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Transamerica Delaval

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Instruction Manual
Volume I

Model DSRV-16-4 Diesel Engine/Generator
Serial Nos. 75051-2814
75052-2815
75053-2816
75054-2817

Cleveland Electric Illuminating Co.
Perry Nuclear Power Plant
Units 1 and 2

Transamerica Delaval Inc.
Engine and Compressor Division

Instruction Manual

For

Model DSRV-16-4
Diesel Engine/Generator

Serial Numbers
75051-2814
75052-2815
75053-2816
75054-2817

Manufactured For:
Cleveland Electric Illuminating Company
Perry Nuclear Power Plant, Units 1 and 2

Date of Issue
March 31, 1983

Manufactured By

Transamerica Delaval Inc.
Engine and Compressor Division
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Oakland, California 94621
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ENGINE DATA

MODEL	DSRV-16-4
SERIAL NUMBERS	75051-2814, 75052-2815, 75053-2816, 75054-2817
FUEL	DIESEL
TYPE INSTALLATION	STATIONARY - NUCLEAR STANDBY
CONFIGURATION	45° VEE
NUMBER OF CYLIDERS	16
BORE	17 IN.
STROKE	21 IN .
CYCLES	FOUR
BMEP	224 PSI
HORSEPOWER	9717
RATED SPEED	450
ROTATION	CLOCKWISE (VIEWED FROM FLYWHEEL END)
STARTING SYSTEM	PILOT AIR - GEAR DRIVEN DISTRIBUTORS
FIRING ORDER	1L-8R-4L-5R-7L-2R-3L-6R-8L-1R-5L-4R-2L-7R-6L-3R
TOTAL DISPLACEMENT	76,266 CU-IN.
FLYWHEEL DIAMETER	70 IN.
FUEL INJECTION TIMING	LEFT BANK 22° (13.439 IN.), RIGHT BANK 21° (12.828 IN.) BEFORE TOP DEAD CENTER
FUEL INJECTION PUMP RACK	SEE ENGINE NAMEPLATES 37.0 MM (75051 & 75052) 38.0 MM (75053 & 75054)
VALVE CLEARANCE	N/A (HYDRAULIC VALVE LIFTERS)

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

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

REFER TO APPENDIX X FOR COPIES OF THE FACTORY TEST LOGS, AND A SUMMARY OF FACTORY TEST RESULTS

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Transamerica
Delaval

Transamerica Delaval Inc.
Engine and Compressor Division
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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:

Form CAT-119-5 (R-4) 5/82

Section 1
Introduction

SECTION 1

INTRODUCTION

PURPOSE.

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

SCOPE OF MANUAL.

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

RELATED MANUALS.

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

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

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

CUSTOMER ASSISTANCE.

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

NOTES, CAUTIONS AND WARNINGS.

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

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

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

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

SAFETY PRECAUTIONS.

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

WORKING PRINCIPLE.

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

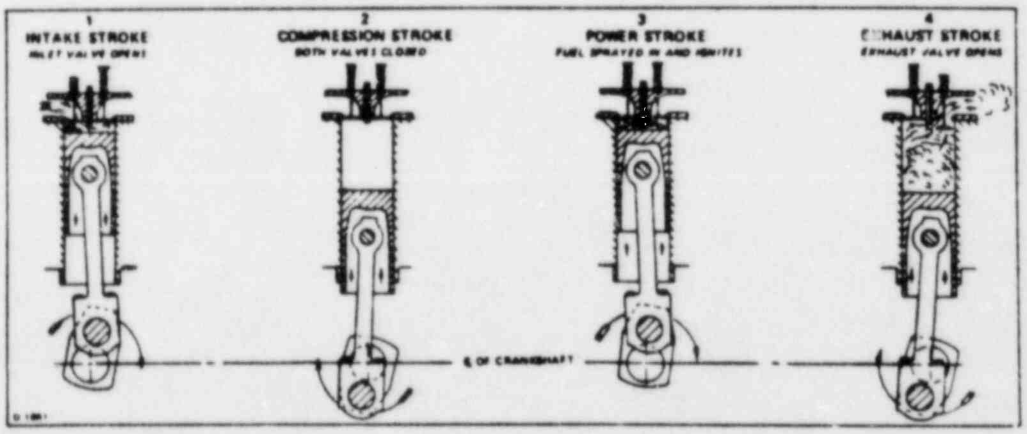


Figure 1-1. Diagram of Working Principle

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

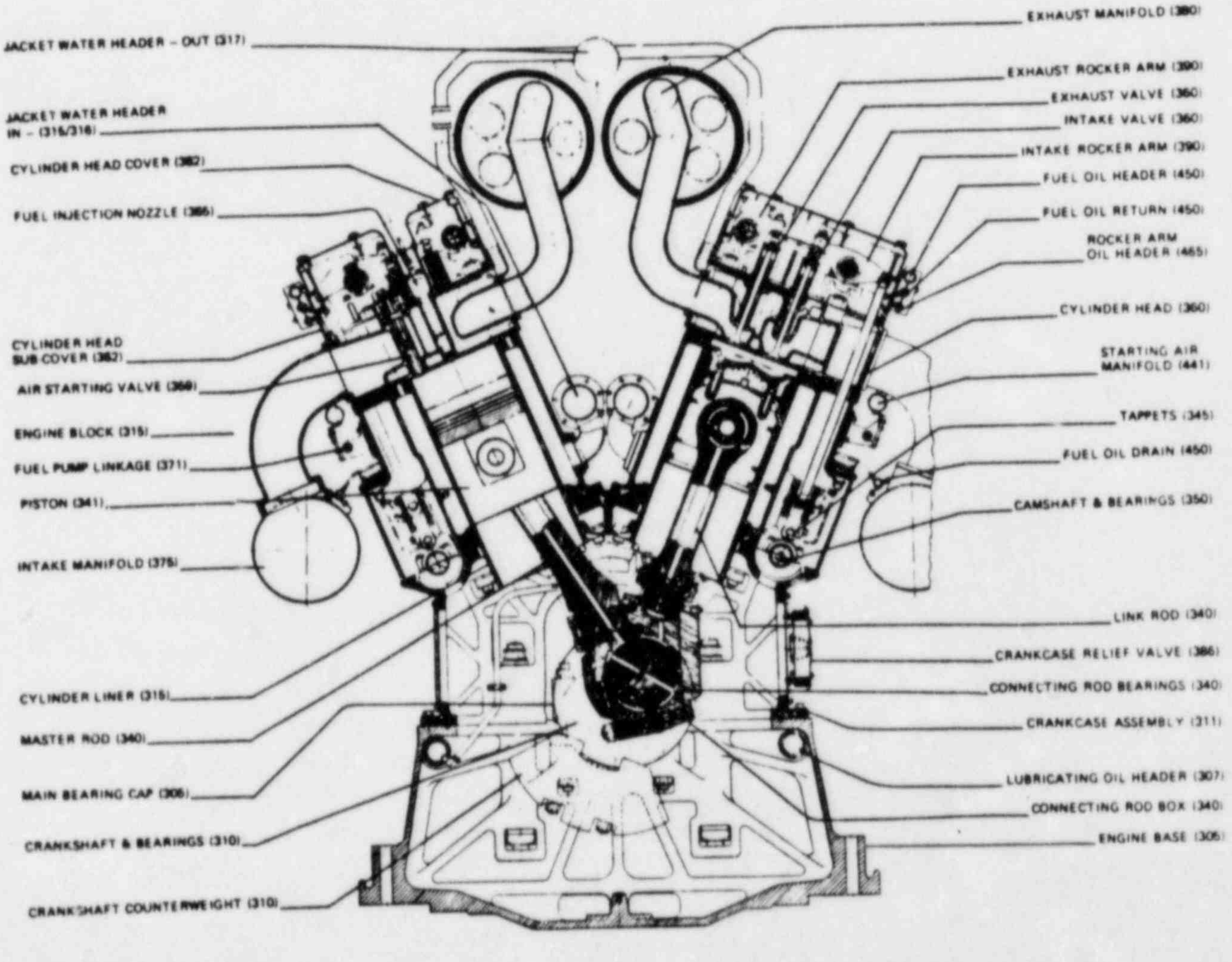
b. COMPRESSION STROKE — Shortly after the piston passes bottom center and starts upward, the intake valve closes and the air is compressed, raising the temperature of the air to well above the ignition temperature of the diesel fuel. Just before the piston reaches top center, diesel fuel is injected 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 RV diesel engine is a four-stroke-cycle, turbocharged, aftercooled, V-type engine. The angle of the Vee is 45 degrees. Trunk-type piston, removable wet-type cylinder liners, pressure lubrication and mechanical fuel injection are features of the engine. Individual fuel injection pumps are provided for each cylinder and, as they are of standard design, are interchangeable. The fuel lines are of equal length and are relatively short, reducing line surge to a minimum. Fuel pumps, nozzles and orifice size and angle are all carefully matched to the engine and the fuel to be used to give a maximum thermal efficiency. Engine rotation and cylinder bank designations are determined while facing the engine at the flywheel end. Number one cylinders are always the pair farthest from the flywheel end.



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

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

Section 2
Installation

SECTION 2

INSTALLATION

GENERAL.

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

FOUNDATION DRAWING.

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

INSTALLATION DRAWING.

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

SYSTEM SCHEMATIC DRAWINGS.

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

HANDLING AND SHIPMENT.

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

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.

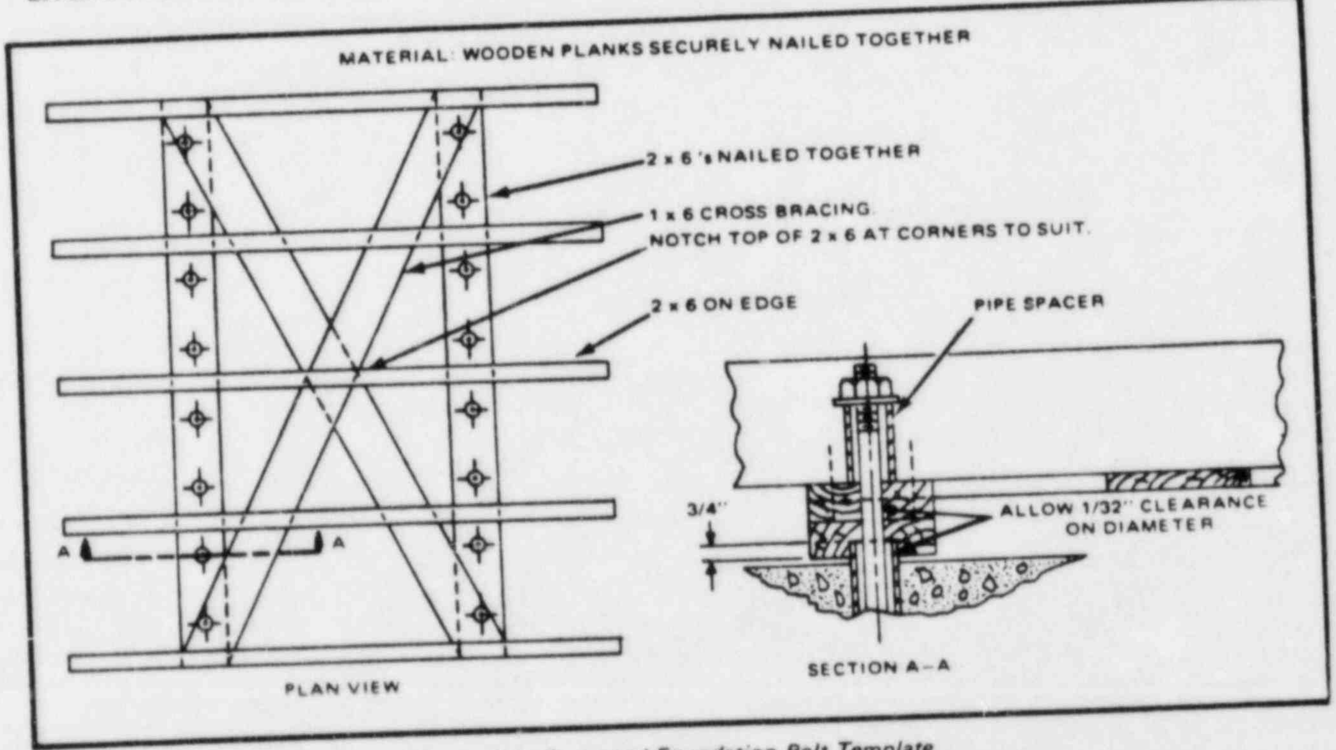


Figure 2-1. Suggested Foundation Bolt Template

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 CONNECTING SHAFT.

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

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.

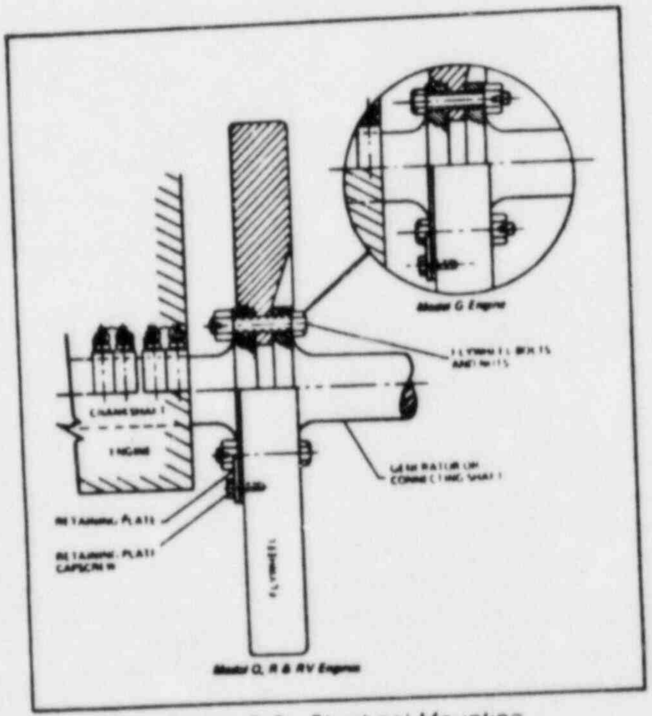


Figure 2-2. Flywheel Mounting

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 186° 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.

The jacket water system is individual for each engine. The recommended water treatment is sodium dichromate and boiler compound. Refer to Section 6 of this manual for the recommended method of treatment. The closed loop jacket water system consists of an engine driven jacket water pump to circulate the coolant, a thermostatic valve to regulate the temperature of the water by diverting the necessary part of the flow through the jacket water cooler, and a standpipe to maintain a constant head on the pump and to allow for expansion and bleeding of entrained air. A heater and "keep warm" pump are provided at the standpipe to circulate heated jacket water through the system while the engine is in the standby status. Refer to the jacket water piping schematic in the "Drawings" section of this manual for the relative location of system components, pipe sizes and the direction of flow.

RAW WATER SYSTEM.

Delaval Engine and Compressor Division does not provide the raw water system for this installation. Rather, raw water is taken into the auxiliary module at connection 276 from the owner's supply source, circulated through the jacket water cooler, and then discharged back to the owner's circuits at connection 277. The raw water, circulating through the jacket water cooler, removes heat from the jacket water.

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.

LUBRICATING OIL SYSTEM.

The lubricating oil system is shown in schematic form on Drawing 09-820-75051. The treatment of piping was discussed in preceeding paragraphs, and all piping supplied by Delaval Engine and Compressor Division will have been so treated and preserved. All piping must be properly supported to minimize pipe vibration and flange loading. Flexible couplings are not recommended at customer connections, however, because of the potential failure hazard during operation. Before starting the engine for the first time, the assembled lubricating oil piping system must be thoroughly flushed with clean 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 circulation of the oil through the pipes without filling the internal lubricating oil system of the engine. Several thicknesses 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. Any continuous duty pump of sufficient capacity, the "keep warm" pump, for instance, can be used to pump oil during the flushing operation. Flushing should continue for at least eight hours if care was exercised during fabrication of the off-engine piping system. As much as 24 hours of flushing may be required for a dirty system. While oil is circulated 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 that testing fluids, water and other liquids are completely removed before attempting to flush the cooler.

Note

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

Disconnect jumper tubes between the engine lubricating oil header and the main bearings, and between the main headers and auxiliary headers. Secure a fine mesh 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 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.

Refer to Drawing 09-805-75051. Each engine has an independent intake system, the combustion air being piped in from outside the engine room through two remotely installed air filters. Two inline silencers are fitted in the piping 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.

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 Drawing 09-805-75051 for a schematic representation of the system.

STARTING AIR SYSTEM.

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

Section 3
Engine
Controls

Section 3
Engine Controls

GENERAL.

The following is a description of the local engine control system and its operation. The system will start, stop, protect, operate and monitor the integrity of the diesel generator in the various modes of operation under guidelines specified by the various regulatory and standards committees.

REFERENCES.

The *Associated Publications Manual* contains 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 pneumatic logic elements as well as a parts breakdown and repair procedures. When ordering spare and replacement parts for the system, refer to *Parts Manual* for the correct part numbers.

DRAWINGS.

The drawings provided with these instructions include system schematics, layouts and connections pertaining to the pneumatic logic board assembly, showing the location and orientation of components on the board, the circuit diagram and checkout procedures. Refer to the control panel group parts list 02-500 for 75051 in the *Parts Manual* for a listing of the drawings applicable to the system.

OPERATING MODES.

There are two base modes incorporated into the system, the NORMAL mode and the INOPERATIVE mode. In the NORMAL mode the unit may be started in response to an emergency start signal, or manually to exercise it on a routine basis. The INOPERATIVE mode permits routine maintenance or repair.

a. While in the NORMAL mode the unit will accept a manually injected starting signal from a local or remote location and, if the unit's entire protective system is permissive, it will start, come up to speed and build voltage automatically. Controls provided by the owner are then used to load the unit onto an energized bus. While running in this mode, both the speed/load and voltage setpoints are adjustable from either the local or remote location. Provided the generator circuit breaker is open, the unit can be stopped from either location by momentarily pressing a guarded stop button.

b. If an emergency "Start Diesel" signal is generated by the owner's equipment, the unit will start if the overspeed and generator differential protection only are permissive, and if panel a-c power is available. The unit will come up to speed and voltage as required and a "Ready To Load" signal will be generated for use in the owner's sequencing equipment. No other protective device is functional under this condition, and control air need not be available to effect a start.

c. If the unit is undergoing its periodic "Exercise Test" at the moment a "Start Diesel" signal is received, whether it is starting, running disconnected, running loaded, tripping on a fault other than overspeed or generator differential, or coasting to a stop, the control system will cause the unit to return to rated speed and voltage, and will disarm all protection except overspeed and generator differential. The "Ready To Load" signal will be sent to the sequencer as above.

d. While running in the emergency state, both speed/load and automatic voltage setpoints are adjustable, either locally or remotely. Every time the engine is shut off, or given an emergency start signal, the setpoint of the governor and the automatic setpoint of the voltage regulator are reset to normal. Fifteen seconds after going to normal, the reset signal is released to allow the operator to control voltage and speed.

