Onan®

OPERATOR'S MANUAL

FOR

GTU

SERIES

GAS TURBINE GENERATOR SET

(OFFSHORE)

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TABLE OF CONTENTS

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.

ONAN recommends that you read your manual and become thoroughly acquainted with it and your equipment before you start your unit. These recommendations and the following safety precautions are for your protection.

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.

WARNING: ONAN USES THIS SYMBOL THROUGHOUT THIS MANUAL TO WARN OF POSSIBLE SERIOUS PERSONAL INJURY.

CAUTION: THIS SYMBOL REFERS TO POSSIBLE EQUIPMENT DAMAGE.

General

Keep your electric generating set and the surrounding area clean and free from obstructions. Remove any debris from set and keep the floor clean and dry.

Provide appropriate fire extinguishers and install them in convenient locations. Consult your local fire department for the correct type of extinguisher to use. Do not use foam on electrical fires. Use extinguisher rated ABC by NFPA.

Make sure that all fasteners on the generating set are secure. Tighten supports and clamps, keep guards in position over fans, driving belts, etc.

Do not wear loose clothing in the vicinity of moving parts, or jewelry while working on electrical equipment. Loose clothing and jewelry can become caught in moving parts. Jewelry can short out electrical contacts; cause shock or burning.

If adjustment must be made while the unit is running, use extreme caution around hot surfaces, moving parts, etc.

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

Protect Against Moving Parts

Keep your hands away from moving parts.

Before starting work on the generating set, disconnect batteries. This will prevent starting the set accidentally.

Fuel System

DO NOT fill fuel tanks while engine is running, unless tanks are outside engine

compartment. Fuel contact with hot engine or exhaust is a potential fire hazard.

DO NOT SMOKE OR USE AN OPEN FLAME in the vicinity of the generator set or fuel tank. Engine fuels are highly flammable.

Fuel lines must be of steel piping, adequately secured, and free from leaks.

Be sure all fuel supplies have a positive shutoff valve.

Guard Against Electric Shock

Remove 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.

Use extreme caution when working on electrical components. High voltages cause injury or death. DON'T tamper with interlocks.

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

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. Do not use exhaust gases to heat a compartment.

Be sure the unit is well ventilated.

Keep the Unit and Surrounding Area Clean

Make sure that oily rags are not left on or near the engine.

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.

If your gas turbine is used in a parallel application, even though it may not be running, the bus on the output (load) side of the circuit breaker could be at high voltage potential.

When working on an ignition unit, short High Tension conductor to ground to discharge high voltage capacitor. This capacitor can hold a high potential charge for a long time period. Disconnect plug lead and touch to ground to discharge capacitor.

All fuel shutoff valves MUST be in perfect working condition to prevent fuel leaks or excessive fumes in turbine compartment. Check fuel lines frequently for any leaks and repair and tighten immediately.

Wear ear protection or plugs to protect against high frequency turbine engine noise.

Take every possible precaution to prevent entry of any foreign objects into the air inlet plenum of turbine compressor unit.

High operating temperatures are characteristic of the gas turbine. Never touch any part of turbine power unit or compressor stages while operating and allow set to cool down prior to performing any repairs on the turbine engine.

DESCRIPTION

General

This Onan electric generating set is a complete system consisting of an engine driven AC generator with Automatic paralleling system which includes all controls and accessories as ordered by the Marathon Oil Co.

Engine

The engine on the system is a Garrett model IE831-800 gas turbine as described in the Garrett Operation and Maintenance manual included with the set. Basic measurements and requirements will be found under SPECIFICATIONS. For detailed operation, maintenance and service information, consult the Garrett Engine manual supplied with this system.

General

The Garrett IE831-800 gas turbine is on open-cycle, single shaft, engine which employs a high pressure ratio compressor section to obtain high system efficiency. The engine and Onan alternator are mounted on a common isolated frame.

Rotating Group

The rotating group is comprised of two radial outflow compressor wheels and three axial flow turbine wheels locked together by means of curvic couplings. A bearing and seal assembly on each end of the shaft supports the assembly. The sleeve type hydrodynamic bearings and labrynth type clearance oil seals assure long life and low oil consumption.

Combustion System

The combustion system employs a single burner can and nozzle for high reliability and ease of maintenance. Type of nozzle varies with fuel system used.

Gearbox

The gearbox is an integral part of the engine assembly. The turbine speed is reduced to generator speed by means of double reduction spur gears. The gearbox also contains an accessory drive gear which is coupled to the direct mounted fuel control and starter motor. All gearbox bearings are of the long life, sleeve, hydrodynamic type with pressure lubrication provided to each. The gearbox base contains the engine oil reservoir and features a side mounted sight glass for visual oil level monitoring.

Lubrication System

The lubrication system is comprised of a oil reservoir (gearbox sump), direct

Lubrication System (Continued)

gearbox driven positive displacement pressure and scavenge pump, filters, cooler, necessary relief and check valves and inter-connecting lines. The oil filter and sump capacity are sized for extended set operation without maintenance or oil additions

AC Generator

The generator is an Onan type "YB", 12 lead, 4-pole, revolving field, brushless unit wired for 277/480 volt, 3-phase operation. The main rotor is mechanically direct-coupled to the Gearbox output power shaft through an easily replaceable shear section. Engine output shaft is 2 13/16 inches in diameter. Generator shaft is 3.125 inches in diameter. Turbine gearbox spee determines generator output frequency. Excitation is achieved as follows:

Residual alternating current from the stator winding is applied to the voltage regulator, where it is compared with a reference voltage, rectified and returned to the field of the exciter. Current induced in the exciter rotor is rectified and fed into the generator rotor. This induces a current in the generator stator which is applied to the load.

Controls

The engine controls are included with the automatic paralleling system as ordered. The operation including inter connection wiring diagrams, initial start-up and adjustments are contained in the Operator's manual #900-0208 which is supplied in the literature package for this system. Major emphasis has been given to system simplicity and flexibility. Either manual or automatic controls are available. Sets may be easily paralleled together in order to meet large or growing system demands.

FOREWORD

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

Read this manual carefully prior to operating the set for the first time and observe all safety precautions, cautions and warnings throughout this manual.

This manual contains operation, start-up and routine maintenance procedures necessary to properly maintain, service and make external adjustments on your Onan GTU Series electric generating set. The set consists of a Garrett IE830-800 gas turbine prime mover directly coupled to an Onan "YB" generator. Refer to Specifications page for specific engine and generator ratings.

This manual should be used in conjunction with the Garrett Operation and Maintenance manual, for specific engine information. Refer also to the Onan Operator's manual for automatic paralleling (#900-0208) also provided with this set.

In addition a separate Onan Service manual (#950-0006) and Parts Catalog (#950-0003) are available at nominal cost from your local Onan Distributor.

Model Identification

Identify your model by referring to the model and Specification No. as shown on the Onan nameplate. Electrical characteristics are shown on the lower portion of the nameplate:

450.0	GTU	4X	/	17756	A
1	2	3		4	5

1. Indicates Kilowatt rating (450.0 kW)

2. Factory code for series identification (Gas Turbine Garrett/Airesearch)

3. Generator voltage code 4x - 277/480 3 phase.

4. Specification No. Factory code for designating Optional equipment, if any.

5. Specification letter. Advances when factory makes production modifications.

When contacting dealer or the factory regarding the set, always mention the Complete Model, Spec No. and Serial No. as given on the Onan nameplate. This nameplate information is necessary to properly identify your unit among the many manufactured by Onan. Refer to engine (Turbine) nameplate when requesting information from its manufacturer. The Onan nameplate is located on the upper right side of the air inlet plenum below the compressor (engine) nameplate. In some cases the nameplate may be on the generator outlet control box (top panel) right rear side of the set.

Left side and right side are considered when viewed from the engine (turbine) end of the generating set.

SPECIFICATIONS

Length	125 inches
Width	42.5 inches
Heigth	68 inches
Weight	6600 lbs.

Engine Details

Engine Manufacturer	Garrett/Airesearch
Engine Series	IE831-800
Engine Type	Open cycle, single shaft constant speed gas turbine
Engine Rotor Speed	41,730 RPM
Pressure ratio	11.1
Shaft Horsepower	
Standby	800
Prime Power	690
Gearbox (output) Shaft Speed	1800 RPM
Gearbox type	Integral design with double reduction spur gears
Fuel system	Dual Fuel (Liquid or Gaseous)
Fuel control	Hydromechanical
Fuel type	Liquid (DF-1, DF-2, Jet A, A1, B, JP-4, JP-5 or Natural Gas)
Fuel Pressure	
Liquid (engine inlet pressure)	5-25 PSI + 2%
Gaseous (control inlet pressure)	200-210 PSI + 2%
Heat value	900-1100 BTU/Ft^3
Combustion system (fuel atomizer)	Single burner can and nozzle.
Starting system	24 VDC solenoid shift 2-wire negative ground
Battery size (2 in series)	
Starting power	SAE type D-8D +
Control power	UIL-18 (as required)
Governor	Woodward EG-3p actuator
(Electrical load sensing type)	and type 2301 control
Engine to Generator Coupling	Direct mechanical with shear section

Generator Details

Type	2-bearing, brushless, 4-pole, revolving field, 4-wire with 3-phase exciter

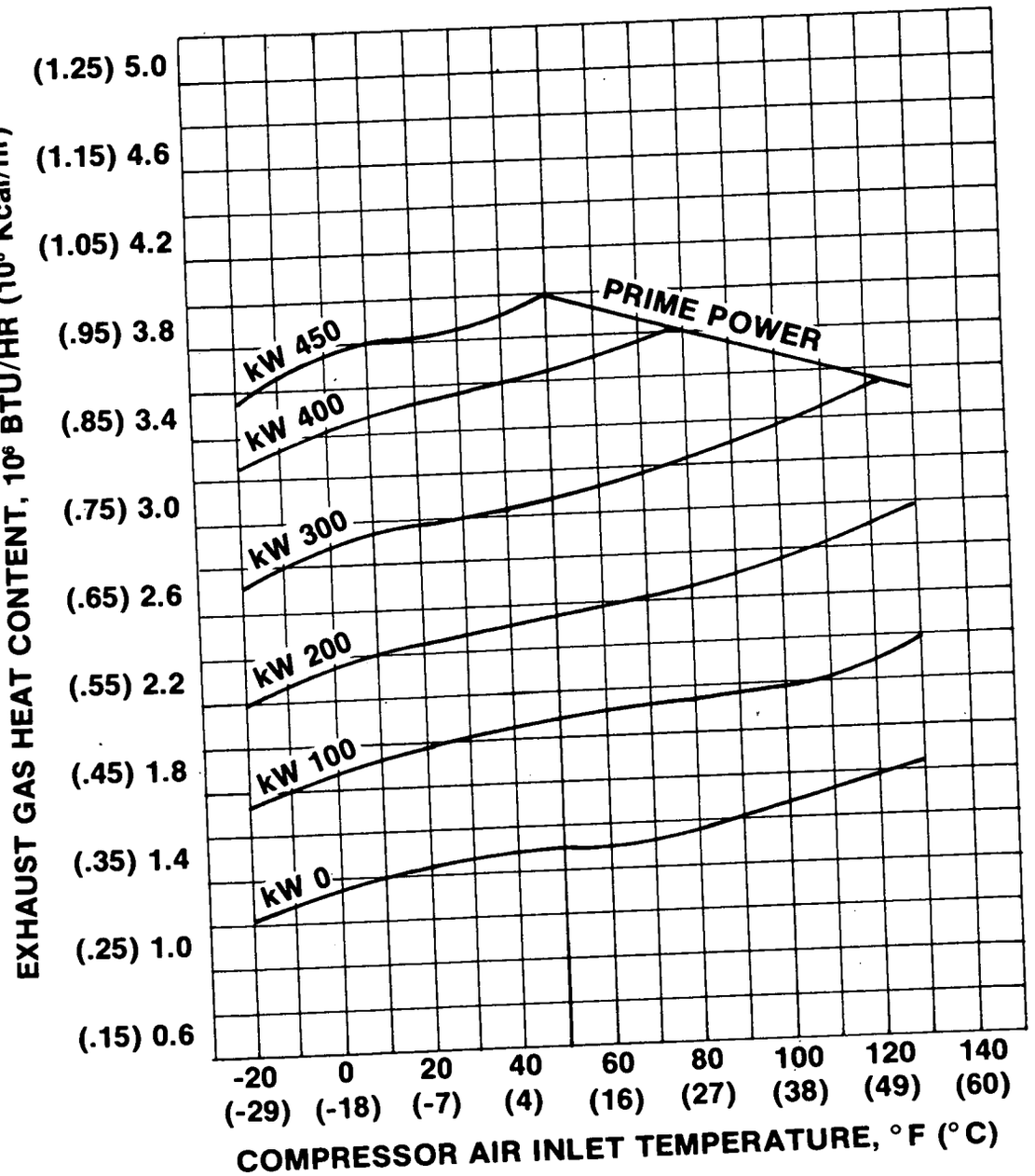
Generator Details (Continued)

Rating (Watts) 60 HZ	
Prime power	450,000 (562 kVA)
Amperage (277/480 volts)	
Prime power	678 Amps
AC voltage regulation	$\pm$ 2%
RPM	1800
AC frequency regulation	Isochronous to 4% droop
Output rating	0.8 PF

Capacities and Requirements

Turbine gearbox oil capacity	13 gallons
Exhaust flange connection size	12 inches (ASA 125# flange)
Air Requirements	
Minimum inlet air flow	6250 CFM ($177 m^3$/min)
Alternator cooling air	1200 CFM ($33.98 m^3$/min)
Minimum exhaust gas flow rate	16,300 DFM ($462 m^3$/min)
Maximum exhaust back pressure	6.0 inches H_2O
Exhaust temperature range	
Continuous	1100 ^oF
Start transient	1650 ^oF
Fuel consumption (rated load, 60 hz, 60 ^oF Sea level)	
Liquid	67 Gallons per hour
Natural Gas (1000 BTU/ft^3)	8,900 ft^3/ hour

