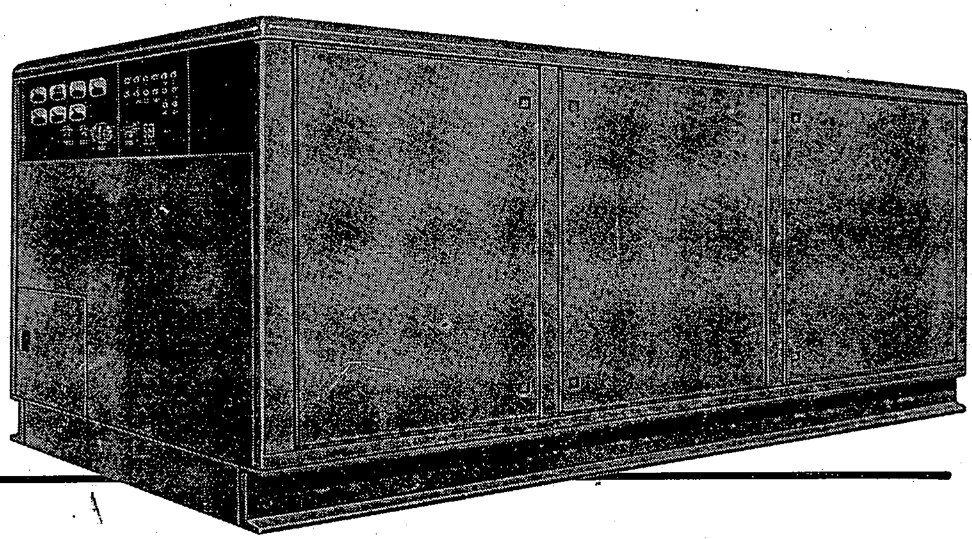
McGRAW-EDISON

Onan

Operators Manual

GTU GenSet



950-0004

December 1981
Printed in U.S.A.

SAFETY PRECAUTIONS

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 **This symbol is used 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 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.
- 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.
- Do not wear loose clothing in the vicinity of moving parts or jewelry while working on electrical equipment. Loose clothing can become caught in moving parts. Jewelry can short out electrical contacts causing shock or burning.

Fuel System

- DO NOT fill fuel tanks while engine is running, unless tanks are outside of 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 Electrical Shock

- Remove electrical 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. Do not 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

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

Miscellaneous

- 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 a 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 the turbine compressor unit.
- High operating temperatures are characteristic of the gas turbine. Do not touch any part of the turbine power unit or compressor stages while operating and allow set to cool down prior to performing any repairs on the turbine engine.

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WARNING

ONAN RECOMMENDS THAT ALL SERVICE INCLUDING INSTALLATION OF REPLACEMENT PARTS ONLY BE DONE BY PERSONS QUALIFIED TO PERFORM ELECTRICAL AND/OR MECHANICAL SERVICE. FROM THE STANDPOINT OF POSSIBLE INJURY AND/OR EQUIPMENT DAMAGE IT IS IMPERATIVE THAT THE SERVICE PERSON BE QUALIFIED.

SPECIFICATIONS

Length	137 inches (348 cm)
Width	56.4 inches (143.2 cm)
Height	72 inches (182.9 cm)
Weight	6800 lbs (3087 kg)
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	Liquid/Gaseous
Fuel Control	Electro-hydraulic
Fuel Type	Liquid (DF-1, DF-2, Jet A, A1, B JP-4, JP-5) Gaseous - Natural Gas
Liquid (engine inlet pressure)	3-27 psi (20.68-186.14 kPa)
Gaseous (engine inlet pressure)	200-210 psi (1.34-1.45 mPa)
Combustion System	
Liquid	Single burner can and air assist or dual orifice atomizer
Gaseous	Single burner can and gas injector nozzle
Dual	Single burner can and compound fuel atomizer/nozzle in a single assembly
Starting System (Electric)	24VDC solenoid shift, 2 wire, negative ground
Battery Size (2 in Series)	Two 12 volt, 225 Ah (810 kC) batteries
Starting Power	SAE type D-80+
Control Power	UIL-18 (as required)
Starting System (Pneumatic)	Dual sliding rotary vane motor
Low Pressure	80-150 psig (552-1034 kPa)
High Pressure	240-250 psig (1.66-1.72 mPa)
Governor (Electric Load Sensing Type)	Woodward EG-3P actuator and type 2301 control
Engine to Generator Coupling	Direct mechanical with flexible coupling
GENERATOR DETAILS	
Type	2 bearing, brushless 4 pole, revolving field, 4 wire with 3 phase exciter
Rating (kilowatts) 60 Hz	
Standby	560.0 kW (700 kVA) ISO
Amperage (277/480 Volts)	
Standby	842 Amps
AC Voltage Regulation	±2%
RPM	1800
AC Frequency Regulation	Isochronous to 4% droop
Output Rating	0.8 PF
CAPACITIES AND REQUIREMENTS	
Turbine Gearbox Oil Capacity	11 gallons (41.64 litres)
Exhaust Flange Connection Size	12 inches (305 mm) (Drilled to 125# ASA)

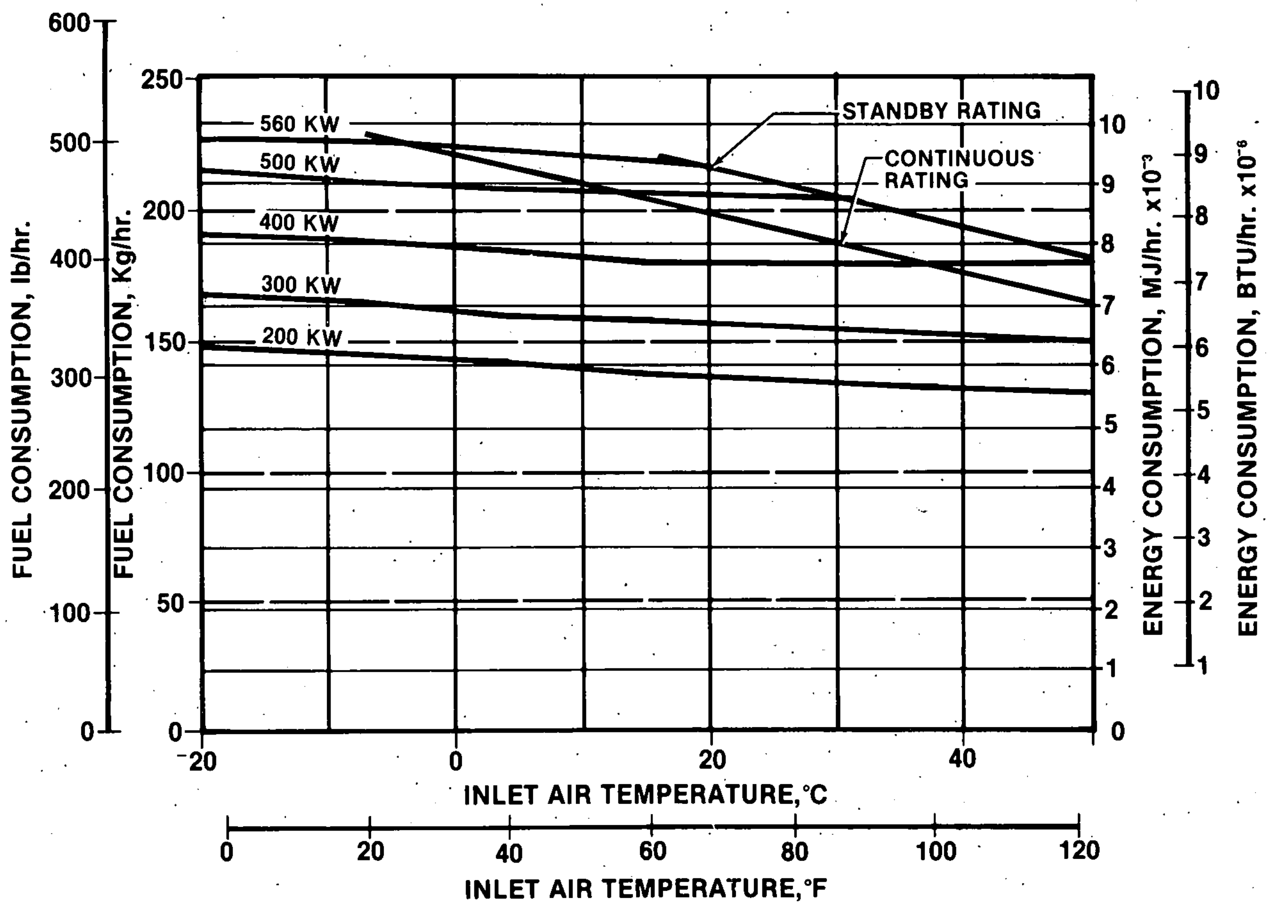
Continued

SPECIFICATIONS (continued)

AIR REQUIREMENTS

Ventilation	7400 CFM (210 m^3/min)
Minimum Inlet Air Flow	6250 CFM (177 m^3/min)
Alternator Cooling Air	3000 CFM (84.96 m^3/min)
Exhaust Gas Flow Rate @ 1100° F (593° C)	17450 CFM (494 m^3/min)
Maximum Exhaust Back Pressure	6.0 inches (152 mm) H_2O
Maximum Inlet Pressure Drop	4.0 inches (102 mm) H_2O
Exhaust Temperature Range	
Continuous	1100° F (593° C)
Start Transient	1550° F (843° C)
Fuel consumption (rated load, 60 Hz, 60° F or 16° C, Sea Level)	
Liquid	67 Gallons per hour (253.62 litres)

Fuel Consumption
Liquid Fuel



Notes:

1. Nominal governed rotor speed equals 41,730 rpm.
2. Liquid Fuel- lower heating value≈42.8 MJ/Kg (18,400 BTU/lbm) Hydrocarbon ratio 0.1679.
3. Ratings are nominal (≈6%) and at sea level conditions- 101.3K Pa abs, (29.92 in Hg abs)
4. Ratings assume no inlet or exhaust duct pressure losses.

5. To correct for duct losses and altitude losses use the following procedure:

5.1. δ equals unit inlet total pressure (KPa abs) divided by 101.3 KPa and may be used to estimate performance up to 3000m (9842 ft.).

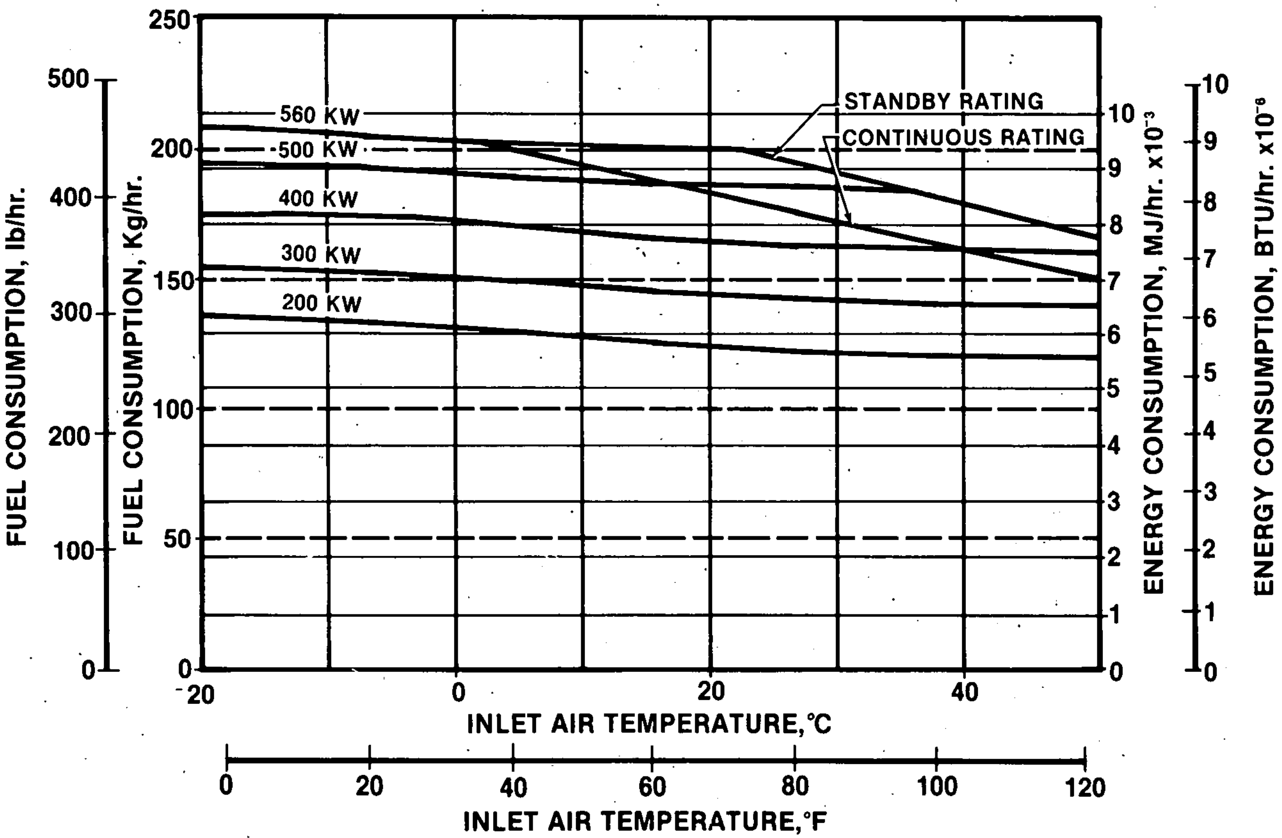
$$\delta = \frac{\text{inlet total pressure}}{101.3\text{KPa}}$$

5.2. ΔP equals turbine discharge static pressure minus turbine inlet total pressure.
ΔP=Exh. duct back pressure-inlet duct loss.

5.3. To find unit output with losses calculate $\frac{\Delta P}{\delta}$. Determine the corresponding $\frac{\Delta KW}{\delta}$ from curve **A**, and solve the following equation:

$$\text{KW with loss} = \left[\left(\frac{KW}{\delta}\right)_{\text{no loss}} + \left(\frac{\Delta KW}{\delta}\right)\right]\delta$$

Fuel Consumption
Gaseous Fuel



Notes:

1. Nominal governed rotor speed equals 41,730 rpm.
2. Natural gas Fuel—lower heating value equals 46.75 MJ/Kg (20,100 BTU/lbm).
3. Ratings are nominal (±6%) and at sea level conditions- 101.3K Pa abs, (29.92 in Hg abs)
4. Ratings assume no inlet or exhaust duct pressure losses.

5. To correct for duct losses and altitude losses use the following procedure:

5.1. δ equals unit inlet total pressure (KPa abs) divided by 101.3 KPa and may be used to estimate performance up to 3000m (9842 ft.).

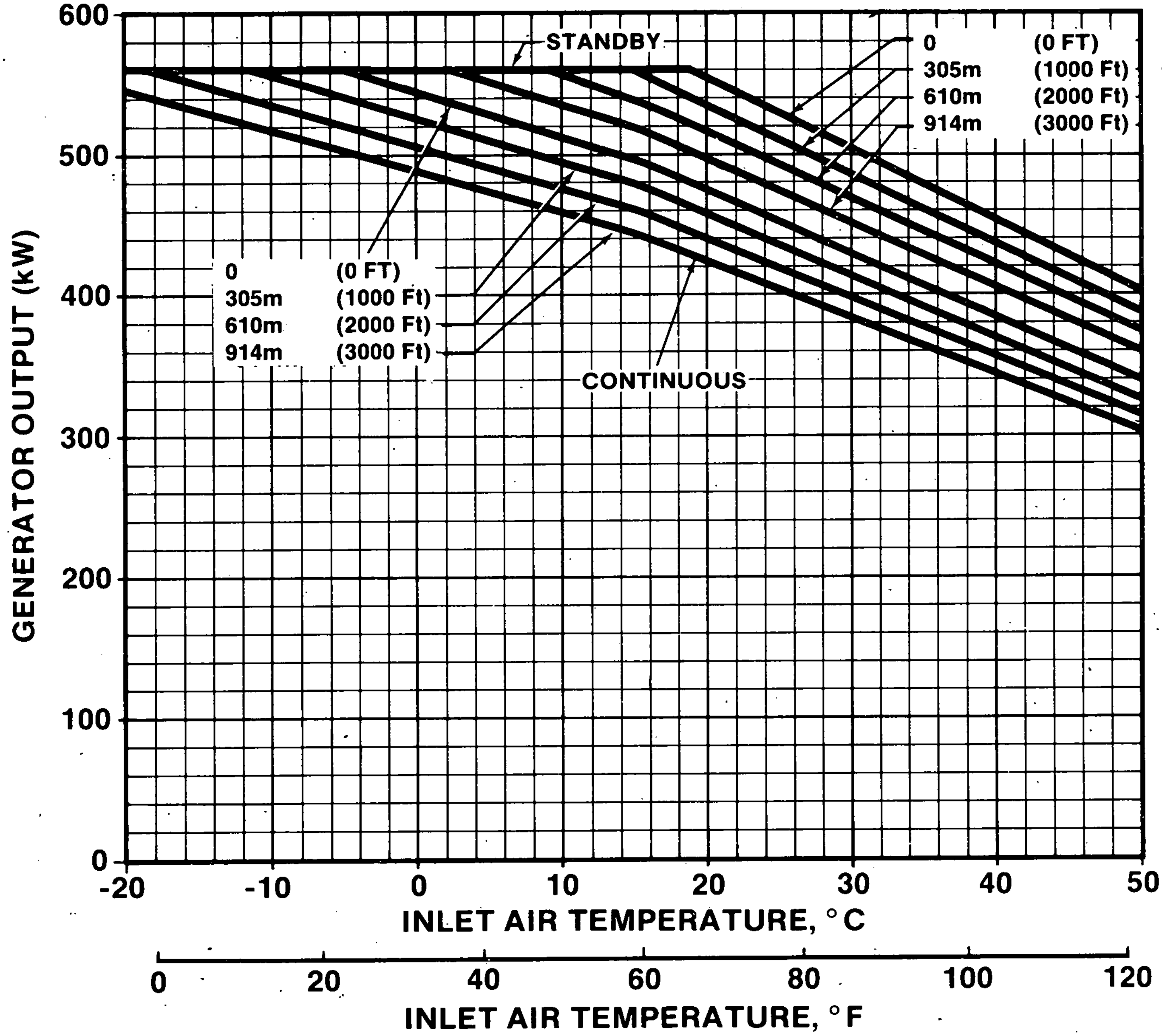
$$\delta = \frac{\text{inlet total pressure}}{101.3\text{KPa}}$$

5.2. ΔP equals turbine discharge static pressure minus turbine inlet total pressure.
ΔP=Exh. duct back pressure-inlet duct loss.

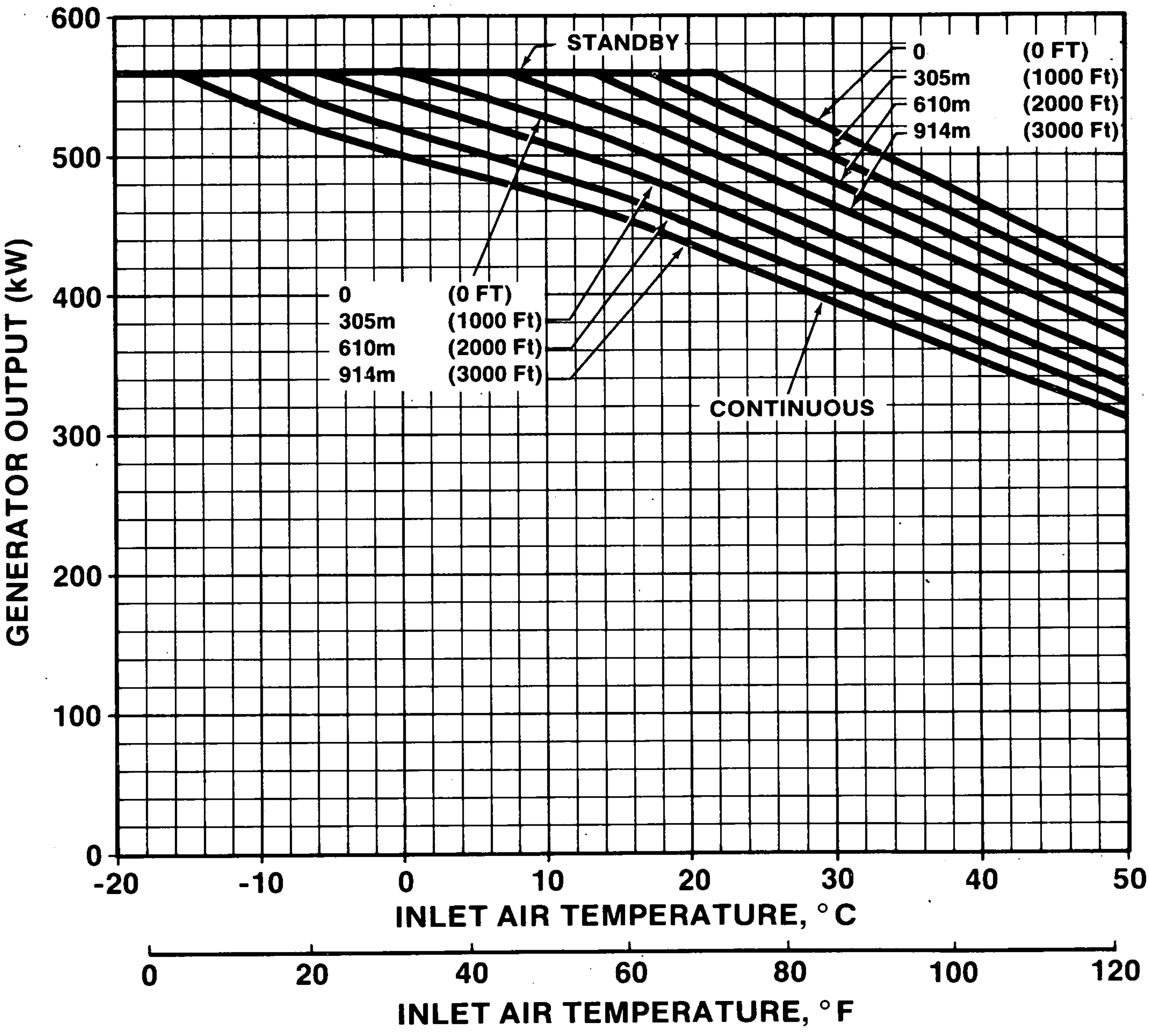
5.3. To find unit output with losses calculate $\frac{\Delta P}{\delta}$. Determine the corresponding $\frac{\Delta KW}{\delta}$ from curve A, and solve the following equation:

$$\text{KW with loss} = \left[\left(\frac{KW}{\delta}\right)_{\substack{no \\ loss}} + \left(\frac{\Delta KW}{\delta}\right)\right]\delta$$

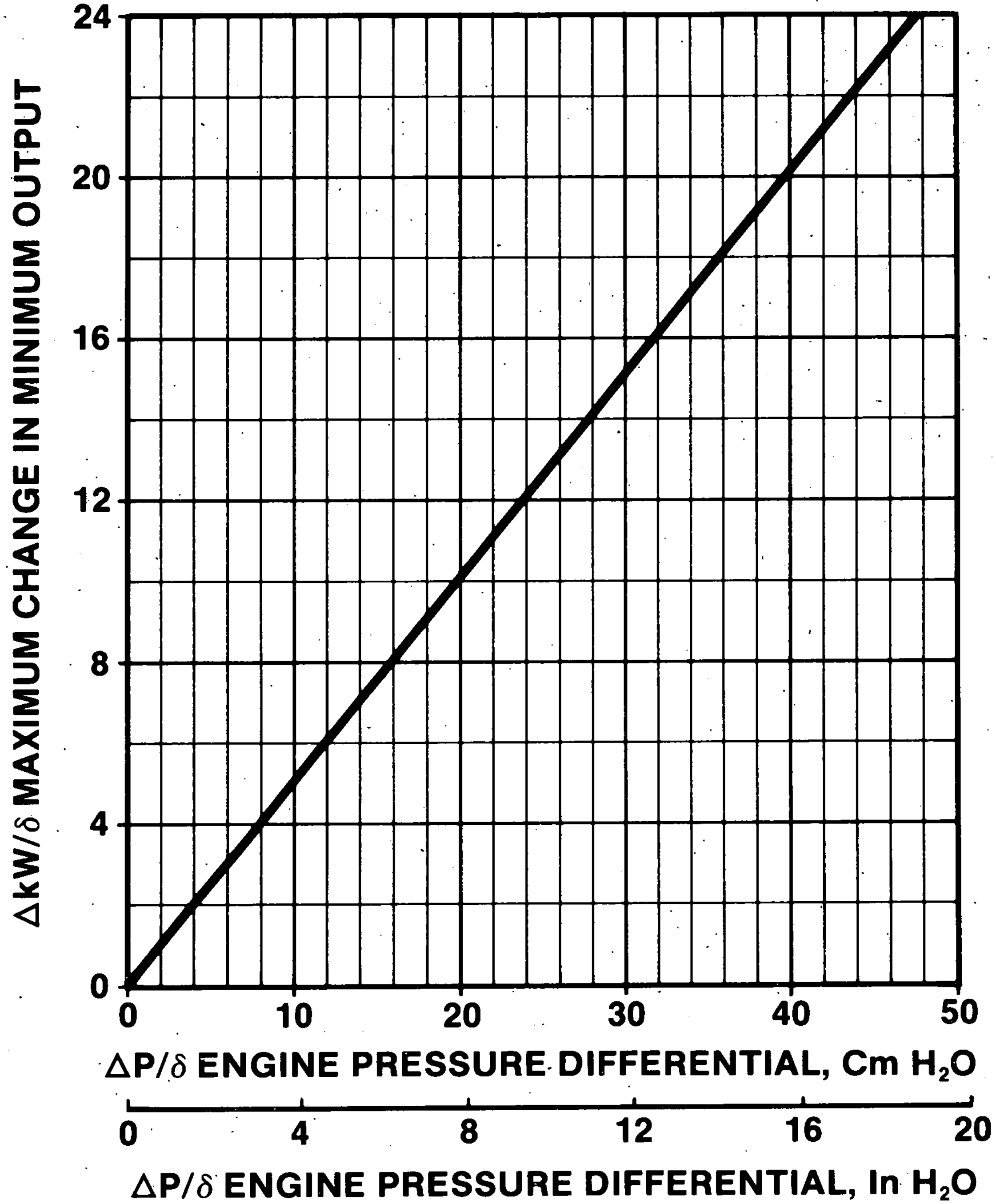
Performance - kW Output
Liquid Fuel



Performance - kW Output
Gaseous Fuel



Duct Loss Correction Curve



FOREWORD

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 description, installation, operation, start-up and routine maintenance and adjustment procedures necessary to properly maintain and service your Onan GTU series electric generating set. The set consists of a Garrett 1E831-800 gas turbine prime mover directly coupled to Onan "UV" 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 and Woodward Manuals for specific component information (e.g. LOAD SHARING AND SPEED CONTROL, EG-3P GOVERNOR, etc.).

