VOGTLE

Transamerica Delaval

Instruction Manual

Model DSRV-16-4 Diesel Engine/Generator
Serial Nos. 76021-2871
76022-2872
76023-2873
76024-2874

Georgia Power Company
Alvin W. Vogtle Nuclear Plant

Transamerica Delaval Inc.
Engine and Compressor Division

Instruction Manual

For

Model DSRV-16-4
Diesel Engine/Generator

Serial Numbers

76021-2871
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76023-2873
76024-2874

Manufactured For:

Georgia Power Company
Alvin W. Vogtle Nuclear Plant

P.O. No. PAV 481 & 6-20

Date Of Issue

Manufactured By

Transamerica Delaval Inc.
Engine and Compressor Division
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AX4AK01-509-1

Engine Data

Model: DSRV-16-4	[x] Stationary [ ] Marine [x] Nuclear Standby [x] Diesel [ ] Dual Fuel [ ] Heavy Fuel [x] V-type [ ] Inline				
Serial No(s): 76021-2871, 76022-2872, 76023-2873, 76024-2874					
No. Cylinders: 16	Bore: 17 IN.	Stroke: 21 IN.	Cycles: 4	Displacement/Cylinder: 4766.6 CU-IN.	Total Displacement: 76266 CU-IN.
bmep: 223.7 PSI	bhp: 9694	rpm: 450	Crankshaft Rotation: CLOCKWISE, WHEN VIEWED FROM FLYWHEEL END		
Controls: RIGHT HAND			Starting System: PILOT AIR, GEAR DRIVEN DISTRIBUTOR		
Firing Order: 1L-8R-4L-5R-7L-2R-3L-6R-8L-1R-5L-4R-2L-7R-6L-3R					
Fuel Injection Timing: RIGHT BANK 22° (13.05 IN.), LEFT BANK 21° (12.46 IN.) BEFORE TOP DEAD CENTER ON A 68 IN. DIAMETER FLYWHEEL					
Fuel Injection Pump Rack at Full Load: 76021: 38 MM, 76022: 37 MM, 76023: 37 MM, 76024: 37.5 MM (REFER TO ENGINE NAMEPLATE)					
Valve Clearance – Cold Engine: INTAKE: 0.040 IN. EXHAUST: 0.040 IN.					
Remarks:					

Always include serial numbers when communicating with Transamerica Delaval Inc., Engine and Compressor Division concerning engine performance, or when ordering spare or replacement parts. Refer to Appendix IX for copies of the Factory Test Logs, and a summary of factory test results.

Power Engines

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VO A3JK 4000 L O Pump

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Transamerica Delaval

Transamerica Delaval Inc.
Engine and Compressor Division
550 85th Avenue
P.O. Box 2161
Oakland, California 94621

GUARANTEE

Unless otherwise specifically stated, all machinery and equipment purchased hereunder is subject to the following warranty: Transamerica Delaval Inc., Engine and Compressor Division (hereinafter called Company) warrants that machinery and equipment manufactured by Company and furnished and delivered to the Purchaser hereunder shall be of the kind and quality described in the Company's specifications, and no other warranty or guaranty except of title is made or shall be implied. If any part of said machinery and equipment thus manufactured by the Company fails because of defective workmanship or material within one year from the date of starting the engine after delivery, but not exceeding fifteen months from the date of shipment, the Company will, provided such machinery and equipment has been used for the purpose and in the manner intended and the Company's examination shall disclose to its satisfaction that such parts are defective, replace such defective parts free of charge, f.o.b. cars at its warehouse in Oakland, California, but the Company will not be liable for repairs or alterations unless the same are made with its written consent or approval. The Company will not be liable for damages or delays caused by such defective material or workmanship, and it is agreed that the Company's liability under all guaranties or warranties, either express or implied, is expressly limited to the replacing of parts failing through defective workmanship or material within the times and in the manner aforesaid. Parts claimed to be defective are to be returned to the Company at its option, transportation prepaid. The Company makes no guaranties or warranties whatsoever in respect to products other than that manufactured by the Company as they are sold under the regular warranties of the respective manufacturers, copies of which will be furnished if requested. All warranties and guaranties as to efficiency and capacity are based upon shop tests when operating under specified conditions, but do not apply to any condition varying from the foregoing. The liability of the Company (except as to title) arising out of the supplying of said machinery or equipment or its use, whether on warranties or otherwise, shall not in any case exceed the cost of correcting defects in the machinery or equipment as herein provided, and upon the expiration of said warranty, as herein provided, all such liability shall terminate.

PRODUCT IMPROVEMENTS

The Company reserves the right, where possible, to include changes in design or material which are improvements. Also reserved is the right to furnish equipment of design modifications best suited to a particular installation, location, or operating condition, as long as such modification exceeds Purchaser's design specifications. The Company cannot be responsible for including improvements made after start of production on Purchaser's equipment.

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Changes

Change Number	Date of Change	Affected Manuals			Purpose of Change
		Inst.	Parts	Assoc. Pubs	

Comments:

Section 1
Introduction

SECTION 1

INTRODUCTION

PURPOSE.

The purpose of this Instruction Manual is to assist the owner and operating personnel in the operation, maintenance, adjustment, overhaul and repair of the equipment described on the data sheet in the front of the manual. The instructions given herein cover generally the operation and maintenance of this equipment. Should any questions arise which are not answered specifically by these instructions, they should be referred to Customer Service Department, Transamerica Delaval Inc., Engine and Compressor Division for further detailed information and technical assistance. The name Transamerica Delaval, as used in this manual, shall be taken to mean the Engine and Compressor Division unless another Transamerica Delaval division is specifically named.

SCOPE OF MANUAL.

This manual cannot possibly cover every situation connected with the operation, adjustment, inspection, test, overhaul and maintenance of the equipment furnished. Every effort is made to prepare the text of the manual so that engineering and design data is transformed to the most easily understood wording. Transamerica Delaval, in furnishing this equipment, must presume that the operating and maintenance personnel assigned thereto have sufficient technical knowledge to apply sound safety and operational practices which may not be otherwise covered herein. In applications where Transamerica Delaval equipment is to be integrated with a process or other machinery, these instructions should be thoroughly reviewed to determine the proper integration of the equipment into the overall plant operational procedures.

RELATED MANUALS.

In addition to this *Instruction Manual*, a *Parts Manual* and an *Associated Publications Manual* are normally provided. The contents of these manuals is as follows.

a. The *Parts Manual* contains engine specifications, assembly parts lists and assembly drawings. Instructions are provided to assist in the ordering of spare and replacement parts. The assembly drawings are intended to assist in the identification of parts, however, it is recommended that the part numbers appearing on these drawings not be used when ordering parts. Rather, use the part numbers shown on the appropriate group parts list.

b. The *Associated Publications Manual* is a compilation of manufacturer's bulletins, forms, instructions, drawings, etc., which are applicable to components and equipment which is furnished with the engine, but not manufactured by the Engine and Compressor Division. The contents are indexed, both alphabetically by manufacturer's name, and numerically by Transamerica Delaval part number. Complete instructions for using the manual are contained in the manual.

CUSTOMER ASSISTANCE.

Transamerica Delaval maintains a staff of factory trained customer service personnel who are available at nominal rates to assist or advise in the installation, overhaul or repair of Enterprise machinery. It is recommended that one of these customer service representatives be requested when extensive repairs are being made on the equipment. If assistance is required, write or wire the Engine and Compressor Division, Customer Service Department, furnishing complete information, including all serial numbers.

NOTES, CAUTIONS AND WARNINGS.

Notes, cautions and warnings, as used in this manual are intended to convey the following meanings.

a. NOTES — operating procedures, conditions, etc., which it is essential to emphasize or highlight because of their importance to the proper operation of the machinery.

b. CAUTIONS — Operating procedures, practices, etc., which, if not strictly observed, could result in damage to, or destruction of equipment.

c. WARNINGS — *Operating procedures, practices, etc., which could result in injury or possible loss of life if not followed correctly.*

SAFETY PRECAUTIONS.

Although the design features of the Transamerica Delaval engine include considerations for the safe operation of the machine, all operating and maintenance personnel should be fully aware of the potential hazards that are present during the operation and maintenance of any large, medium speed, internal combustion engine. These hazards encompass many areas — rotating machinery, temperatures, pressures, handling of heavy weights, flammable liquids, slippery surfaces, and an environment of high nose levels. This Instruction Manual should not be considered all inclusive in the area of safety, but rather as but one source of information for the formulation of a comprehensive plant safety program. Specific safety precautions in the form of cautions and warnings are given throughout this manual for specific conditions and situations. In addition, general precautions are provided in Section 4 for operation of the equipment, and in the beginning of Section 6 for overhaul and repair activities. Safety programs, to be effective, must be the concern of all levels of management as well as the individual worker. Transamerica Delaval will be pleased to advise on any specific situations which are not considered to be adequately covered by these instructions.

WORKING PRINCIPLE.

Transamerica Delaval Enterprise engines operate on the four stroke cycle principle. The complete cycle for each cylinder consists of the intake, compression, power (or expansion) and exhaust strokes, and requires two complete revolutions of the crankshaft.

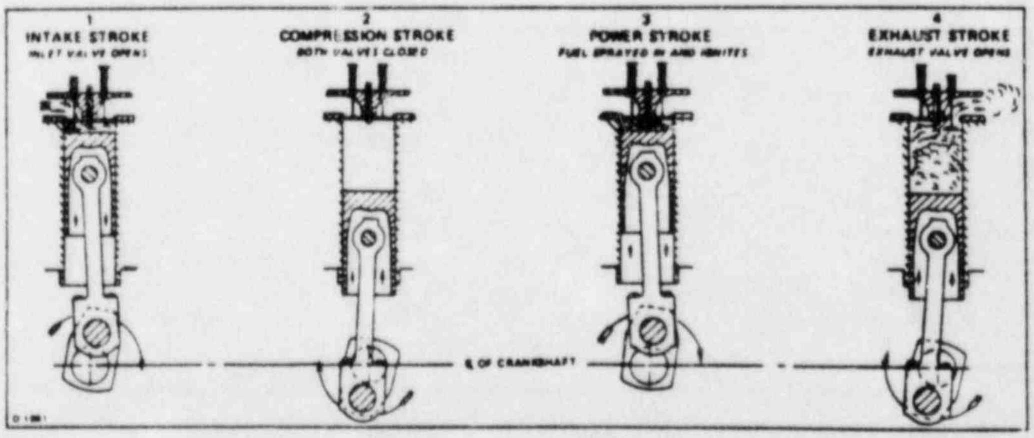


Figure 1-1. Diagram of Working Principle

a. INTAKE STROKE — During the downward movement of the piston on the intake stroke, the intake valve is open and combustion air enters the cylinder. The exhaust valve remains open during the early part of the stroke to scavenge the cylinder of any unburned gases from the previous power stroke. Combustion air enters the cylinder from the turbocharger under pressure.

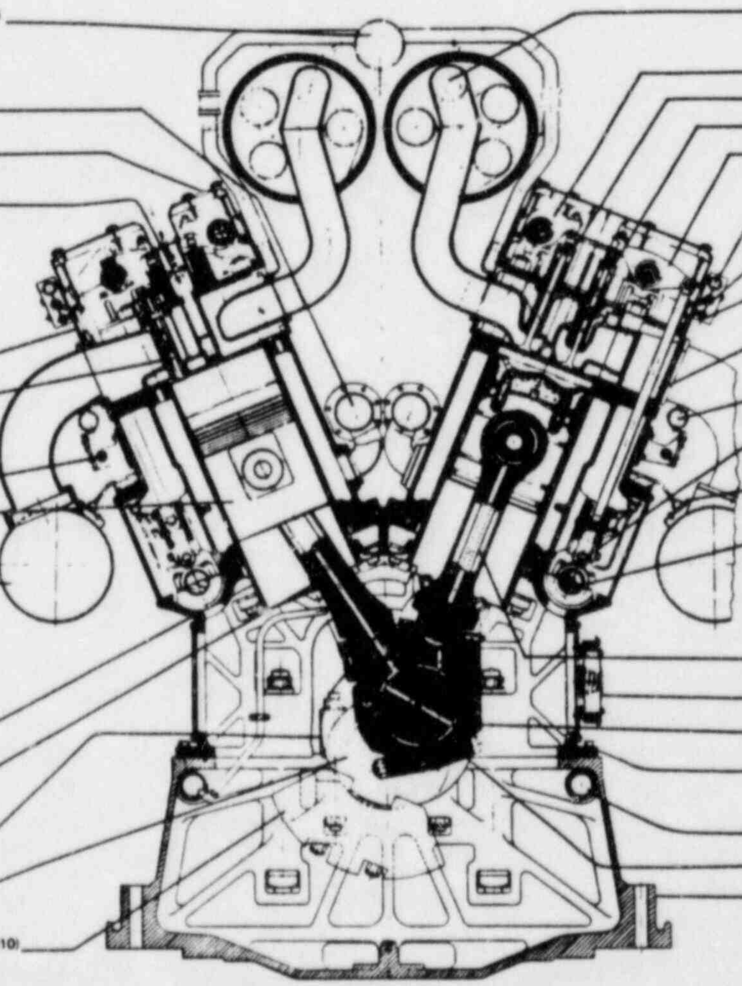
b. COMPRESSION STROKE — Shortly after the piston passes bottom center and starts upward, the intake valve closes and the air is compressed, raising the temperature of the air to well above the ignition temperature of the diesel fuel. Just before the piston reaches top center, diesel fuel is injected into the combustion chamber by a nozzle which atomizes the fuel and sprays it in a pattern that will achieve optimum combustion efficiency. The heat of compression ignites the fuel.

c. POWER STROKE — The burning fuel-air mixture expands and forces the piston downward. This downward thrust transmits power through the connecting rod to the crankshaft, causing it to rotate. Towards the end of the power stroke the exhaust valve opens and exhaust gases start to leave the cylinder.

d. EXHAUST STROKE — As the piston moves upward, past bottom center, exhaust gases are forced out of the cylinder through the open exhaust valves. During the last half of the exhaust stroke the intake valve opens to admit combustion air into the cylinder for scavenging purposes.

GENERAL ENGINE DESCRIPTION.

The Model RV diesel engine is a four-stroke-cycle, turbocharged, aftercooled, V-type engine. The angle of the Vee is 45 degrees. Trunk-type piston, removable wet-type cylinder liners, pressure lubrication and mechanical fuel injection are features of the engine. Individual fuel injection pumps are provided for each cylinder and, as they are of standard design, are interchangeable. The fuel lines are of equal length and are relatively short, reducing line surge to a minimum. Fuel pumps, nozzles and orifice size and angle are all carefully matched to the engine and the fuel to be used to give a maximum thermal efficiency. Engine rotation and cylinder bank designations are determined while facing the engine at the flywheel end. Number one cylinders are always the pair farthest from the flywheel end.



NUMBER IN PARENTHESIS INDICATES THE GROUP PARTS LIST IN WHICH THE ITEM MAY BE FOUND IN THE PARTS MANUAL

Figure 1-2. Cross Section, Typical Model RV Diesel Engine.

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Section 2
Installation

SECTION 2

INSTALLATION

GENERAL.

As the installation requirements for an engine may vary from site to site, the instructions contained in this section of the manual are representative of a typical installation and not necessarily the exact procedure for a specific site. Certified installation and foundation drawings are furnished to each customer which detail the dimensions and installation requirements for that particular unit.

FOUNDATION DRAWING.

The foundation drawing will be accurately dimensioned and must be carefully observed. Carelessness in locating foundation bolts, pipes, conduits and drains will cause difficulty during installation and alignment of the unit. It is essential that the foundation be constructed to the highest standards of accuracy.

INSTALLATION DRAWING.

The installation drawing details the measurements for machinery location, distances required for normal maintenance tasks and the overhead clearances necessary for piston removal. In addition, the drawing will indicate the location and size of connection points for pipes and the electrical requirements for alarm and control mechanisms.

SYSTEM SCHEMATIC DRAWINGS.

Electrical and flow diagrams are furnished for the various systems. Flow diagrams describe graphically the recommended system for interconnecting the various items of equipment in that particular circuit, as well as the minimum pipe sizes.

HANDLING AND SHIPMENT.

Care must be exercised to avoid damage during the handling of the engine and associated equipment during shipment and installation. The unit should be lifted only from the lift pads on the side of the engine base (where provided) as indicated on the installation drawing. When securing the engine during shipment or other movement, make sure no binding stresses are imposed on the engine base or crankshaft.

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FOUNDATION.

Make a foundation bolt template, using the certified foundation drawing to determine the location of the equipment mounting bolts. See figure 2-1 for a suggested method of building the template. Exercise care in locating bolt centers. Place and support the template from the foundation forms. Anchor securely to prevent movement of the template. Thread foundation bolt into lower nut in pipe sleeve being careful not to damage cap at bottom of nut. Insert foundation bolts and sleeves in holes provided in the template then tighten the upper nuts. Sleeves must be securely held in correct position to prevent any movement when pouring concrete. A suggested method is to use reinforcing rods welded to each sleeve or on top of each anchor plate in both rows of bolts, running the length of the engine, and adding "X" bracing between the two rows of bolts. Another suggestion is to tie the bolt assemblies to other reinforcing rods already in the foundation. *Recheck template position, alignment and elevation before pouring concrete.* It is recommended that a Transamerica Delaval Engine and Compressor Division service representative be present to check bolt layout. The foundation is to be poured monolithic and must be suitably reinforced with reinforcing steel. Let concrete set for 10 days before installing equipment, and 30 days before running equipment.

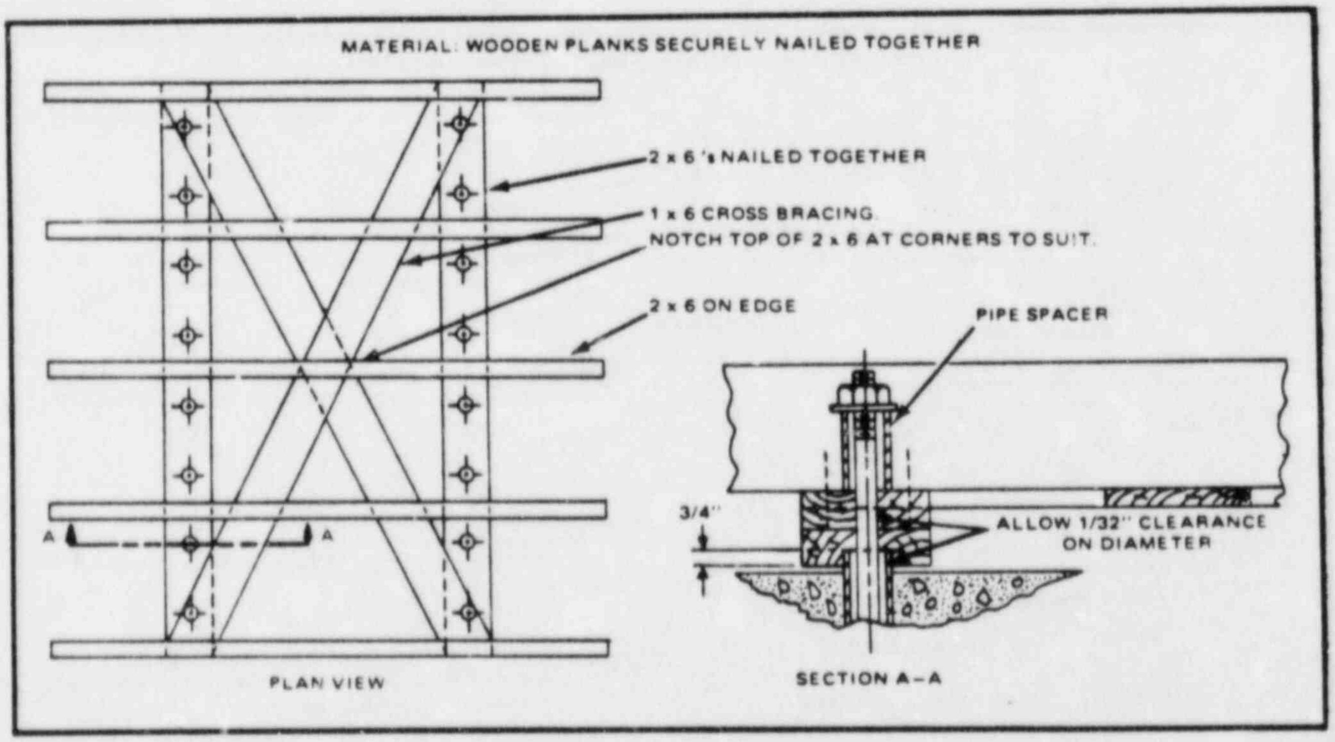

Figure 2-1. Suggested Foundation Bolt Template

FOUNDATION BOLT ASSEMBLIES.

The foundation bolts are so designed that the anchor studs can be removed from the anchors after the foundation has been poured. This permits the engine to be placed over the foundation without any interference or danger of damage to the studs. Once the engine is in place, the studs are installed and screwed into the anchor assemblies.

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PREPARATION FOR INSTALLATION.

Before landing the unit on the foundation; the surfaces of the foundation must be roughened wherever grout is to be applied. Chip and clean as necessary to remove all laitance and foreign matter so that the clean, dry, sharp aggregate required for a good bond to epoxy grout is exposed. The machined surfaces of the sole plates and chocks must be thoroughly cleaned and the leveling screws waxed to prevent their sticking to the grout. The machined bottom faces of the engine base must also be cleaned thoroughly. Remove engine foundation bolts. Place steel plates at jacking screw locations, level plates and grout in place.

PLACING ENGINE OVER FOUNDATION.

Position engine over foundation and insert four toe jacks, one at each corner of the engine, inboard of the shipping skids. If engine is rolled into position, the ends of the jacking screw shields and foundation bolt shields must be protected to avoid damaging shield ends with the rollers. Do not place jacks in the center of the engine as this could cause damage to the engine base. Insure that the combined capacity of the jacks is at least fifty percent greater than the total weight of the engine. See Installation Drawing for weights.

a. Remove shipping skids, thoroughly clean mounting rails and then lower engine to grade. Be sure the foundation bolt holes in the engine base are correctly aligned with the foundation bolt sleeves in the foundation for easy installation of the foundation bolts.

b. Clean sole plates and chocks with a degreasing type solvent. It is recommended that after the sole plates are washed, they be primed with a primer recommended by a grout manufacturer. Lubricate the threads of the jacking screws with a mixture of powdered graphite and engine lubricating oil. The lower end of the jacking screws should be coated with wax to prevent the epoxy grout material from binding to the screws.

c. Place sole plates and chocks in position under the engine as shown in the foundation drawing. Install sole plate retainers on the front and rear sole plates, making sure the sole plates are forced tightly against the shoulder at the inner edge of the engine mounting rails.

d. Lubricate lower threads of the foundation bolts with standard graphite and oil mixture, install bolts in sleeves and screw firmly into the threads at the bottom of the sleeve. Lubricate threads at the upper end of foundation bolts with oil and graphite powder then place washers and nuts on bolts.

e. Level and align the engine. Refer to Section 6, Part D of this manual for the method of taking crankshaft web deflection measurements. Record web deflection measurements on Form D-1063. Insure that all sole plate jacking screws are so adjusted as to distribute the weight evenly on all sole plates. When leveling and alignment is satisfactory, snug down the foundation bolt nuts to prevent movement of the engine during installation of the driven equipment and grouting.

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MOUNTING FLYWHEEL AND CONNECTING SHAFT.

Carefully clean and de-burr the bores and mating surfaces of the flywheel, the crankshaft flange and the connecting flange. Dirt or burrs will cause misalignment between the crankshaft and the connecting shaft.

a. Apply a thin coat of preservative to the mating surfaces of the flywheel and the flange, then mount the flywheel on the engine crankshaft flange. Make sure no dirt is allowed between the mating surfaces while the flywheel is being mounted. Install three retaining plates (see figure 2-2) and draw the flywheel up on the flange until it is seated.

b. Bring the connecting shaft into position, lubricate the mating surfaces with anti-seize lubricant, align the half-inch locating hole in the connecting shaft flange with the locating hole in the flywheel and move the connecting shaft into engagement with the flywheel. Keep dirt from entering the mating area. Use two long one or one and one-quarter inch diameter temporary bolts with washers and nuts to draw the connecting shaft to the flywheel until it is seated. Check with feeler gauges between face of connecting shaft flange and flywheel to be sure the flange is fully seated and square with the flywheel.

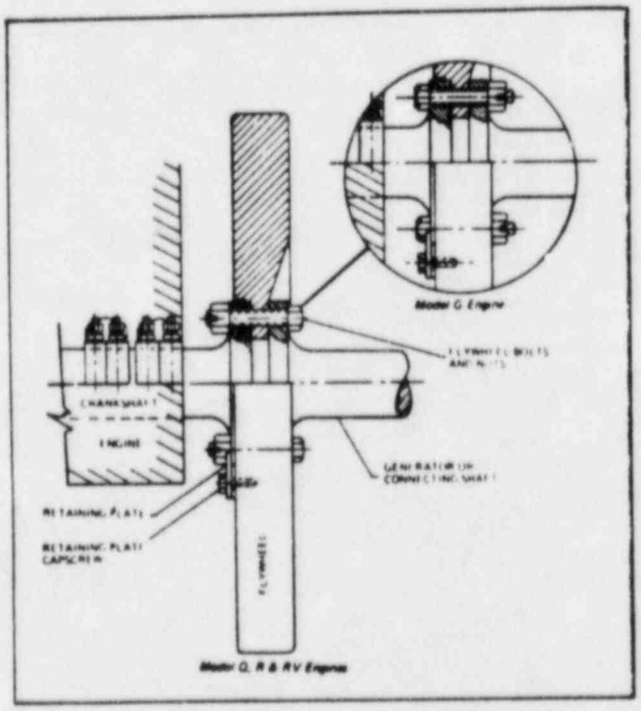

Figure 2-2. Flywheel Mounting

c. Special tapered aligning dowels and a flywheel bolt reamer are available from the Transamerica Delaval Engine and Compressor Division Service Department for use in aligning and fitting the flywheel bolts. Lubricate the two aligning dowels with a thin coat of anti-seize lubricant then tap them into two opposite flywheel bolt holes, aligning the bolt holes with those of the shaft flanges. *Do not drive dowels up hard.* Ream two flywheel bolt holes with the special reamer and measure diameter of reamed hole to the nearest 0.0005 inch, and compare diameter of reamed hole with diameter of bolt. Reamed holes should be approximately 0.0005 inch larger than the bolts to allow for an easy tap fit. *Do not drive the bolts in with a sledge, hydraulic ram or jack.* Coat bolts with an anti-seize lubricant and fit into reamed holes. Lubricate threads with powdered graphite and engine oil, assemble nuts on bolts and draw up tight. Remove two temporary bolts and aligning dowels and fit remaining bolts. Torque all bolts to the torque specified in Appendix IV.

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GROUTING.

Check alignment of crankshaft, then align driven equipment. Tighten foundation bolts on driven equipment moderately with jacking screws in place, then recheck entire alignment including crankshaft. Record crankshaft deflections on *Form D-1063, Crankshaft Alignment Record*. Engine and Compressor Division service representative must be present to supervise alignment procedures.

a. Pour and vibrate the grout under the engine and driven equipment. It is recommended that a representative of the grout supplier be present at the installation to be sure that grout is prepared and placed in accordance with specifications. Do not fill bolt shield holes with grout.

b. After grout has cured, back off the sole plate jacking screws one turn each and torque the foundation bolts to the specified value. Snug all bolts in a criss-cross pattern, then apply a light torque to each, using the same criss-cross pattern. Continue applying torque in increments and in the same pattern until the final torque value is reached.

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JACKET WATER SYSTEM.

The jacket water system is individual for each engine, and provides the cooling medium for the engine, oil cooler, turbochargers, exhaust manifold jackets, the governor and the air coolers. The recommended water treatment is sodium dichromate and boiler compound. Refer to Section 6, Part J of this manual for the recommended method of treatment. The jacket water system consists of an engine-driven jacket water pump to circulate the coolant, a temperature control valve to regulate the temperature of the water, passages within the engine through which the water flows, and where heat is absorbed from the engine, a cooler to cool the water and a standpipe to maintain a constant head on the pump and to allow for expansion and bleeding of entrained air. The standpipe is fitted with a heater for warming the water and a "keep warm" pump for circulating warm water through the system to keep the engine warmed while in a standby status. The pump, engine and cooler are connected in a series circuit, and drains must be installed at all low points and vents at all high points. All piping must be properly supported to minimize pipe vibration and flange loading. Flexible couplings are not recommended at customer connections because of potential failure hazard during operation. Refer to the jacket water piping schematic drawing in Section 9 of the manual for the relative location of system components, recommended pipe sizes and direction of flow.

COOLING WATER SYSTEM.

Transamerica Delaval does not provide the cooling water system for this installation. Nuclear service cooling water from the owner's systems is provided at connected 276 and returned at connection 277 after being circulated through the jacket water cooler, Part No. 76021-104.

FUEL OIL SYSTEM.

The fuel system provides the means for storing fuel in the day tank, removal from the day tank and delivery to the fuel injection pumps at the cylinders. The fuel oil system piping schematic drawing in the "Drawings" section of this manual show the pipe sizes, connections, direction of flow and relative location of all major components. Fuel injection equipment on the engine is hand lapped to extremely close tolerances, therefore, fuel cleanliness is of the utmost importance. The fuel system must be kept clean as possible during installation and assembly, and should be cleaned internally and blown clean before initial start up. All piping must be properly supported to minimize pipe vibration and flange loading. Flexible connections are not recommended at customer connections because of the potential failure hazard during operation. All piping must be mechanically cleaned after welding and preserved to prevent rust. The day tank should be mounted high enough to provide adequate suction at the engine-driven fuel oil booster pump. Drains should be provided at all low points and vents at all high points.

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LUBRICATING OIL SYSTEM.

The lubricating oil system is of the dry sump type which has a sump tank for holding the oil supply. Oil is circulated through the system by an engine-driven pump. Refer to the lubricating oil piping schematic drawing in the "Drawings" section of this manual for the specific details of the system, relative location of major components, direction of flow, and notes relative to installation of the system.

FLOW PRINCIPLE.

Pump suction draws the lubricating oil from the sump tank and discharges it to the lubricating oil cooler. Flow from the cooler is through a lubricating oil filter and pressure strainer to the engine main headers. A branch line from the strainer takes oil to the turbochargers. Return is by gravity flow from the engine base to the sump tank. Separate lines direct return flow from the turbochargers from the sump tank. A relief valve, set at 70 psi, provides protection to the system, and pressure regulating valves regulate the system pressure.

KEEP WARM CIRCUIT.

A "keep warm" circuit is provided to maintain the lubricating oil charge, and thereby the engine, in a warmed and lubricated condition when in the standby status. Heaters at the sump tank warm the oil which is then pumped by the keep-warm pump to the keep-warm filter and strainer and then to the main engine lubricating oil header. To prevent flooding of the turbochargers, there is no supply to the turbochargers in this circuit. The lubricating oil heater thermostat should be set at 150° F.

PLACING LUBRICATING OIL SYSTEM IN SERVICE.

Before the engine is first started, the assembled lubricating oil piping system must be thoroughly flushed with oil. Disconnect the pipe at the pressure strainer inlet and arrange a temporary bypass from this pipe to the sump tank. The bypass will permit oil circulation through the pipes without filling the internal lubricating oil system of the engine. Several thickness of cloth sack should be secured to the outlet of the bypass to catch debris as it is flushed out. The sump tank and engine base must be thoroughly cleaned before being filled. The auxiliary lubricating oil pump, or any other continuous duty pump of sufficient capacity, can be used to pump oil during flushing operations. Flushing should continue for at least eight hours if care was exercised during fabrication of the system. As much as 24 hours of flushing may be required for a dirty system. When oil is circulating through the system, the pipes should be thoroughly pounded several times with a heavy hammer to loosen dirt and debris. Hot flushing oil will clean better than cold oil. Piping around the oil cooler requires special attention to insure that the pipes and oil cooler are properly flushed. Precautions must be taken to insure the complete removal of testing fluids, water or other liquids before attempting to flush the cooler.

Note

> Engines may be received with the strainer mounted on the engine and connected to the engine lubricating oil header. If it is certain that the connections between the strainer and the engine oil header have not been disconnected since the engine left the factory, the following paragraph may be omitted.

Disconnected jumper tubes between the engine lubricating oil header and the main bearings, and between main headers and auxiliary headers. Secure a fine screen such as a nylon stocking over each main header fitting to catch debris that may be washed through as the system is flushed. Cover main bearing fittings and open ends of auxiliary header feeders to prevent the entry of dirt. Engine oil should be pumped through the open system for at least four hours to be sure that any foreign material remaining in the headers is removed. Reassemble internal tubes and brackets as required.

INTAKE SYSTEM.

Each engine has an independent intake system, the combustion air being piped from outside the engine room through a remotely installed air filter. An inline silencer is fitted in the pipe just ahead of the turbocharger air inlet. The air filter protects the working parts of the engine from the entry of dust. Filters should be cleaned at regular intervals to maintain adequate protection against abrasion and wear. Refer to the piping schematic in the "Drawings" section for connections, pipe sizes and relative locations of components.

EXHAUST SYSTEM.

Each engine is provided with an individual, independent exhaust system. The water jacketed, multi-pipe passage manifold discharges directly into the engine mounted turbocharger(s), and the gas then discharges from the turbocharger(s) through exhaust piping and a silencer to atmosphere. As few bends as possible should be used when laying out exhaust piping. Necessary bends should be of long radius. If three to six bends are used, the entire pipe should be increased to the next nominal size. If more than six bends are necessary, pipe size should be increased two nominal sizes. The length of exhaust piping is not critical, however, if an unusually long pipe is used, the pipe size should be increased to reduce back pressure. A length of flexible metal tubing should be installed in the exhaust line as near the engine as possible to allow for movement, heat expansion, and for isolation of vibration. The exhaust line should be lagged to minimize heat radiation in the engine room. A separate support should be provided so the weight of the exhaust silencer and line is not borne by the engine. Refer to the piping schematic in the "Drawings" section for connections, pipe sizes and relative locations of components.

STARTING AIR SYSTEM.

The required redundancy of the starting air system is accomplished by utilizing two separate systems. Each consists of a motor-driven air compressor, an air dryer, an aftercooler and a storage tank. Each storage supply is then piped to solenoid valves, two for each system, which block air flow until a starting signal is applied. Check valves downstream of the solenoid valves prevent back flow from one system to the other. When a start signal is applied, the solenoid valves open, admitting starting air to the interconnected headers on the engine. The two starting air distributors then send timed pilot signals to the starting air valves in the cylinder heads in the correct sequence and, as each starting air valve opens, starting air is admitted to the combustion chamber of that cylinder, forcing the piston downward and rotating the crankshaft. This system permits the engine to be cranked even though one supply system fails to operate, or if three of the four solenoid valves fail to function. Reference should be made to the starting air piping schematic drawing in the "Drawings" section of this manual for complete details of the system.

Section 3
Engine
Controls

SECTION 3

ENGINE CONTROLS

GENERAL

The following is a description of the local engine control system and its operations. The system will start, stop, protect, operate and monitor the integrity of the diesel generator in the various modes of operation.

REFERENCES

The *Associated Publications Manual* contains the manufacturer's literature covering the various components of the system. Of special significance are the ARO Corporation's publications which give a clear, concise explanation of the functions of the pneumatic logic elements used in the pneumatic control circuits. When ordering spare or replacement parts for the system, refer to the *Parts Manual* for the correct part numbers.

DRAWINGS

The drawings provided with these instructions include system schematics, layouts pertaining to the pneumatic logic assemblies, drawings detailing the engine-mounted equipment, and interface drawings for the vendor equipment. Refer to the DRAWINGS section of this manual for the drawings applicable to the control system.

SYSTEM OVERVIEW

The control system provides the means for starting, stopping, running and loading the diesel generator, as well as controlling auxiliary devices. Control operations are normally carried out from the owner's remote control panel. The unit starts automatically in response to remote contact closure, and generator adjustment and loading operations are controlled from the remote location. In addition, controls provided at the local engine control panel and the local generator control panel permit local control of all engine-generator operations.

a. There are two base modes incorporated into the system, the OPERATIONAL mode and the MAINTENANCE mode. Selection of MAINTENANCE mode at the local engine control panel disarms all starting and operating circuits, both remote and local. MAINTENANCE mode is intended for repair and maintenance operations, with the lockout of the start circuitry affording complete safety for maintenance personnel. Return of the unit to OPERATIONAL mode from the local engine control panel arms all start circuits.

b. The LOCAL/REMOTE SWITCH (LRS), located at the local generator control panel, permits selection of control location. Under normal conditions, the switch is placed in the REMOTE position, enabling all starting and operating controls at the remote control location. If the LRS is placed in the LOCAL position, the unit may be controlled from the local control panel, with remote control isolated. Note that selection of MAINTENANCE mode is possible only when LOCAL operation is selected.

c. There are two basic types of start, the Emergency Start and the Normal Start. During Normal Starts the automatic safety shutdown system, a network of malfunction sensing devices, is activated. If a malfunction exists when a Normal Start signal is applied the unit will not start until the malfunction is repaired. If a malfunction occurs when the unit is running, the automatic safety shutdown system will bring the unit to a stop. Normal starts may be applied manually from the remote location, provided the Local/Remote Switch is in the REMOTE position. Conversely, Normal Starts may be applied from the local control panel manual start pushbutton, if the Local/Remote Switch is in the LOCAL position. A Normal Start with full automatic safety shutdown protection is also initiated by closure of the owner's LOOPS (Loss of Offsite Power Start) contacts, provided the Local/Remote Switch is in the REMOTE position.

d. During Emergency Starts, most of the automatic safety shutdown system is disarmed. Only certain major malfunction sensors remain active for tripping during the emergency condition. Two-out-of-three logic is employed for certain vital trip parameters. An emergency start is initiated upon closure of the owner's remote SIAS contacts, provided the Local/Remote Switch is in the REMOTE position. A breakglass station is also provided at the local panel for application of a local emergency start. A Test Bypass pushbutton is provided at the local panel to allow the operator to insure that the shutdown system is properly disarmed during emergency operations. Note that the emergency start condition remains in effect after application until a manual reset signal is initiated from the local control panel. If such a reset signal is applied, the engine may remain running, with shutdown protection reinstated.

e. The unit may be stopped after a Normal Start from either the local or remote location, whichever has been selected for control at the Local/Remote Switch. During emergency start operations, these normal stop controls are disarmed. However, emergency stop controls are provided at both the local and remote stations.

DESCRIPTION OF OPERATIONS

The control system is divided into two subsystems, the pneumatic subsystem and the electrical subsystem. The pneumatic portion of the system is used in the control of the fuel supply permissive, in conjunction with the monitoring of various engine environment parameters, such as pressures and temperatures. Pneumatic control devices and sensors are mounted at the engine, and a pneumatic logic system at the local control panel coordinates pneumatic operations. The electrical portion of the system controls most other functions, including the start and stop inputs, alarm functions, generator interface and control of auxiliaries. Devices such as pressure switches and solenoid valves, which function both electrically and pneumatically, are used to interface the two subsystems. The following instructions begin with a consideration of the electrical circuits for starting. These circuits accept start inputs from the controlling station, and produce signals for starting air admission and also signals used by the pneumatic system for the alarm and shutdown equipment. A detailed discussion of the pneumatic circuitry follows. The various other electrical circuit functions are covered after the pneumatic circuitry. These functions include post-start operations, generator control interconnections, the alarm system and control of the auxiliaries.

ELECTRICAL START CIRCUITRY (See Drawing 09-500-76021)

There are two separate 1E start circuits, the "A" circuit on sheet 3 of the referenced drawing, and the "B" circuit, shown on sheet 4. The redundant circuits are physically spaced as far apart as possible within the panel, and each may be connected to a separate dc power source. Each start circuit controls a pair of solenoid valves, which are mounted on the engine in the starting air piping. When a start signal is applied, each start circuit acts independently to energize two starting air solenoid valves to crank the engine. In addition, each circuit generates signals which are transmitted to the pneumatic circuitry to control the alarm and shutdown equipment. Note that the redundancy of the start circuits permits either circuit alone to start the unit, in the event of the loss of the other circuit. The start circuits function as follows.

a. The "A" circuit is shown on sheet 3 of the referenced drawing. Since the "A" and "B" circuits are virtually identical in start circuitry, only the "A" circuit will be referenced here. Note that the same events occur in the "B" circuit at the same time. An Emergency Start is initiated due to closure of the owner's remote SIAS contacts (line 7). Upon closure of the contacts, solenoid valves SOL-1A, SOL-2A and SOL-202-2A are energized, on lines 7, 8 and 9 respectively. Solenoid valves SOL-1A and SOL-2A, located on the engine, admit a charge of starting air to the engine. Solenoid valve SOL-202-2A acts to de-energize the automatic safety shutdown system. Since this operation occurs in the pneumatic portion of the system, it will be described in a subsequent section. In addition to these solenoid valves, time delay relay TD1A on line 11 is energized by closure of the SIAS contacts on line 11. After one second, the TD1A contact on line 19 closes to energize solenoid valve SOL-202-5A. This solenoid valve transmits a signal to the generator control circuitry for field flash. Note that there are various permissives in the SIAS start circuit. Pressure switch PS-40A must be closed

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indicating that the unit is in the OPERATIONAL mode. The LRS (Local/Remote Switch) at the generator control panel must be in the REMOTE position, arming the remote control panel. Also, the starting air pressure switch, PS-4A, must be closed, indicating at least 150 psi starting air present in the receivers. Note that dc power must be available to the circuit for all of the above to take place.

b. A Local Emergency Start is generated upon closure of pressure switch PS-45A on line 11, sheet 3 of the referenced drawing. Referring to sheet 2 of the same drawing, note that pressure switch PS-45A (and PS-45B for the "B" circuit) is controlled by the manual emergency start valve, which is located at a breakglass station at the local control panel. Pressure switch PS-45A energizes the same emergency start circuit as described above. That is, the starting air solenoid valves at the engine are energized to admit starting air to the engine, and the shutdown de-activate solenoid valve, SOL-202-2A is energized to transmit the shutdown de-activate signal to the pneumatic portion of the system. Time delay relay TD1A is also energized for field flash. Permissives for the local emergency start include the OPERATIONAL mode pressure switch, PS-40A, and the starting air pressure switch, PS-4A, which was noted above. Note that there is no contact of the LRS in the local emergency start circuit.

c. The three remaining start types, Remote Manual Start, Local Manual Start and the Loss of Offsite Power Start (LOOPS) are classified as Normal Starts. As distinct from Emergency Starts, these starts activate the automatic safety shutdown system. The automatic safety shutdown system will prevent a Normal Start from taking place if a malfunction is present when the starting signal is received. If a malfunction occurs while the engine is operating in the Normal Start mode, the automatic safety shutdown system will cause the engine to shut down. The Remote Manual Start contact is shown on line 14 for the "A" circuit. Note that the contact is wired in series with pressure switch PS-40A for OPERATIONAL mode, and with contacts of the LRS switch. The unit must be in OPERATIONAL mode and the LRS must be in REMOTE for a Remote Manual Start to occur. Closure of the Remote Manual Start contact energizes relay R4A on line 15, time delay relay TD2A on line 16 and solenoid valve SOL-202-1A on line 17. Contact R4A-1 isolates the Emergency Start circuits on line 11, contact R4A-2 energizes the starting air solenoid valves on line 14, and contact R4A-3 latches the circuit on line 17. These contacts change state again after five seconds maximum for starting air admission. Note that solenoid valve SOL-202-1A is energized, and a signal is sent to the pneumatic circuitry to arm the automatic safety shutdown system.

d. The Local Manual Start circuit is identical to the Remote Manual Start circuit, except that the source of the initiating signal and the LRS switch are LOCAL. Note that the LRS switch must be in Local position for a Local Manual Start. The Local Start pushbutton is shown on sheet 2 of the referenced drawing. When depressed, the pushbutton causes activation of pressure switch PS-12A (and PS-12B for the "B" circuit). On line 15, sheet 3, closure of PS-12A causes relay R4A, time delay relay TD2A and solenoid valve SOL-202-1A to become energized. Contacts of relay R4A connect the starting air solenoids with the circuit for five seconds.

e. The owner's LOOPS contacts are shown on line 21. Note that the LRS contacts shown in series with the LOOPS contacts indicate that the switch must be in the REMOTE position. Solenoid valve SOL-202-7A, energized on line 21 by closure of the LOOPS contacts, is shown on sheet 2 of the referenced drawing. This valve activates the PS-44 pressure switch group, and pressure switch PS-44A on line 12 closes to initiate a Normal Start. As with Normal Starts previously described, solenoid valve SOL-202-1A is energized to transmit the shutdown activation signal to the pneumatic circuitry, and relay R4A energizes the air start solenoid valves for five seconds.

f. The redundant tachometer relays (item 49, line 30 in circuit "A") play an important role in the starting circuits. Each tachometer relay monitors a magnetic pick-up mounted on the engine. The relay contacts shown at the tachometer relay are shown with the system in the de-energized state. When power is made available to the circuit, the contacts transfer to a state opposite to that shown. The contacts will transfer to the states shown when they reach their rpm setpoints. Contacts SS1A and SS2A transfer at 200 rpm. SS1A is connected at line 18 in the "A" circuit, where it energizes the field flash solenoid valve, SOL-202-7A. Note

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that the tachometer relay contact and the contact of relay TD1A both perform the same function in energizing the field flash solenoid valve. At the tachometer relay, contact SS2A energizes solenoid valve SOL-202-3A on line 34 at 200 rpm. This solenoid valve transmits the "running" signal throughout the electrical circuitry. Tachometer relay contacts SS3A and SS4A transfer at 440 rpm. Contact SS3A acts in conjunction with a contact of the undervoltage relay to energize relay R11A on line 35. This relay transmits the "Ready To Load" signal through the various electrical circuits.

h. In summary, the various start circuits function to admit starting air to the engine, and also send signals to the pneumatic portion of the system for control of the fuel permissive and the automatic safety shutdown system. Emergency starts isolate the automatic safety shutdown system for the most part, while Normal starts arm the shutdown system. Basic permissives include selection of OPERATIONAL mode and selection of the appropriate control station at the Local/Remote Switch. For Emergency Starts, 150 psi starting air must be available. Note that examples given for the "A" circuit above apply to the "B" circuit as well. Before covering the various post-start functions in the electrical circuitry, the following section will survey the functions of the p neumatic portion of the system.

PNEUMATIC CONTROL CIRCUITRY (See Drawing -09-500-76021)

The pneumatic portion of the control system affords malfunction protection for the unit, by means of the automatic safety shutdown system. The system is comprised of various sensors mounted on the engine and other equipment. These sensors are monitored by a series of pneumatic logic circuits mounted inside the local control panel. If a sensor trips due to a malfunction during Normal start operations, the logic circuitry generates a shutdown signal. This signal is used to extend the fuel racks to the NO FUEL position, and the engine stops due to fuel starvation. During Emergency Start operations, the pneumatic logic system locks out most of the malfunction sensors, and will permit fuel operation except when certain major malfunctions occur. Note that the pneumatic portion of the control system also controls Normal and Emergency Stop functions by cutting off fuel supply. In addition to the above referenced drawing, which shows the panel mounted logic circuits, refer also to drawing 09-695-76021, which shows the engine mounted components. The following section details the operations of the pneumatic portion of the control system, and its interface with the electrical circuitry.

a. The pneumatic logic system is shown on sheet 1 of Drawing 09-500-76021. All components shown are mounted inside the Local Engine Control Panel. The core of the system is a series of pneumatic logic boards, which are mounted on a pneumatic mother board. Each distinct logic board assembly is comprised of pneumatic logic elements, which are miniature valves. The logic elements perform digital logic functions, such as AND, OR and NOT. The logic elements are connected by pasages cut in gasket material, and inputs and outputs of the boards are through numbered ports. The heavy lines on the drawing indicate gasket cuts in the mother board, which interconnects the various logic boards. At the left of the drawing are a series of numbered terminals, which are labeled as to their function. These terminals represent pneumatic tubing connections which exit the panel. Referring to Drawing 09-695-76021, note that the pneumatic connections to the engine mounted devices are labeled in a similar manner. The panel mounted logic system communicates with the engine mounted equipment through pneumatic tubing lines. The logic system is interfaced with the electrical portion of the system by means of solenoid valves and pressure switches. Solenoid valves represent inputs from the electrical system, which generate pneumatic signals for use in the pneumatic system. Pressure switches are outputs from the pneumatic system which are used as status and control inputs to the electrical portion of the system. The pneumatic control medium is air at 60 psi, symbolized by Z▶ on the drawings.

b. The system is shown at rest, with control air available at all points marked Z▶. Pressure enters the logic system at Port 10 of logic board 1A-6926, shown in the lower center of the drawing. Pressure at Port 10 enters logic board 1A-6926 and pressurizes the "B" ports of elements MEM-10, DEL-3, MEM-11 and AND-12. Since all of these elements require secondary signals for activation, there is no further signal propagation at assembly 1A-6926 at this time. Note that a control air pressure at Port 10 of logic board 1A-6926 also travels through a mother board gasket cut to Port 9 of logic board 1A-7055, and also to Port 4 of the two redundant 1A-6943 logic assemblies.

c. Pressure at Port 9 of logic board 1A-7055 acts as follows. The "B" ports of elements NOT-1, MEM-23, AND-24 and AND-19 are pressurized. Pressure at port "B" of NOT-1 passes through that element and pressurizes port "B" of elements MEM-10 and AND-9. In addition, the output of element NOT-1 is applied to orifice 5. The pressures at the "B" ports of elements MEM-10 and AND-9 have no further effect at this time. Pressure at the orifice is metered through to Port 2 of logic board 1A-7055. This rising pressure feeds the Group I sensors, on lines E-18 and E-19. As shown on the engine pneumatic drawing, 09-695-76021, the sensors on these lines will be in the blocking position unless a malfunction exists. Assuming that the lube oil and main bearing temperatures are not in trip range at this time, the sensors will block pressure flow, and the sensor lines will fill with air. At the panel, pressure will back up to Port 2 of logic board 1A-7055. Note that a pressure gauge is installed in the line adjacent to the logic board. As rising pressure fills the lines, pressure will equalize across the orifice and flow will stop. Note that port "A" of element NOT-13 and port "B" of AND-14 are pressurized.

d. Pressure at Port 4 of each redundant 1A-6943 logic assembly acts to operate the shutdown circuitry when control air is first made available. At both boards, Port 4 pressure is applied to the "B" ports of elements NOT-8, MEM-7, MEM-6 and MEM-5. Pressure flows through NOT-8 and is applied to the "B" ports of elements NOT-11, NOT-10 and NOT-9. These elements transmit, resulting in outputs from elements AND-15, AND-14 and AND-13. These outputs result in a pressure from element OR-20. The output of OR-20 pressurizes Port 6 of 1A-6943, and also pressurizes port "B" of NOT-12 and orifice/check 16. Note that the pressure at orifice/check 16 is passed to two accumulators at Port 11. After approximately two minutes, these accumulators fill up, and port "A" of element NOT-12 is pressurized. During this two minute period, element NOT-12 has an output. The NOT-12 output passes through element OR-4 and pressurizes Port 12. At the upper board, the Port 12 output is applied to Port 7 of the lower board, and this pressure passes through element OR-4 to produce an output from Port 12. The net result, therefore, is an output from Port 12 of the lower board. This pressure passes through a shuttle valve and is applied to Port 4 of logic board 1A-7055. Note that this signal also actuates the PS-40 pressure switches and pressure switch PS-23N after a delay. At logic board 1A-7055, the Port 4 input passes through element OR-16 to produce a retained output from the memory circuit consisting of elements S/R-20 and MEM-23. This output causes element AND-24 to transmit. The AND-24 output pressurizes Port 7 of 1A-7055. Note that the AND-24 output lasts for approximately two minutes. This is because of one output at AND-24 is metered through orifice 12 to a pair of accumulators at Port 8; when the accumulators are filled, an output from element AND-19 resets element S/R-20 and terminates the memory signal to AND-24. Pressure at Port 7 of 1A-7055 passes through valve P₄ and solenoid valve SOL-3B to charge line E-89. On the engine pneumatic drawing (09-695-76021), pressure in line E-89 pilots a three-way valve (item 11), causing control air at 60 psi from line E-53 to pass through the valve to line E-90. This pressure causes the Fuel Rack Shutdown Cylinder (item 8) to extend, which moves the engine fuel racks to the NO FUEL position. This prevents admission of fuel to the engine. Note that pressure switches at the panel on line E-90 will indicate the shutdown condition to the electrical circuitry.

e. As previously noted, timing circuits within the logic system will reset the shutdown cylinder signal, and the fuel rack shutdown cylinder will retract after two minutes. At this time, the logic system will be fully pressurized, and if the Group I shutdown sensors do not indicate a malfunction, the engine will accept a start signal.

PNEUMATIC FUNCTIONS AT START (See Drawing 09-500-76021)

As described earlier, a start signal is applied through the electrical system, where contact closure results in a signal to the pneumatic portion of the system. During Normal Starts, solenoid valves SOL-202-1A and SOL-202-1B are energized and during Emergency Starts, solenoid valves SOL-202-2A and SOL-202-2B are energized. The following instructions will detail the results of both types of start signal, starting with Normal Starts.

a. The Normal Start solenoid valves, SOL-202-1A and SOL-202-1B, are shown adjacent to logic assembly 1A-6926. When energized, the valves admit 60 psi control air to Port 12 of logic board 1A-6926. In addition, control air passes through a gasket passage to Port 10 of logic board 1A-7055. Pressure at Port 12 of logic board 1A-6926 is directed through element OR-8 and exits from Port 8 to activate the PS-32 group of pressure switches. These pressure switches transmit the "Starting" signal to the electrical circuitry. Pressure at Port 10 of logic board 1A-7055 arms the shutdown system, as follows. Port 10 pressure passes through element OR-2 and is applied to port "C" of element S/R-6. This results in a maintained output from element MEM-10, which produces a maintained output from element AND-9. The output of AND-9 is applied to port "B" of element NOT-13, to port "B" of element T/N-11, and to orifice/check 15. Each of these outputs are very significant for an understanding of the system.

b. The AND-9 output which is applied to port "B" of element NOT-13 arms the shutdown system. At this point in the start sequence, only the Group I shutdowns are active to trip the unit. It will be recalled that the Group I sensors are fed by orifice 5 through Port 2. Assuming that the sensors are blocking, a pressure is present at port "A" of element NOT-13. This pressure acts to inhibit the output of element NOT-13. If one of the Group I sensors detects a malfunction at the time a start signal is applied, pressure at port "A" of element NOT-13 exhausts through the venting sensor. This allows the AND-9 output to pass through element NOT-13, through elements NOT-17 and NOT-18, and through element OR-16 to trigger elements S/R-20. This results in a maintained output from element MEM-23, and a consequent output from element AND-24. The AND-24 output pressurizes Port 7 and line E-89, which causes the fuel rack shutdown cylinder at the engine to extend. This moves the fuel racks to the NO FUEL position, and prevents the engine from starting. Note that loss of a Group I sensor at any time will move the fuel racks to the NO FUEL position. As noted earlier, the shutdown signal is terminated after a delay of approximately two minutes to allow restarting the engine.

c. Assuming that the Group I sensors are good, the AND-9 output is applied to both port "B" of element AND-11 and to orifice/check 15. Note that orifice/check 15 feeds an accumulator at Port 3. The time required for the metered signal to fill the accumulator — approximately 90 seconds — is known as Group II lockout timing. When the timing period is completed, accumulator pressure is applied to port "A" of element T/N-11, which causes T/N-11 to stop transmitting. Note, however, that element T/N-11 has an output throughout Group II lockout timing.

d. The output of element T/N-11 pressurizes Port 12 of logic board 1A-7055, and is also metered through orifice 8 and OR-7 to feed Port 11. The Port 12 signal pilots valve P_3 and is also applied to Port 2 of each of the redundant 1A-6943 logic assemblies. At the upper assembly, note that Port 2 pressure also feeds line E-24. At the engine (drawing 09-695-76021), line E-24 pressure locks out the vibration switches for the engine and turbocharger during start up. At the panel, pressure at Port 2 of the 1a-6943 logic boards is applied to port "A" of element NOT-8, and is also metered through orifice/checks 1, 3, and 5. Pressure at the NOT-8 elements at each board vents the downstream pressure which flowed to element NOT-12 while the engine was at rest. Pressure metered through the orifice/checks feeds Ports 1, 3 and 5 at each of the 1A-6943 logic boards. At the upper board, these lines monitor the engine mounted Low Pressure Lubricating Oil sensors. At the lower board, the same ports monitor the High Temperature Jacket Water sensors. Referring to the engine pneumatic schematic drawing momentarily (drawing 09-695-76021), note that the Jacket Water Temperature sensors are held in the blocking position by spring pressure unless a malfunction is present. The metered pressure from the lower logic board fills the lines leading to the sensors. The Lubricating Oil Pressure sensors will be in the venting position at a start until lube oil pressure builds to 30 psi. As the engine starts and pressure builds, the sensors close to block flow of the metered pressure from the logic system. Assuming that conditions are normal, the lubricating oil pressure and jacket water temperature sensors will be permissive, and pressure will fill the lines leading to Ports 1, 3 and 5 of the 1A-6943 logic boards. These signals pressurize the "A" ports of elements MEM-5, MEM-6 and MEM-7 at each board. As a result, the memory elements produce outputs which are applied to the "A" ports of elements NOT-9, NOT-10 and NOT-11. These signals act to inhibit the outputs of the NOT elements.

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e. Note that there is a metered output from Port 11 of logic board 1A-7055 during Group II lockout timing. This pressure feeds Port 4 of logic board 1A-6926, where it is applied to port "B" of element AND-7, to port "A" of element S/R-6 and to port "B" of element OR-5. The OR-5 signal pressurizes Port 1 of 1A-6926. Port 1 pressure is applied to the pilot of valve P_3 and is also metered to the Group II sensor lines, E-68, E-92, E-14 and E-23. The sensors monitored by these lines are shown on the engine pneumatic schematic drawing. As operating parameters reach normal levels after a start, the sensors close to block the flow of air. By the time the Group II lockout timing period is completed, the lines are filled with air.

f. Group II lockout timing is completed when the output of element AND-9 fills the accumulator at Port 3 of logic board 1A-7055 through orifice/check 15. At that time, the accumulated pressure is applied to port "A" of element T/N-11 and to port "A" of element AND-14. The signal at port "A" of T/N-11 causes that element to stop transmitting after a short delay, and the downstream pressure fed through Port 12 exhausts through T/N-11. Note that pressure downstream of Port 11 is retained, however, as the feed to Port 11 is maintained by element AND-14. Significantly, element AND-14 is also supplied by pressure from orifice 5 at its "B" port. This is the same orifice which feeds the Group I sensor lines through Port 2. The net effect is that the Group I and Group II sensor networks are joined. Note that the loss of the Port 12 output from board 1A-7055 causes a pressure drop at Port 2 of each of the 1A-6943 logic boards. This stops the input pressure to orifice/checks 1, 3 and 5, and the input to port "A" of the NOT-8 elements. The NOT-8 elements are thus free to transmit, but since the integral checks maintain pressure in the sensor lines, elements NOT-9, NOT-10 and NOT-11 inhibit the NOT-8 outputs. Note that loss of Port 2 of the upper board results in a loss of the vibration switch lockout signal in line E-24. This reinstates vibration protection. At this time the engine is running normally with full shutdown protection after a Normal Start.

AUTOMATIC SAFETY SHUTDOWN (See Drawing 09-500-76021)

If the engine is operating in response to a Normal Start signal, a malfunction detected by one of the shutdown sensors will cause the engine to shut down. When a safety sensor vents due to detected malfunction, a control air pressure extends the fuel rack shutdown cylinder at the engine. The cylinder moves the fuel racks to the NO FUEL position, and the engine stops due to fuel starvation. Note that two out of three logic is provided for the low pressure lubricating oil and high temperature jacket water sensors. In addition, the overspeed trip has special features which insure dependable tripping under any circumstances. These shutdown features are discussed in the following paragraphs.

a. As an example of the functions of the logic system during a trip, consider the operation of the Jacket Water Low Pressure sensor, shown on the engine pneumatic schematic drawing, 09-695-76021. If Jacket Water pressure falls below 10 psi, the sensor shifts to the venting position, and air in line E-14 exhausts from the system through the sensor. At the panel, a pressure switch on line E-14 indicates to the electrical system that a malfunction has occurred in the jacket water system. Note that check valves are installed in all sensing lines to insure first out alarm indications. When the sensor trips, all pressure downstream of orifice 5 at logic board 1A-7055 exhausts through the sensor. The vent path is from orifice 5, through elements AND-14 and OR-7 and Port 11 of 1A-7055, through Port 4, element OR-5 and Port 1 of logic board 1A-6926, and out line E-14 through the venting sensor. The critical result is a loss of pressure at port "A" of element NOT-13 at logic board 1A-7055. This permits passage of the AND-9 output through NOT-13, through elements NOT-17 and NOT-18, and through element OR-16 to set gate S/R-20. This results in a memory output from element AND-24. The output of element AND-24 is applied to both Port 7 and to orifice/check 12. Port 7 pressure is the signal to the fuel rack shutdown cylinder, and the signal at the orifice/check will terminate the stop signal and reset the cylinder after a two minute delay. Port 7 pressure passes through valve P_4 and solenoid valve SOL-3B to charge line E-89. At the engine, line E-89 pressure pilots a three way valve which admits line E-53 control air pressure to line E-90. This pressure extends the fuel rack shutdown cylinder, moving the fuel racks to the NO FUEL position. The engine stops due to fuel starvation.

b. The circuitry for overspeed tripping is located on the engine itself. Referring to drawing 09-695-76021, note that the overspeed trip valve (item 22) is shown in the blocking position. Pressure from line E-53 is fed through an 0.014 inch orifice to the valve, and as pressure rises in the blocked line, it pilots a three-way valve. If an overspeed trip occurs, pilot pressure at this three-way valve exhausts through the overspeed trip valve. Pressure from line E-53 then passes through the valve to pressurize line E-20. Pressure in line E-20 passes through the Stop/Run Valve (item 13) and through a shuttle valve to pressurize line E-90. This pressure extends the fuel rack shutdown cylinder, which cuts off the fuel supply to the engine. Note that line E-20 pressure also extends the Air Shutoff Cylinder (item 7) when an overspeed trip occurs. This cylinder controls a butterfly valve in the intake manifold. Closure of the butterfly valve cuts off the supply of combustion air to the engine. Note that the engine shuts down due to both fuel and air strangulation at an overspeed trip.

c. Sensors for High Temperature Jacket Water and Low Pressure Lubricating Oil trips provide two-out-of-three logic for engine shutdown. Since these sensors remain active during both Normal Start and Emergency Start operations, their functioning will be discussed in the following section on Emergency Starts.

EMERGENCY STARTS (See Drawing 09-500-76021)

When an emergency start signal is applied to the system, contact closures in the electrical portion of the system energize solenoid valves SOL-202-2A and SOL-202-2B. These solenoid valves are shown adjacent to logic board 1A-6926 on sheet 1 of the referenced drawing. The system responds as follows.

a. Pressure from the emergency start solenoid valves is applied to Port 7 of logic board 1A-6926. Port 7 pressure produces a maintained output from element MEM-11 in conjunction with element S/R-4, which results in an output from element AND-12. This output pressurizes Port 11 of logic board 1A-6926, and also passes through element OR-8 to pressurize Port 8 of that board. Port 8 pressure activates the PS-32 group of pressure switches. The PS-32 group transmits the "Starting" signal to the electrical circuitry, as in Normal Starts. Note that pressure switch PS-35B2 is activated 30 seconds after the engine reaches 200 rpm at Emergency starts. Pressure switch PS-35B2 acts to delay the protective devices at the generator control equipment. The output from Port 11 of logic board 1A-6926 is applied to Port 6 of logic board 1A-7055. Note that the PS-10 group of pressure switches are activated by Port 6 pressure. These pressure switches transmit the "Emergency Start" signal to the electrical circuitry.

b. Pressure at Port 6 of logic board 1A-7055 performs two functions. First, the Port 6 signal is applied to port "B" of element NOT-4 to charge the malfunction sensor system. Second, the Port 6 signal pressurizes the "A" ports of elements NOT-17 and NOT-18 to inhibit the shutdown line. The NOT-4 input is transmitted to element OR-2, where it produces a maintained output from the memory circuit comprised of elements S/R-6 and MEM-10. This results in an output from element AND-9, which arms the shutdown line at port "B" of element NOT-13, initiates Group II lockout timing by metering pressure to the accumulator at Port 3, and charges the Group II lockout sensors through Ports 11 and 12. For a complete survey of the Group II lockout circuitry, refer to the previous section on Normal Starts. Note that the safety sensor network is charged during Emergency starts in the same manner as during Normal Starts. However, since the shutdown line is inhibited in the emergency condition, a detected malfunction will not cause a shutdown. The shutdown network is charged so that the pressure switches in the sensor lines will remain available to transmit malfunctions to the electrical system. The signal at Port 6 of 1A-7055 acts to inhibit the shutdown line by pressurizing the "A" ports of elements NOT-17 and NOT-18. As explained previously, a venting sensor has the effect of venting pressure downstream of orifice 5 of 1A-7055 through the sensor. This removes the inhibiting signal from port "A" of element NOT-13, and a shutdown signal is sent through elements NOT-17 and NOT-18 to the trip circuit. Since the Emergency Start signal inhibits NOT-17 and NOT-18, a shutdown signal is not produced.

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c. The High Temperature Jacket Water and Low Pressure Lubricating Oil sensors remain active for tripping during the Emergency operation. As shown on drawing 09-695-76021, three sensors are used to monitor each of these parameters. At least two of these sensors must trip before a shutdown occurs. For example, if only the Low Pressure Lubricating Oil sensor on line 10A trips, there is a loss of pressure at Port 1 of the upper 1A-6943 assembly. This causes element MEM-5 to stop transmitting, which, in turn, causes element NOT-9 to have an output. The NOT-9 output is applied to port "A" of element AND-13, and is also applied to Port 8 of the assembly, through elements OR-17 and OR-18. Pressure at Port 8 activates pressure switch PS-48N, which indicates to the electrical system that one of the lube oil sensors has malfunctioned. If a second lube oil sensor were to indicate a malfunction condition, the engine would shut down. For example, if the sensor on line E-10B vents, in addition to the sensor on line E-10A, then the loss of pressure at Port 3 of the upper 1A-6943 board would result in an output from element AND-13. The AND-13 output pressurizes Port 6 of the assembly, and is also applied to both port "B" of element NOT-12, and to an accumulator pair at Port 11 through orifice/check 16. Port 6 pressure causes pressure switch PS-42N to transmit the trip indication to the alarm system. NOT-12 has an output for approximately two minutes, until terminated by the accumulator timer. The NOT-12 output pressurizes Port 12 of the upper assembly, and is transmitted through the lower assembly to pressurize Port 4 of logic board 1A-7055. Note that the Port 4 stop signal bypasses the NOT-17 and NOT-18 elements which inhibit a normal safety shutdown. The Port 4 signal produces a memorized output from element AND-24 which extends the fuel rack shutdown cylinder through Port 7 of 1A-7055. This shutdown signal is terminated after approximately two minutes to allow the engine to be restarted if the problem is corrected.

d. When an emergency start signal is applied to the unit, a TEST BYPASS circuit may be employed to test whether the system is functioning normally. The Test Bypass signal must be applied manually at the local panel. This signal tests the circuitry simulating the action of a venting sensor. The Test Bypass button is shown adjacent to logic board 1A-6926. When depressed, the valve admits air to Port 5 of the logic board. The Port 5 signal pressurizes port "B" of element OR-2 and port "A" of element DEL-3. The signal at element DEL-3 pressurizes element AND-7 after a 1 second delay. The AND-7 output vents to atmosphere, simulating the tripping of a shutdown sensor. That is, pressure downstream from orifice 5 at logic board 1A-7055 exhausts through AND-14, OR-7, Port 11 of 1A-7055, then through Port 4 and element AND-7 at 1A-6926. With the sensor line vented, element NOT-13 at board 1A-7055 is free to transmit. If the shutdown deactivate circuit is functioning properly during Emergency Start operation, however, the shutdown signal produced by NOT-13 will be inhibited by elements NOT-17 and NOT-18. If a failure occurs in the Emergency circuitry, these elements will not inhibit the shutdown signal, and the NOT-13 signal will produce a shutdown signal at Port 7 of 1A-7055. The Port 7 signal will ordinarily pressurize the fuel rack shutdown cylinder at the engine to cut off the fuel supply. This signal is intercepted by the Test Bypass signal, however. Note that the Test Bypass input to Port 5 of 1A-6926 passes through element OR—2 to produce a maintained output from the memory circuit of elements S/R-6 and MEM-10. This signal is applied to port "B" of element AND-1, to Port 2, and to Port 1 through element OR—5. The output from Port 2 pilots valve P_4, which will then block any shutdown signal produced at Port 7 of logic board 1A-7055. The output from Port 1 of 1A-6926 pilots valve P_3, and maintains pressure in the safety sensor monitoring lines. Note that if a shutdown signal is actually produced from board 1A-7055 at Port 7, this pressure is directed to Port 9 of logic board 1A-6926. In conjunction with the Test Bypass signal, this produces an output from element AND-1. The AND-1 signal latches in the memory circuit to maintain the Test Bypass signal, and also pressurizes pressure switch PS-32N. This pressure switch indicates to the electrical circuitry that the emergency bypass system is not functioning properly. Note that in the event of such a malfunction, the signal at valve P_4 is maintained until the shutdown signal resets itself after approximately two minutes. If the shutdown deactivate circuit is functioning properly, no shutdown signal is produced from Port 7 of logic board 1A-7055. In that case, when the Test Bypass pushbutton is released, the vent at AND-7 of 1A-6926 closes. As a result, pressure metered from orifice 5 at 1A-7055 passes from Port 11 of that board to Port 4 of logic board 1A-6926. At the same time the rising pressure resets element S/R-6 to terminate the Test Bypass outputs, the supply to Port 1 of 1A-6926 is taken over through element OR-5. This maintains pressure in the Group II sensors. At this time the test of the shutdown deactivate system is completed, and the engine is running in the emergency state with shutdowns inhibited.

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e. When the emergency condition is completed, the safety shutdown system may be reactivated with the engine running using the Reset From Loca pushbutton. The pushbutton is shown schematically adjacent to logic board 1A-6926. When depressed, the pushbutton causes air admission to Port 6 of logic board 1A-6926. This signal resets element S/R-4, terminating the output of element MEM-11. This stops the outputs from Ports 11 and 8 of 1A-6926. Loss of Port 8 causes the PS-32 group of pressure switches and pressure switch PS-47B to become deactivated. Loss of pressure switch PS-47B reinstates normal generator protective circuits. Loss of the Port 11 output terminates the input to Port 6 of logic board 1A-7055. This removes the inhibiting signal from elements NOT-17 and NOT-18, which permits a shutdown signal to pass through these elements. This has the effect of reinstating normal shutdown protection.

OTHER PNEUMATIC FUNCTIONS (See Drawing 09-500-76021)

Certain control functions not yet discussed are also performed pneumatically, or in a pneumatic combination with the electrical system. Selection of MAINTENANCE and OPERATIONAL modes, for instance, is performed by the pneumatic circuitry. the Stop circuits also act through the pneumatic logic system. In addition, certain design features are included for special situations which should be noted.

a. The MAINTENANCE mode feature permits routine maintenance or repair to the engine with all starting circuits locked out. This allows maintenance personnel to work in and around the engine without the hazard of moving parts. Referring to sheet 4 of the referenced drawing, note that the MAINTENANCE mode pushbutton is shown on line 175. When depressed, the contact closure energizes solenoid valve SOL-201-1B. Note that the LRS contact on line 177 must be closed, indicating that the local station has been selected at the Local/Remote Switch, and relay contacts R5B-3 and R10B-3 on line 175 must also be closed. Relay contact R5B-3 indicates that a LOCA signal is not present, and relay contact R10B-3 indicates that the engine is not running. Assuming that these permissives are satisfied, solenoid SOL-201-1B is energized by selection of MAINTENANCE mode. In the pneumatic portion of the system, on sheet 1 of the referenced drawing, solenoid valve SOL-201-1B is shown in the upper right. When energized, the valve pilots valve P_2, which has a self feeding pilot to maintain its position after the MAINTENANCE pushbutton is released. The output of valve P_2 pressurizes Port 1 of logic board 1A-7055. This pressure inhibits the output of element NOT-1, thereby preventing pressurization of the shutdown sensor system. The output of valve P_2 also activates pressure switches PS-46N, PS-40A, PS-40B and PS-23N. Line E-89 and the pilot of valve P_1 are also pressurized. Pressure switches PS-40A and PS-40B isolate the start signals in the electrical system (see sheet 3, line 9 for the "A" circuit). The other switches are for status and annunciation purposes. Pressure in line E-89 is directed to the fuel rack shutdown cylinder at the engine, as discussed previously. This prevents fuel admission during MAINTENANCE mode. Valve P_1 vents the barring device interlock, which permits operation of the barring device during MAINTENANCE mode. Pressure from line E-85 exhausts from valve P_1. At the engine (drawing 09-695-76021), the barring device lockout cylinder retracts, allowing the interlock valve to shift, which frees the barring device. Note that pressure in line E-48 activates pressure switches PS-13B and PS-13N on sheet 2 of the panel drawing. On line 174, sheet 4 of the panel drawing, note that pressure switch PS-13B latches in the MAINTENANCE mode solenoid valve. This maintains the unit in MAINTENANCE mode until the barring device is locked out again. Another significant feature of MAINTENANCE mode is shown on sheet 3 of the panel drawing, line 9. Pressure switch PS-40A opens at MAINTENANCE mode selection, enabling the engine roll circuit. This allows the engine to be cranked on starting air without starting, a useful maintenance feature.

b. Assuming that the barring device is disengaged and locked out, the unit may be returned to OPERATIONAL mode pushbutton at the local panel. As shown on line 173, sheet 3 of the panel schematic, this causes solenoid valve SOL-201-3B to become energized. At the pneumatic logic system, solenoid valve SOL-201-3B vents pressure from the pilot of valve P_2, which exhausts pressure from the MAINTENANCE lockout circuits.

c. Another significant design feature is shown on sheet 2 of the panel schematic drawing. Note that lines E-31R and E-31F monitor the starting air pressure at front and rear headers. If pressure in these lines falls below 150 psi, valves P_5 and P_6 will admit passage of a 60 psi control air signal. This signal activates pressure switches PS-4A and PS-4B, and is also applied directly to Port 5 of logic board 1A-7055, as shown on sheet 1. The PS-4 switches are installed in the electrical emergency start circuits in both the "A" and "B" circuits. In the "A" circuit, pressure switch PS-4A is shown on line 11. Note that the emergency start signal to the starting air valves is terminated only by the opening of pressure switch PS-33A on line 7, which opens when the engine starts running. If a failure to start occurs, the starting air valves would crank until the air supply were exhausted, unless the PS-4 switches were present in the circuit. If such a start failure were due to a minor problem — a valve closed in the fuel supply line, for instance — the action of the PS-4 switches insures that enough air remains in the receivers for several manual start attempts. Note that the pneumatic signal at logic board 1A-7055 resets the shutdown system to allow such a manual start attempt after a LOCA start failure. The use of this feature is not expected under normal circumstances, but it is present if the need arises.

d. There are two types of intentional Stop signals, Normal stops and Emergency Stops. The sources of these signals will be discussed in a subsequent section dealing with the electrical system. The effect of a Normal Stop signal is energization of solenoid valve SOL-201-2B. This valve admits pressure to Port 4 of logic board 1A-7055. Port 4 pressure triggers a shutdown signal, as the memory circuit produces a timed output from Port 7 of 1A-7055 which pressurizes line E-89. This line extends the fuel rack shutdown cylinder to cut off the fuel supply. The Emergency Stop signal energizes solenoid valve SOL-3B, which admits control air directly to line E-89 to cut off the fuel supply to the engine. In both cases, the engine stops due to fuel starvation.

OTHER ELECTRICAL FUNCTIONS (See Drawing 09-500-76021)

Thus far only the start circuits have been discussed in the electrical portion of the circuitry. In addition to performing a start input functions, the electrical circuits accept inputs for MAINTENANCE and OPERATIONAL modes and also accept Normal and Emergency Stop inputs. The electrical system also provides control of the Lube Oil and Jacket Water Circulating Pumps and the Crankcase Fans. The various alarm and status functions are performed electrically, or in combination with pressure switches which monitor the pneumatic system. Generator status and control interface is also electrically handled. Also, various internal control relays are provided in the electrical circuitry to propagate control and status signals as the unit goes through starting, stopping and shutdown sequences.

a. Control inputs for Stopping and Mode Selection are shown in the "B" circuit, on sheet 4 of the referenced drawing. The local normal stop pushbutton is shown on line 177, and the remote normal stop contact is wired in parallel on line 179. Note that contacts of the Local/Remote Switch are placed as permissives in these circuits, arming the normal stop circuit at the selected station. The contact of relay 186B on line 178 will cause a trip if certain generator faults are detected. Note that contact R5B-2 on line 177 will isolate the normal stop circuits when relay R5B is energized. The relay coil is shown on line 123, where it is energized when pressure switch PS-10B indicates that a LOCA condition exists. In the absence of a LOCA signal, application of a Stop signal from the appropriate station energizes solenoid valve SOL-201-2B, which generates a pneumatic stop signal as previously discussed. The MAINTENANCE and OPERATIONAL pushbuttons, and the solenoid valves they control, are shown in the same area of the "B" circuit as the normal stop controls. The Emergency Stop controls are shown in the "B" circuit also. The various emergency stop contacts act to energize relay R23B on line 139, and contacts of R23 energize both the normal and emergency stop solenoids. The action of these solenoid valves is described in the pneumatic section above. The R23 relay is latched from the following sources. The local Emergency Stop pushbutton, at a breakglass station at the local panel, shown on line 136. A contact of relay R6B on the following line is energized when an Overspeed trip is detected. The remote emergency stop contact on line 138, the generator differential contact of relay 186A on the following line, and pressure switch PS-50B on line 141 all act to energize the emergency stop relay. Pressure switch PS-50B is energized when either the Jacket Water Temperature or Lube Oil Low pressure sensors indicate a two-out-of-three logic malfunction.

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b. When the engine start signal is applied, certain operations are performed automatically, as the start and run signals are propagated through the electrical system. Sheet 5 of the referenced drawing shows the R1 and R1 Auxiliary relays, which are latched in by pressure switch PS-32N1 when the engine starts. Contacts of relay R1 are used in the automatic circuits of the lube oil and Jacket water circulating pumps to stop the pumps at a start. An R1 contact starts the engine hourmeter, and another R1 contact on line 221 energizes relay R8 and timer TD3. Relay R8 controls the crankcase fans and the generator space heater shutoff. Timer TD3 delays the activation of certain Group II status and alarm indications which do not reach normal levels until after the unit has started and warmed up.

c. Status lamps are provided which inform the operator of the condition of various parameters during the operating sequence. Of significance is the "Unit Available" circuit on line 263. Monitored sources include pressure switch PS-29 for Overspeed, pressure switch PS-31N for DC power availability, pressure switch PS-23N for MAINTENANCE lockout, and a contact for availability of starting air at 150 psi.

d. The annunciator circuitry is shown on sheets 7 and 8 of the referenced drawing. The annunciator monitors field contacts for engine parameters, relay contacts for pyrometers, optical isolator contacts for generator faults, and other alarm or failure contacts. The annunciator included both audible and visual alarm functions. Alarm functions test pushbuttons are included in the system to check the operations of the annunciator. Refer to the manufacturer's bulletins in the *Associated Publications Manual* for details on annunciator wiring.

e. Drawing 09-688-76021 shows the wiring details for the engine and skid mounted electrical components. Components are shown schematically on sheet 1 of that drawing, including wire numbers and junction box connections. Sheets 2 and 3 of the drawing show the physical locations of the components in relation to the engine and skid. For further details on the location and relationships of various sensors and other devices to their respective systems, refer to the piping schematics for the various fluid subsystems. A list of these reference drawings is included on sheet 1 of the 688 drawing.

GENERATOR INTERCONNECTIONS (See Drawing 09-500-76021, 52440)

Various signals are sent to the generator control panel from the engine control panel for control and status purposes. The generator control panel also generates signals for use at the engine control panel. Refer to sheet 9 of the control panel drawing for the terminal designation legends which differentiate between circuits used in the respective locations.

a. Connections and contacts from the "A" circuit which connect with the generator control equipment are shown on sheet 3 of drawing 09-500-76021. Beginning on line 43, the governor is connected with the generator panel for speed and frequency control. On line 49, pressure switch PS-9A opens at an engine stop or shutdown, locking out the exciter regulator. Pressure switch PS-30A is used for field flash and enabling the exciter regulator. Pressure switch PS-10A places the voltage regulator and governor in isochronous mode in the LOCA condition, and permits unit parallel operation in normal start mode. The undervoltage relay at the local panel monitors generator leads for developing the "Ready To Load" signal. Note that various contacts from the protective relays at the generator are used in conjunction with an optical isolator to yield trouble alarms and annunciations at the local panel.

b. Similar contacts are present in the "B" circuit. Starting on line 143, the PS-9B2 pressure switch is used in the pre-position circuit for the governor and voltage regulator. The PS-9 and PS-30 switches act in the exciter lockout and field flash circuits as in the "A" circuit. The R6B relay contact and the pressure switch PS-9B1 contact act to trip the generator breaker to disconnect the unit from load whenever an overspeed trip or engine shutdown signal is generated.

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c. Drawing 52440 shows how these contacts interconnect with the equipment at the generator control panel. Sheet 1 shows the automatic voltage regulator adjust circuit and the unit parallel and pre-position circuits. Note that the TDX relay in the pre-position circuit will place the voltage regulator and governor at their preset settings any time a stop or LOCA signal occurs. The TD relay stops the preset signal after 15 seconds to allow the operator to adjust load thereafter. Sheet 2 of 52440 shows the manual voltage adjust circuit and the field flash and exciter shutdown circuits. Note that the field flash coil is energized by operation of the PS-30 pressure switches. Sheet 3 of 52440 shows the auto/manual selector for voltage regulation. Sheet 4 shows the alarm and trip circuits and the governor controls. Refer to the generator control panel manufacturer's documentation for further details on the equipment mounted at the generator control panel.

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Section 4
Engine
Operation

SECTION 4

ENGINE OPERATION

GENERAL.

If the engine is being started for the first time, remove any preservative materials that may have been applied to the control and exterior surfaces of the engine. Rust preventive which has been sprayed inside the engine will mix with the lubricating oil without causing contamination. To reduce the amount of preservative absorbed by the oil charge, however, it may be desirable to wash and clean the interior surfaces of the engine before circulating oil for the first time. Do not attempt to wash connecting rods, crankshaft or pistons as this may deposit dirt between the bearing surfaces. The following inspections and checks are recommended prior to starting the engine for the first time, or after a long shutdown or major overhaul.

a. Check bolts, nuts and capscrews, both inside and outside the engine to insure that all locking wires, clips and cotter pins are in place and secure.

b. Inspect all piping systems. Trace out each system to insure that all connections are secure and that all valves and other control devices are properly positioned for engine operation.

c. Check lubricating oil strainers and filters for cleanliness and proper assembly.

d. Check that lubricating oil and cooling water systems are clean and filled to the proper level.

e. Check starting air system for cleanliness and absence of moisture.

f. Check all control linkages for proper adjustment and freedom of movement. Verify that all fasteners are properly tightened.

g. Check crankshaft web deflections and thrust clearance (See Section 6, Part D).

CLEAR CYLINDER CHECK

An essential part of the pre-start procedure is to check for the presence of water in the combustion chambers and the intake air manifold. In any water cooled engine there is some possibility of internal water leakage. This may be from the internal passages in the engine, the intercooler(s), or from the turbocharger(s). Other possible causes of water leaks include improper maintenance or repair procedures, faulty installation, or improper handling during shipment and storage. Although the presence of water in a combustion chamber, or the intake manifold in any significant quantity is a rare occurance, the consequence of such a condition can be serious. If the engine is cranked with full starting air pressure, and with water in one or more combustion chambers, or in the intake air manifold, the result may well be serious damage to the cylinder head and/or block. Therefore, it is essential that the cylinders and intake manifolds be checked and determined to be free of liquids prior to a start. This check may be considered mandatory when starting the engine for the first time after installation, or after a long shutdown or major overhaul, or whenever the engine has been shut down and allowed to cool for eight hours or more. For maximum protection, it is strongly recommended that the check be performed before each engine start. It is recognized that this may not be practical in installations where remote or unattended operation are a part of the design, therefore, in these cases the status of fluid systems and pressure vessels should be regularly monitored to minimize the risks of water leakage problems. The engine should not be rolled on full starting air pressure until such time that it has been determined that there is no liquid in any of the combustion chambers. Barring the engine over to determine this is satisfactory. Briefly, the procedure for checking to determine that the combustion chamber and the intake manifold(s) are free of moisture involves the following sequence of actions.

a. Open indicator cocks on all cylinders.

b. Check for presence of water in the intake air manifold(s). Striking the sides of the manifold with a mallet and listening to the sound is one method of doing this. If water is detected, the source must be found and the condition corrected before proceeding.

c. Place Stop/Run valve on the engine in the STOP position. This will prevent fuel admission to the engine during the subsequent steps.

d. Bar the engine over slowly with the barring device for two complete revolutions of the crankshaft.

Caution

If any resistance to free turning is encountered, stop cranking and determine cause before proceeding.

e. Check all indicator cocks for presence of moisture. If any liquid has been ejected from any cocks, the source must be found and the defect corrected before proceeding.

f. Roll engine two complete revolutions on starting air then again check all indicator cocks for presence of moisture. If all clear, proceed.

g. Close all indicator cocks.

h. Place Stop/Run valve in RUN.

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SAFETY PRECAUTIONS.

Of all the rules of safety, common sense is foremost. One must admit the frailty of body and senses, and respect the forces present with an operating engine which could destroy him in an instant if not controlled. The following standing rules of safety should be observed at all times when operating the engine, as well as those required by the owner and operator, governmental regulatory agencies, and the dictates of good common sense.

a. Keep area around engine and associated components clean and uncluttered at all times.

b. Do not store tools or parts on platforms or engine.

c. Always monitor instrumentation often enough to be aware of the condition of the running engine.

d. Never start an engine without knowing exactly how the engine can be stopped in an emergency.

e. Never start an engine without visually checking for personnel in dangerous positions.

f. On initial startup after an overhaul, always station a man near the governor.

g. Never run a generator set with the switchgear doors open.

h. Always wait 10 to 15 minutes after shutting down before removing engine covers.

i. Know the top turbocharger speed, and observe it.

j. Never look directly into an air flow nozzle from close proximity. Use a mirror.

k. Never take firing pressure on a detonating engine.

l. Never run with the oil system pressure over 90 psi.

m. Use guards around all rotating wheels and shafts.

n. Never expose the hands to injector pop spray.

o. Never run an engine if a dangerous condition is suspected. *Stop first*, then consult a supervisor.

p. The use of safety glasses and ear protection while the engine is running should be in accordance with the owner's regulations.

q. Do not weld next to crankcase relief doors when engine is running.

Operation: STANDBY MODE STATUS CHECK							
Item	Control/Indicator	Location: Panel	Engine		Other	Position	Remarks
	CONTROL PANEL CHECKS						
1	ANNUNCIATOR TEST PUSHBUTTONS a. TEST b. SILENCE c. ACKNOWLEDGE d. RESET	x				DEPRESS	Depress pushbuttons in sequence to test bulbs and annunciator functions. Replace bulbs if necessary.
2	ANNUNCIATOR LAMP INDICATIONS a. ALL ANNUNCIATOR LAMPS	x				EXTINGUISHED	All lamps should be out. If any lamp is illuminated, stop status check until defect corrected.
3	TURBOCHARGER OIL PRESSURE GAUGE a. RED POINTER b. BLACK POINTER	 x x				 ZERO PSI ZERO PSI	Not pressurized in standby mode
4	JACKET WATER PRESSURE GAUGE	x				10 — 20 PSI	Normal range
5	STARTING AIR PRESSURE GAUGE — LEFT BANK	x				220 — 240 PSI	Normal range
6	STARTING AIR PRESSURE GAUGE — RIGHT BANK	x				220 — 240 PSI	Normal range
7	CONTROL AIR PRESSURE GAUGE	x				60 PSI	
8	LUBRICATING OIL PRESSURE GAUGE	x				10 — 20 PSI	Normal range
9	LUBRICATING OIL FILTER DIFFERENTIAL PRESSURE GAUGE	x				ZERO PSI	Not pressurized in standby mode.
10	COMBUSTION AIR PRESSURE GAUGE a. LEFT BANK b. RIGHT BANK	 x x				 ZERO PSI ZERO PSI	Not pressurized in standby mode.
11	FUEL OIL FILTER DIFFERENTIAL PRESSURE GAUGE	x				ZERO PSI	Not pressurized in standby mode.
12	FUEL OIL PRESSURE GAUGE	x				ZERO PSI	Not pressurized in standby mode.
13	CRANKCASE PRESSURE MANOMETER	x				ZERO INCHES	Not pressurized in standby mode.
14	ENGINE TACHOMETER	x				0 RPM	

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Operation: STANDBY MODE STATUS CHECK (Continued)							
		Location					
Item	Control/Indicator	Panel	Engine		Other	Position	Remarks
15	ENGINE HOURMETER	x				VARIABLE	As occurring.
16	"UNIT AVAILABLE" INDICATOR LAMP	x				ILLUMINATED	
17	"EMERGENCY STOP" INDICATOR LAMP	x				EXTINGUISHED	
18	"LOSS OF OFFSITE POWER" INDICATOR LAMP	x				EXTINGUISHED	
19	"SHUTDOWN SYSTEM ACTIVE" INDICATOR LAMP	x				EXTINGUISHED	
20	"SAFETY INJECTION SIGNAL" INDICATOR LAMP	x				EXTINGUISHED	
21	"IN TEST SEQUENCE" INDICATOR LAMP	x				EXTINGUISHED	
22	"52G CLOSED" INDICATOR LAMP	x				EXTINGUISHED	
23	"TEST BYPASS" INDICATOR LAMP	x				EXTINGUISHED	
24	"READY TO LOAD" INDICATOR LAMP	x				EXTINGUISHED	
25	"STOPPING" INDICATOR LAMP	x				EXTINGUISHED	
26	"BYPASS TEST FAILURE" INDICATOR LAMP	x				EXTINGUISHED	
27	"STARTING" INDICATOR LAMP	x				EXTINGUISHED	
28	EMERGENCY START BREAKGLASS STATION	x				DO NOT DISTURB	For manual emergency start only.
29	START PUSHBUTTON	x				DO NOT DISTURB	For local manual start only.
30	MODE SELECT PUSHBUTTONS a. MAINTENANCE b. OPERATIONAL	 x x				 DO NOT DISTURB DO NOT DISTURB	System in OPERATIONAL Mode during Standby. Operate pushbuttons only when change of mode desired.
31	FUEL OIL DAY TANK LEVEL INDICATOR	x				PUSH TO READ	Check level. Record reading. Add fuel if below minimum level.