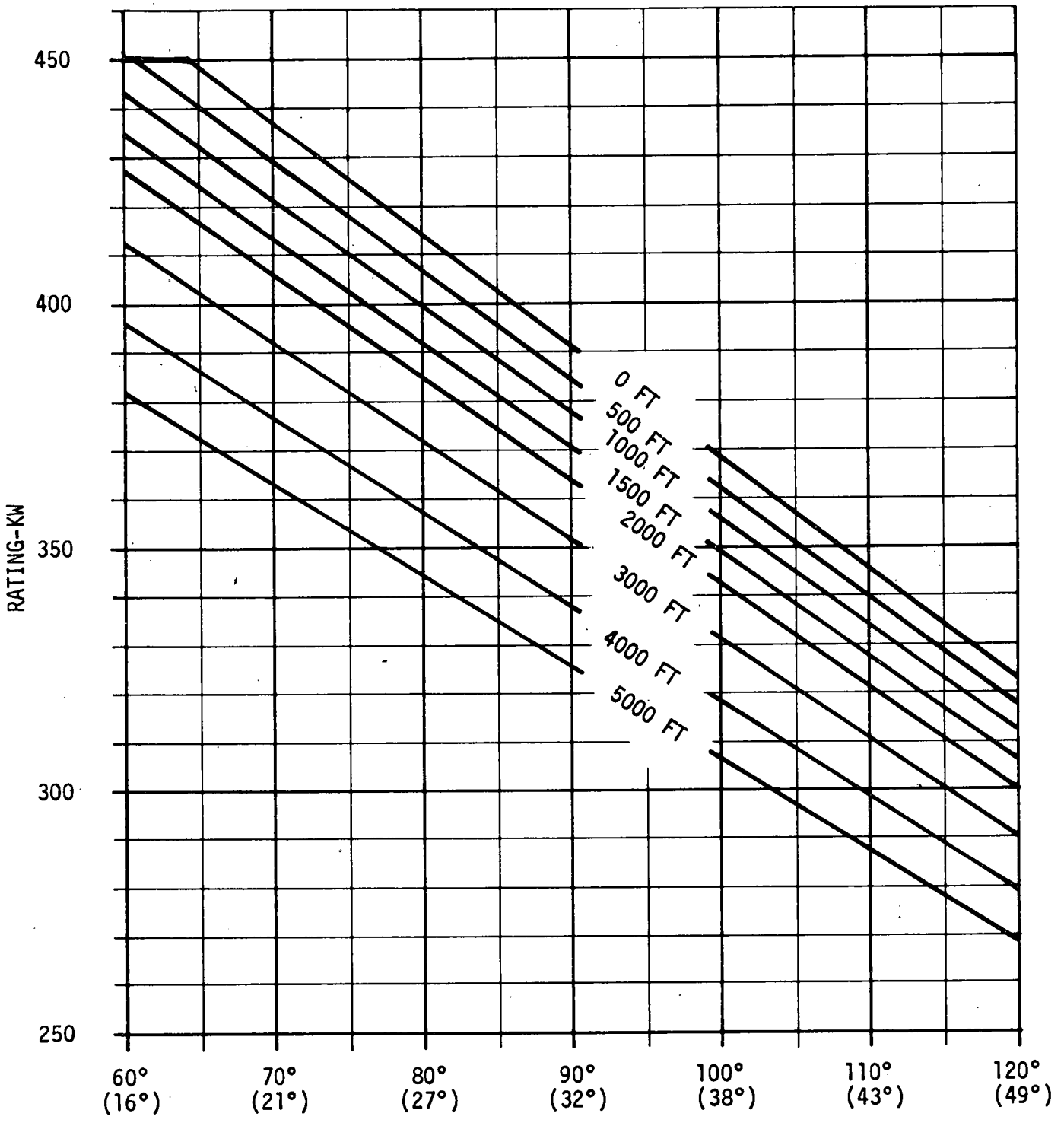
ONAN GTU SERIES
ESTIMATES EXHAUST GAS HEAT CONTENT



NOTES:

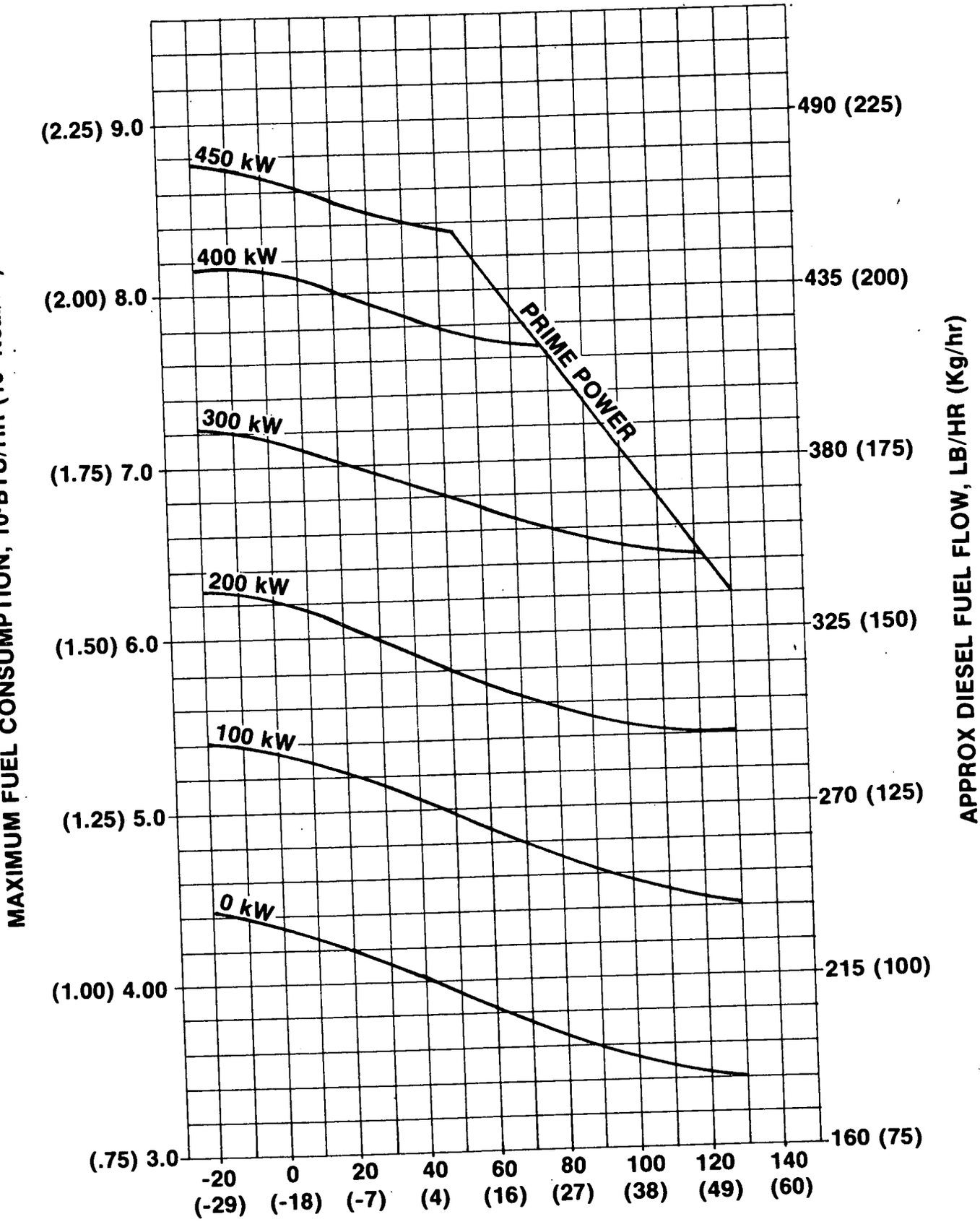
1. NO INLET OR EXHAUST PRESSURE LOSSES
2. 29.92 IN HG BAROMETRIC PRESSURE
3. FUEL LOWER HEATING VALUE EQUALS 18,400 BTU/LB
4. HEAT CONTENT BASED ON SPECIFIC HEAT OF 0.252 BTU/LB-°R AND A REFERENCE TEMPERATURE OF 325°F

ONAN GTU SERIES
PRIME POWER CONTINUOUS RATING



RATING INCLUDES 3 IN H_2O COMPRESSOR LOSS AND
6" H_2O EXHAUST BACK PRESSURE

ONAN GTU SERIES
FUEL CONSUMPTION



NOTE:

1. NO INLET OR EXHAUST PRESSURE LOSSES
2. 29.92 IN HG BAROMETRIC PRESSURE

TYPICAL 500 GTU INSTALLATION CONSIDERATIONS

INSTALLATION SECTION

General

Installations must be considered individually. Use these instructions as a general guide. All installations must meet regulations of state and local building codes, fire ordinances, etc., which may affect installation details.

Requirements to be considered prior to installation:

1. Level mounting surface.
2. Adequate cooling air.
3. Adequate fresh induction air.
4. Discharge of circulated air.
5. Discharge of exhaust gases.
6. Electrical connections.
7. Fuel installation.
8. Accessibility for operation and servicing.
9. Noise levels.

Location

Provide a location that is protected from the weather and is dry, clean, dust free and well ventilated. If practical, install inside a heated building for protection from extreme weather conditions.

Mounting

Generator sets are mounted on a rigid skid base which provides proper support. The engine-generator assembly is isolated from the skid base by rubber mounts which provide adequate vibration isolation for normal installations. For installations where vibration control is critical, install additional spring-type isolators between skid base and foundation.

For convenience in general servicing and changing crankcase oil, mount set on raised pedestal at least 6-inches (150 mm) high. Request ONAN Technical Bulletin T-030 for further installation information.

Base & Mount System

The system includes an inner engine/generator mounting base supported, through three point elastomeric isolators, by an outer housing base. This design maintains drive coupling alignment regardless of housing base deflections caused by handling and uneven mounting surfaces. Also, the isolators provide 85 to 90% attenuation of fundamental frequency vibrations. All major ancillary modules (fuel, lube, housing, exhaust bellows, etc.) are attached to the outer base, which simplifies service and protects the modules from vibration.

The inner base is computer designed to maintain coupling alignment regardless of running torque.

Base & Mount System (Continued)

The outer base is computer designed to assure that the enclosure will not be damaged by deflections caused by handling and installation on uneven surfaces. Tie-down bolt holes are provided in the lower side channel flanges. Lifting eyes are bolted to the upper four corners and extend through the top of the set enclosure.

Ventilation

The set enclosure includes required ventilating fans. Total airflow is 3000 CFM. For proper cooling air circulation, all enclosure doors and panels must be in place. The vent air inlet and outlet silencers include pneumatically controlled dampers to seal out ambient air when the set is not running. The damper controls are wired so that the dampers open any time the engine and fans are running. The fans must be wired to run any time the engine is running and for 1/2 hour after a normal shutdown to remove soak-back heat. Because the enclosure is designed for outdoor installation, there are no provisions for attaching ducts.

Exhaust System

WARNING: Inhalation of exhaust gases can result in death.

Engine exhaust gas must be piped outside building or enclosure. Do not terminate exhaust pipe near inlet vents or combustible materials. An approved thimble must be used where exhaust pipes pass through walls or partitions. Pitch exhaust pipes downward or install a condensation trap at the point where a rise in the exhaust system begins. Avoid sharp bends; use sweeping long radius elbows. Provide adequate support for mufflers and exhaust pipes. Shield or insulate exhaust lines if there is danger of personal contact. Allow at least 9-inches (230 mm) of clearance if the pipes run close to a combustible wall or partition.

SYSTEM ALIGNMENT PROCEDURES

Engine-to-Base Alignment Procedure

Engine-to-base alignment is assured, in the horizontal plane, by two dowel studs and reamed pilot holes. Engine-to-base alignment in the vertical plane must be checked, and adjusted with shims as needed, to assure that the engine centerline is parallel to the longitudinal base channels. This is best done by placing the base on a flat surface, and measuring from that surface to the centers of the exhaust outlet and the output shaft. The dimensions should be equal within 0.12 inch. Reshimming should not be necessary if the engine is removed and replaced, if the original shims are replaced. Tighten engine mounting bolts to 220 ft. lbs.

