McGRAW DISON

Onan

Operato 's Manual

Auxiliary Power Generator For Truck Applications 3.0 kW Unit

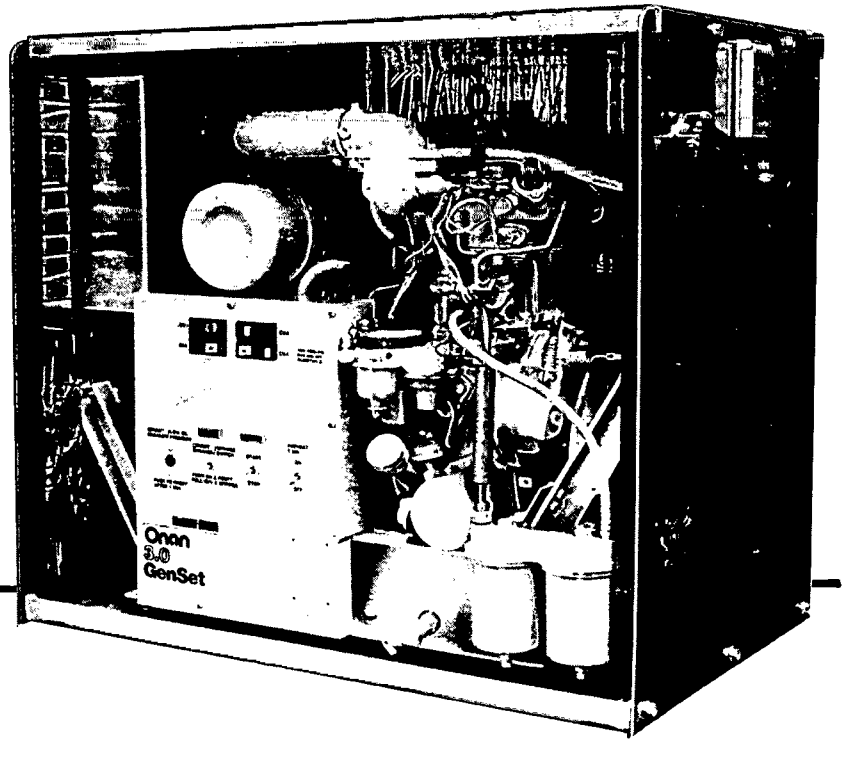
SERIES RDJA

AUX

GenSet

Diesel Driven Liquid-Cooled

Onan AUX



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Safety Precautions

The following symbols in this manual signal potentially dangerous conditions to the operator or equipment. Read this manual carefully. Know when these conditions can exist. Then, take necessary steps to protect personnel as well as equipment.

WARNING ***Onan uses this symbol throughout this manual to warn of possible serious personal injury.***

CAUTION ***This symbol refers to possible equipment damage.***

Do not work on this equipment when mentally or physically fatigued.

Fuels, electrical equipment, batteries, exhaust gases and moving parts present potential hazards that could result in serious, personal injury. Take care in following these recommended procedures.

- **Use Extreme Caution Near Gasoline. A constant potential explosive or fire hazard exists.**

  Do not fill fuel tank with engine running. Do not smoke or use open flame near the unit or the fuel tank.

  Be sure all fuel supplies have a positive shutoff valve between the fuel tank and generator set.

  The fuel supply and return lines must be routed separately and never tied together with any electrical wiring. Use a flexible section of fuel line between generator compartment and stationary remote fuel tank in truck chassis. This flexible section must be 100% NON-METALLIC to prevent electrical current from using it as a conductor.

  Have a fire extinguisher nearby. Be sure extinguisher is properly maintained and be familiar with its proper use. Extinguishers rated ABC by the NFPA are appropriate for all applications.

- **Guard Against Electric Shock**

  Disconnect electric power before removing protective shields or touching electrical equipment. Use rubber insulative mats placed on dry wood platforms over floors that are metal or concrete when around electrical equipment. Do not wear damp clothing (particularly wet shoes) or allow skin surfaces to be damp when handling electrical equipment.

  Jewelry is a good conductor of electricity and should be removed when working on electrical equipment.

  DO NOT PLUG MOBILE, PORTABLE OR STANDBY SETS DIRECTLY INTO A HOUSE RECEPTACLE TO PROVIDE EMERGENCY POWER. It is possible for current to flow from generator into the utility line. This creates extreme hazards to anyone working on lines to restore power.

  Use extreme caution when working on electrical components. High voltages cause injury or death.

  Follow all state and local electrical codes. Have all electrical installations performed by a qualified licensed electrician.

- **Do Not Smoke While Servicing Batteries**

  Lead acid batteries emit a highly explosive hydrogen gas that can be ignited by electrical arcing or by smoking.

- **Exhaust Gases Are Toxic**

  Provide an adequate exhaust system to properly expel discharged gases. Check exhaust system regularly for leaks. Ensure that exhaust manifolds are secure and not warped.

  Be sure the unit is well ventilated. Don't use discharged cooling air for compartment heating since it could contain poisonous exhaust gases.

- **Keep The Unit And Surrounding Area Clean**

  Remove all oil deposits. Remove all unnecessary grease and oil from the unit. Accumulated grease and oil can cause overheating and subsequent engine damage and may present a potential fire hazard.

  Do NOT store anything in the generator compartment such as oil or gas cans, oily rags, chains, wooden blocks, etc. A fire could result or the generator set operation (cooling, noise and vibration) may be adversely affected. Keep the compartment floor clean and dry.

  Do not steam clean the generator set while the engine is running. When cleaning, do not spray directly into the generator, control box, or air cleaner.

- **Protect Against Moving Parts**

  Avoid moving parts of the unit. Loose jackets, shirts or sleeves should not be worn because of the danger of becoming caught in moving parts.

  Make sure all nuts and bolts are secure. Keep power shields and guards in position.

  If adjustments *must* be made while the unit is running, use extreme caution around hot manifolds, moving parts, etc.

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WARNING

ONAN RECOMMENDS THAT ALL SERVICE AND INSTALLATION OF REPLACEMENT PARTS BE DONE BY QUALIFIED ELECTRICAL AND/OR MECHANICAL SERVICE PERSONNEL. FROM THE STANDPOINT OF POSSIBLE INJURY AND/OR EQUIPMENT DAMAGE, IT IS IMPORTANT THAT SERVICE PERSONNEL BE QUALIFIED.

WARNING

EXHAUST GAS IS DEADLY!

Exhaust gases contain carbon monoxide, a poisonous gas that might cause unconsciousness and death. It is an odorless and colorless gas formed during combustion of hydrocarbon fuels. Symptoms of carbon monoxide poisoning are:

- *Dizziness*
- *Headache*
- *Weakness and Sleepiness*
- *Vomiting*
- *Muscular Twitching*
- *Throbbing in Temples*

If you experience any of these symptoms, get out into fresh air immediately, shut down the unit and do not use until it has been inspected.

The best protection against carbon monoxide inhalation is proper installation and regular, frequent inspections of the complete exhaust system. If you notice a change in the sound or appearance of exhaust system, shut the unit down immediately and have it inspected and repaired at once by a competent mechanic.

Introduction

TO THE OWNER

Welcome to the growing family of *Onan Power users*. . . . We are proud to have you as a customer.

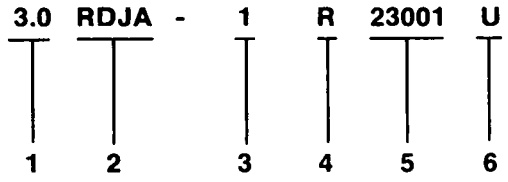
Read this manual carefully and observe all safety rules within. Operating instructions, adjustments and periodic maintenance procedures are given so that you . . . the owner, can keep your unit running like new and expect many years of dependable service from it. Remember . . . any machine, regardless of design or type, will perform only in relation to the services it received.

When contacting your Onan dealer, distributor, or the factory about the generator set, always supply the complete model number and serial number as shown on the nameplate (see *Model Designation* following). This information is necessary to identify your generator set among the many types manufactured by Onan.

Onan electric sets are given a complete running test under various load conditions and are thoroughly checked before leaving the factory. Upon receiving your unit, check it thoroughly for any damage that may have occurred during shipping. Tighten loose parts, replace missing parts and repair any damage before operating the unit.

MODEL DESIGNATION

The following typical model number is broken down into code segments used by Onan.



1. Indicates kilowatt rating.
2. Series identification.
3. Number 1 is the voltage code for 120 volts single phase.
4. Method of starting: R-remote electric starting.
5. Factory code for designating optional equipment if any.
6. Specification letter which advances when the factory makes production modification.

KEEP FUEL

CLEAN!

•

DIRTY FUEL IS ONE OF THE MAJOR CAUSES

OF ENGINE FAILURE

•

REMEMBER—EVEN A TINY PARTICLE OF DIRT IN THE INJEC-

TION SYSTEM MAY STOP YOUR ENGINE!

•

Specifications

The SI metric equivalents are printed in parenthesis immediately following the U.S. customary unit of measure

GENERAL

Nominal Dimensions of Compartment	
Height (without muffler)	31.38 in. (797 mm)
Width	34.00 in. (863 mm)
Depth	23.75 in. (603 mm)
Approximate weight including compartment	560 lbs (254 kg)

ENGINE DETAILS

Engine Design	Vertical, Four Cycle, Water Cooled with Overhead Valves
Number of Cylinders	One
Displacement (cubic inch)	30 (492 cm^3)
Horsepower (bhp)	7 (5.2 kW)
RPM	1800
Cylinder Bore (inches)	3.52 (82.55 mm)
Piston Stroke (inches)	3.625 (92.07 mm)
Compression Ratio	19:1
Battery Charge Rate (Flywheel Alternator Type)	10 Amps*
Fuel Transfer Pump	Mechanical
Fuel	Diesel
Diesel Fuel Lift (Maximum)	6 feet (1.83 m)
Water Pump	Thermostatically Controlled, Belt-driven W/Bronze Impeller
Starting System	Motorized Alternator Cranking
Cranking Current	300 Amperes

GENERATOR DETAILS

Generator Design	Permanently Aligned, Revolving Armature, 4-Pole
Maximum Power Rating	3,000 Watts
Output Voltage (AC) 60 Hertz	120 Volts
Maximum Current Rating	25 Amps
AC Voltage and Frequency Regulation in %	5
Phase	Single
Wire	2

CAPACITIES AND REQUIREMENTS

Battery Voltage	12 Volts
Remote Fuel Tank Capacity	11.5 Gallons (44 L)
Oil Capacity with Filter	6 U.S. Quarts (5.68 L)
Coolant Capacity	1 U.S. Gallon (Approx)
Cooling Water Flow	1.2 - 2.2 GPM

TUNE-UP SPECIFICATIONS

Cylinder Head Bolt Torque (lbs. ft.)	44-46 (60-62 N•m)+
Valve Clearance (Cold)	
Intake	.020 inch (0.51 mm)
Exhaust	.020 inch (0.51 mm)
Flywheel Capscrew (lbs. ft.)	65-70 (88-95 N•m)
Anti-Flicker Point Gap	.025 inch (0.64 mm)

+ - Apply "Never Seeze" or equivalent to capscrew threads and under capscrew head.

