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Transamerica Delaval

UNDERGOING REVISION 4-3-84

Instruction Manual

Model DSR-48 Diesel Engine
Serial Nos. 74010-2604
74011-2605
74012-2606

LONG ISLAND LIGHTING COMPANY
Shoreham Nuclear Power Station
Unit No. 1

Transamerica Delaval Inc.
Engine and Compressor Division

SWEC J.O. NO.: 11600.02
Document No.: 1R43/1

Revision: Insert 12
March 19, 1984

TRANSAMERICA DELAVAL

INSTRUCTION MANUAL

MODEL DSR-48 DIESEL ENGINE

SERIAL NOS. 74010-2604
74011-2605
74012-2606

SHOREHAM NUCLEAR POWER STATION - UNIT 1

LONG ISLAND LIGHTING COMPANY

BROOKHAVEN TOWNSHIP, LONG ISLAND, NEW YORK

This revision to the Transamerican Delaval Instruction Manual incorporates the following E&DCRs:
F-30537, F-32015, F-33599D, F-33599F, F-34711, F-36214, F-37605, F-38251, F-38813, F-38813A, F-38813C, F-39832A, F-44681, F-44795A, F-44984, F-45031C, F-45089D, F-45416A, F-45416B, F-45486, F-45564, F-45577, F-45633, F-45802, F-45802A, F-45843A, F-46239B, F-46245, F-46325 , F-46361, F-46371, F-46372, F-46404, F-46404A, F-46404B and F-46427.

These E&DCRs have revised or incorporated the following pages in the instruction manual:
Pages: 1-3, 2-4, 2-4-A, 2-4-B, 3-4, 3-5, 4-7, 4-8, 5-B-2, 5-B-3, 5-B-4, 5-B-5, 5-B-6, 5-D-12, 6-B-3, 6-B-3-A, 6-B-4, 6-B-5, 6-B-6, 6-B-7, 6-B-8, 6-D-2, 6-D-2-A, 6-D-2-B, 6-F-2, 6-F-3, 6-H-1, 6-H-2, 6-I-1, 8-3, 8-3-A, 8-4, 8-4-A, 8-5, 8-5-A, 8-5-B, 8-8, 8-11C and 8-11D.

Drawings: 52071, 52075, 61-560-7096 and 100399 and 100404.

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SHOREHAM NUCLEAR POWER STATION - UNIT 1

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The following Engineering and Design Coordination Reports have been issued against the Transamerica Delaval Instruction Manual (1R43/1 Vol I), but are not required to be incorporated::

E&DCR	Description
F-32015A	Incorp. E&DCR F-32015 into manual
F-33599	Latest torque values (1979)
F-33599A	Latest torque values (1980) (Flywheel torque decreased)
F-45416	Replace Rocker Arm Tube Plugs

ENGINE DATA

MODEL	DSR-48
SERIAL NUMBERS	74010-2604, 74011-2605, 74012-2606
FUEL	DIESEL
TYPE INSTALLATION	STATIONARY - NUCLEAR STANDBY
CONFIGURATION	IN-LINE
NUMBER OF CYLINDERS	8
BORE	17 IN.
STROKE	21 IN.
CYCLES	FOUR
BMEP	225 PSI
HORSEPOWER	4889
RATED SPEED	450 RPM
ROTATION	CLOCKWISE - VIEWED FROM FLYWHEEL END
STARTING SYSTEM	PILOT AIR - GEAR DRIVEN DISTRIBUTOR
FIRING ORDER	1-4-7-3-8-5-2-6
DISPLACEMENT PER CYLINDER ..	4766.6 CU-IN.
TOTAL DISPLACEMENT	38,133 CU-IN.
FLYWHEEL DIAMETER	73 IN.
FUEL INJECTION TIMING	23° (14.65 IN.) BEFORE TOP DEAD CENTER
FUEL INJECTION PUMP RACK ...	REFER TO ENGINE NAMEPLATE
VALVE CLEARANCE	N/A (HYDRAULIC VALVE LIFTERS)

NOTES: REFER TO ENGINE NAMEPLATES FOR FIRING ORDER AND FUEL PUMP RACK SETTINGS AT FULL LOAD.

REFER TO APPENDIX X IN SECTION 8 FOR COPIES OF THE FACTORY TEST LOGS AND A SUMMARY OF FACTORY TEST RESULTS.

ALWAYS INCLUDE SERIAL NUMBERS WHEN COMMUNICATING WITH TRANSAMERICA DELAVAL INC., ENGINE AND COMPRESSOR DIV. CONCERNING ENGINE PERFORMANCE.

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Section 5 — Inspection and Maintenance

Section 6 — Overhaul and Repair

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Section 6 — Overhaul and Repair (Continued)

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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.

Instruction Manual

Changes

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

Comments:

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.

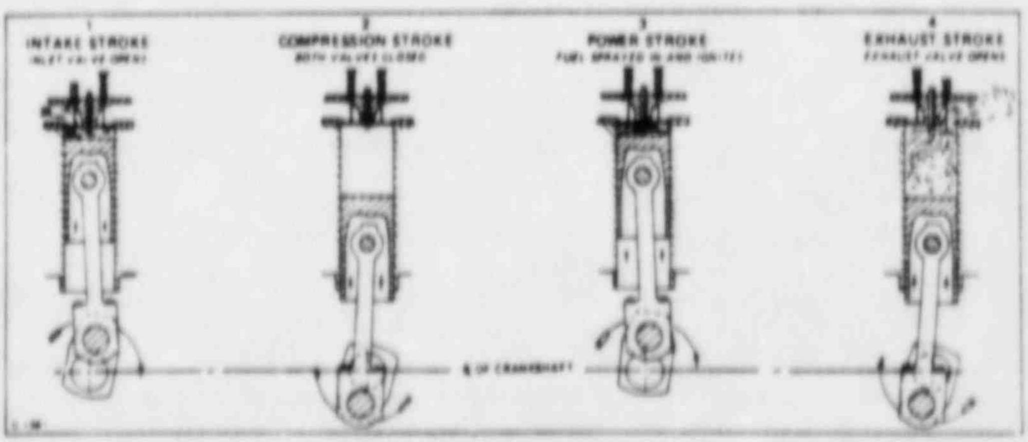

Figure 1-1. Diagram of Working Principle

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 scavange 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 R engine is a four-stroke-cycle, turbocharged, aftercooled, inline diesel engine, built in an 8 cylinder arrangement. Trunk-type pistons, removable wet-type cylinder liners, pressure lubrication and mechanical fuel injection are features of the R 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 maximum thermal efficiency. A gear-driven starting air distributor provides a timed distribution of pilot air to open the air start valves, permitting the engine to be started cold in a few seconds with a ~~250~~ *120 psi starting air supply. Engine ⚠ rotation and cylinder designation are determined while facing the engine at the flywheel end, number one cylinder always being the farthest from the flywheel.

NUCLEAR POWER STANDBY SERVICE.

The engines furnished the Long Island Lighting Company's Shoreham Nuclear Power Station, Unit No. 1 are designed to operate in case of a complete loss of normal and reserve station auxiliary power to supply emergency power to vital equipment. Each engine-generator set is a complete unit, embodying the engine, generator and the basic accessories mounted on a rigid common sub-base. Each engine-generator set is capable of being started either manually, or automatically by electrical signal without local attendance.

* Ref. E&DCR F-36214

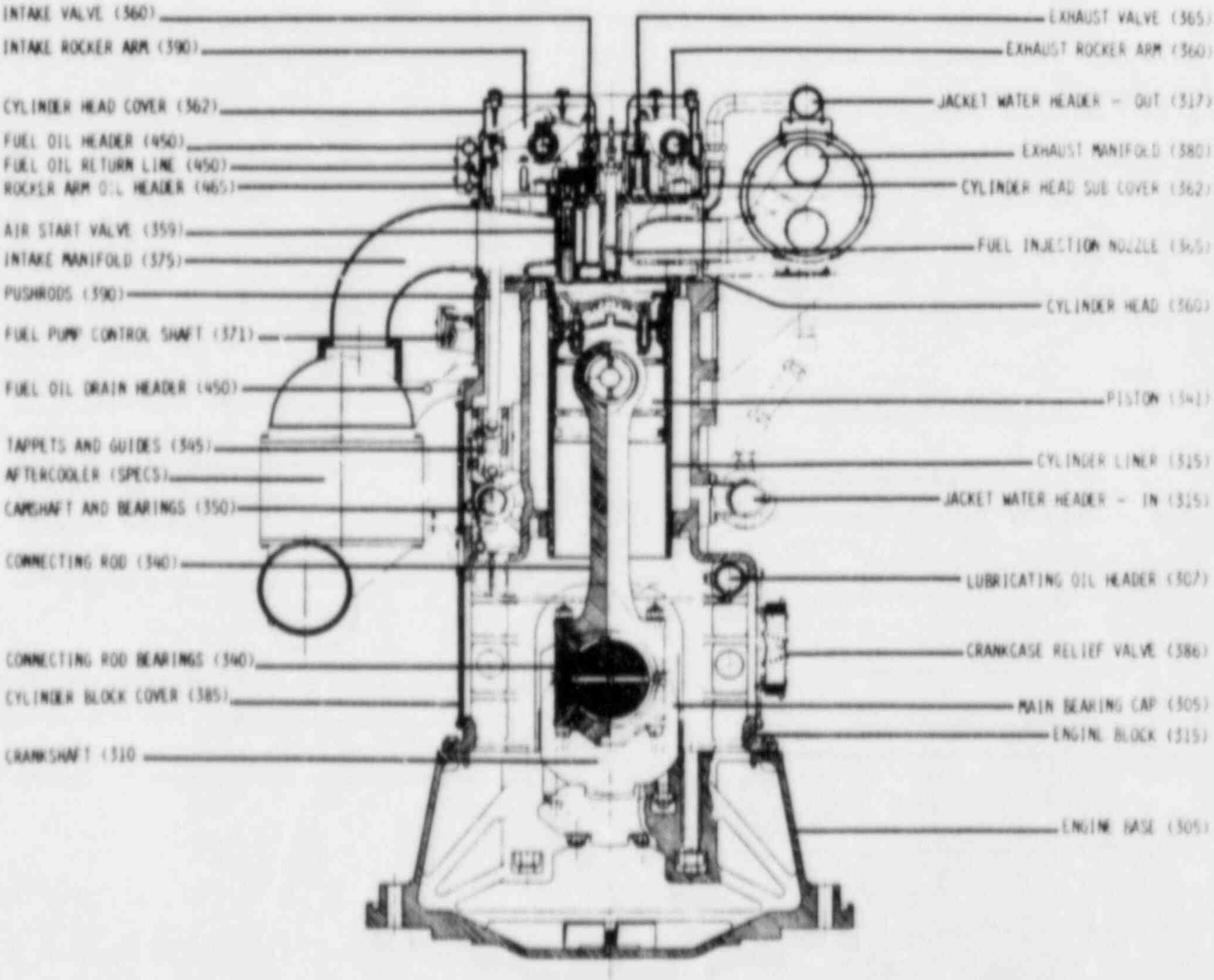

Figure 1-2. Cross Section, Typical Model R-4 Diesel Engine

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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.

R/RV 79

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.

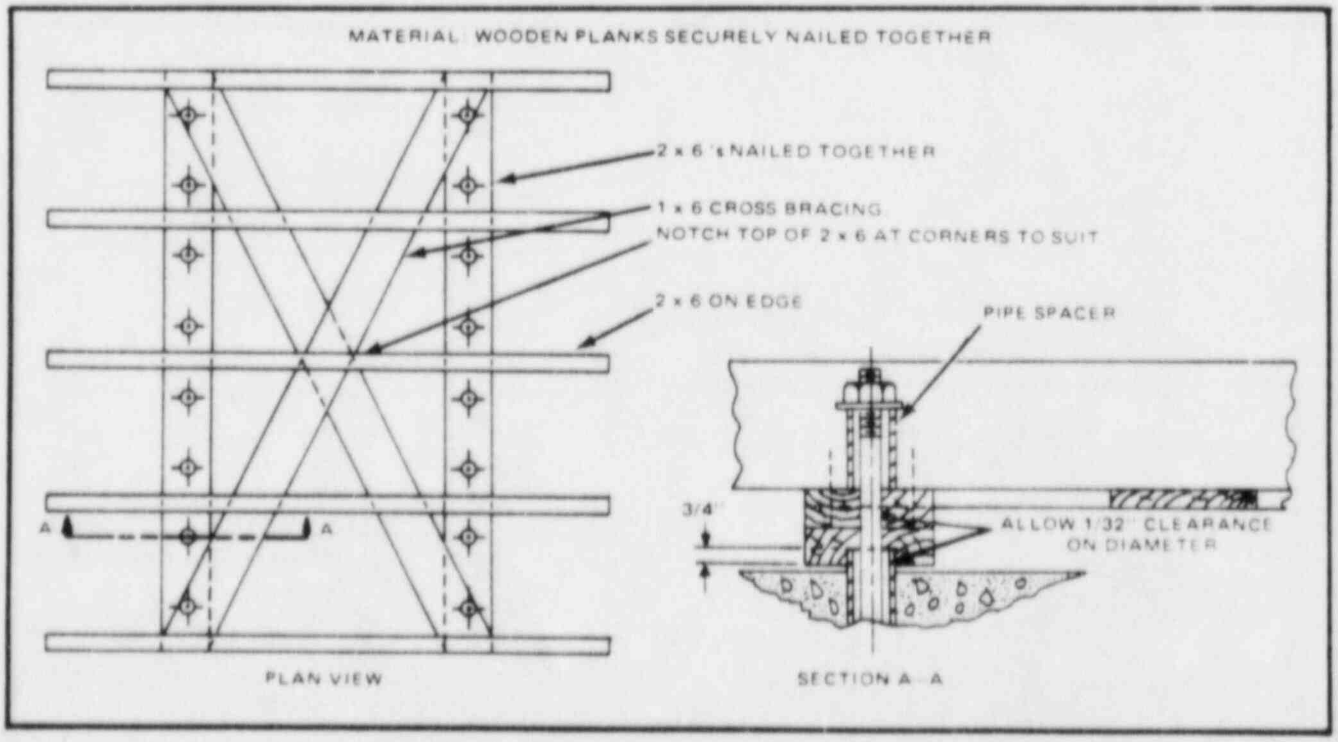


Figure 2-1. Suggested Foundation Bolt Template

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.

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.

MOUNTING FLYWHEEL AND CONNECTI:IG 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. The mating surfaces of the flywheel and the flange must be free of all lubrication. Maximum friction is required for power transmission.

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, 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.

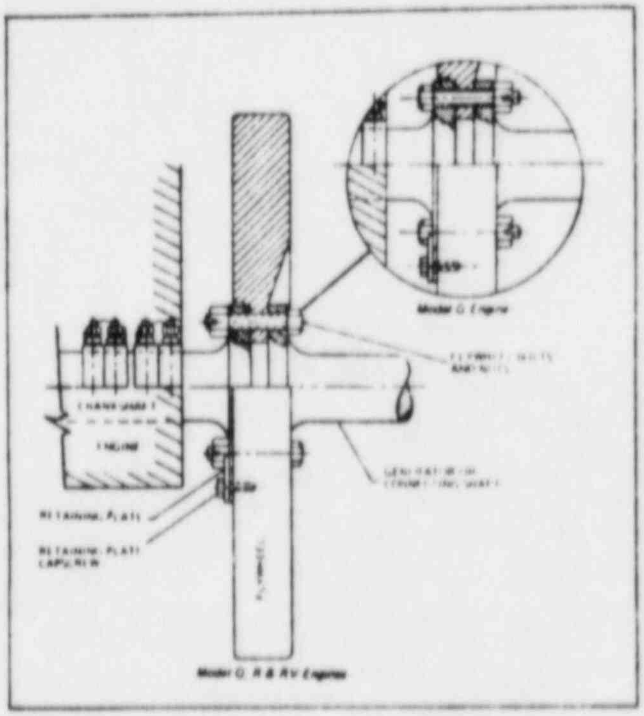


Figure 2-2. Flywheel Mounting

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 and service information memo No. 640. *

*Ref. E&DCR F-38813A
**Ref. E&DCR F-46404B

SUBJECT: FLYWHEEL BOLT, TORQUE INCREASE

AFFECTED ENGINES:

DSR-36 & 46	DMR-36 & 46	DCSR-36 & 46
DSR-38 & 48	DMR-38 & 48	DCSR-38 & 48

DESCRIPTION:

1. The torque on the flywheel bolt nut, on all Model "R" engines, has been increased to 3000 ft/lbs (from a previous torque of 2000 ft/lbs).

METHOD:

1. Untorque each nut in its turn.

2. Clean the bolt threads and the flywheel face.

3. Lubricate the bolt thread with a 50-50 mixture of engine lube oil and powdered graphite.

4. Make a wrench (see Figure 1) to fit the nut.

   4.1 Use an overhead chainfall or come-along to torque the nut, measuring torquing with a Dillon dynamometer.

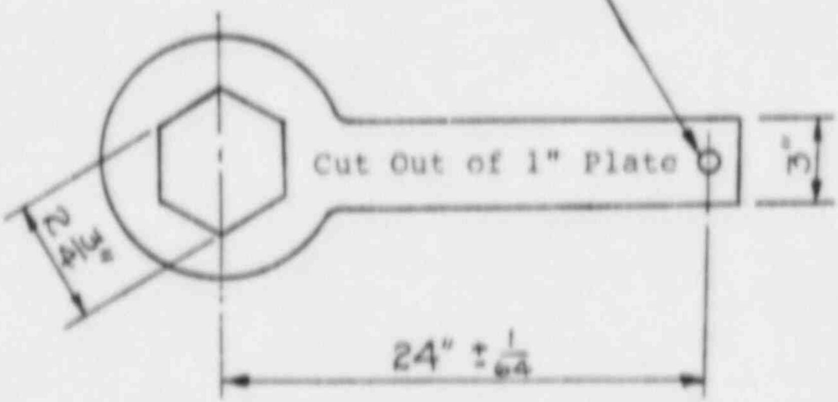
      4.1.1 The Customer Service Department has Dillon dynamometers for rent, as per S.I.M. 209.

5. Torque the nuts to 3000 ft/lbs, in four equal lifts (750, 1500, 2250, 3000) using a criss-cross pattern.

PURPOSE:

1. This torque increase is designed to improve the bolted joint integrity between the engine crankshaft flange and the flywheel.

RECOMMENDED WRENCH



TORQUE CALCULATION:

Torque required = 3000 ft/lbs

Using a wrench length of 24", the reading required on the Dillon Dynamometer for 3000 ft/lbs is:

$\frac{12}{24}$ x 3000 = 1500 lbs.

(750 ft/lbs = 375 lbs; 1500 ft/lbs = 750 lbs;
2250 ft/lbs = 1125 lbs)

2-18-82	Andrew Rush	Subject	FLYWHEEL BOLT TORQUE R ENGINES
	R Pratt 2/18/82		MEMO NO. 640 Pg 2 of 2

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.

PIPING SYSTEMS.

Transamerica Delaval Engine and Compressor Division furnishes suitable piping diagrams to the purchaser or his design agent, recommending minimum pipe sizes for all service lines. In addition, the following should be observed in the fabrication and installation of piping not furnished with the unit, but procured from other sources.

a. Piping must never cause deflection in the mounting of reciprocating or rotating auxiliary equipment, nor should heavy auxiliary equipment ever be supported by service piping.

b. Whenever there is a possibility of deflection, flexibility must be designed into the piping.

c. Chill rings should not be used in welded pipe joints as they tend to retain scale, welding slag and beads which can come loose as the pipe becomes hot during operation.

TREATMENT OF PIPING.

It is strongly recommended by Transamerica Delaval Engine and Compressor Division that all lubricating oil and fuel gas system piping be pickled by a company specializing in this kind of work. Such a company will have the necessary equipment and possess the technical knowledge to completely clean and prepare the pipe for service. Piping which is furnished by Transamerica Delaval Engine and Compressor Division with the unit will have been pickled at the time of fabrication. All piping procured from other sources should be pickled and prepared as follows:

a. Accessible welds inside carbon steel pipes and fittings must be visibly inspected and the welding beads ground off. All fabricated steel pipes, valves and fittings must be blown clean with steam or air to remove loose scale, sand and welding beads, and be cleaned by the following procedure before the pickling process.

(1) Wirebrush the entire surface, including the interior with boiler tube brushes or a commercial pipe cleaning apparatus, then blast thoroughly with air to remove loose particles.

(2) Depending on the degree of contamination, submerge parts for 15 minutes or longer in a solution containing seven to ten ounces of anhydrous trisodium phosphate or sodium hydroxide and one ounce of detergent, Military Specification MIL–D–16791 to one gallon of water at 200° F (93.3° C) to insure complete removal of paint and grease.

(3) Rinse parts in warm, fresh water at 120° F (48.9° C) to prepare them for the acid treatment.

(4) Pickle fabricated carbon steel pipes and fittings by submerging them for 30 to 45 minutes in an acid bath containing one part of sulphuric acid, 66° Baume to 15 parts fresh water, supplemented with an inhibitor. The acid bath must be maintained at a temperature between 160° F (71.1° C) and 180° F (82.2° C). While the parts are submerged, agitate the bath. At the end of the pickling procedure, rinse parts in warm, fresh water. After the rinse the parts must be momentarily submerged in a cooling solution containing four ounces of sodium carbonate per gallon of water, then rinsed in cold fresh water and dried by air blast.

b. Immediately following pickling and rinsing, coat both the inside and the outside of the fabricated steel pipes and fittings with a rust and corrosion preventive compound and seal the ends to prevent entry of dirt. The compound must be soluble in the lubricating oil that will be used, and compatible with it so as not to contaminate the oil. Ordinary lubricating oil will not prevent rust in the pipes. Mechanical cleaning will not completely clean the pipes, therefore, this method is not acceptable. Apply the compound by spraying or flooding the pipes—swabbing with rags or mops will leave lint.

Note

The above procedure is a minimum requirement to produce acceptable clean piping. Substitute methods may produce pipes and fittings of equal or better cleanliness.

JACKET WATER SYSTEM (See Figure 2-3).

The jacket water system is individual for each engine, and in addition to its normal cooling function, it provides the means for keeping the engine in a warmed condition during standby service. The engine-driven jacket water pump draws water from the standpipe and discharges it to a thermostatic valve where it is either directed through the jacket water cooler, or diverted directly to the lubricating oil cooler. After passing through the lubricating oil cooler, part of the water is passed through the intercooler and the remainder is bypassed directly to the engine jacket water header. Flow return is to the standpipe. When the engine is in a standby status, a jacket water circulating pump draws water from the jacket water heater in the standpipe and directs it through the lubricating oil cooler thence through the normal circulation paths through the intercooler and the engine and back to the standpipe. Refer to the jacket water schematic piping diagram in the drawing section of this manual for the relative location of all components, and for pipe sizes and direction of flow.

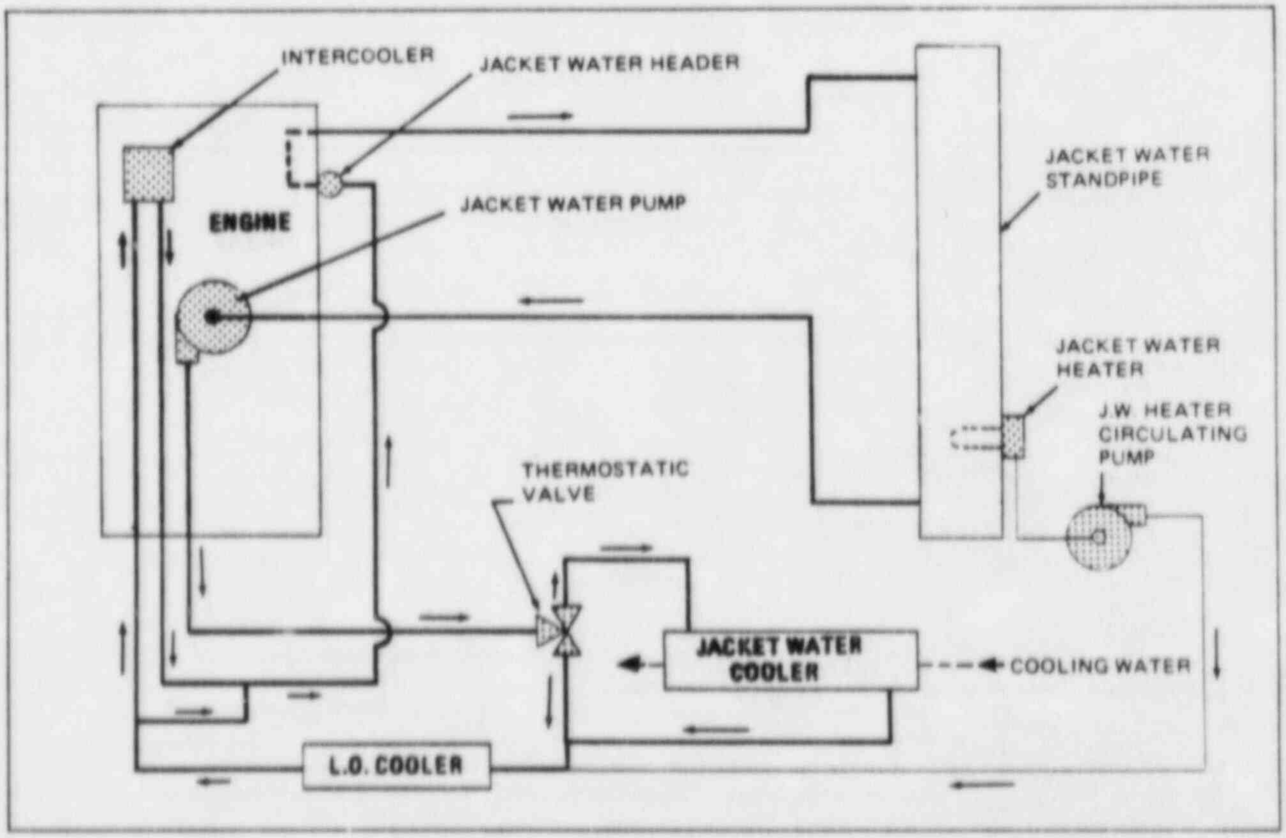


Figure 2-3. Jacket Water Piping System

COOLING WATER SYSTEM.

The cooling water system provides a cooling medium for the jacket water cooler. Cooling water is pumped from its source through the jacket water cooler. Temperature control of the cooling water is not provided.

INTERCOOLER LINES.

The intake air cooler (intercooler), located between the turbocharger air discharge and the intake air manifold, utilizes jacket water as the cooling medium.

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~~ to 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.

Disconnect the jumper tubes between the engine lubricating oil header and the main bearings, and between the 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 aftercooler, an air dryer and two storage tanks. Each storage supply is then piped to a solenoid valve which blocks the supply 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 starting air header. Pilot air is provided through the starting air distributor which then sends 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. Reference should be made to the starting air piping schematic in the "Drawings" section for complete details of the system, including the relative location of components and installation notes.

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Section 3
Engine Controls

GENERAL.

The control system is a electro-pneumatic network which provides the means for starting, operating and stopping the unit from either a local or remote position. Local starts are manual while remote starts may be either manual or automatic. The pneumatic portion of the system uses air as the control medium and utilizes pneumatic logic elements as well as pilot and manually operated valves, regulators, transmitters, indicators and other pneumatic control devices. The electrical components include relays, timers, solenoid valves and pressure switches. The starting circuitry is redundant, designed to permit a start even though one portion of the starting system may fail to function properly.

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 various logic elements as well as a parts breakdown and repair procedures. When ordering spare and 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 and connections pertaining to the logic board assembly, showing the location and orientation of the components on the board, the circuit diagram and checkout procedures. Refer to the control panel group parts list 08-500 for 74010 in the *Parts Manual* for a listing of drawings applicable to the system.

ALARM SYSTEM.

The engine is equipped with an alarm system that provides a visual indication when certain abnormal conditions are present. If one of the alarm or shutdown sensors in the system is activated by an abnormal condition, an indicator on the control panel is illuminated.

CONTROL PANEL (See Drawing 52070).

The engine control panel houses the components of the control system which are not engine or remotely mounted. Access to the cabinet is through a hinged door in the back. The functions of the items on the panel are generally self-explanatory.

OPERATION.

The engine may be started in the manual mode, either locally or from a remote position, and automatically from a remote position only. The mode selector switch on the engine control panel has three positions, LOCKOUT, REMOTE and LOCAL. When the mode selector is in the LOCKOUT position, a 60 psi air signal is applied to Port 5 of the Shutdown Logic Board (1, Dwg. 52071) and also locks the engine out by applying a 60 psi signal to line E-89, causing the shutdown cylinder (16, Dwg. 52075) to extend and prevent fuel rack movement. When the mode switch is in the REMOTE position, the engine may be manually started by actuating the remote manual pushbutton, and the LOCAL mode position permits starting from the engine control panel. Automatic starting may be accomplished with the mode selector in either LOCAL or REMOTE.

LOCAL MANUAL START (See Drawing 52072).

When the mode selector is in the LOCAL position, actuation of the local start pushbutton on the engine control panel will cause relays R4 and R7 to energize, closing their normally open contacts. At the same time, time delays TD1 and TD2 commence timing. Relays R4 and R7 energize solenoid valve SOL-3 which then supplies a 60 psi signal at Port 12 of the Shutdown Logic Board, 1A-5907 (1, Dwg. 52071) and there is an output from ports 2, 9 and 10 of the board. Relays R4 and R7 also energize solenoid valves SOL-1 and SOL-2 which admits starting air to the header on the engine (14, Dwg. 52075) and the engine cranks. Starting air is reduced to 60 psi by a relieving regulator (10, Dwg. 52075)

No.	Pressure	Contacts	Function
PS-3	35 psi falling	N.O.	Low lubricating oil pressure
PS-4	20 psi falling	N.O.	Low turbocharger oil pressure
PS-5	15 psi falling	N.O.	Low fuel oil pressure alarm
PS-5A	25 psi rising	N.C.	Fuel oil boost pump control
PS-6	12 psi falling	N.O.	Low jacket water pressure alarm
PS-7	210 psi falling	N.O.	Low starting air pressure alarm
PS-8	50 psi falling	N.O.	Start permit
PS-8A	50 psi falling	N.O.	Start permit
PS-9	45 psi falling	N.O.	Low lubricating oil pressure shutdown
PS-10	45 psi falling	N.O.	Low turbocharger lubricating oil pressure shutdown
PS-11	45 psi falling	N.O.	Unit locked out
PS-12	45 psi falling	N.O.	High lubricating oil temperature shutdown
PS-13	45 psi falling	N.O.	High jacket water temperature shutdown
PS-14	45 psi falling	N.C.	High crankcase pressure shutdown
PS-15	45 psi rising	N.C.	Engine shutdown
PS-16	45 psi rising	N.O.	Overspeed shutdown

Table 3-1. Pressure Switches

No.	Function	Operated by
SOL-1	Starting air admission	R3, R4, R6 or R7
SOL-2	Starting air admission	R3, R4, R6 or R7
SOL-3	Manual start	R4 or R7
SOL-4	Stop	Stop pushbutton or remote signal
SOL-5	Lockout	Mode selector switch
SOL-6	Shutdown deactivate	R3 or remote signal
SOL-7	Shutdown deactivate	R6 or remote signal

Table 3-2. Solenoid Valves

No.	Time	Contacts	Function
TD1	3 sec	1 N.C.	Provides power to R4 until it times out.
TD2	3 sec	1 N.C.	Provides power to R7 until it times out.
TD3	60 sec	1 N.O.	Provides power to R2 and R2A after it times out.
TD4	30 sec	1 N.O.	Resets R1 upon timing out. Provides Fail To Start indication.

Table 3-3. Time Delays

No.	Contacts	Function
R1	4 N.O.	Provides power to terminal 18 of SS2A Provides power to TD3 and R1A Power to fuel booster pump (auto mode) Power to crankcase fan and hour meter
R1A	6 N.C.	Activates overspeed shutdown Activates high lubricating oil temperature shutdown Activates high jacket water temperature shutdown Provides power to B&A pump (auto mode) Provides power to J.W. keep warm pump (auto mode) Provides power to circuit breaker trip
R2	5 N.C.	Activates low lubricating oil pressure alarm Activates low turbocharger lubricating oil pressure alarm Activates low jacket water pressure alarm Activates low flow raw water alarm Activates low fuel oil pressure alarm
R2A	3 N.C.	Activates low lubricating oil pressure shutdown Activates low turbocharger oil pressure shutdown Activates high crankcase pressure shutdown
R3	4 N.O.	Energizes SOL-1 Energizes SOL-2 Provides power to SS1 Provides latching power to R1
R4	4 N.O.	Energizes SOL-1 Energizes SOL-2 Energizes SOL-3 Provides latching power to R1
R5	1 N.O.	With R8 provides power to Control Power ON light
R6	4 N.O.	Energizes SOL-1 Energizes SOL-2 Provides power to SS2 Provides latching power to R1
R7	4 N.O.	Energizes SOL-1 Energizes SOL-2 Energizes SOL-3 Provides latching power to R1
R8	1 N.O.	With R5 provides power to Control Power ON light
R9	1 N.O.	Power to Remote Alarm

Table 3-4. Relays

and applied to a Timer/Not Logic element (19, Dwg. 52075) which emits a short pulse which momentarily actuates a four-way valve (18, Dwg. 52075). Control air pressure is momentarily applied to the fuel limiting cylinder, extending that cylinder to limit fuel rack movement. This pulse is also applied to the spring side of the fuel rack shutdown cylinder to insure it will be in the fully retracted position. Starting air is also applied to the pilot of a three-way valve (5, Dwg. 52075) and through a shuttle valve (9, Dwg. 52075) to the pilot of another three-way valve. Crankcase pressure signal is removed from the high pressure trip (4, Dwg. 52075) and the trip vent is blocked. Pressure from connection E-68 then builds through the three-way valve back through the shuttle valve, locking the valve in the no-vent position. After approximately three seconds, timing delays TD1 and TD2 time out and solenoid valves SOL-1, SOL-2 and SOL-3 are de-energized to stop cranking. This also removes starting air pressure from the pilot of the three-way valve and from the shuttle valve. The three-way valve shifts, but by this time crankcase pressure has been reduced and the high pressure trip (4, Dwg. 52075) will not vent. The high crankcase pressure upon starting is caused by the venting of the engine's air start valves into the engine.

REMOTE MANUAL START (See Drawing 52072).

When a manual start is initiated from the remote position, the control circuitry functions the same as during a local start.

REMOTE AUTOMATIC START (See Drawing 52072).

When a remote automatic (emergency) start signal is applied to the engine control system, the following takes place.

a. Pressure switches PS-8 and PS-8A are closed (provided there is a minimum of 150 psi starting air pressure available), and, as the engine is below 200 rpm, switches SS1A and SS1B are closed. This permits the start signal to energize relays R3 and R6.

b. When relays R3 and R6 are energized, their normally open contacts close and the relays are latched in until the engine reaches 200 rpm. Relay R1 is latched in and solenoid valves SOL-1 and SOL-2 are energized, admitting starting air to the engine.

c. The engine cranks and when it reaches 200 rpm, switches SS1A and SS1B open, solenoid valves SOL-1 and SOL-2 are de-energized and cranking stops.

d. When relays R3 and R6 were energized, solenoid valves SOL-6 and SOL-7 were energized. This locks out the safety shutdown system, however, the annunciators on the control panel remain operative because only the shutdown ability is inhibited in the logic board.

e. Relay R1 provides a signal through switch SS2A to energize relay R10 and the field is flashed. Timing delay TD-4 starts timing. When the engine reaches 430 rpm, switch SS2A opens, field flashing stops and TD-4 stops timing.

AUTOMATIC SAFETY SHUTDOWN SYSTEM.

During manual operation of the engine, it is protected by an automatic safety shutdown system which senses certain operation conditions. When a sensed condition reaches a pre-determined point, the system initiates an automatic shutdown sequence. There are other conditions which are monitored and which will alarm if they reach their alarm point, but will not shut the engine down. During automatic remote (emergency) operation the shutdown system will not function, but will give a visual indication of an alarm or shutdown condition if one should exist. Shutdowns are placed into two groups. Group I shutdowns are those which must be "GO" in order to start. Group II shutdowns are those that would be in a shutdown (venting) condition until the engine is running. The Group II shutdowns are locked out during engine starts for a fixed time period. The Shutdown Logic Board, 1A-5907 (1, Dwg. 52071) functions to provide the necessary shutdown signals to the engine and, when operating in the remote automatic mode, provides the means for preventing the engine from shutting down while still giving panel indications of an existing shutdown condition. During a start, Port 12 of the board is momentarily pressurized which results in an output from Ports 2, 9 and 10, and 60* seconds later an output from Port 3 and loss of output from Port 9. Ports 2 and 10 pressurize the shutdown sensor circuits. If an unsatisfactory condition should develop which would trip one of the shutdown sensors, there will be a loss of pressure at either Port 10 or Port 2, resulting in an output from Port 8. This pressure is transmitted through a shuttle valve (15, Dwg. 52071) to connection E-89, through another shuttle valve (9, Dwg. 52075) and an orifice to extend the shutdown cylinder (16, Dwg. 52075) and the fuel racks are moved to the "No Fuel" position, shutting the engine down. A shutdown due to engine overspeed is accomplished in a different manner. Air pressure supply at 60 psi from connection E-53 (see drawing 52075) passes through an orifice, and as the overspeed trip valve (2) is blocking flow, the pilot of a three-way valve (5) is pressurized, venting the valve. Actuation of the overspeed trip valve (2) will vent this pressure, the three-way valve will shift to allow E-53 pressure to extend the overspeed shutdown cylinder (15) and the fuel rack shutdown cylinder (16). An air butterfly valve in the intake manifold closes, cutting off combustion air flow, and the fuel racks are moved to the "No Fuel" position. The engine stops as no fuel or combustion air is allowed to enter the combustion chambers. During emergency operation in the remote automatic mode, solenoid valves SOL-6 and SOL-7 are energized, allowing 60 psi air to be applied to Port 7 of the Shutdown Logic Board. This blocks output from Port 8 and there will be no shutdown signal. Shutdown indications, however, will still be displayed on the control panel to inform the operator that an alarm or safety shutdown condition does exist. Overspeed and generator fault protection are still retained, however.

*Tolerance is plus or minus 5 seconds.

NORMAL STOP.

Momentary actuation of the stop pushbutton on the control panel will energize solenoid valve SOL-4 which then applies a 60 psi air signal to port 11 of the Shutdown Logic Board. There is an output from Port 8 and the engine is shutdown in the same manner as during an automatic safety shutdown. Generator fault, through relay contacts of 86 P, perform the same function.

AUTOMATIC SWITCHOVER LOGIC (See Dwg. 52080).

The full flow lubricating oil filters and strainers are equipped with an automatic switch over system which transfers from the operating filter or strainer to the reserve filter or strainer when the differential pressure across the operating unit exceeds a preset limit. In addition to referenced drawing, see drawings 100404 and 61-500-5663 in the "Drawings" section of this manual. Inasmuch as the switchover system used on the filters and strainers is identical, the following describes that used on a filter only for sake of clarity.

a. Flow through the lubricating oil filters is determined by four-inch ball valves at the inlet and outlet of the filter. These valves are ganged together with a maintained position actuator. Both valves rotate simultaneously when a transfer signal is received. The actuator will rotate as long as the transfer signal is maintained. Upon loss of the transfer signal, the valve remains in its last position.

b. The transfer signals are delivered to the actuators by the Automatic Switchover Logic Assembly. When the system is initially pressurized, control air flows through the shutoff valve (6) to the "b" ports of the two NOT logic elements (4), then out the "c" ports of the elements to the selector switch then to both sides of the valve actuator. Since both sides of the actuator is pressurized, the valve remains in the same position.

c. Control air also flows through orifices (3) to differential setpoint valves (1), accumulators (2) then to the "a" ports of the NOT elements (4). When this pressure builds to approximately 45 psi, the NOT elements vent, and the pressure to the valve actuators is lost. Filter selection can now be made by the manual operator. Care must be taken to insure the valve operator assembly is fully transferred before the signal is released.

d. The system is now ready to automatically transfer to the other filter. When the pressure differential across the filter in use exceeds 20 psi, the differential valve (1) shifts and the pressure on the "a" port of the NOT element is vented. The NOT element now has an output at port "c" which is directed through the selector to the actuator and the actuator moves the ball valves to place the standby filter into operation. This signal is maintained until the differential pressure valve (1) spring return resets the valve, permitting air pressure to build in the accumulator. When the accumulator is charged, the NOT element is vented and the pressure on the actuator is released.

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.