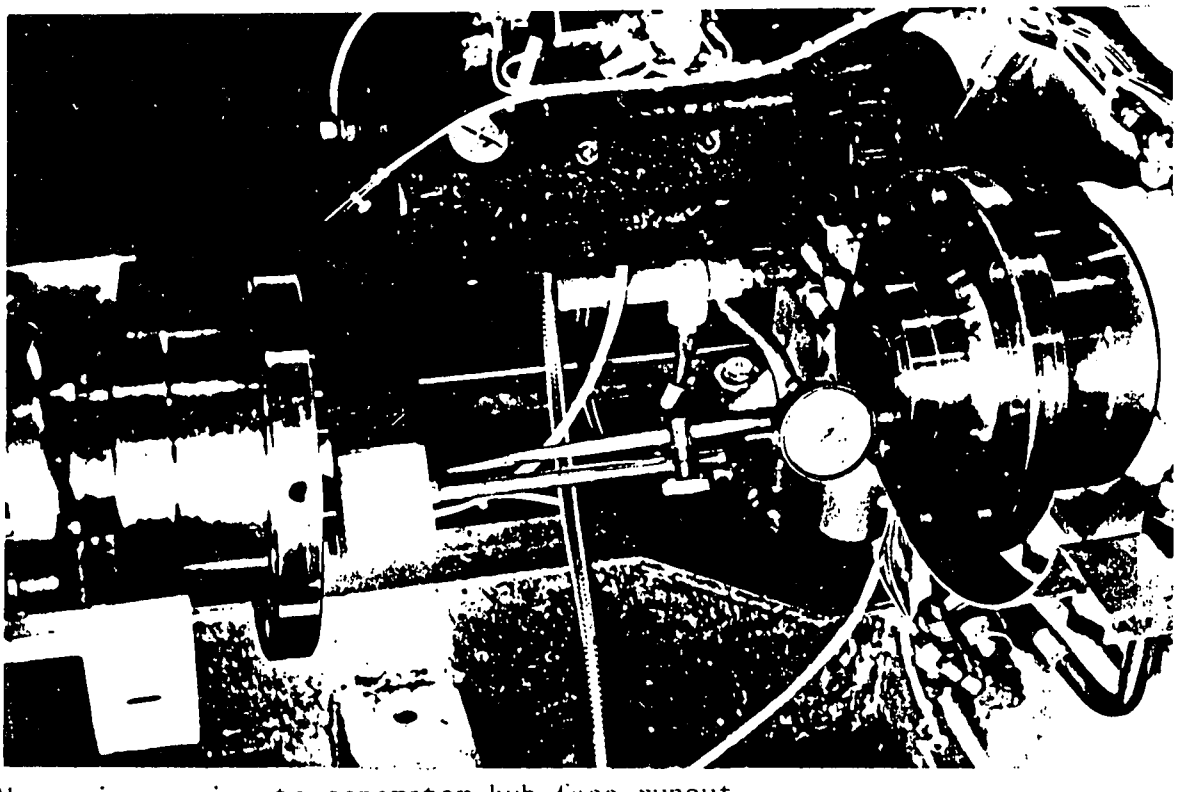
Engine to Generator Alignment Procedure

Engine to generator alignment must be checked, and adjusted as needed to assure maximum coupling life.

To do this:

1) Remove the shear section and slide the coupling flanges back to expose the machined surfaces on the hub. Wipe excess oil from hubs.
2) Measure the distance between the engine and generator hubs. The dimension must be 13.06 inches plus or minus .12 inches. To correct for improper hub separation, use adjusting screws to move generator as required.

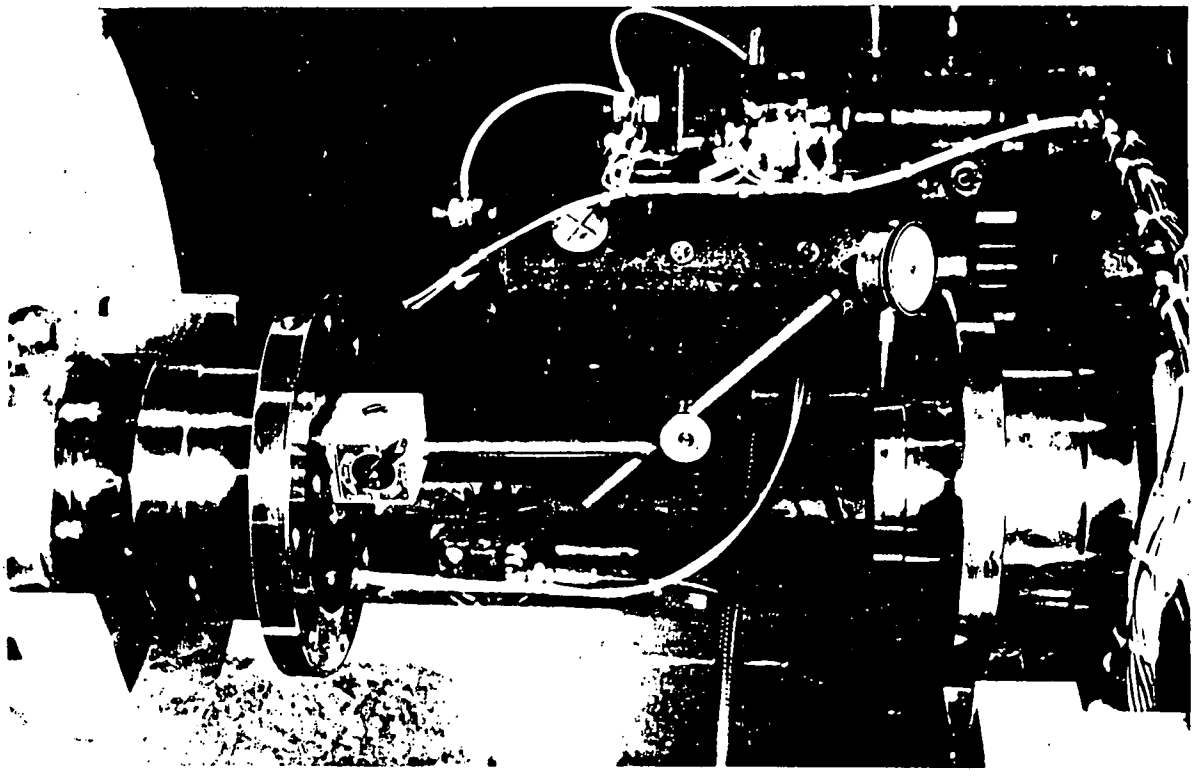
3) With a dial indicator mounted on the generator hub measure and record engine hub face runout while rotating the generator shaft. (See photo for placement of gauge.)



Measuring engine to generator hub face runout.

The allowable face runout is .005 inch TIR (Total Indicator Reading) maximum. This measurement MUST be made at extreme outer edge of HUB face. To correct for misalignment, use adjusting screws to move generator as required.

4) With a dial indicator mounted on the generator hub, measure and record engine HUB diameter runout while rotating the generator shaft. (See photo for placement of gauge.)

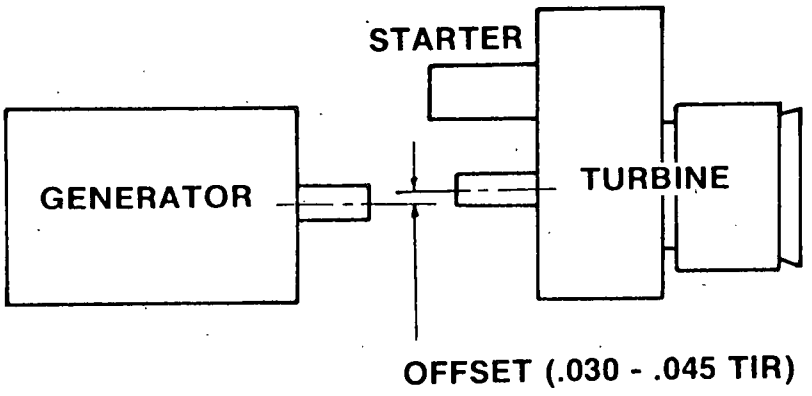


Measuring engine to generator hub diameter runout.

The allowable diameter runout is:

A) In vertical plane: .015 inch TIR maximum.

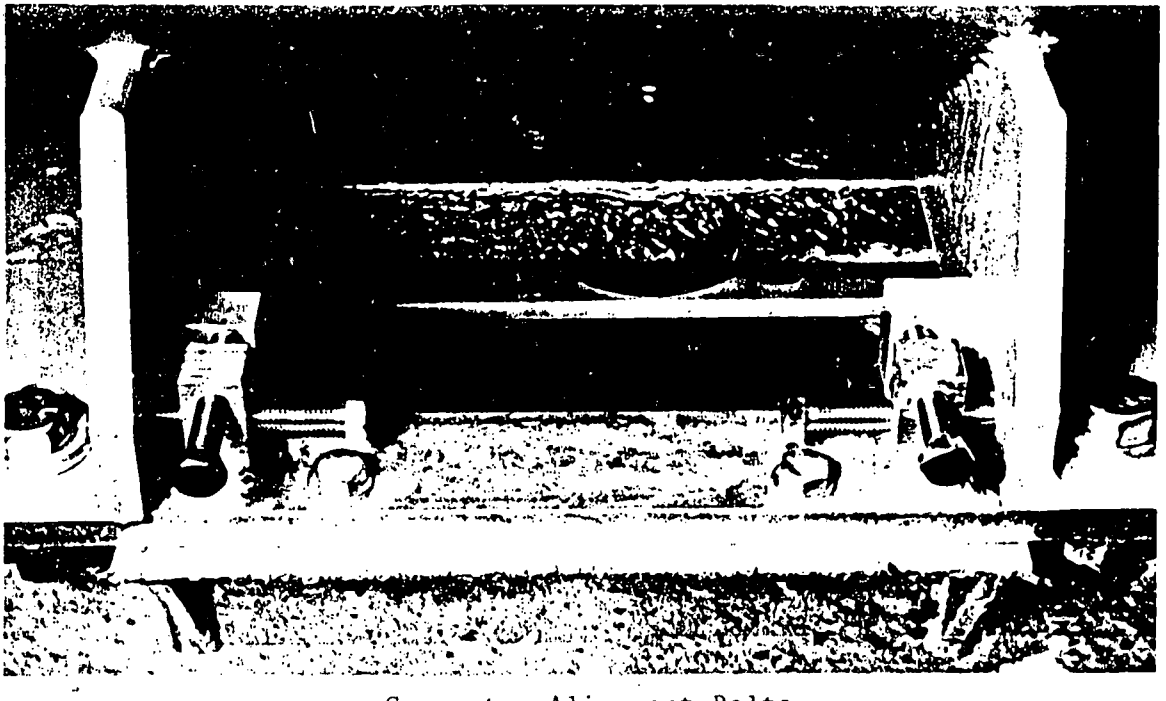
B) In horizontal plane: .030 inch TIR minimum to .045 inch TIR maximum with generator shaft offset away from engine starter motor. (See illustration.) Move generator as required to bring within limits.



SHAFT OFFSET (TOP VIEW)

Generator Shaft Offset (away from Engine Starter)

5) Recheck face runout (step 3) if within specified limits, tighten generator mounting bolts to 300 ft. lbs.
6) Recheck HUB separation and face and diameter runout (steps 2, 3, and 4).
7) After final alignment check (step 6), and when mounting bolts have been properly tightened (step 5), snug-up all 12 generator adjustment bolts to prevent bolts from vibrating loose.
8) Replace shear section, tightening bolts to 80 ft. lbs.
9) Service coupling per instructions in General Maintenance Section of Operator's Manual.



Generator Alignment Bolts

COMPRESSOR AIR INLET DUCT INSTALLATION

A flex section must be provided between the inlet duct and the engine inlet plenum.

Engine inlet static pressure can be measured by inserting a pitot tube through ports provided on the Onan inlet flex section, if used.

Location

The inlet duct opening to outside atmosphere must be located so that heated air from cooling airflow or engine exhaust ducts cannot be drawn into the inlet. Inlet location also has a significant effect on the magnitude of particulate concentration. Typically, inlets must be located as far above the surrounding surface as practicable within the constraints of ducting pressure loss, installation envelope, and economics. Also directing the inlet duct opening away from prevailing winds and areas without ground cover tends to reduce the level of air-entrained particulates.

Inlet Duct Material

Aluminum sheet, aluminized steel sheet, or a good quality mill-galvanized steel sheet is typically used for inlet ducts. Any finish or material that will flake or peel shall not be utilized in the inlet airstream. For installations exposed to a salt atmosphere, stainless steel or a special finish on the duct material is necessary to prevent duct corrosion and the subsequent possibility of engine damage resulting from corrosion-generated debris.

Temperature and Pressure Limitation

Compressor inlet temperature and pressure have a significant effect on engine performance. The inlet duct system, including silencer and filter, must be designed to maintain pressure and temperature within specified limits, and provide flow capacity as follows:

Air Flow (CFM)	Inlet Static Pressure Loss (in. H_2O)	Temp. (^oF)
6,250 (min)	4.0 (max)	110 (max)

EXHAUST SYSTEM INSTALLATION

Exhaust interface details are shown on Drawing 500-1695. A stainless steel exhaust bellows is provided on the engine exhaust to accommodate thermal expansion and vibration of the engine tail pipe. Provisions for thermal growth of the exhaust duct components must be made in the facility duct system design.

Protection must be provided at the atmospheric discharge against excessive entry of rain, snow, hail, dust, and other deleterious atmospheric elements when engine is shut down. Low points, with drain lines and valves, must be provided in the exhaust duct system to prevent entry of liquids into the engine.

Location

Exhaust discharge must be located so that exhaust gases cannot be recirculated into the compressor air inlet. Because of high exhaust gas temperature, the duct system should be insulated to minimize injury to personnel.

Bellows supplied with set accepts up to 0.19 inch radial and 0.50 inch axial movement. Sources of movement are engine/generator transient rocking and running vibration, engine thermal growth (0.012 inch vertical, 0.30 inch axial) and customer exhaust piping movements. Exceeding the limits of the bellows may result in engine damage.

If the exhaust bellows support is used, customer piping must be supported so that the outlet end of the pipe is free to move as thermal growth occurs. Otherwise, a second bellows must be supplied between the support and the customer piping.

Exhaust back pressure cannot be measured by normal field techniques. Due to the high temperature, velocity and turbulence of the exhaust gas, special probes and techniques are required. If measurements are required, consult Onan.