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Operation: STANDBY MODE STATUS CHECK (Continued)							
		Location					
Item	Control/Indicator	Panel	Engine		Other	Position	Remarks
32	LUBRICATING OIL SUMP TANK LEVEL INDICATOR	x				PUSH TO READ	Check level. Record reading. Add oil if below minimum level.
33	"A POWER AVAILABLE" INDICATOR	x				ON	
34	"B POWER AVAILABLE" INDICATOR	x				ON	
35	"C POWER AVAILABLE" INDICATOR	x				ON	
36	THERMOCOUPLE SELECTOR SWITCH	x					Rotate and observe temperature readings
	a. CYLINDERS 1-8 LEFT BANK					Ambient	
	b. CYLINDERS 1-8 RIGHT BANK	x				Ambient	
	c. STACK RIGHT BANK					Ambient	
	d. STACK LEFT BANK					Ambient	
	e. LUBRICATING OIL IN					145 — 165° F	
	f. LUBRICATING OIL OUT					145 — 165° F	
	g. JACKET WATER IN					145 — 165° F	
	h. JACKET WATER OUT					145 — 165° F	
	AT ENGINE CHECKS						
37	JACKET WATER STANDPIPE			x		CHECK LEVEL	Add Jacket Water if required. NOTE: If abnormally large amount of jacket water has been consumed, investigate cause before proceeding or serious damage may occur.
38	BARRING DEVICE		x			DISENGAGED & LOCKED OUT	Verify.
39	GOVERNOR DIAL SETTINGS CHECK		x				Verify that field established settings remain in effect
	a. LOAD LIMIT KNOB					MAXIMUM	
	b. SPE..D DROOP KNOB					5	
	c. SPEED SETTING KNOB					AS NOTED IN TEST RUNS	
	MOTOR CONTROL CENTER CHECKS						
40	AFTERCOOLER FAN #1 SWITCH				x	AUTO	AUTO lamp illuminated ON LAMP illuminated

Operation: STANDBY MODE STATUS CHECK (Continued)							
		Location					
Item	Control/Indicator	Panel	Engine		Other	Position	Remarks
41	AFTERCOOLER FAN #2 SWITCH				x	AUTO	AUTO lamp illuminated ON LAMP illuminated
42	AIR COMPRESSOR #1 SWITCH				x	AUTO	AUTO lamp illuminated ON Lamp illuminated if compressor operating
43	AIR COMPRESSOR #2 SWITCH				x	AUTO	AUTO lamp illuminated ON lamp illuminated if compressor operating
44	JACKET WATER KEEPWARM PUMP SWITCH				x	AUTO	AUTO lamp illuminated ON lamp illuminated
45	JACKET WATER KEEPWARM HEATER SWITCH				x	AUTO	Lamp illuminated if Heater operating — thermostat control
46	LUBRICATING OIL KEEPWARM PUMP SWITCH				x	AUTO	AUTO lamp illuminated ON lamp illuminated
47	LUBRICATING OIL KEEPWARM HEATER SWITCH				x	AUTO	Lamp illuminated if Heater operating — thermostat control
48	GENERATOR SPACE HEATER SWITCH				x	AUTO	Lamp illuminated if Heater operating — thermostat control

Operation: TEST START PROCEDURE							
Item	Control/Indicator	Location: Panel	Location: Engine	Location:	Location: Other	Position	Remarks
1	PRE-START PROCEDURE						
	A. PERFORM "STANDBY MODE STATUS CHEC[illegible]"						See checklist.
	B. REMOTE/LOCAL SWITCH				x	LOCAL	At Generator Panel.
	C. "ENGINE CONTROL IN LOCAL" indicator lamp	x				ILLUMINATED	Verify "LOCAL" control selected.
	D. MAINTENANCE mode pushbutton	x				DEPRESS	
	E. "MAINTENANCE LOCKOUT" annunciator	x				ILLUMINATED	Verify MAINTENANCE mode selected.
	F. "UNIT AVAILABLE" indicator lamp	x				EXTINGUISHED	Note start circuitry isolated in MAINTENANCE mode.
	G. CYLINDER INDICATOR COCKS		x			OPEN	All cylinders.
	H. BARRING DEVICE		x			UNLOCK	
	I. "BARRING DEVICE ENGAGED" indicator lamp		x			ILLUMINATED	Verify annunciator operation.
	J. BARRING DEVICE		x			ENGAGE	Bar engine over slowly. If there is any resistance to free turning, stop barring immediately and check cylinder indicator cocks for ejection of liquid. If no resistance is encountered, continue barring engine over for two complete revolutions. Then check indicator cocks for ejection of liquid. CAUTION: IF LIQUID IS EJECTED FROM INDICATOR COCKS, TERMINATE TEST PROCEDURE. THE CAUSE OF LIQUID EJECTION MUST BE FOUND AND THE DEFECT CORRECTED BEFORE PROCEEDING.

Operation: TEST START PROCEDURE (Continued)							
		Location					
Item	Control/Indicator	Panel	Engine		Other	Position	Remarks
	K. ENGINE ROLL pushbutton	x				DEPRESS	Roll engine on starting air for at least two revolutions, then release pushbutton.
	L. INDICATOR COCKS		x			INSPECT, then CLOSE	Recheck cocks for liquid ejection. Then close indicator cocks at all cylinders.
	M. BARRING DEVICE		x			DISENGAGED & LOCKED OUT	Verify barring device locked out.
	N. "BARRING DEVICE ENGAGED" annunciator	x				EXTINGUISHED	
	O. RETURN TO OPERATION Pushbutton	x				DEPRESS	
	P. "MAINTENANCE LOCKOUT" annunciator	x				EXTINGUISHED	
	Q. "UNIT AVAILABLE" indicator lamp	x				ILLUMINATED	Unit is now ready for test start. Note: 2 min. delay between step "O" and step "Q".
2	TEST START APPLICATION FROM LOCAL PANEL					ILLUMINATED	Verify that local control selected.
	A. "LOCAL CONTROL" indicator lamp	x				DEPRESS	Release pushbutton after momentary actuation. Note engine starting.
	B. MANUAL START Pushbutton	x					
						ILLUMINATED	
						ILLUMINATED	
	C. STARTING indicator lamp	x				ILLUMINATED	
	D. RUNNING indicator lamp	x					
	E. SHUTDOWN SYSTEM ACTIVE indicator lamp	x				ILLUMINATED after delay	Lamp goes on when rated speed and voltage reached after start.
	F. READY TO LOAD indicator lamp	x					

Operation: TEST START PROCEDURE (Continued)							
		Location					
Item	Control/Indicator	Panel	Engine		Other	Position	Remarks
3	APPLICATION OF TEST START FROM REMOTE PANEL						
	A. REMOTE/LOCAL SWITCH				x	REMOTE	Control station selected at generator control panel.
	B. "LOCAL CONTROL" indicator lamp	x				EXTINGUISHED	Verify local control isolated.
	C. REMOTE START Pushbutton				x	DEPRESS	Release pushbutton after momentary actuation. Note engine starts and builds voltage automatically.
	D. REMOTE INSTRUMENTATION				x	OBSERVE	Note engine start and acceleration.

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Operation: EMERGENCY STARTS							
Item	Control/Indicator	Location: Panel	Engine		Other	Position	Remarks
1	AUTOMATIC EMERGENCY START						
	A. REMOTE CONTACT CLOSURE				x		An emergency start is initiated automatically in response to closure of owner's remote start contacts. Unit will start and come up to rated speed & voltage with no operator action required.
2	MANUAL EMERGENCY STARTS						
	A. LOCAL MANUAL EMERGENCY START BREAKGLASS STATION	x				BREAK GLASS, USING HAMMER AT PANEL.	An emergency start is initiated automatically when glass is broken. Unit will come up to rated speed & voltage with no operator action required. NOTE: UNIT WILL NOT RESPOND TO A NORMAL STOP SIGNAL AFTER APPLICATION OF MANUAL EMERGENCY START. EMERGENCY STOP BREAKGLASS STATION ONLY ACTIVE IN THIS CONDITION.
3	TEST BYPASS PROCEDURE						
	A. TEST BYPASS Pushbutton	x				DEPRESS	With engine running in the LOCA condition, depressing pushbutton momentarily will test the bypass circuit. If test unsuccessful, note TEST BYPASS FAILURE indicator lamp comes on. No lamp illuminates if test ok.

Operation: STOPPING ENGINE							
		Location					
Item	Control/Indicator	Panel	Engine		Other	Position	Remarks
1	NORMAL STOP						
	A. LOCAL STOP Pushbutton	x				DEPRESS	Note: Stop signal is applied from the station selected for control at the LOCAL/REMOTE SWITCH.
	B. REMOTE STOP Pushbutton				x		
2	EMERGENCY STOP						
	A. EMERGENCY STOP BREAKGLASS STATION	x				BREAK GLASS, PUSH BUTTON	
	If engine fails to stop upon application of Emergency Stop signal, perform one of the following:						
	B. OVERSPEED TRIP		x			TRIP	Manually trip the overspeed device.
	C. STOP RUN VALVE		x			STOP	Manually push the Stop/Run Valve to the Stop position.
	D. FUEL RACKS		x			PUSH	MANUALLY PUSH the fuel racks to the no fuel position. Hold rack until engine stops.

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Section 5
Inspection &
Maintenance

PART A — PREVENTIVE MAINTENANCE (Continued)

OPERATING REPORTS

A record should be maintained of the conditions of engine operation, and in the case of an engine/generator set, the generator as well. This record may be kept in any form which proves to be suitable to the owner for his purposes, however, it is recommended that as a minimum the following conditions be recorded.

a. Load (%)

b. Engine Speed

c. Crankcase vacuum readings

d. Fuel pump rack positions (mm settings)

e. Temperatures

  (1) Ambient air

  (2) Intake air manifold

  (3) Lubricating oil

  (4) Cooling water

  (5) Exhaust (cylinder and stack)

f. Pressures

  (1) Ambient air

  (2) Intake air manifold

  (3) Lubricating oil

  (4) Fuel

Transamerica Delaval Forms E-276 and E-277, copies of which follow, are available for this purpose, and may be ordered from the Parts Department. Form E-276 provided for a daily recording of data, and Form E-277 is designed to provide a periodic summary of the daily reports. Due to the normally limited operating hours of an engine in nuclear standby service, the frequency of observations will, of course, depend upon the frequency of operation.

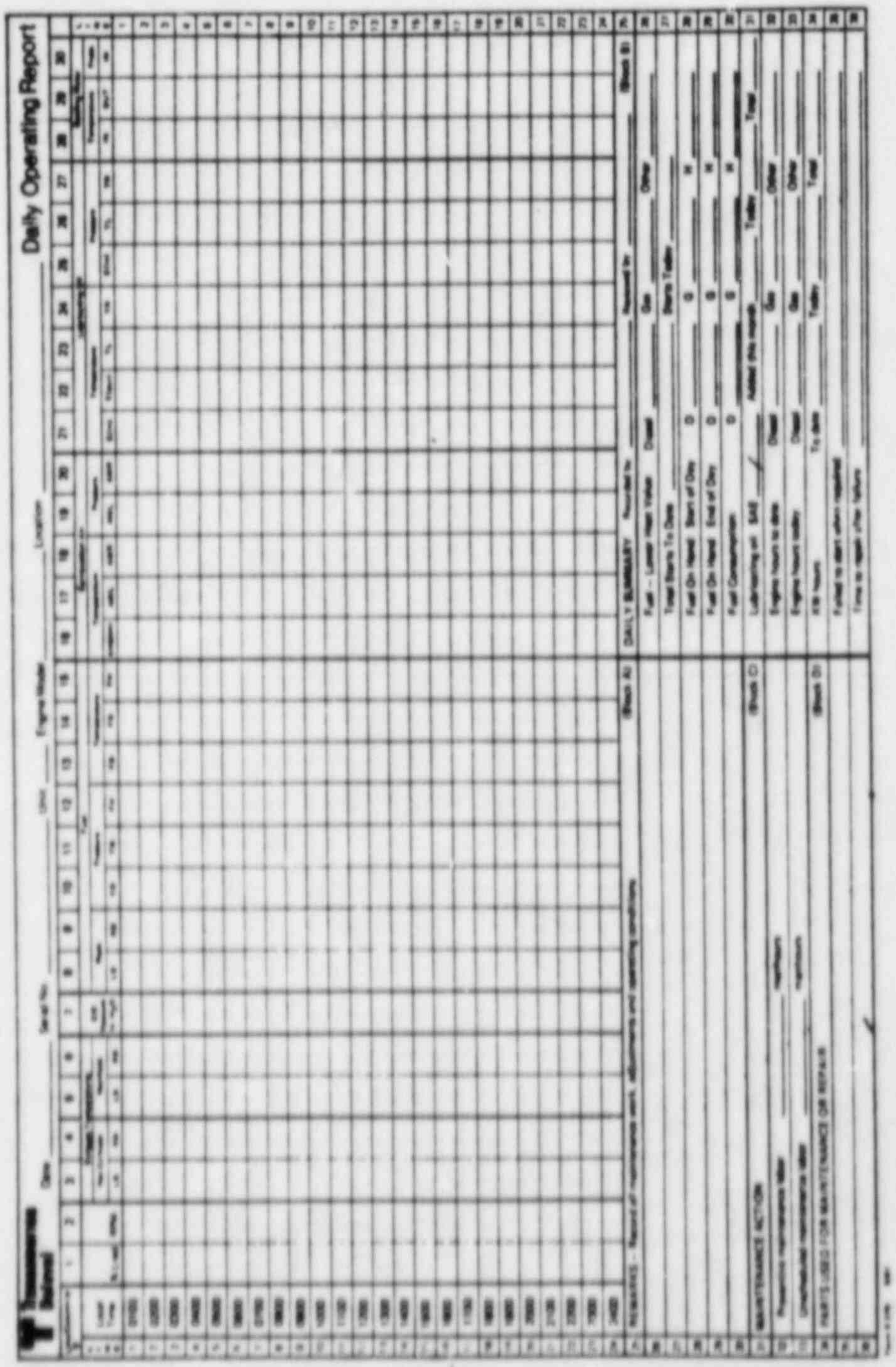
Daily Operating Report

Figure 5-A-1. Daily Operating Report, Form E-276

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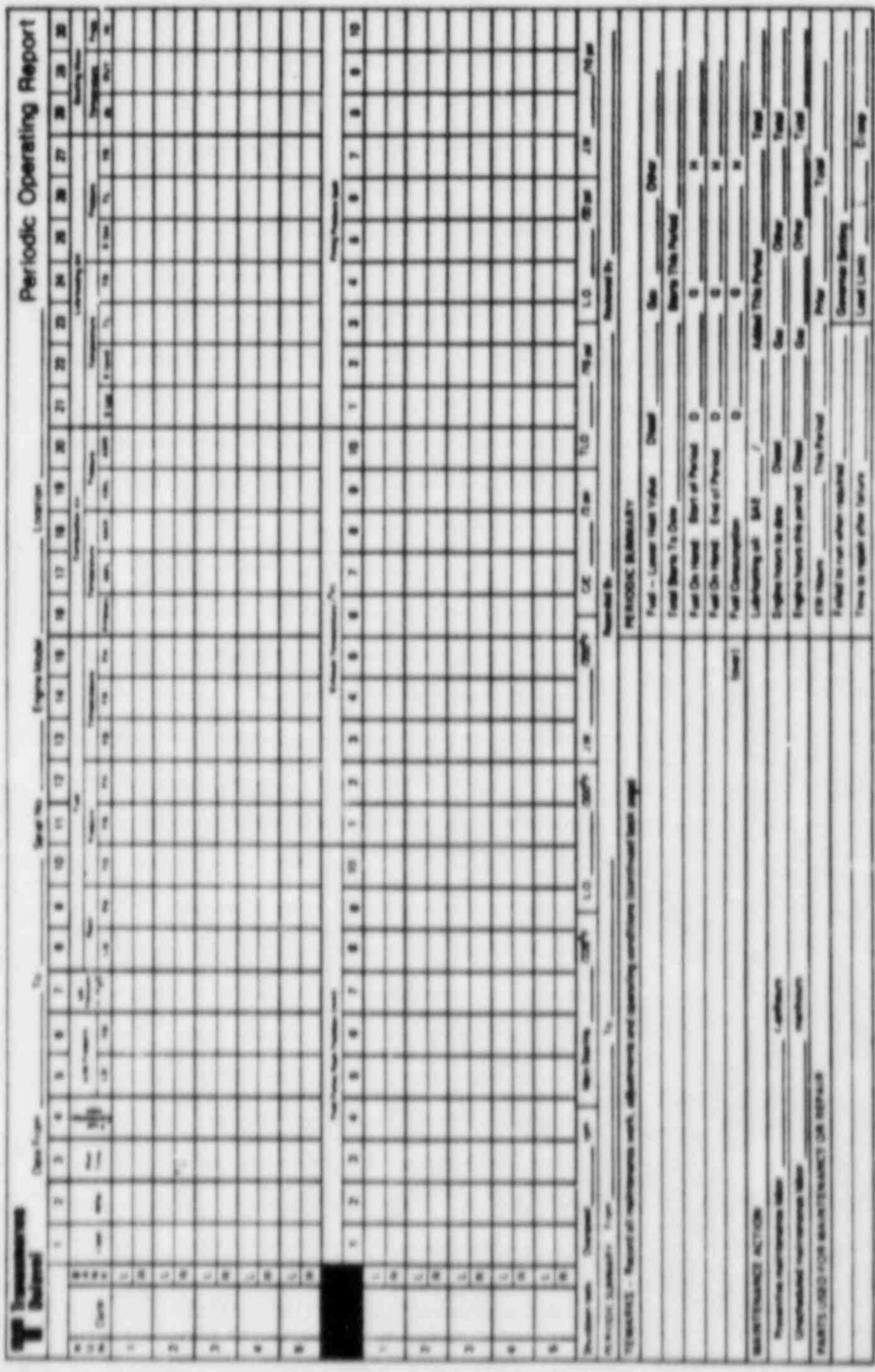

Figure 5-A-2. Periodic Operating Report, Form E-277

PART B — SUGGESTED MAINTENANCE SCHEDULES

GENERAL.

The maintenance schedules outlined on the following pages are those recommended as an acceptable means for maintaining the engine in peak operating condition. Operating experience and the particular needs of the owner may indicate the need for additional inspections. Inspection intervals used are considered to be generally ideal, but operating experience must be used to decide the ultimate suitability of the suggested schedules. Where experience indicates more frequent inspection of a particular part or system is needed, the time interval between inspections should be shortened.

MAINTENANCE SCHEDULES.

Unless otherwise stated on the Inspection Guides, the following inspection intervals are recommended for use.

a. DAILY — Operations which are to be performed on a daily basis, independent of engine operating hours.

b. WEEKLY — Operations which are to be performed weekly, regardless of engine operating hours.

c. MONTHLY/EXERCISE TEST — Operations which should be performed each time the unit undergoes its periodic exercise test, but in no case less frequently than once a month.

d. ANNUAL/EACH PLANT SHUTDOWN — Inspections that should be performed on an annual basis, or at plant shutdown for reactor refueling. The interval may be adjusted to meet plant shutdown schedules.

e. BI-ANNUAL/ALTERNATE PLANT SHUTDOWNS — To be performed at alternate reactor refueling shutdowns, or bi-annually.

f. FIVE YEARS — To be performed at the nearest plant shutdown period prior to a five year interval.

INSPECTIONS GUIDES.

The recommended maintenance actions are listed on Inspection Guides, divided into inspection intervals. The guides are further separated by component groups such as the diesel engine, electrical components, auxiliary equipment, etc. References are provided to direct the user to the sources of information needed to assist in performing the maintenance actions. In addition to those maintenance actions listed on the individual guides, all external parts of the engine should be frequently felt by hand, particularly during the first few hundred hours of operation, to detect any excessive temperatures on heads and crankcase side covers.

PART B — SUGGESTED MAINTENANCE SCHEDULES (Continued)

INSPECTION GUIDE	Frequency: DAILY
Component Group: Diesel Engine	
Special Conditions: Unit in STANDBY	
Item	**Reference**
Observe and record lubricating oil and jacket water temperatures (Keep warm pumps running)	
Drain all low point water collectors, "Y" strainers and air receiver tanks in starting air system.	Instruction Manual, Section 6, Part I
Check engine and auxiliary equipment for oil, water and fuel oil leaks.	
Check level of lubricating oil in sump tank. Add oil as needed.	Instruction Manual, Section 6, Part K
Check level of lubricating oil in governor and pedestal bearing. Add oil as needed.	Associated Publications Manual
Check fuel oil pump rack for freedom of movement through full limit of travel. Do not disconnect from governor.	See assembly drawings in Parts Manual
Check turbocharger bearing lubricating system sight glass for oil flow.	Instruction Manual, Section 6, Part K
Drain water from crankcase vent piping drip legs.	
Verify all controls in proper position for standby.	Instruction Manual, Section 4
Check all governor knob settings: Load: Maximum Droop: Mid-point Speed: To provide mechanical governor control at 470 rpm	Associated Publications Manual

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PART B — SUGGESTED MAINTENANCE SCHEDULES (Continued)

INSPECTION GUIDE	Frequency: WEEKLY
Component Group: Diesel Engine	
Special Conditions: None	
Item	**Reference**
Turn on electrical fuel oil booster pump for a short time and circulate fuel through system. Check strainers for clean fuel.	

PART B — SUGGESTED MAINTENANCE SCHEDULES (Continued)

INSPECTION GUIDE	Frequency: MONTHLY or EACH EXERCISE TEST
Component Group: Diesel Engine	
Special Conditions: MONTHLY, or each test, whichever comes first	
Item	**Reference**
Clean and inspect "Y" strainers in starting air system.	Instruction Manual, Section 6, Part I
Check lubricating oil filter pressure differential. If 15 psi or more, clean or replace element.	Associated Publications Manual
Inspect and clean air filter in starting air distributor.	Associated Publications Manual
Drain water and/or sludge from lubricating oil full flow filter.	Associated Publications Manual
If differential pressure indicates (15 psi or greater), clean or replace strainer screens in fuel oil and lubricating oil pressure strainers.	Associated Publications Manual
Check lubricating oil with a viscosimeter for fuel oil dilution. Send a sample of oil to laboratory for analysis.	Instruction Manual, Section 6, Part K Section 8, Appendix VI
Check pH factor of jacket water. Correct as recommended by chemical supplier. Recommended pH is 8.25 or 9.75.	Instruction Manual, Sec. 6, Part J
Check air butterfly valve(s) in intake manifold for freedom of movement. Lubricate as necessary with automotive type wheel bearing grease. Check may be done manually by disconnecting linkage, or by applying 60 psi air to the actuating cylinder.	Inst. Manual, Sec. 6, Part L
Check tube and shell sides of intercoolers and heat exchangers.	Associated Publications Manual
Record all operating parameters. Compare with baseline data to insure engine is operating properly.	

PART B — SUGGESTED MAINTENANCE SCHEDULES (Continued)

INSPECTION GUIDE	Frequency: ANNUAL/EACH PLANT SHUTDOWN
Component Group: Diesel Engine	
Special Conditions: Annual or each shutdown, whichever comes first	
Item	**Reference**
Drain lubricating oil system. Refill with new oil	Inst. Manual, Sec. 6, Part K, Section 8, Appendix VI
Remove alternate left side doors and examine inside of engine for any abnormal condition. Check with a good light for evidence of babbitt flakes. If excessive water or sludge is present, drain crankcase. Determine cause and take necessary corrective action.	
Check valve lash. (If equipped with hydraulic valve lifters, perform leak down test, reinstall and adjust).	Instruction Manual data sheet, and Section 6, Part B
Remove fuel injector nozzles, clean, reset and reinstall.	Instruction Manual, Sect. 6, Part F Asso. Publications Manual — Bendix
Check connecting rod and link rod bearing clearances.	Instruction Manual, Section 6, Part C and Section 8, Appendix III
Visually inspect foundation for breaks in bond between sole plates and grout.	
Check foundation bolts for correct torque. Retorque as necessary. Check and record crankshaft web deflections.	Instruction Manual, Section 6, Part D and Section 2
Check lubricating oil jets for plugged or broken lines.	
Remove cam covers and cylinder head covers. Inspect cams, tappets, rollers, rocker arms, push rods and springs.	Inst. Manual, Sec. 6, Parts B & E
Drain governor oil. Clean and flush, then refill with new oil. Replace governor drive coupling element.	Instruction Manual, Sec. 6, Part K Asso. Publications Manual - Woodward
Check cold compression pressures and maximum firing pressures. If so indicated, remove cylinder heads, grind valves and reseat. Check rings and liners.	Inst. Manual, Sec. 6, Parts B & C
Remove end plates from heat exchangers and intercoolers. Examine and clean as necessary.	Associated Publications Manual
Inspect intake air filter, and service as recommended by manufacturer.	Associated Publications Manual

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PART B — SUGGESTED MAINTENANCE SCHEDULES (Continued)

INSPECTION GUIDE	Frequency: BI-ANNUAL/ALTERNATE PLANT SHUTDOWNS
Component Group: Diesel Engine	
Special Conditions: Whichever frequency point comes first.	
Item	**Reference**
Inspect gears for general condition. Check backlash and replace worn gears exceeding maximum clearance.	Instr. Manual, Sec. 8, Appendix III
Remove fuel injection pumps. Disassemble, clean, repair and adjust as necessary.	Instruction Manual, Sec. 8, Part F and Asso. Publications Manual, Bendix instructions
Check main bearing shell thickness.	Inst. Manual, Sec. 6, Part D and Section 8, Appendix VI
Inspect main bearing crank journals.	Instruction Manual, Sec. 6, Part D, Section 8, Appendix III
Check crankshaft bearings and idler gear bushings.	Inst. Manual, Sec. 6, Part E, Section 8, Appendix III

PART B — SUGGESTED MAINTENANCE SCHEDULES (Continued)

INSPECTION GUIDE	Frequency: EVERY FIVE YEARS
Component Group: Diesel Engine	
Special Conditions: Nearest plant shutdown to five year point.	
Item	**Reference**
Remove turbocharger(s). Disassemble, clean, inspect, repair and reassemble.	Associated Publications Manual, manufacturer's instructions.

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PART C – PRESERVATION AND STORAGE

PREPARATION FOR SHIPMENT AND/OR STORAGE.

The diesel engine/generator set is prepared for shipment in conformance with contractural requirements, and consistent with the provisions of ANSI N45.2.2-1978, ***"Packaging, Shipping, Receiving, Storage and Handling of Items For Nuclear Power Plants (During The Construction Stage Phase)."*** The degree of preservation will depend upon customer requirements, and the anticipated term of storage. Unless otherwise provided for by contractural arrangement, the following preservation methods and requirements are the normal standard for Transamerica Delaval Inc.

PRESERVATION MATERIALS.

In addition to the tapes, barrier materials, desiccants etc. specified in Section 3 of ANSI N45.2.2-1978, two preservation materials are normally used. These are Tectyl 502-C and Tectyl 890, both manufactured by, and available from Ashland Petroleum Company. The characteristics of these two preservatives are as follows.

a. Tectyl 502-C (U.S. Government specification MIL-C-16173, Grade II, and MIL-P-116G preservative type P-2) is a soft, amber, transparent film preservative which may be applied by spraying, dipping or brushing. It provides extended undercover or indoor protection for the interior or exterior surfaces of machinery, instruments, bearings, etc., and provides limited periods of outdoor protection where metal temperatures do not produce a flow of the film. It may be removed with petroleum solvent, lubricating oil, hot alkali wash, or with a vapor degreaser. Tectyl 502-C should provide adequate protection for six months outdoors, and for 18 months when indoors, or interior surfaces which are sealed off from the elements.

b. Tectyl 890 (U.S. Government specification MIL-C-16173, Grade I, and MIL-P-116G preservative type P-1 is a firm, black, opaque film preservative which may be applied by spraying, dipping or brushing. It provides for preservation of items stored indoors or outdoors, with or without cover where a firm film is required. It may be removed with petroleum solvents, or with a vapor degreaser. Tectyl 890 will provide protection for up to 30 months when outdoors, and in excess of five years when stored indoors, or under cover.

DESICCANTS.

When the use of a desiccant is specified, a silica gel type product such as PROTEK-SORB 121 manufactured by Davison Chemical Division, W.R. Grace & Co. is normally used for this type protection. PROTEK-SORB 121 silica gel is a pure, chemically inert amorphous silica. The action is purely physical, with no change in size or shape of the particles as they become saturated. Even when saturated, the material looks and feels perfectly dry. Desiccants are packaged by "units" rather than by weight, a unit being defined as that weight of desiccant which will absorb at least three grams of water vapor at 20% relative humidity, and at least six grams of water vapor at 40% relative humidity at a temperature of 25°C. Silica gel can be regenerated in a vented oven, following the manufacturer's instructions. Although silica gel provides no visible indications as to the condition of the gel, humidity indicators, or TEL-TALE indicating gel may be used for this purpose. These indicators will gradually change color from a deep blue towards a pale pink as the gel becomes saturated with water vapor.

GENERAL PRESERVATION PROCEDURES.

The following depicts the general procedures used prior to shipment for the preservation of diesel engines and, when appropriate, other appurtances furnished by Transamerica Delaval, Engine and Compressor Division, and for the maintenance of this preservation protection during storage.

a. With the engine running, disconnect the fuel line ahead of engine fuel booster pump and allow the engine to burn about five to ten gallons of pure tectyl 502-C before shutting down. Cap fuel line to engine.

b. Seal all openings to the interior of the engine.

c. Remove fuel injectors and spray Tectyl 502-C inside the combustion chamber, coating the cylinder liners, piston crowns, and cylinder head faces. Replace injectors.

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PART C – PRESERVATION AND STORAGE (Continued)

d. Plug all openings to each fuel pump. Disconnect the drain line and pump Tectyl 502-C through the connection until Tectyl is observed leaking past the fuel rack. The pump is then reversed and all excess Tectyl removed.

e. Drain jacket water and cooling water systems, especially the water pump, thermostatic valves and intercoolers.

f. Remove cylinder head covers and coat all areas inside sub-cover with Tectyl 502-C. Replace covers.

g. Remove cam gallery side doors and thoroughly coat the entire camshaft and housing with Tectyl 502-C. Replace doors.

h. Remove cover plates and inspection doors on gearcase covers. Coat gears with Tectyl 502-C. Replace cover plates and doors.

i. Remove engine side doors and spray all accessible machined interior surfaces within the crankcase with Tectyl 502-C. Replace side doors.

j. Remove upper half of rear oil seal and spray Tectyl 502-C on the shaft and throughout the area. Reinstall upper half of rear oil seal.

k. Carefully examine all gaskets and equipment removed from engine for damage prior to reinstallation. Replace all gaskets that show signs of damage.

l. Wrap rear crankshaft oil seal with duct tape.

m. Coat all machined and unpainted surfaces on the exterior of the engine with Tectyl 890.

n. Fill governor to top with oil. Any good 40 weight automotive type oil will be sufficient.

o. Check that all openings to interior of engine are closed. Replace all covers, plates, blind flanges, etc. that were removed.

LONG TERM STORAGE.

In addition to those procedures outlined in the previous paragraphs, the following procedures can be used prior to shipment of diesel engines and their appurtenances to prepare them for long term (six months or longer) storage. Although each of these procedures is strongly recommended, they must be specified by contract if they are to be performed by Transamerica Delaval.

a. Remove liquid filled gauges from the engine and store them separately to protect them from accidental breakage or damage.

b. Place one 80-unit bag of desiccant per cylinder on a 1 x 3 inch board in the bottom of the crankcase. A blank plate with a tapped hole should be bolted over the crankcase vent opening and a probe type humidity indicator installed in the tapped hole.

c. Place one 80-unit bag of desiccant at either end of the intake manifold. One 16-unit bag of desiccant should be placed within the intake port of each cylinder head and either taped in place, or secured to some kind of wooden block.

d. Place one 4-unit bag under each cylinder head cover.

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PART C – PRESERVATION AND STORAGE (Continued)

e. Grease all gaskets on both sides during reassembly, and bolt all surfaces tightly together.

f. Remove all lines from fuel pumps and injectors. Wrap in plastic bags together with desiccant and tape closed. Store in a box. Cap all injector and pump openings. Tape a 4-unit bag to each pump, staple an indicator to each bag of desiccant and wrap the pump in a plastic bag. Tape shut with duct tape. Make sure all fuel racks and linkages are thoroughly greased, or coated with Tectyl 502-C.

g. The barring device, air distributors, air solenoid valves, governor and overspeed trip should each have a 4-unit bag of desiccant taped to it, together with an indicator and then wrapped in plastic and sealed with duct tape.

h. Each junction box on the engine should have a 4-unit bag of desiccant placed inside and the cover sealed with duct tape.

i. One 16-unit bag of desiccant should be placed within the turbocharger(s) outlet port. Seal all turbocharger openings with blind flanges and duct tape.

j. Highly visible warning placards should be placed on each piece of equipment, or at each access to areas which contain desiccant to warn of the presence of the desiccant, and to serve as a reminder to remove the desiccant before the engine is started.

LEVELS OF STORAGE.

If the engine and associated equipment is to be placed in storage prior to installation, the preservation procedures applied prior to the shipment must be maintained. For long term storage (six months or longer), the following levels of storage, as defined by ANSI N45.2.2-1978 are recommended.

a. Level B – Storage within a fire resistent, tear resistent, weathertight and well ventilated building, or equivalent enclosure, not subject to flooding and with a paved or otherwise surfaced floor with good drainage. Items should be placed on pallets or shoring to permit air circulation. Temperature control and uniform heating to prevent condensation and corrosion, and to provide temperatures between the ranges of 40°F minimum to 140°F maximum. The following types of equipment provided by Transamerica Delaval should be stored in Level B facilities.

1. Motor control centers.
2. Generators.
3. Switchgear.
4. Control Panels.
5. Air filters.

b. Level C – All provisions and requirements of Level B except for heat and temperature control.

1. Engines and attached equipment.
2. Pumps and Valves.
3. Auxiliary skids.
4. Lubricating oil filters and strainers.

c. Transamerica Delaval recommends that items listed for Level C storage have heat and temperature control as well.

Information concerning storage levels extracted from American National Standard Packing, Shipping, Receiving, Storage and Handling of Items for Nuclear Power Plants (During the Construction Phase) ANSI N24.2.2-1978, with the permission of the publisher, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, NY 10017.

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PART C – PRESERVATION AND STORAGE (Continued)

RECEIVING INSPECTION.

A visual examination of the engine and other equipment should be made before off-loading to determine if any damage was incurred during shipment. This inspection should be made in accordance with ANSI N45.2.2-1978. Thefollowing areas of inspection should be conducted.

a. Fire – Charred wood, paper or paint, indicating exposure to fire or extremely high temperatures.

b. Excessive exposure – Weatherbeaten, frayed, rusted, or stained containers indicating prolonged exposure during transit.

c. Environmental damage – Water or oil marks, damp conditions, dirty areas, or salt film (indicating exposure to sea water or winter road salt chemicals).

d. Tiedown failure – Shifted, broken, loose or twisted shipping ties, and worn material under ties, indicating improper blocking and tiedown during shipment.

e. Rough handling – Splintered, torn or crushed containers indicating improper handling. Review of impact recording instrument readings.

f. Item inspection – Unless the package marking prohibits unpacking, the contents of all shipments should be visually inspected to verify that the specified packaging and shipping requirements have been complied with. When items are contained in transparent, separate moisture proof bags or envelopes, a visual inspection without unpacking is preferred. Statistical sampling methods may be used for groups of similar items. Care shall be taken to avoid contamination of the items during inspection. The inspections shall be performed in an area equivalent to the level of storage required for the item. These inspections are examinations shall include the following, as appropriate.

1. Identification and Marking: Verification that identification and markings are in accordance with applicable codes, specifications, purchase orders, drawings, and these instructions.

2. Complete Shipments: Verify that the contents match packing lists. If there are discrepancies, contact Transamerica Delaval, Engine and Compressor Division, Customer Service Department immediately.

3. Manufacturing Documentation: Assurance that the document certifying that the item received was fabricated, tested and inspected prior to shipment in accordance with applicable code, specification, purchase order and/or drawings is included in shipment if applicable.

4. Protective Covers and Seals: Visual inspection to assure that covers and seals are secure.

5. Coatings and Preservatives: Verification that coatings and preservatives are applied in accordance with specifications, purchase orders or manufacturer's instructions.

6. Inert Gas Blanket: Verification that the inert gas blanket pressure is within the acceptable limits, if used.

7. Desiccant: Verification that the desiccant is not saturated, determined by the use of humidity indicators. Desiccants shall be regenerated or replaced as necessary in accordance with manufacturer's instructions.

8. Physical Damage: Visual inspection to assure that parts of items are not broken, cracked, missing, deformed or misaligned and rotating parts turn without binding. Accessible internal and external areas shall be free of detrimental gouges, dents, scratches and burns.

PART C – PRESERVATION AND STORAGE (Continued)

9. Cleanliness: Visual inspection to assure that accessible internal and external areas are within the specification requirements for dirt, soil, mill scale, weld splatter, oil, grease, or stains. Inspection for cleanliness is performed prior to sealing and shipping, therefore, if receiving inspection indicates that there has been no penetration of the sealed boundry, then inspection for internal cleanliness is optional.

g. Conformance Inspection – Unless the completed item was inspected or examined at the source, it should be inspected or examined at the point of receiving to verify that the following characteristics conform to the specified requirements. These inspections or examinations should include such items as the following:

1. Physical Properties: Nondestructive examination to assure that physical properties conform to the specified requirements and the chemical and physical test reports, if required, meet the requirements.

2. Dimensions: Random visual inspection to assure that important dimensions conform with drawings and specifications. Examples: Base plate mounting holes, overall external size, configuration and orientation of parts.

3. Weld Preparations: Random verification that weld preparations are in accordance with applicable drawings and specifications.

4. Workmanship: Visual inspection of accessible areas to assure that the workmanship is satisfactory to meet the intent of the requirements.

5. Lubricants and Oils: Verification of presence of proper lubricants and oils, if required, by either specification, purchase order or manufacturer's instructions.

6. Electrical Insulation: Performance of insulation resistence tests for motors, generators, control and power cable, to ensure conformance with specifications.

h. Special Inspection – Where receiving inspection in addition to that described above is required, the "Special Inspection" procedure, complete with documentation instructions, shall be attached to the item or container, this is in addition to the inspection, and the results of the inspection shall be documented.

ON-SITE PREPARATION FOR STORAGE.

If the engine and other components are to be placed in storage prior to installation, the engine should be offloaded and moved to its storage location. Place engine onto Tectyl coated hardwood blocks. The mounting flanges must be supported by 50% of their area, equally spaced. The engine should be completely covered by a tarpaulin, and the tarpaulin securely fastened to the skid. If the storage is to be long term, the preservation procedures applied prior to the shipment must be maintained. The engine should be stored in the level of storage specified in preceeding paragraphs.

STORAGE INSPECTIONS.

Six month inspections of the unit should be conducted to the following criteria, witnessed by a Transamerica Delaval service representative (upon receipt of a purchase order), or documented by a formal report by the owner's inspector.

a. Do not rotate the engine.

b. Examine all engine cover plates for tightness and sealing ability. Do not open the engine unless it is absolutely necessary.

c. Examine gaskets for any covers removed and replaced if any damage exists.

d. Examine all humidity indicators for 60% saturation. Replace or regenerate the saturated silica gel as necessary. If the interior of the engine is exposed for any reason, reapply Tectyl as needed.

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PART C – PRESERVATION AND STORAGE (Continued)

e. Inspect the hardwood supports for any indication of settling. If settling has occurred during storage, supports should be replaced or adjusted as necessary.

f. Examine intake manifolds and turbocharger(s) for deterioration. Clean and preserve as necessary.

g. Replace tarpaulins and secure.

RECOATING OF PRESERVED SURFACES.

In view of the finite life of the preservative material, it is recommended that the surfaces be recoated as follows during the term of storage.

a. Every six months, or less if inspection indicates need, all outside surfaces of the engine which have been coated with Tectyl 502-C should be recoated.

b. Every 18 months all interior surfaces of the engine and other equipment must be recoated.

c. Every 30 months all exterior surfaces which were coated with Tectyl 890 should be recoated.

GENERATOR.

Large, one bearing generators are shipped disassembled, and are preserved for shipment and storage by the manufacturer. In addition to those requirements specified for engines and associated equipment, the following conditions apply to all generators. Additional requirements may be specified by the manufacturer.

a. Inspect Shipment – Inspect stator, rotor and bearing pedestal to determine condition as received. Damage to skid timbers is evidence of humping or rough handling. Damage to tarpaulins and plastic covers could expose equipment to moisture. Inspect leads and accessories. Check bearing and shaft surface for moisture and rust. Inspect stator and rotor windings and test insulation resistance, a low value indicating presence of moisture or contaminant on coils. If generator is shipped as a sealed unit, do not open for inspection unless there is evidence of external damage to the packing.

b. Insulation Resistance – Take insulation resistance tests on stator and rotor windings every three to six months. Take a one minute reading with a 500 volt megger. Recommended minimum values are: $\frac{\text{Generator volts} + 1}{1000}$ = x megohm on stator and one megohm on rotor. A dry, clean winding will test much higher. A more thorough test of insulation is to continue megger test for one to 10 minutes. The 10 minute reading should be much higher than the one minute reading. For dryout procedure, refer to generator instruction manual. This paragraph applies only if generator is not completely sealed.

c. Storage – Should be in a Level B storage facility as defined by ANSI N45.2.2-1978.

d. Bearing and Shaft – Pedestal bearing should be stored in a clean, dry area and covered or boxed. The sleeve bearing surface is greased or coated with Tectyl for shipment. For long term storage, a desiccant placed inside the covering is recommended.

CAUTION

Some desiccants may be corrosive on contact.

Level C storage is recommended. Bearing and pedestal parts should be inspected after the first month and every three months thereafter. They should be cleaned and regreased if necessary. Unpainted surfaces on bearing housings should be kept covered with grease or Tectyl 502-C. Unpainted parts of the shafts are covered with a rust preventitive such as Cosmoline, or with Tectyl 502-C, and should be inspected every three months. If bearings and shafts are not assembled, then set both parts on a block of wood, preserve with Tectyl 502-C and cover.

e. All generator equipment must be inspected at six month intervals by the manufacturer's service representative. The windings must be megged at this time, and accurate reports sent to Transamerica Delaval, and to the manufacturer of the generator.

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PART D — INSPECTION AND MAINTENANCE RECORDS

GENERAL.

In addition to operating records, and any other record which may be kept by the owner or operator, it is recommended that a permanent record be kept of essential inspection and maintenance observations. A series of "Inspection and Maintenance Record" forms, Transamerica Form E-267 (Figures 5-D-1 through 5-D-16) are available for this purpose. These are used by Customer Service Representatives to record clearances, torques, and other vital inspection observations and conditions. These records will be of great value in the future planning of maintenance and overhaul requirements, and to assess the wear trends and performance characteristics of the engine.

INSTRUCTIONS FOR USE.

To be of value in helping to determine both present and future repair and replacement needs, it is essential that all information be accurately recorded. The following should be observed when using the forms.

a. Torque values should be recorded in foot pounds (ft-lbs) unless otherwise noted.

b. Clearances should be recorded in thousandths of an inch, i.e. 4=0.004 in.; 2=0.002 in.; 25=0.025 in.; 1.2=1.002 in.; 1.25=1.025 in., etc. If other than inches is used, specify on each sheet the unit of measurement used.

c. Where significant, dial indicator readings should be recorded as + or - (plus or minus). A reading not so specified will be assumed to be a plus (+) reading.

d. The heading of each form is filled out as follows.

1. Component Group Title: Pre-printed with name of major component which is covered by that sheet.

2. Parts Group No.: The three digit parts group number to which the component group belongs, and in which it may be found in the *Parts Manual*.

3. Sheet: The identity of the record within a parts group.

4. Page: The page number for a particular parts group/sheet.

5. Customer: Fill in name of owner/operator of equipment.

6. Equipment Location: Physical location of equipment, specified by name, position number, or other descriptive term which may be appropriate to clearly identify the location.

7. Engine Model: Complete model as appearing on nameplate.

8. Serial Number: The number appearing on the engine nameplate. Usually consists of a five digit group, a dash and a four digit group.

9. Customer's designation: When an owner or operator has a specified designation for the engine within his system which serves to identify it to him, enter this designation.

10. Total Engine Hours: Hours since first startup.

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PART D —INSPECTION AND MAINTENANCE RECORDS (Continued)

11. Hours Since Last Inspection: The time between the present Total Engine Hours reading and the last inspection.

12. Date This Inspection: Self explanatory.

13. References: Preprinted. Indicates sources of instructions that should be used in conjunction with the inspection being performed.

e. Ensure that the proper designation is entered on all sheets where the position of the component being inspected serves to identify it. For instance, a separate sheet is needed for each bearing, each cylinder head, each piston and rod, etc. Identify these items.

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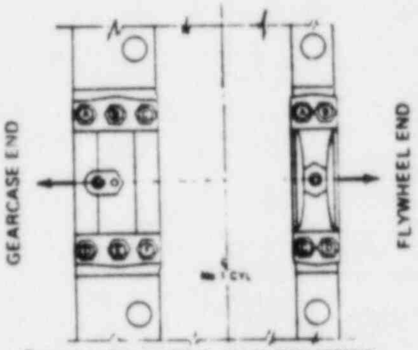
Transamerica Delaval

Inspection and Maintenance Record

Component Group Title: MAIN BEARING CAPS – Model RV Engines		Parts Group No. 305	Sheet 2	Page 1
Customer		Equipment Location		
Engine Model	Serial No.	Customer's Designation		
Total Engine Hours	Hours Since Last Inspection	Date This Inspection		
References: Instruction Manual, Section 6, Part D		Data Recorded By		

MAIN BEARING BOLT ELONGATION, or TORQUE APPLIED WITH A TORQUE WRENCH. [If torque multiplier used with torque wrench, record multiplier ratio]



Torque to be applied in a criss cross pattern
See engine nameplate for correct torque value

DISASSEMBLY

	Record elongation in thousandths of an inch, or torque in foot pounds. Bearing caps numbered starting from gearcase end.											
	1	2	3	4	5	6	7	8	9	10	11	12
A												
B												
C												
D												
E												
F												

ASSEMBLY

	Record elongation in thousandths of an inch, or torque in foot pounds. Bearing caps numbered starting from gearcase end.											
	1	2	3	4	5	6	7	8	9	10	11	12
A												
B												
C												
D												
E												
F												

305-2-1

Figure 5-D-1. Main Bearing Caps

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Transamerica Delaval

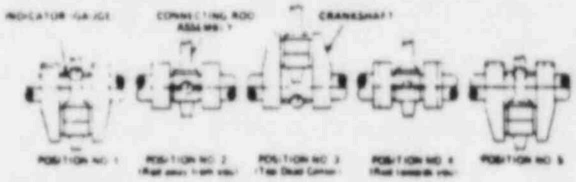
Inspection and Maintenance Record

Component Group Title: CRANKSHAFT – Web Deflection and Thrust Clearance		Parts Group No: 310	Sheet: 1	Page: 1
Customer		Equipment Location		
Engine Model	Serial No	Customer's Designation		
Total Engine Hours	Hours Since Last Inspection	Date This Inspection		
References: Instruction Manual, Section 6, Part D		Data Recorded By		

Measure with a dial indicator while engine is hot, i.e., within 4 hours of shutdown. Record oil temperature in sump tank or engine base, as appropriate. If connecting shaft is solidly coupled to flywheel and engine is grouted on a concrete foundation, desired deflection in position No. 3 is zero to plus (+) one thousandth of an inch in all cranks except the one adjacent to the flywheel. This should be minus 0.0005 inch to allow for distortion of the foundation. If mounted on a steel foundation, compensation for thermal distortion will be based on location and temperatures of fuel and oil tanks adjacent to foundation.

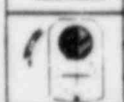
If deflection in any crank exceeds 0.003 inch, corrective action must be taken. Also, if total deflection in any two adjacent cranks exceeds 0.003 inch corrective action must be taken. Example: A +0.002 in. reading in any crank with a -0.002 in. in the next adjacent crank equals a total of 0.004 in. deflection between these adjacent cranks. The exception will be in the case of engines with a flexible coupling between the flywheel and the connecting shaft which have deflection in excess of 0.003 in. at Postion 3 in the crank adjacent to the flywheel. In engines with solidly coupled shafting, excessive deflection at Positions 2, 3 or 4 in the crank adjacent to the external shafting usually indicates misalignment between connecting shaft and crankshaft.

Set deflection gauge at zero at Position 1, and turn crankshaft in direction of normal rotation. Position 1 for placing deflection gauge is 15° after bottom center for all inline engines, and 52° after vertical bottom center for V-type engines. Models HV, HVA and GVB engines are positioned 38° after vertical bottom center.



DATE	SUMP TANK TEMP	THRUST CLEAR	SIGNATURE

Record readings in plus (+) or minus (-) thousandths of an inch.
Example: +0.003 in. write as +3. Write - 0.002 in. as -2, etc.

POSITION	CYLINDER NUMBER STARTING AT GEARCASE END										DATE
	1	2	3	4	5	6	7	8	9	10	
											
											
											
											
											

310-1-1

Figure 5-D-2. Crankshaft Web Deflections

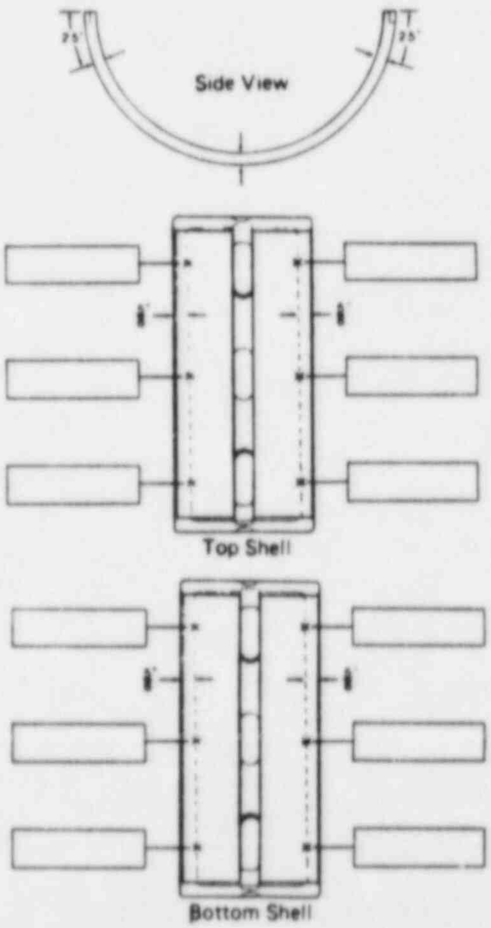
AX4AK01-509-1

Transamerica Delaval

Inspection and Maintenance Record

Component Group Title		Parts Group No.	Sheet	Page
MAIN BEARING SHELLS		310	2	1
Customer		Equipment Location		
Engine Model	Serial No.	Customer's Designation		
Total Engine Hours	Hours Since Last Inspection	Date This Inspection		
References: Instruction Manual, Section 6, Part D		Data Recorded By		

Bearing Shell Position ______________



Record manufacturer's data as it appears on bearing shell.

Upper Shell
Lower Shell

Measure each bearing shell in six positions (marked "X" on drawings to the left), and record measurements in boxes by each measurement position. Use a ball micrometer.

Sketch bearing surface conditions—note any abnormalities.

Perform non-destructive dye check on all surfaces, including sides and ends of both shells. Note results below.

Results
Remarks

Bearings reused? Yes No

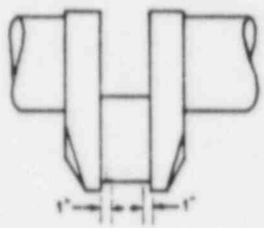
310-2-1

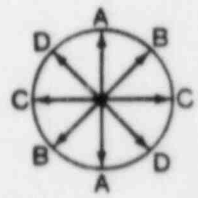
Figure 5-D-3 Main Bearing Shells

Transamerica Delaval

Inspection and Maintenance Record

Component Group Title		Parts Group No.	Sheet	Page
CRANKSHAFT		310	3	1
Customer		Equipment Location		
Engine Model	Serial No.	Customer's Designation		
Total Engine Hours	Hours Since Last Inspection	Date This Inspection		
References: INSTRUCTION MANUAL, SECTION 6, PART D		Date Recorded By		





Measure inside diameter of crank journals, one inch in from web at either end (flywheel end and gearcase end). Measure four different diameters (A–A, B–B, C–C and D–D) at each location. Record measurements in spaces below.

Journal No.	Flywheel End				Gearcase End			
	A–A	B–B	C–C	D–D	A–A	B–B	C–C	D–D
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

310 3 1

Figure 5-D-4. Crankshaft

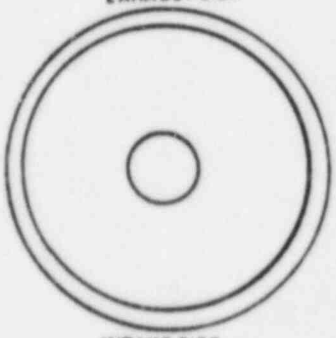
Transamerica Delaval

Inspection and Maintenance Record

Component Group Title: CYLINDER LINERS		Parts Group No.: 315	Sheet: 1 · Page: 1
Customer		Equipment Location	
Engine Model	Serial No.	Customer's Designation	
Total Engine Hours	Hours Since Last Inspection	Date The Inspection	
References: Instruction Manual, Section 6, Part C		Date Recorded By	

Cylinder No./Bank ____________

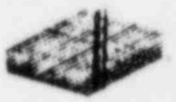
EXHAUST SIDE



INTAKE SIDE

Indicate blemishes on interior surface of cylinder liner as seen from above.

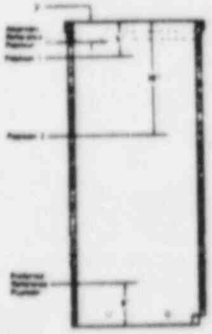
NORMAL CROSSHATCH



SCRATCHES – Long narrow grooves usually caused by foreign material. Crosshatch pattern runs through.

SCUFFING – Caused by piston and/or rings. Can start below oil ring and run up through upper compression ring travel area. Crosshatch pattern cannot be seen.

BRIGHT SPOT – Bearing through crosshatch. Can appear anywhere. Probable cause: Heavy bearing by buildup above top ring land.



DIRECTIONS FOR TAKING MICROMETER READINGS

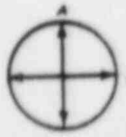
1. Establish reference measurement and record. If piston is out of liner, or if liner is removed from block, use PREFERRED REFERENCE POSITION. If piston is installed in liner, use ALTERNATE REFERENCE POSITION. Take two readings, 90 degrees apart (A and B).
2. Take readings at Position 1 and record.
3. Take readings at Position 2 and record.

	Before Honing		After Honing	
	A	B	A	B
Ref				
1				
2				

Method of honing employed (i.e., glaze breaker/grit Sunnen hone/stone grit)

Remarks

A



B

A = Inboard (exhaust) side
B = Flywheel End

315-1-1

Figure 5-D-5. Inspection and Maintenance Record, Cylinder Liners

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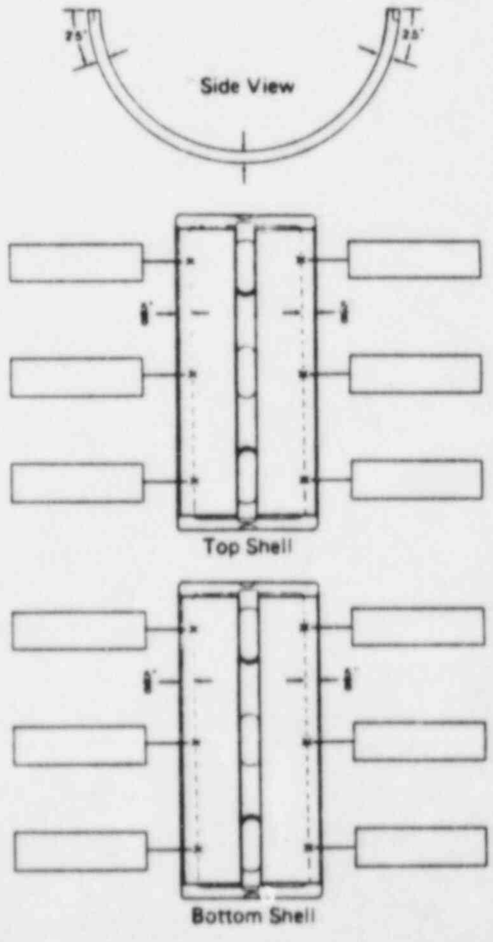
Transamerica Delaval

Inspection and Maintenance Record

Component Group Title		Parts Group No.	Sheet	Page
CONNECTING ROD BEARING SHELLS		340	1	1
Customer		Equipment Location		
Engine Model	Serial No	Customer's Designation		
Total Engine Hours	Hours Since Last Inspection	Date This Inspection		
References: Instruction Manual, Section 6, Part C		Data Recorded By		

Bearing Shell Position ______________



Record manufacturer's data as it appears on bearing shell

Upper Shell
Lower Shell

Measure each bearing shell in six positions (marked "X" on drawings to the left), and record measurements in boxes by each measurement position. Use a ball micrometer.

Sketch bearing surface conditions—note any abnormalities.

Perform non-destructive dye check on all surfaces, including sides and ends of both shells. Note results below.

Results
Remarks

Bearings reused? Yes No

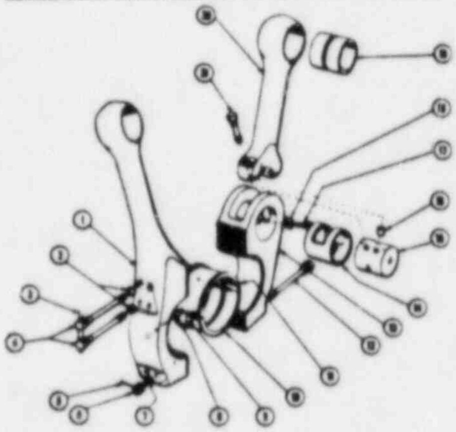
340-1-1

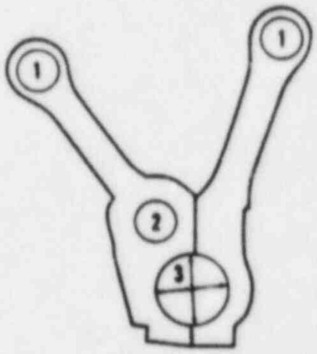
Figure 5-D-6 Inspection and Maintenance Record, Connecting Rod Bearing Shells

Transamerica Delaval — Inspection and Maintenance Record

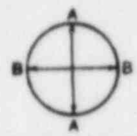
Component Group Title: CONNECTING ROD — Model RV-3 & RV-4 Engine		Parts Group No: 340	Sheet: 2	Page: 1
Customer		Equipment Location		
Engine Model	Serial No	Customer's Designation		
Total Engine Hours	Hours Since Last Inspection	Date This Inspection		
References: Instruction Manual, Section 6, Part C		Data Recorded By		

CYLINDER ________

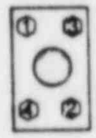




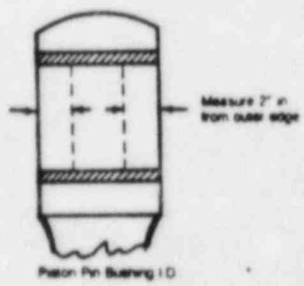
Measurement Locations



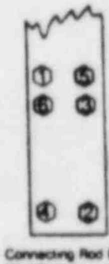
Measurement Planes


Link Rod to Pin Bolt Identification and Tightening Sequence

1. MASTER ROD
2. WASHER
3. LOCKWIRE
4. CONNECTING ROD BOLTS — HEX HEAD
5. COTTER PIN
6. SLOTTED HEAD NUTS
7. WASHER
8. CONNECTING ROD BEARING SHELL DOWEL
9. BEARING SHELL RETAINER RING
10. LOWER CONNECTING ROD BEARING SHELL
11. UPPER CONNECTING ROD BEARING SHELL
12. CONNECTING ROD TO BOX BOLT
13. CONNECTING ROD BOX
14. CONNECTING ROD BOX BUSHING
15. LINK PIN
16. LINK ROD TO PIN DOWEL
17. BOX BUSHING LOCK PIN
18. LOCKING CLIP
19. PISTON PIN BUSHING
20. LINK ROD
21. LINK ROD TO PIN BOLT



Piston Pin Bushing I.D.


Connecting Rod Bolts Identification and Tightening Sequence

Piston Pin Bushings

Measure inside diameter of link rod piston pin bushing with micrometer. Measure in vertical (A-A) and horizontal (B-B) planes 90° apart. Measure on both ends (gearcase and flywheel), two inches from end of bushing. Take same measurements on master rod piston pin bushing.

Step 1	Link Rod		Master Rod	
	A—A	B—B	A—A	B—B
Gearcase End				
Flywheel End				

340-1-1

Figure 5-D-7. Inspection and Maintenance Record, Connecting Rod

AX4AK01-509-1

Transamerica Delaval

Inspection and Maintenance Record

Component Group Title	Parts Group No.	Sheet	Page
CONNECTING ROD – Model RV-3 & RV-4 Engine	340	2	2

Link Pin and Bushings

Measure inside diameter of link pin bushing with micrometer. Take measurements in vertical (A-A) and horizontal (B-B) planes, 90° apart. Measure on both ends (gearcase and flywheel), one inch from end of bushing. Measure outside diameter of link pin with micrometer. Measure on both ends, one inch in from end of pin in both vertical (A-A) and horizontal (B-B) planes.

Step 2	Link Pin Bushing I.D		Link Pin Bushing O.D	
	A–A	B–B	A–A	B–B
Gearcase End				
Flywheel End				

Connecting Rod Bearing Bore

Reassemble connecting rod box to measure for out-of-round conditions at connecting rod bearing bore. Do not install bearings. Torque nuts to full torque value as shown in Instruction Manual. Measure connecting rod bearing bore inside diameter on both ends, one inch in from outer edges. Measure in vertical (A-A) and horizontal (B-B) planes. Take measurement (A-A) one fourth inch in on opposite sides of split line as shown on sketch.

Step 3	Connecting Rod Bearing Bore I.D	
	A–A	B–B
Gearcase End		
Flywheel End		

Non-Destructive Tests

Perform non-destructive test such as dye check on connecting rod box and all fasteners. Record results below.

Step 4	

Bolt Torques

Record disassembly (breakaway) and assembly torques for connecting rod and link rod bolts. Identify bolts by number (see illustration). Torque bolts in sequence shown, applying torque in 20% lifts until final torque is reached. Refer to Instruction Manual for correct torque values.

Step 5A	Link Rod To Pin Bolt Torque (ft-lbs)			
	1	2	3	4
Disassembly				
Assembly				

Step 5B	Connecting Rod to Box & Connecting Rod Hex Head Bolts Torque (ft-lbs)					
	1	2	3	4	5	6
Disassembly						
Assembly						

340 2 2

Figure 5-D-7. Inspection and Maintenance Record, Connecting Rod (Continued)

AX4AK01-509-1

Transamerica Delaval

Inspection and Maintenance Record

Component Group Title: PISTONS – Two Piece		Parts Group No.: 341	Sheet: 1	Page: 1
Customer		Equipment Location		
Engine Model	Serial No	Customer's Designation		
Total Engine Hours	Hours Since Last Inspection	Date This Inspection		
References: Instruction Manual, Section 6, Part C		Date Recorded By		

Cylinder No./Bank

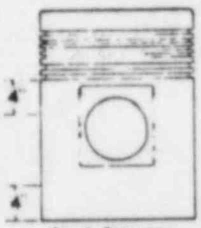


Fig. A Side View

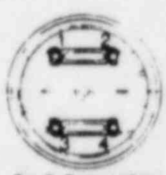


Fig. B Bottom View

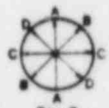


Fig. C

Fig. D

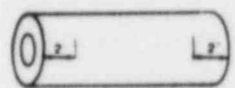


Fig. E Piston Pin

1. Measure piston skirt Outside Diameter and record dimensions below. Measure at two locations, 4 in. below bottom ring groove and 4 in. above bottom of skirt (see Fig. A). Measure four positions (A-A, B-B, C-C, D-D) in each location (see Fig. C).

Position	A-A	B-B	C-C	D-D
Upper				
Lower				

2. Measure piston pin Outside Diameter at two locations, 2 in. from each end (see Fig. E). Measure two positions (A-A, B-B) in each location (Fig. D).

Position	A	B
Forward End		
Aft End		

3. Measure piston pin bore in piston in two positions (A-A, B-B) in each end of bore (see Fig. D).

Position	A	B
Forward End		
Aft End		

4. Record disassembly (breakaway) torque and assembly torque of piston crown stud nuts (see Fig. B).

Position	1	2	3	4
Disassembly				
Assembly				

5. Note condition of O-ring, piston pin plug and general condition of piston.

341-1-1

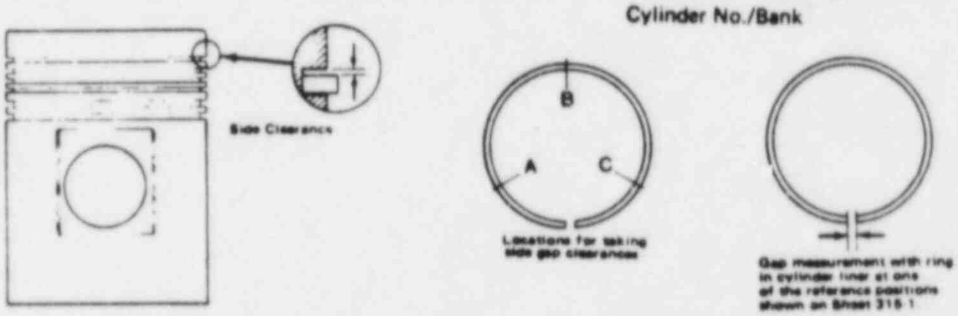
Figure 5-D-8 Inspection and Maintenance Record, Piston — Two Piece

Transamerica Delaval

Inspection and Maintenance Record

Component Group Title		Parts Group No.	Sheet	Page
PISTON RINGS		341	2	1
Customer		Equipment Location		
Engine Model	Serial No.	Customer's Designation		
Total Engine Hours	Hours Since Last Inspection	Date This Inspection		
References: Instruction Manual, Section 6, Part C		Data Recorded By		

Cylinder No./Bank



1. Measure piston ring side clearance in groove with feeler gauge. Measure each ring in three locations, 120 degrees apart. Record results below.
2. Remove rings from piston for cleaning and measurement of end gap clearance. Refer to Instruction Manual and Inspection and Maintenance Record Sheet 315-1 for the proper procedure. Record gap and percent ring face contact.
3. If new rings are installed, note reasons in "Remarks" below.
4. If new rings are installed, record end gap and side clearance in grooves.

	Old (Removed) Rings					New (Replacement) Rings			
	Side Clearance			End Gap	% Face Contact	Side Clearance			End Gap
Ring	A	B	C			A	B	C	
1 Top Compression									
2 Top Compression									
3 Intermediate Compression									
4 Intermediate Compression									
5 Oil Control									
6 Oil Control									

Remarks

341-2-1

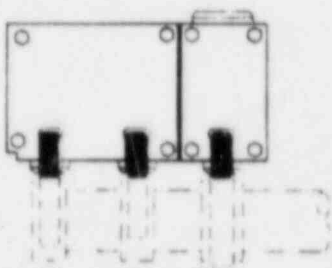
Figure 5-D-9 Inspection and Maintenance Record, Piston Rings

Transamerica Delaval

Inspection and Maintenance Record

Component Group Title: CAMS and TAPPET ASSEMBLIES		Parts Group No: 345	Sheet: 1	Page: 1
Customer		Equipment Location		
Engine Model	Serial No	Customer's Designation		
Total Engine Hours	Hours Since Last Inspection	Date This Inspection		
References: Instruction Manual, Section 6, Part E		Data Recorded By		

Remarks



CAM LOBE CONDITION (Number 1 cylinder at gearcase end)

1R			2R			3R			4R			5R			6R			7R			8R			9R			10R		
IN	EX	FUEL	IN	EX	FUEL	IN	EX	FUEL	IN	EX	FUEL	IN	EX	FUEL	IN	EX	FUEL	IN	EX	FUEL	IN	EX	FUEL	IN	EX	FUEL	IN	EX	FUEL
1L			2L			3L			4L			5L			6L			7L			8L			9L			10L		
CODE X=Intact, C=Chipped, K=Cracked, O=Other (indicate in remarks)																													

TAPPET ROLLER CONDITION (Number 1 cylinder at gearcase end)

1R			2R			3R			4R			5R			6R			7R			8R			9R			10R		
IN	EX	FUEL	IN	EX	FUEL	IN	EX	FUEL	IN	EX	FUEL	IN	EX	FUEL	IN	EX	FUEL	IN	EX	FUEL	IN	EX	FUEL	IN	EX	FUEL	IN	EX	FUEL
1L			2L			3L			4L			5L			6L			7L			8L			9L			10L		
CODE X=Intact, C=Chipped, K=Cracked, G=Galled, O=Other (indicate in remarks)																													

TAPPET ROLLER PIN CONDITION (As indicated using a dial indicator)

1R			2R			3R			4R			5R			6R			7R			8R			9R			10R		
IN	EX	FUEL	IN	EX	FUEL	IN	EX	FUEL	IN	EX	FUEL	IN	EX	FUEL	IN	EX	FUEL	IN	EX	FUEL	IN	EX	FUEL	IN	EX	FUEL	IN	EX	FUEL
1L			2L			3L			4L			5L			6L			7L			8L			9L			10L		
CODE Record measurements in thousandths of an inch, i.e., write 0.004 as 4, 0.025 as 25, etc.																													

345-1-1

Figure 5-D-10. Inspection and Maintenance Record, Cams and Tappet Assemblies

AX4AKU1-509-1

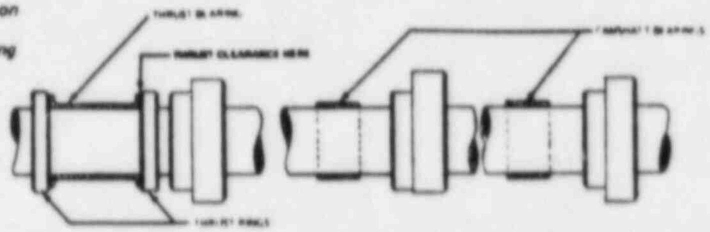
Transamerica Delaval

Inspection and Maintenance Record

Component Group Title	Parts Group No.	Sheet	Page
CAMSHAFT BEARING SHELLS – Model RV Engine	350	1	1

Customer		Equipment Location
Engine Model	Serial No.	Customer's Designation
Total Engine Hours	Hours Since Last Inspection	Date This Inspection
References Instruction Manual, Section 6, Part E		Data Recorded By

For purposes of recording information on this form, bearings are numbered in sequence, starting with the thrust bearing at the gearcase end and proceeding towards the flywheel end.



THRUST CLEARANCE

Move camshaft all the way aft with a bar then measure thrust clearance with a feeler gauge between camshaft thrust collar and thrust bearing.

Bank	Clearance
Left	
Right	

BEARING CLEARANCE/THICKNESS

Measure bearing shell to camshaft clearance with a feeler gauge, or bearing shell thickness with a micrometer. Indicate method used and record in appropriate spaces below.

☐ BEARING-TO-CAMSHAFT CLEARANCE – Feeler Gauge

	1	2	3	4	5	6	7	8	9	10
Left Bank										
Right Bank										

☐ BEARING SHELL THICKNESS – Micrometer

	1	2	3	4	5	6	7	8	9	10
Left Bank										
Right Bank										

Remarks:

350-1-1

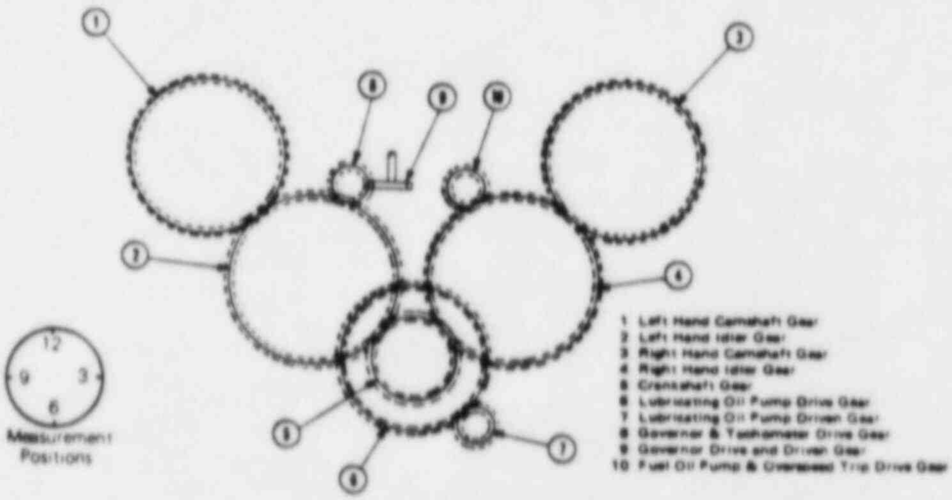
Figure 5-D-11. Inspection and Maintenance Record, Camshaft Bearing Shells

AX4AK01-509-1

Transamerica Delaval

Inspection and Maintenance Record

Component Group Title: GEARSET – Model RV Engine		Parts Group No: 355	Sheet: 1	Page: 1
Customer		Equipment Location		
Engine Model	Serial No	Customer's Designation		
Total Engine Hours	Hours Since Last Inspection	Date This Inspection		
Reference: Instruction Manual, Section 6, Part E & Section 8, Page 4A		Data Recorded By		



Unload valve train by loosening rocker arms, and by lifting fuel tappets and inserting pins through tappet housings to hold them off the fuel cams. Mark each gear in four positions, 90 degrees apart (3, 6, 9, 12 o'clock – see illustration).

Select gear pair to be measured (see table below). Mount a magnetic base dial indicator with its stem resting on the side of the gear listed in the "Rotated" column. Rotate gear to remove all slack. Zero indicator, then rotate gear in opposite direction to remove all slack. *Do Not Move Stationary Gear!* Record backlash in appropriate space on table.

Rotate gear to next three position, recording backlash in each position. Measure backlash in four positions in each gear pair listed on table.

Inspect lubricating oil spray lines. Insure good spray pattern is obtained at all gear meshes.

Gear Pair		Backlash – Thousandths of an Inch			
Rotated	Stationary	3 O'Clock	6 O'Clock	9 O'Clock	12 O'Clock
1	2				
3	4				
2	5				
4	5				
7	6				
8	2				
9	8				
10	4				

Form E 261 8/80 355-1-1

Figure 5-D-12 Inspection and Maintenance Record, Gearset

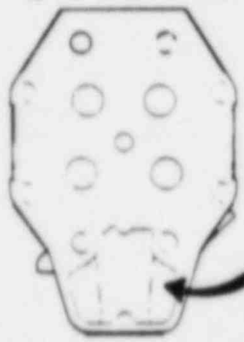
AX4AKC1-5C9-1

Transamerica Delaval

Inspection and Maintenance Record

Component Group Title: CYLINDER HEAD – Four Valve		Parts Group No: 360	Sheet: 1	Page: 1
Customer		Equipment Location		
Engine Model	Serial No	Customer's Designation		
Total Engine Hours	Hours Since Last Inspection	Date This Inspection		
References: Instruction Manual, Section 6, Part B		Data Recorded By		

Top View of Cylinder Head

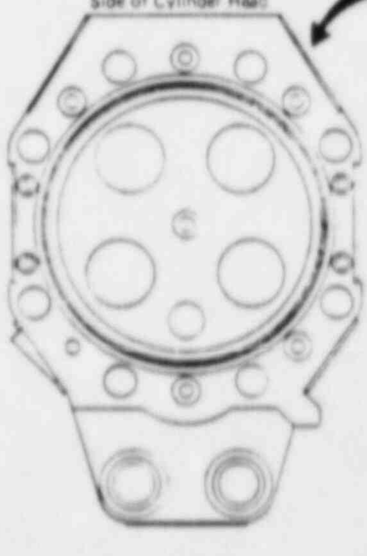


Cylinder No./Bank

Record all identification numbers and letters appearing in this location

Identification Numbers

Combustion Chamber Side of Cylinder Head



Use diagram at left to sketch any abnormalities appearing on the cylinder head combustion surfaces and valve seats. Record comments relative to condition of cylinder head in spaces below.

Combustion Surfaces

Valve Seat Condition

Gasket Surfaces

Other (specify)

360 1 1

Figure 5-D-13 Inspection and Maintenance Record, Cylinder Head

AX4AK01-509-1

Transamerica Delaval

Inspection and Maintenance Record

Component Group Title		Parts Group No.	Sheet	Page
INTAKE and EXHAUST VALVES		360	2	1
Customer		Equipment Location		
Engine Model	Serial No.	Customer's Designation		
Total Engine Hours	Hours Since Last Inspection	Date This Inspection		
References: Instruction Manual, Section 6, Part B		Data Recorded By		

Cylinder No./Bank

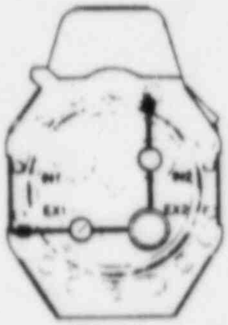


Figure 1

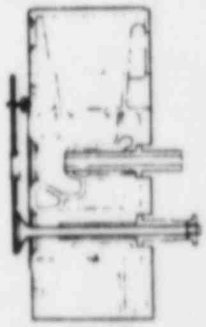


Figure 2

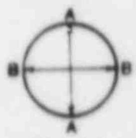


Figure 3

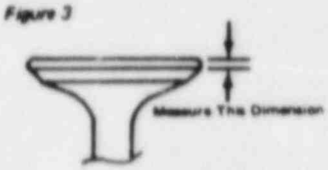


Figure 4

Valve-To-Guide Clearance

Measure by noting deflection on valve head while rocking valve in its guide. Remove wedges, retainers (or rotators) and springs. Lay cylinder head on its side with valve axis in the horizontal plane. Leave a wedge on valve stem and push valve out until stopped by wedge hitting guide (see Figure 2).

Position a dial indicator as shown in Figures 1 and 2 so that spindle of indicator is bearing against side of valve head on the A–A axis (see Figure 3). Zero the indicator, then apply sufficient pressure by hand at a point diametrically opposite the spindle to move the valve in the guide. Record this deflection. Repeat the process in the B–B axis and record all readings in the space provided below. See Figure 1 for valve identification (EX-1, IN-1, etc.).

Axis/Valve	EX-1	EX-2	IN-1	IN-2
A–A				
B–B				

Valve Head Thickness

Measure valve head thickness (Figure 4) with a micrometer and record in space below.

Valve	EX-1	EX-2	IN-1	IN-2
Thickness				

General Inspection

Inspect valve for general condition and not all abnormalities or other significant information below.

Form E 201 6/80 360 2 1

Figure 5-D-14 Inspection and Maintenance Record Intake and Exhaust Valves

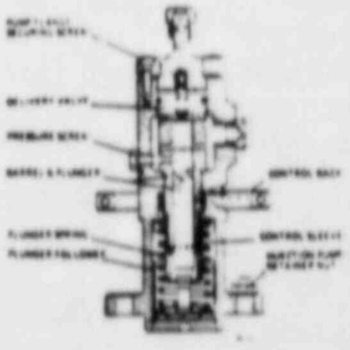
AX4AK01-5C5 1

Transamerica Delaval

Inspection and Maintenance Record

Component Group Title		Parts Group No.	Sheet	Page
FUEL INJECTION PUMP		365	1	1
Customer:		Equipment Location		
Engine Model:	Serial No.	Customer's Designation		
Total Engine Hours	Hours Since Last Inspection	Date This Inspection		
References: Instruction Manual, Section 6, Part F; Associated Publications Manual, see "Bendix"		Data Recorded By		

Cylinder Number	Cylinder Bank	Pump Serial Number (on pump nameplate)	Reason For Inspection	Injector Pump Retainer Nut Torque (ft lbs)	Pump Flange Securing Screw Torque (ft lbs)	Pressure Screw Wear Depth	Delivery Valve	Barrel and Plunger	Plunger Follower	Plunger Spring	Control Rack	Control Sleeve	Timing Set?	Shim Thickness (As left)
1	L													
	R													
2	L													
	R													
3	L													
	R													
4	L													
	R													
5	L													
	R													
6	L													
	R													
7	L													
	R													
8	L													
	R													
9	L													
	R													
10	L													
	R													
Refer to notes as indicated for codes to be used for entering data in columns			Note 1	X	X	Note 2	Note 3						Note 4	X



NOTES

1. R= Routine
   A= Abnormality
2. Measure with depth micrometer
   Max. wear depth 0.020 in.
3. X= Intact
   O= Overhauled
   R= Replaced
4. Y= Yes
   N= No
5. After inspection & maintenance is completed, adjust all fuel pump racks to 3.5 mm.

REMARKS

Form E 267 6/80 365-1-1

Figure 5-D-15 Inspection and Maintenance Record, Fuel Injection Pump

AX4AV01-5 1

Transamerica Delaval

Inspection and Maintenance Record

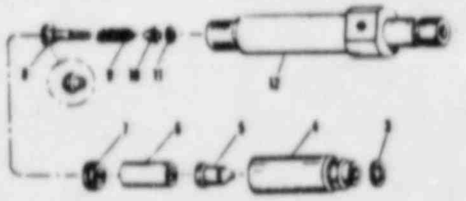
Component Group Title: FUEL INJECTION NOZZLE and HOLDER		Parts Group No. 365	Sheet 2	Page 1
Customer		Equipment Location		
Engine Model	Serial No	Customer's Designation		
Total Engine Hours	Hours Since Last Inspection	Date This Inspection		
References: Instruction Manual, Section 6, Part F; Associated Publications Manual, see "Bendix"		Date Recorded By		

INSPECTION DATA — OVERHAUL DATA

*Indicate parts reworked or replaced by recording the key number of the part as shown on exploded view of nozzle on bottom of page

Cylinder Number	Cylinder Bank	Reason For Inspection	Retainer Nut Torque (ft-lbs)	Pop Test Opening Pressure	Dribble?	Spray Tip	Disposition	Reworked*	Replaced*	Remarks
1	L									
	R									
2	L									
	R									
3	L									
	R									
4	L									
	R									
5	L									
	R									
6	L									
	R									
7	L									
	R									
8	L									
	R									
9	L									
	R									
10	L									
	R									
X		Note 1	X	X	Note 2	Note 3	Note 4			

NOTES
1. R= Routine, A= Abnormality
2. Y= Yes, N= No
3. I= Intact, R= Replaced
4. A= Installed, B= Overhauled, C= Replaced



3 Gasket
4 Assembly Nut
5 Spray Tip
6 Nozzle Valve Assy
7 Stop Plate
8 Spring Guide
9 Nozzle Spring
10 Spring Seat
11 Shim
12 Body

Other Comments

Figure 5-D-16 Inspection and Maintenance Record, Fuel Injection Nozzle and Holder

AX44K01-509-1

Section 6
Overhaul &
Repair

SECTION 6

OVERHAUL AND REPAIR

PART A – GENERAL

ROTATION AND CYLINDER DESIGNATION.

Crankshaft rotation and cylinder bank designations are determined while viewing the engine from the flywheel end. Number one cylinder on each bank is that nearest the gearcase, or auxiliary end, on the opposite end of the engine from the flywheel (see figure 6-A-1). Engines are designated as either right hand or left hand according to the side of the engine on which the controls are mounted.

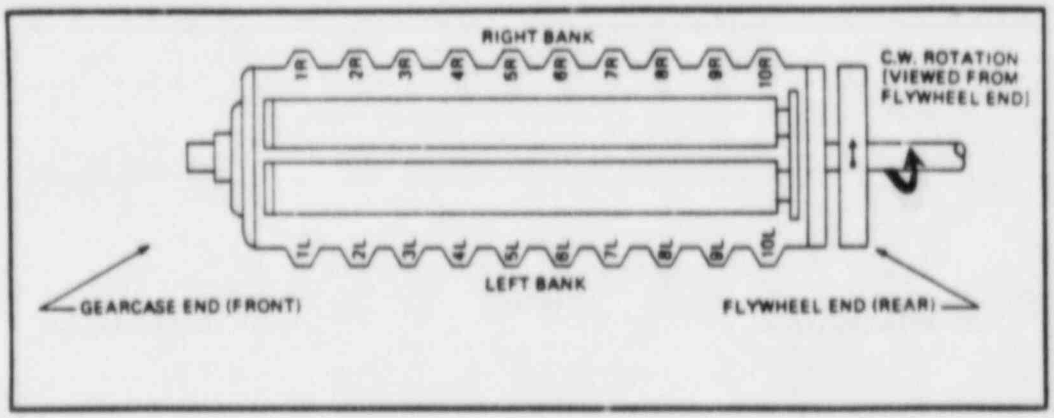


Figure 6-A-1. Engine Rotation and Cylinder Designation

ASSEMBLY OF PARTS.

Before starting any disassembly of the engine, observe that many parts are match-marked and identified by part or assembly number. Engine parts which have been in service should be returned to the same position in the same engine from which they were removed. This applies principally to cylinder liners, pistons, connecting rods and bearing caps. New parts should be marked in the same way as the parts which they replaced. Safety clips, cotter pins and safety wire, where specified, must be re-installed correctly to insure that the parts remain secure in use.

USE OF ASSEMBLY DRAWINGS.

Reference may be made to the assembly drawings in the *Parts Manual* to assist in the disassembly and assembly of various engine components.

Note

Do not use the part numbers on these drawings for ordering replacement parts. The *Parts Manual* should always be used for this purpose.

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PART A – GENERAL (Continued)

CLEANLINESS.

Cleanliness is essential to the proper operation of an engine. Care must be exercised to keep dirt, grit, and other debris from entering any of the lubricating oil, fuel or cooling water systems as well as from the bearing surfaces of moving parts.

TORQUING.

All torque values stated in this manual, unless otherwise specified, are based on the use of a thread lubricant composed of equal parts by volume of engine lubricating oil and Dixon number two medium powdered flake graphite, or equal. They do not apply to dry threads, or to threads lubricated with so-called "Super Lubricants". Dry threads can result in torque readings as much as fifty percent in error. The following procedure should be used when torquing fasteners.

a. Lubricate threads with a mixture of oil and graphite and assemble threads. Tighten hand tight.

b. Tighten all fasteners by snugging the first one, then moving to the one farthest removed and continue in a criss-cross pattern until all fasteners are snug.

c. Unless otherwise specified, apply 20 percent of the required torque to each fastener in the sequence described above, then repeat procedure in increments of 40, 60, 80 and 100 percent of the prescribed torque value.

d. Active nuts which are secured with cotter pins must be brought to the specified torque value before attempting to align the cotter pin holes. If the hole in the bolt is halfway between the slots in the nut, or beyond, the nut should be tightened to make alignment. If the hole is short of the halfway points, nuts on bolts larger than one inch in diameter may be backed off to the nearest point where it will align.

TORQUE TABLES.

Refer to the Torque Tables, Appendix IV, Page 8-5 to find the torque value to be used when tightening fasteners on the engine. The tables are divided into two parts, the first being for those fasteners for which specific torque value has been assigned. The second part contains general torque values for use when no special torque value is assigned. Because of their size, location and high torque requirements, main bearing cap studs are pre-stressed when the stud nuts are installed, rather than being torqued with a wrench. This is accomplished by stretching the studs with a hydraulic tool, then tightening the stud nuts. When the tool is removed, the stress in the stud provides the clamping force to hold the stud nut in place.

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(R 2) 4 81

PART A – GENERAL (Continued)

ADHESIVES AND SEALANTS.

The Ashland Oil Company produces a series of useful adhesives and sealants under the trade name "Locktite". Transamerica Delaval recommends the use of these products, and in certain instances specifies their use. Most Locktite adhesives are anaerobic, that is, they cure or set when denied oxygen. They utilize oxygen to keep the adhesive in a liquid state while in its container, and during application. When the parts are assembled, however, oxygen is excluded and the anaerobic resin hardens into a tough thermoset plastic. The curing mechanism, then, is a combination of contact with metal and the exclusion of oxygen. Copper and brass provide a very fast cure, whereas iron and steel provide a slightly slower rate of cure. Aluminum, cadmium and zinc platings are very slow curing. Nonmetallic surfaces do not initiate a cure, and a special Locktite primer must be used. The following paragraphs and tables are provided to assist maintenance personnel in selecting the best sealants or adhesives for a particular job. It should be noted that in some instances a specific product is recommended for a specific use. For additional information, it is suggested that the product manufacturer be consulted, or that inquiries be directed to the Transamerica Delaval Customer Service Department.

a. THREADLOCKER SEALANTS – An anaerobic adhesive used to prevent a fastener from loosening, corrosion and leakage. Although not essential, the use of a primer will clean off oil, and accelerate curing.

1. Apply to thread engagement area, filling the thread root. Assemble parts.
2. For blind holes, put a few drops into the hold and onto the fastener. Assemble parts.
3. For already assembled parts, clean fastener or nut parting line. Apply Locktite 290 at the interface area and allow the capillary action to carry the adhesive into the threads.
4. Threadlocker sealants act as liquid lockwashers.

CAUTION

Do not use Locktite on any fastener for which a specific torque value is assigned, and which utilizes a lubricant consisting of a 50-50 mixture of powdered graphite and lubricating oil.

LOCKTITE PRODUCT	242	271	277	222	290
Application (Threadlocking)	Nuts, bolts & screws general purpose (medium strength)	Fasteners & studs up to 1" dia. (high strength)	Fasteners & studs over 1" dia. (high strength)	Small screws No. 8 & below (low strength)	Preassembled fasteners (med. to high strength)
Gap-filling ability, inches	.005	.007	.010	.005	.005
Viscosity (cP) mean	1000	500	6500	1000	12
Torque in/lb breakaway/prevailing	60/35	160/225	100/145	40/20	60/200
Shear strength psi	1600	2500	3800	900	1800
Temperature range °F (°C)	-65 to 300 (-55 to 149)	-65 to 300 (-55 to 149)	-65 to 300 (-55 to 149)	-65 to 300 (-55 to 149)	-65 to 400 (-55 to 204)
Cure speeds without primer Fixture/full	20 min/6 hr	20 min/½ hr	30 min/6 hr	20 min/6 hr	10 min/½ hr
Cure speeds with primer fixture/full	5 min/2 hr	5 min/½ - 1 hr	10 min/2 hr	5 min/ 2 hr	Not Required
Recommended primer	T (optional)	T (optional)	T (optional)	T (optional)	None

Table 6-A-1. Threadlocker Adhesives

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PART A – GENERAL (Continued)

b. THREAD SEALANTS – Used to stop leaks in threaded pipes and fittings.

1. Wipe threads with a clean cloth to remove any contamination.

2. Apply sealant behind leading thread, avoiding filling the first thread. Apply to only three-quarters of a thread turn. Assemble parts. Fittings will seal at any angle without heavy wrenching.