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	1=REMOTE 2=PANEL 3=ENGINE 4=OTHER	POSITION	
1.	ANNUNCIATOR TEST PUSHBUTTONS a. TEST b. SILENCE c. ACKNOWLEDGE d. RESET	2	DEPRESS	Depress pushbuttons in sequence to test bulbs and annunciator functions. Replace bulbs if necessary.
2.	ANNUNCIATOR LAMPS	2	OFF	All lamps should be off. If any lamp is ON, stop status check until defect corrected
3.	STARTING AIR PRESSURE GAUGE	2	220-240 PSI	Normal range.
4.	LUBRICATING OIL PRESSURE GAUGE	2	10-20 PSI	Normal range.
5.	JACKET WATER PRESSURE GAUGE	2	10-20 PSI	Normal range.
6.	FUEL OIL PRESSURE GAUGE	2	ZERO PSI	Not pressurized in standby mode.
7.	COMBUSTION AIR PRESSURE GAUGE	2	ZERO PSI	Not pressurized in standby mode.
8.	TURBOCHARGER OIL PRESSURE GAUGE	2	ZERO PSI	Not pressurized in the Standby Mode.
9.	RAW WATER PRESSURE GAUGE	2	ZERO PSI	Not pressurized in the Standby Mode.
10.	"AC POWER" SWITCH	2	ON	Makes AC power available.
11.	"DC POWER" SWITCHES	2	ON	Makes DC power available.
12.	ENGINE HOURMETER	2	VARIABLE	As occurring.
13.	ENGINE TACHOMETER	2	ZERO RPM	
14.	THERMOCOUPLE SELECTOR SWITCH	2	ROTATE	Rotate and observe temperature readings. Cylinders should read at ambient and fluids should be in "keep-warm" status.
15.	"CONTROL POWER" LAMP	2	ON	
16.	START PUSHBUTTON	2	DO NOT DISTURB	

OPERATION: STANDBY MODE STATUS CHECK

ITEM	CONTROL/INDICATOR	1=REMOTE 2=PANEL 3=ENGINE 4=OTHER	POSITION	
17.	SPEED CONTROL SWITCH	2	DO NOT DISTURB	
18.	MODE SELECT SWITCH	2	DO NOT DISTURB	Unit should be in the REMOTE control.
19.	STOP PUSHBUTTON	2	DO NOT DISTURB	
20.	FUEL OIL BOOSTER PUMP SWITCH	2	AUTO	Status lamps will show current operating status of pump.
21.	FUEL OIL TRANSFER PUMP #1 SWITCH	2	AUTO	Status lamps will show current operating status of pump.
22.	FUEL OIL TRANSFER PUMP #2 SWITCH	2	AUTO	Status lamps will show current operating status of pump.
23.	LUBE OIL KEEP WARM PUMP AND HEATER SWITCH	2	AUTO	Status lamps will show current operating status of pump.
24.	JACKET WATER KEEP WARM PUMP AND HEATER SWITCH	2	AUTO	Status lamps will show current operating status of pump.
25.	AIR COMPRESSOR #1 SWITCH	2	AUTO	Status lamps will show current operating status of pump.
26.	AIR COMPRESSOR #2 SWITCH	2	AUTO	Status lamps will show current operating status of pump.
27.	JACKET WATER STANDPIPE	3	CHECK LEVEL	Add make-up water as required. NOTE: If abnormally large amount of jacket water has been consumed, investigate cause before proceeding, or serious damage may occur.
27.	BARRING DEVICE	3	DISENGAGED & LOCKED	Verify.
28.	GOVERNOR DIAL SETTINGS CHECK: a. LOAD LIMIT KNOB b. SPEED DROOP KNOB c. SPEED SETTING KNOB	3	AS SET IN TEST RUNS	Verify that field established settings remain in effect. Make a record of dial positions for future refence.

OPERATION: PRE-START PROCEDURE

ITEM	CONTROL/INDICATOR	1=REMOTE 2=PANEL 3=ENGINE 4=OTHER	POSITION	
1.	PERFORM "STANDBY MCDE STATUS CHECK"			See checklist.
2.	MODE SELECT SWITCH	2	LOCAL	
3.	INTAKE MANIFOLD DRAIN COCK	3	OPEN	Check for presence of water in manifold. Insert rod into drain to clear any blockage. If not equipped with draincock, tap manifold with mallet to check for presence of water.
4.	CYLINDER INDICATOR COCKS	3	OPEN	All cylinders.
5.	BARRING DEVICE	3	ENGAGE	Bar engine over slowly If there is any resistance to free turning, stop barring and check cylinder indicator cocks for ejection of liquids. If no resistance is encountered, continue barring over for two complete revolutions. Then check cylinder cocks for ejection of liquid CAUTION: IF LIQUID IS EJECTED FROM INDICATOR COCKS, TERMINATE TEST PROCEDURE. THE LIQUID SOURCE MUST BE FOUND AND THE DEFECT CORRECTED BEFORE PROCEEDING.
6.	INDICATOR COCKS	3	CLOSE	After successful test, close indicator cocks at all cylinders.
7.	BARRING DEVICE	3	DISENGAGE & LOCK	Lock out barring device.
8.	MODE SELECTOR SWITCH	2	REMOTE	Return to REMOTE mode for starting.

ITEM	CONTROL/INDICATOR	1=REMOTE 2=PANEL 3=ENGINE 4=OTHER	POSITION	
OPERATION: TEST STARTS				
1.	MODE SELECT SWITCH	4	LOCAL OR REMOTE	Select desired station for control.
2.	START PUSHBUTTON	2	DEPRESS	Initiate start from station selected in previous step. Depress pushbutton momentarily
3.	ENGINE HOURMETER	2	VARIABLE	Activated.
4.	ENGINE TACHOMETER	2	450 RPM	Observe acceleration to rated speed
5.	FUEL OIL PRESSURE GAUGE	2	20 - ~~30~~ 35* PSI	Refer to Appendix VII △
6.	JACKET WATER PRESSURE GAUGE	2	~~10~~ **20 - 30 PSI	Refer to Appendix VII △
7.	LUBRICATING OIL PRESSURE GAGUE	2	50 - ~~65~~ 65** PSI	Refer to Appendix VII △
8.	TURBOCHARGER OIL PRESSURE GAUGE	2	~~20~~ 25 - ~~26~~ 35** PSI	Refer to Appendix VII △
9.	COMBUSTION AIR PRESSURE GAUGE	2	1.5 - 20 PSI	Load dependent.
10.	RAW WATER PRESSURE GAUGE	2		System dependent.
11.	THERMOCOUPLE SELECTOR SWITCH	2	ROTATE	Rotate and observe temperature readings.
12.	SPEED CONTROL SWITCH	2	RAISE or LOWER	Use switch to control engine speed during loading operations.

* Ref. E&DCR F-45633
** Ref. E&DCR F-44795A

OPERATION: EMERGENCY STARTS				
ITEM	CONTROL/INDICATOR	1=REMOTE 2=PANEL 3=ENGINE 4=OTHER	POSITION	
1.	AUTOMATIC START	1	CONTACT CLOSURE	Emergency start is initiated due to the closure of the owner's remote contacts. Unit will start and come up to rated speed and voltage with no operator action required.
2.	ENGINE HOURMETER	2	VARIABLE	Activated.
3.	ENGINE TACHOMETER	2	450 RPM	Observe acceleration to rated speed
4.	FUEL OIL PRESSURE GAUGE	2	20 - ~~[illegible]~~ PSI 35*	Refer to Appendix VII
5.	JACKET WATER PRESSURE GAUGE	2	~~10~~ - 30 20** PSI	Refer to Appendix VII
6.	LUBRICATING OIL PRESSURE GAGUE	2	50 - ~~55~~ PSI 65**	Refer to Appendix VII
7.	TURBOCHARGER OIL PRESSURE GAUGE	2	~~20~~ - ~~25~~ 25 PSI 35**	Refer to Appendix VII
8.	COMBUSTION AIR PRESSURE GAUGE	2	1.5 - 20 PSI	Load dependent.
9.	RAW WATER PRESSURE GAUGE	2		System dependent.
10.	THERMOCOUPLE SELECTOR SWITCH	2	ROTATE	Rotate and observe temperature readings.
11.	SPEED CONTROL SWITCH	2	RAISE or LOWER	Use switch to control engine speed during loading operations.

* Ref.E&DCR F-45633
** Ref. E&DCR F-44795A

OPERATION: STOPPING PROCEDURES				
ITEM	CONTROL/INDICATOR	1=REMOTE 2=PANEL 3=ENGINE 4=OTHER	POSITION	
1.	NORMAL STOP			
	a. STOP PUSHBUTTON	1 or 2	DEPRESS	Apply stop signal from station in control. Note that load should be removed, and the engine allowed to cool before a stop signal is applied.
2.	EMERGENCY STOP If engine fails to stop when the stop signal is applied, perform one of the following:			
	b. OVERSPEED TRIP	3	TRIP	Manually trip overspeed device.
	c. STOP/RUN VALVE	3	STOP	Manually push valve to stop position.
	d. FUEL RACKS	3	PUSH	Manually push fuel racks to the no fuel position. Hold rack until engine stops.

SECTION 5

INSPECTION AND MAINTENANCE

PART A – PREVENTIVE MAINTENANCE

GENERAL.

Continuous design refinement and many years of experience in the manufacture of large, medium speed diesel, dual fuel and spark ignited engines have become a part of the Transamerica Delaval "Enterprise" engine. Each engine undergoes a thorough testing program and inspection procedure before shipment. Transamerica Delaval does not recommend the type of progressive maintenance system used by railroad maintenance shops, nor is any specific time interval between major overhauls or cylinder head valve reconditioning recommended. Experience and local operating conditions must be the final determining factors as to the actual frequence of upkeep, overhaul and repair actions.

MAINTENANCE PRACTICES.

To give the engine the longest useful service life with the least amount of down time for unscheduled maintenance or repair, it is necessary to have a program in effect to keep the equipment clean, to inspect it regularly, to take the necessary preventive maintenance actions, and to keep the records of the operation and other useful information.

a. If the engine and other equipment is kept clean, it will be easier to make a good and complete inspection. It will also keep dirt out of moving parts and thus reduce wear. It will also provide a good indication of how well the equipment is being taken care of in general.

b. If the engine and equipment is inspected at regular intervals, small defects can be found and corrected before they become large and require more expensive and time consuming repairs.

c. A program of regular preventive maintenance, together with keeping the unit clean and inspecting it regularly, will permit the replacement of wearing parts before they can cause serious malfunction and/or damage to the engine and equipment.

d. Records, when kept on adequate forms and filled out on a regular basis will keep operating personnel informed of the current running condition of the equipment. Then, when compared with past log sheets, gradual changes in such things as temperatures, pressures, noise, etc., will reveal the general condition of the equipment and greatly assist in the planning of general overhaul requirements.

PERFORMANCE CURVES.

The majority of engine problems are preceeded by some change in the operating data, however, these changes may be so slight and gradual that they are not easily detectible unless the data is recorded in a manner that graphically makes these changes appear as a trend. Charts and performance curves can fulfill this function. As with any technique which depends on the recording of observations, it is essential that the data be accurately read and carefully recorded. The following paragraphs illustrate some of the information that can be obtained from charts and curves. Charts may be kept on graph paper, or any other convenient form, and in the format that will present the data in the most useable form. Logs and daily operating records should be maintained in a form that is suitable for the purposes. Data should be taken and recorded each day under the same load conditions. The load should be selected according to average operating conditions, and should be within the 75% – 100% load range. The following illustrations provide an example of how the data on performance curves can be used in planning future maintenance actions.

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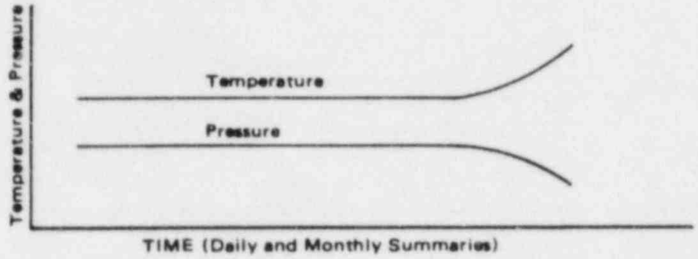
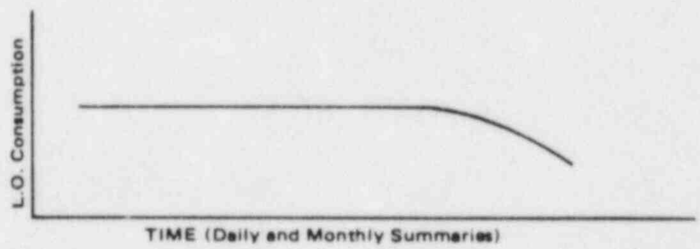
PART A – PREVENTIVE MAINTENANCE (Continued)



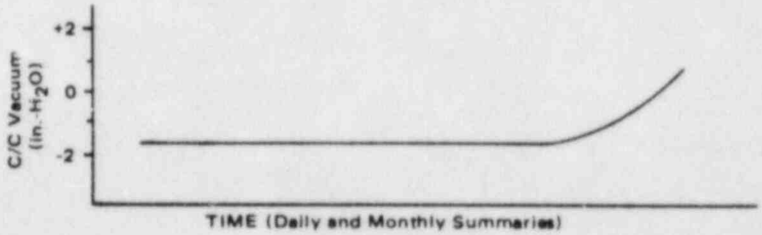
a. If lubricating oil pressure starts to decrease, but the lubricating oil temperature remains constant, this would indicate that bearings are starting to wear to excessive clearances, that the lubricating oil pump is wearing excessively, or that the relief valve is not functioning properly. It could also indicate excessive fuel dilution. If lubricating oil pressure starts to decrease while the lubricating oil temperature rises, it might indicate that the heat exchanger equipment is plugging up.

WARNING

A sudden increase in lubricating oil temperature with an increase in the amount of vapor from the crankcase ventilation discharge may indicate some overheated internal part of the engine. A sudden increase in lubricating oil temperature requires an immediate reduction or removal of the load if this is possible. The cause of the temperature increase must be determined and corrected.

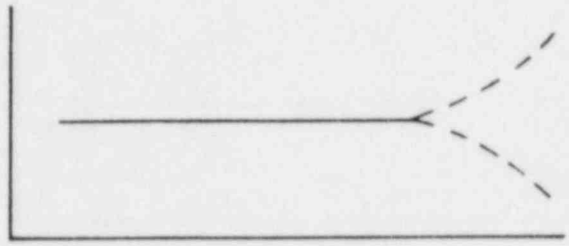


b. If lubricating oil consumption starts to increase it could mean that the piston oil control rings are starting to foul, or have worn excessively. If this is the case, oil is being burned and should show up in the exhaust as a light blue or grey smoke. It could also mean that the intake or exhaust valve guides have worn excessively. A third possibility is a leak in the lubricating oil cooler. This can be checked by looking for evidence of oil in the cooling system.



c. If crankcase vacuum starts to go towards a positive pressure it may indicate that the compression rings on the pistons have worn excessively. This may be checked by taking a set of compression cards.

PART A – PREVENTIVE MAINTENANCE (Continued)



d. If jacket water temperature starts to rise, it could mean that the jacket water cooler is starting to foul. It must be remembered, however, that the temperature control valve starts to open five degrees farenheit before the set point. This means that the controlled outlet temperature may vary 15°F, depending upon ambient conditions. If inlet temperature starts to drop, indicating a greater temperature differential across the engine, it could mean one or more of the following conditions may be present.

(1) Poor combustion.

(2) Leaky head gasket(s).

(3) Scuffed piston(s).

(4) Faulty venting of jacket water system.

(5) Faulty water pump.

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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.

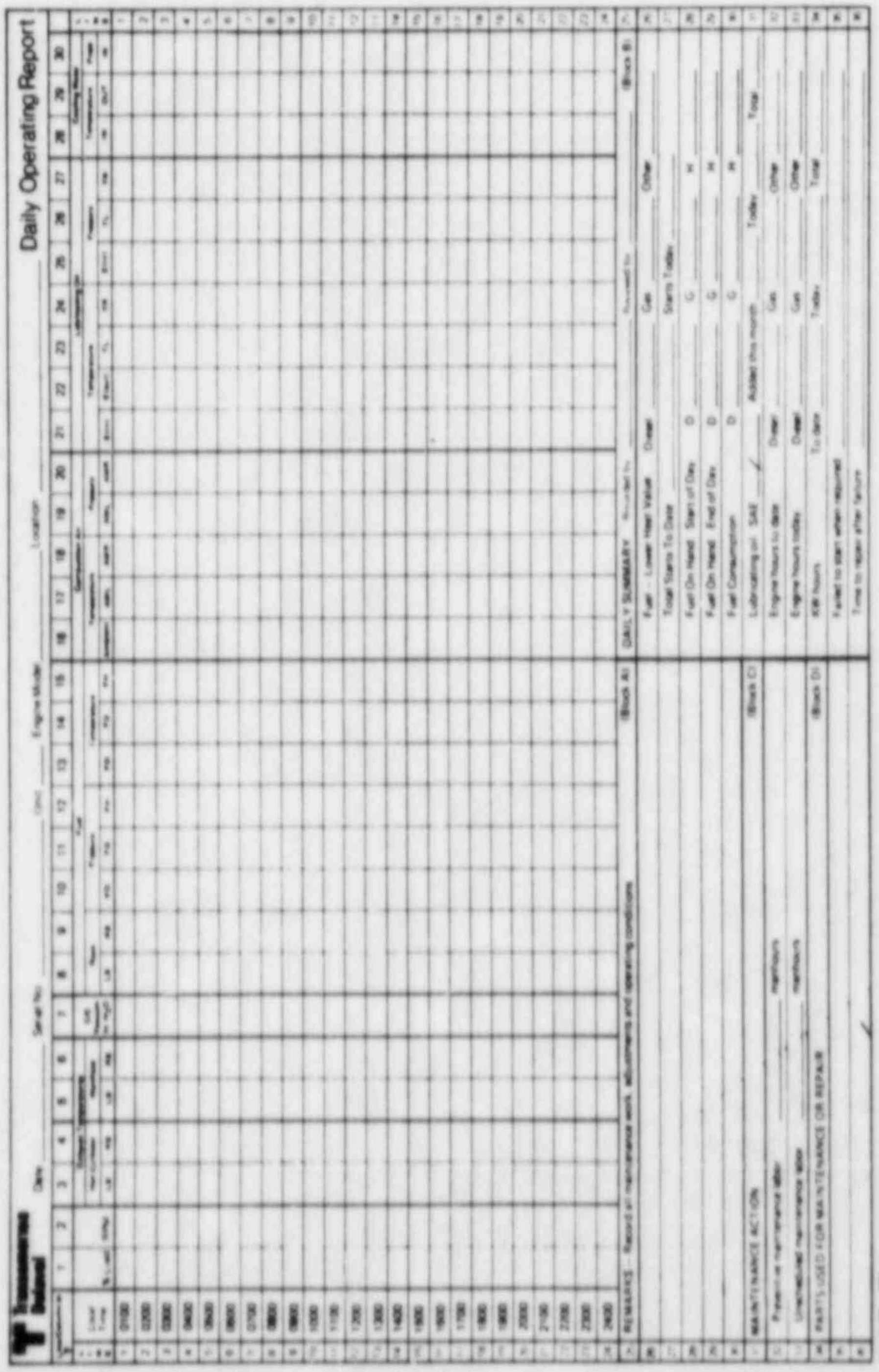

Figure 5-A-1. Daily Operating Report, Form E-276

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: None	

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 **△1
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~~ Zero Speed: To provide mechanical governor control at ~~470~~ 460 rpm	Associated Publications Manual **△1
*If water is found, drain air start system "Y" Strainers. Refer to Note 1 on page 5-B-4.	**△1

** Ref. E&DCR F-46404A

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~~ strainers & filters for clean fuel.*	

△1

*Ref. E&DCR F-46404A

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. 1	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. 2	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~~ 9.0-10.5*	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. 3	Associated Publications Manual **
Record all operating parameters. Compare with baseline data to insure engine is operating properly.	

1. Should excessive moisture or fouling be noted during monthly inspections of "Y" strainers, then increase frequency of draining. **
2. Required frequency for inspecting the starting air distributor filter should be established by periodic inspection results. Frequency can be decreased if warranted by inspection findings.
3. Heat exchanger performance can be evaluated by checking engine operating parameters.

* Ref. E&DCR F-44681
** Ref. E&DCR F-46404A

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PART B — SUGGESTED MAINTENANCE SCHEDULES (Continued)

INSPECTION GUIDE	Frequency: ANNUAL/EACH PLANT SHUTDOWN
Component Group: Diesel Engine	
Special Conditions: Annual if shutdown exceeds 18 months, or annual operation exceeds 8000 hours *	
Item	**Reference**
Drain lubricating oil system, ~~Refill with new oil.~~ and clean sump tank. Depending on results of lube oil analysis, 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, Sec. 6, Part F Asso. Publications Manual — Bendix
Inspect connecting rod bearings. ~~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
Inspect and clean air filter in starting air distributor. **	Associated Publications Manual
Clean turbocharger drip filter	Associated Publications Manual

* Ref E&DCR F-46404

** Ref E&DCR F-46404A

PART B — SUGGESTED MAINTENANCE SCHEDULES (Continued)

INSPECTION GUIDE	Frequency: BI-ANNUAL/ALTERNATE PLANT SHUTDOWNS
Component Group: Diesel Engine	
Special Conditions: Bi-annual if alternate shutdowns exceed 36 months or annual operation exceeds 5000 hrs *	
Item	**Reference**
Inspect gears for general condition. Check backlash and replace worn gears exceeding maximum clearance.	Inst. Manual, Sec. 8, Appendix III
Remove fuel injection pumps. Disassemble, clean, repair and adjust as necessary.	Instruction Manual, Sec. 6, 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~~ camshaft bearings and idler gear bushings. **	Inst. Manual, Sec. 6, Part E. Section 8, Appendix III

* Ref. E&DCR F-46404
** Ref. E&DCR F-46404A

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.

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.

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.

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. The following 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.

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.

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.

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.

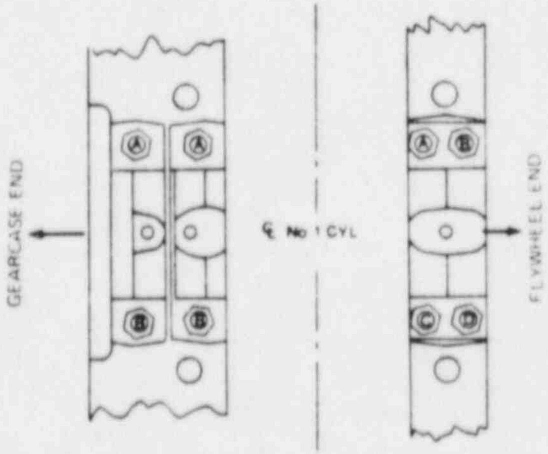
e. Ensure that the proper designation is entered on all sheets where the position of the component being inspected serves to identify it. For instance, a separate sheet is needed for each bearing, each cylinder head, each piston and rod, etc. Identify these items.

Transamerica Delaval

Inspection and Maintenance Record

Component Group Title		Parts Group No	Sheet	Page
MAIN BEARING CAPS -- Model R Engine		305	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 D		Data Recorded By		

REMARKS



Observe and record in the appropriate spaces below the BEARING BOLT ELONGATION, or the TORQUE APPLIED WITH A TORQUE WRENCH for both disassembly and assembly. If a torque multiplier is used with a torque wrench, record the multiplier ratio. Bearing caps are numbered, starting from the gearcase end. Torque is to be applied in a criss-cross pattern. See Engine Nameplate for the correct torque value.

DISASSEMBLY (Breakaway)

	Record elongation in thousandths of an inch, or torque in foot pounds										
	1	2	3	4	5	6	7	8	9	10	11
A											
B											
C											
D											

ASSEMBLY

	Record elongation in thousandths of an inch, or torque in foot pounds										
	1	2	3	4	5	6	7	8	9	10	11
A											
B											
C											
D											

305 1 1

Figure 5-D-1 Main Bearing Caps

Transamerica Delaval

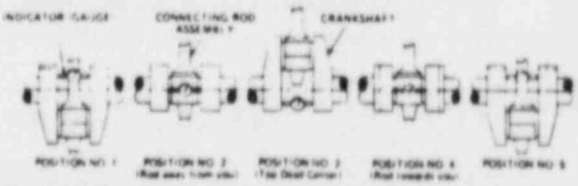
Inspection and Maintenance Record

Component Group Title		Parts Group No	Sheet	Page
CRANKSHAFT – Web Deflection and Thrust Clearance		310	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 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.

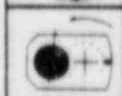
If deflection in any crank exceeds 0.003 inch, corrective action must be taken. Also, if total deflection in any two adjacent cranks exceeds 0.003 inch corrective action must be taken. Example: A +0.002 in. reading in any crank with a -0.002 in. in the next adjacent crank equals a total of 0.004 in. 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 Position 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

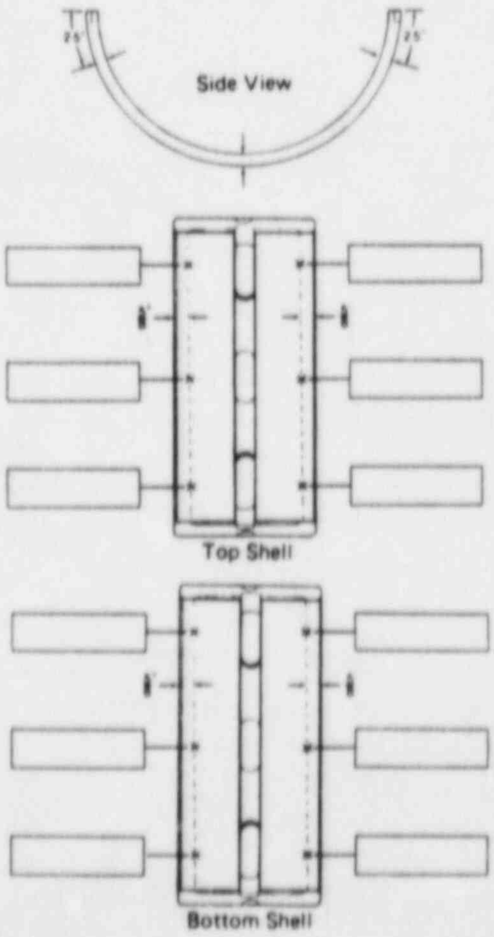
Figure 5-D-2. Crankshaft Web Deflections

Transamerica Delaval

Inspection and Maintenance Record

Component Group Title: MAIN BEARING SHELLS		Parts Group No.: 310	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		

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

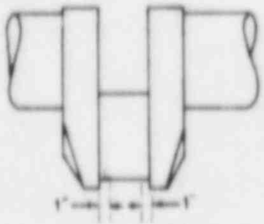
310 2 1

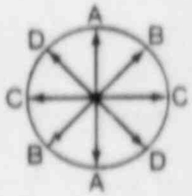
Figure 5-D-3. Main Bearing Shells

Transamerica Delaval

Inspection and Maintenance Record

Component Group Title: CRANKSHAFT		Parts Group No: 310	Sheet: 3	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		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

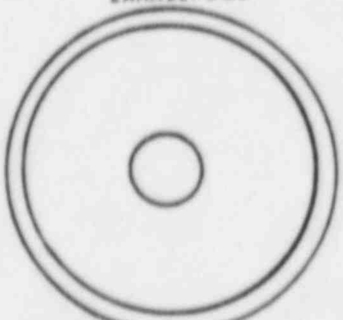
Figure 5-D-4 Crankshaft

Transamerica Delaval

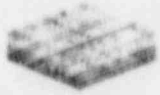
Inspection and Maintenance Record

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 This Inspection		
References: Instruction Manual, Section 6, Part C		Data Recorded By		

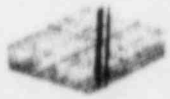
Cylinder No./Bank ____________



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



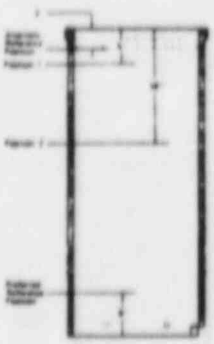
NORMAL CROSSHATCH

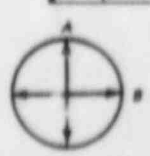


SCRATCHES – Long narrow grooves usually caused by foreign material. Crosshatch pattern runs through.

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.





A= Inboard (exhaust) side
B= Flywheel End

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

315-1-1

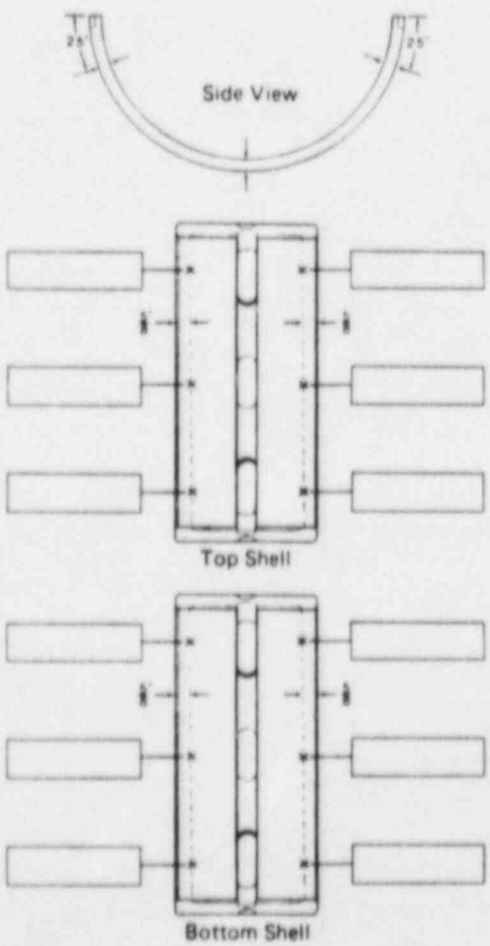
Figure 5-D-5. Inspection and Maintenance Record, Cylinder Liners

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

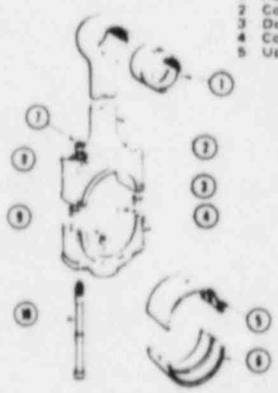
Transamerica Delaval

Inspection and Maintenance Record

Component Group Title		Parts Group No	Sheet	Page
CONNECTING RODS – Model R-3 and R-4 Engines		340	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 C		Date Recorded By		

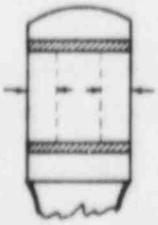
1 Piston Pin Bushing
2 Connecting Rod
3 Dowels
4 Connecting Rod Box
5 Upper Bearing Shell
6 Lower Bearing Shell
7 Connecting Rod Bolt Nut
8 Washer
9 Locking Dowel
10 Connecting Rod Bolt

CYLINDER ____________



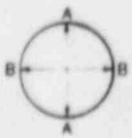
Piston Pin Bushings
Measure inside diameter of piston pin bushing with micrometer. Measure in vertical (A-A) and horizontal (B-B) planes, 90° apart. Measure both ends (gearcase and flywheel), two inches from end of bushing.

Step 1	Piston Pin Bushing I.D.	
	A–A	B–B
Gearcase End		
Flywheel End		



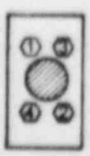
Connecting Rod Bearing Bore
Reassemble connecting rod box to connecting rod to measure for out-of-round conditions at connecting rod bearing bore. Do not install bearings. Torque nuts to full torque value as shown in Instruction Manual. Measure connecting rod bearing bore inside diameter at both ends,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

Step 2	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 3



Bolt Torques
Record disassembly (breakaway) and assembly torques for connecting 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 4	Connecting Rod Bolt Nut Torque (ft lbs)			
	1	2	3	4
Disassembly				
Assembly				

340 3 1

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

Transamerica Delaval

Inspection and Maintenance Record

Component Group Title		Parts Group No	Sheet	Page
PISTONS – Two Piece		341	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		Date Recorded By		

Cylinder No./Bank

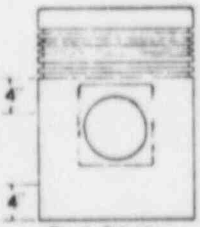


Fig. A Side View

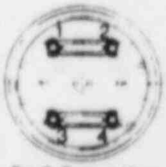


Fig. B Bottom View

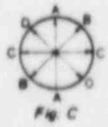


Fig. C

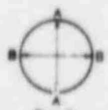


Fig. D

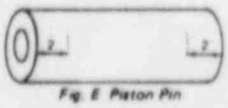


Fig. E Piston Pin

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

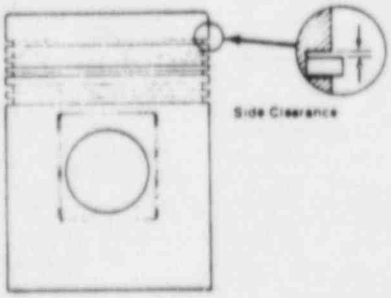
Figure 5-D-8. Inspection and Maintenance Record, Piston — Two Piece

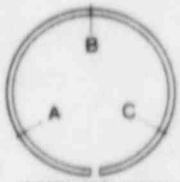
Transamerica Delaval

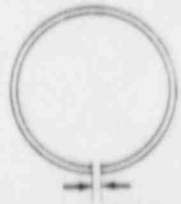
Inspection and Maintenance Record

Component Group Title: PISTON RINGS		Parts Group No: 341	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 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

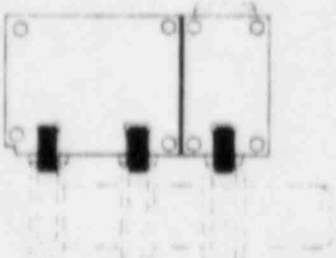
Figure 5-D-9. Inspection and Maintenance Record Piston Rings

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



IN EX FUEL

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.																													

*Code for Insitu: F=Roller free to rotate and no measureable clearance between pin and roller.

345-1-1

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

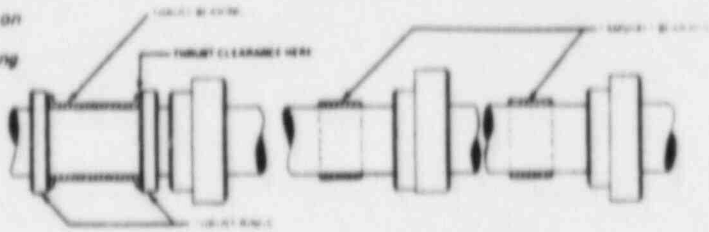
*Ref. E&DCR F-46404B

Transamerica Delaval

Inspection and Maintenance Record

Component Group Title		Parts Group No	Sheet	Page
CAMSHAFT BEARING SHELLS – Model R Engines		350	2	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		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.

Clearance

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

☐ **BEARING SHELL THICKNESS – Micrometer**

1	2	3	4	5	6	7	8	9	10

Remarks

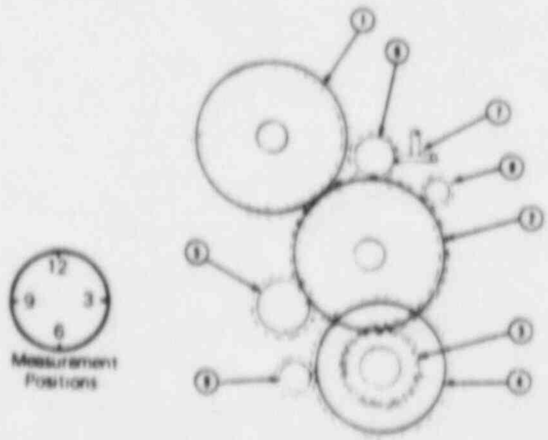
350 2 1

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

Transamerica Delaval

Inspection and Maintenance Record

Component Group Title: GEARSET – Model R Engine		Parts Group No: 355	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 E & Section 8, Page 4A		Data Recorded By		



1 Camshaft Gear
2 Idler Gear
3 Crankshaft Gear
4 Water Pump Drive Gear
5 Lubricating Oil Pump Gear
6 Governor & Tachometer Drive Gear
7 Governor Drive and Driven Gear
8 Fuel Oil Pump & Overspeed Trip Drive Gear
9 Water Pump Gear

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				
2	3				
2	5				
2	6				
2	8				
4	9				
6	7				

Form E 267 6/80 350 2 1

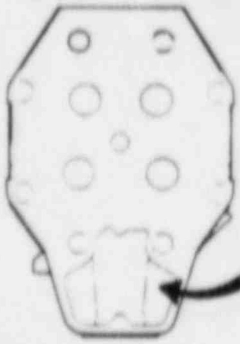
Figure 5-D-12 Inspection and Maintenance Record, Gearset

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

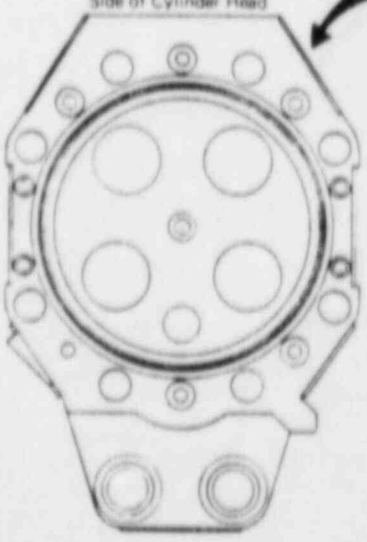


Cylinder No./Bank

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

Transamerica Delaval

Inspection and Maintenance Record

Component Group Title: INTAKE and EXHAUST VALVES		Parts Group No.: 360	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 B		Data Recorded By		

Cylinder No./Bank

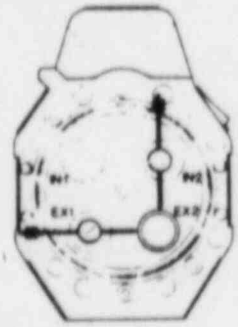


Figure 1

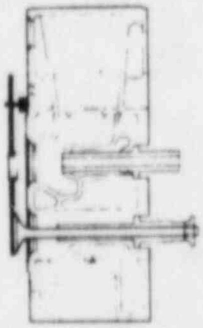


Figure 2

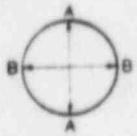


Figure 3

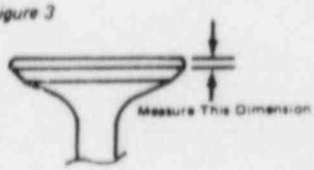


Figure 4

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 287 6/80 360 2 1

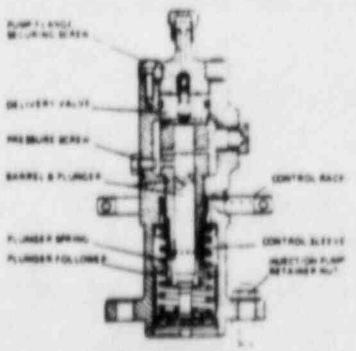
Figure 5-D-14 Inspection and Maintenance Record Intake and Exhaust Valves

Transamerica Delaval

Inspection and Maintenance Record

Component Group Title: FUEL INJECTION PUMP		Parts Group No: 365	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 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

Transamerica Delaval

Inspection and Maintenance Record

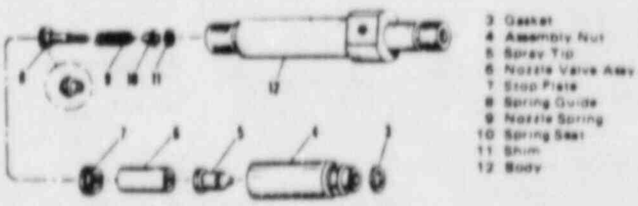
Component Group Title		Parts Group No	Sheet	Page
FUEL INJECTION NOZZLE and HOLDER		365	2	1
Customer		Equipment Location		
Engine Model	Serial No	Customer's Designation		
Total Engine Hours	Hours Since Last Inspection	Date This Inspection		
References: Instruction Manual, Section 6, Part F; Associated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

SECTION 6

OVERHAUL AND REPAIR

PART A – GENERAL

ROTATION AND CYLINDER DESIGNATION.

Crankshaft rotation is determined from the flywheel end of the engine. Number one cylinder 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.

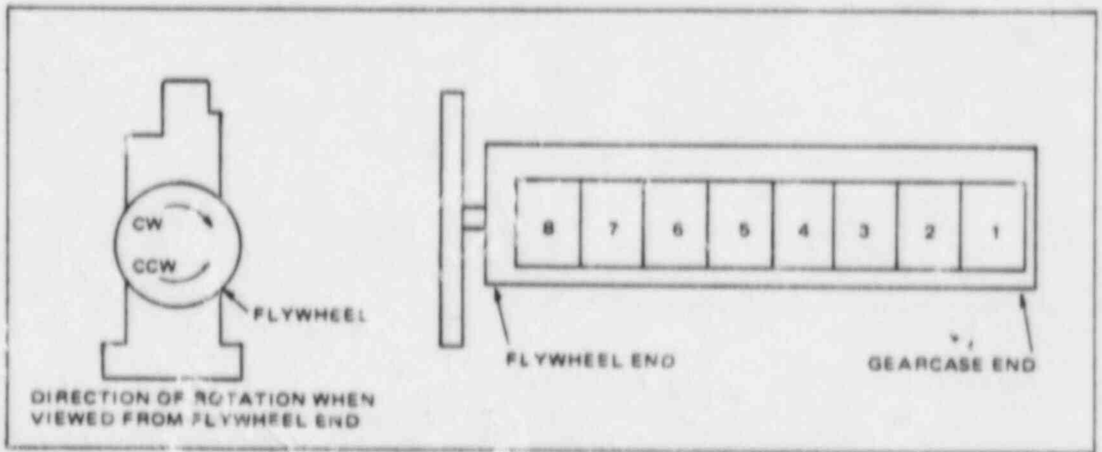


Figure 6-A-1. Engine Rotation and Cylinder Designation

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.

R-81

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 point, 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 a specific torque value has been assigned. The second part contains general torque values for use when no special torque value has been assigned.

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

00 81

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 superior 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

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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.

l. When performing repair work involving disassembly of any spring loaded device, be aware of the deadly force present which, if accidentally released, could cause severe injury.

m. Use no cleaning agents other than those approved by the cognizant local occupational safety and health authorities. Never use gasoline for cleaning purposes.

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.