Temperature and Pressure Limitations

Exhaust system total pressure loss decreases engine performance and affects engine starting. Losses resulting from installation ducting and/or noise reduction equipment must not be excessive. Individual exhaust ducts are required in multi-generator set installations. When the exhaust of two or more engines is fed into a common duct, leak-tight check valves must be used. Exhaust gas leakage back through a non-operating engine will result in engine damage due to exposure of the power section bearings to the exhaust gas temperature without the benefit of cooling lubricant flow. Exhaust duct system (including silencer), must be designed to meet flow, pressure, and temperature conditions as follows:

Flow (CFM)	System Total Pressure Loss (in. H_2O)	Temp. ($^oF.$)
17,540	6.0 (max)	1100 (max continous) 1650 (start transient)

FLUID SYSTEMS

Lube Oil System

The engine oil system is fully automatic in operation and consists of an oil pump, oil pressure switches, check valve, dual oil filter system, pressure regulator, temperature switch, all necessary tubing and fittings and oil pressure gauges, temperature sensor and oil cooler (Young). For additional information refer to the Garrett Operation & Maintenance Manual, Section II. Oil capacity (engine only) is 13 gallons. For recommended oil, refer to Garrett Operation & Maintenance Manual, Section I, page 30, table 1-2. Oil pressure is controlled by an adjustable engine mounted pressure regulator.

Oil Filters

The duplex lube oil filter system (schematic 179-0480) provides extended filter life and filter service without shutdown.

Filters were selected for proper flow, filtration, pressure rating and availability of replacement elements.

Filters are mounted with the element up to allow plumbing the drains to a common set waste drain. This arrangement traps air and requires that the filter be bled before it is activated, to prevent a LOPKO shutdown. The procedure is posted on the set near the filter.

Normal filter pressure drop is about 20 psid with clean elements. The element must be changed when the drop exceeds 35 psid, to avoid internal bypass. Field experience will establish the normal service interval.

The filter selector valve was chosen for proper flow, pressure drop, burst rating, and corrosion resistance properties. At either side position, full flow is directed to one filter and the other filter is completely shutoff. In the center position the valve is open to both filters, but the restriction is high and most of the oil bypasses through the relief valve. This valve position is used only to allow safe filter bleeding. The Garrett oil filter protects the engine during bypass operation.

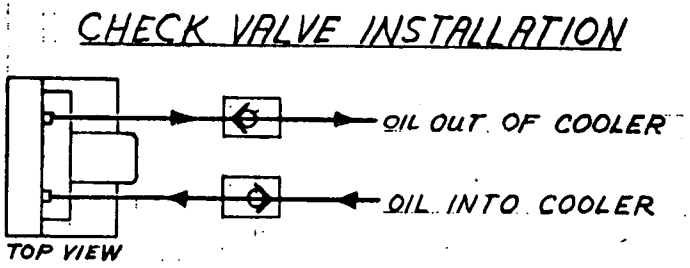
Oil Cooler

The oil cooler must be remote mounted due to space limitations of the set design

Oil coolers must limit engine inlet oil temp to $160^{o}F$.

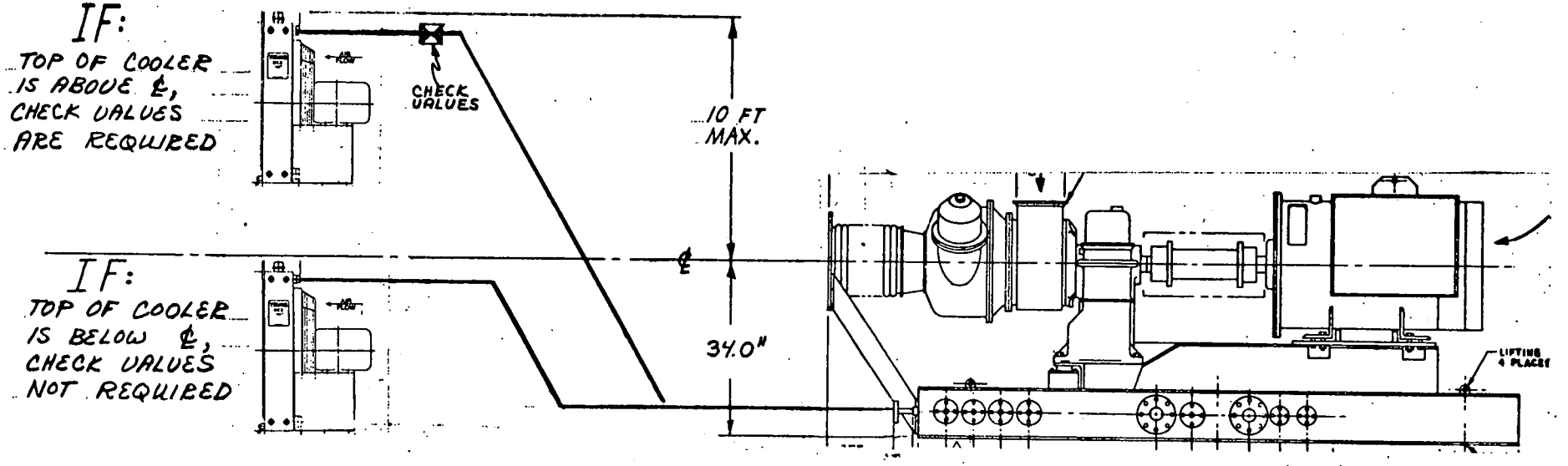
If the customer installs the coolers with the highest oil level below the engine centerline, backflow check valves are not required. If the oil level is raised, the customer will have to install such valves per illustration as shown on the next page.
The remote oil cooler is a stock Young unit specified by the customer to match

NOTE: If the remote (Young) oil coolers are installed with the highest oil level BELOW the engine centerline, backflow check valves are NOT required.
If the oil level is raised ABOVE the engine centerline, the customer MUST install the check valves as shown on this illustration.



CHECK VALVE SPECS:

- MINIMUM $C_V = 7.2$
- CRACKING PRESSURE:
  3.5 PSI MIN.
  5.0 PSI MAX.
- MIN. WORKING PRESS = 1000 PSI
- CHECK-ALL #LN-3-075-SS (OR EQUIVALENT)



OIL COOLER CHECKVALVE INSTALLATION

Oil Cooler (Continued)

units which are currently in service. These coolers do not require cold start by-pass valves as core design eliminates need for those valves. The oil flow is 14 GPM with heat rejection of 1400 BTU/min. The chart below outlines supply and return line sizing necessary for use with any remote oil cooler. The oil cooler serves as the principal means for dissipating rejected heat from the bearings and gears.

Lowest Expected Ambient	MAXIMUM ONE WAY EQUIVALENT LENGTH FOR			
	3/4" Pipe (.824" ID)	1" Pipe (1.049" ID)	1-1/4" Pipe (1.38" ID)	1-1/2" Pipe (1.610" ID)
30F	15 FT	39 FT	116 FT	217 FT
10F	5 FT	13 FT	39 FT	71 FT

Fuel System

The turbine engine used on the Onan GTU set is designed for use with ASTM No. 2 diesel fuel or natural gas operation. Both systems are fully automatic. For gaseous fuel, a customer supplied regulated natural gas supply of clean dry fuel at 200 - 210 psi input pressure is required. The heating valve of the natural gas should be between 900- 1100 BTU/Ft^3. For liquid fuel systems, a customer supplied source of clean #2 diesel fuel is required. Additional information on description and operation of both fuel systems is covered in Section 7 of the Garret Operation Maintenance Manual.

Gaseous Fuel System

The set mounted gaseous fuel system consists of a final 1 micron filter, solenoid valves (double-block and vent), metering valve, and all inter-connecting lines.

Fuel Connections

All fuel system customer interfaces are located on the set skid base.

Check regulations governing the installation of a fuel supply tank.

In any turbine engine installation, fuel system cleanliness is of utmost importance. Make every effort to prevent entrance of moisture or contaminants of any kind. Do not use lines or fittings of galvanized material.

A fuel lift in excess of 12-feet (3.6 m) is not recommended without a day tank installation, because of fuel drainage.

Specified Liquid Fuels

The engine will operate satisfactorily on any of the fuels listed below:

Fuel	Specification	Approved Fuel Temperature Range
Diesel #1	ASTM D975 VV-F-800	-10 F. to 130 F. (-23 C. to 54 C.)
Diesel #2	MILL-F-16884 MILL-R-46005	+40 F. to 130 F. (+40 C. to 54 C.)
Jet A, A-1	ASTM D1655	-20 F. to 130 F. (-29 C. to 54 C.)
JP-4 AND	MIL-T-5624	-20 F. to 130 F. (-29 C. to 54 C.)

Consult the factory for the suitability of fuels other than those listed above. Liquid fuel delivered to the engine must be at 5 to 25 PSIG and cyclic pressure variations less than $\pm$ 2 PSIG.

Liquid Fuel Drain System

An automatic plenum drain system is provided which assures complete drainage of any unburned liquid fuel. Also, the drain system is designed to drain any fuel which

Drain System (Continued)

could possibly seep past the gearbox mounted fuel pump shaft seal.

Fuel inlet connections to the set are outlined on the interface installation drawings (one for gaseous and one for liquid fuel). These drawings are included in the literature package.

The liquid fuel system (schematics 179-0481 and 179-0482) provides extended filter service intervals, filter service with the engine running, fuel inlet pressure control and gravity fed fuel for starting.

The filters were selected for proper flow, filtration, pressure rating and availability of replacement elements. Actual service life and acceptable pressure differential will be determined by field experience.

Normal filter pressure differential is less than 5 PSID with new elements. When filter pressure differential exceeds 20 PSID, the filters should be changed. The boost pump outlet pressure is 30-40 PSI. The normal engine inlet fuel pressure is 15-25 PSI.

The filter selector valve is the same as on the lube oil system, except with smaller ports. Due to the lower flow rate and viscosity of the diesel fuel, the system will operate properly with the valve in any position.

The fuel boost pump provides required flow, lift and supply pressure. A 480 VAC motor was used because 24 VDC motors are not readily available. The motor must be powered from the platform main bus to allow operation with the generator disabled.

The reservoir tank provides gravity feed fuel for starting. The set will operate for several minutes from the tank, which generally allows plenty of time to activate the main bus and boost pump. A port on the tank allows manual filling if required. The system is self-bleeding.

The gaseous fuel system (schematics 179-0481 and 179-0483) provides a final filter and valving required to assure positive and timely shutdown of the set under normal and fault conditions.

The filter was selected to provide final, fine particulate and liquid removal, to protect the valves. Service life will be very short if inlet fuel quality requirements are not met.

The main shutoff valve was chosen to conform to Garrett Specifications.

The vent valve was sourced from the same vendor as the main valve.

The secondary valve was chosen to match what Garrett will supply on future gaseous fuel engines. When Garrett supplies it, it will be mounted on the engine. Note that this valve is used differently on single and auto dual fuel systems, as shown on the schematics.

OPERATION SECTION

General

Onan GTU Series electric generating sets are given a complete running test under various load conditions and are thoroughly checked before leaving the factory. Inspect your unit closely for loose or missing parts and damage which may have occurred in transit. Tighten loose parts, replace missing parts and repair any damage before putting set into operation.

Batteries

Ensure that the cable connections to the batteries are secure. Coat connections with petroleum based or non-conductive grease to retard formation of corrosive deposits.

Check level of electrolyte to be at split ring mark. Measure specific gravity of electrolyte: SG 1.280 at 80°F (26.7°C). If distilled water has been added or specific gravity is less than 1.280, place batteries on charge until desired reading is reached. Do not over charge.

Fuel System

Refer to the Garrett engine manual, section 7, for fuel oil specifications. Check with fuel supplier and ensure that fuel supplied meets the specifications. Filter or strain fuel when filling tank. Fuel supply tanks should be kept as nearly full as possible by topping up each time engine is used. Warm fuel returning from the liquid fuel valve heats the fuel in the supply tank. If the fuel level is low in cold weather, the upper portion of the tank not heated by returning fuel tends to increase condensation. In warm weather both the supply tank and fuel are warm. Cool night air lowers the temperature of the tank more rapidly than the temperature of the fuel. Again this tends to increase condensation.

Condensate mixing with the sulphur in the fuel forms a sulphurous acid which will corrode and damage the engine. KEEP FUEL CLEAN.

WARNING: DO NOT SMOKE while handling fuel. Diesel fuel is flammable.

Pre-Start Servicing

Prior to initial "first" start and any time set is restarted after fuel and lubrication (oil) systems have been drained; complete system must be primed and purged prior to initial "first" start. Proceed as follows.

Turbine Gear Box

Fill gear box through top oil fill plug. Oil capacity is 13 U.S. gallons. Refer to Garrett operation and maintenance manual, section 1 for recommended oils.

Priming Remote Oil Cooler and Oil Filters

Disconnect output pressure line from top of oil pump as shown by arrow on illustration. Also disconnect remote oil cooler return line at oil pressure regulator valve on gearbox as shown by arrow on illustration. Open remote oil cooler plug and oil filter bleed valves (2); put selector valve in bypass position. Supply oil under pressure (20 - 50 PSI) to line previously disconnected at top of oil pump. See illustration. Pump oil through system until oil runs out of bleed valves on oil filters and also from remote oil cooler plug. Close remote oil cooler plug and oil filter bleed valves (2). Continue priming until oil flows out of line disconnected at oil pressure regulator valve on gearbox. See arrow on illustration. Reconnect line on top of oil pump and line at oil pressure regulator valve on gearbox.

Priming Turbine Engine

Remove plug at oil pressure sequencing switch on gearbox near oil filter. See illustration. Disconnect oil return line at rear bearing below exhaust plenum. See illustration. Supply oil under pressure (20 - 50 PSI) until oil flows out of return line (just disconnected) at turbine rear bearing below exhaust plenum. See illustration. Reconnect oil return line at turbine rear bearing. Replace plug at oil pressure sequencing switch. See illustration. This insures that oil is present in the power section bearings and that pressure pump will be able to pressurize the system within 10 seconds after rotation begins.