In addition, a separate Onan Parts Catalog (#950-0003) is included with the Operator's Manual.

Model identification can be made by referring to the model and specification number as shown on the Onan nameplate. Electrical characteristics are shown on the lower portion of the nameplate:

560.0	GTU	4XR/	18521	F
1	2	3	4	5

1. Indicates kilowatt rating (560.0 kW)
2. Factory code for series identification (Gas Turbine Garrett/Airesearch)
3. Generator voltage code 4X = 277/480 3 phase.
4. Specification number 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 and serial number as shown on the Onan nameplate.

This nameplate information is necessary to properly identify your unit among the many manufactured by Onan. Refer to engine nameplate when requesting information from its manufacturer. The Onan nameplate is located on the upper right side of the air inlet plenum below the engine nameplate. In some cases the nameplate may be on the generator outlet control box (top panel) right rear side of the set. Left and right sides are derived when viewing the engine from the turbine end of the generating set.

GENERAL DESCRIPTION

GENERAL

This Onan continuous standby electric generating system (Figure 3-1) consists of a Garrett gas turbine engine, Woodward governor controls, and a type "UV" AC generator, set mounted control with relay type logic and necessary meters and sensors for monitoring set operation and fault sensing. In case of a major fault the set will shut down to prevent any serious engine damage. All components are mounted within a single SKID BASE (Item 1). The entire system is designed with the "modular" approach for convenience in repairing or adding optional modules at a later date.

ENGINE

The system engine is a Garrett Model IE831-800 gas turbine as described in the Garrett Operation and Maintenance manual included with the set.

The Garrett IE831-800 gas turbine (Item 2) is an 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 (Item 3).

ROTATING GROUP

The rotating group (Item 4) is comprised of two radial outflow compressor wheels and three axial flow turbines mounted on a common shaft and locked together by means of curvic couplings. A bearing and seal assembly on each end of the shaft supports the assembly. The sleeve type hydro-dynamic bearings and labyrinth type clearance oil seals assure long life and low oil consumption.

COMBUSTION SYSTEM

The combustion system employs a single burner can, fuel nozzle, and igniter for high reliability and ease of maintenance. Nozzle type varies with fuel system used (Item 5).

GEARBOX

The gearbox (Item 6) 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 governor and starter motor and main lube oil pump. 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 (Item 7) for visual oil level monitoring.

Lubrication System

The lubrication system is comprised of an oil reservoir (gearbox sump), direct gearbox positive displacement pressure and scavenge pumps (Item 8), filters, 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 (Item 9) is an Onan type "UV", 12 lead, 4 pole, revolving field, brushless unit wired for 277/480 volt, 3 phase operation. The main rotor is directly coupled to the gearbox output power shaft through a flexible coupling (Item 10). Turbine gearbox speed determines generator output frequency. Excitation is achieved as follows:

Residual voltage 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 voltage in the generator stator which is applied to the load.

ENGINE LOGIC CONTROLS

The logic is a relay type system providing basic operational control, fault shutdown, and status signals for the gas turbine. It also provides for proper sequencing of engine electrical components during start-up, running, and shutdown cycles.

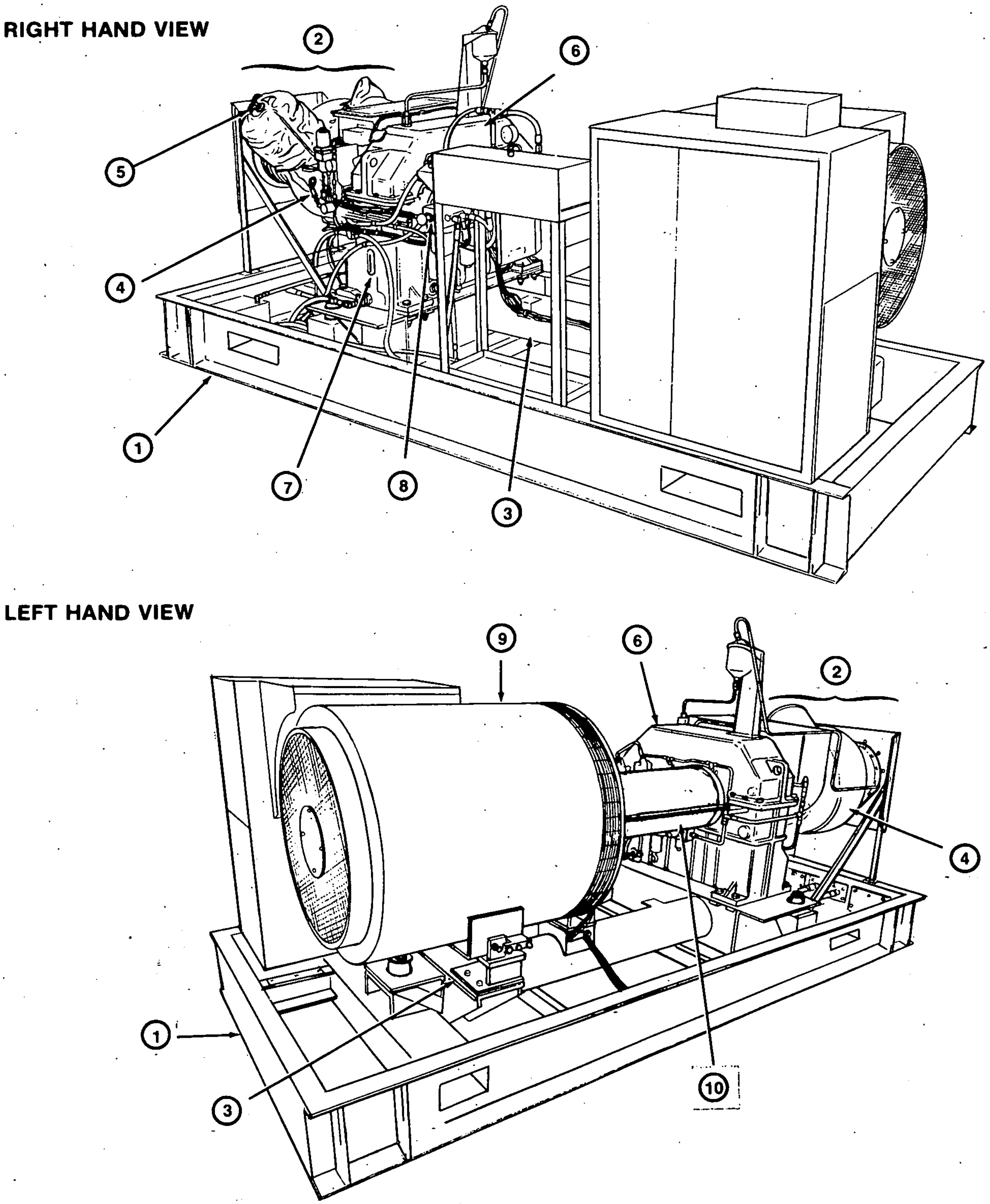


FIGURE 3-1. GAS TURBINE GENERATOR

INSTALLATION

GENERAL

Installations must be considered on an individual basis. Use these instructions as a general guideline. All installations must meet regulations of state and local building codes, fire ordinances, etc., which may affect installation details. The following requirements are 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 supply 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

Turbine-generator sets are mounted on a rigid skid base (Figure 4-1) which provides proper support for engine-generator. The engine-generating 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 rubber pad isolators between skid base and foundation.

BASE AND MOUNT ASSEMBLY

The system includes an inner engine/generator mounting base (Item 1) supported, through three point elastomeric isolators, by an outer housing base (Item 2). 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. 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.

SYSTEM ALIGNMENT PROCEDURES

Engine to Generator Alignment

See Adjustment - Gearbox & Coupling Section Page 6-4.

VENTILATION

Turbine-generator sets create considerable heat which must be removed by proper ventilation. Outdoor installations rely on natural air circulation but indoor installations need properly sized and positioned vents for the required air flow. See SPECIFICATIONS for volume of ventilation air required to operate with rated load under normal conditions.

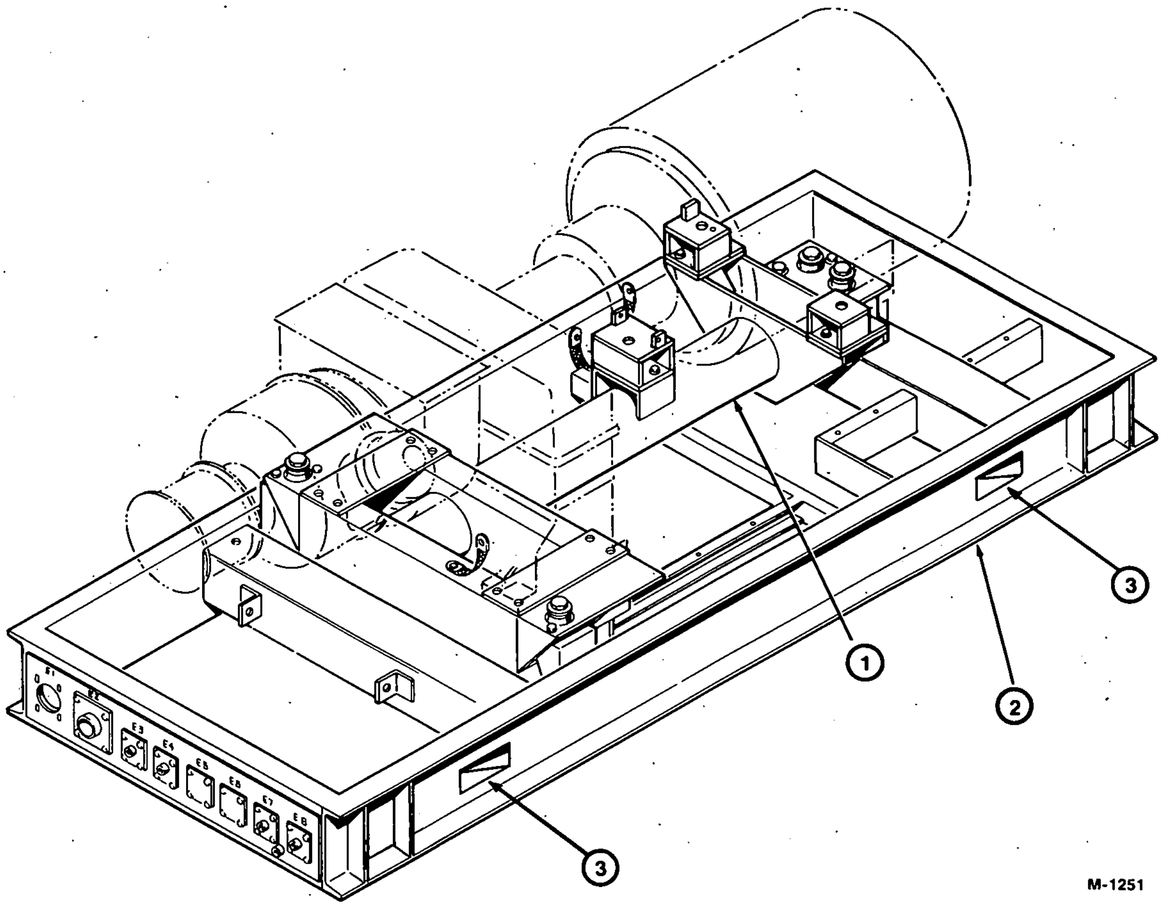


FIGURE 4-1. SKID BASE AND INNER MOUNTING

EXHAUST SYSTEM

WARNING ***Inhalation of exhaust gases can result in serious personal injury or death.***

Engine exhaust gas must be piped outside of building or enclosure. 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 partiiton.

EXHAUST SYSTEM INSTALLATION

A stainless steel exhaust bellows (Figure 4-2) is provided on the engine exhaust to accommodate thermal expansion and vibration. Provisions for thermal expansion of 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 harmful 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.

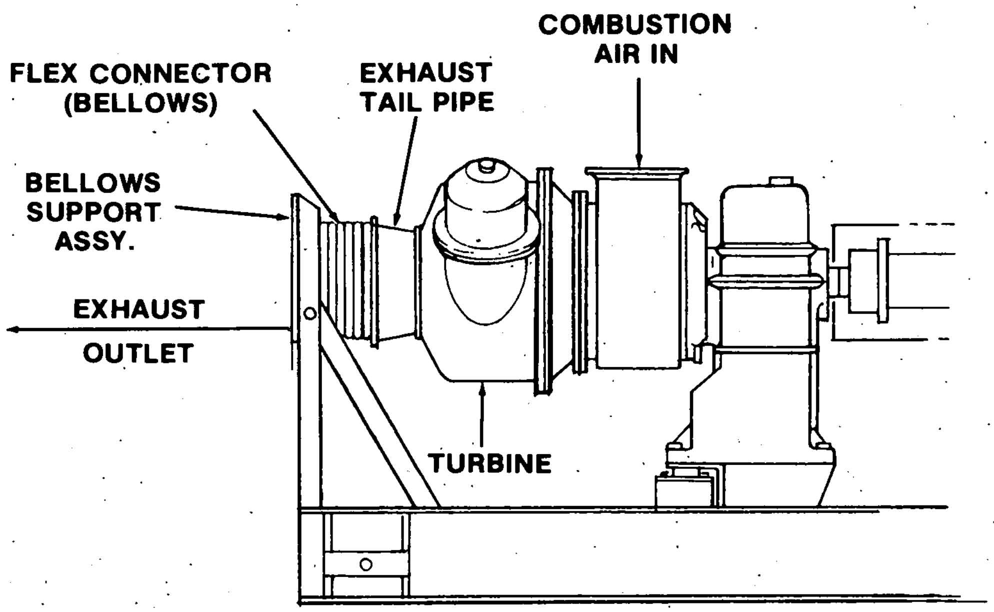


FIGURE 4-2. TURBINE EXHAUST

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 properly insulated to prevent injury to personnel.

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. Maximum recommended pressure limit is 6 inches (152 mm) H_2O.

INTERFACE

The interface consists of an access plate and appropriate connectors mounted at the end of the outer skid (turbine end). It provides for the interfacing of cables and piping between the turbine generator set and ancillary equipment. See Figure 4-3 for illustration and description of cable and piping connectors.

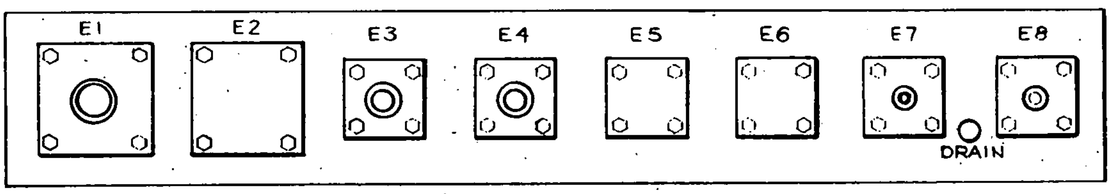


FIGURE 4-3. INTERFACE

Piping and cabling is connected in the following manner:

E1 - Battery Cable Access, or Air Supply for Pneumatic Start.
E2 - Pneumatic Starter Discharge Air
E3 - To Oil Cooler
E4 - Return from Oil Cooler
E5 - Gaseous Fuel Supply
E6 - Gaseous fuel Vent
E7 - Liquid Fuel Return
E8 - Liquid Fuel Supply
Drain - For Fuel and Lube

TURBINE SUBASSEMBLIES

This section deals with the Operation, Adjustment, Maintenance, and Troubleshooting of the following turbine-generator sub-assemblies: Starting System, Combustion Air System, Fuel System, Lubrication System, Exhaust System, Electrical System, Relay Logic System, and Operator Panel.

STARTING SYSTEM (ELECTRIC)

GENERAL

A 24VDC starter motor (standard) is used in the electric starting system. Initial starter-motor surge current is approximately 2000 amperes for two seconds. The power source and cable system must supply a minimum of 14VDC to the starter terminals with a continuous drain of 650 amperes during the entire engine cranking cycle of 60 seconds maximum duration. See Figure 5-1, starter location.

The electric starter motor is a 15 HP Delco starter with a positive engagement spline-type pinion. It is a six-coil, twelve brush, high torque unit, incorporating a totally enclosed shift lever and solenoid plunger mounted on top of starter.

OPERATION

The electric starter functions by energizing the solenoid switch which engages the spline to the gear assembly spline adapter and applies cranking motor electrical power through a switching circuit.

When the start switch is closed, electrical power is applied to the two solenoid windings; the pull-in winding and hold-in winding. The pull-in winding pulls the solenoid plunger into position and in so doing, disables itself, but energizes the hold-in winding which completes the circuit path through the starter motor as the main contactor closes. As the plunger moves, it pulls the shift lever forward moving the spline into position to engage the starter gear in the gearbox. This action is mechanically sequenced by shift mechanism linkage (see Figure 5-2).

When the speed sensing circuits have detected that the engine speed has been reached (95 percent), the signal to the solenoid is removed and the shift assembly is disengaged by the loaded spring.