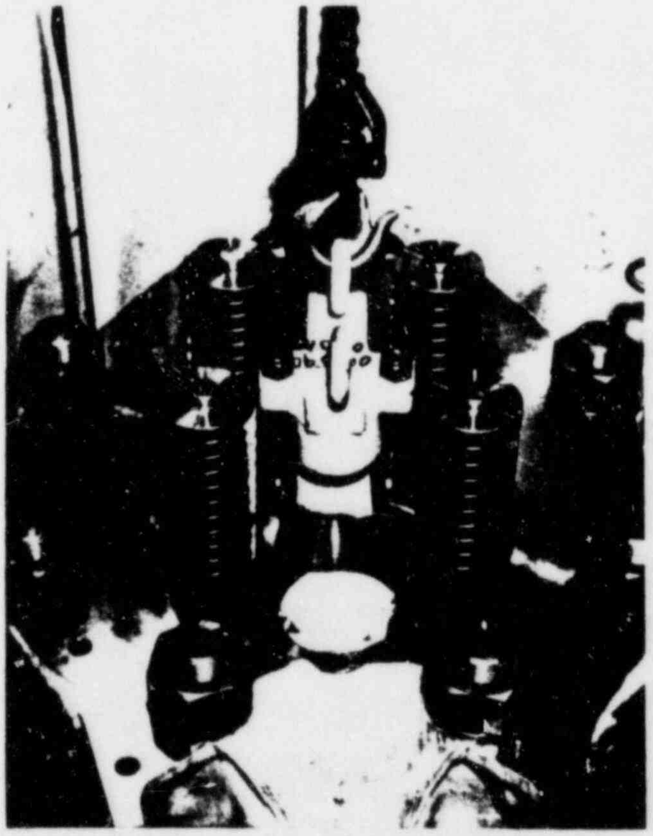

Figure 6-B-1. Cylinder Head Lifting Fixture

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.

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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.

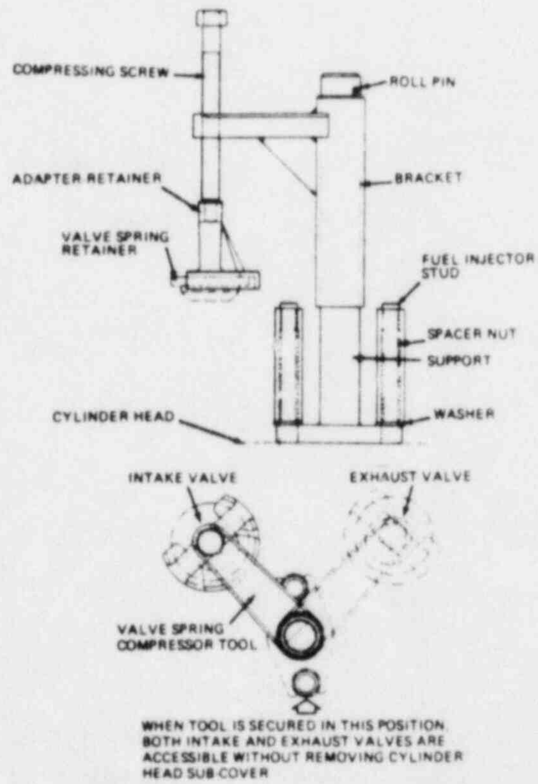

Figure 6-B-2. Valve Spring Compressor Tool

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.

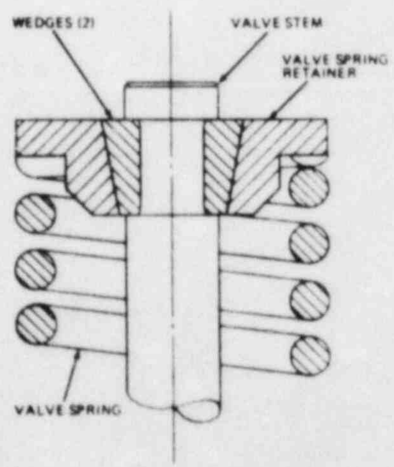

Figure 6-B-3. Valve Spring Retainer

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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 $\pm$ 1/64 inch (1.51 $\pm$ 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.

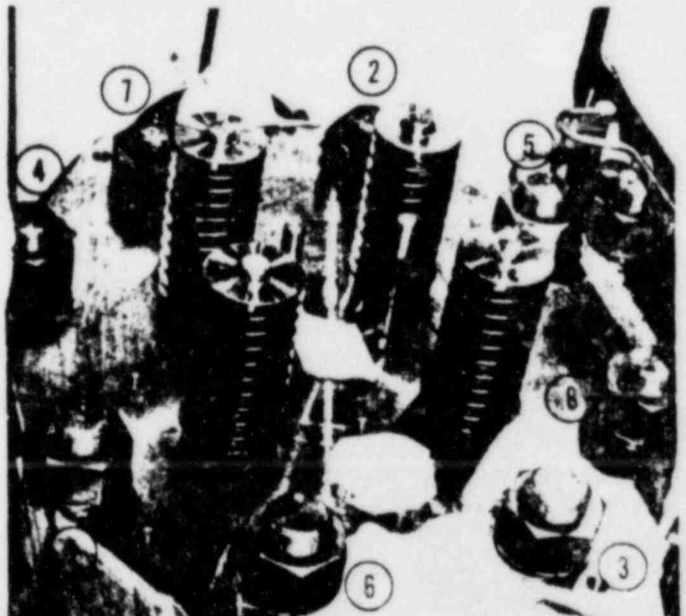

Figure 6-B-4. Tightening Sequence For Cylinder Head Stud Nuts

*Refer to page 6-B-3-A for revised cylinder head installation procedure.

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PART B – CYLINDER HEADS AND VALVES (Continued)

CYLINDER HEAD INSTALLATION

*1. Install cylinder head stud using Locktite 242, 272 or equal, with an air motor of 1" max. size, at a maximum of 60 psi air supply pressure. Desired torque of stud is 80-120 ft/lbs. Do not use impact tools. Stud should be moderately landed on lockwasher. Do not overtighten. Check height above cylinder block - length should be 15" + 1/16". To remove" Preheat to a max. of 300°F, checking Temp. with a templestik. Do not overheat.

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

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

4. Maintain tension on lifting fixture so that the cylinder head is just in contact with the gasket surfaces. Rotate the head within the limits of the cylinder head studs to obtain optimum alignment with the intake and exhaust elbows.

5. Lubricate, install and snug capscrews in the intake and exhaust elbow flanges to maintain alignment with cylinder head.

6. Lower the cylinder head to rest on gasket and remove lifting fixture.

7. 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.

8. 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.

9. Torque intake and exhaust flange capscrews in accordance with Appendix IV, Torque Tables.

NOTE: When performing Step 3, capscrews should only be snugged to prevent rotation of cylinder head during Step 4. Capscrews should not be tightened to where they prevent vertical movement of flange connection and induce stress in elbows during final lowering of head.

*Ref. E&DCR F-45848A

Ref. E&DCR F-45089D

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PART B – CYLINDER HEADS AND VALVES (Continued)

HYDRAULIC VALVE LIFTERS. *

If the engine is equipped with hydraulic valve lifters, the lifters are installed in both the exhaust and intake valve rocker arms, between the adjusting screw and the swivel pad. Pressure oil from the engine lubricating oil system is supplied to the lifters by means of drilled passages in the rocker arms. When the cam follower rollers are on the base circle (off the lobes) the plunger in the valve lifter assembly is extended by a combination of internal oil pressure and plunger spring force. As the valve is lifted from its seat by the rocker arm, the valve lifter plunger is forced into its barrel, increasing the spring force and slightly increasing the internal oil pressure. This causes the lifter check valve to close and trap the oil in the pressure chamber. When the cam follower roller returns to the base circle, force on the valve lifter plunger is reduced, internal oil pressure and spring force extend the plunger, the check valve comes off its seat and oil flows into the pressure chamber to replace any that was lost when the plunger was depressed.

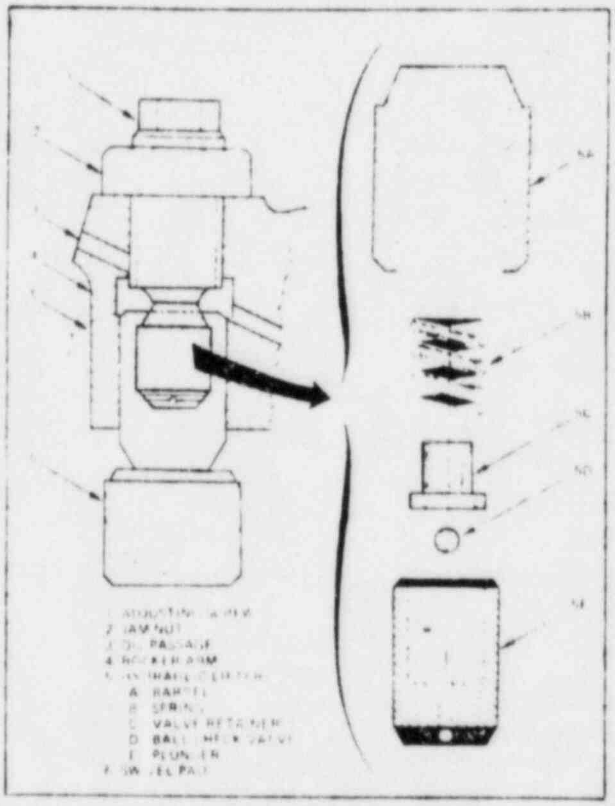

Figure 6-B-5. Hydraulic Valve Lifter

VALVE LIFTER MAINTENANCE.

The valve gear should require little maintenance under normal operating conditions. Since hydraulic lifters compensate for small amounts of wear in the valve mechanism, it is not necessary to make valve adjustments as often as would be necessary with solid valve lifters. If noise should develop in the valves it is usually due to one of the following reasons.

a. Insufficient oil supply to lifters.

b. Air or air bubbles in the lifter mechanism.

c. Incorrect adjustment screw setting.

d. Dirt in the lifter mechanism.

e. Lacquer or varnish deposits in the valve lifter mechanism due to the lubricating oil conditions.

It is not necessary to remove the lifters from the rocker arm assemblies to perform a routine adjustment. When such an adjustment is to be made, omit the following two paragraphs and proceed directly to the paragraph on adjustment.

LIFTER REMOVAL AND DISASSEMBLY.

If it is necessary to remove the lifters from the rocker arms for inspection and/or cleaning, or when installing new lifter mechanisms, the following procedure should be followed.

a. Remove the adjusting screws and pull valve lifter assemblies from cavity in swivel pad with a magnetic pickup tool.

* In order to eliminate possible Lube Oil draining, Hydraulic lifters are inverted in nuclear standby engines only. (Ref. E&DCR F-45564)

PART B – CYLINDER HEADS AND VALVES (Continued)

b. Insert a soft wire in one of the plunger fill holes then slide the plunger out of the barrel, taking care not to let the ball check valve and the valve retainer drop. Remove the spring from the barrel cavity and wash all items in kerosene. Use lacquer thinner to remove lacquer and varnish deposits caused by lubricating oil conditions. Do not use grinding compound or a hard tool to clean the barrel or plunger as this may scratch the surfaces which are built to close tolerances. Wipe all parts with a clean, lint-free rag.

c. The condition of the unit may be best determined by performing a leakdown test. Specifications for a new unit require that, with the unit completely assembled and filled with kerosene, the plunger should travel 0.125 inch in one and one-half to three seconds when subjected to a 50 pound load. Plungers are not interchangeable in the barrel as the units are factory assembled for a specific leakdown rate.

ASSEMBLY AND INSTALLATION OF LIFTERS.

Assemble lifters in the reverse order of disassembly. Insure that all parts are clean, free of dirt or other foreign matter, and do not stick or bind. Fill and purge the assembled unit then install in the engine as follows:

a. Hold the check valve off its seat by inserting a soft wire about 3/8 inch into one of the fill holes, then submerge the unit in clean SAE-10 or SAE-20 grade oil. Push in and release the plunger repeatedly until air is no longer expelled from the assembly. This will purge the unit of air and fill it with oil.

b. Remove the wire from the fill hole and remove the assembly from the oil. The plunger should extend 1/8 inch from the barrel and should not compress when pushed in by hand.

c. With the rocker arms completely assembled and installed on the cylinder except for the hydraulic valve lifter assemblies and adjusting screws (the swivel pad assembly is held in the rocker arm by a roll pin), fill the cavity of the swivel pad with clean oil.

d. Insert the valve lifter into the swivel pad cavity. The rocker arm must be kept in a near horizontal position after the lifter has been inserted to keep the lifter submerged in oil. Install the adjusting screw and locknuts.

ADJUSTMENT.

After the lifters have been installed, or if a periodic adjustment is to be made, bar the engine over to position the cylinder being worked on at top dead center on the compression stroke and adjust lifters by one of the following methods. The first method (Method "A") involves advancing the adjusting screw until it just contacts the lifter, but does not compress it, then advancing the screw one additional turn. The alternate method (Method "B") is to completely collapse the lifter, then back off one full turn from the point where the valve just seats. Either method, if properly done, will accomplish the same thing. It must be kept in mind, however, that cold oil will increase the time required for the lifter to leak down to complete collapse when using the latter method.

a. METHOD "A".

(1) Hold the rocker assemblies tight against the pushrods to remove all play, then advance adjusting screw by hand until the end of the screw just contacts the lifter under it, taking up all the slack in the valve operating gear. Make sure the swivel pad rests squarely on the valve stem. Due to variations in threads, the feel of turning the adjusting screw is not sensitive enough to make an accurate determination as to when all slack has been removed, therefore, the feel for taking up the slack has to be on the pushrod or cross (intermediate) rod and the swivel pad on the adjusting screw. Lift each swivel pad by hand to make sure that all clearance is removed between the swivel pad and the valve stem.

PART B – CYLINDER HEADS AND VALVES (Continued)

(2) Turn the adjusting screw one full turn (0.070 inch) with a wrench and tighten the locknut. This will locate the lifter plunger near the middle of its 1/8 inch travel.

b. METHOD "B".

(1) Advance adjusting screw with a wrench until the valve begins to lift off its seat, then advance adjusting screw at least two additional turns.

(2) Wait approximately ten seconds (longer if oil is cold) then back off on adjusting screw until valve seats. The point at which the valve seats may be easily felt by the reduced torque required to turn the screw.

(3) Note the position of the wrench at the point where the valve just seats, then advance screw at least one-half turn.

(4) Back out adjusting screw until valve just seats. If the position of the wrench is the same as (3) above, the lifter is fully collapsed. If not, repeat procedure until the position of the wrench is the same each time the valve seats.

(5) Back out adjusting screw one full turn from position where valve seated then tighten locknut.

c. Swivel pads should now be free to be rotated by hand. If they cannot be rotated, the adjusting screw has collapsed the lifter to the end of its 1/8 inch travel and the valve has been lifted off its seat.

d. Swivel pad clearance should be such that the pad cannot be rocked on top of its valve stem. If the swivel pad can be rocked it means that the lifter is either fully extended and not at the mid point of its travel, or that it has not been completely purged of air. This may be due to an improper adjustment caused by burrs or dirt on the adjusting screw threads, or because of incomplete purging of air from the assembly.

PROCEDURE FOR REPLACING GA-012-000-RIVET
REFERENCE TDI ASSYMBLY DRAWING 03-390-04

1) Remove the two adjusting screws (7) on the intake rocker arm assy (7).

2) Place a large wrench against the two adjusting screws (7) on the exhaust rocker arm (3) and using a 4' pry bar, compress the exhaust valves, and remove the connector push rod (14).

3) Remove the two adjusting screws (7) on the exhaust rocker arm assembly (3).

4) Remove the hydraulic lifters (8) with a magnet.

5) Roll each rocker arm so that the side with the adjusting screws is as high as possible.

6) Using a 1/8" pin punch remove roll pins (9) from all rocker arm ends.

7) Remove swivel pad assembly (4) from the bottom of the rocker arm ends, valve side.

8) With a ½" cold chisel, tap around the existing rivet in the rocker arm ends, valve side only, until it lifts approximately 1/16" then remove with a pair of pliers.

) Using a flat steel punch slightly smaller than 3/8", attempt to drive out the small piece of tubing presently inserted in the rocker arm end. See Detail "D" of marked print.

10) If the tubing cannot be removed, drill through with a 7/16" drill supplied. Check the angle before drilling by inserting an 1/8" drill in the hole in the tube.

11) Tap with ¼" NPT tap.

12) Coat the ¼" NPT pipe plug with loctite RC/601 and insert it in the tapped hold. ¼" NPT Plug is TDI Part No. CB-005-127.

13 Stake the plug with a cold chisel or a punch in two places at 90° from each other.

14) Reassembly in reverse order from step 7 to step 1.

15) Adjust valve lash as directed in Volume I.
Note: If it is desire to replace the rivets on the pushrod end of the rocker arms, remove the rocker arms from the engine following the procedure in Volume I.
   1a) After removing the rivets as outlined in Step 8, drill the hole to 3/8" and a depth of 9/16".
   2a) Tap and plug as outlined in Step 10 through Step 13.
   3a) Replace the rocker arms as outlined in Volume I.

Ref. E&DCR F-45416B

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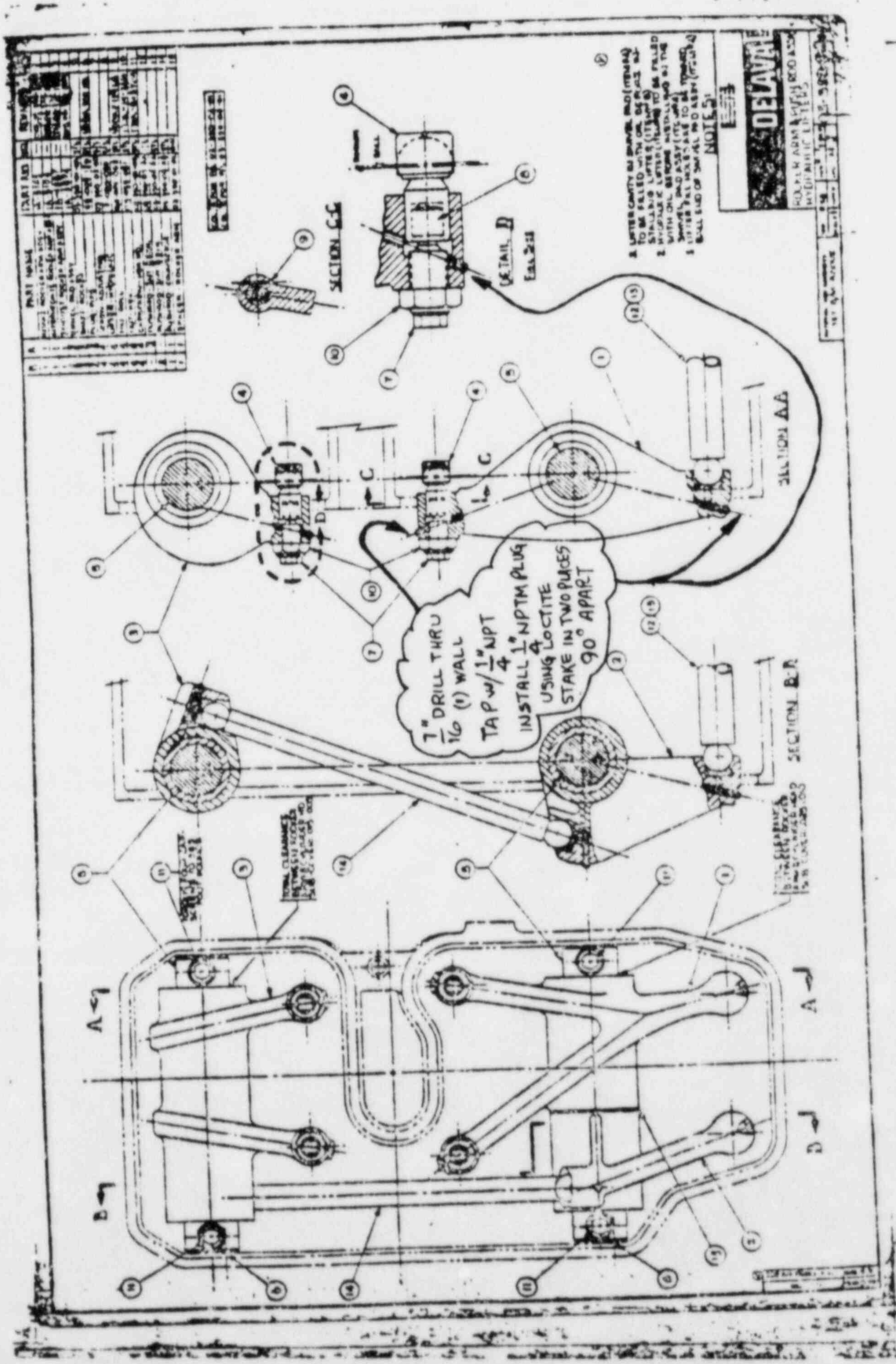
7/16" DRILL THRU (1) WALL
TAP w/ 1/4" NPT
INSTALL 1/4" NPTM PLUG
USING LOCTITE
STAKE IN TWO PLACES
90° APART
SECTION C-C
DETAIL D
SECTION A-A
SECTION B-B
DELAVAL

PART C – PISTONS AND RODS

GENERAL.

Pistons and connecting rods may be removed from the engine by pulling them out through the cylinder liners. Connecting rod bearings may be removed and installed without having to pull the cylinder heads.

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 prior to 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 be permitted to extend any part of his body under any suspended part.

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.

SPECIAL TOOLS.

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

a. Piston Pulling Fixture, Part No. 00-590-01-OW.

b. Piston Ring Guide, Part No. 18661.

c. Ring Compressor, Part No. 02-590-01-AN.

d. Piston Holder Plates, Part No. 12561.

e. Connecting Rod Cap Lifting Lug, Part No. 03-590-01-AB.

f. Cylinder Liner Pulling Fixture, Part No. 00-590-01-OV.

g. Liner O-Ring Installation Ring, Part No. 02-590-01-AE.

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REPLACING CONNECTING ROD BEARINGS.

The following procedures for replacement of connecting rod bearings may be performed for that purpose alone, or in conjunction with the removal of the piston and rod from the engine. In the latter case, the cylinder head of the cylinder involved must also be removed.

PART C – PISTONS AND RODS (Continued)

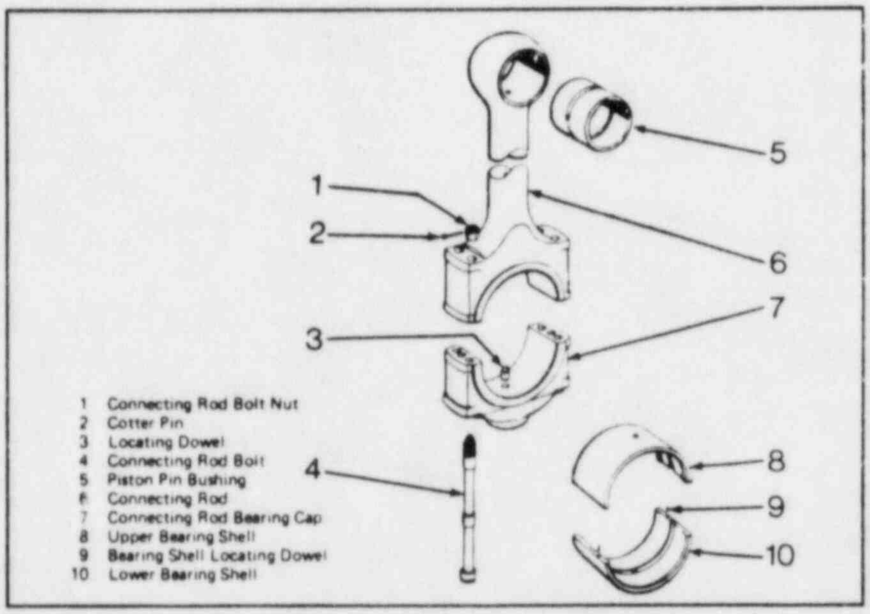

Figure 6-C-1. Connecting Rod and Bearings

a. Position piston at top dead center. Remove engine side doors on both sides of engine adjacent to crank journal of piston and rod involved.

b. Install two Piston Holder Plates, Part No. 12561, in the lower end of the cylinder liner to support the weight of the piston and rod. This tool bolts to the lower part of the liner and extends vertically to support the bottom of the piston skirt.

c. Install an eyebolt, or other suitable lifting bracket, into the tapped holes in the side of the connecting rod bearing cap (see fig. 6-C-2). This tapped hole may not be present in all case. If not, use a Connecting Rod Cap Lifting Lug, Part No. 03-590-01-AB to provide a lifting point on the cap. This special tool has two fingers, welded to a lifting lug. The fingers are inserted into the connecting rod bolt holes after the bolts have been removed. This provides a lifting point on either side of the cap. Remove bolts one side at a time, insert the tool on that side and attach a suitable lifting device such as a chainfall or chain puller. Remove the other two bolts and install the tool on that side.

d. Lower bearing cap sufficiently to allow for removal of the bearings. If piston and rod are to be removed, the bearing cap may be maneuvered out of the engine side door as illustrated in Figure 6-C-3.

e. Lift lower bearing shell out of cap.

f. Carefully bar engine over sufficiently to cause piston to rest on Holder Plates (Part No. 12561). Continue to rotate crankshaft until upper bearing shell can be rotated out of the journal. Remove bearing shell.

g. Upon completion of bearing inspection, or if bearings are to be replaced, liberally lubricate bearing shells with clean engine lubricating oil. Roll upper shell into position, then bar engine over until weight of rod and piston is taken by the bearing and journal.

h. Position lower bearing shell in connecting rod cap, then raise cap into position on the crankshaft journal. Insure locating dowels enter dowel holes (see figure 6-C-1).

PART C – PISTONS AND RODS (Continued)

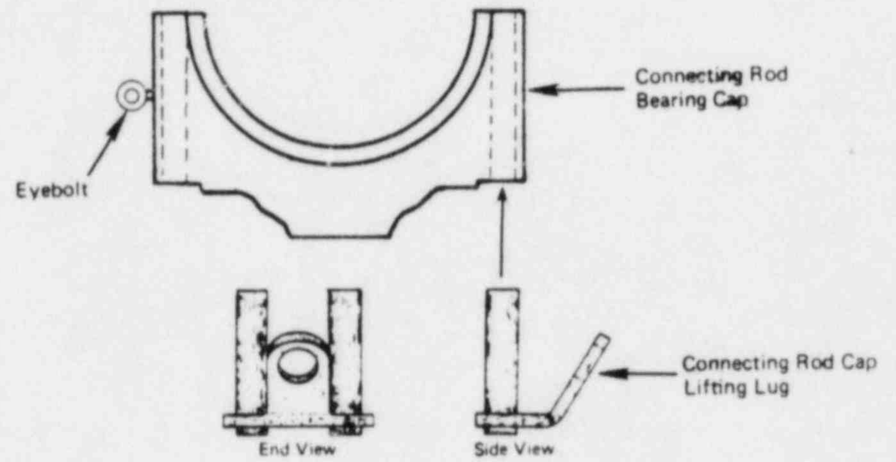

Figure 6-C-2. Connecting Rod Cap Lifting Methods

i. If the Connecting Rod Cap Lifting Lug tools are used, one tool should be removed to permit the installation of the connecting rod bolts on that side. It may be necessary to insert a long bolt through the remaining tool and assemble a washer and nut to the other end to clamp the cap in place until the connecting rod bolts on the other side have been installed and their nuts assembled.

j. Remove tool from other side and install connecting rod bolt nuts. Tighten nuts in a criss-cross pattern to the specified torque value (see Appendix IV).

REMOVING PISTON AND CONNECTING ROD.

With the cylinder head removed, and the engine side door covers removed, bar engine over until piston is at top dead center, then block crankshaft to prevent further movement. Refer to Figure 6-C-4 for the installation of the special tools required to remove the piston and rod. Care must be exercised to completely remove carbon and other combustion deposits from the upper end of the cylinder liner before removal of the piston is attempted. Failure to clean off the combustion deposits from the area above the ring travel area in the liner will result in damage to the piston rings if the piston is withdrawn from the cylinder, and may interfere with the piston skirt to the extent that the piston cannot be withdrawn from the cylinder.

a. Attach Piston Pulling Fixture, Part No. 00-590-01-OW to the crown of the piston.

b. Attach a chainfall or overhead hoist to the piston pulling tool and take up the slack.

c. Attach eyebolts to tapped holes in sides of connecting rod bearing cap (if so configured). If no holes are present, proceed to next paragraph. Attach a chain puller or other suitable lifting device to the eyebolts on both sides and take up the slack. Remove four bolts holding box to rod.

d. If there are no tapped holes in the sides of the bearing caps, install Connecting Rod Cap Lifting Lug, Part No. 03-590-01-AB as described in "Replacing Connecting Rod Bearings" (see figure 6-C-1).

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PART C – PISTONS AND RODS (Continued)

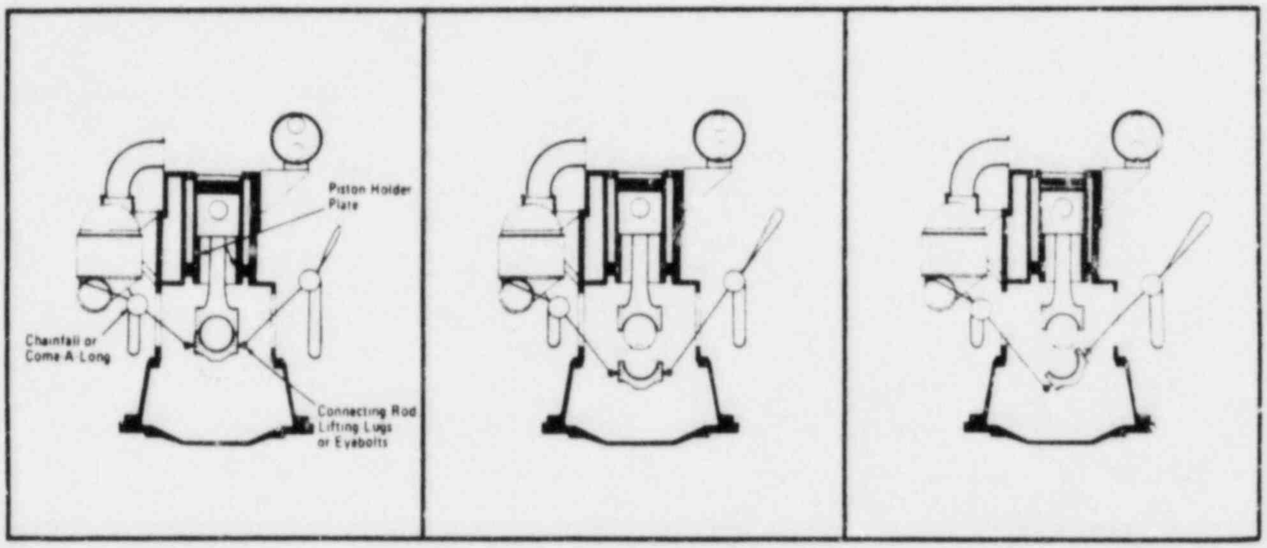

Figure 6-C-3. Removing Connecting Rod Bearing Cap

e. Maneuver bearing cap outside door as shown in figure 6-C-3.

f. Carefully lift piston and attached rod with an overhead hoist, taking care not to allow piston to bind in liner (see figure 6-C-4). Continue to lift until piston and rod are clear of liner. Set piston and rod down on a pre-fabricated stand, or rotate piston and rod by attaching a second hoist to the lower end of the rod with a nylon strap. With position reversed, detach hoist from lifting fixture, remove fixture, then set piston and rod down on floor, resting on piston crown.

g. Remove piston pin retaining rings from grooves at end of piston pin. Slide piston pin out of bore, then lift rod out of piston and set aside.

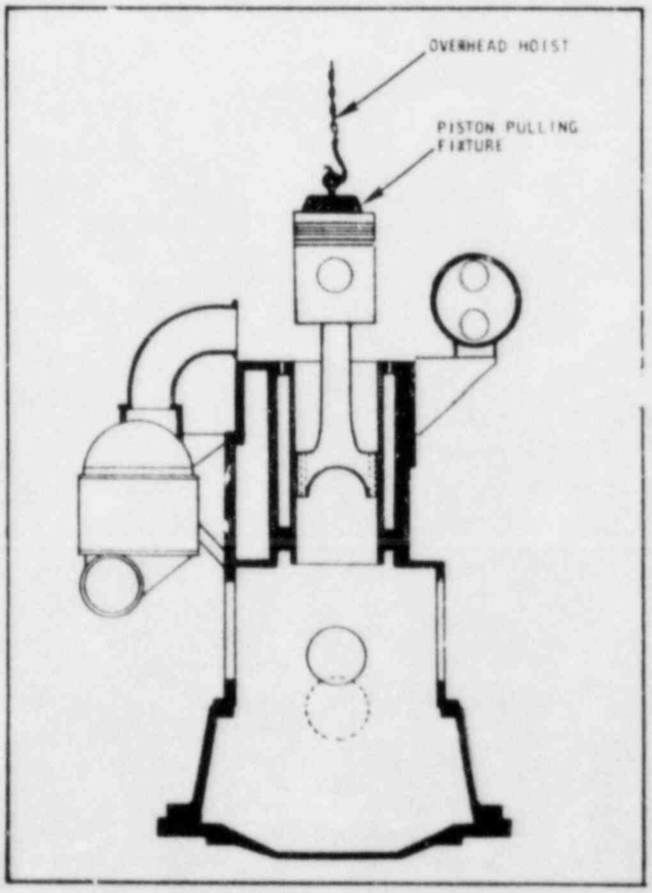

Figure 6-C-4. Lifting Piston And Rod From Liner

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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.

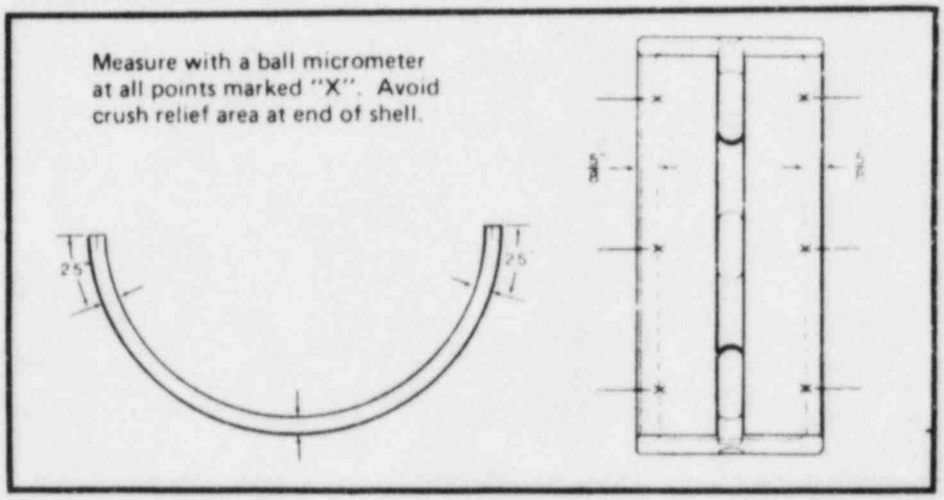

Figure 6-C-5. Measuring Bearing Shell Thickness

b. Measure thickness of bearing shells. Use a ball micrometer and measure each shell at six points, as indicated in Figure 6-C-5. 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-6). 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.

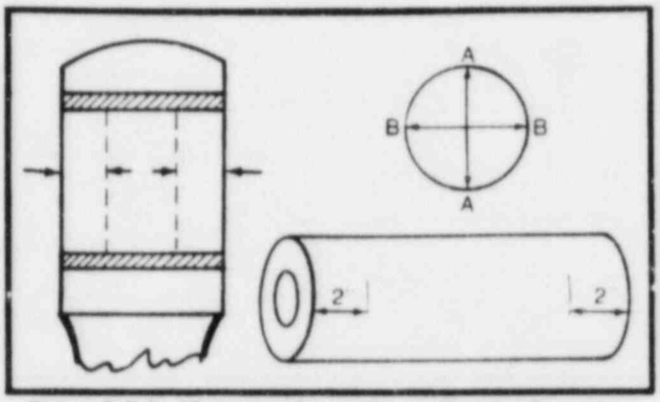

Figure 6-C-6. Measuring Piston Pin In Bushing Clearances

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-7). Record measurements and consult Appendix III for permissible clearances.

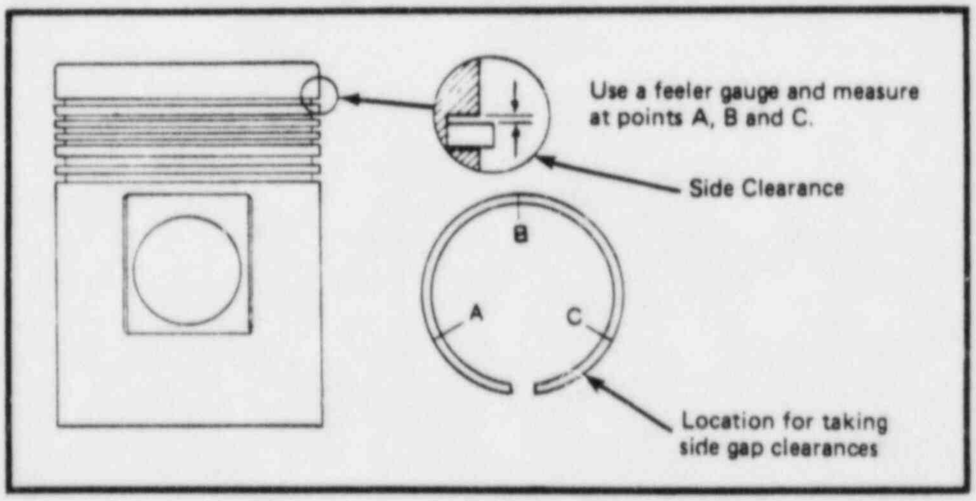

Figure 6-C-7. Piston Ring Side Clearance

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-8) 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).

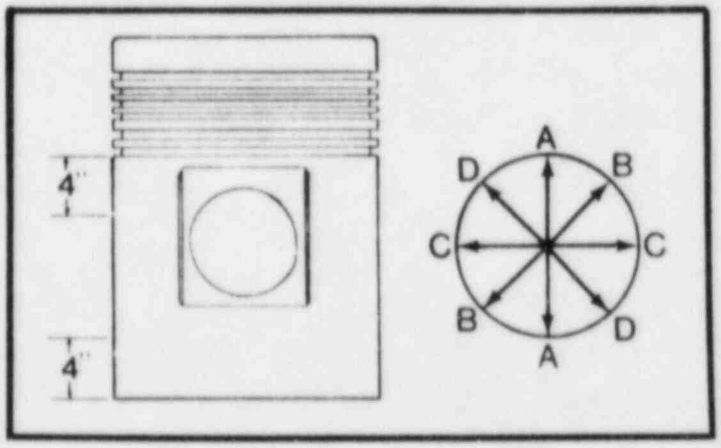

Figure 6-C-8. Piston Measurements

DISASSEMBLING PISTON (See Figure 6-C-9).

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)

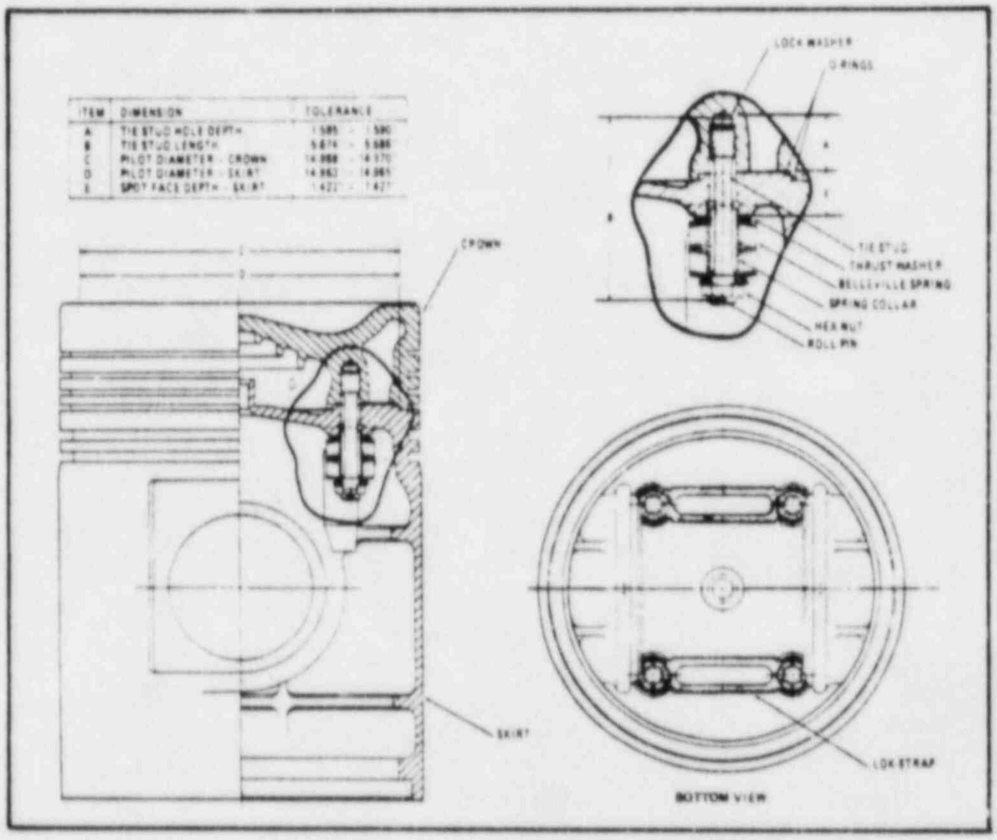

Figure 6-C-9. Piston Assembly

(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 (See Figure 6-C-9).

Assemble the piston as follows.

(1) 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-9).

(2) 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.

(3) Measure length of tie stud from lock washer end to centerline of groov-pin hole (B, Fig. 6-C-9). Acceptable tie studs must be within tolerances.

PART C – PISTONS AND RODS (Continued)

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

(5) Take a micrometer measurement of crown and skirt pilots (C, D, Fig. 6-C-9). Must be within tolerances to ensure ease of assembly without damage to O-rings.

(6) Measure skirt spot face depth (E, Fig. 6-C-9). Should be within stated tolerances.

(7) 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.

(8) 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.

(9) 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.

(10) 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.

(11) Install spring collars on each tie stud, then install two lok-straps as shown in Figure 6-C-9.

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

(13) 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.