Purge Cycle

Place operation selector switch on remote control cabinet in manual position. Push crank switch on remote control cabinet and hold "in" for a minimum of 30 seconds. Return operation selector switch to off position. Check all oil lines for leaks.

Repeat the purge cycle one more time. Check gearbox oil level. If level is not midway between gauge marks, add oil as necessary.

Priming Liquid Fuel System

Run boost pump until engine inlet pressure gauge registers 15 to 25 PSI.

Purging Liquid Fuel System

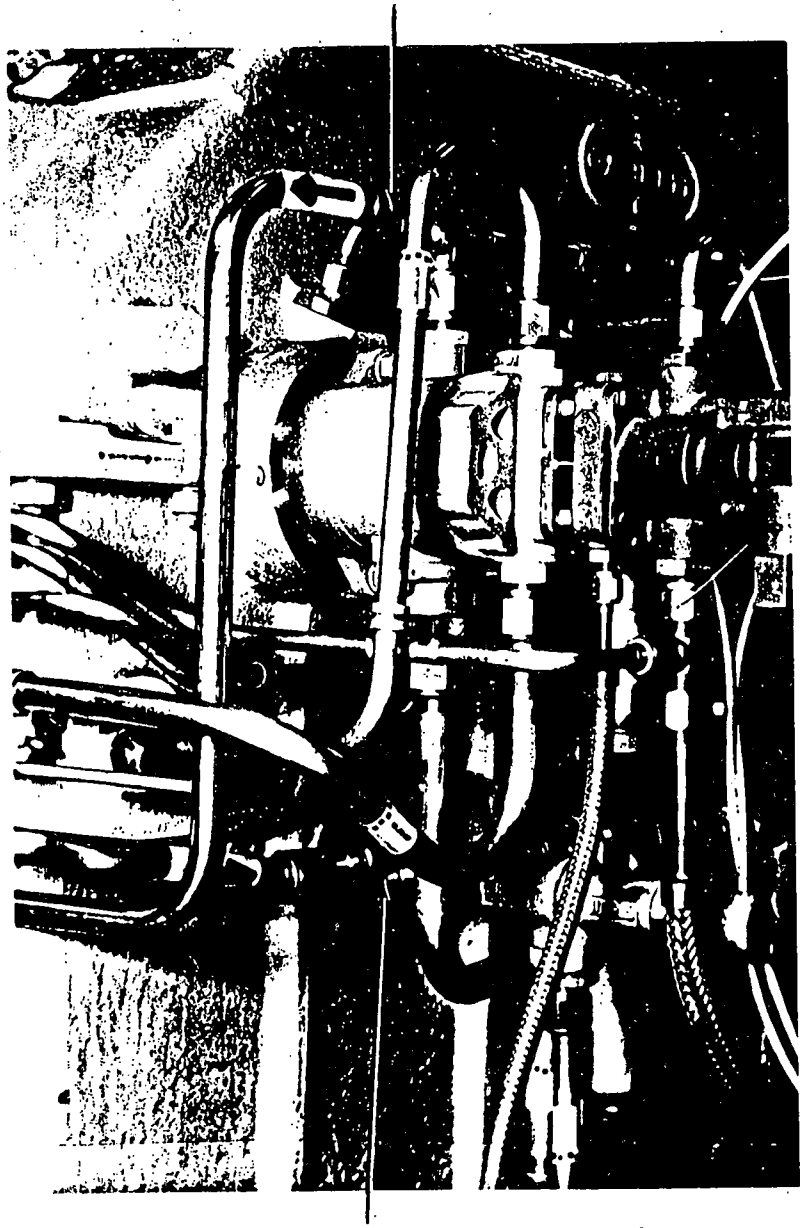
Disconnect fuel line at atomizer (fuel nozzle) on top of combustor can. Disconnect 24 volt input plug at igniter box. See illustration.

Place remote control operation selector switch in manual position.

Press start switch.

Run engine on starter until fuel flows from line previously disconnected at atomizer (fuel nozzle) on top of combustor can. Immediately place operation

Disconnect this line (as shown) and pump new oil into this line under pressure (20-50 PSI). Pump in the direction of heavy arrow.



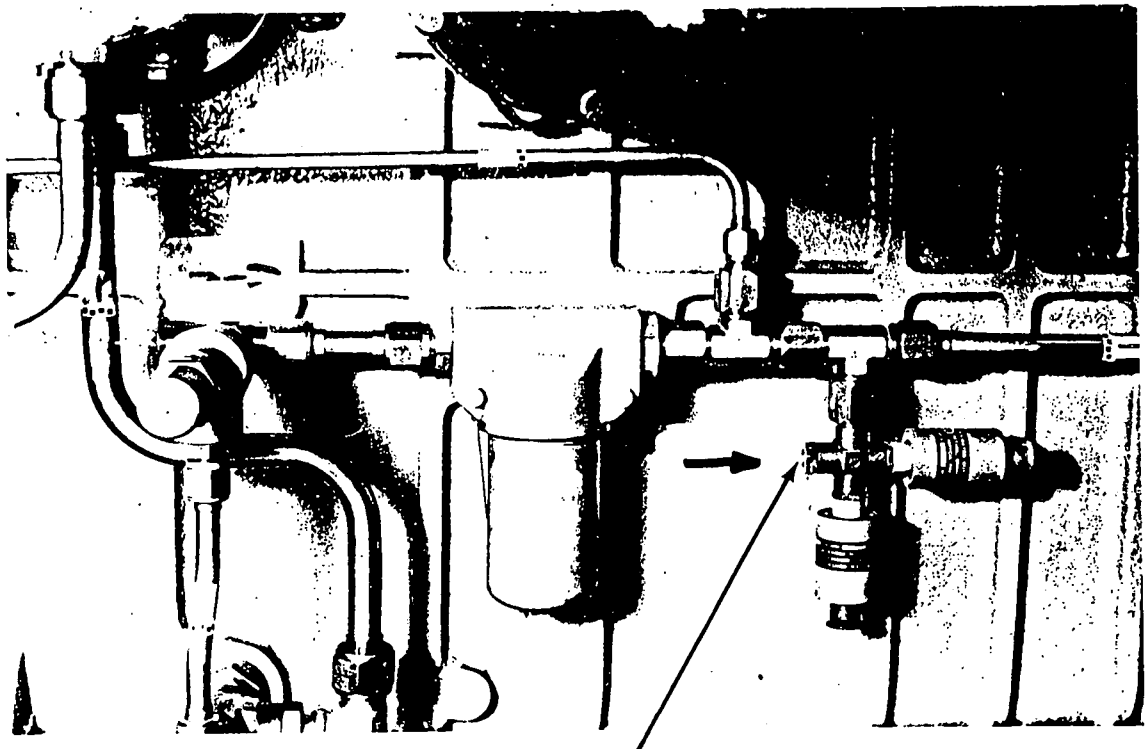
Disconnect this line and pump new oil into upper line (see arrow above) until oil flows freely from this point.

PRIMING REMOTE OIL COOLER AND OIL FILTERS AS SHOWN.

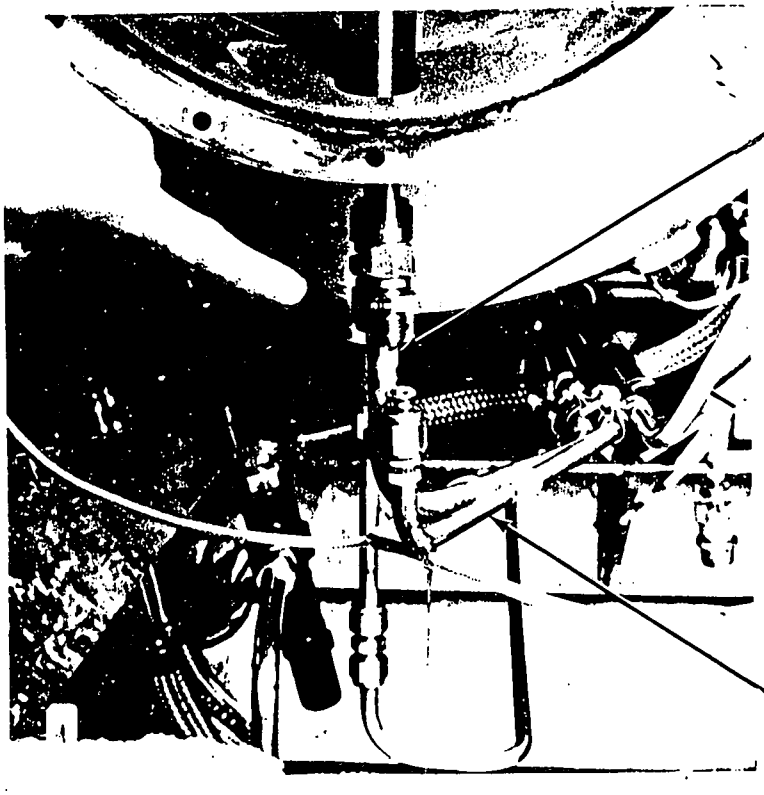
(Refer to text for procedure on previous page).

PRIMING TURBINE ENGINE

(Refer to text on page 26 for details



Remove this plug and pump new oil into this point under pressure (20-50 PSI) Pump in direction of heavy arrow.

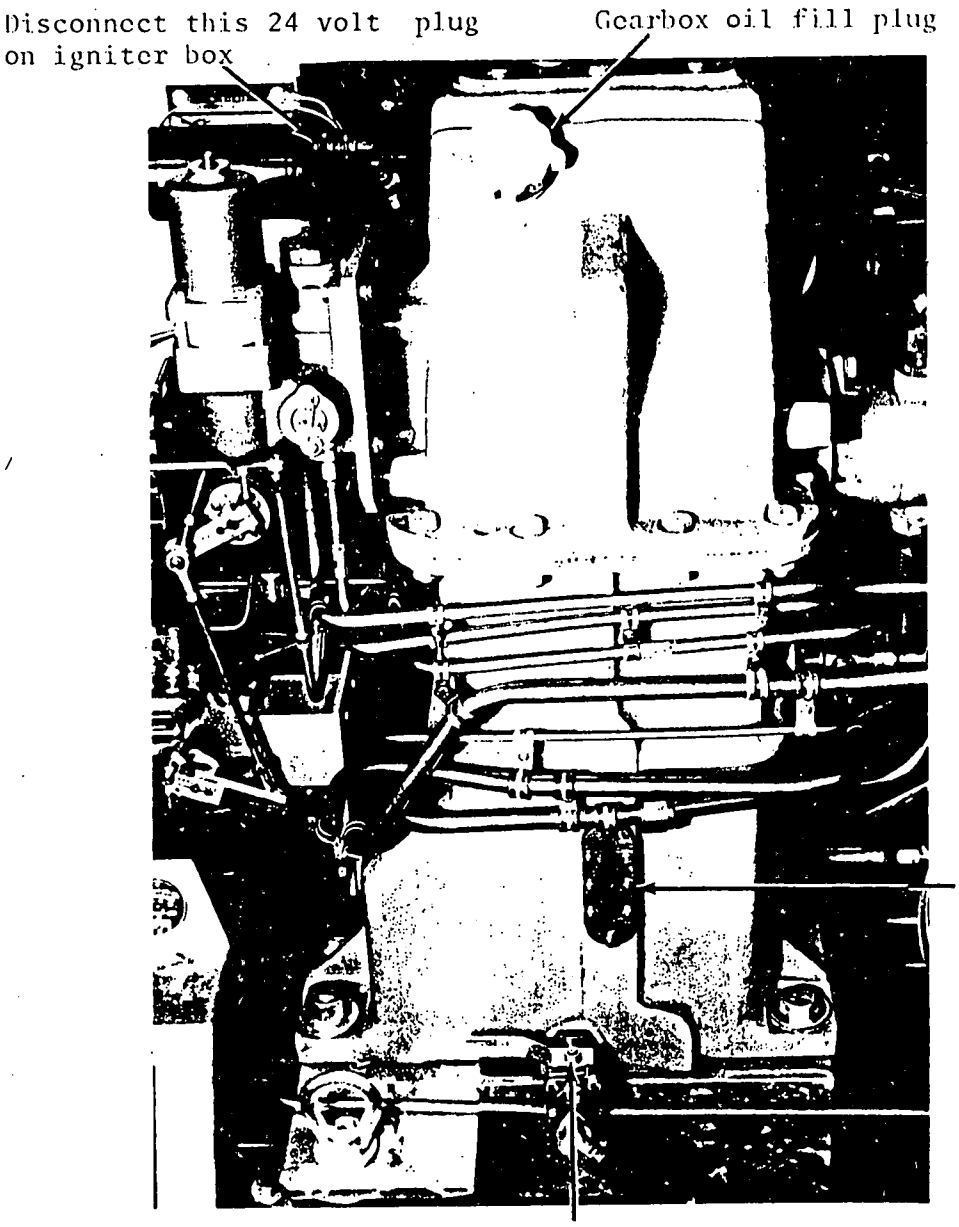


Disconnect this line and pump new oil into point shown above until oil flows freely from this point. Then reconnect this rear bearing return line.

Rear bearing oil return line. Disconnect prior to pumping in new oil as shown above.

PURGING LIQUID FUEL SYSTEM

(Refer to text on page 26 for procedure.)



Purging Liquid Fuel System (Continued)

selector switch to off position. Reconnect atomizer fuel line and 24 volt plug on ignitor box. Check fuel system for leaks.

Control System

The standard control console provided is complete with engine start-stop controls and AC output control.

A remote control console contains circuit breaker and automatic start and load transfer equipment details and is covered in the 900-0208 manual.

Starting Sequence Summary

A start sequence is the initiation of control functions required to accelerate the engine from 0 to 100% speed.