3. For pipes greater than two-inch diameter, apply sealant to both male and female thread surfaces.

4. For leaking castings, isolate leak area, heat to drive out oils, then apply Locktite 290.

5. Pipe Sealant with Teflon (PST) seals moderate pressures instantly, and is supe.ior to tape. It can be used anywhere teflon tape is used.

LOCKTITE PRODUCT	Pipe Sealant With Teflon	Hydraulic Sealant	Stainless Steel PST	290
Application (Sealing)	General purpose thread sealing	Fluid power system connections	Stainless steel & monel threaded pipe & fittings	Porosity leakage (pinhole leaks)
Gap-filling ability, inches	.020	.005	.020	.005
Viscosity (cP) Mean	200,000	400	400,000	12
Temperature range, °F (°C)	-65 to 400 (-55 to 204)	-65 to 300 (-55 to 149)	-65 to 500 (-55 to 260)	-65 to 300 (-55 to 149)
Cure speeds without primer fixture/full	24 hr/72 hr	45 min/2 hr	carbon steel: 30 min/4 hr stainless steel: 3 hr/24 hr	10 min/1-2 hr
Cure speeds with primer fixture/full	15 min/5 hr	Not Required	Stainless steel: 5 min/2 hr	Not Required
Recommended primer	NF	None	N (Optional)	None

Table 6-A-2. Thread Sealants

c. GASKETING (Anaerobic) – For sealing flanges. For gaps over 0.010 inch primer should be used. Clean contamination from flange surfaces, apply continuous bead to one surface. If primer is applied to speed the curing rate, or to cure through larger gaps, both flange surfaces should be primed. Allow one to two minutes for primer to dry, then assemble parts with minimal interface movement. Torque fasteners to metal-to-metal firmness. Allow sealant to cure before pressurizing.

LOCKTITE PRODUCT	Gasket Eliminator 515	Gasket Eliminator 510	Gasket Eliminator 504	Master Gasket	Gasket Eliminator 515	Plastic Gasket 568
Application (Gasketing)	General purpose	High Temperature	Large gaps, Instant seal	Maintenance & repair	Sealing or coating conventional gaskets	High adhesion/ structural strength
Gap-filling ability, inches unprimed/primed	.010/.050	.010/.020	.030/–	–/.050	.010/.050	.010/.020
Viscosity (cP) mean	200,000 to 500,000	700,000 to 1,200,000	1,000,000 to 2,000,000	200,000 to 500,000	200,000 to 500,000	6000 to 7000
Strength, psi shear/tensile	2000/1900	1350/2000	1300/1350	2000/1900	2000/1900	/5000
Temperature range °F (°C)	-65 to 300 (-55 to 149)	-65 to 400 (-55 to 204)	-65 to 300 (-55 to 149)	-65 to 300 (-55 to 149)	-65 to 300 (-55 to 149)	-65 to 300 (-55 to 149)
Cure speeds without primer fixture/full	1 hr/12 hr	4 hr/12 hr	30 min/12 hr	———	1 hr/12 hr	12 hr/24 hr
Cure speeds with primer fixture/full	15 min/2 hr	30 min/4 hr	Not Required	15 min/2 hr	15 min/2 hr	6 hr/12 hr
Recommended primer	N (Optional)	N (Optional)	None	Master Gasket Primer	N (Optional)	T

Table 6-A-3. Gasketing Material

00.81

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PART A – GENERAL (Continued)

d. RETAINING COMPOUNDS (Anaerobic) – Used to improve cylindrical part assembly.

1. Clean both surfaces with Locktite Safety Solvent, or equivalent.

2. If faster cure is required, or if surfaces are inactive, apply Locquic Primer T to both surfaces. Allow Primer T to visibly dry (two to five minutes) before applying retaining compound.

3. Apply retaining compound to both surfaces. If Primer T has been used, parts must be joined within four minutes after retaining compound is applied.

LOCKTITE PRODUCT	RC/601	RC/680	RC/620
Application (Retaining or Mounting Cylindrical Parts)	General purpose	High strength	High temperature
Gap-filling ability, inches	.005	.015	.015
Viscosity (cP) mean	100	2000	7000
Shear strength psi steel/alum.	3000/600	4000/600	3000/600
Temperature range °F (°C)	-65 to 300 (-55 to 149)	-65 to 300 (-55 to 149)	-65 to 450 (-55 to 232)
Cure speeds (steel) without primer fixture/full	10 min/1-6 hr	30 min/4-6 hr	30 min/8-10 hr
Cure speeds (steel) with primer fixture/full	5 min/30 min	5 min/4-6 hr	5 min/8-10 hr
Recommended primer	T (optional)	T (optional)	T (optional)

Table 6-A-4. Retaining Compounds

e. SUPERFLEX SILICONE ADHESIVE SEALANT – Forms a cured silicone rubber for use in gasketing, sealing, bonding and caulking. Clean surface with Methyl Ethyl Ketone (MEK) or Locktite Safety Solvent 755. Apply Superflex to one surface and assemble parts.

Gap-Filling Ability, Inches	Temperature Range °F (°C)	Viscosity (P) Mean	Strength psi Tensile	Cure Speed Tack/Full
.250	-95 to 400 -70 to 204	Paste	400	30 min/24 hr

Table 6-A-5. Superflex Silicone Adhesive Sealant

f. PRIMERS – Locquic Primers (more accurately, Activators) are curing agents for Locktite anaerobic adhesives and sealants.

1. Locquic Primer N assures fixture of parts within 15 to 30 minutes, and full fixture in 12 hours or less.

2. Locquic Primer T assures fixture of parts within 5 minutes, and full fixture in six hours or less.

3. Locquic Primer NF assures fixture of parts within 15-30 seconds, and full cure in four hours or less.

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PART A – GENERAL (Continued)

SAFETY PRECAUTIONS.

Personnel performing maintenance, overhaul and repair work on the engine and its associated equipment must be aware of the hazards involved in this type of work, and observe all safety precautions. In addition to those precautions listed in Section 4 for engine operation, the following are some of the areas in which safety practices are indicated.

a. Observe all specific Warnings listed in this manual for the operation being performed.

b. If, in the course of maintenance work, it becomes necessary to crank or operate the engine, those precautions listed in Section 4 should be observed.

c. When handling heavy weights, all weight handling equipment must be inspected before use.

d. Exercise extreme care to insure that the weight of all parts being handled is under complete control at all times.

e. Under no circumstances should any person extend any part of his body under any suspended heavy part.

f. When handling liquid nitrogen, or other super cold liquid, wear suitable gloves to protect the hands. Gloves should be of a type approved for protection against extremely low temperatures.

g. Crankshaft should be blocked to prevent inadvertant movement when working in the crankcase.

h. Do not exceed maximum allowable hydraulic pressure on hydrostatically operated tools and equipment.

i. Do not disconnect any pressurized line until you have determined positively that no pressure exists in the line.

j. Exercise good housekeeping practices to provide good footing on platforms, ladders and other areas around the engine and associated equipment.

k. Under no circumstances should any interlock, safety switch, or other safety device be bypassed, blocked or otherwise rendered inactive.

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COMPONENT WEIGHTS.

The component weights listed below are approximate, and are intended to assist in handling and assembly operations. Suitable weight handling equipment of sufficient weight lifting capacity must always be used when handling heavy and unwieldy parts and assemblies.

Item		Approximate Weight (lbs)
Cylinder head		1100
Piston and rings (less pin)		600
Piston pin		120
Master rod		624
Link rod and box		700
Cylinder liner		600
Cylinder head sub-cover		365
Cylinder head cover		30
Camshaft (less cams)	RV-12	675
	RV-16	750
Cams (average)		20
Main bearing caps	Front	370
	Intermediate	200
	Front rear	300
	Rear rear	300

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PART B – CYLINDER HEADS AND VALVES

CYLINDER HEAD REMOVAL.

Each cylinder head may be removed from the block independently of the other cylinder heads. The cylinder head has two intake and two exhaust valves, together with their associated springs, wedges, retainers, etc. Valve springs may be replaced with the cylinder head installed on the engine provided the piston is at top dead center to prevent the valves from falling into the cylinder. To remove a cylinder head from the engine, proceed as follows.

a. Drain jacket water from engine.

b. Remove cylinder head cover.

c. Remove air jumpers.

d. Disconnect exhaust and intake air manifolds.

e. Disconnect fuel injection lines and nozzle drain fittings.

f. Remove rocker assemblies and push rods. Remove hydraulic valve lifters if engine is so equipped.

g. Remove fuel injection nozzles and holder assemblies.

h. Remove cylinder head sub-cover.

i. Attach lifting fixture to the fuel injection studs as shown in Figure 6-B-1. Attach an overhead hoist to the lifting ring of the fixture.

j. Remove cylinder head stud nuts and washers.

Figure 6-B-1. Cylinder Head Lifting Fixture

k. Lift head from block. If head sticks it may be necessary to take a strain on the hoist and break the head loose by striking the sides with a babbitt or lead hammer.

INSPECTION.

Clean inside of combustion chamber. Bar engine over until piston is at bottom dead center and clean and inspect upper portion of cylinder bore. Clean gasket surfaces of engine block and cylinder head. Remove intake and exhaust valves. Reface and reseat as necessary, following the procedures outlined in subsequent paragraphs.

PART B – CYLINDER HEADS AND VALVES (Continued)

VALVES.

Intake and exhaust valves on diesel engines are interchangeable. When replacing valves that have been removed for grinding and seating, however, they should be returned to the same relative location as that from which they were removed.

VALVE SPRING REPLACEMENT (Cylinder Head Not Removed).

Valve springs may be replaced without removing the cylinder head from the block. Remove rocker arm assemblies and fuel injector, then bar engine over until the piston of the cylinder being worked on is at top dead center. This is important as the valves can fall into the combustion chamber if piston not at top center. Attach a valve spring compressor tool, part number 00-590-6155 (see figure 6-B-2) to the cylinder head by positioning the tool support over the fuel injector studs. Place a washer on each stud, then thread a spacer-nut on each stud to hold tool in place. Slide the adapter-retainer over the valve spring retainer (figure 6-B-3), then swing bracket to position compressing screw over adapter-retainer. Turn screw in until all slack is removed, check proper engagement of the adapter-retainer to the valve spring retainer, then continue to turn screw in, compressing the valve spring. When spring is compressed sufficiently to permit removal of the two wedges (figure 6-B-3), lift valve by its stem and remove the two wedges. Slack off on compressing screw and swing bracket arm clear. Remove valve spring retainer and valve springs. Tool can then be used to remove other valve springs on that cylinder head. Note that when tool is mounted on injector studs, all four valves are accessible without removing cylinder head sub-cover. An alternate method is to mount the tool on the starting air valve studs, however, only the intake valve springs can be removed with tool in this position. Installation is the reverse of removal.

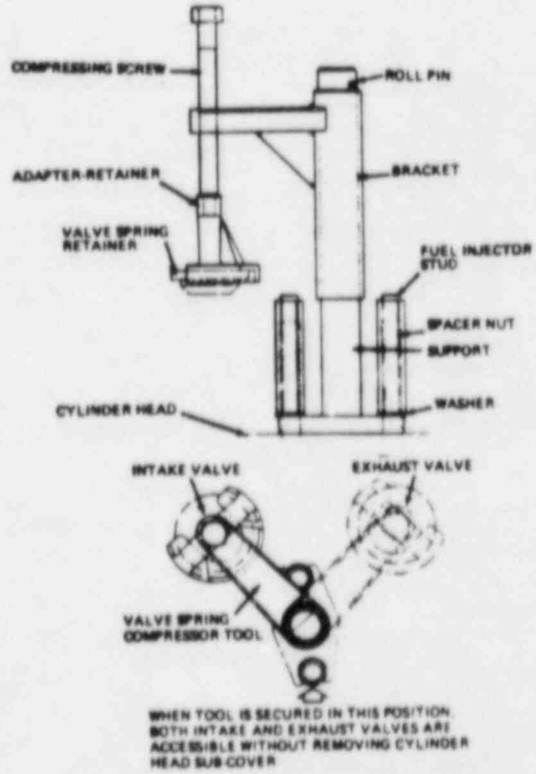

Figure 6-B-2. Valve Spring Compressor Tool

VALVE REMOVAL FROM CYLINDER HEAD.

With cylinder head removed from engine, install valve spring removal tools as shown above, and remove valve springs. Remove valves by pushing out of guides on the combustion chamber side of the head.

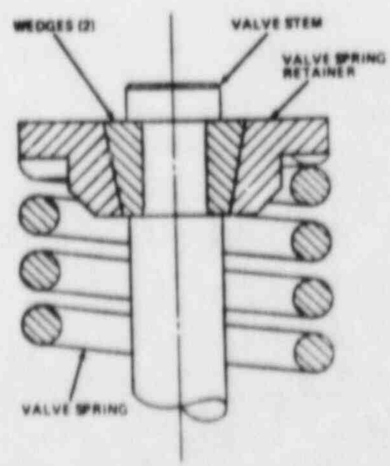

Figure 6-B-3. Valve Spring Retainer

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PART B – CYLINDER HEADS AND VALVES (Continued)

VALVE INSPECTION AND RECONDITIONING.

The seating surface of valves, particularly exhaust valves, may have the appearance of pitting due to small carbon particles which may have been trapped on the seats and impressed on the metal. This condition has no effect on operation unless there is an indication of blowby, in which case the valves should be reseated. Valves may be re-faced on a standard valve re-facing machine, or on an ordinary lathe. The seating should be exactly 45 degrees. If done on a lathe with a cutting tool, be sure to use very fine feed and a sharp tool for the final cut. If a grinding wheel is used, the wheel should be dressed for exact trueness before the final grinding cut is taken. Remove just enough material to eliminate pits and to make the seat run exactly true with the stem. If the valve guide is worn, a new guide should be installed before re-facing valve seats. Re-seat head with a valve grinder. If a grinder is not available, use a 45 degree hand reamer. Face just enough for trueness and removal of pits. Limit width of valve seat to 19/32 ± 1/64 inch (1.51 ± 0.04 cm) with a 45 degree tool. If the engine is equipped with valve rotators, the rotators must be replaced whenever the valves are serviced. Before removing intake valve guides from the cylinder head, match-mark both the cylinder head and the guide to insure proper alignment when guides are reinstalled in the heads. Remove, clean and inspect valve guides as necessary. It is not practical to measure exhaust valve-in-guide clearances directly. Therefore, wear is determined by measuring the diameter of the exhaust valve guide bore at two points, one at a point one-half inch from the top of the bore and the other two inches from the bottom of the bore. Refer to Appendix III for the proper bore diameters.

CYLINDER HEAD INSTALLATION.

Use new seals when the cylinder head is installed on the engine block. Make sure all areas are clean and free of dirt or other foreign matter.

a. Attach lifting fixture to cylinder head and hoist head in place over cylinder head studs.

b. Carefully lower head into place, taking care not to damage stud threads or seals.

c. Lubricate cylinder head studs and nut threads with a 50-50 mixture of graphite and lubricating oil. Assemble washers and nuts on studs and run down on the threads.

d. Tighten nuts in increments, and in a criss-cross pattern, following the sequence shown in figure 6-B-4. Torque to the specified torque value. This procedure will pull the head down evenly.

Figure 6-B-4. Tightening Sequence For Cylinder Head Stud Nuts.

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PART C – PISTONS AND RODS

GENERAL.

The design features of the Enterprise® Model RV engine makes it possible to remove the pistons and their attached rods by pulling them straight out through the cylinder liners. Normal procedure is to remove the link rod and piston first, then the master rod and its piston. It is possible, however, to remove either rod without having to remove the other, including its cylinder head. The procedure for removing the master rod without first removing the link rod is slightly different than if the link rod were removed. Connecting rod bearings may be removed without removing either rod and piston, and without having to remove either cylinder head.

WARNING

The procedures in the following paragraphs involve the handling of heavy and unwieldy parts in a confined space. All weight handling equipment must be inspected before use, and extreme care must be exercised to insure that the weight of the parts being handled is under complete control at all times. ***Under no circumstances should any person to extend any part of his body under any suspended part.***

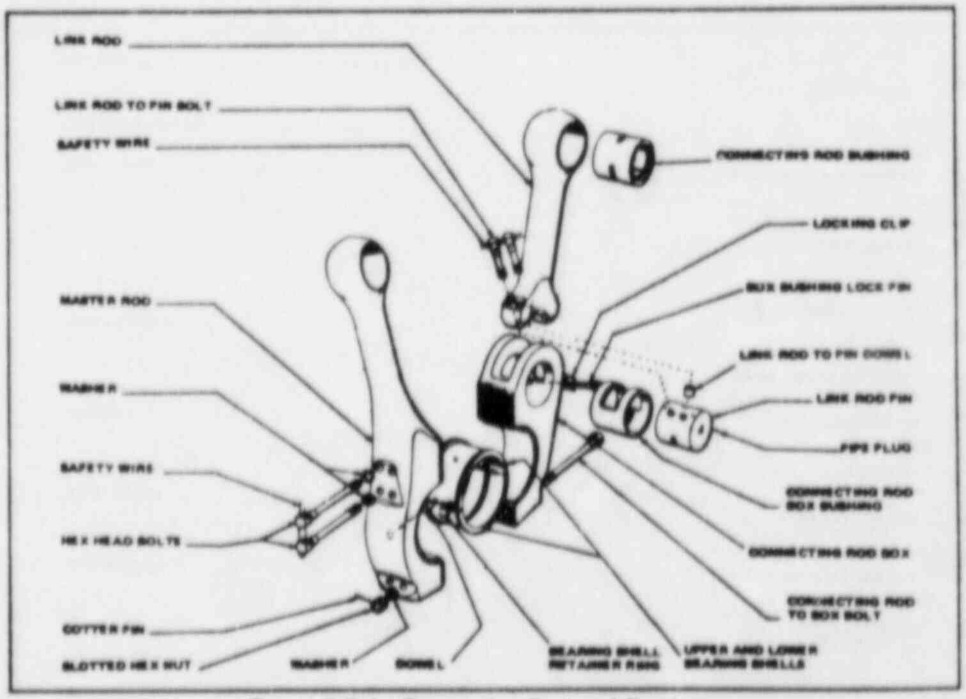

Figure 6-C-1. Connecting Rod and Bearings

PARTS LISTS.

Refer to the below listed group parts lists in the ***Parts Manual*** for a breakdown of the parts covered in this part of the manual.

a. 340 Group Parts List, Connecting Rods.

b. 341 Group Parts List, Pistons.

c. 315 Group Parts List, Cylinder Block and Liners.

d. 590 Group Parts List, Special Tools

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PART C – PISTONS AND RODS (Continued)

SPECIAL TOOLS.

The following special tools, listed in the 590 Group Parts List in the ***Parts Manual*** are required to perform the operations outlined in this part of the manual.

a. Piston Pulling Fixture, Part No. 00-590-01-OW
b. Piston Ring Guide, Part No. 18661
c. Piston Holder Spacer Rings, Part No. 00-590-01-BM
d. Chain Puller Bracket, Part No. 16103
e. Connecting Rod Saddle, Part No. 00-590-01-OS
f. Saddle Plate, Part No. 00-590-01-OT
g. Master Rod Bar Assembly, Assembly No. 1A-3036
h. Chain Puller, Part No. 15484
i. Chain Assembly, Part No. 16097
j. Locking Ring Assembly, Assembly No. 1A-1846
k. Liner O-ring Installation Ring, Part No. 02-590-01-AE

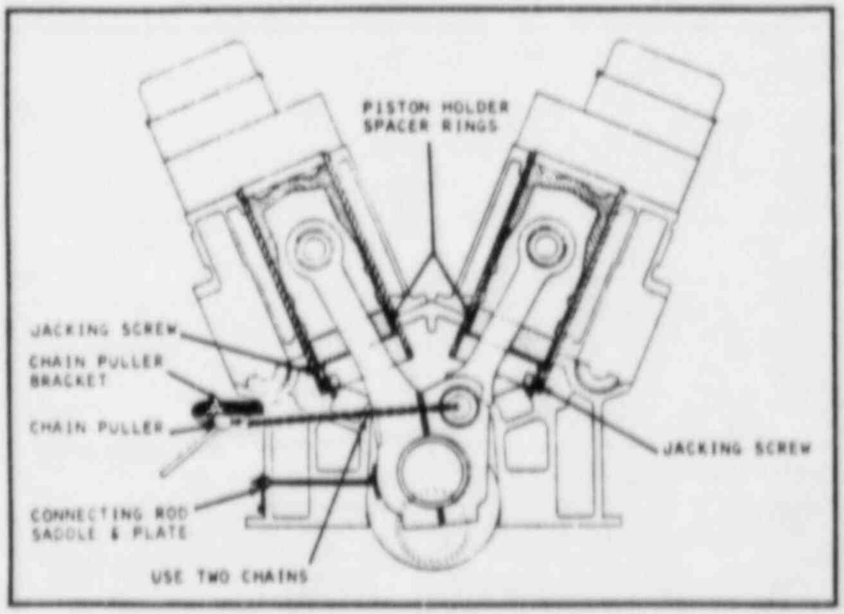

Figure 6-C-2. Bearing Replacement Tool Arrangement

REPLACING CONNECTING ROD BEARINGS (See Figure 6-C-2).

Connecting rod bearing shells may be removed for inspection and/or replacement without having to remove the pistons and rods from the engine. Special tools, positioned as shown in figure 6-C-2, are needed to accomplish the job. Remove engine side doors adjacent to the bearing to be pulled. Position crankshaft with crank at the twelve o'clock position and block crankshaft to prevent further movement. Proceed as follows.

a. Loosen four connecting rod bolts and rod-to-box bolt slightly, but do not remove.

b. Install connecting rod saddle and plate on master rod side of engine. Adjust jacking screw of tool to position saddle snug against master rod to hold rod in place against crankpin.

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PART C – PISTONS AND RODS (Continued)

c. Attach chain puller bracket to side of crankcase, then attach chain puller. Attach chains to each end of link pin with capscrews, connect other end of chains to chain puller and take up slack with chain puller as necessary to hold the link rod firmly against the crankpin.

d. Place a piston holder spacer ring in the lower end of each cylinder liner, then install two jacking assemblies in each cylinder liner and bolt in place to retain the spacer rings.

e. Adjust locking ring assembly jacking screws until spacer ring is snug against skirt of piston, holding it in place in the liner.

f. Remove connecting rod bolts and rod-to-box bolts to free connecting rod box from master rod. Slack off chain puller to allow box to swing clear of bearing shell. Adjust locking ring assembly jacking screw as necessary to prevent binding.

g. Back of on connecting rod saddle jacking screw until master rod is clear of crankpin.

h. Support lower bearing shell by hand, remove locking clips, then remove both bearing shells.

i. Inspect, clean and replace bearing shells before working on any other bearings. Only one set at a time should be removed.

j. Install bearing shells and lock in place with clips.

k. Use connecting rod saddle jacking screw to position master rod firmly against bearing shell. Locking ring assembly and jacking screws may be used to adjust vertical position of rod. It may be necessary to rotate the bearing shells slightly to help with dowel engagement.

l. Tighten chain puller and guide connecting rod box into engagement with crankpin and serrated joint of master rod.

m. Install connecting rod bolts and torque to the value specified in Appendix IV.

n. Remove all tools and blocking from engine.

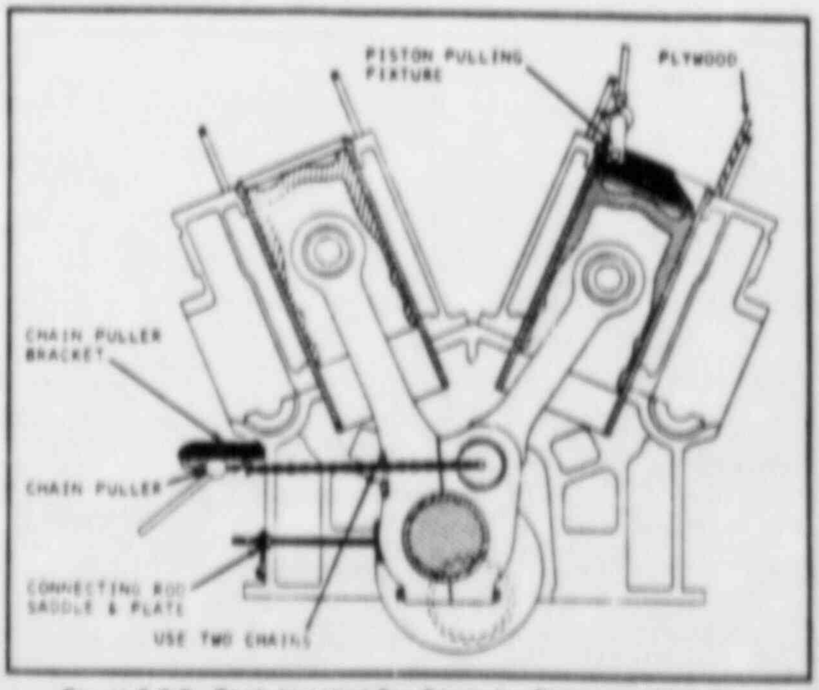

Figure 6-C-3. Tools Installed For Removing Piston and Link Rod

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PART C – PISTONS AND RODS (Continued)

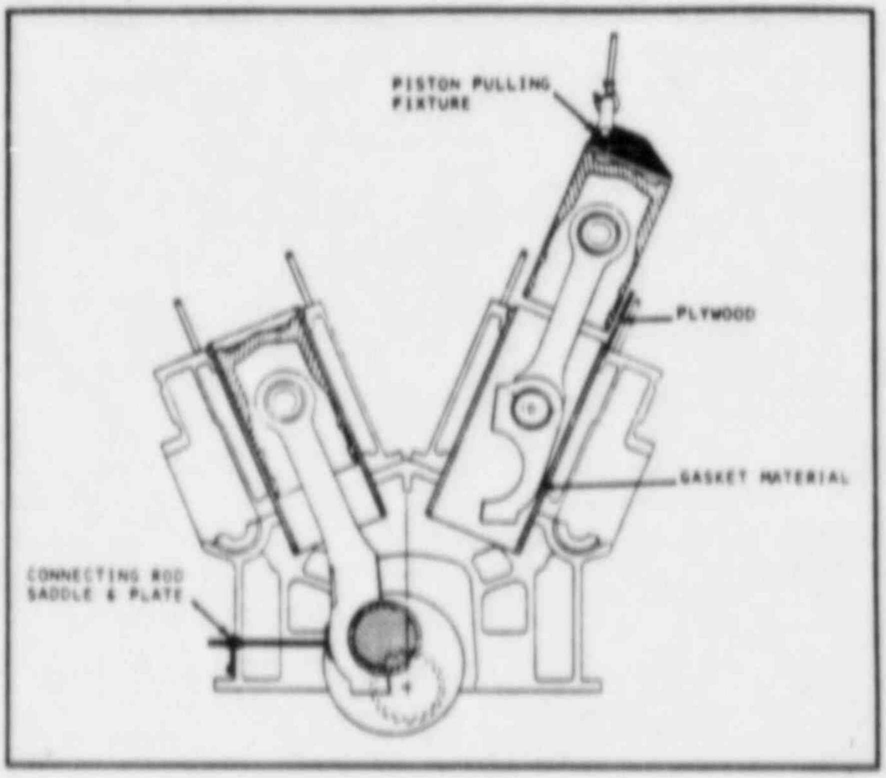

Figure 6-C-4 Lifting Piston and Link Rod From Cylinder Liner

LINK ROD AND PISTON REMOVAL.

With the cylinder heads removed and the engine side doors removed, bar engine over until master rod piston is at top dead center, then block crankshaft to prevent further movement. Refer to figure 6-C-3 for installation of the special tools that are required for piston and rod removal.

a. Attach piston pulling fixture to crown of link rod piston.

b. Place a piece of one-half inch plywood vertically on inner side of outer cylinder head studs to prevent piston from coming into contact with studs.

c. Suspend a one-ton capacity chainfall from plant crane hook and attach hook to side lifting hole of pulling fixture.

d. Attach chain puller bracket and chain puller to master rod side of crankcase.

e. Install connecting rod saddle and plate to master rod side of crankcase. Adjust to hold rod snug against crankshaft.

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PART C – PISTONS AND RODS (Continued)

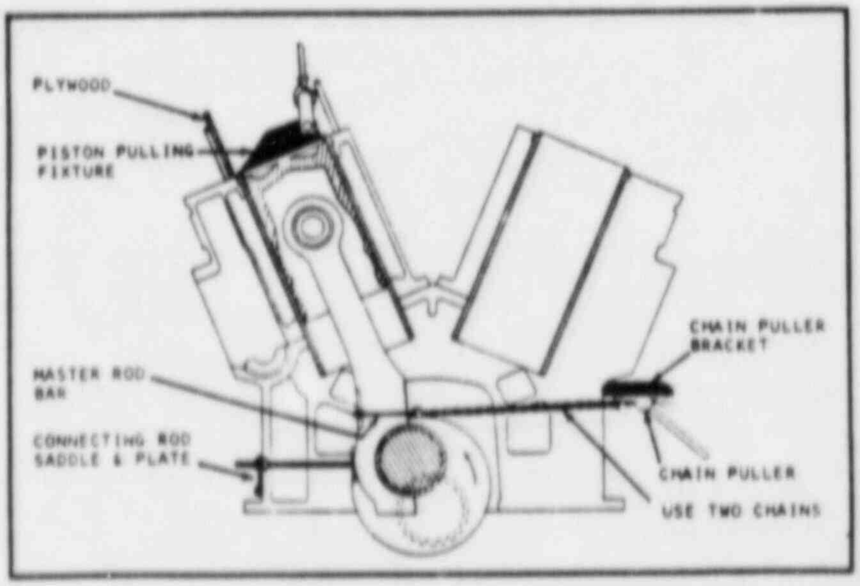

Figure 6-C-5. Tools Installed For Piston and Master Rod Removal

f. Attach a chain to each end of link pin with capscrews and connect other ends to chain puller and take up slack in chain.

g. Remove connecting rod bolts and rod-to-box bolts (see figure 6-C-1) then slack off on chain puller, allowing link rod box to swing clear of crankpin.

h. Use chain puller as necessary to position connecting rod while clearing box from crankshaft. Adjust until link rod is in line with the axis of the cylinder liner.

i. Coat walls of cylinder liner with clean lubricating oil, then place a piece of 3/32-inch compressed gasket material between link rod box and liner wall to prevent box from scoring liner wall. Coat side of gasket material which contacts liner wall with clean lubricating oil.

j. Carefully hoist piston and rod out of liner with one ton chainfall, taking care not to allow piston to bind in liner (see figure 6-C-4).

k. When bottom end of connecting rod box is clear of liner, move piston and rod clear of engine and lower to floor or a suitable stand.

PART C – PISTONS AND RODS (Continued)

PISTON AND MASTER ROD REMOVAL (Link Rod Removed).

Attach special tools as shown in figure 6-C-5 and take up slack with chain puller to hold master rod in place against the crankshaft.

a. Loosen connecting rod saddle assembly then slack off on chain puller until master rod swings clear of crankshaft and is in line with the cylinder liner bore. It may be necessary to adjust the position of the piston and rod with the chainfall.

b. Rotate crankshaft approximately 30° past top center, away from master rod to permit rod to clear crankshaft journal.

c. Pull piston and rod in the same manner as piston and link rod were pulled (see figure 6-C-6).

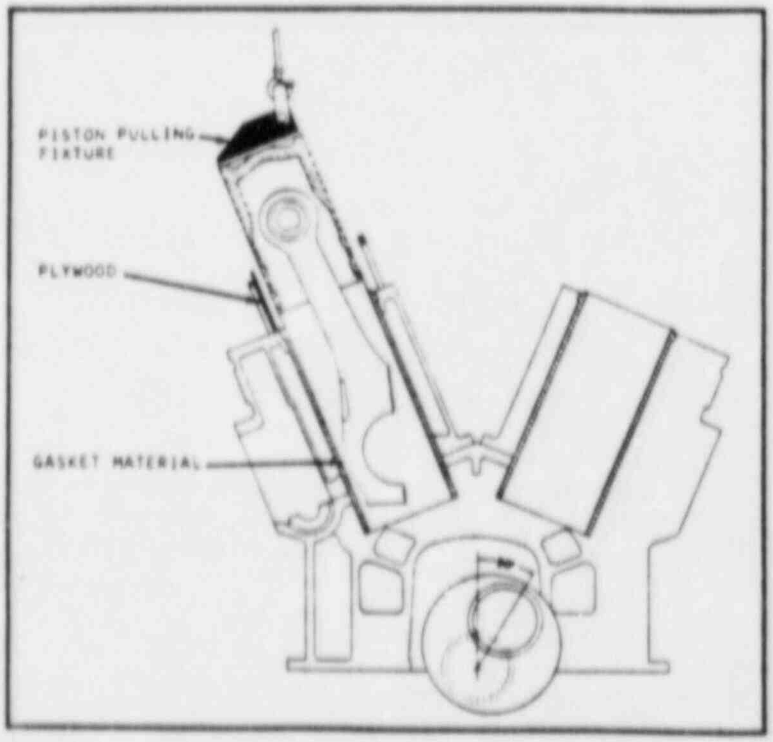

Figure 6-C-6. Lifting Master Rod and Piston From Cylinder Liner

PISTON AND MASTER ROD REMOVAL (Link Rod Not Removed).

The master rod and piston may be removed from the engine without having to remove the link rod, connecting rod box and piston, or the cylinder head on the link rod side.

a. Position crankshaft with the crankpin for piston to be removed at approximately 30° past top center. Block flywheel to prevent further movement of the crankshaft.

b. Remove cylinder head on the master rod side, above the piston to be pulled.

c. Install tools and handling equipment as shown in figure 6-C-2 except that a piston holder spacer ring need not be installed on the master rod side. Attach a piston pulling fixture to the master rod piston and attach hook of overhead crane.

PART C – PISTONS AND RODS (Continued)

d. Separate connecting rod box from master rod, and slack off on chain puller until connecting rod box is well clear of crankpin with the link rod resting against the lower end of the cylinder liner. A piece of compressed gasket material or leather should be used to protect the liner.

e. Remove chain puller, chain and puller bracket from master rod side of engine and install on link rod side. Connect chain to master rod as shown in figure 6-C-5 and take up slack.

f. Back off on connecting rod saddle jacking screw and remove tool. Slack off on chain puller and lift piston and rod out through cylinder liner.

REMOVAL OF PISTON FROM ROD.

Suspend piston and attached rod with the piston down from the overhead hoist. Lower until the weight of the assembly is resting lightly on the piston crown. Remove piston pin retainer rings from grooves on ends of piston pin then slide pin out of piston. Lift rod assembly clear of piston.

REMOVAL OF A SEIZED STUD.

When it is evident that a bolt has seized in the connecting rod box, do not attempt to force it. The following procedure is recommended for the removal of a seized connecting rod bolt.

a. Position crankshaft to place connecting rod at its closest point to the engine side door and block crankshaft to prevent movement.

b. Leave at least one good bolt in position to hold master rod and connecting rod box together while seized bolt is being removed.

c. Form a shield of a suitable fireproof material around master rod to catch molten metal and slag, and to prevent it from falling into the engine base.

d. Cut off head of seized bolt with an oxy-acetylene cutting torch. Exercise great care not to damage the master rod with the cutting flame.

e. Clean out slag and burned metal, and remove shield material.

f. Install a connecting rod saddle and plate to hold master rod firmly against crankshaft journal. Install tools and fixtures necessary to remove link rod and piston. See figure 6-C-3.

g. Remove remaining bolts and carefully disengage link rod and connecting rod box from master rod. Carefully guide headless bolt stud through its hole in the master rod. Allow the link and box to rest against the lower edge of the cylinder liner.

h. Place a shallow pan of water beneath the stub of the seized bolt to catch the molten metal and slag when the stub is cut off, then cut the stub off approximately one inch from the surface of the connecting rod box.

i. Clean debris from the area then remove the link rod and piston assembly from the engine in the normal mann. . Remove the connecting rod box from the link rod.

j. Set connecting rod box up on a good radial drill and drill out the remainder of the seized bolt. Exercise care to drill the bolt on dead center to prevent damage to the threads in the tapped hole in the connecting rod box.

k. Try a new bolt in the hole to be sure the threads are good and that the bolt will run free in the tapped hole.

l. Reassemble the link rod and connecting rod box and place the piston and connecting rod assembly in the engine in the normal manner. Use new locking devices when assembling the link rod to the link pin.

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PART C – PISTONS AND RODS (Continued)

INSPECTING CONNECTING ROD BEARINGS.

Inspect both upper and lower bearing shells for wear and general condition. Record all information (on the appropriate Inspection and Maintenance Record sheet) for future information.

a. Visually inspect all surfaces of bearing shells for scratches, nicks, burrs, evidence of heat and excessive wear.

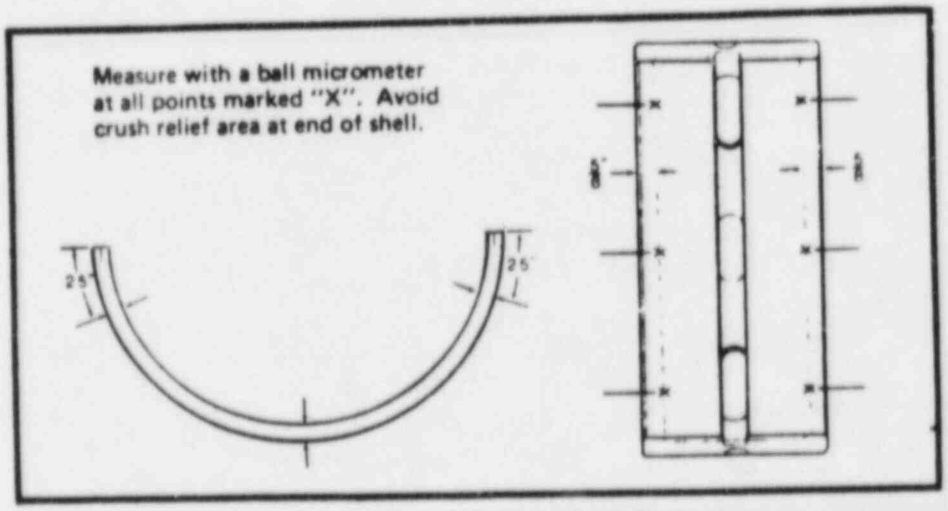

Figure 6-C-7. Measuring Bearing Shell Thickness

b. Measure thickness of bearing shells. Use a ball micrometer and measure each shell at six points, as indicated in Figure 6-C-7. Refer to Appendix III for permissible limits.

c. Perform a non-destructive dye check on all surfaces of both shells.

d. Based upon the results of the above inspections, make a determination as to whether the bearing shells are acceptable for further service.

CHECKING PISTON PIN CLEARANCES.

An ideal time to measure piston pin to bushing clearance is when the piston and rod are disassembled. Take and record the following measurements.

a. Measure inside diameter of piston pin bushing with a micrometer. Measure in the vertical (A-A) and the horizontal (B-B) planes, 90° apart (see Figure 6-C-8). Measure both ends (flywheel and gearcase), two inches from end of bushing.

b. Measure piston pin outside diameter in two locations, two inches in from each end, in the vertical (A-A) and horizontal (B-B) planes in each location.

c. Compare differences in measurements. Consult Appendix III for the specified clearance limits.

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PART C – PISTONS AND RODS (Continued)

INSPECTING CONNECTING ROD.

Make a careful and thorough inspection of the connecting rod, the piston pin bushing and the piston. Remove all carbon and varnish deposits from piston and accessible areas of ring grooves. If it is deemed necessary to remove piston rings for cleaning or replacement, or if it is necessary to disassemble the piston itself, refer to the appropriate paragraphs that follow.

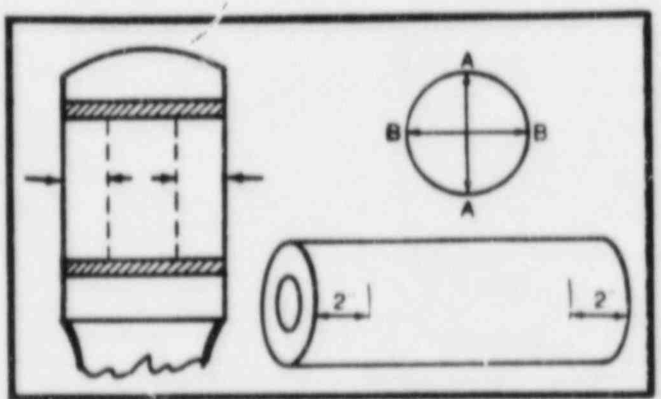

Figure 6-C-8. Measuring Piston Pin In Bushing Clearances

CHECKING PISTON RING SIDE CLEARANCES.

Measure piston ring side clearances in the groove with a feeler gauge in three positions, 120 degrees apart (see Figure 6-C-9). Record measurements and consult Appendix III for permissible clearances.

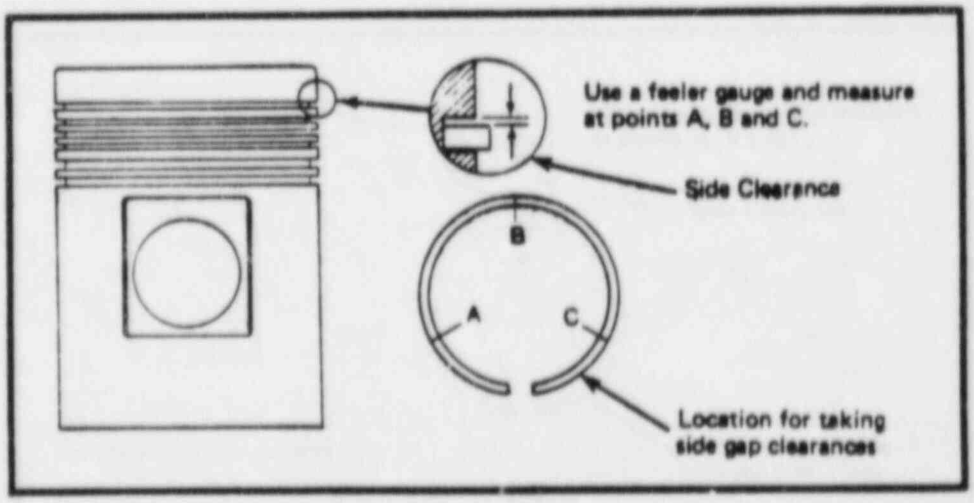

Figure 6-C-9. Piston Ring Side Clearance

PISTON RING REPLACEMENT.

Piston rings may be removed from power cylinder pistons for cleaning, inspection and end gap clearance measurement, provided care is exercised in the removal and handling of rings. The decision as to whether to reuse the piston rings, or to install new rings must be based on an evaluation of the condition of the rings, and the prospect of their giving adequate performance for an acceptable length of time. A piston ring expander tool must be used when piston rings are removed from a piston. The practice of using strips of leather, pieces of belting or other means to grasp the ends of the piston rings to remove them by hand is discouraged. The use of such makeshift tools will usually distort the rings and make them unfit for further use. A *K-D Manufacturing Company* tool, No. 892 has been found to be an excellent ring expanding tool. Starting with the top ring, expand the ring and slide it up and off the piston. If the rings are to be re-used, they should be identified and tagged as to the piston and groove so that they will be returned to the same relative position.

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PART C – PISTONS AND RODS (Continued)

CLEANING PISTON RINGS.

Hardened steel scrapers, steel wire brushes or power wire buffers must not be used to clean piston rings. Rings can best be cleaned by immersing them in a commercial cleaning agent such as *Turco, Transpo, Oakite Carbaway, Pennwalt Cleaner 45*, or equal. Follow the manufacturer's directions for the cleaning agent selected.

CHECKING PISTON RING GAP CLEARANCES.

Gap (end or butt) clearance of the piston rings is measured with the ring in the liner. Used rings must be measured in the liner from which they were removed, and if new rings are to be used, their end clearance must be measured when installed in the liner in which they will be used. The rings must be square with the surface of the bore. Position ring in one of two positions in the liner, the preferred position being six inches from the bottom of the liner, the alternate position being three inches from the top of the liner. Ensure that ring is the same distance from the top or bottom of the liner all around to make sure it is square in the liner. Measure gap between ends of ring with a feeler gauge and record the measurement for the engine records. Appendix III, Table of Clearances lists clearances when new, and the replacement clearances. In the case of used rings, it is suggested that it is economically unwise to attempt to reuse piston rings with end clearance exceeding 0.155 inch for chrome faced compression rings, 0.150 inch for taper faced compression rings, and 0.110 for oil control rings.

INSPECTING PISTON.

Inspect piston for wear and other abnormal conditions such as scuffing, scratches, etc. Pistons can be cleaned by immersing them in one of the commercial cleaning solutions listed for cleaning piston rings. Measure skirt outside diameter of piston at two locations, four inches below bottom ring groove and four inches above bottom of skirt. Take four measurements (A-A, B-B, C-C and D-D, Fig.6-C-10) at each location. Measure piston pin bore inside diameter at either end in two directions, perpendicular to one another (A-A and C-C, or B-B, D-D).

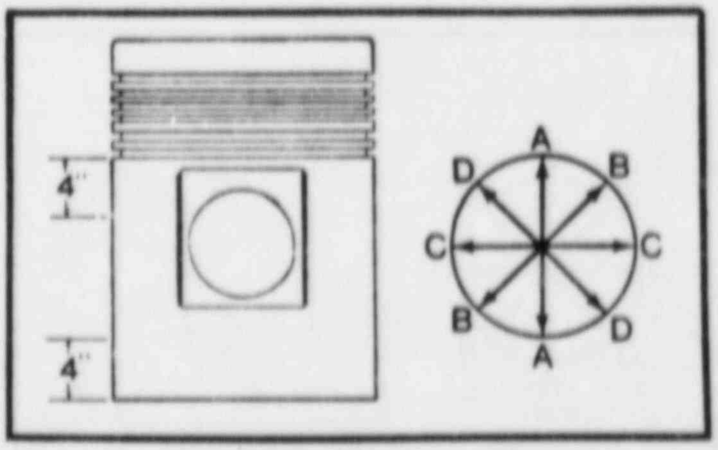

Figure 6-C-10. Piston Measurements

DISASSEMBLING PISTON (See Figure 6-C-11).

If it is determined to be necessary to disassemble the piston crown from the skirt for further inspection, or replacement, proceed as follows.

a. Inspect connecting rod bearing shells for evidence of scratches, nicks, burrs, excessive heat and wear. Clearance tables should be consulted for the required bearing shell wall thickness.

b. Inspect pistons for wear or abnormal conditions. Remove all carbon and varnish deposits from pistons and accessible areas of the ring grooves. Unless they are to be replaced, do not remove piston rings from grooves. If necessary, disassemble pistons as follows.

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PART C – PISTONS AND RODS (Continued)

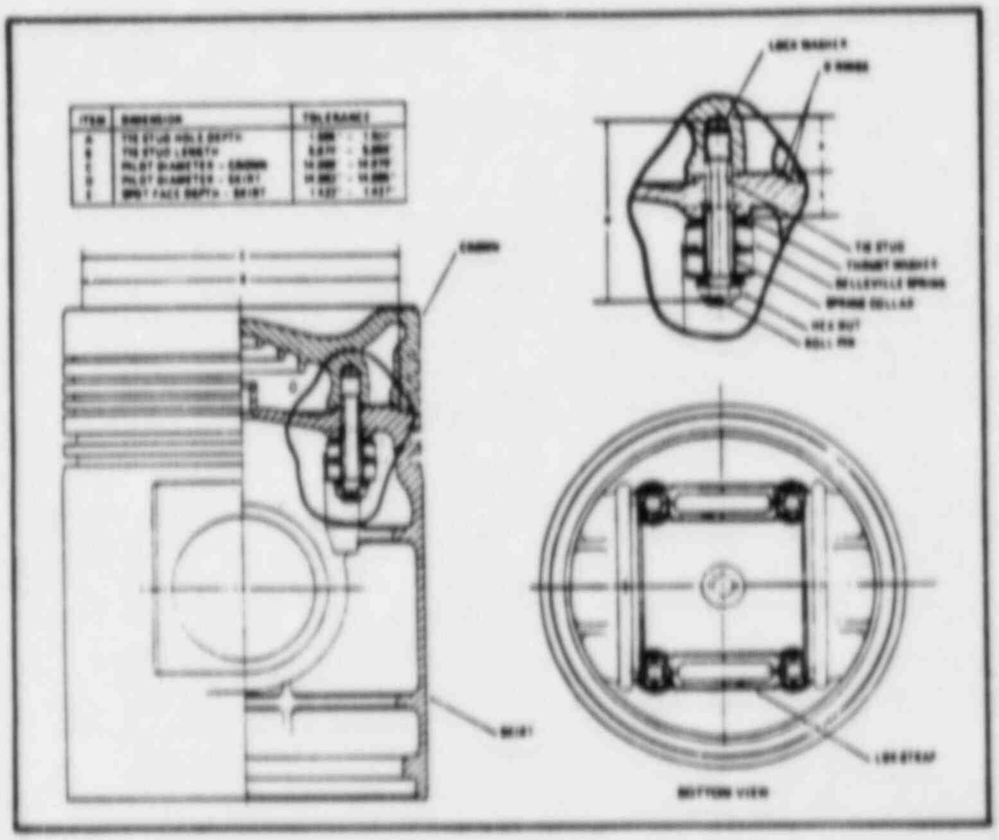

Figure 6-C-11. Piston Assembly

(1) Bend lok-strap tabs clear of hex nuts, remove roll pins from tie studs and remove hex nuts.

(2) Remove lok-straps, spring collars, belleville springs and thrust washers from tie studs.

(3) Separate crown from skirt and remove O-rings.

(4) Clean parts thoroughly. If crown is to be replaced, remove four tie studs and split washers in tie stud holes in crown.

ASSEMBLING PISTON.

Assemble the piston as follows:

a. Measure depth of crown stud holes. Measure from raised inner ring towards the center of the crown, not from the 0.007" deep relieved area. Must be within tolerances (A, Fig. 6-C-11).

b. Install a heavy spring lock washer in each of the four tie stud holes. Use Enterprise Part No. GA-002-091 washer (0.388" I.D., 0.691" O.D., 0.115" thick). Do not substitute.

c. Measure length of tie stud from lock washer end to centerline of groov-pin hole (B, Fig. 6-C-11). Acceptable tie studs must be within tolerances.

PART C – PISTONS AND RODS (Continued)

d. Install tie studs in crown with groov-pin hole up. Use Locktite "Threadlocker 242" on threads, and torque studs to 100 ft-lbs.

e. Take a micrometer measurement of crown and skirt pilots (C, D, Fig. 6-C-11). Must be within tolerances to ensure ease of assembly without damage to O-rings.

f. Measure skirt spot face depth (E, Fig. 6-C-11). Should be within stated tolerances.

g. Install O-rings on skirt. Do not twist rings during installation. Use no adhesive, grease or solvent on rings. Mineral oil may be used to ease entry of O-rings into crown.

h. Assemble crown to skirt. Observe that there is a dowel pin in the crown which must enter the dowel hole in the skirt. Check O-rings for proper positioning.

i. Clean each Belleville spring and the spring collars by dipping them in solvent then thoroughly drying. Dip all springs and collars into a 50-50 mixture of graphite and engine oil, making sure washer faces are completely wetted.

j. Install thrust washer on each tie stud, then install exactly 13 Belleville springs on each stud, concave side towards skirt. Install 13 more Belleville springs on studs, concave side towards crown.

k. Install spring collars on each tie stud, then install two lok-straps as shown in Figure 6-C-11.

l. Apply Locktite "Threadlocker 222" to stud threads, and assemble hex nuts to studs and tighten finger tight. Do not lubricate threads.

m. Align each washer stack with fingers so outer edge of washer stack is even. Torque each nut to 115 ft-lb, then back off three-quarter turn.

n. Retorque each nut to 105 ft-lbs and check alignment of tie stud groov-pins holes with nut slots. Increase torque as necessary to align groov-pin holes with closest nut slot. Do not exceed 115 ft-lbs.

o. Check for proper assembly. Groov-pin hole in stud should be even with, or a maximum of 1/16" above base of nut slot. If within this tolerance, clean groov-pin hole and install groov-pin, using Locktite "Threadlocker 222". If not within tolerance, check assembly of parts for proper size and correct number of springs.

p. Bend lok-strap tabs up securely against side of nuts.

INSTALLING PISTON RINGS (See Figure 6-C-9).

Use the piston ring expander tool when replacing piston rings on the piston. If the rings are being reused, insure that each ring is returned to its original position. Rings are marked either "UP" or "TOP M" on their upper sides. Rotate rings in grooves so that gaps are staggered around circumference of piston. Take care not to spread rings excessively while installing them on piston. Measure and record piston ring side clearance in groove. Take measurements in three positions (A,B,C) for each ring.

REPLACING PISTON PIN BUSHING.

Use the following method to replace the piston pin bushing in the connecting rod.

a. If an arbor press is available, press the bushing from the rod, otherwise, carefully split the bushing with a hacksaw and drive it out of the rod. Remove all burrs and clean the connecting rod.

PART C – PISTONS AND RODS (Continued)

b. Place the new bushing in a suitable container such as a bucket or a deep pan.

c. Fill the container with liquid nitrogen. Nitrogen level should be approximately one inch from the top of the bushing to allow for handling.

d. Lay connecting rod on its side on a suitable support. Both ends of the piston pin bushing bore should be accessible.

WARNING

Wear suitable gloves when handling bushing to avoid injury to the hands. Gloves should be of a type approved for protection against extreme low temperatures.

e. When the nitrogen stops boiling, remove the bushing from the container and insert in the bore, taking care to align the oil holes with the oil passages in the connecting rod. Insure that the bushing protrudes the same distance on both ends. The operation must be done quickly before the bushing expands due to heat pickup.

REPLACEMENT OF LINK PIN BUSHING.

If the link bushing requires replacement, proceed as follows:

a. Remove the bushing lock pin, split the bushing with a hacksaw to relieve stress, then drive bushing out of connecting rod box.

b. Clean the connecting rod box, removing all burrs and rough surfaces.

c. Place new bushing in a suitable container such as a bucket or a deep pan.

d. Fill container with liquid nitrogen. Nitrogen level should be approximately one inch from the top of the bushing to allow for handling.

e. Lay the connecting rod box on its side on a suitable support. Three pieces of 1½-inch rough stock, laid parallel on a piece of metal plate, will provide adequate support for the box and act as a stop for the bushing so that it will be flush with the side of the box when it is inserted.

WARNING

Wear suitable gloves when handling bushing to avoid injury to the hands. Gloves should be of a type approved for protection against extreme low temperatures.

f. When the nitrogen stops boiling, remove the bushing from the container.

g. Insert the bushing in the connecting rod box, taking care to line up the bushing cutouts with the internal surface contour of the box. Insure that both ends of the bushing are aligned with the side of the box. This must be done quickly before the bushing expands due to heat pickup.

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PART C – PISTONS AND RODS (Continued)

ASSEMBLY OF PISTONS TO RODS.

Assemble pistons, rods and connecting rod box as follows. Make sure pistons and rods are reassembled in the same relative position as they occupied before disassembly.

a. Insert link rod pin in connecting rod box bore and position link rod on link pin.

b. Apply a lubricant consisting of a 50-50 mixture of powdered graphite and lubricating oil to the threads of the link-rod-to-pin bolts. Torque bolts to specified torque and secure with lockwire.

c. Place piston upside down, resting on its crown. Lift connecting rod with rod turning plate then lower end of connecting rod into piston, aligning piston pin hole in rod with that of piston.

d. Coat piston pin with molybdenum disulphide prior to assembling in bushing. Use a rag or soft bristle brush. Molybdenum disulphide is available from Transamerica Delaval under Part No. B-6099-9.

CAUTION

Do not permit molybdenum disulphide, or any mixture of it to come into contact with any threaded fasteners. The presence of molybdenum disulphide will allow specified torques to overstress the fasteners. All torque values are based on the use of a 50-50 mixture of powdered graphite and lubricating oil.

e. Insert piston pin through piston and rod. Clean piston groove and the outside end of the piston pin retainer rings and insert retainer rings into piston grooves at either end of piston pin. Apply "Locktite" to ends of retainer rings to prevent rings from rotating in the grooves.

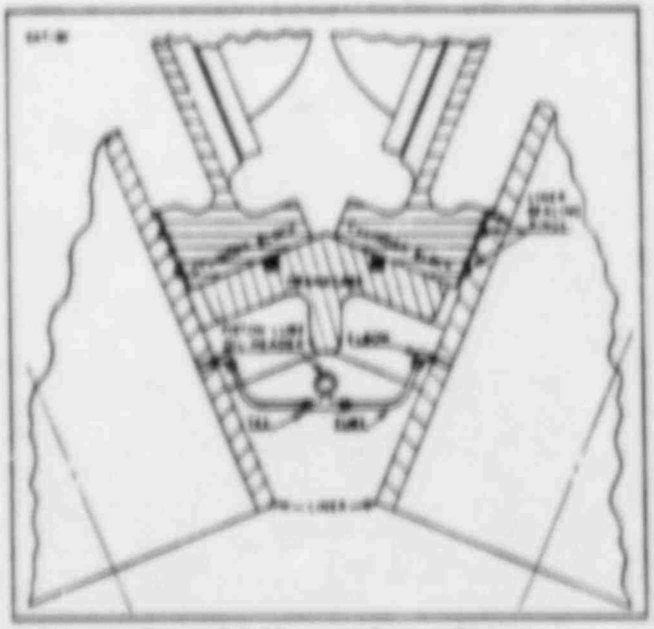

Figure 6-C-12. Liner Sealing Rings

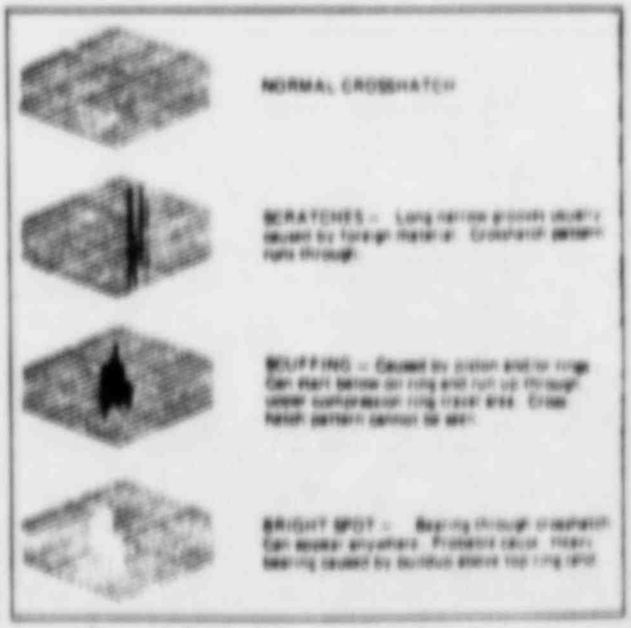

Figure 6-C-13. Cylinder Liner Wear Patterns

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PART C – PISTONS AND RODS (Continued)

INSPECTING CYLINDER LINERS.

The water contact type cylinder liners fit into the cylinder block. Three sealing rings in grooves at the lower end of the liner prevent water from entering the crankcase. The silicone seal goes into the lower sealing ring groove. It is recommended that the liner be deglazed before pistons and rings are replaced in the engine. In the case of new piston rings, they should be installed only in new liners, or in liners that have been deglazed. The glazed surfaces of a cylinder liner which has been in service will not seat new piston rings quickly or correctly. Rings which are not correctly seated will allow blowby of combustion gasses, and cause excessive usage of lubricating oil. Severe blowby can destroy the oil film on the liner surface and cause ring scuffing and possibly even piston seizure. Chrome faced compression rings will not conform to cylinder liners which are out of round by more than 0.003 inch per inch of bore diameter (0.051 inch for Model R & RV Engines). Taper faced compression rings and conformable oil control rings will not conform to liners which are out of round by more than 0.001 inch per inch of bore diameter (0.017 inch for Model R/RV engines). No piston rings will seal in liners which have grooves, ridges, or low spots on the surface of the liner bore. Carbon deposits from the top of the liner above the piston ring travel area should have been removed prior to pulling the pistons. Wash inside of liner with solvent and let dry. Visually inspect liner and note any of the conditions illustrated by Figure 6-C-13.

LINER DEGLAZING PROCEDURE.

The *Sunnen* Model AN-815 portable hone with double length stone holders, and *Sunnen* W47-J19 or W47-J47 stones in the stone holders has been found to be effective for deglazing. The cutting ability of the stones can be improved by cutting angular slots across the face of the stones. A hacksaw can be used to cut the slots. The slots allow the honing fluid to more easily wash the cuttings from the stones. The honing fluid can be kerosene, solvent or soapy water. Patented honing oils are available, but are expensive and do not appear to do any better job than the fluids mentioned. Diesel oil makes a very poor honing fluid.

a. Maintain a firm pressure between the stones and the surface of the liner bore to make sure the stones are cutting.

b. Maintain a steady flow of honing fluid to the stones to wash away the cuttings and to prevent stone glazing. Arrange a sheet metal trough under the bottom of the cylinder liner to carry off the fluid and cuttings. Do not allow the cutting laden fluid to flow over the crankshaft and into the main bearings. Lay a series of clean wiping rags between the crankshaft webs and the main bearing caps to prevent splashed fluid from entering the main bearings. Exercise care when removing the rags that cuttings do not fall into the main bearings.

c. Drive the hone with a powerful, slow turning electric air drill motor. The surface speed of the hone stones must be in the range of 25-50 rpm hone speed, and maintain a stroking rate of approximately 30 complete cycles per minute.

d. After the first minute of honing, remove the hone from the liner and wash the bore surface and dry it. Inspect the surface carefully to determine if there are any low spots. If low spots are found, measure the bore carefully with inside micrometer to determine if liner will be useable, or if it must be replaced.

e. Continue honing until all surface glaze is removed. A properly deglazed liner will have a uniform satin gray appearance with a good crosshatch pattern. The lines of the crosshatch pattern should intersect at an angle of approximately 90 degrees.

Note

Each set of *Sunnen* stones has an instruction pamphlet which describes the honing procedure. This is an excellent publication.

f. When honing is finished, wash the liner bore well with a stiff scrub brush and hot soap and water. Household laundry detergent in hot water can be used. After washing, the surface must be dried completely, and oiled with engine lubricating oil to prevent rust. Use an air jet to blow out the lubricator tubes or other liner lubrication fittings to remove hone grit which may have entered these fittings during honing.

PART C – PISTONS AND RODS (Continued)

REMOVING CYLINDER LINER.

If it is determined to be necessary to remove the cylinder liner from the block, first disconnect the lubricating oil lines at the bottom of the liner, including the elbow. Install a Cylinder Liner Pulling Fixture, Part No. 00-590-01-OV to the bottom of the liner, and attach a chain hoist to the lifting pad on the tool. Pull liner straight out of the block. It may be necessary to use blocking and a hydraulic jack to break the liner free of the cylinder block.

INSTALLING CYLINDER LINER.

Installation of the liner is the reverse of removal with certain additional requirements. Use new sealing rings and coat them with a liquid dishwashing soap, or a tire installing lubricant before mounting in liner grooves. The bottom seal is silicone and should be handled carefully to prevent tearing or nicking. It is essential that the liners be replaced in their original positions in the block, and that the scribe marks on top of the liner be aligned with the marks on the block. A tool, Part No. 02-590-01-AE facilitates the installation of the liner in the block. A split ring device, it fits into the top bore of the block, and allows the liner with sealing rings installed to be lowered into the upper bore block. After the rings have passed through the upper block bore, remove the rings then continue to lower liner until seated in block. Remove liner pulling fixture.

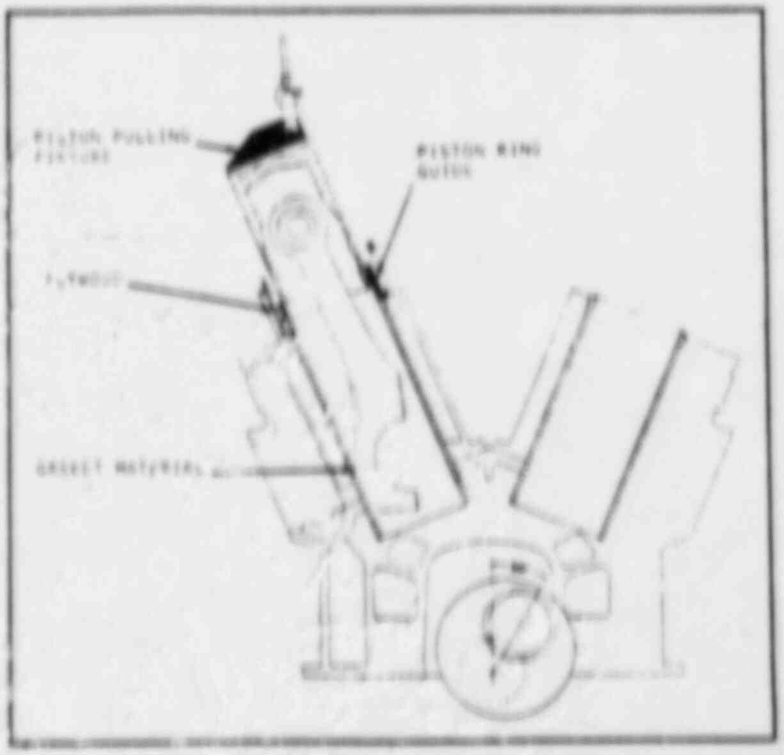

Figure 6-C-14. Piston and Rod Installation

INSTALLATION OF PISTON AND MASTER ROD.

The following procedure applies to the installation of the piston and attached master rod. If the link rod was not removed from the engine there will be a minor variation in the method of connecting the master rod and link rod box. This will be covered in a subsequent paragraph.

a. Lubricate walls of cylinder liner with clean lubricating oil.

b. Install piston ring guide over top of cylinder liner.

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PART C – PISTONS AND RODS (Continued)

c. Place a piece of one-half plywood vertically on inner side of outer cylinder head studs.

d. Position crankshaft with crankpin approximately 30° past top center, away from master rod side.

e. Install a piston pulling fixture on the piston crown. Pick up piston and rod with overhead hoist and position over cylinder liner.

f. Lubricate one side of a piece of 3/32-inch compressed gasket material with clean lubricating oil. Wrap around lower end of connecting rod with oiled side towards liner wall.

g. Lower rod into cylinder liner (see figure 6-C-14). Hold piston rings in place as they enter the piston ring guide. Insure ring gaps are staggered around the circumference of the piston.

h. Continue to lower piston until connecting rod bore is opposite crankpin. Remove gasket material.

i. Attach chain puller bracket, chain puller, chains and master rod bar, then rotate crankshaft towards rod. By adjusting rod and crankshaft positions bring master rod into engagement with crankpin. Make sure dowel seats in dowel hole. Rotation of bearing may be necessary.

j. Install connecting rod saddle and plate on master rod side of crankcase (see figure 6-C-5). Adjust to hold master rod tight against crankpin.

WARNING

Do not rotate crankshaft until link rod has been assembled and bolted to master rod. Block crankshaft to prevent further movement.

INSTALLING PISTON AND LINK ROD.

Use the same procedure for lifting and lowering the piston and rod into the liner as was used with the master rod. If the link rod and piston were not removed, but were retained in the liner with a piston holder spacer ring, the foregoing will not apply. The following procedure, however, is applicable in all cases.

a. Attach chain puller bracket to master rod side of crankcase. Attach chains in same way as was done for master rod removal (see figure 6-C-3). Draw connecting rod box into engagement with crankpin and master rod. Be sure serrated joints are properly engaged. In the case where the link rod is retained by the piston holder spacer ring, adjustment of the jacket screws and spacer ring may be necessary to achieve the necessary alignment of parts.

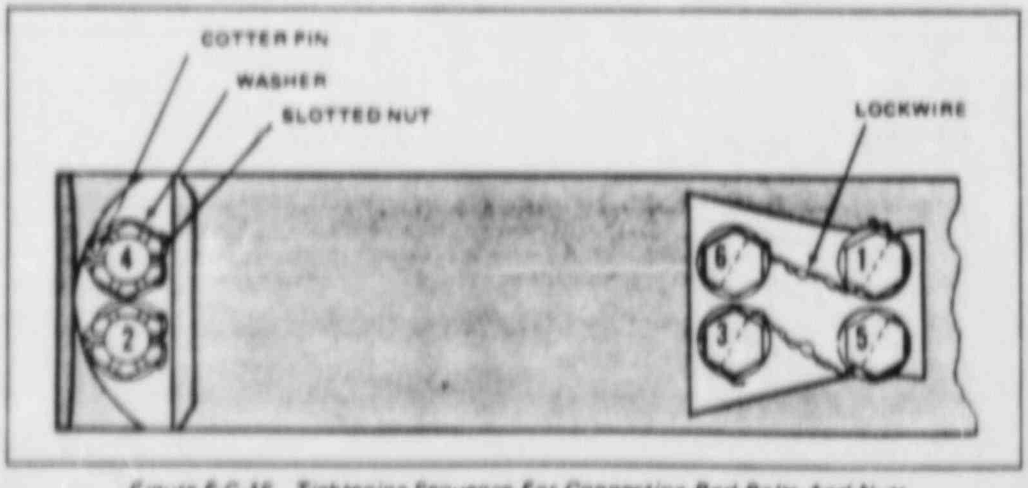

Figure 6-C-15. Tightening Sequence For Connecting Rod Bolts And Nuts

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PART C – PISTONS AND RODS (Continued)

b. Apply a mixture of powdered graphite and lubricating oil to the threads of the connecting rod bolts and the rod-to-box bolts. Assemble bolts, washers and nuts. Install washers so that bolt head or nut rests in the counterbore of the washer. Tighten to torque specified in the Torque Tables, Appendix IX in three steps, and in the sequence shown in figure 6-C-15. Safety wire the bolt heads and install cotter pins in the slotted nuts as shown in figure 6-C-15.

c. Remove all installation tools, brackets, fixtures and other installation equipment. Install cylinder heads.

SEATING NEW RINGS IN LINER.

New piston rings must be seated in the liner as quickly as is practical in order to assure a good gas seal, and an acceptable lubricating oil consumption rate. The following run in schedule should accomplish these objectives.

a. Replace all covers on the engine except cylinder head covers.

b. Start engine and run on diesel fuel at one-half speed and no load for 15 minutes (Note: Direct connected marine propulsion engines driving fixed pitch propellers will have a small amount of load). During the run inspect rocker arms, valves, pushrods, fuel injection pumps, nozzle holders, high pressure fuel injection lines, and drip return header to be sure all are secure, functioning properly, and that there are no fuel leaks.

c. Stop engine and remove crankcase side door covers. Feel connecting rod bearing boxes, main bearing caps, crank webs, cylinder liners and pistons to be sure there are no indications of excessive heat. Do not overlook the areas adjacent to the piston pins.

d. Replace all covers and run engine at 20 percent load for one hour.

e. Stop engine and remove side door covers and cylinder head covers. Bar engine over to place each piston in turn at top center. Inspect the lower part of the liner bore. Bar engine over to place each piston in turn at bottom center and inspect piston skirt. Inspect rocker arms, rocker shafts, nozzle holders, high pressure fuel injection lines, drip return header connections, and all other mechanisms under the cylinder head cover to be sure all is in good order and that there are no fuel leaks.

f. Replace all covers and run at 35 percent load for one hour.

g. Increase load to 50 percent and run for two hours.

h. Increase load to 75 percent and run for two hours.

i. Reduce load to 25 percent and run for one hour.

j. Increase load to 100 percent and run for two hours.

k. Stop engine and make a hot crankshaft web deflection check. Record on Transamerica Delaval Form D-1063.

l. Allow engine to cool, then make a thorough internal inspection as a sub-paragraph e. above.

m. Replace all covers and start engine. Take and record cold compression pressures. Cold compression check should be made at 185 rpm.

n. Compare operating data during 100 percent load run with that of the factory test record, and with operating records to be sure the engine is operating as it should.

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Note

Loads for engines not driving generators can be determined by fuel injection pump rack position, by referring to load/speed curves, or by observing the relative position of the fuel control linkage or the governal terminal shaft lever.

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PART D – CRANKSHAFT AND BEARINGS

MAIN BEARINGS.

Main bearings are made of aluminum alloy, the upper and lower bearings being interchangeable. The upper shell is held in place on the bearing cap by two lock rings and socket head capscrews. Main bearings are front, intermediate and rear, the number of intermediate bearings being determined by the number of cylinders. Bearing caps are secured to the engine base by studs (see figure 6-D-1). Oil passages through the bearing cap provide for bearing shell lubrication. To prevent axial movement of the crankshaft, thrust rings are attached to the rear bearing caps, each secured with button head capscrews (see figure 6-D-2).

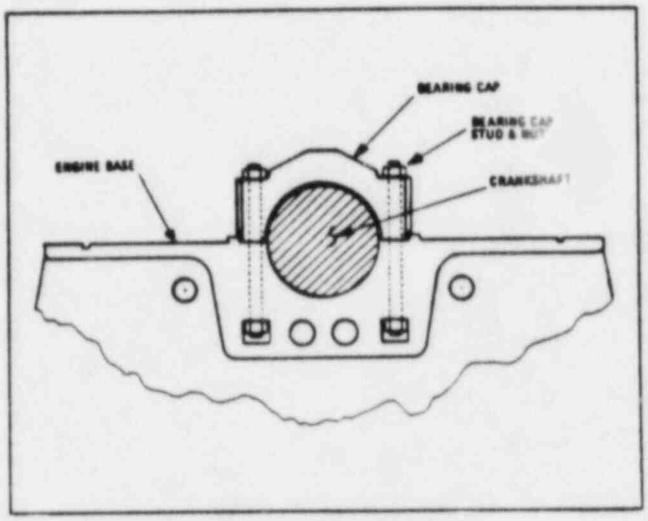

Figure 6-D-1. Main Bearing Cap

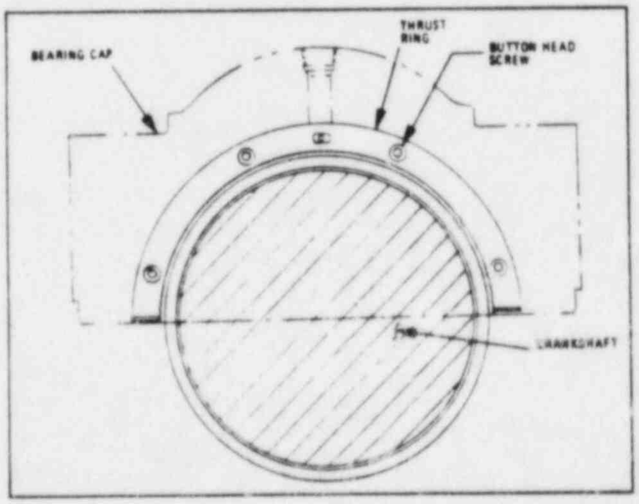

Figure 6-D-2. Crankshaft Thrust Rings

BEARING CAP REMOVAL.

Main bearing caps are pre-stressed by means of a special tool, normally furnished with the engine. The tool consists of a pre-stresser assembly (Part No. 1A-1801), and adapter (Part No. 00-590-01-0K) and a spacer (Part No. 00-590-01-0J).

a. Remove lubricating oil fittings, temperature sensing devices and locking plates from stud nuts.

b. Attach adapters to pre-stresser assemblies and place a spacer over each of two diagonally opposite stud nuts.

c. Use jacking screws on micrometer bar to force piston flange against top of cylinder, then back off jacking screws one-quarter inch.

d. Assemble a pre-stresser to each of the two main bearing cap studs, running them down on the stud threads until pre-stressers are snug against adapters.

e. Attach hydraulic hose between two pre-stressers, and between one pre-stresser and a suitable hydraulic pumping unit. Bleed air from system by opening pipe plug on second pre-stresser then operating pumping unit to supply a small pressure. When all air bubbles disappear, tighten pipe plug.

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PART D – CRANKSHAFT AND BEARINGS (Continued)

f. Slowly apply hydraulic pressure to pre-stresser assemblies until bearing cap studs have stretched sufficiently to permit stud nut to be loosened. Approximately 10,500 psi pressure will be required. Use a brass drift pin through the spacer side opening to loosen nut. Do not turn nut up tight against lower face of adapter as it will bind when hydraulic pressure is released. *Do not exceed maximum allowable pressure of 11,500 psi.*

g. Relieve hydraulic pressure on pre-stressers, remove pre-stressers, spacers and adapters from stud. Remove stud nuts.

h. Repeat procedure on remaining studs, following a criss-cross pattern. Remove all stud nuts and lift bearing cap from crankshaft.

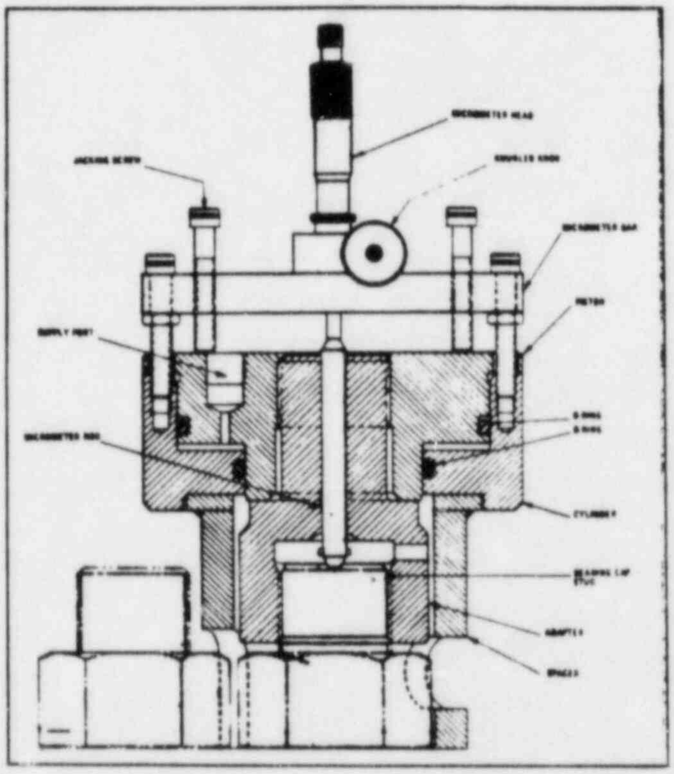

Figure 6-D-3. Pre-Stresser Assembly

BEARING SHELL REPLACEMENT.

If it is necessary to remove the main bearings, remove the two socket head capscrews and lock rings that hold the upper bearing shell to the main bearing cap and carefully remove the shell from the cap. Install a bearing shell removal tool (Part No. 00-590-01-AE) in the crankshaft journal oil hole then slowly rotate the crankshaft until the tool is bearing against the bearing shell. Slowly continue to rotate the crankshaft and roll the bearing shell out of the journal. To remove the thrust rings from the rear bearing caps, remove the button head screws and pull the thrust rings. Reverse the procedure to install thrust rings and bearing shells.

BEARING CAP INSTALLATION.

Install bearing cap in position in the reverse order of removal. Take care not to damage the bearing shells. The bearing cap studs are tightened as follows.

a. Install pins to lock lower stud nuts to studs, then place wedges between lower nuts and the base cavity bottom and side walls. Check that height of stud end is 11-3/16 inch above cap mounting surface to permit proper engagement with the pre-stresser assembly.

b. Lubricate threads with 50-50 mixture of oil and graphite and tighten upper stud nuts hand tight. Place spacers (Part No. 00-590-01-0K) to the pre-stresser assemblies. Use jacking screws to force piston flange tight against top of cylinder. Back off jacking screws 1/4 inch.

c. Install pre-stresser assemblies on two diagonally opposite studs and assemble the micrometer bar on the units.

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PART D – CRANKSHAFT AND BEARINGS (Continued)

d. Insert micrometer head into the hole in the micrometer bar, making sure that it is fully seated. Tighten knurled knob to hold micrometer head in place.

e. Attach hoses to pre-stressers and apply pressure to bleed air.

f. Run micrometer spindle against the micrometer pin until the pin is snug against the end of the bearing cap stud. Observe and record the micrometer reading.

g. Loosen knurled knob and remove micrometer head from the micrometer bar. Insure that jacking screws on pre-stressers and backed off one-quarter inch for each stud.

CAUTION

Failure to back off on micrometer spindle will result in damage to the micrometer.

h. Apply 10,500 psi pressure to pre-stressers and hold while using brass drift pin through spacer opening to tighten nut snugly (about 50 ft-lb). Relieve pressure.

Note

This operation is necessary to insure proper seating of parts and to minimize the effect of dirt or high spots on future readings.

i. Apply 10,500 psi pressure and hold. Tighten nuts to a snug fit with drift pin (about 50 ft-lb).

WARNING

Do not exceed maximum allowable pressure of 11,500 psi.

j. Relieve hydraulic pressure and install micrometer head in the micrometer bar. Run spindle snug against micrometer pin and record reading. Subtract the first reading from this reading. This is the amount the stud has stretched. Stud should stretch 0.056"-0.051". Repeat operation if stretch is not within specified range.

k. Remove pre-stresser assemblies and repeat operation on next pair of diagonally opposite studs.

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PART D – CRANKSHAFT AND BEARINGS (Continued)

CRANKSHAFT ALIGNMENT AND THRUST CLEARANCE.

It must be emphasized that excessive crankshaft deflection can lead to an ultimate catastrophic failure of the crankshaft. This is costly in both time and money. It is recommended that crankshaft alignment and thrust clearance be measured immediately after grouting or chocking of the unit, the day before initial start up, after the first seven days of continuous operation, and at six month intervals thereafter. Refer to Transamerica Delaval Engine and Compressor Division Form D-1063 (see figure 6-D-4) for an outline of these procedures. Note that space is provided for recording both deflection and thrust clearance readings. Copies of this form may be obtained from Transamerica Delaval.

CHECKING THRUST CLEARANCE.

Experience has shown that the feeler gauge method of measuring thrust clearance does not always produce satisfactory results. The dial indicator method is recommended to produce the desired accuracy of readings. A Starrett No. 196, or similar, type dial indicator with magnetic base and extension rod long enough to allow the indicator to be mounted between the engine and flywheel with the spindle bearing on the flywheel. Check thrust clearances as follows:

a. Start auxiliary (B&A) lubricating oil pump. Bar engine over at least one-half revolution to establish an oil film between the main bearings and their journals. This should permit easy movement of the crankshaft.

b. Mount dial indicator on rear of engine frame, between frame and flywheel. Spindle of indicator must bear on flywheel to measure horizontal movement of the crankshaft.

c. The crankshaft may be moved forward and aft in the horizontal plane with a pry bar such as a heavy, spade-type, tempered steel digging bar, approximately six feet long. Make sure bar is clean enough for use inside the engine. Insert bar between rear crank web and nearest frame member inside crankcase. Do not insert bar deeply enough to damage either the main bearing shell or the crankshaft journal.

d. Pry crankshaft forward, towards the gearcase end as far as it will go. If the crankshaft is all the way forward, it should be impossible to insert a 0.0015 inch feeler gauge between the crankshaft rear thrust collar and the rear thrust ring. Zero the dial indicator, allowing for at least 0.050 inch movement towards the minus direction.

Note

If crankshaft cannot be moved to the limit of its possible travel by use of the pry bar alone, it may be necessary to bar the engine over with the barring device while at the same time exerting a horizontal force on the crankshaft with the bar to move it.

e. Reposition pry bar to move crankshaft to the rear, towards the flywheel end. Pry crankshaft to the rear as far as it will go as indicated by the inability to insert a 0.0015 inch feeler gauge between the forward crankshaft thrust collar and the forward thrust ring.

f. Observe dial indicator. The number of thousandths (minus) indicated on the dial is the crankshaft thrust clearance. Record reading in the appropriate space on Form D-1063, and compare with previous thrust clearance readings.

Note

If there is any doubt as to the accuracy of the reading, repeat procedure.

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PART D – CRANKSHAFT AND BEARINGS (Continued)

CRANKSHAFT WEB DEFLECTION.

The importance of crankshaft web deflection measurements is such that the care and attention to detail required to obtain and record these measurements cannot be overemphasized. Placement of the dial indicator is vital if accurate readings are to be obtained. Form D-1063 (see figure 6-D-4) illustrates the five positions of the crankshaft at which web deflections are to be measured, and the starting position of the crankshaft for each crank web. Care must be exercised to insure that the dial indicator is positioned in the center of the web, exactly opposite the center of the crankpin, and one-fourth inch from the edge of the crankweb. Take deflections as follows:

a. Remove engine side doors to gain access to the crankcase.

b. Bar engine over in direction of normal rotation with barring device until number one crank is 52 degrees after vertical bottom center.

c. Insert dial indicator between web for number one crank. Double check that crankshaft is properly positioned. If not in correct position, it is possible that the connecting rod will knock the dial indicator out of the web as the engine is barred over to the next position. Insure the two bearing points of the indicator are in a line exactly parallel to the centerline of the crankshaft. If indicator is not parallel, erroneous readings will be obtained. Zero the indicator.

d. With the dial indicator in place and not disturbed, bar the engine over, stopping at each position (2,3,4 & 5) as indicated on form D-1063. Record reading at each position in mils (plus or minus) in the appropriate space for each position.

e. Repeat entire procedure for each crankshaft web and record readings on Form D-1063.

f. Compare all readings with each other and with previous measurements. Evaluate results, based on the standards set forth in the following paragraph, and determine need for corrective action.

DEFLECTION STANDARDS.

If the deflection in any crank of an engine in service exceeds 3 mils (0.003 inch/0.0762 mm), corrective action is indicated. If the deflection in any web exceeds 6 mils (0.006 inch/0.1524 mm), the engine should be taken out of service until the fault is corrected. Corrective action is also necessary of the total deflection in any pair of adjacent cranks exceeds 3 mils. For example, if the deflection in one crank is plus two mils, and the deflection in an adjacent crank is minus two mils, the total deflection is four mils, and corrective action is indicated.

CORRECTIVE ACTION.

The nature of the corrective action needed to deal with excessive crankshaft deflections will vary, depending upon the specific cause of the defect. The cause may be worn main bearings, improper foundation bolt torque, the foundation itself, or the grouting, misalignment of the engine and/or driven equipment, or a combination of elements. For instance, excessive deflection at positions two, three or four in the crank web adjacent to the external shafting on engines having a solidly coupled connecting shaft usually indicates misalignment between the connecting shafting and the engine crankshaft. In some cases replacement of main bearings may correct the problem, and often the problem is correctable by realignment of the engine. If one portion of the engine base is found to be lower than other parts, it may be necessary to jack the base with jacking screws and shim the low area. It must be emphasized that engine alignment is a complex, trial and error procedure which should be undertaken only by experienced and qualified personnel who are capable of correctly interpreting the web deflection pattern, and of taking the appropriate measures to correct defects. It is recommended that the Transamerica Delaval Engine and Compressor Division Customer Service Department be consulted prior to undertaking any corrective measures involving a suspected or confirmed crankcase alignment problem

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PART D – CRANKSHAFT AND BEARINGS (Continued)

CRANKSHAFT WEB DEFLECTION AND THRUST CLEARANCE RECORD

CUSTOMER ______________________ ENGINE MODEL __________ SERIAL NO. __________

Use this form to record crankshaft deflection and thrust clearance information. Thrust clearance should be measured by the dial indicator method. Deflection and thrust clearance should be checked and recorded immediately after grouting or chocking the unit, the day before unit start up, after 7 days (168 hours) of continuous operation, and each 6 months thereafter. Deflection and thrust clearance checks made after the unit is in service should be made while the engine is hot, i.e., within 4 hours after the unit has been shut down. Record the temperature of the oil in the engine lube oil sump tank or engine base.

When an engine in which the connecting shaft is solidly coupled to the flywheel is grouted on a concrete foundation, the desired deflection at crank position No. 3 is zero to plus (+) 1 mil (one thousandth) in all cranks except the crank adjacent to the flywheel which should be minus (-) 1/2 mil. This deflection allows for thermal distortion of the concrete foundation.

When an engine is mounted on a steel foundation, i.e., marine installations, appropriate compensations for thermal distortions of the foundation will be based on the locations and temperatures of fuel and lubricating oil tanks adjacent to the engine foundation.

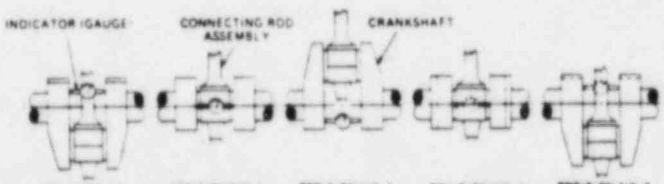
If the deflection in any crank in an engine in service exceeds 3 mils, corrective action must be taken. Also, if the total deflection value in any two adjacent cranks exceeds 3 mils, corrective action must be taken. Example, a +2 mils in any crank with a -2 mils in the next adjacent crank adds up to a total of 4 mils deflection between these adjacent cranks. The exception to the above will be engines that have a flexible coupling between the flywheel and the connecting shaft. These engines may have in excess of 3 mils deflection at position No. 3 in the crank adjacent to the flywheel. In engines with solidly coupled connecting shafting, excessive deflection at positions No. 2, 3, or 4 in the crank adjacent to the external shafting usually indicates misalignment between the connecting shafting and the engine crankshaft.

Set the deflection gauge at zero at position No. 1 and turn the crankshaft in the direction of normal rotation.

Position No. 1 for placing the deflection gauge is as follows:

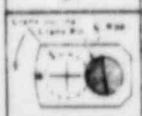
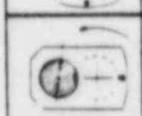
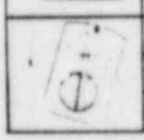
ALL INLINE ENGINES	15° AFTER BOTTOM CENTER
HV, HVA & GVB ENGINES	38° AFTER VERTICAL BOTTOM CENTER
RV ENGINES	52° AFTER VERTICAL BOTTOM CENTER

Record oil sump temperature and thrust clearance and *sign the form.*



DATE	SUMP TANK TEMP	THRUST CLEAR	SIGNATURE

Record readings in mils, i.e., 1-¼ rather than 0.00125 inches.

POSITION	CYLINDER NUMBER STARTING AT GEARCASE END										DATE
	1	2	3	4	5	6	7	8	9	10	
											
											
											
											
											

Form D 1063 (R 2) 1/75

Figure 6-D-4. Crankshaft Alignment Record, Form D-1063.

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AX44K(1-5C9-1

PART E – CAMS, CAMSHAFTS AND BEARINGS

GENERAL.

The induction hardened steel cams are shrink fit on the precision ground camshaft, using hydraulic expansion of the cam bore to position them on the camshaft. Camshaft bearings are aluminum alloy and are pressure lubricated. Cams, camshafts and associated operating gear should be checked periodically for wear and/or damage.

CAMSHAFT BEARING REPLACEMENT.

Should it be necessary to inspect and replace camshaft bearings, do the following.

a. Remove covers over camshaft.

b. Disconnect lubricating oil line from bearing cap.

c. Remove bearing cap, lock rings and upper bearing shell, then roll lower bearing shell out of its saddle.

d. Inspect bearings for evidence of damage or wear. Refer to Appendix III for permissible wear limits.

e. Installation is the reverse of removal.

CAM REPLACEMENT.