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

(15) 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.

(16) Bend lok-strap tabs up securely against side of nuts.

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

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.

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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.

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-10.

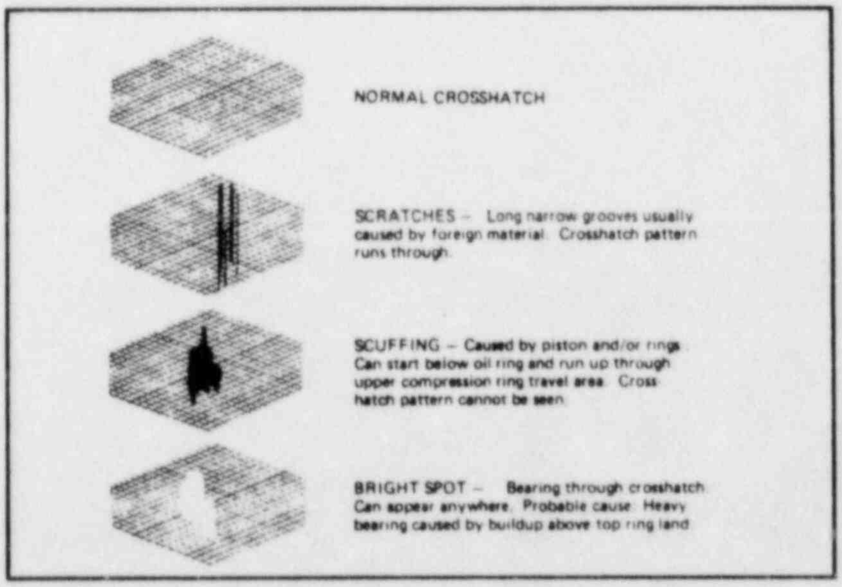

Figure 6-C-10. Cylinder Liner Wear Patterns

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PART C – PISTONS AND RODS (Continued)

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.

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. 00-590-01-0V 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.

PART C – PISTONS AND RODS (Continued)

INSTALLING PISTON AND ROD.

Installation is the reverse of removal. Be careful that rings do not catch on piston ring guide. Exercise particular care not to chip or break oil control rings. Damaged rings must be replaced.

a. Lubricate liner with clean lubricating oil.

b. Install Piston Ring Guide, Part No. 18661 over top of liner.

c. Attach a hoist to lower end of piston rod. Lift rod and position it over the piston. Carefully lower rod until piston pin bore is aligned with bushing bore in rod.

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. Slide piston pin into bore then install retainer rings on either end of pin.

f. Take weight of piston and rod on the overhead hoist. When piston is clear of floor, bolt a Piston Pulling Fixture, Part No. 00-590-01-OW to the top of the piston pin crown. Attach second hoist to the lifting fixture and rotate the piston and rod until weight is borne by the lifting fixture. Detach hoist and strap from lower end of rod.

g. Lower piston and rod into the liner. Hold piston rings in place as they enter the Ring Compressor Tool. Insure gaps are staggered around circumference of piston.

h. Install upper bearing shell in rod and lower rod until weight of piston and rod is being borne by the crankshaft journal. Hoist connecting rod cap into position. Install lower bearing then raise cap into engagement with the rod, insuring that locating dowels on bearings engage their respective holes.

i. If the Connecting Rod Cap Lifting Lug tools are used, one tool should be removed to permit the installation of the connecting rod bolts on that side. It may be necessary to insert a long bolt through the remaining tool and assemble a washer and nut to the other end to clamp the cap in place until the connecting rod bolts on the other side have been installed and their nuts assembled.

j. Remove tool from other side and install connecting rod bolt nuts. Tighten nuts in a criss-cross pattern to the specified torque value (see Appendix IV). Install cotter pins.

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.

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PART C – PISTONS AND RODS (Continued)

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.

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 aluminum, the upper and lower bearing shells 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 bearing being determined by the number of cylinders. Bearing caps are secured to the engine base by studs. 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.

BEARING REMOVAL.

Remove bearing cap lock plates and stud nuts from four bearing cap studs. Lift bearing cap off crankshaft and remove upper bearing from bearing cap. Install a bearing shell removal tool 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.

INSTALLATION OF BEARING CAP.

With the upper bearing shell secured in place on the bearing cap, position the bearing cap over the studs and lower it into position. Assemble locking plates and stud nuts on each stud and torque to the value specified in Appendix IV. Bend locking clip to hold stud nut in place.

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-1) 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 clearance 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 will 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.

PART D – CRANKSHAFT AND BEARINGS (Continued)

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 place 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.

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-1) 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 crank web. Take web deflections as follows.

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

b. Bar engine over in the direction of normal rotation with barring device until number one crank is fifteen degrees past bottom dead center.

c. Insert dial indicator between web for number one cylinder. 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 engine over, stopping at each position (2,3,4 and 5) as indicated on Form D-1063. Record each position reading 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. Determine need for corrective action.

DEFLECTION STANDARDS.

If the deflection in any crank of an engine in service exceeds 4.5 mils (0.0045 inch/0.1143 mm), corrective action is indicated. If the deflection in any web exceeds 9 mils (0.009 inch/0.2286 mm), the engine should be taken out of service until the fault is corrected. Corrective action is also necessary if the total deflection in any pair of adjacent cranks exceeds 4.5 mils. For example, if the deflection in one crank is 3 mils and the deflection in an adjacent crank is minus two mils, the total deflection would be five mils.

Refer to page 6-D-2A and B for specific guidelines for crankshaft alignment for Shoreham Diesel Engines.* ⚠

*Ref. E&DCR F-46361

Transamerica Delaval

Transamerica Delaval Inc
Engine and Compressor Division
550 85th Avenue
P O Box 2161
Oakland California 94621
(415) 577-7400

6-D-2-A

November 11, 1983

Mr. John C. Kammeyer
Stone & Webster Engineering Corporation
P. O. Box 604
North Country Road
Wading River, New York 11792

Subject: Diesel Generators, TDI S/N 74010/12
Diesel Engine Alignment

Dear John:

This letter serves to clarify the basic guidelines for crankshaft alignment provided by the TDI Crankshaft Web Deflection and Alignment Record. The following Shoreham specific guidelines for crankshaft alignment are recommended:

(1) Engines designated for nuclear stand-by service are subjected to infrequent operation and are seldom operated under load long enough for the engine, sub-base and foundation to reach stable temperature; it is therefore desirable to align the engine for a compromise between keep-warm and hot web deflections.

(2) Crankshaft position nos. 2 and 4 have the same web deflection criteria as position 3, these positions provide an indication of horizontal base alignment and seldom require corrective action. Crankshaft position 5 for an in-line engine should closely correspond with position 1 since there is only 30° of rotation between the two positions. This position can provide an indication of reading accuracy, while 3 mils remains the criteria; any reading in position 5 which exceeds 1 mil should be repeated with the deflection gauge reseated.

(3) The maximum of 3 mils deflection in any single crank applies to cylinders 1 through 7, a total deflection value of 3 mils between any two adjacent cranks applies to all cylinders. Due to the greater vertical growth expected at the rear of the engine, the limits for web deflection on the number 8 crank should be increased to 4 mils.

(4) Maximum allowable deflections apply to both hot and cold readings.

(5) Maximum allowable deflections apply to all crank positions for cylinder 1 through 7, reference comments concerning position 5 in item 2 above and number 8 cylinder in item 3 above.

Should you have any further questions regarding this subject, please feel free to contact me.

Sincerely yours,

R. Johnston
Service Engineer

RJ/mmd

PART D – CRANKSHAFT AND BEARINGS (Continued)

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 shaftings 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 type of procedure which should be undertaken by only 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 crankshaft alignment problem.

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.

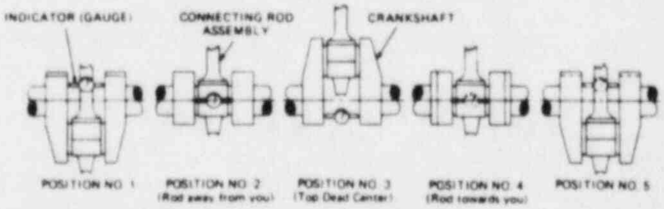
If the deflection in any crank in an engine in service exceeds 3 mils, corrective action must be taken. Also, if the total deflection value in any two adjacent cranks exceeds 3 mils, corrective action must be taken. Example, a +2 mils in any crank with a -2 mils in the next adjacent crank adds up to 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:

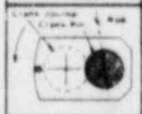
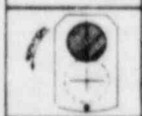
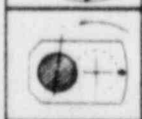
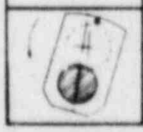
ALL INLINE ENGINES	15° AFTER BOTTOM CENTER
HV, HVA & GVB ENGINES	38° AFTER VERTICAL BOTTOM CENTER
RV ENGINES	52° AFTER VERTICAL BOTTOM CENTER

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) 1/78

Figure 6-D-1. Crankshaft Alignment Record, Form D-1063

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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.

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.

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 gear are match-marked for proper positioning at reassembly. If a new gear is to be installed, check to insure that the number one fuel injection pump is correctly timed. Fuel injection pump timing marks will serve as a reference point when reinstalling the gear.

e. Remove idler gear and bracket assembly.

(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 assembly.

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(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.

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 gear is damaged, inspect camshaft with dial indicator to determine if shaft is bent.

a. Clean camshaft taper and check fit of drive key in hub.

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 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.*

R 75

(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.

PART E – CAMS, CAMSHAFTS AND BEARINGS (Continued)

(3) Set flywheel to fuel injection point (see Engine Data Sheet in front of manual).

(4) Set the left bank camshaft so that number one fuel injection pump timing marks are matched.

c. Install idler gear and bracket assembly.

(1) Camshaft, idler and crankshaft gears are match-marked at the factory. If the original gears are being replaced, install and align gears with these marks. If a new gear is being installed the following procedures must be used to insure correct camshaft timing and engine firing order.

(2) Lift the idler gear and bracket assembly into position with a chainfall and suitable sling. Align with match-marks (if present) and mesh teeth. The camshaft gear may be moved part of a tooth to allow gears to mesh.

(3) Install a long capscrew through the top bracket mounting hole to serve as a guide. Seat bracket on engine block and install all capscrews.

d. Adjust backlash clearance between gears.

(1) Make four brass shims, 0.010 inch thick by one-half inch wide and six inches long. Insert shims between crankshaft gear and idler gears, and between idler gears and camshaft gears.

(2) Loosen capscrews holding idler gear bracket to engine block, and lift idler gear assembly until shims are held tight between gear teeth. This will establish the required backlash between each gear. Tighten idler gear retaining capscrews.

(3) Rotate the flywheel and check backlash clearance in at least four places around gear. Refer to the Table of Clearances. If backlash is within tolerances, tighten all idler assembly retaining capscrews to torque values shown in Appendix IV. Remove shims.

(4) Drill and ream two holes in each idler bracket, install No. 108–2 dowels in holes, and stake in place.

CAMSHAFT TIMING.

The camshaft of four-valve head model engines must be timed to the engine crankshaft by the fuel injection pump tappet lift method only. These camshafts are equipped with hydraulically expanded keyless cams and cannot be timed by the cam key method.

a. Remove number one fuel injection pump.

b. Bar the flywheel over until the tappet roller for number one fuel injection pump tappet is on the base circle of its cam.

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. Zero the indicator.

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

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PART E – CAMS, CAMSHAFTS AND BEARINGS (Continued)

e. Continue barring the flywheel until the degree mark for fuel injection for number one cylinder 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) Remove two fitted bolts that fasten camshaft ring to gear hub.

(2) Loosen remaining four bolts and rotate camshaft gear hub 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 teeths, 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 with 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.

h. Re-check fuel injection pump timing and cylinder head valve lash.

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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.

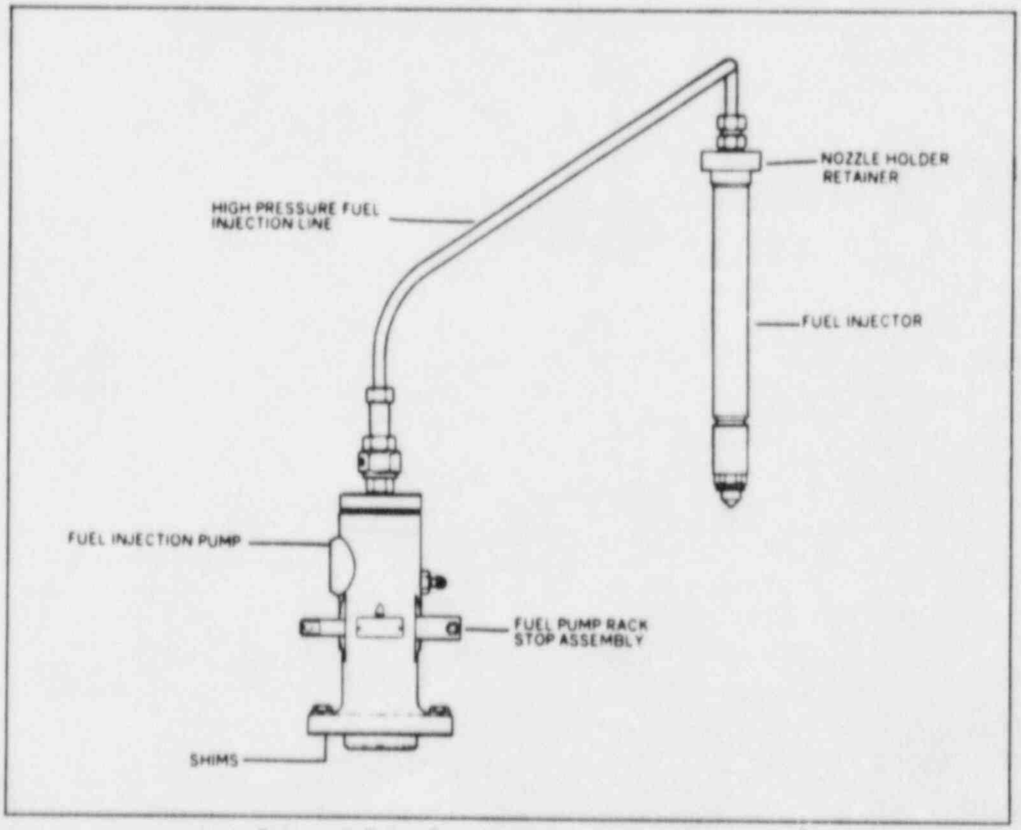

Figure 6-F-1. Typical Fuel Injection System

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

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-cm^2) plus 200 psi (14.06 kg-cm^2), 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.

PART F — FUEL SYSTEM (Continued)

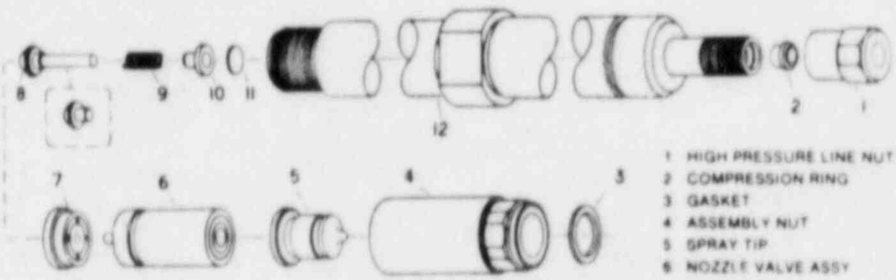

Figure 6-F-2 Fuel Injection Nozzle Assembly

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.

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.

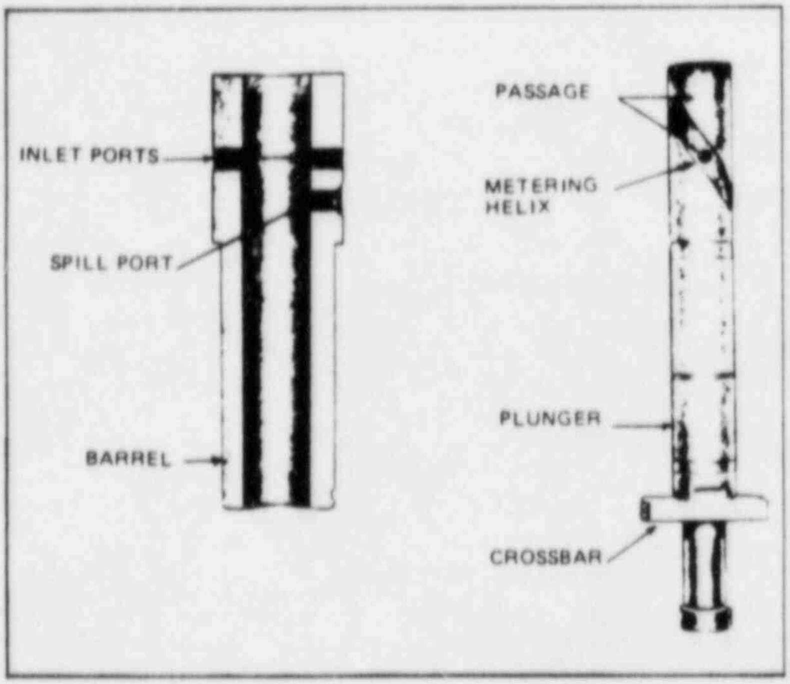

Figure 6-F-3. Pump Plunger and Barrel Arrangement

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.

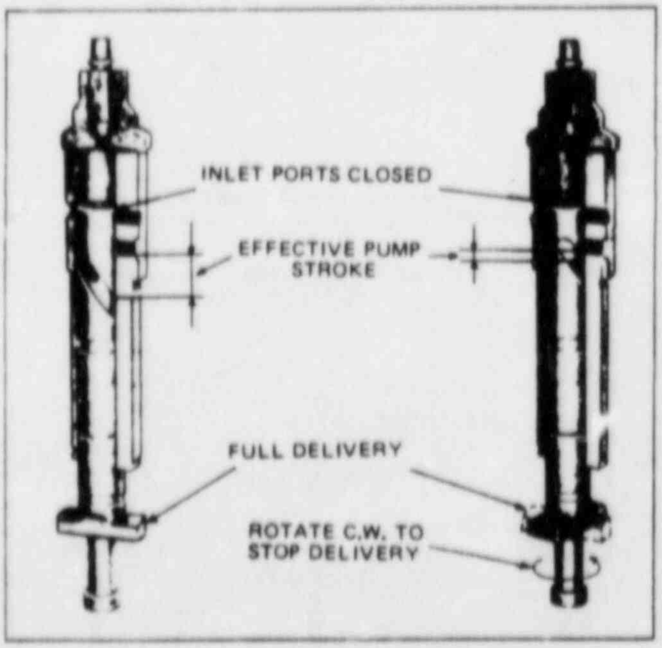

Figure 6-F-4. Effective Stroke

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.

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.

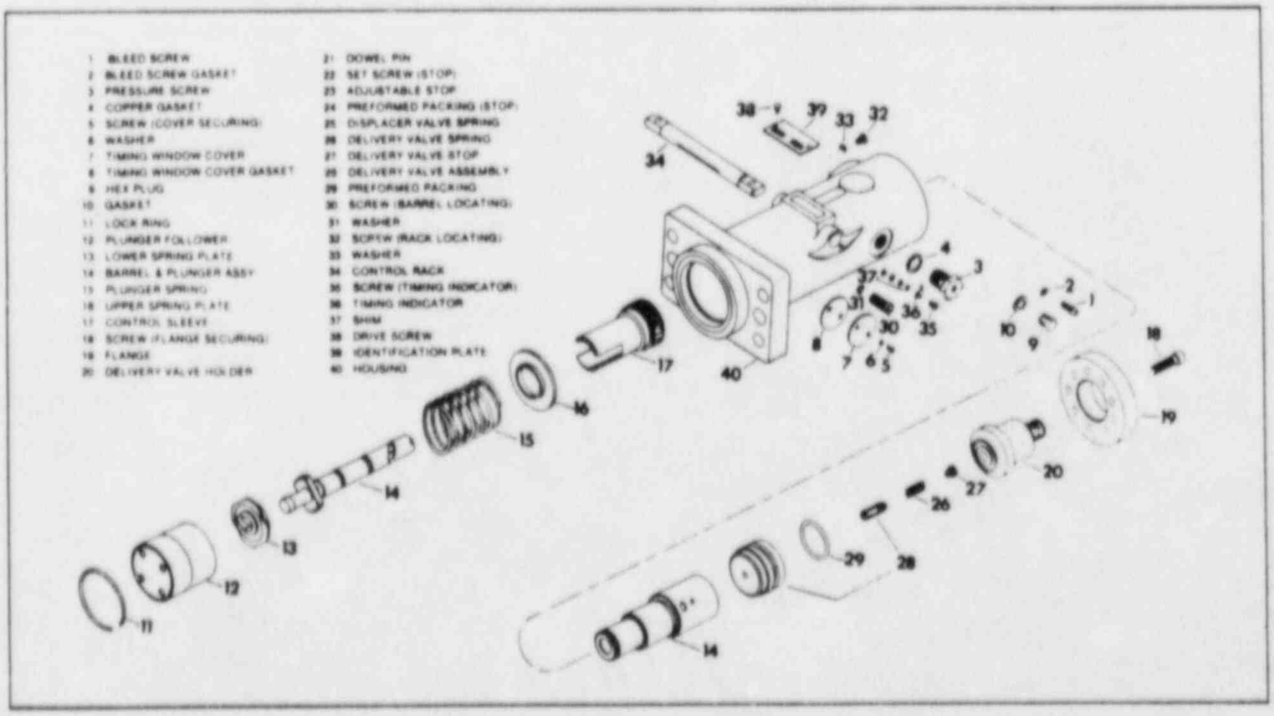

Figure 6-F-5. Fuel Pump

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, and 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 lockwasher 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.

PART F — FUEL SYSTEM (Continued)

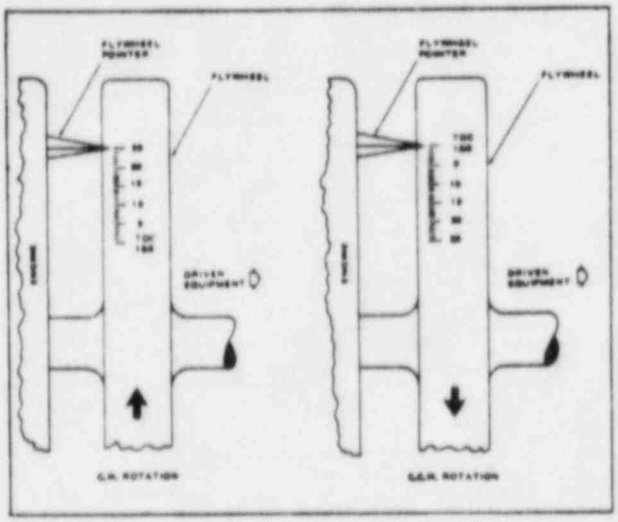

Figure 6-F-6. Flywheel Timing Marks

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.

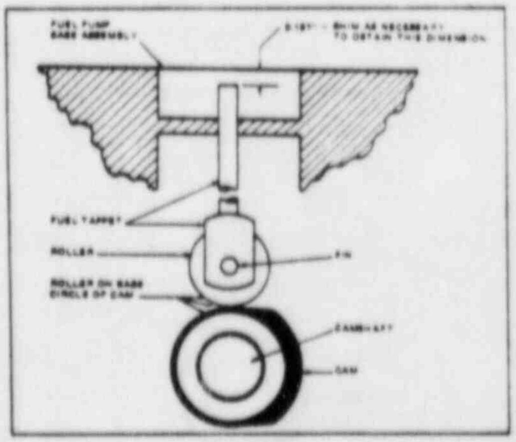

Figure 6-F-7. Pump Base To Tappet Adjustment

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.

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.

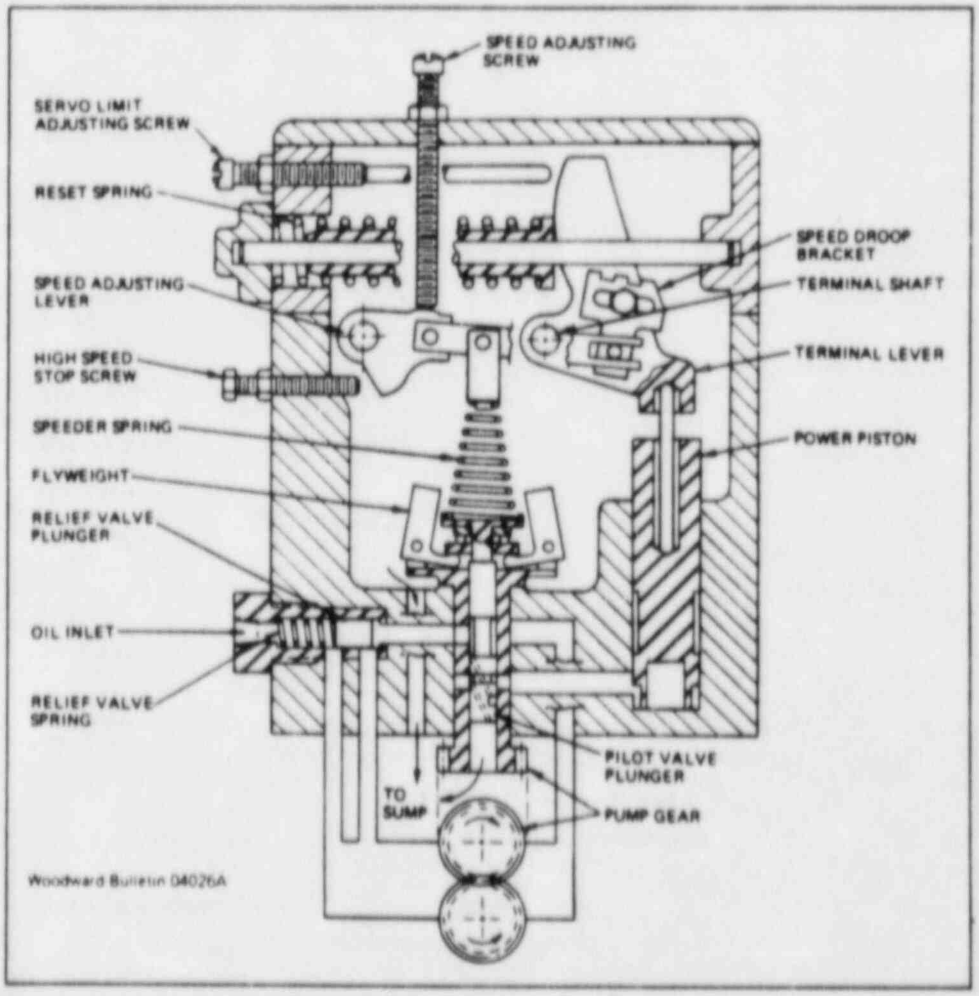

Figure 6-G-1. Overspeed Trip Governor

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)

GOVERNOR DRIVE ELEMENT REPLACEMENT.

Because of its operating environment, the Buna N flexible drive element (part no. AK-007-001) in the governor drive coupling should be changed annually. The element is a wrap around design (see Figure 6-G-2), joined by a split insert which permits easy removal and installation.

a. Remove fasteners all around on both hubs.

b. Pull end of element at split insert and remove element.

c. Install new element. Use Locktite on fastener threads.

d. If coupling was in proper alignment before replacement of the drive element, no additional alignment is necessary.

e. If alignment is considered necessary, it may be accomplished with only a straight edge.

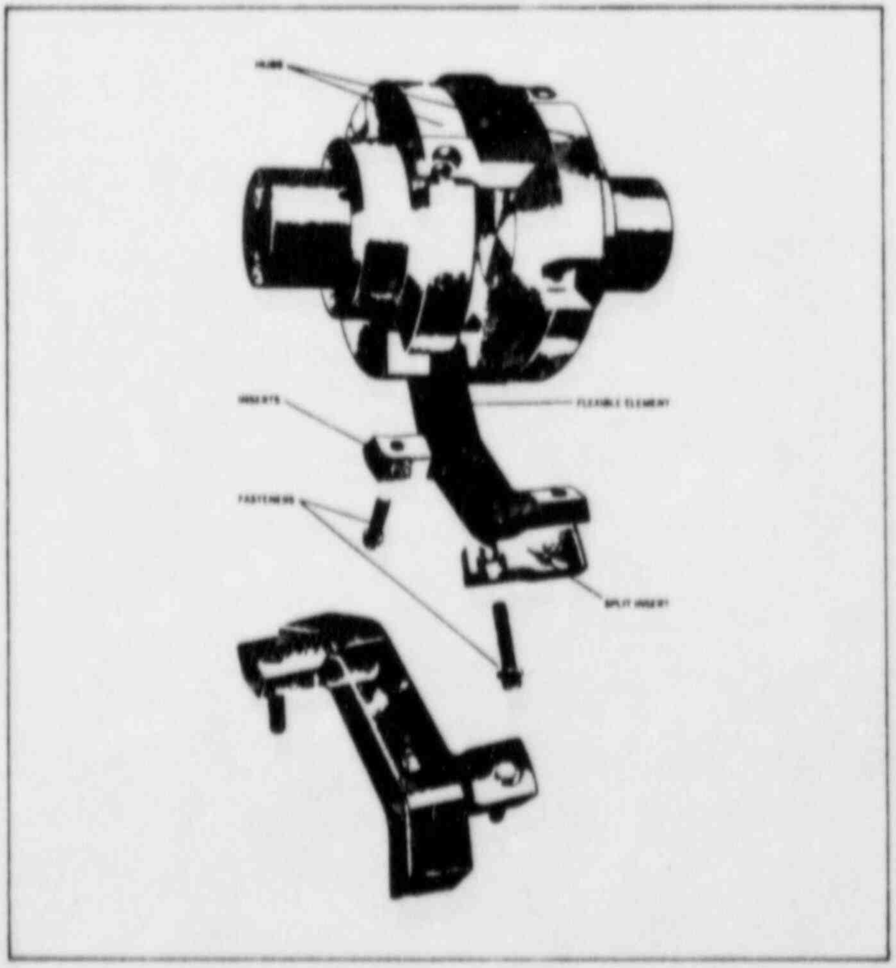

Figure 6-G-2. Governor Drive Coupling

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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^{o}, 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.

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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.

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~~ 220* psig (~~17.57~~ 15.47* kg/cm²), and the full ~~250~~ 220* 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 remotely controlled, solenoid valves in the air supply line, a camshaft driven starting air distributor, an air filter for the 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, 220* ~~250~~ psig (15.47* ~~17.57~~ kg/cm²) starting air is admitted into the starting air manifold and, therefore, to the air starting valves in the cylinder heads as well as to the starting air distributor. Individual spool valves in the distributor (one for each cylinder) 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 distributor emits 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. △

*Ref. E&DCR F-36214

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.

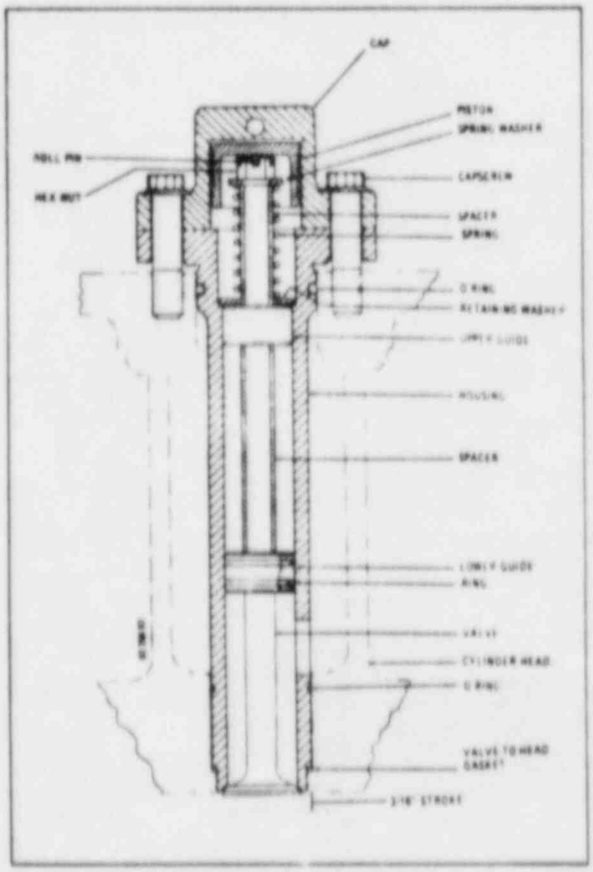

Figure 6-I-1. Starting Air Valve

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.

PART I – STARTING AIR SYSTEM (Continued)

TIMING THE STARTING AIR DISTRIBUTOR

The starting air distributor is timed at the factory when it is installed. If it should become necessary to re-time it, the following procedure may be used.

a. Bar the engine over in direction of normal rotation until number one cylinder is five degrees before top dead center (BTDC) on the end of the compression stroke.

b. Remove hex head capscrews that secure distributor cover to housing. Remove cover and gasket to gain access to interior of distributor.

c. Disconnect tubing and elbow at number one cylinder port on distributor. Remove cap, spring and spool from number one position. Re-install spool.

d. Loosen capscrews in elongated holes in distributor housing sufficiently to permit slight rotation of housing assembly.

e. Direct a beam of bright light into spool-valve opening at top of distributor housing to observe position of spool valve for number one cylinder. When valve is open, light should be visible through tubing port. While holding spool tight against cam, rotate housing until light is just visible through tubing port. This is the correct timing point. Without moving distributor housing, tighten capscrews in elongated holes to secure distributor housing to engine.

f. Re-check timing by rotating crankshaft in direction of normal rotation until light just becomes visible in tubing port. The flywheel pointer should indicate that crankshaft is five degrees BTDC with number one cylinder on the end of its compression stroke. If it is not, repeat timing procedure.

g. Remove spool from number one position in distributor housing, install spring, spool and cap. Connect elbow and tubing to port on housing. Install gaskets, cover and hex head bolts.

AIR FILTER INSPECTION

The air filter in the supply line to the distributor should be inspected and cleaned at regular intervals. The frequency of inspection and cleaning should be determined by operating conditions and experience.

STRAINERS

Low point water collectors, "Y" strainers and air receiver tanks must be drained daily whether engine/generator is run or not. Inspect and clean "Y" strainers weekly. If the fouling of the strainers is such that more frequent inspection is warranted, shorten the inspection interval.

Non-adjustable cam distributor

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 through the system by a jacket water pump with practically no loss in quality. The water supply for the jacket water system must be completely treated for both scale and corrosion, and raw, untreated water must never be introduced into the system. For the first run of an engine, distilled water is imperative.

WATER TREATMENT PROGRAM.

Transamerica Delaval does not specify any particular water treatment program, recommending instead that a water specialist be consulted about the degree and frequency of treatment, depending upon the type of water used. There are a number of reliable water treatment companies who will contract to properly condition engine jacket water to prevent corrosion and/or scale in the engine jacket water passages, and in the piping systems and coolers. Nalco Chemical Company, Drew Corporation, and Magnus Maritec International are examples of such companies. It is recommended that such a company be employed for this purpose. When a contract is entered into, it is suggested that a weekly test requirement be written into the contract.

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, the 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 the 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 system until after the temperature of the cooling surfaces have dropped to approximately that of the inlet water.

USE OF ETHYLENE GLYCOL.

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 the radiator cooling capacity approximately 12%. Therefore, unless the cooling system was originally designed for this coolant mixture, the Transamerica Delaval Customer Service Department should be consulted prior to the use of such a coolant.

SCALE AND CORROSION.

All water contains some impurities suspended in the water. The impurities in an engine cooling system can form scale which will prevent the proper transfer of heat from the hot enigne parts to the cooling water. The use of distilled or softened water in the system simplifies the control of scale forming substances. Generally scale only forms on the hot surfaces of the internal passages of an engine cooling system and not throughout the entire system. Scale is a very poor conductor of heat. Improper heat transfer, particularly uneven heat transfer, causes stresses in the affected parts. These stresses may cause cylinder liners, cylinder heads and other parts of the engine to fail prematurely. Improperly treated water may allow the internal surfaces of an engine to become pitted by corrosion. The fatigue limit of iron and steel is greatly reduced by corrosion. Corrosion in the cooling system may lead to failure in the liners and heads, and may cause serious damage to other parts of the cooling system.

TREATMENT OF JACKET WATER.

To minimize serious corrosion and scale deposits, and to prolong the life of the cooling system, the treated water must be maintained within specified limits. Actual treatment will vary depending upon the nature of the water supply. The treatment of water in an engine cooling system requires the use of chemicals to maintain the alkalinity and chromate concentration of water as specified levels. If the alkalinity and chromate concentrations are properly maintained, scale formation and corrosive action will be greatly reduced. The pH value of the water must be maintained within the range of 8.25 to 9.75. A minimum value is specified because lower values can result in accelerated corrosion. To avoid

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PART J – COOLING WATER SYSTEMS (Continued)

corrosion which occurs in highly alkaline waters, the alkalinity should not be allowed to exceed a 9.75 ph value.

a. SODIUM DICHROMATE AND BOILER COMPOUND TREATMENT – Sodium dichromate is a convenient and inexpensive source of alkaline chromate which has been found to form a protective film on metallic surfaces which prevents attack on the metal by corrosive elements in the jacket water. It must be noted that sodium dichromate is an acid compound which must have an alkaline compound such as boiler compound added to convert the sodium dichromate to an effective alkaline chromate form.

b. SODIUM AND DISODIUM PHOSPHATE TREATMENT – When using sodium chromate and disodium phosphate for cooling water treatment, the procedures for preparing the system, mixing the solution, testing and controlling the chromate concentration and alkalinity are the same as that used for sodium dichromate and boiler compound treatment. The only differences between the two are first, the chemicals used, and second, the amounts used. When using either of the above chemical treatments, specific proportions should be recommended by a water treatment company for the specific water to be treated and for the water capacity of the system.

WARNING

The chromate chemicals used for water treatment of cooling systems are classified as a health hazard. Personnel should avoid any contact of skin or eyes with chromates when in a solid form, or in a solution. Breathing of chromate dust or solution spray should be avoided. Plant personnel, when handling chromate chemicals, should be provided with protective equipment which is consistent with the type and degree of hazard involved.

WARNING

When skin has come into contact with chromates, the affected areas should be washed with large quantities of soap and water immediately after exposure.

ENVIRONMENTAL CONSIDERATIONS.

When environmental considerations are paramount, nitrite compounds such as sodium nitrite, $NaNO_2$, are suggested as a substitute. However, the selection of a chromate treatment over a nitrite treatment is strongly urged. Nitrites may adversely affect the fatigue life of the major cast parts such as cylinder heads. Whenever possible, chromate compounds should be used.

CLEANING THE JACKET WATER SYSTEM.

Should the cleaning of the jacket water system be required to remove rust or scale from the system, the recommendations of the water treatment company should be obtained as to a suitable cleaner. Transamerica Delaval's Customer Service Department should be called upon for advice as to the compatibility of the cleaner with the cooling system materials. Whenever it is necessary to change from one type of water treatment to another, completely drain and flush the system free of any chromates or glycol antifreeze to prevent any mixing of these materials.

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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.

LUBRICATING OIL PUMP.

The engine-driven lubricating oil pump is a positive displacement, rotary type. As the pump rotates, the unmeshing of the teeth of the two gears produces a vacuum which draws oil between the tooth spaces. Oil is confined in the space between the gear teeth and the housing, and is carried to the discharge side of the pump. The meshing of the gears forces the oil into the discharge line by displacing the oil from the tooth spaces as the opposite gear enters the space. The pump is mounted on the engine gearcase by means of an adapter, and is driven by the idler gear through a gear carrier assembly. A spline on the pump shaft engages internal splines on the gear carrier shaft coupling. Refer to figure 6-K-1 for mounting details.

REMOVING PUMP.

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 [illegible]

c. Remove the capscrews that secure the pump to the adapter and pull the pump directly away from the engine until it is clear.

PART K – LUBRICATING OIL SYSTEM (Continued)

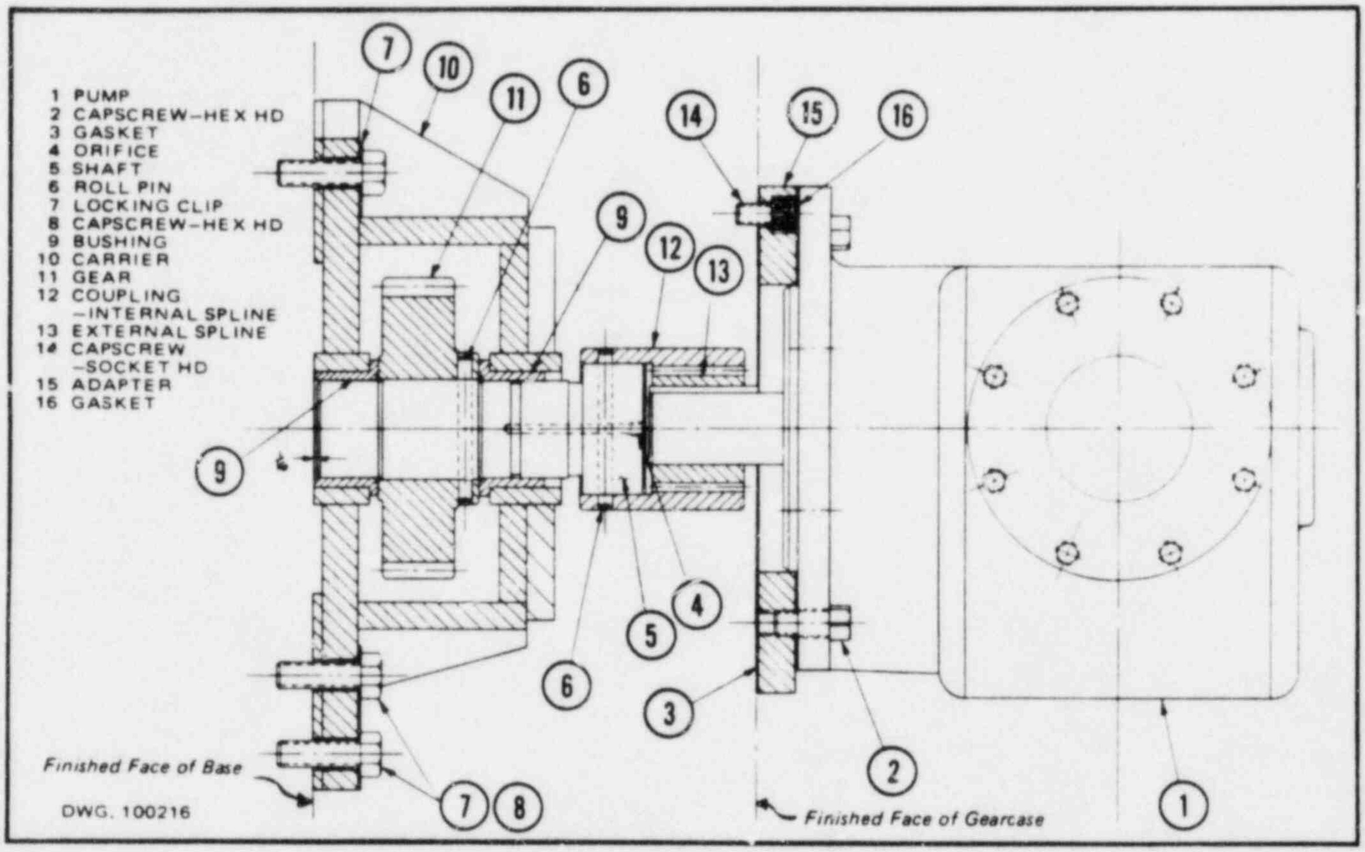

Figure 6-K-1. Lubricating Oil Pump Assembly

PUMP DISASSEMBLY (See Figure 6-K-1).