* - Variable depending upon battery condition "State of Charge" and auxiliary generator set cyclic DC loads.

Pre-Start

PRE-START SERVICING

Preparations for operation should include checks of the oil, fuel, cooling, and electrical systems. Before the generator set is put into operation, check all components for mechanical security. If an abnormal condition, defective part, or operating difficulty is detected, repair or service as required. The generator set should be kept free of dust, dirt and spilled oil or fuel.

COOLING SYSTEM

The generator set cooling system is a closed system with it's own coolant flow solenoid valve, water pump, thermostat, fill tank and safety shutdowns. Two flexible cooling lines are connected between the truck cooling system and the generator compartment. The generator set coolant is used to warm the truck engine when the truck engine is NOT running and also to dissipate the heat of the generator set. After the generator set was installed on the truck and the flexible cooling lines properly connected to the truck engine cooling system, it should have been primed as outlined in the *Cooling System Section* of the Installation Guide 974-0625.

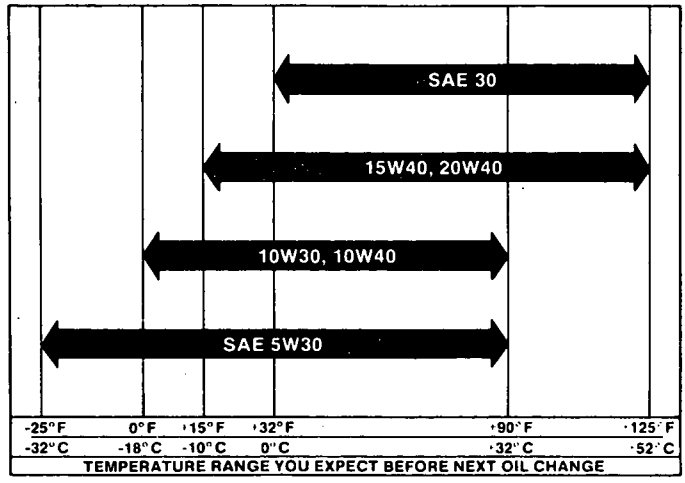
Check to be sure all drains have been closed and hose clamps tightened properly. Be sure truck cooling system is filled to required levels prior to starting the generator set. Be sure AC cord for coolant flow solenoid valve is plugged into the duplex receptacle on top of the generator set between the air cleaner and the engine inside the set housing.

CRANKCASE OIL

The generator set oil capacity is 6 U.S. quarts (5.8 L) including oil filter. Use an oil with the American Petroleum Institute (API) designation CD/SF or CD/SE. CD is the API classification for severe duty diesel lubricating oil. Refer to the oil chart for recommended viscosity according to the ambient temperature extremes expected before the next oil change interval. The designations CC/SE are also satisfactory for the SAE 5W-30, 10W-30 and 10W-40 oils within the recommended temperature ranges shown in the oil chart.

Fill the crankcase until oil reaches the "FULL" mark on the oil level indicator as shown in Figure 1. Do NOT OVERFILL. Overfilling may cause foaming and engine shutdown. Always change the oil filter when changing crankcase oil.

USE THESE SAE VISCOSITY GRADES



CAUTION ***Do not overfill crankcase. Too much oil causes higher operation temperatures. Excess oil may cause foaming or clogging of the breather system.***

WARNING ***Do NOT check oil while the generator set is operating. Hot oil could cause burns by blowing out of oil fill tube due to crankcase pressure.***

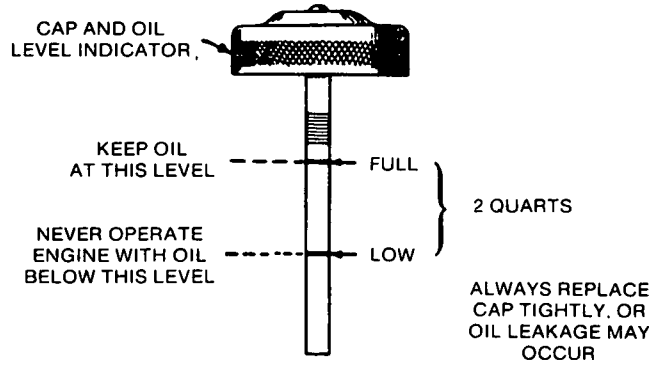


FIGURE 1. OIL LEVEL INDICATOR

Check the oil level daily or after every 8 operating hours and add as required. Use the same brand of oil as in the crankcase when adding oil between changes. It is not unusual to have to add oil when the oil level is checked. If operating in very dusty, dirty conditions, hot or cold temperature extremes or rapidly fluctuating temperatures, the oil and filter MUST be changed more frequently. Correct viscosity is critical in colder temperatures for reliable starting and equally important in hotter temperatures for sufficient lubrication.

OPTIONAL SEPARATE REMOTE FUEL TANK KIT (415-0520)

The remote fuel tank has a capacity of 11.5 U.S. gallons (44 L) of diesel fuel. Be sure both the supply and return lines are properly connected between the remote fuel tank and the bulkhead connectors on the rear of the generator compartment housing. The supply line should be connected to the "FUEL IN" fitting on the rear housing panel and the return line is connected to the "FUEL OUT" fitting on the rear panel. Refer to the Fuel Recommendations following for proper fuel according to expected ambient temperatures.

CAUTION ***Due to the precise tolerances of diesel injection systems, it is extremely important the fuel be kept clean. Dirt in the system can cause severe damage to both the injection pump and the injection nozzles.***

DIESEL FUEL RECOMMENDATIONS

ASTM 1-D diesel fuel is acceptable for use in all temperatures. ASTM 2-D fuel is more economical and has better lubrication properties but is susceptable to waxing problems in freezing temperatures. Specific fuel recommendations apply for use in cold weather climates to control fuel waxing, ensure easier "cold starts" and provides dependable operation in rapidly fluctuating temperatures. Unlike the truck engine, the auxiliary generator set has no means of heating the fuel in the remote fuel tank to control fuel waxing problems and clogged fuel filters. For this reason, the fuel recommendations and temperature limitations are critical for the generator set to perform properly in colder temperatures.

BLEEDING THE FUEL SYSTEM

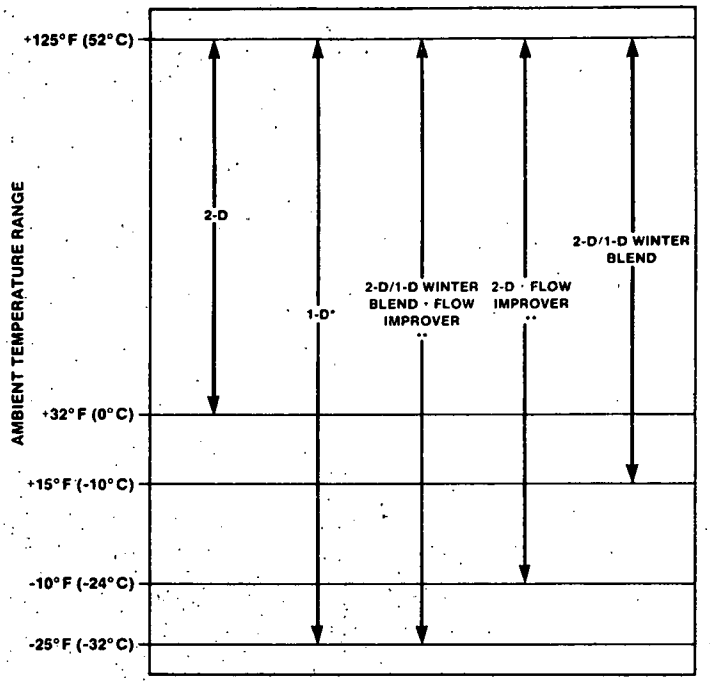
WARNING ***Whenever performing any maintenance work on the generator set, pull out the Circuit Breaker/Service Switch on the front of the set control panel to prevent accidental starting from the remote control panel.***

Check the fuel system to be sure fuel supply is adequate and that the lines are free of air. Bleed air from fuel system as follows: Disconnect the fuel return line. See Figure 2. Operate the hand priming lever on diaphragm type fuel transfer pump until there are no air bubbles in fuel flowing from the fuel return line fitting. Then connect the fuel return line.

If the camshaft pump lobe is up, crank engine one revolution to permit hand priming. When finished, return priming lever inward (disengaged position) to permit normal pump operation.

Fuel system must be bled if fuel tank is run dry even though system was purged of air during initial start-up.

FUEL RECOMMENDATION CHART



*Kerosene, Jet A or Jet A-1 may be substituted for ASTM 1-D.
**Flow improver (pour point depressant) MUST be blended with the diesel fuel when the remote tank is being filled. Follow manufacturer's instructions for mixing ratios. Proper mixing of diesel fuel and flow improver additive is impossible once the temperature drops to the point that the fuel in the remote tank has already started to wax up. Flow improver is ineffective if added under these circumstances.