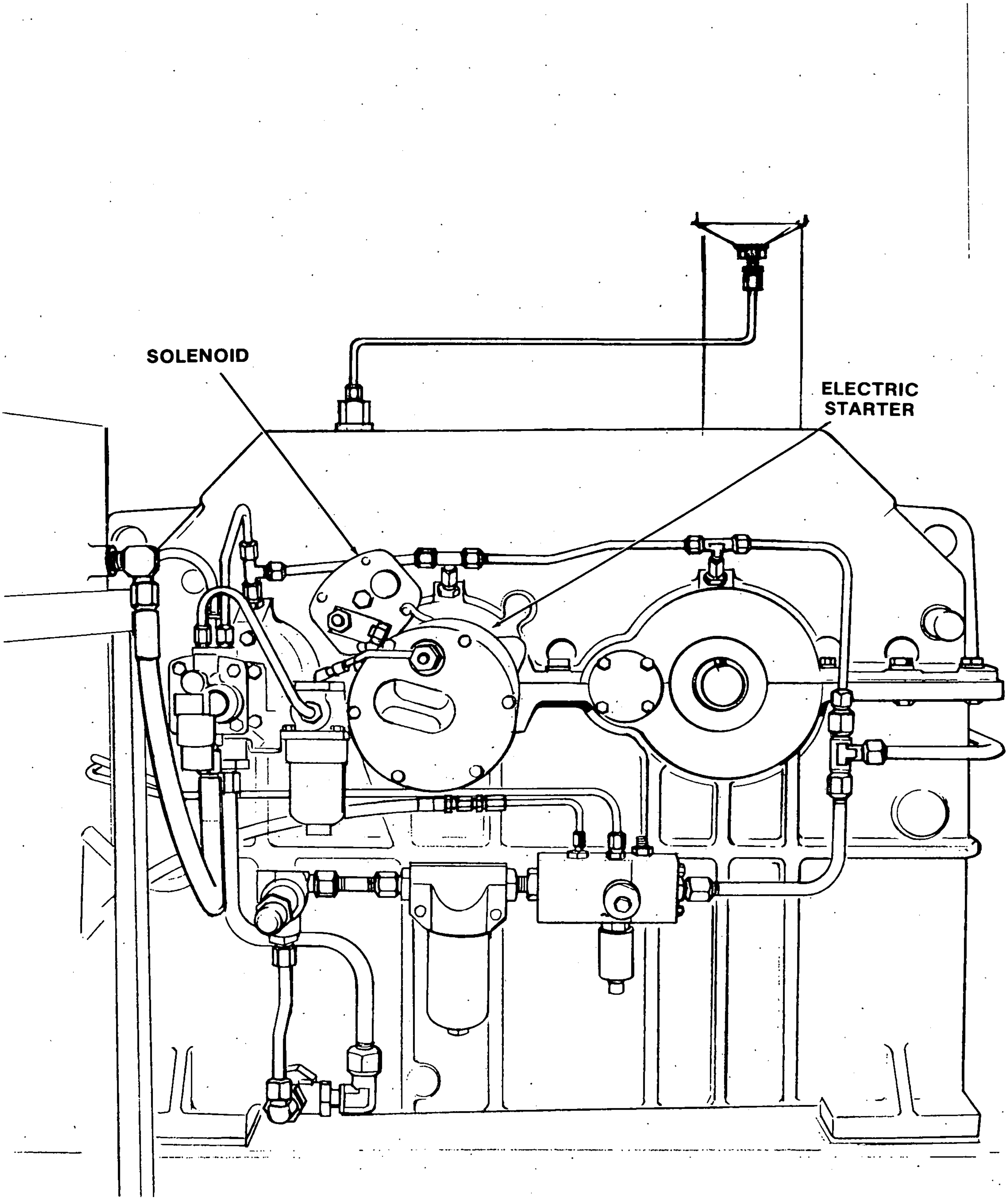


FIGURE 5-1. STARTER LOCATION

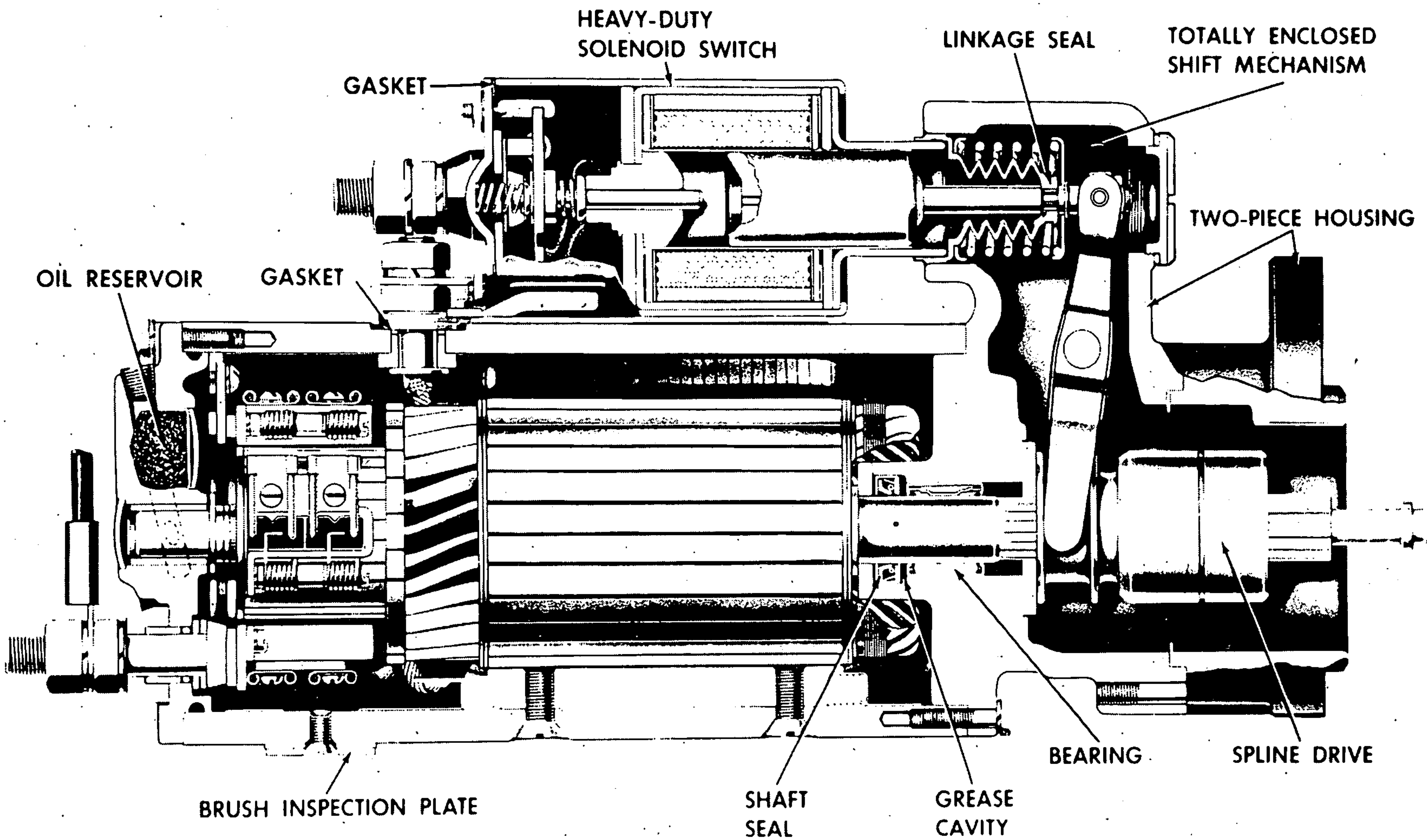


FIGURE 5-2. ELECTRICAL STARTER

ADJUSTMENT

Adjust Pinion Clearance as Follows:

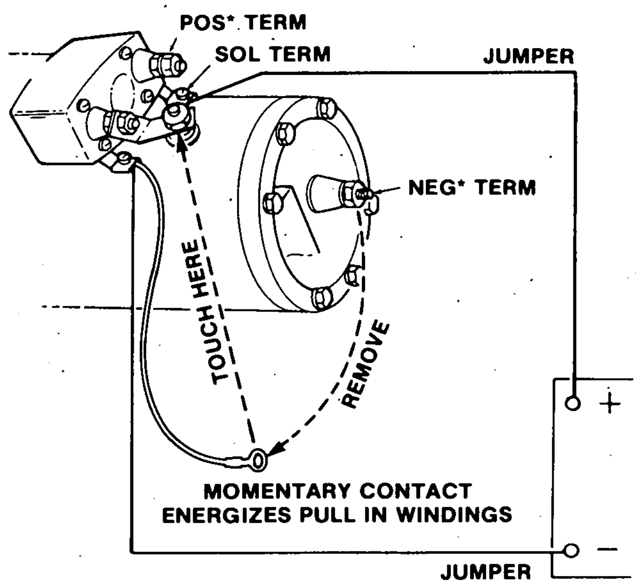
1. Disconnect field coil connector from starter solenoid terminal.
2. Connect a 24-volt battery to solenoid switch terminal to solenoid frame or ground terminal as shown in Figure 5-3.
3. Momentarily close circuit from solenoid motor terminal to solenoid frame or ground terminal. The drive will shift into cranking position and remain so until battery is disconnected.
4. Load drive back toward commutator end to eliminate slack (Figure 5-4).
5. Measure dimension A, shown in Figure 5-4.
6. Adjust clearance, if required, by removing plug from starter housing (Figure 5-4) and adjusting shaft nut to meet requirement of dimension A.
7. Replace plug.

MAINTENANCE

Inspect Electric Starter System as Follows:

1. Inspect all electrical connections for corrosion and looseness.
2. Inspect drive splines for burning, broken or chipped splines.
3. Inspect brushes for wear. If brushes are worn down to one-half their original length when compared with a new brush, they should be replaced.
4. Inspect brushes for proper seating on armature and that spring tension is sufficient to make firm contact. If brushes are worn unevenly, they should be replaced.
5. Inspect brush holders for corrosion and binding of brushes.
6. Inspect brush leads for corrosion.
7. Inspect battery condition and security of installation once a month.

Lubrication of the starter bushing is recommended at 150 start intervals. One plug is removed for oiling. See Figure 5-2.



0.10 - 0.70" ON DRIVE END-CLEARANCE BETWEEN GEAR AND RETAINER RING

JUMPER WIRES ENERGIZE HOLD IN WINDINGS.
*NOTE: WESTERN ELECTRIC SETS ARE POSITIVE GROUND

FIGURE 5-3. ENERGIZING STARTER

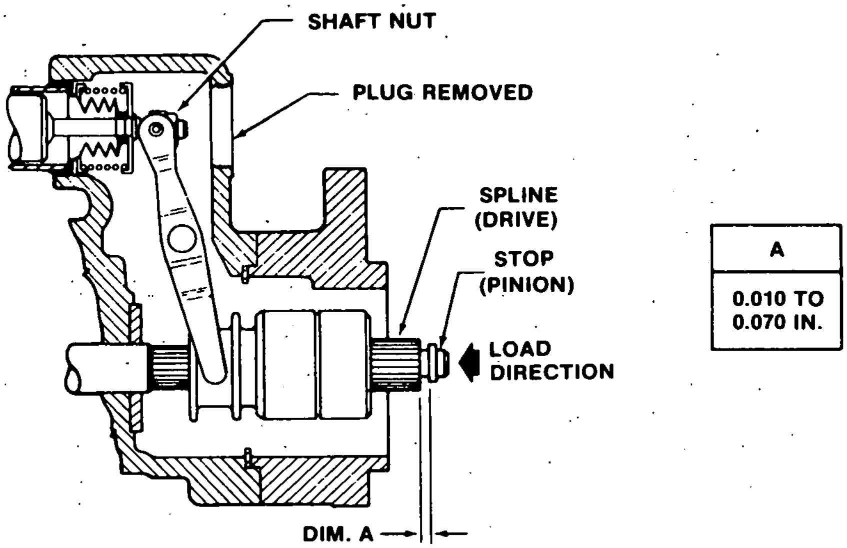


FIGURE 5-4. ADJUSTMENT TO PINION STOP CLEARANCE

STARTING SYSTEM TROUBLESHOOTING

MALFUNCTION	PROBABLE CAUSE	REMEDY
Starter does not crank turbine	Operation selector switch not in "RUN" position.	Place switch in appropriate position.
	Circuit breakers off or tripped.	Reset circuit breakers.
	Batteries discharged or disconnected.	Check for loose connection check battery voltages; recharge or replace battery.
	Starter motor connections loose.	Tighten loose connections.
	Insufficient voltage to starter.	Check voltage at starter terminals.
	Fault alarm energized.	Manually reset alarm via operation selector.
	Coast down timer not timed out.	Wait for timer to time out.
Starter cranks, but does not disengage.	Starter cut-off relay malfunctioning.	Check operation of relay, speed switch start contactor, starter solenoid, end-engaging mechanism.
Starter cranks turbine, but combustion does not occur.	Batteries inadequately charged or terminals loose or corroded.	Recharge or replace batteries. Clean and tighten terminals.
	Ignition system malfunction.	Contact service representative.

STARTING SYSTEM (PNEUMATIC)

GENERAL

Under certain conditions, a pneumatic starter (optional) is preferred to the electric starting system. If the gas turbine location has an existing supply of compressed air or natural gas, the battery requirement is reduced. The pneumatic starter has greater torque capabilities than the electric unit, providing sufficient quantity of high pressure air is available; thereby reducing acceleration time for a given driven load and providing the capability of cranking larger driven loads.

WARNING ***When using pressurized gaseous fuels, discharge gas must be confined and vented through a controlled system such as vent stacks, or possible personal injury may result.***

WARNING ***Personal contact with high pressure compressed air may cause injury.***

There are two pneumatic starting systems available. One system is the high pressure 10 second start with air assist*, and the other is the low pressure with air assist*.

***Reference liquid fuel system for a functional description of the air assist fuel nozzle.**

The pneumatic starter used is a Startmaster dual sliding rotary vane motor unit, Figure 5-5. Power capability depends upon the pneumatic pressure and flow. Regulated supply pressure must be sufficient to motor the turbine to 20-30 percent speed. Engine motoring speed is a function of driven load; starter inlet pressure is established by regulator adjustment during initial system start up. This pressure will be in the 80-150 psig (552-1034 kPa) range for the low pressure system and 240-250 psig (1.66-1.72 mPa) range for the high pressure system, supplied through plumbing capable of flowing 1500 SCFM (42.5 m^3/min.) Plumbing, valves, a pressure switch and a starter lubricator are required for operation of pneumatic starter.

OPERATION

Activation of the engine start circuit opens the two-way and three-way solenoid valves. The three-way valve delivers regulated servo pressure to the starter engagement mechanism. See Figures 5-6 and 5-7. As engagement occurs, a servo signal port is uncovered allowing air flow to the two-way solenoid valve and fuel nozzle, thereby enabling a more consistent light-off by aiding liquid fuel atomization. Engagement also allows the pressure control valve to open, thus permitting full regulated flow through the air filter and in-line lubricator to the starter motor to begin cranking action.

As the gas turbine accelerates, compressor discharge pressure (CDP) increases and activates the CDP switch which disengages the start motor by de-energizing the three-way solenoid valve. The normally closed CDP switch setting is 25 to 30 psig (172 to 206 kPa) with rising pressure. Since CDP, for a given gas turbine speed, will vary with ambient conditions, the speed of starter disengagement cannot be precisely given. It should occur at approximately 55-65 percent speed.

When the three-way start solenoid is de-energized, servo signal pressure to the starter engagement mechanism and start valve is diverted to the start motor discharge line. When using natural gas, the gas must flow from the discharge line to a vent stack. If using compressed air, the air flows from the discharge line to a muffler. Disengagement of the start motor is controlled by the three-way start solenoid; and, as a backup, the engine speed switch will cause disengagement at approximately 95 percent engine speed.

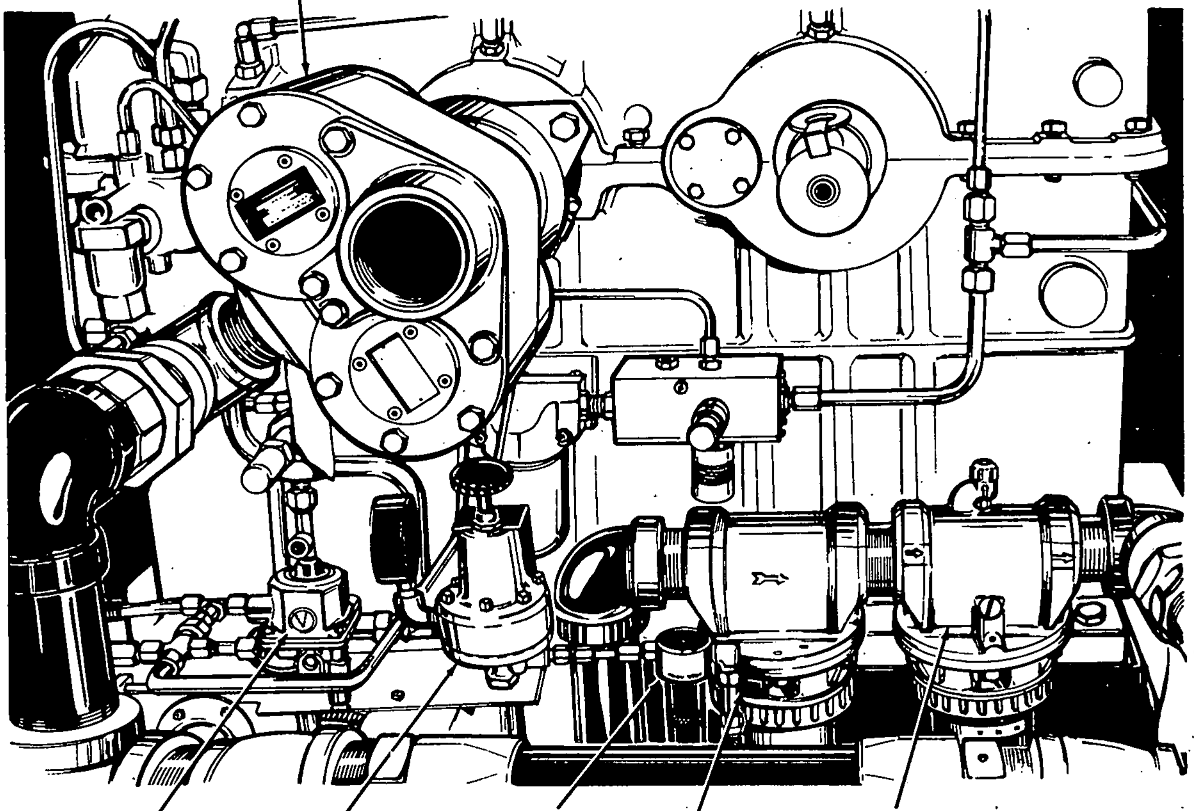


FIGURE 5-5. PNEUMATIC STARTER (TYPICAL)

MAINTENANCE

Due to the low duty cycle of this system, it is virtually maintenance free. During the normal lifetime of the generator set, the only maintenance required should be servicing the air filters and adding oil to the lubricator. The only service necessary is to periodically check for air leaks and ensure that the pilot air gauge reads between 240-250 psig [1.66-1.72 mPa] (High Pressure System), or 80-150 psig [552-1034 kPa] (Low Pressure System). Air line lubricator selector should be set on number 4, and reservoir should be full of SAE #20 lubricating oil.

WARNING ***Compressed air systems require special fittings and plumbing. Do not replace any plumbing without contacting authorized factory service. Using unauthorized hardware may result in personal injury and also damage to the unit.***

In-line lubricator provides up to 60 drops of oil per minute to the starter assembly.

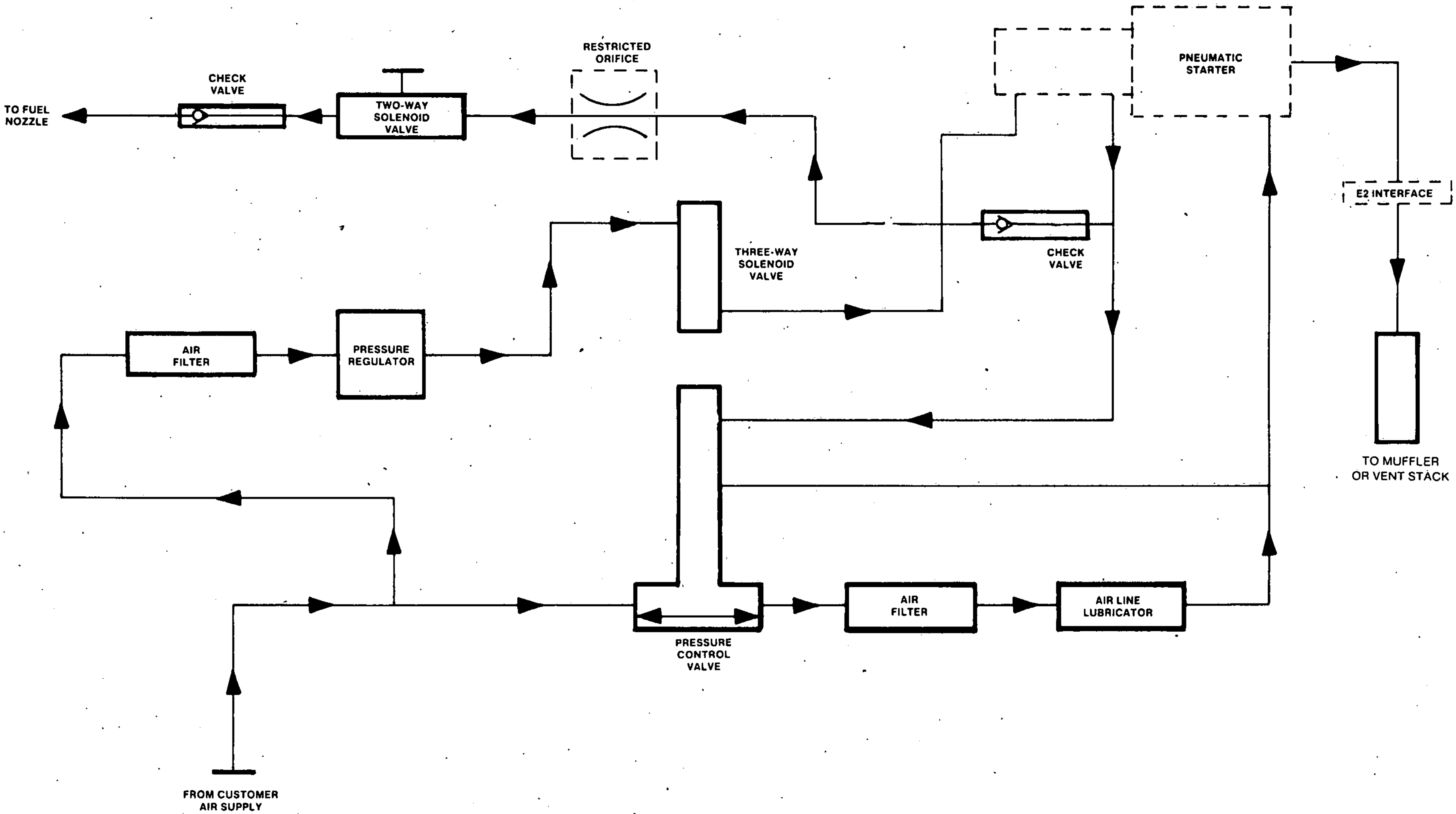


FIGURE 5-6. HIGH PRESSURE PNEUMATIC STARTING SYSTEM

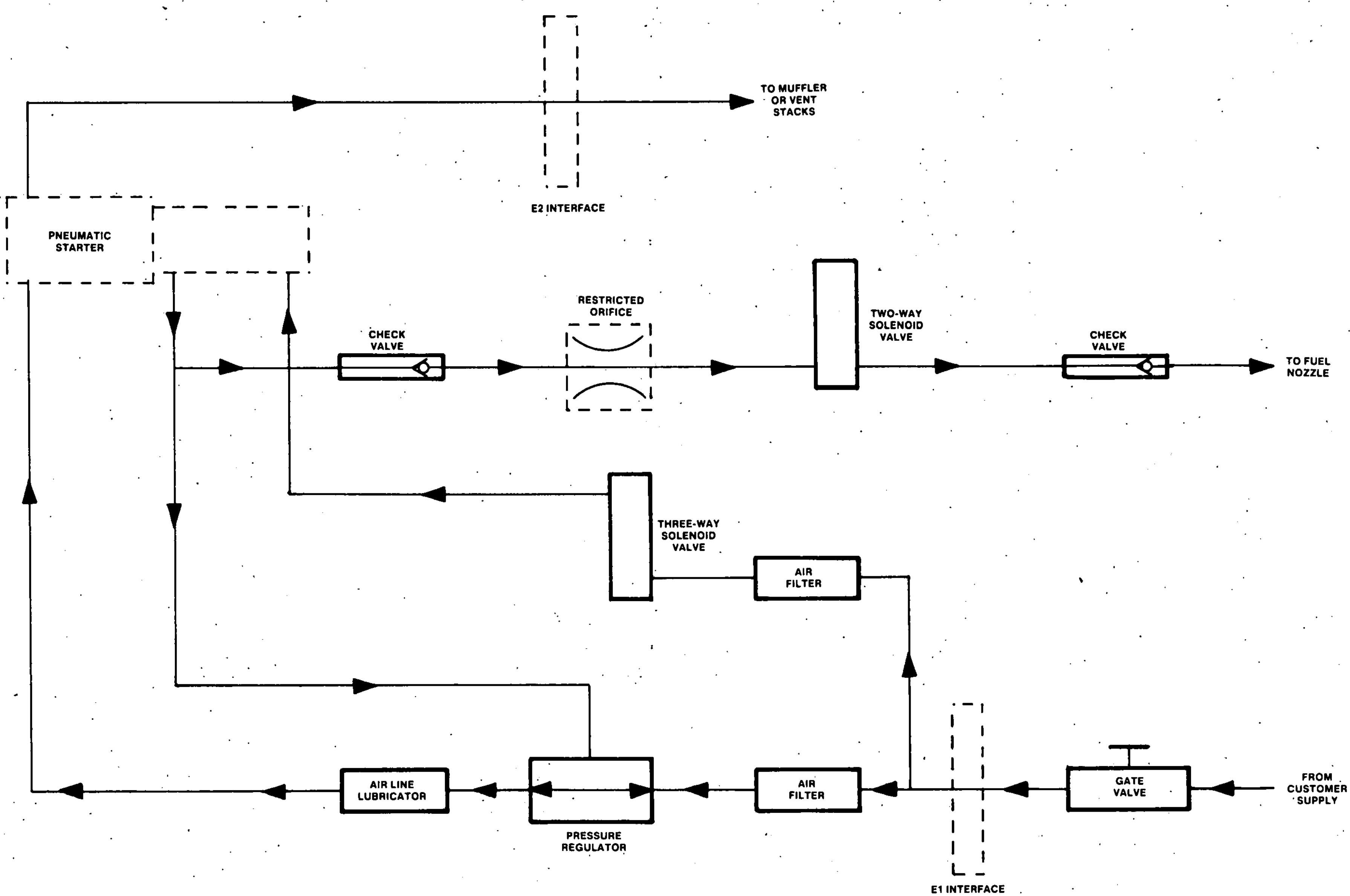


FIGURE 5-7. LOW PRESSURE PNEUMATIC STARTING SYSTEM

STARTING SYSTEM TROUBLESHOOTING

MALFUNCTION	PROBABLE CAUSE	REMEDY
Starter does not crank turbine.	Operation selector switch not in "RUN" position.	Place switch in appropriate position.
	Circuit breakers off or tripped.	Reset circuit breakers.
	Fault alarm energized.	Manually reset alarm via operator selector.
	Coast down timer not timed out.	Wait for timer to time out.
	Customer Gate valve closed.	Open valve.
	Pressure Regulator out of adjustment.	Adjust pressure regulator to read 240-250 psig [1.66-1.72 mPa] (High Pressure System) and 80-150 [552-1034 kPa] (Low Pressure System) on pressure gauge.
	3-way solenoid valve inoperable.	Check valve and voltage, repair or replace.
	Pressure control valve inoperable.	Check valve, repair or replace.
Starter cranks, but does not disengage.	Compressor discharge pressure switch inoperable.	Replace switch.
	3 way solenoid valve failed to close	Replace 3 way solenoid valve.
Starter cranks turbine, but combustion does not occur.	Ignition system malfunction.	See Ignition System Troubleshooting.
	Fuel system malfunction.	See Fuel System Troubleshooting.