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. Remove spline from pump shaft, taking care not to exert any internal forces on the pump parts.

b. Remove hex head screws from the faceplate end of the pump and remove the faceplate which contains two bearings.

c. Remove idler gear and shaft, then the drive gear and shaft.

d. Remove hex head screws from backplate end of pump housing and remove backplate which contains two bearings.

e. Carefully examine the surfaces of the gears. Slight burrs or feather edges may be removed with a hand stone.

f. Examine bearings and clean oil grooves and passages.

g. Remove burrs and foreign matter on gasketed surfaces of end plate and case.

h. Check bearing wear, using the table of clearances provided on next page.

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PART K – LUBRICATING OIL SYSTEM (Continued)

TABLE OF CLEARANCES
Roper Pump Company Figure 2877 Type 1

SHAFT OUTSIDE DIAMETER TO BEARING INSIDE DIAMETER*	
Bearing Inside Diameter	2.0050" – 2.0055"
Shaft Outside Diameter	2.0000" – 1.9995"
Diametric Clearance	0.0050" – 0.0055"
Maximum permissible operating clearance	0.0100"
NOTE: Wear can occur in bearing ID or shaft OD. Total of both not to exceed 0.010".	
GEAR OUTSIDE DIAMETER TO CASE BORE*	
Case Bore	5.667" – 5.669"
Gear Outside Diameter	5.658" – 5.657"
Initial Clearance	0.009" – 0.012"
PUMP LATERAL CLEARANCE**	
Case Width	8.751" – 8.750"
Gear Width	8.750" – 8.749"
Total Compressed Gasket Thickness	0.014" – 0.016"
Total Initial Lateral Clearance	0.018" – 0.014"

*Not considering roundness, concentricity and positioning tolerance.
**Not considering squarness, perpendicularity and positioning tolerance.

PUMP REASSEMBLY.

Assembly is the reverse of disassembly. The spline must be mated to the shaft without exerting any internal forces on the pump parts. The tapered end of the idler gear should be meshed to the opposite end of the drive gear. Taper ends are designated by the letter "T" appearing in the root area of the gear teeth.

INSTALLATION OF PUMP.

Before mounting pump on engine, make sure pump rotates freely. Mount pump to adapter, engaging dowel and the pump shaft spline with that of the gear carrier shaft. Use a gasket between the pump and the adapter. Assemble nuts on studs, and capscrews. Tighten. Lubricate pump through ports with any good grade of light weight oil to insure pump will not be dry at the time of initial starting. When installing piping, do not force as the strain imposed will cause undue wear on the pump. No external lubrication is required as the pump is self lubricated by the oil it pumps during operation.

PUMP GEAR CARRIER ASSEMBLY.

The pump gear carrier assembly consists of a shaft, supported by two bronze bushings, pressed in the carrier assembly with their flanges to the inside. The pump end of the shaft has an internally splined adapter, attached to the shaft with a roll pin, which accepts the spline on the pump shaft. The drive gear is mounted on the shaft between the two bushings and engages the idler gear. The carrier assembly is secured to the engine block by capscrews and locking clips.

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PART K – LUBRICATING OIL SYSTEM (Continued)

DISASSEMBLY AND ASSEMBLY OF GEAR CARRIER ASSEMBLY.

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 bushings 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)

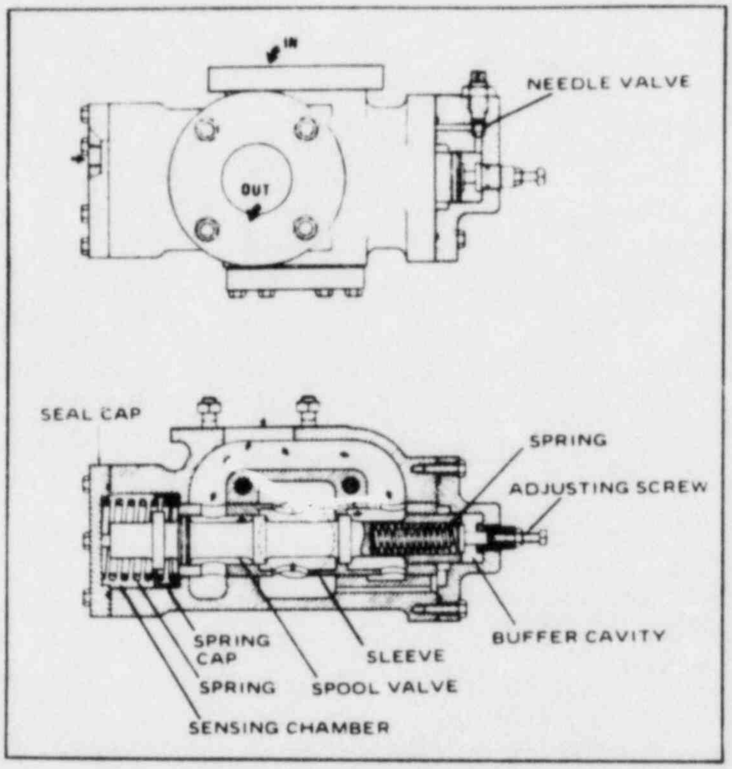

Figure 6-K-2. Oil Pressure Regulating Valve

PRESSURE REGULATING VALVE.

Lubricating oil header pressure in the engine is regulated by a pressure regulating valve, mounted on the pump discharge piping so that the pump discharge is directed to this valve before reaching any other system components. Set at 50 psig, it senses header pressure and regulates the bypass volume to maintain the set header pressure. Besides regulating header pressure, the valve protects the system from excessive pressure during starts with cold oil, or when flow in the system is restricted between the pressure regulating valve and the header pressure sensing point. The functioning of the valve is as follows.

a. The "IN" port of the valve is connected to the pump discharge line and the "OUT" port is connected to a bypass line leading back to the engine base. A sensing tube, connecting the valve seal cap to a point on the main engine oil header, applies header pressure to the valve pressure sensing chamber.

b. The pressure in the sensing chamber acts against the end of a spool valve, compressing a spring at the adjusting screw end of the assembly. If the sensed pressure rises above the set point, the lands of the spool valve will clear the lands on a sleeve. Oil then flows from the inlet section to the outlet-section of the regulating valve and back to the engine base to bypass a part of the pump discharge to reduce the pressure in the header.

c. A drilled passage connects the inlet section of the valve to the annular space around the spool valve at the adjusting screw end. This allows pump discharge pressure to act against the end of the sleeve and oppose the spring force at the other end. When an excessive pressure differential exists between the pump discharge and the header pressures, such as when starting with cold oil, or because of an obstruction in the system between the regulating valve and the header pressure sensing point, the sleeve is forced towards the sensing chamber end, compressing the spring. This will uncover the lands of the spool valve and the excess oil will bypass through the spool valve and the excess oil will bypass through the outlet side of the valve back to the engine base.

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 a fill 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.

PART K – LUBRICATING OIL SYSTEM (Continued)

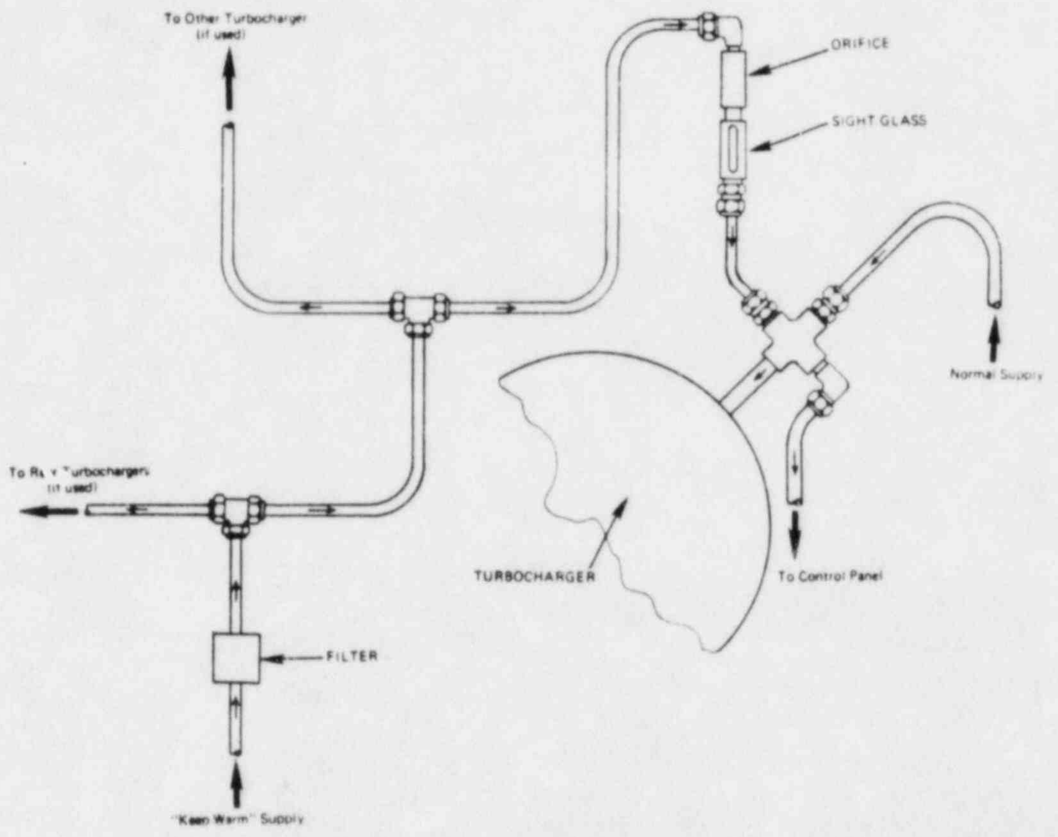

Figure 6-K-5. Turbocharger Bearing Drip Lubrication System

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.

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.

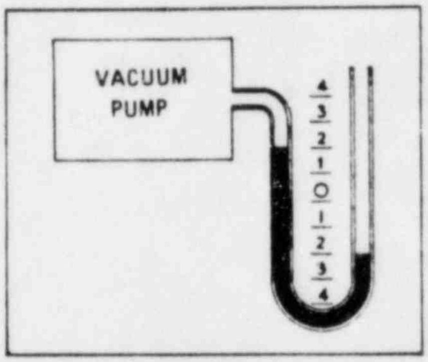

Figure 6-L-1. Manometer with Vacuum Pump

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.

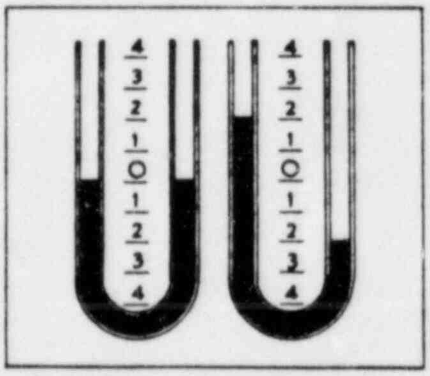

Figure 6-L-2. Reading Manometer

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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. A motor-driven blower is used to draw directly from the crankcase through an oil separator, and discharges directly to atmosphere outside the engine room. Oil particles suspended in the air are removed as the air passes through the separator, and the oil drains back to the engine crankcase. The blower motor is started automatically when the engine is started, and shuts 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 readings indicate a loss of crankcase vacuum, the cause should be promptly determined and corrected.

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.

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.
	i. 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, re-face, 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, check 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.

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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. Laquering 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.

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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. Check fuel and filters.
	f. Nozzle valve stuck in closed position or nozzle orifices closed.	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

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:

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	182.655	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	855.301	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	306.355	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	Centigrade		Fahrenheit	Centigrade		Fahrenheit	Centigrade		Fahrenheit
-273.17	**-459.7**		-20.6	**-5**	23.0	11.1	**52**	125.6	54.4	**130**	266
-268	**-450**		-17.8	**0**	32.0	11.7	**53**	127.4	57.2	**135**	275
-262	**-440**					12.2	**54**	129.2	60.0	**140**	284
-257	**-430**		-17.2	**1**	33.8	12.8	**55**	131.0	62.8	**145**	293
-251	**-420**		-16.7	**2**	35.6	13.3	**56**	132.8	65.6	**150**	302
-246	**-410**		-16.1	**3**	37.4				68.3	**155**	311
-240	**-400**		-15.6	**4**	39.2	13.9	**57**	134.6	71.1	**160**	320
-234	**-390**		-15.0	**5**	41.0	14.4	**58**	136.4			
			-14.4	**6**	42.8	15.0	**59**	138.2	73.9	**165**	329
-229	**-380**		-13.9	**7**	44.6	15.6	**60**	140.0	76.7	**170**	338
-223	**-370**		-13.3	**8**	46.4	16.1	**61**	141.8	79.4	**175**	347
-218	**-360**					16.7	**62**	143.6	82.2	**180**	356
-212	**-350**		-12.8	**9**	48.2	17.2	**63**	145.4	85.0	**185**	365
-207	**-340**		-12.2	**10**	50.0	17.8	**64**	147.2	87.8	**190**	374
-201	**-330**		-11.7	**11**	51.8				90.6	**195**	383
-196	**-320**		-11.1	**12**	53.6	18.3	**65**	149.0	93.3	**200**	392
-190	**-310**		-10.6	**13**	55.4	18.9	**66**	150.8	96.1	**205**	401
			-10.0	**14**	57.2	19.4	**67**	152.6	98.9	**210**	410
-184	**-300**		-9.4	**15**	59.0	20.0	**68**	154.4	100.0	**212**	414
-179	**-290**		-8.9	**16**	60.8	20.6	**69**	156.2	102	**215**	419
-173	**-280**					21.1	**70**	158.0	104	**220**	428
-169	**-273**	-459.4	-8.3	**17**	62.6	21.7	**71**	159.8	107	**225**	437
-168	**-270**	-454	-7.8	**18**	64.4	22.2	**72**	161.6	110	**230**	446
-162	**-260**	-436	-7.2	**19**	66.2				113	**235**	455
-157	**-250**	-418	-6.7	**20**	68.0	22.8	**73**	163.4	116	**240**	464
-151	**-240**	-400	-6.1	**21**	69.8	23.3	**74**	165.2			
			-5.6	**22**	71.6	23.9	**75**	167.0	118	**245**	473
-146	**-230**	-382	-5.0	**23**	73.4	24.4	**76**	168.8	121	**250**	482
-140	**-220**	-364	-4.4	**24**	75.2	25.0	**77**	170.6	124	**255**	491
-135	**-210**	-346				25.6	**78**	172.4	127	**260**	500
-129	**-200**	-328	-3.9	**25**	77.0	26.1	**79**	174.2	129	**265**	509
-123	**-190**	-310	-3.3	**26**	78.8	26.7	**80**	176.0	132	**270**	518
-118	**-180**	-292	-2.8	**27**	80.6				135	**275**	527
-112	**-170**	-274	-2.2	**28**	82.4	27.2	**81**	177.8	138	**280**	536
-107	**-160**	-256	-1.7	**29**	84.2	27.8	**82**	179.6	141	**285**	545
			-1.1	**30**	86.0	28.3	**83**	181.4	143	**290**	554
-101	**-150**	-238	-0.6	**31**	87.8	28.9	**84**	183.2	146	**295**	563
-96	**-140**	-220	0.0	**32**	89.6	29.4	**85**	185.0	149	**300**	572
-90	**-130**	-202				30.0	**86**	186.8	154	**310**	590
-84	**-120**	-184	0.6	**33**	91.4	30.6	**87**	188.6	160	**320**	608
-79	**-110**	-166	1.1	**34**	93.2	31.1	**88**	190.4	166	**330**	626
-73.3	**-100**	-148.0	1.7	**35**	95.0				171	**340**	644
-67.8	**-90**	-130.0	2.2	**36**	96.8	31.7	**89**	192.2	177	**350**	662
-62.2	**-80**	-112.0	2.8	**37**	98.6	32.2	**90**	194.0			
			3.3	**38**	100.4	32.8	**91**	195.8	182	**360**	680
-59.4	**-75**	-103.0	3.9	**39**	102.2	33.3	**92**	197.6	188	**370**	698
-56.7	**-70**	-94.0	4.4	**40**	104.0	33.9	**93**	199.4	193	**380**	716
-53.9	**-65**	-85.0				34.4	**94**	201.2	199	**390**	734
-51.1	**-60**	-76.0	5.0	**41**	105.8	35.0	**95**	203.0	204	**400**	752
-48.3	**-55**	-67.0	5.6	**42**	107.6	35.6	**96**	204.8	210	**410**	770
-45.6	**-50**	-58.0	6.1	**43**	109.4				216	**420**	788
-42.8	**-45**	-49.0	6.7	**44**	111.2	36.1	**97**	206.6	221	**430**	806
-40.0	**-40**	-40.0	7.2	**45**	113.0	36.7	**98**	208.4			
			7.8	**46**	114.8	37.2	**99**	210.2	227	**440**	824
-37.2	**-35**	-31.0	8.3	**47**	116.6	37.8	**100**	212.0	232	**450**	842
-34.4	**-30**	-22.0	8.9	**48**	118.4	40.6	**105**	221	238	**460**	860
-31.7	**-25**	-13.0				43.3	**110**	230	243	**470**	878
-28.9	**-20**	-4.0	9.4	**49**	120.2	46.1	**115**	239	249	**480**	896
-26.1	**-15**	5.0	10.0	**50**	122.0	48.9	**120**	248	254	**490**	914
-23.3	**-10**	14.0	10.6	**51**	123.8	51.7	**125**	257	260	**500**	932

The formulas at the right may also be used for converting Centigrade or Farenheit degrees into the other scales.

Degrees Cent., $°C = \frac{5}{9}(°F + 40) - 40 = \frac{5}{9}(°F - 32)$

Degrees Fahr., $°F = \frac{9}{5}(°C + 40) - 40 = \frac{9}{5}(°C + 32)$

Degrees Kelvin, $°K = °C + 273.2$

Degrees Rankine, $°R = °F + 459.7$

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	.956
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	23.99	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	6	-14	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	18.273^{-1}	21.0	.406	.0285
90,000	17.1	27,459	-57	-59	5.200^{-1}	13.2	.255	.0179
100,000	18.9	30,510	-51	-46	3.290^{-1}	8.36	.162	.0114
170,000	22.8	36,612	-26	-48	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}	16.97^{-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}	3.67^{-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	242	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
Centimtrs. of Mercury	0.01316	Atmospheres
Centimtrs. of mercury	0.4461	Feet of water
Centimtrs. of mercury	136.0	Kgs./sq. meter
Centimtrs. of mercury	27.85	Lbs./sq. ft.
Centimtrs. 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	4.95×10^{-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-pwr. (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.

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.) x 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
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
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

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

APPENDIX II

OPERATING PRESSURES AND TEMPERATURES

PRESSURES

The following pressures should be present for starting:

Starting Air Supply	Δ ~~250~~ psi	Δ ~~17.6~~ kg/sq cm
Starting Air Header	Δ ~~250~~ psi	Δ ~~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~~ Δ	101.8 — ~~112.0~~ Δ	3.52 — ~~3.87~~ Δ
Lubricating Oil at Turbocharger Inlet	~~20 — 25~~ Δ	~~40.7 — 50.9~~ Δ	~~1.41 — 1.76~~ Δ
Jacket Water	10 — 30	20.4 — 61.1	0.70 — 2.11
Fuel Oil	20 — ~~30~~ Δ	40.7 — ~~61.1~~ Δ	1.41 — ~~2.11~~ Δ

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)~~ Δ

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). The exhaust temperature limits for sustained operation is 150° F between any two cylinders and 1100° F maximum.

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). The firing pressure limits for sustained operation is 200 psi between any two cylinders.

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.

Δ For revised values refer to supplement page 8-3-A

APPENDIX II
OPERATING PRESSURES AND TEMPERATURES

PRESSURES

The following pressures should be present for starting:

Starting Air Supply ****220-230 psi ....15.47-16.17 kg/sq cm
Starting Air Header ****220-230 psi ....15.47-16.17 kg/sq cm

While running at rated speed, the operating pressures should be as follows:

	psi	in-hg	kg/sq cm
Lubricating Oil*	50-65**	101.8-132.0	3.52-4.57
Lubricating Oil at Turbocharger Inlet	25-35**	50.9-71.3	1.76-2.46
Jacket Water	20-30**	40.7-61.1	1.41-2.11
Fuel Oil	20-35***	40.7-71.26	1.41-2.46

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 160°F-170°F(71.1°C-76.6°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). The exhaust temperature limits for sustained operation is 150°F between any two cylinders and 1100°F maximum.

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). The firing pressure limits for sustained operation is 200 psi between any two cylinders.

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 dertermining the proper corrective action.

*When using SAE 40 lubricating oil in engine
** Ref. E&DCR F-44795A
***Ref. E&DCR F-45633
****Ref. E&DCR F-36214

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APPENDIX III

TABLE OF CLEARANCES
MODEL R-4 ENGINE

Item	Clearance When New – Inches	Clearance When New – Millimeters	Replace When Over – Inches	Replace When Over – Millimeters	Notes
Crankshaft to Main Bearings	0.007/0.011	0.179/0.279	– – –	– – –	See bearing shell thickness figures
Crankshaft to Thrust Rings	0.022/0.030	0.559/0.762	0.040	1.016	Replace at least one
Connecting Rod Bearing to Crankshaft	0.006/0.010	0.152/0.254	– – –	– – –	See bearing shell thickness figures
Camshaft Bearings to Camshaft (intermediate)	0.004/0.007	0.102/0.178	– – –	– – –	See bearing shell thickness figures
Camshaft Thrust Adjustment	0.004/0.007	0.102/0.178	– – –	– – –	Adjust at 0.012" or over
Piston Pin to Rod Bushing	0.009/0.015	0.229/0.381	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	0.002/0.005	0.051/0.127	0.010	0.254	
Idler Gear Thrust to Bracket (shimmed)	0.004/0.007	0.102/0.178	– – –	– – –	Reshim at 0.012 or over
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)	0.005/0.015	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 first 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 figure
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 in 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 B 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	0.621/0.620	15.773/15.748	0.615	15.621	Lower Shell
Main Bearing Thrust Rings	0.616/0.613	15.646/15.570	– – –	– – –	See "Crankshaft to Thrust Rings"
Connecting Rod Bearing Shells	0.621/0.620	15.773/15.748	0.615	15.621	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	5.259/ 5.283	– – –	– – –	See "Camshaft Thrust Adjustment"

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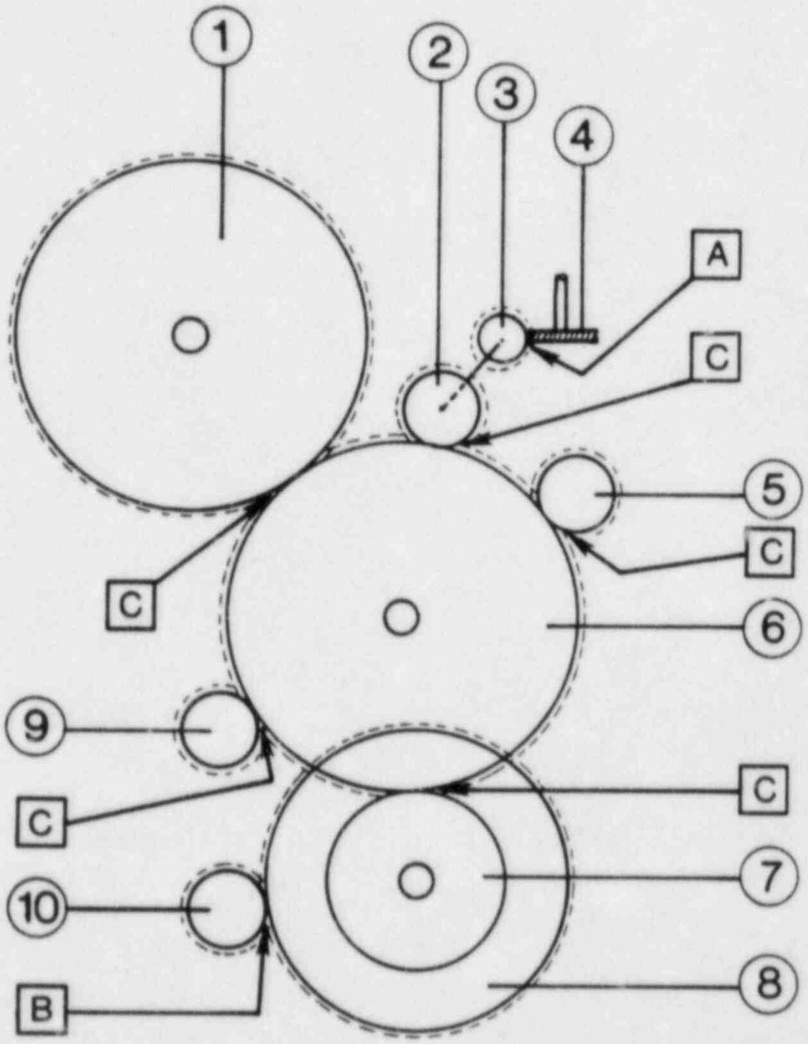
APPENDIX III-1

GEAR SET AND BACKLASH CLEARANCES
MODEL R-4 ENGINE



ITEM	DESCRIPTION	GPL
1	CAMSHAFT GEAR	350
2	TACHOMETER DRIVE GEAR	402
3	GOVERNOR DRIVE GEAR	402
4	GOVERNOR DRIVEN GEAR	402
5	ACCESSORY DRIVE GEAR	410
6	IDLER GEAR	355
7	CRANKSHAFT GEAR	310
8	CRANK TO PUMP GEAR	355
9	L. O. PUMP GEAR CARRIER GEAR	420
10	WATER PUMP GEAR	425

POS	BACKLASH INCHES	BACKLASH CENTIMETERS
A	0.006/0.010	0.015/0.025
B	0.004/0.006	0.010/0.015
C	0.008/0.012	0.020/0.031

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APPENDIX IV

TORQUE TABLES
Model R-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, 1½-8)	1400*	193.6
NUT, Main Bearing Cap Stud	2150	297.24
NUT, Cylinder Block to Base Thru-bolt		
First bolt on each side (gearcase end) (2¼")	3350	462.5
First bolt on each side (gearcase end) (2")	3000	415
Intermediate Bolts (2¼")	2800	386.5
Intermediate Bolts (2")	2500	345
Last bolt on each side (flywheel end) (2¼")	3900	539
Last bolt on each side (flywheel end) (2")	3500	484
NUT, Connecting Rod Bolt (1⅜")	875	121
NUT, Cylinder Head Stud	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
NUT, Idler Gear Stub Shaft	300	41.49
NUT, Flywheel Bolt	3000	414.75
NUT, Crankshaft Counter Weight	1000	138
CAPSCREW, Rocker Shaft	365	50.5
CAPSCREW, Sub-Cover to Cylinder Head	120	16.6
CAPSCREW, Cylinder Block Foot to Base	325	44.9
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.

**Retorque this item every 8 hours of operation after installing new copper gaskets until no change in tight torque is observed.

SPECIAL TORQUE VALUES (continued)

Item	Torque ft-lb	kg-m
+ Capscrew, Exhaust Pipe Flange	100 ...	13.83
x Nut, Rocker Arm Hydraulic Lifter Retaining Assy.....	150 ...	20.74
# Capscrews, Turbocharger to Mounting Bracket	100 ...	13.83
# Capscrews, Exhaust Manifold Adapter to Turbocharger.	100 ...	13.83
▽ Bolt, A325 Bolts in Robertshaw Bronze Body Valve ...	20 ...	2.76

*** Tolerance on Special Torque Values Above 800 ft-lbs is ± 6 %.

+ Ref. E&DCR F-44984
x Ref. E&DCR F-45486
Ref. E&DCR F-46245
▽ Ref. E&DCR F-46325
*** Ref. E&DCR F-33599F

GENERAL TORQUE VALUES

The torque values given on the preceding page are for specific applications and are to be used. The following torque values are for general application where no specific values are given.

	Bolt Size & No. Threads	Torque (ft-lb)	Torque (kg-m)
	3/8–16	12	1.66
	3/8–24	15	2.08
	1/2–13	30	4.15
	1/2–20	35	4.74
	5/8–11	60	8.29
	5/8–18	70	9.68
	3/4–10	100	13.83
	3/4–16	115	15.90
	7/8–9	160	22.13
	7/8–14	180	24.89
	1–8	245	33.78
	1–14	290	40.11
	1-1/8–7	335	46.33
	1-1/8–8	355	48.00
	1-1/8–12	395	54.53
	1-1/4–7	480	66.38
	1-1/4–8	500	69.15
	1-1/4–12	550	76.07
	1-3/8–6	620	85.75
	1-3/8–8	680	94.04
	1-3/8–12	745	103.03
	1-1/2–6	735	101.65
	1-1/2–8	800	110.64
	1-1/2–12	865	119.63
*	¼–20	4	0.55
*	¼–28	5	0.69
*	5/16–18	8	1.11
*	5/16–24	8.6	1.19

△1

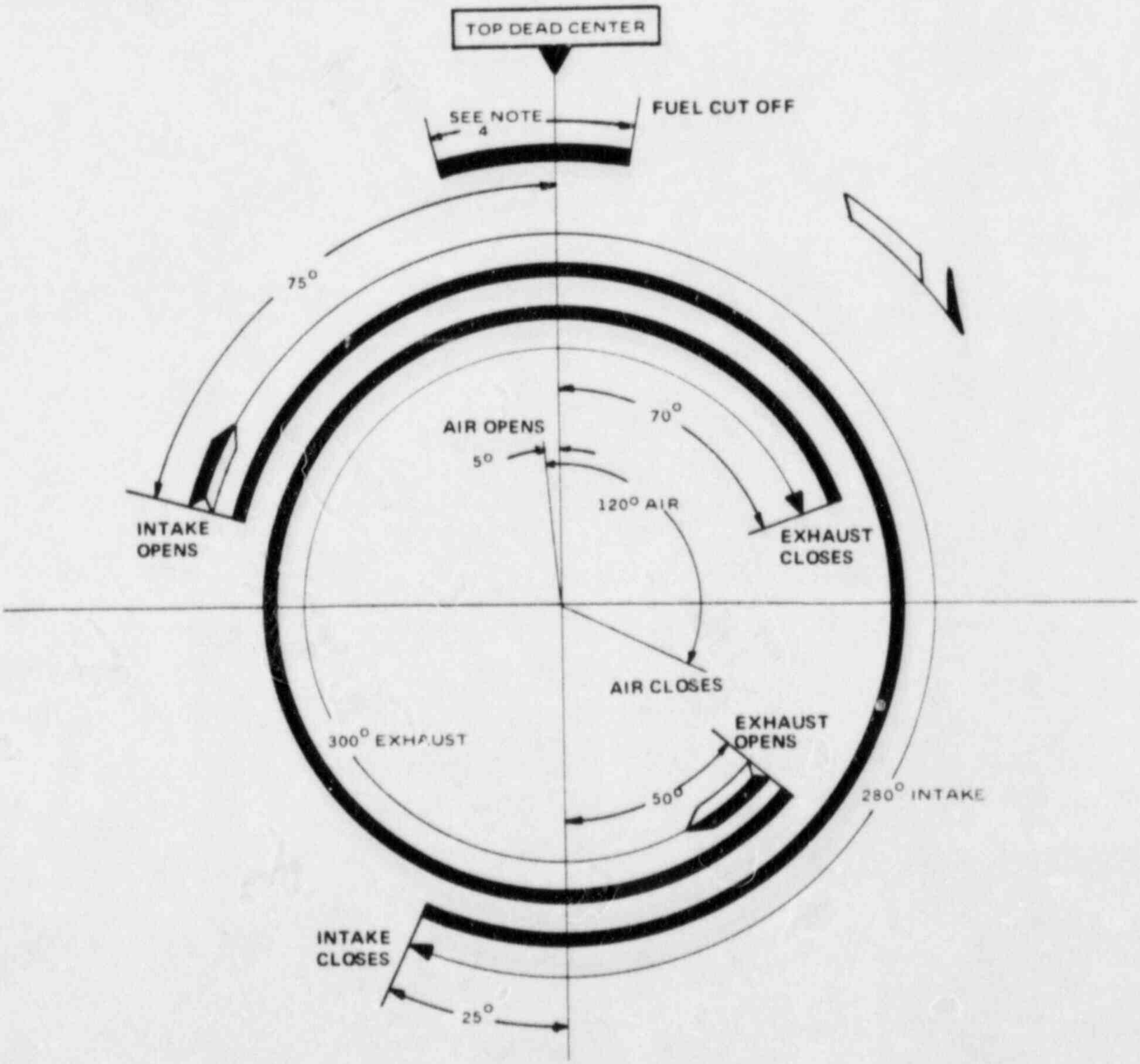
\+ General torque values given do not apply to flanged bolted pipe joints.
Simple wrenching using standard piping skills shall be used in bolting gasketed flanged joints.
Tolerence of -0% and +10% is to be used for general torque values.

* Incorp. E&DCR F-45802
\+ Incorp. E&DCR F-45802A

APPENDIX V

TIMING DIAGRAM

MODEL	TYPE		FUEL
R-8, RV-16, RV-20	Hydraulic Lifters - Long Duration Exhaust Cams		DIESEL
INTAKE CAM		EXHAUST CAM	ROTATION
02-350-04-0T		02-350-06-AF	CLOCKWISE



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.

APPENDIX VI

LUBRICATING OIL RECOMMENDATIONS

The performance of the lubricating oil used in engines manufactured by Transamerica Delaval is of critical importance to assist the owner in achieving maximum economic benefit from his units. Unfortunately, selection of the one best lubricant is not easy, since the choice is dependant upon type of engine, fuel being used, lubricating oil treatment equipment and service conditions encountered. While Transamerica Delaval cannot recommend lubricating oils by brand name, it has identified certain necessary and desirable physical and performance characteristics of an oil from engine design parameters and service experience in a wide range of conditions. These requirements are set forth below.

It is the responsibility of the owner to consult with the lubricating oil supplier concerning the proper selection of a lubricant which will perform best under the conditions to be encountered. Transamerica Delaval will stand ready to assist in any way possible.

RECOMMENDED LUBRICATING OIL PHYSICAL CHARACTERISTICS

All lubricating oils, regardless of service conditions, must have the following *physical* characteristics.

SAE Viscosity Grade	40
Viscosity at 100° C	12.5 C ST Min.
	16.3 C ST Max.
Viscosity Index — Min.	70
Flash Point — Min.	220° C (428° F)
Pour Point — Max.	0° C (32° F)

In addition to the above physical characteristics, lubricating oils must have certain *performance* characteristics. These characteristics are not as easily defineable as physical characteristics, and depend on service conditions and engine type. They are highly important features of the oil.

A. DIESEL ENGINES

Lubricating oils for diesel engines must meet the American Petroleum Institute Class CD performance requirements, and most importantly, must be *specifically compounded* for use in 4 cycle, medium speed, highly turbocharged diesel engines. The oil should resist coking, have good alkalinity retention in service, have anti-wear and anti-scuff protection, and be readily filterable. In addition the oil should have the following relationship between fuel sulfur content (by weight) and alkalinity, as measured by the Total Base Number of the oil (TBN - ASTM D-2896).

Fuel Sulfur — % by Weight	TBN
0.5% or less	10 to 12
0.5% to 1.5%	12 to 15
1.5% to 3.0%	30
3.0% or more	40

Note

It is not recommended to specify significantly greater alkalinity than shown in the above table. Therefore, if fuel sulfur content is expected to change drastically for a significant period of time, the alkalinity of the lubricating oil should be adjusted accordingly. The fuel oil and lubricating oil supplier must therefore work in concert to achieve optimum results.

B. DUAL FUEL ENGINES

The lubricating oil for dual fuel engines must meet the American Petroleum Institute Class CC performance requirement and must be *specifically compounded* for use in 4 cycle, medium speed, highly turbocharged dual fuel engines. The oil should resist coking, have anti-wear and anti-scuff protection, and have resistance to nitration and oxidation. It should have a minimum Total Base Number (TBN) of 6 (ASTM D-2896) and a maximum sulfated ash content of 1.2%. When the diesel pilot fuel being used exceeds 0.5% in sulfur (by weight) and/or the fuel gas is high in sulfur compounds, Transamerica Delaval should be consulted.

C. SPARK IGNITED GAS ENGINES

Lubricating oil for gas engines must meet the American Petroleum Institute Class CC performance requirement, and be *specifically compounded* for 4 cycle, medium speed, highly turbocharged gas engines. The oil should resist coking, have anti-wear and anti-scuff protection, and have high resistance to nitration and oxidation. Oils classifed as "low ash" (less than 0.5% sulfated ash) are recommended. Oils classified as "ashless" are *not* recommended.

LUBRICATING OIL CONDITION AND TESTING

There is available to every engine user, an extremely effective tool with which engine and oil condition can be determined without disassembling the machine or even stopping it. That tool is an ongoing program of lubricating oil analysis performed by a laboratory with sufficient experience to draw hard conclusions from the results of the testing. A qualified lubricating oil supplier will own or have access to such a laboratory with the required experience.

Lubricating oil sampling is not as straightforward as it may seem. Pitfalls to avoid are dirty or moist sample containers, illegible or incomplete data entered on the container label, and failure to flush the sampling line before drawing the sample. Furthermore, samples should be taken at least every three months and, importantly, should be collected just *before* adding makeup oil and/or changing oil filter cartridges.

The amount of makeup oil added for any reason, e.g. normal consumption, filter changes, etc., must be carefully logged in the engine records.

A valuable judgement of engine condition cannot be made if wear particles entrained in the oil are removed from the sample by the lubricating filter. Therefore it is recommended that samples be drawn from the piping system (not from the sump tank) before the filter/centrifuge inlet, and while the engine is running and up to temperature.

Lubricating oil test reports should be retained, and the values reported should be converted to chart form vs engine hours, since individual values of oil parameters are not nearly as important as are the long term trend of changes in these values. A sudden departure from the trend line of any parameter can then visually alert the owner that further investigation into either engine condition and/or the oil's suitability for continued service is required.

APPENDIX VII

ALARMS AND SAFETY SHUTDOWNS

The following sensed parameters will initiate an alarm and/or an automatic safety shutdown as indicated, wh[illegible] operating in the manual mode.

	ITEM	ALARM SETTING	SHUTDOWN SETTING
TEMPERATURES	Engine lubricating oil	190° F rising	200° F rising
	Jacket water	190° F rising	200° F rising
	Jacket water	130° F falling	
	* Turbocharger Lubricating Oil	250° F	
	* High Lubricating Oil - in	175° F	
	* High Lubricating Oil - out	190° F	
	* Low Lubricating Oil - in	140° F	
	* Low Lubricating Oil - out	140° F	
	* High Jacket Water - in	175° F	
	* High Jacket Water - out	190° F	
	* Low Jacket Water - in	140° F	
	* Low Jacket Water - out	140° F	
	* Aftercooler water - in	155° F	
	* O.B. Bearing	155° F	165° F
PRESSURES	Engine lubricating oil *	40 ~~35~~ psi falling *	30 psi falling
	Turbocharger lubricating oil	20 psi falling	15 psi falling
	Jacket water	12 psi falling	* 10 psi falling
	Starting air	210 psi falling	
	Storage tank strainer	High pressure	
	Fuel oil header	15 psi falling	* 10 psi
	* Crankcase pressure	.3-.5 psi	High .3 psi
	*Fuel gas header	20 psi	15 psi
	*Raw water-inlet	10 psi	
	*Air cleaner ΔP	5 inc. H_2O	
	*Fuel Filter ΔP	20 psi	
	*Fuel Strainer ΔP	20 psi	
	*Oil filter ΔP	20 psi	
	* Oil strainer ΔP	20 psi	
**	Engine overspeed (15% ~~10%~~ above rated speed)		517 ~~506~~ rpm
MISCELLANEOUS	Jacket water level	Low	
	Fuel tank level	High or low	
	Lubricating oil level	Low	
	Auxiliary switch	Off	
	Storage tank level	Low	
	Service water	Low flow	
	Unit fail to start	X	
	Unit not available	X	

* Incorp E&DCR F-32015
** Incorp E&DCR F-37605

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.