PART C – CONTROL SYSTEM (Continued)

e. If the emergency is corrected, and the maintained "Start Diesel" signal is terminated, the unit will remain running, and the protective system will automatically return to full operation. Once this is done, however, it will require the receipt of another "Start Diesel" signal from the owner's equipment to disarm the shutdown system again. In addition, a keyed manual start switch is used at the local panel which will allow only authorized personnel to initiate a start from the local panel.

f. Mode selection is accomplished so as to afford maximum protection for the plant and also for maintenance personnel. If the system is in the INOPERATIVE mode, only the local operator can place it in the NORMAL mode. If the unit is in the NORMAL mode, the LOCAL/REMOTE switch must be in LOCAL and a key is required to place the system in the INOPERATIVE mode. Status lights report the system's mode in the remote location. Further, in NORMAL mode, the barring device cannot be engaged; while in INOPERATIVE mode it must be disengaged and locked out in order to switch to OPERATIONAL mode.

PROTECTIVE SYSTEM.

The unit's protective system is a hybrid electro-pneumatic system. Since pneumatic devices function better than other types in the diesel environment, vital shutdown functions are performed pneumatically. All faults, both alarm and shutdown are displayed on a solid state, dual rate flashing annunciator with horn silence provisions. Handoff contacts for use with a remote annunciator or mimic display are provided. When running as a result of an emergency start signal, even though most of the shutdown system is not able to effect a unit trip, the action of the individual tripping devices is monitored and displayed on the annunciator so that the operator will be aware when a vital device has acted. Status lamps, separate from the annunciator, are used to show the condition of the unit as it proceeds through a starting sequence. The engine starting circuits are duplicated in total, and can receive d-c power from two separate conduit entries, if desired. Further, ancillary devices are arranged so that, even if they fail to function as intended, the unit will start and generator voltage will build up. It is possible that starting air will not be shut off as intended after a start if certain devices fail, but the balanced design of the engine's air start valves will keep them closed as soon as combustion occurs.

PANEL ELECTRICAL CONTROL (See Drawing 09-500-75051).

The local engine control panel electrical circuitry is shown in schematic form on sheets 3 of 10 through 10 of 10 of the referenced drawing.

a. Starting circuitry is shown on sheets 3 and 4. Note that there are two redundant circuits, each having a separate d-c power source. These circuits are physically spaced as far apart as possible on the panel. Solenoid valves SOL-1A, SOL-1B, SOL-2A and SOL-2B are located on the engine, and when energized admit starting air to the starting air headers on the engine. They are controlled by relays R4A and R4B during normal or emergency starts.

b. The redundant "Start Diesel" signal contacts are from the owner's equipment. When either set of contacts close, an emergency start is initiated, provided pressure switch PS-40A or PS-40B is closed, indicating that the unit is in NORMAL mode, and if K1 is closed (i.e., if the unit is not running at rated speed), and if pressure switch PS-3A or PS-5B is closed, indicating at least 150 psi starting air is left in the receivers. These pressure switches are present so that, if for some reason the unit does not fire (valve closed in fuel supply line, for instance), there will be enough starting air left for several manual starts.

c. Note that upon application of an emergency "Start Diesel" signal, SOL-6A or SOL-6B becomes energized, either of which cause the shutdown system to disarm, except for overspeed and generator differential. Note also that if K1 fails to transfer, or even if the device is faulty and fails to function in any way, K1 remains closed and the unit will start. If it fails to open at the prescribed speed, combustion will close the air start valves and no damage is done.

PART C – CONTROL SYSTEM (Continued)

d. At a manual start, either of the switch contacts (local or remote) shown are closed which causes relay R4A or R4B to energize for five seconds. The shutdown system deactivating solenoid is not used; instead, solenoid valve SOL-3A or SOL-3B is activated by either R4A or R4B which initiates the shutdown system arming sequence.

e. Note that the mode selector must be in NORMAL mode for any of the above to take place. If it is in the OPERATIVE mode, the engine roll button, on the local panel only, is operative. If the barring device is locked out, the pressure switch shown will be closed and the unit can be turned over on starting air without starting, a useful maintenance feature.

f. When the unit receives a start signal, pressure switch PS-32E closes, latching relays R1 and R1AUX, if PS-9D shows the unit not tripped. The Field Flash solenoid valves, SOL-9A and SOL-9B are energized by PS-33A and PS-33B which close when engine speed reaches 200 rpm, or by time delay TD1A or TD1B which are energized by R4A and R4B for a timed period. Note that as in the start circuits, K1 failure will not prevent field flashing. Time delays TD4 and TD5 are present to reset the R1 relays should the unit fail to achieve ready-to-load status for any reason.

g. The two R2 relays shown are responsive to the latching of R1, but there is a 60 second time delay (TD3) before R2 latches. Contacts of R2 and R2A are used to disarm various alarm functions which are normally in a fault state when the unit is stopped, starting, or stopping.

NUMBER	SETTING	FUNCTION
PS-3A, C	150 psi falling	Starting Air Admission – Left Bank
PS-5B, C	150 psi falling	Starting Air Admission – Right Bank
PS-9A, B, C, D	45 psi rising	Unit Tripped
PS-10B, BB, E, F	45 psi rising	Emergency Start
PS-12A, B	45 psi rising	Local Manual Start
PS-13B, D	45 psi rising	Barring Device Engaged
PS-14C	45 psi falling	High Temperature Jacket Water Trip
PS-15C	45 psi falling	High Temperature Bearing Trip
PS-16C	45 psi falling	High Temperature Lube Oil Trip
PS-17C	20 psi rising	High Differential Pressure Lube Oil Filter
PS-18C	20 psi rising	High Differential Pressure Fuel Filter
PS-19C	45 psi falling	Turbocharger Oil Pressure Trip
PS-20C, D	20 psi falling	Turbocharger Oil Low Pressure
PS-22C	15 psi falling	Low Pressure Jacket Water
PS-23D	45 psi rising	Locked Out with Delay
PS-24C	45 psi falling	Lube Oil Pressure Trip
PS-25C	45 psi falling	Low Pressure Lube Oil
PS-26C	45 psi falling	Vibration Trip
PS-27C	45 psi falling	High Pressure Crankcase Trip
PS-28C	20 psi falling	Low Pressure Fuel Oil
PS-29C, D	45 psi rising	Overspeed Trip
PS-30A, B	45 psi rising	Field Flash
PS-31C	45 psi rising	DC power available
PS-32A, C, D, E	45 psi rising	Starting
PS-33AA, BB, A, B, C, D, E	45 psi rising	200 RPM
PS-34A	45 psi rising	Up To Speed
PS-36C, D	10 psi falling	Fuel Pump/Overspeed Failure
PS-39C	45 psi falling	Control Air Pressure
PS-40A, B	45 psi rising	Inoperative/Normal

Table 3-C-1. Pressure Switches

PART C – CONTROL SYSTEM (Continued)

SOLENOID	FUNCTION	OPERATED BY
SOL-1A	Starting Air Admission	R4A
SOL-1B	Starting Air Admission	R4B
SOL-2A	Starting Air Admission	R4A
SOL-2B	Starting Air Admission	R4B
SOL-3A	Activate Shutdowns	R4A, PS-12A, Remote Start signal
SOL-3B	Activate Shutdowns	R4B, PS-12B, Remote Start signal
SOL-5A	Mode Selection-Inoperative	Mode Selector Switch, PS-13A
SOL-6A	Deactivate Shutdowns	Emergency Start signal
SOL-6B	Deactivate Shutdowns	Emergency Start signal
SOL-7A	200 RPM	Tach transmitter contact K1
SOL-7B	200 RPM	Tach transmitter contact K3
SOL-8A	Engine Up to Speed	Tach transmitter contact K1
SOL-8B	Engine Up to Speed	Tach transmitter contact K3
SOL-9A	Field Flash	PS-33AA, TD1A
SOL-9B	Field Flash	PS-33BB, TD1B
SOL-10A	Mode Selection-Normal	Mode Selector Switch
SOL-11A	DC power	Circuit Breaker
SOL-11B	DC power	Circuit Breaker
SOL-12B	Stop	Local & Remote Stop Pushbuttons

Table 3-C-2. Solenoid Valves

RELAY	CONTACTS		TIME	FUNCTION
TD1A	TD1A	N.O.	1 sec.	Energizes SOL-9A after timing out
TD1B	TD1B	N.O.	1 sec.	Energizes SOL-9B after timing out
TD2A	TD2A	N.C.	5 sec.	Provides power to R4A until it times out
TD2B	TD2B	N.C.	5 sec.	Provides power to R4B until it times out
TD3	TD3-1	N.O.	60 sec.	Provides latching power to R2 and R2 AUX after it times out
TD4	TD4-1	N.O.	5 sec.	Provides power to R12 circuit after timing out
	TD4-2	N.O.	5 sec.	Provides power to R12 after timing out

Table 3-C-3. Time Delay Relays

PART C – CONTROL SYSTEM (Continued)

RELAY	CONTACTS		FUNCTION
R1-1	R1-1	N.O.	Provides power to TD4
	R1-2	N.O.	Provides power to TD3
	R1-3	N.O.	Provides power to "Shutdown System Active" status light
	R1-4	N.O.	Provides power to "Start" status light
	R1-5	N.C.	Provides power to "Stopped" status light
	R1-6	N.O.	Engine Start Chart Recorder input
R1 AUX	R1 AUX-1	N.O.	Provides power to R1A and R1AA
	R1 AUX-2	N.O.	Provides power to DC Fuel Booster Pump
	R1 AUX-3	N.C.	Arms Lube Oil High Temperature Trip Alarm
	R1 AUX-4	N.C.	Arms High Temperature Engine Bearings Trip Alarm
	R1 AUX-5	N.C.	Arms Engine Vibration Trip
	R1 AUX-6	N.O.	Provides power to DC Fuel Oil Booster Pump
R1A	R1A-1	N.C.	Provides power to Lube Oil Circulating Pump and Heater
	R1A-2	N.C.	Provides power to Jacket Water Circulating Pump and Heater
	R1A-3	N.O.	Run Relay Customer Contacts
	R1A-4	N.O.	
	R1A-5	N.O.	
	R1A-6	N.O.	
R1AA	R1AA-1	N.O.	Run Relay Customer Contacts
	R1AA-2	N.O.	
	R1AA-3	N.O.	
	R1AA-4	N.O.	
R2	R2-1	N.C.	Arms Low Pressure Turbocharger Oil Left Bank Alarm
	R2-2	N.C.	Arms Low Pressure Turbocharger Oil Right Bank Alarm
	R2-3	N.C.	Arms Low Pressure Turbocharger Oil Trip Alarm
	R2-4	N.C.	Arms Low Pressure Lube Oil Alarm
	R2-5	N.C.	Arms Low Pressure Lube Oil Trip Alarm
	R2-6	N.C.	Arms High Pressure Crankcase Alarm
R2 AUX	R2 AUX-1	N.C.	Arms Fuel Oil Pressure Low Alarm
	R2 AUX-2	N.C.	Arms High Temperature Jacket Water Alarm
	R2 AUX-3	N.C.	Arms Low Pressure Turbocharger Trip Alarm
	R2 AUX-4	N.C.	Arms Fuel Pump/Overspeed Drive Failure
	R2 AUX-5	N.O.	Customer Contact
	R2 AUX-6	N.O.	Customer Contact
R4A	R4A-1	N.C.	Provides power to SOL-1A, SOL-2B and TD1A at Automatic Start
	R4A-2	N.O.	Provides power to SOL-1A, SOL-2B and TD1A at Manual Start
	R4A-3	N.O.	Provides power to SOL-3A, TD1A, TD2A, R4A, SOL-1A and SOL-2B after Start valve released

Table 3-C-4. Relays

PART C – CONTROL SYSTEM (Continued)

RELAYS	CONTACTS		FUNCTION
R4B	R4B-1	N.C.	Provides power to SOL-1B, SOL-2A and TD1B at Automatic Start
	R4B-2	N.O.	Provides power to SOL-1B, SOL-2A and TD1B at Manual Start
	R4B-3	N.O.	Provides power to SOL-3B, TD1B, TD2B, R4B, SOL-1B and SOL-2A after Start valve released
R5B	R5B-1	N.O.	Provides power to Lube Oil Circulating Pump and Heater
R6B	R6B-1	N.O.	Provides power to Jacket Water Circulating Pump and Heater
R7	R7-1	N.O.	Provides power to R15
R8	R8-1	N.O.	Customer Contacts
	R8-2	N.O.	Customer Contacts
	R8-3	N.O.	Provides power to "Unit Available Emergency Status" status light
	R8-4	N.O.	Activates Field Flash 125 VDC Power Loss alarm
R12	R12-1	N.O.	Provides reset power to R1 and R2 relays
	R12-2	N.C.	Provides latching power to R1 relays
	R12-3	N.C.	Activates Diesel Generator Failure To Start Alarm
R14A	R14A-1	N.O.	Unit Available Emergency Status Customer Contacts
	R14A-2	N.C.	
R15	R15-1	N.O.	Provides Power to Alarm Horn
	R15-2	N.C.	Customer Contact
R16	R16-L	N.C.	Activates Low Temperature Lube Oil IN alarm
	R16-H	N.O.	Activates High Temperature Lube Oil IN alarm
R17	R17-L	N.C.	Activates Low Temperature Lube Oil OUT alarm
	R17-H	N.O.	Activates High Temperature Lube Oil OUT alarm
R18	R18-L	N.C.	Activates Low Temperature Jacket Water IN alarm
	R18-H	N.O.	Activates High Temperature Jacket Water IN alarm
R19	R19-L	N.C.	Activates Low Temperature Jacket Water OUT alarm
	R19-H	N.O.	Activates High Temperature Jacket Water OUT alarm

Table 3-C-4. Relays (Continued)

PART C – CONTROL SYSTEM (Continued)

LOCAL ENGINE CONTROL PANEL (See Drawing 00-500-75051).

The local engine control panel houses those control components which are not engine or remotely mounted. Access to the panel is through hinged doors in the back and removable access panels on either side. A 60 point annunciator is mounted in the upper portion of the face of the panel. Beneath this, and at eye level, are ten pressure gauges which monitor lubricating oil, turbocharger oil, fuel oil, jacket water, combustion air and starting air system pressures. An electronic temperature indicator with digital readout and integral linearization and cold juncture compensation is used to monitor thermocouples inserted in the engine exhaust, lubricating oil and jacket water systems. Temperature alarm sensing is done in the lubricating oil and water systems.

a. Status lamps are provided as follows.

1. DC control power ON – lights if all d-c circuits are energized.
2. AC power ON.
3. Unit Available For Start – Lights when the following conditions have been met.
    - (a) DC Booster Pump in AUTO.
    - (b) Mode Selector in NORMAL.
    - (c) DC power available – sufficient circuits to start.
    - (d) Starting air pressure available.
    - (e) Overspeed device not tripped.
    - (f) Generator lockout relay not tripped.
4. Unit Starting – lights when PS-32C actuated.
5. Unit Shutdown System Active – lights when relay R1 energized.
6. Start – lights when relay R1 energized.
7. Stopped – lights wh en relay R1 energized.
8. 200 RPM
9. Ready To Load.
10. Unit Tripped.

b. There are two level gauges used, one to indicate fuel oil day tank level and one to indicate lubricating oil sump tank level.

c. An engine hourmeter is provided which is responsive to relay R1AUX. A tachometer is also included, reading the speed in rpm directly from the speed transmitter. A remote output is available from this transmitter by removing the burden resistor and connecting on the 4-20 MA terminals.

PART C – CONTROL SYSTEM (Continued)

d. Delaval engines are arranged so that the engine-driven fuel oil pump is driven from the free end of the overspeed drive assembly. For nuclear service, a d-c booster pump is used in parallel with the engine driven pump. If the drive fails the operator would have no indication that there is no longer overspeed protection. An annunciator is provided which senses the loss of engine fuel pump pressure and, therefore, alerts the operator of possible loss of overspeed protection.

AUTOMATIC SAFETY SHUTDOWN SYSTEM (See Drawing 09-500-75051).

Refer to sheet one of the referenced drawing. The shutdown system is a network of vent-on-fault pneumatic devices which are arranged in the various systems of the engine. The venting of such a device is sensed by the pneumatic logic circuitry, and this circuitry then produces a 60 psi pressure signal which operates a cylinder on the engine to shut off fuel. This shutdown signal is automatically vented after the unit has rolled to a stop, retracting the cylinder and readying the unit for a restart. Note that the sensor network is always pressurized; it is merely the shutdown signal which is inhibited in the emergency condition. Upon application of starting air, several things occur directly from the air start header. The governor oil pressure is pneumatically boosted, and the Stop/Run valve is pressure driven to the RUN position. Note that only the overspeed trip and generator fault trip remain active in the emergency condition. Shutdowns are placed in two groups, Group I shutdowns being those which must be "GO" in order for the engine to start, and Group II shutdowns are those which would be in a shutdown (venting) condition until the engine is running. Lubricating oil pressure, for instance. Group II shutdowns are locked out during engine starts for a fixed period of time. The Shutdown Logic Board, 1A-6147 (1) functions to provide the necessary shutdown signals to the engine: When operating in response to an emergency start signal, it prevents the engine from shutting down while still giving panel indications on an existing shutdown condition. The logic board functions as follows.

a. If the INOPERATIVE mode is selected (assuming that 60 psi control air is present at all points marked $\boxed{Z}$▶, solenoid valve SOL-5A is energized, admitting 60 psi control air to a three-way valve P_2 which shifts to allow passage of a 60 psi signal. This signal is transmitted to Port 5 of the Shutdown Logic Board where it is applied to the "A" port of element NOT-6, acting to inhibit the passage of control air through that element. This prevents pressurization of Port 10 of the board and, therefore, charging of the Group I shutdown network. In addition, control air from P_2 is transmitted through a shuttle valve (19) to pressurize line E-89 and the pilot of valve P_1 which vents the barring device. Pressure in line E-89 actuates the pilot of a three-way valve (10, Dwg. 09-695-75051), causing control air to pass through a shuttle valve (14, Dwg. 09-695-75051) to line E-90, where it extends the shutdown cylinder (5, Dwg. 09-695-75051) which moves the fuel racks to the "No Fuel" position, shutting off fuel delivery.

b. If NORMAL mode is selected, assuming that the barring device is disengaged and locked, control air will pressurize Port 4 of the Shutdown Logic Board and pass through element NOT-6 as well as pressurizing the "B" ports of elements MEM-15, AND-11 and AND-7. Output from element NOT-6 pressurizes port "B" of MEM-13 and port "B" of AND-17 and also passes through a metering orifice (10) to pressurize port "A" of NOT-18, port "B" of AND-14 and Port 10. The Port 10 output arms the Group I shutdowns, and the unit is ready for a start.

c. A MANUAL START, initiated from either the local or remote location, will cause solenoid valves SOL-3A and SOL-3B to energize momentarily, causing admission of a 60 psi control air signal to Port 12 of the Shutdown Logic Board. This signal is transmitted through OR-4 to the "C" port of S/R-22 which converts the momentary signal to a constant output from the "C" port of MEM-13. Note that this output will remain after the momentary signal to S/R-22 is lost. The MEM-13 output pressurizes port "A" of AND-17 and, due to the presence of control air at the "B" port of that element, there is an output at port "C" of AND-17. This output pressurizes port "B" of NOT-18, but the