COMBUSTION AIR SYSTEM

GENERAL

Care must be taken in the design and installation of the air inlet system so as to ensure full engine performance. The inlet duct opening to the outside atmosphere must be located so that heated air from cooling airflow or engine exhaust cannot be drawn into the inlet plenum. 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. Engine intake air must be free of water, dust, and other particulates. An optional air filtering system is available for removing particulate concentrations to .01 milligrams/ft^3 or less.

OPERATION

Combustion air enters engine inlet plenum, Figure 5-8. From inlet plenum air enters compressor section where it is compressed, providing air to the combustor at required pressure and flow rate. At normal speed the compressor pumps 6,250 ft^3 (177 m^3) of air per minute through the gas turbine. Inlet static pressure loss should not exceed 4.0 inch (max) H_2O (10.0 mbar). Inlet air temperature should not exceed 0°F (-18°C) max.

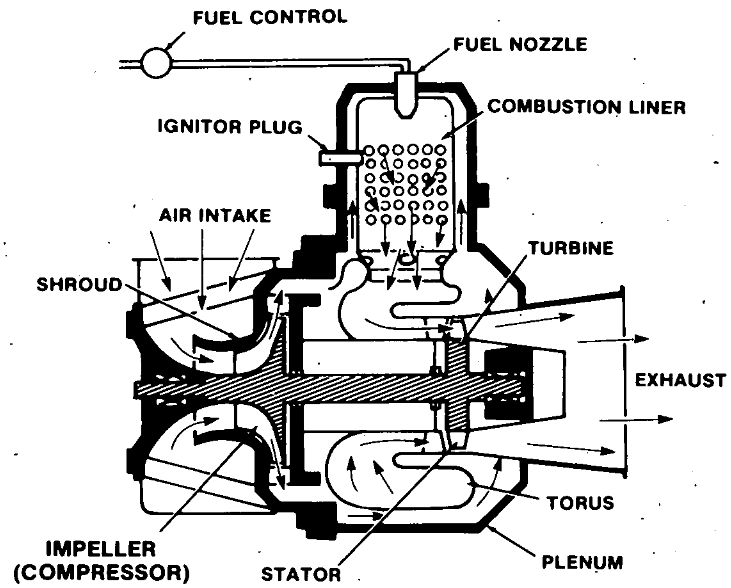


FIGURE 5-8. COMBUSTION AIR FLOW

MAINTENANCE

Air filters (Optional Equipment) should be serviced whenever air inlet system pressure drop exceeds 4.0 inches (102 mm) H_2O. After filters have been detached from housing, they can be cleaned in one of two ways.

1. If the filters are loaded with fine dust particles, a compressed air hose should be used, at 30 psi (208 kPa) to blow air through the filter element until clean.
2. If the restriction has been caused by carbon, soot, oil, sand or larger particles of dust, the filter should be soaked in a solution of water and D-1400, a special detergent compound produced by the Donaldson Company for cleaning filter elements.

FUEL SYSTEM (LIQUID)

GENERAL

The fuel system consists mainly of the following: mechanically driven fuel pump, fuel boost pump, fuel valve, fuel shut-off valve and filters as required, plus an atomizer to spray fuel into the combustion chamber.

The IE 831-800 gas turbine will operate on a variety of liquid fuels. Refer to Table 5-1 for list of approved fuels.

TABLE 5-1. APPROVED LIQUID FUELS

APPROVED TYPE FUEL	GRADE	SPECIFICATION
DIESEL	No. 1 & No. 2	ASTM D396
DIESEL	No. 1-D & No. 2-D	ASTM D975
DIESEL	No. 1-GT & No. 2-GT	ASTM D2880
DIESEL	DF-1 & DF-2	VV-F 800
DIESEL	ALL	MIL-R-46005
DIESEL	Class B-1	BS2869
KEROSENE	Jet A, A-1 & B	ASTM D1655
KEROSENE	JP-4 & JP-5	MIL-T-5624
*ETHYL-ALCOHOL	—	—

The maximum allowable vanadium content for any of the specified fuels is 2ppm by weight.

*A fuel mixture of ethyl-alcohol and water with a lower heating valve of 9500 to 9900 BTU/lb. will enable the engine to function satisfactorily and meet specified performance. Fuel shall not exceed a kinematic viscosity of 12 centistrokes.

OPERATION

Fuel from the customer source is pumped by the boost pump to the primary filter, where particulate matter of 10 microns is removed from the fuel. The fuel boost pump (jet or electric), pumps fuel from a source not exceeding 15 ft (4.57 m) lift. From the primary filter, the fuel flows to the day tank and positive displacement engine driven pump. The fuel leaves the pump under high pressure and enters the final filter and fuel control valve. The fuel flows from the fuel control valve to the two-way solenoid valve and fuel atomizer. See Figure 5-9.

The atomizer with air assist, breaks up fuel entering the combustion chamber into a fine mist, which enables more consistent light-offs.

CAUTION ***Do not allow rotation of fuel pump without the presence of fuel in the pump. Pump bushings and shaft are both cooled and lubricated by fuel flow.***

During the engine start cycle, the fuel control valve meters fuel flow for proper engine acceleration. As engine speed increases, compressor discharge pressure (CDP) is directed to the fuel control valve which increases fuel flow to the atomizer. Once engine reaches rated speed, the governor maintains engine speed during all operating conditions.

AIR ASSIST

An integral part of the atomizer is the air-assist system which improves fuel atomization, enabling more consistent light-offs. The system uses a motor-compressor with electric starting engines or compressed air from pneumatic starting engines.

Air assist is used on liquid fuel system only.

On the electric start system, air pressure is produced by a motor-compressor. During "START" initiate, the motor compressor starts compressing air for the atomizer. When the pressure reaches 9 psi and engine reaches 10 percent speed, the solenoid valve opens energizing the "Start Permit" switch, which initiates the "Start Sequence."

Compressed air is provided during light-off and acceleration. The motor compressor is deactivated at 95 percent engine speed when used with the electric start.

On the pneumatic start system, air pressure is supplied by starter engagement pilot air. See pneumatic Starting System diagram. This air pressure then enters a restricted orifice where the pressure is reduced to 9-15 psi. The compressed air then flows to the solenoid valve and fuel atomizer. The compressed air to the fuel atomizer terminates when the starter disengages.

FUEL DRAIN

An automatic plenum drain system is provided which assures complete drainage of any unburned liquid fuel upon shutdown. Also, the drain system is designed to drain any fuel that could possibly seep past the gearbox mounted fuel pump shaft seal.

MAINTENANCE

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

Fuel system filter elements should be serviced every 500 hours. Fuel quality may dictate more frequent service. Remove, clean and inspect fuel atomizer every 500 hours.

FUEL SYSTEM TROUBLESHOOTING

MALFUNCTION	PROBABLE CAUSE	REMEDY
No light off.	No fuel.	Check fuel supply; replenish if necessary.
	Day tank fuel level low.	Check float valve.
	Loose fuel connection.	Tighten fuel connections as required.
	Excessive air in fuel system.	Repair condition that caused air to enter fuel system, bleed fuel system.
	Excessive water in fuel system.	Check tank and remedy.
	Contaminated fuel supply.	Clean and refill fuel tank. Replace filter elements.
	Fuel system components or circuits defective.	Contact service representative.
	Plugged fuel filters.	Replace filter elements.
Turbine lights off, but flames out.	Fuel system malfunction.	See cause and remedy above.
		Check compressor air line for leaks.
	Minimum fuel setting too low.	Adjust minimum fuel setting on fuel control valve to higher setting (contact service representative).
Lights off, but does not accept full load.	See Engine Troubleshooting.	

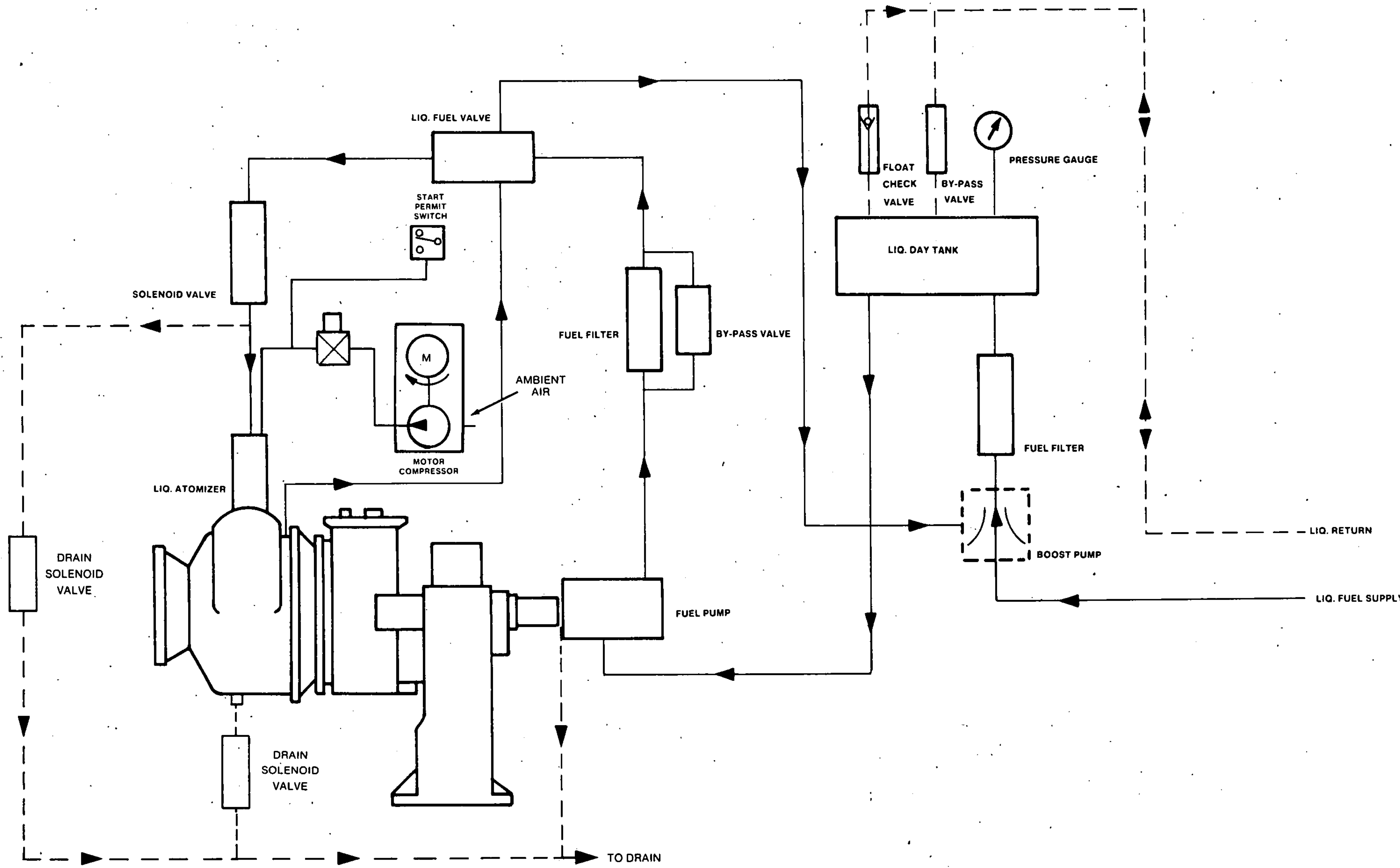


FIGURE 5-9. LIQUID FUEL SYSTEM

FUEL SYSTEM (GASEOUS)

GENERAL

The fuel system consists mainly of the following: Filter, solenoid valves, fuel control valve and fuel nozzle. The filter, main fuel shut-off valve, pressure gauge, temperature switch, and the vent valve are attached to a manifold which facilitates a common plumbing connection point.

The IE 831-800 gas turbine will operate on gaseous fuel meeting the following specifications: 900 to 1000 BTU/ScF, cyclic pressure variations not to exceed ± 2 psig, sulphur content must be less than 0.5 percent by weight, and the fuel must be free of liquid hydrocarbons and ice forming moisture.

OPERATION

Gaseous fuel from customer source enters the primary filter, where particulate matter of 2 microns is removed from fuel. Fuel then enters the main fuel shut-off solenoid, Figure 5-10. Upon "START" initiation the main and secondary shut-off solenoids open, allowing fuel to flow to the fuel control valve and fuel nozzle.

The main shut-off solenoid (Normally closed) shuts off the gas supply to the system. The secondary shut-off solenoid (Normally closed) and check valve protect against back pressure from the gas turbine combustion system. The supply line between the shut-off valves is vented to the atmosphere through the solenoid vent valve (Normally open).

During the engine start cycle, the fuel control valve meters fuel flow for proper engine acceleration. As engine speed increases, compressor discharge pressure (CDP) is directed to the fuel control valve which increases fuel flow to the nozzle. Once engine reaches rated speed, the governor maintains engine speed during all operating conditions. On shutdown the main and secondary fuel shut-off solenoid valves close, and the vent solenoid opens venting residual fuel vapors to the atmosphere via the vent stacks.

On gaseous units there is a ten second purge cycle prior to "START" initiate.

MAINTENANCE

Fuel system filter elements should be serviced every 500 hours. Fuel quality may dictate more frequent service. Remove, clean and inspect fuel nozzle every 3000 hours.

FUEL SYSTEM TROUBLESHOOTING

MALFUNCTION	PROBABLE CAUSE	REMEDY
No light - off.	No fuel.	Check fuel supply.
		Check manual shut-off valve.
	Excessive moisture in fuel system or dirty filter elements.	Replace filter elements and purge fuel system.
	Fuel system components or circuits defective.	Contact service representative.
Turbine lights - off, but flames out.	Fuel system malfunction.	See cause and remedy above.
		Check compressor air line for leaks.
	Minimum fuel setting too low.	Adjust minimum fuel setting on fuel control valve to higher setting (contact service representative).
Lights - off but does not accept full load.	See Engine Troubleshooting.	

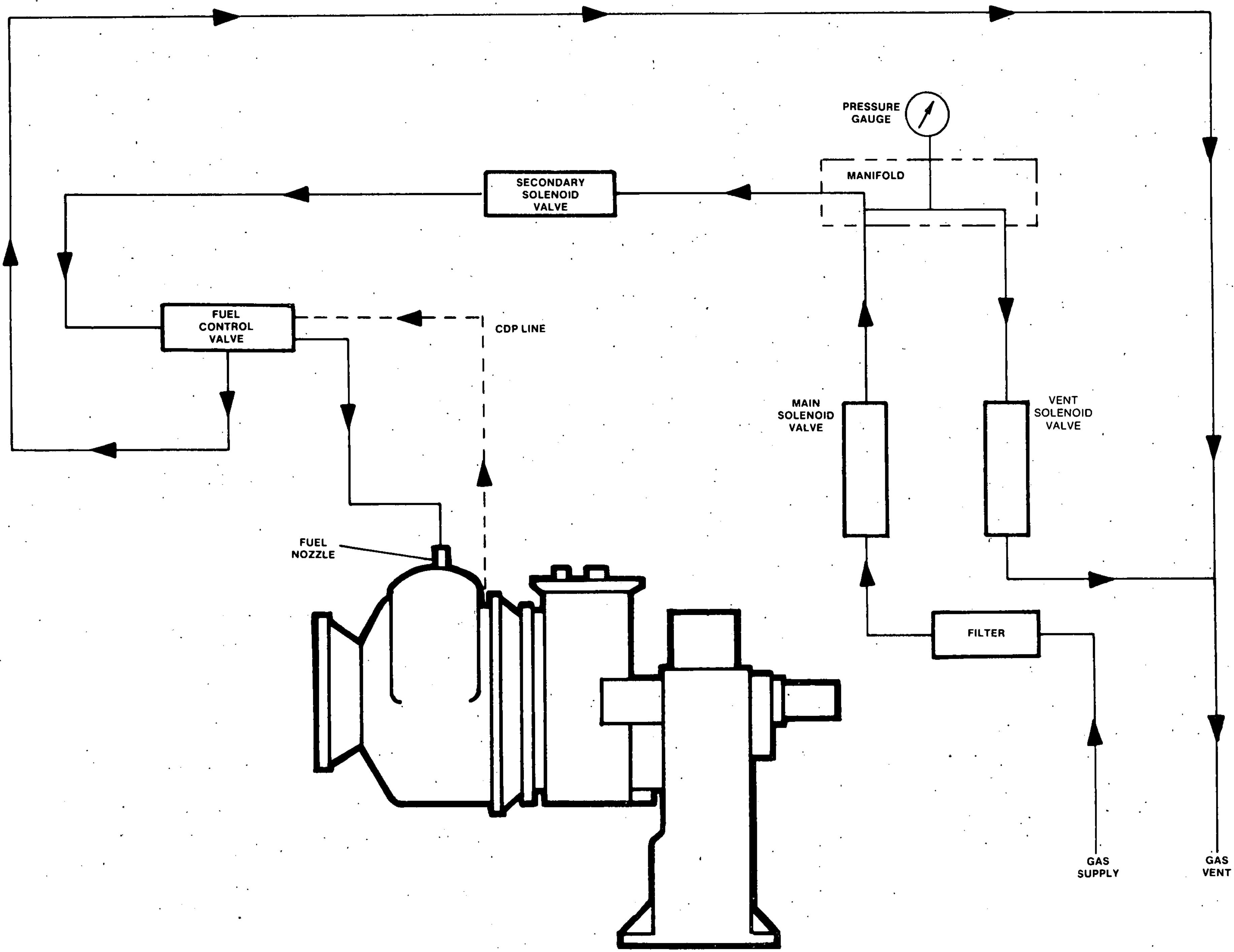


FIGURE 5-10. GASEOUS FUEL SYSTEM

FUEL SYSTEM
(DUAL FUEL)

GENERAL

The dual fuel option enables the engine to light-off, accelerate, and operate at governed speed on either liquid or gaseous fuels. The dual fuel provides the capability to switch-on-the-fly from liquid to gaseous and also provides the capability to switch from gaseous to liquid with a 500 millisecond delay.

OPERATION

The operation of this system (Figure 5-11) is similar to that described under the liquid and gaseous fuel systems. The main difference is that this system incorporates a compound fuel atomizer/nozzle contained in a single assembly. This assembly introduces either gaseous or liquid fuel to the combustion chamber.

The other difference is that the dual fuel engine is equipped with a gaseous and liquid fuel control each governed by a common EG-3P actuator. In the gaseous mode, liquid fuel is diverted at the two-way solenoid valve back to the storage tank. In liquid mode, the main and secondary fuel solenoid valves are in the normally closed position, and the vent solenoid is in the normally opened position.

A quick response temperature switch is placed between the shut-off valves and the normally open solenoid vent valve. The temperature switch is required to detect combustion air leakage (CDP backflow causing over-temperature). If leakage occurs, the temperature switch will automatically shut down the engine.

MAINTENANCE

Refer to liquid and gaseous fuel system maintenance.

TROUBLESHOOTING

Refer to liquid and gaseous fuel system troubleshooting.

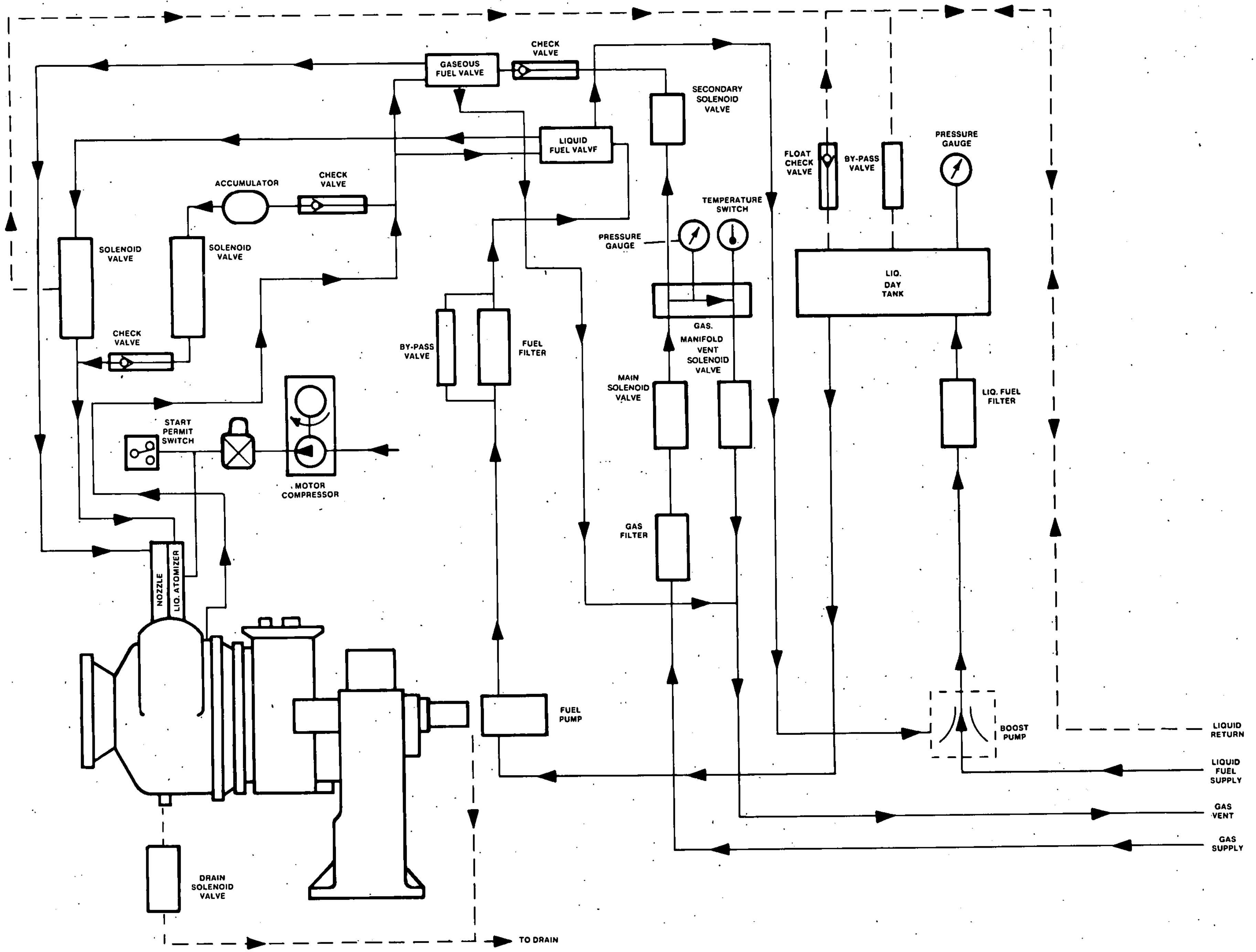


FIGURE 5-11. DUAL FUEL SYSTEM

LUBRICATION SYSTEM

GENERAL

The engine oil system is fully automatic in operation and consists of a dual oil pump, pressure switches, check valve, oil filter, pressure regulator, temperature switch, oil pressure gauges, temperature sensor, oil cooler and the necessary plumbing and fitting.