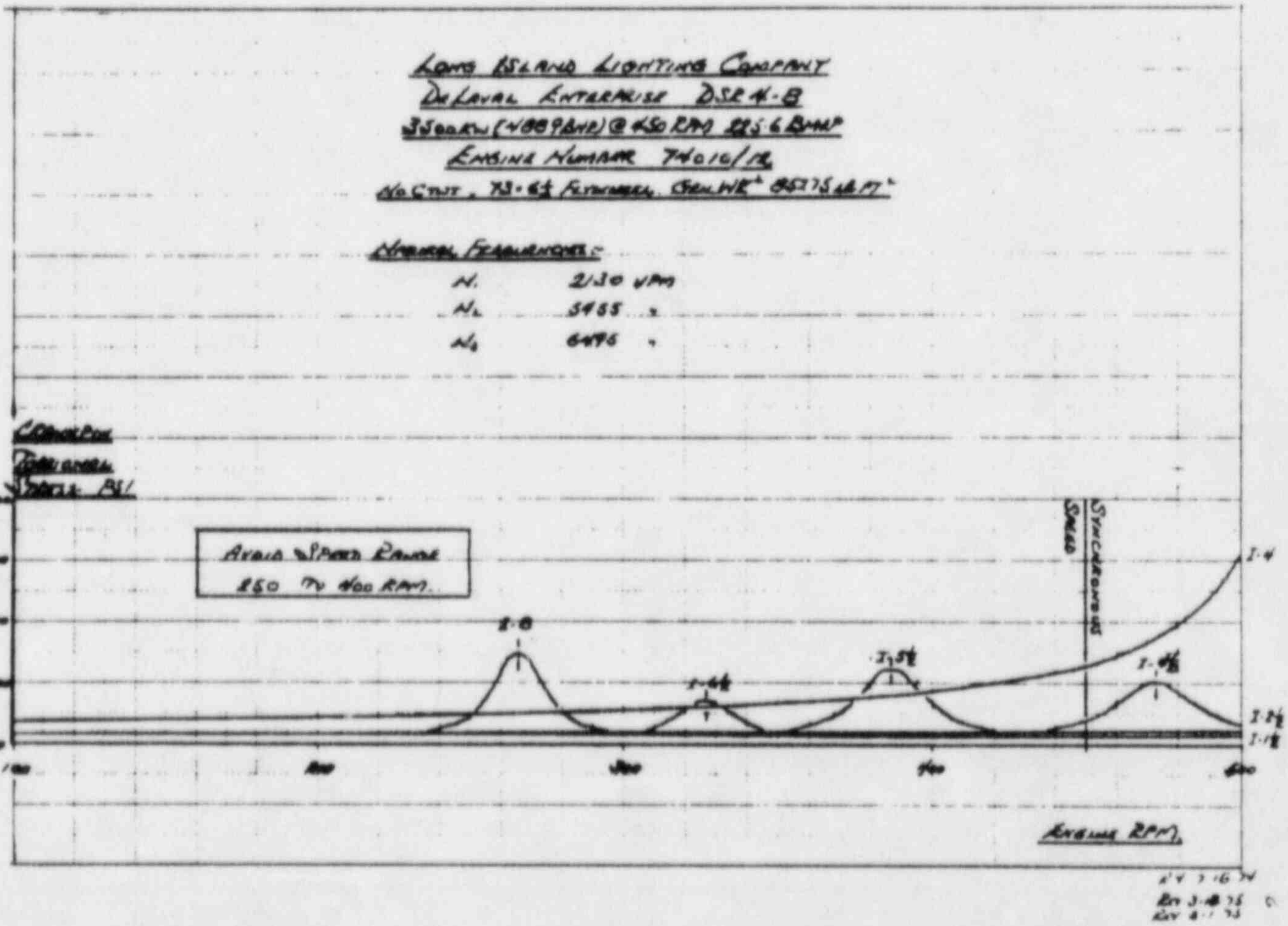
The above specification covers fuel oils classed as Grade F.S. No. 2.

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.

Appendix IX

Torsional Stress and Critical Speeds



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

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.)
74010-2604	51.5 IN.-HG	170°F	29.77 IN.-HG	62°F	914°F
74011-2605	49.9 IN.-HG	164°F	29.96 IN.-HG	62°F	930°F
74012-2606	52.3 IN.-HG	165°F	30.14 IN.-HG	67°F	946°F

FACTORY TEST LOG - ENGINE NO. 74010-2604

Customer: LILCO | Model: DSR 48 | 23 | 74010 | 2604 | 6880 | 225 | Log 1 A

1	9/9	525	530	25	220	1456	573	56	18 4							
2	9/10	2250	2350	25	[illegible]	[illegible]	707	56	19.5	19.5	19.5	19.5	19.5	19.5	19.0	19.5
3	9/10	2280	[illegible]	25	[illegible]	[illegible]	771	56	19.5	19.0	19.5	[illegible]	19.5	19.5	19.5	19.5
4	9/11	[illegible]	[illegible]	50	[illegible]	[illegible]	[illegible]	116	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	50	[illegible]	[illegible]	[illegible]	113	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	2800	75	[illegible]	[illegible]	[illegible]	169	29.0	29.0	30.0	31.0	30.0	30.0	30.5	30.5
7	[illegible]	[illegible]	2015	[illegible]	[illegible]	[illegible]	[illegible]	225	38.0	38.5	38.5	39.0	39.0	38.5	38.5	39.0
8	[illegible]	1015	2115	[illegible]	[illegible]	[illegible]	[illegible]	205								
9	9/11	1810	2220	[illegible]	[illegible]	[illegible]	[illegible]	215	37.0	37.0	38.0	38.0	37.5	38.0	38.0	38.5
10	9/11	2255		25	[illegible]	[illegible]	1213	56	19.5	21.0	20.0	20.5	19.5	20.0	20.0	20.5

1	1.1	1.1	1.0	69	73	82	.7	29.62 69
2	1.7	1.6	1.8	62	82	65	1.1	29.77
3	2.8	4.4	4.5	63	101	79	2.0	29.77 62
4	7.9	16.2	16.0	62	157	148	7.6	29.77 62
5	[illegible]	[illegible]	[illegible]	64	184	162	6.9	29.77 69
6	16.3	19.5	19.5	62	[illegible]	165	10.6	29.79 62
7	30.6	[illegible]	[illegible]	61	315	157	12.9	29.76 61
8	30.9	32.9	[illegible]	62	317	170	17.8	29.77 62
9	30.6	28.7	[illegible]	69	317	[illegible]	17.5	29.77 69
10	9.6	8.0	7.4	67	125	67	2.0	29.74 67

1	41	38	77	35	1480	119	3214	1313	
2	37	[illegible]							
3	37	37.7	72	36.5	[illegible]	250	[illegible]		.542
4	37	38.0	79	36.2	[illegible]	600	[illegible]		.556
5	38.5	39.0	80	36.0	[illegible]	650	2695		.562
6	40	38.8	77	36.1	[illegible]	[illegible]	3085		.539
7	36.5	32.8	80	35.0	[illegible]	1474	3077		.362
8	32	32.8	80	35.8	[illegible]	820	1787		.363
9	32	31.7	78	35.9	[illegible]	[illegible]	3097		.369
10	39.5	34.0	85	35.5	1837	530	3497		.392

Remarks:
1135 - 1150
15 MIN RUN - HEAT CHECK +
INT INSP OK [illegible]
1535 COLD COMP
9-10-75 2115 START UNIT
15 MIN RUN 2130 SHUT UNIT
[illegible]
9-11-75 0860 Shut Down to check Piston #4
Load #7 - Shut Unit Down To Remove Fuel Line #3.
Load #8 Shut Unit Down To Remove #1 Indicator Cock.

F-10 | 25 | 6-21 | 12283 | Date 9-9-75 | Log No. 1 A

Customer: LILCO | Model: DSR48 | STA. | 2604 | 74010 | CW | Log 1 B

1	428	478	457	461	437	465	464	458	437
2	418	467	465	465	455	461	465	470	456
3	487	533	525	521	529	521	533	530	536
4	680	687	687	690	687	690	690	691	671
5	712	719	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	765	841	837	816	801	829	817	827	806
7	816	920	912	910	861	920	906	916	890
8	843	948	890	869	869	915	871	925	869
9	817	951	891	913	889	920	908	529	893
10	563	629	621	631	627	605	614	632	692

1	17	139	141	141	71	75	600	575	575	575	585	580	584	580
2	17	149	150	150	66	66								
3	17	157	161	159	78	79	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	570	590
4	17	150	161	155	107	124	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	17	162	166	158	106	180	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	17	146	162	153	109	219	1180	1200	1200	1140	[illegible]	1200	1160	1200
7	17	147	168	168	186	229	1400	1390	1390	1405	1410	1410	1395	1390
8	17	146	163	156	109	213	1600	1600						
9	16.5	142	163	152	106	215	1600	1600	1570	1570	1570	1580	1570	1600
10	17.0	139	161	157	102	109	1600	600	605	600	615	590	604	610

1	80	54	20	140	123	9
2	78	56	31	120	125	2.2
3	81	59	72	141	146	2.2
4	76	57	25	157	166	1.9
5	76	57	29	157	170	1.8
6	76	57	26	158	172	1.3
7	76	55	27	155	176	.5
8	76	55	27	155	176	.6
9	76	57.5	26.5	156	176	.5
10	76.5	56.0	29.0	157	166	.9

Remarks:
9-9-75 · 0300 · installed a Bypass line on the intercooler water out · installed [illegible] water cooler [illegible]

Line 8 Replace [illegible] GUAGE WITH NEW ONE

Date 9-9-75 | Log 1 B | 2604

FACTORY TEST LOG - ENGINE NO. 74011-2605

Customer: LILCO Model: DSR-48 Test stand: 2B Job no. 2608 Engine no. 74011 Full load rating: 4880 RPM 450 BMEP 225 Log 1 A

Line	Date	Clock in	Clock out	% Load	RPM				Cyl. 1	2	3	4	5	6	7	8
1	1/24	1605	1705	25	450	14157	1213	96	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
2	1/24	1845	1945	50	450	28488	2440	113	25.6	25.0	25.8	25.8	25.5	25.5	25.7	25.5
3	1/24	1015	1115	75	450	42763	3660	169	31.0	31.0	31.7	31.0	31.5	31.0	31.5	31.5
4	1/24	1245	1345	100	450	56995	4880	225	38.0	38.5	38.0	38.7	38.5	38.3	38.5	38.5
5	1/24	1345	1445	100	450	56995	4880	225	38.6	38.5	38.7	38.0	38.5	38.3	38.5	38.6
6	1/24	1709	1805	110	450	62660	5368	248	42.0	42.0	42.0	42.0	42.0	42.0	42.0	42.0

Air flow nozzle size D = 18"

Line										
1	14.7	8.1	8.1	66	122	134		2.9	4992	29.96 66
2	10.4	20.4	20.2	67	195	180		6.4	7416	30.02 67
3	18.2	23.9	22.7	66	248	153		11.2	9820	30.02 66
4	30.9	30.2	30.0	62	314	164	18000	19.1	12846	29.98 62
5	30.1	30.2	29.9	62	314	164	18000	18.4	12623	29.96 62
6	30.0	30.3	30.0	67	302	163		22.0	13741	29.98 67

Line									
1	59	36.6	76	35.4	.8390	.314	2413	1467	.389
2	38	36.4	75	35.4	.8390	774	3186	876	.360
3	57	36.8	76	36.4	.8390	1080	2048	1778	.363
4	36	36.8	76	35.4	.8390	1810	3090	1759	.364
5	36	36.4	79	35.4	.8390	1800	3104	1781	.363
6	35	36.6	76	35.4	.8390	1480	2715	1962	.370

Inject. ignition timing: 33
Fuel oil spec: F-10
Air flow nozzle coefficient: 0.12583
Operator: Kapperman Date: 1-24-76
Engineer: R. Kanga Log no. 1 A

Customer: LILCO Model: DSR-48 Type service: NUC. STBY Job no. 2608 Engine no. 74011 Direction of rotation: CW Log 1 B

Exhaust temperatures - °F

Line	Turbine inlet	Cyl. 1	2	3	4	5	6	7	8	Avg
1	628	675	677	648	673	634	647	680	654	658
2	727	735	801	761	718	758	775	753	759	763
3	779	860	854	861	852	856	832	857	875	851
4	813	949	944	929	933	919	920	930	939	934
5	814	946	942	920	935	911	914	927	936	930
6	863	1017	1001	979	981	971	964	984	981	985

Firing pressures - PSI

Line					Cyl. 1	2	3	4	5	6	7	8	Avg
1	31	184	158	187	620	620	620	640	620	640	630	640	629
2	29	183	161	158	1040	1020	980	1000	980	1020	1000	1030	1003
3	29	184	164	181	1320	1340	1300	1340	1330	1330	1340	1320	1329
4	31	183	166	162	1620	1620	1600	1640	1630	1630	1640	1640	1628
5	31	184	166	168	1620	1610	1600	1650	1630	1640	1640	1650	1631
6	31.5	184	168	163	1700	1690	1700	1780	1710	1720	1740	1760	1721

Lubricating oil pressure - PSI / Lubricating oil temperature °F

Line							
1	60	58		29.5	187	167	-1.2
2		56		29	187	170	-0.9
3		58		28	186	173	-0.8
4		58		26.5	186	176	-0.1
5		58		26.5	186	176	-0.1
6	60	58		26	186	177	-0.8

Legend: 1 LB LEFT BANK 1 - ENGINE FRONT AT NO. 1 CYLINDER
2 RB RIGHT BANK 8 - ENGINE REAR FLYWHEEL END

Operator: Kapperman Date: 1-24-76

FACTORY TEST LOG - ENGINE NO. 74012-2606

Customer: LILCO — DSR-48 — 23 — 2606 — 74012 — Full load rating 4880 — RPM 450 — 225 — Log 1 A

Line	Date	Start	End	% Load	RPM		KW								
1	3/19	1850	1950	25	450	11157	1213	56	18.0	18.0	19.0	18.5	18.5	18.0	18.0	18.0
2	3/19	0915	0935	50	450	11600	2458	113	26.0	25.0	25.0	26.0	25.0	25.0	26.0	25.0
3	3/19	1530	1630	75	450	12183	3664	169	29.0	27.0	29.5	29.5	29.0	29.5	29.0	29.0
4	3/19	1630	1730	100	450	11155	4880	225	34.0	34.0	34.0	35.5	35.5	34.0	34.0	34.0
5	3/19	1730	1830	100	450	11155	4880	225	34.0	34.0	34.0	35.5	35.5	34.0	34.0	34.0
6	3/19	2000	2100	110	450	12150	5360	248	42.0	42.0	42.0	42.5	42.5	42.0	42.0	42.0

Line										
1	5.5	8.6	8.4	65	118	126	2.9	5012	30.14	65
2	17.3	19.6	19.0	70	170	172	10.3	9397	30.12	70
3	19.5	32.2	34.6	63	229	168	40.9	9695	30.12	67
4	33.4	52.7	52.3	67	270	167	47.6	12323	30.14	67
5	33.6	52.7	52.3	67	299	165	47.7	12358	30.14	67
6	37.8	60.1	57.8	64	329	167	30.6	13370	30.14	64

Line										
1	34.5	36.0	76	35.4	18317	350	2644	477		.397
2	37.5	36.6	80	34.6	18365	720	2918	898		.365
3	32.5	36.0	76	34.9	18389	1070	2976	1294		.357
4	31.0	36.2	77	35.0	18389	1280	2589	1780		.369
5	31.0	36.2	77	35.0	18389	1350	2721	1786		.370
6	30.0	36.0	75	35.2	18395	1410	2615	2040		.379

Date 3-19-76

Customer: LILCO — Model DSR-48 — Type service STATIONARY — 2606 — 74012 — Direction of rotation CW — Log 1 B

Line									
1	578	571	672	657	594	622	616	683	672
2	739	787	712	790	782	816	832	795	753
3	752	830	749	810	830	830	853	823	790
4	825	930	942	952	953	955	945	943	932
5	826	936	950	951	933	955	950	951	940
6	841	997	1009	998.5	985	1017	1008	1001	983

Line														
1	32	151	155	154	144	139	600	680	600	620	640	620	650	650
2	27	155	163	161	87	101	820	820	820	830	840	840	830	840
3	30	154	163	161	122	159	1210	1220	1200	1255	1295	1305	1240	1295
4	31.5	155	167	164	162	194	1450	1490	1620	1700	1680	1630	1620	1690
5	31.5	155	168	165	158	190	1450	1640	1620	1700	1680	1630	1620	1690
6	32	159	169	165	157	198	1700	1780	1700	1900	1790	1700	1790	1600

Line					
1	55	28	157	167	1.6
2	55	27	157	170	.7
3	55	25	158	171	.7
4	55	24	157	177	0
5	55	24	157	177	0
6	55	23.5	157	178	.3

EL BOTO — LEVERING — D. REID — Date 3-19-76 — 1 B

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-3884	J	INSTALLATION DRAWING
R-3886	A	FOUNDATION DRAWING, SKID MOUNTED
52070	K	PANEL INSTALLATION
52071	L	PANEL PNEUMATIC SCHEMATIC
52072	AC	PANEL ELECTRICAL SCHEMATIC (3 SHEETS)
52075	G	ENGINE PNEUMATIC SCHEMATIC
52076	E	ENGINE ELECTRICAL SCHEMATIC
52080	B	AUTOMATIC SWITCH OVER LOGIC
52091	-	SOLENOID MANIFOLD
52122	G	AUXILIARY MODULE CONTROL WIRING
100398	E	EXHAUST, INTAKE & CRANKCASE VACUUM SCHEMATIC PIPING DIAGRAM
100399	H	FUEL OIL SCHEMATIC PIPING DIAGRAM
100400	F	JACKET WATER SCHEMATIC PIPING DIAGRAM
100402	J	STARTING AIR SCHEMATIC PIPING DIAGRAM
100404	F	LUBE OIL SCHEMATIC PIPING DIAGRAM
61-500-5663	B	AUTOMATIC SWITCH OVER LOGIC ASSEMBLY
61-560-7096	-	SHUTDOWN PNEUMATIC LOGIC BOARD ASSEMBLY

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. Pumps
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
153	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

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

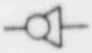
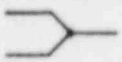
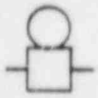
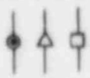
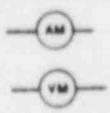
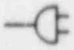
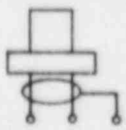
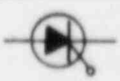
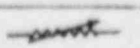
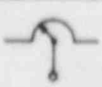
Piping Symbols

	MANOMETER		PRESSURE REDUCER	L	LEVEL GAUGE
P	PRESSURE SWITCH		GATE VALVE		PLUGGED
T	DIAL THERMOMETER		GLOBE VALVE		STRAINER
T	TEMPERATURE SWITCH		PLUG VALVE	→	DIRECTION OF FLOW
S	SIGHT FLOW GAUGE		BUTTERFLY VALVE (Tight Sealing Type)		WELD REDUCER
SP	ENGINE SHUT DOWN PRESSURE SWITCH		CHECK VALVE		SCREWED CAP AND NIPPLE
PYR	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.)	L	LEVEL SWITCH
	STRAINER "Y"	S	SOLENOID VALVE		
	TEMPERATURE SHUT DOWN ELEMENT		DRESSER COUPLING		
	ELECTRIC WIRING		EXPANSION JOINT		
	CAPILLARY TUBING		ORIFICE		
	BLIND FLANGE	A	ALARM CIRCUIT		
	THERMOMETER	P	PRESSURE GAUGE		
T	TEMPERATURE GAUGE	M	METER		
	FLOAT VALVE	F	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
	SELECTORS
	Normally Closed Manual
	Normally Open Manual
	Normally Open Held Closed
	Normally Closed Held Open
	Three Position Spring Return to Center
	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
	Relay Coil – numbers to right of ladder indicate contact locations - normally closed contacts are underlined
	Normally Open contact
	Normally Closed contact
	Latch/Reset Relay Coil - numbers indicate contact locations, normally closed contacts underlined
	Time Delay Relay Coil - Slow Operating Type - On energization, contacts change state after delay and reset immediately on de-energization (5 sec. shown)
	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					
	Fuse		Rheostat		
	Horn		Thermocouple		
	Alarm Bell		Terminals		
	Plug & Receptacle		Meters		
	Line Plug		Transformer		
	Receptacle		Magnetic Pick Up With Shield		
	Fixed Capacitor		Motor, AC		
	Adjustable Capacitor				
	Diode				
	SCR				
	Earth Ground				
	Chassis Ground				
	Lamp				
	Motor Starter or Contactor				
	Motor, DC				
	Remote Location				
	Resistor				
	Adjustable Resistor				
	Potentiometer				

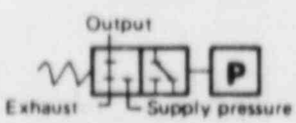
00-81

Valve Symbols

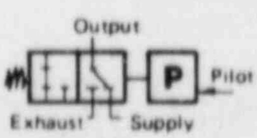
TWO POSITION VALVE (W/O ACTUATOR)	ACTUATORS
Basic two position	Spring return
Two way, two position	Manual push actuator
Three way, two position	Manual pull actuator
Four way, two position	Detented manual actuator (Det.)
Five way, two position	Pressure actuator
THREE POSITION VALVE (W/O ACTUATOR)	Solenoid actuator
Basic three position	Vibration actuator
Three way, closed center, three position	Flow actuator
Three way, open center, three position	Liquid level actuator
Four way, closed center, three position	Temperature actuator
Four way, open center, three position	1. Actuators (there may be one or two) are shown attached to either end of valve symbol.
Five way, open center, three position	2. Valve symbols are always shown in non-actuated, i.e., "Normal, relaxed" condition.
Five way, closed center, three position	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

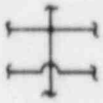
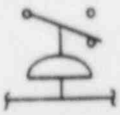
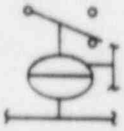
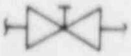
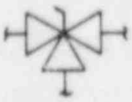
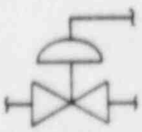


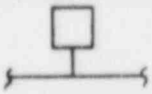
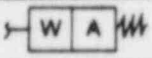
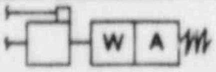
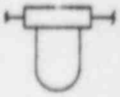
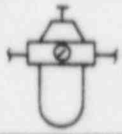
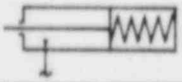
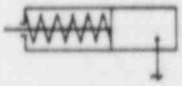
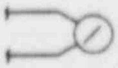
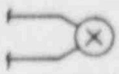
Valve connected normally closed (supply shut off when no pilot pressure exists). Note output is connected to exhaust.



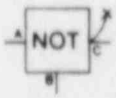
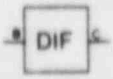
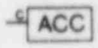
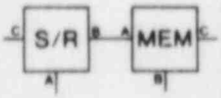
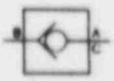
Valve shown with pilot pressure applied (actuated). Supply is now connected to output, and exhaust is blocked. Note that connections have not moved, and valve body is shifted to the left, causing the right passage block to come beneath the connections. Also note, this view will not show up on drawings.

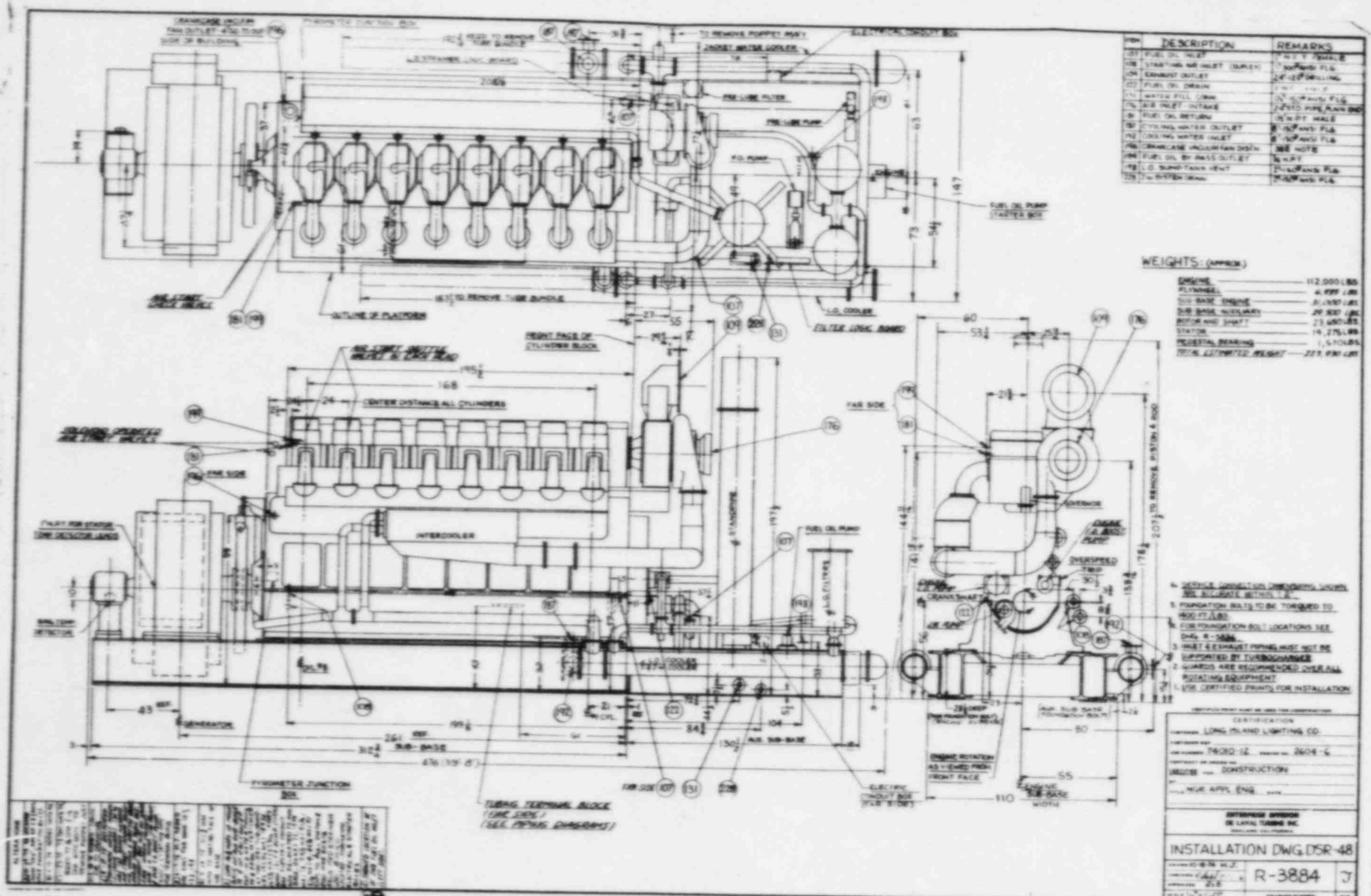
Pneumatic Control Device Symbols

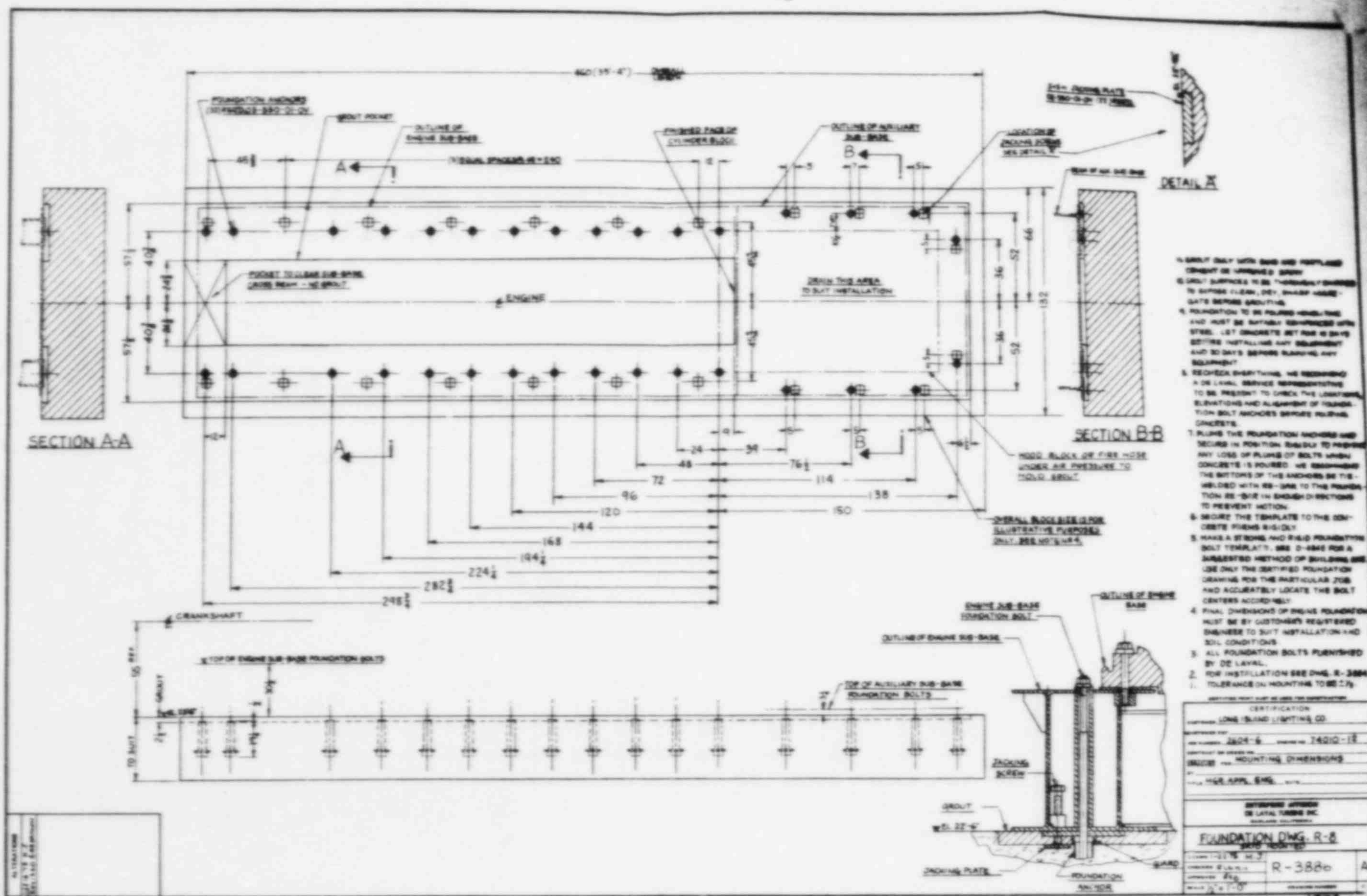
Symbol	Device
	Tubing connections Connected Not connected
	Pressure Switch
	Differential Pressure Switch
	Manually Operated Two way Valve – normally open unless otherwise indicated
	Manually Operated Three way valve
	Shuttle Valve
	Pressure Relief Valve
	Pilot Operated Two way Valve – normally closed unless otherwise indicated
	Manometer, "U" type
	Bulkhead Termination
	Capped Test Tee

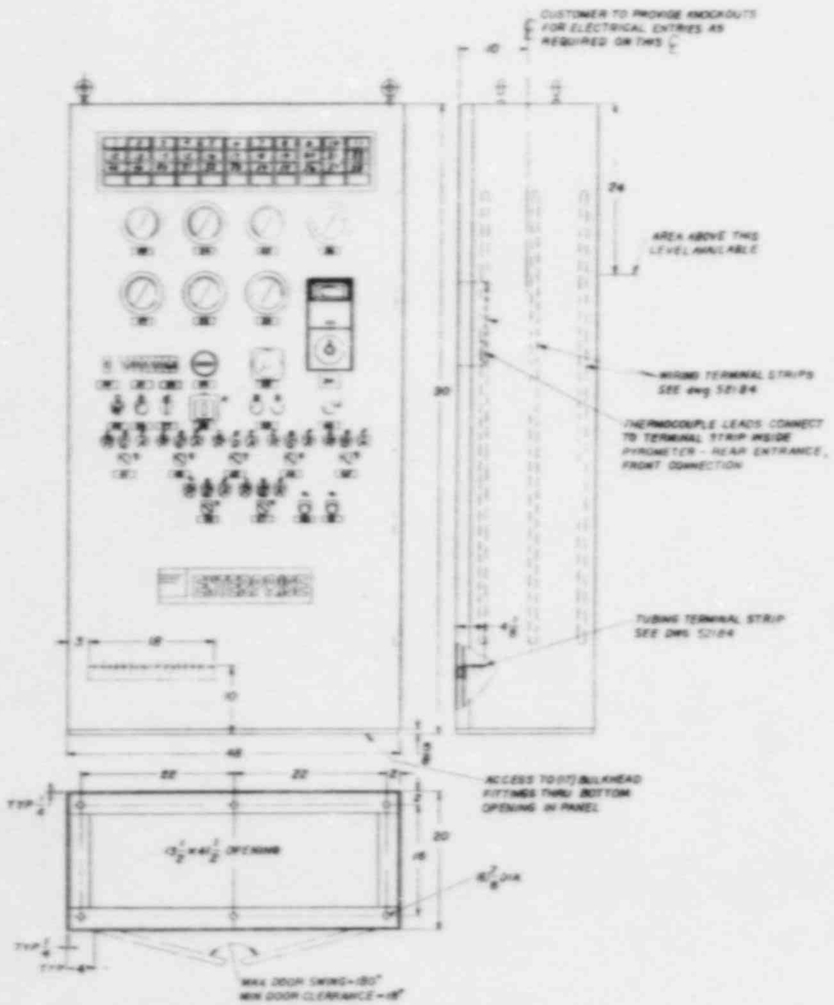
Symbol	Device
	Pneumatic Flag Indicator
	Pneumatic Indicator, Spring Return Type
	Pneumatic Indicator, Spring Return Type, With Position Lock
	Pressure Regulator with Pressure Gauge
	Filter
	Filter-Regulator with Pressure Gauge
	Single Acting Pneumatic Cylinder – Spring Extended, Pressure Retracts Piston
	Single Acting Pneumatic Cylinder – Spring Retracted, Pressure Extends Piston
	Pressure Gauge
	Differential Pressure Gauge
	Duplex Pressure Gauge

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 Plunged 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.


DESCRIPTION
REMARKS
WEIGHTS: (APPROX)
INTERCOOLER
CENTER DISTANCE ALL CYLINDERS
FRONT FACE OF CYLINDER BLOCK
OUTLINE OF PLATFORM
L.O. COOLER
FUEL OIL PUMP
PYROMETER JUNCTION BOX
TUBING TERMINAL BLOCK
ENGINE ROTATION AS VIEWED FROM FRONT FACE
CRANKSHAFT
GOVERNOR
GENERATOR
SUB-BASE
CERTIFICATION
LONG ISLAND LIGHTING CO.
74010-12
2604-6
CONSTRUCTION
INSTALLATION DWG. DSR-48
R-3884
J


SECTION A-A
SECTION B-B
DETAIL A
ENGINE
POCKET TO CLEAR SUB-BASE
DRAIN THIS AREA TO SUIT INSTALLATION
GROUT POCKET
OUTLINE OF ENGINE SUB-BASE
FINISHED FACE OF CYLINDER BLOCK
OUTLINE OF AUXILIARY SUB-BASE
HOLD BLOCK OF FIRE HOSE UNDER AIR PRESSURE TO HOLD GROUT
CRANKSHAFT
TOP OF ENGINE SUB-BASE FOUNDATION BOLTS
TOP OF AUXILIARY SUB-BASE FOUNDATION BOLTS
JACKING SCREW
GROUT
JACKING PLATE
FOUNDATION ANCHOR
ENGINE SUB-BASE FOUNDATION BOLT
OUTLINE OF ENGINE SUB-BASE
OUTLINE OF ENGINE BASE
5. RECHECK EVERYTHING. WE RECOMMEND A DE LAVAL SERVICE REPRESENTATIVE TO BE PRESENT TO CHECK THE LOCATIONS, ELEVATIONS AND ALIGNMENT OF FOUNDATION BOLT ANCHORS BEFORE POURING CONCRETE.
7. PLUMB THE FOUNDATION ANCHORS AND SECURE IN POSITION RIGIDLY TO PREVENT ANY LOSS OF PLUMB OF BOLTS WHEN CONCRETE IS POURED. WE RECOMMEND THE BOTTOMS OF THE ANCHORS BE TIE-WELDED WITH RE-BAR TO THE FOUNDATION RE-BAR IN ENOUGH DIRECTIONS TO PREVENT MOTION.
6. SECURE THE TEMPLATE TO THE CONCRETE FORMS RIGIDLY.
5. MAKE A STRONG AND RIGID FOUNDATION BOLT TEMPLATE. SEE D-4840 FOR A SUGGESTED METHOD OF BUILDING ONE. USE ONLY THE CERTIFIED FOUNDATION DRAWING FOR THE PARTICULAR JOB AND ACCURATELY LOCATE THE BOLT CENTERS ACCORDINGLY.
4. FINAL DIMENSIONS OF ENGINE FOUNDATION MUST BE BY CUSTOMER'S REGISTERED ENGINEER TO SUIT INSTALLATION AND SOIL CONDITIONS.
3. ALL FOUNDATION BOLTS FURNISHED BY DE LAVAL.
2. FOR INSTALLATION SEE DWG. R-3884.
1. TOLERANCE ON MOUNTING TO BE ±1/8
CERTIFICATION
LONG ISLAND LIGHTING CO.
2604-6
74010-18
MOUNTING DIMENSIONS
DE LAVAL TURBINE INC.
FOUNDATION DWG. R-8
R-3886
A



NAMEPLATES

1 LUBE OIL LOW PRESS
2 LUBE OIL HIGH TEMP
3 TURBO OIL LOW PRESS
4 JACKET WTR HIGH TEMP
5 JACKET WTR LOW PRESS
6 FUEL TANK HIGH LEVEL
7 STORAGE TK LOW LEVEL
8 GEN FIELD MANUAL SHUTDOWN
9 SERV WTR LOW FLOW
10 START AIR LOW PRESS
11 AUX PUMP CONTROL SW OFF POS
12 LUBE OIL LOW LEVEL
13 SPARE
14 SPARE
15 JACKET WTR LOW TEMP
16 JACKET WTR LOW LEVEL
17 FUEL TANK LOW LEVEL
18 FUEL OIL LOW PRESS
19 GEN HEATER LOSS CONTROL
20 SPARE
21 UNIT FAIL TO START
22 UNIT NOT AVAILABLE
23 STARTING AIR PRESS 1H43-PI-808A,B,C
24 ENGINE LUBE OIL PRESS 1H43-PI-801 A,B,C
25 JACKET WATER PRESS 1H43-PI-811 A,B,C
26 FUEL OIL PRESS 1H43-PI-803 A,B,C
27 COMBUSTION AIR PRESS 1H43-PI-800 A,B,C
28 TURBO OIL PRESS 1H43-PI-802 A,B,C
29 RAW WATER PRESS 1P41-PI-046 A,B,C
30 AC POWER
31 DC POWER
32 ENGINE HOURS
33 ENGINE SPEED
34 EXHAUST TEMPERATURES 1H43-TI-800 A,B,C
1-8 CYLINDERS 1H43-TE-800 A,B,C
9 TURBO INLET 1H43-TE-808 A,B,C
10 TURBO OUTLET 1H43-TE-809 A,B,C
35 CONTROL POWER
36 START
37 SPEED CONTROL
38 MODE SELECT
39 ALARM FUNCTIONS
40 STOP
41 FUEL BOOSTER PUMP
42 FUEL OIL TRANSFER PUMP NO. 1
43 FUEL OIL TRANSFER PUMP NO. 2
44 B & R PUMP & HEATER
45 JACKET WATER HEATER CIRCULATING PUMP
46 AIR COMPRESSOR NO. 1
47 AIR COMPRESSOR NO. 2
48 LUBE OIL LOW PRESS SHUTDOWN
49 LUBE OIL HIGH TEMP SHUTDOWN
50 TURBO OIL LOW PRESS SHUTDOWN
51 JACKET WTR HIGH TEMP SHUTDOWN
52 CRANKCASE HIGH PRESS SHUTDOWN
53 OVERSPEED SHUTDOWN
54 FUEL OIL PUMP STRAINER ΔP HIGH
55 FUEL OIL BOOSTER PUMP ΔP HIGH
56 }
57 } SPARE
58 MAIN BOARD CONTROL DISABLED
59 V REG DC POWER
60 START CIRCUIT NO. 1
61 START CIRCUIT NO. 2

LIGHTS	SWITCHES
A AMBER	a TEST
G GREEN	b ACKNOWLEDGE
R RED	c ON
W WHITE	d RAISE LOWER
	e OFF
	f AUTO
	g HAND OFF AUTO
	h START
	j STOP
	k REMOTE LOCAL LOCKOUT

1. THE PANEL HAS 17 PNEUMATIC CONN. 13 ARE ¼ & 2 ARE ⅜. SEE dwg. 52071.
2. NAMEPLATES 1-22 AND 48-53 ARE ENGRAVED ON ANNUNCIATOR FACEPLATE. 48-53 HAVE RED REAR LENSES.
3. NAMEPLATES 23-33 & 35-46, 47, 60, 61 ARE 2¾ x ⅞ BLACK WITH ⅛ WHITE LETTERING. 34 IS 8 2 x 3 BLACK WITH ⅛ WHITE LETTERING. SECURE NAMEPLATES TO PANEL WITH (2) #6-32 x ¼ LG SCREWS.

REFERENCE DRAWINGS

52071 PANEL PNEU SCHEM
52072 PANEL ELEC SCHEM
52073 ENGINE PNEU SCHEM
52074 ENGINE ELEC SCHEM

PAINT SPEC

PANEL EXTERIOR TO BE ... HIGH GLOSS FINISH, ASA61 GRAY, 2 DRY FILM. INTERIOR TO BE NON-REFLECTIVE WHITE, 2 DRY FILM.