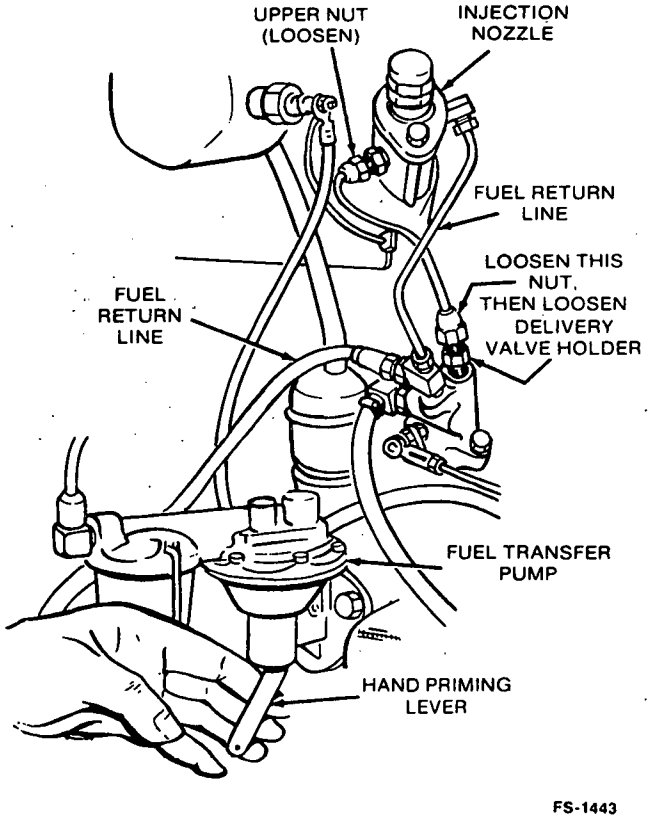


FIGURE 2. BLEEDING THE FUEL SYSTEM

If the engine wil not start after performing the above procedure, use this alternate method of bleeding the fuel system. Completely loosen the upper nut on the injection pump to nozzle fuel line. Loosen the delivery valve holder, located next to the fuel line nut, until it can be turned with the fingers. Crank engine until clear fuel emerges around the loosened delivery valve holder. Retighten the fuel line and torque the delivery valve holder to 30 lbs. ft. (41 N•m) torque. Fuel injection should occur almost immediately when engine is cranked.

Reset (push on) circuit breaker/service switch on the front of the set control panel after bleeding fuel system or set will not start.

CAUTION ***Due to the precise tolerances of diesel injection systems, it is extremely important the fuel be kept clean. Dirt in the system can cause severe damage to both the injection pump and the injection nozzles.***

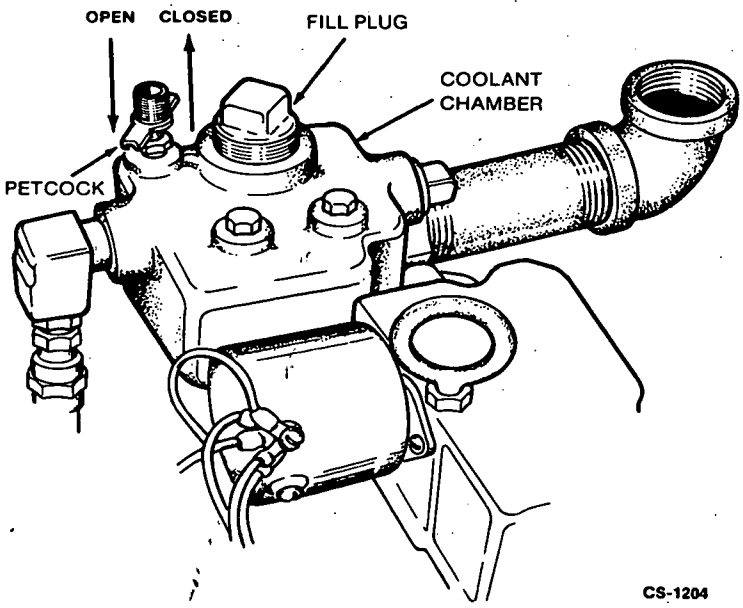


FIGURE 3. PRIMING COOLING SYSTEM

INITIAL FILL AND VENTING OF GENERATOR SET COOLING SYSTEM

After the auxiliary generator is installed and the generator set cooling system has been properly connected to the truck engine cooling system; the entire cooling system must be primed as follows:

1. Close all drains and refill truck engine radiator using anti-freeze/water mixture for the coldest expected ambient temperature (a 50/50 mixture of water and ethylene glycol type anti-freeze protects to -34° F).
2. Remove fill plug on top of generator set engine coolant fill tank and open petcock (vent) next to the fill plug as shown in Figure 3.
3. Add approximately one gallon of water/anti-freeze mixture to generator set. Replace fill plug using pipe thread sealing compound but leave petcock (vent) open.
4. Connect the AC plug of the generator set coolant flow solenoid valve into an external 115-volt AC source to open the valve for coolant flow.
5. Start truck engine and run until clean coolant flows out of the open petcock (vent) on the generator set engine. Then close petcock on generator set.

CAUTION ***No coolant flow may indicate incorrect cooling line connections between truck cooling system and generator set compartment inlet and outlet connections on rear panel.***

6. Run truck until thoroughly warm and then check for any coolant leaks at both the truck engine coolant line connection points and all coolant lines inside the generator compartment.
7. Stop truck engine and reconnect the coolant flow solenoid valve AC plug to the duplex receptacle on top of the generator set. Recheck all coolant line clamps and connections for leaks. After truck engine cools down, remove radiator cap and add coolant if required.

Operation

CONTROL PANEL COMPONENTS

The generator set control panel is mounted on the front of the set inside the housing compartment. Front cover of housing must be removed for access to this control. A remote control panel is provided in the unit accessory kit which can be mounted inside the truck cab in either a wall or shelf configuration as desired.

Generator Set Control Panel (Figure 4)

The generator set control panel contains the following components:

Start-Stop Switch: Toggle-type switch for starting and stopping the set.

On-Off Preheat Switch: Toggle-type switch which provides control for manifold heater and glow plug for cold diesel engine starting.

Circuit Breaker/Service Switch: Push-pull type circuit breaker for isolating DC control and ignition circuits for servicing the set. Prevents accidental starting of the generator set from either the set mounted control panel or the remote control panel during routine maintenance or service. The red "switch off" lamp will light up if this switch is pulled out to the "off" position and the unit is signaled to start or preheat.

Circuit Breaker/Low Oil Pressure: Opens to shut down unit in the event of a low oil pressure condition after a time delay.

Circuit Breakers: When a circuit is overloaded or a short occurs, the circuit breaker will automatically open the faulty circuit. The switch on the open circuit breaker will be in the CENTER position. When the fault is corrected, turning the switch handle to OFF and then to ON resets the circuit breaker.

Road vibration or shock may sometimes cause the circuit breakers to trip to the center position.

CB1: 20-amp AC load circuit breaker for truck accessories such as a roof top air conditioner/heater.

CB2 and CB3: 15-amp AC load circuit breakers for truck accessories.

CB4: 15-amp GFCI circuit breaker for protection against ground fault hazards. The ground fault circuit breaker is wired to all AC duplex receptacles provided on the generator set and in the remote control panel. Any additional receptacles added at a later date MUST also be wired to this ground fault circuit breaker.

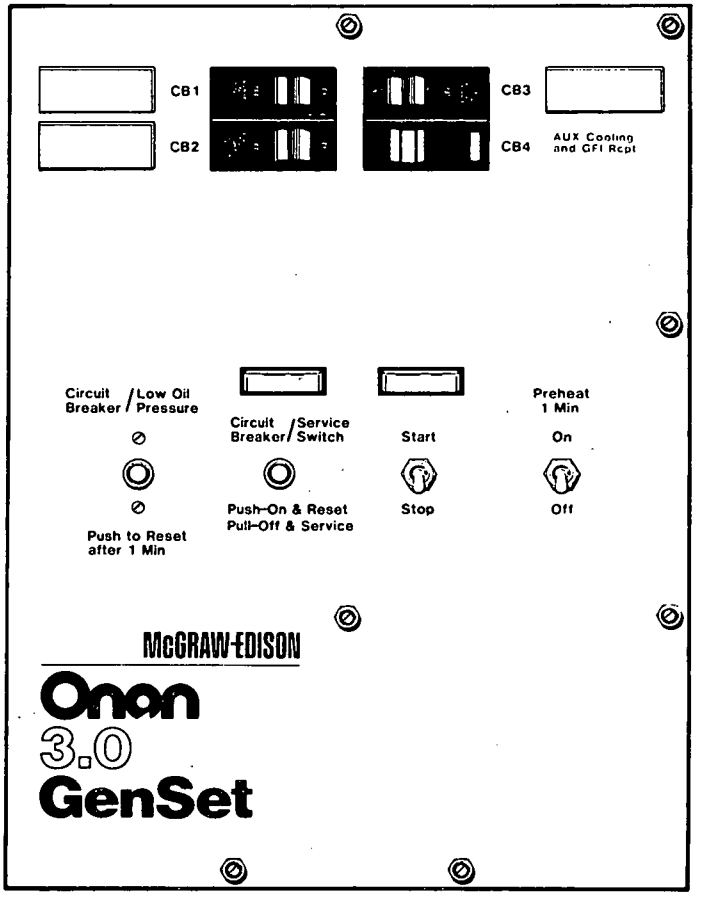


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FIGURE 4. GENERATOR SET CONTROL PANEL

Testing: Test the ground fault circuit breaker monthly to verify that the ground fault protection device operates properly.

With the generator set running and the switch in the ON position, push the TEST button on the ground fault circuit breaker. The switch handle should immediately move to the center position. Replace if the test indicates the ground fault protection device is faulty. Reset circuit breaker by moving the switch to the OFF position and then to the ON position. Do NOT leave this circuit breaker in the tripped or off position. This circuit breaker also supplies power for the generator set cooling system.

Indicator Light (Green): Lights up when set is running.

Remote Control Panel (Figure 5)

The remote control panel, which is usually mounted inside the truck cab, contains the following components:

Start-Stop Switch: A spring-loaded, rocker-type switch is used to start or stop set. Indicator light (part of switch) glows when set is running. Switch must be held in "Start" position until engine comes up to speed. Place switch in "stop" position momentarily to stop unit. Switch returns to center position when running or stopped.

Preheat-Off-Alarm Switch: This rocker-type switch is spring loaded in preheat position (returns to off after starting), which provides control for manifold heater and glow plug for cold diesel engine starting. In "Alarm" position (not spring-loaded), activates buzzer monitor alarm after set is running to signal driver if unit shuts down during normal operation.

Running Time Meter: Registers the total number of hours (to nearest 0.1 hour) that unit has run. Time on meter is accumulative and cannot be reset.

Receptacle: Heavy duty nylon faced duplex receptacle with 15 amp rating.

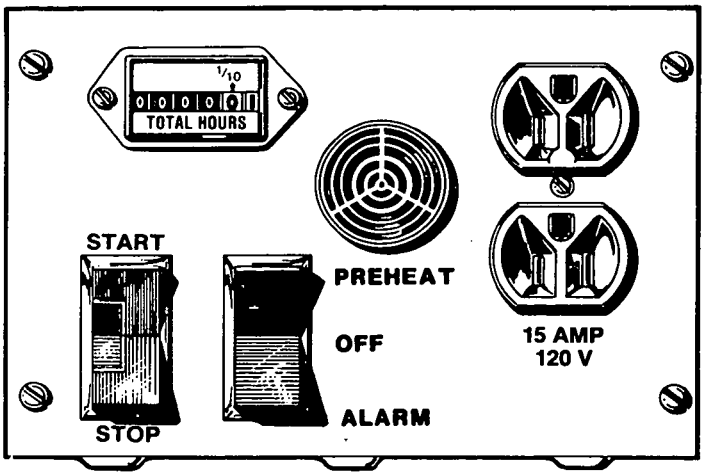


FIGURE 5. REMOTE CONTROL PANEL

STARTING/STOPPING

The generator is constructed with an exciter cranking winding that allows it to operate as the starting motor. During cranking, current from the battery is supplied to the starting windings in the generator. This causes the generator to operate as a motor until the engine starts and battery current is cut off.