Only those oils listed in TABLE 5-2 are approved for use in the Garrett gas turbine engine. In the event of conflict due to change, the Garrett Operation and Maintenance manual shall take precedence.

TABLE 5-2. APPROVED ENGINE OILS

APPROVED LUBRICATION BRAND NAME	AMBIENT TEMPERATURE	
	MINIMUM	MAXIMUM
MINERAL OIL		
Standard Teresstic 32 (Formerly Terristic 43)	-4 C (+25F)	54C (130F)
Exxon/Esso Teresstic 32 (Formerly Terristic 43)	-4 C (+25F)	54C (130F)
SYNTHETIC OIL		
Aero Shell Turbine Oil 500/555	-29C (-20F)	54C (130F)
Brayco 899S	-29C (-20F)	54C (130F)
Caltex RPM Jet Engine Oil 5	-29C (-20F)	54C (130F)
Castrol 205	-29C (-20F)	54C (130F)
Chevron Jet Oil No. 5	-29C (-20F)	54C (130F)
Exxon/Esso Turbo Oil 2380	-29C (-20F)	54C (130F)
Hatcol 3211	-29C (-20F)	54C (130F)
Mobile Jet II	-29C (-20F)	54C (130F)
Monsanto Skylube 450	-29C (-20F)	54C (130F)
Stauffer Jet II	-29C (-20F)	54C (130F)
Texaco or Caltex Sato 7730	-29C (-20F)	54C (130F)

OPERATION

The oil system (Figure 5-12) is a wet sump type providing lubrication for all moving engine assembly parts and also serves as a means for dissipation of heat rejected by the bearings and gears. A supply of cooled, filtered oil is continuously circulated.

When the engine is started, oil is drawn from the oil sump by the pressure section of the pump and flows through the oil cooler to the pressure regulator and filter assembly. The pressure regulator maintains proper oil pressure and allows excess oil to by-pass to the oil sump. Obstruction of the oil filter will result in a decreasing oil pressure. In the event of extreme blockage, the filter by-pass will open, allowing continued engine operation and lubrication to the engine and gears. Extreme blockage may cause low oil pressure shutdown.

Oil flows from the oil filter to the engine bearings and gearbox assembly. Oil is returned from the engine assembly by means of the scavenge section of the pump. The gearbox assembly is designed for gravity drainage back into the oil sump. The aspirator, mounted on the gearbox, serves as an oil separator separating oil from gearbox vapors. Vapors from the aspirator are channeled to the exhaust and oil from the aspirator is channeled back to the gearbox.

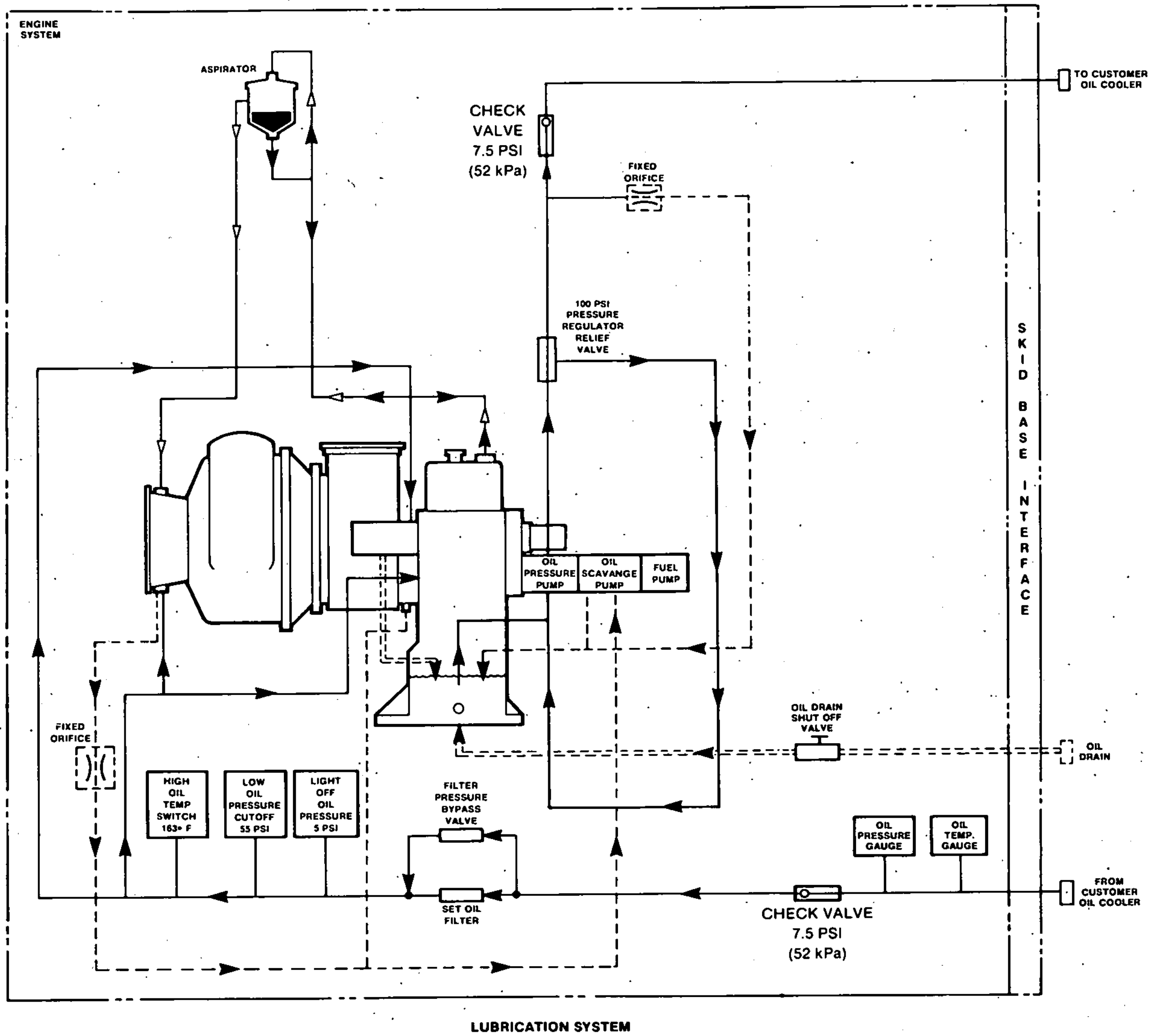


FIGURE 5-12. LUBRICATION SYSTEM

Pressure switches and a temperature sensing switch act as protective devices to shutdown the engine in the event of low oil pressure or high oil temperature. A pressure gauge indicates system oil pressure. A temperature gauge indicates temperature of oil from oil cooler.

MAINTENANCE

Oil system filter elements should be changed every 500 hours. Perform oil acidity test (per ASTM STD D664 or D974) every 6 month or 1000 hours, whichever comes first.

OIL COOLER

Oil coolers may be either set or remote mounted. Both the remote and set equipped oil coolers use an electric motor to operate the cooling fan.

Oil coolers must limit engine oil temperature to 160°F (71°C).

Check valves are standard and set mounted. Remote oil coolers must be mounted with the highest oil level less than 10 feet (3 meters) above the engine centerline, Figure 5-13.

NOTE: Check valves are standard and set mounted.

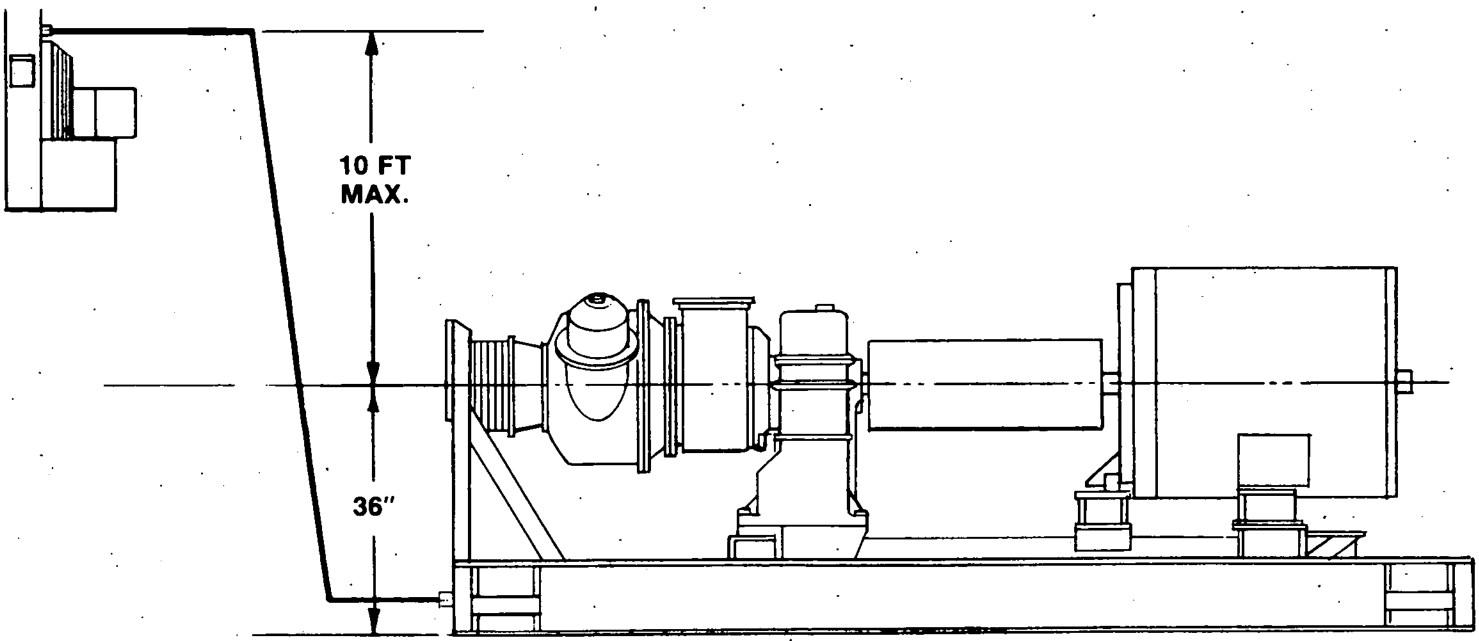


FIGURE 5-13. REMOTE OIL COOLER INSTALLATION

EXHAUST SYSTEM

WARNING

ENGINE EXHAUST GAS (CARBON MONOXIDE) IS DEADLY!

Carbon monoxide is an odorless, colorless gas formed by incomplete combustion of hydrocarbon fuels. Carbon monoxide is a dangerous gas that can cause unconsciousness and is potentially lethal. Some of the symptoms or signs of carbon monoxide inhalation are:

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

If you experience any of the above symptoms, get out into fresh air immediately.

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 by a competent mechanic.

GENERAL

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

Engine exhaust diffuser duct loading, due to installation effects, must not exceed 65 lbs along any of the three perpendicular axis.

OPERATION

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 - 17.540 CFM @ 1100°F (494 m^3/min @ 593°C)
System Total Pressure Loss - 6.0 inch (152 mm) H_2O Max.
Temperature - 1100°F (593°C) Max. Continuous, 1550°F (843°C) Start Transient

ELECTRICAL SYSTEM

GENERAL

This section deals with electrically operated control and monitoring devices for the gas turbine engine from either a local or remote control panel. The section also deals with electrical operation and some maintenance of individual components.

OPERATION

Monopole

The monopole is a small permanent magnet generator located adjacent to the main shaft in the turbine power section and next to the retaining nut that holds the seal and bearing rotors in place (Figure 5-14).

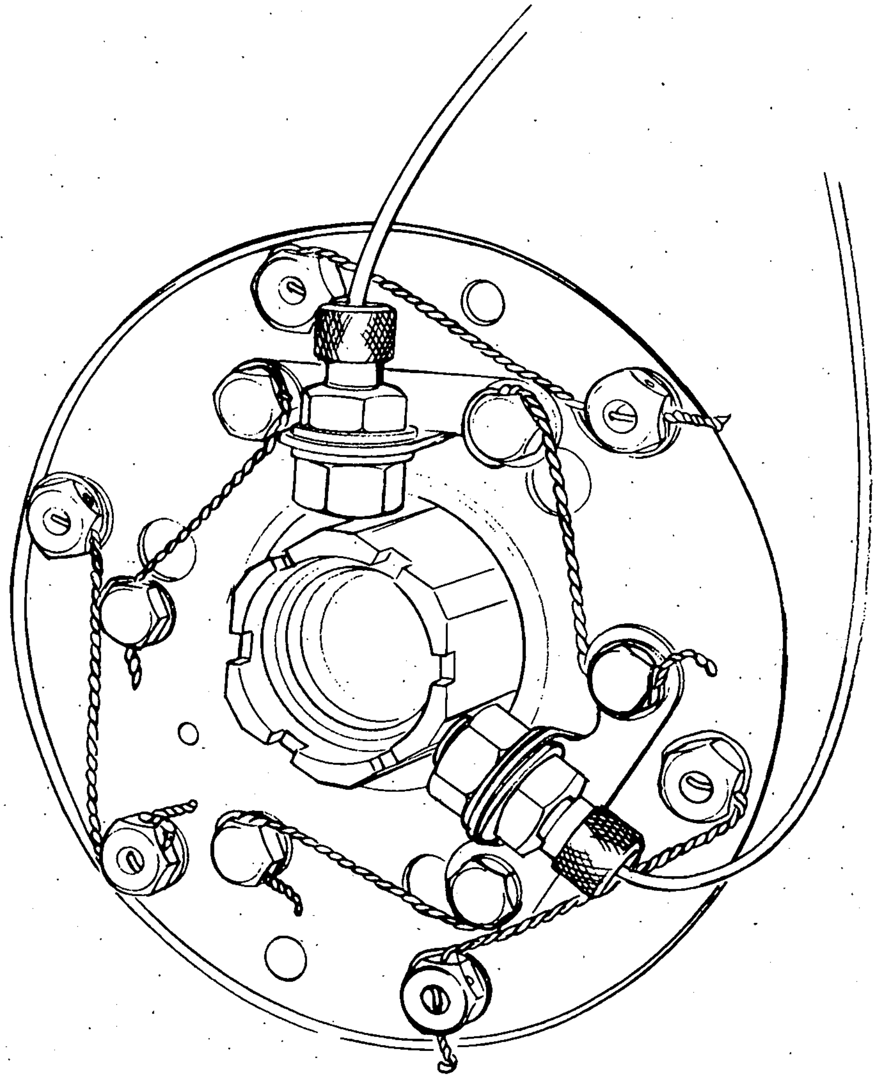
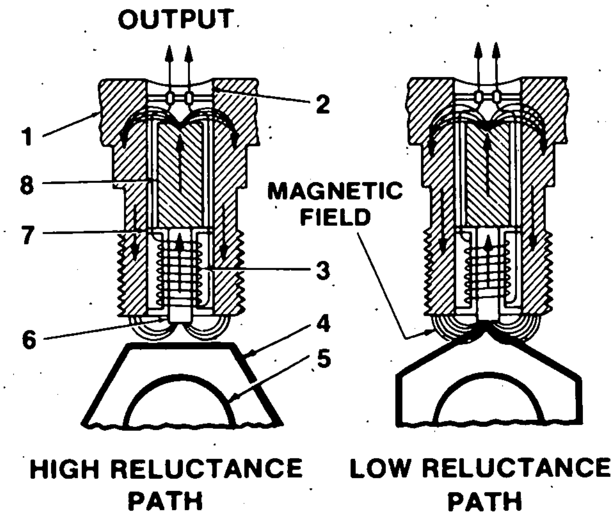


FIGURE 5-14. MONOPOLE LOCATION

As the main shaft rotates, the rotating nut causes a change to occur in the magnetic field strength inducing a voltage in the monopole. See Figure 5-15. Frequency and magnitude of this voltage is proportional to the rate-of-change of the flux through the monopole coil (i.e., increase engine speed, increase voltage and frequency).



1. BODY
2. POTTING
3. COIL
4. NUT
5. SHAFT
6. SOFT IRON CORE
7. SPOOL (INSULATION)
8. PERMANENT MAGNET

FIGURE 5-15. MONOPOLE SPEED PICK-UP

The nut on the rotating group that is responsible for the frequency changes has six apexes. At an engine speed of 41,730 rpm (100 percent speed), monopole frequency is 4,173 Hz.

$$\frac{41{,}730 \text{ RPM}}{60 \text{ sec}} \times 6 \text{ apexes} = 4173 \text{ Hz.}$$

Hence the monopole is a frequency detector providing signals to the engine control components.

The monopole signal is applied to the speed switch providing the basis for sequencing and overspeed protection of the gas turbine. Electric governors use a load and speed control panel which requires a second separate monopole. This ensures a signal unaffected by interference from other system circuits.

THERMOCOUPLES

Exhaust Gas Temperature (EGT) and Electronic Temperature Control (ETC) thermocouples utilize insulated chrome-alumel wires that join at a welded bead and are housed in a capped stainless steel tube.

The function of the EGT thermocouple signal is to drive the exhaust gas temperature indicator. This unit is used to evaluate engine temperature during operation and also when adjusting controls or troubleshooting.

The Electronic Temperature Control thermocouple provides a signal input for the Electronic Temperature Control panel, for switching the start enrichment valve, and for overtemperature protection.

ELECTRONIC TEMPERATURE CONTROL (ETC)

This system consists of an inlet air temperature sensor thermocouple and the ETC control box. The ETC provides switch points for the acceleration overtemperature shutdown and run overtemperature shutdown.

The ETC box (Figure 5-16) is a solid state device, mounted in an environment not to exceed a maximum ambient temperature of 156° F (69° C). Switch points are established during assembly and there is no provision for external adjustment.

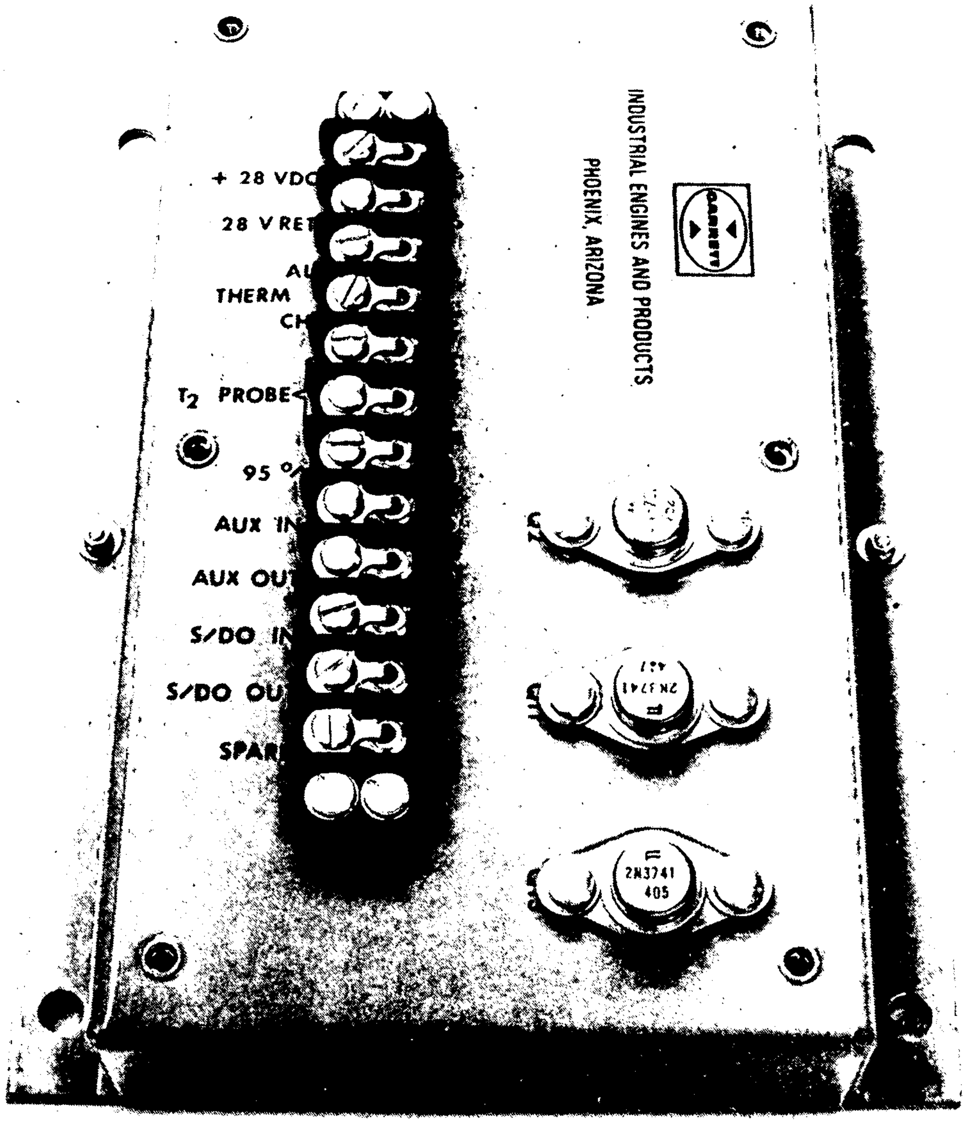


FIGURE 5-16. ELECTRONIC TEMPERATURE CONTROL

SOLENOID VALVES

Shutoff and atomizer drain valves used on liquid fueled units are actuated with 24VDC nominal battery voltage. A valve consists of a solenoid coil, valve plunger and body. No service is required; replace if defective.

SEQUENCE SWITCH

The assembly (also called Start Oil Pressure Switch) contains a diaphragm actuated micro switch. When switch actuation is completed, further diaphragm movement is prevented by a back-plate. The plate also prevents damage to the switch assembly when oil pressure reaches operating level.

The switch completes an electrical circuit to the fuel solenoid valves and ignition system during engine start cycle. It functions in series with the 10 percent speed switch assuring that approximately 5 psig (34.5 kPa) is present in the oil circuit which prevents engine starting in the absence of oil pressure.

SPEED SWITCH

The speed switch operates relays at speed trip points for sequencing and protection and provides an output for a speed indicator. It is a speed sensor and amplifier combined into a single assembly. One type is currently in use: Air Pax (Figure 5-17).