SEE D-4849 FOR GENERAL CONTROL CABINET SPEC.

MATERIAL AND HARDWARE

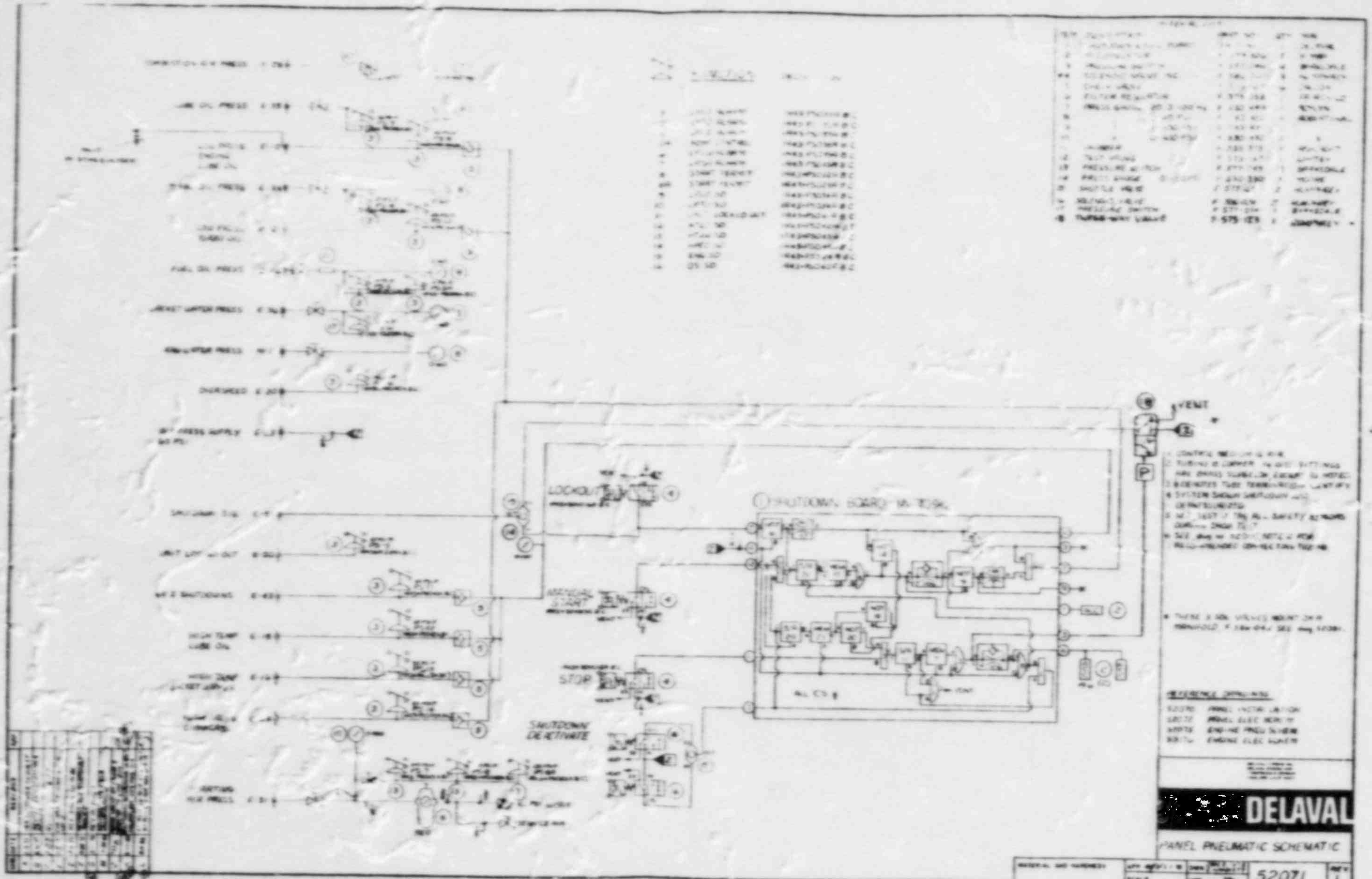
DELAVAL

PANEL INSTALLATION

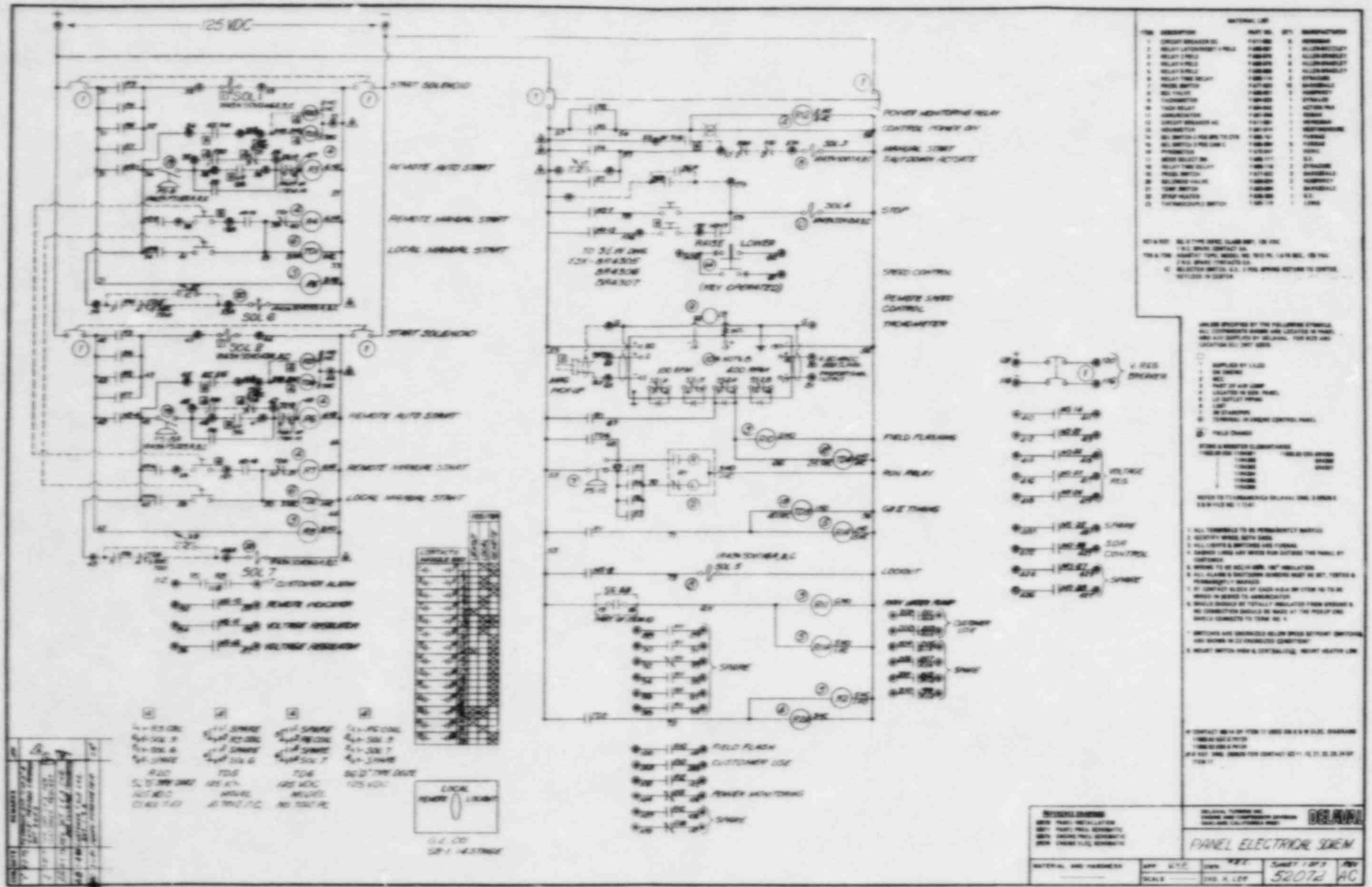
SCALE 1/8

52070 REV K

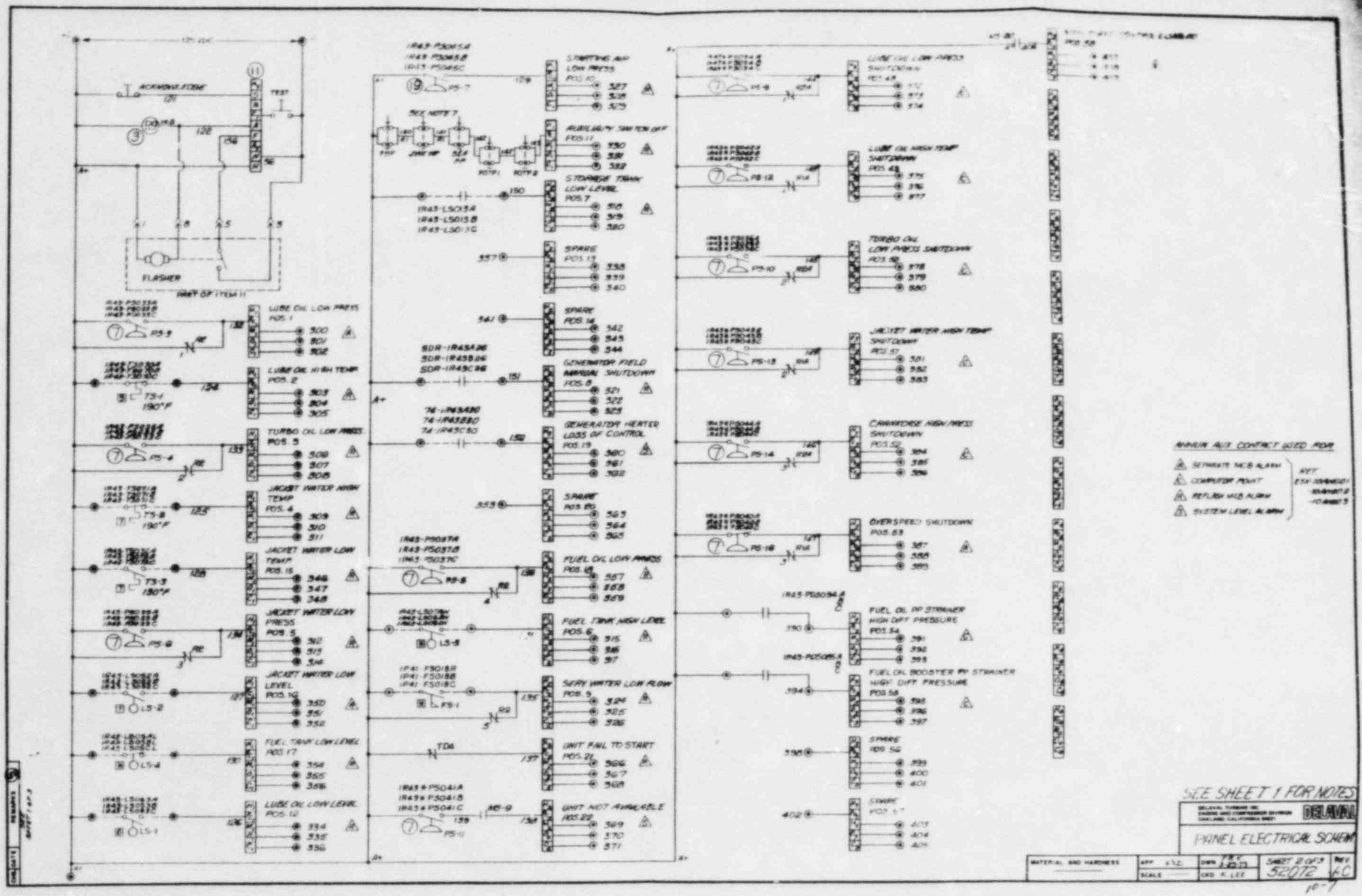
10-7



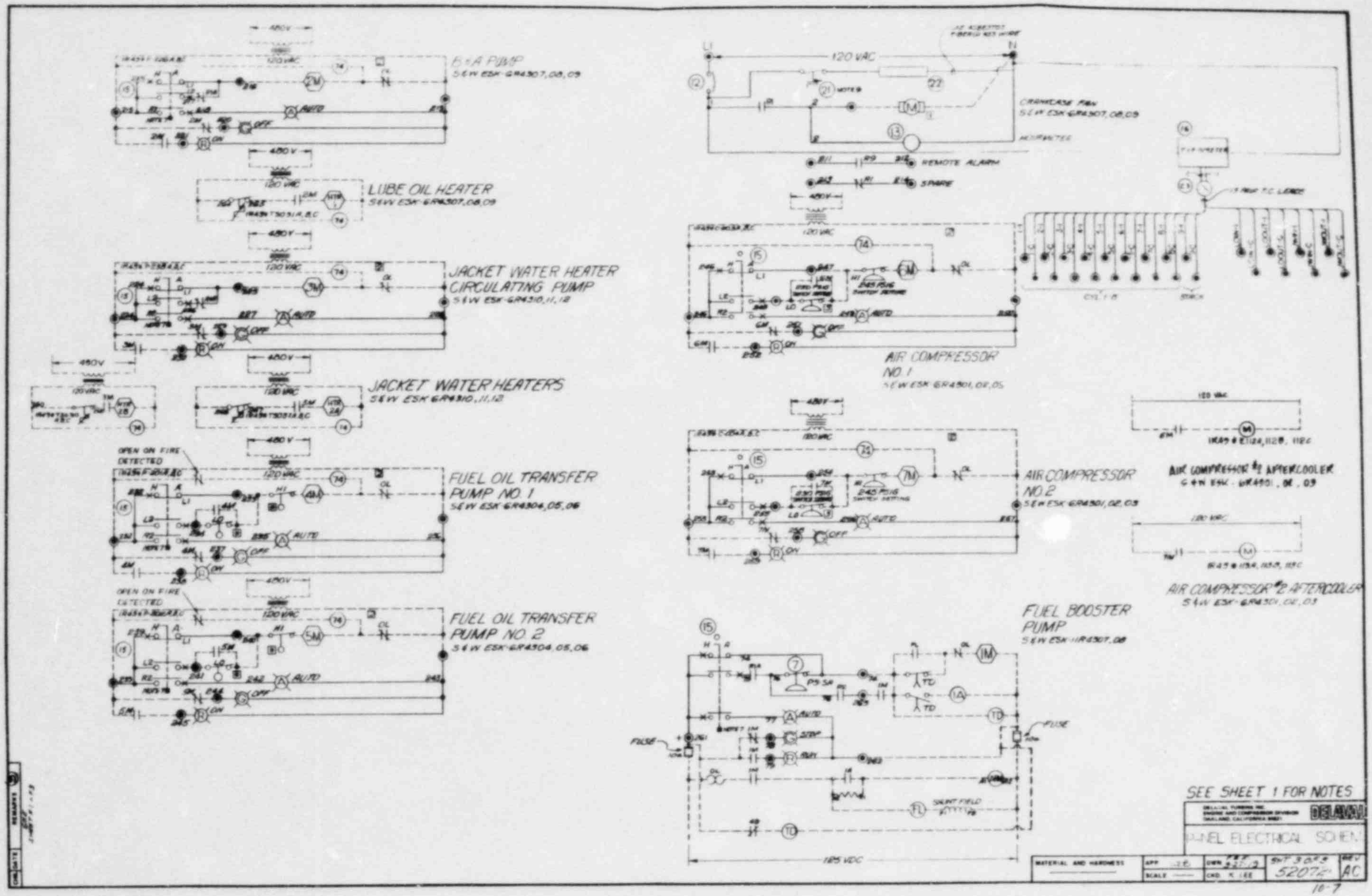
⚠ *Ref. E &DCR F-46371



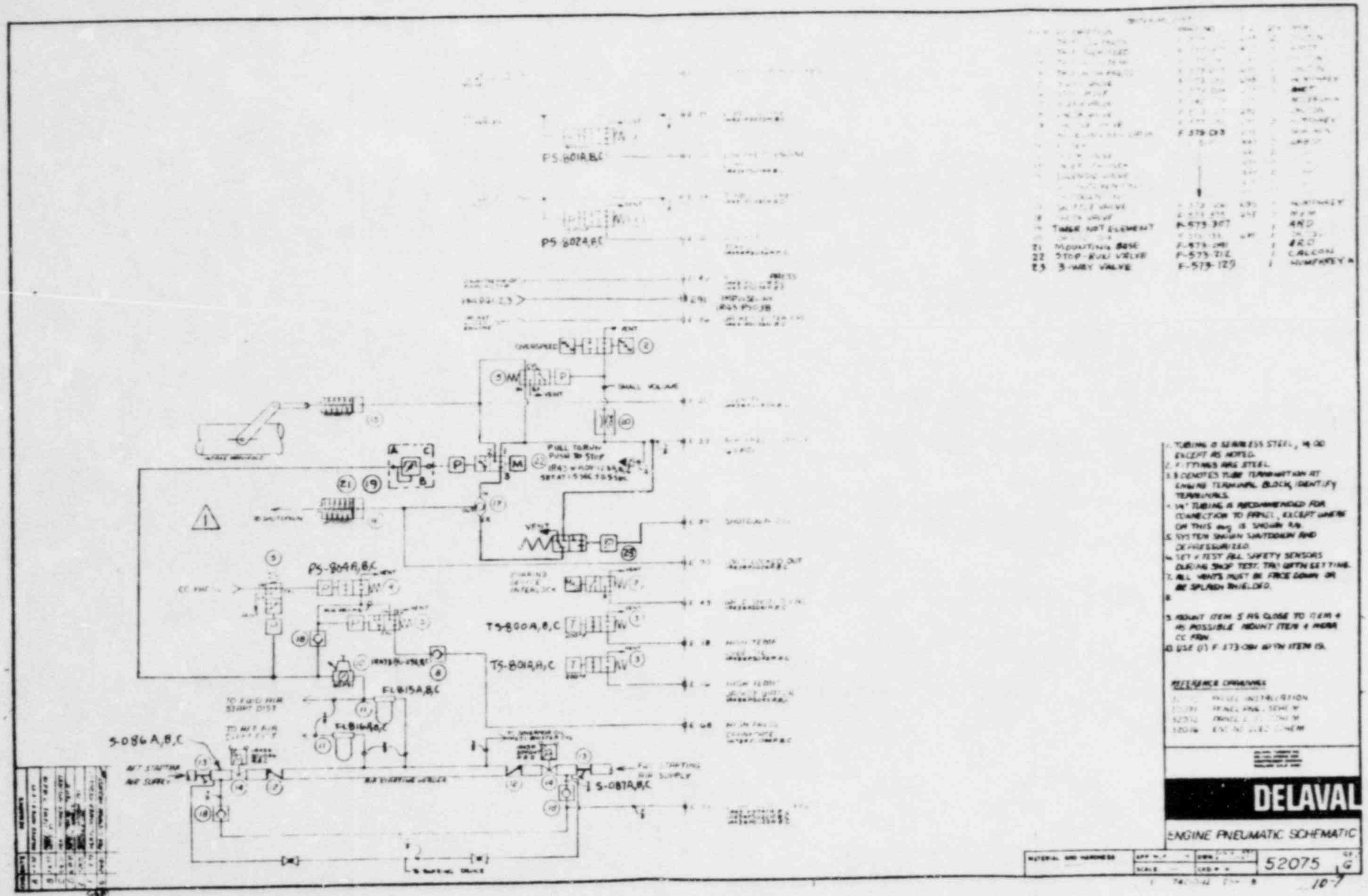
125 VDC
START SOLENOID
REMOTE AUTO START
REMOTE MANUAL START
LOCAL MANUAL START
SOL 6
SOL 8
SOL 7
CUSTOMER ALARM
POWER MONITORING RELAY
CONTROL POWER OFF
MANUAL START
SHUTDOWN ACTIVATE
STOP
RAISE
LOWER
(KEY OPERATED)
SPEED CONTROL
REMOTE SPEED CONTROL
TACHOMETER
FIELD FLASHING
RUN RELAY
GATE TIMING
LOCKOUT
SPARE
VOLTAGE REG.
SPARE
SPD CONTROL
SPARE
CUSTOMER USE
SPARE
FIELD FLASH
CUSTOMER USE
POWER MONITORING
SPARE
V. REG. BREAKER
LOCAL
REMOTE
G.E. CO.
SB-1 14 STAGE
PANEL ELECTRICAL SCHEM
52072
AC
10-7



ACKNOWLEDGE
TEST
FLASHER
PART OF ITEM 11
LUBE OIL LOW PRESS POS. 1
LUBE OIL HIGH TEMP POS. 2
TURBO OIL LOW PRESS POS. 3
JACKET WATER HIGH TEMP POS. 4
JACKET WATER LOW TEMP POS. 15
JACKET WATER LOW PRESS POS. 5
JACKET WATER LOW LEVEL POS. 16
FUEL TANK LOW LEVEL POS. 17
LUBE OIL LOW LEVEL POS. 12
STARTING AIR LOW PRESS POS. 10
AUXILIARY SHUTDOWN OFF POS. 11
SEE NOTE 7
STORAGE TANK LOW LEVEL POS. 7
SPARE POS. 13
SPARE POS. 14
GENERATOR FIELD MANUAL SHUTDOWN POS. 8
GENERATOR HEATER LOSS OF CONTROL POS. 19
SPARE POS. 20
FUEL OIL LOW PRESS POS. 18
FUEL TANK HIGH LEVEL POS. 6
SERV WATER LOW FLOW POS. 9
UNIT FAIL TO START POS. 21
UNIT NOT AVAILABLE POS. 22
LUBE OIL LOW PRESS SHUTDOWN POS. 49
LUBE OIL HIGH TEMP SHUTDOWN POS. 48
TURBO OIL LOW PRESS SHUTDOWN POS. 50
JACKET WATER HIGH TEMP SHUTDOWN POS. 51
CRANKCASE HIGH PRESS SHUTDOWN POS. 52
OVERSPEED SHUTDOWN POS. 53
FUEL OIL PP STRAINER HIGH DIFF PRESSURE POS. 54
FUEL OIL BOOSTER PP STRAINER HIGH DIFF. PRESSURE POS. 55
SPARE POS. 56
SPARE POS. 57
ANNUN AUX CONTACT USED FOR
SEPARATE MCB ALARM
COMPUTER POINT
REFLASH MCB ALARM
SYSTEM LEVEL ALARM
SEE SHEET 1 FOR NOTES
DELAVAL
PANEL ELECTRICAL SCHEM
MATERIAL AND HARDNESS
SHEET 2 OF 3
52072
REV. 6C



B & A PUMP
S&W ESK-6R4307,08,09
LUBE OIL HEATER
S&W ESK-6R4307,08,09
JACKET WATER HEATER
CIRCULATING PUMP
S&W ESK-6R4310,11,12
JACKET WATER HEATERS
S&W ESK-6R4310,11,12
FUEL OIL TRANSFER
PUMP NO.1
S&W ESK-6R4304,05,06
FUEL OIL TRANSFER
PUMP NO.2
S&W ESK-6R4304,05,06
OPEN ON FIRE DETECTED
480V
120 VAC
CRANKCASE FAN
S&W ESK-6R4307,08,09
REMOTE ALARM
SPARE
AIR COMPRESSOR
NO.1
S&W ESK-6R4301,02,03
AIR COMPRESSOR
NO.2
S&W ESK-6R4301,02,03
AIR COMPRESSOR #1 AFTERCOOLER
S&W ESK-6R4301,02,03
AIR COMPRESSOR #2 AFTERCOOLER
S&W ESK-6R4301,02,03
FUEL BOOSTER
PUMP
S&W ESK-11R4307,08
FUSE
125 VDC
SEE SHEET 1 FOR NOTES
DELAVAL
PANEL ELECTRICAL SCHEM
MATERIAL AND HARDNESS
52072
AC
10-7

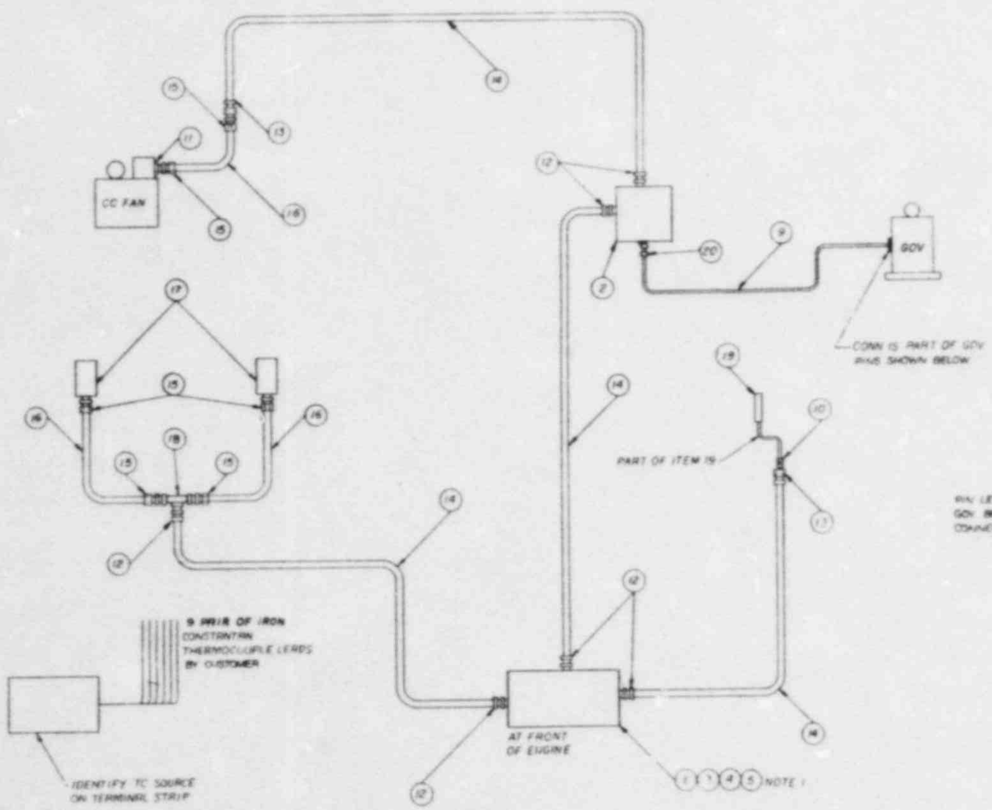


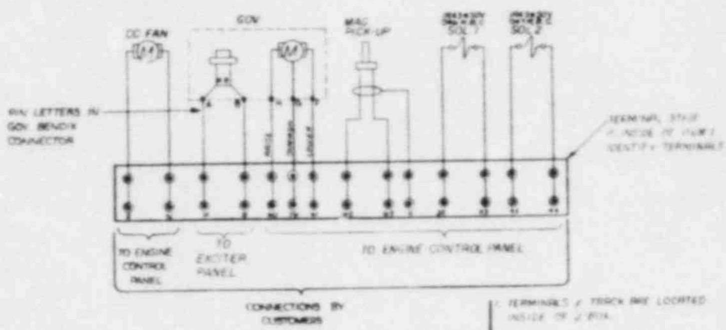
Ref. E&DCR F-45577

MATERIAL LIST

QTY	DESCRIPTION	PART NO.	REMARKS	ITEM
1	J/T BOX	F 510 [illegible]	6 x 8 x 4	1
1	J/T BOX	F 510 [illegible]	4 x 4 x 3	2
4	TERMINAL 2 POLE	F 591 047		3
6	TERMINAL 3 POLE	F 591 048		4
AR	TERMINAL TRACK	F 591 [illegible]		5
				6
				7
				8
AR	CABLE	F 509 [illegible]		9
1	CABLE CONNECTOR	F [illegible]		10
1	OILTITE GRSKET ASSY	F 509 [illegible]		11
6	EMT CONN	F 509 [illegible]	1/2	12
2	COUPLING EMT TO [illegible]	F 509 [illegible]		13
AR	EMT	F [illegible]	1/2	14
6	CONN SEALTITE	F 509 [illegible]	1/2	15
AR	SEALTITE	F 509 [illegible]	1/2	16
2	SOL VALVE	——	SEE [illegible] LIST	17
1	UNILET TEE	F 509 021	1/2	18
1	MAG PICKUP	[illegible] 004 000		19
1	CABLE CONNECTOR	F 509 [illegible]		20
				21
				22
				23
				24
				25
				26
				27
				28

* USE WITH [illegible] 509 041 GASKET & [illegible] 509 [illegible] COVER





1. TERMINALS & TRACK ARE LOCATED INSIDE OF J/BOX.

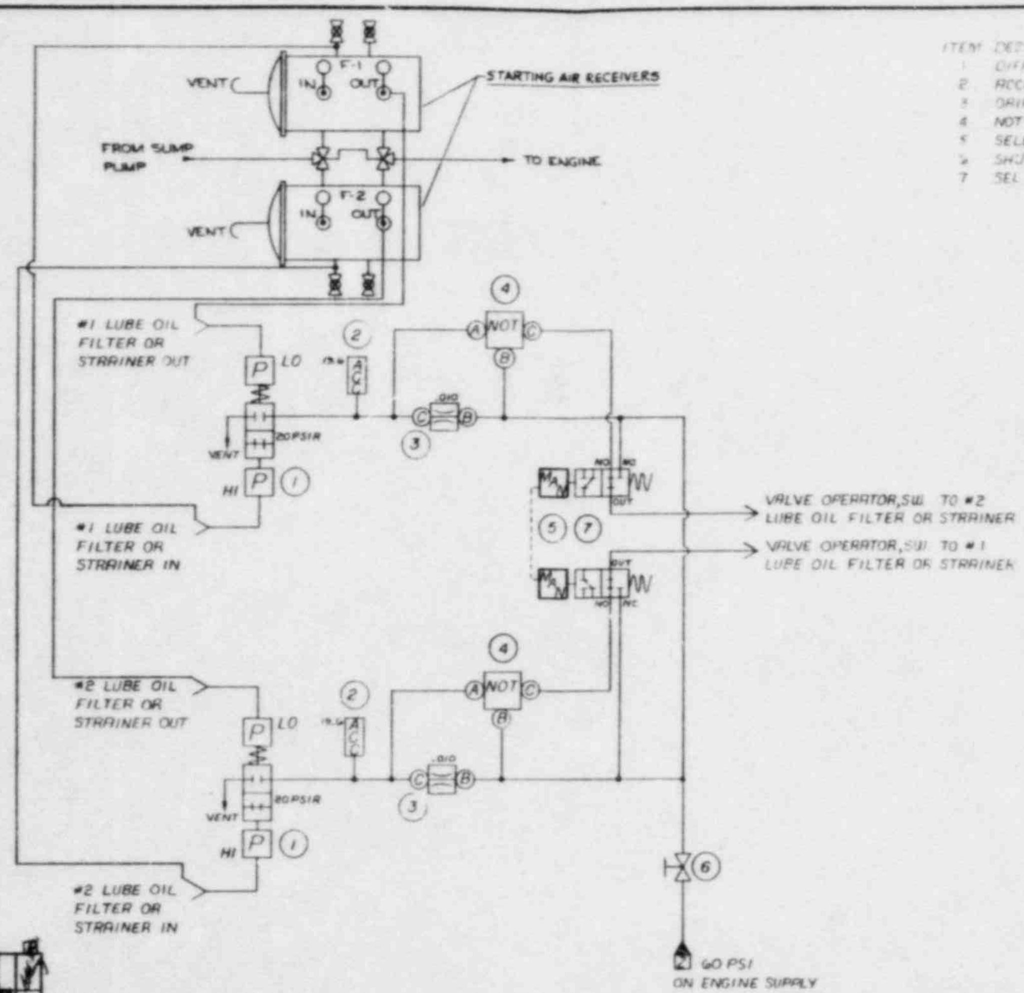
DELAVAL

ENGINE ELECTRICAL SCHEMATIC

MATERIAL AND HARDWARE

52076

107



MATERIAL LIST

ITEM	DESCRIPTION	PART NO.	QTY	MFR
1	DIFFERENTIAL VALVE	F-573-276	2	CALCON
2	ACCUMULATOR	F-573-326	2	BIMBA
3	ORIFICE	F-573-219	2	CALCON
4	NOT LOGIC ELEMENT	F-573-006	2	ARO
5	SELECTOR SWITCH	F-573-047	1	ARO
6	SHUTOFF VALVE	F-573-054	1	WHITEY
7	SEL OPERATOR SPG RET	F-585-080	1	FURNAS

NOTE: WITH 50 PSI PRESSURE ON LOW SIDE, SET DIFFERENTIAL FOR 20 PSIR BY APPLYING AIR TO HIGH SIDE. SET & TAG DIFF. VALVE.

REFERENCE DRAWINGS
52075 ENGINE PNEU SCHEM.
61-561-5663 AUTO SW OVER LOGIC ASSY

CHG	DATE	REMARKS	APP'D
A	4-9-75	ADD ITEM 7	
B	4-30-[illegible]	ADDED (2) STARTING AIR RECEIVER	

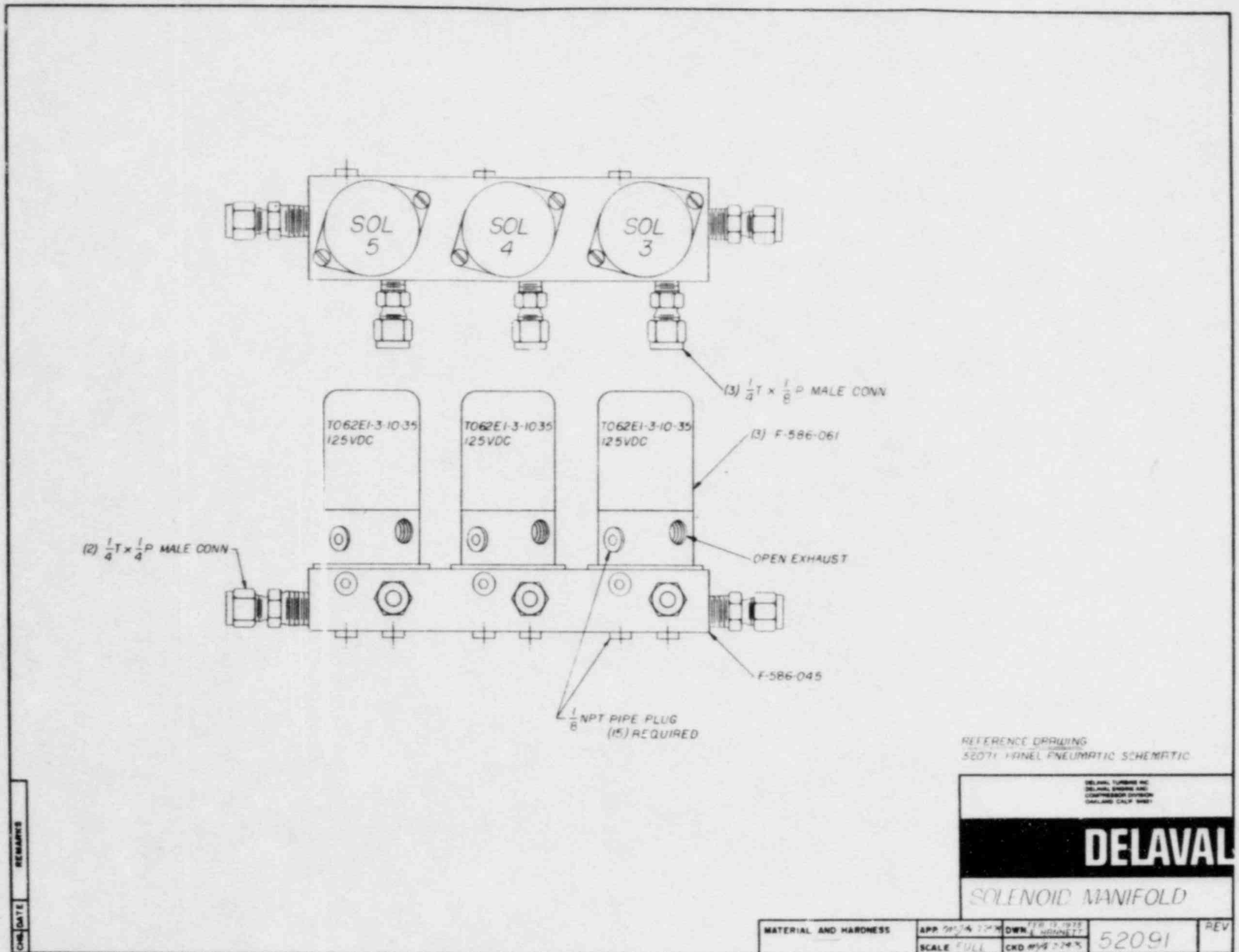
DELAVAL

AUTOMATIC SWITCH OVER LOGIC

MATERIAL AND HARDNESS	APP.	DWN.	52080	REV B
—	SCALE —	CKD.		

LILCO 74010-12

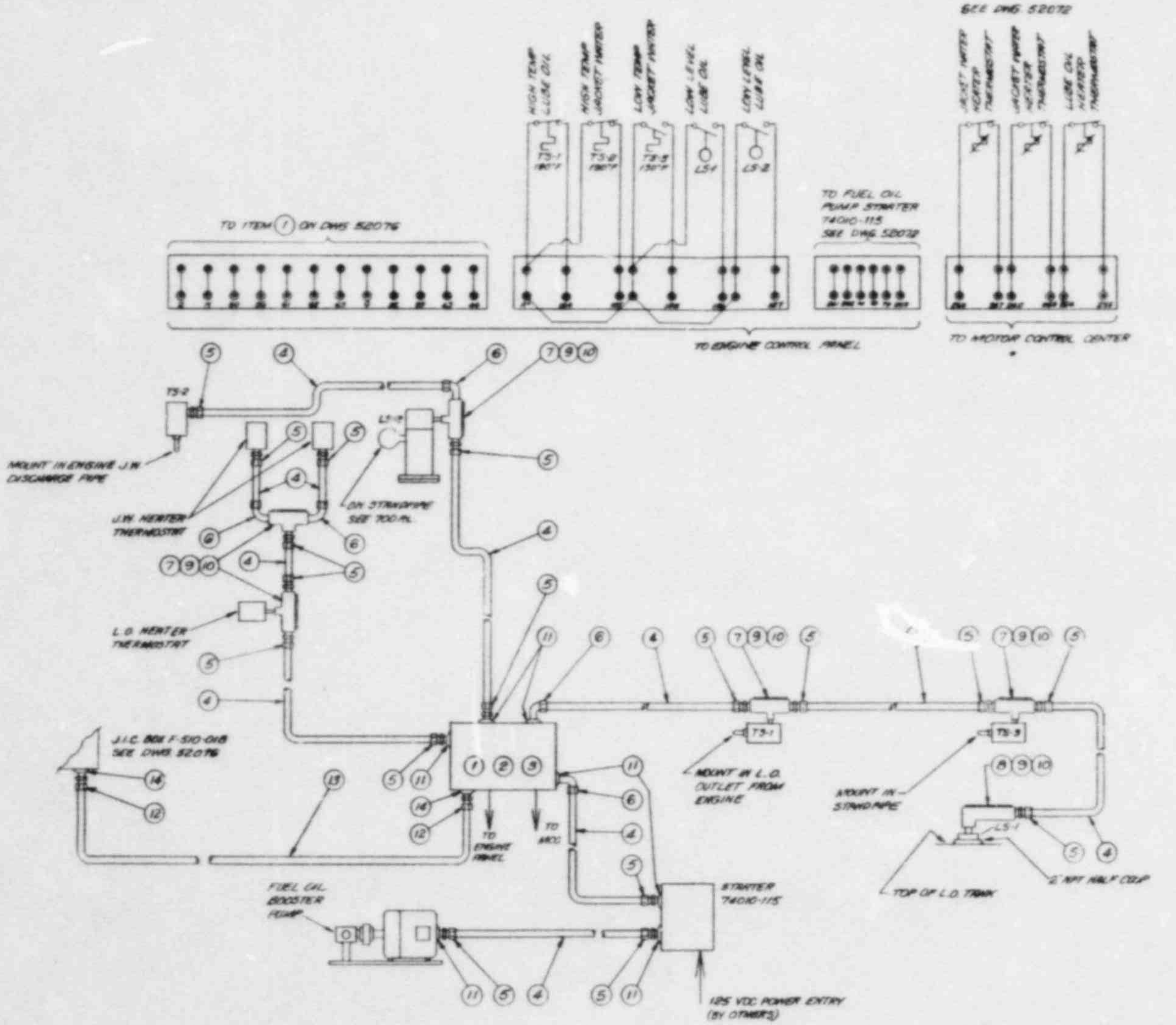
6-3

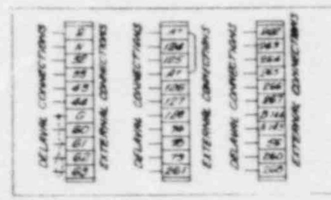


LILCO 74010-12

6-3

QTY	DESCRIPTION	PART NO	REMARKS	ITEM
1	J.I.C. BOX	F-510-019		1
12	TERMINAL	F-591-067		2
AR	TERMINAL TRACK	F-591-066		3
AR	EMT CONDUIT	F-509-001	[illegible]	4
17	EMT CONNECTOR	F-509-043	[illegible]	5
4	EMT ELBOW	F-509-005	[illegible]	6
5	UNILET "TE"	F-509-021	½	7
1	UNILET ELBOW	F-509-033	½	8
6	UNILET COVER	F-509-037		9
6	UNILET GASKET	F-509-241		10
7	OILTIGHT GASKET	F-509-078	½	11
2	EMT CONNECTOR	F-509-051	1"	12
AR	EMT CONDUIT	F-509-003	1"	13
2	OILTIGHT GASKET	F-509-080	1"	14





EXTERNAL CONNECTIONS: MCC, DIESEL CONTROL PANEL & GENERATOR CONTROL PANEL.

TERMINAL 62 & 63 ARE A TWO CONDUCTOR SHIELDED CABLE WITH TERMINAL [illegible] USED FOR TERMINATION OF THE SHIELD.

