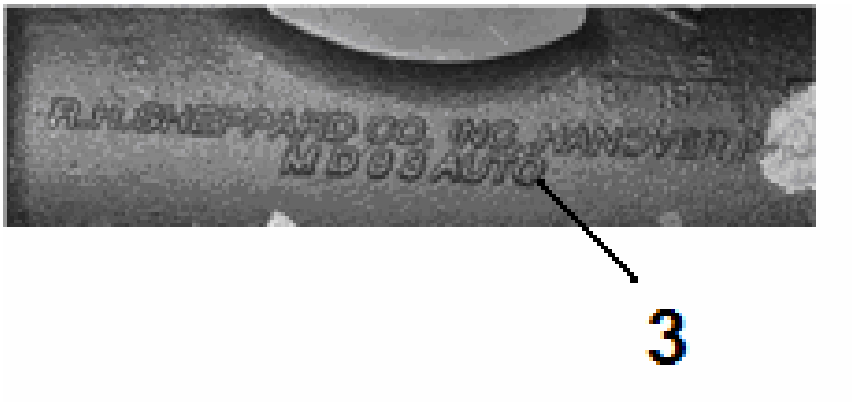
Wear gloves and goggles when lifting and lowering vehicle.

Failure to set or adjust the relief plungers could result in damage to the steering system. Plungers MUST be set or adjusted whenever a steering gear is replaced.

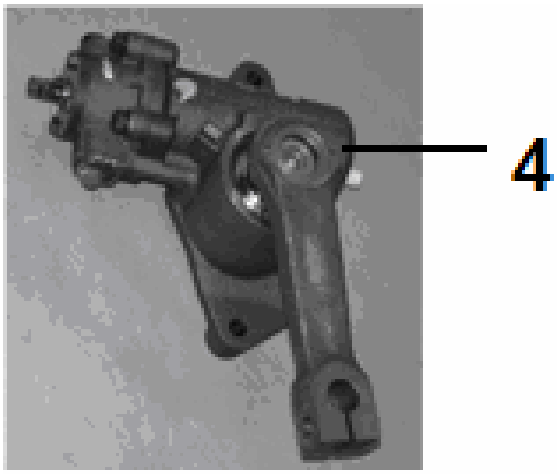
4. Testing

1. Park vehicle on clean, even, dry, concrete in a large, clear area.
2. Using a suitable lifting device and jacks, raise the steer tires off the ground.
3. Start the engine.
4. Allow the engine to IDLE.
5. Make sure the axle stops are set for maximum wheel cut with a minimum of 1” clearance between the tire and any part of the chassis.
6. Set the automatic plungers by turning the steering wheel from side to side until the axle stops contact the axle. This allows the piston in the steering gear to contact the automatic plunger assembly and push it back to its set position. The stops MUST contact the axle.

Automatic plunger gears are identified in two ways:



a. The word AUTO (in raised letters) is cast into the side of the steering gear housing (3).



b. Plastic caps on each end of the gear cover the plunger hole (4).

7. Using the suitable lifting device and jacks, lower the vehicle so the full weight is on the front tires.
8. Turn the steering wheel completely from stop to stop. The chassis should not flex when the steering reaches the end of travel. Normally, there is a small gap between the axle stop and the axle.

9. Reset the automatic plungers by tapping them in with a ¼” punch and hammer until you feel the plunger bottom out in the bore.

NOTE

Be careful not to score the plunger bore. Scoring the bore will cause a leak that cannot be repaired.

10. Make sure the steering wheel is turning within specifications.

5. Follow-On Maintenance

a) Engine ON.
b) Master Power Switch ON.
c) Remove wheel chocks.
d) Test drive vehicle.
e) Verify operation of steering.
f) Engine shut OFF.
g) Master Power Switch OFF.
h) Parking brake set.
i) Chock wheels.

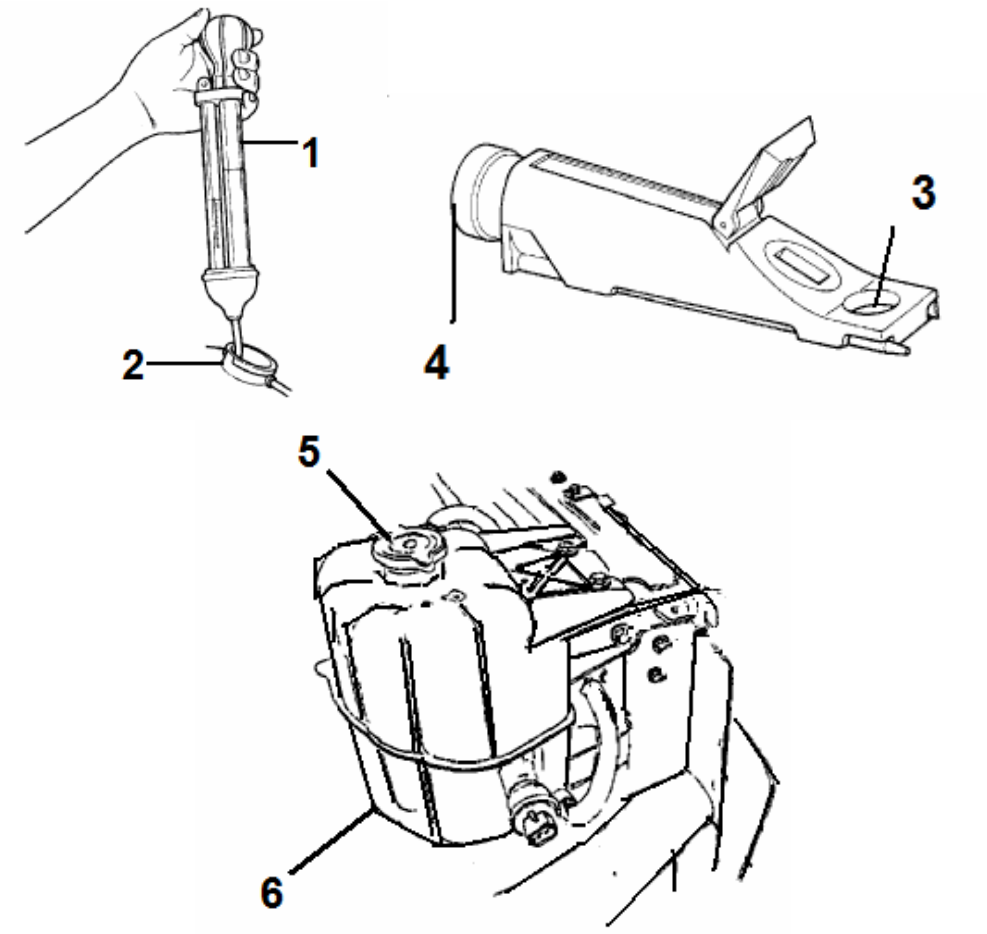
2-21 Extended Coolant Life Test

Engine components become extremely hot during normal operation. Always allow engine to cool completely prior to performing any task or procedures on it. Working in close quarters in engine compartment can be difficult moving around. Wear proper safety equipment; safety goggles, work gloves, long sleeves or shop coat. Failure to comply may result in serious burns, cuts, or injury or death to personnel.

Cooling system components become pressurized and extremely hot during normal operation. Use extreme care when working around hot components. DO NOT open hot radiator cap under pressure, hot coolant can/will spray out. Failure to comply may result in serious injury or death to personnel.

Inadequate concentration of coolant additive can result in major corrosive damage to cooling system components. Over concentration can cause silica-gel to form that can plug passages and cause overheating. Water alone is not an effective or safe coolant for engine components. An approved antifreeze or inhibitor must be added to the water to prevent rust, scale and deposits.

a) Preparation for Test



1. Place a folded shop rag over radiator cap (5). This is done as a precaution for hot coolant spray.
2. If pressurized coolant system, slowly loosen the radiator cap (5) one notch at a time from passenger surge tank (6). This is done to avoid hot coolant spray.
3. Once pressure is released, remove cap (5) and set aside.

b) Test

CAUTION

Readings that are not within specification should be taken care of right away. Too high or too low a percentage solution can severely damage vehicle equipment.