PART C – CONTROL SYSTEM (Continued)

element does not transmit due to pressure at its "A" port. The output from AND-17 also pressurizes port "B" of element NOT-9, causing an output from port "C" of that element, which pressurizes Port 9. The Port 9 signal charges line E-24, locking out the vibraswitch trip during a start sequence. In addition, NOT-9 output is metered through a 0.028 inch orifice and element OR-5 to feed the Group II shutdowns at Port 2. Note, however, that the Group II shutdown sensors are in a venting condition until operating pressures and temperatures are reached. As an example, the Lube Oil Pressure sensor (Dwg. 09-695-75051) will be in a venting condition until actual lube oil pressure reaches 30 psi. Therefore, the metered Port 2 signal will not be able to charge the Group II trip lines at this time.

d. In addition to pressurizing port "B" of NOT-9, the AND-17 output is metered through a 0.006 inch orifice to an accumulator at Port 1. The 60-90 sec. time delay required for the metered signal to fill the accumulator is known as Group II lockout timing. Referring to page 3-C-3, section g. of this manual, note that an electrical timing circuit is also initiated at a start. The normally closed contacts of relay R2 are used to disarm the alarms for the Group II sensors for 60 seconds. As operating temperatures and pressures are achieved, the sensors shift to the blocking position, and the metered Port 2 signal begins to fill the trip lines. By the time the electrical timer energizes R2 and arms the alarm system, the pneumatic lines should be fully charged. Upon completion of Group II lockout timing at the accumulator at Port 1, pressure builds up at port "A" of NOT-9 and port "A" of AND-14. The inhibitory signal at port "A" of NOT-9 causes the element to cease transmitting, and the pressure at Port 9 exhausts back through NOT-9, which reinstates vibraswitch protection. Although the metered signal through OR-5 is lost when NOT-9 vents, Port 2 supply is maintained as accumulator pressure at port "A" of AND-14 causes the element to transmit a signal through OR-5 to Port 2. Note that Port 2 is now fed through AND-14 by orifice (10), the same orifice that supplies the Group I shutdowns. At this time all Group II alarms and trips are active, and the unit is running with full shutdown protection.

e. If an unsatisfactory condition should develop which would trip one of the sensors there will be a loss of pressure at Port 2 of the Shutdown Logic Board in the case of a Group II shutdown trip, or at Port 10 in the case of a Group I shutdown. Both ports follow the same vent path. After Port 2 vents the "B" port of OR-5 and the "B" port of AND-14, pressure is lost at the "A" port of NOT-18. Due to the action of the metering orifice (10), pressure is maintained at the "B" port of NOT-18 and the element conducts a signal to the "B" port of NOT-24. The signal passes through NOT-24 and NOT-20 and is transmitted through OR-16 to the "C" port of S/R-12, causing an output at the "C" port of MEM-15. Since control air is present at port "B" of AND-11, MEM-15 output transmits through AND-11 and pressurizes Port 8. Port 8 output is conducted through a shuttle valve (21) to line E-89 where it extends the shutdown cylinder, cutting off fuel delivery and shutting the unit down.

f. Note that AND-11 output is also passed through an orifice/check (3) and two accumulators (19) at Port 6, causing a timed delay. When this delay is completed, and shutdown has been accomplished, a signal is passed through AND-7 which is transmitted to the reset port (port A) of S/R-22, causing a loss of pressure at port "B" of NOT-18 which terminates the shutdown signal. Element AND-7 also transmits through OR-8 to the reset port of S/R-12 which vents Port 8, retracting the shutdown cylinder and readying the unit for a restart.

g. A shutdown due to engine overspeed is accomplished in a different manner. Refer to drawing 09-695-75051 which shows the system in the shutdown state, depressurized and de-energized. A 60 psi control air signal is present at Line E-53 and, if the engine is running, the Stop/Run valve (15) will be in the RUN position, blocking the passage of control air. Control air is also fed through an orifice (16) and, if the overspeed trip valve (9) is not tripped, pressure will build on the pilot of a three-way valve (11) which shifts to prevent the passage of control air. When the overspeed trip valve is actuated, the three-way valve vents, allowing passage of control air through the valve which activates the sensors on line E-20 and also extends the air shutoff cylinder thereby closing the butterfly valve in the air intake manifold and cutting off combustion air to the engine. Note that control air is also passed through the Stop/Run valve (15) and through a shuttle valve (14) to line E-90 where it activates the "Unit Tripped" sensors, and also extends the shutdown cylinder (5) which moves the fuel racks to the "No Fuel" position. The engine is stopped due to both fuel and air starvation.

PART C – CONTROL SYSTEM (Continued)

h. If a normal stop signal is applied from either the local or remote location, or if an emergency stop signal is applied, solenoid valve SOL-12B is energized, admitting 60 psi control air to Port 11 of the Shutdown Logic Board. This signal is transmitted through OR-16 to the "C" port of S/R-12 which causes an output from port "C" of MEM-15. This output is transmitted through AND-11 to Port 8 which pressurizes line E-89 and extends the shutdown cylinder. After shutdown has been accomplished a delayed signal acts to vent Port 8 and retract the shutdown cylinder, readying the unit for a restart.

i. Upon receipt of an emergency start signal from the owner's equipment, either solenoid valve SOL-6A or SOL-6B or both will become energized, admitting 60 psi air to Port 7 of the Shutdown Logic Board. This signal is transmitted through element OR-8 to the reset port of S/R-12, which vents MEM-15, AND-11 and Port 8, venting the shutdown line and allowing movement of the fuel racks. The Port 7 signal is also transmitted to the "B" ports of elements AND-19, AND-23 and OR-4. The OR-4 signal acts to pressurize Ports 2 and 10 of the board as outlined in paragraphs c. and d. above. Note that the output from OR-5, which pressurizes Port 2, also passes through a check valve to the blocked Port 3 and then to the "A" ports of elements AND-19 and AND-23. Due to Port 7 pressure at these elements, a signal is transmitted from each to the "A" ports of elements NOT-24 and NOT-20. This causes the shutdown signal, which is normally transmitted through these elements, to be inhibited. Note that the shutdown sensors fed through Ports 2 and 10 are still active and continue to monitor the condition of the unit and display fault indications on the annunciator on the control panel. However, since the shutdown line is inhibited, these sensor signals will not be able to effect a shutdown while the unit is operating in response to an emergency start signal.

Section 4
Engine
Operation

SECTION 4

ENGINE OPERATION

GENERAL.

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

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

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

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

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

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

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

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

CLEAR CYLINDER CHECK

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

a. Open indicator cocks on all cylinders.

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

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

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

Caution

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

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

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

g. Close all indicator cocks.

h. Place Stop/Run valve in RUN.

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.

CONTROL OPERATIONS.

All control operations, such as pre-start procedures, starting, running and loading of the diesel-generator, may be carried out from either the Local Engine Control Panel or the owner's Remote Control Room equipment. A switch is provided on the Generator Control Panel which allows selection of REMOTE or LOCAL control. In addition, mode selection control is provided at the Local Engine Control Panel. Note that the Mode Selector Switch has a keyed interlock, which allows authorized personnel to lock the system in either the INOPERATIVE or NORMAL mode.

PRE-START PROCEDURE.

When starting a cool engine after a shutdown, it is very important that the following procedure be carried out prior to attempting a start, and prior to placing the unit in NORMAL mode.

a. Switch "REMOTE/LOCAL" switch on Generator Control Panel to "LOCAL...

b. Place Mode Selector Switch in INOPERATIVE position.

c. Barring device interlock locked out.

d. Open indicator cocks on all cylinder heads.

e. Push the "Engine Roll" pushbutton on the Local Engine Control Panel, allow the engine to roll at least two revolutions, then release button.

f. Inspect all indicator cocks. If liquid has been ejected from any of the cocks, the source must be found and defect corrected before proceeding.

g. Close indicator cocks.

PLACING THE UNIT IN NORMAL MODE.

The following operations must be performed to return the unit to NORMAL mode from the INOPERATIVE mode.

a. Check levels of fuel oil day tank and lubricating oil tank.

b. Select the fuel oil transfer pump to be used if day tank requires filling. Select either HAND or AUTO operation, as desired.

CAUTION

If HAND operation is selected, operator attendance is required to prevent overfilling of the tank.

c. Check that lubricating oil circulating pump and heater and jacket water circulating pump and heater are in AUTO or START positions, as desired.

d. Check that DC Fuel Oil Booster Pump, and Starting Air Compressor switches are in AUTO or ON positions, as desired.

e. Check AC and DC power indicator lamps ON.

f. Check Starting Air Pressure.

g. Check that Overspeed device not tripped.

h. Place "REMOTE/LOCAL" switch on Generator Control Panel in "LOCAL" or "REMOTE" as desired.

i. Place Mode Selector Switch in NORMAL position.

STARTING PROCEDURE.

LOCAL MANUAL START.

To start the unit manually from the local panel while in the NORMAL mode, perform the following.

a. Place "REMOTE/LOCAL" switch in LOCAL position.

b. Pull and hold start valve. As soon as the engine has fired once or twice, release valve.

c. If the unit's entire protective system is permissive, it will start, come up to speed and build voltage automatically.

REMOTE MANUAL START.

A manual start may be initiated from the remote location while the unit is in the NORMAL mode by performance of the following steps.

a. Place the "REMOTE/LOCAL" switch in the REMOTE position.

b. Momentarily switch the AUTO/OFF/START switch at the remote panel to the START position.

c. The control system will automatically activate all shutdowns and the unit will start, come up to speed and build voltage automatically.

EMERGENCY START.

The unit will accept an emergency "Start Diesel" signal generated by the owner's equipment if the REMOTE/LOCAL switch is in the REMOTE position, and if the AUTO/OFF/START switch is in the AUTO position. If the unit is at rest, coasting to a stop, or otherwise operating at less than 200 rpm, receipt of a "Start Diesel" signal will cause starting air to be injected into the cylinders, and the unit will start, come up to rated speed and voltage automatically, and disarm all protection except for overspeed and generator differential. If the unit is being manually operated at speeds in excess of 200 rpm, receipt of a "Start Diesel" signal will cause the unit to come to rated speed and voltage, and will disarm all protection except overspeed and generator differential. In such a case the air start valves are not actuated, due to the action of a pressure switch which isolates the air start devices at speeds above 200 rpm.

MANUAL STOP.

Reduce load and open the main circuit breaker. When engine temperatures have cooled to the desired level, actuate the normal stop pushbutton if the unit is being operated from the local panel. If the remote location is in control, place the AUTO/OFF/START switch in the OFF position.

EMERGENCY STOP.

Perform one of the following actions to stop the engine in an emergency situation.

a. Open main circuit breaker and actuate stop switch in previously selected control location.

b. Actuate "Emergency Stop" pushbutton at Local Control Panel, if unit is in LOCAL control. Note that only the "Emergency Stop" pushbutton, not the normal stop pushbutton at the local panel, is operational while the unit is being operated in response to a "Start Diesel" signal.

c. Manually place the STOP/RUN valve on the engine to the STOP position.

d. Manually place the governor load limit switch on the governor to zero load.

e. Manually trip the overspeed device.

f. If none of the above procedures work, the engine may be stopped by pushing a fuel pump lever towards the engine block. This will rotate the fuel shaft and cut off pump delivery. Hold the lever until the engine stops.

STARTING, STOPPING AND OPERATING PRECAUTIONS.

As soon as the engine is running, all gauges should be checked for proper operating pressures and temperatures as shown in Appendix II.

WARNING

Use only compressed air for starting. Substitution of compressed gases, especially oxygen, may result in a violent explosion.

Section 5
Inspection &
Maintenance

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.

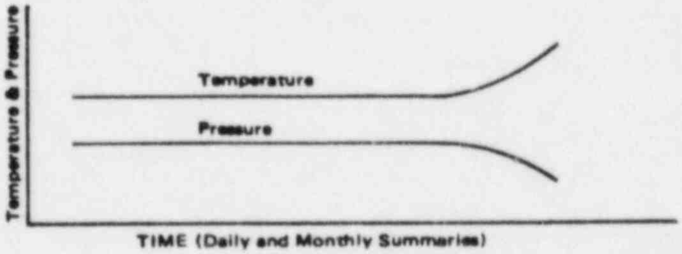
c. A program of regular preventive maintenance, together with keeping the unit clean and inspecting it regularly, will permit the replacement of wearing parts before they can cause serious malfunction and/or damage to the engine and equipment.

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.

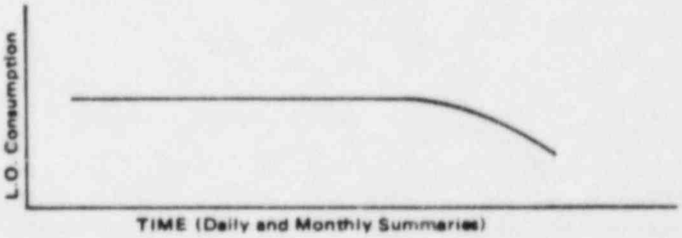
PART A – PREVENTIVE MAINTENANCE (Continued)



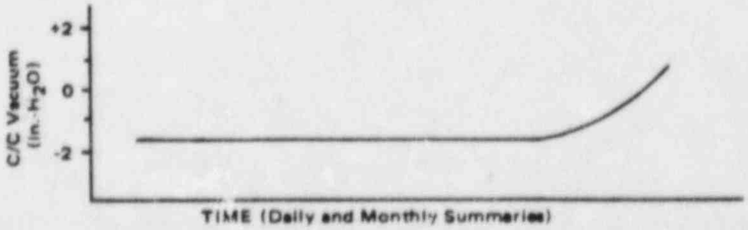
a. If lubricating oil pressure starts to decrease, but the lubricating oil temperature remains constant, this would indicate that bearings are starting to wear to excessive clearances, that the lubricating oil pump is wearing excessively, or that the relief valve is not functioning properly. It could 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.

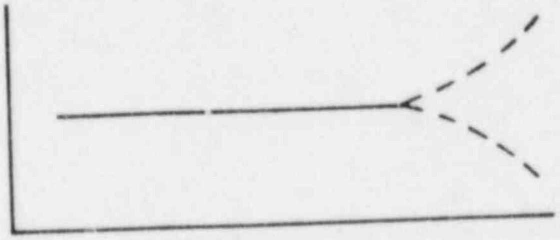


b. If lubricating oil consumption starts to increase it could mean that the piston oil control rings are starting to foul, or have worn excessively. If this is the case, oil is being burned and should show up in the exhaust as a light blue or grey smoke. It could also mean that the intake or exhaust 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.

PART A — PREVENTIVE MAINTENANCE (Continued)

OPERATING REPORTS.

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

a. Load (%)

b. Engine Speed

c. Crankcase vacuum readings

d. Fuel pump rack positions (mm settings)

e. Temperatures

   (1) Ambient air

   (2) Intake air manifold

   (3) Lubricating oil

   (4) Cooling water

   (5) Exhaust (cylinder and stack)

f. Pressures

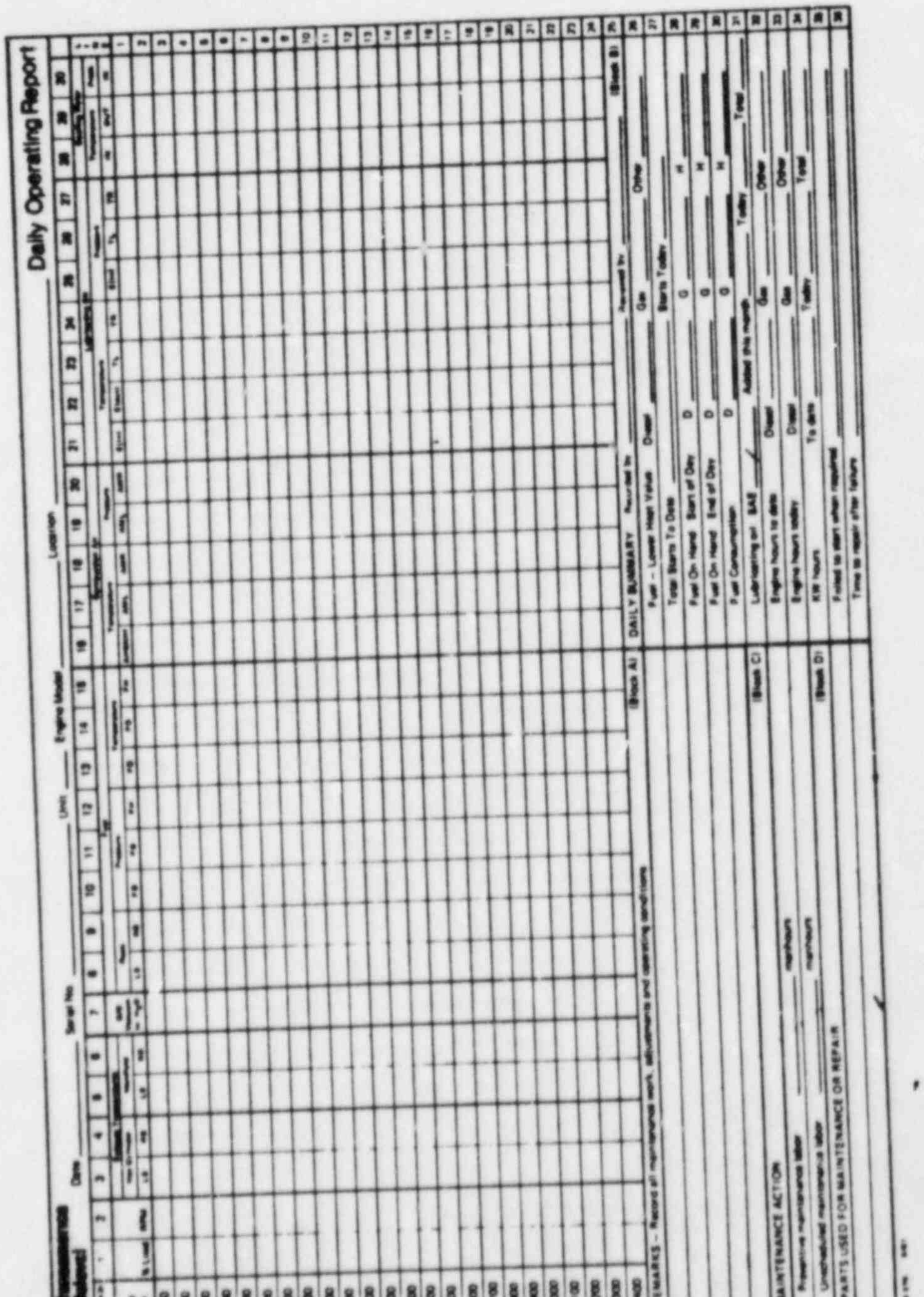
   (1) Ambient air

   (2) Intake air manifold

   (3) Lubricating oil

   (4) Fuel

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



Daily Operating Report

Date ____ Serial No. ____ Unit ____ Engine Model ____ Location ____

0100
0200
0300
0400
0500
0600
0700
0800
0900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400

(Block A) (Block B)

REMARKS – Record all maintenance work, adjustments and operating conditions

DAILY SUMMARY Recorded by ____ Reviewed by ____

Fuel – Lower Heat Value Diesel ____ Gas ____ Other ____

Total Starts To Date ____ Starts Today ____

Fuel On Hand Start of Day D ____ G ____ H ____

Fuel On Hand End of Day D ____ G ____ H ____

Fuel Consumption D ____ G ____ H ____

Lubricating oil SAE ____ Added this month ____ Today ____ Total ____

(Block C)