Cams are positioned on the camshaft at the factory by hydraulically expanding the cam bore and sliding the cam into position on the shaft. If it ever becomes necessary to remove and replace cams in the field, the following procedure is recommended.

a. Cams are located on the camshaft by scribe marks on the cams and the camshaft, placed there during manufacture. Circumferential marks locate the cams longitudinally on the camshaft, and longitudinal marks locate the cams circumferentially. Cams have a radial scribe mark on the side of the cam which passes through the center of the hole in the side of the cam.

b. Make a sketch of the camshaft assembly, indicating the location of the cams and the distance between each. Make sure the camshaft and all cams are scribed.

c. Clean the camshaft and place on Vee blocks on top of a clean workbench. Make sure all burrs, dents and other irregularities are reduced to the common diameter of the camshaft. Irregularities will prevent removal of the cams.

d. Obtain a hydraulic pump unit, such as a "Porto-Power", complete with a hose and fittings, and a pressure gauge capable to reading up to 20,000 psig.

e. Remove camshaft gear from camshaft, then connect hydraulic unit to the first thrust ring. Raise pressure to approximately 2000 psig and slide thrust collary off camshaft. Repeat procedure to remove other thrust ring.

f. Connect hydraulic unit to first cam nearest the tapered end of camshaft. Apply approximately 16,000 psig pressure (or pressure that will allow the cam to slide on the camshaft) and move the cam towards the drive end of the shaft.

R/RV 75 (Hyd. Applied Cams)

AX44KC1-509-1

PART E – CAMS, CAMSHAFTS AND BEARINGS (Continued)

WARNING

The camshaft has a taper near the drive end which serves as a starting ramp when installing the cams. As the cams reach the taper there is a strong tendency for them to shoot off the shaft with considerable velocity. Arrange a stop plate at the end of the shaft to keep the cams from shooting off the camshaft.

g. Remove all cams in order.

h. Wash and dry the camshaft and the replacement cams. Check that scribe marks are clean, sharp and clearly visible. Lay cams out on a clean surface in the correct sequence and orientation for installation. Refer to the sketch and make sure the cams are facing in the proper direction.

i. Choose the cam which will be farthest from the drive end of the camshaft and slide it up on the starting ramp as far as it will go.

j. Attach the hydraulic unit to the cam and start raising the pressure. A vigorous effort will be required to move the cam up the starting ramp to the straight part of the shaft. Approximately 16,000 psig pressure will be required.

k. Move the cam to its correct location on the shaft. Align the edge of the cam bore with the circumferential scribe mark and align the radial (longitudinal) scribe mark on the shaft with the mark on the cam. Release the hydraulic pressure when the cam is correctly aligned.

l. Install and position the remaining cams in order, then replace the thrust rings.

R (7/V 75 (Hyd. Applied Cams)

AX4EKC1-509-1

PART E – CAMS, CAMSHAFTS AND BEARINGS (Continued)

TIMING GEARS.

Timing gears are enclosed in the gearcase, and are lubricated by jets of oil. Gearcase covers should be removed periodically, and the gears inspected for wear and for backlash. Refer to Appendix III for backlash clearances. If the prescribed backlash clearance is exceeded by 0.006 inch, or if damage is discovered, perform the following disassembly steps to the degree necessary to accomplish the required inspection and repair. Accessories are doweled at assembly. If it is necessary to remove a dowel to reposition an accessory, drill and ream another dowel hole of the proper size in the accessory mounting flange and in the gearcase.

a. Remove the governor, overspeed trip, pumps and other accessories which would interfere with gearcase removal. As the pumps are removed, cover the shaft, drive gears and openings in the pump housing to exclude dirt and to prevent damage. Cover the open ends of connecting pipes and tubing.

b. Remove gearcase from engine. The gearcase is heavy and difficult to handle, therefore, rigging must be done very carefully to insure that it is under control at all times.

(1) Rig chainfalls and slings for handling gearcase.

(2) Remove bolts and capscrews, then lift gearcase from engine. Do not let it drop or swing. Set aside, secured in such a manner that it cannot fall.

c. Remove the governor drive assembly, and the overspeed trip and fuel booster pump drive assembly.

d. Insure that the crankshaft, camshaft and idler gears are match-marked for proper positioning at reassembly. If a new gear is to be installed, check both cylinder banks to insure that the number one fuel injection pumps are correctly timed. Fuel injection pump timing marks will serve as a reference point when reinstalling the gears.

e. Remove idler gear and bracket assemblies.

(1) Rig a small chainfall and wire rope sling to lift the idler gear and bracket assembly from the engine.

(2) Straighten locking clips. Remove top bracket retaining capscrew and replace with a long capscrew to serve as a guide and safety device while removing the gear and bracket assembly.

(3) Remove remaining capscrews and take a strain on the chainfall.

(4) Carefully pry bracket assembly free of the aligning dowels at the top and bottom of the bracket.

(5) Slide gear teeth clear of other gears, taking care not to damage any teeth.

(6) Remove long guide capscrew, and move bracket assembly clear of engine.

f. Remove camshaft gear assemblies.

(1) Remove cotter pins from camshaft gear hub retaining nut. A gear puller may be needed to start the gear hub off the shaft. The gear assembly will usually jump when it breaks free of the taper. If the initial movement is too great the ram effect may cause displacement of camshaft collars or upset thrust clearance. To prevent this, loosen hub retaining nut only far enough to limit this initial movement to 1/16 inch.

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PART E – CAMS, CAMSHAFTS AND BEARINGS (Continued)

(2) If the gear assembly will not come loose with a gear puller, use an oxy-acetylene torch and quickly apply heat to expand the hub. Protect the front camshaft bearing from the torch flame. *Do not overheat.*

(3) Remove camshaft gear hub retaining nut and slide gear off shaft.

g. Remove camshaft gear.

(1) Protect the front main bearing with a wet asbestos heat dam.

(2) Make two 3/4-inch diameter handling rods, 24 inches long with 3/4–10 threads at one end, and screw rods into the two tapped holes in the gear.

(3) Use two "Rosebud" type heating torches to quickly heat the gear until it can be slipped off the crankshaft with the handling rods. Be sure the exposed end of the crankshaft is clean and free of burrs.

INSPECTION.

Inspect gears for broken teeth, or other damage. If gears are damaged, inspect camshaft with dial indicator to determine if shaft is bent.

a. Clean camshaft tapers and check fit of drive keys in hubs.

b. Clean gear seat area of crankshaft.

c. If it is necessary to remove the idler gear from the bracket, cut the safety wire and remove the four bolts that hold the idler gear stub shaft in the bracket. Remove the stub shaft then carefully slide the gear out of the bracket. When reassembling the idler gear in the bracket take care not to damage the bushings or the gear teeth.

ASSEMBLY.

a. Install camshaft gear.

(1) Lubricate camshaft taper with white lead and lubricating oil. If a new gear hub is being installed, fit a new key in the key slot.

(2) If a new gear and hub are being installed, position the slotted holes in the hub over the drilled holes in the gear. Install camshaft gear to hub bolts, washers and nuts. Tighten to hold gear and hub together.

(3) Using a chainfall and sling, lift gear assembly into position and slide onto camshaft taper. Assemble washer and nut, tighten, and install cotter pin.

b. Install crankshaft gear.

(1) Heat camshaft gear to 350° F in hot oil. *Do not overheat.*

(2) Screw two handling rods into tapped holes in gear. Lift gear out of the oil with rods, and with one smooth, continuous motion, position heated gear against the shoulder. This must be done quickly before the gear cools. Allow gear to cool, then proceed.

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PART E – CAMS, CAMSHAFTS AND BEARINGS (Continued)

c. Set up a one-inch travel dial indicator on the pump base for number one fuel injection pump with the spindle of the indicator bearing on top of the tappet pin for number one fuel tappet, master rod bank, and zero the indicator.

d. Bar the flywheel in the direction of normal rotation until the tappet roller for number one fuel injection pump starts up the lifting ramp of its cam.

e. Continue barring the flywheel until the degree mark for fuel injection for number one master rod bank is directly in line with the flywheel pointer. This degree mark is shown on the Engine Data Sheet in front of the manual, and on the engine nameplate.

f. Observe the dial indicator to determine the lift of the fuel tappet at this point. Lift should be 0.197 inch. If lift is other than 0.197 inch, camshaft timing must be corrected.

(1) Loosen two fitted bolts that fasten camshaft ring gear to gear hub.

(2) Loosen remaining four bolts and rotate camshaft gear within ring gear to raise or lower the tappet as necessary.

(3) If there is not enough travel in the slotted holes in the gear hub to allow the required correction, it will be necessary to lift the gear end of the camshaft until the cam gear teeth disengage from the idler gear teeth, and slip the mesh one or more teeth as judged necessary. Re-engage the teeth of the cam gear and idler.

(4) Observe dial indicator to find tappet lift after correction. Make final correction by rotating the camshaft gear hub within ring gear.

(5) When correct tappet lift is obtained, lock up the four bolts in the slotted holes and drill and ream for two fitted bolts. New holes for fitted bolts should be moved approximately one inch from the original holes.

(6) Torque six bolts that fasten ring gear to hub to a torque value of 70 ft-lb, plus or minus 20 ft-lb as required to align cotter pin holes. Tighten and lock camshaft bearing cap bolts if they were loosened to slip gear tooth mesh.

g. Replace number one fuel injection pump, master rod bank.

h. Bar flywheel to place fuel injection timing point for number one, master rod bank, directly under flywheel pointer.

i. Remove number one, link rod bank fuel injection pump. Set up dial indicator in same manner as was done for master rod bank.

j. Bar the flywheel in the direction of normal rotation approximately 315 degrees to position the degree mark for fuel injection for number one, link rod bank cylinder directly in line with the flywheel pointer. Refer to Engine Data Sheet or engine nameplate for the correct degree mark. This will place the timing and firing order of the master rod bank and the link rod bank in the correct relationship.

k. Time the number one, link rod bank fuel injection pump in the same manner as used to time the master rod bank pump.

l. When both banks are timed, recheck fuel injection pump timing and cylinder head valve lash for both banks.

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PART F — FUEL SYSTEM

FUEL INJECTION EQUIPMENT.

Each cylinder is fitted with an individual fuel injection pump and injection nozzle assembly. The fuel supply to the pumps is from a common header, and a separate high pressure line connects each pump to its respective nozzle assembly. Fuel injection equipment, particularly the injection pumps and nozzles, is built to extremely close tolerances and, therefore, it is essential that the fuel be delivered in as clean a condition as is possible. This requires that the fuel filtration equipment be maintained in the highest possible condition of cleanliness for efficient operating conditions.

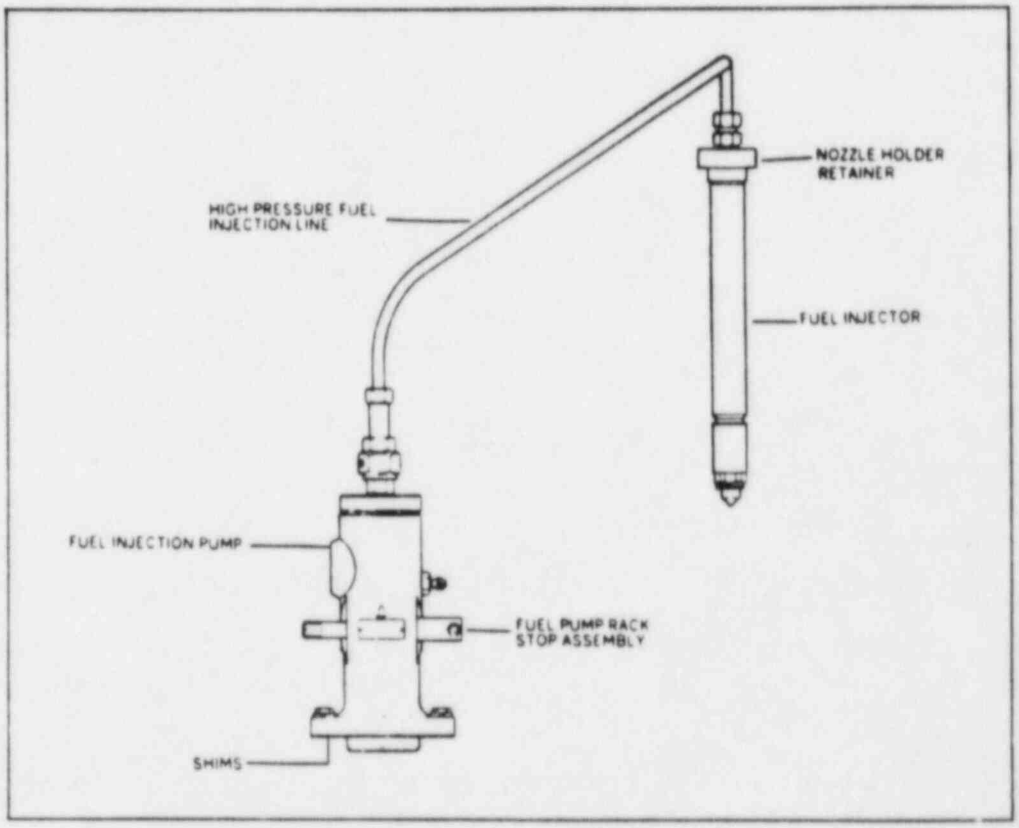

Figure 6-F-1. Typical Fuel Injection System

PARTS LISTS.

Refer to the below listed group parts lists in the *Parts Manual* for a breakdown of the parts covered in this part of the manual.

a. 365 Group Parts List, Fuel Injection Equipment.
b. 371 Group Parts List, Fuel Pump Linkage.
c. 445 Group Parts List, Fuel Oil Booster Pump.
d. 450 Group Parts List, Fuel Oil Header.
e. 455 Group Parts List, Fuel Oil Filter.
f. 590 Group Parts List, Special Tools.
g. 825 Group Parts List, Fuel Oil Equipment.

AX4HKUI-5C4

FUEL SYSTEM (Continued)

FUEL INJECTION NOZZLES.

Because nozzles and tips are subjected to extremes in pressure and temperature, they normally are among the first sources of engine trouble. A nozzle in good condition must pop open at the proper pressure without dribble, then close completely almost immediately. When subjected to a steady pressure at the opening pressure, it should "chatter", that is, open and close rapidly. The spray form should be a uniform, finely atomized mist pattern, never a solid stream. If the fuel nozzle is suspected of malfunctioning, remove from engine and test as follows.

a. Disconnect high pressure line and drain connections.

b. Remove nuts from injector studs and remove nozzle retainer.

c. Lift or pry the nozzle holder assembly from the cylinder head. The use of a nozzle assembly puller tool (part no. 00-590-01-BB) is recommended. This tool is available for purchase from the Transamerica Delaval parts sales department.

d. Plug opening in cylinder head to prevent dirt or other foreign matter from entering the combustion chamber.

e. Test the nozzle holder and tip assembly on a suitable nozzle tester, checking for the following conditions.

(1) Apply pressure and check nozzle for popping action. The valve should chatter if it is seating properly.

(2) Raise pressure slowly to determine pressure at which valve opens. The valve should open at 3000 psi (211 kg-cm²) plus 200 psi (14.06 kg-cm²), minus zero psi. The opening pressure is adjusted by means of shims in the valve assembly, requiring disassembly of the unit. See Figure 6-F-2.

(3) Dry off spray tip and raise pressure to within 100 psi of the opening pressure and observe tip for dribbing of fuel.

(4) Check to see if any spray tip holes are plugged.

(5) Place a clean piece of paper under nozzle tip and check spray pattern for uniform density and a symmetrical pattern.

(6) Nozzles that fail to perform satisfactorily should be repaired or replaced. Refer to manufacturer's instructions in the *Associated Publications Manual*.

WARNING

The penetrating power of atomized fuel under high pressure is sufficient to puncture the skin and serious injury can result. To avoid this danger, the hands must be kept away from a spraying nozzle.

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PART F — FUEL SYSTEM (Continued)

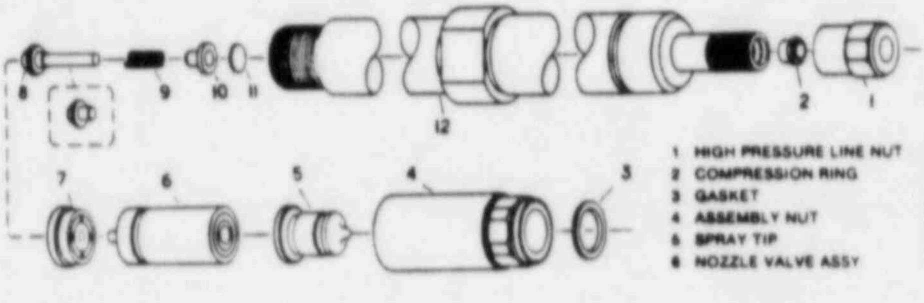

Figure 6-F-2. Fuel Injection Nozzle Assembly

NOZZLE ADJUSTMENT (See Figure 6-F-2).

Nozzle opening pressure is adjusted by means of shims (11), located between the body (12) and the spring seat (10). If the opening pressure does not conform to 3000 psi, plus 200 psi, minus 0 psi, adjust as follows.

a. Install nozzle and holder assembly on a pop tester then rapidly actuate pop tester handle four to six times to allow the needle to set properly. Pump the pressure up to the point where the pressure gauge needly falls away quickly. This point is the nozzle opening pressure.

b. If pressure is not correct, do the following.

(1) Disassemble the holder.

(2) Add shims if opening pressure is too low, or remove shims if opening pressure is too high.

(3) Reassemble and check opening pressure. If fuel leaks around the assembly nut, it indicates poor lapped fits. Re-examine the parts.

(4) Always use a new gasket (3) when installing nozzle and holder assembly on engine.

CLEANING SPRAY TIPS.

Bendix stresses the importance of maintaining the original high polish on spray tips, especially on the nose, in order to reduce carbon deposits as far as possible. Careful reference should be made to the Bendix publications in the *Associated Publications Manual* for the recommended procedures to be used in maitaining this level of cleanliness.

FUEL INJECTION PUMPS.

The fuel injection pumps are of the constant stroke, variable output type. Equally important with clean, properly adjusted fuel nozzles are clean, properly adjusted fuel injection pumps. Refer to the Bendix instructions in the *Associated Publications Manual* for complete details of the fuel injection pumps installed on this engine.

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PART F — FUEL SYSTEM (Continued)

DESCRIPTION OF OPERATION.

The following is a general discussion of the operation of the fuel injection pumps.

a. The pumps are of the constant stroke design, but the effective stroke, or that portion of the plunger movement in which fuel is actually delivered, is governed by a fuel metering helix in the plunger (see figure 6-F-3). On some pumps there is a second helix to retard the point of delivery at low fuel settings.

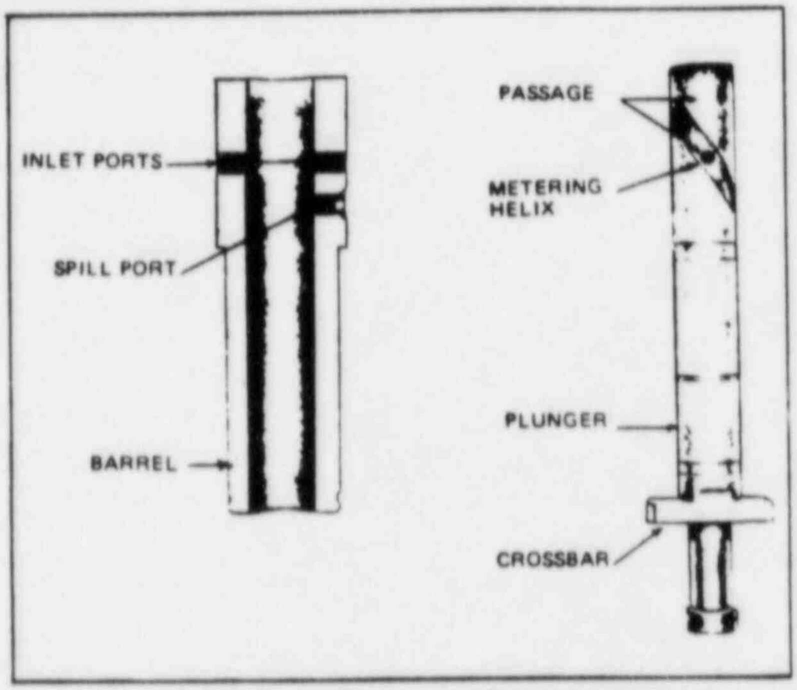

Figure 6-F-3. Pump Plunger and Barrel Arrangement

b. To pump fuel at high pressure it is necessary to bring it into a pressure chamber through an inlet, close the inlet and apply pressure for injection; terminate injection pressure and re-open the inlet to admit more fuel. The fuel injection cycle is accomplished by the location of inlet and spill ports in the barrel. It is further accomplished by the metering helix and a passage in the plunger that extends from the end of the plunger to the metering helix on the side of the plunger. This passage allows fuel in the pressure chamber to spill into the inlet chamber when the helix uncovers the spill port.

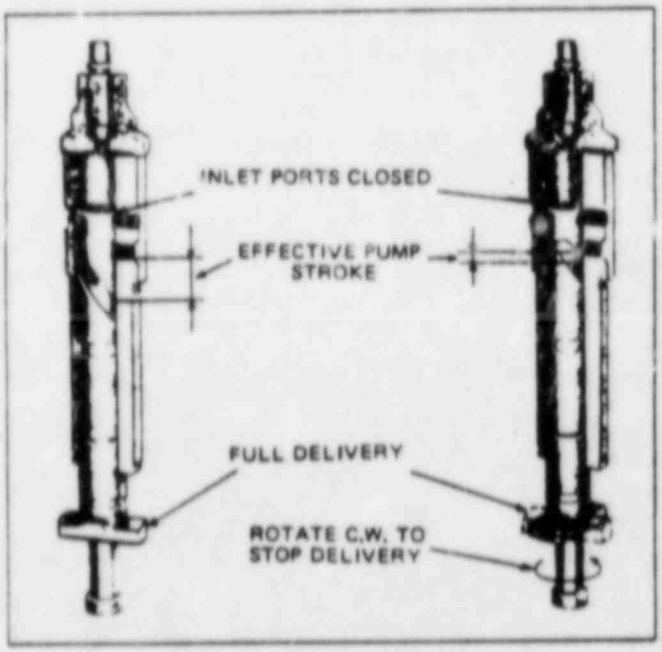

Figure 6-F-4. Effective Stroke

c. When the plunger is at its lowest point, fuel enters the barrel through the inlet port. As the plunger rises, it closes off the inlet port, pressure starts to rise and the delivery valve opens. Fuel injection continues until the upper edge of the metering helix reaches the lower edge of the spill port. Pressure is then release through the passage in the plunger to the spill port and delivery stops. The delivery valve closes. The effective stroke is the distance between the upper edge of the helix and the lower edge of the spill port at the moment the inlet port closes. The rotation of the plunger and its helix, then, determines the duration of the fuel injection.

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PART F — FUEL SYSTEM (Continued)

MALFUNCTIONING PUMP.

Should a fuel pump be suspected of malfunctioning, the following checks should be made before removing the pump from the engine for inspection and repair, unless it is known for certain that the pump is defective.

a. Check to insure that the fuel oil is being delivered to the pump. With the fuel oil system pressurized, loosen air bleed screw on pump. Fuel should flow freely with complete absence of air bubbles.

b. If air is present in fuel oil, loosen nuts on high pressure line connection at nozzle holder end and bar engine over until all bubbles disappear.

c. If fuel oil flow is sluggish at the pump, it is a good indication that the fuel filters are clogged. Check and clean filter.

d. If fuel oil does not flow, check fuel level in tank and for closed valves in lines.

e. Having made certain of fuel oil flow, operate engine and if pump still does not function properly, remove and replace with spare pump.

PUMP REMOVAL.

Fuel injection pumps are removed from the engine as follows.

a. Disconnect high pressure line fitting and remove high pressure line from pump.

b. Disconnect supply and return lines from fuel pump.

c. Disconnect fuel control rack from linkage.

d. Remove hold down nuts and lift pump off mounting studs.

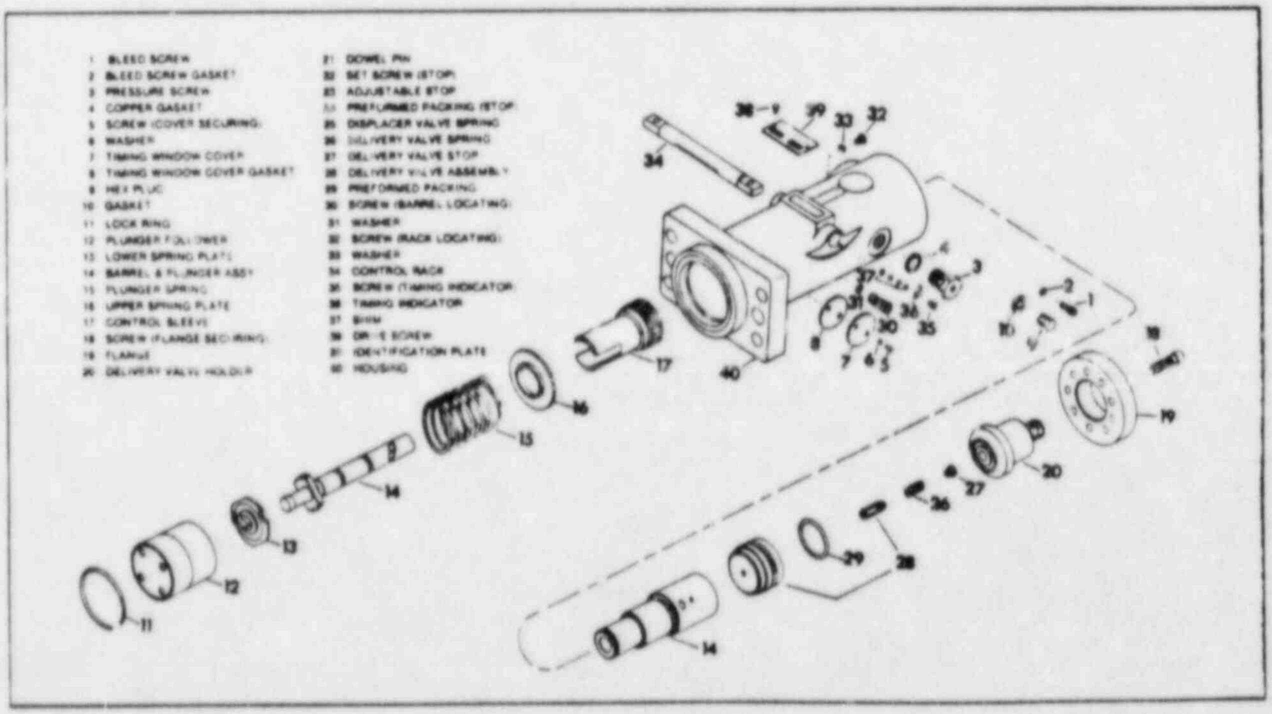

Figure 6-F-5. Fuel Pump

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PART F — FUEL SYSTEM (Continued)

DISASSEMBLY OF PUMP (See Figure 6-F-5)

The manufacturer's instructions contained in the *Associated Publications Manual* provide detailed instructions for the overhaul and repair of fuel injection equipment, an' should be consulted when any work is being done on fuel injection pumps. Pumps may ve disassembled as follows.

a. Secure pump in the inverted position in a soft jawed vise. Depress the plunger follower and insert a ⅛ inch diameter pin in the hole in the pump flange.

b. Remove lock ring by prying it out with a screwdriver. Again depress follower and remove ⅛ inch pin.

c. Remove plunger follower. Take lower spring seat from plunger, then carefully remove plunger from barrel. Carefully submerge plunger in spindle oil.

d. Remove plunger spring, then pull control sleeve using a specially fabricated puller, or a pair of pliars whose jaws are wrapped with masking tape. The upper spring plate will come out with the control sleeve.

e. Remove pump from vise and re-secure in an upright position.

f. Remove delivery valve flange and delivery valve holder. Remove and discard preformed packing.

g. Remove delivery valve stop and spring, then, using a delivery valve puller, carefully remove delivery valve.

h. Remove barrel locating screw then slide barrel from housing.

i. Remove control rack locating screw and control rack. Do not remove timing indicator or shims unless pump is to be re-calibrated.

PART F — FUEL SYSTEM (Continued)

ASSEMBLY OF PUMP (See Figure 6-F-5).

Assemble the pump as follows, observing the manufacturer's instructions in the *Associated Publications Manual.*

a. Secure pump housing in a vise in an upright position.

b. Position control rack in housing with teeth facing center of pump. Install lockwasher and control rack locating screw, making sure the screw enters the rack locating groove.

c. Insert barrel in pump housing. Locating groove must be aligned with locating screw hole. Install lock-washer and locating screw.

d. Invert pump and install control sleeve so that tooth directly under timing mark meshes between two teeth indicated by timing dot on control rack.

e. Install upper spring plate and plunger spring then carefully start plunger into barrel. It should settle in of its own weight. Turn plunger so marked end of crossbar will go into control sleeve slot that has a mark adjacent to it.

f. Position lower spring plate on end of plunger. Fit plunger follower into housing. Compress and insert pin in housing flange. Install lock ring and remove pin.

g. Install delivery valve assembly in pump housing. Lubricate and install preformed packing and install delivery valve spring and delivery valve stop. Assemble flange in housing.

h. Install pressure screw and new copper gasket. Install bleed screw and new gasket.

i. After pump is completely assembled, hold it horizontally with the control rack vertical. The rack should settle to its lower extreme by its own weight.

j. If pump will not be immediately installed, fill inlet and outlet with clean, anti-corrosive lubricating oil and close openings with caps.

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PART F — FUEL SYSTEM (Continued)

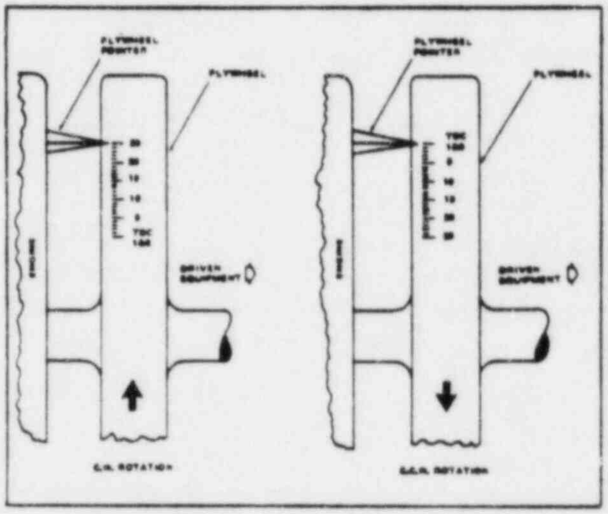

Figure 6-F-6. Flywheel Timing Marks

PUMP INSTALLATION AND TIMING.

Refer to the Engine Data Sheet in the front of the manual, and to page 6-A-1 for determination of engine rotation, bank designation (V-type engines) and cylinder numbering. The flywheel is marked to locate top dead center (TDC) of each cylinder, and is laid out in one degree increments for the twenty-five crankshaft degrees preceeding TDC (see figure 6-F-6). For instance, on a six cylinder inline engine, there will be marks "TDC 1&6", "TDC 2&5" and "TDC 3&4", each preceeded by degree marks. On eight cylinder inline engines the markings will be for cylinder pairs 1&8, 2&7, 3&6 and 4&5. Markings on the flywheel for V-type engines follow the same pattern, except that the banks are also designated. Refer to the Engine Data Sheet in the front of the manual for the fuel injection point. Install and time fuel pumps as follows.

a. Before mounting pump on engine, and with the fuel tappet roller on the base circle of the fuel cam (see figure 6-F-7), measure distance from the fuel pump mounting surface on the base assembly to the tappet with a depth micrometer. Add or remove shims from the top of the base assembly to obtain a measurement of approximately 0.197 inch.

b. Place pump on base assembly and install nuts on studs. Torque nuts as specified in Appendix IV.

c. Bar engine over in the direction of normal rotation until the flywheel pointed is aligned with the fuel injection point (degrees BTDC specified on Engine Data Sheet or Nameplate) for the cylinder served by the fuel pump being installed.

d. Observe plunger follower timing mark in pump timing window. If the plunger follower timing mark does not line up with the index mark on the timing window, remove pump and add or remove shims between the pump and the pump base assembly as necessary so that the marks will line up. Re-install the pump and bar engine through one complete injection cycle to insure that marks do align at the fuel injection point.

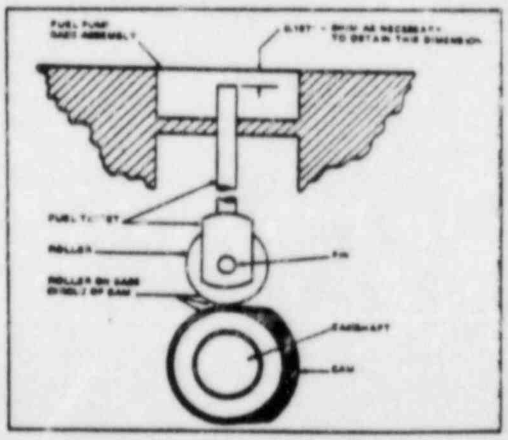

Figure 6-F-7. Pump Base To Tappet Adjustment

CAUTION

The timing mark on the plunger follower must never go beyond the upper or lower edge of the timing window. If it does, the pump may be severely damaged.

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PART G – ENGINE CONTROLS

OVERSPEED TRIP (See Figure 6-G-1).

A Woodward Model SG overspeed trip governor is mounted on the gearcase end of the engine. At a pre-set engine speed (15% above rated speed) it will initiate positive engine shutdown by tripping a dump valve which vents the automatic safety shutdown system. Operation of the overspeed trip governor is as follows.

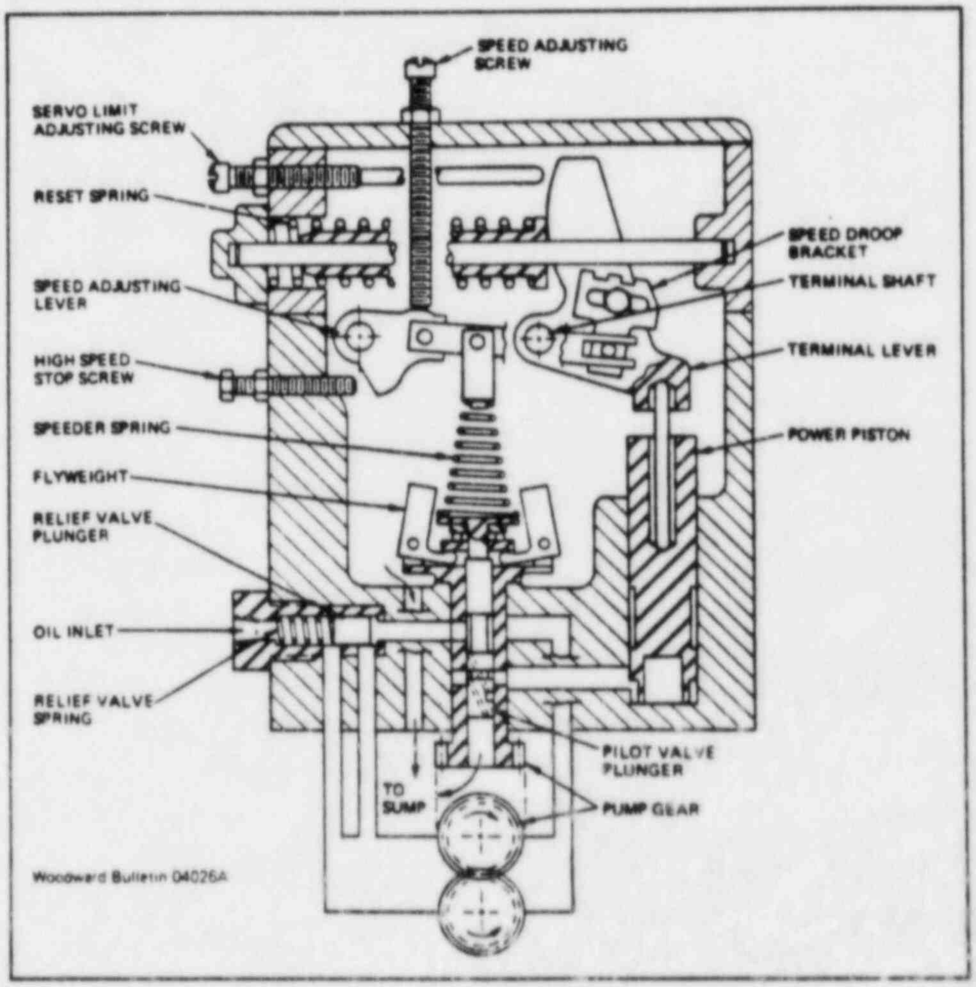

Figure 6-G-1. Overspeed Trip Governor

a. Oil enters the overspeed trip at the oil inlet, drops down into the cavity on the suction side of the pump gears, then around to the pressure side of the pump. If the supply of pressure oil is greater than required, the pump builds up pressure until the relief valve plunger is pushed to the left against the force of the relief valve spring. This uncovers the bypass hole in the relief valve sleeve and oil is recirculated through the pump. If the overspeed trip requires more oil than is being recirculated, pressure will be reduced and the spring will move the relief valve to the right, blocking the recirculating passage to maintain operating pressure. Additional oil, as needed, will enter the pump through the inlet port.

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PART G – ENGINE CONTROLS (Continued)

b. The pilot valve plunger controls the movement of the power piston by directing oil to or from the area beneath the power piston. The power piston in turn controls the position of the terminal lever, and, therefore, the position of the terminal shaft. Two opposing forces act upon the pilot valve plunger - the speeder spring force tends to push the plunger down and the centrifugal force developed by the rotating flyweights tends to lift the plunger.

c. When the engine is operating below the trip set point the speeder spring force holds the pilot valve plunger down and connects the oil under the power piston to drain. The reset spring, pushing the reset rod against the terminal lever, holds the power piston down.

d. If engine speed rises above tripping speed the centrifugal force of the flyweights overcomes the speeder spring force and lifts the pilot valve plunger. As the plunger rises, pressure oil flows to the underside of the power piston, forcing the piston up. As the terminal lever is rotated by the upward movement of the power piston, the pin in the speed droop bracket raises the right end of the floating lever. This decreases the downward force of the speeder spring and the flyweights move to their extreme out position. The power piston then moves to the top of its stroke, as allowed by the terminal lever, which rotates the terminal shaft. The external lever on the terminal shaft then actuates the trip valve.

e. When engine speed drops back below the reset speed the speeder spring pushes the pilot valve plunger down and the area under the power piston is again connected to the sump. The reset spring rotates the terminal lever and pushes the power piston down. Oil is then recirculated through the pump as before.

OVERSPEED TRIP ADJUSTMENT.

The speed at which the unit trips is determined by the position of the speed adjusting screw. Turning the screw into the cover raises the tripping speed, and turning it out lowers tripping speed. The overspeed set point is adjusted at the factory, and under normal conditions should not be changed in the field. If it becomes necessary to reset the trip point, follow these steps.

a. Back out servo limit adjusting screw so that it does not limit travel in the power piston.

b. Make tentative speed droop bracket setting at approximately one-half its travel from minimum to maximum droop.

c. Make preliminary tripping speed adjustment with speed adjusting screw.

d. Readjust speed droop bracket to obtain approximately ten percent excess range, then readjust tripping speed. The speed adjusting lever can be locked in place by tightening the high speed stop screw against the speed adjusting lever.

e. Reset overspeed trip at a speed slightly below the desired reset speed. The servo limit adjusting screw affects only the reset speed. Turn in to raise the reset speed to the desired value.

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PART G – ENGINE CONTROLS (Continued)

LOGIC BOARD TROUBLE SHOOTING.

Trouble shooting of the logic boards should be approached in a logical manner, eliminating the obvious first. The following steps will assist in the finding of faults in the system.

a. Check that there is proper supply pressure in the system, as specified on the applicable system drawings.

b. Check that all operator controls are in the correct positions for the selected mode of operation.

c. Check the board for the proper output signals. Since the system is designed to provide a predictable series of output signals, the first place to start trouble shooting is to determine if the output signals that should be present are present, and which ones should not be present when the problem occurs. Check out procedures for individual logic boards are shown on the drawing for that board. Also, check to see if the signals come on and off sharply without gradual increases or decreases in pressure unless this is called for in the check out procedures. If the increase or decrease is slow, check for leaks, pinched tubes, etc. If the proper signals are present, then the malfunction may be in one of the power devices.

d. Check for proper input signals to the logic board. Once the determination has been made that the output signals from the board are not on and off at the proper time, check the input signals to the board to make sure they are correct. Once again, return to the control schematic drawings and determine which input signals are to be on and which are supposed to be off when the problem occurs. Of equal importance is the order in which they go on and off.

e. Once the output signal conditions have been checked and found to be incorrect, and after the input signals have been checked and found to be correct, then and only then is the circuit board to be considered for trouble shooting. Make sure the problem is in the circuit board before proceeding.

CHECKING LOGIC ELEMENTS.

If a logic board is not performing properly, the logic elements should be checked for proper installation on the board before removing them. Then, if the functioning of an element is suspect, it may be removed and replaced. Testing and the repair of the elements should be in accordance with the manufacturer's instructions in the ***Associated Publications Manual***.

a. Refer to the layout diagram on the appropriate assembly drawing and check element location on the circuit board to make certain that all elements are in their proper locations.

b. Check for proper rotation of each element. Elements can be rotated 180°, providing two different positions that it can assume on the board. The rotation is selected at the time the circuit is designed and must agree with the circuit pattern layout. Each element has an "a" or a "b" located on its top cover and these letters are to be oriented as shown on the assembly drawing. Any element that is mislocated or rotated should be changed and the circuit rechecked.

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PART H – ENGINE BALANCING

GENERAL.

The load on a diesel engine should be evenly divided between all cylinders. If it is not, one or more of the cylinders will be forced to carry more than their share of the load while other cylinders loaf with a resulting loss in operating economy and the possibility of experiencing one or more of the following conditions.

a. Scored pistons and liners.

b. Excessive vibration.

c. Excessive piston, valve, bearing and crankshaft wear.

d. Excessive fuel consumption.

e. Excessive lubricating oil usage.

CYLINDER BALANCE.

The balance between power cylinders on Enterprise diesel engines is obtained by having all the fuel injection pumps read the same millimeter of rack position when the governor is in a position equivalent to full load. In order to accomplish this it is essential that all fuel pumps be calibrated in accordance with the fuel pump manufacturer's specifications. The fuel pump rack levers are adjusted during factory test and the lever clamps are then doweled to the fuel rack shaft.

CAUTION

This setting should not be changed in the field, nor should shimming ever be used between the fuel rack lever clamp and the fuel rack lever to change fuel rack settings for individual cylinders. Also, the female rod end which connects the fuel rack lever to the fuel rack should not be adjusted. When a variation in cylinder exhaust temperatures indicates on overloaded or an underloaded cylinder, this condition should not be remedied by changing the individual fuel rack settings. Rather, the real cause of the malfunction should be determined and corrected.

FUEL INJECTION EQUIPMENT.

Clean fuel is essential to the operation of a diesel engine. Injection equipment is manufactured with close working tolerances and, therefore, dirt or other impurities in the fuel can cause pumps or spray nozzles to malfunction. Small depressions in injector valve seats, some so small they are not visible to the naked eye, may be caused by small particles of dirt and will affect spray patterns in the combustion chamber. Pumps and valves must be checked and cleaned periodically. The frequency of cleaning can best be determined from experience, however, care must be taken not to wait too long before cleaning. Fuel pumps should deliver exact amounts of fuel according to the millimeter settings of their fuel pump racks. If they do not, obviously the balance of the cylinders will be affected and the problem must be corrected. It is recommended that whenever a fuel pump is disassembled for any reason, it be recalibrated in accordance with the manufacturer's specifications.

ENGINE OUT OF TUNE.

Spray nozzles are usually suspect if an engine is out of tune or smoking. There are other factors which may also contribute to these conditions. All of them should be considered when evaluating engine performance.

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PART H – ENGINE BALANCING (Continued)

a. Ignition timing.

b. Short or long burning lag in some fuels.

c. Cetane rating of the fuel.

d. Low compression pressure due to leaking valves.

e. Worn piston rings and/or liners.

f. A change in fuel oil.

g. Defective fuel injection pump(s).

h. Valve or linkage maladjustment.

PREVENTIVE MAINTENANCE.

All available operating information should be used as diagnostic tools for determining the condition of an engine and in planning preventive maintenance actions to maintain the engine in peak operating condition. Among the conditions to be considered, peak firing pressures and cylinder exhaust temperatures are very valuable indicators of the condition of a cylinder. The pyrometer and thermocouples provide individual cylinder exhaust temperature information. There are a number of commercial instruments available to take peak firing pressures and cold compression pressures, and the manufacturer of the model selected can provide detailed instructions for its use. The engine log is also an excellent tool for use in recording engine performance and making diagnostic evaluations for preventive maintenance purposes. Readings should be taken and recorded hourly and be supplemented with written observations of all pertinent factors.

TROUBLE SHOOTING.

When trouble shooting the engine, all available information should be used to determine the cause of a malfunction. The trouble shooting tables in Section 7 can be of assistance, as well as the preventive maintenance curves and the engine logs.

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PART I – STARTING AIR SYSTEM

GENERAL.

The engine is started by the timed admission of high pressure starting air to the power cylinders during the equivalent of the power strokes of the respective cylinders. The air is admitted at approximately top center of the power stroke, and admission continues until approximately the opening of the exhaust valves. The pressure is then relieved, thereby creating rotation of the engine comparable to the normal power stroke. As the engine accelerates on starting air, the heat of compression of the combustion air plus the starting air develops sufficient temperature to ignite the injected fuel within a few revolutions and the engine then initiates normal combustion and begins to accelerate under its own power without further aid of starting air.

AIR SUPPLY.

There are two separate, independent air supply systems, each consisting of a motor driven air compressor, a refrigerant drier and a storage tank. Each supply is available to the engine, independent of the other. The starting air supply is stored at 250 psig (17.57 kg/cm^2), and the full 250 psig pressure is available to the starting air header without reduction to provide maximum acceleration for extremely fast and reliable starting.

OPERATION.

The on-engine portion of the starting air system consists of a remotely controlled, pilot operated diaphragm valve in the air supply line, two camshaft driven starting air distributors, one for each cylinder bank, an air filter for each distributor, and a pilot operated air starting valve (figure 6-I-1) in each cylinder head. When the starting air admission valve in the supply line is opened, 250 psig (17.57 kg/cm^2) starting air is admitted into the starting air manifold and, therefore, to the starting air valves in the cylinder heads as well as to the starting air distributors. Individual spool valves in the distributors (one for each cylinder of the bank serviced) are engaged by air pressure and follow the profile of the starting cam attached to the end of the camshaft. The cam profile is such that at least one spool valve is always in position to emit a pilot signal to its respective starting valve in the cylinder, allowing starting air to enter the combustion chamber of that cylinder, rotating the engine. As the engine rotates, the starting air cam will cause the spool valves to emit timed and sequenced pilot air signals to the starting air valves. The starting process will continue until the signal to the starting air admission valve is terminated. The starting air distributors emit a timed pilot air signal that starts five degrees before top dead center and ends at 115 degrees after top dead center on the power stroke.

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PART I – STARTING AIR SYSTEM (Continued)

STARTING AIR VALVE REMOVAL

Disconnect pilot air line(s) from valve cap and remove 12 point flanged capscrews holding valve to cylinder head. Pull valve assembly from cylinder head.

VALVE DISASSEMBLY (See Figure 6-I-1).

The starting air valve may be disassembled for inspection and/or repair as follows.

a. Lift valve cap from housing and remove piston.

b. Remove roll pin securing hex nut then, using a pin spanner or other suitable device in the two holes in the valve head to hold the valve in position, remove hex nut from threaded end of valve stem.

c. Slide valve out through bottom of valve housing. Slide spacers and guides off valve stem.

d. Remove spring, retaining washer and spring washer from housing.

e. Remove O-rings and valve-to-head gasket.

f. Inspect all surfaces of valve, guides, rings and piston. Replace defective parts.

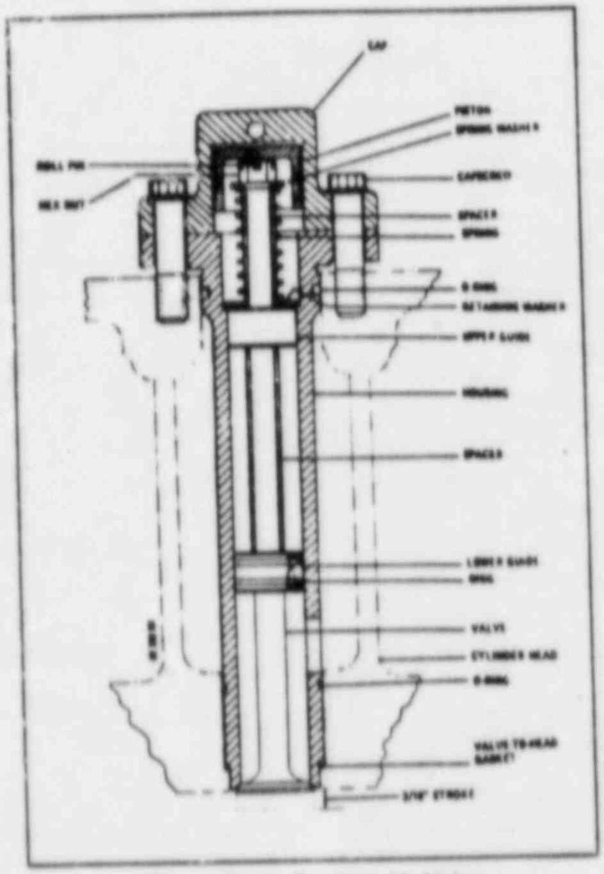

Figure 6-I-1. Starting Air Valve

VALVE ASSEMBLY (See Figure 6-I-1).

Assembly of the valve is the reverse of disassembly.

a. Assemble lower guide with rings in place, long spacer and upper guide to valve stem.

b. Slide valve into housing from bottom, taking care not to damage rings on lower guide.

c. Slide short spacer down over top of valve stem, ensuring it seats in the upper valve guide.

d. Slide retaining washer down over short spacer, ensuring it seats on the shoulder of the housing bore. Slide down the spacer and install spring washer.

e. Assemble hex nut to the valve stem and tighten. Install roll pin then install piston and valve cap.

VALVE INSTALLATION

Assemble O-rings and valve-to-head gasket to the valve assembly. Insert valve assembly into valve hole in cylinder head. Lubricate threads of capscrew(s) with a 50-50 mixture of lubricating oil and powdered graphite and thread capscrew(s) into cylinder head. Torque capscrews to 150 ft-lbs. Connect pilot air line(s). To insure that the capscrews stay tight as the copper gasket squeezes into the voids in the gasket cavity, the capscrews should be retorqued every eight hours of operation until no change in the high torque value is observed. To prevent capscrew fatigue, it is important that they maintain their preload.

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PART J – COOLING WATER SYSTEMS.

GENERAL.

All enterprise engines are cooled by a closed loop system in which a fixed supply of treated water is continuously circulated by the jacket water pump with practically no loss in quality. The water supply for the jacket water system should be completely treated for both scale and corrosion, and raw untreated water must never be introduced into the system. The degree and type of treatment depends on the source of the water. Distilled water and rain water are usually considered as being completely soft and non-corrosive, but they generally require treatment for dissolved corrosive gases such as oxygen which may accelerate rusting. Plain distilled water is not recommended unless it is properly treated. Rain water may also require treatment for fungus picked up in the air or from contamination from air pollutants. Delaval Engine and Compressor Division does not specify any particular form of water treatment, or the frequency of water analysis. Rather, it is recommended that a water treatment specialist be consulted. The degree and frequency of treatment, then, will be based on the water being used. It must be remembered, however, that additives to the cooling water supply should not alter the heat transfer characteristics to which the system was designed. The specific heat of the jacket water system should be kept as close to $1.0 \frac{Btu}{lb\ ^{o}F}$ as possible. The following discussions of water treatment are suggestions only. The actual means used to treat jacket water should be determined by the owner.

OPERATION.

All cooling surfaces must be kept free of scale or other deposits as any such accumulation will degrade the cooling capability of the system and, therefore, cooling water temperatures will not accurately indicate the extent of cooling. Any coating on the cooling surfaces will act as an insulating material and will prevent transfer of heat. If for any reason there is a disruption of the circulation of cooling water flow, the engine should be shut down as soon as practicable to prevent a build up of temperatures and possible serious damage to the engine. To avoid thermal shock, which could cause damage to the engine, do not admit cold water to the cooling system until the temperature of the cooling surfaces in the engine have dropped to approximately that of the inlet water. The use of ethylene glycol antifreeze in the cooling water will materially affect the cooling capacity of radiators and other cooling devices. A 50% ethylene glycol mixture will reduce radiator cooling capacity approximately 12%. Therefore, unless the cooling system was originally designed for this coolant mixture, the Delaval Engine and Compressor Division Customer Service Department should be consulted prior to using such a coolant.

TREATMENT OF JACKET WATER.

The pH value of the jacket water should be maintained within a range of 8.25 and 9.75. The minimum pH value is necessary to prevent acid attack on the metallic surfaces, and the 9.75 maximum value will prevent corrosion due to high alkaline content in the water. A suggested water treatment material for jacket water systems is sodium dichromate and a commercial boiler compound, however, it is recommended that a commercial water treatment company be consulted to insure that local conditions are taken fully into account. Sodium dichromate is an inexpensive source of alkaline chromate (CrO_4) which has been found to form a protective film on metallic surfaces that prevents attack by the corrosive elements found in the jacket water. Sodium dichromate is an acid compound which must have an alkaline compound such as boiler compound added to convert the dichromate to an effective alkaline chromate form. The alkaline chromate concentration must be maintained between 700 and 1700 parts per million (ppm). Less than 700 ppm can result in accelerated corrosion while more than 1700 ppm serves no useful purpose and is a waste of material. The cloride content must not be allowed to exceed 100 ppm as the effectiveness of alkaline chromate decreases as the cloride content increases. When initiating alkaline chromate water treatment for the first time, or after the system has been refilled, the water should be tested daily for alkaline chromate concentration and for pH value. When the treatment becomes stable, the test interval can be extended to weekly tests. After each addition of chemicals, the water should be circulated through the system, then tested to insure that the required limits are met.

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PART J – COOLING WATER SYSTEMS (Continued)

WATER SOFTENERS.

Depending on the location of the installation and the source of the cooling water supply, it may be advisable to utilize some means of softening the water. This can best be accomplished by consulting a commercial water treatment company for technical assistance so that the specific needs may be determined and the proper treatment method instituted.

CLEANING THE JACKET WATER SYSTEM.

The following methods may be used to clean rust and scale from the jacket water system. Most water treatment companies have their own proprietary solutions and method for cleaning engine jacket water systems which are equally as effective. The following acid cleaning method *can not be used* for systems which have components containing aluminum.

a. Rust can be removed from the jacket water system by filling the system with a solution of 75 pounds of ammonium citrate in enough fresh water to make 100 gallons of solution. Make enough solution to fill the jacket water system then operate the engine for two hours. The jacket water system must then be flushed with fresh water and neutralized.

b. Scale can be removed from the system by using a scale solvent solution composed of 7 gallons of 20° Baume muratic (hydrochloric) acid, one-half gallon of liquid inhibitor and 92½ gallons of fresh water at 160°F. Make enough solution to fill the system. Circulate the acid solution through the system for one or two hours, depending on the extent of the scale deposit. The temperature of the acid solution must be maintained at 160°F during circulation. After circulating the acid solution, drain the jacket water system and then fill with clean fresh water and flush it thoroughly. After flushing, neutralize the system with a solution composed of 20 pounds of soda ash (sodium carbonate) and enough fresh water at 160°F to make 100 gallons of neutralizing solution. Fill the jacket water system with the neutralizing solution and circulate it through the system for one-half hour. Maintain the temperature of the during circulation.

ENVIRONMENTAL RESTRICTIONS.

Alkaline chromate water treatment compounds, such as sodium dichromate, may be considered environmentally objectionable in some locations, or may be prohibited. In these instances, nitrite compounds such as sodium nitrite ($NaNO_2$) are suggested as adequate substitutes. When using sodium nitrite, the concentration must be 500 ppm with a pH of 7.5 to 8.5 to achieve effective corrosion control. Nitrite compounds for treating engine jacket water systems are available from most commercial chemical supply houses, and instructions for their use are available from the chemical supplier.

PART K – LUBRICATING OIL SYSTEM

FILTERS AND STRAINERS.

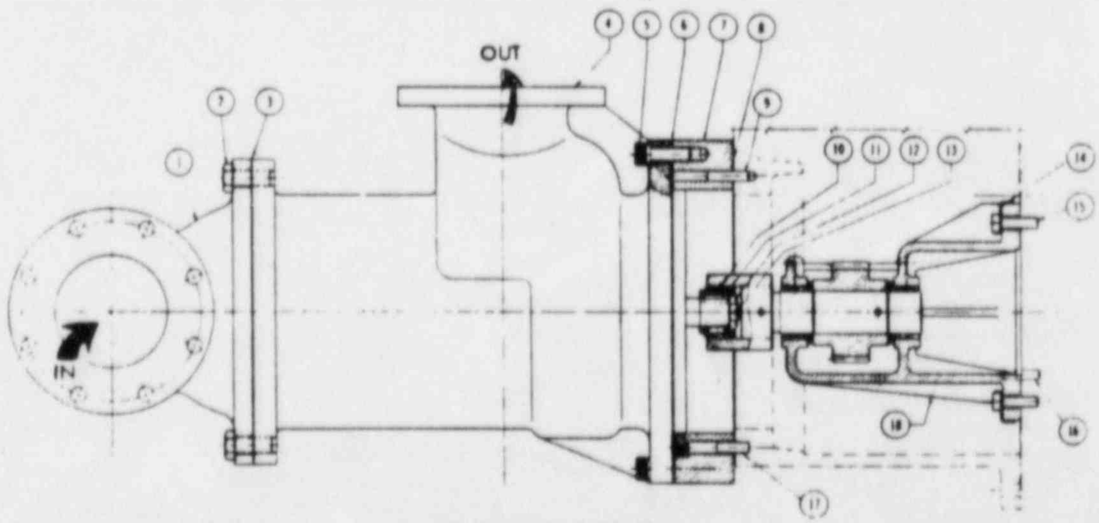
The full flow filter continuously filters all of the lubricating oil from the pump before it passes to the oil strainer. The length of time that the lubricating oil and the filter elements may remain in service can best be determined by carefully watching the result of oil analysis and the pressure drop across the oil filter. Change period will vary with the operating conditions to which each individual engine is subjected. During the first two or three days of engine operation after initial installation, or after a major overhaul, the strainer at the pump suction and the strainer at the oil header inlet should be checked and cleaned as necessary to remove any debris and other foreign matter that may be present. If at any time the oil pressure gauge shows a low reading, the following should be done to the degree necessary to correct the situation.

a. Check the oil level in the sump tank.

b. Inspect strainer, filter and lubricating oil cooler. A leak in the cooler may be detected by a sudden increase in oil consumption, and by the presence of oil in the cooling water system. Leakage may occur in the packing between the tubes and the tube sheet, or may be due to tube erosion, depending on the construction of the cooler.

c. Inspect all external and internal piping for tightness and freedom from obstructions.

d. Dismantle and inspect pump.



1 ELBOW	10 SPLINE – EXTERNAL
2 CAPSCREW	11 SQUARE KEY
3 GASKET	12 HEX NUT
4 L.O. PUMP	13 COTTER PIN
5 CAPSCREW	14 LOCKING CLIP
6 GASKET	15 CAPSCREW
7 ADAPTER	16 DOWEL
8 GASKET	17 CAPSCREW
9 DOWEL	18 GEAR CARRIER

Figure 6-K-1. Lubricating Oil Pump and Gear Carrier Assembly

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PART K – LUBRICATING OIL SYSTEM (Continued)

LUBRICATING OIL PUMP.

A Delaval IMO, constant displacement, rotary screw type lubricating oil pump is used. Lubricating oil in the pump is propelled axially in a constant, uniform flow through the action of but three moving parts – a power rotor and two idler rotors. The smooth intermeshing of these rotors propells the lubricating oil in a steady flow without any churning, pocketing or pulsation. There are no timing gears, cams, valves, sliding vanes or reciprocating parts to wear or become noisy. The pump is mounted on the front of the gearcase, and is coupled to a carrier assembly by a splined coupling. The carrier assembly is mounted on the front of the engine base, and is driven by the crankshaft speedup gear. Once the pump has been placed in service it should continue to operate satisfactorily with little attention other than an occasional inspection. Noisy pump operation is usually indicative of excessive suction lift, air in the system, misalignment or, in the case of an oil pump, excessive wear.

REMOVING PUMP (See Figure 6-K-1).

To remove the pump from the engine, do the following.

a. Remove the inlet and discharge piping as well as any other interfering piping or accessories.

b. Position a sling on the pump and attach to a chainfall and take up the slack.

c. Remove the capscrews that secure the pump to the adapter and pull the pump directly away from the engine until it is clear.

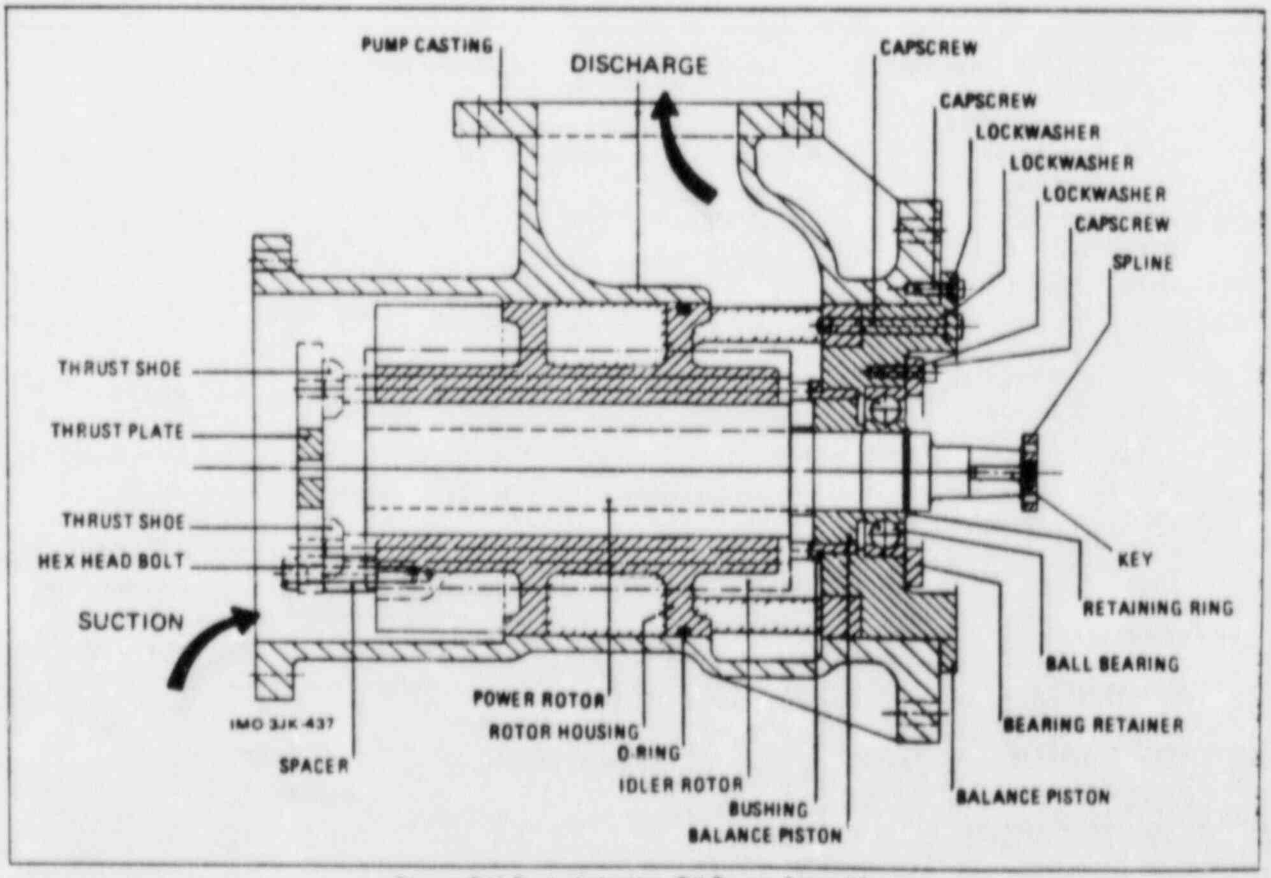

Figure 6-K-2. Lubricating Oil Pump Assembly

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PART K – LUBRICATING OIL SYSTEM (Continued)

PUMP DISASSEMBLY (See Figure 6-K-2).

If it is necessary to disassemble the pump, exercise care to keep the parts clean so that no dirt, grit or other foreign matter will be present when the pump is assembled. Disassemble as follows.

a. Set pump on suction end and remove capscrews and lockwashers holding balance piston housing in pump casing. Remove two capscrews with lockwashers from opposing positions, 180 degrees apart and insert ½ – 13 eyebolts into vacated holes. Lift internal assembly out of pump case and set assembly on its side. *Do not* set it down on thrust plate. Remove eyebolts.

b. Remove bolts, lockwashers, spacers and thrust plate from suction end of rotor housing. Note location of each spacer with respect to the rotor housing. Support and remove each spacer as each bolt is removed. Set parts aside in order of removal.

c. Grasp thrust shoe on end of each idler rotor and unscrew idler rotors from rotor housing. Do not remove thrust shoe from idler rotor.

d. Remove capscrew with lockwashers and bearing retainer. Grasp coupling end of power rotor shaft and pull power rotor out of rotor housing. Avoid hitting bushing with end of power rotor as it is removed. Inspect power rotor and ball bearing.

e. If it is necessary to replace the ball bearing, proceed as follows. Remove retaining ring. Obtain wheel or gear puller and small piece of soft metal. Place soft metal over end of power rotor shaft and use puller to remove the ball bearing from balance piston. Discard bearing.

f. Remove retaining capscrews with lockwasher and separate balance piston housing from rotor housing. Do not disassemble bushing from balance piston housing unless it requires replacement. This completes disassembly necessary for maintenance purposes.

PUMP REASSEMBLY (See Figure 6-K-2).

a. If ball bearing was removed, pressure a new bearing into position on the balance piston. Replace retaining ring. If a new bushing is required, coat outside diameter of new bushing with *Locktite Retaining Compound* and insert bushing into balance piston housing.

b. Set rotor housing on suction end and install new O-ring. Place balance piston housing on discharge end of rotor housing and fasten down with four capscrews and lockwashers, leaving two holes, 180 degrees apart, vacant.

c. Lay rotor housing on its side and insert power rotor into housing from discharge end. Fasten bearing retainer to balance piston housing with capscrews and lockwashers.

d. Insert idler rotors into rotor housing from suction end. Reassemble thrust plate to rotor housing with bolts and washers, making sure that each spacer is assembled to the housing in its original location. Note: *The four spacers have been machined to close tolerances to assure accurate spacing between thrust plate and rotor housing. A minimum torque of 800 in.-lb applied to each bolt should assure proper spacing between thrust plate and rotor housing. Improper spacing will result in accelerated wear of internals.*

e. Insert two ½" x 13 eyebolts into vacated holes in balance piston housing and lift internal assembly into position over pump case. Insert assembly into pump case, being careful not to damage O-ring during process. Fasten internal assembly to pump case with capscrews and lockwashers.

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PART K – LUBRICATING OIL SYSTEM (Continued)

f. This completes pump reassembly. Before mounting to gearcase, make sure that pump turns freely. Do not force piping into place as the strain on the casing may cause excessive pump wear.

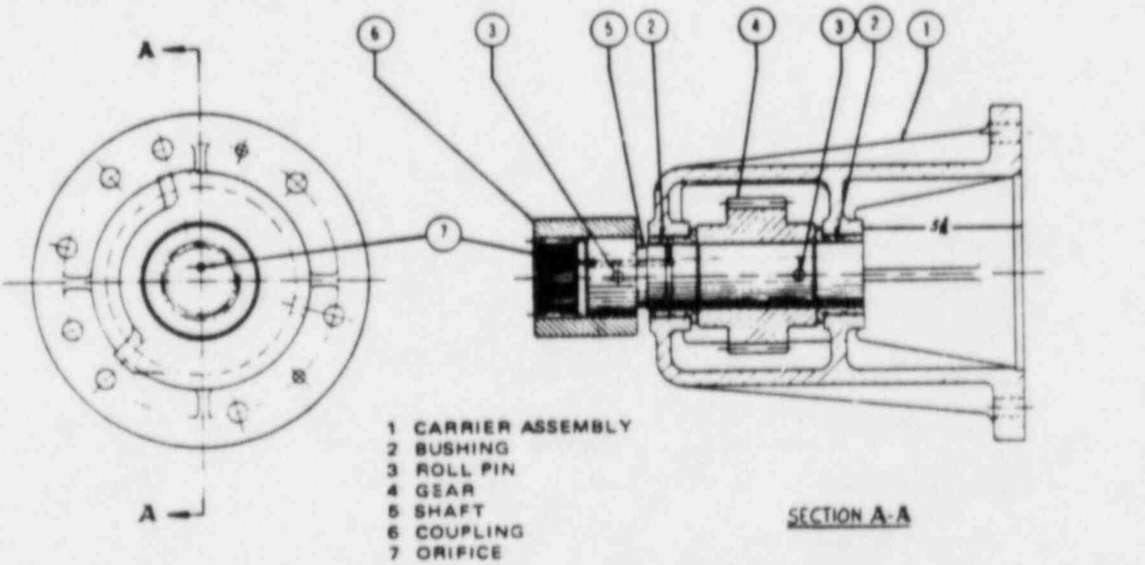

Figure 6-K-3. Gear Carrier Assembly

OIL PUMP GEAR CARRIER ASSEMBLY (See Figure 6-K-3).

The pump gear carrier assembly consists of a shaft supported by two bronze bushings, pressed into the carrier assembly with their flanges to the inside. The pump end of the shaft has an internally splined coupling, attached to the shaft by a roll pin, which accepts the external spline adapter secured to the end of the pump power rotor shaft. The drive gear is mounted on the shaft between the two bushings and engages the speedup gear. The carrier assembly is secured to the engine block by capscrews and locking clips, and is located by two dowels.

DISASSEMBLY AND ASSEMBLY OF GEAR CARRIER ASSEMBLY (See Figure 6-K-3).

To remove the pump gear carrier assembly, the pump must be removed as outlined above, then the gearcase removed.

a. Remove lubricating oil lines from carrier assembly.

b. Bend back locking clips and remove capscrews. Remove carrier assembly.

c. To remove gear, shaft and bushings from carrier assembly, remove gear-to-shaft roll pin then press shaft out of gear. With shaft and gear removed, press bushing out of drive bracket.

d. Assembly is the reverse of disassembly. Use new locking clips.

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PART K – LUBRICATING OIL SYSTEM (Continued)

d. The oil in the annular space around the spool valve, at the adjusting screw end, will leak past the sealing grooves of the spool valve and into a cavity in the cap. This cavity functions as a buffer chamber. To stop valve oscillation, an adjustable needle valve controls oil spillage from the buffer cavity to the outlet-section of the valve.

e. The oil header pressure is set by increasing or decreasing the spring force acting against the header pressure in the valve sensing chamber. Turning the adjusting screw in will increase header pressure, and backing it out will decrease pressure.

f. Normal lubricating oil pressure is 50 psi, measured between the engine lubricating oil strainer and the engine oil header which is also the pickup point for all gauges and other instrumentation that show or indicate engine lubricating oil pressure. Lubricating oil pressure shutdown devices may take their sensing point at the opposite end of the engine in which case the shutdown set pressure will take into account the normal change in pressure between the supply end of the engine and the shutdown sensor under all conditions of engine speed and lubricating oil temperature.

ADDING LUBRICATING OIL.

The lubricating oil sump tank is provided with [illegible]ill connection and a dipstick, located on the top of the intake section of the tank. A level indicator may be provided at the control panel for monitoring purposes, however, the level in the sump tank should be verified by means of a visual reading of the dipstick before oil is added to the system, and the expected rise in the level in the sump tank must be verified by means of the dipstick. Oil may be added to the system with the engine running or with the engine stopped. The dipstick has two sets of marks, one for the static condition and one for the running condition. The markings are "Full Static" and "Low Static" on one side of the dipstick, and "Full Run" and "Low Run" on the other. Before oil is added, it should be determined that the correct oil is available. Appendix VI of this manual contains the recommended specifications for the lubricating oil to be used.

CAUTION

Oil must never be added from any location other than the fill connection on the sump tank. Do not overfill. Attempting to fill from any other location could result in oil reaching other than design locations.

PART K – LUBRICATING OIL SYSTEM (Continued)

SELECTION OF A LUBRICATING OIL.

The selection of a lubricating oil to be used in the engine is a complex matter, and is very important to the engine's successful operation. The recommendations of both the oil supplier and the engine manufacturer should be carefully considered. Transamerica Delaval's recommendations for a suitable lubricating oil are stated in Section 8, Appendix VI. Other factors to be considered include the price, service life, load factor and fuel sulphur content as well as the filtration and oil purification system used.

CHANGING LUBRICATING OIL.

Once an oil has been selected the engine user, in consultation with the oil supplier, should map out a plan for periodic sampling and laboratory analysis of the oil. A careful review of these results by the owner, the oil supplier and the testing laboratory can then become the basis for deciding whether or not the oil needs to be changed. Transamerica Delaval recommends that oil be changed on the basis of condition of the used oil rather than on a time schedule.

ANALYSIS OF OIL.

Various chemical and physical tests have been developed to classify and identify new oil, and to determine what changes have occured in these oils while in service. The American Society for Testing Materials (ASTM) has standardized these tests, and certain of these tests have been approved as an American National Standard by the American National Standards Institute, Inc. (ANSI). Transamerica Delaval, as stated in Section 5, recommends that representative oil samples be submitted to a qualified laboratory for analysis on a monthly basis, or oftener if operating conditions indicate. The following tests should be conducted.

a. OIL VISCOSITY – Tested in accordance with ASTM D88, D445, ANSI Z11.2 and ANSI Z11.107. The viscosity test will indicate whether the proper grade of oil is being used, and will indicate oxidation (by increased viscosity) or fuel dilution (decreased viscosity). The oil supplier can provide advice regarding the significance of the specific values obtained.

b. WATER/GLYCOL CONTAMINATION – A measure of water and/or glycol contamination of the oil can give warning of potential problems. Water or glycol contamination can come from liner seals, turbocharger casings or faulty lubricating oil heat exchangers.

c. NEUTRALIZATION VALUE – Test in accordance with ASTM D664, D974, ANSI Z11.59 and ANSI Z11.131. Engine oils are intentionally formulated slightly alkaline so that they are capable of neutralizing the acidic compounds that form from products of combustion and of oil oxidation. Generally this reserve alkalinity is depleted and the weak organic acids that attack bearing surfaces can be destructive. Periodic evaluation of Total Base Number (TBN) and Total Acid Number (TAN) are an important measure of oil degradation. As time goes on, TBN is depleted and TAN begins to rise.

d. PENTANE AND BEZINE INSOLUBLES – ASTM D893. This test is a measure of oil insoluble materials, oil resinous matter from oil or additive degradation, external contamination, fuel carbon and highly carbonized materials from degradation of fuel, oil, additives, engine wear and corrosive materials.

e. SPECTROGRAPHIC ANALYSIS – This test is used to measure quantitively the mineral elements in the oil including wear or corrosion metals such as aluminum, chromium, iron, copper, silver, lead and tin. Also, dirt contaminants from the coolant such as boron, potassium and sodium.

Note

The Transamerica Delaval Customer Service Department in Oakland, California will welcome any correspondence regarding oil selection and/or testing. Although Transamerica Delaval cannot recommend a specific lubricant, nor accept any responsibility for the performance of the lubricant selected by the owner, it will be pleased to discuss its experience with a given oil product, or review your oil analysis and offer comments.

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PART K – LUBRICATING OIL SYSTEM (Continued)

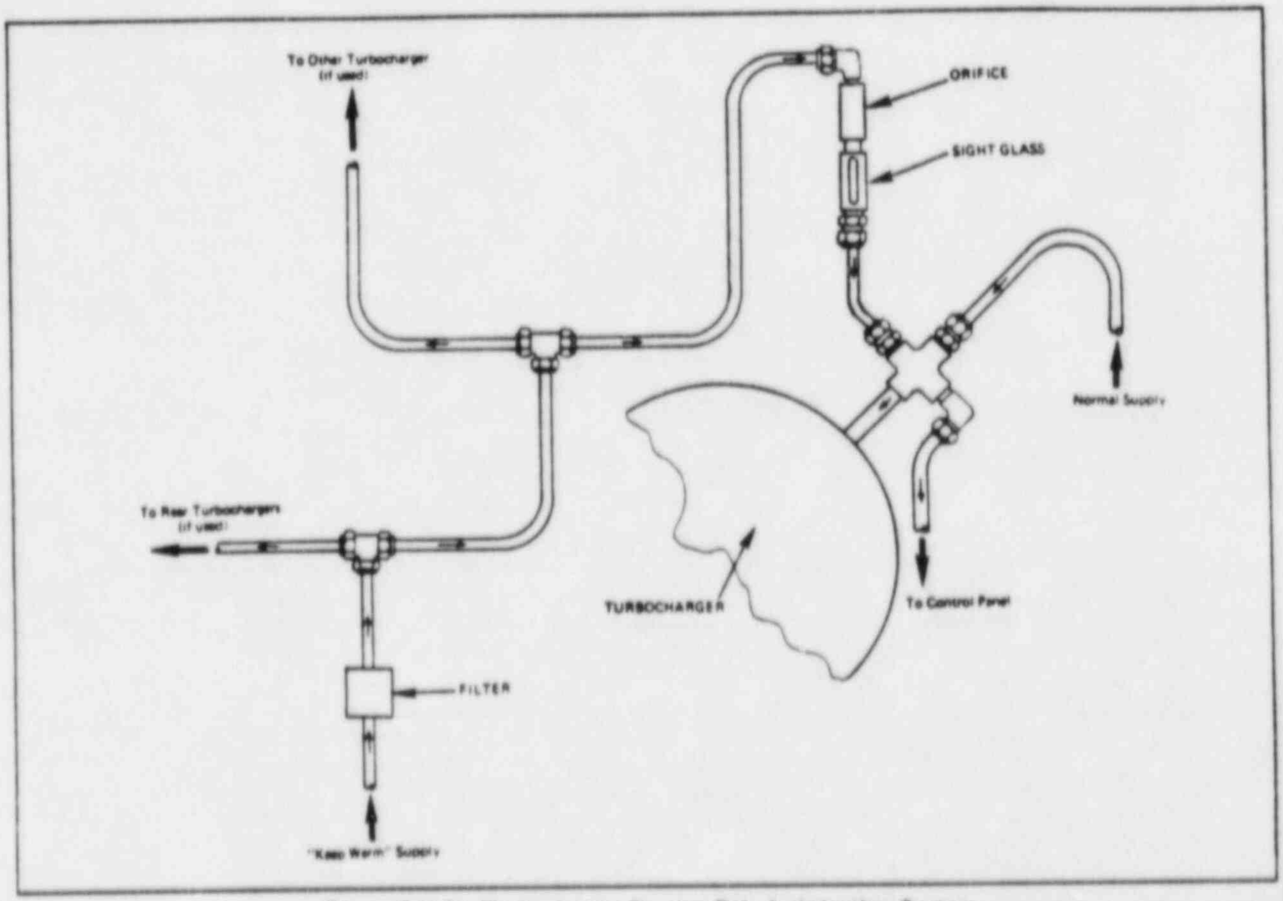

Figure 6-K-5. Turbocharger Bearing Drip Lubrication System

TURBOCHARGER BEARING LUBRICATION.

The turbocharger bearings are lubricated by the engine lubricating oil system during normal engine operation. On the other hand, when the engine is in standby status oil is not circulated to the turbocharger. The design features of the Elliott BCO 90G turbocharger are such that the prolonged circulation of oil to the bearings while the turbocharger is at rest will result in oil intruding past the bearings into the turbine section. To prevent failure of the bearings during a start, however it is essential that the bearings be properly lubricated during prolonged periods in standby. A drip lubrication system is provided to perform this function (see figure 6-K-3). Lubricating oil from the "keep warm" supply is passed through a 60 micron filter then through a 0.014 inch diameter orifice to a sight glass. The sight glass, one for each turbocharger, provides a means for positive determination of oil flow to the bearings. This flow is sufficient to provide for proper lubrication of the bearings without flooding the turbocharger. Little maintenance should be required other than the possible replacement of filter elements.

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PART L – MISCELLANEOUS

MANOMETER.

The U-type manometer is a primary standard for the measurement of pressure. No other device offers a higher degree of accuracy of result. The vertical distance between the two levels of fluid in the U-tube is a measurement of the difference in pressure between the two sides of the manometer. The difference may be expressed in linear units of the indicating fluid, such as inches of water or inches of mercury. Because the pressure being measured acts directly on the indicating liquid in the tube rather than through any mechanical devices, the column will respond directly and immediately to the slightest change in applied pressure. For example, if water is the indicating medium, a pressure change of one ounce per square inch will change the indicating levels approximately one inch. As standard scales are graduated in tenths of an inch, very accurate readings are possible.

MEASURING VACUUM.

Vacuum and pressure, in the sense used here, are the same thing, vacuum being merely the degree to which the pressure has been brought below atmospheric pressure. Vacuum is normally read in inches of mercury. If a vacuum pump were to be connected to one leg of a U-type manometer while the other leg remained open to atmosphere (see figure 6-L-1), the pressure on the pump side would be reduced as the pump works. Atmospheric pressure, then being the greater pressure, will force the column of mercury down on the open side and consequently, the column of the leg will rise. The resultant difference in the height of the column is the measure of vacuum in inches of mercury created by the pump.

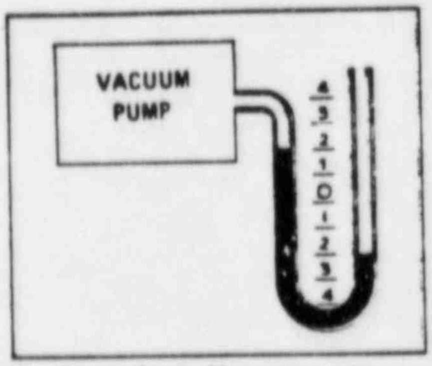

Figure 6-L-1. Manometer with Vacuum Pump

OPERATION AND MAINTENANCE.

With both legs of the manometer open to atmosphere as shown in figure 6-L-2, indicating fluid is placed in the tube until the level is at the center, or zero graduation of the scale. If the level of the two columns is less than zero, fluid should be added. If the reading is more than zero, fluid should be removed. Minor adjustments may be made by moving the scale to obtain an exact zero reading. Application of pressure to the right leg will force the fluid column down in the right leg and up in the left. The instrument is then read by noting the deflection from zero in both legs, then adding the two. In the case of the manometer illustrated on the right side of figure 6-L-2, the difference is the sum of two inches below zero and two inches above, or four inches.

Figure 6-L-2. Reading Manometer

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PART L – MISCELLANEOUS

CRANKCASE PRESSURE.

The crankcase is fully enclosed and theoretically air tight. To remove gases and vapors from the crankcase, crankcase pressure is maintained at a level slightly below atmospheric, measured in inches of water by a standard U-type manometer.

CRANKCASE VENTILATION SYSTEM.

The crankcase ventilation system is designed to expel vapors from the crankcase while the engine is running. The system will also assist in determining the general condition of the engine, particularly piston ring and cylinder liner wear. If piston ring and/or liner wear becomes excessive, piston blowby will cause a rise in crankcase pressure and, therefore, will be evidenced by a change in the crankcase pressure towards a positive pressure. Two motor-driven blowers are used to draw directly from the crankcase through an oil separator and discharge directly to atmosphere outside the engine room. Oil particles suspended in the air are removed as the air passes through the separators, and the oil drains back to the engine crankcase. The blower motors are started automatically when the engine is started, and shut down when the engine is stopped.

CRANKCASE VACUUM.

A crankcase vacuum of 0.2 to 0.5 in.-H_2O is normal when the engine is operating at rated load and speed. Crankcase vacuum readings should be taken carefully, and compared with previous readings. In this way gradual changes can be detected and investigated so that minor problems can be corrected before they reach major proportions. Should the readings indicate a loss of crankcase vacuum, the cause should be promptly determined and corrected.

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PART L — MISCELLANEOUS (Continued)

AIR BUTTERFLY VALVE.

Grease fittings are provided on both ends of the air butterfly valve shaft. The shaft should be manually checked for freedom of movement, and the bushings lubricated as determined to be necessary. This action should be performed at the intervals specified in the recommended maintenance procedures (See Section 5, Part B), or oftener if local conditions should warrant. A standard automotive wheel bearing grease is acceptable, such as Mobil Oil *Mobilgrease 532*, *Mobilgrease MP*, *Mobilgrease Special*, or equal. The valve shaft is notched at the lever end to indicate the orientation of the valve. Adjust the linkage between the actuating cylinder and the butterfly valve lever so that the butterfly valve is fully open when the cylinder rod is fully retracted.

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Section 7
Trouble
Shooting

SECTION 7

TROUBLE SHOOTING

GENERAL.

Effective maintenance trouble shooting requires a sound knowledge of the engine in both a theoretical and a practical sense. The mechanic must analyze the cause and effect of different conditions and, where the cause is not readily apparent, he must employ a fine sense of logic based upon the use of all the tools available to determine that cause. Section 5 of this manual illustrates some trouble shooting data that can be obtained from the charts and curves which are recommended. In addition, this section contains a listing of possible troubles that may be encountered, their possible causes, and the action that would appear to be appropriate.

RECORDS.

All possible malfunctions and their probable causes cannot be foreseen and recorded in advance. Each engine will develop and display characteristics which may not be common to all engines of the same model or type. Also, the same operator or mechanic will not always perform the trouble shooting and repair work. It is, therefore, suggested that the owner establish a detailed repair and trouble shooting record system. Each malfunction should be recorded in a readily usable form, listing the indications and findings for each malfunction encountered together with the repair action required. This record will be of assistance in determining the cause of any future malfunctions, and will be a valuable training aid for all operators and mechanics.

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TROUBLE	POSSIBLE CAUSE	ACTION
1. Engine fails to turn over when air start valve turned on.	a. Air line valves closed.	Check air line valves.
	b. Air pressure too low.	Check pressure. Check for clogged air strainer.
	c. Air start valve leaking or stuck.	Release cylinder pressure by opening indicator cocks. Remove air start valve and examine.
	d. Air distributor out of time.	Adjust timing.
	e. Control system electrical power turned OFF.	Turn switch ON.
2. Engine turns on starting air but will not start.	a. Fuel line valve closed.	Open all fuel valves.
	b. Fuel low in day tank.	Fill tank.
	c. Air in fuel system.	Vent system by opening fuel pump bleeder screws.
	d. Fuel lines clogged.	Clean lines.
	e. Dirty or plugged fuel oil filter(s).	Clean filter(s).
	f. Water in fuel oil.	Drain and refill system with clean fuel oil.
	g. Fuel control linkage sticking.	Free and lubricate.
	h. Fuel oil relief valve stuck open.	Free valve.
	i. Fuel rack shutoff cylinder not actuated.	Check engine control system.
	j. Overspeed shutoff cylinder not actuated.	Check overspeed trip and valve. Check control system.
	k. Stuck valve.	Free, clean and lubricate.
	l. Air intake blocked.	Check overspeed shutdown butterfly valve. Check intake air filter and lines.
	m. Valves riding open.	Adjust valve clearance or, if equipped with hydraulic lifters, check lifter adjustment.
	n. Valve seats worn.	Reseat valves.
	o. Leaking cylinder head gasket.	Replace with new gasket(s).
	p. Piston rings stuck.	Replace rings as required, using oversized rings if necessary. Replace liners if scored or worn.
3. Running engine slows or stops.	a. Safety shutdown system tripped.	Check control panel annunciator for cause.
	b. Low fuel level in day tank.	Fill tank.
	c. Water in fuel oil system.	Drain and fill with new oil.
	d. Fuel filters plugged or dirty.	Clean filters.
	e. Engine overloaded.	Reduce load.
	f. Restriction in exhaust line.	Clear obstruction.
	g. Intake air supply restricted.	Check and clear obstruction. Check intake air filter, overspeed air butterfly valve.
	h. Seized piston.	Actual piston siezure makes a high pitched, squeaking noise. STOP ENGINE IMMEDIATELY. Check pistons, liners and cooling system.
4. Engine fires irregularly when running.	a. Low fuel oil day tank level.	Fill tank.
	b. Air in fuel oil system.	Vent system by opening fuel pump header screws.
	c. Water in fuel oil system.	Drain and fill with new fuel oil.
	d. Fuel lines clogged.	Clean lines.
	e. Plugged or dirty fuel oil filter(s).	Clean filters.
	f. Fuel injection nozzle stuck, clogged, damaged or dirty.	Replace with spare and examine.
	g. Injection tube connections leaking.	Clean joints and tighten.
	h. Fuel nozzle bleeder valve open.	Close valve.
	Fuel injection pump dirty, worn or damaged.	Replace with spare and examine.
	j. Fuel injection pumps out of time.	Adjust timing (see engine data sheet).
	k. Fuel injection pumps out of balance with other pumps.	Check millimeter setting of all pumps with setting at full load shown on engine data sheet. Check individual cylinder exhaust temperatures.
	l. Lack of compression.	See paragraph 2 above.
5. Engine has black exhaust while running.	a. Fuel nozzle stuck, clogged, damaged or worn.	Replace with spare and examine.
	b. Fuel injection pump(s) out of time.	Adjust timing.
	c. Fuel injection pump out of balance.	See 4.k. above.
	d. Air intake blocked.	See 2.l. above.
	e. Engine overloaded.	Check load. Reduce as necessary.