1. With antifreeze (coolant) testing equipment (1) or (4), take sample of coolant in radiator surge tank (5) and check level of extended life.
2. For tester (1) place end (2) into radiator and extract enough into the tester. Read level where float rests.

3. Check reading against chart below.
4. For tester (4) place a few drop from plastic tube included with tester to take sample from radiator surge tank (5) and place in pocket (3). Lift tester up and look through sight to check readings.
5. Check reading against chart below.

Coolant Antifreeze (Ethylene Glycol Based) Percentage Chart		
Freezing Point °F (°C)	Percentage Antifreeze Concentration by Volume	Specific Gravity @ 60°F (16°C)
+32 (0)	**0**	**1.000**
+20 (-7)	**15**	**1.025**
+10 (-12)	**25**	**1.040**
0 (-18)	**33**	**1.053**
-10 (-23)	**40**	**1.062**
-20 (-29)	**45**	**1.070**
-30 (-34)	**48**	**1.074**
-40 (-40)	**53**	**1.080**
-50 (-46)	**56**	**1.088**
-60 (-51)	**59**	**1.092**
-70 (-57)	**62**	**1.095**
-80 (-63)	**65**	**1.097**
-90 (-68)	**67**	**1.098**
-92 (-69)	**68**	
NOTE: **As shown below, a further increase in antifreeze volume raises the freezing point.**		
-80 (-63)	**71**	**1.100**
-70 (-57)	**75**	**1.106**
-60 (-51)	**79**	**1.110**
-50 (-46)	**83**	**1.113**
-40 (-40)	**87**	**1.117**
-30 (-34)	**91**	**1.119**
-18 (-28)	**95**	**1.123**
- 8 (-22)	**100**	**1.127**

c) Follow-On Maintenance

1. Install radiator cap back on surge tank.
2. Tighten cap.
3. Master Power Switch ON.
4. Adjust coolant/antifreeze, if needed.
5. Start engine and run until fan kicks on.
6. Shut engine OFF, let cool, and re-test if adjustment was needed.

2-22 Air Tanks Tests

The reservoir is a storage tank; its function is to provide a volume of compressed air for braking which will be adequate in relation to the volume used by the brake chambers and auxiliary devices. Reservoirs also provide a location in the system where the air, heated by compression, may be cooled and the water vapor condensed.

Operation

The reservoirs in the air brake system primarily serve to store energy in the form of compressed air. They also perform the less obvious function of providing a means of cooling the air as delivered from the compressor and thereby condensing water vapor into a liquid as well as collecting oil passed by the compressor. This water and oil collects as an emulsion: the greatest amount in the reservoir nearest the compressor. It should be drained off either manually or by means of an automatic drain device.

Operation of Integral Check Valve

The integral check valve provides a one-way passage of air from the upstream compartment to the downstream. This check valve serves to meet the requirement for a check valve to protect the service brake system in case of failure in the compressor, discharge lines or first reservoir compartment.

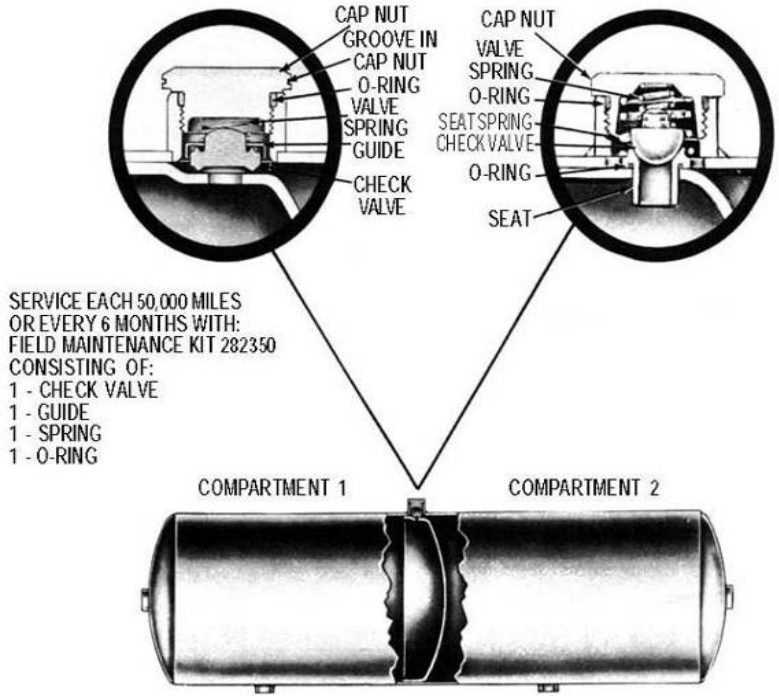
Preventive Maintenance

All reservoirs should be drained daily. If an automatic drain device is used, it should be checked periodically for proper functioning. If an air dryer or aftercooler is used, the reservoirs should be manually drained periodically to verify the proper function of the drying device. Reservoirs, which have collected a considerable oily emulsion, should be drained by opening the drain cock and allowed to drain until all drainage has stopped.

Every six months, 1800 operating hours or 50,000 miles the check valve on the two compartment reservoir should be tested for leakage and damage or deterioration. If signs of leakage or damage are evident, repair or replace as necessary.

Operating and Leakage Test For Two Compartment Reservoir Check Valve

1. Determine the direction of the air flow.
2. Build up system air pressure to governor cut-out and turn the engine OFF.



3. Completely drain compartment #1.

NOTE

It may be necessary to remove automatic drain device if so equipped.

4. To determine pressure retention in #2 compartment, perform one of the following tests:
   a. Check dash air gauges (if connected to the #2 compartment).
   b. Apply service brake (if supplied from the #2 compartment).
   c. Momentarily open drain device on the #2 compartment.

NOTE

Do not completely drain the #2 Compartment.

   d. Apply a soap solution to the drain ferrule #1 compartment. A slight bubble leakage is permitted.

   e. If the #2 compartment fails to hold air pressure or if excessive leakage is evident at the drain ferrule of the #1 compartment, the check valve should be inspected for serviceability and it replaced, if necessary.

2-23 Air Brake System Troubleshooting Tests

Park vehicle on a level surface and chock wheels to prevent movement and then release the parking brake. Build up air tanks to air governor cut-out pressure; stop engine; let air pressure gauges stabilize for one minute, then time the pressure drop on the gauges. Pressure should not drop more that 2 psi per minute. If the gauges do not drop excessively, then the leakage must be from the wet tank (not indicated on gauge) up stream of the service tanks. This is most easily checked by separating lines at various junctions and applying shop air to the system while feeling and listening for leaks. Soapy water and high frequency acoustic detectors may also be helpful.

If vehicle is equipped with an air dryer system, check for information and air leaks for the type of air dryer being serviced. Also, refer to Troubleshooting for other possible causes.

a. **TEST ONE**

1. This test checks the low pressure warnings, pressure buildup and governor cut-out and cut-in.
2. Park the vehicle on flat level surface and chock the wheels.
   a. Drain all reservoirs (air tanks) to 0 psi.
   b. Start the engine and run it at fast idle.
   c. Is the low pressure indicator buzzer working? ( ) OK ( ) Not OK
3. Observe the low pressure warning dash light – does it switch off at or above 60 psi? ( ) OK ( ) Not OK

NOTE

On vehicles with antilock, the ABS indicator lamp will also come on momentarily when the ignition is turned ON.

Troubleshooting: If the low pressure warning light or buzzer does not come on:

a. Check the wiring and/or bulb.
b. Repair or replace the wiring, buzzer, bulb or low pressure indicator switch as needed.