MAINTENANCE ACTION

Engine hours to date Diesel ____ Gas ____ Other ____

Preventive maintenance labor ____ manhours

Engine hours today Diesel ____ Gas ____ Other ____

Unscheduled maintenance labor ____ manhours

(Block D)

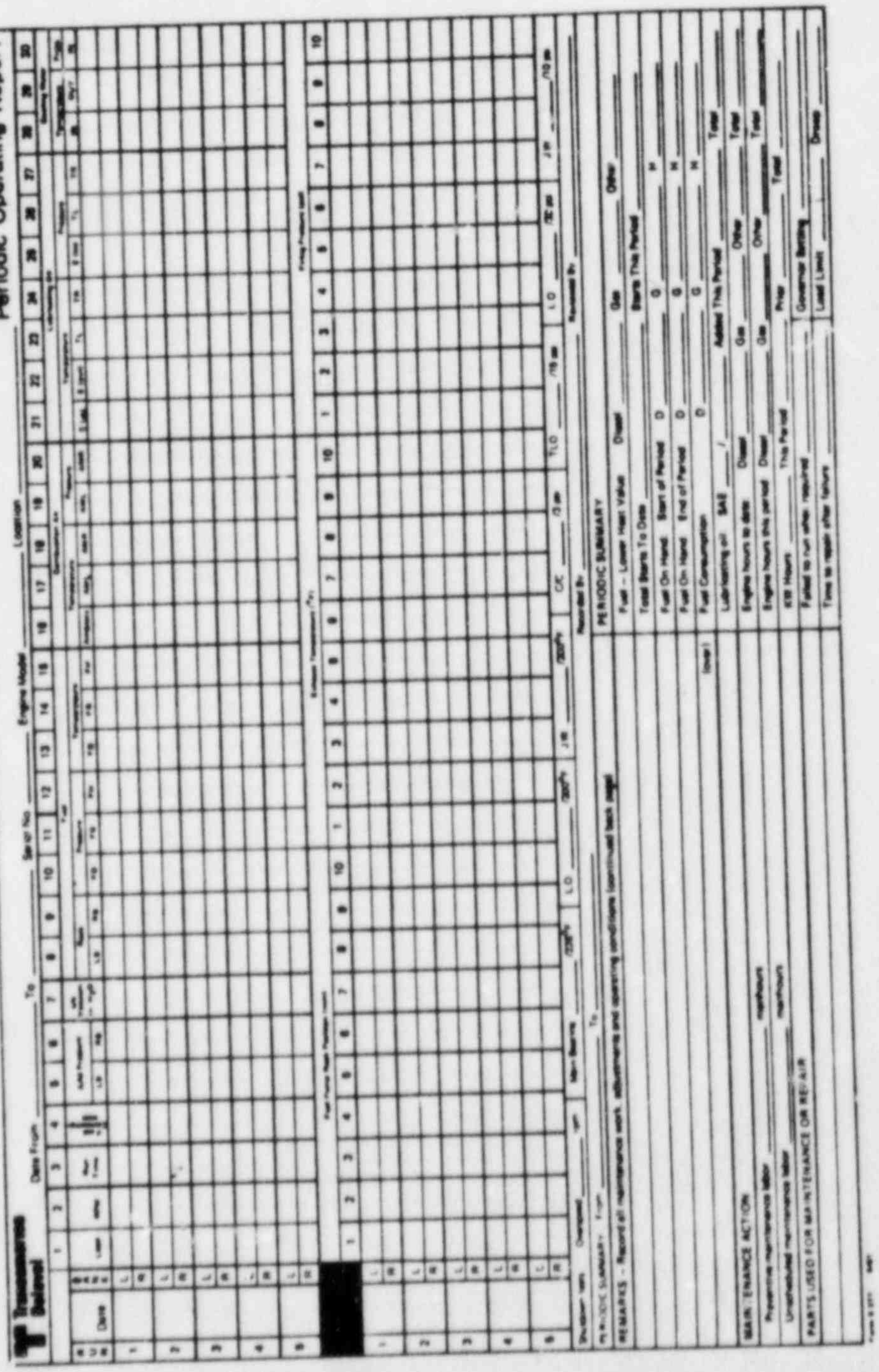
KW hours To date ____ Today ____ Total ____

PARTS USED FOR MAINTENANCE OR REPAIR

Failed to start when required ____

Time to repair after failure ____

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



Transamerica Delaval

Periodic Operating Report

Date From ______________ To ______________ Serial No ________ Engine Model ____________ Location ______________

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

RUN | Date | BANK

Fuel

Combustion Air

Lubricating Oil

[redacted]

1 2 3 4 5 6 7 8 9 10 1 2 3 4 5 6 7 8 9 10 1 2 3 4 5 6 7 8 9 10

Shutdown tests Overspeed ________ rpm | Main Bearing ______ /220°F | L.O. ______ /200°F | J.W. ______ /200°F | C/C ______ /3 psi | T.L.O. ______ /15 psi | L.O. ______ /30 psi | J.W. ______ /10 psi

Recorded By ______________ Reviewed By ______________

PERIODIC SUMMARY From ______________ To ______________

REMARKS – Record all maintenance work, adjustments and operating conditions (continued back page)

(over)

MAINTENANCE ACTION

Preventive maintenance labor ______________ manhours

Unscheduled maintenance labor ______________ manhours

PARTS USED FOR MAINTENANCE OR REPAIR

PERIODIC SUMMARY

Fuel – Lower Heat Value Diesel ________ Gas ________ Other ________

Total Starts To Date ______________ Starts This Period ______________

Fuel On Hand Start of Period D ________ G ________ H ________

Fuel On Hand End of Period D ________ G ________ H ________

Fuel Consumption D ________ G ________ H ________

Lubricating oil SAE ____ / ________ Added This Period ________ Total ________

Engine hours to date Diesel ________ Gas ________ Other ________ Total ________

Engine hours this period Diesel ________ Gas ________ Other ________ Total ________

KW Hours ________ This Period ________ Prior ________ Total ________

Failed to run when required ________ Governor Setting ________

Time to repair after failure ________ Load Limit ________ Droop ________

Form E-277

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

PART B — SUGGESTED MAINTENANCE SCHEDULES

GENERAL.

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

MAINTENANCE SCHEDULES.

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

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

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

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

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

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

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

INSPECTIONS GUIDES.

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

PART B — SUGGESTED MAINTENANCE SCHEDULES (Continued)

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

PART B — SUGGESTED MAINTENANCE SCHEDULES (Continued)

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

PART B — SUGGESTED MAINTENANCE SCHEDULES (Continued)

INSPECTION GUIDE **Frequency:** MONTHLY or EACH EXERCISE TEST

Component Group: Diesel Engine

Special Conditions: MONTHLY, or each test, whichever comes first

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

PART B — SUGGESTED MAINTENANCE SCHEDULES (Continued)

INSPECTION GUIDE **Frequency:** ANNUAL/EACH PLANT SHUTDOWN

Component Group: Diesel Engine

Special Conditions: Annual or each shutdown, whichever comes first

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

PART B — SUGGESTED MAINTENANCE SCHEDULES (Continued)

INSPECTION GUIDE | **Frequency:** BI-ANNUAL/ALTERNATE PLANT SHUTDOWNS

Component Group: Diesel Engine

Special Conditions: Whichever frequency point comes first

Item	Reference
Inspect gears for general condition. Check backlash and replace worn gears exceeding maximum clearance.	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 bearings and idler gear bushings.	Inst. Manual, Sec. 6, Part E, Section 8, Appendix III

PART B — SUGGESTED MAINTENANCE SCHEDULES (Continued)

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

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.

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.

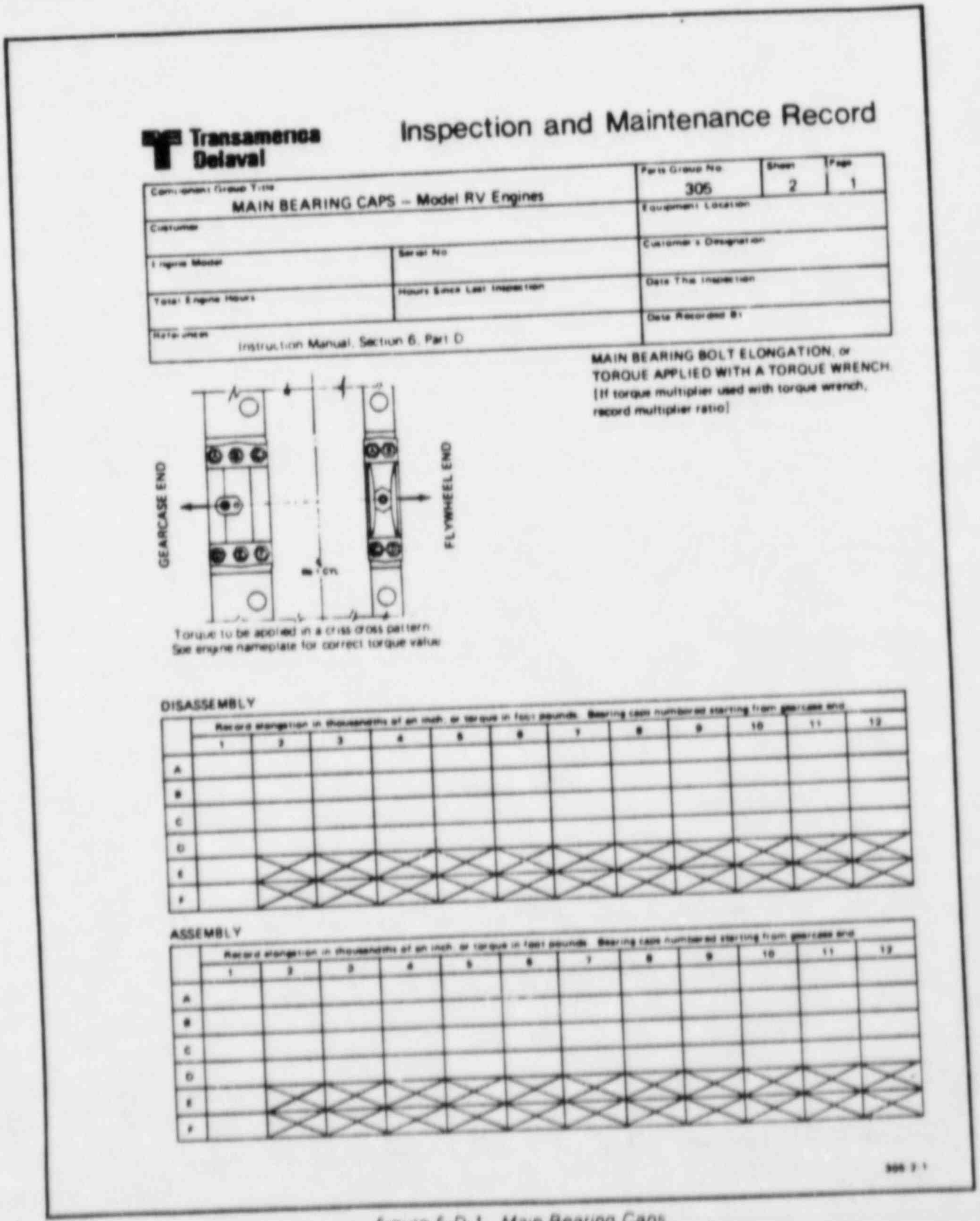
PART D —INSPECTION AND MAINTENANCE RECORDS (Continued)

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

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

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

DISASSEMBLY

Record elongation in thousandths of an inch, or torque in foot pounds. Bearing caps numbered starting from gearcase end

	1	2	3	4	5	6	7	8	9	10	11	12
A												
B												
C												
D												
E												
F												

ASSEMBLY

Record elongation in thousandths of an inch, or torque in foot pounds. Bearing caps numbered starting from gearcase end

	1	2	3	4	5	6	7	8	9	10	11	12
A												
B												
C												
D												
E												
F												

306 2 1

Figure 5-D-1. Main Bearing Caps

Transamerica Delaval

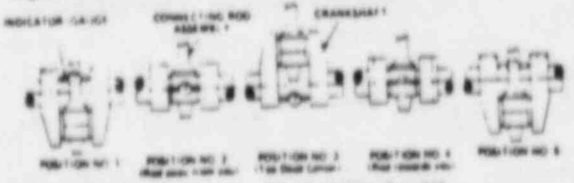
Inspection and Maintenance Record

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

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

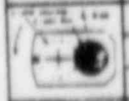
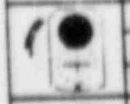
If deflection in any crank exceeds 0.003 inch, corrective action must be taken. Also, if total deflection in any two adjacent cranks exceeds 0.003 inch corrective action must be taken. Example: A +0.002 in. reading in any crank with a -0.002 in. in the next adjacent crank equals a total of 0.004 in. deflection between these adjacent cranks. The exception will be in the case of engines with a flexible coupling between the flywheel and the connecting shaft which have deflection in excess of 0.003 in. at 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

Parts Group No: 310

Sheet: 2

Page: 1

Component Group Title: MAIN BEARING SHELLS

Equipment Location

Customer

Customer's Designation

Engine Model

Serial No

Date This Inspection

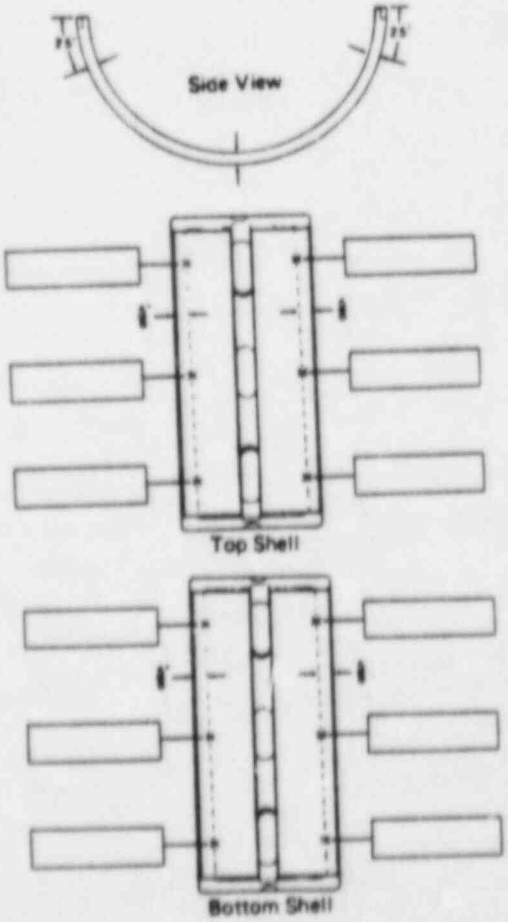
Total Engine Hours

Hours Since Last Inspection

Data Recorded By

References: Instruction Manual, Section 6, Part D

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

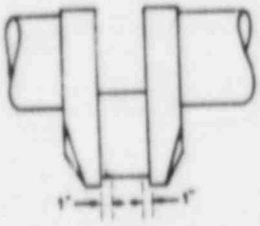
310 2 1

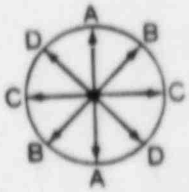
Figure 5-D-3. Main Bearing Shells

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
Reference INSTRUCTION MANUAL, SECTION 6, PART D		Date Recorded By



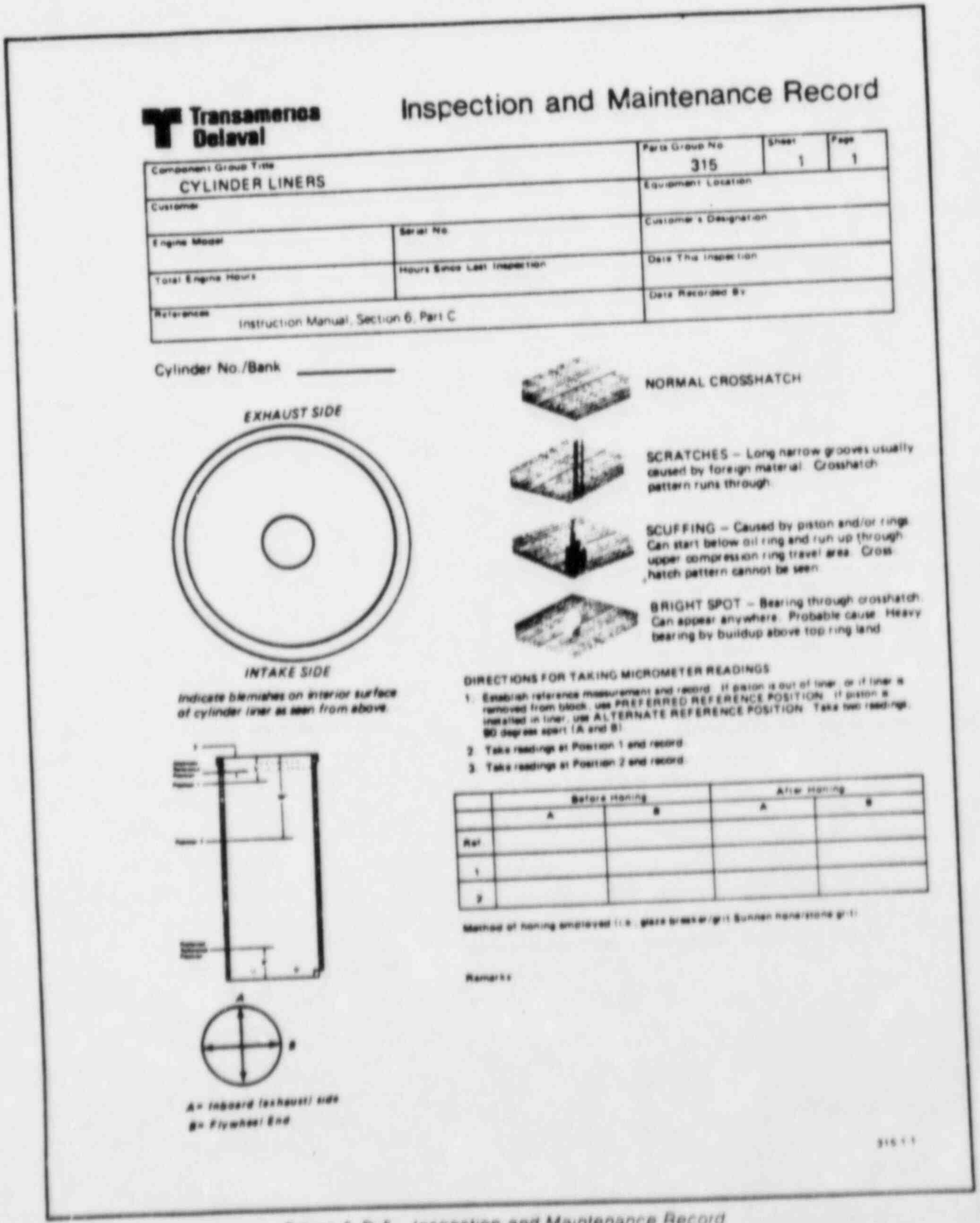


Measure inside diameter of crank journals, one inch in from web at either end (flywheel end and gearcase end). Measure four different diameters (A–A, B–B, C–C and D–D) at each location. Record measurements in spaces below.