The circuit breaker/service switch on the front of the generator set control panel (inside compartment) MUST be pushed IN ("ON"-position) to permit starting set at either the remote panel or the generator set control panel.

Starting (At Remote Control Panel)

After pre-start servicing procedures are completed and operator has become familiar with the control component functions; preheating for one minute is recommended before starting generator set.

1. Depress and hold Preheat switch in preheat position for one minute.
2. Continue to hold Preheat rocker switch in preheat position and also depress and hold start/stop rocker switch in "Start" position. Hold both switches in Preheat and start position until engine comes up to speed without misfire. Running light (part of start switch) glows when set is running. Continue to hold the preheat switch until smooth running occurs.

   CAUTION ***Do not exceed the one minute preheat periods to prevent heater burn out and conserve the battery. Longer preheating time prior to cranking the engine can ruin the manifold heater and glow plugs because there is no incoming air flow to cool them. Additional operation of the preheaters for a few seconds during cranking in cold weather may help to preheat the incoming combustion air and prevent misfires as the engine starts running.***

3. If engine fails to start after 20 seconds of cranking, wait one minute to conserve battery and repeat steps 1 and 2. Absence of blue exhaust smoke during cranking indicates no fuel is being delivered.
4. In extreme cold (below 32° F) it may be necessary to maintain preheating for 2 minutes after engine starts to obtain smooth firing, especially at no load or light loads.
5. With set running, place Preheat-Off-Alarm switch in "Alarm" position.

Starting (At Generator Set Control Panel)

The preheat interval and start sequence is the same as when using remote control except that the "Start/Stop" and "Preheat-On/Off" switches are spring-loaded toggle-type switches instead of rocker-type switches. The "Alarm" circuit cannot be activated at the set control panel, but once the set is running, this circuit can be turned on using the remote control "Alarm" rocker switch.

Stopping

Place the spring-loaded start/stop toggle switch in the stop position momentarily to stop the set.

INITIAL BREAK-IN

Controlled break-in with the proper oil and a conscientiously applied maintenance program will help to assure satisfatory service from your Onan electric generating set.

For a new unit, run the unit with as much load as is available (without exceeding nameplate rating) for approximately 2 hours. This procedure promotes better ring seating and lower oil consumption which leads to longer over-all service life.

CAUTION ***Continuous running with less than one-half load during the first few hundred hours may result in poor piston ring seating, causing higher than normal oil consumption and blowby.***

Drain and replace the crankcase oil and oil filter after initial 50 hours of operation; drain while the engine is warm.

The generator set is designed to operate under load. Avoid running the generator set for extended periods of time without a load, especially during the first 50 hours of operation. Failure to follow the recommended break-in procedure may result in poor piston ring seating.

APPLYING LOAD

Allow set to warm up before connecting a heavy load. Continuous generator overloading may cause high operating temperatures that can damage the windings. The generator can safely handle an overload temporarily, but for normal operation, keep the load within nameplate rating value. The exhaust system may form carbon deposits during operation at light loads; apply full load occasionally before shutdown to prevent excessive carbon accumulations. Table 1 lists power requirements for many appliances and accessory items.

SAFETY DEVICES

In case of dangerously high coolant (water) temperature or low oil pressure, the cut-off switch stops the unit. After an emergency stop, investigate and correct the cause.

DERATING

The generator set maximum power rating is based on operation at 1000 feet above sea level at 85° F ambient temperature. When the generator set is operated at altitudes above 1000 ft. or at temperatures above 85° F, the power rating must be reduced or derated. The reduction in the power rating is necessary to compensate for the reduction in engine horsepower that occurs at higher altitudes or higher temperatures.

A general rule applies for derating a generator set because of changes in temperature or altitude. A one percent deration can be expected for every 10° F rise in temperature above 85° F. A four percent deration can be expected for every 1000 feet increase in altitude above 1000 feet.

TABLE 1
POWER REQUIREMENTS FOR APPLIANCES AND ACCESSORIES

Winter Starting Aids	Approx. Running Wattage
Lube Oil Heater	300
Battery Charger	1000
Battery Heater	300
Vehicle Accessories	
Sleeper Heater	850-1250
Air Conditioner	1400-2200
Microwave Oven	1200-1500
Refrigerator	240
Appliances and Tools	
Television	50-200
Electric Fry Pan	1000-1350
Coffee Pot	550-700
Radio	50-200
Electric Drill	250-750
Electric Blanket	50-200
Toaster	1000

HIGH TEMPERATURE CONDITIONS

1. See that nothing obstructs airflow to and from the generator set or the compartment cooling fan.
2. Keep cooling system clean. Maintain the coolant level in a closed cooling system.

LOW TEMPERATURE CONDITIONS

1. Use correct SAE grade oil for temperature conditions. Change oil only when engine is warm.
2. Use good quality fuel free of moisture and with proper cetane number.
3. Keep fuel system clean, and batteries in a well-charged condition.
4. Use additional preheating during cold starts (see *Onan Diesel Starting Guide).*

DUSTY AND DIRTY CONDITIONS

1. Keep the generator set clean. Keep cooling system clean.
2. Change crankcase oil more frequently, at least twice as often or more, than the normal 600 hour change interval.
3. Keep governor linkage clean.

EMERGENCY STOPPING PROCEDURE

If the normal stop switch on either the remote control panel or the set mounted control fails to stop the set, pull out the Circuit Breaker/Service Switch on the front of the set control panel. If this fails to stop the set, manually override the governor and hold it in "Minimum fuel" position until the set stops completely. If all else fails, disconnect the fuel supply line at the "Fuel In" fitting on the rear panel of the generator compartment. Have the unit checked and repaired by qualified service personnel as soon as possible.

COMPARTMENT EXHAUST FAN

A thermostatically controlled fan assembly inside the compartment that is powered by the generator set maintains the compartment temperature within an acceptable range to prevent overheating of the set. Check to be sure that nothing is installed in front of the louvers on the side of the compartment to block this air flow. The fan cycles on and off depending on the ambient temperature within the compartment. If the ambient temperature exceeds 65°F, the fan will operate continuously. If the ambient temperature is below 45°F, the fan probably will not run at all.

ONAN DIESEL STARTING GUIDE

IMPORTANT!

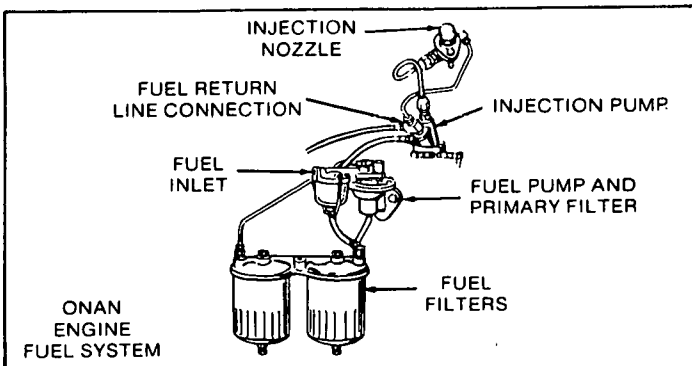
KEEP ENTIRE FUEL SYSTEM CLEAN AND FREE FROM WATER

- DIESEL INJECTION PUMPS WILL FAIL IF SYSTEM CLEANLINESS IS NEGLECTED

INJECTION PUMPS AND NOZZLES ARE NOT FIELD REPAIRABLE

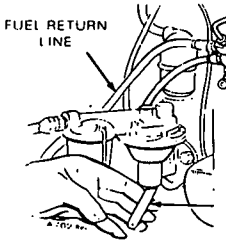
- WHEN TROUBLESHOOTING, CHECK ALL OTHER COMPONENTS FIRST

WARNING **DO NOT USE ETHER STARTING AIDS! ETHER IS EXTREMELY EXPLOSIVE AND MAY CAUSE SERIOUS PERSONAL INJURY. ENGINE DAMAGE IS ALSO LIKELY.**



BEFORE STARTING:

CHECK FUEL SUPPLY. BE SURE SHUTOFF VALVES ARE OPEN.



WORK TRANSFER PUMP PRIMING LEVER UNTIL FUEL FLOWS FROM RETURN LINE FITTING OF INJECTION PUMP. ALWAYS RETURN PRIMER LEVER TO LOWEST POSITION.

PRIME FUEL SYSTEM IF: FUEL FILTERS WERE DRAINED OR CHANGED, SYSTEM WAS JUST INSTALLED, FUEL TANK RAN DRY.

TO PRIME PUMP, MOVE PRIMING LEVER UP AND DOWN UNTIL FUEL FLOWS STEADILY FROM RETURN LINE (DISCONNECTED). IF NECESSARY, USE SURER ALTERNATE METHOD AS DESCRIBED IN MANUAL.

PREHEAT COLD ENGINE: PUSH PREHEAT SWITCH AND HOLD —

- **30 SECONDS IF ABOVE 55°F (13°C);**
- **60 SECONDS IF BELOW 55°F (13°C).**

TO START:

RELEASE PREHEAT

ENGAGE START SWITCH

LIMIT CRANKING TO 15 TO 20 SECONDS TO CONSERVE BATTERY. ALLOW 1 MINUTE BEFORE RE-CRANKING.

IF ENGINE DOES NOT START:

IF ENGINE FIRED, REPEAT ABOVE PROCEDURES, INCLUDING PRE-HEAT. IF IT STILL DOES NOT START, PROCEED AS FOLLOWS:

TEMPERATURES BELOW 32°F (0°C): **USE NUMBER 1 DIESEL FUEL. USE CORRECT VISCOSITY OIL. KEEP BATTERIES FULLY CHARGED. DO NOT USE ETHER STARTING AID.**

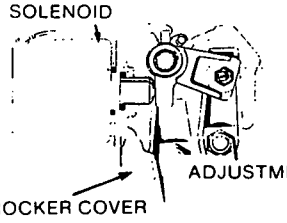
OBSERVE ENGINE EXHAUST "SIGNALS":

BLUE-WHITE EXHAUST SMOKE: ENGINE IS GETTING FUEL (FUEL FLOWS STEADILY FROM FUEL RETURN LINE).