4. Time how long it takes to build air pressure from 85 psi up to 100 psi. Does this take less than 40 seconds? ( ) OK ( ) Not OK

Troubleshooting: If build up time exceeds 40 seconds:

a. Examine the compressor air strainer and clean or replace as needed.
b. Check for a restricted inlet line in the compressor does not have a strainer, repair or replace as necessary.
c. Check compressor discharge port and line for excessive carbon (more than 1/16in. coating). Clean or replace as necessary.
d. With the air brake system charged, engine off and governor compressor in unloaded mode, listen for leakage at the compressor inlet. If leakage can be heard, apply a small amount of oil around the unloader pistons. If no leakage is indicated, then the leakage is through the compressor discharge valves.
e. Check the compressor drive for slippage.

5. Check manufacturer's recommendation for full air tank pressure. Does the governor cut-out at the correct pressure? (Typically between 100-130 psi)
( ) OK ( ) Not OK

   Troubleshooting: If the governor cut-out is higher or lower than specified by the vehicle manual:

   a. For adjustable governors, adjust using a temporarily installed gauge of known accuracy. If the vehicle has a non-adjustable governor, replace it.

   b. See the Service Data sheet for the compressor to verify that the unloader mechanism is operating correctly before replacing governor.

6. Reduce reservoir (air tank) pressure by repeatedly applying the service brakes until the governor cut-in. Is the difference between cut-in and cut-out pressure 25 psi or less? ( ) OK ( ) Not OK

   Troubleshooting: A difference of less than 25 psi indicates a malfunctioning governor. Replace the governor.

   a. Retest to check out all items repaired or replaced.

   b. Make sure of all necessary repairs before proceeding to Test Two.

b. TEST TWO

Air Leakage

1. Inspect for air leaks when working on a vehicle and repair them promptly.
2. Park vehicle on a flat level surface and chock the wheels. Build system pressure to governor cut-out and allow the pressure to stabilize in system for one full minute.

   Step 1: Observe the two dash air gauges located on the right-hand side of the instrument cluster for an additional two minutes without the service brakes applied.

   Step 2: Apply the service brakes and allow the pressure to stabilize. Continue holding the service brake for two minutes. Observe the dash air gauges.

3. If you see a decrease of the dash air gauge readings of more than: 4 psi for either service reservoir, during either two minute test, repair leaks and repeat this test to confirm that the air leaks have been repaired.

NOTE

A leak detector or soap solution will aid in locating the leak.

4. Air leaks can also be found in the charging system, parking brakes, and/or other components (e.g. supply lines and fittings, low pressure indicator, relay valves, antilock modulators, dual brake valves, park control valves, spring brake actuators, safety valve in supply reservoir, governor, compressor discharge valves) – inspect and repair as necessary.
5. Retest to check out all items repaired or replaced.
6. Make sure of all necessary repairs before proceeding to Test Three.

c. TEST THREE

Brake Chamber Push Rod Travel

Check brake chamber push rod travel. (Refer to chart for allowable tolerances)

Brake Chamber Size	Maximum Stroke Before Readjustment
12	1 1/8”
16	1 3/4”
20	1 3/4”
24	1 3/4”
30	2”

The angle formed between the brake chamber push rod and the slacker arm should be approximately 90° with an 80-90 psi brake application (as measured with a test gauge either at the control gladhand or at the brake valve primary delivery). If the angle between the brake chamber push rod and the slack adjuster arm is not approximately 90°, then adjust slack adjuster arm to obtain desired setting. If the brake chamber push rod travel exceeds the allowable tolerance, then adjust the adjuster arm to obtain the desired setting.

Retest to check out all items repaired or replaced.

Make sure of all necessary repairs before proceeding to Test Four.

d. TEST FOUR

Parking Brake Application

Check with completely full air system pressure and engine idling between 600-900 rpm.

1. Manually operate the park control valve and note that parking brakes apply and release promptly as the control valve button is pulled out and pushed in.

   If sluggish performance is noted in test, check for:

   a. Dented or kinked lines.
   b. Improperly installed hose fitting.
   c. A faulty relay emergency valve.
   d. A faulty modulator.

2. Retest to check out all items repaired or replaced.
3. Make sure of all necessary repairs before proceeding to Test Five.

e. TEST FIVE

Automatic Emergency System

Check with air system at full pressure and the engine in the OFF position.

1. Drain front axle reservoir to 0 psi.
    a. Rear axle reservoir should not lose pressure.
    b. On combination vehicles, the trailer air system should remain charged.
    c. Tractor and trailer brakes should not apply automatically.
2. With no air pressure in the front axle reservoir, make a brake application.
    a. Rear axle brakes should apply and release.
    b. On combination vehicles, the trailer brakes should also apply and release.
    c. The stop lamps should illuminate.
3. Slowly drain rear axle reservoir pressure.
    a. With the button out, supply either supply port with 120 psi of air. Then push the button in. The air pressure should rise in the delivery volume equivalent to supply pressure. Pull the button out. The delivery pressure should exhaust to 0 psi. Build each supply source to 120 psi and decrease supply pressure at the secondary service reservoir supply port at a rate of 10 psi per second. Primary supply pressure and delivery pressure should not drop below 100 psi. Repeat the test for decreasing primary service reservoir pressure. Build each supply source to 120 psi. Then decrease both supply pressures to below 20 – 30 psi. The button should automatically “POP” out when the pressure drops within the range.
    b. The tractor protection valve should close between 45 psi and 20 psi and the trailer supply hose should be exhausted.
    c. Trailer brakes should apply after tractor protection closes.
4. Slowly drain the rear axle reservoir pressure.
5. Close drain cocks, recharge the system and drain the rear axle reservoir to 0 psi.
    a. Front axle reservoir should not lose pressure
    b. On combination vehicles, the trailer air system should remain charged.

6. With no air pressure in the rear axle reservoir, make a brake application.
   a. The front axle brakes should apply and release.
   b. On combination vehicles, the trailer brakes should also apply and release.
   c. If the vehicle is equipped with an inverting relay spring brake control valve, the rear axle brakes should also apply and release.
7. If the vehicle fails to pass any of the tests above, check the following components for leakage, proper installation and proper operation:
   a) Fittings.
   b) For kinked hoses or tubing.
   c) Single check valves.
   d) Double check valves.
   e) Tractor protection valve.
   f) Tractor protection control valve.
   g) Parking control valve.
   h) Relay valves (antilock modulators).
   i) Trailer spring brake control valve.
   j) Inverting relay spring brake control valve (optional).
   k) Retest to check-out all items repaired or replaced.

2-24 Fire Suppression System (FSS) Fault Diagnostics

Operation Panel for Fire Suppression System

Engine system

SYMPTOM	CAUSE	SOLUTION
Light on operation panel is on	Engine Fire Extinguisher is empty	Replace the extinguisher
	Low pressure on the Engine Fire Extinguisher	Replace the extinguisher
	Harness connector is not connected to cylinder Connector	Clean the connectors with air pressure and connect them again
	Harness connector is not plugged correctly into cylinder Connector	Connect the connector correctly
	Harness is broken	Replace the Harness

Tires System

SYMPTOM	CAUSE	SOLUTION
Light on operation panel is on	Engine Fire Extinguisher is empty	Replace the extinguisher
	Low pressure on the Engine Fire Extinguisher	Replace the extinguisher
	Harness connector is not connected to cylinder Connector	Clean the connectors with air pressure and connect them again
	Harness connector is not plugged correctly into cylinder Connector	Connect the connector correctly
	Harness is broken	Replace the Harness

Body System

SYMPTOM	CAUSE	SOLUTION
Light on operation panel is on	Engine Fire Extinguisher is empty	Replace the extinguisher
	Low pressure on the Engine Fire Extinguisher	Replace the extinguisher
	Harness connector is not connected to cylinder Connector	Clean the connectors with air pressure end connect them again
	Harness connector is not plugged correctly into cylinder Connector	Connect the connector correctly
	Harness is broken	Replace the Harness