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TROUBLE	POSSIBLE CAUSE	ACTION
6. Engine has blue smoky exhaust.	a. Piston rings stuck. b. Worn piston rings or liners. c. Burning lubricating oil. d. Crack or hole in piston.	Free, clean ring grooves and oil drain holes. Replace rings as required. If necessary, use oversized rings. Replace liners if scored or worn. Check piston rings, ring grooves and liners. Replace piston.
7. Engine knocks while running.	a. Fuel nozzle stuck, clogged, damaged or worn. b. Fuel injection pump out of time. c. Poor fuel oil quality. d. Defective fuel tappet. e. Piston loose in liner. f. Loose piston pin or pin bushing. g. Connecting rod bearing defective. h. Defective main bearings.	Replace with spare and examine. Adjust timing. Check specifications of fuel being used against standards. Check, replace worn parts. Shut off fuel to suspected cylinder. If knock decreases, check piston and ring clearances. Replace worn parts. Place piston at bottom dead center. With pry bar, check piston for loose fit. Replace pin or bushing as necessary. Check clearances. Check clearances.
8. Low lubricating oil pressure.	a. Low oil level in sump tank. b. Lubricating oil suction clogged. c. Loose lubricating oil piping. d. Loaded filter elements. e. Sticking relief valve. f. Defective lubricating oil pump. g. Pressure regulating valve set too low. h. Loose or worn bearings.	Add oil. Check strainer and clean. Check and retighten as necessary. Clean or replace elements. Free and clean valve. Inspect pump. Repair or replace. Adjust valve. Check bearing clearances.
9. High lubricating oil pressure.	a. Relief valve stuck. b. Dirty lubricating oil cooler or full flow filter. c. Pressure regulating valve set too high.	Free and clean. Clean. Adjust to correct pressure.
10. High jacket water inlet temperature.	a. Jacket water pressure too low. b. Air in water system. c. Pump suction or discharge clogged. d. Pump airbound. e. Water passage clogged with scale. f. Inadequate heat exchanger coolant. g. Dirty heat exchanger. h. Engine overloaded. i. Loose piping. j. Inadequate raw water supply.	Check and tighten connections. Check water pump — bleed air. Check and clean. Open vents on pump, or on top of suction. Clean with recognized solvent. Inspect and clean as necessary. Inspect and clean. Reduce load. Check and tighten. Check.
11. Excessive vibration.	a. Cylinder misfiring. b. Stuck valve. c. Mechanical problems.	Check fuel injector nozzles, fuel pump, cylinder fuel cut off. Free, reface, reseat or replace. Investigate all systems and auxiliaries, particularly moving or rotating parts.
12. Excessive exhaust temperatures, all cylinders.	a. Engine overloaded. b. Low manifold air pressure. c. Piston sticking. d. Bearing failure. e. Dirty intake air filter.	Reduce load. Increase manifold pressure. Remove, clean, chank clearances. Inspect and check clearances. Clean.
13. Unequal exhaust temperatures (wide spread with engine loaded)	a. Valve leakage. b. Fuel injection pump out of adjustment.	Check valves, grind and reseat. Adjust.
14. Rising exhaust temperature in one cylinder.	a. Burned exhaust valve. b. Bad fuel injection nozzle. c. Faulty pyrometer.	Replace valve. Check and replace if necessary. Check thermocouples and pyrometer.
15. High pre-turbine exhaust temperature.	a. Engine overloaded. b. Low manifold air pressure. c. Sticking piston. d. Bearing failure. e. Dirty intake air filter.	Reduce load. Increase pressure. Remove, clean, check clearances. Inspect and check clearances. Clean.

TROUBLE	POSSIBLE CAUSE	ACTION
16. Low exhaust temperature in one cylinder.	a. Bad fuel pump. b. Bad fuel pump nozzle. c. Faulty pyrometer.	Check and replace if indicated. Check and replace if indicated. Check thermocouples and pyrometer.
17. Erratic speed variations (hunting)	a. Injection pump improperly timed. b. Injection nozzle tip clogged. c. Injection nozzle improperly adjusted. d. Injection pump plunger stuck. e. Low oil level in governor. f. Low fuel oil pressure. g. Governor or linkage sticking. h. Governor adjustment.	Retime pump. Clean nozzle. Adjust. Free plunger. Fill governor with clean oil. Increase pressure. Lubricate linkage with engine oil. Refer to governor manufacturer's bulletins. Refer to manufacturer's bulletins.
18. Constant engine speed fluctuation.	a. Governor. b. Sticking control linkage. c. Speed signal control air pressure.	Refer to manufacturer's bulletins. Clean and lubricate with engine oil. Check system and supply.
19. Excessive venting and/or vapors from vent holes in each end of starting air header.	a. Leaking starting air valves.	Check valves. Repair or replace.
20. Low jacket water pressure.	a. Defective water pump. b. Water pump airbound.	Check and repair. Bleed air.
21. Low raw water pressure.	a. Defective water pump. b. Air in system. c. Dirty strainer.	Check and repair. Bleed air. Clean.
22. Low compression pressure.	a. Worn piston rings. b. Burned valves. c. Valve tappets improperly adjusted.	Replace. Replace. Adjust valve clearance, or if equipped with hydraulic valve lifters, adjust lifters.
23. Low fuel oil pressure.	a. Dirty filters or strainers. b. Relief valve stuck open. c. Defective booster pump. d. Air leak in suction line.	Check and clean. Free and check. Check and repair or replace. Repair.
24. Excessive lubricating oil consumption.	a. Worn piston rings or liners. b. Leak in sump or piping. c. Lacquering of liners.	Check clearances. Replace if clearance is excessive. Repair. Hone.
25. Loss of crankcase vacuum.	a. Faulty manometer indications. b. Defective blower motor. c. Defective pressure sensing switch. d. Loose electrical connection. e. Air leak around cylinder head covers. f. Air leak at fuel line entrance to head sub covers. g. Air leak past valve guides. h. Piston blowing by. i. Plugged vent line. j. Fuming lubricating oil. **WARNING** This heavy vapor may be very explosive and the engine should be stopped immediately. Allow to rest for 15 minutes to allow fumes and vapors to dissipate before removing any engine covers.	Check tubing for leaks or obstructions. Repair or replace. Replace. Repair. Check gasket condition and tightness of cover. Check grommet and fuel line gaskets. Check clearances. Check for stuck piston rings. Check for excessive piston ring wear. Check and clean line. Check for hot spots in crankcase.

TROUBLE	POSSIBLE CAUSE	ACTION
26. No fuel pump delivery, or insufficient delivery.	a. Fuel tank empty, or valve in line closed.	Refill tank with fuel oil. Check if transfer pump delivers fuel to tank. Open all valves in fuel lines.
	b. Fuel inlet pipe clogged or filter element dirty.	Clean pipe. Clean filter element.
	c. Air lock in pump.	Vent pump and nozzle.
	d. Pump plunger remains suspended in barrel.	Thoroughly clean all parts, particularly plunger and barrel. If either are damaged, replace both with spares.
	e. Broken plunger spring.	Replace with spare.
	f. Delivery valve not seating properly.	Clean delivery valve and seat. If either are damaged, replace with spare.
	g. Delivery valve spring broken.	Replace.
	h. Leakage back to suction chamber from surfaces between top of barrel and delivery valve seat.	Clean faces. Remove burrs and scratches from delivery valve seat and barrel.
	i. Worn or defective plunger or barrel.	Replace with spare.
	j. Dirt causing pump plunger to jam.	Dismantle pump and clean.
	k. Control rack(s) coated with dirt.	Clean and lubricate.
	l. Supply connection leaks.	Install new gasket or replace connection if damaged.
	m. Leakage past spring guide caused by worn plunger, or improper seal of barrel in main body.	Replace defective parts with spares.
	n. High pressure connection leaks.	Install high pressure tube only on the cylinder for which it was factory fitted. Replace line if cone is damaged.
27. Injection nozzle valve sticking.	a. Dirt in nozzle.	Remove and clean nozzle.
	b. Poor lubricating quality of fuel oil.	*Analize fuel oil sample. Change if tests indicate.
	c. Nozzle body and valve corroded, or eroded due to acid, water or dirt in fuel oil.	Check fuel and filters. Replace nozzle body and valve with spares.
	d. Joint between nozzle holder and nozzle not tight.	Clean faces. Remove burrs and scratches from nozzle body and holder.
	e. Nozzle valve worn and loose in nozzle body.	Replace nozzle body and valve with spares.
	f. Nozzle valve stuck in closed position or nozzle orifices closed.	Check fuel and filters. Remove and clean nozzle.
	g. Carbon deposits on nozzle.	Clean nozzle.
		*Check fuel being used for conformance to approved specifications. Introduce additive in fuel if recommended.
28. High peak firing pressure.	a. Overload condition.	Reduce load.
	b. Early injection.	
	c. Malfunctioning nozzle.	
29. Low peak firing pressure.	a. Late ignition.	

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Section 8
Appendices

Section 8
Appendices

The purpose of this section of the manual is to provide a single location for data which, if located within the text of the manual, would be more difficult to locate. As a general rule, specific values, such as pressures, clearances, torques, etc., have been omitted from the text and, where appropriate, reference is made to the applicable appendix.

The following appendices are provided in this section:

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Appendix I

Conversion Factors And Other Useful Information

The purpose of this appendix is to provide a ready reference for frequently used formulae, conversion factors and other data.

FORMULAE

Brake Mean Effective Pressure (bmep)

$$bmep = \frac{bhp \times 33{,}000}{L \times A \times N}$$

where

bhp = Brake horsepower per cylinder
L = Stroke of piston in feet
A = Net piston area (sq-in.)
N = Number of power strokes per cylinder per minute

Circumference of a Circle	=	diameter x 3.1416
Radius of a Circle	=	Circumference x 0.159155
Area of a Circle	=	Radius^2 x 3.1416

Conversion Factors and Other Useful Information

Areas of Circles
(Diameters in Inches, Area in Square Inches)

Diameters	Area	Diameters	Area	Diameter	Area	Diameters	Area	Diameters	Area
1/16	.00307	3		10		22		1/2	1046.349
1/8	.01227	5/8	10.3206	1/4	82.5161	1/2	397.609	3/4	1060.732
3/16	.02761	11/16	10.6783	3/8	84.5409	3/4	406.494	37	1075.213
1/4	.04909	3/4	11.0447	1/2	86.5903	23	415.477	1/4	1089.792
5/16	.07670	13/16	11.4158	5/8	88.6643	1/4	424.558	1/2	1104.469
1/8	.1104	7/8	11.7933	3/4	90.7628	1/2	433.737	3/4	1119.244
7/16	.1503	15/16	12.1767	7/8	92.8858	3/4	443.015	38	1134.118
1/2	.1964	4	12.5664	11	95.0334	24	452.389	1/4	1149.089
9/16	.2485	1/8	13.3641	1/8	97.2055	1/4	461.864	1/2	1164.159
5/8	.3068	1/4	14.1863	1/4	99.4022	1/2	471.436	3/4	1179.327
11/16	.3712	1/8	15.0330	3/8	101.6234	3/4	481.107	39	1194.593
3/4	.4418	1/2	15.9043	1/2	103.8691	25	490.875	1/4	1209.95
13/16	.5185	5/8	16.8002	5/8	106.1394	1/4	500.742	1/2	1225.42
7/8	.6013	3/4	17.7206	3/4	108.4343	1/2	510.706	3/4	1240.98
15/16	.6903	7/8	18.6655	7/8	110.7537	3/4	520.769	40	1256.64
1	.7854	5	19.6349	12	113.098	26	530.929	1/4	1272.39
1/16	.8866	1/8	20.6289	1/4	117.859	1/4	541.189	1/2	1288.25
1/8	.9940	1/4	21.6476	1/2	122.719	1/2	551.547	3/4	1304.20
3/16	1.1075	3/8	22.6907	3/4	127.677	3/4	562.003	41	1320.25
1/4	1.2272	1/2	23.7583	13	132.733	27	572.557	1/4	1336.40
5/16	1.3530	5/8	24.8505	1/4	137.887	1/4	583.209	1/2	1352.65
1/8	1.4849	3/4	25.9673	1/2	143.139	1/2	593.959	3/4	1369.00
7/16	1.6230	7/8	27.1086	3/4	148.489	3/4	604.807	42	1385.45
1/2	1.7671	6	28.2744	14	153.938	28	615.754	1/4	1401.99
9/16	1.9175	1/8	29.4648	1/4	159.485	1/4	626.789	1/2	1418.63
5/8	2.0739	1/4	30.6797	1/2	165.122	1/2	637.941	3/4	1435.37
11/16	2.2365	3/8	31.9191	3/4	170.874	3/4	649.182	43	1452.20
3/4	2.4053	1/2	33.1831	15	176.715	29	660.521	1/4	1469.14
13/16	2.5802	5/8	34.4717	1/4	182.665	1/4	671.959	1/2	1486.17
7/8	2.7612	3/4	35.7848	1/2	188.692	1/2	683.494	3/4	1503.30
15/16	2.9483	7/8	37.1224	3/4	194.828	3/4	695.128	44	1520.53
2	3.1416	7	38.4846	16	201.062	30	706.858	1/4	1537.86
1/16	3.3410	1/8	39.8713	1/4	207.395	1/4	718.689	1/2	1555.29
1/8	3.5466	1/4	41.2826	1/2	213.825	1/2	730.618	3/4	1572.81
3/16	3.7583	3/8	42.7184	3/4	220.354	3/4	742.645	45	1590.43
1/4	3.9761	1/2	44.1787	17	226.981	31	754.769	1/4	1608.16
5/16	4.2000	5/8	45.6636	1/4	233.706	1/4	766.992	1/2	1625.97
1/8	4.4301	3/4	47.1731	1/2	240.529	1/2	779.313	3/4	1643.89
7/16	4.6664	7/8	48.7071	3/4	247.447	3/4	791.732	46	1661.91
1/2	4.9087	8	50.2656	18	254.469	32	804.247	1/4	1680.02
9/16	5.1572	1/8	51.8487	1/4	261.587	1/4	816.865	1/2	1698.23
5/8	5.4119	1/4	53.4563	1/2	268.803	1/2	829.579	3/4	1716.54
11/16	5.6727	3/8	55.0884	3/4	276.117	3/4	842.391	47	1734.95
3/4	5.9396	1/2	56.7451	19	283.529	33	855.[illegible]01	1/4	1753.45
13/16	6.2126	5/8	58.4264	1/4	291.040	1/4	868.309	1/2	1772.06
7/8	6.4918	3/4	60.1322	1/2	298.648	1/2	881.415	3/4	1790.76
15/16	6.7771	7/8	61.8625	3/4	30[illegible].355	3/4	894.618	48	1809.56
3	7.0686	9	63.6174	20	314.159	34	907.922	1/4	1828.46
1/16	7.3662	1/8	65.3968	1/4	322.063	1/4	921.323	1/2	1847.46
1/8	7.6699	1/4	67.2008	1/2	330.064	1/2	934.822	3/4	1866.55
3/16	7.9798	3/8	69.0293	3/4	338.164	3/4	948.418	49	1885.75
1/4	8.2958	1/2	70.8823	21	346.361	35	962.115	1/4	1905.04
5/16	8.6179	5/8	72.7599	1/4	354.657	1/4	975.909	1/2	1924.43
3/8	8.9462	3/4	74.6621	1/2	363.051	1/2	989.789	3/4	1943.91
7/16	9.2806	7/8	76.5888	3/4	371.543	3/4	1003.788	50	1963.49
1/2	9.6211	10	78.5398	22	380.134	36	1017.878	1/4	1983.18
9/16	9.9678	1/8	80.5158	1/4	388.822	1/4	1032.065	1/2	2002.97
								3/4	2022.85

Conversion Factors and Other Useful Information (contd)

Temperature Conversion Chart

NOTE: The center column of numbers in boldface refers to the temperature in degrees, either Centigrade or Fahrenheit, which it is desired to convert into the other scale. If converting from Fahrenheit to Centigrade degrees, the equivalent temperature will be found in the left column, while if converting from degrees Centigrade to degrees Fahrenheit, the answer will be found in the column on the right.

Centigrade		Fahrenheit
-273.17	**-459.7**	
-268	**-450**	
-262	**-440**	
-257	**-430**	
-251	**-420**	
-246	**-410**	
-240	**-400**	
-234	**-390**	
-229	**-380**	
-223	**-370**	
-218	**-360**	
-212	**-350**	
-207	**-340**	
-201	**-330**	
-196	**-320**	
-190	**-310**	
-184	**-300**	
-179	**-290**	
-173	**-280**	
-169	**-273**	-459.4
-168	**-270**	-454
-162	**-260**	-436
-157	**-250**	-418
-151	**-240**	-400
-146	**-230**	-382
-140	**-220**	-364
-135	**-210**	-346
-129	**-200**	-328
-123	**-190**	-310
-118	**-180**	-292
-112	**-170**	-274
-107	**-160**	-256
-101	**-150**	-238
-96	**-140**	-220
-90	**-130**	-202
-84	**-120**	-184
-79	**-110**	-166
-73.3	**-100**	-148.0
-67.8	**-90**	-130.0
-62.2	**-80**	-112.0
-59.4	**-75**	-103.0
-56.7	**-70**	-94.0
-53.9	**-65**	-85.0
-51.1	**-60**	-76.0
-48.3	**-55**	-67.0
-45.6	**-50**	-58.0
-42.8	**-45**	-49.0
-40.0	**-40**	-40.0
-37.2	**-35**	-31.0
-34.4	**-30**	-22.0
-31.7	**-25**	-13.0
-28.9	**-20**	-4.0
-26.1	**-15**	5.0
-23.3	**-10**	14.0

Centigrade		Fahrenheit
-20.6	**-5**	23.0
-17.8	**0**	32.0
-17.2	**1**	33.8
-16.7	**2**	35.6
-16.1	**3**	37.4
-15.6	**4**	39.2
-15.0	**5**	41.0
-14.4	**6**	42.8
-13.9	**7**	44.6
-13.3	**8**	46.4
-12.8	**9**	48.2
-12.2	**10**	50.0
-11.7	**11**	51.8
-11.1	**12**	53.6
-10.6	**13**	55.4
-10.0	**14**	57.2
-9.4	**15**	59.0
-8.9	**16**	60.8
-8.3	**17**	62.6
-7.8	**18**	64.4
-7.2	**19**	66.2
-6.7	**20**	68.0
-6.1	**21**	69.8
-5.6	**22**	71.6
-5.0	**23**	73.4
-4.4	**24**	75.2
-3.9	**25**	77.0
-3.3	**26**	78.8
-2.8	**27**	80.6
-2.2	**28**	82.4
-1.7	**29**	84.2
-1.1	**30**	86.0
-0.6	**31**	87.8
0.0	**32**	89.6
0.6	**33**	91.4
1.1	**34**	93.2
1.7	**35**	95.0
2.2	**36**	96.8
2.8	**37**	98.6
3.3	**38**	100.4
3.9	**39**	102.2
4.4	**40**	104.0
5.0	**41**	105.8
5.6	**42**	107.6
6.1	**43**	109.4
6.7	**44**	111.2
7.2	**45**	113.0
7.8	**46**	114.8
8.3	**47**	116.6
8.9	**48**	118.4
9.4	**49**	120.2
10.0	**50**	122.0
10.6	**51**	123.8

Centigrade		Fahrenheit
11.1	**52**	125.6
11.7	**53**	127.4
12.2	**54**	129.2
12.8	**55**	131.0
13.3	**56**	132.8
13.9	**57**	134.6
14.4	**58**	136.4
15.0	**59**	138.2
15.6	**60**	140.0
16.1	**61**	141.8
16.7	**62**	143.6
17.2	**63**	145.4
17.8	**64**	147.2
18.3	**65**	149.0
18.9	**66**	150.8
19.4	**67**	152.6
20.0	**68**	154.4
20.6	**69**	156.2
21.1	**70**	158.0
21.7	**71**	159.8
22.2	**72**	161.6
22.8	**73**	163.4
23.3	**74**	165.2
23.9	**75**	167.0
24.4	**76**	168.8
25.0	**77**	170.6
25.6	**78**	172.4
26.1	**79**	174.2
26.7	**80**	176.0
27.2	**81**	177.8
27.8	**82**	179.6
28.3	**83**	181.4
28.9	**84**	183.2
29.4	**85**	185.0
30.0	**86**	186.8
30.6	**87**	188.6
31.1	**88**	190.4
31.7	**89**	192.2
32.2	**90**	194.0
32.8	**91**	195.8
33.3	**92**	197.6
33.9	**93**	199.4
34.4	**94**	201.2
35.0	**95**	203.0
35.6	**96**	204.8
36.1	**97**	206.6
36.7	**98**	208.4
37.2	**99**	210.2
37.8	**100**	212.0
40.6	**105**	221
43.3	**110**	230
46.1	**115**	239
48.9	**120**	248
51.7	**125**	257

Centigrade		Fahrenheit
54.4	**130**	266
57.2	**135**	275
60.0	**140**	284
62.8	**145**	293
65.6	**150**	302
68.3	**155**	311
71.1	**160**	320
73.9	**165**	329
76.7	**170**	338
79.4	**175**	347
82.2	**180**	356
85.0	**185**	365
87.8	**190**	374
90.6	**195**	383
93.3	**200**	392
96.1	**205**	401
98.9	**210**	410
100.0	**212**	414
102	**215**	419
104	**220**	428
107	**225**	437
110	**230**	446
113	**235**	455
116	**240**	464
118	**245**	473
121	**250**	482
124	**255**	491
127	**260**	500
129	**265**	509
132	**270**	518
135	**275**	527
138	**280**	536
141	**285**	545
143	**290**	554
146	**295**	563
149	**300**	572
154	**310**	590
160	**320**	608
166	**330**	626
171	**340**	644
177	**350**	662
182	**360**	680
188	**370**	698
193	**380**	716
199	**390**	734
204	**400**	752
210	**410**	770
216	**420**	788
221	**430**	806
227	**440**	824
232	**450**	842
238	**460**	860
243	**470**	878
249	**480**	896
254	**490**	914
260	**500**	932

The formulas at the right may also be used for converting Centigrade or Fahrenheit degrees into the other scales.

Degrees Cent. $^\circ C = \frac{5}{9}(^\circ F + 40) - 40 = \frac{5}{9}(^\circ F - 32)$

Degrees Fahr. $^\circ F = \frac{9}{5}(^\circ C + 40) - 40 = \frac{9}{5}(^\circ C) + 32$

Degrees Kelvin $^\circ K = {^\circ C} + 273.2$

Degrees Rankine $^\circ R = {^\circ F} + 459.7$

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Conversion Factors and Other Useful Information (cont'd)

Altitude and Atmospheric Pressures

Altitude Above Sea Level			Temperature**		Barometer*		Atmospheric Pressure	
Feet*	Miles	Meters*	°F	°C	Inches Hg Abs.	mm Hg Abs.	PSIA	Kg/sq cm Abs.
-5000		-1526	77	25	35.58	903.7	17.48	1.229
-4500		-1373	75	24	35.00	889.0	17.19	1.209
-4000		-1220	73	23	34.42	874.3	16.90	1.188
-3500		-1068	71	22	33.84	859.5	16.62	1.169
-3000		-915	70	21	33.27	845.1	16.34	1.149
-2500		-763	68	20	32.70	830.6	16.06	1.129
-2000		-610	66	19	32.14	816.4	15.78	1.109
-1500		-458	64	18	31.58	802.1	15.51	1.091
-1000		-305	63	17	31.02	787.9	15.23	1.071
-500		-153	61	16	30.47	773.9	14.96	1.052
0		0	59	15	29.92	760.0	14.696	1.0333
500		153	57	14	29.38	746.3	14.43	1.015
1000		305	55	13	28.86	733.0	14.16	.996
1500		458	54	12	28.33	719.6	13.91	.978
2000		610	52	11	27.82	706.6	13.66	.960
2500		763	50	10	27.32	693.9	13.41	.943
3000		915	48	9	26.82	681.2	13.17	.926
3500		1068	47	8	26.33	668.8	12.93	.909
4000		1220	45	7	25.84	656.3	12.69	.892
4500		1373	43	6	25.37	644.4	12.46	.876
5000	0.95	1526	41	5	24.90	632.5	12.23	.860
6000	1.1	1831	38	3	23.98	609.3	11.78	.828
7000	1.3	2136	34	1	23.10	586.7	11.34	.797
8000	1.5	2441	31	-1	22.23	564.6	10.91	.767
9000	1.7	2746	27	-3	21.39	543.3	10.50	.738
10,000	1.9	3050	23	-5	20.58	522.7	10.10	.710
15,000	2.8	4577	5	-15	16.89	429.0	8.29	.583
20,000	3.8	6102	-12	-24	13.76	349.5	6.76	.475
25,000	4.7	7628	-30	-34	11.12	282.4	5.46	.384
30,000	5.7	9153	-48	-44	8.903	226.1	4.37	.307
35,000	6.6	10,679	-66		7.060	179.3	3.47	.244
40,000	7.6	12,204	-70	-57	5.558	141.2	2.73	.192
45,000	8.5	13,730	-70	-57	4.375	111.1	2.15	.151
50,000	9.5	15,255	-70	-57	3.444	87.5	1.69	.119
55,000	10.4	16,781	-70	-57	2.712	68.9	1.33	.0935
60,000	11.4	18,306	-70	-57	2.135	54.2	1.05	.0738
70,000	13.3	21,357	-67	-55	1.325	33.7	.651	.0458
80,000	15.2	24,408	-62	-52	8.273^{-1}	21.0	.406	.0286
90,000	17.1	27,459	-57	-50	5.200^{-1}	13.2	.255	.0179
100,000	18.9	30,510	-51	-46	3.290^{-1}	8.36	.162	.0114
120,000	22.8	36,612	-26	-32	1.358^{-1}	3.45		
140,000	26.6	42,714	4	-16	5.947^{-2}	1.51		
160,000	30.4	48,816	28	-2	2.746^{-2}	6.97^{-1}		
180,000	34.2	54,918	19	-7	1.284^{-2}	3.26^{-1}		
200,000	37.9	61,020	-3	-19	5.846^{-3}	1.48^{-1}		
220,000	41.7	67,122	-44	-42	2.523^{-3}	6.41^{-2}		
240,000	45.5	73,224	-86	-66	9.955^{-4}	2.53^{-2}		
260,000	49.3	79,326	-129	-90	3.513^{-4}	8.92^{-3}		
280,000	53.1	85,428	-135	-93	1.143^{-4}	2.90^{-3}		
300,000	56.9	91,530	-127	-88	3.737^{-5}	9.49^{-4}		
400,000	75.9	122,040			6.3^{-7}	1.60^{-5}		
500,000	94.8	152,550			1.4^{-7}	3.56^{-6}		
600,000	114	183,060			5.9^{-8}	1.50^{-6}		
800,000	152	244,080			1.6^{-8}	4.06^{-7}		
1,000,000	189	305,100			5.1^{-9}	1.30^{-7}		
1,200,000	228	366,120			2.0^{-9}	5.08^{-8}		
1,400,000	266	427,140			8.2^{-10}	2.08^{-8}		
1,600,000	304	488,160			3.8^{-10}	9.65^{-9}		
1,800,000	342	549,180			1.8^{-10}	4.57^{-9}		
2,000,000	379	610,200			9.2^{-11}	2.34^{-9}		

Data from NASA Standard Atmosphere (1962).

*Temperature and barometer are approximate for negative altitudes.

**Temperatures are average existing at 40° latitude and are rounded to even numbers.

†Negative exponent shows number of spaces the decimal point must be moved to the left.

Conversion Factors and Other Useful Information (cont'd)

Conversion Factors

Multiply	By	To Obtain
Atmospheres	76.0	Cms. of mercury
Atmospheres	29.92	Inches of mercury
Atmospheres	33.90	Feet of water
Atmospheres	1.0333	Kgs./sq. cm.
Atmospheres	14.70	Lbs./sq. inch
Atmospheres	1.058	Tons/sq. ft.
Barrels—Oil	42	Gallons—Oil
British Thermal Units	0.2520	Kilogram-calories
British Thermal Units	777.5	Foot-lbs.
British Thermal Units	3.927×10^{-4}	Horse-power-hrs.
British Thermal Units	107.5	Kilogram-meters
British Thermal Units	2.928×10^{-4}	Kilowatt-hrs.
B.T.U./min.	12.96	Foot-lbs./sec.
B.T.U./min.	0.02356	Horse-power
B.T.U./min.	0.01757	Kilowatts
B.T.U./min.	17.57	Watts
Centares (Centiares)	1	Square meters
Centigrams	0.01	Grams
Centiliters	0.01	Liters
Centimeters	0.3937	Inches
Centimeters	0.01	Meters
Centimeters	10	Millimeters
Centimeters of Mercury	0.01316	Atmospheres
Centimeters of mercury	0.4461	Feet of water
Centimeters of mercury	136.0	Kgs./sq. meter
Centimeters of mercury	27.85	Lbs./sq. ft.
Centimeters of mercury	0.1934	Lbs./sq. inch
Centimeters/second	1.969	Feet/min.
Centimeters/second	0.03281	Feet/sec.
Centimeters/second	0.036	Kilometers/hr.
Centimeters/second	0.6	Meters/min.
Centimeters/second	0.02237	Miles/hr.
Centimeters/second	3.728×10^{-4}	Miles/min.
Cms./sec./sec.	0.03281	Feet/sec./sec.
Cubic centimeters	3.531×10^{-5}	Cubic feet
Cubic centimeters	6.102×10^{-2}	Cubic inches
Cubic centimeters	10^{-6}	Cubic meters
Cubic centimeters	1.308×10^{-6}	Cubic yards
Cubic centimeters	2.642×10^{-4}	Gallons
Cubic centimeters	10^{-3}	Liters
Cubic centimeters	2.113×10^{-3}	Pints (liq.)
Cubic centimeters	1.057×10^{-3}	Quarts (liq.)
Cubic feet	2.832×10^{4}	Cubic cms.
Cubic feet	1728	Cubic inches
Cubic feet	0.02832	Cubic meters
Cubic feet	0.03704	Cubic yards
Cubic feet	7.48052	Gallons
Cubic feet	28.32	Liters
Cubic feet	59.84	Pints (liq.)
Cubic feet	29.92	Quarts (liq.)
Cubic feet/minute	472.0	Cubic cms./sec.
Cubic feet/minute	0.1247	Gallons/sec.
Cubic feet/minute	0.4720	Liters/sec.
Cubic feet/minute	62.43	Lbs. of water/min.
Cubic feet/second	0.646317	Million gals./day
Cubic feet/second	448.831	Gallons/min.
Cubic inches	16.39	Cubic centimeters
Cubic inches	5.787×10^{-4}	Cubic feet
Cubic inches	1.639×10^{-5}	Cubic meters
Cubic inches	2.143×10^{-5}	Cubic yards
Cubic inches	4.329×10^{-3}	Gallons
Cubic inches	1.639×10^{-2}	Liters
Cubic inches	0.03463	Pints (liq.)
Cubic inches	0.01732	Quarts (liq.)
Cubic meters	10^{6}	Cubic centimeters
Cubic meters	35.31	Cubic feet
Cubic meters	61,023	Cubic inches
Cubic meters	1.308	Cubic yards
Cubic meters	264.2	Gallons
Cubic meters	10^{3}	Liters
Cubic meters	2113	Pints (liq.)
Cubic meters	1057	Quarts (liq.)
Cubic yards	7.646×10^{5}	Cubic centimeters
Cubic yards	27	Cubic feet
Cubic yards	46,656	Cubic inches
Cubic yards	0.7646	Cubic meters
Cubic yards	202.0	Gallons
Cubic yards	764.6	Liters
Cubic yards	1616	Pints (liq.)
Cubic yards	807.9	Quarts (liq.)
Cubic yards/min.	0.45	Cubic feet/sec.
Cubic yards/min.	3.367	Gallons/sec.
Cubic yards/min.	12.74	Liters/sec.
Decigrams	0.1	Grams
Deciliters	0.1	Liters
Decimeters	0.1	Meters
Degrees (angle)	60	Minutes
Degrees (angle)	0.01745	Radians
Degrees (angle)	3600	Seconds
Degrees/sec.	0.01745	Radians/sec.
Degrees/sec.	0.1667	Revolutions/min.
Degrees/sec.	0.002778	Revolutions/sec.
Dekagrams	10	Grams
Dekaliters	10	Liters
Dekameters	10	Meters
Drams	27.34375	Grains
Drams	0.0625	Ounces
Drams	1.771845	Grams
Fathoms	6	Feet
Feet	30.48	Centimeters
Feet	12	Inches
Feet	0.3048	Meters
Feet	1/3	Yards
Feet of water	0.02950	Atmospheres
Feet of water	0.8826	Inches of mercury
Feet of water	0.03048	Kgs./sq. cm.
Feet of water	62.43	Lbs./sq. ft.
Feet of water	0.4335	Lbs./sq. inch
Feet/min.	0.5080	Centimeters/sec.
Feet/min.	0.01667	Feet/sec.
Feet/min.	0.01829	Kilometers/hr.
Feet/min.	0.3048	Meters/min.
Feet/min.	0.01136	Miles/hr.
Feet/sec./sec.	30.48	Cms./sec./sec.
Feet/sec./sec.	0.3048	Meters/sec./sec.
Foot-pounds	1.286×10^{-3}	British Thermal Units
Foot-pounds	5.050×10^{-7}	Horse-power-hrs.
Foot-pounds	3.241×10^{-4}	Kilogram-calories
Foot-pounds	0.1383	Kilogram-meters
Foot-pounds	3.766×10^{-7}	Kilowatt-hrs.
Foot-pounds/min.	1.286×10^{-3}	B.T. Units/min.
Foot-pounds/min.	0.01667	Foot-pounds/sec.
Foot-pounds/min.	3.030×10^{-5}	Horse-power
Foot-pounds/min.	3.241×10^{-4}	Kg.-calories/min.
Foot-pounds/min.	2.260×10^{-5}	Kilowatts
Foot-pounds/sec.	7.717×10^{-2}	B.T. Units/min.
Foot-pounds/sec.	1.818×10^{-3}	Horse-power
Foot-pounds/sec.	1.945×10^{-2}	Kg.-calories/min.
Foot-pounds/sec.	1.356×10^{-3}	Kilowatts
Gallons	3785	Cubic centimeters
Gallons	0.1337	Cubic feet
Gallons	231	Cubic inches
Gallons	3.785×10^{-3}	Cubic meters
Gallons	4.951×10^{-3}	Cubic yards
Gallons	3.785	Liters
Gallons	8	Pints (liq.)
Gallons	4	Quarts (liq.)
Gallons, Imperial	1.20095	U.S. Gallons
Gallons, U.S.	0.83267	Imperial gallons
Gallons water	8.3453	Pounds of water
Gallons/min.	2.228×10^{-3}	Cubic feet/sec.
Gallons/min.	0.06308	Liters/sec.
Gallons/min.	8.0208	Cu. ft./hr.
Gallons water/min.	6.0086	Tons water/24 hrs.
Grains (troy)	1	Grains (avoir.)
Grains (troy)	0.06480	Grams
Grains (troy)	0.04167	Pennyweights (troy)
Grains (troy)	2.0833×10^{-3}	Ounces (troy)
Grains/U.S. gal.	17.118	Parts/million
Grains/U.S. gal.	142.86	Lbs./million gal.
Grains/Imp. gal.	14.286	Parts/million
Grams	980.7	Dynes
Grams	15.43	Grains
Grams	10^{-3}	Kilograms
Grams	10^{3}	Milligrams
Grams	0.03527	Ounces
Grams	0.03215	Ounces (troy)
Grams	2.205×10^{-3}	Pounds
Grams/cm.	5.600×10^{-3}	Pounds/inch
Grams/cu. cm.	62.43	Pounds/cubic foot
Grams/cu. cm.	0.03613	Pounds/cubic inch
Grams/liter	58.417	Grains/gal.
Grams/liter	8.345	Pounds/1000 gals.
Grams/liter	0.062427	Pounds/cubic foot
Grams/liter	1000	Parts/million
Hectograms	100	Grams
Hectoliters	100	Liters
Hectometers	100	Meters
Hectowatts	100	Watts
Horse-power	42.44	B.T. Units/min.
Horse-power	33,000	Foot-lbs./min.
Horse-power	550	Foot-lbs./sec.
Horse-power	1.014	Horse-power (Metric)
Horse-power	10.70	Kg. calories/min.
Horse-power	0.7457	Kilowatts
Horse-power	745.7	Watts
Horse-power (boiler)	33,479	B.T.U./hr.
Horse-power (boiler)	9.803	Kilowatts
Horse-power-hours	2547	British Thermal Units
Horse-power-hours	1.98×10^{6}	Foot-lbs.
Horse-power-hours	641.7	Kilogram-calories
Horse-power-hours	2.737×10^{5}	Kilogram-meters
Horse-power-hours	0.7457	Kilowatt-hours
Inches	2.540	Centimeters
Inches of mercury	0.03342	Atmospheres
Inches of mercury	1.133	Feet of water
Inches of mercury	0.03453	Kgs./sq. cm.
Inches of mercury	70.73	Lbs./sq. ft.
Inches of mercury	0.4912	Lbs./sq. inch
Inches of water	0.002458	Atmospheres
Inches of water	0.07355	Inches of mercury
Inches of water	0.002540	Kgs./sq. cm.
Inches of water	0.5781	Ounces/sq. inch
Inches of water	5.202	Lbs./sq. foot
Inches of water	0.03613	Lbs./sq. inch
Kilograms	980,665	Dynes
Kilograms	2.205	Lbs.
Kilograms	1.102×10^{-3}	Tons (short)
Kilograms	10^{3}	Grams
Kgs./meter	0.6720	Lbs./foot
Kgs./sq. cm.	0.9678	Atmospheres
Kgs./sq. cm.	32.81	Feet of water
Kgs./sq. cm.	28.96	Inches of mercury
Kgs./sq. cm.	2048	Lbs./sq. foot
Kgs./sq. cm.	14.22	Lbs./sq. inch
Kgs./sq. millimeter	10^{6}	Kgs./sq. meter
Kiloliters	10^{3}	Liters
Kilometers	10^{5}	Centimeters
Kilometers	3281	Feet
Kilometers	10^{3}	Meters
Kilometers	0.6214	Miles
Kilometers	1094	Yards
Kilometers/hr.	27.78	Centimeters/sec.
Kilometers/hr.	54.68	Feet/min.
Kilometers/hr.	0.9113	Feet/sec.
Kilometers/hr.	0.5396	Knots
Kilometers/hr.	16.67	Meters/min.
Kilometers/hr.	0.6214	Miles/hr.
Kms./hr./sec.	27.78	Cms./sec./sec.
Kms./hr./sec.	0.9113	Ft./sec./sec.
Kms./hr./sec.	0.2778	Meters/sec./sec.

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Conversion Factors and Other Useful Information (cont'd)

Conversion Factors (cont'd)

Multiply	By	To Obtain
Kilowatts	56.92	B.T. Units/min.
Kilowatts	4.425×10^4	Foot-lbs./min.
Kilowatts	737.6	Foot-lbs./sec.
Kilowatts	1.341	Horse-power
Kilowatts	14.34	Kg.-calories/min.
Kilowatts	10^3	Watts
Kilowatt-hours	3415	British Thermal Units
Kilowatt-hours	2.655×10^6	Foot-lbs.
Kilowatt-hours	1.341	Horse-power hrs.
Kilowatt-hours	860.5	Kilogram-calories
Kilowatt-hours	3.671×10^5	Kilogram-meters
Liters	10^3	Cubic centimeters
Liters	0.03531	Cubic feet
Liters	61.02	Cubic inches
Liters	10^{-3}	Cubic meters
Liters	1.308×10^{-3}	Cubic yards
Liters	0.2642	Gallons
Liters	2.113	Pints (liq.)
Liters	1.057	Quarts (liq.)
Liters/min.	5.886×10^{-4}	Cubic ft./sec.
Liters/min.	4.403×10^{-3}	Gals./sec.
Lumber Width (in.) × Thickness (in.) / 12	Length (ft.)	Board feet
Meters	100	Centimeters
Meters	3.281	Feet
Meters	39.37	Inches
Meters	10^{-3}	Kilometers
Meters	10^3	Millimeters
Meters	1.094	Yards
Meters/min.	1.667	Centimeters/sec.
Meters/min.	3.281	Feet/min.
Meters/min.	0.05468	Feet/sec.
Meters/min.	0.06	Kilometers/hr.
Meters/min.	0.03728	Miles/hr.
Meters/sec.	196.8	Feet/min.
Meters/sec.	3.281	Feet/sec.
Meters/sec.	3.6	Kilometers/hr.
Meters/sec.	0.06	Kilometers/min.
Meters/sec.	2.237	Miles/hr.
Meters/sec.	0.03728	Miles/min.
Microns	10^{-6}	Meters
Miles	1.609×10^5	Centimeters
Miles	5280	Feet
Miles	1.609	Kilometers
Miles	1760	Yards
Miles/hr.	44.70	Centimeters/sec.
Miles/hr.	88	Feet/min.
Miles/hr.	1.467	Feet/sec.
Miles/hr.	1.609	Kilometers/hr.
Miles/hr.	0.8684	Knots
Miles/hr.	26.82	Meters/min.
Miles/min.	2682	Centimeters/sec.
Miles/min.	88	Feet/sec.
Miles/min.	1.609	Kilometers/min.
Miles/min.	60	Miles/hr.
Milliers	10^3	Kilograms

Multiply	By	To Obtain
Milligrams	10^{-3}	Grams
Milliliters	10^{-3}	Liters
Millimeters	0.1	Centimeters
Millimeters	0.03937	Inches
Milligrams/liter	1	Parts/million
Million gals./day	1.54723	Cubic ft./sec.
Miner's inches	1.5	Cubic ft./min.
Minutes (angle)	2.909×10^{-4}	Radians
Ounces	16	Drams
Ounces	437.5	Grains
Ounces	0.0625	Pounds
Ounces	28.349527	Grams
Ounces	0.9115	Ounces (troy)
Ounces	2.790×10^{-5}	Tons (long)
Ounces	2.835×10^{-5}	Tons (metric)
Ounces (troy)	480	Grains
Ounces (troy)	20	Pennyweights (troy)
Ounces (troy)	0.08333	Pounds (troy)
Ounces (troy)	31.103481	Grams
Ounces (troy)	1.09714	Ounces (avoir.)
Ounces (fluid)	1.805	Cubic inches
Ounces (fluid)	0.02957	Liters
Ounces/sq. inch	0.0625	Lbs./sq. inch
Parts/million	0.0584	Grains/U.S. gal.
Parts/million	0.07016	Grains/Imp. gal.
Parts/million	8.345	Lbs./million gal.
Pennyweights (troy)	24	Grains
Pennyweights (troy)	1.55517	Grams
Pennyweights (troy)	0.05	Ounces (troy)
Pennyweights (troy)	4.1667×10^{-3}	Pounds (troy)
Pounds	16	Ounces
Pounds	256	Drams
Pounds	7000	Grains
Pounds	0.0005	Tons (short)
Pounds	453.5924	Grams
Pounds	1.21528	Pounds (troy)
Pounds	14.5833	Ounces (troy)
Pounds (troy)	5760	Grains
Pounds (troy)	240	Pennyweights (troy)
Pounds (troy)	12	Ounces (troy)
Pounds (troy)	373.24177	Grams
Pounds (troy)	0.822857	Pounds (avoir.)
Pounds (troy)	13.1657	Ounces (avoir.)
Pounds (troy)	3.6735×10^{-4}	Tons (long)
Pounds (troy)	4.1143×10^{-4}	Tons (short)
Pounds (troy)	3.7324×10^{-4}	Tons (metric)
Pounds of water	0.01602	Cubic feet
Pounds of water	27.68	Cubic inches
Pounds of water	0.1198	Gallons
Pounds of water/min.	2.670×10^{-4}	Cubic ft./sec.
Pounds/cubic foot	0.01602	Grams/cubic cm.
Pounds/cubic foot	16.02	Kgs./cubic meter
Pounds/cubic foot	5.787×10^{-4}	Lbs./cubic inch

Multiply	By	To Obtain
Pounds/cubic inch	27.68	Grams/cubic cm.
Pounds/cubic inch	2.768×10^4	Kgs./cubic meter
Pounds/cubic inch	1728	Lbs./cubic foot
Pounds/foot	1.488	Kgs./meter
Pounds/inch	178.6	Grams/cm.
Pounds/sq. foot	0.01602	Feet of water
Pounds/sq. foot	4.883×10^{-4}	Kgs./sq. cm.
Pounds/sq. foot	6.945×10^{-3}	Pounds/sq. inch
Pounds/sq. inch	0.06804	Atmospheres
Pounds/sq. inch	2.307	Feet of water
Pounds/sq. inch	2.036	Inches of mercury
Pounds/sq. inch	0.07031	Kgs./sq. cm.
Quarts (dry)	67.20	Cubic inches
Quarts (liq.)	57.75	Cubic inches
Quintal, Argentine	101.28	Pounds
Quintal, Brazil	129.54	Pounds
Quintal, Castile, Peru	101.43	Pounds
Quintal, Chile	101.41	Pounds
Quintal, Mexico	101.47	Pounds
Quintal, Metric	220.46	Pounds
1 / Sq. ft./gal./min.	8.0208	Overflow rate (ft./hr.)
Temp. (°C.)+273	1	Abs. temp. (°C.)
Temp. (°C.)+17.78	1.8	Temp. (°F.)
Temp. (°F.)+460	1	Abs. temp. (°F.)
Temp. (°F.)−32	5/9	Temp. (°C.)
Tons (long)	1016	Kilograms
Tons (long)	2240	Pounds
Tons (long)	1.12000	Tons (short)
Tons (metric)	10^3	Kilograms
Tons (metric)	2205	Pounds
Tons (short)	2000	Pounds
Tons (short)	32000	Ounces
Tons (short)	907.18486	Kilograms
Tons (short)	2430.56	Pounds (troy)
Tons (short)	0.89287	Tons (long)
Tons (short)	29166.66	Ounces (troy)
Tons (short)	0.90718	Tons (metric)
Tons of water/24 hrs.	83.333	Pounds water/hour
Tons of water/24 hrs.	0.16643	Gallons/min.
Tons of water/24 hrs.	1.3349	Cu. ft./hr.
Watts	0.05692	B.T. Units/min.
Watts	44.26	Foot-pounds/min.
Watts	0.7376	Foot-pounds/sec.
Watts	1.341×10^{-3}	Horse-power
Watts	0.01434	Kg.-calories/min.
Watts	10^{-3}	Kilowatts
Watt-hours	3.415	British Thermal Units
Watt-hours	2655	Foot-pounds
Watt-hours	1.341×10^{-3}	Horse-power hours
Watt-hours	0.8605	Kilogram-calories
Watt-hours	367.1	Kilogram-meters
Watt-hours	10^{-3}	Kilowatt-hours

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Conversion Table

inch	decimal	mm.	inch	decimal	mm.
1/64	0.015625	0.3969	33/64	0.515625	13.0969
1/32	0.031250	0.7938	17/32	0.531250	13.4938
3/64	0.0467875	1.1906	35/64	0.546875	13.8906
1/16	0.062500	1.5875	9/16	0.562500	14.2875
5/64	0.078125	1.9844	37/64	0.578125	14.6844
3/32	0.093750	2.3812	19/32	0.593750	15.0812
7/64	0.109375	2.7781	39/64	0.609375	15.4781
1/8	0.125000	3.1750	5/8	0.625000	15.8750
			41/64	0.640625	16.2719
9/64	0.140625	3.5719	21/32	0.656250	16.6688
5/32	0.156250	3.9688	43/64	0.671875	17.0656
11/64	0.171875	4.3656	11/16	0.687500	17.4625
3/16	0.187500	4.7625			
			45/64	0.703125	17.8594
13/64	0.203125	5.1594	23/32	0.718750	18.2562
7/32	0.218750	5.5562	47/64	0.734375	18.6531
15/64	0.234375	5.9531	3/4	0.750000	19.0500
1/4	0.250000	6.3500			
			49/64	0.765625	19.4469
17/64	0.265625	6.7469	25/32	0.781250	19.8437
9/32	0.281250	7.1438	51/64	0.796875	20.2406
19/64	0.296875	7.5406	13/16	0.812500	20.6375
5/16	0.312500	7.9375			
			53/64	0.828125	21.0344
21/64	0.328125	8.3344	27/32	0.843750	21.4312
11/32	0.343750	8.7312	55/64	0.859375	21.8281
23/64	0.359375	9.1281	7/8	0.875000	22.2250
3/8	0.375000	9.5250			
25/64	0.390625	9.9219	57/64	0.890625	22.6219
13/32	0.406250	10.3188	29/32	0.906250	23.0188
27/64	0.421875	10.7156	59/64	0.921875	23.4156
7/16	0.437500	11.1125	15/16	0.937500	23.8125
29/64	0.453125	11.5094	61/64	0.953125	24.2094
15/32	0.468750	11.9062	31/32	0.968750	24.6062
31/64	0.484375	12.3031	63/64	0.984375	25.0031
1/2	0.500000	12.7000	1	1.000000	25.4000

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APPENDIX II

OPERATING PRESSURES AND TEMPERATURES

PRESSURES

The following pressures should be present for starting:

Starting Air Supply	250 psi	17.6 kg/sq cm
Starting Air Header	250 psi	17.6 kg/sq cm

While running at rated speed, the operating pressures should be as follows:

	psi	in.-hg	kg/sq cm
Lubricating Oil*	50 — 55	101.8 — 112.0	3.52 — 3.87
Lubricating Oil at Turbocharger Inlet	20 — 25	40.7 — 50.9	1.41 — 1.76
Jacket Water	10 — 30	20.4 — 61.1	0.70 — 2.11
Fuel Oil	20 — 30	40.7 — 61.1	1.41 — 2.11

TEMPERATURES

While running under rated load, the outlet temperatures should be as follows:

Lubricating Oil out of Engine*	170° F — 180° F (76.6° C — 82.2° C)
Jacket Water out of Engine	170° F — 180° F (76.6° C — 82.2° C)

EXHAUST TEMPERATURES.

The exhaust temperatures shown on the "Factory Test Results" page are the average for all cylinders during factory test under *local ambient conditions*. Temperatures in the field, therefore, may exceed this average temperature. Exhaust temperatures may be considered normal if within plus or minus 50° F of the average taken for all cylinders. Temperatures, high or low, exceeding this range should be investigated (see Section 7).

FIRING PRESSURES.

Firing pressures may be considered normal if within plus or minus 75 psi of the average for all cylinders. High or low pressures exceeding this range should be investigated (see Section 7).

NOTES.

Operating pressures and temperatures listed are established as a guide to proper operation. Except as noted for exhaust temperatures and firing pressures, they should be held to within plus or minus 10 percent. Sudden changes in readings require immediate investigation and correction.

When making adjustments as a result of a high or low cylinder exhaust temperature, or firing pressure, both temperature and pressure readings must be taken into account when determining the proper corrective action.

*When using SAE 40 lubricating oil in engine.

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APPENDIX III

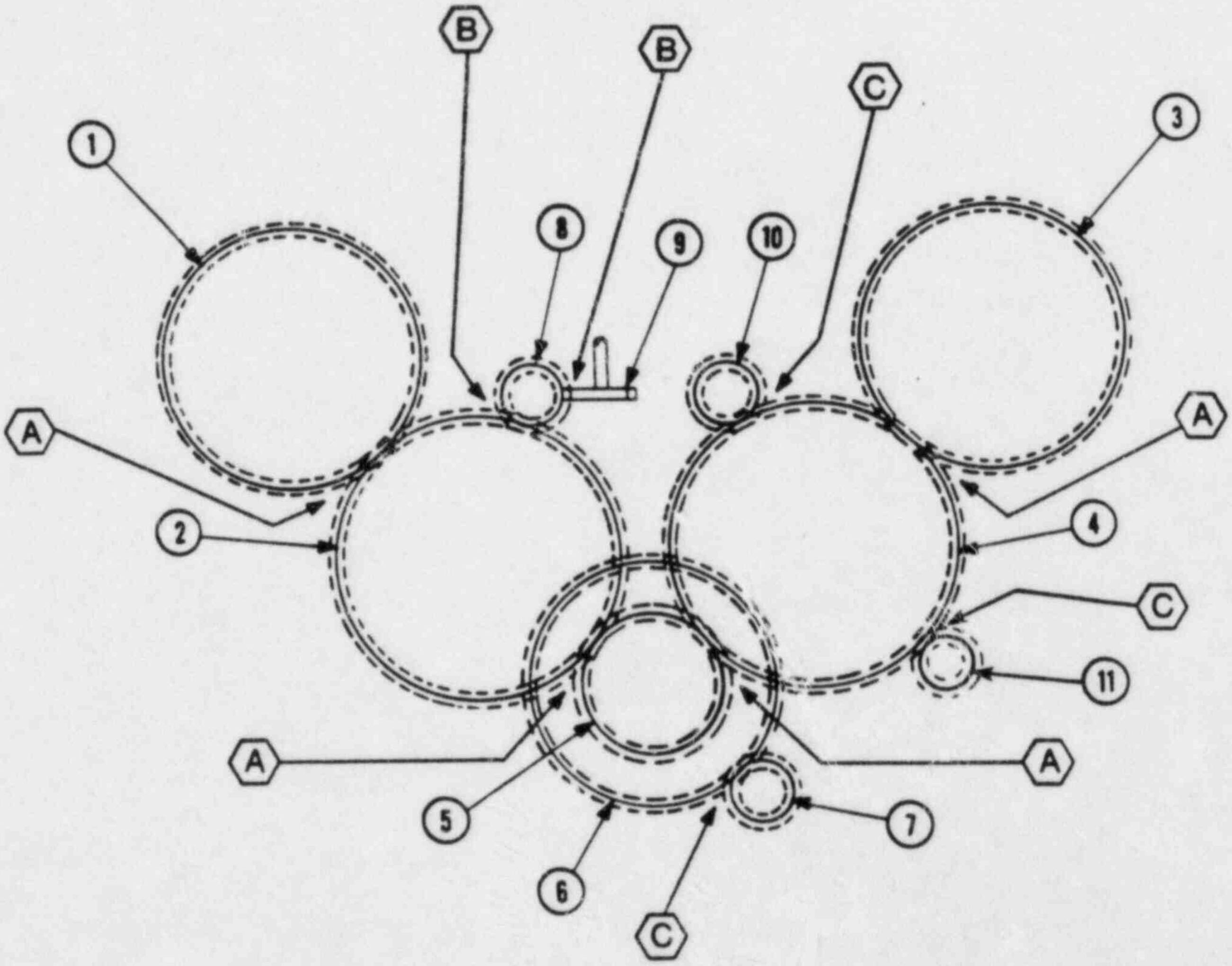
TABLE OF CLEARANCES
MODEL RV-4 ENGINE

Item	Clearance When New — Inches	Clearance When New — Millimeters	Replace When Over — Inches	Replace When Over — Millimeters	Notes
Crankshaft to Main Bearings	0.010/0.014	0.254/0.356	— — —	— — —	See bearing shell thickness figures
Crankshaft to Thrust Ring	0.022/0.030	0.559/0.762	0.040	0.016	Replace at least one
Connecting Rod Bearing to Crankshaft	0.010/0.014	0.254/0.356	— — —	— — —	See bearing shell thickness figures
Camshaft Bearings to Camshaft (intermediate)	0.004/0.008	0.102/0.203	— — —	— — —	See bearing shell thickness figures
Camshaft Thrust Adjustment	0.004/0.007	0.102/0.178	— — —	— — —	Adjust at 0.012" or over
Connecting Rod Link Pin to Bushing	0.006/0.011	0.152/0.279	0.015	0.381	
Piston Pin to Rod Bushing	0.010/0.015	0.254/0.381	0.020	0.508	
Piston Pin to Piston	0.002/0.004	0.051/0.102	0.005	0.127	
Idler Gear Bushings to Shaft	0.003/0.005	0.076/0.127	0.010	0.254	
Idler Gear Thrust to Bracket	0.005/0.009	0.127/0.229	0.015	0.381	
Rocker Arm Bushing to Shaft	0.004/0.006	0.102/0.152	0.012	0.305	
Intake Rocker Arm Assy. to Sub Cover (end clearance)	0.010/0.025	0.254/0.635	0.045	1.143	
Exhaust Rocker Arm Assy. to Sub Cover (end clearance)	0.005/0.011	0.127/0.381	0.030	0.762	
Intake and Exhaust Tappets in Guide	0.004/0.006	0.102/0.152	0.015	0.381	
Fuel Tappet in Guide	0.003/0.005	0.076/0.127	0.012	0.305	
Tappet Roller in Roller Bushing	0.002/0.004	0.051/0.102	0.006	0.152	
Roller Bushing to Pin Bushing	0.001/0.002	0.025/0.051	0.004	0.102	
Pin Bushing to Pin	0.001/0.002	0.025/0.051	0.005	0.127	
Air Valve Piston in Cap	0.001/0.003	0.025/0.076	0.009	0.229	
Piston To Liner					
Crown Top Land (Tapered) — Top	0.050/0.072	1.270/1.829	— — —	— — —	Radial Clearance
Crown Top Land — Above 1st Ring	0.030/0.050	0.762/1.270	— — —	— — —	Radial Clearance
Skirt — Bearing Surface	0.017/0.019	0.432/0.483	— — —	— — —	See liner replacement figures
Piston Ring End Gap					
Top Compression Ring (No. 1)	0.075/0.090	1.905/2.286	0.200	5.080	
Compression Ring (No. 2)	0.075/0.090	1.905/2.286	0.200	5.080	
Compression Ring (No. 3)	0.050/0.065	1.270/1.651	0.200	5.080	
Compression Ring (No. 4)	0.050/0.065	1.270/1.651	0.200	5.080	
Oil Control Ring (Upper)	0.035/0.060	0.889/1.524	0.200	5.080	
Oil Control Ring (Lower)	0.035/0.060	0.889/1.524	0.200	5.080	
Piston Ring Side Clearance in Groove					
Top Compression Ring (No. 1)	0.007/0.011	0.178/0.279	0.020	0.508	
Compression Ring (No. 2)	0.005/0.009	0.127/0.229	0.020	0.508	
Compression Ring (No. 3)	0.005/0.009	0.127/0.229	0.020	0.508	
Compression Ring (No. 4)	0.012/0.019	0.305/0.483	0.030	0.762	
Oil Control Ring (Upper)	0.003/0.007	0.076/0.178	0.020	0.508	
Oil Control Ring (Lower)	0.003/0.007	0.076/0.178	0.020	0.508	
Intake Valve Stem to Guide	0.005/0.007	0.127/0.178	0.012	0.305	
Intake Valve Guide Inlet Diameter to Guide	0.007/0.011	0.178/0.279	0.016	0.406	Dual fuel engines only
Gas Injection Piston Ring End Gap	0.0018/0.015	0.046/0.381	0.040 @ 1.500 dia.	1.016 @ 38.10 dia.	Dual fuel engines only
Exhaust Valve Stem to Guide (Upper)	0.006/0.008	0.152/0.203	— — —	— — —	See valve rocking test
Exhaust Valve Stem to Guide (Lower)	0.058/0.080	1.473/2.032	— — —	— — —	See valve rocking test
Exhaust Valve Rocking (movement) Test	0.012/0.017	0.305/0.432	0.045	1.143	See Section 6, Part 8 for method of taking measurement
	Diameter		Over/Out Of Round		
Liner Bore	17.000/17.001	431.8/431.825	17.060/0.020	433.324/0.508	
	Thickness When New		Replace when/or less		
Bearing Thickness (Shells, Rings)					
Main Bearing Shells	0.619/0.616	15.723/15.697	0.613	16.570	Lower shell
Main Bearing Thrust Rings	0.616/0.614	15.646/15.596	— — —	— — —	See "Crankshaft to Thrust Rings"
Connecting Rod Bearing Shells	0.619/0.618	15.723/15.697	0.613	15.570	Upper shell
Camshaft Bearing Shells (intermediate)	0.208/0.207	5.283/5.258	0.202	5.131	Lower shell
Camshaft Bearing Thrust Flange	0.211/0.208	5.359/5.283	— — —	— — —	See "Camshaft Thrust Adjustment"

AX44KU1-509-1

APPENDIX III-1

GEAR SET AND BACKLASH CLEARANCES MODEL RV ENGINE



ITEM	DESCRIPTION	GPL
1	CAMSHAFT GEAR, LEFT HAND	350
2	IDLER GEAR, LEFT HAND	355
3	CAMSHAFT GEAR, RIGHT HAND	350
4	IDLER GEAR, RIGHT HAND	355
5	CRANKSHAFT GEAR	310
6	LUBRICATING OIL PUMP DRIVE GEAR	355
7	LUBRICATING OIL PUMP DRIVEN GEAR	420
8	GOVERNOR & TACHOMETER DRIVE GEAR	411
9	GOVERNOR DRIVEN AND DRIVEN GEAR	411
10	FUEL OIL PUMP & OVERSPEED TRIP DRIVE GEAR	410
11	JACKET WATER PUMP DRIVE GEAR	425

POS.	BACKLASH	
	INCHES	CENTIMETERS
A	0.008 — 0.010	0.020 — 0.025
B	0.004 — 0.006	0.010 — 0.015
C	0.005 — 0.008	0.013 — 0.025

Fuel Oil Booster Pump/L.O. Pump Drive Gear

AX4AK01-509-1

APPENDIX III-2
VALVE SPRINGS

Part Number: 03-360-02-OM

Direction of coils	Right hand
Active coils	10
Total coils	12
Load Rate	163.5 lbs/in
Load at maximum working length	281/310 lbs
Load at minimum working length	475/525 lbs
Free length	9.060 in.
Maximum working length	7.250 in.
Minimum working length	6.000 in.
Solid length (ref.)	4.872 in.
Inside diameter	2-15/32 in
Outside diameter	3-9/32 in.
Wire diameter	0.409/0.403 in

R/RV 79

AX4AK01-509-1

APPENDIX IV

TORQUE TABLES
Model RV-4 Engine

The first portion of this torque table, Special Torque Values, applies to those nuts, bolts, capscrews and other threaded fasteners for which a specific torque value has been assigned. If no specific torque value is listed for a fastener, refer to the General Torque Values portion of the table, using the torque listed for the thread size of the item in question. All torque values are based upon the use of a thread lubricant consisting of a 50-50 mixture by volume of powdered graphite and engine lubricating oil. All torques are listed in both foot pounds and in kilograms per meter. Where applicable, bolt sizes in the special torque section are shown in parenthesis.

SPECIAL TORQUE VALUES

Item		Torque ft-lb	Torque kg-m
NUT, Foundation Bolt (heat treated steel*)		3800	525.6
NUT, Main Bearing Cap Stud (1¾")**		3000	415
NUT, Base to Crankcase Thru-Bolt		8000	1106
CAPSCREW, Crankcase to Base (1")		425	58.8
NUT, Cylinder Block to Crankcase Thru-Bolt (2½")		4500	622
NUT, Cylinder Block to Crankcase Thru-Bolt (2")		3000	425
NUT, Connecting Rod Bolt (1½")		1700	235
NUT, Connecting Rod Bolt (1⅞")		2600	359.5
BOLT, Link Connecting Rod to Link Pin (1¼")		1050	145.2
NUT, Cylinder Head Stud (2-8NC)**		3600	497.7
NUT, Fuel Injection Nozzle Retainer***	Minimum	75	10.37
	Maximum	80	11
NUT, Fuel Pump Stud		80	11
CAPSCREW, Fuel Pump Base (Allen)		120	16.6
CAPSCREW, Camshaft Bearing Cap		200	27.6
CAPSCREW, Idler Gear Mount Bracket		120	16.6
NUT, Flywheel Bolt		4500	622.3
NUT, Crankshaft Counter Weight (13" Crankpin)		2450	338.7
CAPSCREW, Rocker Shaft		365	50.5
CAPSCREW, Sub-Cover to Cylinder Head		120	16.6
Camshaft Gear Retainer Nut		1800	248.9
CAPSCREW, Air Start Valve to Cylinder Head***		150	20.74

*Heat treated bolts are identified by the figure "4" stamped on end of bolt.

**Not applicable if pre-stressing method is used.

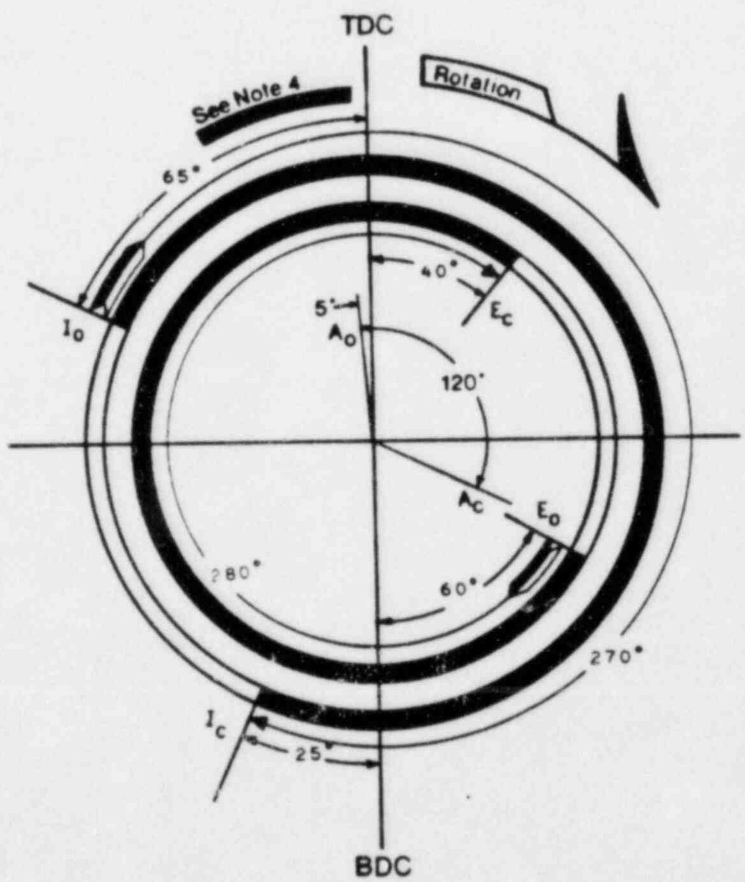
***Retorque this item every 8 hours of operation after installing new copper gaskets until no change in tight torque is observed.

AX4AK01-509-1

APPENDIX V

TIMING DIAGRAM

ENGINE MODEL: R/RV
ENGINE TYPE: STATIONARY — MECHANICAL LIFTERS
FUEL: DIESEL
ROTATION: CLOCKWISE
INTAKE CAM: 02-350-06-AK
EXHAUST CAM: 02-350-06-AJ



TDC TOP DEAD CENTER
BDC BOTTOM DEAD CENTER
I_o INTAKE VALVE OPENS
I_c INTAKE VALVE CLOSES
E_o EXHAUST VALVE OPENS
E_c EXHAUST VALVE CLOSES
A_o AIR STARTING VALVE OPENS
A_c AIR STARTING VALVE CLOSES

NOTES:
1. Diagram is in crankshaft degrees.
2. See engine data sheet in front of manual, or engine nameplate for firing order.
3. See engine nameplate for cylinder and bank designation.
4. See engine data sheet for diesel fuel injection point.

AXLA-01-509-1

APPENDIX VI

LUBRICATING OIL RECOMMENDATIONS

The Transamerica Delaval Engine and Compressor Division does not recommend lubricants by brand name. The final measure of the quality of an oil is its performance in service. The lubricant supplier must work with the fuel oil supplier to insure the use of the proper lubricant. *The consistent quality and performance of a suitable heavy duty oil must, therefore, be the responsibility of the company making the lubricant.*

CAUTION

It must be the concern of the operator to consult with the oil supplier concerning the proper selection of a lubricant which will perform compatibly with the type of fuel to be used in order to insure the most satisfactory performance and life with overall economical operation. In the case of unresolved questions, the Transamerica Delaval Engine and Compressor Division should be consulted.

To determine the condemning limits for oil in service, have the oil supplier take representative samples at regular intervals for oil analysis. His recommendations, then, for either further service or for condemnation will be based on qualitative factors. The following applies to new oil only.

RECOMMENDED LUBRICATING OIL CHARACTERISTICS

SAE GRADE 40 OIL

	Maximum	Minimum
Viscosity Index (ASTM D567)	–	70
Gravity, A.P.I. at 60°F (25.6°C) (ASTM D287)	30	20
Flash Point °F (ASTM D92)	–	425 (218° C)
Pour Point °F (ASTM D97)	–	10 (5.6° C) below coldest oil starting temperature

OIL RECOMMENDATIONS

DIESEL ENGINES (Using fuel oil with less than 1.05% sulfur):

Engines rated 205 bmep and below – API/SAE Classification "CC" or better.

Engines rated 206 bmep and above – API/SAE Classification "CD" or better.

R/RVID/SAE 401 78

AXLAK01-509

APPENDIX VII
ALARMS AND SAFETY SHUTDOWNS

During normal operation of the diesel engine/generator set, it is protected by an automatic safety shutdown system which senses certain operating conditions. When a sensed condition reaches a pre-determined setpoint, the system initiates an automatic shutdown sequence. There are other conditions which are monitored, and which will alarm if they reach their alarm setpoint, but which will not shut the engine down. If the unit is operating in response to an emergency start signal from the owner's equipment, only those shutdowns identified by an asterisk (*) on the following list will cause a shutdown. All other shutdowns will alarm while operating in an emergency condition, but will not initiate a shutdown sequence. The following conditions are monitored by the system's protective network.

FUNCTION	ALARM [Setting]	SHUTDOWN [Setting]
Temperatures:		
Lubricating oil in (low)	140°F falling	- -
Lubricating oil out (low)	140°F falling	- -
Lubricating oil in (high)	175°F rising	- -
Lubricating oil out (high)	190°F rising	200°F rising
Engine main bearings	- -	228°F rising
Jacket water in (low)	140°F falling	- -
Jacket Water out (low)	140°F falling	- -
Jacket water in (high)	190°F rising	200°F rising
Panel	130°F rising	- -
Generator control panel	Field Set	
Generator bearing	Field set	
Pressures:		
Jacket water	8 psi falling	- -
Crankcase pressure	- -	3 psi rising
Lubricating oil	40 psi falling	30 psi falling
Turbocharger, right bank	20 psi falling	15 psi falling
Turbocharger, left bank	20 psi falling	15 psi falling
Lubricating oil filter Δ P	20 psi rising	- -
Fuel oil	15 psi falling	- -
Fuel oil filter Δ P	20 psi rising	- -
Control air	55 psi falling	- -
Starting air	210 psi falling	- -
	265 psi rising	- -
Engine Overspeed	- -	517.5 rpm Increasing*

POWER ENGINES — Nuclear Standby Service

EYLLVC1-509-1

APPENDIX VII
ALARMS AND SAFETY SHUTDOWNS (Continued)

FUNCTION	ALARM (Setting)	SHUTDOWN (Setting)
Miscellaneous:		
Lubricating oil level	Low	- -
Engine vibration	- -	Excessive
Lubricating oil pressure sensor Malfunction	On Malfunction	- -
Jacket water level	Low	- -
Jacket water temperature sensor malfunction	On Malfunction	- -
Main fuel tank level	High	- -
Main fuel tank level	Low	- -
Fuel day tank level	High or Low	- -
Generator trouble	When detected	- -
Low voltage	When detected	- -
Engine control in LOCAL	When selected	- -
Low excitation	When selected	- -
Generator fault	When detected	- -
Generator differential	- -	When detected
Maintenance lockout	When selected	- -
Failed to start	On failure	- -
Switch NOT IN AUTO	MCC Switches	- -
Barring Device Engaged	When occurring	- -
Panel intrusion	When detected	- -
Emergency start	When initiated	- -

AX4AK01-509-1

APPENDIX VIII

FUEL OIL SPECIFICATIONS

	Maximum	Minimum
Viscosity, S.S.U. at 100° F	45	32
*Gravity, Deg. A.P.I.	38	26
Sulphur, %	1.05	–
Sulphur, Corrosion Test (Copper Strip, 3 hrs. at 212° F)	Pass	Pass
Conradson Carbon, %	0.20	–
Ash, %	0.10	–
Water & Sediment, %	0.50	–
Flash Point, ° F (P.M.C.C.)		150 or legal
Pour Point, at least 10° F below coldest fuel oil temperature		
DISTILLATION, ° F		
90% Point	675	
IGNITION QUALITY		
Cetane Number		40

*Heat Value – determine from A.P.I. gravity limits shown to determine total or net Btu/lb or gallon.

The above specification covers fuel oils classed as Grade F.S. No. 2.

Fuels heavier than the above can be burned in Enterprise engines provided proper treating and pre-heating facilities are available. In the event it is desirable to use such fuels, Transamerica Delaval Engine and Compressor Division should be consulted for advice as to the arrangements that need to be made. An analysis of the particular fuel to be used must be provided.

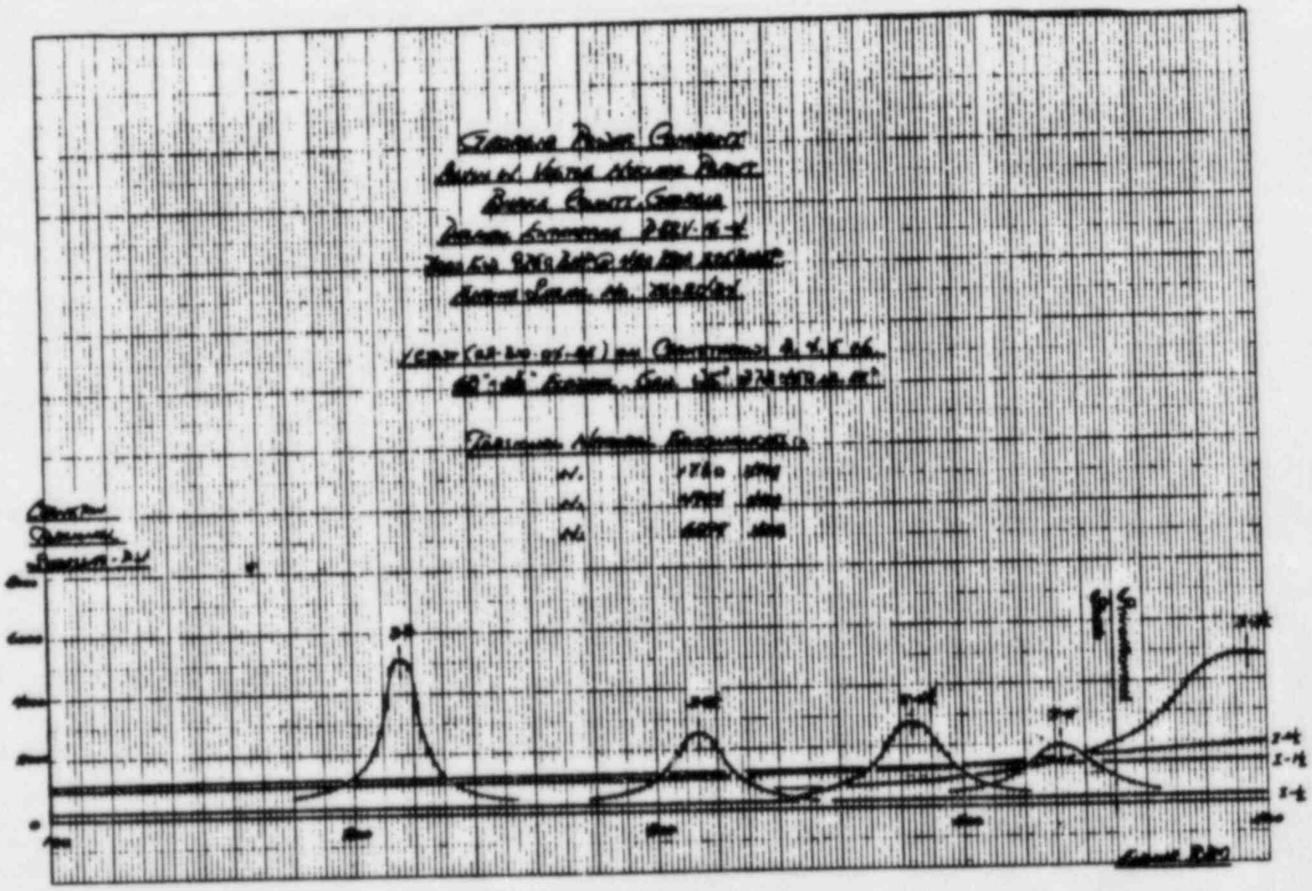
For lubricating oil recommendations, refer to Appendix VI.

G/R/RV/GVB 74

AX4AK01-509-1

Appendix IX

Torsional Stress and Critical Speeds



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Appendix X

Factory Test Logs

Copies of the Power Engine Factory Test Logs and a summary of the tests are provided in this appendix to assist operating personnel in becoming familiar with the operating characteristics of the engine(s). The data included is that recorded during the actual factory test of the engine. For ready reference, a summary of the factory test results is also provided. It should be noted that the exhaust temperatures are those recorded at the factory, under local ambient conditions. Temperatures experienced by the owner/operator, therefore, may exceed this average temperature.

AXLAKU1-509-1

FACTORY TEST RESULTS.

Below is a summary of the results of the factory tests to which the engine(s) was/were subjected. Exhaust temperatures are the average for all cylinders under *LOCAL AMBIENT CONDITIONS*. Temperatures in the field, therefore, may exceed this average temperature. Refer to the Factory Test Logs that follow for a more complete detail of the factory tests.

Engine Serial Number	Air Manifold Pressure	Air Manifold Temperature	Barometric Pressure	Ambient Air Temperature	Exhaust Temperature (ave.)
76021-2871	47.9 IN.-HG	129°F	29.94 IN.-HG	84°F	958°F
76022-2872	50.2 IN.-HG	129°F	29.96 IN.-HG	76°F	945°F
76023-2873	48.5 IN.-HG	129°F	30.22 IN.-HG	74°F	940°F
760242874	50.2 IN.-HG	126°F	29.88 IN.-HG	73°F	947°F

[illegible]1-509-1

ENTERPRISE ENGINE

CUSTOMER Georgia Power Company

MODEL DSRV-16-4 ENGINE NUMBER 76021 JOB NUMBER 2871

DATE November 6, 1981

CUSTOMER REPRESENTED BY

TEST CERTIFIED CORRECT
Transamerica Delaval Inc.
Engine and Compressor Division
BY A. R. Fleischer
TITLE Manager, Research & Development

REPORT
OF
ENGINE SHOP TESTING

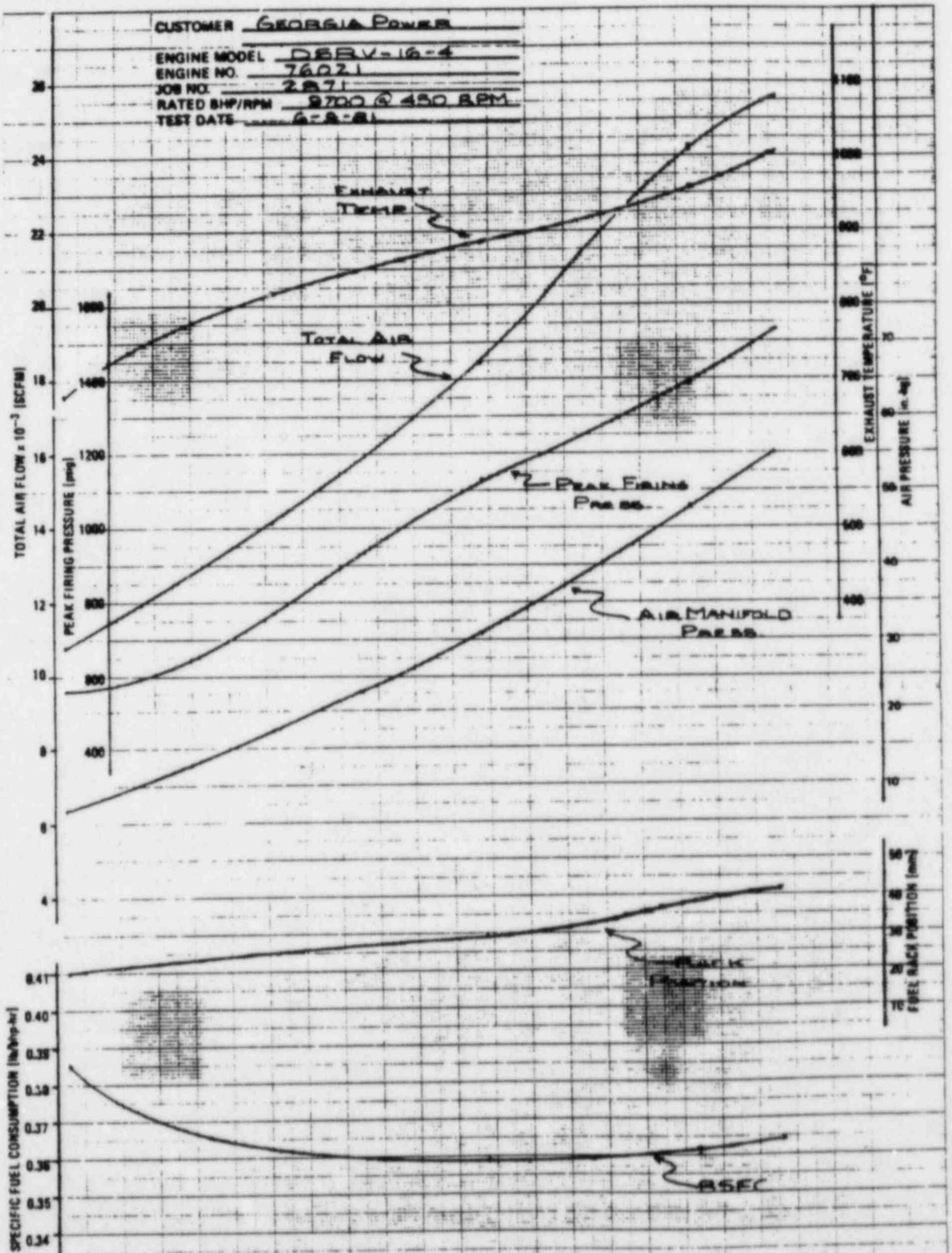
SERIAL NO. 76021-2871

Transamerica Delaval

Transamerica Delaval Inc.
Engine and Compressor Division
550 85th Avenue P.O. Box 2161
Oakland, California 94621

AX4AK01-509-1

Form D-13 (R-1) 7/73



BY S Wagner DATE 6-22-81

Form D-4361 (Diesel) (R 2) 8/79

AX4AKC1-204

Power Engine Factory Test Log

LOG 1 A

CUSTOMER GEORGIA POWER MODEL DSRV-16-4 TEST STAND 25 JOB NO 2871 ENGINE NO 76021 FULL LOAD RATING 9700 BHP @ 450 RPM 222.8 BMEP

Line	Date	Wall Clock Time On Load	Wall Clock Time This Log	% Load	Dynamometer RPM	Scale	BHP (Corr)	BMEP	A.C. Gen. UVC Revs	Time	Power Factor	A.C. Volts	A.C. Amps	KW	Gen Eff	BHP (Corr)	BMEP	Gov Load Limit
1	6/10	0955	1055	50	450	56608	4850	112										
2	6/10	1055	1155	75	450	84907	7275	168										
3	6/10	1310	1410	100	450	113210	9700	222.8										
4	6/10	1410	1510	100	450	113210	9700	222.8										
5	6/10	1515	1615	25	450	28304	2425	56										
6	6/10	1745	1845	110	450	124531	10670	246										
7																		
8																		
9																		
10																		

Line	Fuel Pump Rack Position 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R
1	26	26	25	26	26	25	26	25			25	25	26	26	26	26	26	26		
2	29	29	29	29	29	29	29	29			29	29	29	29	29	29	29	29		
3	38	38	38	38	38	38	38	38			38	38	38	38	38	38	38	38		
4	38	38	38	38	38	38	38	38			38	38	38	38	38	38	38	38		
5	20	20	20	20	20	20	20	20			20	20	20	20	20	20	20	20		
6	42	42	42	42	42	42	42	42			42	42	42	42	42	42	42	42		
7																				
8																				
9																				
10																				

TURBOCHARGER PRESSURES

Line	Blower Inlet (in. H_2O) LF	RF	LR	RR	Blower Discharge (in. Hg) LF	RF	LR	RR	Air Rcvr LB	RB	Turbine Inlet (in. Hg) LF	RF	LR	RR	Turbine Exhaust (in. H_2O) LF	RF	LR	RR
1	3.0	3.0			17.6	17.6			17.4	17.4								
2	5.8	5.2			31.1	30.9			30.7	30.7								
3	9.0	8.9			48.1	48.1			47.9	47.9								
4	9.1	9.0			48.1	48.1			47.8	47.8								
5	1.8	1.8			6.9	7.0			6.8	6.8								
6	10.1	10.2			56	56			55	56								
7																		
8																		
9																		
10																		

TURBOCHARGER TEMPERATURES / AIR FLOW NOZZLE SIZE 14 / 14

Line	Blower Inlet (°F) LF	RF	LR	RR	Blower Discharge (°F) LF	RF	LR	RR	Air Rcvr (°F) LB	RB	Turbocharger RPM LF	RF	LR	RR	Nozzle ΔP (in. H_2O) LF	RF	LR	RR	Air Flow SCFM Total	Ambient Baro (Corr) in. Hg	Air (°F)
1	79	79			185	181			120	120					3.1	3.0			14163	29.94	79
2	79	79			240	240			128	129					5.2	5.2			18494	29.94	79
3	84	84			315	313			127	132					9.0	9.0			24218	29.94	84
4	84	84			316	313			126	131					9.1	9.0			24283	29.94	84
5	86	86			141	188			107	107					1.8	1.8			10811	29.94	86
6	88	88			330	348			126	127					10.1	10.2			25590	29.94	88
7																					
8																					
9																					
10																					

FUEL OIL DATA / DIESEL BSFC / FUEL GAS DATA / GAS BSFC / DUAL FUEL BSFC

Line	[illegible]	API Gravity As Read	@ °F	API Corrected To 60°F	LHV (Btu/lb)	LBS Weighed	Time (sec)	lb/hr	lb/bhp-hr	(Corr) lb/bhp-hr	Fuel Gas [illegible]	LHV	To Gas Meter in. Hg	°F	Corr Factor	ft³ Meas	Time (sec)	ft³/hr (Corr)	Btu/bhp-hr	Pilot	Gas	Total	Remarks
1	46.0	38.2	82		18300	1390	2980	1749		.362													
2	33.5	38.0	78		18309	1500	2082	2594		.359													
3	34	33.2	82		18300	1880	1600	3489		.362													
4	30	38.2	82		18300	1880	1607	3472		.360													
5	33	33.4	84		18300	680	2420	966		.385													
6	41	33.4	84		18300	1700	1981	3868		.364													
7																							
8																							
9																							
10																							

INJECTION IGNITION TIMING °BTDC 22 LB 21 RB
FUEL OIL SPEC #2 DIESEL
LUBE OIL SPEC MOBIL GARD 412

Transamerica Delaval
Transamerica Delaval Inc.
Engine and Compressor Division

AIR FLOW NOZZLE COEFFICIENT
LF 17205 RF 17205
LR ____ RR ____
(FLYWHEEL END)

OPERATOR C. LYONS
ENGINEER
WITNESS

DATE 6-9-81
LOG NO 1 A
JOB NO 2871

Power Engine Factory Test Log

LOG 1 B

CUSTOMER GEORGIA POWER MODEL DSRV-16-4 TYPE SERVICE GENERATOR JOB NO 2871 ENGINE NO 76021 DIRECTION OF ROTATION (AS VIEWED FROM FLYWHEEL END) CW

EXHAUST TEMPERATURES - °F

LINE	Turbine Inlet (T - Top, B - Bottom) LFTL	LFTR	LFB	RFT	RFB	LRT	LRB	RRTL	RRTR	RRB	Turbine Exhaust LF	RF	LR	RR
1											776	702		
2											837	770		
3											857	830		
4											856	828		
5											640	524		
6											885	864		
7														
8														
9														
10														

EXHAUST ELBOWS

LINE	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1	876	897	787	873	868	906	834	856			749	793	827	766	774	735	775	795			807
2	928	969	853	934	922	949	884	911			840	838	[illegible]	849	830	817	830	835			880
3	976	1020	912	966	954	988	971	963			950	1000	941	944	948	908	948	954			939
4	972	1020	910	965	952	989	971	962			980	999	940	944	918	908	946	959			937
5	725	734	645	721	712	746	708	692			636	660	684	635	644	609	649	643			678
6	1019	1070	988	1009	993	1027	1013	1007			999	1080	959	996	963	994	996	1013			1004
7																					
8																					
9																					
10																					

LINE	Engine Water Pres To Engine	To Engine (°F)	From Engine (°F)	Turbocharger Water Outlet (°F) LF	RF	LR	RR	Aftercooler Water Inlet (°F) F	R	Outlet (°F) F	R
1	19	162	166	167	168			121		125	
2	18	163	168	169	170			128		139	
3	20.5	162	170	172	172			123		149	
4	30	162	169	170	171			122		148	
5	17	158	161	162	162			106		108	
6	21	164	171	173	174			115		147	
7											
8											
9											
10											

FIRING PRESSURES - PSIG

LINE	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1	800	780	760	770	800	780	780	780			800	760	760	760	740	760	740	760			772
2	1160	1120	1100	1160	1160	1120	1120	1120			1130	1100	1140	1150	1120	1120	1130	1150			1130
3	1410	1380	1380	1400	1380	1380	1400	1380			1410	1380	1380	1380	1380	1400	1380	1410			1389
4	1410	1390	1390	1400	1380	1380	1390	1390			1410	1390	1390	1380	1380	1380	1390	1400			1391
5	580	540	540	560	560	560	560	540			580	580	560	540	560	540	560	580			559
6	1530	1520	1500	1520	1520	1500	1520	1520			1560	1540	1580	1560	1560	1590	1580	1560			1534
7																					
8																					
9																					
10																					

LINE	Lubricating Oil Pressure - PSIG From Pump	To Engine	Cam Header	To Turbocharger LF	RF	LR	RR	Lubricating Oil Temperature °F To Engine	From Engine	Turbocharger Drain Frame	Supply		Return	Crank Case Press (in. H2O)	Remarks
1	59	55		32.5	31.5			162	175	[illegible]	84	571	0	-3.0	
2	59	55		32	30.5			162	178	[illegible]	84	571	0	-2.8	
3	59	55		31.5	30			160	181	[illegible]	84	571	0	-2.5	
4	59	55		31.8	30			160	180	[illegible]	84	571	0	-2.6	
5	59	65		34.6	33			163	173	[illegible]	82	588	0	-3.5	
6	60	56						160	181	[illegible]	84	571	0	-2.5	
7															
8															
9															
10															

LEGEND L, LB - LEFT BANK F - ENGINE FRONT AT NO 1 CYLINDER
R, RB - RIGHT BANK R - ENGINE REAR FLYWHEEL END
(WHEN VIEWED FROM FLYWHEEL END)

Transamerica Delaval
Transamerica Delaval Inc
Engine and Compressor Division

TURBOCHARGER MAKE & MODEL
LF ____ RF ____
LR ____ RR ____
BB - Brown Boveri DE - Delaval EL - Elliott

OPERATOR C. Lyons DATE 6-8-81
ENGINEER LOG 1 B
WITNESS JOB NO 2871

AXLAK01-509-1

ENTERPRISE ENGINE

CUSTOMER Georgia Power Company

MODEL DSRV-16-4 ENGINE NUMBER 76022 JOB NUMBER 2872

DATE November 6, 1981

CUSTOMER REPRESENTED BY

TEST CERTIFIED CORRECT
Transamerica Delaval Inc.
Engine and Compressor Division
BY A. R. Fleischer
TITLE Manager, Research & Development

REPORT
OF
ENGINE SHOP TESTING

SERIAL NO. 76022-2872

Transamerica Delaval

Transamerica Delaval Inc.
Engine and Compressor Division
550 85th Avenue P.O. Box 2161
Oakland, California 94621

DELAVAL ENGINE AND COMPRESSOR DIVISION, OAKLAND, CALIFORNIA

POWER ENGINE FACTORY TEST LOG — LOG 1 A

CUSTOMER: GEORGIA POWER — MODEL: DSRV-16-4 — TEST STAND: 23 — JOB NO: 2512 — ENGINE NO: 74056 — FULL LOAD RATING: 7000 — BHP @ 450 RPM — 225.5 BMEP

Line	Date	Wall Clock Time On Load	Time Log	% Load (Nom.)	Dyna RPM	Scale (lb)	BHP (Corr.)	BMEP	Disc Revs	Time (sec)	Power Factor	A.C. Volts	A.C. Amps	KW	Gen Eff	BHP (Corr.)	BMEP	Gov Load Limit
1	10/8	1740	1840	25	210	21402	1132	56										
2	10/8	2130	2230	25	270	21302	1455	56										
3	10/8	2240	2340	25	380	28302	2046	56										
4	10/8	2355	055	50	400	56605	4811	112										
5	10/9	1/5	145	0	450	0	0	0										
6	10/9	0745	0845	50	450	56605	4850	112										
7	10/9	0850	0950	75	450	84907	7275	168										
8	10/9	0955	1055	100	450	113210	9700	225										
9	10/9	1055	1155	100	450	113210	9700	225										
10	10/9	1200	1300	25	450	28302	2425	56										

Fuel Pump Rack Position (MM)

Line	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R
1	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5			15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5		
2	18	18	18	18	18	18	18	18			18	18	18	18	18	16	18	18		
3	18	18	18	18	18	18	18	18			18	18	18	18	18	18	18	18		
4	23	23	23	23	23	23	23	23			23	23	23	23	23	23	23	23		
5	11	11	11	11	11	11	11	11			11	11	11	11	11	11	11	11		
6	25	25	25	25	25	25	25	25			25	25	25	25	25	25	25	25		
7	29	29	29	29	29	29	29	29			29	29	29	29	29	29	29	29		
8	37	37	37	37	37	37	37	37			37	37	37	37	37	37	37	37		
9	37	37	37	37	37	37	37	37			37	37	37	37	37	37	37	37		
10	19	19	19	19	19	19	19	19			19	19	19	19	19	19	19	19		

Turbocharger Pressures

Line	Blower Inlet (in. H2O) LF	RF	LR	RR	Blower Discharge (in. Hg) LF	RF	LR	RR	Air Manif. LR	RR	Turbine Inlet (in. Hg) LF	RF	LR	RR	Turbine Exhaust (in. H2O) LF	RF	LR	RR
1	0.2	0.2			1.9	1.9			1.3	1.3								
2	0.5	0.5			2.0	2.0			1.9	1.9								
3	0.9	0.9			4.9	4.9			4.7	4.7								
4	2.1	2.1			15.4	15.4			15.1	15.1								
5	--	—			—	—			1.2	1.2								
6	3.2	3.2			[illegible]	[illegible]			19.1	19.1								
7	5.5	5.5			33.0	33.0			32.6	32.6								
8	9.2	9.2			51.0	51.5			50.2	50.2								
9	9.2	9.2			51.0	51.5			50.2	50.2								
10	1.6	1.6			8.0	8.0			7.7	7.7								

Turbocharger Temperatures / Air Flow

Air flow nozzle size: 14 14

Line	Blower Inlet (°F) LF	RF	LR	RR	Blower Discharge (°F) LF	RF	LR	RR	Air Manif. (°F) LR	RR	Turbocharger RPM LF	RF	LR	RR	Nozzle ΔP (in. H2O) LF	RF	LR	RR	Air Flow SCFM Total	Ambient Baro (Corr.) in. Hg	Ambient Air (°F)
1	74	74			55	55			92	92					0.2	0.2			3642	29.92	74
2	73	73			92	92			92	92					0.5	0.5			5764	29.92	73
3	73	73			112	112			98	101					0.9	0.9			7734	29.92	73
4	73	73			162	163			126	125					2.1	2.1			11814	29.92	73
5	71	71			—	—			97	97					—	—			~~14345~~	2992	71
6	74	74			177	180			125	127					3.1	3.1			14345	29.94	74
7	74	74			239	239			127	127					5.5	5.5			19114	29.96	74
8	76	76			299	304			129	129					9.2	9.2			24675	29.96	76
9	77	77			299	301			129	129					9.2	9.2			24656	29.92	77
10	77	77			133	133			120	122					1.6	1.6			10782	29.92	77

Fuel Oil Data / Diesel BSFC

Line	Manif. (in. Hg)	API Gravity As Read	@ °F	API Corrected to 60°F	LHV (Btu/lb)	LBS Weigh	Time (sec)	lb/hr	lb/bhp-hr	(Corr.) lb/bhp-hr
1	42									
2	42									
3	41									
4	40									
5	42									
6	41	32.4	66°		18340	1800	2500	1798		.359
7	40	32.2	64°		18340	1500	2150	2512		.348
8	32	32.5	68°		18340	1550	1637	3409		.354
9	32	33.7	70°		18340	1550	1643	3398		.353
10	40	33.0	76°		18910	680	2562	955		.397

Fuel Gas Data / Gas BSFC / Dual Fuel BSFC: (no entries)

Remarks:

HEAT CHECK OK. 1645–1700

10-9-81

1 hr. INTERNAL INSPECTION OK. E.L.