CHECK PREHEAT SYSTEM:

- **ENGAGE PREHEAT AND OBSERVE HEATER THRU AIR INLET HOLE OR BY REMOVING AIR CLEANER. ELEMENT SHOULD GLOW RED WITHIN 30 SECONDS—IF NOT, CHECK FOR CLEAN, TIGHT CONNECTIONS. CHECK FOR 12 VOLTS DC TO HEATER**

CHECK DECOMPRESSION MECHANISM:



- **CHECK ADJUSTMENT AS OUTLINED IN MANUAL.**
- **AS CRANKING SPEED INCREASES, OIL PRESSURE SWITCH ACTIVATES SOLENOID, EXHAUST VALVE CLOSES AND CAUSES COMPRESSION AFTER ABOUT A THREE SECOND TIME DELAY**
- **CHECK LOW OIL PRESSURE CIRCUIT BREAKER ON SET CONTROL PANEL. RED PLUNGER SHOULD BE IN.**

LITTLE OR NO SMOKE. PRIME FUEL SYSTEM AS SHOWN ABOVE.

LITTLE OR NO FUEL FLOW FROM RETURN LINE.

CHECK FUEL SUPPLY SYSTEM:

- **FUEL TANK EMPTY?**
- **SHUTOFF VALVES CLOSED?**
- **FUEL LINES KINKED?**
- **LOOSE CONNECTIONS?**
- **CLOGGED FUEL FILTERS?**

FUEL FLOW FROM RETURN LINE, STILL NO SMOKE?

USE ALTERNATE BLEEDING METHOD AS STATED IN MANUAL. SEE PAGE 5.

CHECK TRANSFER PUMP:

- **CRANK ENGINE AND OBSERVE FUEL FLOW FROM RETURN LINE. IF FUEL DOES NOT SPURT OUT, PUMP MAY BE DEFECTIVE.**

IF ENGINE STILL DOES NOT START, CONTACT AUTHORIZED ONAN SERVICE REPRESENTATIVE

Periodic Maintenance Schedule

Regularly scheduled maintenance is the key to lower operating costs and longer service life for the unit. The following schedule can be used as a guide. However, actual operating conditions under which a unit is run should be the determining factor in establishing a maintenance schedule. When operating in very dusty or dirty conditions, some of the service periods may have to be reduced. Check the condition of the crankcase oil, the filters, etc., frequently until the proper service time periods can be established.

For any abnormalities in operation, unusual noises from engine or accessories, loss of power, overheating, etc., contact your nearest authorized Onan dealer.

WARNING ***Always allow generator set to cool off before performing any maintenance or installation work on the set. Working on a hot set could cause severe burns.***

SERVICE THESE ITEMS	AFTER EACH CYCLE OF INDICATED HOURS				
	DAILY	50	600 or 6 MOS.	1200 or 12 MOS.	5000
General Inspection	X				
Check Oil Level	X				
Check and Retorque Cylinder Head Bolts		X	X		
Change Crankcase Oil and Filter			X[1]		
Drain Water From Fuel Filters*			X		
Clean Fuel Transfer Pump Sediment Bowl			X		
Clean Governor Linkage			X		
Clean Crankcase Breather			X		
Replace Primary Fuel Filter			X		
Adjust Valve Lash (Cold)			X		
Check Flicker Points				X	
Replace Air Cleaner Element				X	
Check Generator Brushes and Commutator				X	
Blow Out Generator (Dry Air)				X	
Replace Secondary Fuel Filter (If Plugged)					X
Check Nozzle Spray Pattern					X[2]
Test Ground Fault Circuit Breaker	Monthly				

1 - Perform more often in extremely dusty or dirty conditions.
2 - Contact an authorized service center for service.
* - If set develops loss of power (cannot take load), change fuel filters. Water or foreign material in fuel is evidenced by black slime on filters caused by bacteria. Water or foreign material in fuel can ruin the injection system. If inspection shows water or excessive dirt in sediment bowl or if premature plugging of the primary fuel filter occurs, fuel handling and fuel tanks should be checked and situation corrected. Primary fuel filter must be replaced following correction of any fuel contamination problem.

Periodic Maintenance

GENERAL

Follow a regular schedule of inspection and servicing, based on operating hours. Keep an accurate logbook of maintenance, servicing, and operating time. Regular service periods are recommended for normal service and operating conditions. For continuous duty, extreme temperature, etc., service more frequently.

WARNING ***Accidental starting of the set might cause severe personal injury or death. Disconnect the negative (-) battery cable before performing any maintenance or repair work on engine, generator, or controls and pull out the Circuit Breaker/Service Switch on the front of the set control panel.***

Operator should periodically make a complete visual inspection with set running at rated load. Some of the things to check for are as follows:

1. Check all fuel and oil lines for possible leakage.
2. Inspect exhaust lines and mufflers for possible leakage and cracks.
3. Periodically drain moisture from condensation traps.
4. Inspect electrical wires and connections for security and fray damage.

If generator requires major repair or servicing, contact an authorized Onan dealer or distributor.

BATTERY CARE

To increase battery life, the operator can perform a number of routine checks and some preventive maintenance.

1. Keep the battery case clean and dry.
2. Make sure the battery cable connections are clean and tight. Use a terminal puller when removing cables for any reason.
3. Coat the battery terminals with a mineral grease or petroleum jelly to reduce corrosion and oxidation.
4. Identify each battery cable to be positive or negative before making any connection. Always connect the ground (negative) cable last.
5. Maintain the electrolyte level by adding water (drinking quality or better) as needed for filling to split level marker. The water ingredient of the electrolyte evaporates, but the sulphuric acid ingredient remains. Therefore, add water, not electrolyte.

FUEL TRANSFER PUMP SEDIMENT BOWL

Every 600 hours, remove the sediment bowl from the fuel transfer pump (Figure 6). Clean out any water or particulate from the bowl and filter. When re-installing the sediment bowl, make sure the filter and gasket are in place.

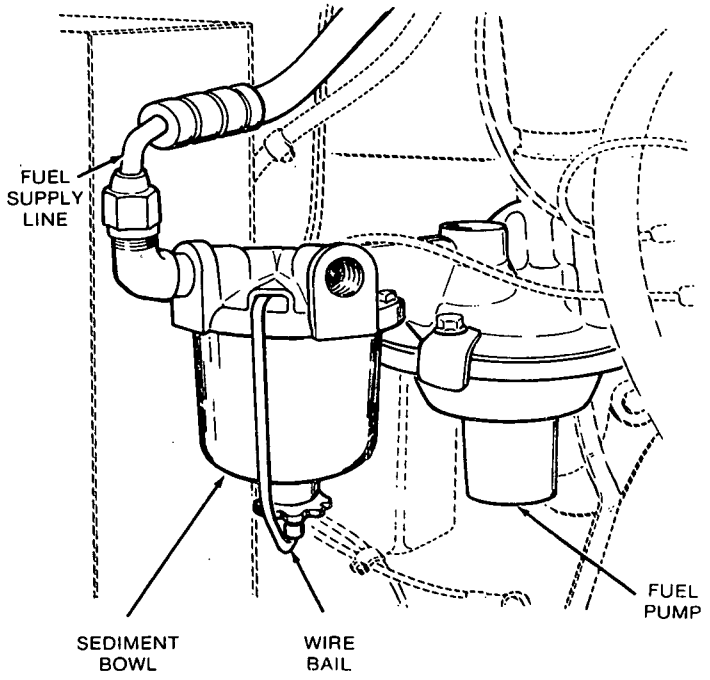


FIGURE 6. FUEL TRANSFER PUMP SEDIMENT BOWL

FUEL FILTERS

Every 600 hours, open the drains on the bottom of the fuel filter assembly (Figure 7) and allow any water to escape. The drain plug on the fuel filter can tolerate only a limited amount of torque. Use two wrenches in combination for breaking the plug loose and for final tightening.

Every 600 hours, change the primary fuel filter by removing the washer and capscrew on top of the fuel filter body. Every 5000 hours, change the secondary fuel filter in the same manner as the primary fuel filter.

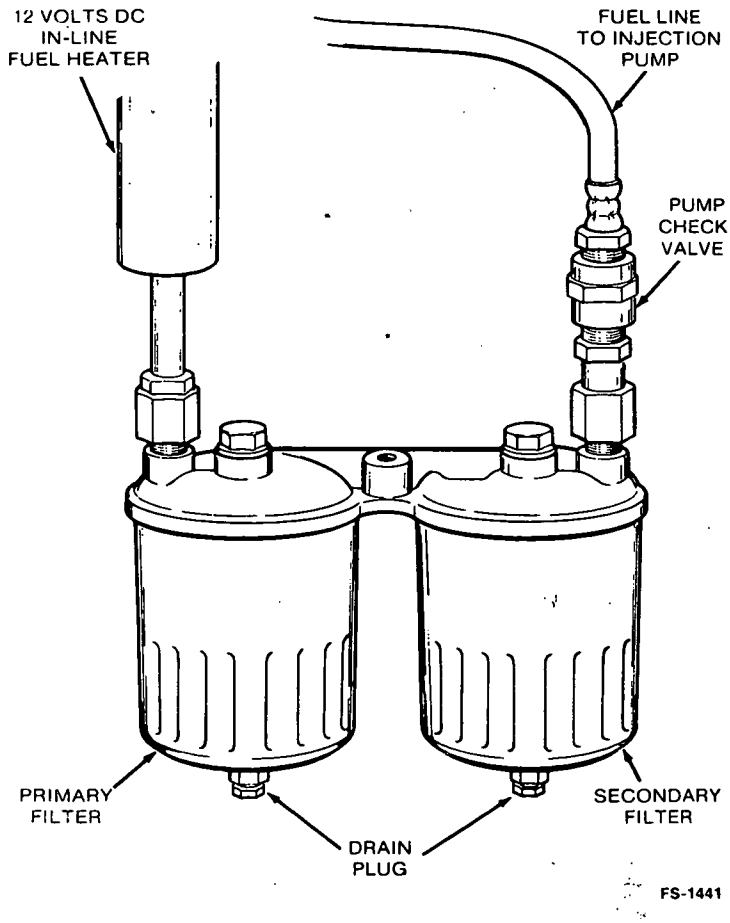


FIGURE 7. DUAL FUEL FILTERS

GOVERNOR LINKAGE

Every 600 hours, carefully pull the governor ball joints apart and clean. Do not lubricate. See Figure 8.