Fuel Tank System

SYMPTOM	CAUSE	SOLUTION
Light on operation panel is on	Engine Fire Extinguisher is empty	Replace the extinguisher
	Low pressure on the Engine Fire extinguisher	Replace the extinguisher
	Harness connector not connected to cylinder Connector	Clean the connectors with air pressure end connect them again
	Harness connector not plugged correctly into cylinder Connector	Connect the connector correctly
	Harness is broken	Replace the Harness

Cabin System

SYMPTOM	CAUSE	SOLUTION
Light on operation panel is on	Engine Fire Extinguisher is empty	Replace the extinguisher
	Low pressure on the Engine Fire Extinguisher	Replace the extinguisher
	Harness connector is not connected to cylinder Connector	Clean the connectors with air pressure and connect them again
	Harness connector is not plugged correctly into cylinder Connector	Connect the connector correctly
	Harness is broken	Replace the Harness

Main System

SYMPTOM	CAUSE	SOLUTION
Light on operation panel is off	24 V switch is off	Turn the ON-OFF / Fuse switch ON
	Automatic Fuse tripped	Turn the ON-OFF / Fuse switch on
	Connectors are not plugged correctly into the Control Panel	Plug the connectors correctly

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Chapter 3 - PMCS MAINTENANCE INSTRUCTIONS

3-1 Intervals

a. Unit maintenance, assisted by operator/crew, will perform the checks and services contained in table 2-1 at the following intervals:

(1) **Semiannual**. Every 6 months or 6,000 miles (9,654 kilometers), whichever occurs first.

(2) **Annual**. Every 12 months or 12,000 miles (19,308 kilometers), whichever occurs first.

(3) **Biennial**. Every 24 months or 23,000 miles (38,616 kilometers), whichever occurs first.

b. Perform all semiannual inspections, in addition to annual inspections, at the time of the annual inspection. Perform all annual and semiannual inspections, in addition to biennial inspections, at the time of the biennial inspection.

3-2 Reporting Repairs

All uncorrected defects will be recorded on Equipment Inspection and Maintenance Worksheet, DA form 5988E, in accordance with DA Pam 738-750.

3-3 General Service and Inspection Procedures

a. While performing specific PMCS procedures, ensure items are correctly assembled, secure, serviceable, not worn, not leaking, and adequately lubricated as defined below:

(1) An item is CORRECTLY ASSEMBLED when all parts are present and in proper position.
(2) When wires, nuts, washers, hoses, or attaching hardware cannot be moved by hand, wrench, or pry bar, they are secure.
(3) An item is UNSERVICEABLE if it is worn beyond established wear limits or is likely to fail before the next scheduled inspection.
(4) An item is WORN if there is play between joining parts, or warning and caution plates are not readable.
(5) LEAKS. The Operators Manual contains definitions of class I, II, and III leaks and their effect on vehicle operation.

b. Where the instruction “tighten” appears in a procedure, you must tighten with a wrench to the given torque value even when the item appears to be secure.

Drycleaning solvent is flammable and will not be used near open flame. Keep fire extinguisher nearby. Use only in well-ventilated places. Failure to do so may result in injury to personnel.

c. Where the instruction “clean” appears in a procedure, you must use drycleaning solvent, Type II (SD-2) (PD-680) biodegradable, to clean grease or oil from metal parts. After the item is cleaned, rinsed, and dried, apply a light grade of oil to unprotected surfaces to prevent rusting. To clean rubber and plastic materials, use soap and water.

3-4 Specific PMCS Procedures

a. The preventive maintenance checks and services for which you are responsible are provided in table 3-1. The checks and services listed area arranged in logical order.

b. The following columns are left to right on the PMCS schedule:

(1) **Item Number.** Provides logical order for PMCS performance and is used as a source number for DA Form 5988E, on which your PMCS results will be recorded.

(2) **Interval.** Indicates when check or service is to be performed.

(3) **Item to Check/Service.**

a. Lists the system, common name, or location of the item to be inspected.
b. The letters RPL in this column indicate replacement parts are required to complete the task or procedures.

(4) **Procedure**. Provides instructions for servicing, inspection, replacement, or equipment and, in some cases, having an item repaired at a higher level. If a defect is found, repair fill, remove, or adjust as needed.

(5) **Not Fully Mission Capable.** Provides information for dead lining a vehicle when checks or services reveal a defect or deficiency of a component(s) of the vehicle.

Table 3-1. Unit Preventive Maintenance Checks and Services

ITEM NO.	INTERVAL	ITEM TO CHECK/ SERVICE	PROCEDURE	NOT FULLY MISSION CAPABLE
1	Semi-annual		**ROAD TEST** Perform all During operation checks listed in PMCS in addition to those that follow. Drive vehicle at least 5 mi. (8 km) over varied terrain, both on and off road. This will provide ample time to check reported malfunctions and to locate unreported malfunctions. Lubrication intervals of every 1,000 mi. (1,600 km) or monthly, and 3,000 mi. (4,800 km) or 3 months, will be performed with maintenance or, when practical, lubrication services will be made to coincide with the semiannual preventive maintenance services. For this purpose, a 10 percent tolerance (variation) in specified lubrication point mileage is permissible.	
2	Semi-annual	Brakes	a. Check brake pedal for free travel. Adjust brake pedal if required. b. Reach a desired speed and lightly apply brake pedal with steady force. Vehicle should slow down immediately and stop smoothly, without side pull or chatter. c. After stopping vehicle, and with transmission select lever in 1-5 (drive), release brake pedal. All wheel brakes should release immediately and without difficulty.	
3	Semi-annual	Engine	a. Check engine throughout the range of operating speeds. b. Check engine instruments.	
4	Semi-annual	Trans-mission	a. Check transmission oil temperature gauge. Normal range is 120°-250°F (49°-104°C). b. Check for response to shifting and smoothness of operation in all speed ranges.	a. Oil temperature exceeds 300°F (149°C).
5	Semi-annual	Transfer Case	Shift transfer case to button, on 6-pack located center dash, between HI and LOW positions to ensure proper operations. Observe for smoothness of engagements.	
6	Semi-annual	Suspension	Observe how vehicle responds to road shock. Constant bouncing or swaying from side-to-side is an indication of a malfunction.	

Table 3-1. Unit Preventive Maintenance Checks and Services (Continued)

ITEM NO.	INTERVAL	ITEM TO CHECK/ SERVICE	PROCEDURE	NOT FULLY MISSION CAPABLE
7	Semi-annual	Air Filter	 **If NBC exposure is suspected, all filter media should be handled by personnel wearing protective equipment. Consult your unit NBC officer or NBC NCO for appropriate handling or disposal instructions.** a. Inspect filter element for tears and presence of dirt and oil. 1. If dirt is present, clean filter element. 2. If oil is present, replace filter element.	
8	Semi-annual	Batteries	 **Wear safety glasses or goggles when checking batteries. Always check electrolyte level with engine stopped. Do not smoke or use exposed flame when checking batteries; explosive gases are present, and severe injury to personnel can result.** **Remove all jewelry such as rings, dog tags, bracelets, etc. If jewelry contacts battery terminal, a direct short may result in instant heating of tools, damage to equipment, and injury or death to personnel.** **Remove or disconnect batteries in proper sequence and turn master Master Power switch off prior to performing maintenance in immediate area or working on electrical system. Such disconnects prevent electrical shock to personnel and equipment.** a. Clean and inspect batteries. Replace if required. b. Inspect battery box for security of mounting and completeness of assembly. c. Inspect battery cables and terminals for frays, splits, and security. Repair battery cables or terminals or replace as necessary.	