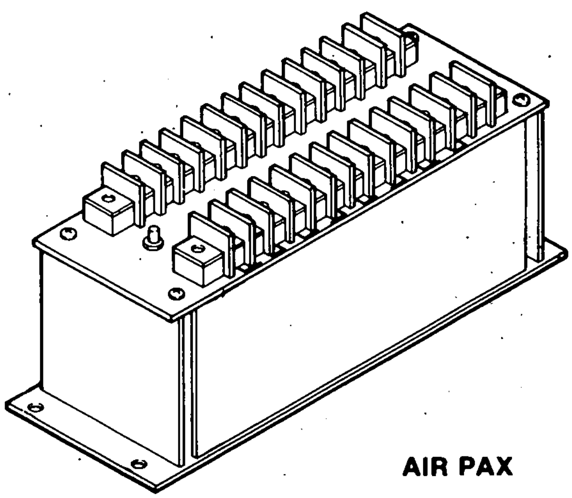


FIGURE 5-17. SPEED SWITCH

A 24VDC supply is required to energize the unit. Two zener-regulated supplies are self contained: One supply is for the circuit network and the other for speed trip points reference. The speed sensor converts the pulsed speed signal into a signal proportional to the pulsed frequency. A differential amplifier compares the speed and trip point signals. At speeds below the trip point, a positive error signal is amplified to energize the relay. As the speed reaches and exceeds the trip point, the error signal goes negative causing the relay to drop out. Hence the speed switch is inherently power fail safe. When power is applied to the unit at speeds below the trip point, the relay picks up. It drops out if either the speed attains trip point or if power is lost.

Trip point adjustments are factory set, but adjustment of the switches and tachometer signal should be performed if the speed switch is replaced. A variable frequency generator is used to simulate monopole output and the frequency checked with a precise meter to verify calibration.

The speed switch is mounted separate from the engine. It is not sensitive to mounting attitude but should be protected against moisture and ambient temperatures in excess of 150° F (66° C).

HIGH OIL TEMPERATURE SWITCH

The assembly is a factory set thermal switch set to function if lubricating oil temperature reaches 162 to 168° F (72 to 76° C): this results in an immediate engine shutdown. (The switch requires a hot immersion facility for evaluation of calibration. The switch is not field adjustable; replace if defective.)

LOW OIL PRESSURE SWITCH

Diaphragm operated switch closes when oil pressure rises to approximately 55 psig (380 kPa) during acceleration. If oil pressure switch has not closed by 95 percent, the unit will shutdown. If, during operation, oil pressure decreases to 55 psig (380 kPa), immediate automatic shutdown will occur protecting the engine from oil starvation damage.

IGNITION SYSTEM

The ignition system consists of an ignition exciter, shielded plug wire and an ignitor plug.

The ignition exciter is a high energy capacitor discharge system feeding a surface air gap ignitor plug with a spark of short duration and high intensity. This system has a limited duty cycle but since spark ignition is terminated as the unit passes 95 percent speed cycle, time for each start may be less than one minute.

The ignition lead connects the ignition exciter to the ignition plug. It consists of a high tension cable covered by a protective layer of stainless steel or nickel alloy wire braid.

The igniter plug is flange mounted into the combustor cap and the spark air gap extends into the combustion area for ignition of the fuel-air mixture.

The system should always be checked as a system with all three components connected together. Failure to have either ignitor plug or lead in place may cause failure of the component due to insulation break down.

WARNING ***Exercise care when testing and handling ignition systems! An electrical shock from this system could cause serious injury or death.***

When removing ignition exciter, short electrode to ground before disconnecting, bleeding off any static buildup on exciter capacitor. The frequency of the ignition spark is based upon primary input voltage. Typical frequency is three sparks per second. This may decrease to one spark per second while cranking the engine.

This system is checked by providing an integral or external source of 24VDC to the exciter and observing the accompanying spark.

Check ignitor as follows, observing all WARNINGS and CAUTIONS.

WARNING ***The ignition system is a system of extremely high voltage. Serious personal injury or death may result from contact with a an energized spark ignitor. Do not touch any part of the ignition system when it is energized.***

WARNING ***Do not perform this procedure in an area where there is the possibility of a fuel leak or explosive gas. Serious personal injury or death may result.***

CAUTION ***Do not operate ignition exciter with ignitor plug disconnected. Damage to exciter may otherwise result.***

1. Remove ignitor plug (with ignition cable attached) from combustor. Disconnect fuel solenoid valve electrical connector.
2. Initiate start. If spark rate is at least 3 to 5 sparks per second at 24VDC, proceed to *Fuel System Troubleshooting;* if not, contact Service Representative.

MAINTENANCE

Remove, clean and inspect Ignition Plug every 3000 hours.

IGNITION SYSTEM TROUBLESHOOTING

MALFUNCTION	PROBABLE CAUSE	REMEDY
Starter cranks turbine, but combustion does not occur.	Batteries inadequately charged or terminals loose or corroded.	Recharge or replace batteries. Clean and tighten terminals.
	Interruption of 24VDC to exciter.	Check connections from DC power source to exciter.

EG-3P GOVERNOR ACTUATOR

The essential element of the EG-3P is an electro-hydraulic transducer which controls the fuel flow to and from the power piston through the action of a polarized solenoid. The position of the output terminal shaft is proportional to the input current to the solenoid coil controlling the pilot valve plunger.

The actuator will go to minimum fuel position if the electrical signal is interrupted.

Oil for the unit is taken directly from the gearbox. The integral oil pump is driven at 3600 rpm by the gearbox governor drive shaft.

Speed setting of the actuator is accomplished by adjusting a potentiometer on the contol panel. There are no internal adjustments to this unit.

2301 LOAD AND SPEED CONTROL

The load and speed control (Figure 5-18) is used in conjunction with the electrical governor and fuel valve. This control is primarily intended for multiple load sharing installations.

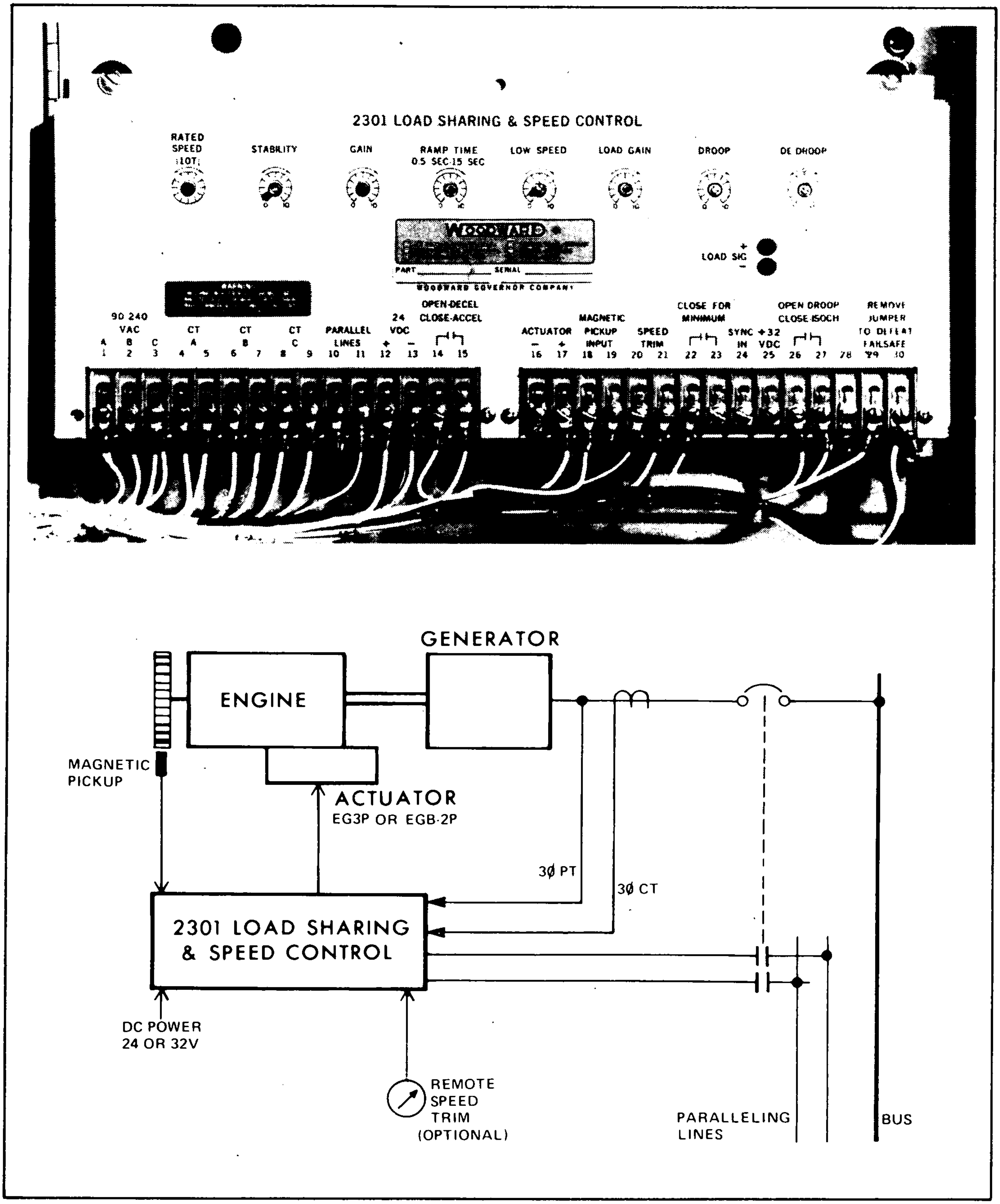


FIGURE 5-18. LOAD SHARING AND SPEED CONTROL AND BASIC 2301 SYSTEM

The unit (2301 Woodward) is housed in a single sheet steel chassis containing a single printed circuit board. The terminal blocks mount directly to circuit board which has printed circuits on both sides. All adjusting potentiometers and load signal connectors are accessible from the front of the chassis.

Principal control system components include a 2301 control, external 24VDC power source, monopole magnetic pickup for sensing engine speed, and generator output signals to develop the electrical governor input. For example, if speed was greater than the speed setting, the control amplifier would decrease its output and the actuator would decrease the fuel to the engine (the EG-3P actuator is forward acting and the EG-2P is reverse acting).

Kilowatt load sharing between two or more sets is accomplished via the load sensing circuitry. Each generator's load is measured continuously by its respective 2301 control and compared to other units on the line. Continuous corrections to the control loop gives Kilowatt load sharing. Isochronous operation provides constant engine speed while droop operation provides speed regulation.

The speed sensing fail-safe will shut down the engine if the monopole signal fails. The fail-safe circuit is self clearing when engine cranks. A 1.0 VAC signal to the control indicates that the monopole signal is correct and automatically clears the fail-safe section.

ONAN ENGINE RELAY LOGIC SYSTEM

The purpose of the logic system is to monitor and control engine-generator operations. Should a major malfunction occur, the logic system will initiate an automatic shutdown of the engine-generator set.

The logic system (Figure 5-19) is comprised of 24 VDC 3 amp relays and discrete components mounted on a printed circuit board. The relays function as logic gates and latches with millisecond switching characteristics. Also included on the printed circuit board are light emitting diodes (LED) used in testing and maintenance of the turbine set. See Figure 5-19.

Following is a functional description of the various logic relays and operator maintenance/indicator panel.

RELAY	FUNCTION
K1	Provides a 500 m sec overlap time delay for switching from gaseous to liquid.
K2	When energized in conjunction with K20, selects gaseous fuel.
K3	Monitors run terminal, so that a fuel change can occur only if the unit is not running, or if unit has reached ready to load status.
K4	Selects which fuel system interlocks with K3.
K5	When energized selects liquid fuel.
K6,K7	Controls atomizer purge solenoid. When the unit is running on liquid, K6 latches through K7. When unit is stopped or goes off liquid fuel, purge solenoid is energized and K7 begins timing, after 10 seconds K6 drops out de-energizing K7.
K8	Latches liquid fuel "ON," operates in conjunction with K1, K2.
K9	When energized in conjunction with K19, selects gaseous fuel.
K10	Crank Pilot Relay - Controls engine cranking through K40 auxiliary start relay.

RELAY	FUNCTION
K11	Coast Down Timer Relay - Allows a 3 minute time delay period, after engine shutdown, to allow the unit to stop rotating prior to re-engagement of starter. Also lights coast down lamp.
K12	Coast Down Lockout Relay - Arms K11 when both cranking and fuel circuits become de-energized. Allows cranking to re-continue after K11 time-out.
K13	Fuel Control A Relay - Fuel control relay completes necessary logic interlock functions.
K14	Fail to Ignite Relay - Protects the unit from cranking for long periods of time, after the fuel is on, if ignition does not occur. It begins a 16 second time delay when fuel is turned on by K13. Also lights fail to ignite lamp.
K15	Gas Purge Relay - Disables the fuel circuit for the first 10 seconds of each cranking period to ensure that no fuel remains in the combustion chamber. (On gaseous units only.)
K16	Overcrank Relay - Limits the amount of time that the unit can take to start. It allows 75 seconds, after initialization, for unit to reach 95% speed. If time expires K16 arms K24 alarm relay. Also lights overcrank lamp.
K17	Generator Arming Relay - Energizes the generator exciter field when engine reaches 95% of rated speed.
K18	Ready to Load Relay - A time delay that is energized by the 95% switch and which times out 1.0 second after energized. Also lights the ready to load lamp. Closes generator main circuit breaker if provided.
K19	Fuel Transfer Relay - Used on dual fuel configuration for transferring from gaseous to liquid fuel. Bypasses K15 on liquid fuel systems.
K20	Fuel Control B Relay - Fuel control relay completes necessary logic interlock functions.
K21	Underspeed Relay - Energizes alarm relay K24 via normally closed contact of the 95 percent speed switch. Also lights underspeed lamp.
K22	5 psi Pilot Relay - Energized when there is more than 5 psi at pressure switch.
K23	5 psi Bypass Relay - Bypasses 5 psi pressure switch on start-up. It is a 16 second time delay which starts timing when cranking begins. The time delay can be overridden by the 30 percent switch.
K24	Common Alarm Relay - When energized, it removes 24 VDC from the control circuit and disables other fault circuits to give first out indication. Relay also sets off an audible alarm if fault condition exist.
K25	Remote Fault Relay - Similar to emergency stop circuitry K26. For customer and future use must be manually reset. Also lights remote fault lamp.
K26	Emergency Fault Relay - Gives immediate shutdown and lockout. Energizes K24. This fault must be manually reset at unit. Also lights emergency stop lamp.

RELAY	FUNCTION
K27	Low Air Pressure Relay - Used on pneumatic starting systems. Provides an alarm and start initializing lockout only. The alarm and lockout reset automatically when air pressure is restored. Also lights low air pressure lamp.
K28	Spare Fault Relay - See K25.
K29	High Housing Temperature Relay - Relay delays actual shutdown for 5 minutes when relay is energized by either the ambient temperature switch or air flow switch. Must be manually reset. Also lights high HSG lamp.
K30	Generator Fault Relay - The relay may be connected to any of the following signals for fault indication: Field breaker open signal, main breaker overcurrent lockout signal, or generator undervoltage. Signal must be manually reset. Also lights generator fault lamp.
K31	High Oil Temp. Relay - Energized when oil temperature switch senses high temp. Must be manually reset. Also lights high oil temp. lamp.
K32	Low Oil Pressure Relay - Energized if oil pressure falls below 55 psi while engine is running. Also lights low oil pressure lamp.
K33	High Exhaust Gas Temperature Relay - Energizes if turbine exceeds temperature limits. Also lights the EGT lamp.
K34	High Exhaust Gas Temperature Relay latch.
K35	Overspeed Relay - Energizes if the speed switch attains 108 percent. Also lights the overspeed lamp.

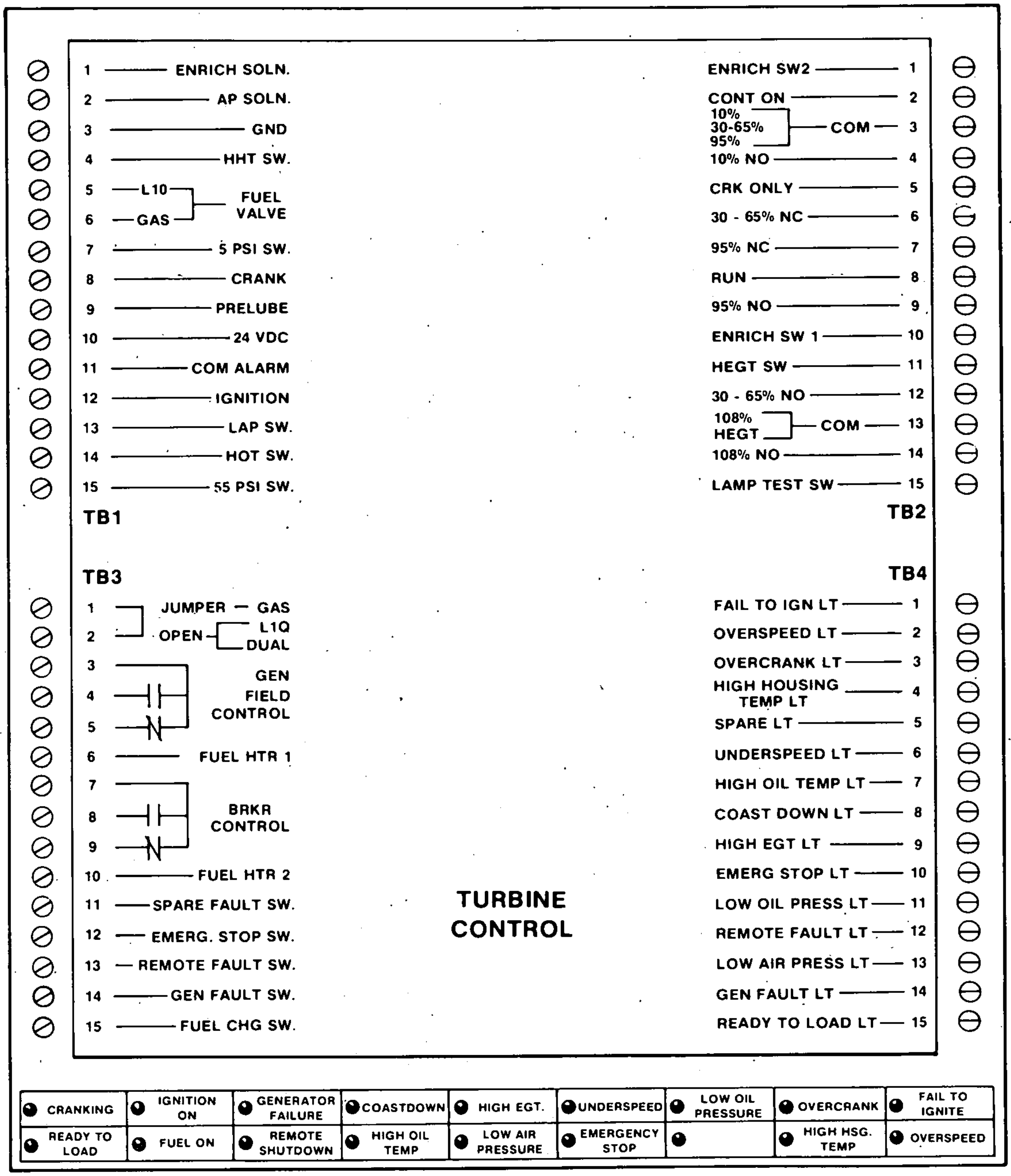


FIGURE 5-19. ONAN RELAY CONTROL LOGIC

TESTING AND MAINTENANCE LED'S

Following is a functional description of the Testing and Maintenances LED's, Figure 5-20. The LED's are located on the relay logic board.

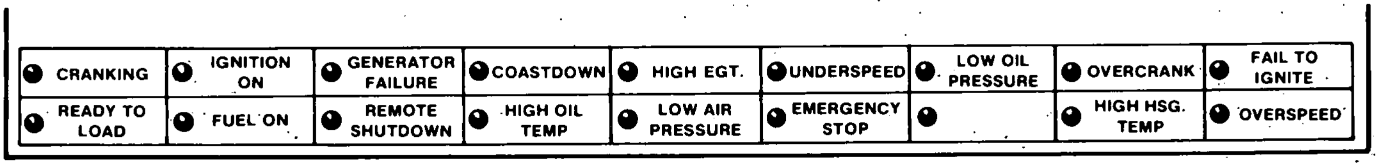


FIGURE 5-20. CONTROL LOGIC LED'S

LED	FUNCTION
Cranking	Indicates that cranking circuit is energized.
Ready To Load	Indicates that engine has reached 95 percent speed.
Ignition	Indicates that ignition circuit is energized.
Fuel On	Indicates that fuel valve circuit is energized.
Generator Failure	Indicates failure of generator circuit. (See relay K30 function).
Remote Shutdown	Indicates unit shutdown from remote location.
Coast Down	Indicates that 3 minute time delay circuit is energized.
High Oil Temperature	Indicates above normal oil temperature.
High EGT	Indicates above normal exhaust gas temperature.
Low Air Pressure	Indicates low air pressure on pneumatic starting system.
Under Speed	Indicates that engine speed has fallen below 95 percent.
Emergency Stop	Indicates emergency shutdown when emergency stop switch is depressed.
Low Oil Pressure	Indicates below normal oil pressure (less than 55 psi)
Overcrank	Indicates that engine cranked for 75 seconds or more without reaching 95 percent speed.
High HSG Temp.	Indicates above normal housing temp.
Fail To Ignite	Indicates ignition failed to occur.
Overspeed	Indicates that engine speed surpassed 108 percent.

OPERATOR PANEL

The turbine generator set is started, monitored and stopped by utilizing the Operator Panel, Figure 5-21.

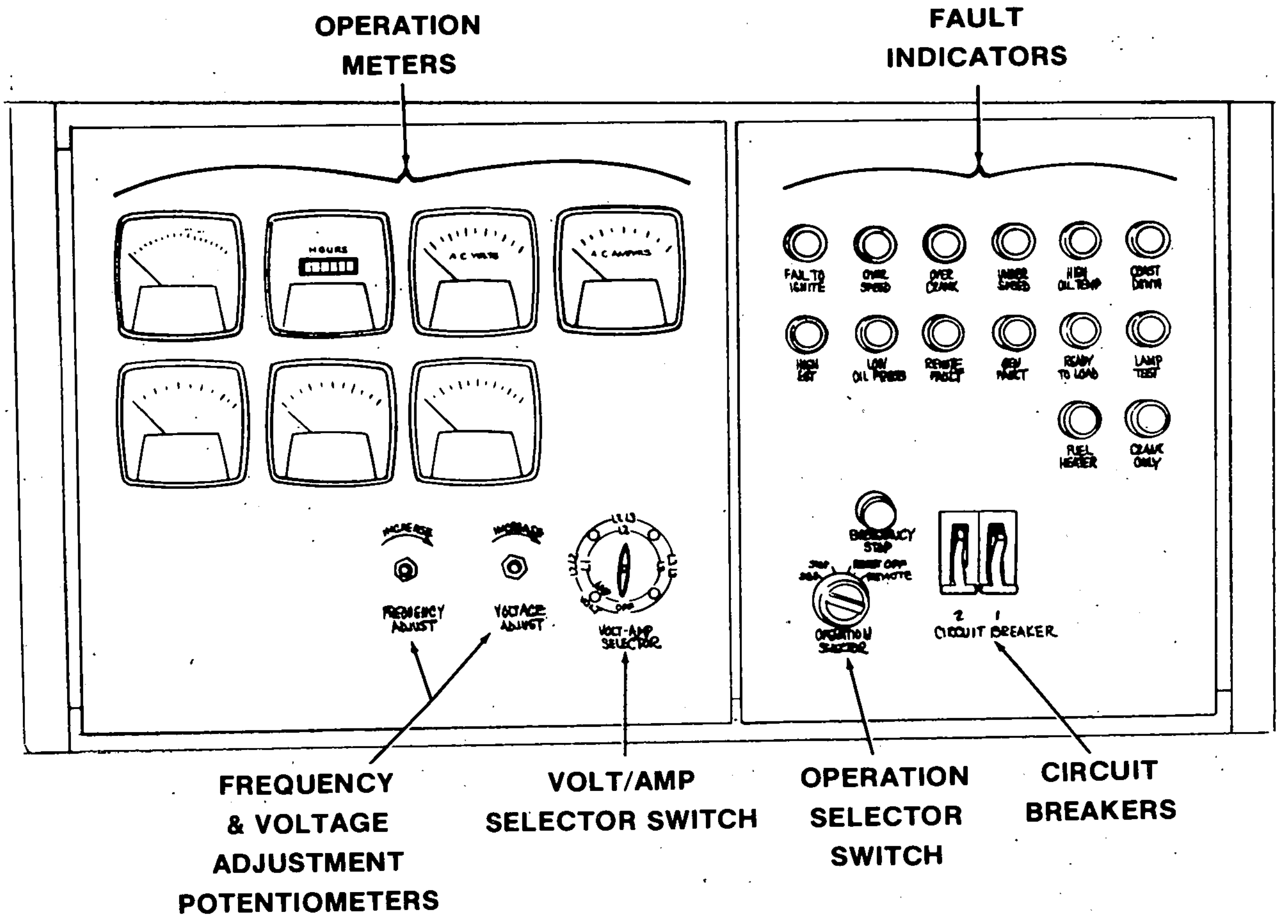


FIGURE 5-21. OPERATOR PANEL

GEARBOX AND COUPLING

WARNING ***Rotating machinery can cause serious personal injury or death. Stay clear of rotating equipment and ensure that protective shields and guards are in place.***

GENERAL

The gearbox assembly (Figure 6-1) provides support for the 1E831-800 engine and provides mounting provisions for the power section. It contains the reduction gearing for the power section to drive, supporting accessories and output shaft at approximate speeds. See Figure 6-2. The lower section of the gearbox forms the oil sump. The gearbox provides pads for mounting the starter, governor, lube and scavage pumps, plus a liquid fuel pump.