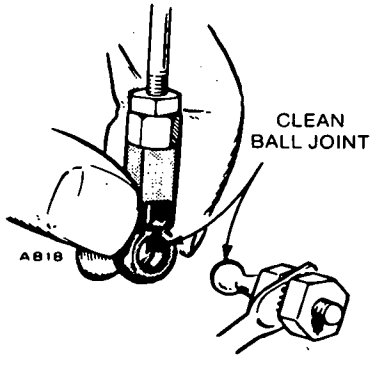


FIGURE 8. GOVERNOR BALL JOINT

WARNING ***Use extreme care when cleaning petroleum base solvent due to fire hazard.***

AIR CLEANER

The dust bowl should be emptied every 600 hours, and the element replaced every 1200 hours of operation. See Figure 9.

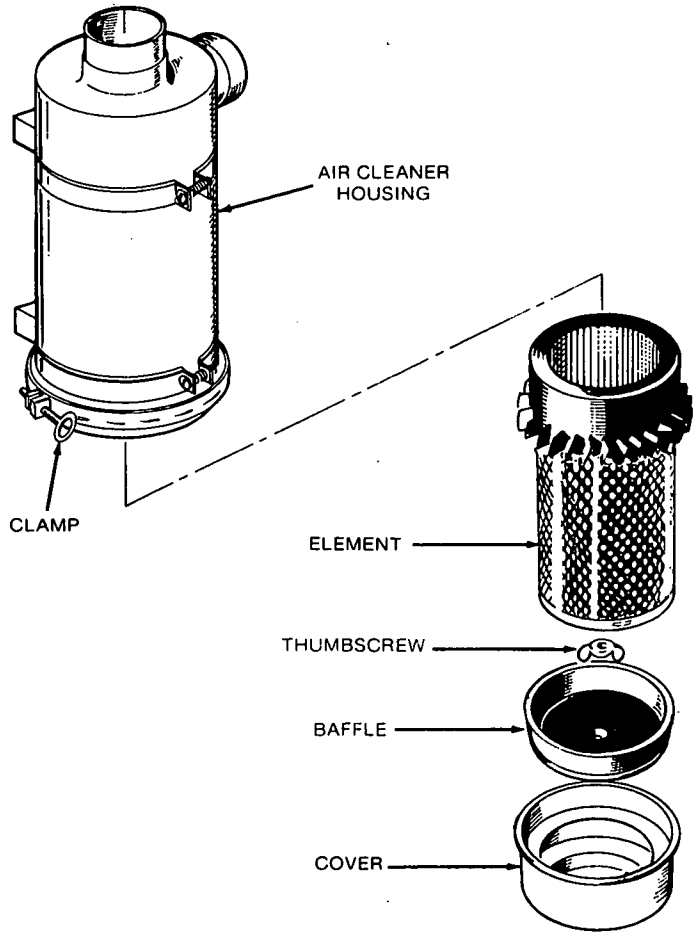


FIGURE 9. AIR CLEANER ASSEMBLY

1. Remove pre-cleaner and wash out dirt. Dry and re-install.
2. Loosen clamp and remove end cover.
3. Remove thumbscrew and take out element. Wash element in detergent and water (use new element after 6 washings or every 200 hours). Dry and re-install.
4. Remove air cleaner baffle from cover, wash out dirt, and re-install in cover.
5. Install cover with "TOP" up and tighten clamp.

CRANKCASE BREATHER

This engine uses a crankcase breather valve for maintaining crankcase vacuum. No maintenance is generally required. If the crankcase becomes pressurized as evidenced by oil leaks at the seals, clean baffle and valve in a suitable solvent. Check for cracks or breaks in the breather hose and replace if necessary. See Figure 10.

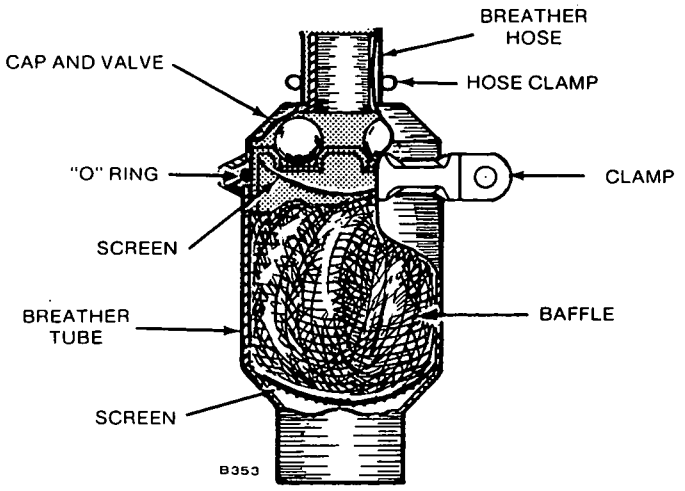


FIGURE 10. CRANKCASE BREATHER

CRANKCASE OIL

Oil Level: Check oil level at least every 8 hours of operation. Check more frequently on a new or reconditioned engine as oil consumption may be higher until the piston rings seat properly.

Oil Change: Drain the oil from the crankcase while the engine is warm. When completely drained, close the valve and refill the engine with the recommended oil (see *PRE-START* section). The interval between oil changes should never exceed 600 operating hours.

OIL FILTER CHANGE

Change the oil filter every time the crankcase oil is changed. Remove the filter by turning counterclockwise, using a filter wrench. Clean filter mounting area. Coat rubber gasket on new filter with a light film of oil before installing filter. Wipe up any oil spills on baseplate of generator set. Install new filter (turning clockwise) until gasket touches mounting base. Then tighten an additional 1/2 turn. Do NOT overtighten.

THERMOSTAT

A thermostat is located in the cylinder head. See Figure 11. Replace the thermostat if damaged by corrosion or other causes. If the thermostat is replaced, always install a new thermostat gasket.

TESTING THERMOSTAT

If a sticking or faulty thermostat is suspected, test as follows:

1. Remove thermostat from cylinder head. (Figure 11).
2. Heat a pan of water to approximately 150°F (66°C). Check temperature using a thermometer immersed in water.
3. With thermostat suspended in water at temperature of 150°F (66°C), thermostat should start to open.
4. After thermostat has opened completely, remove it from hot water and allow it to cool in surrounding air. The thermostat should close within a short time.
5. If the thermostat sticks or does not operate properly, replace it with a new one.
6. Always install a new gasket when replacing the thermostat.

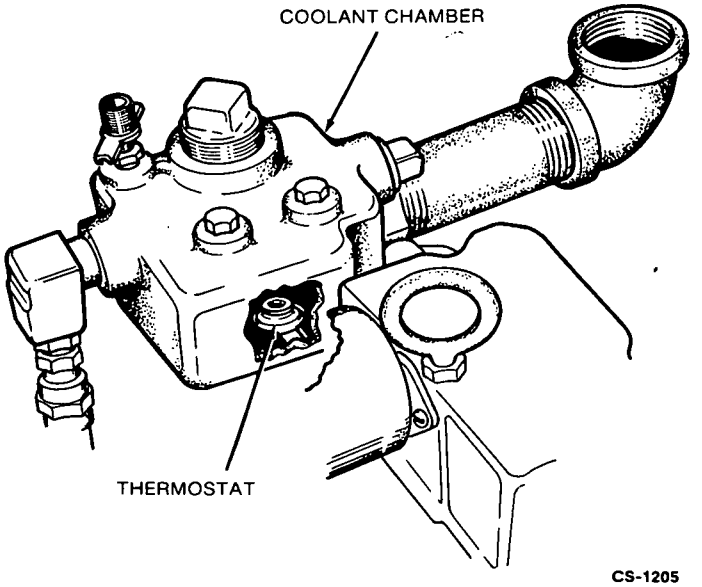


FIGURE 11. THERMOSTAT LOCATION

GENERATOR MAINTENANCE

The generator normally needs little care other than a periodic check of the brushes, commutator and collector rings. If major repair of the generator is necessary, have the unit checked by a competent electrician who is thoroughly familiar with the operation of electric generators and controls. Contact your nearest Onan Service Center.

Brushes

To examine the brushes, remove the end bell band and cover. Replace the brushes when they wear to the Onan name and part number. At this point there is about 5/8 inch (16 mm) of brush remaining. If the brush is not replaced, the slip rings or commutator will be damaged. See Figure 12.

Remove the old brushes and clean the holders so the new brushes can move easily in their holders. Install the new brushes in the same manner as the old ones. Always use the correct brush as listed in the PARTS

CATALOG. Never substitute a brush which may appear to be the same for it may have different characteristics. New brushes are shaped to fit and seldom need sanding to seat properly. If some brush sparking occurs after replacing brushes, run the set under a light load until the brushes wear to a good seat.

Collector rings acquire a glossy brown finish in normal operation. Do not attempt to maintain a bright newly machined appearing surface. Ordinary cleaning with a dry, lint free cloth is usually sufficient. Very fine sandpaper (#200) may be used to remove slight roughness.

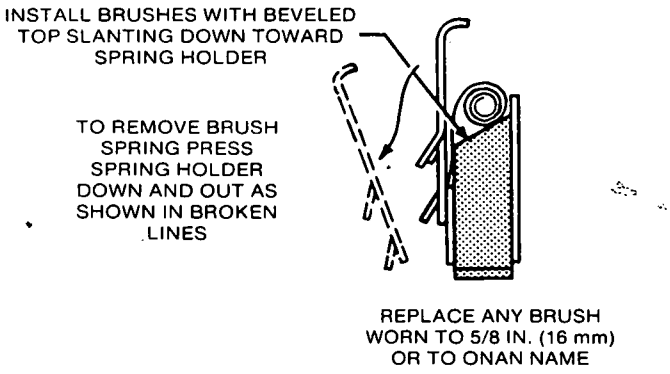


FIGURE 12. BRUSH INSTALLATION

NOZZLES

The injection nozzles are the conventional inward-opening pintle type with adjustable opening pressure. They are factory adjusted to open at 1900 to 1950 psi (13.110 to 13,455 kPa). However, after several hundred hours of operation the nozzle pressure will decrease to approximately 1750 psi (12.075 kPa). Do not attempt to disassemble the nozzles or adjust nozzle pressure without the proper test equipment. A nozzle pressure tester is essential to do this work.

Inspection: To inspect the nozzle spray pattern remove the nozzle from the cylinder head. Crank the engine, let the nozzle spray into the air and watch the pattern. The spray should be cone shaped with a solid appearing center surrounded by cloudlike fog in which the spray is evenly atomized. An apparent chattering of the nozzle is normal. See Figure 13.

If streamers are visible, the pattern is badly distorted or the nozzle drips before it reaches opening pressure, it is defective and must be cleaned or replaced.