Table 3-1. Unit Preventive Maintenance Checks and Services (Continued)

ITEM NO.	INTERVAL	ITEM TO CHECK/ SERVICE	PROCEDURE	NOT FULLY MISSION CAPABLE
8	Semi-annual	Batteries-Continued	d. Inspect slave receptacle and wiring for security of mounting and damage. Repair or replace if damaged. f. Lightly coat battery terminals and slave receptacle contacts with grease.	
9	Semi-annual	Cab Components	a. Open cab door. Lubricate door hinge every 1,000 mi. (1,600 km) or monthly, whichever occurs first.	
10	Semi-annual	Front Winch	a. Inspect winch for security of mounting, loose or missing mounting bolts, and broken or missing parts. **WARNING** **Wire rope can become frayed or contain broken wires. Wear heavy leather-palmed work gloves when handling wire rope. Frayed or broken wires can injure hands.** **Never let moving wire rope slide through hands, even when wearing gloves. A broken wire could cut through glove and cut hand.** b. Unwind entire cable, lubricate with GAA, and inspect for kinks, frays, and wear.	
11	Semi-annual	Compressed Air Systems	a. Inspect front emergency and service air couplings for serviceability and seals. **NOTE** Inspection of emergency and service air lines and fittings will be accomplished over complete vehicles. Tighten, repair, and/or replace components of these compressed air systems as required. If maintenance is required at a higher level, records should reflect closest point of reference to ensure proper identification of components requiring service. b. Inspect air lines and fittings for security of mounting, tightness of connections, and damage that could cause air leaks.	

Table 3-1. Unit Preventive Maintenance Checks and Services (Continued)

ITEM NO.	INTERVAL	ITEM TO CHECK/ SERVICE	PROCEDURE	NOT FULLY MISSION CAPABLE
12	Semi-annual	Frame and Crossmembers	Inspect crossmembers for missing bolts and obstructions to other components, and breaks. **NOTE** Inspection of crossmembers, bolts, and rivets will be accomplished over complete vehicle. Tighten, repair, and/or replace components of the frame as required. If maintenance is required at a higher level, records should reflect closest point of reference to ensure proper identification of components requiring service.	
13	Semi-annual	Front Wheels, Hubs, and Drums	**FRONT WHEELS, HUBS, DRUMS, BRAKES, SPRINGS, AXLE, AND STEERING**  **Use caution when inflating tires. Ensure tire is in a tire cage and properly seated on rim before inflating. An improperly seated tire can burst with explosive force. Failure to comply can cause death or serious injury to personnel.** **Do not work on any component supported only by lift jacks or hoist. Always use blocks or proper stands to support the component prior to any work. Equipment may fall and cause injury or death to personnel.** **NOTE** Similar left and right side components are inspected in the same manner and will be accomplished simultaneously. Procedures cover left side only. When documenting discrepancies for similar left and right side components, indicate which side is affected. a. Inspect axle drive yokes for oil leaks. If oil appears to be leaking from axle drive yokes, notify your supervisor.	

Table 3-1. Unit Preventive Maintenance Checks and Services (Continued)

ITEM NO.	INTERVAL	ITEM TO CHECK/ SERVICE	PROCEDURE	NOT FULLY MISSION CAPABLE
13	Semi-annual	Front Wheels, Hubs, and Drums	b. Clean, inspect, and lubricate axle shaft and universal joints.  **Do not allow grease or oil to contact brake linings. Linings can absorb grease and oil, causing early glazing and very poor braking action. Failure to comply could cause serious injury or death to personnel.** c. Check brakeshoes for condition and brakeshoe-to-drum clearance. Replace brakeshoes if worn beyond brake adjustment.	
14	Semi-annual	Air Lines and Brake Chambers	a. Inspect front service brake air lines and fittings for loose connections, cracks, splits, or damage that could cause potential air leaks. Tighten loose air lines and fittings connections, and replace any air line or fitting that has cracks, splits, or damage that could cause potential air leaks. b. Inspect front service brake chambers for condition and security of mounting. Replace a service brake chamber that is damaged, defective, or inoperative.	
15	Semi-annual	Steering System	a. Inspect steering knuckles, steering gear, tie rod assembly, steering arms, drag link, pitman arm, and lower steering gear shaft for breaks, cracks, rust, wear, and signs of damage and/or unserviceable condition. 1. Treat for corrosion of steering knuckles, tie rod assembly, steering arms, drag link, pitman arm, or steering gear shaft. 2. Replace tie rod assembly, drag link, pitman arm, lower steering gear shaft, or power steering cylinder if broken, cracked, worn, or signs of an unserviceable condition are present. 3. If steering knuckles, steering arms, or steering gear are broken, cracked, worn, or have other signs of an unserviceable condition repair/replace as needed.	

Table 3-1. Unit Preventive Maintenance Checks and Services (Continued)

ITEM NO.	INTERVAL	ITEM TO CHECK/ SERVICE	PROCEDURE	NOT FULLY MISSION CAPABLE
15	Semi-annual	Steering System - Continued	**NOTE** Lubricate grease fittings every 3,000 mi. (4,800 km) or 3 months, whichever occurs first. When practical, lubrication services will be made to coincide with the semiannual preventive maintenance service. For this purpose, a 10 percent tolerance (variation) in specified lubrication point mileage is permissible. b. Lubricate at steering knuckle grease fittings, tie rod assembly grease fittings, steering shaft grease fittings, drag link grease fittings, and front left and right slack adjuster grease fittings. **NOTE** An assistant is required to perform the following step. c. Inspect steering stops for presence and security. If any stop is missing or has broken welds, notify DS maintenance. d. With engine shut off, turn steering wheel slowly right and left. 1. Inspect steering gear while steering wheel is rotated. 2. Check for free play between steering knuckles and tie rod ends, drag link and pitman arm to drag link If free play is present, tighten steering knuckle nuts and drag link-to-pitman arm nut to 120-160 lb-ft (163-218 N•m). Tighten to minimum torque and continue to tighten as needed to align slot in nut and cotter pin hole. 3. Inspect hydraulic hoses and fittings behind armor and cylinder for loose connections, cracks, splits, or damage that could cause hydraulic leaks. Tighten hydraulic lines and fittings connections. Replace any hydraulic lines and fitting that has cracks, splits, or damage that could cause hydraulic leaks.	

Table 3-1. Unit Preventive Maintenance Checks and Services (Continued)

ITEM NO.	INTERVAL	ITEM TO CHECK/ SERVICE	PROCEDURE	NOT FULLY MISSION CAPABLE
15	Semi-annual	Steering System - Continued	e. Inspect power steering pump for security of mounting, leaks, and signs of damage. Tighten loose mounting hardware. f. Inspect power steering pressure and return hoses and fittings for loose connections, cracks, splits, or damage that could cause potential hydraulic leaks. Tighten loose hydraulic lines and fittings, and replace any hydraulic line or fitting that has cracks, splits, or damage that could cause potential hydraulic leaks. g. Inspect steering gear for security of mounting and signs of leaks. 1. Tighten steering gear mounting locknuts to 350 lb-ft (474 N•m). 2. Tighten tie-rod locknuts 160-215 lb-ft (217-292 N•m).	
16	Semi-annual	Front Springs, Propeller Shaft, Universal and Slip Joints, and Axle	a. Inspect axle for security of mounting on springs. Tighten nuts on spring U-bolts 260-300 lb-ft (353-407 N•m). b. Inspect springs and shackles for cracks, breaks, and security of mounting. Tighten spring shackle mounting nuts 325-400 lb-ft (441-543 N•m). **CAUTION** **Wipe fittings clean before servicing to prevent damage to shackle pins and bushings.** c. Lubricate spring U-bolts and shackles every 3,000 mi. (4,800 km) or 6 months, whichever occurs first. 1. Inspect front spring bolts and bushing at both ends of shackle.	