The primary output, a 2.8125 inch (71.438 mm) shaft with a keyway, is sealed with a replaceable lip-type seal. Speed of this shaft is determined by gear ratio combination (installed at factory). Standard rates will produce 1800 rpm. Other ratios are also available.

Shaft rotation is counterclockwise (CCW), facing the output shaft of the gearbox.

The gearbox and turbine power section are joined with studs and nuts. Transfer of power from power section to gearbox is made by a torsional quill shaft connecting the compressor end of the rotating group with the input side of the gearbox and accessory drive section.

The quill shaft is a torque limiting device and functions as a shear point in the event of sudden stoppage of either gearbox or its load or the seizure of the turbine group. Protection is thereby provided to the non-failing component by shearing of the quill shaft. This will only occur when failure and subsequent stoppage is so rapid that the normal operation of the control system cannot react to the failure (i.e., out of phase paralleling).

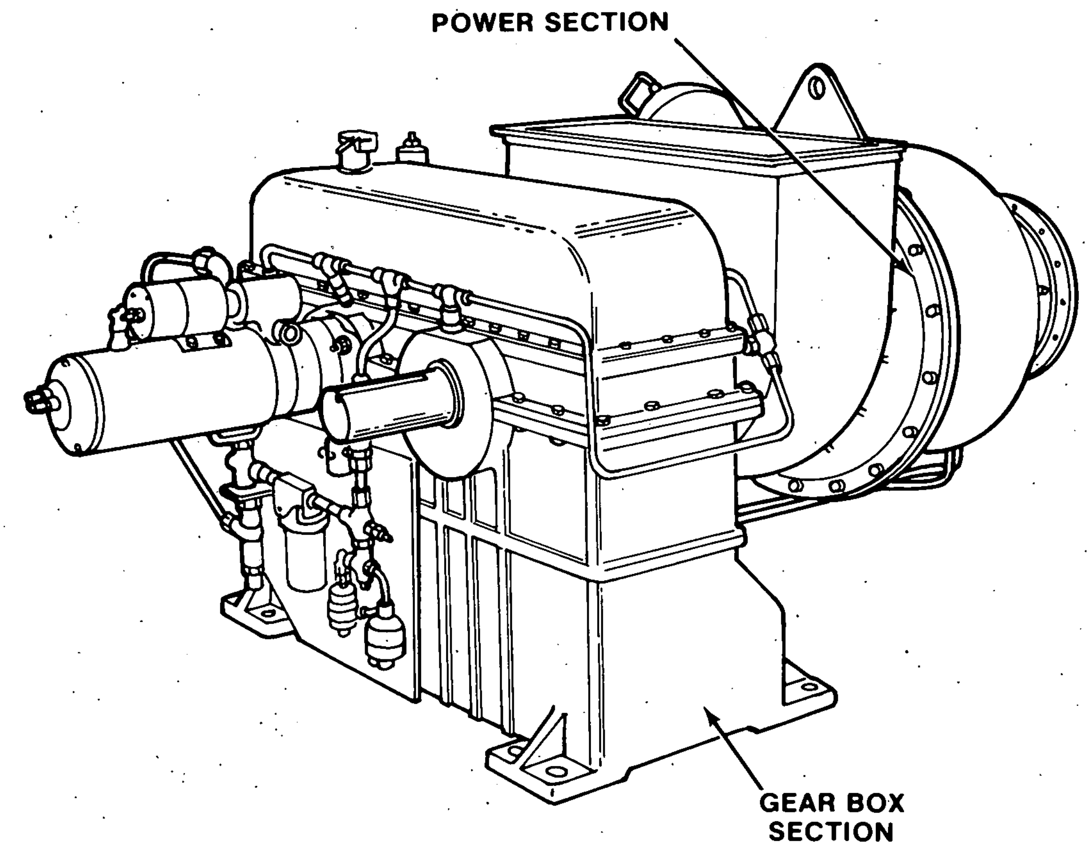


FIGURE 6-1. GEARBOX

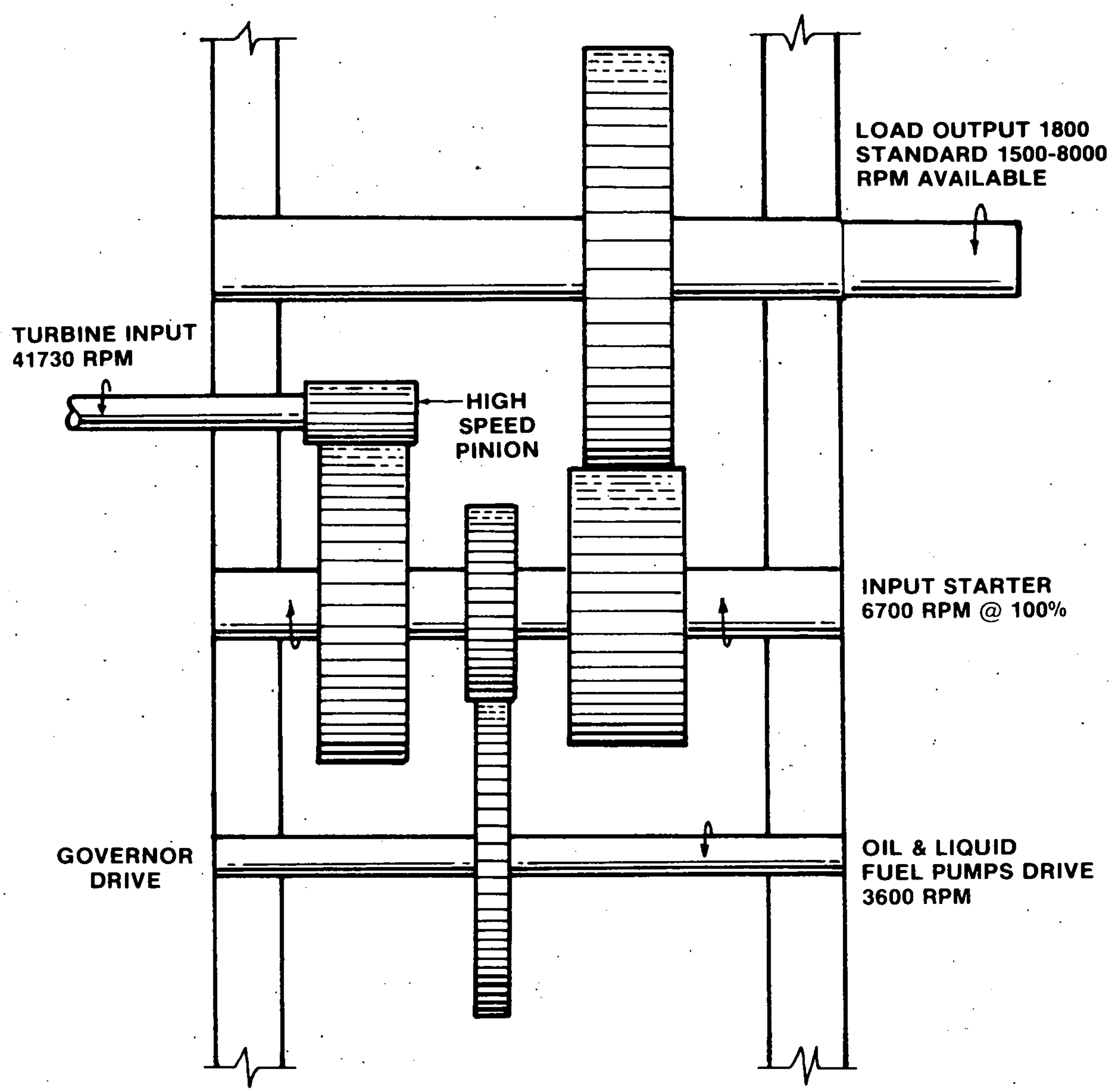


FIGURE 6-2. GEARBOX SCHEMATIC

FLEXIBLE COUPLING

The flexible coupling (Figure 6-3) interfaces the gearbox output shaft with the generator input shaft.

The coupling consists of the following items: keyed metal housing, consisting of a highly flexible vulcanized rubber and fiber inner element (generator side), a metal shaft containing a flange at either end, and a keyed metal hub (gearbox side). See Figure 6-3.

The coupling is designed to operate at -22° F to +176° F (-30° C to +80° C) ambient temperature with a maximum continuous torque of 27,000 in lbs. (305 N•m) at 1800 rpm. It also has the capability of retaining its integrity during intermittent short circuits.

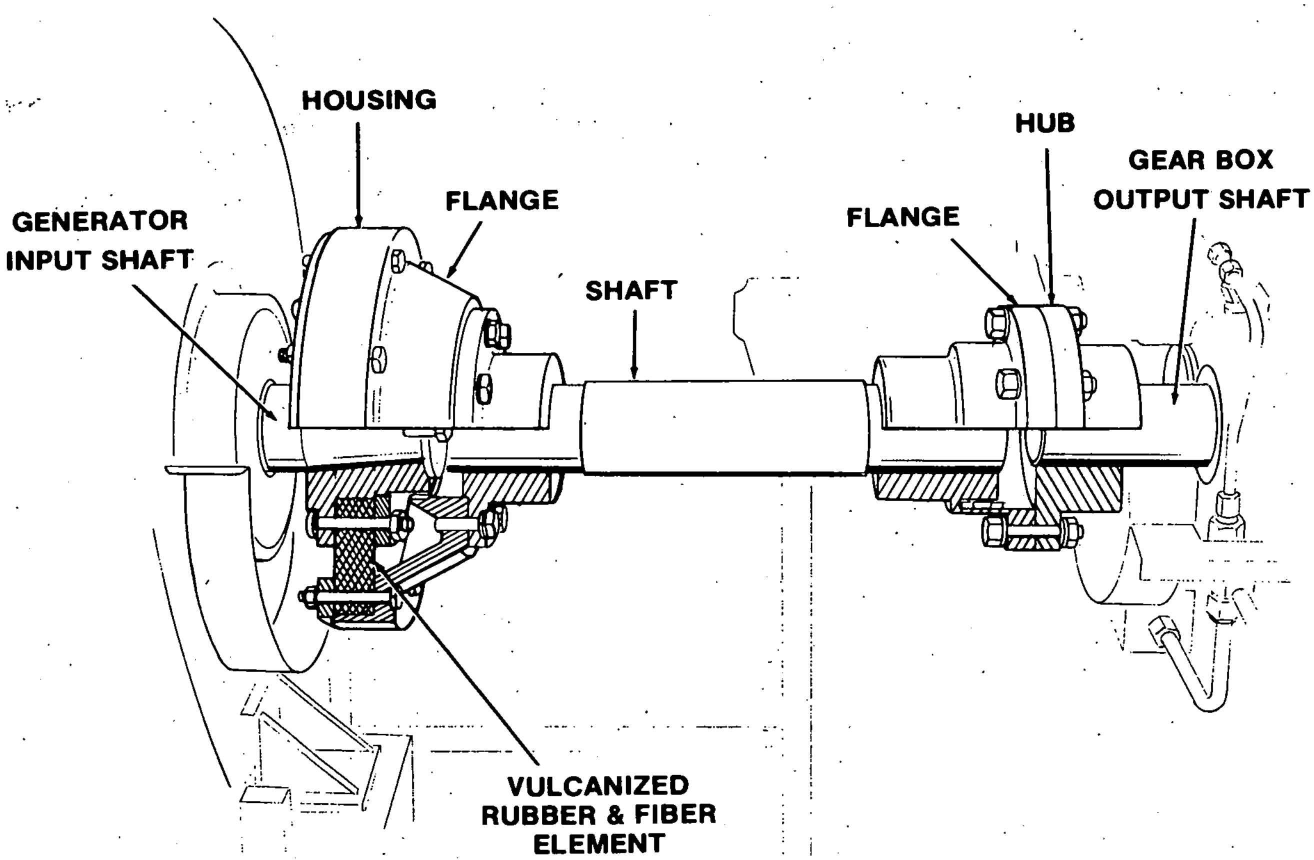


FIGURE 6-3. FLEXIBLE COUPLING

ADJUSTMENTS

The following text describes the coupling alignment procedure.

CAUTION ***Coupling alignment should only be done by qualified service personnel. Damage to machinery may otherwise result.***

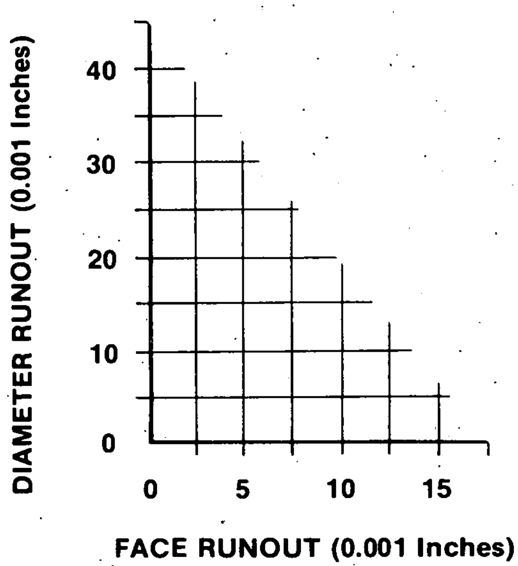
The intersection of the face runout and the diameter runout must fall inside the grid area on the graph. See Table 6-1.

The diameter runout must be measured from the generator shaft to the outer diameter of the output shaft hub (Figure 6-4).

The face runout must be measured from the generator shaft to the maximum diameter of the output shaft hub face (Figure 6-4).

The coupling is designed for 20 +5/32 inch shaft separation.

TABLE 6-1. RUNOUT GRAPH



Example: Face runout = 0.010 inch, diameter runout must not exceed 0.020 inch.

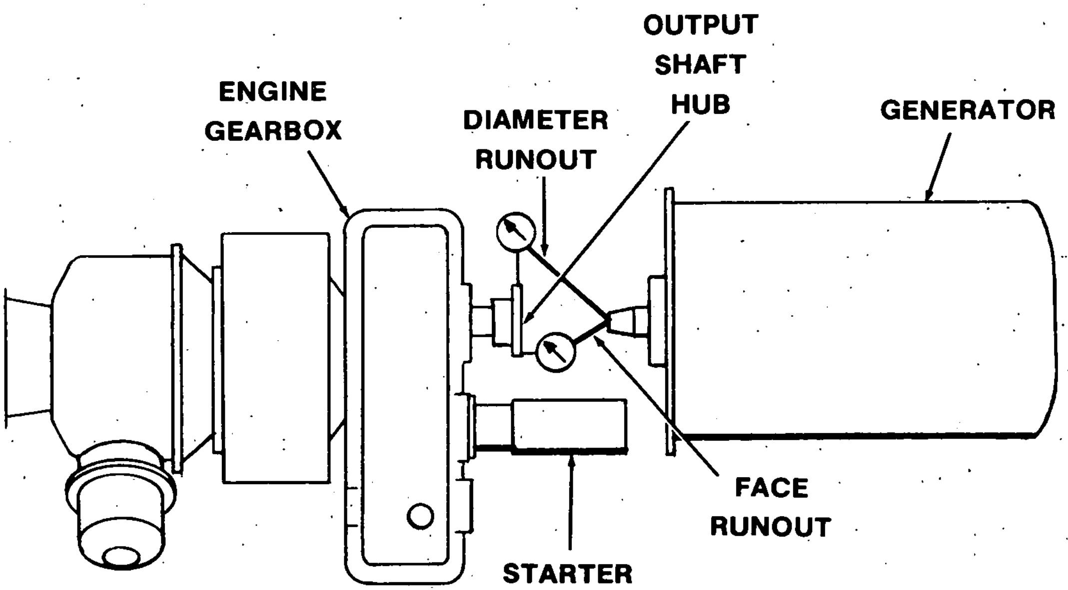


FIGURE 6-4. RUNOUT CHECK

MAINTENANCE

Maintenance should be performed on a yearly basis unless there is an excessive accumulation of lubricant on coupling guard, in which case the coupling should be removed and checked.

The yearly maintenance consists of removing the grease plug and visually checking for the presence of lubricant.

The coupling holds 5 to 6 ounces of lubricant. The recommended lubricants are listed in Table 6-2.

TABLE 6-2. RECOMMENDED LUBRICANTS

Amoco	Coupling Grease
Brooks	Kling Fast #370
Exxon	Ten-O-Led EP
Gulf	Gulfmill EP-S
Mobil	Mobilux EP-1
Shell	Alvania EP-1
Texaco	Marfak-1

GENERATOR

GENERAL

The generator is an Onan type "UV," 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 shaft through a flexible coupling. Turbine gearbox speed determines generator output frequency.

Exciter rotor and main rotor assemblies are mounted on a common shaft (Figure 7-2). The exciter rotor end of the shaft is a full-wave, six diode rotating rectifier assembly. At the other side of the rotor are two mounting plates, each having an iron-selenium, 11 plate 600 volt suppression rectifier.

The rotor shaft assembly is supported at each end by a heavy duty bearing. The generator stator contains six windings on four poles. Leads from the windings are brought out to a bus-bar connector system. These leads are factory connected in either series or parallel wye configuration to produce customer requested voltage and current.

The load is connected to the bus bars through a circuit breaker and appropriate switch gear.

Excitation is achieved as follows: residual voltage 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 (Figure 7-1). 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.

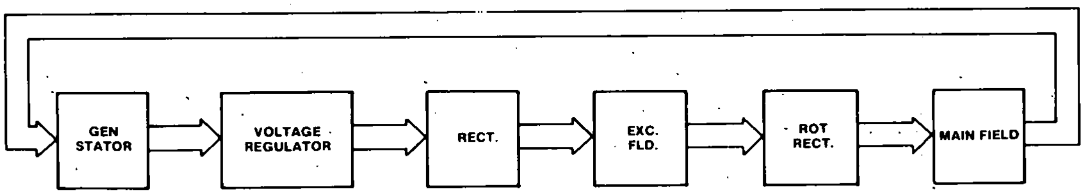


FIGURE 7-1. EXCITER BLOCK DIAGRAM

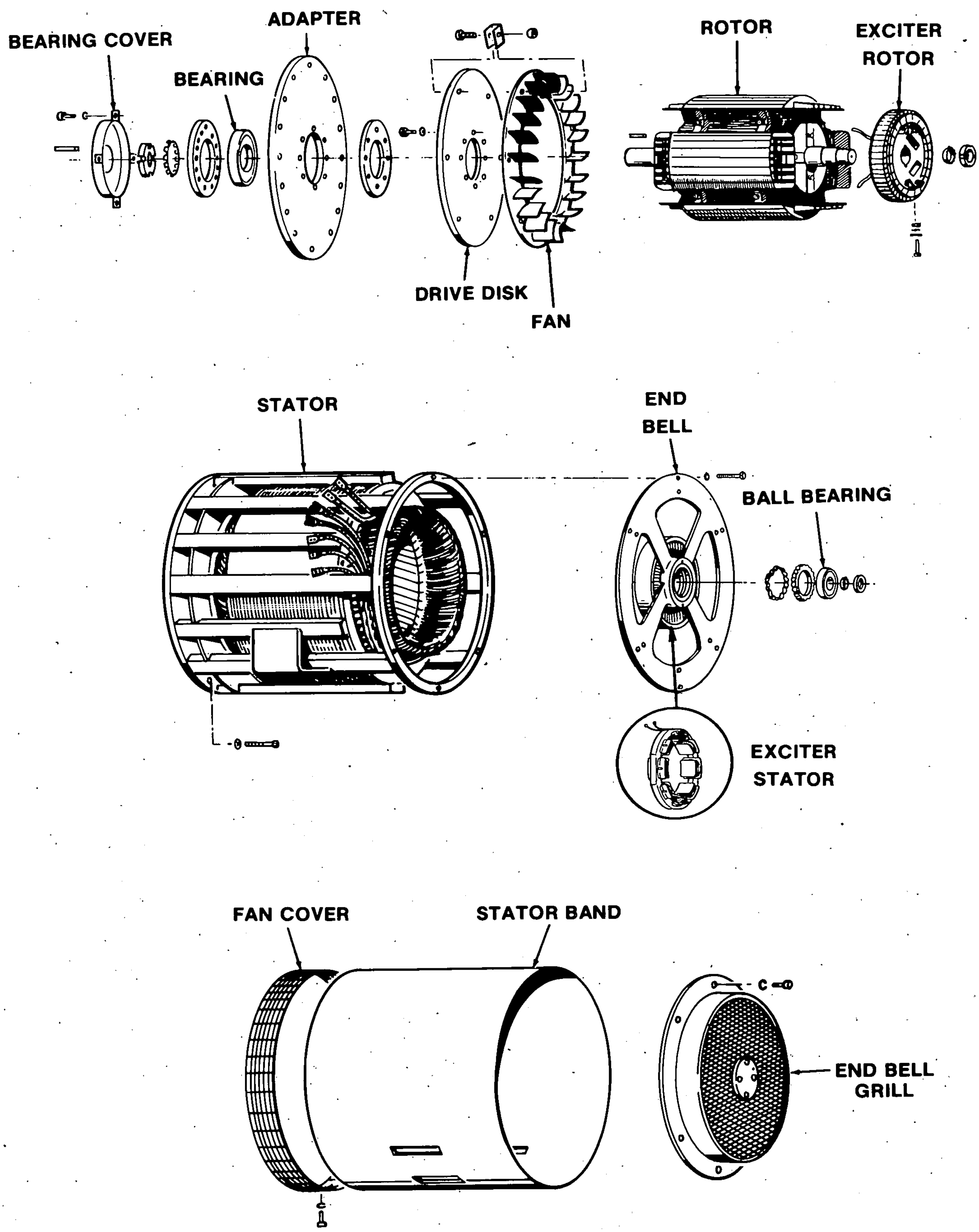


FIGURE 7-2. GENERATOR ASSEMBLIES

SIMPLIFIED OPERATION

At initial generator rotation, residual voltage induced into the main field (stator) windings, usually in the magnitude of 5 to 10 VAC is applied to the voltage regulator where it is rectified to 5 to 10 VDC and supplied to the exciter field (stator). The resultant AC voltage produced in the exciter rotor is rectified (via the rotating rectifier assembly) and supplied as DC to the main generator rotor. The high flux thus produced will cause an increase in voltage induced into the main field windings which in turn will make the voltage regulator clamp the current flow to the exciter at a predetermined amount and maintain a constant level of output for load application.