WARNING ***Do not let the nozzle spray againt your skin. The fuel can penetrate flesh and cause a serious infection.***

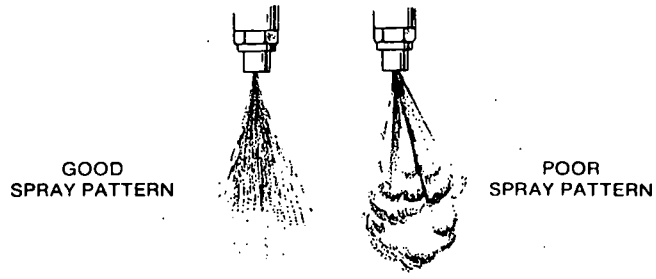


FIGURE 13. NOZZLE SPRAY PATTERN

CYLINDER HEAD RETORQUE PROCEDURE

As recommended in the periodic maintenance schedule, the cylinder head capscrews should be checked and retorqued every 600 hours after the initial 50 hour check. Proceed as follows:

1. Remove any components on the set which prevent access to the cylinder head capscrews.
2. Tighten cylinder head capscrews in a clockwise rotation as shown in Figure 14 to the proper torque which is 44-46 foot pounds (60-62 N•m).
   A. Use steady, even pull on torque wrench.
   B. Do NOT over-torque. Capscrews should be turned just enough to reach final torque.
3. Repeat torque sequence (Step 2).
4. Reassemble any components that were removed for the retorque procedure in Step 1.

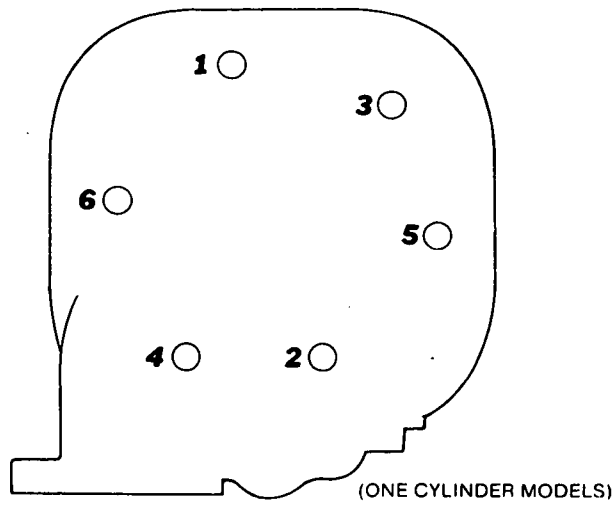


FIGURE 14. CYLINDER HEAD CAPSCREW TORQUE SEQUENCE

CHECKING RECEPTACLES WITH GROUND FAULT TESTER

All AC duplex receptacles powered by the auxiliary generator set should be tested monthly using a tester similar to the one shown in Figure 15. Proceed according to the instructors on the tester.

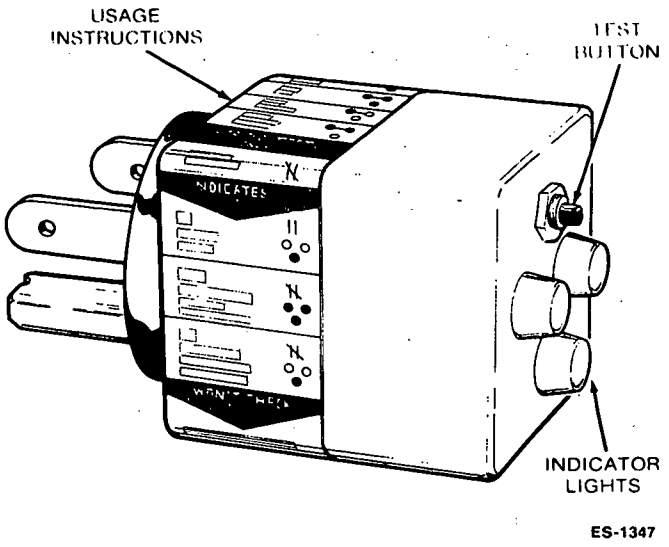


FIGURE 15. TESTING GROUND FAULT RECEPTACLES FOR PROPER OPERATION

Adjustments

GOVERNOR

The governor controls engine speed. Rated speed and voltage appear on the set nameplate (also see *SPECIFICATIONS*). On a 4-pole generator, engine speed equals frequency multiplied by 30. Thus 1800 rpm gives 60-hertz output. Preferred speed does not vary more than 3 hertz from no-load to full-load operation. Be sure throttle, linkage, and governor mechanism operate smoothly.

Speed Adjustment

To change the governor speed, change the spring tension by turning the governor spring nut (Figure 16). Turn the nut clockwise (more spring tension) to increase rpm and counterclockwise to reduce governed speed. Hold a tachometer against flywheel cap screw. Set speed at 1845-rpm (61.5 to 63.0 Hz), no load.

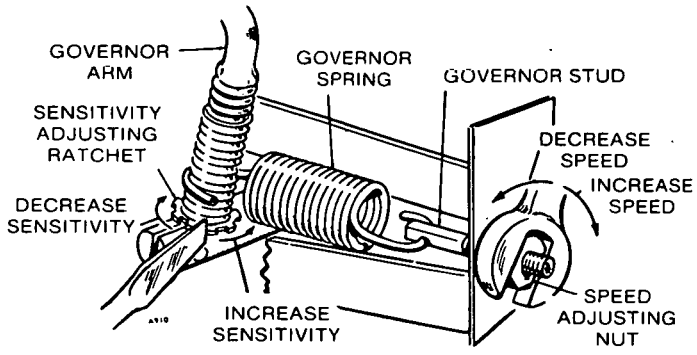


FIGURE 16. GOVERNOR ADJUSTMENT

Sensitivity Adjustment

To adjust governor sensitivity (no load to full load speed droop) turn the sensitivity adjusting ratchet. Counterclockwise gives more sensitivity (less speed drop when full load is applied), clockwise gives less sensitivity (more speed drop). If the governor is too sensitive a rapid hunting condition occurs (alternate increasing and decreasing speed). Adjust for 54 to 90 rpm speed droop when full load is applied. Check for hunting at 0, 1/4, 1/2, 3/4 and full load. After sensitivity adjustment, the speed will require readjustment. After adjusting the governor, secure speed stud lock nut.

Excessive droop may be caused by engine misfiring. Correct this condition before adjusting governor.

CHECK ANTI-FLICKER POINTS

The anti-flicker circuit eliminates flare or flickering of lights due to engine rpm change on the power stroke. Replace burned or faulty points. If only slightly burned, dress smooth with file or fine stone. Measure gap with thickness gauge, Figure 17. Loosen and adjust stationary contact to correct gap.

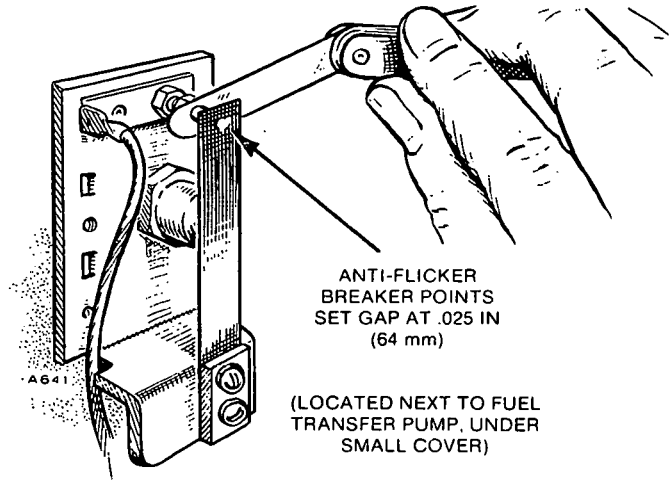


FIGURE 17. ANTI-FLICKER POINTS

VALVE CLEARANCE

Check valve clearance when the engine is at room temperature, about 70°F (21°C).

1. Turn the flywheel until the cylinder is on its compression stroke. Use a socket wrench on the flywheel screw hex head.

   To determine if the cylinder is in its compression stroke, observe the action of the push rods as the engine is rotated in a clockwise direction. The exhaust valve push rod will be in its lowest position and the intake valve push rod will be moving downward. As the piston reaches top dead center, the flywheel timing mark should be aligned with the timing pointer and the valve push rods stationary.

2. Now turn the flywheel clockwise for an additional 10 to 45 degrees. There is no timing mark for this position, so it must be estimated. With the piston located in this position, it will be in its power stroke with both valves completely closed.

3. Cylinder head bolt torques should be 44 to 46 foot-pounds (60-62 N•m). To change the setting of valve clearance, adjust the locknut which secure the rocker arm to the cylinder head (Figure 18). Loosen the locknut to increase clearance and tighten it to reduce clearance.

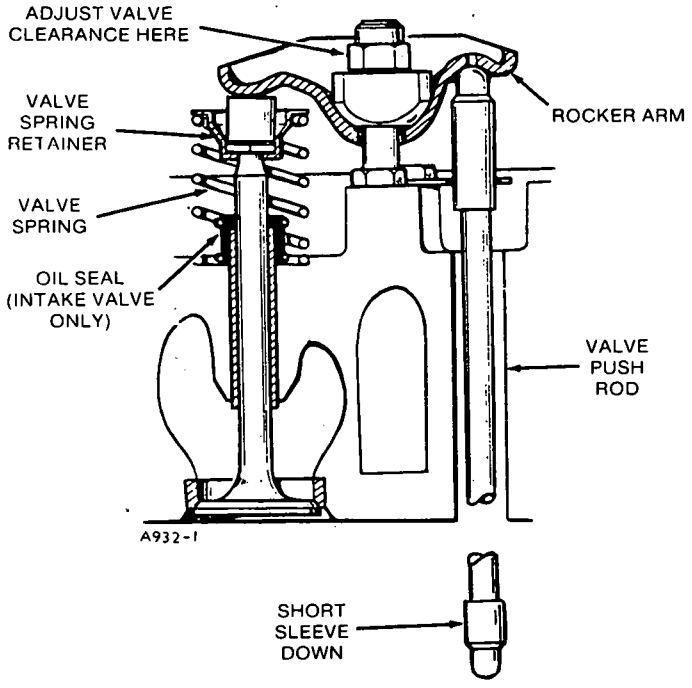


FIGURE 18. SETTING VALVE CLEARANCE

4. Check valve clearance with a feeler gauge between the rocker arm and the valve (Figure 19). Increase or reduce the clearance until the proper gap is established. Correct valve clearance (engine cold) is .020 inches (0.51 mm) for both the intake and exhaust valves.