Table 3-1. Unit Preventive Maintenance Checks and Services (Continued)

ITEM NO.	INTERVAL	ITEM TO CHECK/ SERVICE	PROCEDURE	NOT FULLY MISSION CAPABLE
16	Semi-annual	Front Springs, Propeller Shaft, Universal and Slip Joints, and Axle - Continued	**NOTE** Lubrication of universal and slip joints will be accomplished while performing other inspection tasks in that same area. Tighten, repair, and/or replace components of universal, slip joints, and propeller shafts when found to be damaged or worn, as required. If maintenance is required at a higher level, records should reflect closest point of reference to ensure proper identification of components requiring service. d. Lubricate universal slip joints on transfer case-to-front axle propeller shaft adapter every 3,000 mi. (4,800 km) or 3 months, whichever occurs first. e. Inspect universal and slip joints on transfer case-to-front axle propeller shaft for damage or worn components. Replace worn components. **CAUTION** **Breathers and axle around breathers must be wiped clean before servicing to prevent damage to axle from contamination**. f. Remove, clean, and lubricate axle breathers every 1,000 mi. (1,600 km) or monthly, whichever comes first. g. Remove differential fill plug and check oil level in differential every 3,000 mi. (4,800 km) or 3 months, whichever occurs first. Fill if necessary. Level should be within ½ in. (12.7 mm) from hole of fill plug when oil is cold, and to the hole of fill plug when hot. h. Inspect differential drainplug and fill plug for tightness and signs of leakage. Tighten drainplug 35-50 lb-ft (48-67 N•m) and fill plug 35-50 lb-ft (48-67 N•m).	

Table 3-1. Unit Preventive Maintenance Checks and Services (Continued)

ITEM NO.	INTERVAL	ITEM TO CHECK/ SERVICE	PROCEDURE	NOT FULLY MISSION CAPABLE
17	Semi-annual	Underside of Engine and Transmission	i. Inspect underside of engine for fuel, water, and oil leaks. j. Inspect oil pan and drainplug for leaks. If oil pan is loose or if leaks are present, tighten oil pan screws to 24 lb-ft (32 N•m). If drainplug is loose or if leaks are present, tighten drainplug 50 lb-ft (68 N•m). Notify your supervisor if leaks still occur. k. Inspect transmission body for cracks or loose bolts that could cause leaks.	
18	Semi-annual	Cooling System	a. Inspect coolant lines, hoses, and fittings for loose connections, cracks, frays, wear, and damage that could cause leaks. Tighten loose connections. Replace any oil line, hose, or fitting that is cracked, frayed, worn, or damaged and could cause leaks. b. Inspect air hoses and fittings for loose connections, cracks, frays, wear, and damage that could cause leaks. Tighten loose connections. Replace any air line, hose, or fitting that is cracked, frayed, worn, or damaged and could cause leaks. c. Inspect radiator core for clogged or bent fins, leaks, and protruding debris. Clean clogged core and remove debris. d. Inspect water pump pulley and fan for play. e. Check drivebelt(s) for proper tension. f. Inspect fan blade for security, breaks, and damage which could cause an out-of-balance condition. g. Inspect surge tank, water manifold, thermostat housing, radiator, engine oil cooler, and hoses for leaks, condition, and security of mounting(s). h. Inspect coolant temperature sensor for mounting & leaks. Inspect sending unit wiring for frays, splits, breaks, and worn or missing insulation.	

Table 3-1. Unit Preventive Maintenance Checks and Services (Continued)

ITEM NO.	INTERVAL	ITEM TO CHECK/ SERVICE	PROCEDURE	NOT FULLY MISSION CAPABLE
19	Semi-annual	Air Compressor	a. Check compressor for security of mounting and leaks. b. Check condition and security of cooling lines to air compressor. Tighten cooling lines, if loose. Replace cooling lines if split, cracked, or damaged in such a manner as to cause leaks. c. Check condition of compressor oil line and fittings. Tighten fittings and oil line if loose. Replace oil line if split, cracked, or damaged in such a manner as to cause leaks. d. Check condition and security of input tube and hoses, output air line, and governor control air line. Tighten output and governor control air lines, if loose. Replace input tube or hoses if split, cracked, collapsed, distorted, or damaged in such a manner as to prevent a tight seal or restrict incoming air.	
20	Semi-annual	Engine Lubrication System and Oil Lines	a. Inspect all engine oil lines, hoses, and fittings for loose connections, cracks, frays, wear, and damage that could cause leaks. Tighten loose connections, and replace any oil lines, hoses, and fittings that are cracked, frayed, worn, or damaged and could cause leaks. **NOTE** Oil filter is located on lower right side of engine. b. Inspect vehicles for security of oil filter housing. Ensure filter center bolt is tight. If center bolt is loose, tighten to 19 lb-ft (26 N•m). c. Inspect vehicle for security of oil filter head. Ensure spin-on oil filter is tight. If spin-on oil filter is loose, hand-tighten, then tighten an additional ¾ turn with a wrench. d. Check engine oil and dipstick for metal particles. Notify supervisor if metal particles are found.	

Table 3-1. Unit Preventive Maintenance Checks and Services (Continued)

ITEM NO.	INTERVAL	ITEM TO CHECK/ SERVICE	PROCEDURE	NOT FULLY MISSION CAPABLE
20	Semi-annual	Engine Lubrication System and Oil Lines - Continued	**NOTE** **Accidental or intentional introduction of liquid contaminants into the environment is in violation of state, federal, and military regulations. Refer to Army POL for information concerning storage, use, and disposal of these liquids.** e. Collect engine oil sample or change oil as required. f. Inspect valve cover(s) and gasket(s) for evidence of leaks.	
21	Semi-annual	Fuel System Engine	**NOTE** Replace fuel filter every Semi-Annual Service and Annual Service. a. Inspect fuel filter/water separator mounting and housing for dents and cracks, and damage to inlet, outlet, and bleeder fittings that could cause leaks. b. Inspect fuel lines for tightness of connections. c. Check fuel system components. 1. Inspect fuel injector lines, injector pump lines, and manifold line and screws for leaks and damage. Tighten fuel injector lines, injector pump lines, and manifold line and screws if leaking, and replace if damaged. 2. Inspect injector line holddown bolts for security of mounting. If loose, tighten. d. Check fuel priming pump or fuel priming/transfer pump for security of mounting and proper operation.	
22	Semi-annual	Engine Compartment Electrical Wiring	Inspect all engine compartment wiring for frays, splits, missing or damaged insulation, or poor connections. Repair or replace affected wiring.	

Table 3-1. Unit Preventive Maintenance Checks and Services (Continued)

ITEM NO.	INTERVAL	ITEM TO CHECK/ SERVICE	PROCEDURE	NOT FULLY MISSION CAPABLE
23	Semi-annual	Fuel Lines and Tank	a. Inspect fuel tank for dents, cracks, and broken welds that could cause leaks. b. Visually inspect fuel ICP Sensor and wiring for loose connections, presence, frays, splits, and missing insulation. Repair or replace wiring that is missing or shows signs of frayed, split, or missing insulation. Tighten loose connections. c. Visually inspect tube(s) and hose(s) at fuel tank for loose connections, cracks, and splits. Replace fuel tank tube(s) and hose(s) that are cracked or split. Tighten loose fuel tank tube(s) and hose(s) connections.	
24	Semi-annual	Transmission and Transfer Case	 **If transmission oil temperature is above 220°F (104°C), allow transmission oil to cool before removing dipstick.** **Accidental or intentional introduction of liquid contaminants into the environment is in violation of state, federal, and military regulations. Refer to Army POL (para. 1-8) for information concerning storage, use, and disposal of these liquids. Failure to do so may result in injury or death.** **CAUTION** **Do not remove transmission dipstick before cleaning dirt away from access plate, filler tube, and dipstick. Dirt may enter and damage transmission.** **Do not overfill transmission. Internal transmission component damage will result.** **Change transmission oil when contamination by fuel, water, or other foreign material is evident. Failure to do so may result in failure of internal transmission components.**	

Table 3-1. Unit Preventive Maintenance Checks and Services (Continued)