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

Equipment Location:

Customer:

Customer's Designation:

Engine Model:

Serial No:

Date This Inspection:

Total Engine Hours:

Hours Since Last Inspection:

Data Recorded By:

References: Instruction Manual, Section 6, Part C

Cylinder No./Bank ____________

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

A= Inboard (exhaust) side

B= Flywheel End

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. Cross hatch pattern cannot be seen.

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

DIRECTIONS FOR TAKING MICROMETER READINGS

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

	Before Honing		After Honing	
	A	B	A	B
Ref				
1				
2				

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

Remarks:

315 1 1

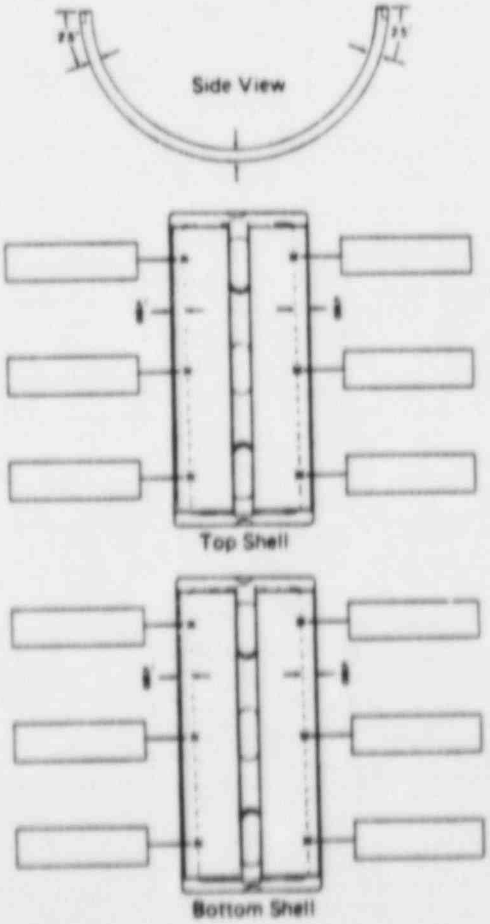
Figure 5-D-5 Inspection and Maintenance Record Cylinder Liners

Transamerica Delaval

Inspection and Maintenance Record

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

Bearing Shell Position ______________



Record manufacturer's data as it appears on bearing shell

Upper Shell
Lower Shell

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

Sketch bearing surface conditions—note any abnormalities.

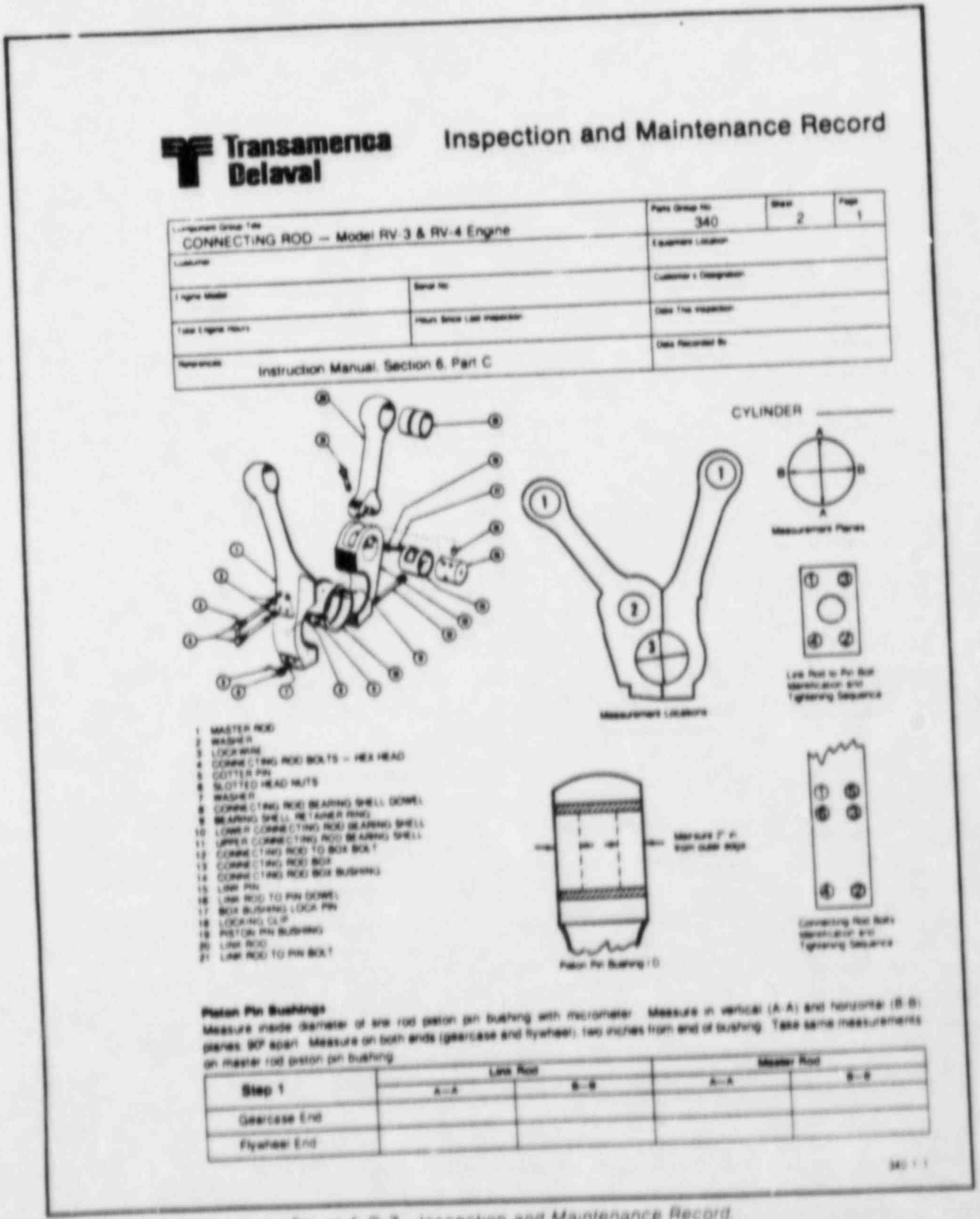
Perform non destructive dye check on all surfaces including sides and ends of both shells. Note results below.

Results
Remarks

Bearings reused? Yes No

340-1-1

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



Transamerica Delaval

Inspection and Maintenance Record

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

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

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

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

340 1 1

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

Transamerica Delaval

Inspection and Maintenance Record

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

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

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

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

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

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

Step 4

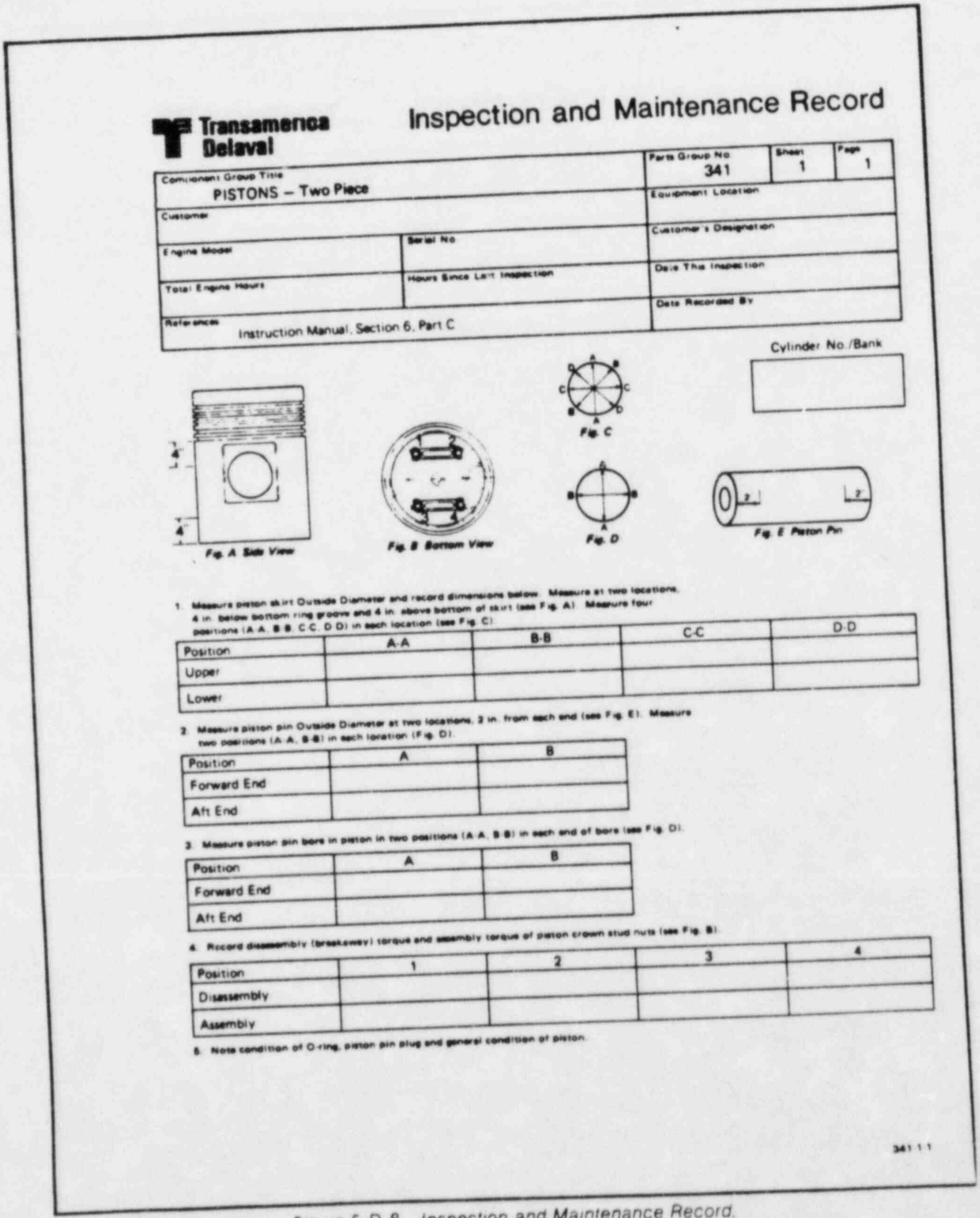
Bolt Torques
Record disassembly (breakaway) and assembly torques for connecting rod and link rod bolts. Identify bolts by number (see illustration). Torque bolts in sequence shown, applying torque in 20% lifts until final torque is reached. Refer to Instruction Manual for correct torque values.

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

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

340 2 2

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



Transamerica Delaval

Inspection and Maintenance Record

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

Cylinder No./Bank

Fig. A Side View

Fig. B Bottom View

Fig. C

Fig. D

Fig. E Piston Pin

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

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

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

Position	A	B
Forward End		
Aft End		

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

Position	A	B
Forward End		
Aft End		

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

Position	1	2	3	4
Disassembly				
Assembly				

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

341 1 1

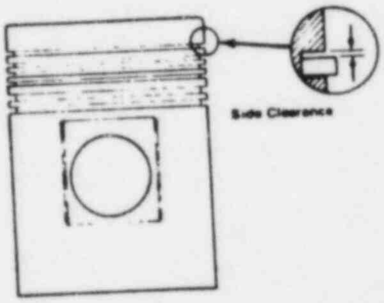
Figure 5-D-8. Inspection and Maintenance Record, Piston — Two Piece

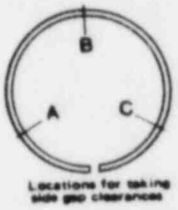
Transamerica Delaval

Inspection and Maintenance Record

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

Cylinder No./Bank





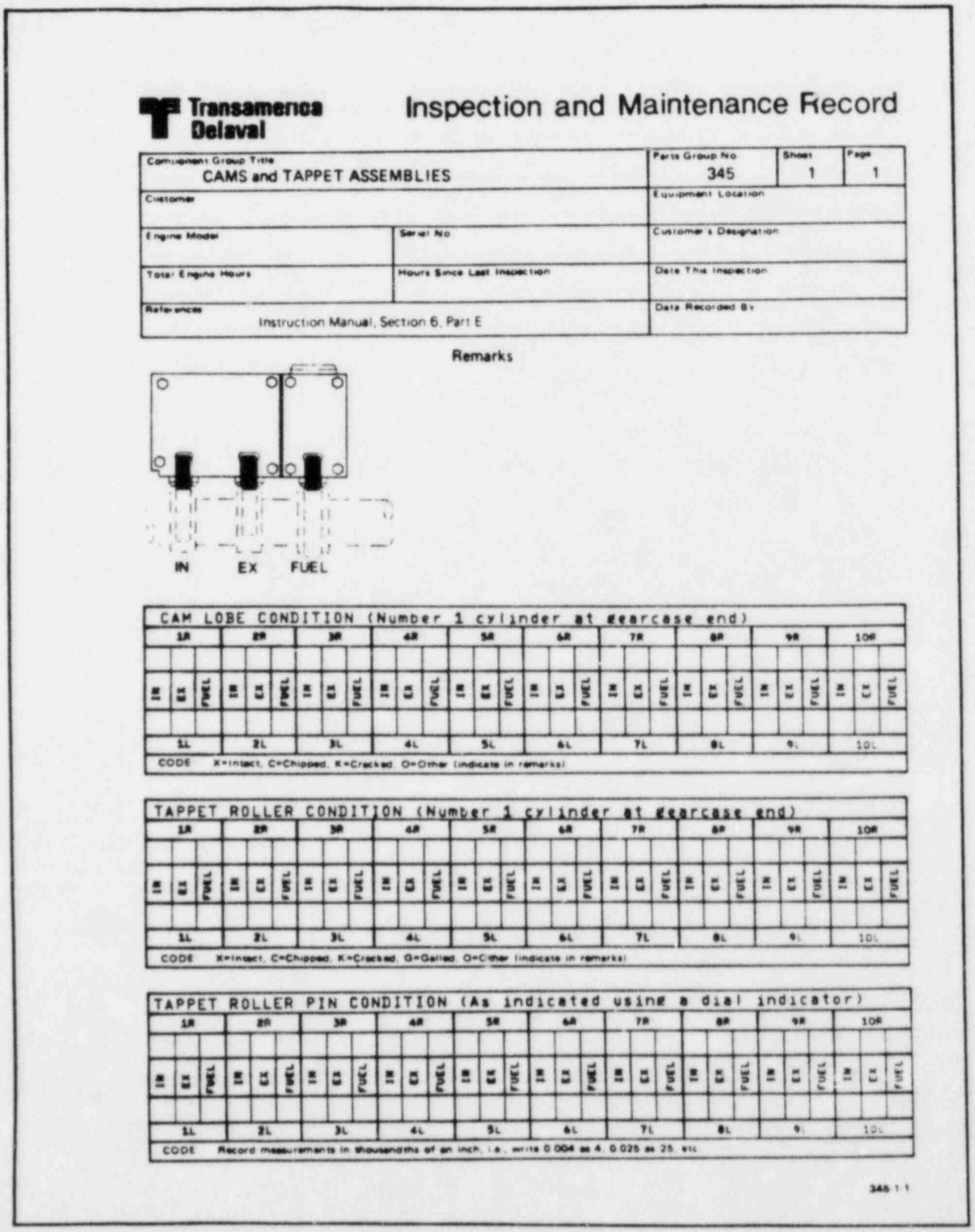
1. Measure piston ring side clearance in groove with feeler gauge. Measure each ring in three locations, 120 degrees apart. Record results below.
2. Remove rings from piston for cleaning and measurement of end gap clearance. Refer to Instruction Manual and Inspection and Maintenance Record Sheet 315-1 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



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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)

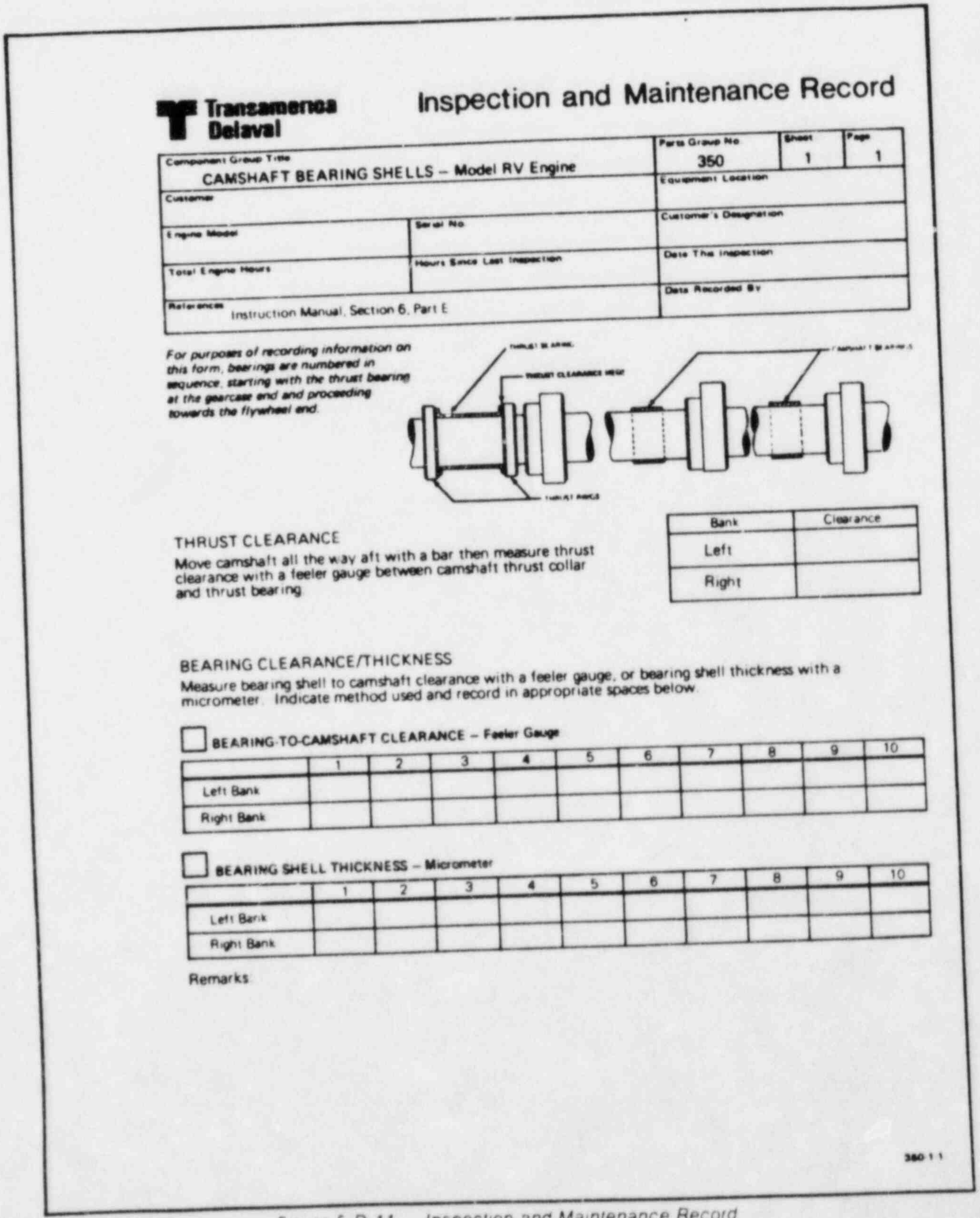
TAPPET ROLLER PIN CONDITION (As indicated using a dial indicator)

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.