The start sequence may be initiated manually or automatically by start and load transfer equipment.

When the engine logic receives a start signal and there is no fault signal present, the start sequence will begin by energizing the starter motor. The engine will start accelerating; and when a predetermined minimum oil pressure is attained, the engine logic will energize the fuel solenoid and electronic igniter. With fuel and ignition on, the engine will continue to accelerate to 95% speed and at this time the logic will deactivate the starter motor and the electronic ignition. The ready to load light will then come on and the turbine will further accelerate to 100% of rated speed. At this point the set is controlled by the Woodward governor system.

Starting Procedures

After all prestart servicing has been completed and all alarm systems have been tested for proper operation, refer to the paralleling control operator's manual #900-0208 for initial start-up and operating procedures.

No Load Operation

Periods of no load operation should be held to a minimum. If it is necessary to keep the engine running for long periods of time when no electric output is required, best engine performance will be obtained by connecting a "dummy" electrical load. Such a load could consist of heater elements, etc.

Day Tank

Generator set installations may be equipped with a separate fuel day tank. A float operated valve controls fuel flow into the fuel tank. The correct level is maintained to assure a constant source of fuel. It is necessary to install an overflow line between the day tank and main fuel tank. Refer to the installations included with the tank. Tank and lines must be below level of return outlet.

Battery

Use two 12-volt (see SPECIFICATIONS) batteries for a normal installation. Connect the batteries in series (negative post of first battery to positive post of second). Service the batteries as necessary. Infrequent unit use may allow the batteries to self-discharge to the point where they cannot start the unit. If installing an automatic transfer switch that has no built-in charge circuit, connect a separate trickle charger.

WARNING: Do not smoke while servicing batteries. Lead acid batteries give off explosive gases while being charged.

TOTAL BATTERY CABLE RESISTANCE SHALL BE .0016 OHMS AT 20°C, LOWER RESISTANCE MAY RESULT IN STARTER DAMAGE AND HIGHER RESISTANCE WILL REDUCE STARTER PERFORMANCE, RECOMMEND 21 FEET OF #2/0 A.W.G. CONDUCTOR. TO PREVENT DAMAGE TO STARTER, MAXIMUM PEAK CURRENT MUST BE LIMITED TO 2000 AMPERES.

Start and Control Power Source

The electric starter and engine controls require 24 Vdc operating power. Recommended power sources are batteries as follows:

Battery	Type	Manufacturer	Qty.	Configuration	Ambient Temperature Range
Control Power	UIL-18	Exide/Willard	2	Series	0 to 110°F (-18 to 43°C)
Start Power	D-8D+	Exide/Willard	2	Series	0 to 110°F (-18 to 43°C)

Wiring Connections

Most local regulations require that wiring connections be made by a licensed electrician and that the installation be inspected and approved before operation. All connections, wire sizes, etc. must conform to requirements of electrical codes in effect at the installation site.

Generator set grounding must be in accordance with National Electrical Code (NFPA 70-1975) Article 250.

Internal wiring is installed as part of assembling the set prior to shipment.

Wiring Connections (Continued)

Installation wiring requirements, therefore, consist of interface connections between the set and operating facility and between the set and remote control panel.

Conduit should enter through the removable panel in the drip pan, and then through the bottom of the outlet box.

Battery, Hot Location

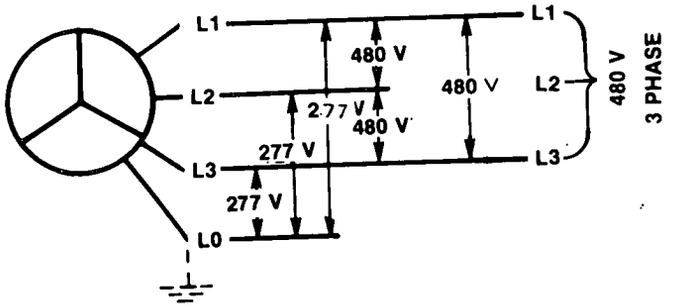
Batteries will self discharge very quickly when installed where the ambient temperature is consistently above 90°F (32.3°C) such as in a boiler room. To lengthen battery life, dilute the electrolyte from its normal 1.275 specific gravity reading at full charge to a 1.225 reading. The cranking power is reduced slightly when the electrolyte is so diluted, but if the temperature is above 90°F (32.2°C), this should not be noticed. The lengthened battery life will be worth the effort.

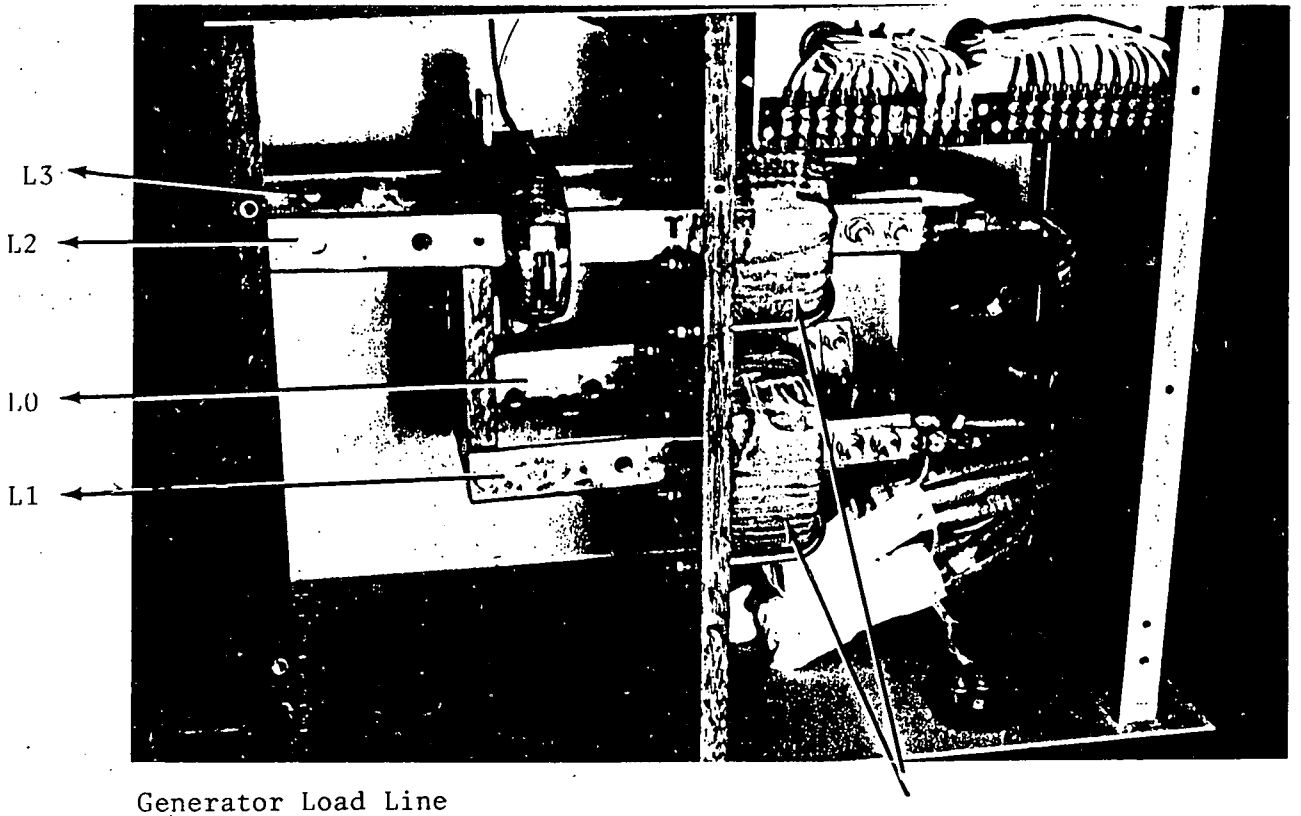
1. Fully charge the battery.
2. With the battery still on charge, draw off the electrolyte above the plates in each cell. DO NOT ATTEMPT TO POUR OFF; use a hydrometer or filler bulb and dispose of it in a safe manner. Avoid skin or clothing contact with the electrolyte.
3. Refill each cell with distilled water, to normal level.
4. Continue charging for 1 hour at a 4 to 6 hour rate.
5. Test each cell. If the specific gravity is still above 1.255, repeat steps 2, 3, and 4 until the reading is reduced to 1.225. Usually, repeating steps twice is sufficient.

Generator Connections

The alternator is a two-bearing brushless, 4-pole, revolving field type. It incorporates a rotating rectifier exciter and solid-state voltage regulator. The alternator is a 3-phase, 4-wire, insulated neutral and is rated at 500 KW, 625 KVA at 0.8 power factor lagging. See illustration below.

The generator is connected in a series wye configuration to give the line-to-neutral or line-to-line 277/480 voltage code. Line-to-neutral voltage is the lower voltage rated on the unit nameplate; line-to-line voltage is the higher rating. See illustration on following page for an example of 277/480 voltage connection.





Generator Load Line
Wiring Connections

These Current Transformers are
actually inside Control Panel
of Paralleling Switchgear.

Control Wiring Connection (Interface)

For necessary wiring interconnection between the generator set terminal box and the control switch boards, refer to diagram #630-1015 in the 900-0208 operator's manual. This diagram is also included in the paralleling literature package supplied with the set. The terminal box on the generator set is located on the bottom of the inner skid base between the turbine and the generator. Remove cover to expose terminal strip J1.

Engine Sensors

The control incorporates fault indicating lights and a manual reset for excessive overspeed, low lubricating oil pressure, high lubricating oil temperature, high turbine temperature and loss of electrical control signal. To operate those protective devices requires the following turbine engine sensors.

Overspeed

An electronically activated speed switch shuts down the turbine when the engine speed exceeds 110%. Engine speed is sensed directly off the high speed turbine shaft by a monopole generator.

Low Lubrication Pressure

A pressure switch shuts down the engine if the oil pressure drops below 55 PSI minimum.

Minimum Light-Of Lubricating Oil Pressure

A pressure switch prevents energizing the igniter and fuel solenoid valve until a minimum start oil pressure of 5 PSI is attained.

High Lubricating Oil Temperature

A temperature switch shuts the engine down if the oil temperature exceeds an established maximum of 165^{o}F.

High Turbine Temperature

An electronic temperature control shuts down the engine when exhaust gas temperature exceeds established limits during start cycle (acceleration) or during normal operation (run). The run temperature shutdown point varies through a predetermined range, according to compressor inlet temperature as described in Section I of the Garrett manual.

Electric Governing System

An electrical load-sensing type governor system comprised of the Woodward EG-B2P or EG-3P actuator and type 2301 control.

The electric governor equipped alternator set is capable of being operated with other alternator sets in the droop-droop or droop-isochronous modes. In addition, the isochronous-isochronous mode of parallel operation is possible if both alternator sets are equipped with similar electric load-sensing governors.

The EG-B2P actuator incorporates a backup centrifugal governor system, which provides control in the event of a failure of the electric governor or the related electrical load sensing circuits. (EG-B2P not used on Marathon sets.)

Governor systems are directly gearbox mounted and are lubricated by the engine's pressure lubrication system. Fuel control mechanisms are designed for over 500 hours of stable operation without requiring servicing or adjustment.

The fuel control schedules minimum and maximum fuel flows to prevent turbine flameout or overspeed under any operating conditions within the electircal and ambient conditions contained in this specification.

Governor Adjustments - Engine Speed

Governor is set at the Onan testing facility and does not require further adjustment for normal service.

If the governor is removed for service, refer to the appropriate Woodward manual for your model or section 9 and 9A of the Garrett operation and maintenance manual.

On gaseous fueled sets, the fuel control valve must be readjusted to compensate for variations in the BTU content of the natural gas supply.

GENERAL MAINTENANCE SECTION

General

Establish and adhere to a definite schedule of maintenance inspection and servicing, application and environment being the governing factors in determining such a schedule. If your set is a prime power application, base your schedule on operating hours. Use the running time meter to log hours run; maintain an accurate record of hours and service for warranty support.

Refer to Garrett manual for engine services and maintenance procedures. Adjust your schedule to satisfy the following conditions:

Continuous duty (prime power)

Extremes in ambient temperature

Exposure to elements

Exposure to salt water or sea water

Exposure to dust, sand, etc.

Consult with your ONAN distributor or dealer for a schedule of maintenance and service more suitable to the unique environment and application of your set.

WARNING: Before commencing any maintenance work on the engine, generator, control panel, automatic transfer switch or associated wiring, disconnect batteries. Failure to do so could result in damage to the unit or serious personal injury in the event of inadvertent starting.

Inspection and Cleaning

When inspecting the rotating rectifier assembly, make sure diodes are free of dust, dirt and grease. Excessive foreign matter on these diodes and heat sinks will cause the diodes to overheat and will result in their failure. Blow out the assembly periodically, with filtered, low pressure air. Also check to see that diodes and leadwires are properly torqued. The diodes should be torqued to 30 in. lb. or finger tight plus a quarter turn.

Batteries

Check the condition of the starting batteries at least every two weeks. See that connections are clean and tight. A light coating of non-conductive grease will retard corrosion at terminals. Keep the electrolyte at the proper level above the plates by adding distilled water. Check specific gravity, recharge if below 1.280.

Connections (Fuel, Exhaust, etc.)

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

Connections (Fuel, Exhaust, etc.) (Continued)

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

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

AC Generator

There are no brushes, brush springs or collector rings on these generators, therefore they require very little servicing. Periodic inspections, to coincide with engine oil changes, will ensure good performance.

Generator Bearings

Inspect the bearings every 1,000 hours with the unit running. Grease bearings annually. Remove plug on side of bearing housing; grease zerk fitting until grease comes out of plug. Replace plug. Use low temperature grease that conforms to mil-standard G 23827 such as lubriplate or equivalent.