ITEM NO.	INTERVAL	ITEM TO CHECK/ SERVICE	PROCEDURE	NOT FULLY MISSION CAPABLE
24	Semi-annual	Transmission and Transfer Case - Continued	a. Inspect transmission, dipstick, and oil. 1. Check for evidence of metal particles. Notify your supervisor if metal particles are found. 2. Check for evidence of dilution by coolant. If oil is diluted by coolant, notify your supervisor. 3. Check oil level in transmission. If oil levels are excessive, drain excess. b. Inspect transmission oil lines, hoses and fittings for loose connections, cracks, frays, wear, and damage that could cause leaks. Tighten loose connections if any oil line, hose, or fitting is cracked, frayed, worn, or damaged and could cause leaks. c. Inspect transmission oil level sending unit for security and signs of leaks, and wiring for frays, splits, breaks, and missing insulation. Tighten oil level sending unit if loose or leaking. Replace if necessary. Repair or replace wiring that is missing, or shows signs of frayed, split, or missing insulation. Tighten loose connections. d. Inspect for security of mounting and leaks. Notify your supervisor if mounting is loose or leakage is present. e. Remove transfer case fill plug and check oil level in transfer case every 3,000 mi. (4,800 km) or 3 months, whichever comes first. Fill as necessary. Level should be within ½ in. (12.7 mm) from fill hole when oil is cold, or to the fill hole when hot. f. Inspect transfer case drainplug and fill plug for tightness and signs of leakage. Tighten fill plug & drain plug to 35-50 ft-lb (47-68 N•m). g. Inspect transfer case for leaks. Notify your supervisor if leaks are detected.	

Table 3-1. Unit Preventive Maintenance Checks and Services (Continued)

ITEM NO.	INTERVAL	ITEM TO CHECK/ SERVICE	PROCEDURE	NOT FULLY MISSION CAPABLE
24	Semi-annual	Transmission and Transfer Case - Continued	1. Inspect for security of mounting and leaks. 2. Inspect oil and air lines and fittings on transfer case for loose connections, cracks, frays, wear, and damage that could cause leaks. Tighten loose connections. Replace any oil or air line, hose, or fitting that is cracked, frayed, worn, or damaged and could cause leaks. 3. Inspect hydraulic pump for security of mounting, leaks, and sign of damage that could cause leaks. Tighten mounting of hydraulic pump. 4. Inspect hydraulic lines and fittings for loose connections, cracks, frays, wear, and damage that could cause leaks. Tighten loose connections. Replace any oil line, hose, or fitting that is cracked, frayed, worn, or damaged and could cause leaks. 5. Check transfer oil cooler for damage and leaks.	
25	Semi-annual	Air Intake Tubes	a. Inspect vent lines for serviceability and security of connections. b. Inspect air intake piping and air cleaner assembly for condition and security of mountings. c. Test air cleaner indicator for proper operation.	
26	Semi-annual	Rear Wheels and Hubs, and Suspension	**NOTE** Similar left and right side components are inspected in the same manner and will be accomplished simultaneously. a. Clean, inspect, and lubricate inner and outer rear wheel bearings. b. Inspect service and service/spring brake air lines and fittings for loose connections, cracks, splits, or damage that could cause air leaks. Tighten loose air lines and fittings and replace any air line or fitting that has cracks, splits, or damage that could cause air leaks.	

Table 3-1. Unit Preventive Maintenance Checks and Services (Continued)

ITEM NO.	INTERVAL	ITEM TO CHECK/ SERVICE	PROCEDURE	NOT FULLY MISSION CAPABLE
26	Semi-annual	Rear Wheels and Hubs, and Suspension - Continued	c. Check brakeshoe-to-drum clearance and condition of brakeshoes. If clearance is more than 0.020 in. manually adjust brakes or notify your supervisor of inoperative adjusters. Replace brakeshoes if worn beyond chamfer on linings. d. Inspect service brake chambers for condition and security of mounting. Replace service brake chambers and/or component parts if condition could impair operation of brakes. e. Inspect service/spring brake chambers for condition and security of mounting. Replace service/spring brake chambers and/or component parts if condition could impair operation of brakes. f. Inspect rear modules for condition and security of mounting and air lines and fittings for loose connections. Replace rear module valves and/or component parts if condition could impair operation of ABS system. Tighten loose air lines and fittings. g. Inspect air lines and fittings for loose connections, cracks, splits, or damage that could cause air leaks. Tighten loose air lines and fittings. h. Visually inspect spring leaves for cracks, breaks, and security of mounting. Replace spring leaves, if cracked or broken. Secure mounting, if loose. i. Tighten nuts on spring U-bolts 260-300 lb-ft (353-407 N•m). **CAUTION** **Clean breathers and axle around breathers before servicing to prevent damage to axle from contamination**. j. Inspect differential seals for leaks.	
27	Semi-annual	Towing Pintle and Glad Hand Connections	Lubricate towing pintle every 3,000 mi. (4,800 km) or 3 months, whichever occurs first.	

Table 3-1. Unit Preventive Maintenance Checks and Services (Continued)

ITEM NO.	INTERVAL	ITEM TO CHECK/ SERVICE	PROCEDURE	NOT FULLY MISSION CAPABLE
28	Semi-annual	Glad Hand and Air Lines	a. Inspect emergency and service air and dummy couplings for serviceability and tightness of seal. Replace emergency or service air or dummy coupling(s) that are broken, bent, cracked, or have seals that leak. b. Inspect emergency and service air lines and fittings for security of mounting, tightness of connections, and damage that could cause air leaks.	
29	Semi-annual	Rear Lighting and Trailer Receptacle	Inspect rear lights, trailer receptacle, and wiring for damage. Repair if damaged.	
30	Semi-annual	Hydraulic Ramp Oil Tank Level	**FINAL ROAD TEST** **After all services and inspections have been completed, perform a short road test to ensure all corrections have been implemented. Correct any defects or malfunctions that may occur during this test.** **ANNUAL INSPECTION** **NOTE** Perform all semi-annual checks listed in this table. a. Unscrew cap and visually check level. Fill as needed.	
31	Annual	Front End	a. Check front end alignment with toe-in gauge. Correct toe-in is 1/16-3/16 in. (1.588-4.763 mm). When toe-in is correct, tighten cross shaft and nuts 160-215 lb-ft. b. Inspect axle housings and differential for cracks. c. Inspect shock absorbers and mounting brackets for looseness, wear, cracks, serviceability, and leaks. Replace leaking shock absorbers if more than a class I leak is detected.	

Table 3-1. Unit Preventive Maintenance Checks and Services (Continued)

ITEM NO.	INTERVAL	ITEM TO CHECK/ SERVICE	PROCEDURE	NOT FULLY MISSION CAPABLE
31	Annual	Front End - Continued	d. Check each tire using tire depth gauge. Tread depth should at least 1/8 in. (3 mm) or as indicated on tire depth gauge.	
32	Annual	Engine Compartment and Cab	a. Inspect front & rear cab mounting brackets for security, wear, cracks, splits, broken welds, and missing bolts. Replace front cab mounting brackets if worn, cracked, split, or welds are broken.	
33	Annual	Rear Suspension	a. Inspect front and rear axle housing and differentials for cracks.	
34	Annual	Air Dryer System	a. Inspect air dryer, two purge valves, and check valve for security of mounting and signs of damage that could cause leaks. **NOTE** Air dryer will whistle when filter needs to be replaced. b. Replace filter in air dryer. c. Inspect filter in water separator. d. Inspect all tubes and fittings for damage or cracks that could cause leaks.	
35	Annual	Towing Pintle	Check operation of towing pintle hook. Inspect pintle and bracket for cracks, breaks, wear, and play of 0.003-0,017 in. (0.07-0.43 mm).	