345 1 1

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



Transamerica Delaval

Inspection and Maintenance Record

Component Group Title CAMSHAFT BEARING SHELLS – Model RV Engine		Parts Group No 350 · 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

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

THRUST CLEARANCE

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

Bank	Clearance
Left	
Right	

BEARING CLEARANCE/THICKNESS

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

☐ **BEARING-TO-CAMSHAFT CLEARANCE – Feeler Gauge**

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

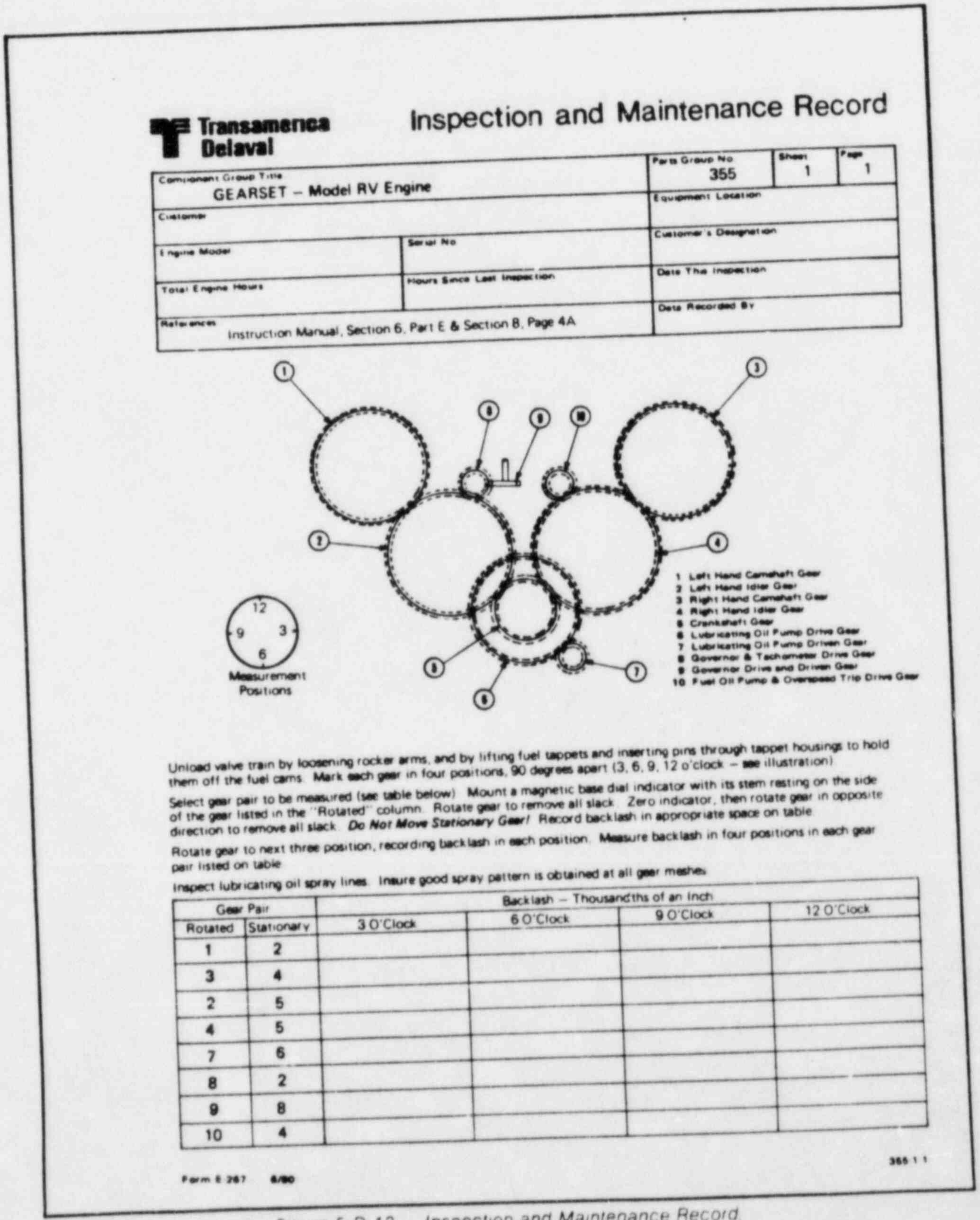
☐ **BEARING SHELL THICKNESS – Micrometer**

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

Remarks:

350-1-1

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



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Inspection and Maintenance Record

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

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

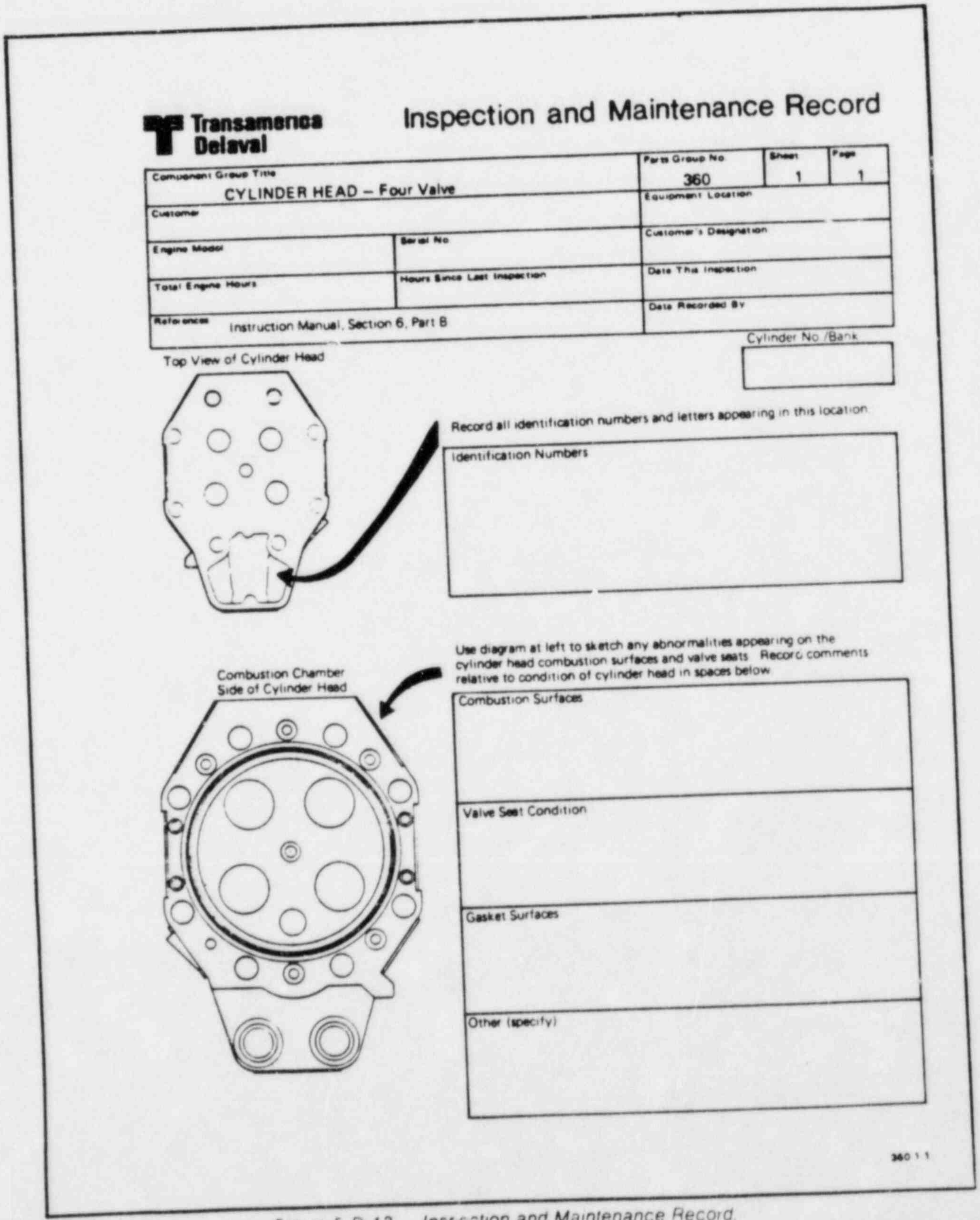
Inspect lubricating oil spray lines. Insure good spray pattern is obtained at all gear meshes

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

355 1 1

Form E 287 6/80

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

Equipment Location:

Customer:

Customer's Designation:

Engine Model:

Serial No:

Date This Inspection:

Total Engine Hours:

Hours Since Last Inspection:

Date Recorded By:

References: Instruction Manual, Section 6, Part B

Cylinder No /Bank:

Top View of Cylinder Head

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:

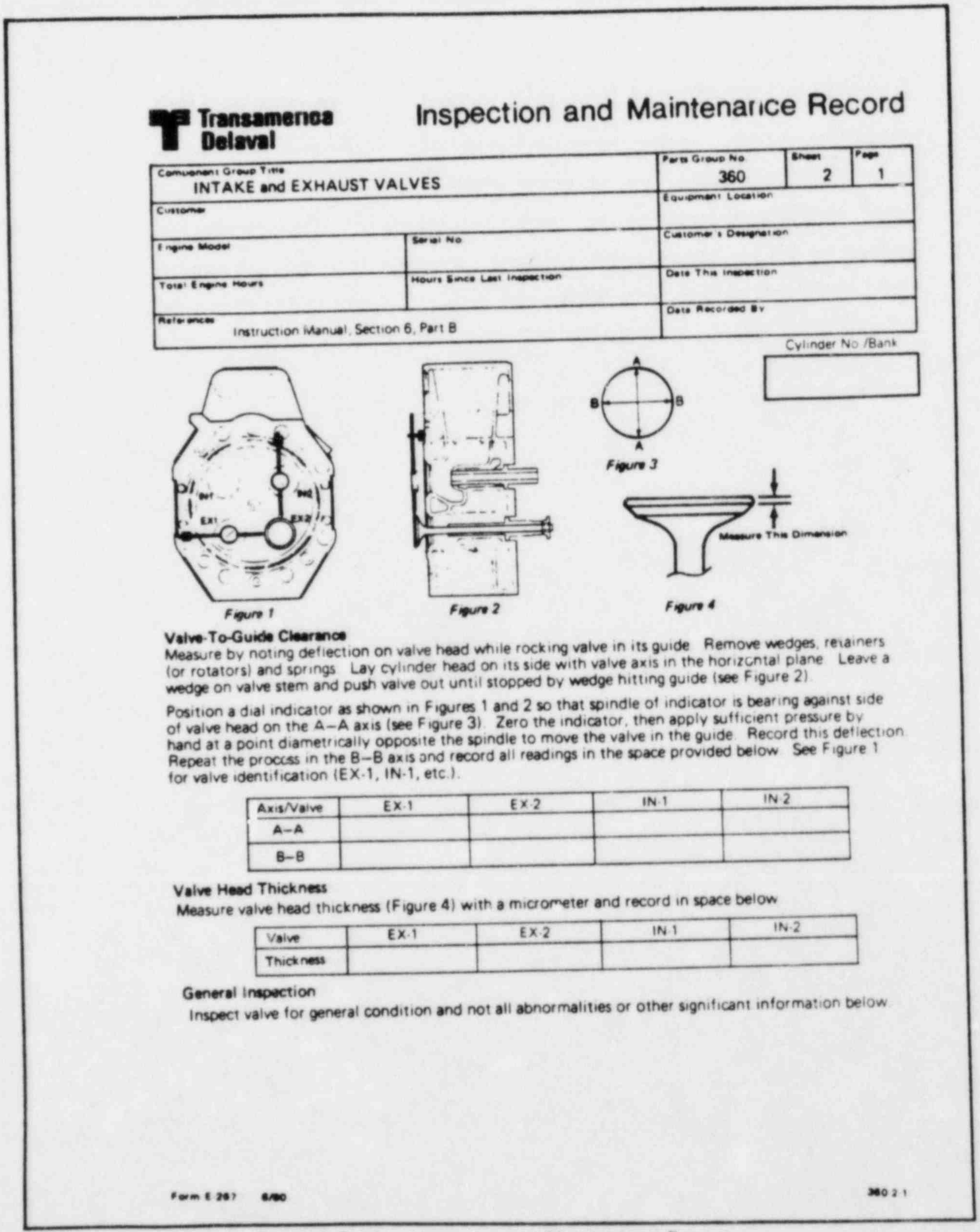
Valve Seat Condition:

Gasket Surfaces:

Other (specify):

360 1 1

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



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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		Date Recorded By

Cylinder No /Bank

Figure 1

Figure 2

Figure 3

Measure This Dimension

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 267 6/80

360 2 1

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

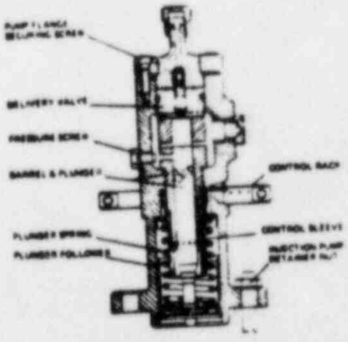
Transamerica Delaval

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 Associatnd Publications Manual, see "Bendix"	Date 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	☒	☒	Note 2	Note 3						Note 4	☒

REMARKS



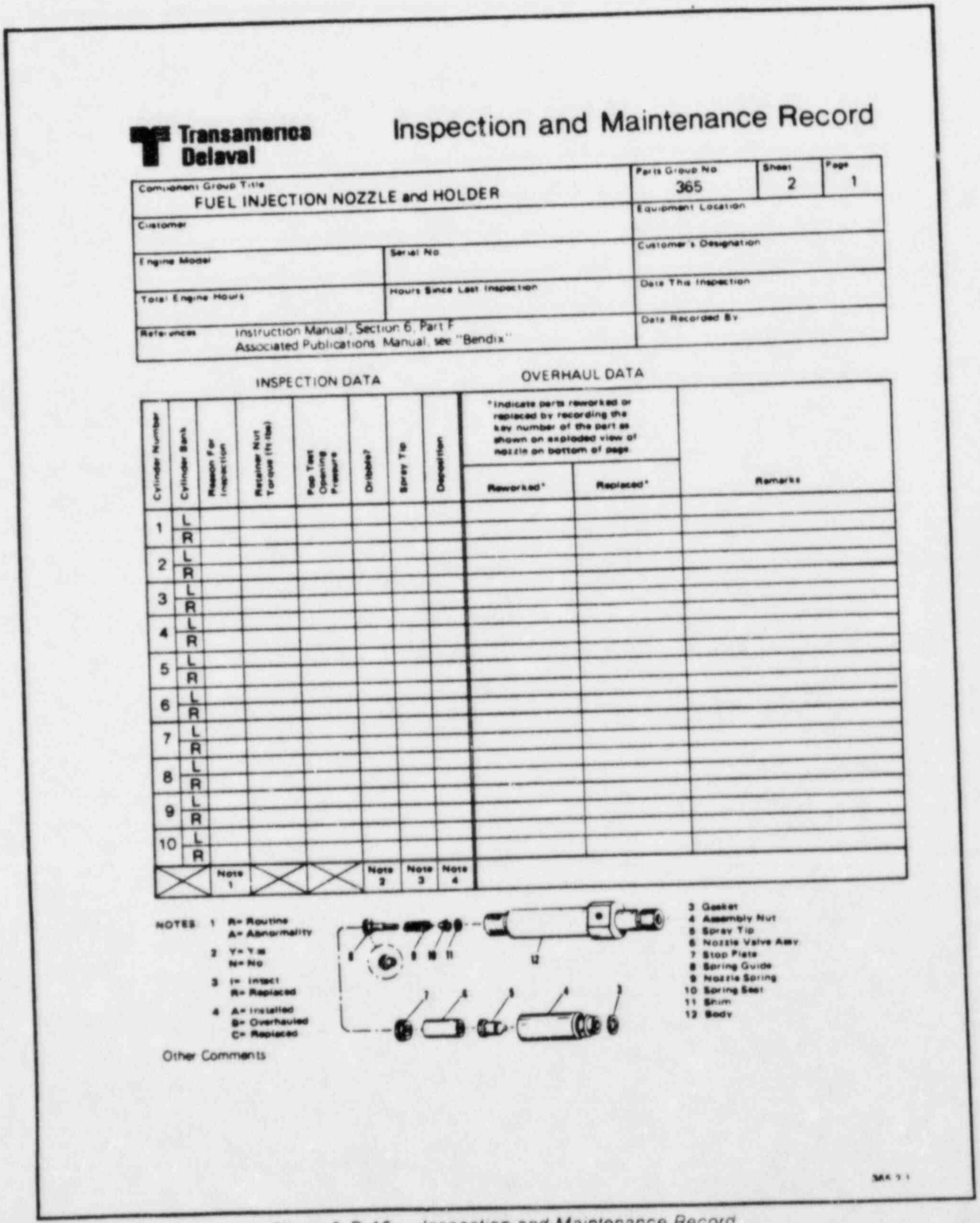
NOTES

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

365 1 1

Form E 267 6/80

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



Transamerica Delaval

Inspection and Maintenance Record

Component Group Title FUEL INJECTION NOZZLE and HOLDER		Parts Group No 365	Sheet 2
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	

Page 1

INSPECTION DATA

OVERHAUL DATA

Cylinder Number	Cylinder Bank	Reason For Inspection	Retainer Nut Torque (ft lbs)	Pop Test Opening Pressure	Dribble?	Spray Tip	Disposition	*Indicate parts reworked or replaced by recording the key number of the part as shown on exploded view of nozzle on bottom of page 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

[illegible]

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

Section 6
Overhaul & Repair

SECTION 6

OVERHAUL AND REPAIR

PART A – GENERAL

ROTATION AND CYLINDER DESIGNATION.

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

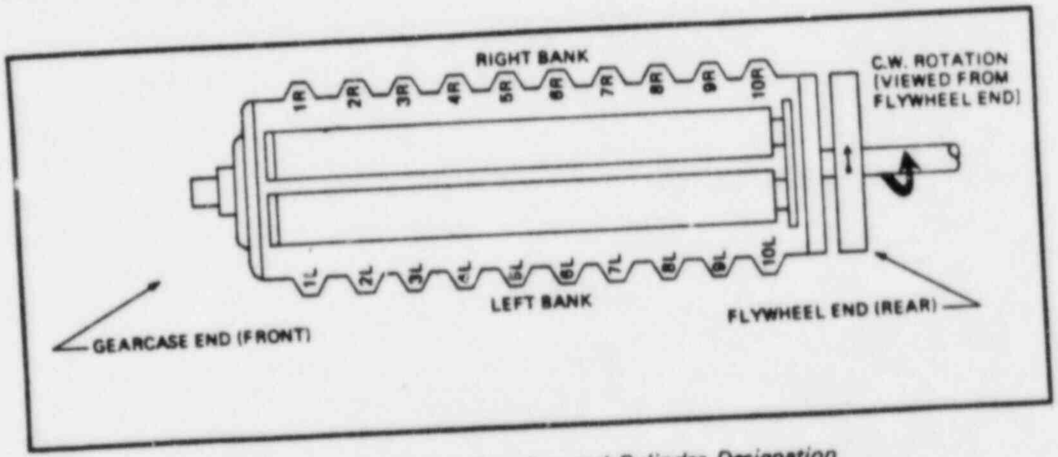


Figure 6-A-1. Engine Rotation and Cylinder Designation

ASSEMBLY OF PARTS.