Check generator voltage. It may be necessary to make a slight readjustment of the voltage rheostat to obtain the preferred voltage at average load.

Gearbox Oil Level

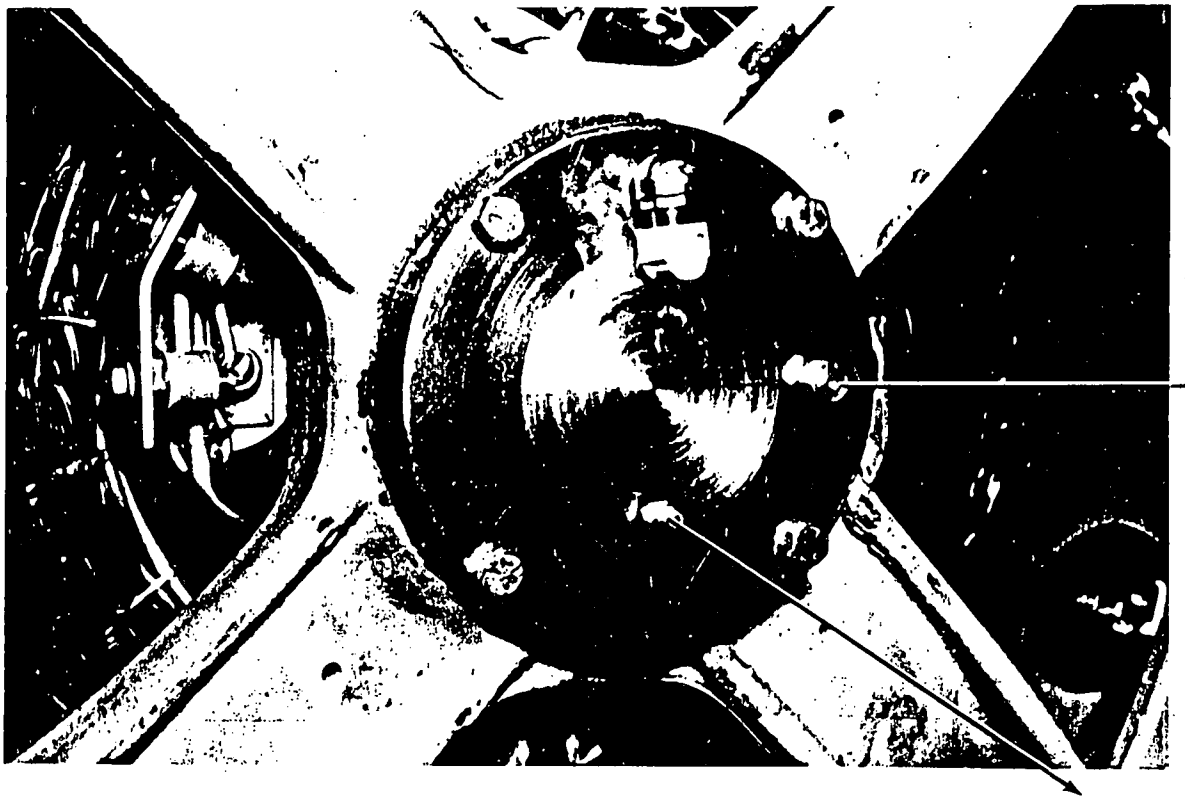
A sight glass is provided on the left side of the gearbox for purposes of maintaining proper lube oil level. Normal operating level is midway between the red indicating lines. If level falls below the lower red mark, add oil as necessary to obtain midpoint on gauge. Oil pump capacity is approximately 13 U.S. gallons. For recommended oil, refer to Garrett Operation & Maintenance Manual, Section 1.

Lubrication Oil Filters

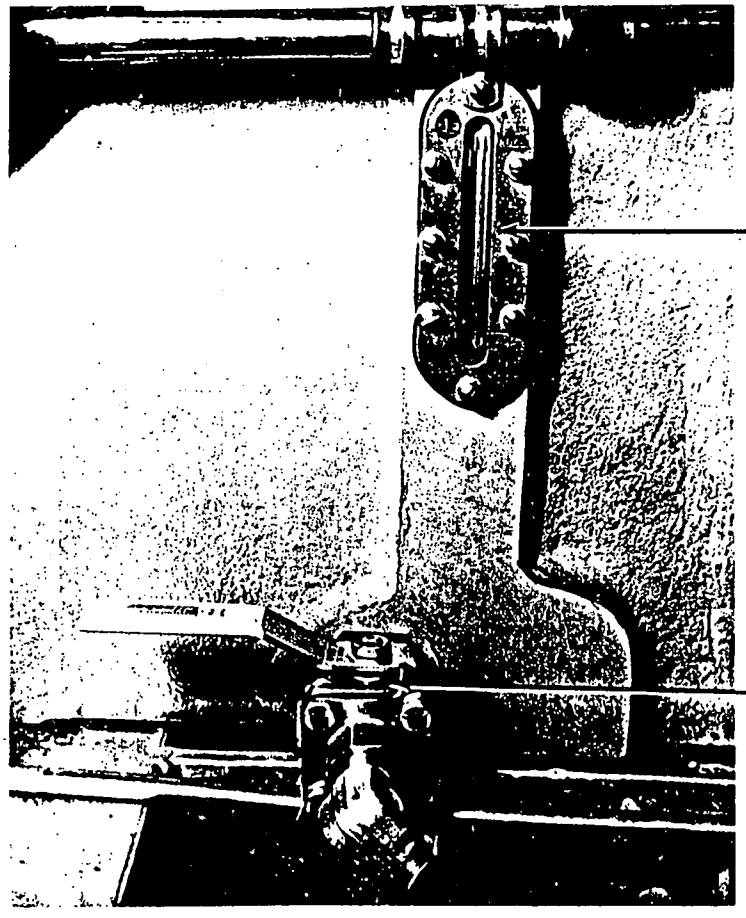
The lubrication oil filters (2) must be changed whenever filter pressure drop exceeds 35 PSID on gauge. Proceed as follows:

SWITCHING LUBE FILTERS WHEN ENGINE IS RUNNING

1. Open "bleed" valve on top of inactive filter.
2. Switch transfer valve to "bypass".
3. Wait until oil flows from "bleed" valve.
4. Close "bleed" valve.
5. Switch transfer valve to activate filter.



Lubricating Generator Bearings



Checking Gearbox Oil Level

Lubrication Oil Filters (Continued)

REPLACING INACTIVE FILTER ELEMENT

A. Differential pressure gauge must read "0".
B. Open "drain" and "bleed" valves.
C. Replace element.
D. Close "drain" and "bleed" valves.
E. Activate per step 1 thru 5.
F. Check for leaks.
G. Check oil level, replenish as required.

These instructions are also posted on the set for reference purposes. The normal oil system pressures are:

Oil filter differential pressure - 15 PSID with new elements.

Engine inlet oil pressure is 120-150 PSI.
Normal oil temperature is 100-160°F.

The turbine oil filter elements are equipped with a bypass valve to assure engine oil flow in the event of filter plugging. The oil filter and pump capacity (13 gallons) are sized for extended set operation without maintenance or oil additions.

CAUTION: Do not operate in "bypass" position except when switching filters.

Fuel Oil Filters

The diesel fuel filters must be changed whenever filter pressure drop exceeds 20 PSID on gauge.

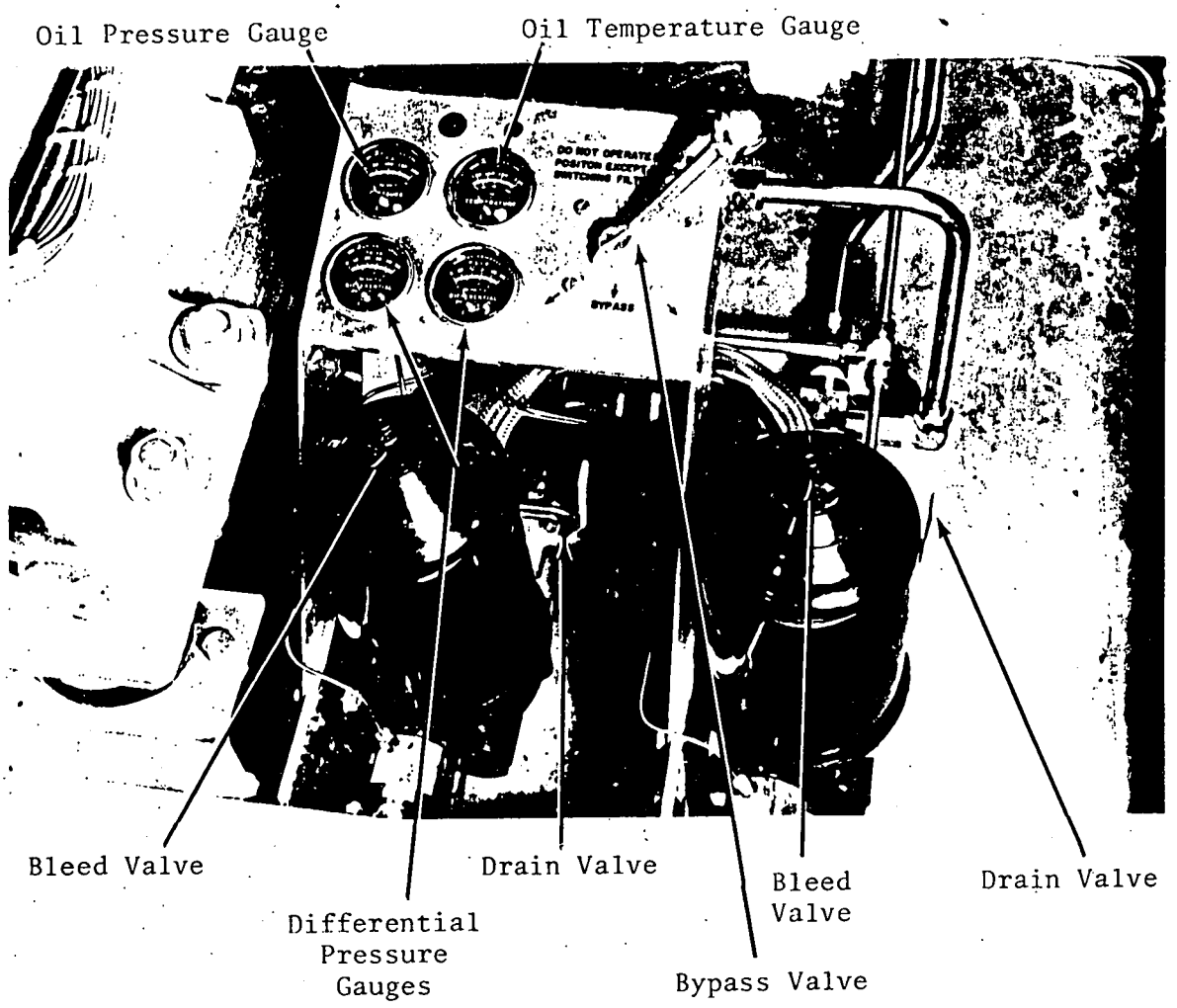
The fuel filter differential pressure is less than 5 PSID with new filter elements. Fuel boost pump outlet pressure is 30-40 PSI. Engine inlet fuel pressure (at engine driven pump inlet) is 15-25 PSI. No special fuel filter service instructions are necessary.

Gaseous Fuel Filter

The gaseous fuel filter should be bled at least once a week (open petcock on bottom of filter). If water content is excessive, filter service life will be very short. Field experience will establish the normal service interval. Natural gas inlet pressure must be 200-210 PSI. Maximum temperature is 140°F.

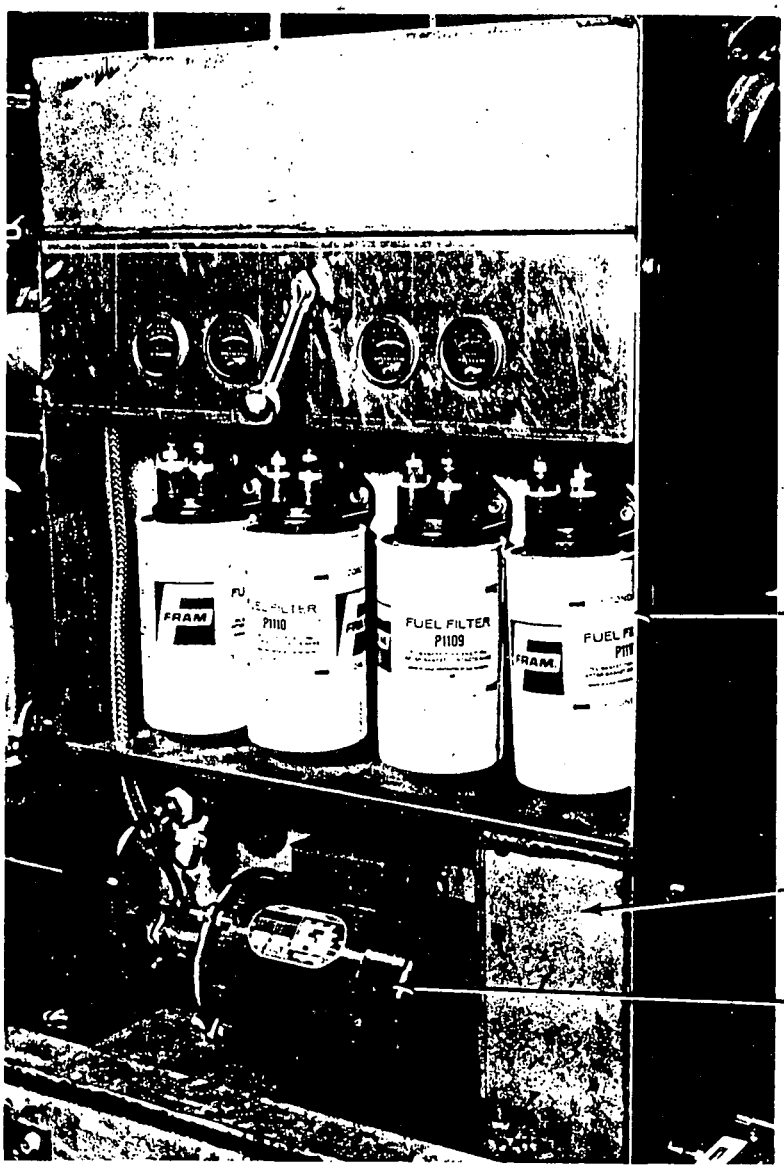
Air Boost System Lubrication

Mineral oil in air pump should be changed every 3 months using same type of oil as used in engine. Oil capacity is 5.5 ounces.