GENERATOR SPECIFICATIONS

Manufacturer	Onan
Series	UV (2 Bearing)
Type	Single-voltage, brushless, revolving field
kW	533
kVA	666
Power Factor	0.8
Frequency	60 Hz
Phase	3
Phase Rotation	CCW (ACB)
Voltage Regulation	±2 %
Sensitivity	Voltage
Adjustments	Voltage and Damping
Voltage Adjust Rheostat	±5 % of Rated Voltage regardless of load
Voltage	277/480 (Series Wye)
Amperes	801

GENERATOR TROUBLESHOOTING

MALFUNCTION	PROBABLE CAUSE	REMEDY
No voltage build-up	Loose or broken lead wires between voltage regulator and field exciter unit.	Contact service representative.
	Loose or broken lead wires between rotating rectifiers and generator field or exciter armature.	Contact service representative.
	One or more defective diodes in rotating rectifier.	Contact service representative.
	Generator or exciter unit windings open or shorted.	Contact service representative.
Generator output voltage too low.	Voltage adjusting rheostat improperly adjusted.	Adjust
	Generator overloaded or load unbalanced.	Reduce or balance load as necessary.
	Open diode in rotating rectifier.	Contact service representative.
Generator output voltage too high	Voltage adjusting rheostat improperly adjusted.	Adjust.
	Voltage regulator not operating properly.	Contact service representative.

PRE-START SERVICING

Prior to initial start and any time set is restarted after fuel and lubrication (oil) systems have been drained, a complete system priming and purging must be made prior to starting. Proceed as follows:

CAUTION ***Do not allow rotation of fuel pump without the presence of fuel in the pump. Pump bushings and shaft are both cooled and lubricated by fuel flow.***

TURBINE GEARBOX

Fill gearbox through top oil filler. Oil capacity is 11 U.S. gallons (41.64 liters).

PRIMING OIL FILTER AND OIL COOLER

Disconnect output pressure line from top of oil pump as shown by arrow in Figure 8-1. Also disconnect oil cooler return line at oil pressure regulator valve and output side of oil filter. Open oil cooler plug. Pump oil under pressure (20-50 psi [138-345 kPa]) to line previously disconnected at top of oil pump (see illustration). Pump oil through system until oil runs out of oil cooler plug. Close oil cooler plug. Continue priming until oil flows out of line disconnected at pressure regulator valve on gearbox. Reconnect pressure regulator line. Continue priming until oil flows out of oil filter. Reconnect oil filter line and line on top of oil pump.

PRIMING TURBINE ENGINE

Remove plug at oil pressure sequencing switch on gearbox near oil filter as shown in Figure 8-2. Disconnect oil return line at rear bearing below exhaust plenum. Pump oil under pressure (20-50 psi [138-345 kPa]) to line previously disconnected at rear bearing below exhaust plenum. Reconnect oil return line at turbine rear bearing. This ensures that oil is present in the power section bearings and that the pressure pumps will be able to pressurize the system within 10 seconds after rotation begins. Depress "Crank" switch and crank engine 30 seconds with fuel and ignition turned off (Operation Selection Switch in "STOP" position).

PRIMING LIQUID FUEL SYSTEM

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

Prior to initiation of priming, ensure that fuel tank is filled with approved liquid.

Disconnect fuel line at atomizer (fuel nozzle) on top of combustor can. Disconnect 24 volt input plug at igniter box, Figure 8-3. Place Operation Selector Switch in "Stop" position.

Run engine on starter (depress "Crank" switch) until fuel flows from line previously disconnected at atomizer (fuel nozzle) on top of combustor can. Immediately release crank switch. Reconnect atomizer fuel line and 24 volt plug on ignitor box. Check fuel system for leaks.

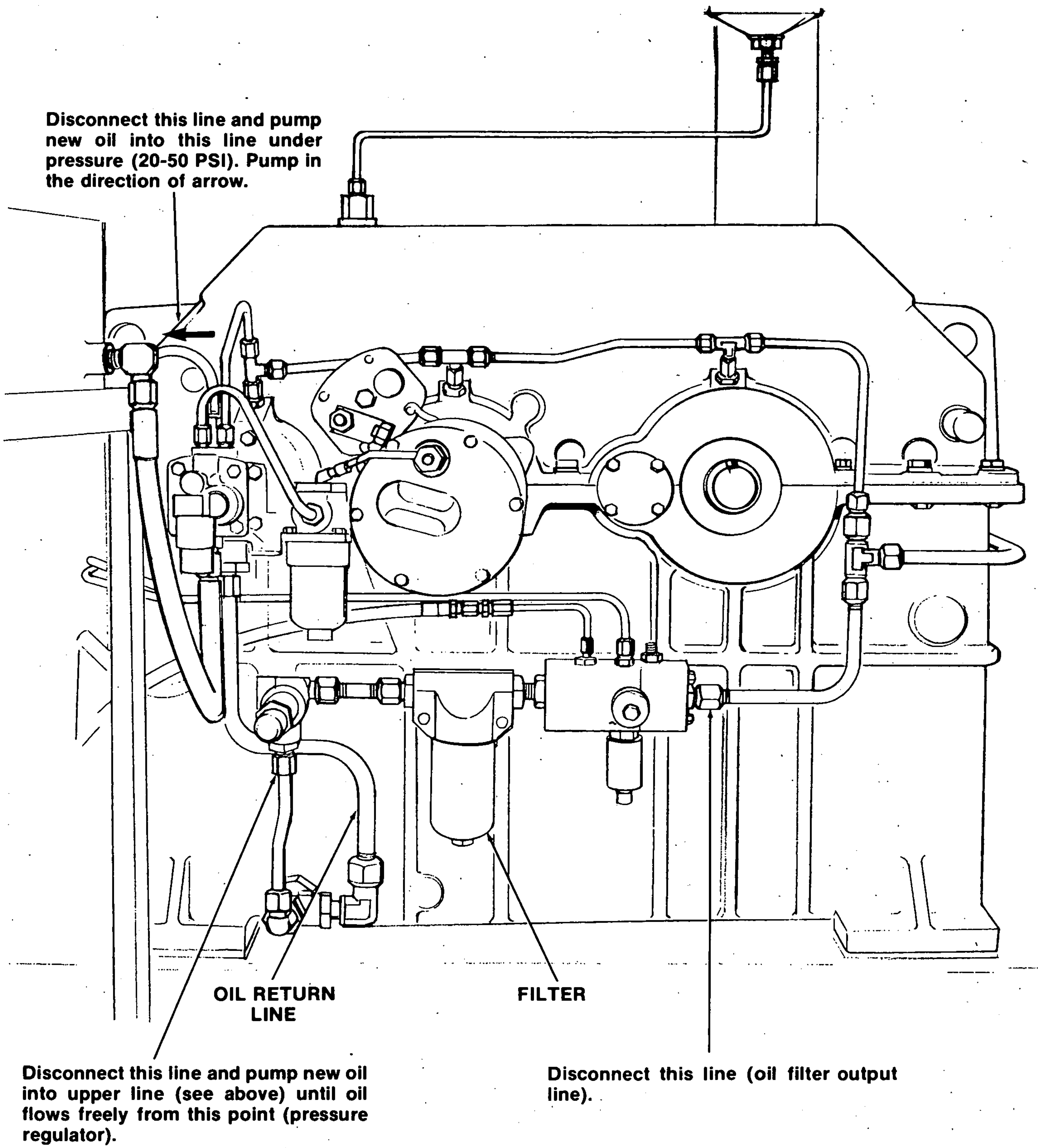


FIGURE 8-1. OIL COOLER AND FILTER PRIMING

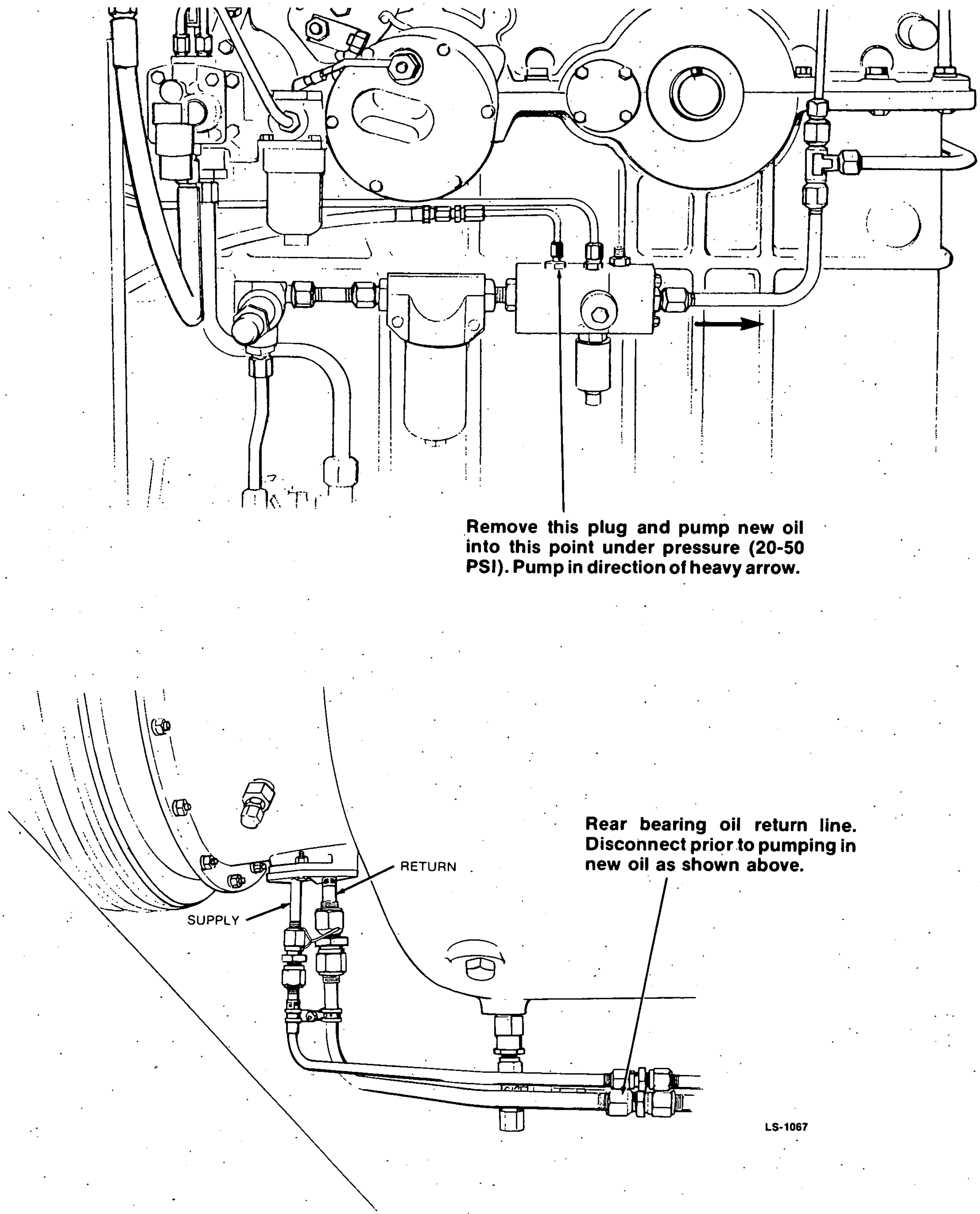


FIGURE 8-2. TURBINE ENGINE OIL PRIMING

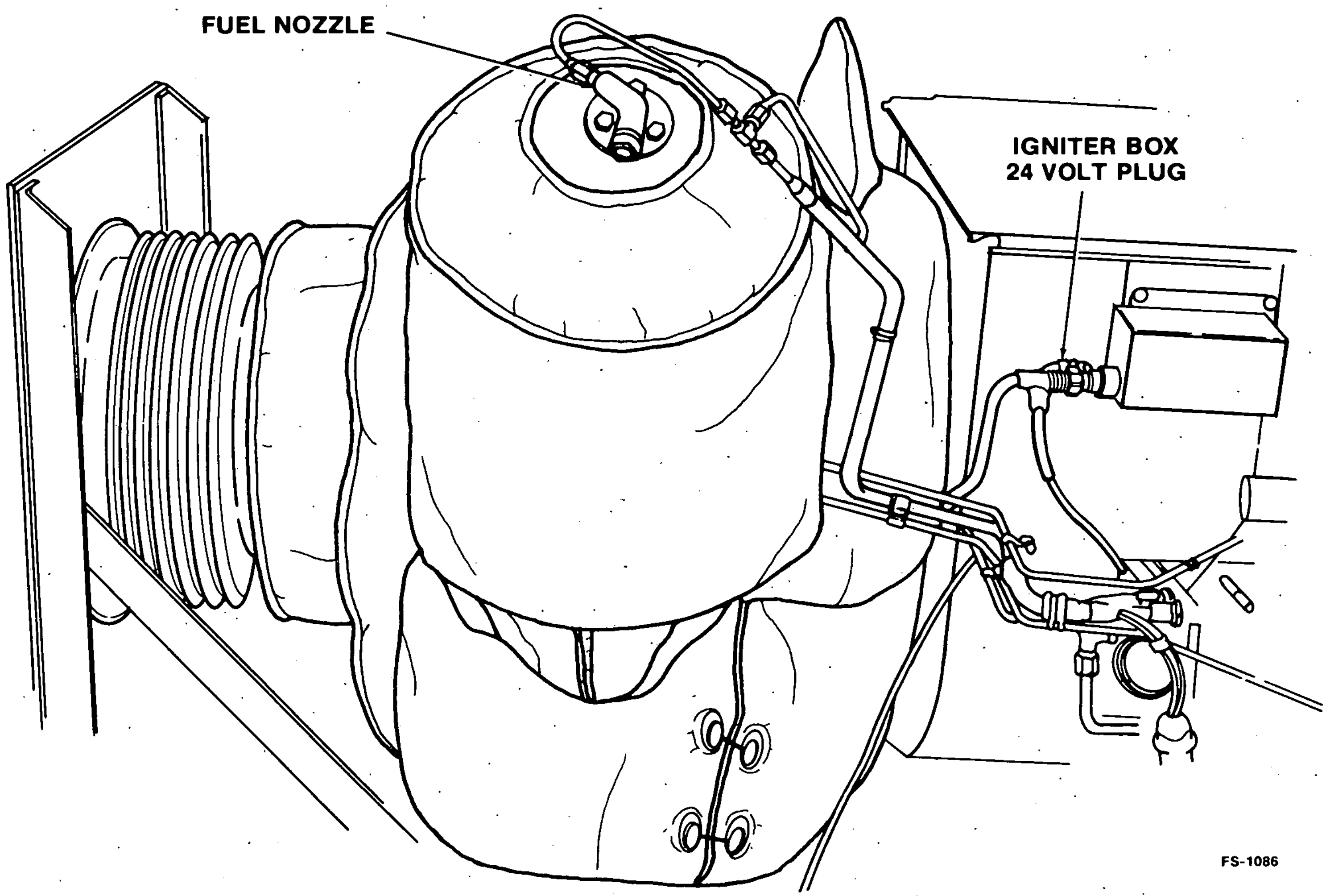


FIGURE 8-3. LIQUID FUEL SYSTEM PURGING

STARTING PROCEDURES

After all prestart servicing has been completed (as listed in prestart procedures) and all alarm systems have been tested, perform initial start-up and adjustments before operating the power system.

An Onan authorized representative must be present at initial start-up to validate warranty.

Perform initial start-up in the following sequence:

1. Connect a phase rotation meter or three phase motor to the generators output leads at the transfer switch.
2. Move the following switches to "OFF" on the operator control panel:
   a. Operator selector switch
   b. Volt/Amp meter selector switch
   c. Main D.C. Control Breaker (CB1)
   d. Generator Field Breaker (CB2)
3. Connect 24 VDC control batteries (+ lead) to terminal board #6 terminal #1 and (- lead) to ground stud, below TB 20 as indicated on the wiring schematic.
4. Place main D.C. control (CB1) and generator field circuit (CB2) breakers "ON". Turn the operation selector switch to "RUN". The fuel heater lamp will light. Start-up will be delayed for 0-60 seconds depending on setting of adjustable time delay. If ambient temperature is 70° F (21° C) or greater start-up will be immediate.
5. As soon as unit starts, check oil and fuel pressure, and check for any leaks.
6. Allow the unit to run for a minimum of 1 hour, note operating temperature and general operation.
7. Check phase rotation of generator by observing the phase rotation meter or three phase motor. Ensure that phase rotation is the same as the incoming service.
8. If phase rotation is the same as the incoming service, note and record, then proceed to step 16. If phase rotation is not the same as the incoming service proceed to step 9.
9. Stop the unit by placing operation selector switch in "STOP". Allow unit to coast down to a complete stop.
10. Move D.C. control (CB1) and field circuit breakers (CB2) to "OFF". Disconnect the control batteries.
11. Reverse generator output leads L1 and L2 at the transfer switch.
12. Remove the phase rotation meter or three phase motor from the transfer switch.
13. Reconnect control batteries.
14. Place D.C. control (CB1) and field circuit (CB2) breakers "ON".
15. Place operation selector switch to "RUN". The unit will start and run.
16. Observe frequency on frequency meter. It should read 60 hertz. If not, adjust control clockwise to increase frequency or counterclockwise to decrease frequency.
17. Check generator voltage/amperage by turning the volt/ampere meter switch to the different positions. If voltage is not at the desired level (480V), turn the voltage adjust control clockwise to increase voltage and counterclockwise to decrease voltage.
18. To stop unit place operation selector switch to "STOP".
19. Place operation selector switch in "REMOTE". Power system is now ready for operation.

ENGINE TROUBLESHOOTING

MALFUNCTION	PROBABLE CAUSE	REMEDY
Turbine lights off, but will not accelerate to rated speed.	Fuel drain blocked.	Unblock fuel drain port on rear of unit.
	Fuel system malfunction.	See cause and remedy under fuel system.
	Restricted engine air inlet or exhaust.	Inspect engine inlet duct and filter. Clean or correct as necessary.
	Insufficient compressor discharge air to fuel control assembly.	Remove line and inspect for kinks or blockage. Check for leaks using soap solution.
	Starting batteries not delivering sufficient power (High EGT usually present).	Recharge or replace batteries.
	Starter defective (High EGT usually present).	Check starter motor.
	Governor actuator oil supply restricted.	Check governor actuator for restrictions. Check oil supply. Remove actuator as necessary.
	Low Governor speed setting.	Increase speed setting gradually until rated speed is reached.
	Compressor discharge pressure not present at fuel control valve.	Check compressor air line for leaks.
	Fuel control valve not moving off minimum fuel stop as engine accelerates.	Inspect fuel valve for binding.
Turbine Lights Off, but goes into surge*.	See caution.	
Low-speed surge.	Acceleration control malfunctioning.	Replace Fuel Control Valve.
High-speed surge during acceleration.	Inlet air restricted.	Check inlet air route; clear or repair as required.
	Fuel delivery excessive.	Contact service representative. (Adjust fuel control valve).

* **CAUTION** ***A surge condition is indicated by a rapid increase in exhaust temperature with no corresponding increase in speed. It is usually accompanied by loud, rapid, popping sounds. IMMEDIATELY SHUT DOWN ENGINE USING EMERGENCY STOP pushbutton. DO NOT WAIT FOR AUTOMATIC SHUTDOWN TO OCCUR. Allow turbine to coast to a stop. After approximately 5 minutes, attempt a restart. If surge occurs a second time, proceed with care and remedy above.***

ENGINE TROUBLESHOOTING (Cont.)

MALFUNCTION	PROBABLE CAUSE	REMEDY
Turbine accelerates to 95 percent rated speed, then shuts down.	Lube oil supply low.	Replenish oil supply.
	Lube oil pressure switch malfunctioning.	Check that switch closes above 55 psi. Adjust or replace as necessary.
	Oil temperature switch malfunctioning.	Replace switch if oil temperature is below 160° F, yet engine lube oil alarm is present.
Turbine accelerates to rated speed, then flames out.	Fuel control valve out of adjustment.	Contact service representative.
Turbine accelerates to rated speed, but does not sustain full rated load.	High-or-low pressure fuel filter clogged.	Clean or replace as necessary.
	Restriction in customer. fuel components.	Clean or remedy as required.
	Overloaded circuits.	Maintain loads within altitude, temperature, and installation limit.
	Compressor discharge pressure to fuel control valve is inadequate.	Check compressor discharge lines for kinks, leaks, or blockage.
	Restricted turbine air supply.	Inspect air inlet duct and filter. Clean or repair as necessary.
	Governor actuator oil supply inadequate.	Inspect actuator oil lines for blockages and kinks.
	Fuel control valve linkage stuck.	Adjust or replace linkage as necessary.
High exhaust temperature indication during starting	Battery charge low.	Check charge: recharge or replace batteries.
	Starter motor defective.	Check starter motor.
	Acceleration control malfunctioning.	Contact service representative (replace control).
	Late light off.	Contact service representative (check ignition and fuel systems).
	Restriction of air inlet or exhaust.	Check for, and eliminate, any blockage.

ENGINE TROUBLESHOOTING (Cont.)

MALFUNCTION	PROBABLE CAUSE	REMEDY
	Start attempted with initial combustor temperature too high.	Attempt a second start after exhaust gas temperature falls below 300° F (149° C).
	Mechanical failure in turbine or generator.	Contact service representative.
No exhaust gas temperature indication during start with ignition.	Defective exhaust gas temperature indicator.	Replace indicator.
	Malfunction in exhaust gas temperature circuit.	Contact service representative. (Replace or repair defective circuit).
High exhaust temperature during operation (No shutdown).	Restriction of air inlet or Exhaust.	Check for and eliminate, any blockage.
	Malfunction in exhaust gas temperature circuit.	Contact service representative (Replace or repair defective circuit).
	Generator overloaded.	Check generator load.
	Mechanical failure in turbine or generator.	Contact service representative.
Turbine shuts down during operation. Low oil pressure indication.	Low Oil Pressure.	Contact service representative.
	Damaged or leaking oil line.	Inspect lube oil plumbing, and tighten or replace lines as necessary.
	Oil pump failure.	Contact service representative (Replace oil pump).
	False indication due to faulty indicator or circuit.	Check circuit and components Repair or replace as necessary.
Turbine shuts down during operation. High exhaust temperature indication.	Turbine overloaded.	Check for proper load. Restart turbine and load in small increments.
	Restriction of air inlet or exhaust.	Check for, and eliminate, any blockage.
	Exhaust gas temperature circuit malfunctioning.	Contact service representative (Replace or repair defective circuit).
Turbine shuts down during operation. High oil temperature indication.	Low Oil Supply.	Check gearbox sight gauge and replenish oil supply if necessary.

ENGINE TROUBLESHOOTING (Cont.)

MALFUNCTION	PROBABLE CAUSE	REMEDY
	Oil cooler ineffective.	Check cooler for obstructions in air passages. Remove or repair as necessary. Check for proper circulation of oil through cooler. Repair or replace as necessary. Check fan motor for proper operation. Repair or replace as necessary.
	Oil temperature switch or circuit malfunctioning.	
Turbine shuts down during operation. Overspeed indication.	Governor malfunctioning.	Contact service representative.
	Engine speed monitoring unit malfunctioning.	Contact service representative.

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