Injection/Ignition Timing °BTDC ____ LB ____ RB

Fuel Oil Spec: #2 Diesel

Lube Oil Spec: MOBIL GARD 412

Air Flow Nozzle Coefficient: LF 17765 RF ____ LR ____ RR ____ (FLYWHEEL END)

Operator: [illegible signature] 6-10 — Engineer: [illegible signature] — Witness: ____

Date: 10-9-81 — Log No: 1 A — Job No: 2372

Form D-4172

AX4AK01-509-1

Power Engine Factory Test Log

LOG 1 B

CUSTOMER Georgia Power MODEL DSR-16-4 TYPE SERVICE ______ JOB NO 2812 ENGINE NO 76022 DIRECTION OF ROTATION (AS VIEWED FROM FLYWHEEL END) CCW

EXHAUST TEMPERATURES °F

LINE	TURBINE INLET LFTL	LFTR	LFB	RFT	RFB	LRT	LRB	RRTL	RRTR	RRB	TURBINE EXHAUST LF	RF	LR	RR
1											460	425		
2											474	450		
3											563	527		
4											736	686		
5											—	—		
6											745	700		
7											796	753		
8											819	801		
9											819	800		
10											627	583		

LINE	EXHAUST ELBOWS 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	451	436	472	[illegible]	454			478
2	536	531	533	523	516	539	522	523			526	519	510	503	508	494	509	499			518
3	620	634	623	605	604	627	612	618			608	607	590	591	575	593	577	591			607
4	753	810	780	762	769	791	777	797			720	748	754	716	712	716	733	731			752
5	—	—	—	—	—	—	—	—			—	—	—	—	—	—	—	—			
6	804	857	840	819	822	853	826	825			763	794	781	773	767	771	785	750			801
7	852	949	913	904	868	896	905	887			823	889	822	832	834	836	809	826			865
8	936	1018	956	920	915	956	943	943			889	960	915	920	898	917	[illegible]	925			925
9	932	1015	956	984	913	954	940	943			892	958	915	919	895	920	890	925			924
10	694	725	701	682	699	720	689	690			662	668	655	640	650	633	666	649			677

LINE	ENGINE WATER FROM TO ENGINE	TO ENGINE (°F)	FROM ENGINE (°F)	TURBOCHARGER WATER OUTLET (°F) LF	RF	LR	RR	AFTERCOOLER WATER INLET (°F) F	R	OUTLET (°F) F	R
1	16	121	122	123	123			74		74	
2	16	160	161	161	161			74		94	
3	19	162	163	165	164			78		108	
4	20	163	166	169	168			123		125	
5	—	—	—	—	—			—	-	—	
6	22	161	165	167	167			128		131	
7	23	162	167	169	169			127		133	
8	23	164	170	172	172			126		141	
9	23	164	170	172	172			126		141	
10	23	158	160	161	161			97		130	

FIRING PRESSURES - PSIG

LINE	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1																					
2																					
3																					
4	790	780	790	800	810	790	815	800			800	790	795	790	800	810	800	790			795
5	—	—	—	—	—	—	—	—			—	—	—	—	—	—	—	—			
6	840	820	810	810	830	830	820	810			840	820	810	820	840	800	810	810			820
7	1120	1100	1090	1090	1100	1110	1090	1090			1120	1100	1090	1100	1110	1090	1100	1100			1100
8	1460	1420	1420	1410	1420	1410	1420	1420			1460	1420	1420	1460	1440	1410	1420	1420			1428
9	1440	1420	1420	1420	1430	1420	1420	1420			1450	1420	1420	1450	1440	1450	1430	1430			1430
10	600	580	570	580	600	580	580	580			600	570	580	600	600	580	580	580			586

LINE	LUBRICATING OIL PRESSURE - PSIG FROM PUMP	TO ENGINE	CAM HEADER	TO TURBOCHARGER LF	RF	LR	RR	LUBRICATING OIL TEMPERATURE °F TO ENGINE	FROM ENGINE	TURBOCHARGER DRAIN LF	RF	6462	RR	CRANK CASE PRESS (in. H2O)
1	57	63		31	31			108	111					[illegible]
2	59	55		33	33			138	140					2.2
3	59	55		33	32			159	162					2.2
4	59	55		31	31			164	174					2.0
5	—	—		—	—			—	—					—
6	59	55		31	30			163	175	93	93	6502	6325	-2.0
7	59	55		29.5	29			162	178		93	6502	6325	-1.8
8	59	55		29.0	28.5			160	180		93	6502	6325	-1.4
9	59	55		29.0	28.5			160	180		93	6502	6325	-1.5
10	60	55		33	32			163	173		93	6502	6325	-2.4

REMARKS

LEGEND L, LB - LEFT BANK F - ENGINE FRONT AT NO. 1 CYLINDER
R, RB - RIGHT BANK R - ENGINE REAR, FLYWHEEL END
(WHEN VIEWED FROM FLYWHEEL END)

Transamerica Delaval
Engine and Compressor Division

TURBOCHARGER MAKE & MODEL
LF FL ______ RF FL ______
LR ______ RR ______

OPERATOR C. Lyons 6-10
ENGINEER [illegible]
WITNESS
DATE 10-9-81
LOG 1 B
JOB NO 2872

AX4AK01-509-1

ENTERPRISE ENGINE

CUSTOMER Georgia Power Company

MODEL DSRV-16-4 **ENGINE NUMBER** 76023 **JOB NUMBER** 2873

DATE December 8, 1981

CUSTOMER REPRESENTED BY ______________________

TEST CERTIFIED CORRECT
Transamerica Delaval Inc.
Engine and Compressor Division
BY A. R. Fleischer
TITLE Manager, Research & Development

REPORT
OF
ENGINE SHOP TESTING

SERIAL NO. 76023-2873

Transamerica Delaval

Transamerica Delaval Inc.
Engine and Compressor Division
550 85th Avenue P.O. Box 2161
Oakland, California 94621

DELAVAL ENGINE AND COMPRESSION DIVISION, OAKLAND, CALIFORNIA

POWER ENGINE FACTORY TEST LOG — LOG 1 A

CUSTOMER Georgia Power MODEL DSRV-16-4 TEST STAND 23 JOB NO 2873 ENGINE NO 76023 FULL LOAD RATING 9700 BHP @ 450 RPM 223.8 BMEP

Line	Date	Wall Clock Time: On Load	Wall Clock Time: Time Log	% Load (Nom.)	Dyna: RPM	Dyna: Scale (lbs)	Dyna: BHP (Corr)	Dyna: BMEP	A.C. Gen: Disc Revs	Time (sec)	Power Factor	A.C. Volts	A.C. Amps	KW	Gen Eff	BHP (Corr)	BMEP	Gov Load Limit
1	10/21	2250	2150	25	210	29302	1132	56										
2	10/?	230	330	25	270	28302	1453	56										
3	10/22	0535	0635	25	360	28302	2048	56										
4	10/22	0640	0740	50	400	56605	4311	112										
5	10/22	0830	0930	50	450	56605	4850	112										
6	10/22	0930	1030	75	450	84902	7325	168										
7	10/22	1030	1130	100	450	113210	9700	223.8										
8	10/22	1130	1230	100	450	113210	9700	223.8										
9	10/22	1330		25	450	28303	2425	56										
10	10/22	1230	1330	110	450	14453	10620	246										

FUEL PUMP RACK POSITION (mm)

Line	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R
1	19	19	19	19	19	19	19	19			19	19	19	19	19	19	19	19		
2	19	19	19	19	19	19	19	19			19	19	19	19	19	19	19	19		
3	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5			19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5		
4	25	25	25	25	25	25	25	25			25	25	25	25	25	25	25	25		
5	25	25	25	25	25	25	25	25			25	25	25	25	25	25	25	25		
6	28.5	28.5	28.5	28.5	28.5	28.5	28.5	28.5			28.5	28.5	28.5	28.5	28.5	28.5	28.5	28.5		
7	37	37	37	37	37	37	37	37			37	37	37	37	37	37	37	37		
8	37	37	37	37	37	37	37	37			37	37	37	37	37	37	37	37		
9	19	19	19	19	19	19	19	19			19	19	19	19	19	19	19	19		
10	40	40	40	40	40	40	40	40			40	40	40	40	40	40	40	40	40	40

TURBOCHARGER PRESSURES

Line	Blower Inlet (in. H2O) LF	RF	LR	RR	Blower Discharge (in. Hg) LF	RF	LR	RR	Air Exit LB	RB	Turbine Inlet (in. Hg) LF	RF	LR	RR	Turbine Exhaust (in. H2O) LF	RF	LR	RR
1	0.4	0.4			1.3	1.3			1.2	1.2								
2	0.6	0.6			2.6	2.5			2.3	2.3								
3	1.1	1.0			4.6	4.8			4.5	4.7								
4	2.5	2.3			15.5	15.4			15.1	15.1								
5	3.0	3.0			18.3	18.2			17.8	17.8								
6	5.3	5.4			32.4	32.3			31.9	31.9								
7	8.9	8.8			49.1	49.1			48.5	48.5								
8	9.0	9.0			49.2	49.3			48.6	48.6								
9	7.6	7.6			7.6	7.6			7.4	7.4								
10	11.0	11.0			55.8	55.8			56.5	56.5								

TURBOCHARGER TEMPERATURES — AIR FLOW NOZZLE SIZE ► 14" 14"

Line	Blower Inlet (°F) LF	RF	LR	RR	Blower Discharge (°F) LF	RF	LR	RR	Air Manif (°F) LB	RB	Turbocharger RPM LF	RF	LR	RR	Nozzle Δh (in. H2O) LF	RF	LR	RR	Air Flow SCFM Total	Ambient Baro (Corr) in. Hg	Air (°F)
1	71	71			88	87			86	84					0.4	0.4			5185	30.15	71
2	71	71			94	92			90	91					0.6	0.6			6351	30.15	71
3	71	71			112	108			110	108					1.1	1.0			8402	30.17	71
4	73	73			164	162			120	119					2.4	2.3			12537	30.18	73
5	75	75			176	176			125	125					3.0	3.0			14160	30.20	75
6	72	72			234	236			127	122					5.3	5.3			18791	30.22	72
7	76	76			297	307			127	128					8.8	8.8			24237	30.22	76
8	72	72			296	303			128	129					8.9	8.9			24458	30.20	72
9	82	82			131	130			101	101					[illegible]	[illegible]			10370	30.20	82
10	75	75			388	337			129	131					10.5	10.5			26867	30.20	75

FUEL OIL DATA / DIESEL BSFC

Line	Barom. (mm)	API Gravity as read	@ °F	API Corrected to 60°F	LHV (Btu/lb)	Lbs Read	Time (sec)	lb/hr	lb/bhp-hr	(Corr) lb/bhp-hr
1	42									
2	42									
3	45									
4	45									
5	40	33.6	86°		18300	1050	2168	1744		.362
6	42	32.3	68°		18305	1600	2298	2507		.347
7	32	32.2	66°		18305	1600	1683	3422		.355
8	32	32.2	66°		18305	1600	1687	3414		.357
9	40	33.0	76°		18300	610	2356	932		.387
10	30	32.7	74°		16300	1600	1508	3820		.360

FUEL GAS DATA / GAS BSFC / DUAL FUEL BSFC

Line	Barom.	LHV Btu/ft³	To Gas Meter: in. Hg	°F	Corr. Factor	ft³ Read	Time (sec)	ft³/hr (Corr.)	Btu/bhp-hr	Pilot Btu/bhp-hr	Gas Btu/bhp-hr	Total Btu/bhp-hr
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

REMARKS

2015-2030 15 min HeaT Check OK- E. [illegible]-10-21

1 hr internal inspection OK 10-22-81

Shut Eng 330 F.S. Filter leaking oil at O Ring.

INJECTION/IGNITION TIMING °BTDC 22° LB 21° RB

FUEL OIL SPEC #2 Diesel

LUBE OIL SPEC Mobil Gard 412

Form D4173 (8-?)

AIR FLOW NOZZLE COEFFICIENT LF 17705 RF 17705 LR ____ RR ____ (FLYWHEEL END)

OPERATOR [illegible] 3-10 DATE 10-21-81

ENGINEER [illegible] LOG NO 1 A

WITNESS E. Bogert [illegible] JOB NO 2873

AX4AK01-509-1

1

Power Engine Factory Test Log

LOG 1 **B**

CUSTOMER [redacted] GEORGIA POWER MODEL DSRV-16-4 TYPE SERVICE GEN JOB NO 2873 ENGINE NO 76023 DIRECTION OF ROTATION (AS VIEWED FROM FLYWHEEL END) CW

EXHAUST TEMPERATURES - °F

LINE	TURBINE INLET (T - TOP, B - BOTTOM) LFTL	LFTR	LFB	RFT	RFB	LRT	LRB	RRTL	RRTR	RRB	TURBINE EXHAUST LF	RF	LR	RR	EXHAUST ELBOWS 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1											484	433			544	524	506	523	521	493	503	511			508	513	473	451	466	445	44	447			492
2											519	462			575	555	543	560	556	536	538	552			552	544	502	482	498	472	476	478			526
3											573	506			654	639	607	632	634	615	597	685			622	619	570	547	562	533	544	542			599
4											734	670			805	809	759	794	791	755	762	816			755	782	708	677	701	666	692	710			748
5											737	702			802	848	803	817	822	797	822	895			757	807	765	751	783	773	825	794			803
6											791	768			844	923	846	896	871	853	887	940			831	902	818	825	855	856	871	854			870
7											824	815			936	1004	958	954	920	923	949	973			933	991	920	896	918	925	950	953			943
8											820	811			926	993	948	949	911	913	936	963			928	983	925	889	911	917	944	948			933
9											613	568			666	692	673	677	626	668	692	727			611	643	656	619	650	686	673	643			662
10											841	843			973	1045	993	982	947	959	970	1006			979	1040	979	942	956	965	1000	1005			983

LINE	ENGINE WATER PSIG TO ENGINE	TO ENGINE (°F)	FROM ENGINE (°F)	TURBOCHARGER WATER OUTLET (°F) LF	RF	LR	RR	AFTERCOOLER WATER INLET (°F) F	R	OUTLET (°F) F	R
1	18.5	138	139	140	135			73		76	
2	19	164	165	166	159			75		96	
3	22	163	164	165	165			82		90	
4	22	162	166	168	168			118		120	
5	21.5	144	147	149	149			125		127	
6	23	163	168	170	170			126		134	
7	23	162	168	170	170			125		141	
8	23	163	169	172	172			126		143	
9	23	157	159	160	160			101		103	
10	23.5	165	172	174	174			124		146	

FIRING PRESSURES - PSI

LINE	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1																					
2	620	610	600	620	640	600	600	600			600	600	600	600	580	560	580	580			599
3	600	600	600	620	690	610	600	600			600	590	590	600	580	590	580	580			597
4	870	860	860	880	870	840	840	850			850	840	840	840	830	820	800	800			843
5	830	840	830	840	850	840	830	850			820	820	830	840	830	830	820	830			833
6	1130	1150	1130	1160	1160	1150	1140	1160			1140	1140	1120	1150	1160	1160	1140	1130			1145
7	1460	1470	1450	1460	1470	1460	1440	1440			1460	1440	1440	1450	1460	1460	1440	1440			1452
8	1460	1460	1450	1460	1460	1450	1440	1440			1450	1450	1440	1440	1460	1450	1450	1440			1453
9	600	580	580	590	580	600	580	590			600	580	580	600	600	580	570	580			588
10	1580	1570	1560	1560	1560	1560	1590	1560			1560	1540	1550	1560	1550	1560	1540	1540			1558

LINE	LUBRICATING OIL PRESSURE - PSIG FROM PUMP	TO ENGINE	CAM HEADER	TO TURBOCHARGER LF	RF	LR	RR	LUBRICATING OIL TEMPERATURE °F TO ENGINE	FROM ENGINE	TURBOCHARGER DRAIN LF	RF	LR	RR	CRANK CASE PRESS " in. H2O	REMARKS
1	59	55		33	31			125	126					0	
2	59	55		34.5	[illegible]			166	166					1.3	
3	59	55		34.5	32			165	167					-2.5	
4	58	55		32	30			163	169					-1.9	TOOK COLD COMP. @ 450 ø LOAD RW.
5	58	55		32	30			163	169					-1.8	
6	58	55		31	29			162	173					-1.5	
7	58	55		30	28			161	175					-1.3	
8	58	55		30	28			161	175					-1.3	
9	59	55		34	34.5			163	168					-2.2	
10	58	55		29.5	27.5			160	175					-1.1	

LEGEND: L LB - LEFT BANK F - ENGINE FRONT AT NO 1 CYLINDER
R RB - RIGHT BANK R - ENGINE REAR FLYWHEEL END
(WHEN VIEWED FROM FLYWHEEL END)

Form D-4114 (R-1) 9/79

Transamerica Delaval
Transamerica Delaval Inc.
Engine and Compressor Division

TURBOCHARGER MAKE & MODEL
LF DE RF DE
LR RR
BB - Brown Boveri DE - Delaval EL - Elliott

OPERATOR [signature] 3-10
ENGINEER [signature]
WITNESS [signature] 113 [signature]

DATE 10-21-81
LOG 1 **B**
JOB NO 2873

AX4AK01-509-1

ENTERPRISE ENGINE

CUSTOMER Georgia Power Company

MODEL DSRV-16-4 ENGINE NUMBER 76024 JOB NUMBER 2874

DATE December 8, 1981

CUSTOMER REPRESENTED BY

TEST CERTIFIED CORRECT
Transamerica Delaval Inc.
Engine and Compressor Division
BY A. R. Fleischer
TITLE Manager, Research & Development

REPORT
OF
ENGINE SHOP TESTING

SERIAL NO. 76024-2874

Transamerica Delaval

Transamerica Delaval Inc.
Engine and Compressor Division
550 85th Avenue P.O. Box 2161
Oakland, California 94621

DELAVAL ENGINE AND COMPRESSOR DIVISION, OAKLAND, CALIFORNIA

POWER ENGINE FACTORY TEST LOG — LOG 1 A

CUSTOMER GEORGIA POWER — MODEL DSRV-16-4 — TEST STAND 23 — JOB NO 2874 — ENGINE NO 76024 — FULL LOAD RATING 9700 BHP @ 450 RPM 223.8 BMEP

LINE	DATE	WALL CLOCK TIME ON LOAD	TST LOG	% LOAD	RPM	SCALE	BHP	BMEP	DISC REVS	TIME	POWER FACTOR	A.C. VOLTS	A.C. AMPS	KW	GEN EFF	BHP	BMEP	GOV LOAD LIMIT
1	11/3	1425	1525	25	370	28302	1132	56										
2	11/3	1730	1930	25	270	28302	1955	56										
3	11/3	1930	2030	25	360	28302	2047	56										
4	11/3	2040	2140	50	400	56605	4311	112										
5	11/3	2150	2220	0	450	0	0	0										
6	11/3	2310	010	50	450	56605	4850	112										
7	11/4	0905	0905	50	450	56605	4850	112										
8	11/4	1000	1310	75	450	84907	7275	168										
9	11/4	1310	1410	100	450	113210	9700	223.8										
10	11/4	1410	1510	100	450	113210	9700	223.8										

FUEL PUMP RACK POSITION

LINE	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R
1	18	18	18	18	18	18	18	18			18	18	18	18	18	18	18	18		
2	18	18	18	18	18	18	18	18			18	18	18	18	18	18	18	18		
3	19	19	19	19	19	19	19	19			19	19	19	19	19	19	19	19		
4	24	24	24	24	24	24	24	24			24	24	24	24	24	24	24	24		
5	11	11	11	11	11	11	11	11			11	11	11	11	11	11	11	11		
6	26	25	25	25	25	25	26	25			25	25	25	25	25	25	25	25		
7	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5			24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5		
8	28	28	28	28	28	28	28	28			28	28	28	28	28	28	28	28		
9	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5			32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5		
10	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5			30.5	32.5	32.5	32.5	32.5	32.5	30.5	32.5		

TURBOCHARGER PRESSURES

LINE	BLOWER INLET (in H2O) LF	RF	LR	RR	BLOWER DISCHARGE (in Hg) LF	RF	LR	RR	AIR BOX LB	RB	TURBINE INLET (in Hg) LF	RF	LR	RR	TURBINE EXHAUST (in H2O) LF	RF	LR	RR
1	.3	.3			1.0	1.0			1.0	1.0								
2	.6	.6			2.1	2.1			1.9	1.9								
3	1.2	1.2			5.0	5.0			4.8	4.8								
4	2.2	2.2			15.0	15.0			14.7	14.7								
5	—	—			—	—			—	—								
6	2.7	2.7			17.0	17.0			16.8	16.8								
7	3.0	2.8			18.4	18.4			18.1	18.1								
8	5.3	5.2			32.1	32.0			31.7	31.2								
9	9.1	9.1			50.4	50.6			50.2	50.3								
10	9.3	9.3			50.8	50.7			50.3	50.3								

TURBOCHARGER TEMPERATURES — AIR FLOW NOZZLE SIZE 19" 19"

LINE	BLOWER INLET (°F) LF	RF	LR	RR	BLOWER DISCHARGE (°F) LF	RF	LR	RR	AIR BOX (°F) LB	RB	TURBOCHARGER RPM LF	RF	LR	RR	NOZZLE ΔP (in H2O) LF	RF	LR	RR	AIR FLOW SCFM TOTAL	BARO (in Hg)	AIR (°F)
1	74	74			86	87			96	87					.3	.3			8461	29.92	74
2	70	70			80	91			98	92					.6	.6			6333	29.92	70
3	71	71			108	112			99	100					1.2	1.2			8949	29.92	71
4	70	70			153	161			120	120					2.1	2.2			11987	29.92	70
5	70	70			—	—			—	—					—	—			~~13994~~	29.92	70
6	73	73			168	173			125	126					2.7	2.7			13394	29.91	73
7	71	71			168	180			120	120					3.0	3.0			14123	29.93	71
8	74	74			222	240			126	127					5.2	5.2			18564	29.89	74
9	75	75			266	262			127	128					9.1	9.1			24531	29.88	75
10	71	71			246	246			126	125					9.3	9.3			24892	29.88	71

FUEL OIL DATA / DIESEL BSFC

LINE	BARO (in Hg)	API GRAVITY	@ °F	LHV (Btu/lb)	LB MEAS	TIME (sec)	LB/HR	BSFC (lb/bhp-hr)
1	43	[redacted]	[redacted]	[redacted]				
2	45							
3	45							
4	44							
5	48							
6	44							
7	32	32.0	66°	18500	1050	2190	1726	.358
8	40	32.3	70°	18500	1500	2??	2591	.346
9	34	32.6	75°	18500	1650	1745	3404	.353
10	34	32.6	75°	18500	1650	1662	3404	.355

REMARKS

1. 1305-1320 15 min H.P. Check OK
1 hr. internal inspection OK
3. Shut Eng Down, indicator Hole
4. Plug on LB 5-Head. 1830
5. Cold Comp. C.L. 11-3-81
7. shutdown to check F.O. Ejector
8. shutdown to still wrong

INJECTION/IGNITION TIMING BTDC 22° LB 21° RB
FUEL OIL SPEC #2 DIESEL
LUBE OIL SPEC MOBIL GARD 412

AIR FLOW NOZZLE COEFFICIENT LF 17705 RF 17705

OPERATOR — ENGINEER — WITNESS E.J. Burgart Bechtel 11/4/81

DATE 11-3-81 — LOG NO 1 A — JOB NO 2874

AX4AK01-509-1

Power Engine Factory Test Log

LOG 1 B

CUSTOMER GEORGIA POWER MODEL DSRV-16-4 TYPE SERVICE GEN JOB NO. 2874 ENGINE NO. 76024 DIRECTION OF ROTATION (AS VIEWED FROM FLYWHEEL END) CW

EXHAUST TEMPERATURES - °F

LINE	Turbine Inlet LFTL	LFTR	LFB	RFT	RFB	LRT	LRB	RRTL	RRTR	RRB	Turbine Exhaust LF	RF	LR	RR	Exhaust Elbow 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1											483	441			524	544	523	520	520	502	509	501			472	487	479	499	495	498	479	481			501
2											504	463			537	566	541	544	543	625	549	629			493	508	502	518	497	521	501	504			523
3											573	527			619	656	616	628	627	612	621	614			575	604	597	598	575	601	597	599			608
4											743	685			764	820	762	800	789	756	782	789			698	791	720	790	728	761	736	760			757
5											—	—			—	—	—	—	—	—	—	—			—	—	—	—	—	—	—	—			
6											729	726			773	825	732	824	765	772	801	727			769	774	799	800	827	837	793	831			797
7											737	724			792	897	789	834	813	791	856	752			762	797	796	838	833	855	824	786			815
8											793	786			855	965	857	955	873	852	904	848			855	881	835	909	914	916	878	885			876
9											823	816			950	1010	916	1002	932	925	976	927			941	925	943	948	929	967	950	962			950
10											832	808			982	1002	912	994	932	921	921	926			941	970	936	947	916	966	944	965			945

LINE	Engine Water Rise to Engine	To Engine (°F)	From Engine (°F)	Turbocharger Water Outlet (°F) LF	RF	LR	RR	Aftercooler Water Inlet (°F) F	R	Outlet (°F) F	R	Firing Pressures - PSIG 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1	17	151	151	152	152			74		73																						
2	20	162	163	164	164			73		77		600	600	600	600	570	580	590	600			560	590	560	590	590	590	560	580			581
3	21	162	163	164	164			76		108		600	600	600	600	600	640	600	600			560	580	680	580	580	580	580	540			587
4	22	162	166	167	168			120		122		860	840	860	840	840	820	840	840			800	800	800	800	800	820	800	820			823
5	—	—	—	—	—			—		—		—	—	—	—	—	—	—	—			—	—	—	—	—	—	—	—			
6	22	162	166	167	167							810	850	850	870	860	830	830	840			840	850	880	830	820	810	810	810			832
7	24	154	157	159	159			120		123		860	860	830	840	830	840	860	830			800	860	840	860	860	860	840	840			848
8	24	162	167	168	166			128		133		1160	1170	1140	1160	1140	1140	1160	1140			1140	1160	1160	1150	1120	1120	1140	1140			1151
9	24	163	169	171	171			124		140		1500	1440	1460	1460	1480	1460	1470	1480			1440	1510	1460	1480	1500	1480	1480	1480			1476
10	23	163	169	171	171			123		137		1500	1480	1470	1460	1480	1480	1460	1480			1470	1500	1470	1480	1500	1480	1480	1480			1480

LINE	Lubricating Oil Pressure - PSIG From Pump	To Engine	Cam Header	To Turbocharger LF	RF	LR	RR	Lubricating Oil Temperature °F To Engine	From Engine	Turbocharger Drain LF	RF	LR	RR	Crank Case Press.	Remarks
1	53	50		29.5	27			125	125					-2.5	
2	59	65		32	29			142	145					2.6	
3	59	55		31	29.5			165	166					2.5	
4	59	55		30.6	28.5			163	168					2.2	
5	59	55		32	31			—	—					2.6	
6	59	55		31	30			169	170					2.2	
7	58.5	55		30	27			164	169					-2.1	
8	58	54.5		28	25.5			162	172					-1.8	
9	60	55.5		28	25			161	175					-1.3	
10	60	55.5		28	25			161	175					-1.4	

LEGEND: L, LB - LEFT BANK; R, RB - RIGHT BANK; F - ENGINE FRONT AT NO. 1 CYLINDER; R - ENGINE REAR FLYWHEEL END (WHEN VIEWED FROM FLYWHEEL END)

Transamerica Delaval — Engine and Compressor Division

TURBOCHARGER MAKE & MODEL: LF DF RF DF

OPERATOR [illegible] DATE 11-3-81
ENGINEER [illegible] LOG 1 B
WITNESS E. J. Bogard [illegible] 11/4/81 JOB NO. 2874

AX4AK01-509-1

Section 9
Drawings

SECTION 9
DRAWINGS

The drawings listed below apply to this installation, and are intended to assist in the installation operation, overhaul and repair of the engine. In addition, the pages in the front part of this section contain information to assist in the use of the drawings as well as other information of a general nature intended to provide ready reference data to the user.

Dwg No	Rev	Title
R-4032	B	FOUNDATION BOLTING PLAN
R-4033	J	INSTALLATION DRAWING
R-4099	-	ARRANGEMENT DWG, AUX. SKID BASE EQUIPMENT
52431	L	BLOCK DIAGRAM
52439	F	OPTICAL ISOLATOR ASSEMBLY
52440	G	GENERATOR CONTROL SCHEMATIC (4 SHEETS)
100232	D	SUGGESTED CONCRETE FOUNDATION DETAILS
02-550-03	D	ENGINE MOUNTING
00-500-76021	F	ENGINE CONTROL PANEL INSTALLATION
09-500-76021	G	ENGINE CONTROL PANEL SCHEMATIC (9 SHEETS)
09-688-76021	D	ENGINE & SKID ELECTRICAL SCHEMATIC & WIRING (3 SHTS)
09-691-76021	B	OFF-ENGINE ALARMS
09-695-76021	F	ENGINE PNEUMATIC SCHEMATIC
09-805-76021	D	EXHAUST, INTAKE & CRANKCASE PIPING SCHEMATIC
09-810-76021	H	JACKET WATER PIPING SCHEMATIC
09-820-76021	G	LUBE OIL PIPING SCHEMATIC
09-825-76021	E	FUEL OIL PIPING SCHEMATIC
09-835-76021	F	STARTING AIR PIPING SCHEMATIC
61-560-6926	A	TEST SD BLOCK & SD ACTIVATE SEL. LOGIC BOARD
61-560-6927	B	PNEUMATIC MOTHER BOARD ASSY
61-560-6943	-	TWO OUT OF THREE LOGIC BOARD ASSY.
61-560-7055	A	SHUTDOWN PNEUMATIC LOGIC BOARD ASSY
62-500-76021	B	WIRING CONNECTIONS (3 SHEETS)
65-500-76021	A	WIRING DIAGRAM (10 SHEETS)

AX-AP01-509-1

Piping Connection Numbers

All engine and related auxiliary equipment connections are identified by a standard series of numbers applicable to all series of engines. These numbers are used on all equipment and installation drawings for the identification of external connections.

ITEM	LUBE OIL CONNECTIONS
104 –	Lube Oil Pressure Pump Suction
105 –	Lube Oil Scavenge Pump Discharge
114 –	Four-Way Valve to Lube Oil Cooler
115 –	Four-Way Valve from Lube Oil Cooler
123 –	Emergency Lube Oil Inlet
124 –	Lube Oil Sump Outlet
125 –	Lube Oil to Clarifier
128 –	Emergency Lube Oil Outlet
152 –	Line to Relief Valve – Lube Oil
155 –	Lube Oil Inlet
167 –	Lube Oil Pressure Pump Outlet
168 –	Lube Oil Strainer Inlet
182 –	Lube Oil Regulating Valve Outlet
186 –	Lube Oil from Clarifier
190 –	Lube Oil Pump Safety Valve Outlet
191 –	Lube Oil Scavenge Pump Inlet
193 –	Lube Oil Relief Valve Return
198 –	L.O. Sump Tank Vent Connection
200 –	L.O. Pressure Control Connection
208 –	Pre-Lube Pump Suction Conn. – Compressor
209 –	Pre-Lube Pump Discharge Conn. – Compressor
210 –	Compressor L.O. Regulator Inlet
211 –	Compressor Crankcase L.O. Drain
212 –	Engine L.O. Regulator Inlet
213 –	Engine L.O. Drain
218 –	Pre-Lube Pump Suction (Engine)
219 –	Lubricator Supply – Compressor
220 –	Pre-Lube Pump Inlet – Engine
221 –	Turbo L.O. Drain
224 –	Engine L.O. Fill
225 –	Compressor L.O. Fill
226 –	Compressor Cylinder Lube Oil Pump Inlet
227 –	Compressor Lube Oil Meter Inlet
241 –	L.O. Pressure Regulator Return
242 –	L.O. Strainer & Filter Vent
245 –	L.O. Return from By-Pass Filter
246 –	Lube Oil Return from Gear
247 –	L.O. Supply to Compressor
248 –	Compressor Seal Oil Recirc.
249 –	Compressor Seal Oil Pump Outlet
255 –	Extra Distance Piece Lube Oil Drain
258 –	Vent from Lube Oil Filter
259 –	Compressor Motor L.O. Inlet
260 –	Compressor Motor L.O. Outlet
261 –	Compressor Motor L.O. Supply
262 –	Compressor Motor L.O. Return
263 –	Compressor L.O. Module Inlet
264 –	Compressor L.O. Module Outlet
265 –	Compressor L.O. Module Inlet for Aux. L.O. Pump
266 –	Filter Dirty L.O. Drain
267 –	Filter Clean L.O. Drain
268 –	L.O. Strainer Drain
269 –	L.O. Cooler Drain
280 –	L.O. Filter Outlet
281 –	L.O. Clarifier Skid Inlet
282 –	L.O. Clarifier Skid Outlet
283 –	L.O. Clarifier Sludge Outlet
293 –	L.O. Heater Steam Inlet
294 –	L.O. Heater Steam Outlet
300 –	L.O. Inlet to Filter
311 –	L.O. Sump Tank Drain

ITEM	FUEL OIL AND GAS CONNECTIONS
106 –	Emergency Fuel Oil – Inlet
107 –	Fuel Oil Suction, Engine
122 –	Fuel Oil Drain
134 –	Fuel Oil Suction, Transfer
135 –	Fuel Oil Discharge, Transfer
148 –	Fuel Oil Header Inlet
149 –	Emergency Fuel Oil Outlet
155 –	Heavy Fuel Oil Inlet
157 –	Fuel Oil Pressure Pump Discharge
162 –	Fuel Oil Inlet – Settling Tank to Filter
178 –	Gas Inlet
181 –	Fuel Oil Return
183 –	Heavy Oil Bypass Outlet
197 –	Vent, Gas Shut-Off Valve
199 –	Fuel Oil Bypass Outlet
229 –	Relief Valve Discharge – Gas
139 –	Fuel Injection Line Shroud – Drain
244 –	Fuel Oil Pressure Pump Inlet
284 –	Fuel Oil Centrifuge Sludge Outlet
285 –	Diesel Oil Centrifuge Sludge Outlet
286 –	Fuel Oil Centrifuge Outlet
287 –	Diesel Oil Centrifuge Outlet
288 –	Diesel Oil Inlet – Storage Tank to Strainer
289 –	Diesel Oil Pressure Pump Inlet
290 –	Diesel Oil Filter Outlet
291 –	Fuel Oil Heater – Steam Inlet
292 –	Fuel Oil Heater – Steam Outlet
295 –	Fuel Oil Filter Steam Inlet
296 –	Fuel Oil Filter Steam Outlet
297 –	Fuel Oil Viscometer Outlet
303 –	Fuel Oil Drip Tank Vent
313 –	Centrifuge Desludge Water Inlet

ITEM	STARTING AIR, EXHAUST, MISCELLANEOUS CONNECTIONS
108 –	Starting Air Inlet (or Gas)
109 –	Exhaust Outlet
113 –	Compressor Outlet
156 –	Air Inlet – Fuel Shut Down Valve
176 –	Air Inlet – Supercharger
196 –	Crankcase Exhaust Outlet
203 –	Starting Air Outlet (or Gas)
204 –	Cylinder Head Vent
205 –	Turbo Air Vent
214 –	Distance Piece Vent, Compressor
215 –	Distance Piece Drain, Compressor
236 –	Control System Vent
238 –	Power Air for Unloaders
254 –	Extra Distance Piece Vent
256 –	Sweet Gas Inlet
257 –	Rod Packing Vent
279 –	Starting Air Tank Drain
302 –	Air Inlet – Barring Device
308 –	Start Air Module Outlet
309 –	Air Dryer Inlet
310 –	Start Air Tank Outlet
312 –	Air Intake – Intake Silencer

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Piping Connection Numbers (cont'd)

ITEM	WATER CONNECTIONS
100 –	Fresh Water Pump Suction
101 –	Fresh Water Pump Discharge
102 –	Salt Water Pump Suction – Marine Raw Water Pump Suction – Stationary
103 –	Salt Water Pump Discharge – Marine Raw Water Pump Discharge – Stationary
110 –	Jacket Water Vent
112 –	Emergency Circulating Water – Inlet
116 –	Fresh Water Inlet to Engine Manifold
117 –	Jacket Water Manifold Outlet
119 –	Thrust Bearing Water Outlet
120 –	Bilge Pump Suction
121 –	Bilge Pump Discharge
126 –	Sea Water Discharge
130 –	Surge Tank Connection from Tank
131 –	Fill Line – Water System
133 –	Circulating Water Outlet – Supercharger
137 –	Cooling Water Vent – Supercharger
138 –	Alt. Cooling Water Vent – Supercharger
154 –	Bilge Pump Priming Connection
158 –	Thrust Bearing Water Inlet
159 –	Water Inlet – Lube Oil Cooler
160 –	Thermostatic Valve – Inlet
161 –	Jacket Water Outlet to Cooler
163 –	Emergency Circulating Water Outlet
164 –	Emergency Sea Water Inlet
165 –	Jacket Sea Water Inlet
166 –	Jacket Sea Water Outlet
170 –	Jacket Water Outlet By-Pass
171 –	Water By-Pass Inlet
179 –	Water Inlet Compressor
180 –	Water Outlet Compressor
184 –	Raw Water Inlet – Turbo Water Cooler
185 –	Raw Water Outlet – Turbo Water Cooler
187 –	Water Outlet – Lube Oil Cooler
188 –	Water Inlet – Intercooler
189 –	Water Outlet – Intercooler
192 –	Raw Water Inlet
194 –	Water Inlet Turbocharger
206 –	Cooling Water to Compressor L.O. Cooler
207 –	Cooling Water from Compressor L.O. Cooler
228 –	Jacket Water Drain & Fill Conn.
230 –	Intercooler Pump Suction
231 –	J.W. Standpipe Overflow to Aux. Surge Tank
232 –	Return to J.W. Standpipe from Aux. Surge Tank
243 –	Cylinder Block Drain
250 –	Cooling Water to Radiator
251 –	Cooling Water from Radiator
252 –	Sea Water to Cooler
253 –	Sea Water from Cooler
270 –	Drain, Compressor Water Supply Pipe
271 –	J.W. Skid Inlet
272 –	J.W. Skid Outlet
273 –	Raw Water Pump Outlet
274 –	Raw Water – L.O. Cooler Inlet
275 –	Raw Water – L.O. Cooler Outlet
276 –	Raw Water – J.W. Cooler Inlet
277 –	Raw Water – J.W. Cooler Outlet
278 –	Raw Water – Discharge
298 –	Governor – L.O. Cooler Water Inlet
299 –	Governor – L.O. Cooler Water Outlet
301 –	J.W. Drain
304 –	Steam Condensate Outlet

ITEM	INSTRUMENTS, ALARMS, THERMOMETERS, ETC.
111 –	Fresh Water Alarm
118 –	Lube Oil Alarm
127 –	Sea Water Alarm Contact Connector
129 –	Lube Oil Alarm – Supercharger
132 –	Water Temp. Alarm – Supercharger
136 –	Thermocouple to Instrument Board
139 –	Lube Oil Pressure Gage Connection
140 –	Jacket Water Circ. Pump Discharge Pressure Gage Connection
141 –	Lube Oil Pressure Switch Connection
142 –	Thermometer – Lube Oil to Engine
143 –	Lube Oil Pressure Gage to Engine
144 –	Lube Oil Pressure Gage Connection – Supercharger
145 –	Intake Manifold Pressure Manometer
146 –	Fuel Oil Pressure Gage Connection
147 –	Conduit Terminal to Alarm
150 –	Jacket Water Inlet Thermometer
151 –	Jacket Water Outlet Thermometer
172 –	Pilot House Remote Control Inlet (Astern)
173 –	Pilot House Remote Control Inlet (Ahead)
174 –	Pilot House Governor Control Inlet (Slow)
175 –	Pilot House Governor Control Inlet (Fast)
177 –	Pilot House Governor Control (Speed)
195 –	Lube Oil Temp. Gage
305 –	Fuel Oil Inlet – Aux. Module
306 –	Fuel Oil Drip Return – Aux. Module
307 –	Fuel Oil Drip Tank Drain

ITEM	POWER GAS CONNECTIONS
216 –	Pre-Lube Pump Motor Inlet
217 –	Pre-Lube Pump Motor Outlet
222 –	Pre-Lube Pump Motor Inlet (Compressor)
223 –	Pre-Lube Pump Motor Outlet (Compressor)

ITEM	HYDRAULIC CONNECTIONS
201 –	Hydraulic Connections
202 –	Hydraulic Pump Discharge
233 –	Expansion Tank Gas Supply
234 –	Expansion Tank Relief Valve Outlet
235 –	Bleed Line Return to Expansion Tank
237 –	Hydraulic Pump Discharge (Compressor)
240 –	Hydraulic Pump Relief Valve Discharge

Piping Symbols

MANOMETER	PRESSURE REDUCER	LEVEL GAUGE
PRESSURE SWITCH	GATE VALVE	PLUGGED
DIAL THERMOMETER	GLOBE VALVE	STRAINER
TEMPERATURE SWITCH	PLUG VALVE	DIRECTION OF FLOW
SIGHT FLOW GAUGE	BUTTERFLY VALVE (Tight Sealing Type)	WELD REDUCER
ENGINE SHUT DOWN PRESSURE SWITCH	CHECK VALVE	SCREWED CAP AND NIPPLE
PYROMETER	STOP COCK	UNION
PRESSURE SHUT DOWN ELEMENT	SAFETY OR RELIEF VALVE	WELD CAP
TEMPERATURE CONNECTION — Requires ¼" half coupling for all dial thermometers and separable socket thermometer wells and ½" half couplings for temperature switches, etc. (Field locate as directed by owner.)	PRESSURE CONNECTION — Requires ½" coupling, nipple, stop cock, ½" x ¼" bushing and ¼" plug. (Field locate as directed by owner.)	LEVEL SWITCH
STRAINER "Y"	SOLENOID VALVE	
TEMPERATURE SHUT DOWN ELEMENT	DRESSER COUPLING	
ELECTRIC WIRING	EXPANSION JOINT	
CAPILLARY TUBING	ORIFICE	
BLIND FLANGE	ALARM CIRCUIT	
THERMOMETER	PRESSURE GAUGE	
TEMPERATURE GAUGE	METER	
FLOAT VALVE	FLOAT SWITCH	
DIAPHRAGM CONTROL VALVE	THERMOSTATIC TEMP. CONTROL VALVE	This form same as Form D-4313

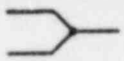
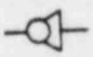
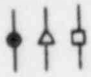
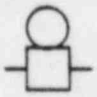
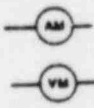
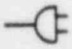
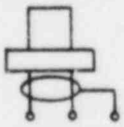
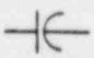
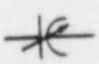
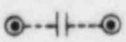
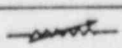
Electrical Schematic Symbols

Symbol	Device
SWITCHES – General	
	Disconnect (2 pole)
	Circuit Breaker (2 pole)
	Normally Open Limit
	Normally Closed Limit
	Held Closed Limit
	Held Open Limit
	Normally Open Liquid Level
	Normally Closed Liquid Level
	Normally Open Pressure
	Normally Closed Pressure
	Normally Open Differential Pressure
	Normally Closed Differential Pressure
	Dual Contact Differential Pressure
	Normally Open Temperature
	Normally Closed Temperature
	Normally Open Thermostatic – Adjustable
	Normally Closed Thermostatic – Adjustable
	Normally Open Flow
	Normally Closed Flow

Symbol	Device
SELECTORS	
	Normally Closed Manual
	Normally Open Manual
	Normally Open Held Closed
	Normally Closed Held Open
	Three Position Spring Return to Center
HAND AUTO	Three Position Maintained Position (shown in Hand position)
PUSHBUTTONS	
	Normally Open
	Normally Closed
	Normally Closed, Held Open
	Multiple Contacts, Mechanically Connected
CONDUCTORS	
	Not Connected Connected
RELAYS	
3.7	Relay Coil – numbers to right of ladder indicate contact locations - normally closed contacts are underlined
	Normally Open contact
	Normally Closed contact
15.18	Latch/Reset Relay Coil - numbers indicate contact locations, normally closed contacts underlined

Symbol	Device
5.8	Time Delay Relay Coil - Slow Operating Type - On energization, contacts change state after delay and reset immediately on de-energization. (5 sec. shown)
7.10	Time Delay Relay Coil - Slow Release Type - on energization, contacts change state immediately and reset after delay on de-energization
	Slow Operating Normally Open Energized Contact
	Slow Operating Normally Closed Energized Contact
	Slow Release Normally Open Energized Contact
	Slow Release Normally Closed Energized Contact
OTHER COILS	
	Solenoid
	Overload, Thermal

Electrical Schematic Symbols (cont'd)

Symbol	Device	Symbol	Device		
MISCELLANEOUS			Rheostat		
	Fuse		Thermocouple		
	Horn		Terminals		
	Alarm Bell		Meters		
	Plug & Receptacle		Transformer		
	Line Plug		Magnetic Pick Up With Shield		
	Receptacle		Motor, AC		
	Fixed Capacitor				
	Adjustable Capacitor				
	Diode				
	SCR				
	Earth Ground				
	Chassis Ground				
	Lamp				
	Motor Starter or Contactor				
	Motor, DC				
	Remote Location				
	Resistor				
	Adjustable Resistor				
	Potentiometer				

Valve Symbols

TWO POSITION VALVE (W/O ACTUATOR)
Basic two position
Two way, two position
Three way, two position
Four way, two position
Five way, two position

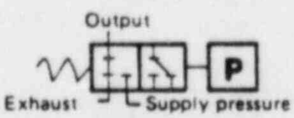
THREE POSITION VALVE (W/O ACTUATOR)
Basic three position
Three way, closed center, three position
Three way, open center, three position
Four way, closed center, three position
Four way, open center, three position
Five way, open center, three position
Five way, closed center, three position

ACTUATORS	
	Spring return
M	Manual push actuator
M	Manual pull actuator
M Det.	Detented manual actuator
P	Pressure actuator
S	Solenoid actuator
V	Vibration actuator
F	Flow actuator
L	Liquid level actuator
T	Temperature actuator

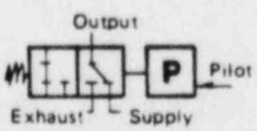
1. Actuators (there may be one or two) are shown attached to either end of valve symbol.
2. Valve symbols are always shown in non-actuated, i.e., "Normal, relaxed" condition.
3. The tube or pipe connections to the valve are considered to be immoveable, while the internal passage blocks are mentally shifted between the external connections to visualize valve action.

EXAMPLES

Three-way valve, two position, pressure actuated, spring return

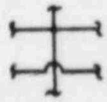
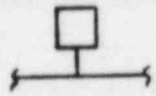
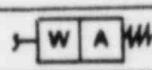
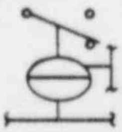
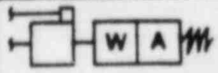
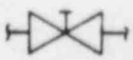
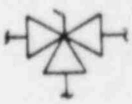
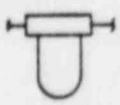
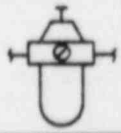
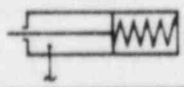
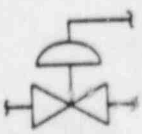
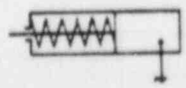
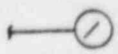
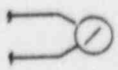
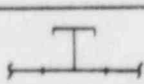
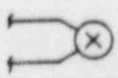


Valve connected normally closed (supply shut off when no pilot pressure exists). Note output is connected to exhaust.



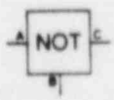
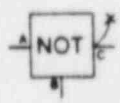
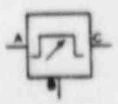
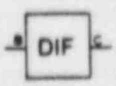
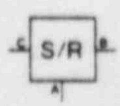
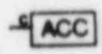
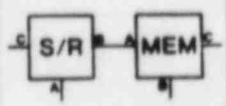
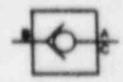
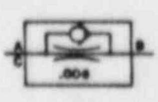
Valve shown with pilot pressure applied (actuated). Supply is now connected to output, and exhaust is blocked. Note that connections have not moved, and valve body is shifted to the left, causing the right passage block to come beneath the connections. Also note, this view will not show up on drawings.

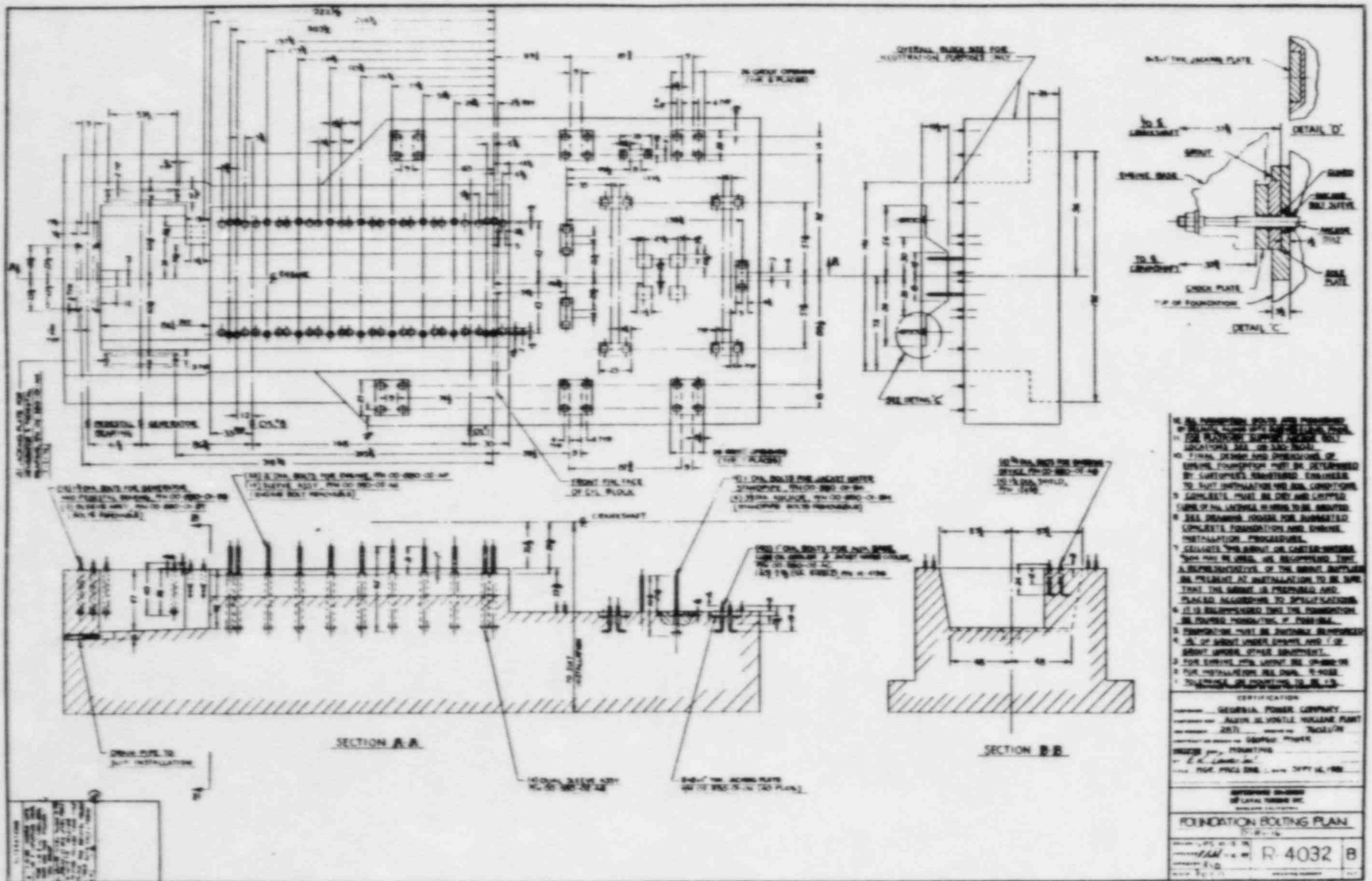
Pneumatic Control Device Symbols

Symbol	Device	Symbol	Device
	Tubing connections Connected Not connected		Pneumatic Flag Indicator
	Pressure Switch		Pneumatic Indicator, Spring Return Type
	Differential Pressure Switch		Pneumatic Indicator, Spring Return Type, With Position Lock
	Manually Operated Two way Valve – normally open unless otherwise indicated		Pressure Regulator with Pressure Gauge
	Manually Operated Three way valve		Filter
	Shuttle Valve		Filter-Regulator with Pressure Gauge
	Pressure Relief Valve		Single Acting Pneumatic Cylinder – Spring Extended, Pressure Retracts Piston
	Pilot Operated Two way Valve – normally closed unless otherwise indicated		Single Acting Pneumatic Cylinder – Spring Retracted, Pressure Extends Piston
	Manometer, "U" type		Pressure Gauge
	Bulkhead Termination		Differential Pressure Gauge
	Capped Test Tee		Duplex Pressure Gauge

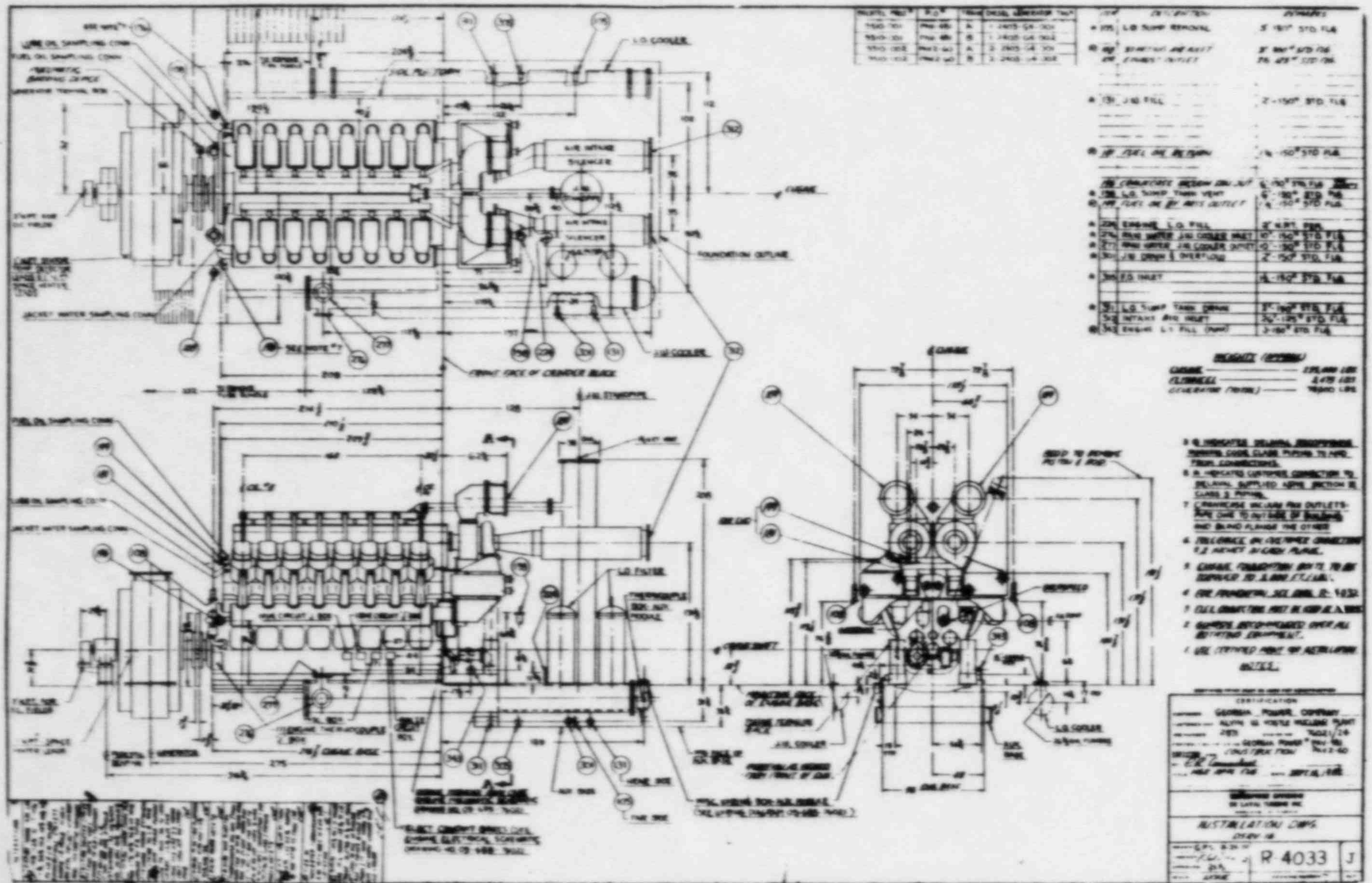
03-81

Pneumatic Logic Element Symbols

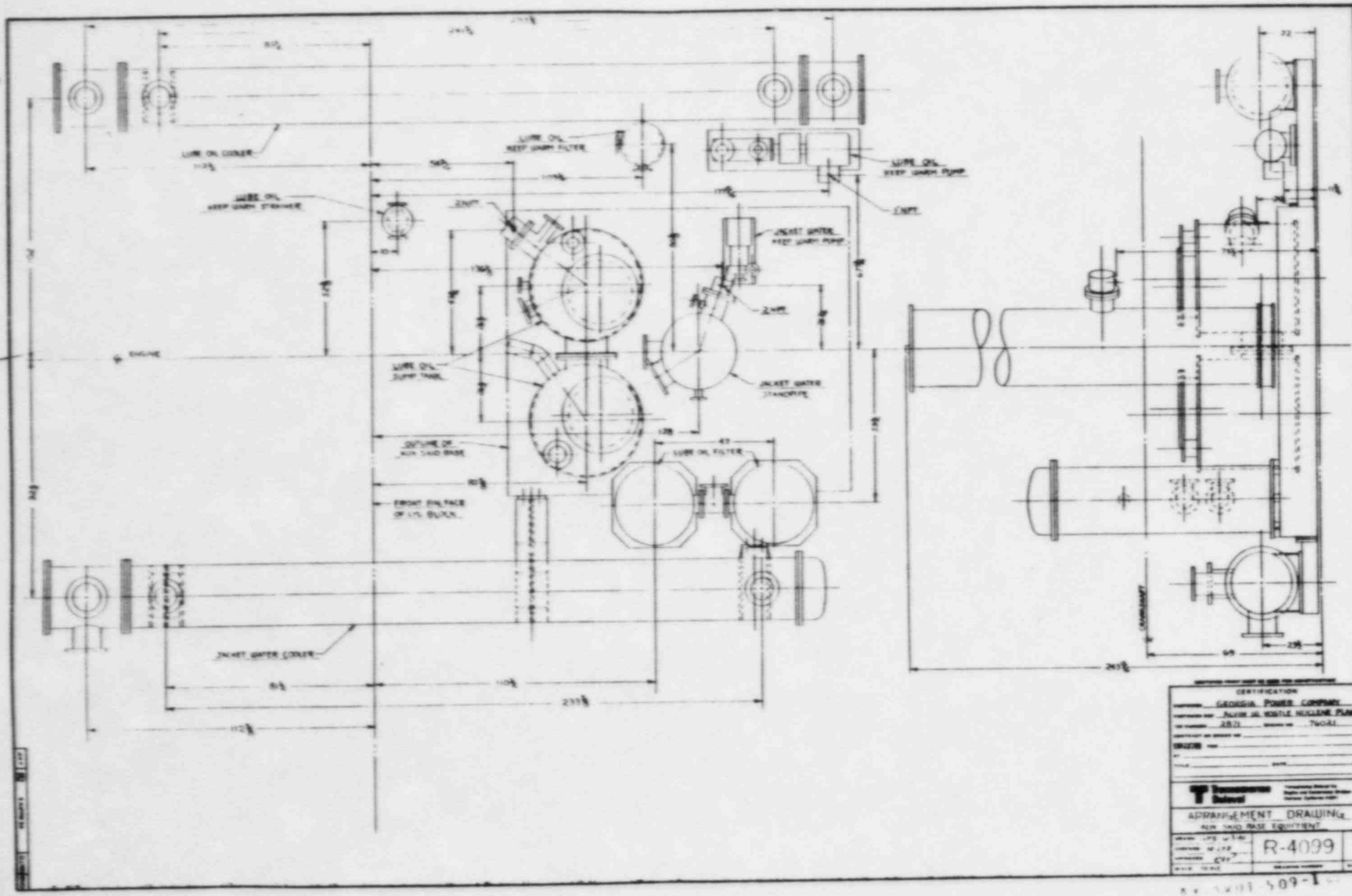
Symbol	Device
	**AND** Pressure flows from port B to port C when there is pressure at A and B. If either A or B is depressurized, C will vent through internal exhaust port. With 60 psi supply at B, element snap acting at 40 psi rising and 20 psi falling (typical).
	**OR** Pressure flows from port A to port C, or from port B to port C when there is pressure at A or B. Without pressure at either A or B, pressure vents back from C to B.
	**NOT** Pressure flows from port B to port C except when there is pressure at port A. With pressure at A, C vents through internal exhaust port. Element snap acting at 40 psi rising and 20 psi falling (typical).
	**NOT With Plugged Exhaust Performs** NOT function as above, but exhaust port is blocked. Pressure flows from B to C except when there is pressure at A. With pressure at A, pressure flow from B to C stops, but C does not vent. Pressure retained downstream of C.
	**TIMER** Provides timing with slow pressure rise, from 0.08 to 7.5 seconds adjustable. With supply pressure at A, slow rising pressure at C, reaching full pressure when delay completed. Without pressure at A, C vents through internal exhaust port.
	**DELAY** With pressure at B only, no pressure flow from B to C. When pressure applied to A, flow permitted from B to C after time delay. Output delay adjustable from 0.08 to 7.5 seconds. Ports A and B sometimes connected to common source for time delay output functions.
	**TIMER/NOT** With pressure at port B only, pressure flows from port B to port C. When pressure is applied to port A, pressure flow from port B to port C is terminated after delay. Output termination time adjustable from 0.08 to 7.5 seconds. Ports A and B sometimes connected to common source for single shot pulse output.
	**DIFFERENTIATOR** With pressure at input port B, there is a single shot output pulse from port C. Pulse output duration is 80 msec.
	**SET/RESET** Pressure flow from port C to port B will set element. Pressure output at port B remains trapped when input at port C is removed. Pressure applied at port A causes pressure at port B to exhaust through port C. Pressure at port C overrides pressure at port A if both pressures present at the same time.
	**ACCUMULATOR** A fixed volume chamber used for timing purposes. Commonly used in conjunction with an orifice, the accumulator is filled by a metered pressure to delay or dampen circuit functions.
	**MEMORY** Pressure flows from B to C if A is pressurized. By pressurizing, then blocking A, B to C flow is maintained because some port C pressure bleeds back to port A to overcome pressure leakage, if any. If port A vents completely, port C vents through internal exhaust port.
	**SET/RESET – MEMORY** Common configuration of Set/Reset and Memory elements combined to convert momentary input signals to maintained outputs. Pressure input at port C of S/R causes pressure flow to port B of S/R, which flows to port A of MEM element. With pressure at port A of MEM element, pressure flows from port B of MEM to port C of MEM. When pressure removed from port C of S/R element, pressure remains trapped between port B of S/R and port A of MEM. Pressure flow from port B of MEM to port C of MEM continues, despite loss of S/R input signal. With no pressure at port C of S/R element, pressure applied at port A of S/R element causes pressure between port B of S/R and port A of MEM to exhaust through port C of S/R. With no pressure at port A of MEM, no pressure flow from port B to port C of MEM.
	**CHECK VALVE** Permits one way pressure flow from port B to common output ports A and C. Prevents pressure backflow from common ports A and C to B.
	**ORIFICE** Provides a restriction between two parts of a circuit. With pressure applied to common ports A and C, pressure is metered through orifice to port B. Orifice size is indicated on drawing.
	**PARALLEL ORIFICE/CHECK** Combines functions of orifice and check valve in parallel. With pressure applied at common input ports A and C, pressure is metered through orifice portion of the element to port B. When pressure is vented upstream of common inputs A and C, pressure at port B exhausts quickly through check valve portion of the element. Orifice size indicated on drawing.
	**SERIES ORIFICE/CHECK** Combines function of orifice and check valve in series. With pressure applied at port B, pressure passed through check valve and is metered through orifice to common output ports A and C. The check valve portion of the element prevents pressure flow from ports A and C to port B. Orifice size indicated on drawing.

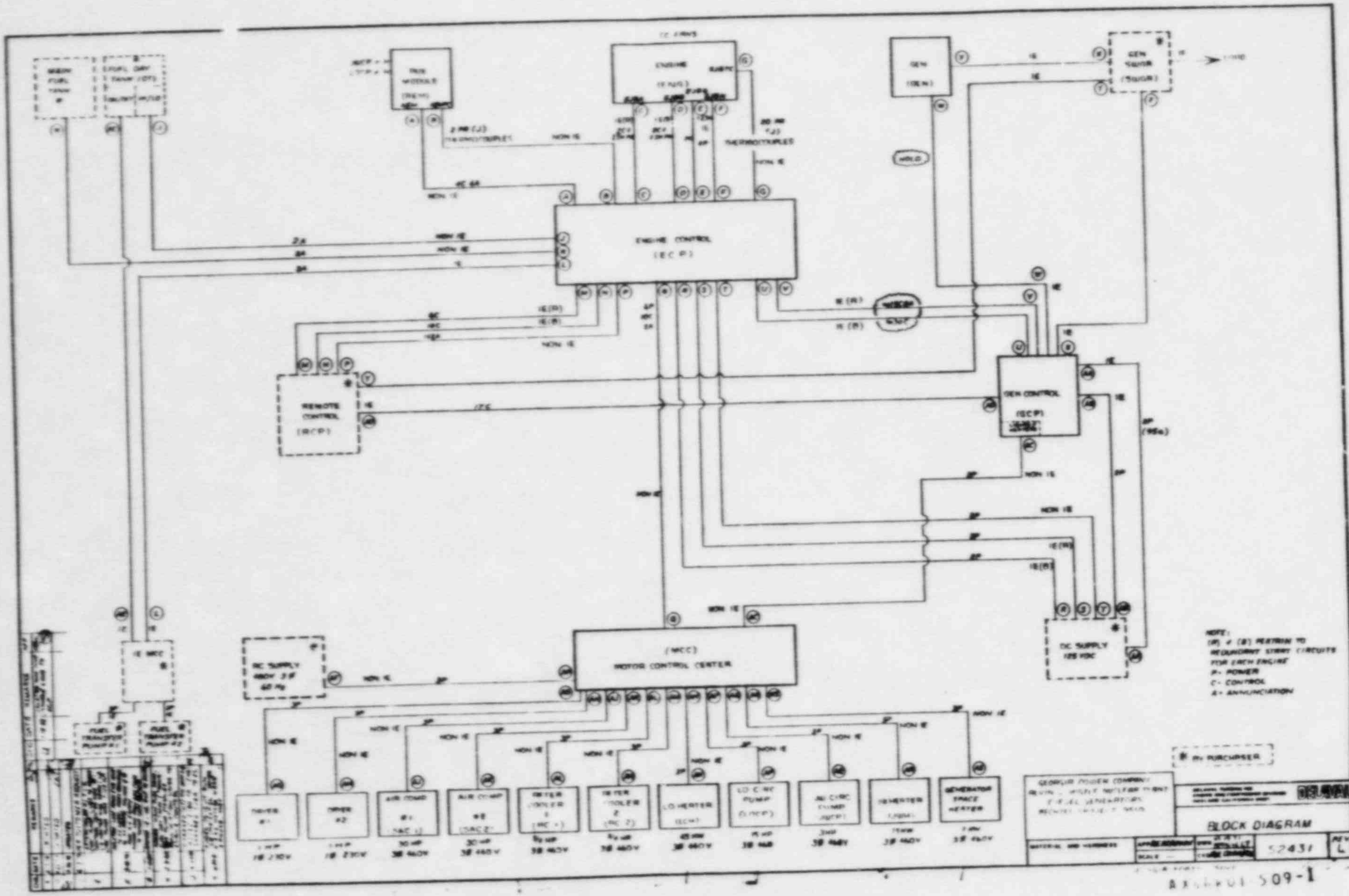


DETAIL 'D'
DETAIL 'C'
SECTION A-A
SECTION B-B
CERTIFICATION
GEORGIA POWER COMPANY
FOUNDATION BOLTING PLAN
R-4032
B


L.O. COOLER
AIR INTAKE SILENCER
FOUNDATION OUTLINE
FRONT FACE OF CYLINDER BLOCK
L.O. FILTER
NOTES:
CERTIFICATION
GEORGIA POWER COMPANY
INSTALLATION DWG.
DSRV-16
R 4033
J

8709??01-509-1

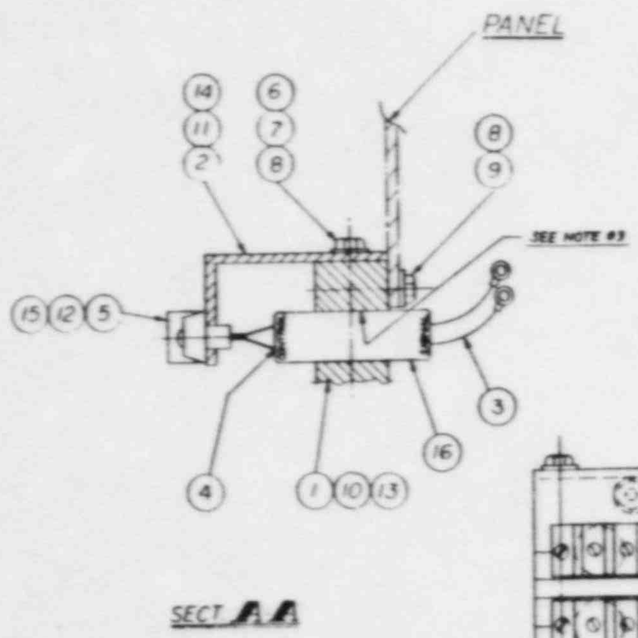

LUBE OIL COOLER
LUBE OIL KEEP WARM FILTER
LUBE OIL KEEP WARM PUMP
LUBE OIL KEEP WARM STRAINER
JACKET WATER KEEP WARM PUMP
JACKET WATER STANDPIPE
LUBE OIL SUMP TANK
OUTLINE OF AUX SKID BASE
FRONT END FACE OF CYL BLOCK
LUBE OIL FILTER
JACKET WATER COOLER
℄ ENGINE
CERTIFICATION
GEORGIA POWER COMPANY
ALVIN W. VOGTLE NUCLEAR PLANT
Transamerica Delaval
ARRANGEMENT DRAWING
AUX SKID BASE EQUIPMENT
R-4099



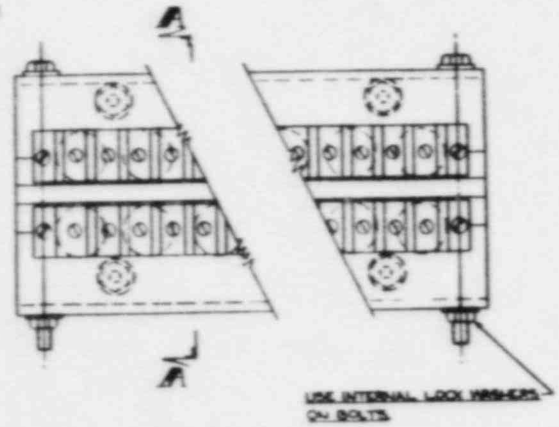
AX66R01-509-1

QTY			PART NAME	PART NO.	MAT'L	REMARKS	ITEM
—	—	1	MOUNTING BLOCK	61 560 01 6E	ALUM		1
—	—	2	TERMINAL MTG	61 560 01 6F	ALUM		2
10	8	12	PHOTOCONDUCTIVE CELL	F 537 002	—		3
10	8	12	NEON LIGHT	F-575-220	—		4
—	—	2	TERMINAL STRIP 12 CKT	F-591 131	—		5
2	2	2	CAPSCREW, HEX HD	GB 086 018	STL	#8-32 x 3½ LG	6
2	2	2	NUT, HEX HD	GB 038 008	STL	#8-32	7
8	8	8	WASHER	GA 001 037	STL		8
4	4	4	CAPSCREW, HEX HD	GB 086 061	STL	1/4-20UNC x 1"LG	9
—	1	—	MOUNTING BLOCK	61 560 01 6W	ALUM		10
—	2	—	TERMINAL MTG	61 560 01 6X	ALUM		11
—	2	—	TERMINAL STRIP 8 CKT	F-591-127	—		12
1	—	—	MOUNTING BLOCK	61 560 01 6Y	ALUM		13
2	—	—	TERMINAL MTG	61 560 01 6Z	ALUM		14
2	—	—	TERMINAL STRIP 10 CKT	F-591-129	—		15
10	8	12	HOUSING, ISOLATOR	52480	ALUM		16

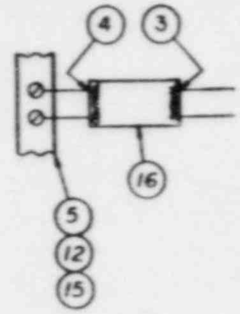
IR 6963
IR 6699
IR 6700



SECT A-A



USE INTERNAL LOCK WASHERS ON BOLTS.



3. USE SILICONE RUBBER SEALANT, F-537-427, TO SECURE ITEMS 3, 4 & 16 AT ASSY.
2. SECTIONS OF ITEM 1, 10 & 13 MATCH MARKED FOR CORRECT ASSY.
1. DO NOT SCALE DRAWING.