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

USE OF ASSEMBLY DRAWINGS.

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

Note

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

PART A – GENERAL (Continued)

CLEANLINESS.

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

TORQUING.

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

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

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

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

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

TORQUE TABLES.

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

PART A – GENERAL (Continued)

ADHESIVES AND SEALANTS.

The Ashlano 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

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

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 (-65 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.

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.

COMPONENT WEIGHTS.

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

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

PART B – CYLINDER HEADS AND VALVES

CYLINDER HEAD REMOVAL.

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

a. Drain jacket water from engine.

b. Remove cylinder head cover.

c. Remove air jumpers.

d. Disconnect exhaust and intake air manifolds.

e. Disconnect fuel injection lines and nozzle drain fittings.

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

g. Remove fuel injection nozzles and holder assemblies.

h. Remove cylinder head sub-cover.

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

j. Remove cylinder head stud nuts and washers.

Figure 6-B-1. Cylinder Head Lifting Fixture

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

INSPECTION.

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

PART B – CYLINDER HEADS AND VALVES (Continued)

VALVES.

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

VALVE SPRING REPLACEMENT (Cylinder Head Not Removed).

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

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.

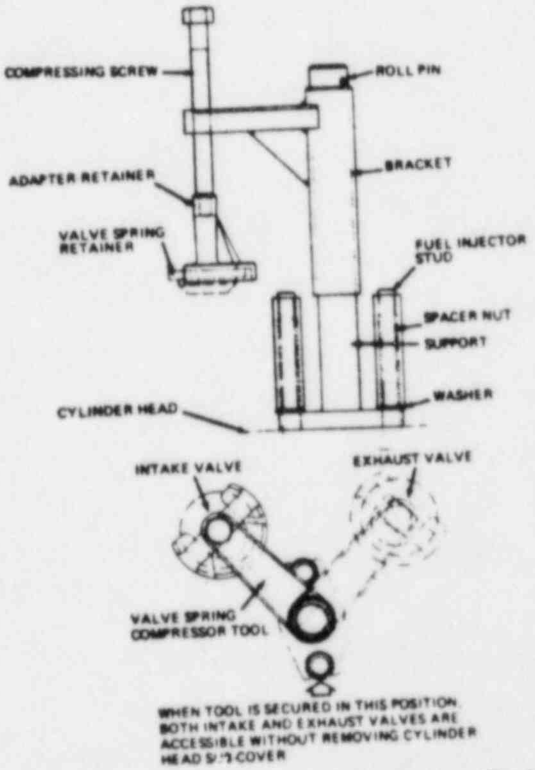


Figure 6-B-2. Valve Spring Compressor Tool

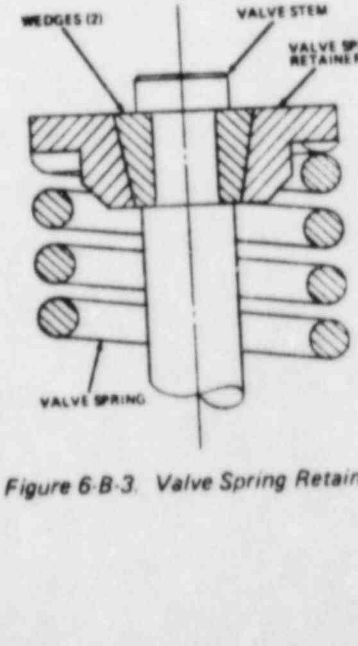


Figure 6-B-3. Valve Spring Retainer

PART B – CYLINDER HEADS AND VALVES (Continued)

VALVE INSPECTION AND RECONDITIONING.

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

CYLINDER HEAD INSTALLATION.

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

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

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

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

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

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

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.

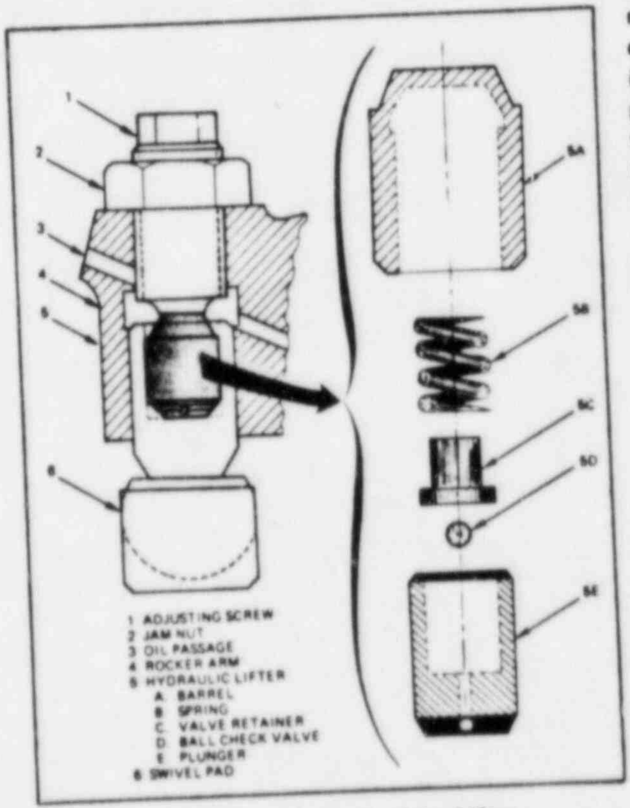


Figure 6-B-5. Hydraulic Valve Lifter

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.

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.

PART C – PISTONS AND RODS

GENERAL.

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

WARNING

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

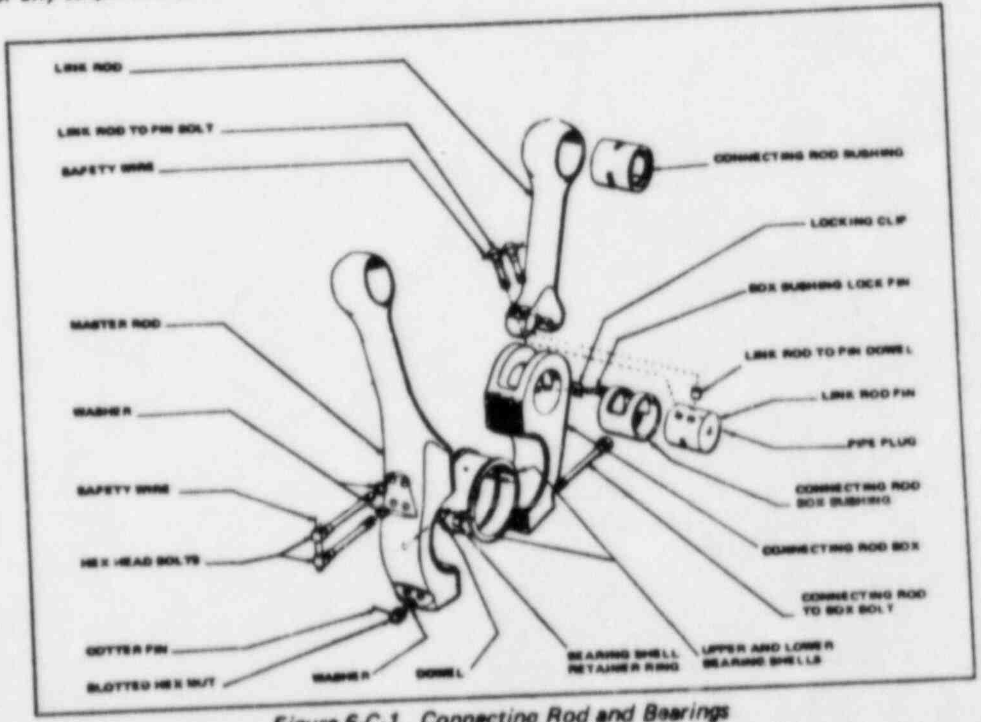


Figure 6-C-1. Connecting Rod and Bearings

PARTS LISTS.

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

a. 340 Group Parts List, Connecting Rods.

b. 341 Group Parts List, Pistons.

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

d. 590 Group Parts List, Special Tools

PART C – PISTONS AND RODS (Continued)

SPECIAL TOOLS.

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

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

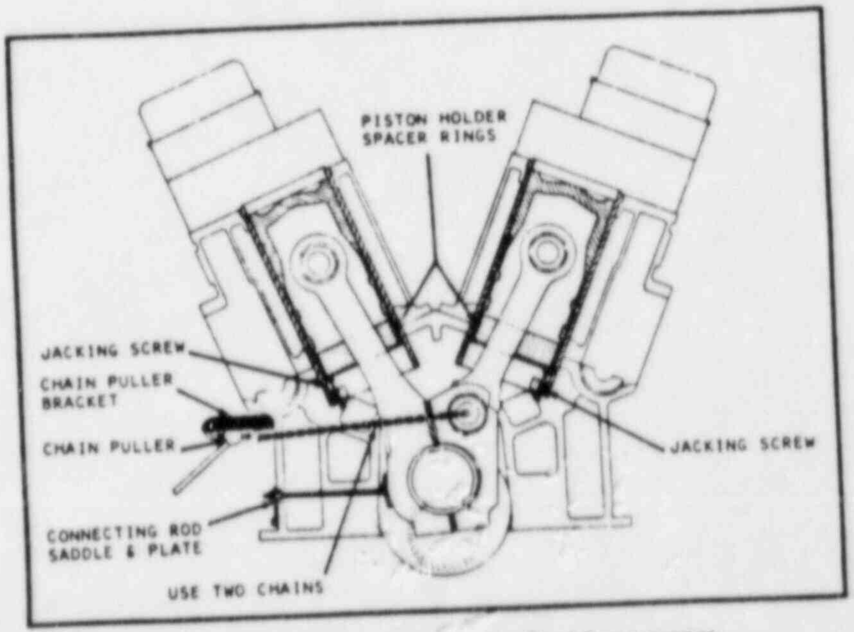


Figure 6-C-2. Bearing Replacement Tool Arrangement

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

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

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

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

PART C – PISTONS AND RODS (Continued)

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

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

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

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

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

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

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

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

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

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

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

n. Remove all tools and blocking from engine.

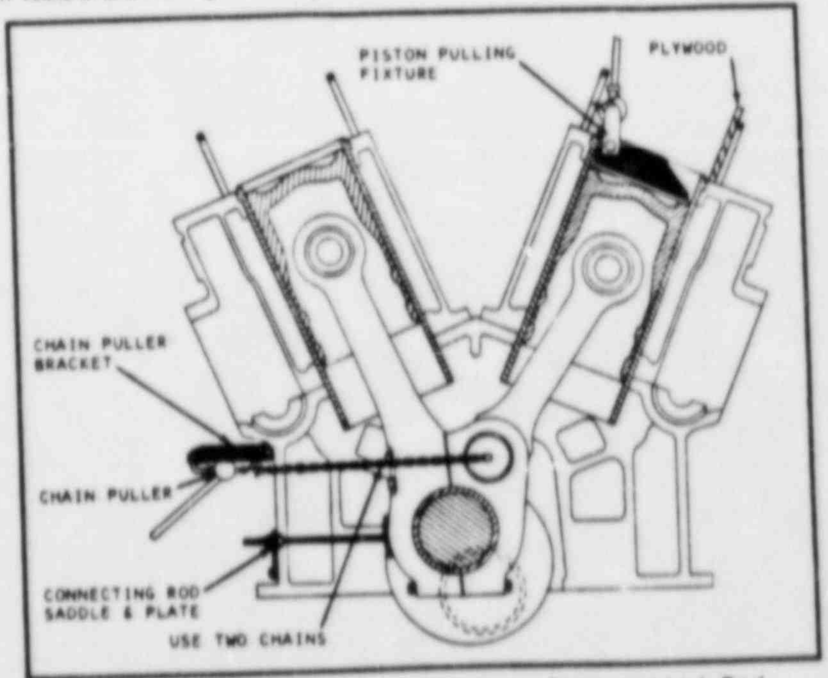


Figure 6-C-3. Tools Installed For Removing Piston and Link Rod

PART C – PISTONS AND RODS (Continued)

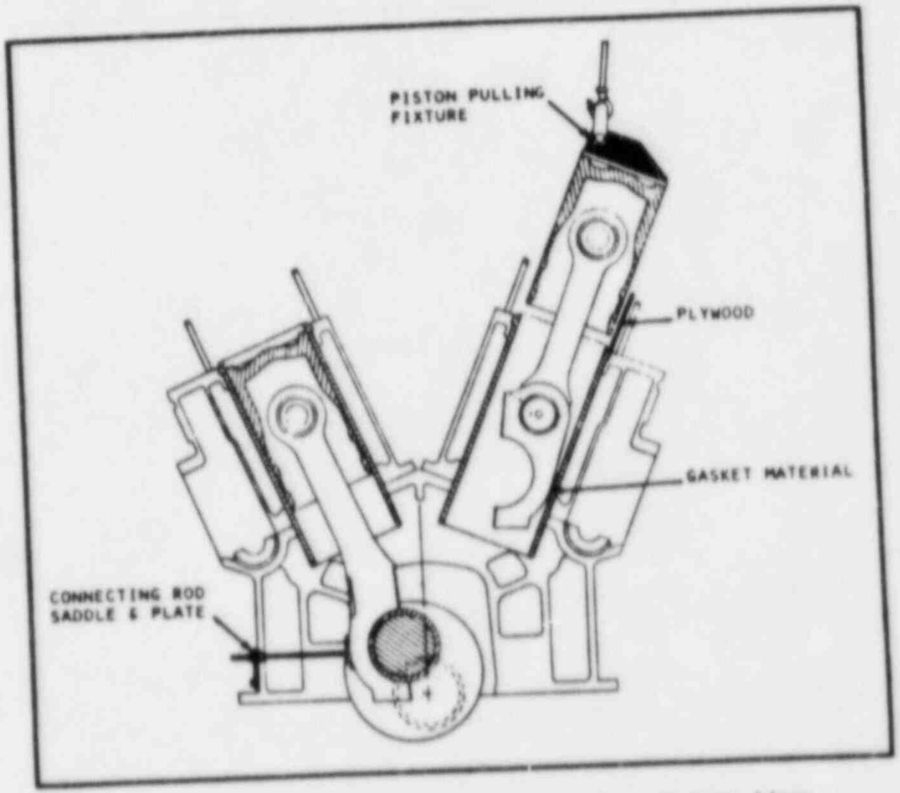


Figure 6-C-4. Lifting Piston and Link Rod From Cylinder Liner

LINK ROD AND PISTON REMOVAL.

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

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

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

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

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

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

PART C – PISTONS AND RODS (Continued)

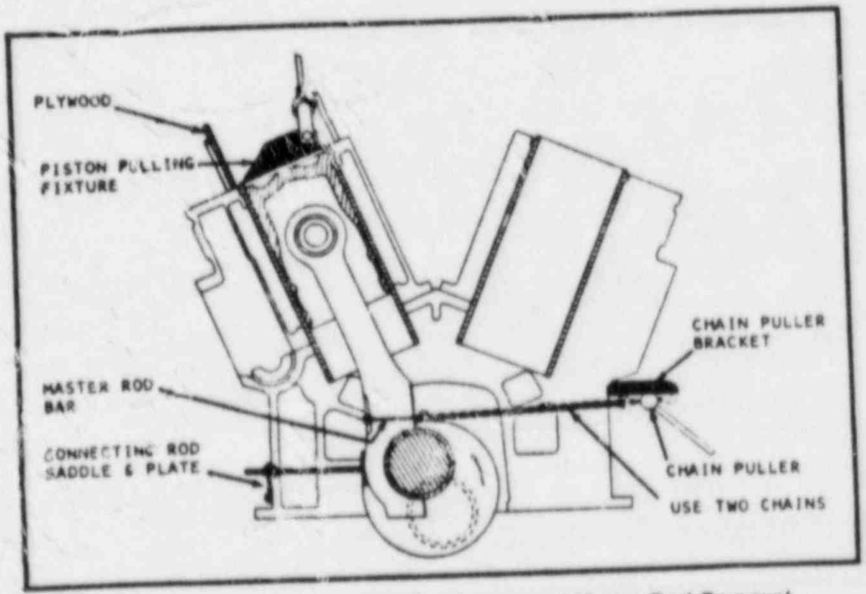


Figure 6-C-5. Tools Installed For Piston and Master Rod Removal

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

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

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

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

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

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

PART C – PISTONS AND RODS (Continued)

PISTON AND MASTER ROD REMOVAL (Link Rod Removed).

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

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

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

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

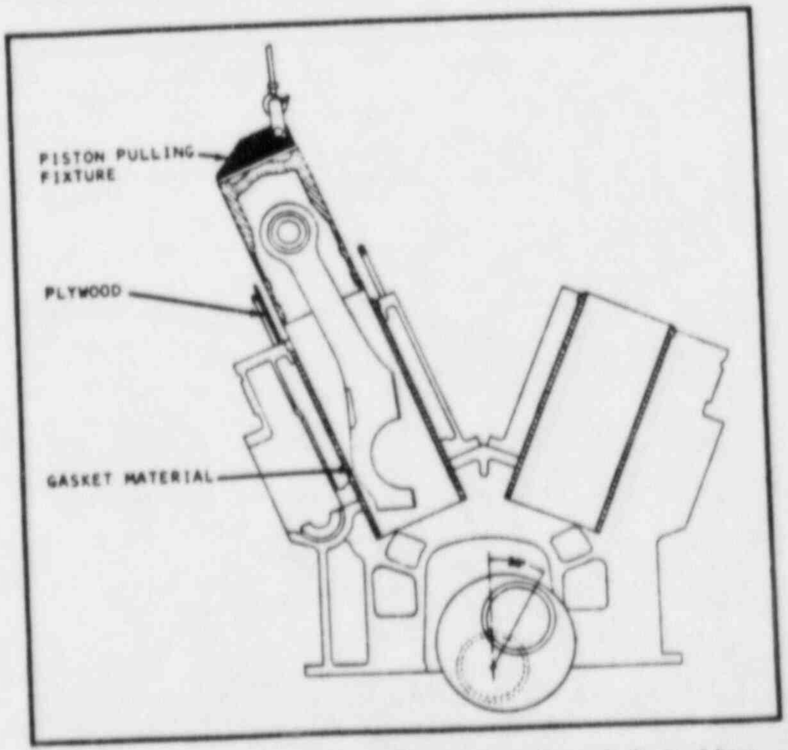


Figure 6-C-6. Lifting Master Rod and Piston From Cylinder Liner

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

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

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

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

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

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PART C – PISTONS AND RODS (Continued)

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

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

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

REMOVAL OF PISTON FROM ROD.

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

REMOVAL OF A SEIZED STUD.