Lubricating Oil Filters
(Refer to text on pages 36 and 38 for changing filters.)

LIQUID FUEL FILTER SYSTEM
(Refer to text on page 38
for maintenance procedures.)



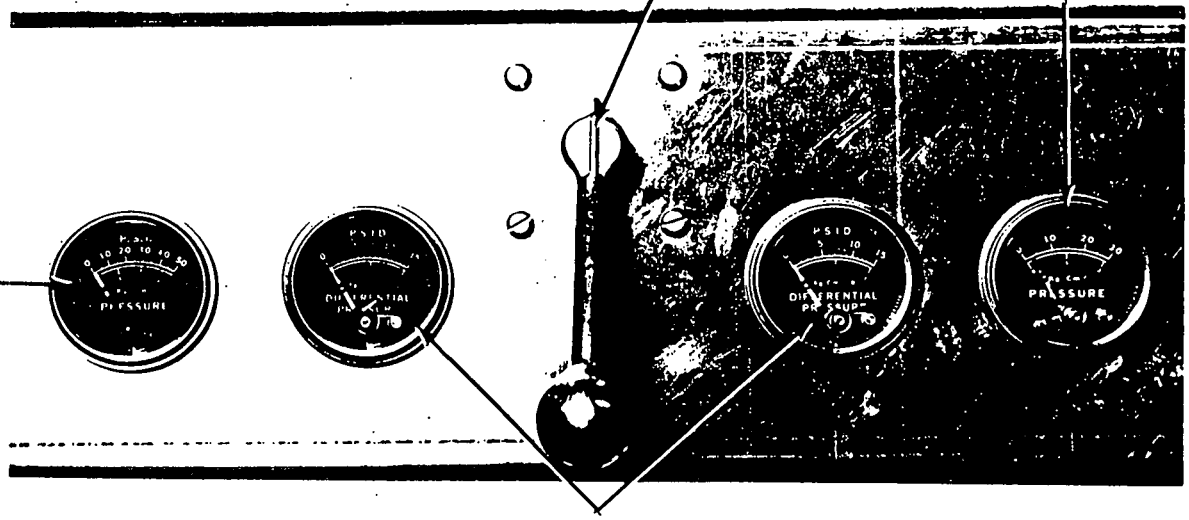
Primary and Secondary
Fuel Filters

Drain Tank

Liquid Fuel Boost Pump

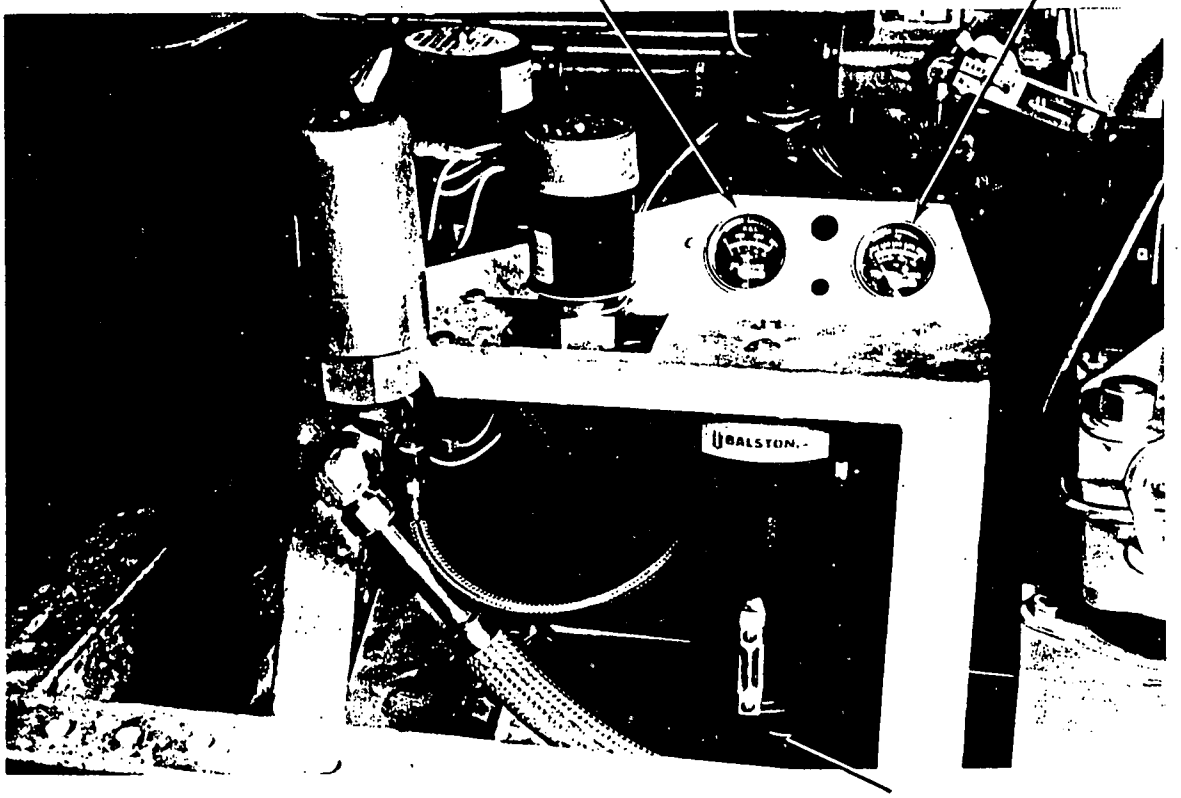
Liquid Fuel
Pressure Gauge

Fuel Selector Valve

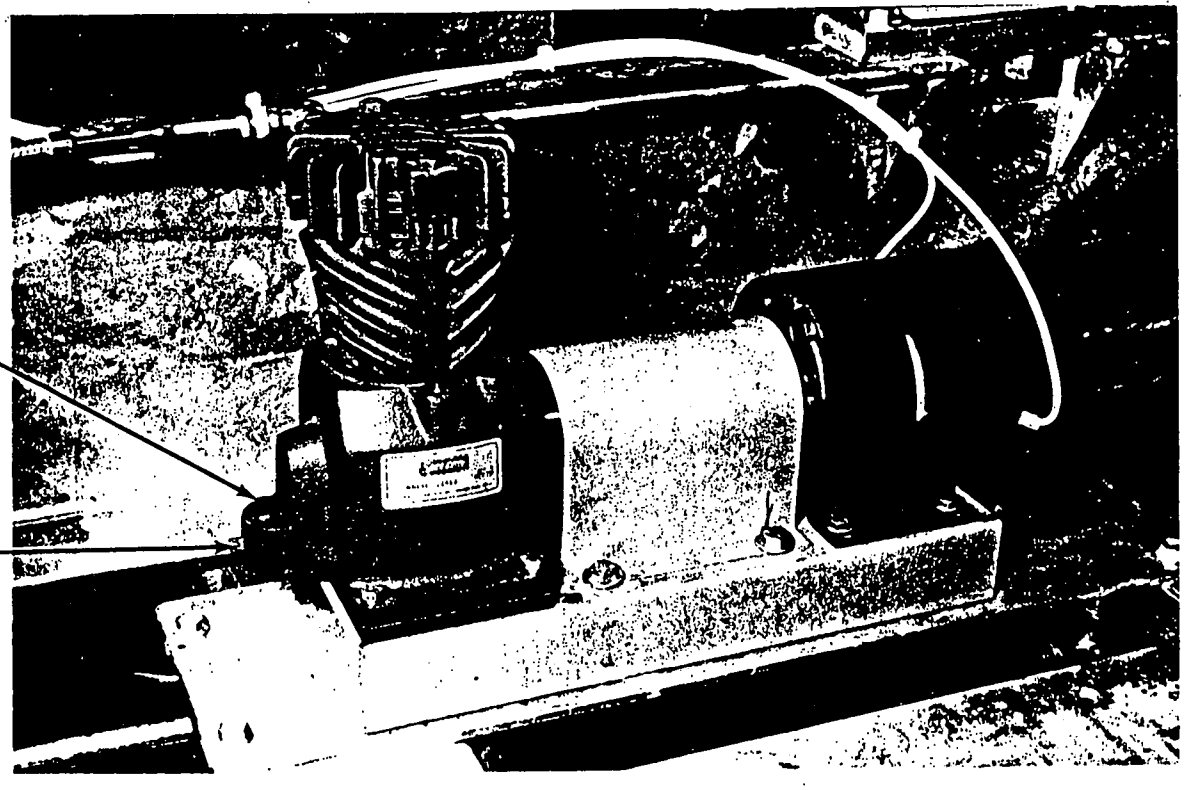


Liquid
Fuel
Pressure
Gauge

Fuel Differential Pressure Gauge



GASEOUS FUEL FILTER
(Refer to text on page 38
for maintenance procedures.)



LIQUID FUEL AIR ASSIST PUMP

Gearbox Oil Sump

The oil level in the gearbox should fall midway between the upper and lower red marks on the sightglass. Gearbox capacity is 13 U.S. gallons. Refer to section 1 of the Garrett operation and maintenance manual for specific type and grade of oil to use. Check oil level daily. See illustration on page 37.

Drive Coupling Lubrication

The coupling is a Koppers model FM, size #3 with FSS hubs and a shear groove spacer. The coupling gear sets are rated to carry 3975 lb.-ft. continuous torque, the shear spacer will fail at 5000 lb.-ft. torque, and the maximum running torque is 2000 lb.-ft. torque.

The preferred flex hub lubricant is SAE #90 or #140 gear oil. EP-1 type grease may also be used, but must be flushed out and replaced annually. Lube capacities are;

- Oil : 1/4 pint volume per end, 1/2 pint total
- Grease: 3/4 pint volume per end, 1-1/2 pints total
  (11 oz. weight per end, 22 oz. total)

The shear spacer support piece must be thoroughly coated with EP-1 type grease.

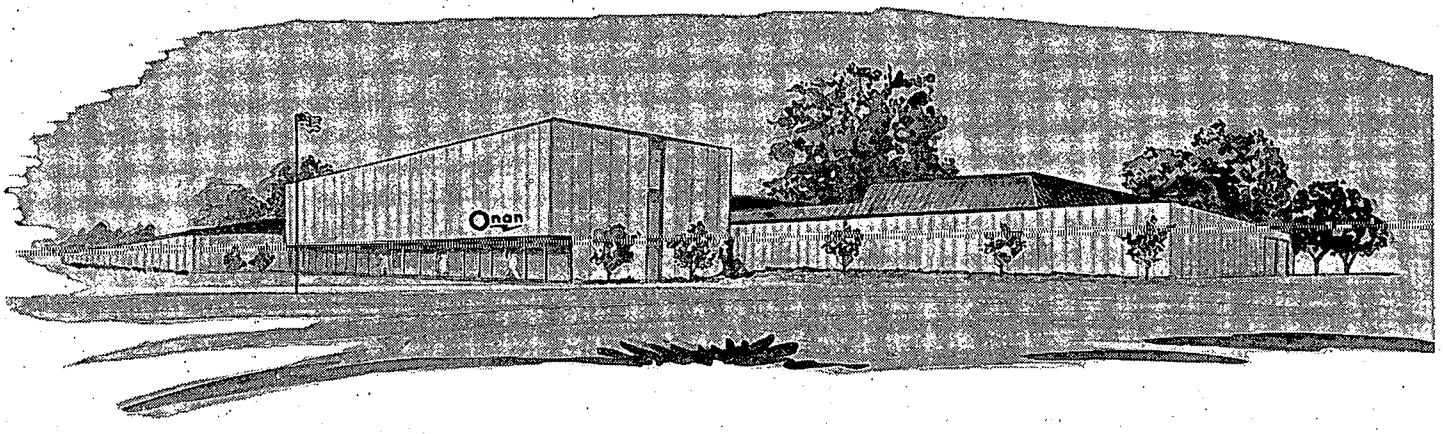
Parts Information

The following Running Replacement parts list consists of external items which may require replacement due to normal wear and service and can usually be installed by the operator.

For additional information on parts or service, contact your nearest authorized Onan dealer or Service Center. A complete parts catalog will be available at a later date. Until such time we recommend stocking the following parts to eliminate down time.

RUNNING REPLACEMENT PARTS LIST

Set Mechanical Parts	
Fuel Filter (Liquid, Primary)	149-1521
Fuel Filter (Liquid, Secondary)	149-1522
Element - Oil Filter	122-0448
Element - Gaseous Fuel Filter	148-0781
Engine Only Parts	
Element - Lube Oil	425-0163
Element - Liquid Fuel	425-0193
Valve - Fuel Control	Consult Garrett Manual - Volume II Varies with engine used.
Nozzle - Fuel	Consult Garrett Manual - Volume II Varies with engine used.



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