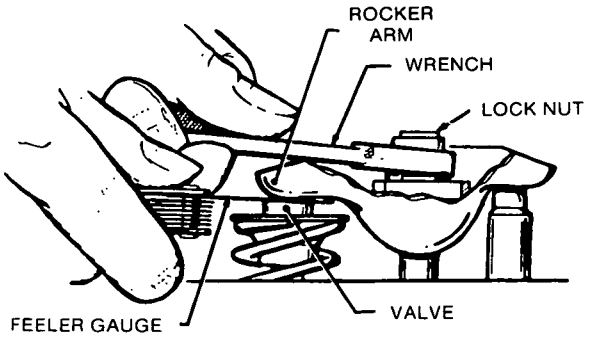


FIGURE 19. CHECKING VALVE CLEARANCE

DECOMPRESSION SOLENOID

The decompression release mechanism (Figure 20) holds the exhaust valve open long enough for cranking speed (rpm's) to build up without opposition from compression. The release solenoid energizes when starting speed is attained to release the exhaust valve for operation as long as the engine runs. The solenoid de-energizes when the engine is shut down allowing the release mechanism to open the exhaust valve and stop the engine by decompression.

Before adjusting the decompression mechanism, the valves must be set for the correct clearance.

To adjust the decompression mechanism, remove solenoid and valve cover and proceed as follows:

1. With piston 10 degrees to 45 degrees past TDC on power stroke, hold arm in decompression position (tension against spring): Turn set screw so it just touches exhaust rocker arm. The release arm must be tight against snap ring during adjustment. Then turn screw exactly one revolution clockwise. Original factory setting is marked with white or yellow paint.

   CAUTION ***If screw is tightened more than one turn, piston could hit exhaust valve and cause major damage.***

   Hold the set screw and lock it into position with the attached nut. Turn the nut hand tight plus 1/4 to 1/2 turn to lock the mechanism.

2. Release mechanism to allow compression and check the clearance between screw and rocker arm. Insert a feeler gauge between valve and rocker arm to take up valve clearance for this check. If there is not clearance, back off set screw until it just clears rocker arm.

   When reassembling the rocker cover, remove the solenoid, dip the plunger "O" ring in oil and reinstall when cover is on the engine. Align solenoid so terminal "SW" is above terminal "IGN."

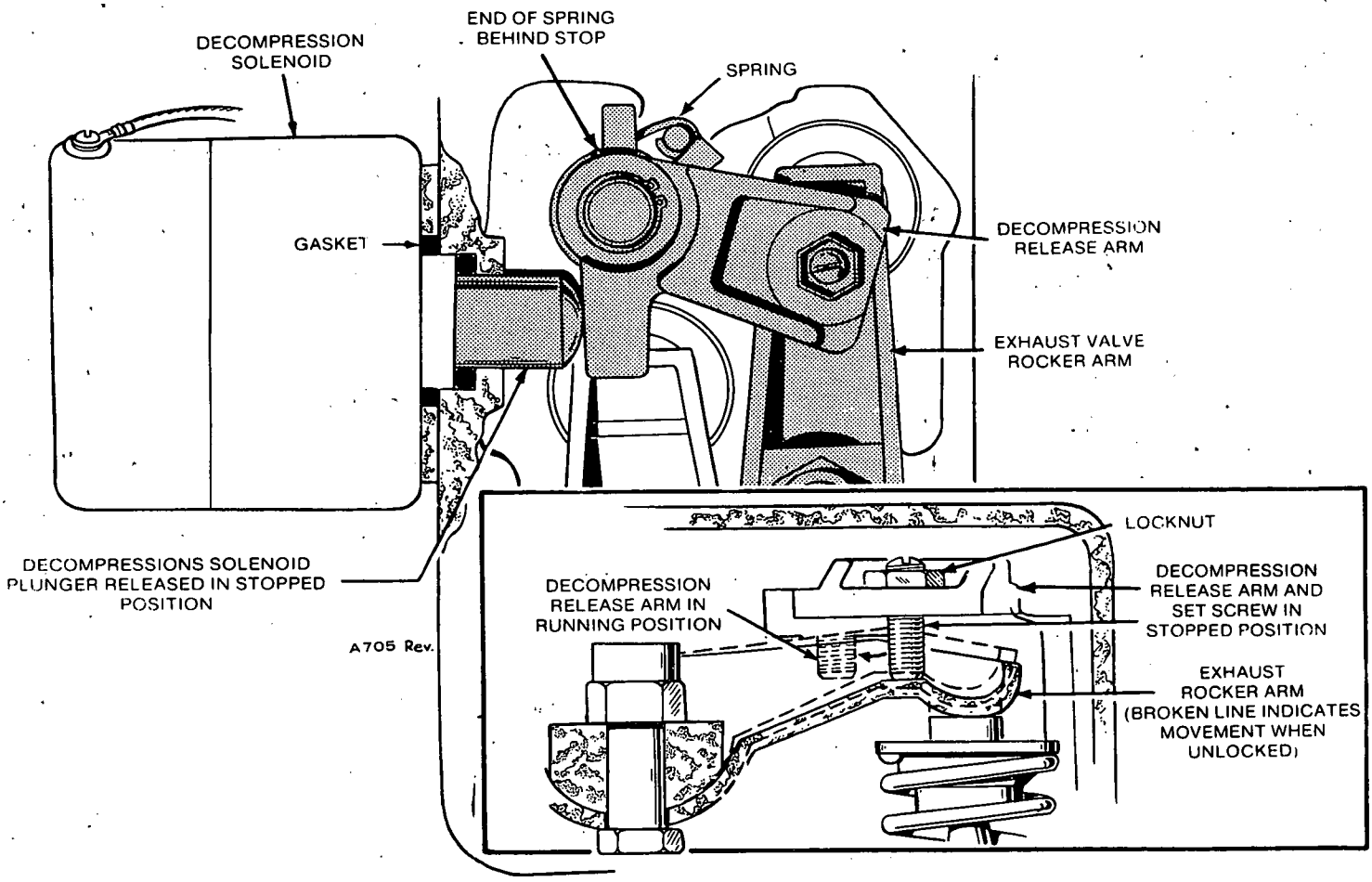


FIGURE 20. DECOMPRESSION MECHANISM

DIESEL ENGINE TROUBLESHOOTING GUIDE LIQUID OR AIR COOLED

TROUBLE / CAUSE	Compression Poor	Connecting Rod, Bushings, Bearings Worn	Coolant Temperature Too High (Fresh Water System)	Coolant Temperature Too Low (Fresh Water System)	Coolant Loss (Fresh Water System)	Engine Misfire	Engine Power Low	Engine Overheat	Engine Speed Too Low	Engine Speed Too High	Fuel Consumption Excessive - Black Smokey Exhaust	Fuel Consumption Excessive	Fuel Knocks	Governor Control Loss	Hunting	Injection Pump Timing Incorrect	Mechanical Knocks	Oil Consumption Excessive - Light Blue Smokey Exhaust	Oil Consumption Excessive - No Smoke Increase	Oil Diluted	Oil Pressure High	Oil Pressure Low	Piston, Cylinder and Ring Wear	Starter Speed Slow	Starter Motor Does Not Turn	Starting Hard, or Failure to Start	Sensitivity Poor	Valve Breakage	Valve Burning	Valve Sticking
STARTING SYSTEM																													
Discharged or Defective Battery																								•	•				
Defective Glow Plug or Lead						•					•		•												•				
Load Connected When Starting																									•				
Defective Solenoid																							•	•	•				
Defective Starter																							•	•	•				
Defective Control Circuit																								•	•				
FUEL SYSTEM																													
Defective Fuel System						•	•				•	•		•											•				
Air in Fuel System						•	•					•		•											•				
Incorrect Timing						•	•				•	•	•			•									•				
Restricted Air Intake - Dirty Air Filter						•	•				•	•										•			•				•
Poor Quality Fuel						•	•				•	•	•												•				
Dirty Fuel Filters						•	•					•													•				
Out of Fuel or Shut Off Closed																									•				
Worn or Damaged Transfer Pump, Leaking Diaphragm												•					•								•				
Faulty Injection Pump, Nozzles or Gaskets						•	•				•	•	•			•									•				
Fuel Line Leaks						•	•					•			•										•				
Wrong Timing Button in Injection Pump							•								•														
Wrong Thickness Pump Mounting Gaskets							•								•														
Run For Long Periods of Time at NO LOAD	•						•									•													
LUBRICATION SYSTEM																													
Low Oil Supply		•	•													•				•	•								
Defective Oil Gauge																				•									
Excess Oil in Crankcase																•				•									
Oil Leaks From Engine Base or Connections																	•												
Light or Diluted Crankcase Oil		•														•	•				•	•							
Leaky Oil Seals																	•												
Improper Lubrication		•	•													•					•	•							•
Faulty Oil By-Pass																	•			•	•								
Worn Oil Pump		•																		•									
Heavy Oil or Clogged Passages		•																		•									
Dirty Oil Filter		•																											•
GOVERNOR SYSTEM																													
Loose or Disconnected Linkage							•		•	•				•	•										•				
Binding Linkage							•		•	•				•	•										•				
Excessive Wear in Linkage								•	•	•				•	•										•				
Incorrect Governor Adjustment								•	•	•				•	•										•				
High Spring Sensitivity									•					•	•														
Incorrectly Installed Governor Yoke or Cup									•					•															
Overloaded Generator		•						•			•	•																	
COOLING SYSTEM																													
Insufficient Coolant		•					•																						
Faulty Thermostat		•	•		•		•																						
Worn Water Pump or Defective Seals		•		•			•																						
Water Passages Restricted		•					•																						
Blown Head Gasket	•	•		•	•	•											•												
Overheating																•	•			•	•						•	•	
Restricted or Too Long Water Lines							•																						
Defective Expansion Tank Pressure Cap		•		•																									
Dirt on Cooling Fins (Air Cooled)							•																						
Inadequate Air Circulation (Air Cooled)							•																						
INTERNAL ENGINE																													
Poor Compression						•			•	•						•									•				
Loose Piston																•					•								
Loose Connecting Rod or Crankshaft Bearing																•				•									
Incorrect Valve Clearance	•					•	•			•						•								•	•		•	•	•
Broken or Weak Valve Spring	•					•	•									•										•	•	•	•
High Exhaust Back Pressure							•																			•	•		
Valves Not Seating Properly	•					•	•		•	•	•													•					
Worn Bearings																•				•		•							
Worn Cylinder Walls, Pistons, Rings	•					•	•			•						•	•			•									
Sticking Valves	•					•	•			•							•												
Worn or Dirty Valve Guides																•										•		•	•

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