CHG	DATE	REMARKS
F	[illegible]	[illegible]
G	[illegible]	[illegible]

DELAVAL TURBINE INC. ENGINE AND COMPRESSOR DIVISION OAKLAND, CALIFORNIA

AUXILIARY MODULE CONTROL WIRING

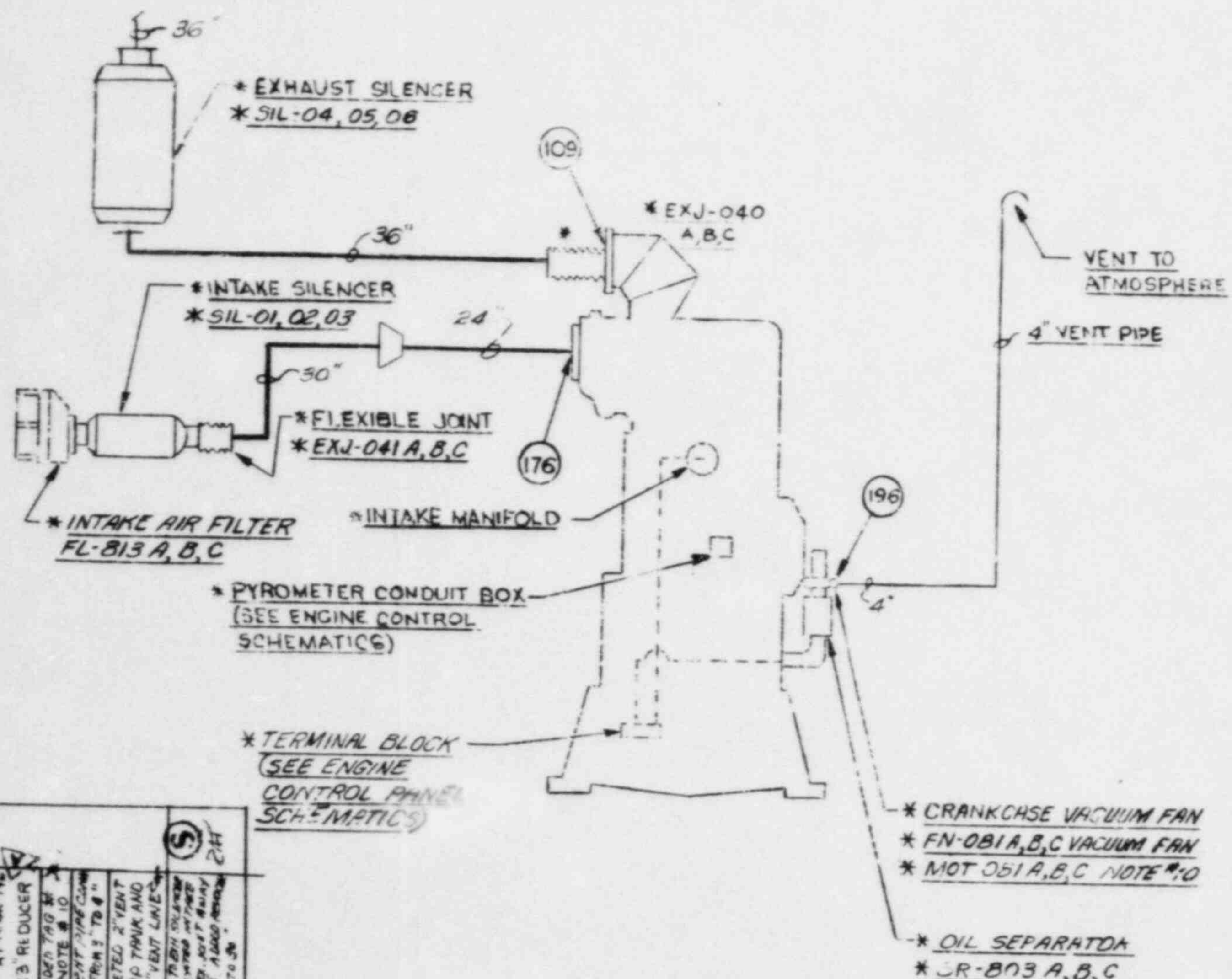
MATERIAL AND HARDNESS

APP RCB | DWN [illegible] | SCALE — | CKD K LEE

52122 | REV G

LILCO 74010

14-8



1. ITEMS MARKED * ARE SUPPLIED BY TRANSAMERICA DELAVAL WITH THE ENGINE.
2. (100) NUMBERS CORRESPOND TO NUMBERED PIPE CONNECTIONS ON INSTALLATION DRAWING.
3. FOR PIPING SYMBOLS SEE DRAWING D-4313.
4. INTAKE PIPING TO BE MECHANICALLY CLEANED AND PAINTED WITH RUST-O-LEUM OR EQUAL.
5. INSTALLATION CONTRACTOR(S) TO SUPPLY EQUIPMENT AND VALVES NOT SUPPLIED WITH ENGINE AND INSTALL ALL OFF ENGINE EQUIPMENT.
6. DOTTED LINES INSIDE OF (100) NUMBERED CONNECTIONS REPRESENT ENGINE MOUNTED PIPING AND FITTINGS SUPPLIED BY TRANSAMERICA DELAVAL.
7. EXHAUST AND INTAKE PIPING MUST NOT BE SUPPORTED BY TURBOCHARGER.
8. ALL PIPING TO BE PROPERLY SUPPORTED.
9. LOCATE INTAKE AIR SILENCER AS CLOSE AS POSSIBLE TO THE TURBOCHARGER AIR INLET ADAPTER. SOUND INSULATION IS REQUIRED ON THE PIPE BETWEEN THE TURBO AND SILENCER TO ATTENUATE RADIATED NOISE IN THE 2000 TO 8000 HZ FREQUENCIES. THE NOMINAL NOISE LEVEL TO BE ATTENUATED IS 115 DBA @ 4000 HZ. THE NOIZE LEVEL DROPS OFF AT FREQUENCIES ON EITHER SIDE OF 4000 HZ. INSULATING TO BE PROVIDED BY OTHERS.
10. MOTORS NOT SHOWN.

REVISIONS	APP.
A) 8-25-76 ADDED 4"x3" REDUCER	
B) 4-2-80 ADDED TAG # & NOTE # 10	
C) 10-16-80 VENT PIPE CONN CHANGED FROM 3" TO 4"	
D) 2-6-81 DELETED 2" VENT LINE FROM SUMP TANK AND VALVE FROM 4" VENT LINE	
E) 5-15-81 [illegible] CHANGE LINE TO 36"	(S) 2H

CUSTOMER: LONG ISLAND LIGHTING CO.

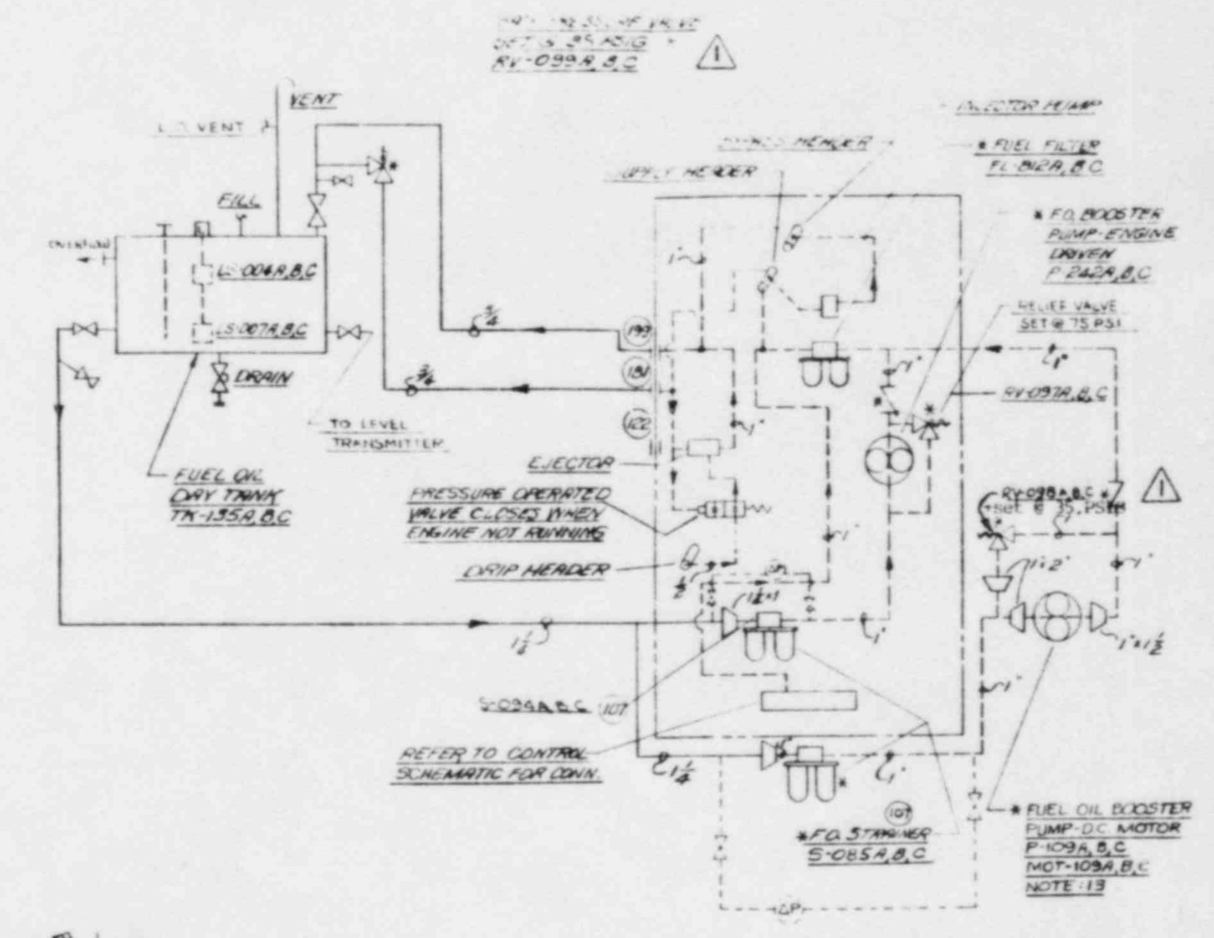
CUSTOMER REF: SHOREHAM UNIT NO. 1

ENGINE NO.: 74010/12

EXHAUST, INTAKE & CRANKCASE VACUUM SCHEMATIC PIPING DIAGRAM

DRAWN	RL 9-25-74
CHECKED	MJ
APPROVED	REB
SCALE	NONE

100398 E



1. ITEMS MARKED * ARE SUPPLIED BY TRANSAMERICA DELAVAL WITH THE ENGINE.
2. (100) NUMBERS CORRESPOND TO NUMBERED PIPE CONNECTIONS ON INSTALLATION DRAWING
3. FOR PIPING SYMBOLS SEE DRAWING D-4313
4. ALL PIPING TO BE MECHANICALLY CLEANED AND PRESERVED WITH TECTYL NO. C-507
5. ISOLATING VALVES ARE TO BE INSTALLED AS REQUIRED DETERMINED BY EQUIPMENT LOCATION. ONLY FUNCTIONAL VALVES ARE SHOWN
6. INSTALLATION CONTRACTOR(S) TO SUPPLY ALL OFF ENGINE PIPING, PIPE FITTINGS, EQUIPMENT AND VALVES NOT SUPPLIED WITH THE ENGINE AND INSTALL ALL OFF ENGINE EQUIPMENT
7. DOTTED LINES INSIDE OF (100) NUMBERED CONNECTIONS REPRESENT ENGINE OR SKID MOUNTED PIPING AND FITTINGS SUPPLIED BY TRANSAMERICA DELAVAL.
8. PIPE SIZES SHOWN ARE MINIMUM FOR MOST INSTALLATIONS BUT MAY VARY IF LENGTH OF PIPING, NUMBER OF FITTINGS AND VALVES RESULT IN EXCESSIVE PRESSURE DROP
9. INSTALL DRAINS AT ALL LOW POINTS AND VENTS AT ALL HIGH POINTS.
10.
11. ALL PIPING MUST BE PROPERLY SUPPORTED
12. ELEVATION OF DAY TANK MUST BE SUCH THAT FUEL WILL HAVE POSITIVE PRESSURE AT CONNECTION NO. 107
13. MOTOR NOT SHOWN

CHG	DATE	REMARKS	APPD
		GENERAL REVISIONS	
		ADDED RELIEF VALVE	
		RELIEF VALVE SET AT 50 PSI ... RELIEF VALVES SET AT 75 PSI ...	
J	1/4	Incorp E&DCR F-45633	

CERTIFIED PRINT MUST BE USED FOR CONSTRUCTION

CERTIFICATION

CUSTOMER LONG ISLAND LIGHTING CO
CUSTOMER REF SHOREHAM UNIT NO.1
JOB NUMBER ______ ENGINE NO 74010/12
CONTRACT OR ORDER NO ______
CERTIFIED FOR STONE & WEBSTER ENG.
BY
TITLE
DATE

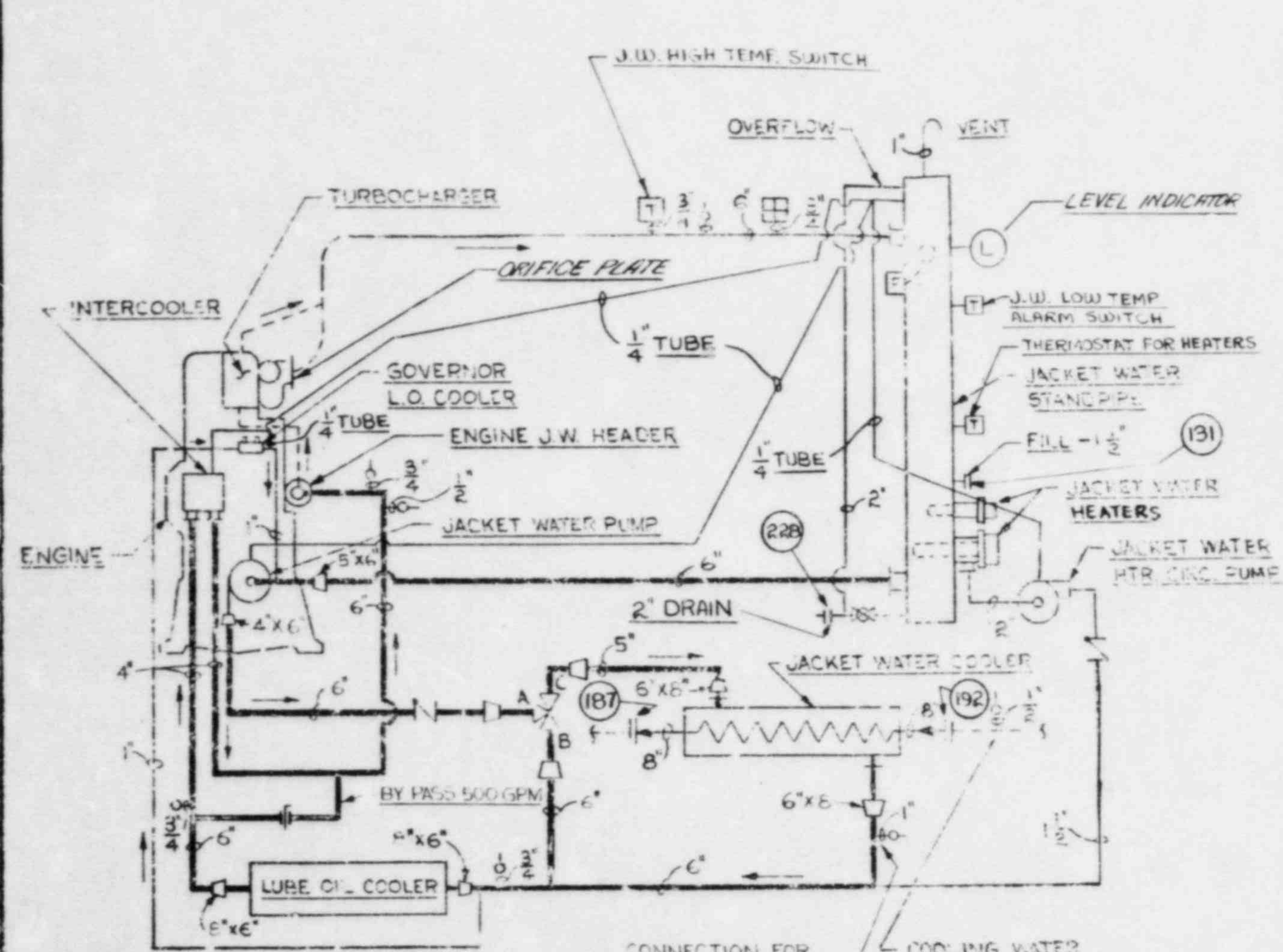
Transamerica Delaval

FUEL OIL
SCHEMATIC PIPING DIAGRAM

DRAWN F.E.K.
CHECKED M LEE
APPROVED
SCALE ______

DRAWING NUMBER 100399 | ALT J

9.18 1



1. ITEMS MARKED * ARE SUPPLIED BY DELAVAL WITH THE ENGINE.
2. 100 NUMBERS CORRESPOND TO NUMBERED PIPE CONNECTIONS ON INSTALLATION DRAWING.
3. FOR PIPING SYMBOLS SEE DRAWING D-4313.
4. ISOLATING VALVES ARE TO BE INSTALLED AS REQUIRED, DETERMINED BY EQUIPMENT LOCATION, ONLY FUNCTIONAL VALVES ARE SHOWN.
5. ISOLATING VALVES ARE TO BE TIGHT SEALING BUTTERFLY VALVES.
6. ALL EQUIP. SHOWN ON UNIT SIDE OF CONN. 161 AND 188 IS SUPPLIED AND INSTALLED BY DELAVAL, BEYOND THESE CONN. BY OTHERS, EXCEPT AS NOTED.
7. PIPE SIZES SHOWN ARE MINIMUM FOR MOST INSTALLATIONS, BUT MAY VARY IF LENGTH OF PIPING, NUMBER OF FITTINGS AND VALVES RESULT IN EXCESSIVE PRESSURE DROP.
8. INSTALL DRAINS AT ALL LOW POINTS AND VENTS AT ALL HIGH POINTS.
9. ALL PIPING MUST BE PROPERLY SUPPORTED.
10. TAPPINGS ARE REQUIRED FOR CONTROLS NOT SHOWN HERE. REFER TO CONTROL SCHEMATICS FOR SIZE AND LOCATION.

CUSTOMER LONG ISLAND LIGHTING CO
CUSTOMER NO. SHOREHAM UNIT NO 1
ENGINE NO. 74010/12

JACKET WATER
SCHEMATIC PIPING DIAGRAM

9-30-74

100400 F

REVISIONS

A) 8-26-75 2 1/2 NPT DRAIN WAS 2 1/2 DRAIN, INDICATE 1" VENT

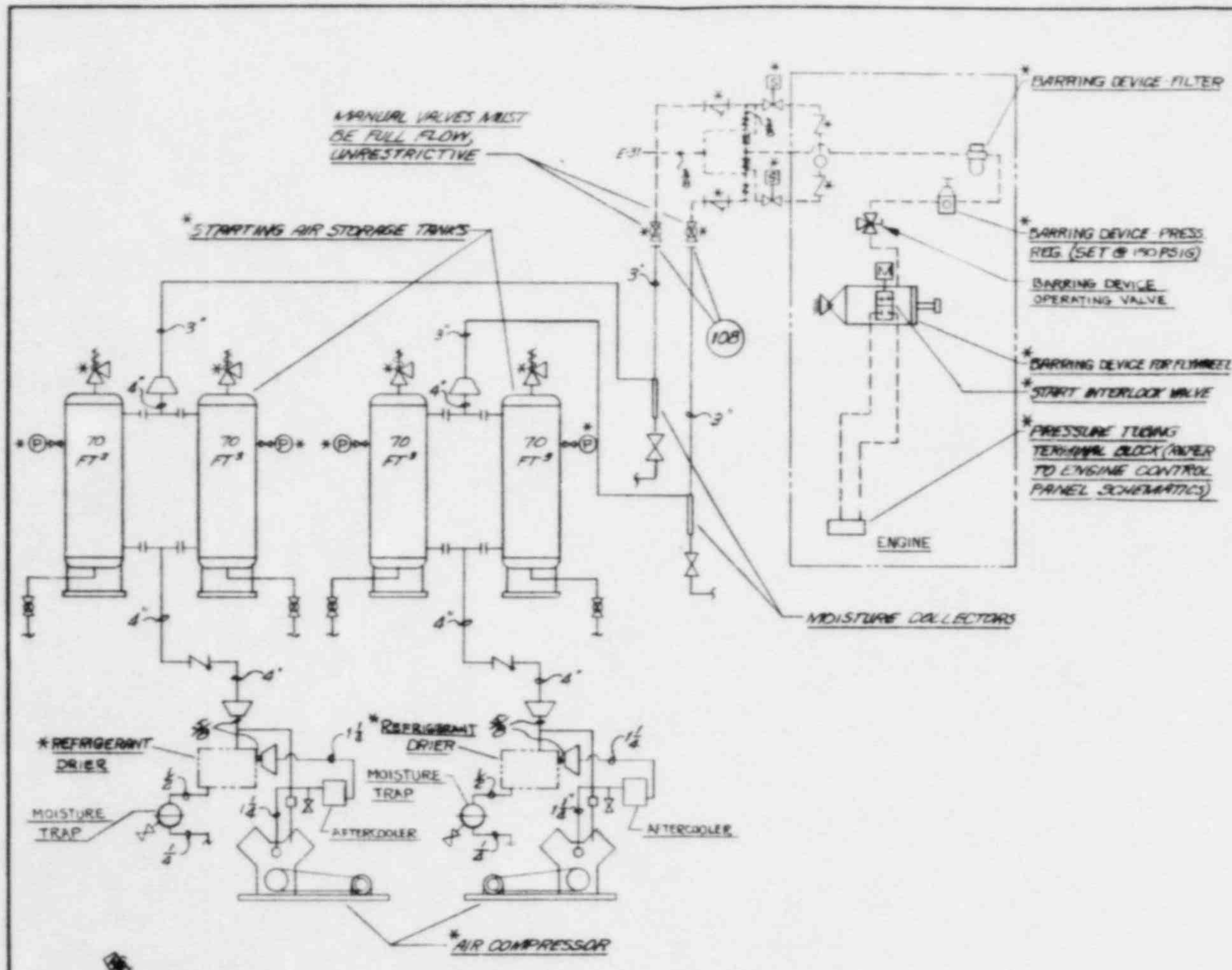
B) 11-4-75 ADDED CONN 131, 2" DRAIN WAS 2 1/2" NPT DRAIN, IDENTIFY CONN. 187, 192 & 228

C) 11-20-75 ADDED 1/4" TUBE FROM INTERCOOLER JACKET WATER ... TO JACKET WATER STANDPIPE

D) 5-6-80 DELETED SIGHTING ... DIFF PRESS. GAGE TO BE FURNISHED BY INSTALLER.

E) 7-80 ADDED ORIFICE PLATE

F) ...81 GENERAL REVISIONS



1. ITEMS MARKED (*) ARE SUPPLIED BY DELAVAL WITH THE ENGINE.
2. ITEM NUMBERS CORRESPOND TO NUMBERED PIPE CONNECTIONS ON INSTALLATION DRAWING.
3. FOR PIPING SYMBOLS, SEE DRAWING D-4313.
4. ALL PIPING TO BE MECHANICALLY CLEANED, BLOWN OUT AND PRESERVED.
5. ISOLATING VALVES ARE TO BE INSTALLED AS REQUIRED. ONLY FUNCTIONAL VALVES ARE SHOWN.
6. INSTALLATION CONTRACTOR(S) TO SUPPLY ALL OFF-ENGINE PIPING, PIPE FITTINGS, [illegible] AND VALVES NOT SUPPLIED WITH ENGINE AND INSTALL ALL OFF-ENGINE EQUIPMENT.
7. DOTTED LINES INSIDE OF (100) NUMBERED CONNECTIONS REPRESENT ENGINE MOUNTED PIPING AND FITTINGS SUPPLIED BY DELAVAL.
8. PIPE SIZES SHOWN ARE MINIMUM FOR MOST INSTALLATIONS, BUT MAY VARY IF LENGTH OF PIPING, NUMBER OF FITTINGS AND VALVES RESULT IN EXCESSIVE PRESSURE DROP. (10 PSI MAX. PRESSURE DROP FROM AIR RECEIVER TO ENGINE HEADER).
9. ALL PIPING TO BE "SCHEDULE 80" AND PIPE FITTING TO BE 300 LBS. ASA" FOR 250 PSIG WORKING PRESSURE.
10. AIR SUPPLY PIPING SHOULD BE RUN AT A LOWER LEVEL THAN ENGINE INLET CONNECTION NO. 108. INSTALL MOISTURE COLLECTORS AND DRAINS IN PIPING AT LOW POINT NEAR ENGINE INLET AND ANY OTHER LOW POINTS IN THE SYSTEM.
11. ALL PIPING TO BE PROPERLY SUPPORTED.
12. TAPS IN OFF-ENGINE PIPING FOR INSTRUMENTS OR CONTROLS NOT SHOWN HERE, ARE REQUIRED AS SHOWN ON CONTROL SCHEMATICS.
13. "Y" STRAINERS MUST BE INSTALLED IN A HORIZONTAL RUN OF PIPE.

CHG	DATE	REMARKS	APP
		GENERAL REVISIONS	
		ADDED 4 GATE VALVES	
		BARRING DEVICE PRESS. REG. WAS 100 PSIG.	

CERTIFIED PRINT MUST BE USED FOR CONSTRUCTION

CERTIFICATION

PROJECT ENGINEER [signature]

CUSTOMER LONG ISLAND LIGHTING CO.

CUSTOMER REF SHOREHAM UNIT NO. 1

ENGINE NO. 74010/12

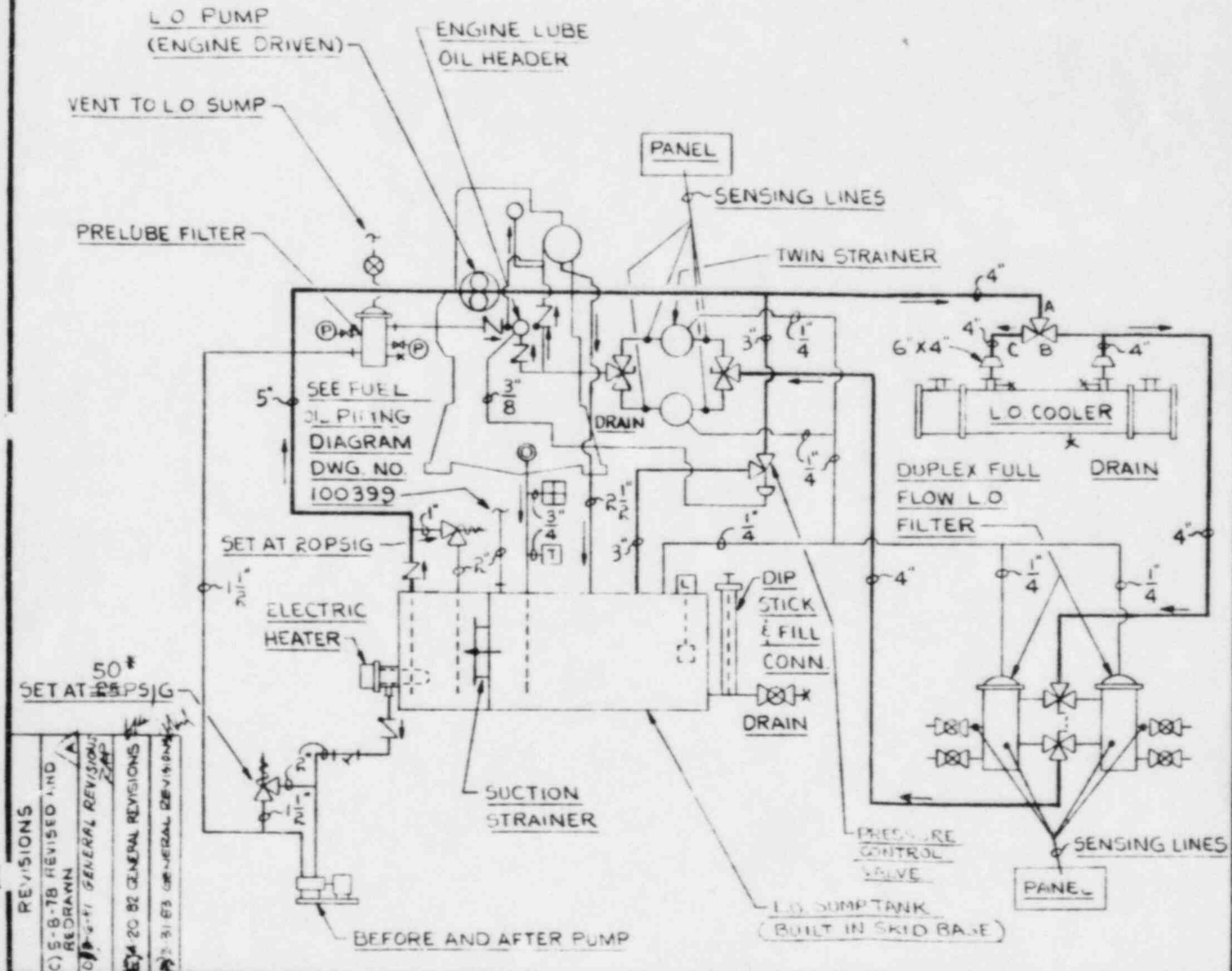
DELAVAL TURBINE INC.
ENGINE AND COMPRESSOR DIVISION
OAKLAND, CALIFORNIA 94621

DELAVAL

STARTING AIR
SCHEMATIC PIPING DIAGRAM

DRAWN FE K 3-23-79			
CHECKED K. LEE		100402	J
APPROVED REB			
SCALE —		DRAWING NUMBER	ALT

9-18



REVISIONS
C) 5-8-78 REVISED AND REDRAWN
D) GENERAL REVISIONS
E) 20 82 GENERAL REVISIONS
F) 31 83 GENERAL REVISIONS

1. ALL ITEMS SHOWN ARE SUPPLIED BY DELAVAL ON ENGINE
2. HOO NUMBERS CORRESPOND TO NUMBERED PIPE CONNECTIONS ON INSTALLATION DRAWING
3. FOR PIPING SYMBOLS SEE DRAWING D-
4. ALL PIPE IS TO BE HOT PICKLED AFTER FABRICATION AND PRESERVED WITH TECTYL NO. -502 BY A RECOGNIZED COMMERCIAL PICKLING COMPANY
5. OPEN ENDS OF SECTIONS OF PIPE ARE TO BE PROTECTED WITH WOODEN BLANKS OR OTHER MEANS OF COVERING IN ORDER TO PROTECT AGAINST CONTAMINATION
6. L.O. PIPING PROCEDURE SET FORTH IN DELAVAL FORM D-4597 IS TO BE COMPLIED WITH
7.
8. NO MAIN LINE ISOLATING VALVES ARE TO BE INSTALLED
9. INSTALLATION CONTRACTOR(S) TO SUPPLY ALL OFF-ENGINE PIPING, PIPE FITTINGS, EQUIPMENT AND VALVES NOT SUPPLIED WITH THE ENGINE AND INSTALL ALL OFF ENGINE EQUIPMENT
10. PIPE SIZES SHOWN ARE MINIMUM FOR MOST INSTALLATIONS, BUT MAY VARY IF LENGTH OF PIPING, NUMBER OF FITTINGS AND VALVES PRODUCE EXCESSIVE PRESSURE DROP
11. NO CAST IRON FITTINGS SHALL BE USED IN THE SYSTEM
12. INSTALL DRAINS AT ALL LOW POINTS AND VENTS AT ALL HIGH POINTS
13. ALL PIPING TO BE PROPERLY SUPPORTED
14. DO NOT USE CHILL OR BACK UP RINGS.

* REF: E&DCR F-45051C

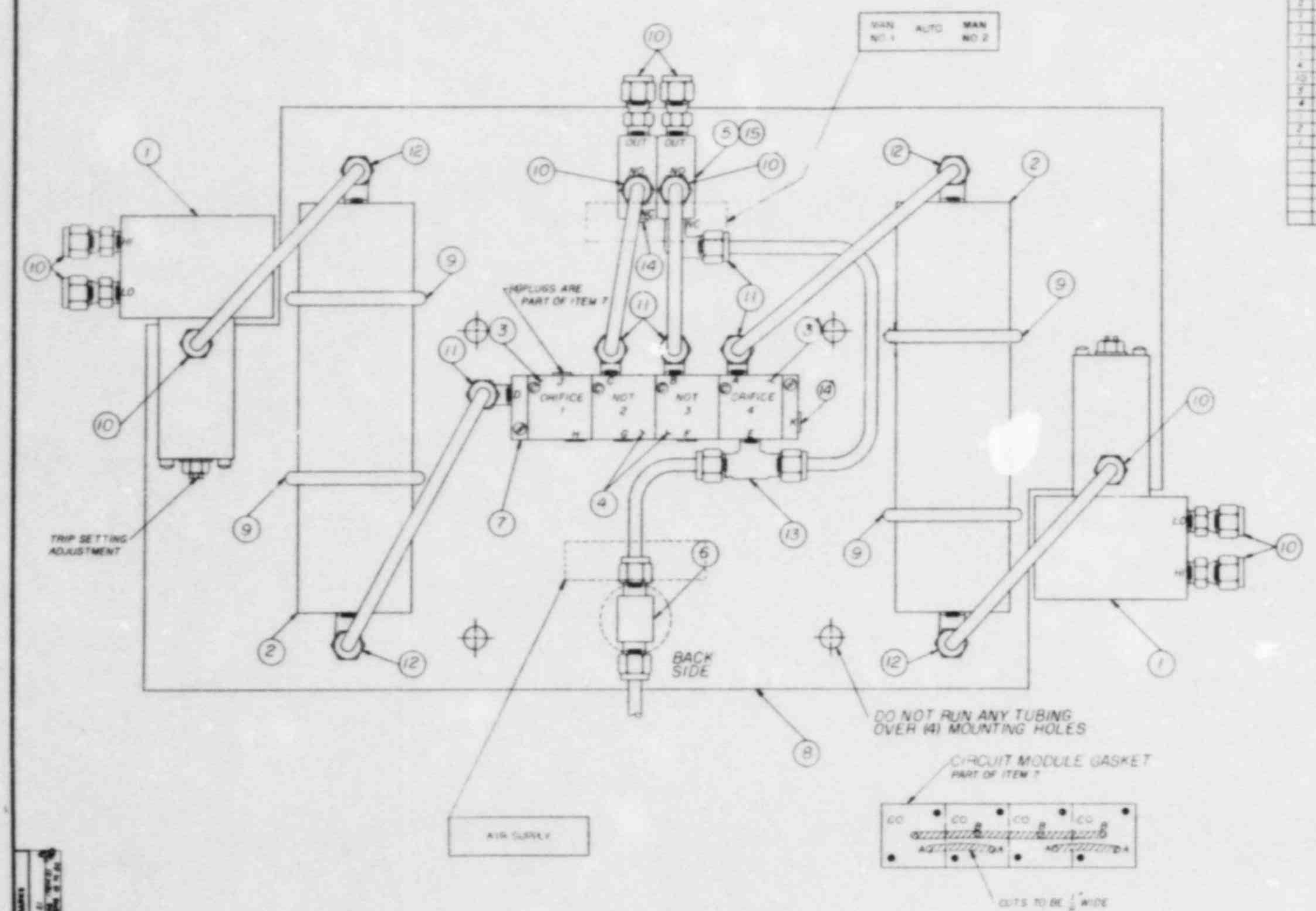
CUSTOMER: LONG ISLAND LIGHTING CO.
CUSTOMER REF: SHOREHAM UNIT NO. 1
ENGINE NO.: 74010/12

DELAVAL TURBINE INC
DELAVAL ENGINE AND COMPRESSOR DIVISION
OAKLAND, CALIF 94621

DELAVAL

LUBE OIL
SCHEMATIC PIPING DIAGRAM

DRAWN	RL 5-8-78	100404	F
CHECKED	C.P.		
APPROVED			
SCALE	NONE	DRAWING NUMBER	ALT



MATERIAL LIST

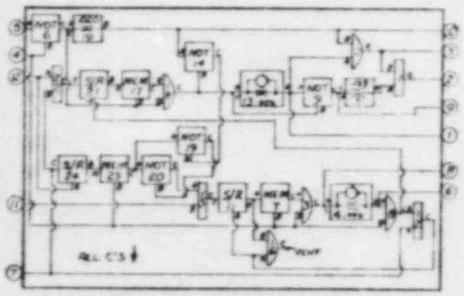
QTY	DESCRIPTION		PART NO.	REMARKS	ITEM
1	DIFFERENTIAL VALVE		F 573 27[illegible]		1
2	ACCUMULATOR		F 573 26[illegible]		2
2	ORIFICE		F 578 219		3
2	NOT LOGIC ELEMENT		F 573 [illegible]		4
1	SELECTOR SWITCH		F 573 047		5
1	SHUTOFF VALVE		F 573 284		6
1	ELEMENT BASE		F 579 290		7
1	MOUNTING PLATE		[illegible]		8
4	U-BOLT		CW 004 [illegible]		9
10	MALE CONN	1/4T x 1/4P	CE 003 [illegible]		10
3	MALE ELBOW	1/4T x 1/4P	CE 001 [illegible]		11
4	MALE ELBOW	1/4T x 1/4P	CE 001 [illegible]		12
1	MALE TEE	1/4T x 1/4P	CE 010 [illegible]		13
2	PIPE PLUG	1/4 P	CP 003 [illegible]		14
1	SEL. OPERATOR	SPG RET	F 586 080		15
					16
					17
					18
					19
					20
					21

DELAVAL

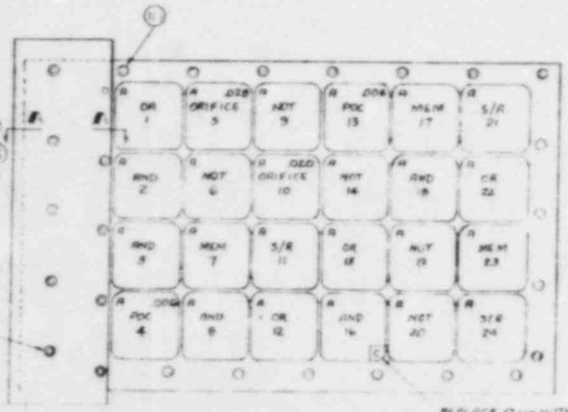
AUTOMATIC SWITCH OVER LOGIC ASSEMBLY

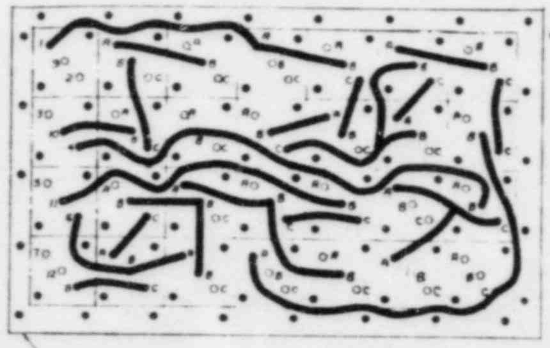
MATERIAL AND HARDNESS

61-500-5663 REV. B

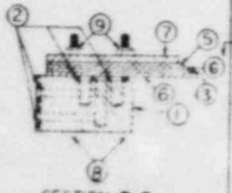


CIRCUIT DIAGRAM





⑤ CUTOUT AS SHOWN - 1/8" WIDE CHANNELS
CIRCUIT MODULE GASKETS USE F-573-291
③ CLEAR GASKET HOLES AND ADJACENT CUTS BY 1/8"



SECTION A-A

REPLACE PLUG WITH VENT SEAL (CALCON #U-3681)

NOTE PORT DESIGNATIONS MATCH LOGIC ELEMENTS TO POSITION SHOWN

LOGIC BOARD ASSEMBLY

MATERIAL LIST

ITEM	QTY	DESCRIPTION	PART NO.
1	1	CONNECTOR - 12 PORT	61 560 01 22
2	24	O-RING	F 573-066
3	1	CIRCUIT MODULE GASKET	AS REQ'D
4			
5	1	CIRCUIT MODULE GASKET	AS REQ'D
6	2	CIRCUIT BASE PLATE	F 573 288
7	1	CIRCUIT COVER PLATE	F 573 289
8	10	SCREW, ALLEN HEAD #6-32 X 2" LG	08-097 265
9	22	NUT, HEX LIGHT #6-32 UNC-2B	F 533 229
10	25	SCREW, ALLEN HEAD #6-32 X 5/8 LG	08 097 258
OR	4	OR LOGIC ELEMENT	F 573 004
AND	5	AND LOGIC ELEMENT	F 573 005
NOT	5	NOT LOGIC ELEMENT	F 573 006
MEM	3	MEMORY LOGIC ELEMENT	F 573 007
S/R	3	SET/RESET LOGIC ELEMENT	F 573 026
POC	2	PARALLEL ORIFICE CHECK .006	F 573 288
ORIFICE	1	ORIFICE .020	F 875 721
ORIFICE	1	ORIFICE .029	F 873 722

* ITEM 10 TO BE USED TO MOUNT ORIFICE PAL TO LOGIC BOARD

FUNCTION: TO PROVIDE NECESSARY SHUTDOWN SIGNALS TO ENGINE

TEST PROCEDURE:

** ± 15 secs.
* ± 5 secs.
Reference E&DCR F-38251 ⚠*

NOT TO SCALE DRAWING

DELAVAL

SHUTDOWN
PNEUMATIC LOGIC BOARD ASSY

MATERIAL AND HARDNESS | APP | DWG | SCALE | CHK | 61 560 7096

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

50-322

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,

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

~~8405080029~~