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RECOMMENDED CHANGES TO PUBLICATIONS AND BLANK FORMS For use of this form, see AR 25-30; the proponent agency is DAAG.	Use Part II (reverse) for Repair Parts and Special Tool Lists (RPSTL) and Supply Catalogs/Supply Manuals (SC/SM).	DATE
TO: (Forward to proponent of publication or form) (Include ZIP Code) PM-MRAP, AMSTA-LC-GMM, 6501 E. 11 Mile Road, Warren, MI 48397-5000	FROM: (Activity and location) (Include ZIP Code)	

PART I - ALL PUBLICATIONS (EXCEPT RPSTL AND SC/SM) AND BLANK FORMS

PUBLICATION/FORM NUMBER	DATE	TITLE
TM 9-2355-106-23-1		Maintenace Manual COTS for International Mine Resistant Vehicle Category 1 2355-01-553-4634 Category II 2355-01-553-4636

ITEM	PAGE	PARA-GRAPH	LINE	FIGURE NO.	TABLE	RECOMMENDED CHANGES AND REASON

* Reference to line numbers within the paragraph or subparagraph.

TYPED NAME, GRADE OR TITLE	TELEPHONE EXCHANGE/AUTOVON, PLUS EXTENSION	SIGNATURE

DA FORM 2028, FEB 74 REPLACES DA FORM 2028, 1 DEC 68, WHICH WILL BE USED. USAPA V3.01

TO: *(Forward direct to addressee listed in publication)*	FROM: *(Activity and location) (Include ZIP Code)*	DATE

PART II - REPAIR PARTS AND SPECIAL TOOL LISTS AND SUPPLY CATALOGS/SUPPLY MANUALS

PUBLICATION NUMBER	DATE	TITLE

PAGE NO.	COLM NO.	LINE NO.	NATIONAL STOCK NUMBER	REFERENCE NO.	FIGURE NO.	ITEM NO.	TOTAL NO. OF MAJOR ITEMS SUPPORTED	RECOMMENDED ACTION

PART III - REMARKS *(Any general remarks or recommendations, or suggestions for improvement of publications and blank forms. Additional blank sheets may be used if more space is needed.)*

TYPED NAME, GRADE OR TITLE	TELEPHONE EXCHANGE/AUTOVON, PLUS EXTENSION	SIGNATURE

USAPA V3.01

By Order of the Secretary of the Army:

GEORGE W. CASEY, JR.
General, United States Army
Chief of Staff

Official:

JOYCE E. MORROW
Administrative Assistant to the
Secretary of the Army
0726006

Distribution:

To be distributed in accordance with the initial distribution number (IDN) 990003, requirements for TM 9-2355-106-23-1.

THE METRIC SYSTEM AND EQUIVALENTS

LINEAR MEASURE

1 Centimeter = 10 Millimeters = 0.01 Meter = 0.3937 Inch
1 Decimeter = 10 Centimeters = 3.94 Inches
1 Meter =10 Decimeters = 100 Centimeters
= 1000 Millimeters = 39.37 Inches
1 Dekameter = 10 Meters = 32.8 Feet
1 Hectometer =10 Dekameters = 328.08 Feet
1 Kilometer =10 Hectometers = 1000 Meters
= 0.621 Mile = 3,280.8 Feet
Millimeters = Inches times 25.4
Inches = Millimeters divided by 25.4

WEIGHTS

1 Centigram = 10 Milligrams = 0.154 Grain
1 Decigram = 10 Centigrams = 1.543 Grains
1 Gram = 0.001 Kilogram = 10 Decigrams
=1000 Milligrams = 0.035 Ounce
1 Dekagram = 10 Grams = 0.353 Ounce
1 Hectogram = 10 Dekagrams = 3.527 Ounces
1 Kilogram = 10 Hectograms = 1000 Grams
= 2.205 Pounds
1 Quintal = 100 Kilograms = 220.46 Pounds
1 Metric Ton = 10 Quintals = 1000 Kilograms
= 1.1 Short Tons

LIQUID MEASURE

1 Milliliter = 0.001 Liter = 0.034 Fluid Ounce
1 Centiliter = 10 Milliliters = 0.34 Fluid Ounce
1 Deciliter = 10 Centiliters = 3.38 Fluid Ounces
1 Liter = 10 Deciliters = 1000 Milliliters
= 33.82 Fluid Ounces
1 Dekaliter = 10 Liters = 2.64 Gallons
1 Hectoliter = 10 Dekaliters = 26.42 Gallons
1 Kiloliter = 10 Hectoliters = 264.18 Gallons

SQUARE MEASURE

1 Sq Centimeter = 100 Sq Millimeters = 0.155 Sq Inch
1 Sq Decimeter = 100 Sq Centimeters = 15.5 Sq Inches
1 Sq Meter (Centare) = 10 Sq Decimeters
= 10,000 Sq Centimeters = 10.764 Sq Feet
1 Sq Dekameter (Are) = 100 Sq Meters = 1,076.4 Sq Feet
1 Sq Hectometer (Hectare) = 100 Sq Dekameters
= 2.471 Acres
1 Sq Kilometer = 100 Sq Hectometers
= 1,000,000 Sq Meters = 0.386 Sq Mile

CUBIC MEASURE

1 Cu Centimeter = 1000 Cu Millimeters = 0.061 Cu Inch
1 Cu Decimeter = 1000 Cu Centimeters = 61.02 Cu Inches
1 Cu Meter = 1000 Cu Decimeters
= 1,000,000 Cu Centimeters= 35.31 Cu Feet

TEMPERATURE

5/9 (°F - 32°) = °C
(9/5 x °C) + 32° = °F
-35° Fahrenheit is equivalent to -37° Celsius
0° Fahrenheit is equivalent to -18° Celsius
32° Fahrenheit is equivalent to 0° Celsius
90° Fahrenheit is equivalent to 32.2° Celsius
100° Fahrenheit is equivalent to 38° Celsius
212° Fahrenheit is equivalent to 100° Celsius

APPROXIMATE CONVERSION FACTORS

TO CHANGE	TO	MULTIPLY BY
Inches	Centimeters	2.540
Feet	Meters	0.305
Yards	Meters	0.914
Miles	Kilometers	1.609
Square Inches	Square Centimeters	6.451
Square Feet	Square Meters	0.093
Square Yards	Square Meters	0.836
Square Miles	Square Kilometers	2.590
Acres	Square Hectometers	0.405
Cubic Feet	Cubic Meters	0.028
Cubic Yards	Cubic Meters	0.765
Fluid Ounces	Milliliters	29.573
Pints	Liters	0.473
Quarts	Liters	0.946
Gallons	Liters	3.785
Ounces	Grams	28.349
Pounds	Kilograms	0.454
Short Tons	Metric Tons	0.907
Pound-Feet	Newton-Meters	1.356
Pounds-Inches	Newton-Meters	0.11375
Pounds per Square Inch	Kilopascals	6.895
Ounce-Inches	Newton-Meters	0.007062
Miles per Gallon	Kilometers per Liter	0.425
Miles per Hour	Kilometers per Hour	1.609

TO CHANGE	TO	MULTIPLY BY
Centimeters	Inches	0.394
Meters	Feet	3.280
Meters	Yards	1.094
Kilometers	Miles	0.621
Square Centimeters	Square Inches	0.155
Square Meters	Square Feet	10.764
Square Meters	Square Yards	1.196
Square Kilometers	Square Miles	0.386
Square Hectometers	Acres	2.471
Cubic Meters	Cubic Feet	35.315
Cubic Meters	Cubic Yards	1.308
Milliliters	Fluid Ounces	0.034
Liters	Pints	2.113
Liters	Quarts	1.057
Liters	Gallons	0.264
Grams	Ounces	0.035
Kilograms	Pounds	2.205
Metric Tons	Short Tons	1.102
Newton-Meters	Pound-Feet	0.738
Kilopascals	Pounds per Square Inch	0.145
Kilometers per Liter	Miles per Gallon	2.354
Kilometers per Hour	Miles per Hour	0.621
°Fahrenheit	°Celsius	°C = (°F-32)x5/9
°Celsius	°Fahrenheit	°F = (9/5x°C)+32

PIN: 084302-000