OPTICAL ISOLATOR ASSEMBLY

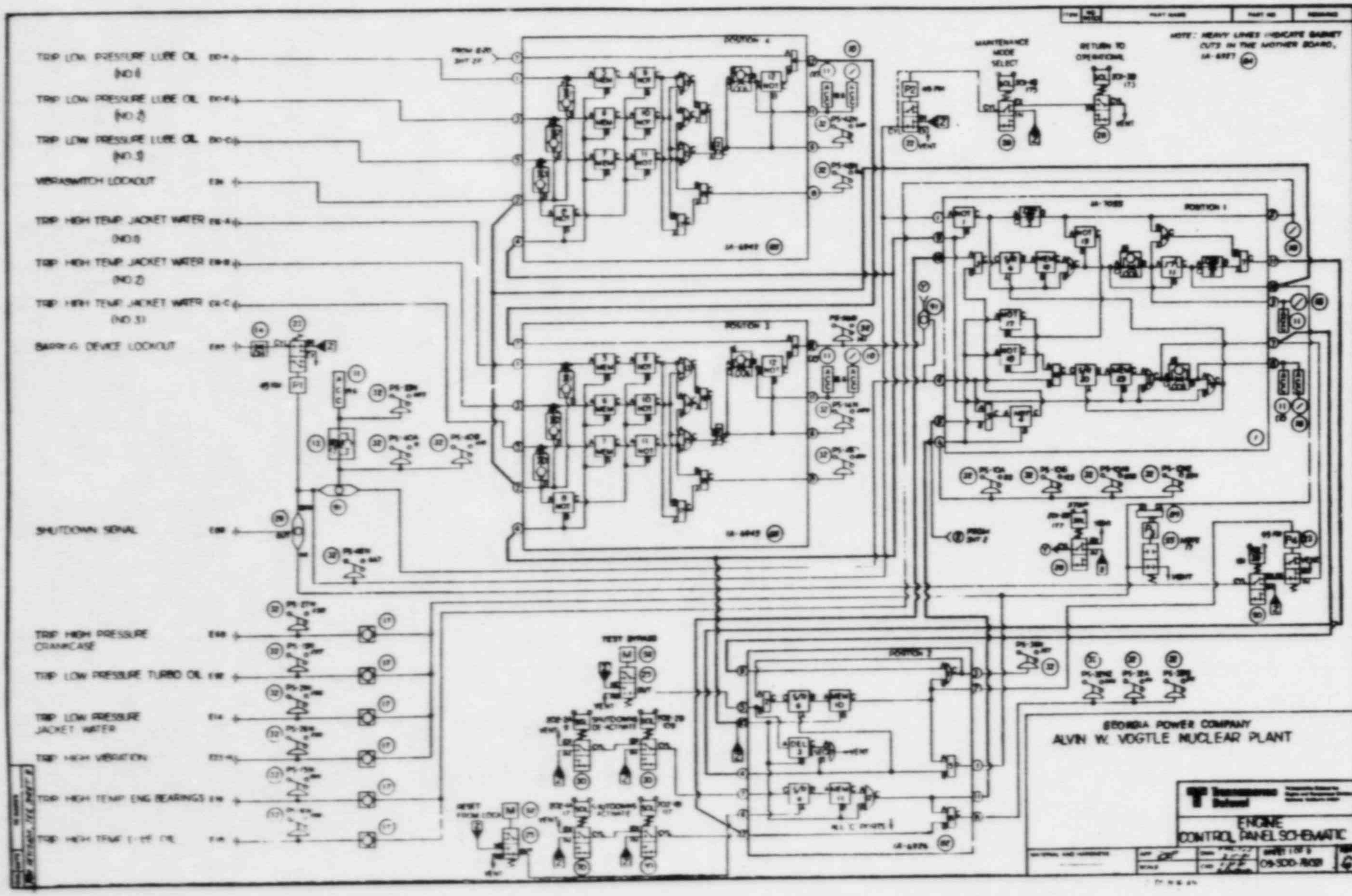
MATERIAL AND HARDNESS: SEE P.N. ABOVE

SCALE: FULL

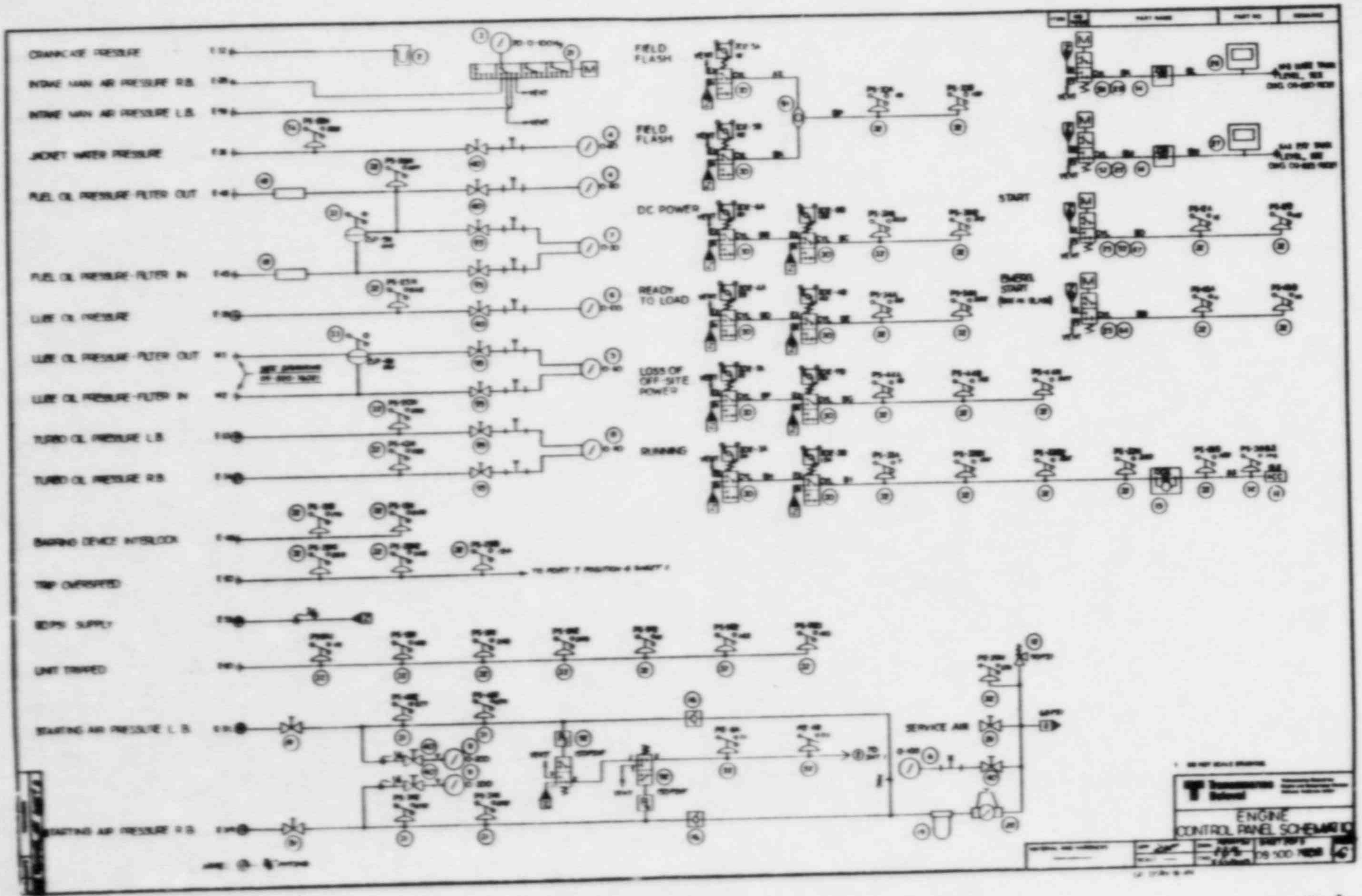
52439

{illegible} 509-1

1

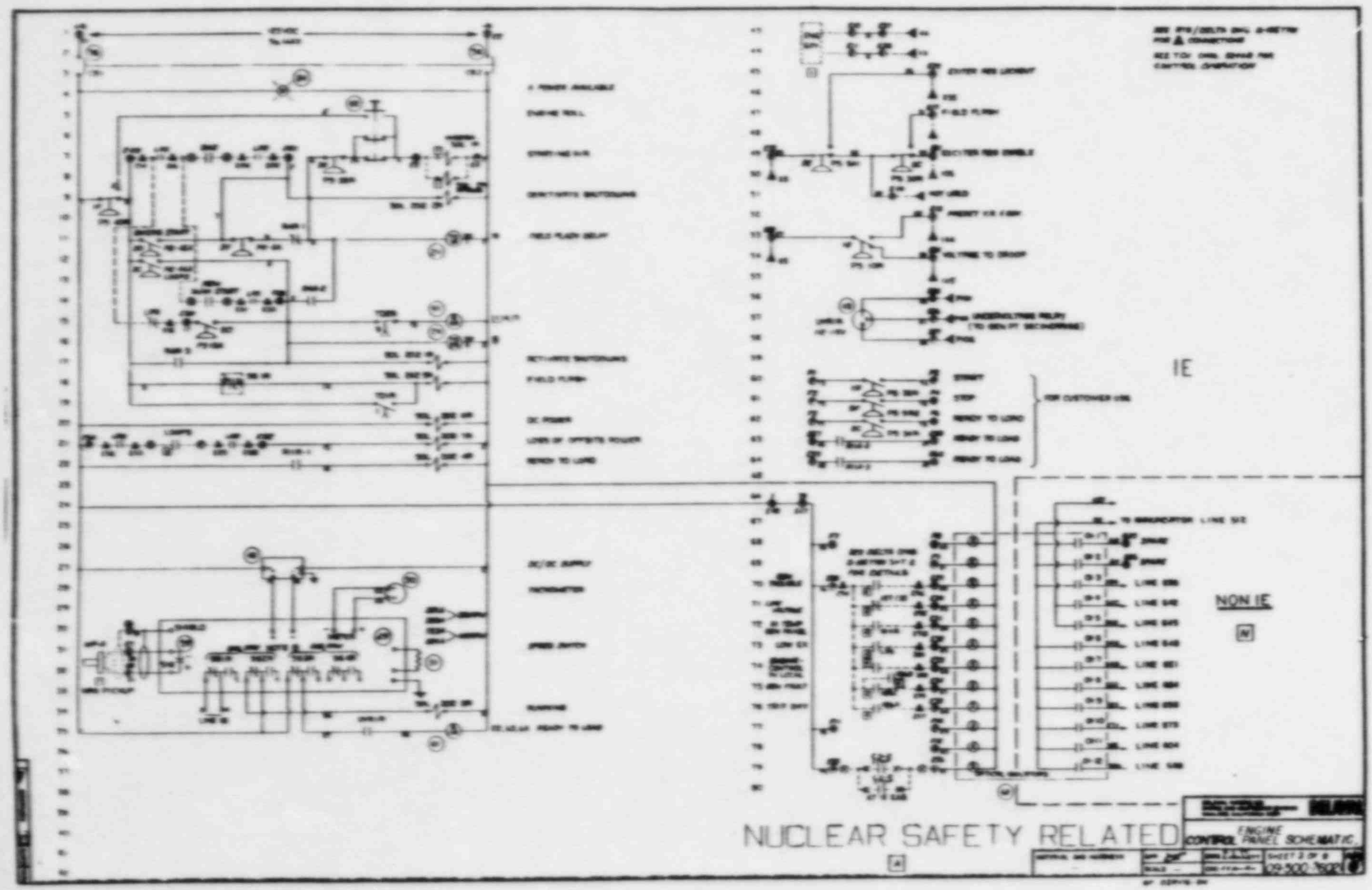


AX4AK01-509-1



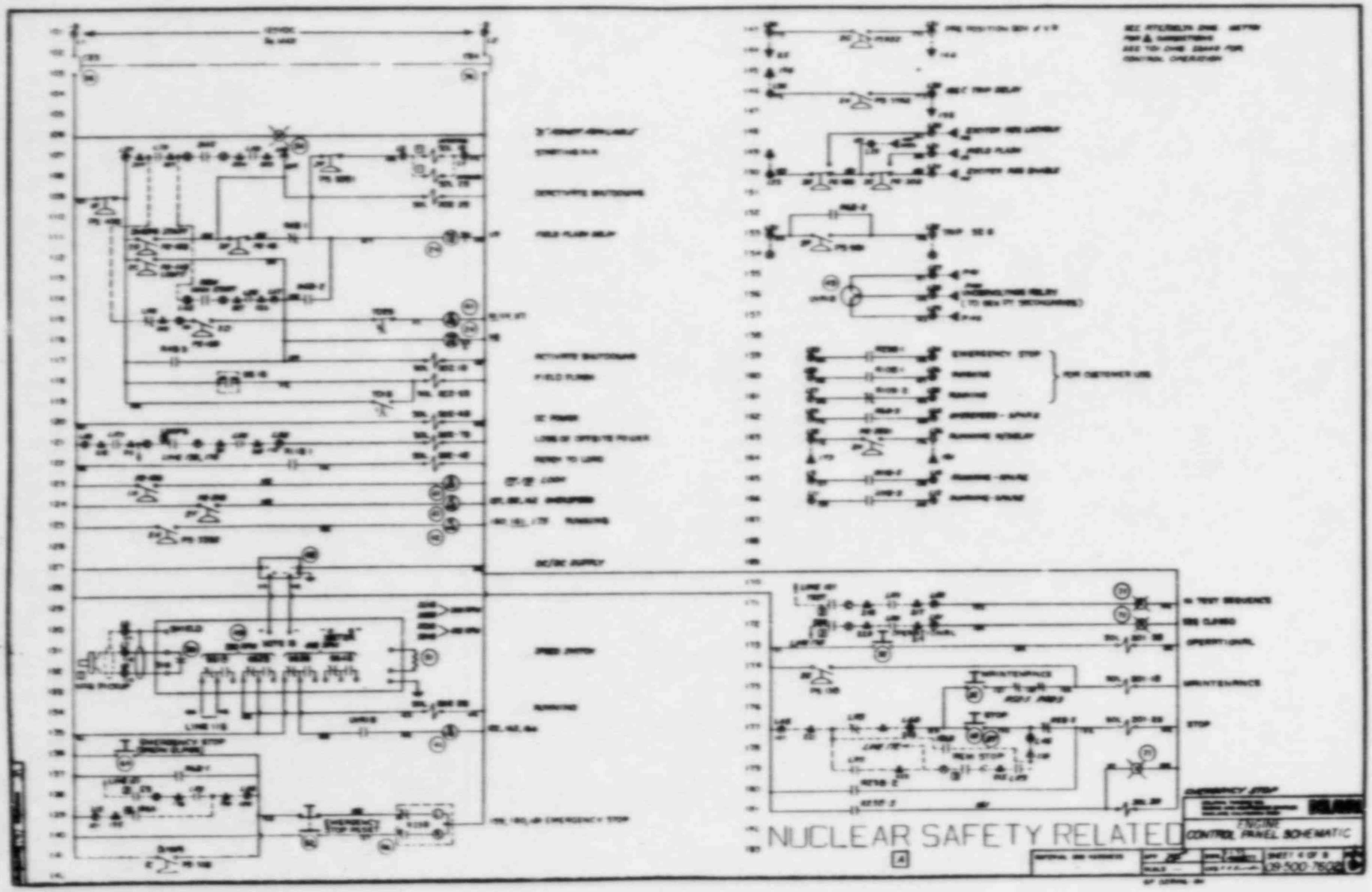
CRANKCASE PRESSURE
INTAKE MAN AIR PRESSURE R.B.
INTAKE MAN AIR PRESSURE L.B.
JACKET WATER PRESSURE
FUEL OIL PRESSURE FILTER OUT
FUEL OIL PRESSURE-FILTER IN
LUBE OIL PRESSURE
LUBE OIL PRESSURE-FILTER OUT
LUBE OIL PRESSURE-FILTER IN
TURBO OIL PRESSURE L.B.
TURBO OIL PRESSURE R.B.
BARRING DEVICE INTERLOCK
TRIP OVERSPEED
UNIT TRIPPED
STARTING AIR PRESSURE L.B.
STARTING AIR PRESSURE R.B.
FIELD FLASH
FIELD FLASH
DC POWER
START
READY TO LOAD
LOSS OF OFF-SITE POWER
RUNNING
SERVICE AIR
ENGINE
CONTROL PANEL SCHEMATIC

ex-Aut-509-1


IE
NON IE
NUCLEAR SAFETY RELATED
ENGINE
CONTROL PANEL SCHEMATIC
09-500-7602

1

...-509-1



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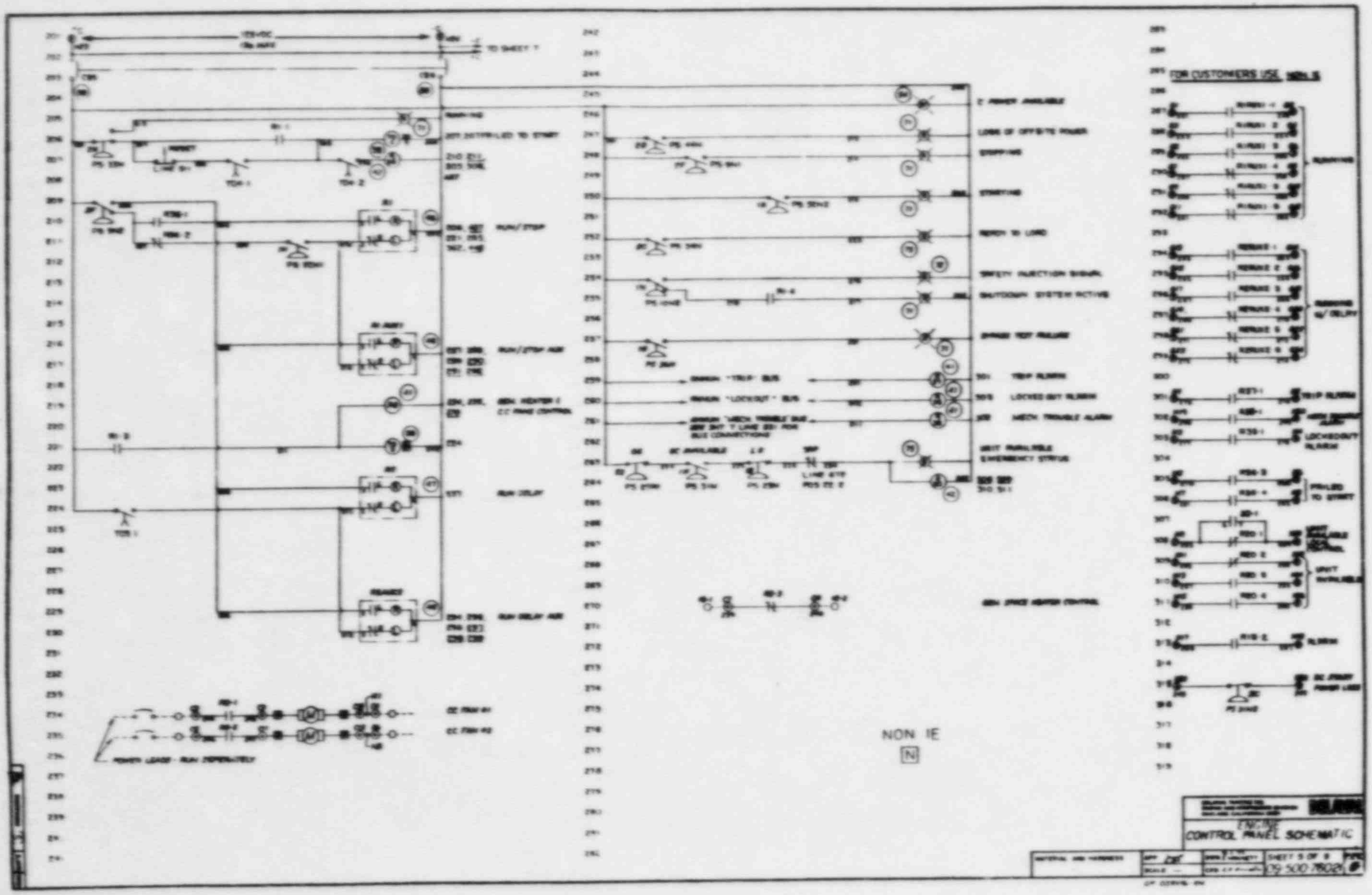
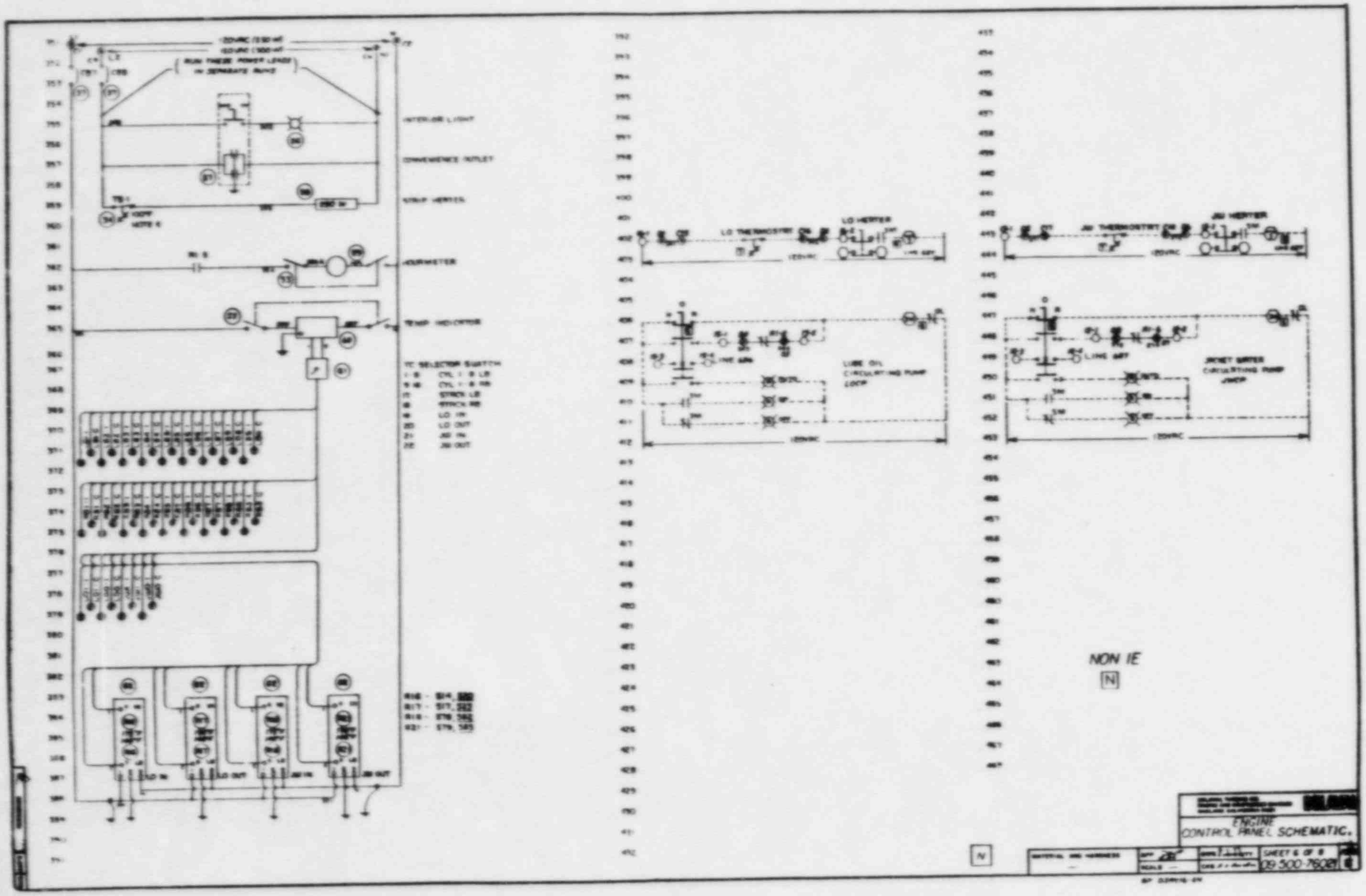
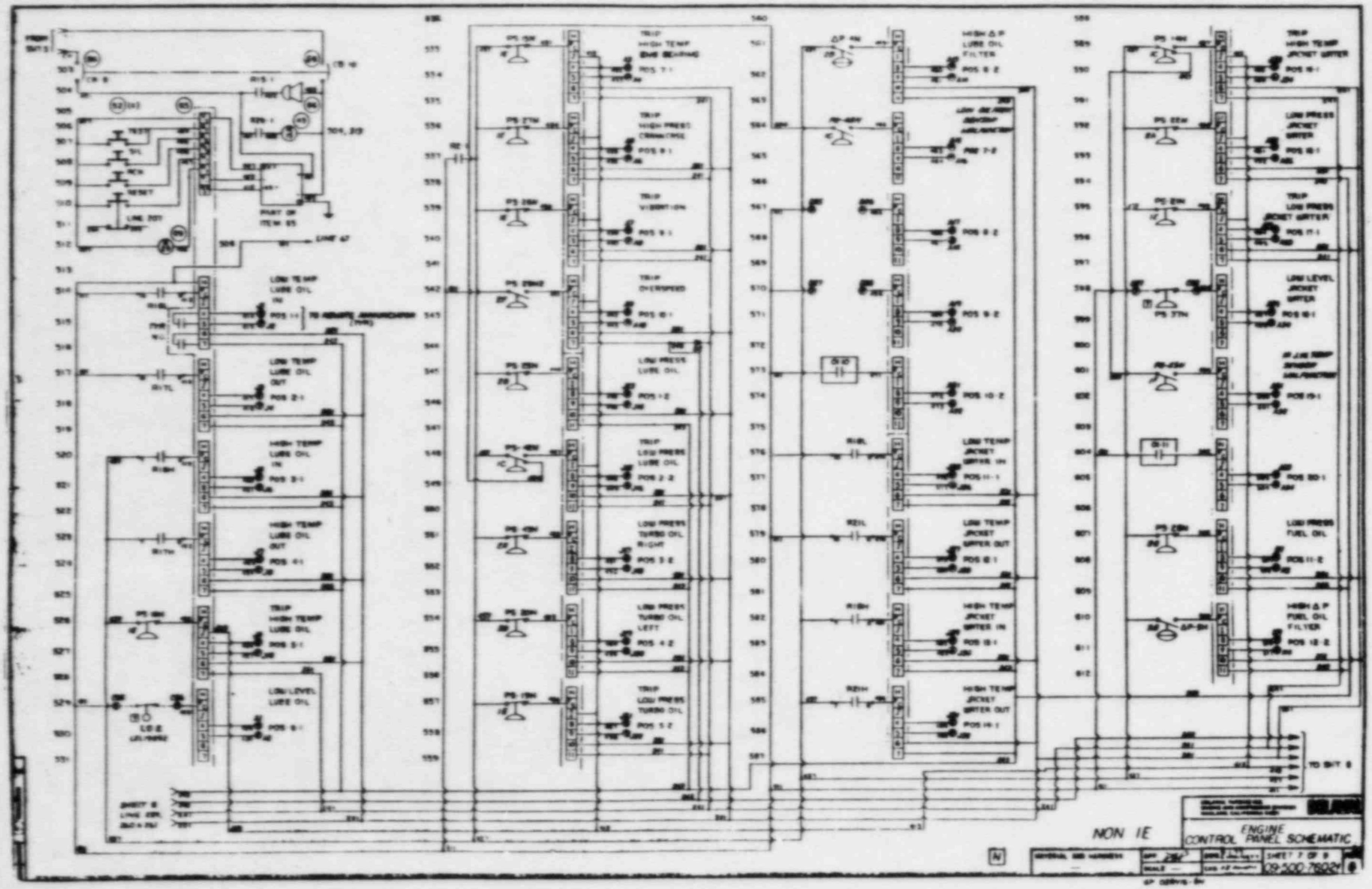


8801?401-509-1

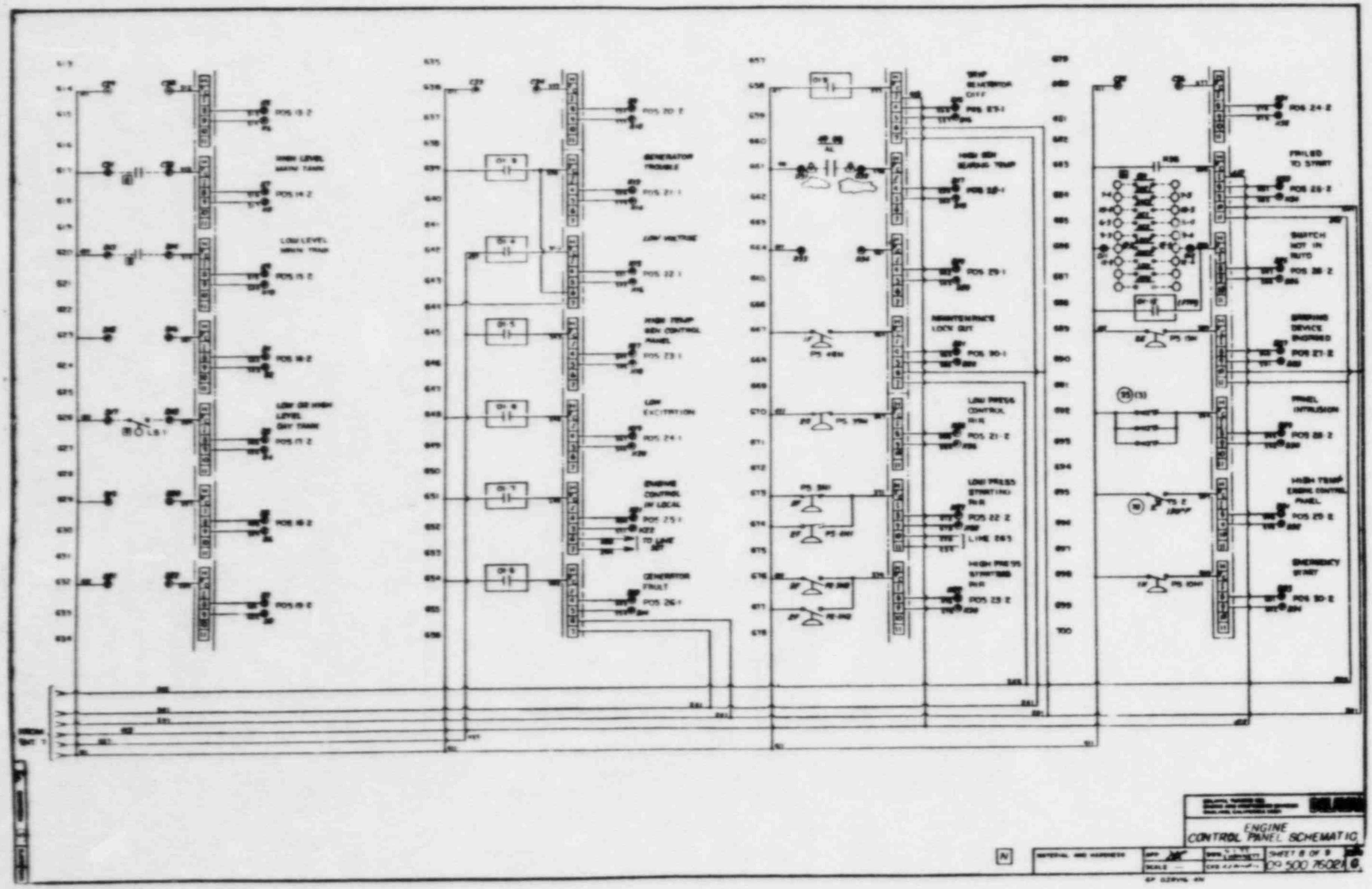


INTERIOR LIGHT
CONVENIENCE OUTLET
STRIP HEATER
HOURMETER
TEMP INDICATOR
LO THERMOSTAT
LO HEATER
JW THERMOSTAT
JW HEATER
LUBE OIL CIRCULATING PUMP LOOP
JACKET WATER CIRCULATING PUMP LOOP
120VAC
NON IE
N
ENGINE CONTROL PANEL SCHEMATIC.
SHEET 6 OF 8
09-500-76028

509-1



ANGRRUT 101-1


HIGH LEVEL MAIN TANK
LOW LEVEL MAIN TANK
LOW OR HIGH LEVEL DAY TANK
GENERATOR TROUBLE
HIGH TEMP GEN CONTROL PANEL
LOW EXCITATION
ENGINE CONTROL IN LOCAL
GENERATOR FAULT
MAINTENANCE LOCK OUT
LOW PRESS CONTROL AIR
LOW PRESS STARTING AIR
HIGH PRESS STARTING AIR
FAILED TO START
SWITCH NOT IN AUTO
BARRING DEVICE ENGAGED
PANEL INTRUSION
HIGH TEMP ENGINE CONTROL PANEL
EMERGENCY START
ENGINE CONTROL PANEL SCHEMATIC
SHEET 8 OF 9

1-509-1

SETTING	FUNCTION
[illegible]	[illegible] STARTING AIR
[illegible]	[illegible] STARTING AIR
[illegible]	[illegible] STARTING AIR
[illegible]	[illegible] STARTING AIR
[illegible] 9	45PSIG UNIT TRIPPED
A,B,HE,HI 10	45PSIG TO DE ACTIVATE
B,H 12	45PSIG MANUAL START
H,B 13	45PSIG BARRING DEVICE LOCKOUT
H 14	45PSIG TRIP HTJW
H 15	45PSIF TRIP HI BRG
H 16	45PSIF TRIP HTLO OUT
Δ P14	20PSIG HOP LO FILTER
Δ P15	20PSIG HOP FO FILTER
H 19	45PSIF TRIP LPTO
H 20	20PSIF LPTO LB
H 21	45PSIF TRIP LPJW
H 22	8PSIF LPJW
H 23	45PSIG LOCKOUT W/DELAY
H 25	45PSIF LPLO
H 26	45PSIF TRIP VIB
H 27	45PSIF TRIP HPCC
H 28	20PSIF LPFO
[illegible] 29	45PSIG TRIP ON
B,A 30	45PSIG FIELD FLASH
[illegible] 31	45PSIG DC AVAILABLE
[illegible] 32	45PSIG STARTING
[illegible] 33	45PSIG SYNCHRONOUS SPEED
H,B,A 34	45PSIG READY TO LOAD
[illegible] 35	45PSIG SPEED & DELAY
H 36	45 PSIG SHUTDOWN
H 39	[illegible]PSIF LPTA
B,H 40	45PSIG LOCKOUT
H 37	37" H2O LOW LEVEL JW [illegible]
H 42	45PSIG TRIP LPLO
H 43	20PSIF LPTO RB
H,B,A 44	45PSIG GEN OFF
B,H 45	45PSIG EXCITE START
H 46	45PSIG MAINTENANCE
H 48	45PSIG LOP MALFUNCTION
H 49	45PSIG AUXT MALFUNCTION
B 50	45 PSIF EMERG STOP

1. PNEUMATIC CONTROL MEDIUM IS AIR
2. [illegible] INDICATES [illegible] CONTROL AIR
3. [illegible] SHOWN [illegible] DE PRESSURIZED & DE ENERGIZED
4. SET, TEST & TAG ALL SAFETY SENSORS BEFORE INSTALLATION
5. PSIF INDICATES ACTUATION AT SETTING ON A FALLING PRESS. PSIR INDICATES ACTUATION AT SETTING ON A RISING PRESS.
6. SEE D [illegible] FOR VALVE SYMBOLS
7. [illegible] DENOTES SUPPLY/LOW BULKHEAD TUBE TERMINATION NEAR BOTTOM OF CABINET. IDENTIFY TERMINALS.
8. TUBING IS 1/4" OD COPPER EXCEPT AS NOTED. FITTINGS ARE BRASS.
9. 1/4 OD TUBING IS RECOMMENDED FOR CONNECTION TO PANEL, EXCEPT WHERE TERMINATION ON THIS DWG IS SHOWN 3/8.
10. FOR 3/8 EXTERNAL CONNECTIONS SEE DWG [illegible]
11. IDENTIFY BOTH ENDS OF WIRES.
12. WIRING TO BE #14 GA STRANDED [illegible] INSULATED COPPER
13. CONTACTS TRANSFER WHEN ENERGIZED.
14. MOUNT HIGH IN CABINET, CENTRALIZED.
15.
16. RELAY [illegible] TRANSFER WITH A START OR AT A STOP. RELAY [illegible] TRANSFERS [illegible] SEC AFTER A START OR AT A STOP.
17. SET PS IN FIELD TO TRIP WHEN [illegible]
18. [illegible] 27 TO USE YELLOW TRACED WIRE. [illegible] 24 TO USE BLUE TRACED WIRE.

CLASS 1E

ITEM	DESCRIPTION	PART NO	QTY	MFR
1	SHUTDOWN LOGIC BD	[illegible]-7095	1	CILLAVAL
2	MANOMETER	F 562 001	1	MERIAM
3	PRESS GAUGE 20-0 INCH Hg	F 530 619	1	ROYLYN
4	PRESS GAUGE 0-80	F 530 [illegible]	2	ASHCROFT
5	PRESS GAUGE 0-80 DIFF	F 530 [illegible]	1	ASHCROFT
6	PRESS GAUGE 0-100	F 530 [illegible]	2	ASHCROFT
7	PRESS GAUGE 0-30 DIFF	F 530 [illegible]	1	ASHCROFT
8	PRESS GAUGE 0-60 DUPLEX	F 530 [illegible]	1	ASHCROFT
9	PRESS GAUGE 0-300	F 530 [illegible]	2	ASHCROFT
10	PRESS GAUGE 0-100	F 530 530	3	MOORE
11	ACCUMULATOR 19.6 CU IN	F 573 326	1	[illegible]
12	RELIEF VALVE	F 573 390	1	NUPRO
13	PARALLEL ORIFICE CHECK .020	F 573 141	1	CALCON
14	ORIFICE .014	F 573 133	3	CALCON
15	PARALLEL ORIFICE CHECK .006	F 573 144	1	CALCON
16	CHECK VALVE	F 573 375	2	[illegible]
17	CHECK VALVE	F 573 127	6	NUPRO
18	SNUBBER	F 535 375	2	ASHCROFT
19	FILTER	F 527 002	1	NORGREN
20	REGULATOR	F 579 081	1	BELLOFRAM
21	TEST VALVE	F 573 298	1	WHITEY
22	3 WAY VALVE	F 573 387	1	HUMPHREY
23	3 WAY VALVE NO	F 573 132	2	HUMPHREY
24 #	TIME DELAY DC 50	F 590 112	4	SYRACUSE
25	3 WAY VALVE NC MANUAL	F 573 090	4	[illegible]
26	LEVEL GAUGE LO	F 530 [illegible]	1	MERCOID
27	LEVEL GAUGE DRY	F 530 [illegible]	1	MERCOID
28 #	SOL VALVE ASSY	[illegible]-201	1	HUMPHREY
29	SHUTTLE VALVE	F 573 126	1	HUMPHREY
30 #	SOL VALVE ASSY	[illegible]-202	2	HUMPHREY
31 #	PRESS SW	F 577 045	4	BARKSDALE
32 #	PRESS SW	F 577 048	[illegible]	BARKSDALE
33	PRESS SW DIFF	F 577 053	2	BARKSDALE
34	TEMP SW	F 595 012	1	FENWAL
35	MICRO SW	F 125 004	3	MICRO
36 #	CIRCUIT BREAKER DC [illegible]AMP	F 511 [illegible]	4	HEINEMANN
37	CIRCUIT BREAKER AC [illegible]AMP	F 511 001	2	HEINEMANN
38	TIME DELAY DL 50	F 590 116	1	SYRACUSE
39 #	CAPACITOR	F 514 006	2	SPRAGUE
40	SHUTOFF VALVE - 1/4	F 573 [illegible]	6	WHITEY

ITEM	DESCRIPTION	PART NO.	QTY	MFR
41 #	RELAY DC 4 POLE	F 580 078	[illegible]	PB
42 #	RELAY DC 6 POLE	F 580 080	2	PB
43 #	RELAY UNDERVOLTAGE	F 580 228	2	[illegible]
44				
45	RELAY DC 2 POLE	F 580 078	1	PB
46 #	RELAY DC 6 POLE L/R	F 580 [illegible]	4	PB
47 #	RELAY DC 2 POLE L/R	F 580 080	1	PB
48 #	POWER SUPPLY	F 596 010	2	[illegible]
49 #	TACH RELAY	F 594 048	2	AIRPAX
50 #	TACHOMETER	F 594 049	1	G.E.
51 #	RESISTOR 50 OHM	F 583 019	2	OHMITE
52 #	PUSHBUTTON BLACK	F 576 [illegible]	[illegible]	FURNAS
53	TOGGLE SW 2 POS	F 585 100	2	C H
54 #	LIGHT, WHITE	F 576 174	2	FURNAS
55	PRESSURE SENSOR	F 573 [illegible]	1	CALCON
56	INTERIOR LIGHT	F 555 033	1	CROUSE-HINDS
57	CONVENIENCE OUTLET & SWITCH	F 561 051	1	HUBBELL
58	STRIP HEATER	F 635 409	1	G.E.
59	HOURMETER	F 561 014	1	WESTINGHOUSE
60	TEMP INDICATOR	F 518 041	1	DORIC
61	TC SELECTOR SW	F 585 119	1	LEWIS
62	TC SETPOINT RELAY DUAL	F 540 [illegible]	4	ACTION PAK
63 #	OPTICAL ISOLATOR	[illegible]-5263	1	DELAVAL
64 #	BREAKGLASS PUSHBUTTON	F 576 084	2	SQUARE D
65	ANNUNCIATOR	[illegible]-200	1	[illegible]
66	HORN	F 596 015	1	FEDERAL
67				
68 #	PUSHBUTTON RED	F 576-[illegible]	1	FURNAS
69	RELAY 2 POLE 24VDC	F 580 021	1	PB
70	TEMPERATURE SWITCH	F-[illegible]	1	FENWAL
71 #	LIGHT, RED	F-576-[illegible]	9	FURNAS
72	LIGHT, GREEN	F-576-176	1	↓
73	LIGHT, BLUE	F-576-173	9	↓
74	PRESS SW	F-577-[illegible]	1	BARKSDALE
75				
76				
77	TERMINALS, 12 TERMINAL	F-[illegible]	[illegible]	[illegible]
78	TERMINALS, [illegible] TERMINAL	F-[illegible]	[illegible]	[illegible]
79	TERMINALS, 6 TERMINAL	F-[illegible]	1	[illegible]
80	TERMINALS, 12 TERMINAL	F-[illegible]	6	[illegible]
81	SHUTOFF VALVE - 3/8	F-573-[illegible]	3	WHITEY
82	TEST-LOCKOUT BOARD	[illegible]	1	DELAVAL
83				
84	PNEUMATIC [illegible] BOARD	[illegible]	1	DELAVAL
85	[illegible] BOARD	[illegible]	2	DELAVAL
86	CIRCUIT BREAKER DC [illegible]AMP	F-511-[illegible]	2	HEINEMANN
87	PUSHBUTTON BOARD	F-576-[illegible]	3	FURNAS
88	CIRCUIT BREAKER DC 15AMP	F-511-[illegible]	2	HEINEMANN
89	OR LOGIC ELEMENT	F-573-[illegible]	1	[illegible]
90	[illegible] VALVE 3-WAY [illegible]	F-[illegible]	1	HUMPHREY
91	SHUTTLE VALVE	F-573-131	3	HUMPHREY
92	PRESSURE SENSOR	F-573-[illegible]	2	CALCON
93	SHUT OFF VALVE	F-573 [illegible]	6	WHITEY

☐ INDICATES LOCATION
+ PROVIDED BY OWNER

1. ON ENGINE (ENG)
2. ON GENERATOR (GEN)
+3. IN REMOTE CONTROL PANEL (RCP)
4. IN GENERATOR CONTROL PANEL (GCP)
5. IN SWITCHGEAR (SWGR)
+6. IN MCC (MCC)
7. ON AUX EQUIPMENT MODULE (AEM)
+8. ON AUX EQUIP BY OTHERS (AUX)
9. ON STARTING AIR COMPRESSOR

TERMINAL IDENTIFICATION:

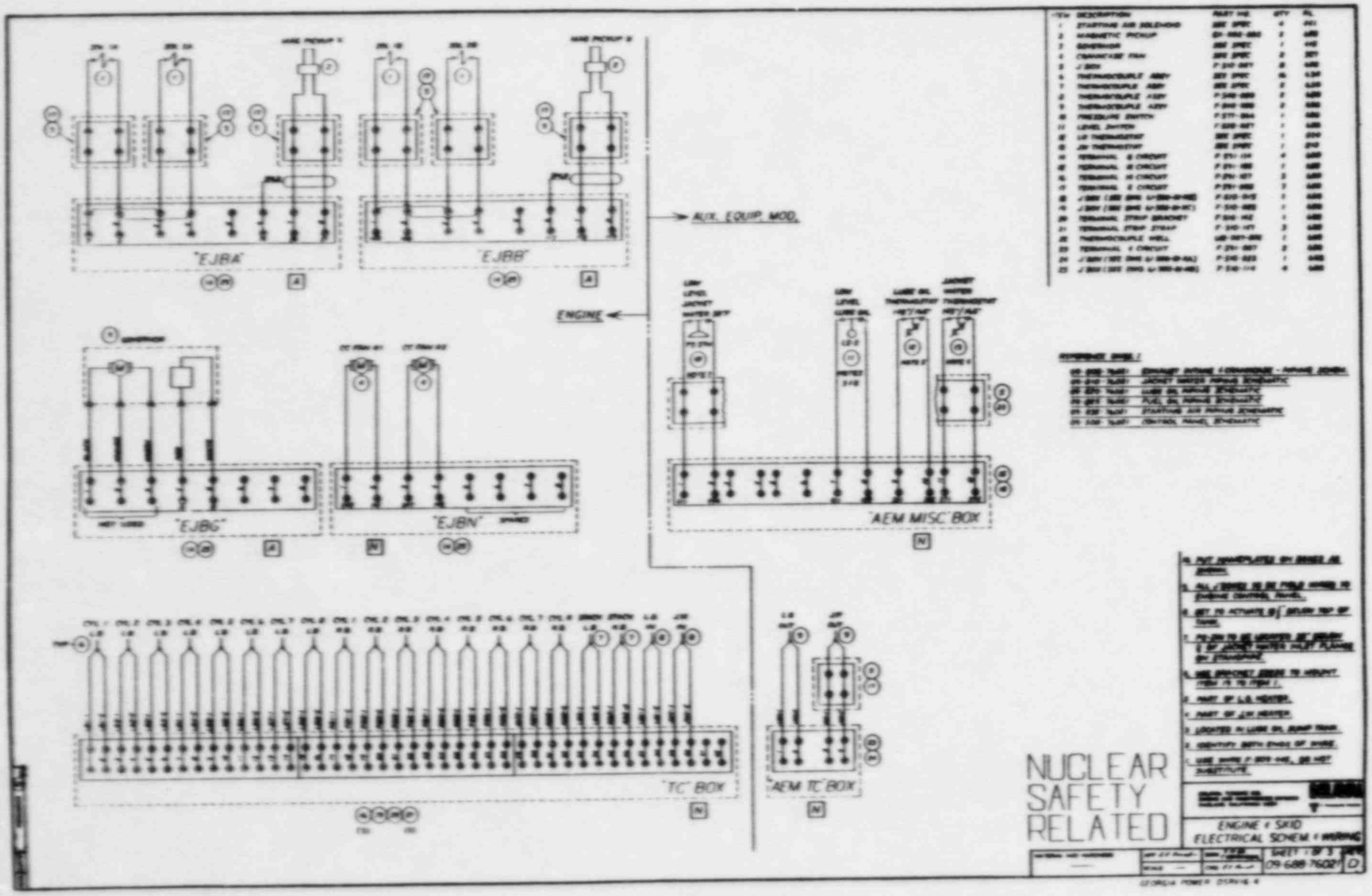
●	ENGINE CONTROL PANEL	ECP
▲	GENERATOR CONTROL PANEL	GCP
○	MOTOR CONTROL CENTER	MCC
●	REMOTE CONTROL PANEL	RCP
■	ENGINE OR AUX MODULE	ENG/AUX

[illegible]

ENGINE
CONTROL PANEL SCHEMATIC

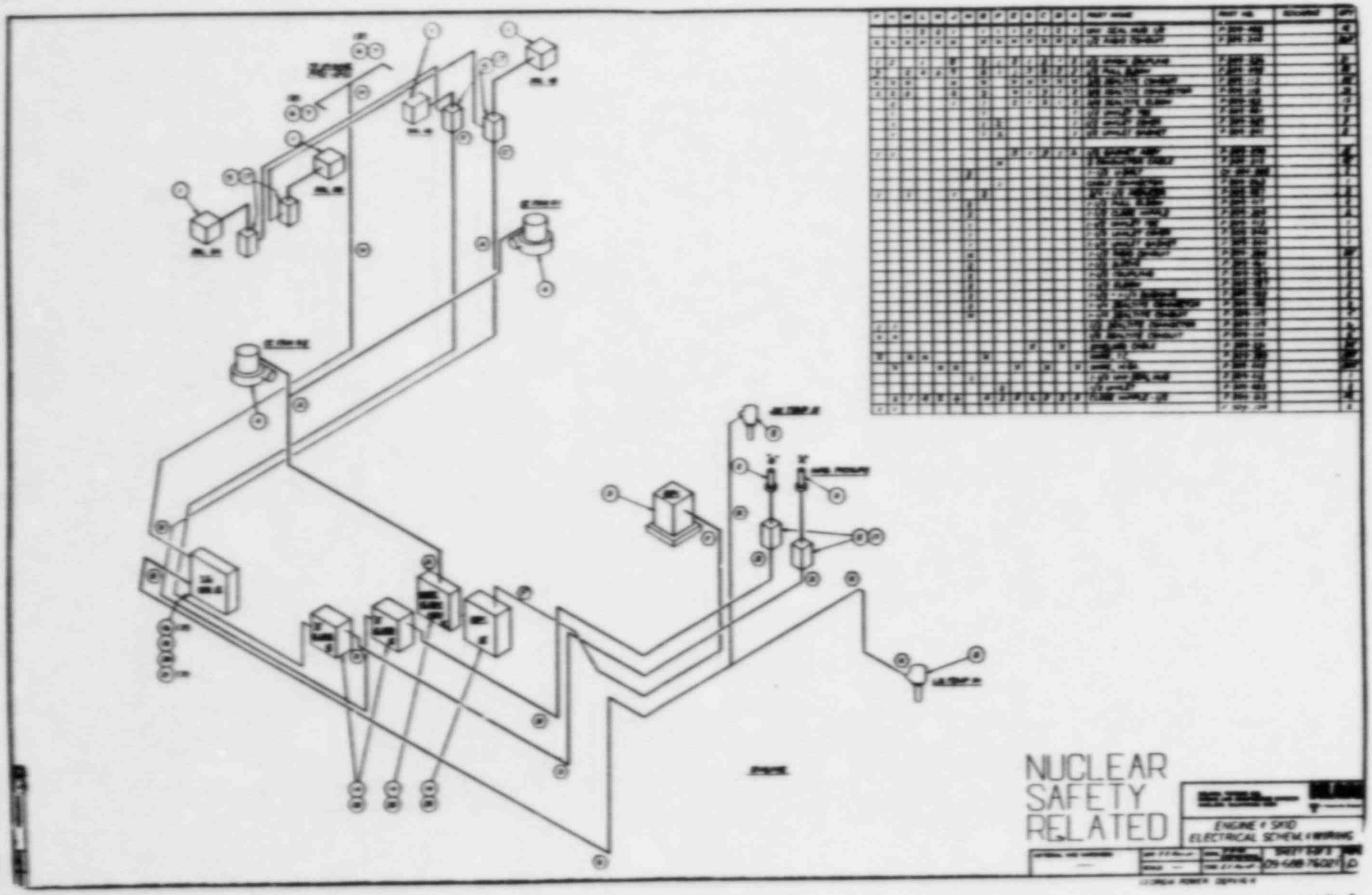
MATERIAL AND HARDNESS —
SCALE —
SHEET [illegible] OF [illegible]
09 500 75021 6

[illegible] 509-1

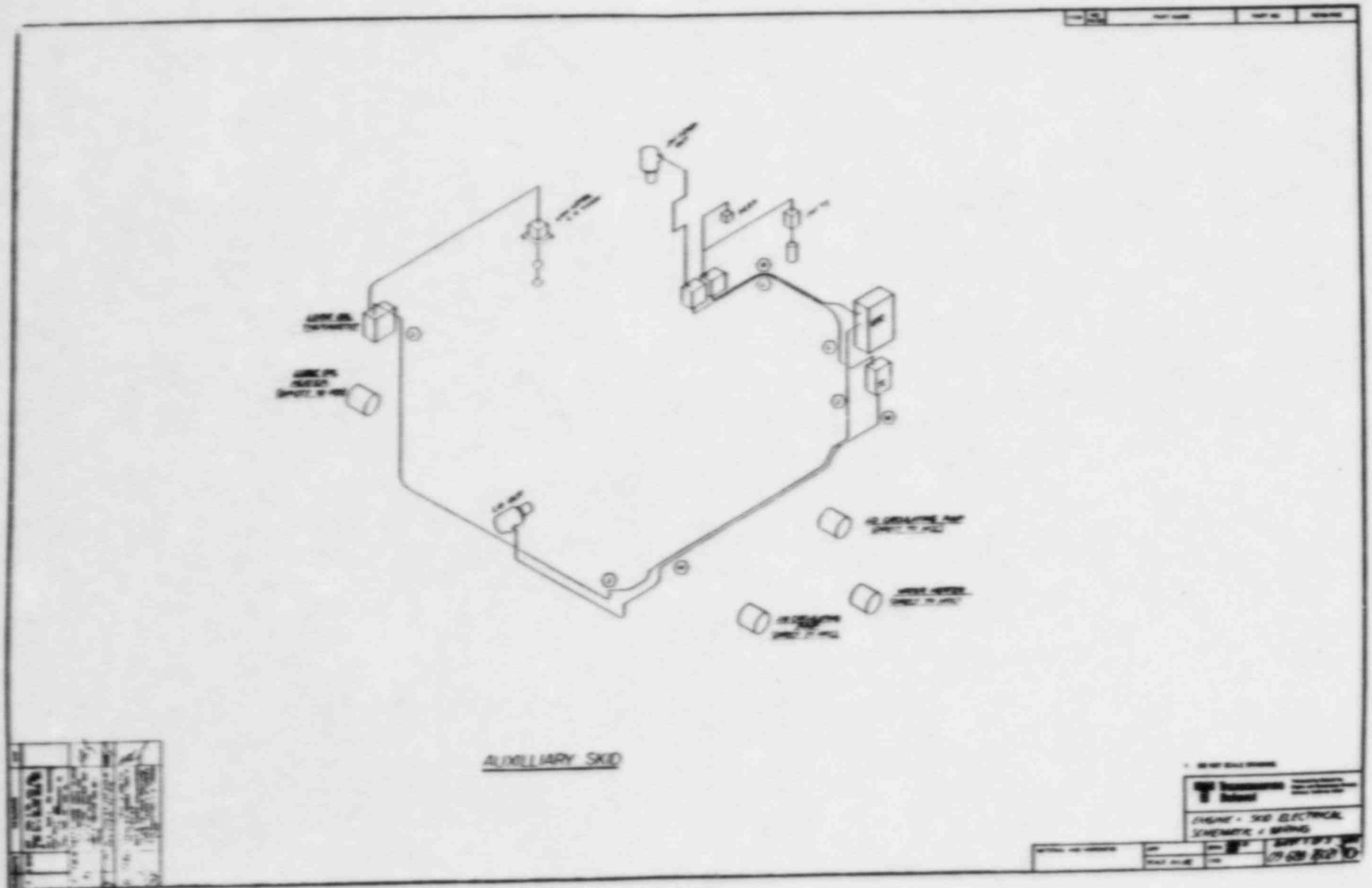


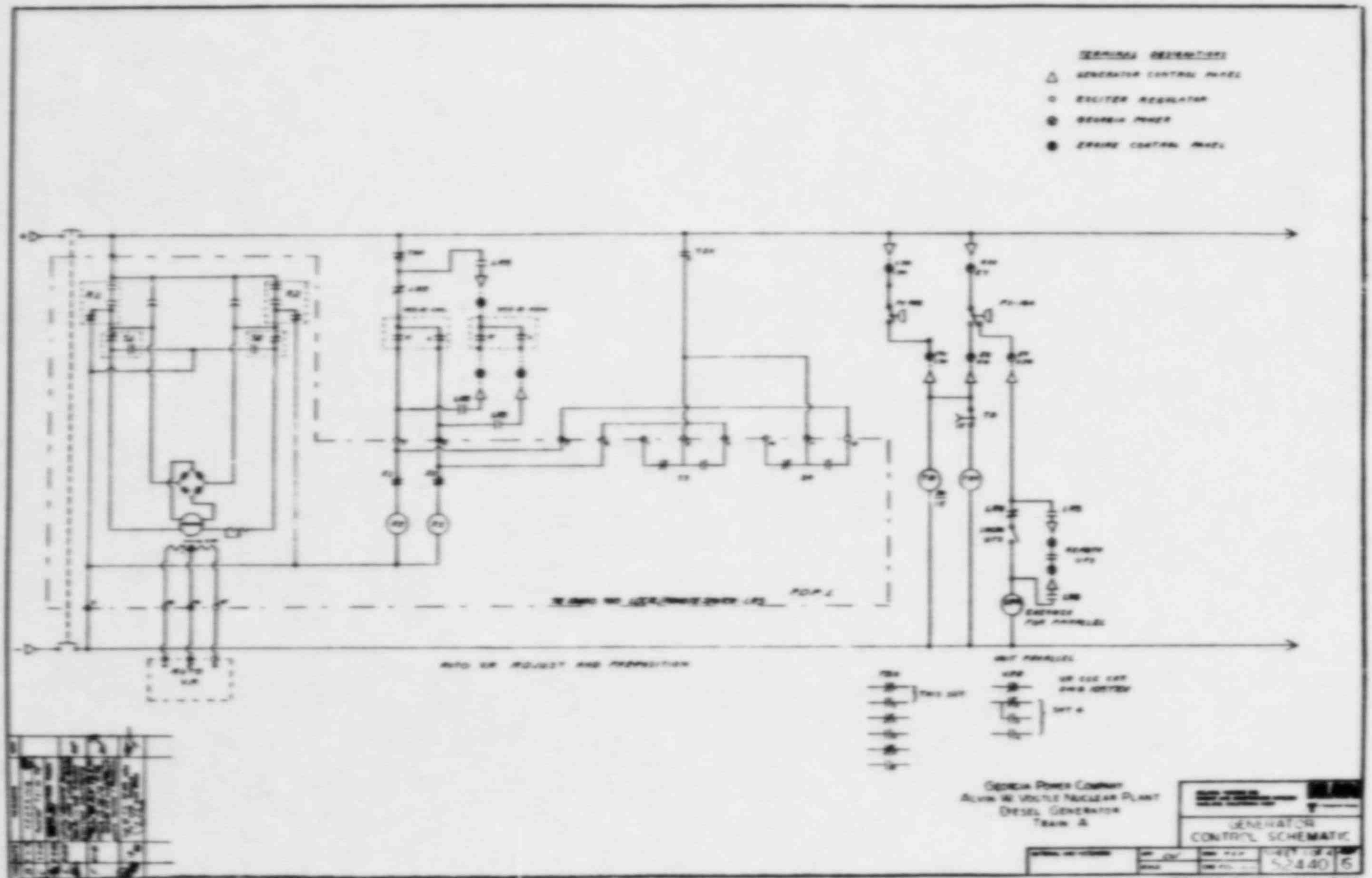
"EJBA"
"EJBB"
AUX. EQUIP. MOD.
ENGINE
"EJBG"
"EJBN"
"AEM MISC" BOX
"TC" BOX
"AEM TC" BOX
NUCLEAR
SAFETY
RELATED
ENGINE & SKID
ELECTRICAL SCHEM & WIRING
09-688-76021
D
GEORGIA POWER DSRV16-4

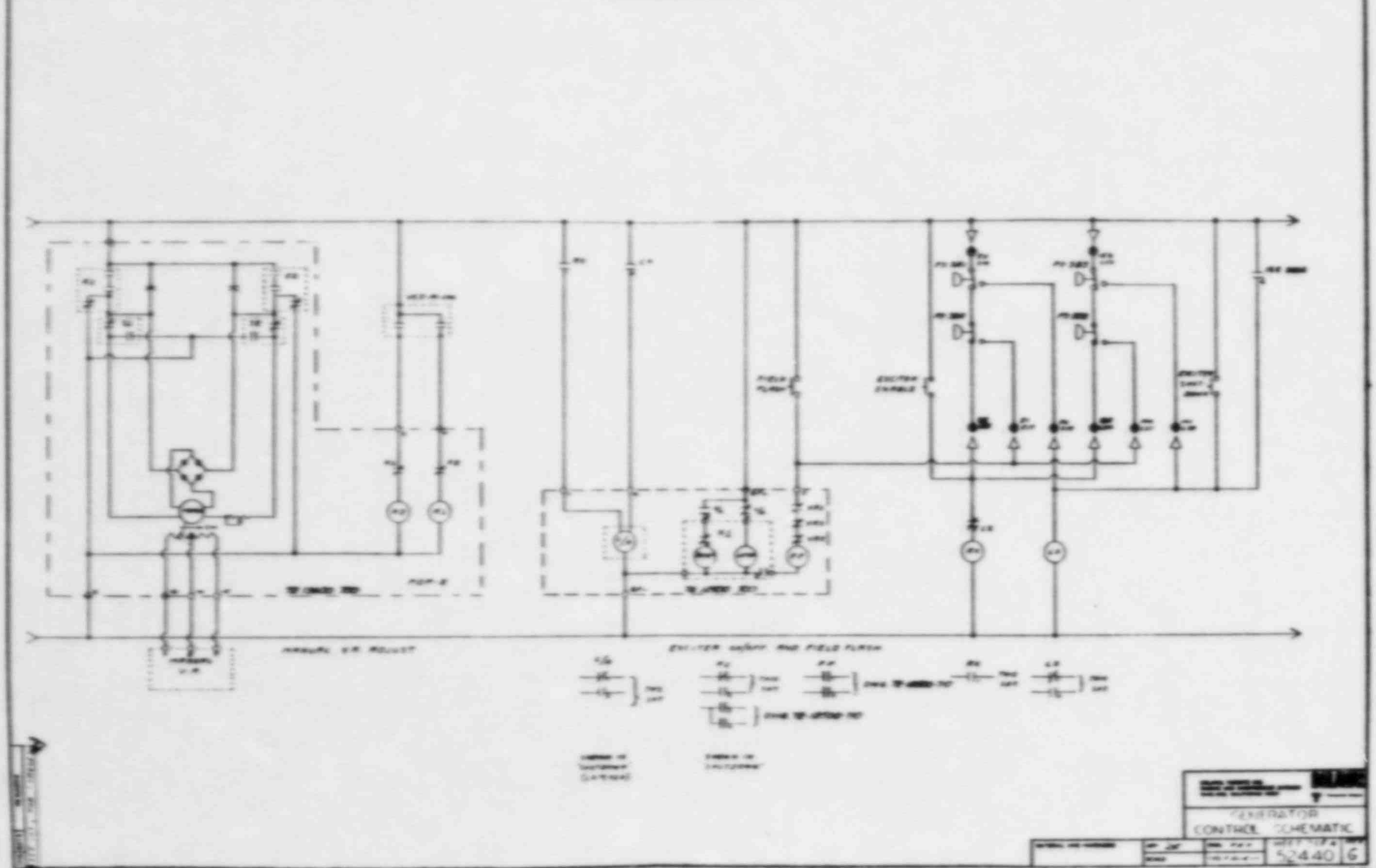
-1-509-1

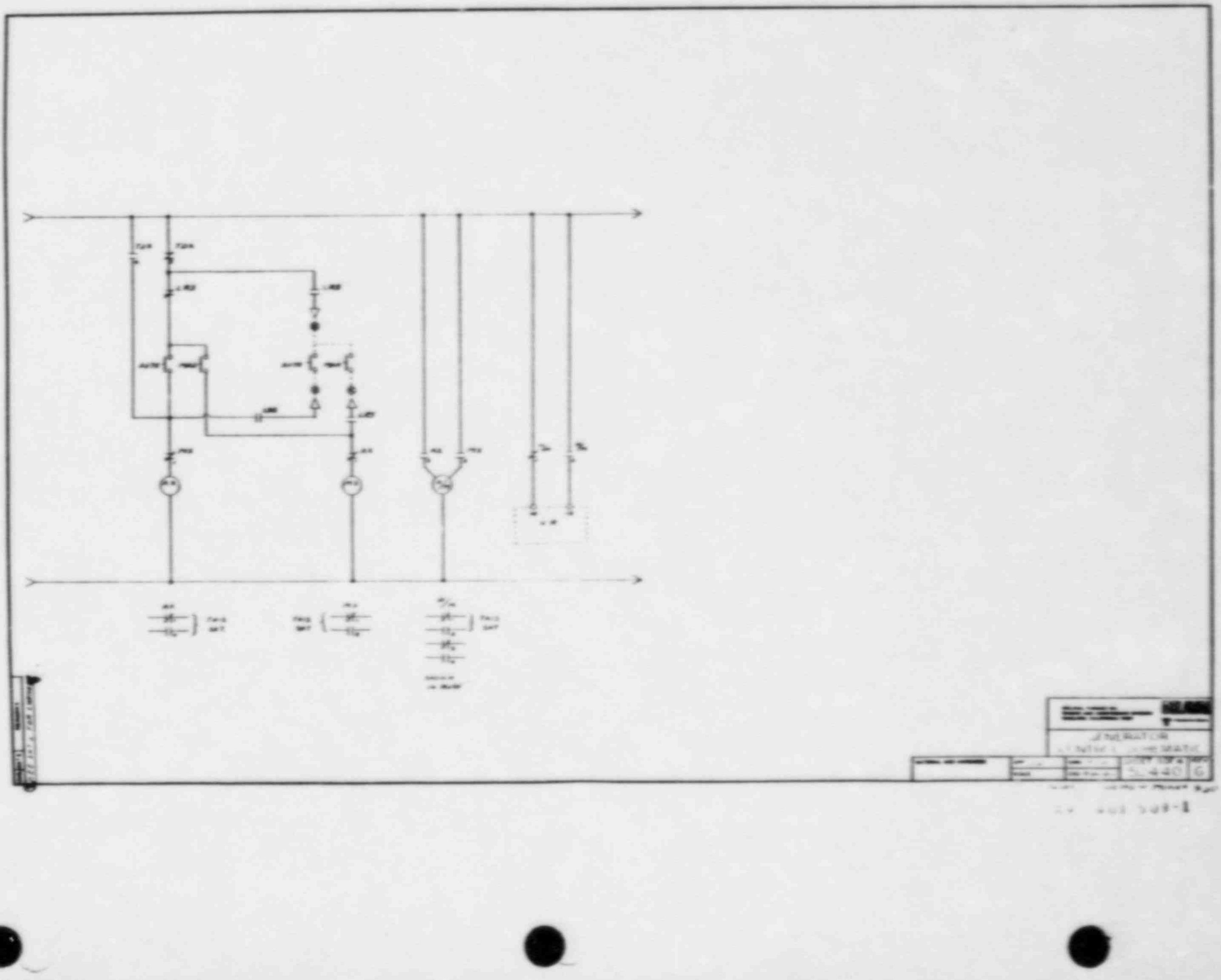


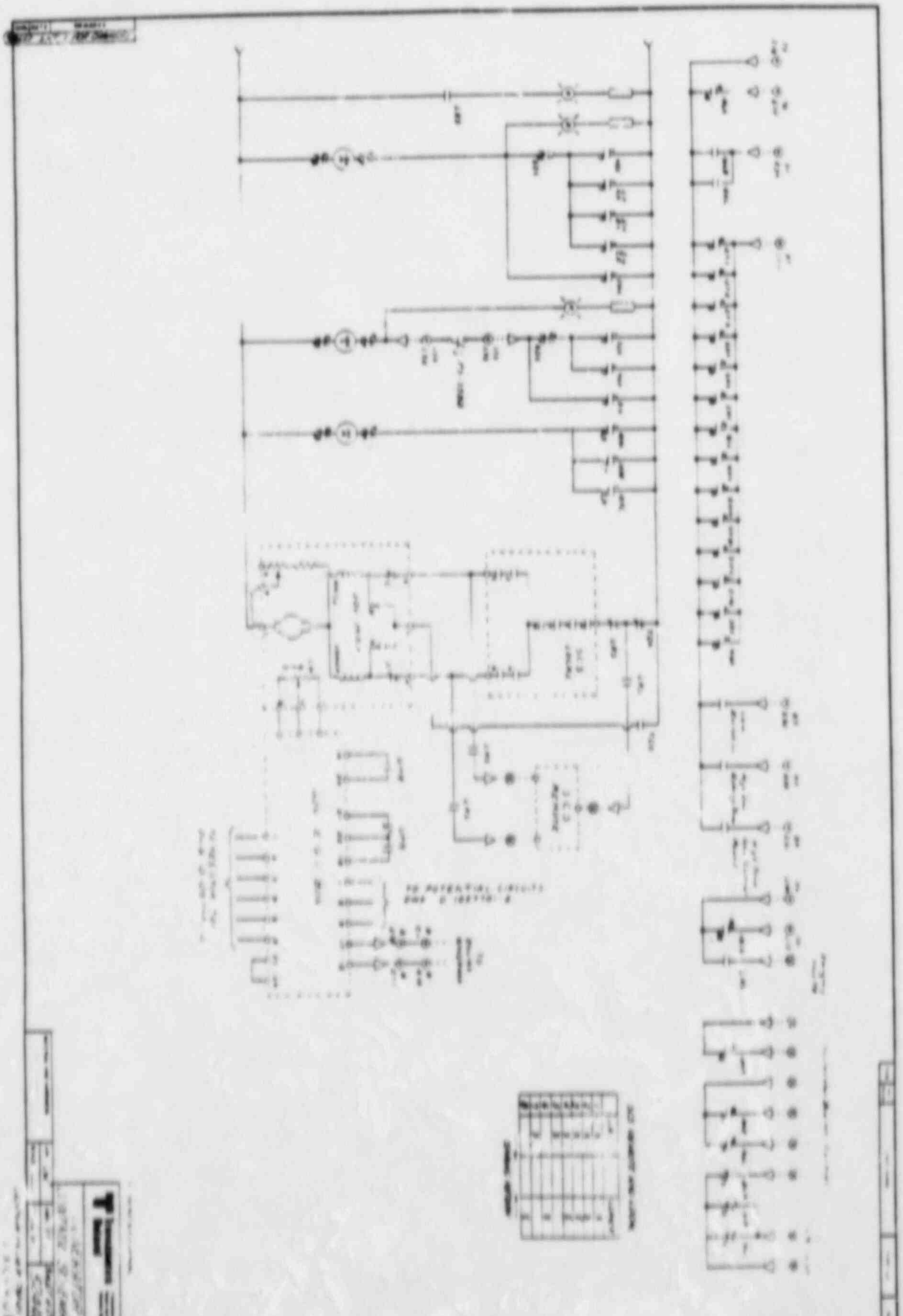
AX4AK01-509-1

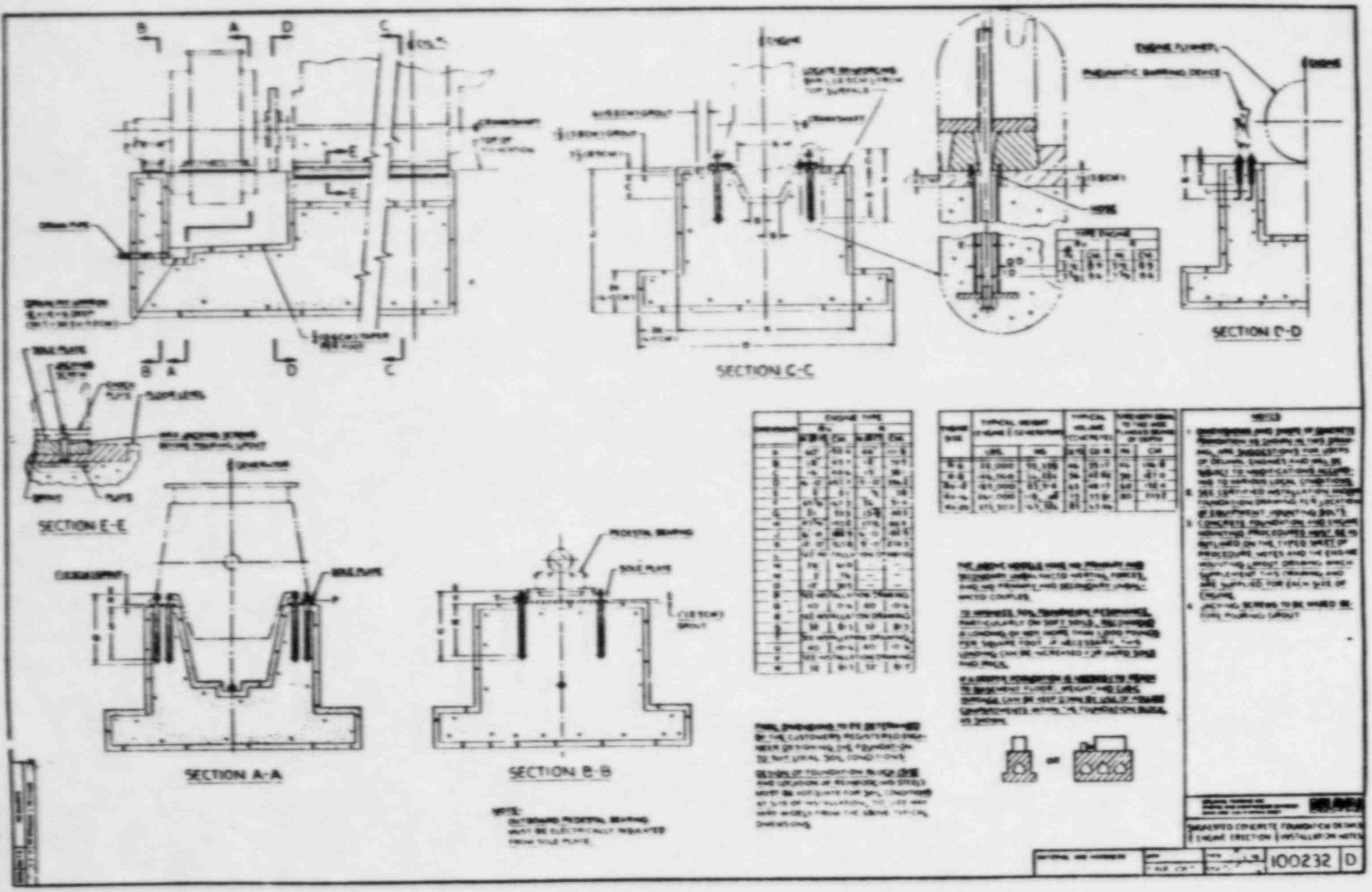

AUXILLIARY SKID
ENGINE - SKID ELECTRICAL
SCHEMATIC & WIRING


TERMINAL DESIGNATIONS
GENERATOR CONTROL PANEL
EXCITER REGULATOR
GEORGIA POWER
ENGINE CONTROL PANEL
AUTO VR ADJUST AND PROTECTION
EMERGENCY FOR PARALLEL
GEORGIA POWER COMPANY
ALVIN W. VOGTLE NUCLEAR PLANT
DIESEL GENERATOR
TRAIN A
GENERATOR
CONTROL SCHEMATIC
52440
6


GENERATOR
CONTROL SCHEMATIC
52440
6

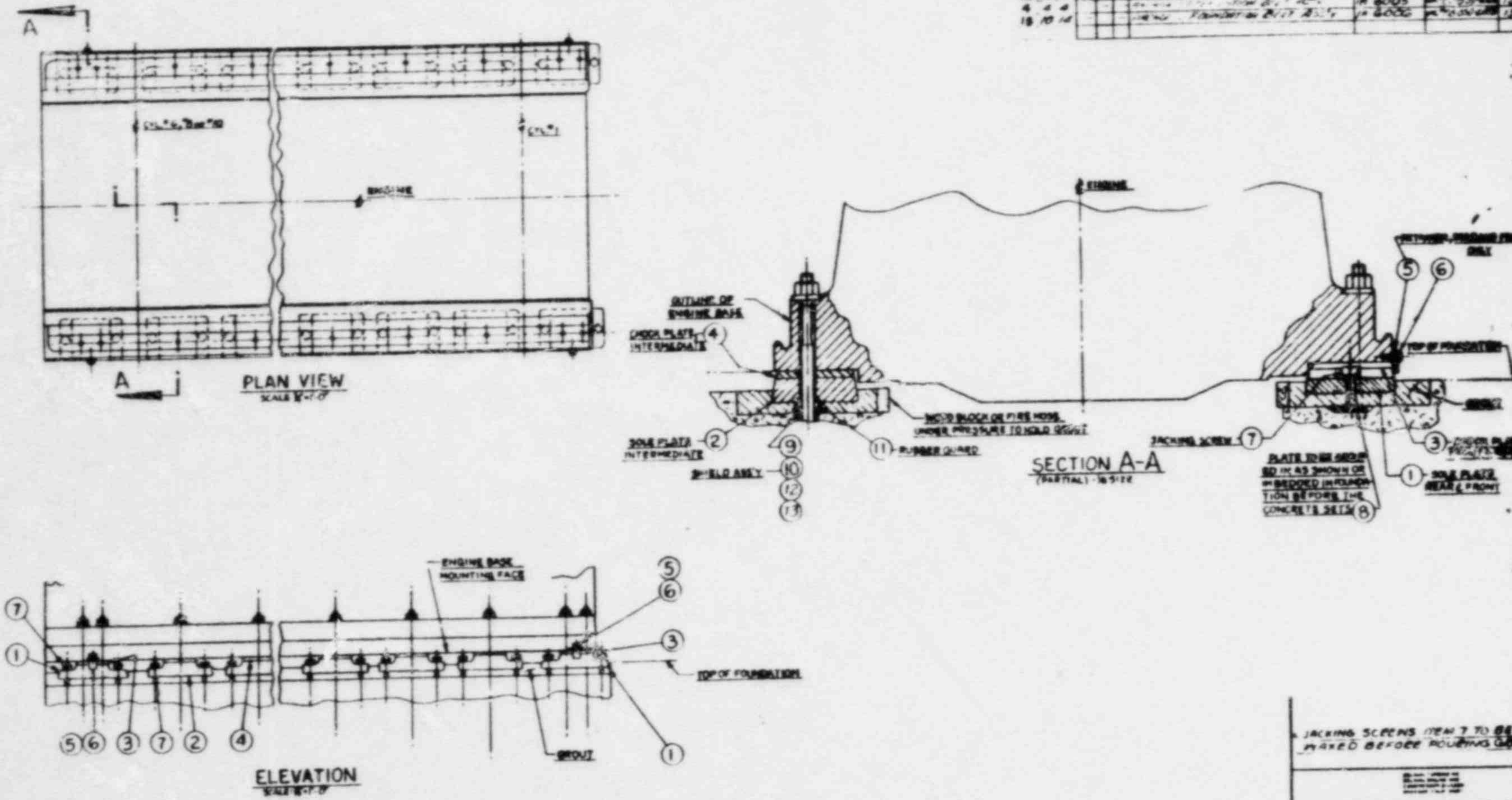

GENERATOR
CONTROL SCHEMATIC
5-440
6





SECTION A-A
SECTION B-B
SECTION C-C
SECTION D-D
SECTION E-E
100232
D

Part Name	Part No.	Remarks	Item
SOLE PLATE, REAR AND FRONT	02-550-01-[illegible]		1
SOLE PLATE, INTERMEDIATE	02-550-02-[illegible]		2
CHOCK PLATE, REAR AND FRONT	02-550-03-[illegible]		3
CHOCK PLATE, INTERMEDIATE	[illegible]		4
RETAINER, FRONT AND REAR SOLE PLATES	17039		5
CAPSCREW, HEX HD	[illegible]	[illegible]	6
JACKING SCREW	[illegible]-130		7
PLATE, JACKING SCREW	[illegible]		8
SHIELD ASSY - INTERMEDIATE	[illegible] 6006	[illegible]	9
SHIELD ASSY - REAR AND FRONT	[illegible] 6007	[illegible]	10
GUARD, RUBBER	R-2121	[illegible]	11
[illegible]	[illegible] 6005	[illegible]	12
[illegible]	[illegible] 6006	[illegible]	13

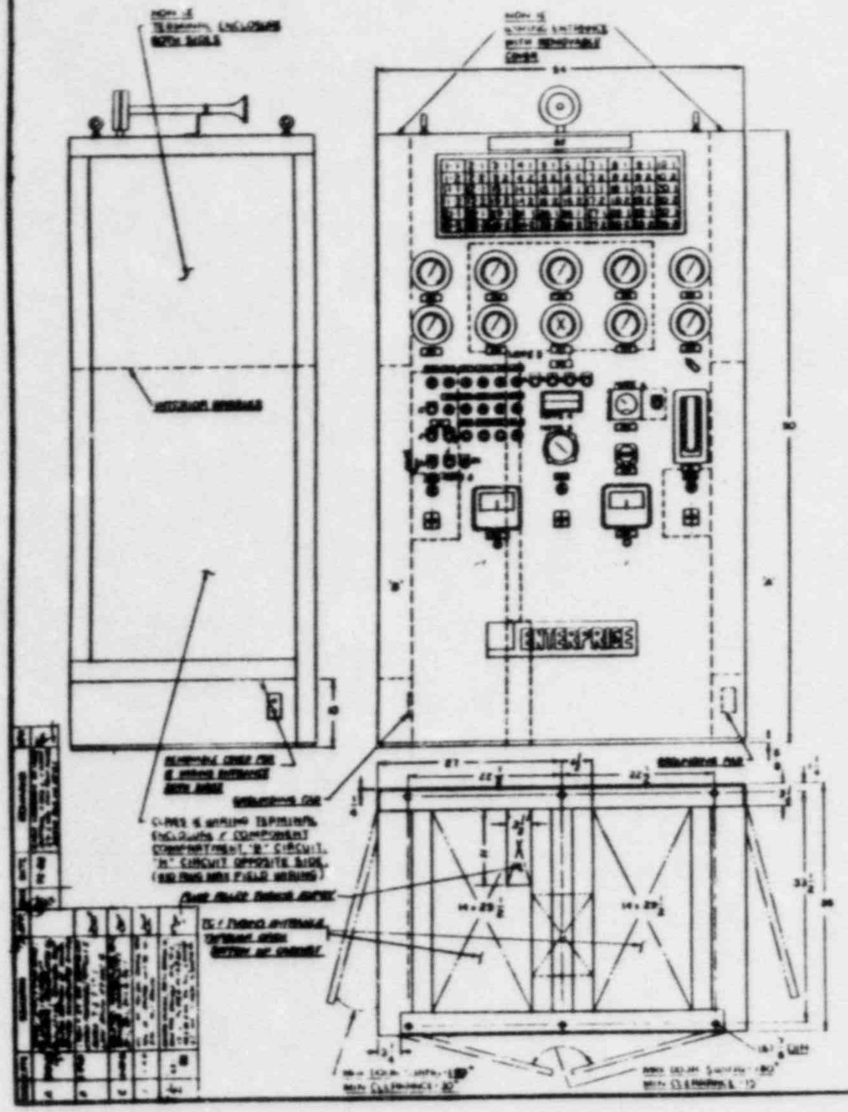


JACKING SCREWS ITEM 7 TO BE WAXED BEFORE POURING GROUT

DELAVAL

ENGINE MOUNTING

02-550-03



1-1 LOW TEMP LUBE OIL IN
2-1 LOW TEMP LUBE OIL OUT
3-1 HIGH TEMP LUBE OIL IN
4-1 HIGH TEMP LUBE OIL OUT
5-1 TRIP HIGH TEMP LUBE OIL
6-1 LOW LEVEL LUBE OIL
7-1 TRIP HIGH TEMP ENG BEARING
8-1 TRIP HIGH PRESS CRANKCASE
9-1 TRIP VIBRATION
10-1 TRIP OVERSPEED
1-2 LOW PRESS LUBE OIL
2-2 TRIP LOW PRESS LUBE OIL
3-2 LOW PRESS TURBO OIL RIGHT
4-2 LOW PRESS TURBO OIL LEFT
5-2 TRIP LOW PRESS TURBO OIL
6-2 HIGH Δ P LUBE OIL FILTER
7-2 LOW CAL PRESS SENSOR MALFUNCTION
8-2
9-2
10-2

11-1 LOW TEMP JACKET WATER IN
12-1 LOW TEMP JACKET WATER OUT
13-1 HIGH TEMP JACKET WATER IN
14-1 HIGH TEMP JACKET WATER OUT
15-1 TRIP HIGH TEMP JACKET WATER
16-1 LOW PRESS JACKET WATER
17-1 TRIP LOW PRESS JACKET WATER
18-1 LOW LEVEL JACKET WATER
19-1 HI JW TEMP SENSOR MALFUNCTION
20-1
11-2 LOW PRESS FUEL OIL
12-2 HIGH Δ P FUEL OIL FILTER
13-2
14-2 HIGH LEVEL MAIN TANK
15-2 LOW LEVEL MAIN TANK
16-2
17-2 LOW OR HIGH LEVEL DAY TANK
18-2
19-2
20-2

21-1 GENERATOR TROUBLE
22-1 LOW VOLTAGE
23-1 HIGH TEMP GENERATOR CONTROL PANEL
24-1 LOW EXCITATION
25-1 ENGINE CONTROL IN LOCAL
26-1 GENERATOR FAULT
27-1 TRIP GENERATOR DIFF
28-1 HIGH GEN BEARING TEMP
29-1
30-1 MAINTENANCE LOCK OUT
21-2 LOW PRESS CONTROL AIR
22-2 LOW PRESS STARTING AIR
23-2 HIGH PRESS STARTING AIR
24-2
25-2 FAILED TO START
26-2 SWITCH NOT IN AUTO
27-2 BARRING DEVICE ENGAGED
28-2 PANEL INTRUSION
29-2 HIGH TEMP ENG CONTROL PANEL
30-2 EMERGENCY START

31 TURBO OIL PRESS RED RIGHT BLACK LEFT
32 JACKET WATER PRESS
33 STARTING AIR PRESS LEFT BANK
34 STARTING AIR PRESS RIGHT BANK
35 CONTROL AIR PRESS
36 LUBE OIL PRESS
37 DIFFERENTIAL PRESS LUBE OIL FILTER
38 COMBUSTION AIR PRESS LEFT TEST RIGHT
39 DIFFERENTIAL PRESS FUEL OIL FILTER
40 FUEL OIL PRESS
41 CRANKCASE PRESS
42 ENGINE SPEED
43 ENGINE HOURS
44 UNIT AVAILABLE
45 EMERGENCY STOP
46 LOSS OF OFF SITE POWER
47 SHUTDOWN SYSTEM ACTIVE
48 SAFETY INJECTION SIGNAL
49 IN TEST SEQUENCE
50 T2G CLOSED
51 TEST BYPASS
52 READY TO LOAD
53 RUNNING
54 STOPPING
55 [illegible]
56 STARTING
57 ALARM FUNCTIONS
58
59 EMERGENCY START (BREAK GLASS)
60 START (GUARDED)
61 MODE [illegible]
62 DAY TANK LEVEL PUSH TO READ
63
64 LUBE TANK LEVEL PUSH TO READ
65 ENGINE CONTROL PANEL TAG #: [illegible]
66 A POWER AVAILABLE
67 B POWER AVAILABLE
68 C POWER AVAILABLE

a TEST
b SILENCE
c ACKNOWLEDGE
d RESET
e ENGINE ROLL
f OPERATIONAL
g [illegible]
h ENGINE STOP (BREAK GLASS)
j ENGINE STOP RESET
k STOP (GUARDED)
m RESET FROM LOCA

1. ALL ANNUNCIATOR LENSES ARE WHITE TRANSLUCENT & ENGRAVED WITH 1/8" BLACK LETTERING AS SHOWN. THE FOLLOWING POSITIONS ARE RED REAR LENSES FOR TRIP INDICATIONS: [illegible]
2. NAMEPLATES [illegible] ARE ENGRAVED WITH 1/8" WHITE LETTERING ON 3/4" x 2" LAMACOID. ALL OTHERS ARE ENGRAVED WITH 1/8" WHITE LETTERING ON 3/4" x 2 3/4" LAMACOID. [illegible]
3. [illegible] NAME PLATES AS SHOWN
4. DIGITAL TEMPERATURE INDICATOR
5. THERMOCOUPLE SELECTOR SWITCH: [illegible]
6. ISOLATION FOR CLASS 1E COMPONENTS.
7. GUARDED PUSHBUTTON
8. [illegible] STATION
9. WATER PROOF BOX FOR FLUID FILLED INSTRUMENTS

GEORGIA POWER COMPANY
ALVIN W. VOGTLE NUCLEAR PLANT

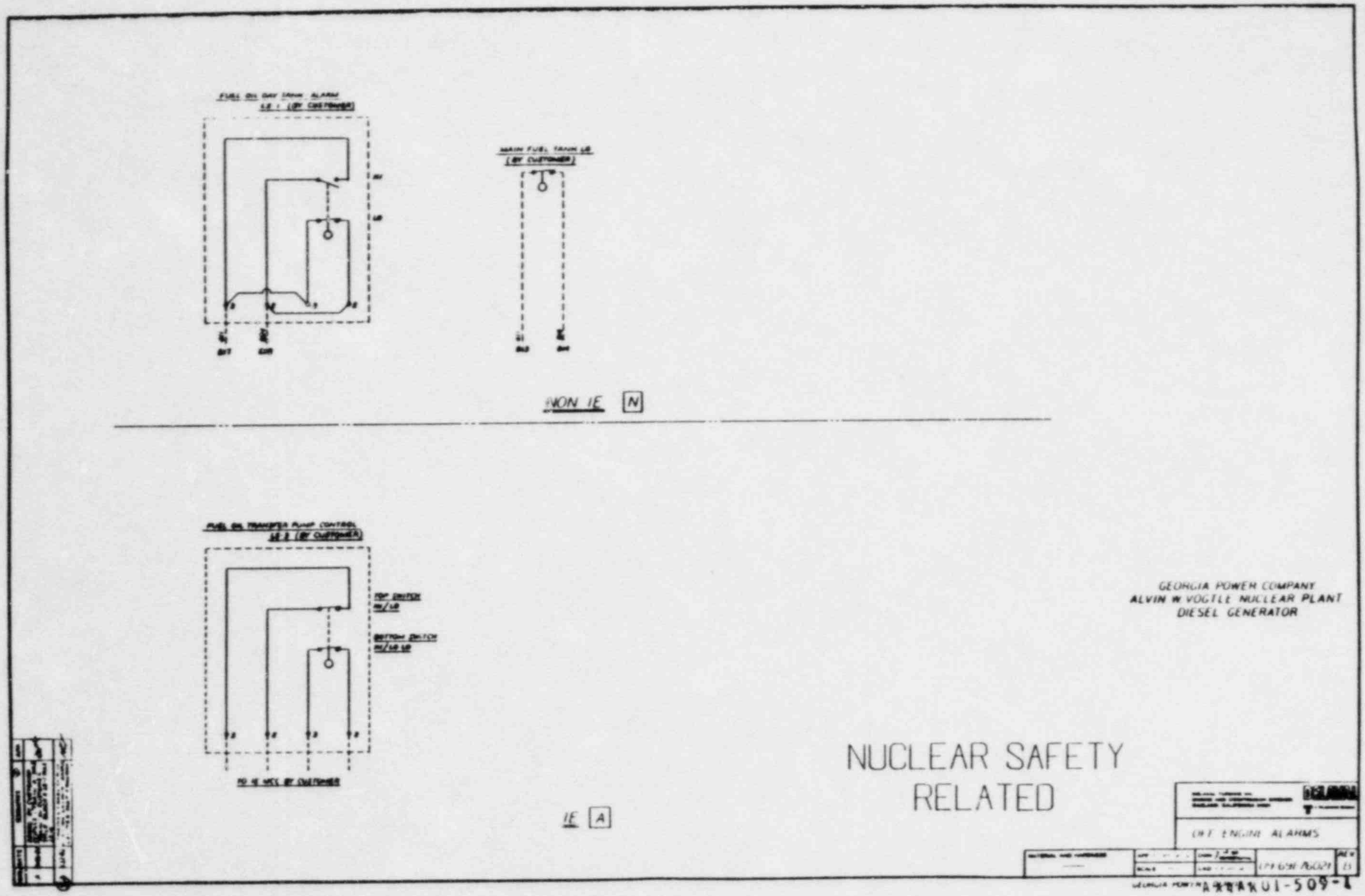
[illegible]
PAINT BOTTOM SURFACES WITH [illegible] NEOPRENE ASPHALT, [illegible]

MATERIAL AND HARDWARE

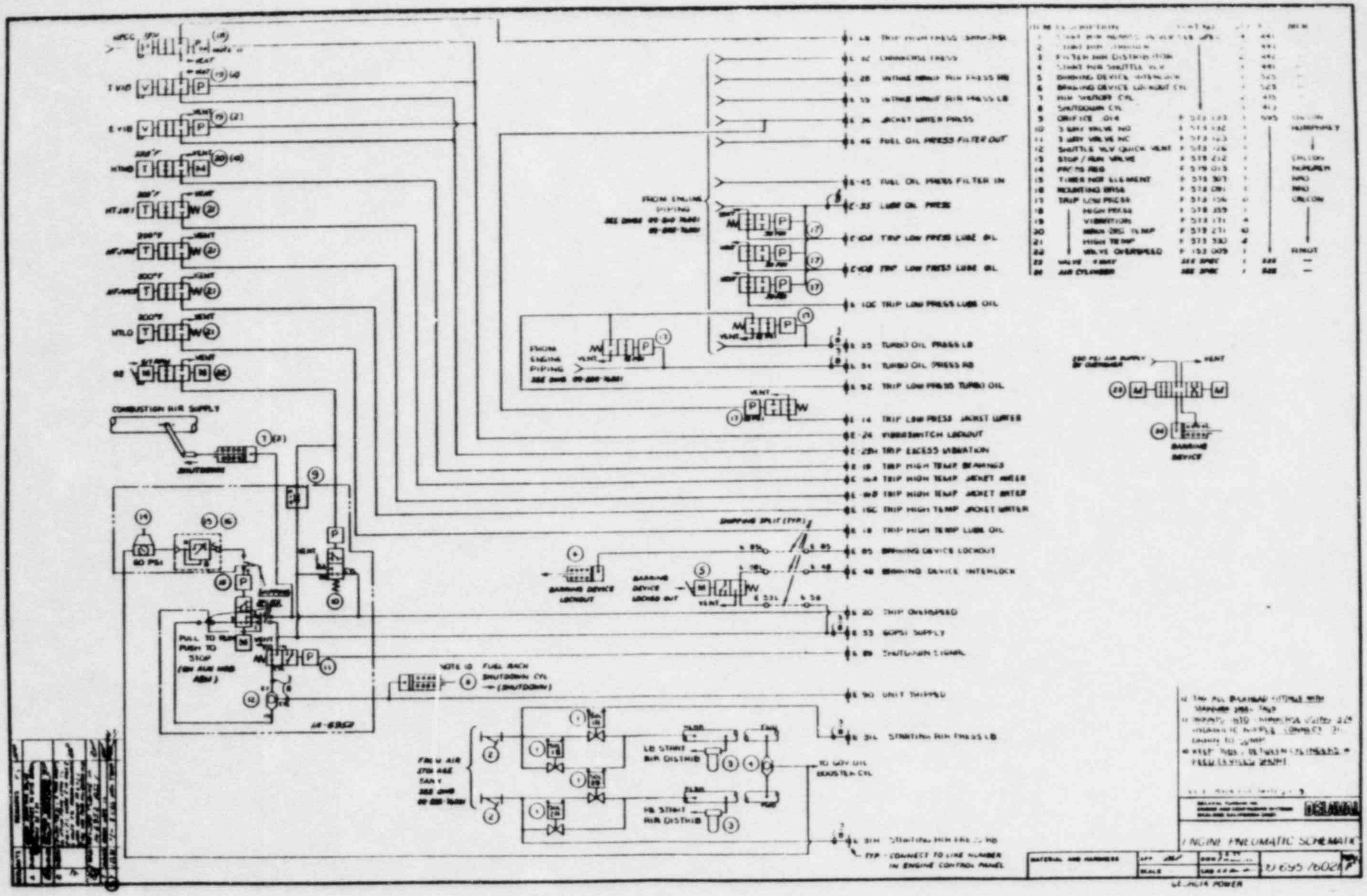
ENGINE CONTROL PANEL INSTALLATION

00-500-76021 REV F

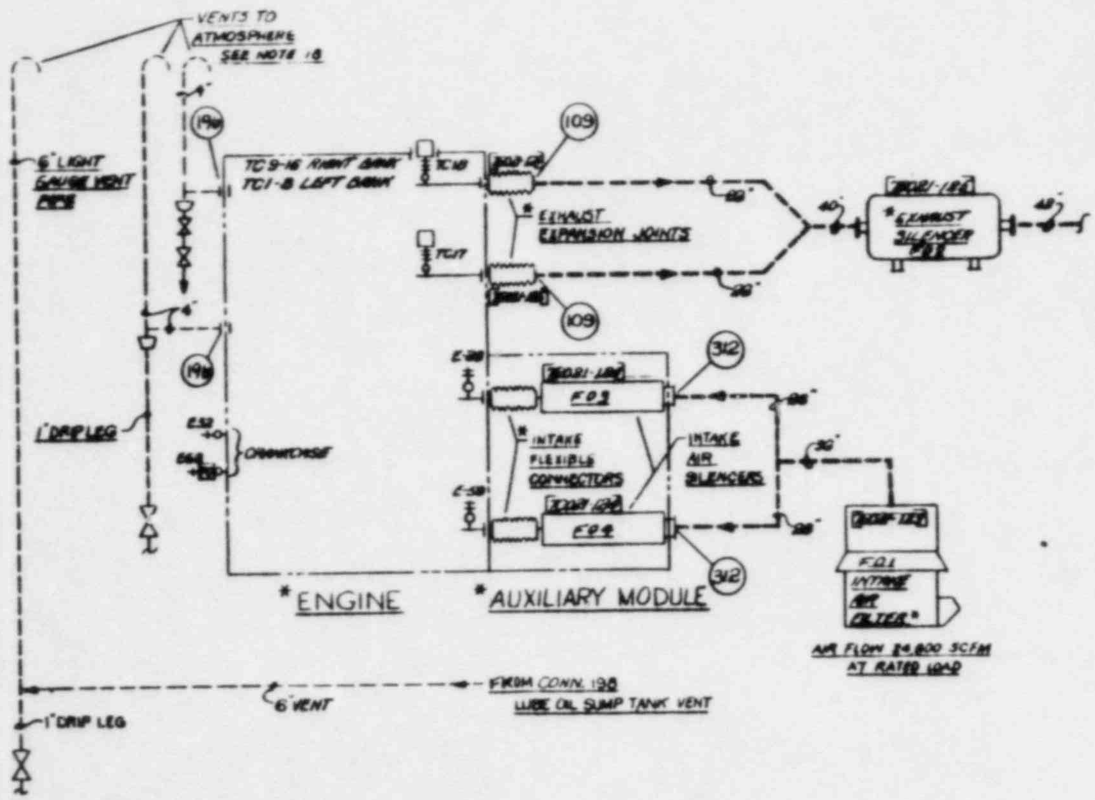
GEORGIA POWER



FUEL OIL DAY TANK ALARM
LS-1 (BY CUSTOMER)
MAIN FUEL TANK LS
(BY CUSTOMER)
NON IE N
FUEL OIL TRANSFER PUMP CONTROL
LS-2 (BY CUSTOMER)
TOP SWITCH
BOTTOM SWITCH
TO IE MCC BY CUSTOMER
IE A
GEORGIA POWER COMPANY
ALVIN W VOGTLE NUCLEAR PLANT
DIESEL GENERATOR
NUCLEAR SAFETY
RELATED
OFF ENGINE ALARMS
01-509-1



AXLAK01-509-1



BECHTEL PROJECT NO. 9510-001, -002
EQUIPMENT NUMBERS INDICATED ARE FOR DIESEL GENERATOR SETS:
1-2403-G4-001, -002
2-2403-G4-001, -002

CERTIFIED FOR SCHEMATIC SYSTEM INTERCONNECTION ONLY — NOT FOR CONSTRUCTION

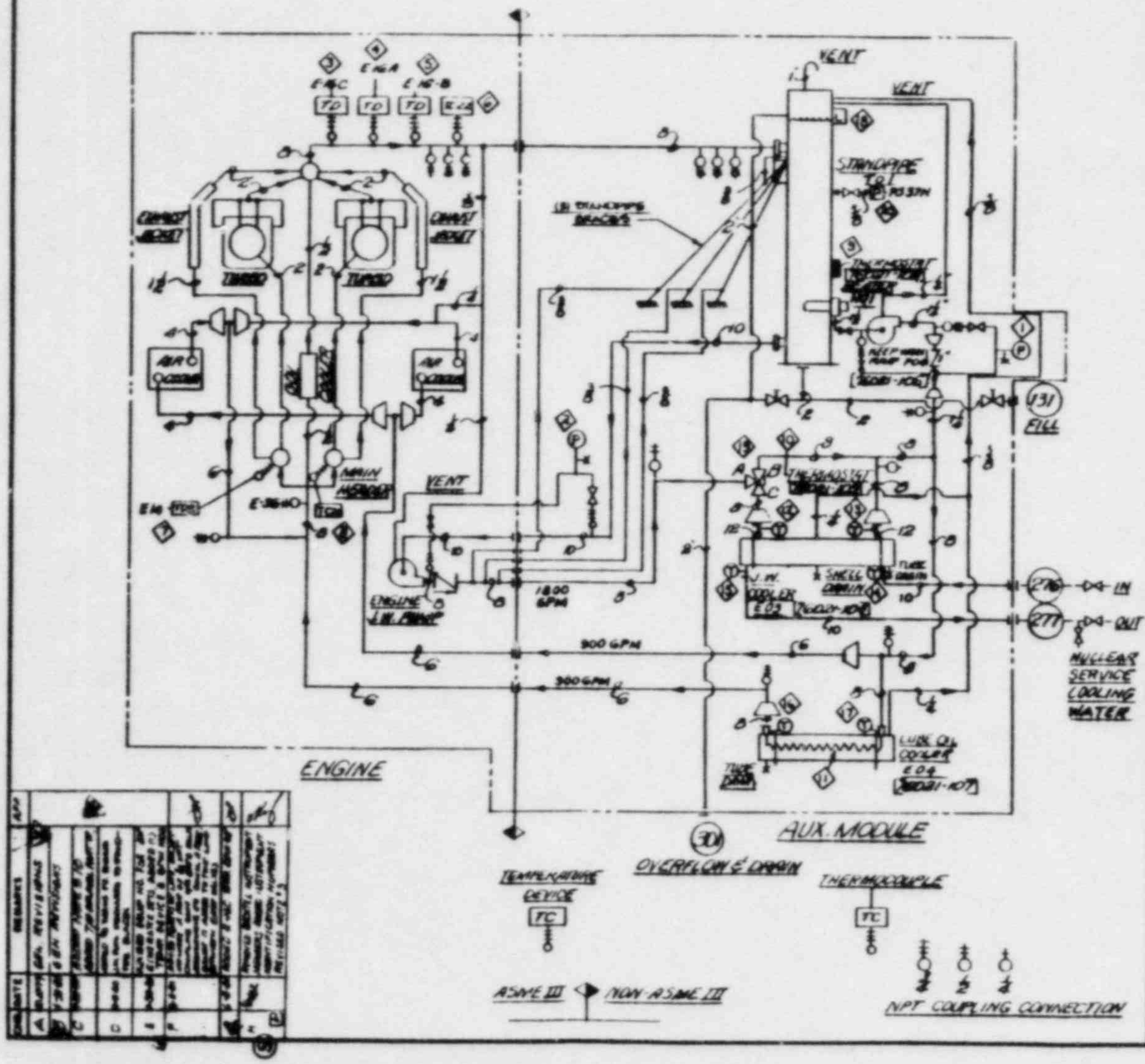
CERTIFICATION
CUSTOMER GEORGIA POWER COMPANY
CUSTOMER REF ALVIN VOGTLE NUCLEAR PLANT

Transamerica Delaval

EXHAUST, INTAKE & CRANKCASE PIPING SCHEMATIC

09-805-76021 D

AXCAR01-509-1



1. ITEMS MARKED * ARE SUPPLIED BY TRANSAMERICA DELAVAL
2. (100) & (300) NUMBERS CORRESPOND TO NUMBERED PIPE CONNECTIONS BY CUSTOMER
3. FOR PIPING SYMBOLS SEE DRAWING D-4515
4. FLEXIBLE COUPLINGS ARE NOT RECOMMENDED AT CUSTOMER CONNECTIONS BECAUSE OF POTENTIAL FAILURE HAZARD DURING OPERATION
5. ALL PIPING TO BE PROPERLY SUPPORTED TO MINIMIZE PIPE VIBRATION AND FLANGE LOADING
6. CONTROLS ARE NOT SHOWN. SEE CONTROL SCHEMATIC FOR SIZE AND LOCATION
7. PROVIDE DRAINS AT ALL LOW POINTS AND VENTS AT ALL HIGH POINTS IN OFF ENGINE PIPING
8. INSTRUMENTATION CONNECTIONS NOT USED ARE PLUGGED
9. FOR INSTRUMENT IDENTIFICATION SEE DRAWING 09-801-76021
10. NUMBERS IN BRACKETS [76021-107] INDICATE BASIC TRANSAMERICA DELAVAL PART NOS. FOR AUXILIARY EQUIPMENT ITEMS

BECHTEL PROJECT Nº 3510
FOR DIESEL GENERATOR SETS:

CERTIFIED FOR SCHEMATIC SYSTEM INTERCONNECTION ONLY NOT FOR CONSTRUCTION

CERTIFICATION

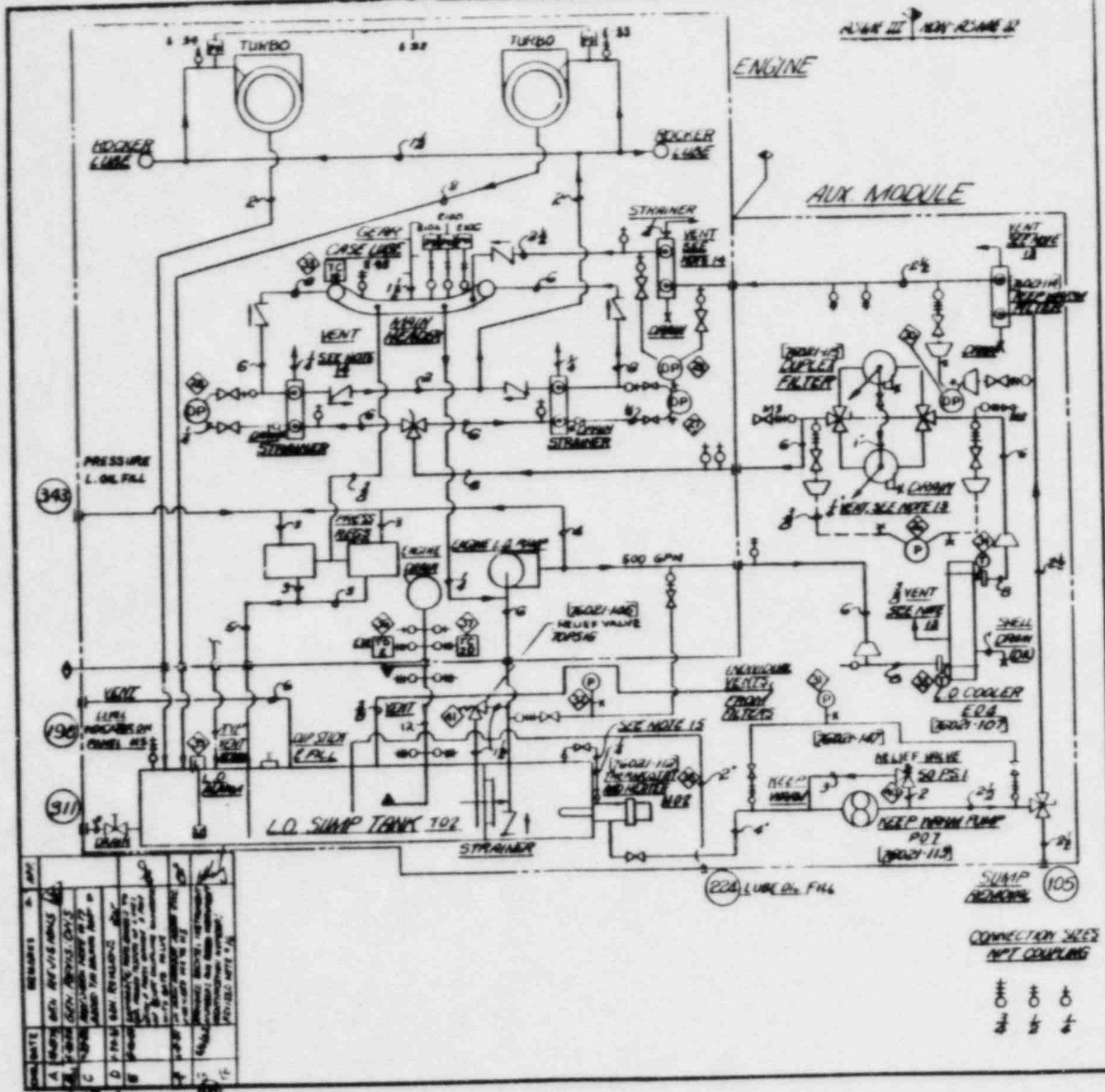
CUSTOMER GEORGIA POWER COMPANY
CUSTOMER [illegible] ALVIN VOGTLE NUCLEAR PLANT
[illegible] NUMBER ______ [illegible] NO 76021/[illegible]
CONTRACT OR ORDER NO
[illegible] Conformance
BY C.R. [illegible]
TITLE Mgr. Proj. Engrg. DATE May 6, 1982

Transamerica Delaval

JACKET WATER PIPING SCHEMATIC

DRAWN FEK 5979	09-810-76021	H
CHECKED K. LEE		
APPROVED [illegible]		
SCALE	DRAWING NUMBER	ALT

AXGAK01-509-1



1. ITEMS MARKED * ARE SUPPLIED BY TRANSAMERICA DELAVAL
2. (100) & (300) NUMBERS CORRESPOND TO NUMBERED PIPE CONNECTIONS BY CUSTOMER. SEE INSTALLATION DRAWING
3. FOR PIPING SYMBOLS SEE DRAWING D-4515
4. FLEXIBLE COUPLINGS ARE NOT RECOMMENDED AT CUSTOMER CONNECTIONS BECAUSE OF POTENTIAL FAILURE HAZARD DURING OPERATION
5. ALL PIPING TO BE PROPERLY SUPPORTED TO MINIMIZE PIPE VIBRATION AND FLANGE LOADING
6. PIPING, PIPING FITTINGS, EQUIPMENT & VALVES NOT SUPPLIED WITH ENGINE MODULE
7. NO BACK-UP RINGS OR CAST IRON FITTINGS SHALL BE USED IN THE SYSTEM
8. ALL PIPING TO BE MECHANICALLY CLEANED AFTER WELDING AND PRIOR TO ASSEMBLING
9. TRANSAMERICA DELAVAL RECOMMENDS THAT NO ISOLATING VALVES BE INSTALLED IN THE MAIN LUBE OIL PIPING
10. OPEN ENDS OF SECTIONS OF PIPE ARE TO BE PROTECTED WITH STEEL BLIND FLANGES & GASKETS IN ORDER TO PROTECT AGAINST CONTAMINATION
11. PRECAUTIONS FOR LUBE OIL SYSTEM, TRANSAMERICA DELAVAL FORM D-4987 ARE TO BE COMPLIED WITH
12. INSTRUMENTATION CONNECTIONS NOT USED ARE PLUGGED
13. VENTS FOR OFF-ENGINE FILTERS, STRAINERS AND COOLER CONNECT INDIVIDUALLY TO L.O. SUMP TANK TOP. DO NOT USE VALVES. USE 1 OD TUBE UNLESS OTHER SIZE SPECIFIED
14. VENT FOR ON-ENGINE STRAINERS CONNECT INDIVIDUALLY TO ENGINE GEAR CASE
15. VENT LINE TO BE OPEN EXCEPT REMOVING OIL FROM TANK WITH KEEP WARM PUMP
16. FOR INSTRUMENT IDENTIFICATION SEE DRAWING 09-801-76021
17. NUMBERS IN BRACKETS [76021-00] INDICATE BASIC TRANSAMERICA DELAVAL PART NOS. FOR AUXILIARY EQUIPMENT ITEMS

BECHTEL PROJECT Nº 9510
FOR DIESEL GENERATOR SETS:

CERTIFIED FOR SCHEMATIC SYSTEM INTERCONNECTION ONLY – NOT FOR CONSTRUCTION

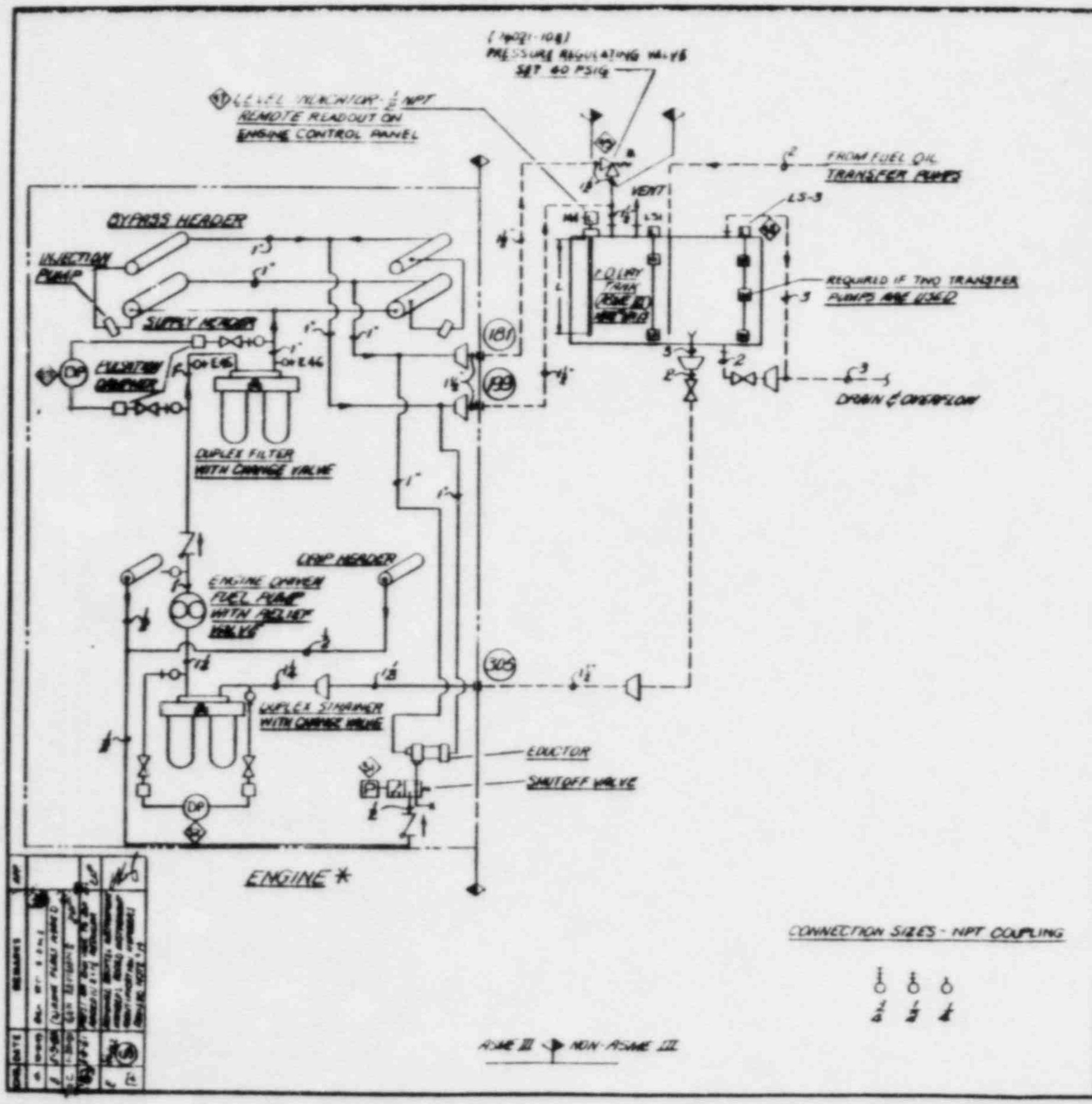
CUSTOMER: GEORGIA POWER COMPANY
CUSTOMER REF: ALVIN VOGTLE NUCLEAR PLANT
JOB NUMBER: 76021/24
CONTRACT OR ORDER NO.:
SOURCE: Count...
BY: C.E. Carmichael
TITLE: Mgr. Eng. Engrg. DATE: May 6, 1982

Transamerica Delaval

LUBE OIL PIPING SCHEMATIC

DRAWN: F.E.K. 5-10-79	09-820-76021	G
CHECKED: K. LEE		
APPROVED: E.L.B.		
SCALE: —	DRAWING NUMBER	ALT

AXLHKU1-509-1



1. ITEMS MARKED * ARE SUPPLIED BY TRANSAMERICA DELAVAL
2. (100) & (300) NUMBERS CORRESPOND TO NUMBERED PIPE CONNECTIONS BY CUSTOMER
3. SOLID LINES INSIDE OF (100) & (300) SERIES NUMBERED CONNECTIONS REPRESENT PIPING & FITTINGS SUPPLIED BY TRANSAMERICA DELAVAL
4. FOR PIPING SYMBOLS SEE DRAWING D-4513
5. FLEXIBLE COUPLINGS ARE NOT RECOMMENDED AT CUSTOMER CONNECTIONS BECAUSE OF POTENTIAL FAILURE HAZARD DURING OPERATION
6. ALL PIPING TO BE PROPERLY SUPPORTED TO MINIMIZE PIPE VIBRATION AND FLANGE LOADING
7. CONTROLS ARE NOT SHOWN. SEE CONTROL SCHEMATIC FOR SIZE AND LOCATION
8. CUSTOMER TO SUPPLY AND INSTALL ALL PIPING SHOWN AS DASHED LINES
9. ALL PIPING TO BE MECHANICALLY CLEANED AND PRESERVED WITH MIL SPEC C-2346 OR C-46715-D TO PREVENT RUST. COMMERCIALLY THIS IS MET BY LPS NO 3 MANUFACTURED BY LPS RESEARCH LABORATORIES OF WEST LOS ANGELES, CALIF
10. CLEAN PIPES AFTER WELDING AND PRIOR TO ASSEMBLING
11. PIPE SIZES SHOWN ARE MINIMUM FOR MOST INSTALLATIONS BUT MAY VARY WHEN LENGTH OF PIPING, NUMBER OF FITTINGS AND VALVES RESULT IN EXCESSIVE PRESSURE DROP
12. TANK TO BE AT ELEVATION TO PROVIDE FLOODED SUCTION AT BOOSTER PUMP
13. ALL ITEMS MARKED III ARE A.S.M.E. SECTION III, CLASS 3
14. FOR INSTRUMENT IDENTIFICATION SEE DRAWING 09-801-76021
15. NUMBERS IN BRACKETS (7602I-HO) INDICATE BASIC TRANSAMERICA DELAVAL PART NOS. FOR AUXILIARY EQUIPMENT ITEMS

BECHTEL PROJECT No 9510
FOR DIESEL GENERATOR SET

CERTIFIED FOR SCHEMATIC SYSTEM INTERCONNECTION ONLY NOT FOR CONSTRUCTION

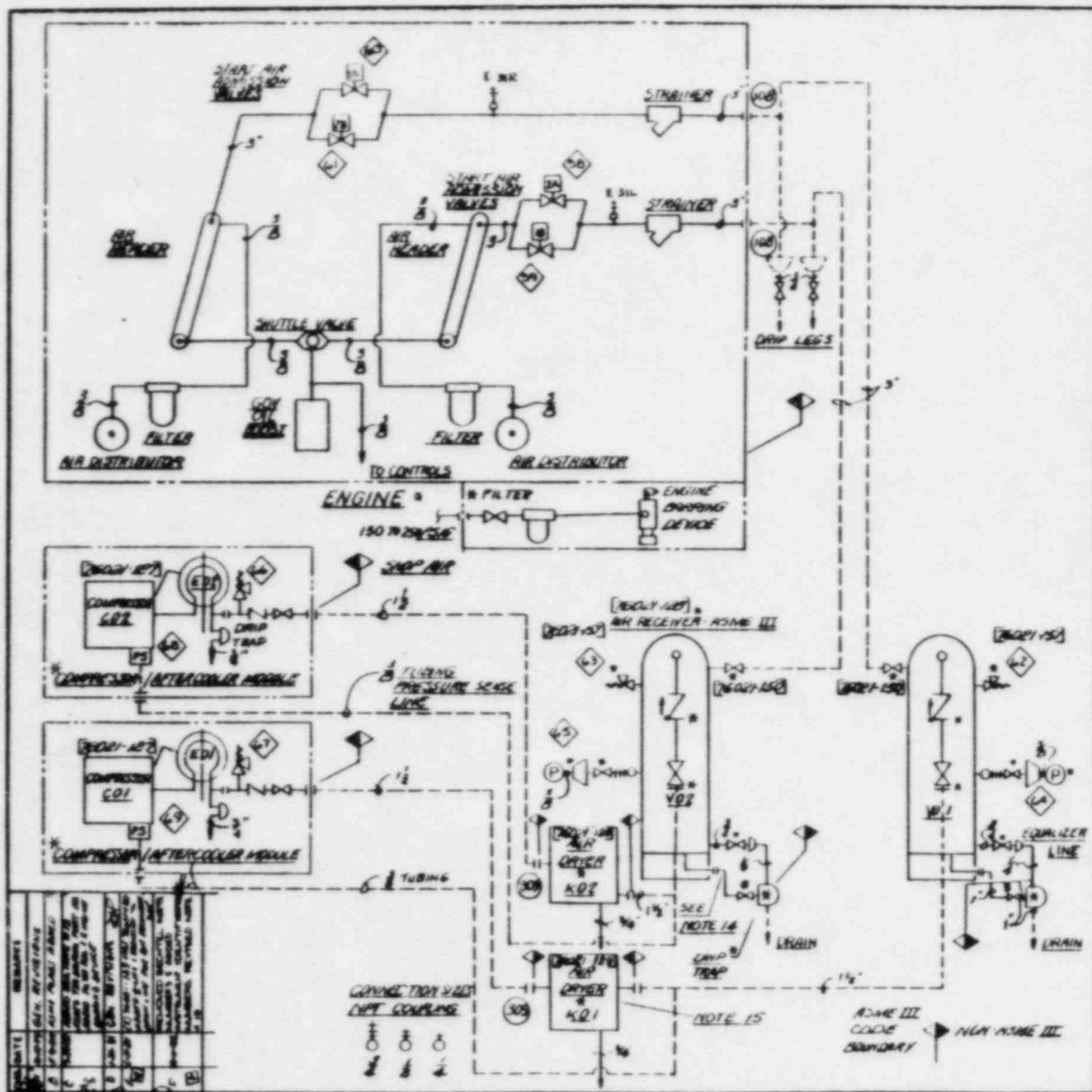
CUSTOMER: GEORGIA POWER COMPANY
CUSTOMER REF: ALVIN VOGTLE NUCLEAR PLANT
ORDER NUMBER: 7CB9/24
CERTIFIED FOR: Commonwealth
BY: C. L. Carmichael
TITLE: Mgr. Eng. Engineering ... May 8, 1981

Transamerica Delaval

FUEL OIL PIPING SCHEMATIC

DRAWN: PBA 2-19-72
CHECKED: K. LEE
APPROVED: DLG
09-825-76021 E

AAL-RDI-509-1



1 ITEMS MARKED * ARE SUPPLIED BY TRANSAMERICA DELAVAL
2 (100) & (300) NUMBERS CORRESPOND TO NUMBERED PIPE CONNECTIONS BY CUSTOMER
3 SOLID LINES INSIDE OF (100) & (300) SERIES NUMBERED CONNECTIONS REPRESENT PIPING & FITTINGS SUPPLIED BY TRANSAMERICA DELAVAL
4 FOR PIPING SYMBOLS SEE DRAWING D-4313
5 FLEXIBLE COUPLINGS ARE NOT RECOMMENDED AT CUSTOMER CONNECTIONS BECAUSE OF POTENTIAL FAILURE HAZARD DURING OPERATION
6 ALL PIPING TO BE PROPERLY SUPPORTED TO MINIMIZE PIPE VIBRATION AND FLANGE LOADING
7 CUSTOMER TO SUPPLY AND INSTALL ALL PIPING SHOWN IN DOTTED LINE (- - -)
8 ALL PIPING TO BE CLEANED INTERNALLY AND BLOWN CLEAN PRIOR TO STARTUP
9 CUSTOMER PIPING SHOULD BE RUN AT A LOWER LEVEL THAN ENGINE INLET CONNECTION NO (108). INSTALL MOISTURE COLLECTORS AND DRAINS IN PIPING AT LOW POINTS NEAR INLET CONNECTION AND ANY OTHER LOW POINTS IN SYSTEM
10 CUSTOMER PIPE SIZES ARE MINIMUM FOR MOST INSTALLATIONS BUT MAY VARY IF LENGTH OF PIPING, NUMBER OF FITTINGS & VALVES RESULT IN EXCESSIVE PRESSURE DROP. 10 PSI MAXIMUM PRESSURE DROP FROM AIR TANK TO ENGINE HEADER
11 ALL PIPING TO BE SCHEDULE 80 AND PIPE FITTINGS TO BE "300 LBS. ASA" FOR 275 PSI WORKING PRESSURE
12 "Y" STRAINERS MUST BE INSTALLED IN A HORIZONTAL RUN OF PIPE
13 UNLABELED INSTRUMENTATION CONNECTIONS ARE NOT USED AND ARE PLUGGED. THESE ARE STANDARD ON TRANSAMERICA DELAVAL ENGINES FOR USE AS REQUIRED
14 DUE TO LACK OF HEIGHT BETWEEN BOTTOM DRAIN AND FLOOR, THE TEE AND RUNS OF PIPE SHOWN HERE WILL ALL BE IN THE HORIZONTAL PLANE
15 REFRIGERATION TYPE DRIERS ARE INDICATED AND WOULD BE FLOOR MOUNTED
16 PIPING, VALVES AND FITTINGS ON STARTING AIR TANKS BETWEEN INLET AND OUTLET FLANGES, AND THE TANK ITSELF ARE TO CODE ASME III CLASS 3
17 INTERCONNECTING PIPING BETWEEN MAJOR COMPONENTS IS ASME III CLASS 3 BY CUSTOMER
18 FOR INSTRUMENT IDENTIFICATION SEE DRAWING 09-801-76021
19 NUMBERS IN BRACKETS (76021-150) INDICATE BASIC TRANSAMERICA DELAVAL PART NOS. FOR AUXILIARY EQUIPMENT ITEMS.

BECHTEL PROJECT No 9510
FOR DIESEL GENERATOR SETS

CERTIFIED FOR SCHEMATIC SYSTEM INTERCONNECTION ONLY – NOT FOR CONSTRUCTION

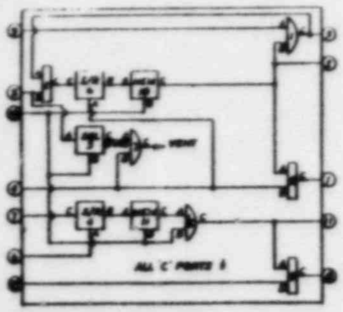
CUSTOMER GEORGIA POWER COMPANY
CUSTOMER REF ALVIN VOGTLE NUCLEAR PLANT
JOB NUMBER ______ ENGINE NO 76021/24
CONTRACT OR ORDER NO
CERTIFIED FOR Connections
BY C. R. Carmichael
TITLE Mgr. Eng. Engineering DATE May 6, 1982

Transamerica Delaval

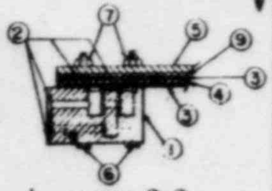
STARTING AIR PIPING SCHEMATIC

DRAWN EEK 5-9-72	09-835-76021	F
CHECKED K LEE		
APPROVED		
SCALE	DRAWING NUMBER	ALT

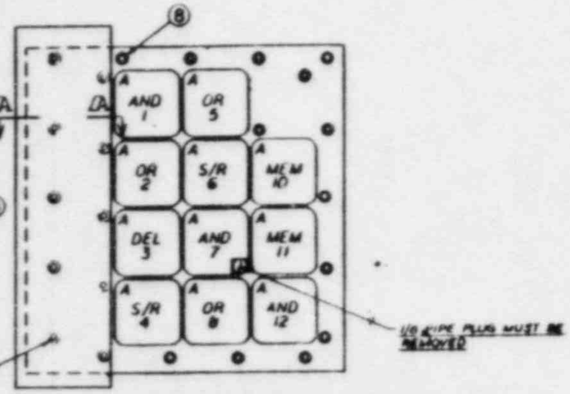
RAC-RUI-509-1



CIRCUIT DIAGRAM

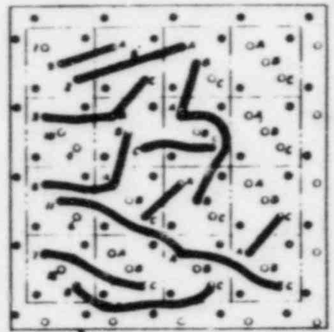


SECTION A-A

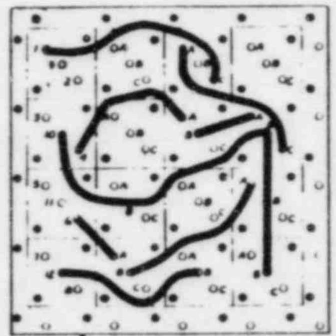


NOTE PORT DESIGNATIONS MATCH LOGIC ELEMENTS TO POSITION SHOWN

LOGIC BOARD ASSEMBLY



ITEM (9) USE F-573-003
CUTOUT AS SHOWN - 1/8 WIDE CHANNELS
CLEAR GASKET HOLES & ADJACENT CUTS BY 1/8



ITEM (4) USE F-573-003
CUTOUT AS SHOWN - 1/8 WIDE CHANNELS
CLEAR GASKET HOLES & ADJACENT CUTS BY 1/8

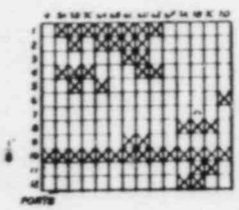
CIRCUIT MODULE GASKETS

QTY	PART NAME	PART NO.	REMARKS	ITEM
1	CONNECTOR	[illegible]	12 PORT	1
24	O RING	F 573 [illegible]		2
2	CIRCUIT BASE PLATE	F 573 [illegible]		3
1	CIRCUIT MODULE GASKET		AS REQ'D	4
1	CIRCUIT COVER PLATE	F 573 00[illegible]		5
10	SCREW, ALLEN HEAD	[illegible]	[illegible]	6
25	NUT, HEX LIGHT	F 535 [illegible]	#6 [illegible]	7
[illegible]	SCREW, ALLEN HEAD	[illegible]	#8 [illegible]	8
1	CIRCUIT MODULE GASKET	—	AS REQ'D	9
				10
3	OR LOGIC ELEMENT	F 573 004		OR
3	AND LOGIC ELEMENT	F 573 00[illegible]		AND
2	MEM LOGIC ELEMENT	F 573 007		MEM
2	S/R LOGIC ELEMENT	F 573 006		S/R
1	DEL LOGIC ELEMENT	F 573-346		DEL

FUNCTION: TO TEST SHUTDOWN LOCKOUT STATUS AND PROVIDE MANUAL RESET FROM LOCA STATUS

TEST PROCEDURE:

1. ALL INPUTS AND OUTPUTS ARE 60 PSI
2. SEE CHART FOR ALL PORT PRESSURES
3. BLOCK PORTS 1, 2, 3, 8 & 11
4. PRESSURISE PORT 10
5. A PRESSURISE PORT 4
   B PRESSURISE PORT 5, NOTE ALSO AFTER 1 SEC. VENTING AT 'C' PORT OF AND 7 (ADJUST DEL FOR 1 SEC).
   C VENT PORT 5, NOTE ALSO CESSATION OF VENTING AT 'C' PORT OF AND 7
6. A VENT PORT 4 AND PRESSURISE PORT 9
   B VENT PORT 5
   C PRESSURISE PORT 9
   D PRESSURISE PORT 4
   E VENT PORT 9
   F VENT PORT 4
7. A PRESSURISE PORT 12
   B MOMENTARILY PRESSURISE PORT 7
   C VENT PORT 12
   D PRESSURISE PORT 6



NO PRESSURE
PRESSURE
MOMENTARILY PRESSURE

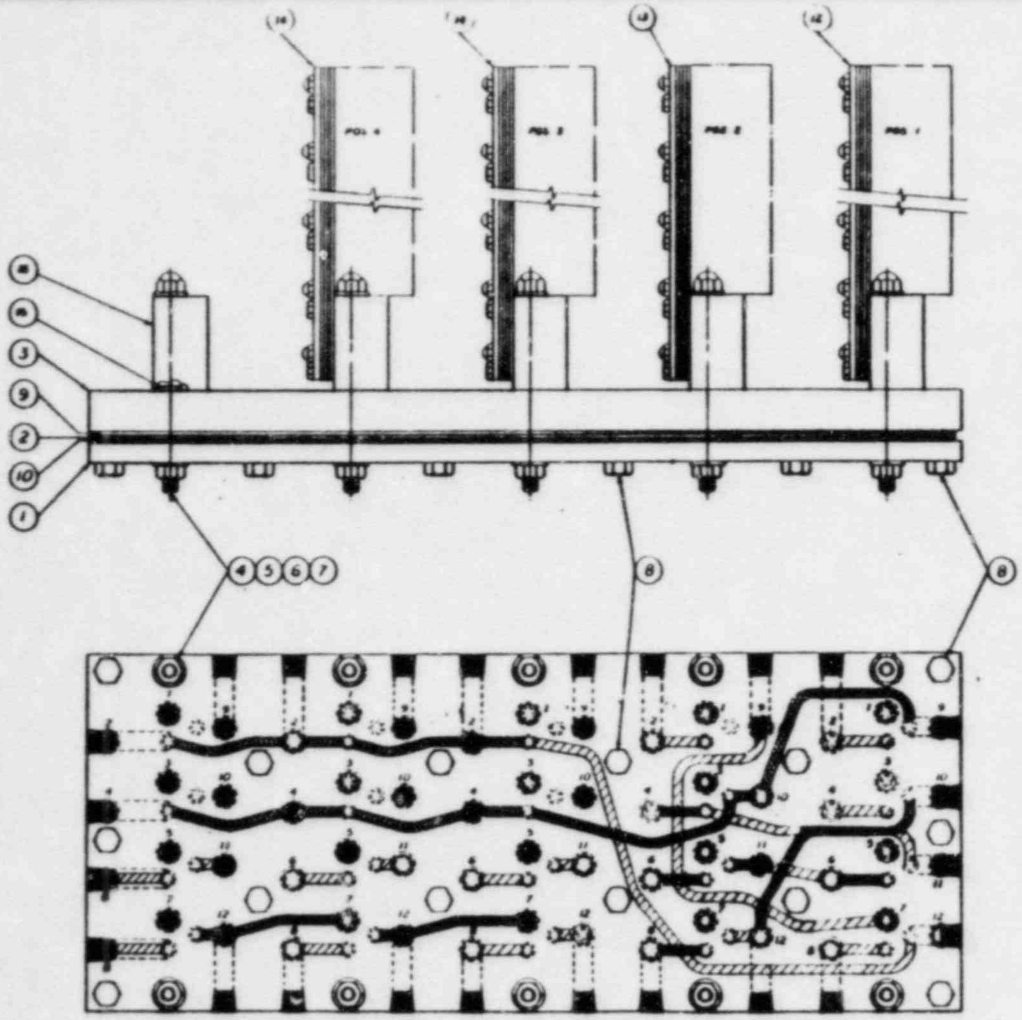
ENTERPRISE DIVISION
DE LAVAL TURBINE INC.

TEST SD BLOCK & SD ACTIVATE SEL
PNEUMATIC LOGIC BOARD ASSY

24C

DI 360 65[illegible]

[illegible] 509-1



QTY	PART NAME	PART NO	MAT'L	REMARKS	ITEM
1	BOTTOM PLATE	61 360 01 [illegible]	[illegible]		1
1	SEPARATION PLATE	61 360 01 [illegible]	[illegible]		2
1	TOP PLATE	61 360 01 [illegible]	[illegible]		3
10	STUD	61 360 01 [illegible]	[illegible]		4
10	NUT HEX	68 094 001	STL	1/4 20	5
20	WASHER	68 001 001	STL	1/4	6
10	NUT CAP	68 094 008	STL	1/4 20	7
14	CAPSCREW, HEX HD	68 001 007	STL	1/4 20 x 1 1/2 LG	8
1	GASKET	*			9
1	GASKET	*			10
56	PIPE PLUG	CB 008 186	STL	1/8 NPT	11
1	SHUTDOWN LOGIC BD	1A [illegible]			12
1	TEST LOGIC BD	1A 6926			13
[illegible]	TWO/THREE SHUTDOWN LOGIC BD	1A [illegible]			14
[illegible]	PORT BLANK OFF	61 360 01 [illegible]	[illegible]		15
8	O-RING	P 272-044	[illegible]		16

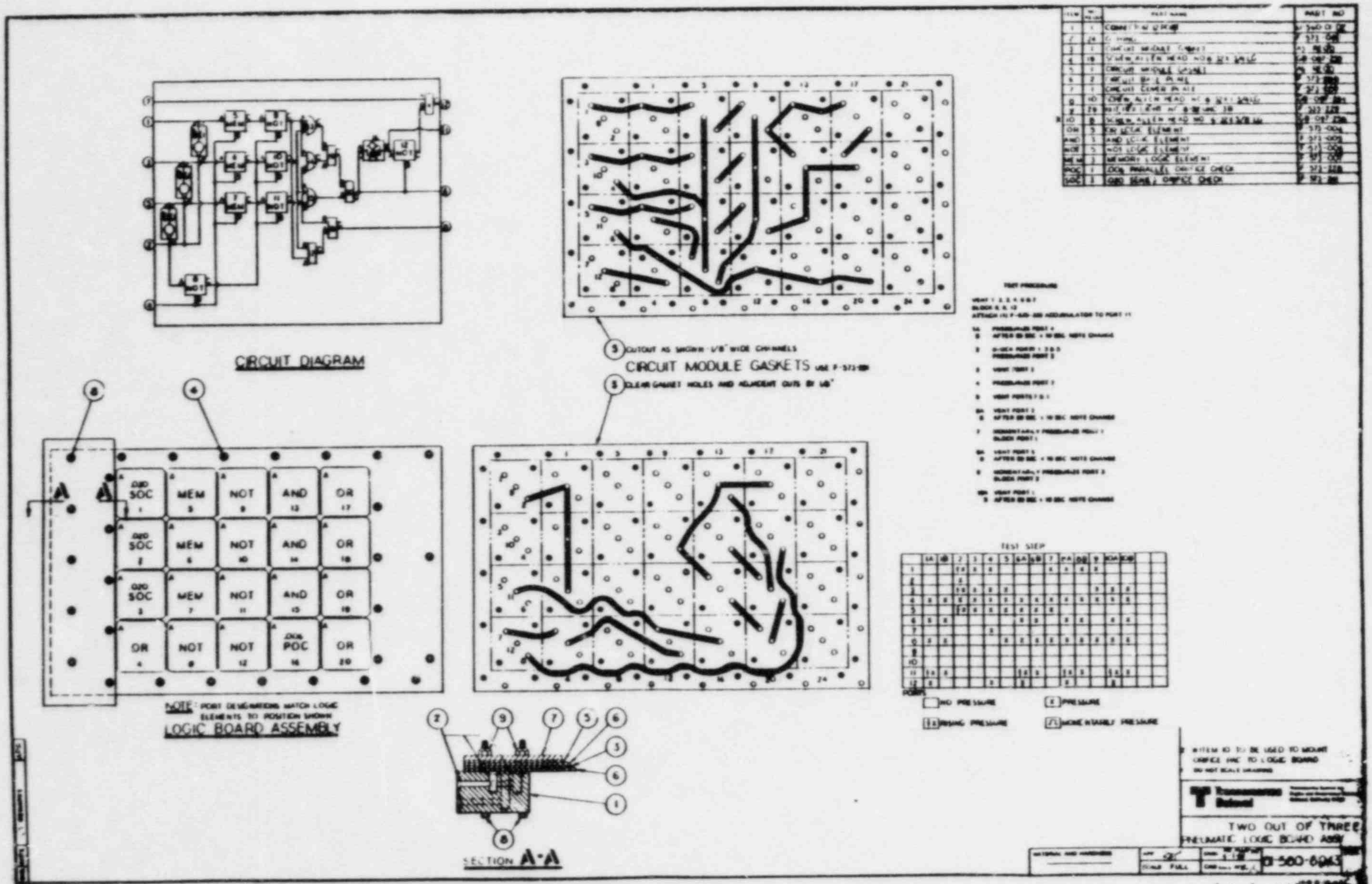
* USE GASKET ASSY 61 360 01 18

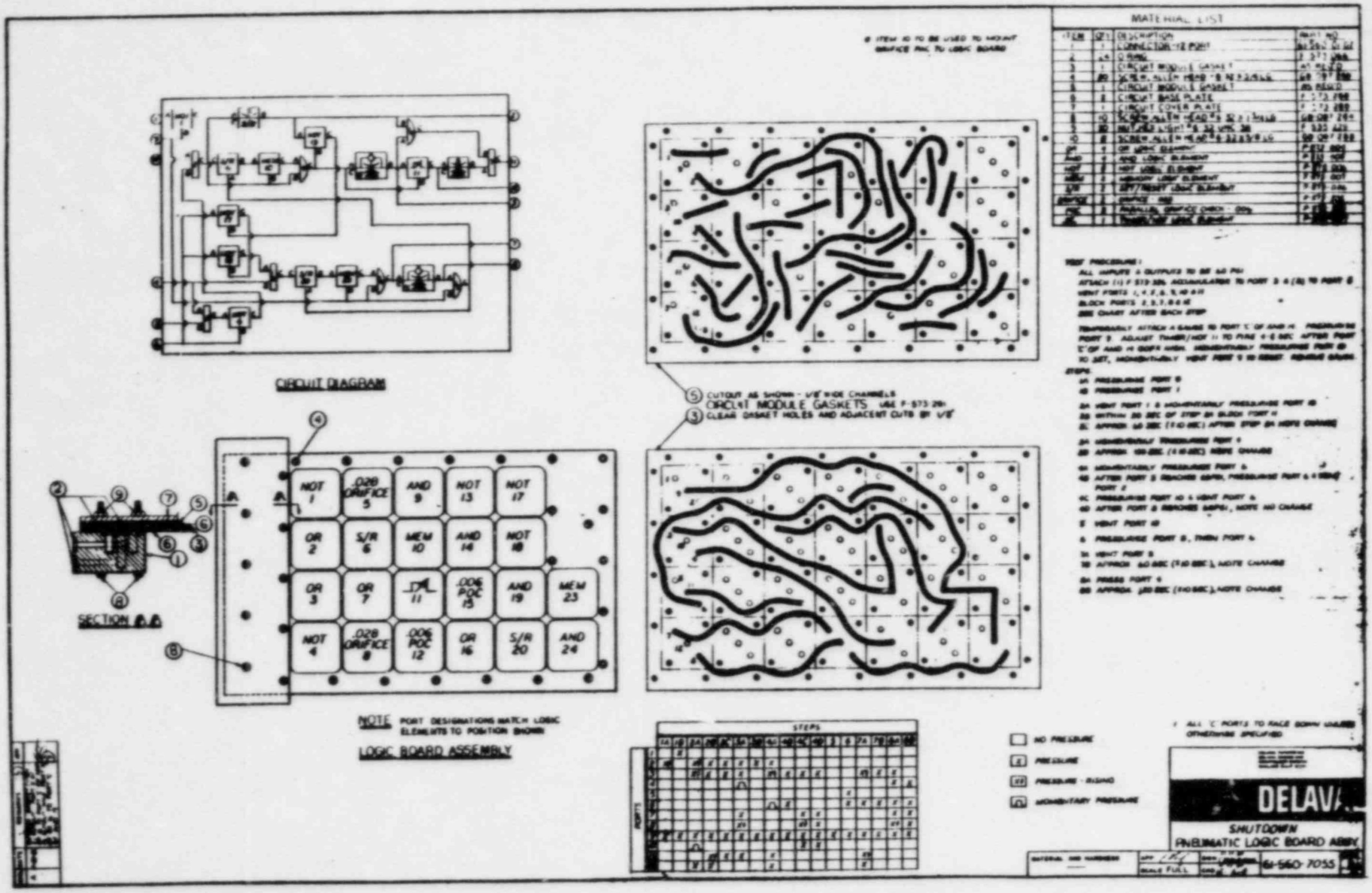
1. [illegible] ARE PLUGGED PORTS, SEE ITEM 11
2. [illegible] IS A GASKET CUT IN ITEM 9
3. [illegible] IS A GASKET CUT IN ITEM 10
4. [illegible] IS A GASKET CUT IN ITEM 9 AND ALSO IN ITEM 10
5. GASKET CUTS TO BE 1/8 WIDE AND MUST CLEAR PORTS & BOLT HOLES BY 1/8" MIN.

PNEUMATIC MOTHER BD ASSY

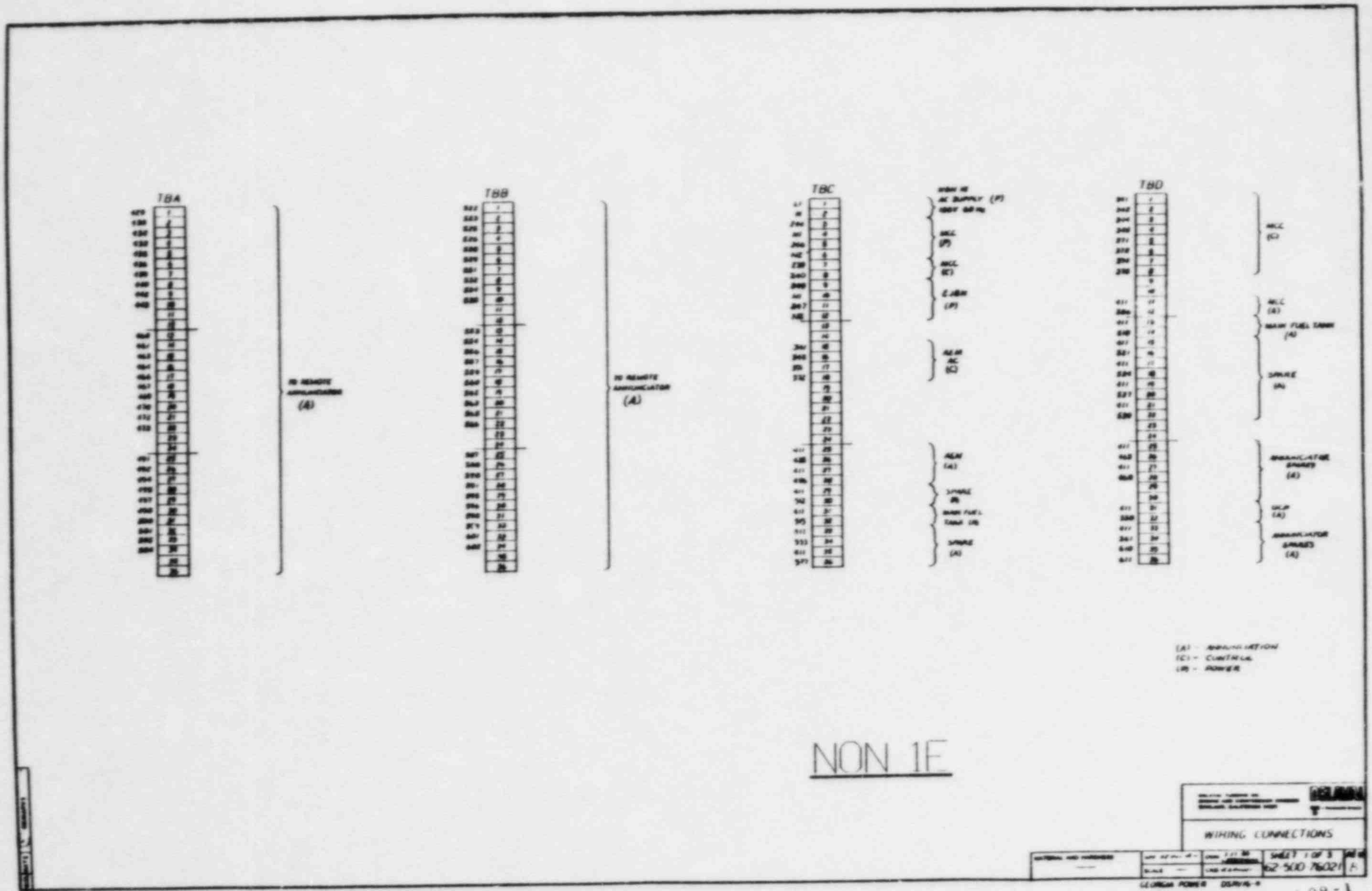
MATERIAL AND HARDNESS: SEE B/M ABOVE — SCALE FULL — 61-560-0527 — REV B

AX-ROI 507-1

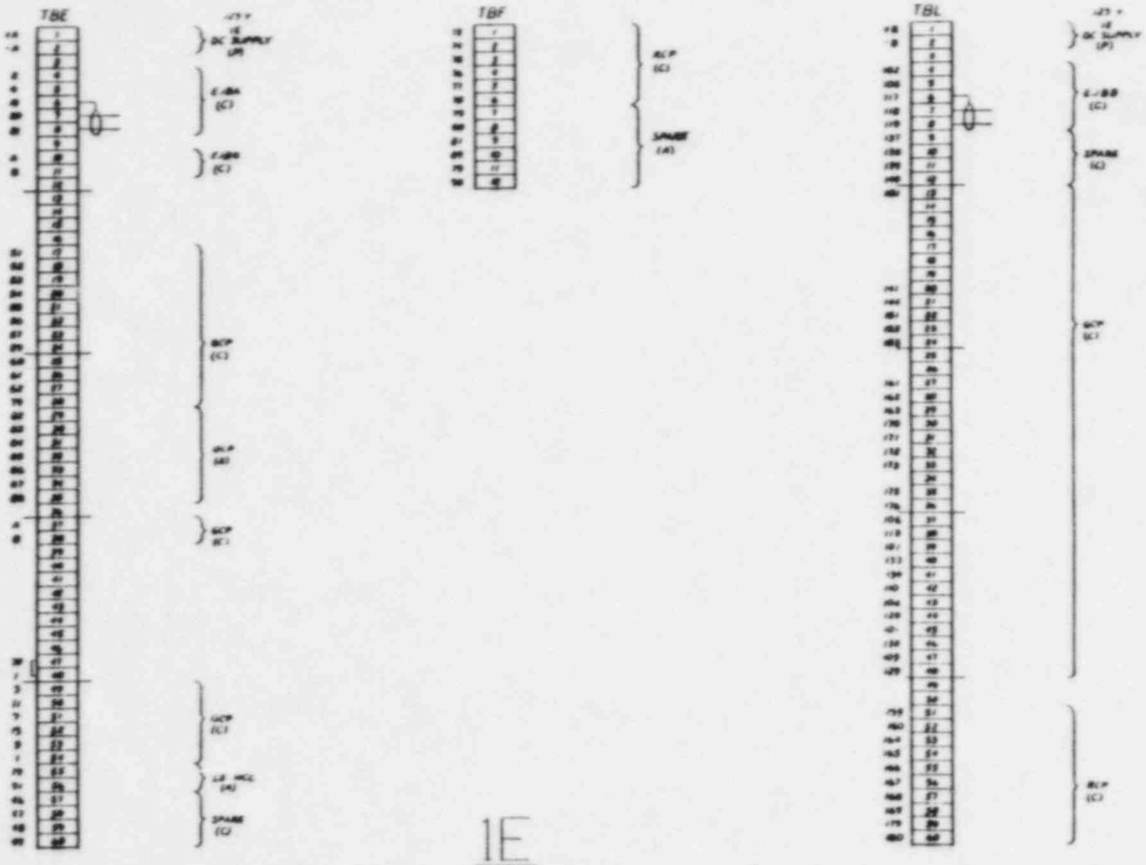

CIRCUIT DIAGRAM
CIRCUIT MODULE GASKETS
CUTOUT AS SHOWN 1/8" WIDE CHANNELS
SOC
MEM
NOT
AND
OR
POC
NOTE: PORT DESIGNATIONS MATCH LOGIC ELEMENTS TO POSITION SHOWN
LOGIC BOARD ASSEMBLY
SECTION A-A
TEST PROCEDURE
TEST STEP
NO PRESSURE
PRESSURE
RISING PRESSURE
MOMENTARILY PRESSURE
ITEM
PART NAME
PART NO
OR LOGIC ELEMENT
AND LOGIC ELEMENT
NOT LOGIC ELEMENT
MEMORY LOGIC ELEMENT
TWO OUT OF THREE
PNEUMATIC LOGIC BOARD ASSY
D-560-6063



AA4AK01-509-1

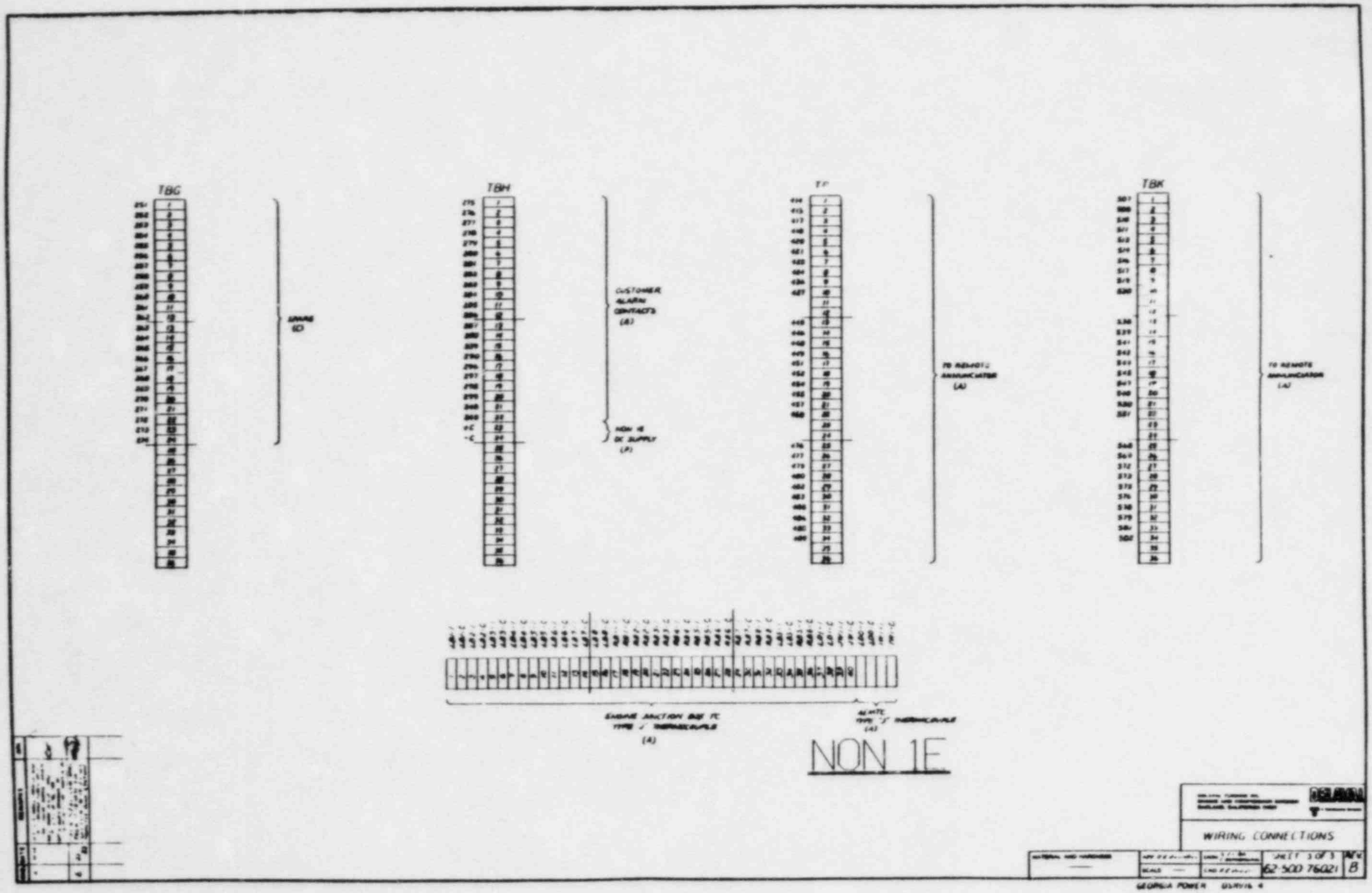


TBA
TBB
TBC
TBD
TO REMOTE ANNUNCIATOR (A)
MCC (C)
MAIN FUEL TANK (A)
SPARE (A)
ANNUNCIATOR SPARES (A)
(A) - ANNUNCIATION
(C) - CONTROL
(P) - POWER
NON 1E
WIRING CONNECTIONS
SHEET 1 OF 3
62-500-76021
GEORGIA POWER DSRV16-4

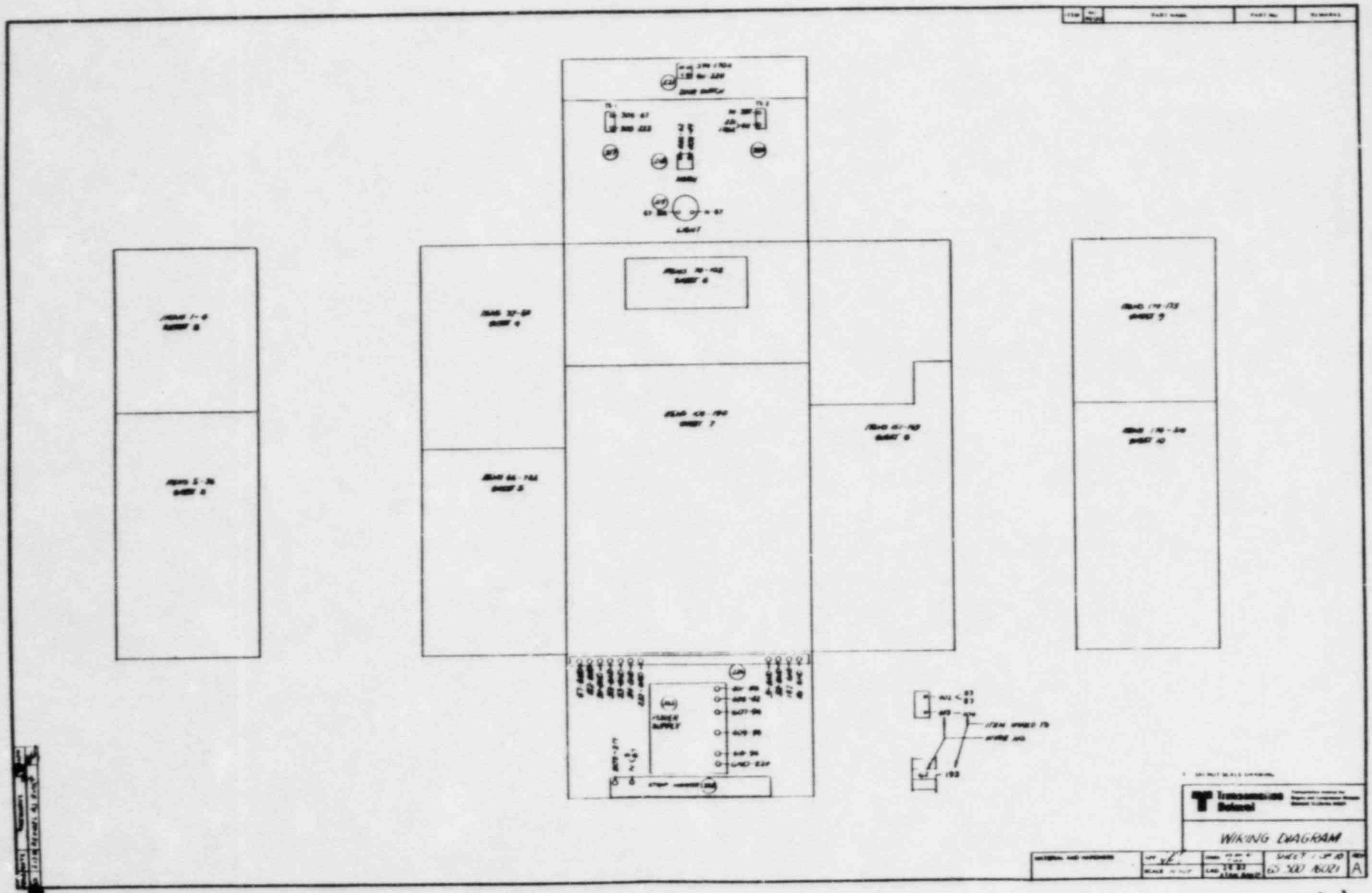


1E
NUCLEAR SAFETY RELATED

WIRING CONNECTIONS


TBG
TBH
TBK
CUSTOMER ALARM CONTACTS (A)
NON 1E DC SUPPLY (A)
TO REMOTE ANNUNCIATOR (A)
TO REMOTE ANNUNCIATOR (A)
NON 1E
WIRING CONNECTIONS
62-500 76021
B
GEORGIA POWER

509-1



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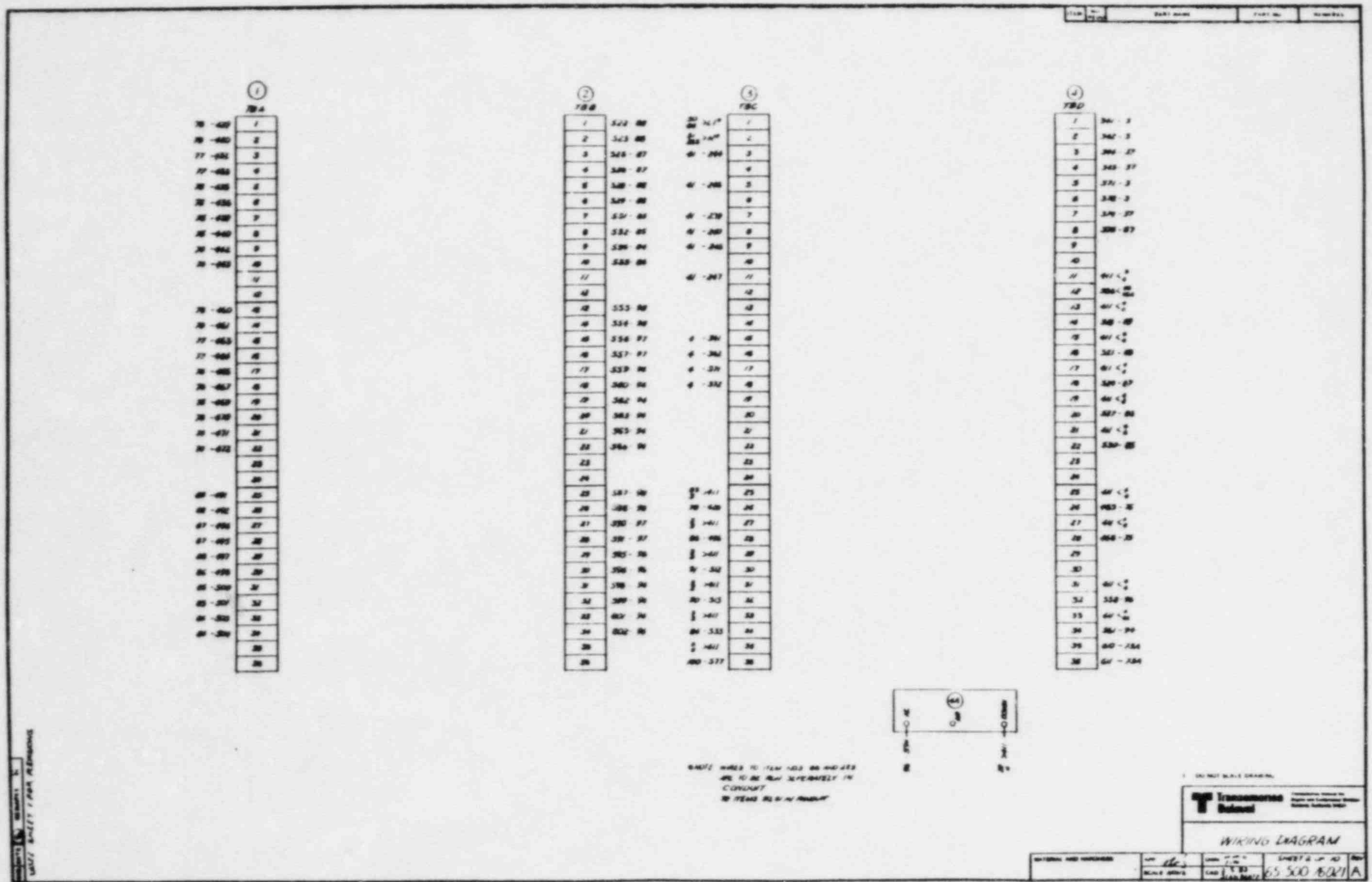

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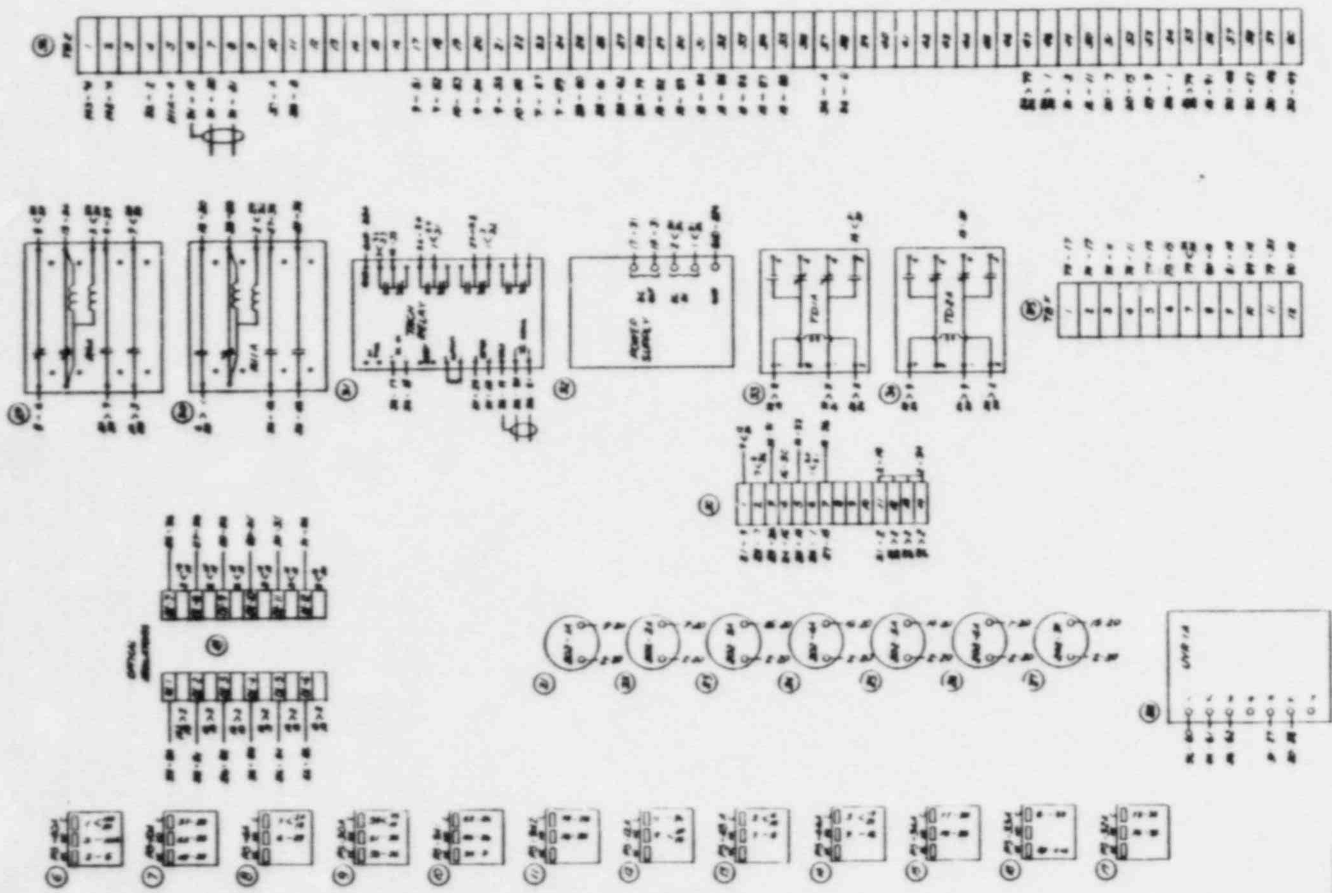

WIRING DIAGRAM

65 500-7802 A

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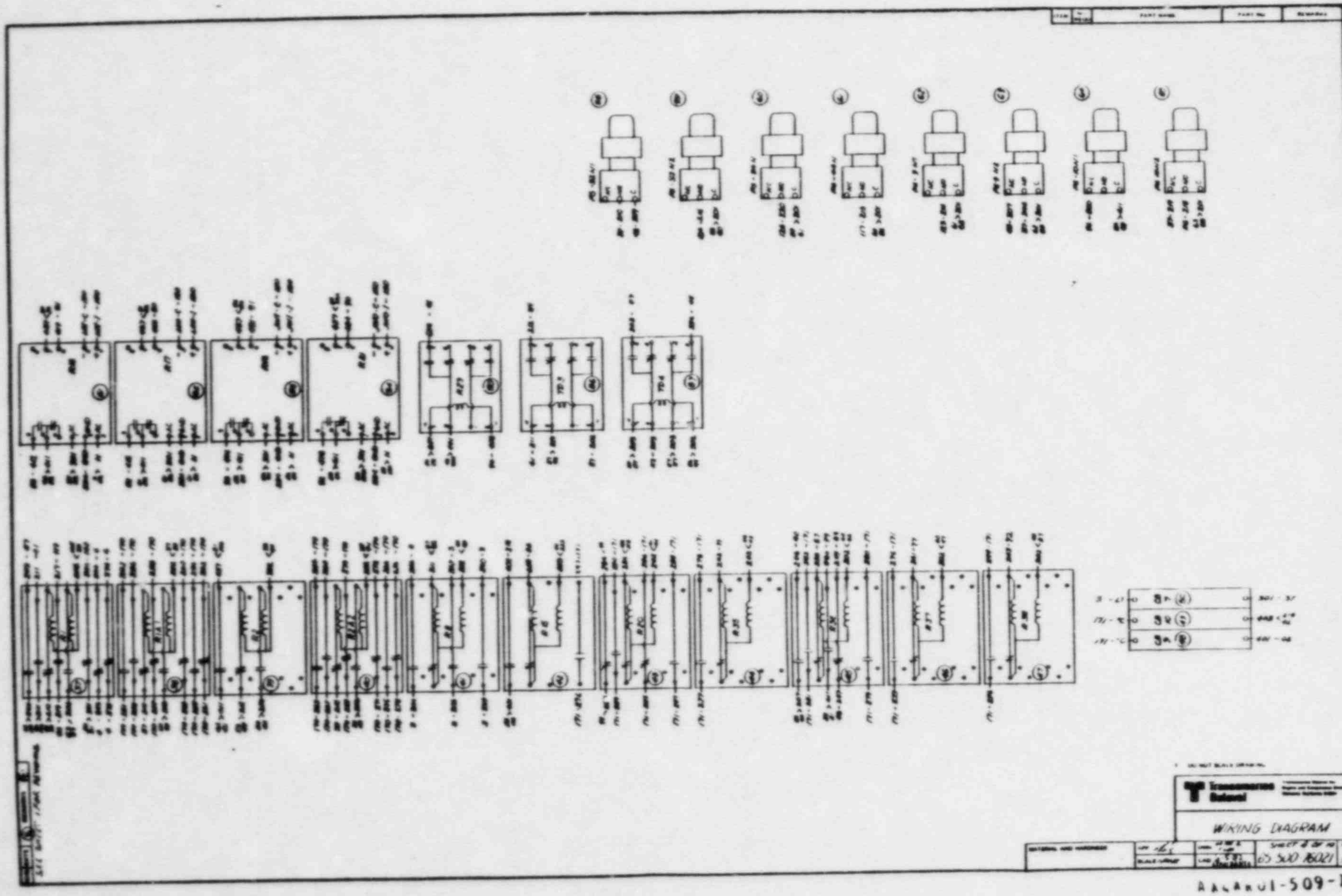

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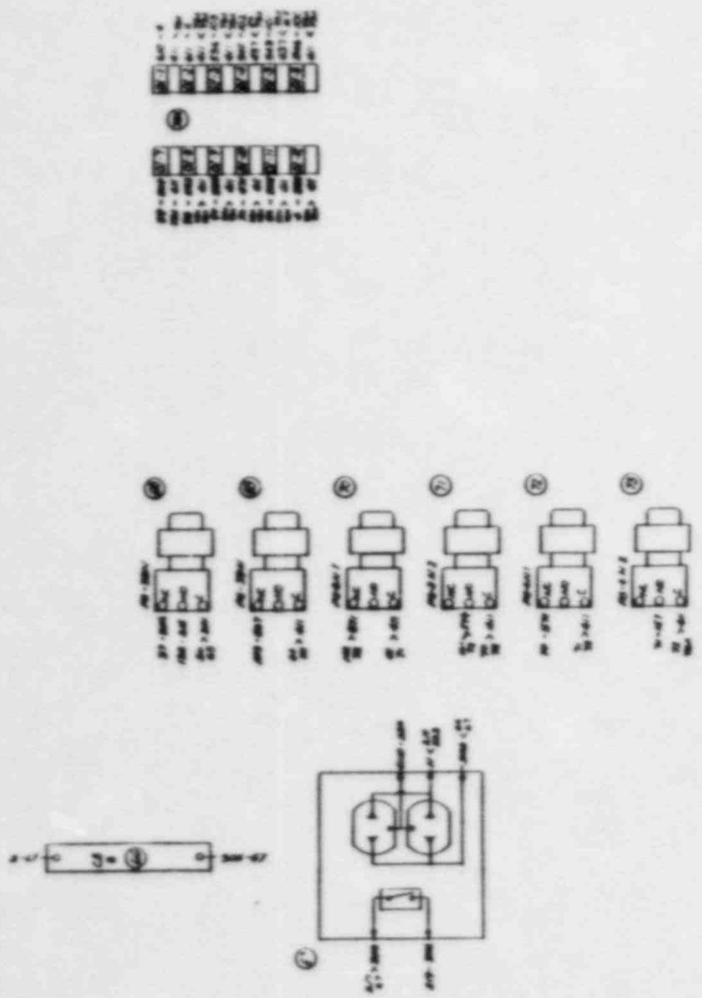
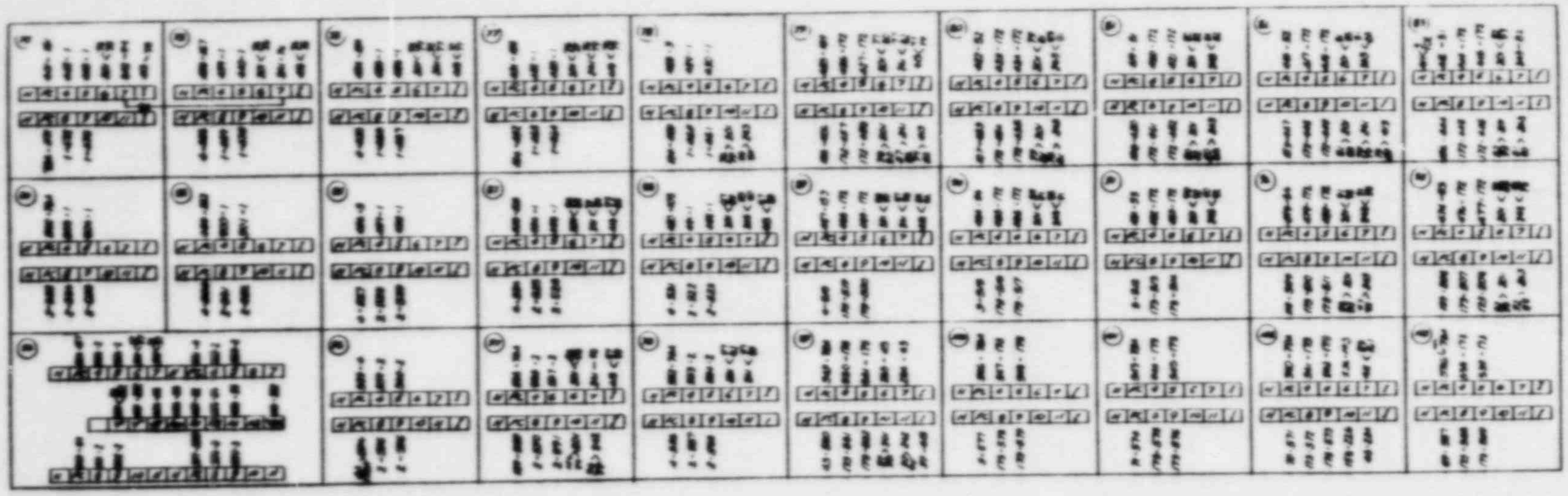


WIRING DIAGRAM

A

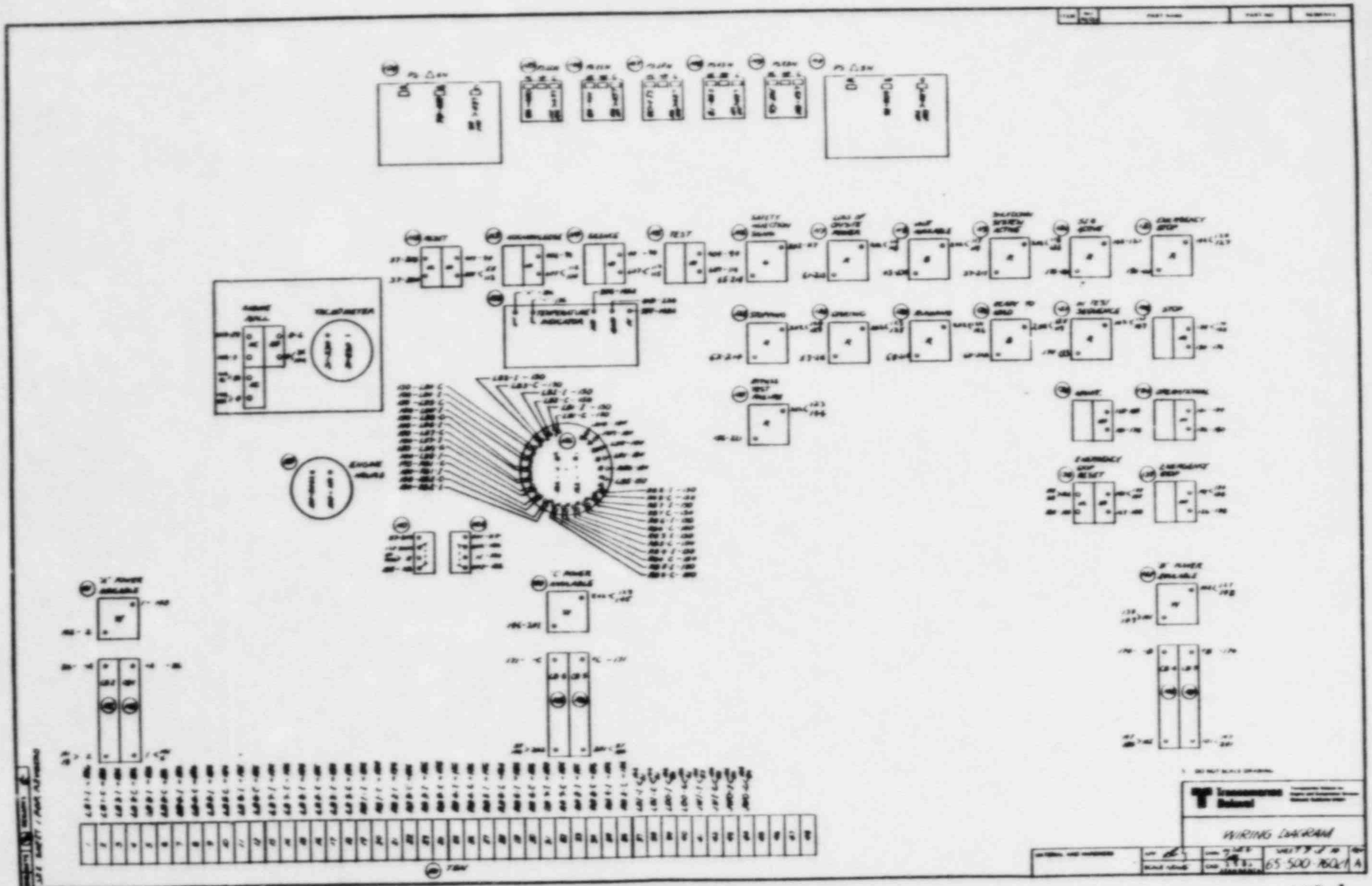
509-1



WIRING DIAGRAM

65-500-8020 A

AX4AK01-504 1



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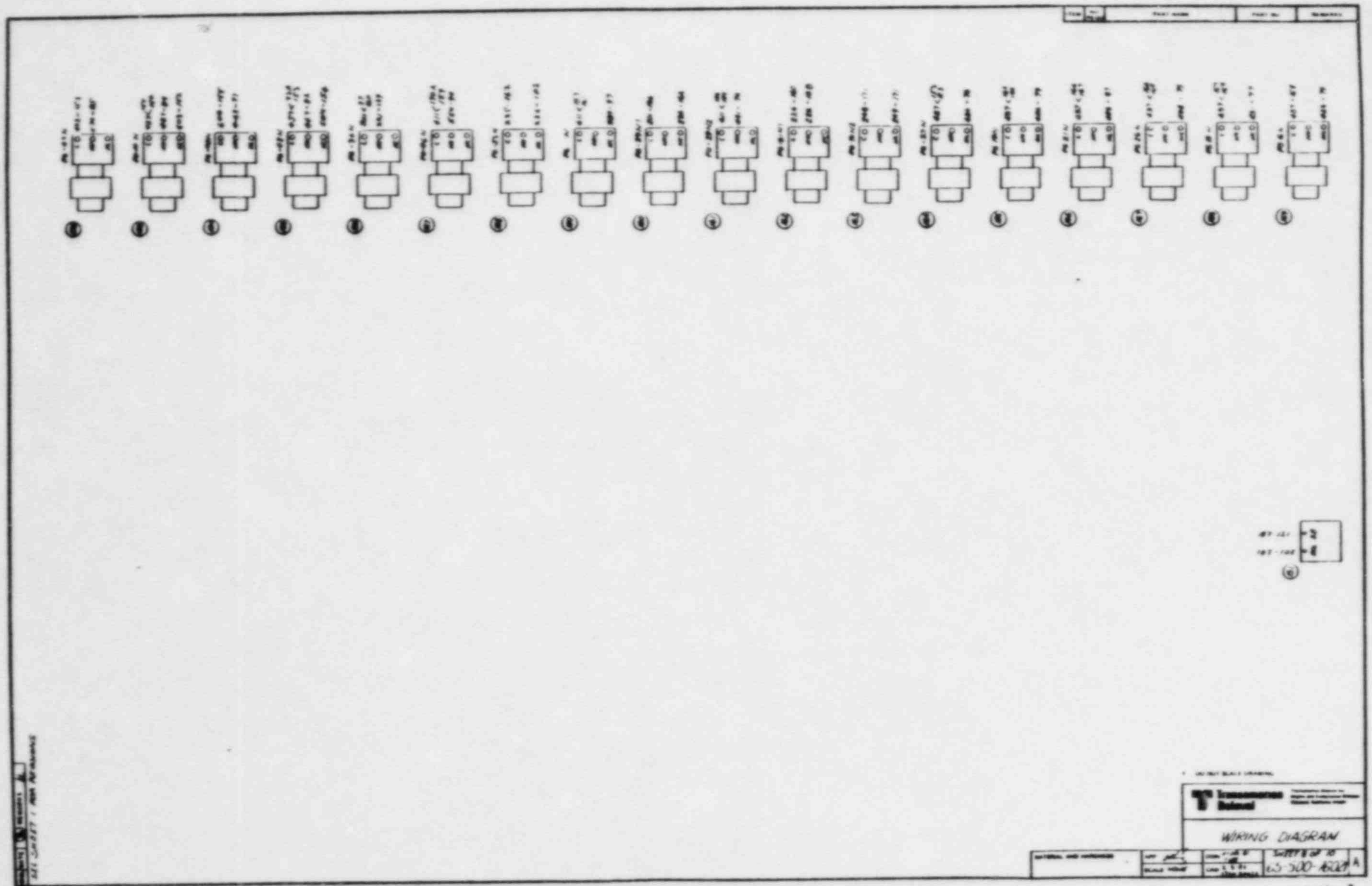

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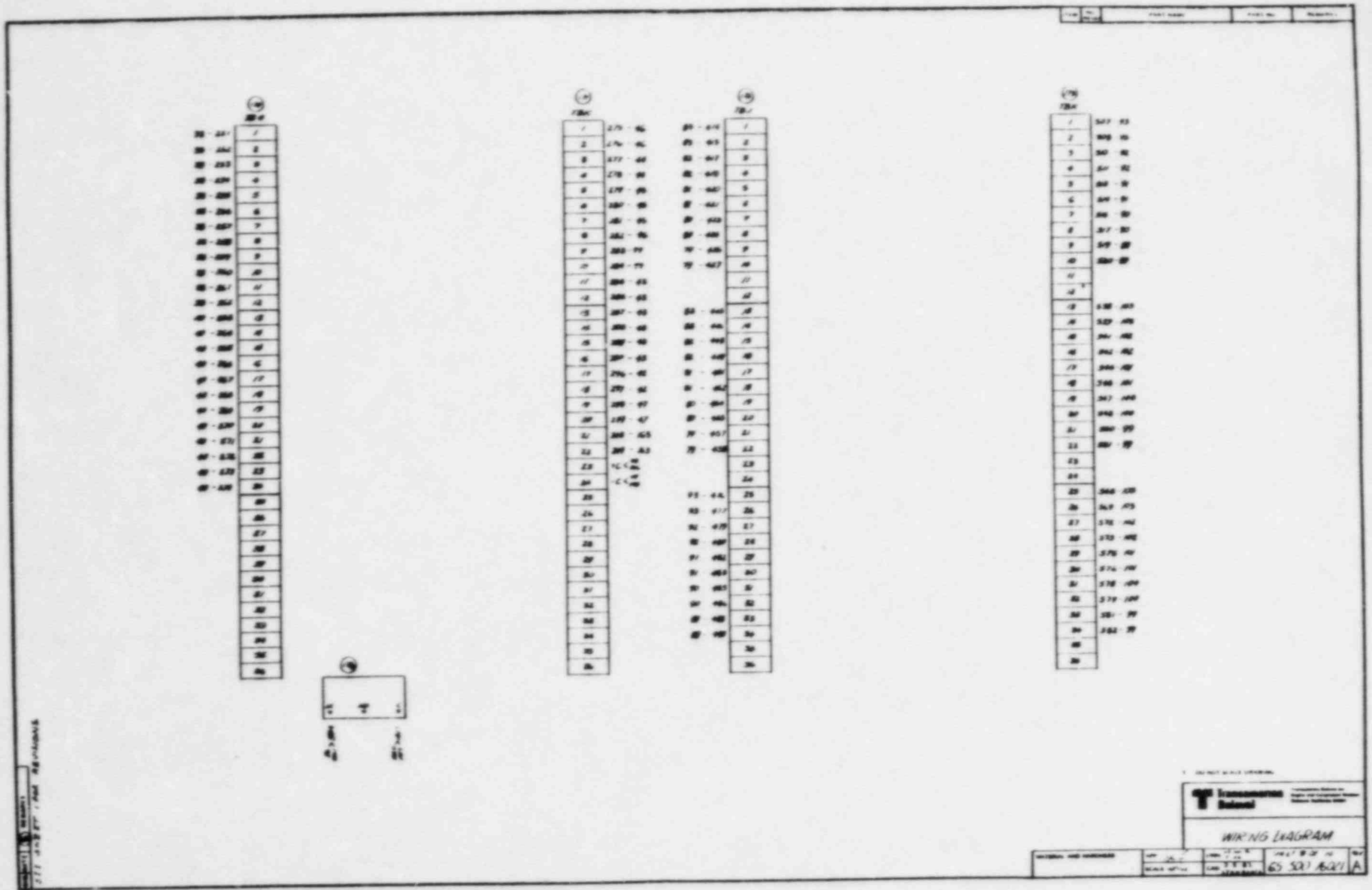

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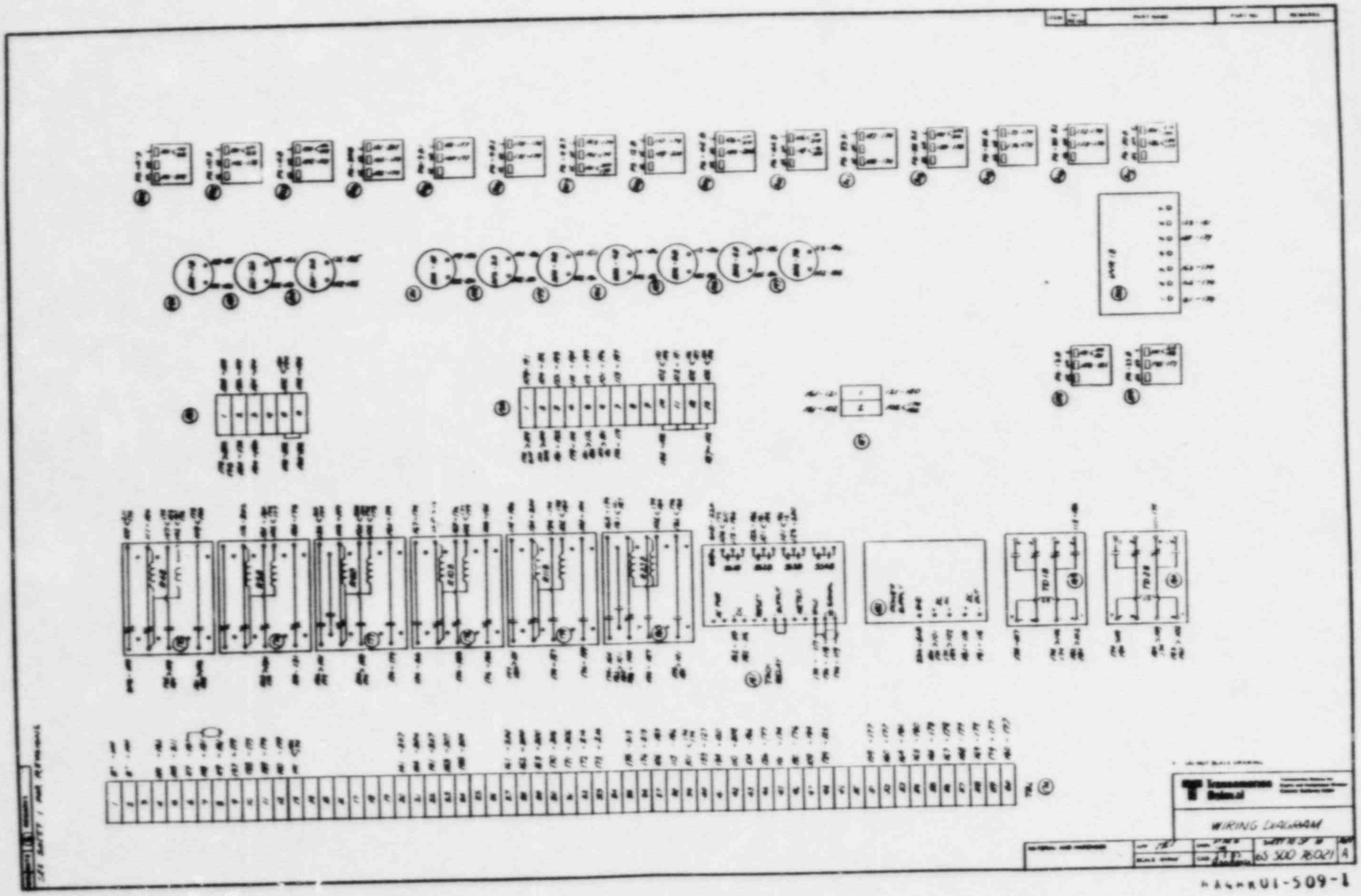

Transamerica Delaval
WIRING DIAGRAM
A

LILCO

LONG ISLAND LIGHTING COMPANY
SHOREHAM NUCLEAR POWER STATION
P.O. BOX 618, NORTH COUNTRY ROAD • WADING RIVER, N.Y. 11792

Direct Dial Number

April 27, 1984 TDI-20

H. R. Denton, Director
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

50-424/425/426/427

Dear Mr. Denton:

Your letter of February 28, 1984 requested certain information relating to the TDI Diesels from the TDI Owners' Group, the majority of which have been responded to. The last request outstanding from this letter is for a copy of the Engine Instruction Manual for each of the TDI Owners' Group Diesel Engines.

Accordingly, enclosed please find one copy each of the TDI Engine Instruction Manual for all TDI Owners' Group Diesel Engines with the exception of River Bend (Gulf States Utilities). We are attempting to obtain the Instruction Manual for this plant and will forward it to NRC on receipt. This manual is presently under revision and the copy which will be forwarded to NRC will not incorporate all changes.

As indicated on the cover of the Shoreham Instruction Manual, that document is also being revised and does not incorporate all changes. Please note that these engine manuals are continually revised to incorporate TDI recommended changes as well as utility modifications.

Very truly yours,

W. J. Museler FOR

W. J. Museler
Technical Program Director
TDI Diesel Generator Owners' Group

enclosure

RA/vf

cc: C. Berlinger
R. Caruso
W. Laity (Battelle Pacific Northwest Lab.)

B031 1/1

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