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

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

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

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

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

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

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

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

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

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

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

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

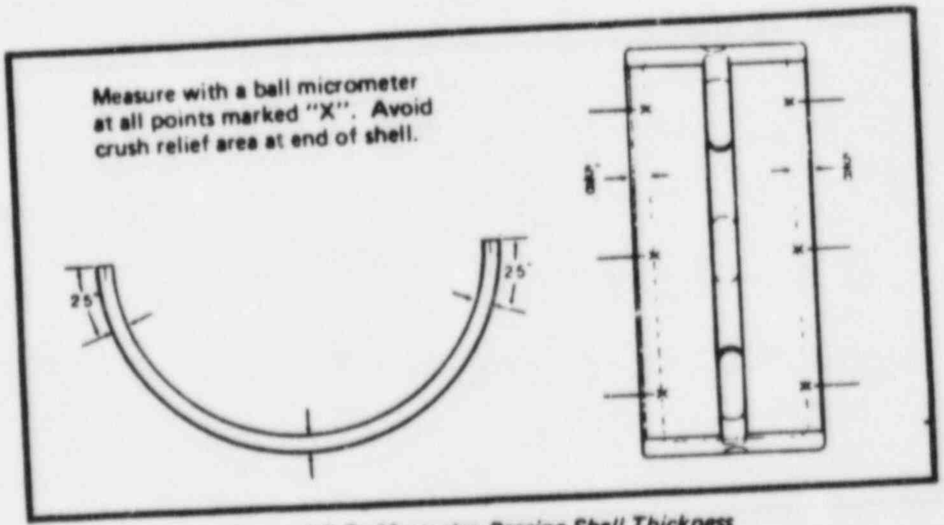
l. Reassemble the link rod and connecting rod box and place the piston and connecting rod assembly in the engine in the normal manner. Use new locking devices when assembling the link rod to the link pin.

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.



Measure with a ball micrometer at all points marked "X". Avoid crush relief area at end of shell.

Figure 6-C-7. Measuring Bearing Shell Thickness

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

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

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

CHECKING PISTON PIN CLEARANCES.

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

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

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

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

PART C – PISTONS AND RODS (Continued)

INSPECTING CONNECTING ROD.

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

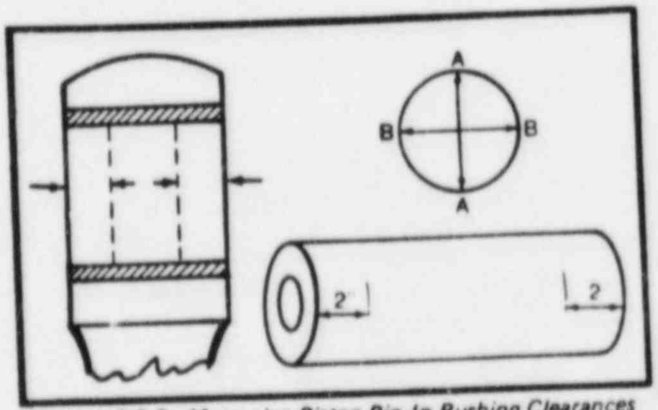


Figure 6-C-8. Measuring Piston Pin In Bushing Clearances

CHECKING PISTON RING SIDE CLEARANCES.

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

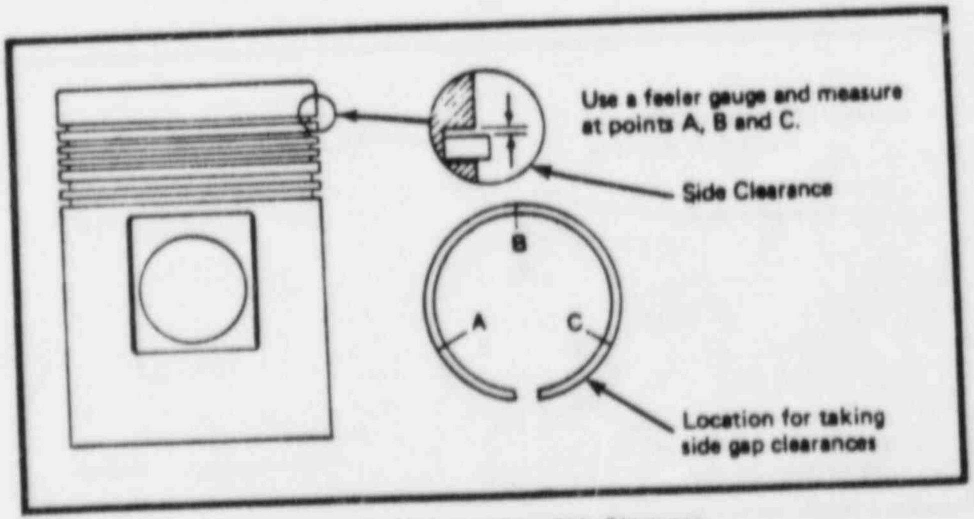


Figure 6-C-9. Piston Ring Side Clearance

PISTON RING REPLACEMENT.

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

PART C – PISTONS AND RODS (Continued)

CLEANING PISTON RINGS.

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

CHECKING PISTON RING GAP CLEARANCES.

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

INSPECTING PISTON.

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

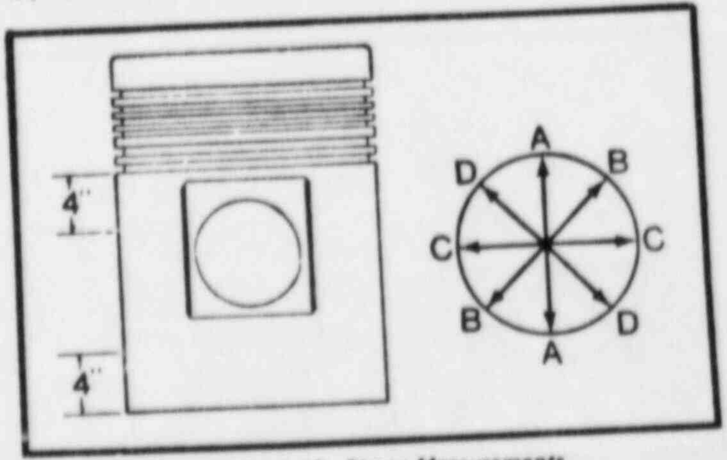


Figure 6-C-10. Piston Measurements

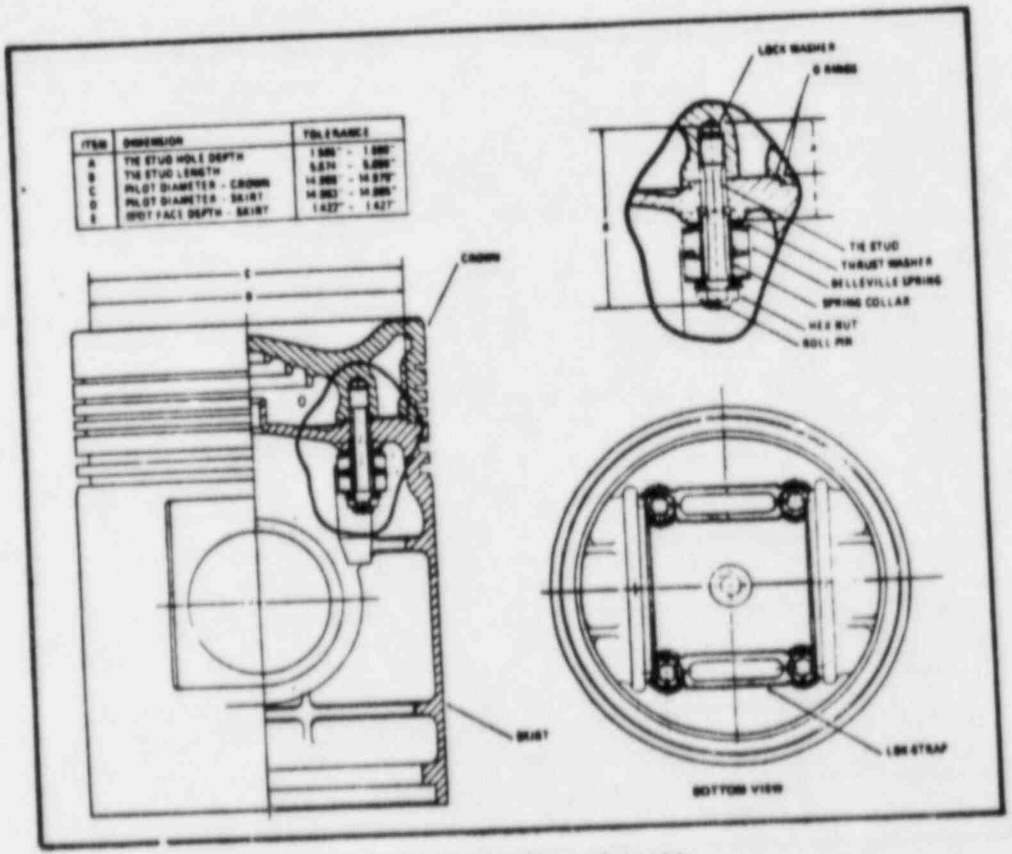
DISASSEMBLING PISTON (See Figure 6-C-11).

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

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

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

PART C – PISTONS AND RODS (Continued)



ITEM	DIMENSION	TOLERANCE
A	TIE STUD HOLE DEPTH	1.5[illegible]" - 1.[illegible]"
B	TIE STUD LENGTH	5.574 - 5.[illegible]"
C	PILOT DIAMETER - CROWN	14.[illegible]" - 14.879"
D	PILOT DIAMETER - SKIRT	14.863 - 14.[illegible]"
E	SPOT FACE DEPTH - SKIRT	1.422" - 1.427"

Figure 6-C-11. Piston Assembly

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

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

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

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

ASSEMBLING PISTON.

Assemble the piston as follows.

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

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

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

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PART C – PISTONS AND RODS (Continued)

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

REPLACING PISTON PIN BUSHING.

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

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

PART C – PISTONS AND RODS (Continued)

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

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

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

WARNING

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

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

REPLACEMENT OF LINK PIN BUSHING.

If the link bushing requires replacement, proceed as follows.

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

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

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

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

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

WARNING

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

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

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

PART C – PISTONS AND RODS (Continued)

ASSEMBLY OF PISTONS TO RODS.

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

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

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

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

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

CAUTION

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

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

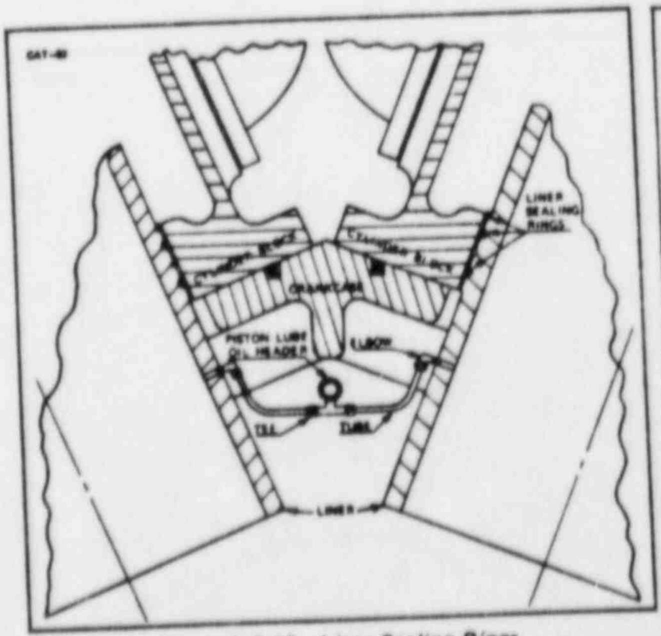


Figure 6-C-12. Liner Sealing Rings

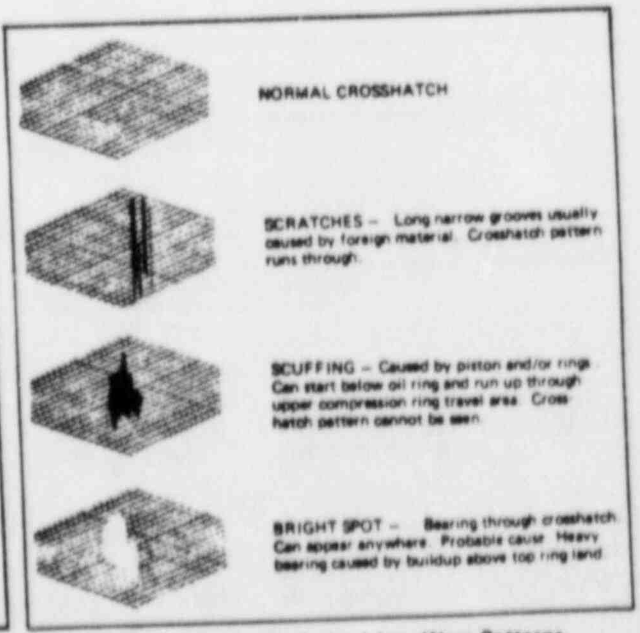


Figure 6-C-13. Cylinder Liner Wear Patterns

PART C – PISTONS AND RODS (Continued)

INSPECTING CYLINDER LINERS.

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

LINER DEGLAZING PROCEDURE.

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

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

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

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

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

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

Note

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

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

PART C – PISTONS AND RODS (Continued)

REMOVING CYLINDER LINER.

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

INSTALLING CYLINDER LINER.

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

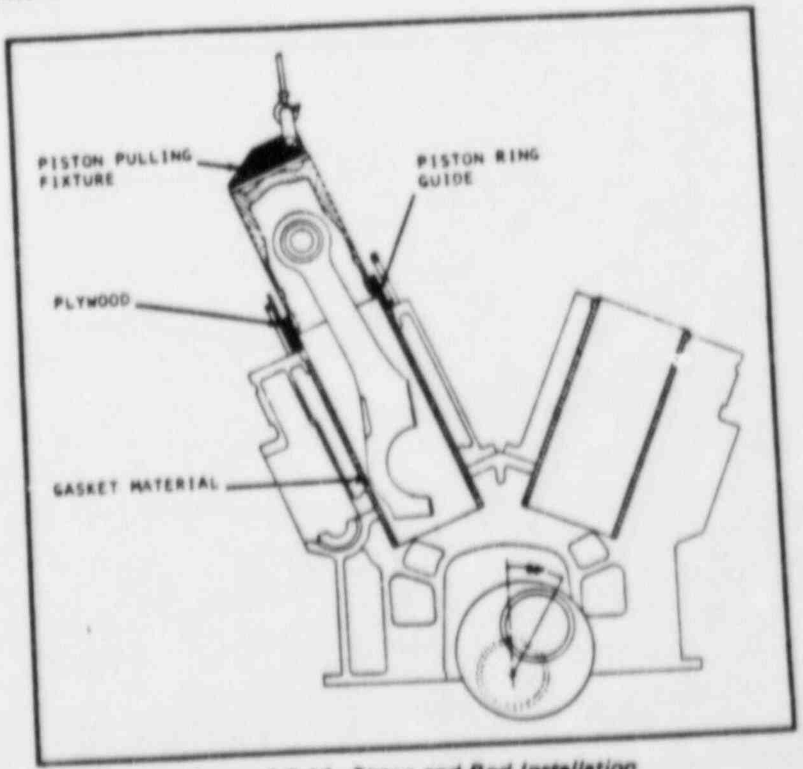


Figure 6-C-14. Piston and Rod Installation

INSTALLATION OF PISTON AND MASTER ROD.

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

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

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

PART C – PISTONS AND RODS (Continued)

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

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

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

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

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

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

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

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

WARNING

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

INSTALLING PISTON AND LINK ROD.

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

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

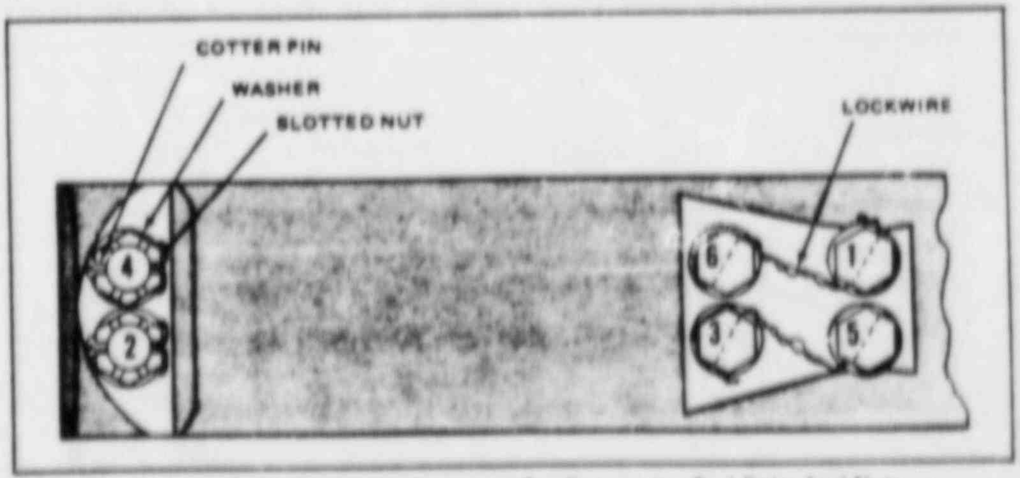


Figure 6-C-15. Tightening Sequence For Connecting Rod Bolts And Nuts

PART C – PISTONS AND RODS (Continued)

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

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

SEATING NEW RINGS IN LINER.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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.

PART D — CRANKSHAFT AND BEARINGS

MAIN BEARINGS.

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

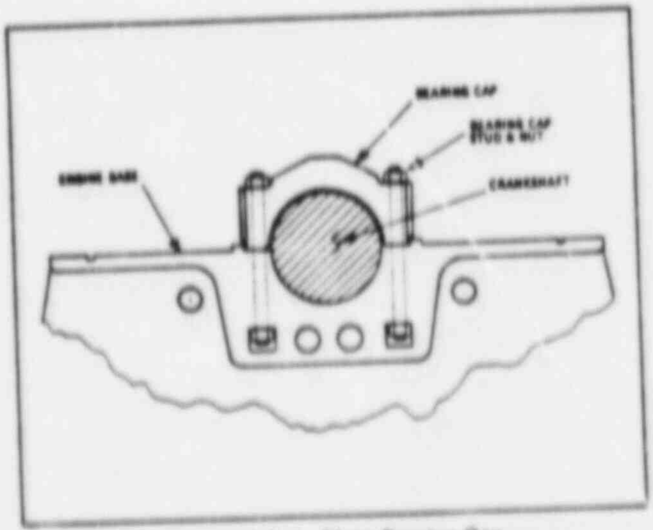


Figure 6-D-1. Main Bearing Cap

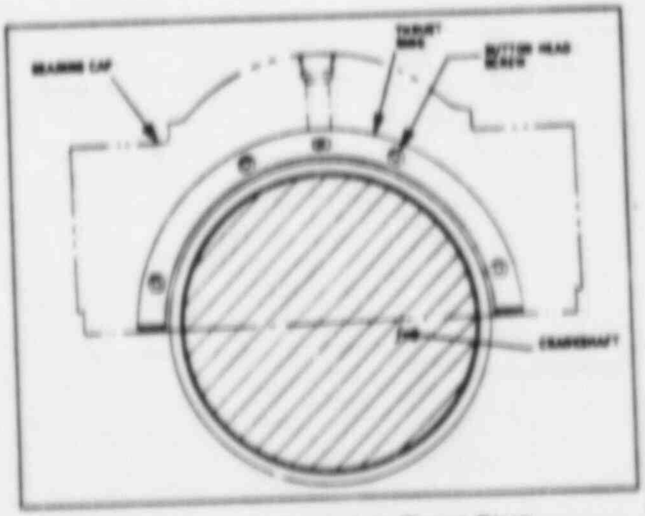


Figure 6-D-2. Crankshaft Thrust Rings

BEARING CAP REMOVAL.

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

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

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

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

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

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

PART D – CRANKSHAFT AND BEARINGS (Continued)

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

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

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

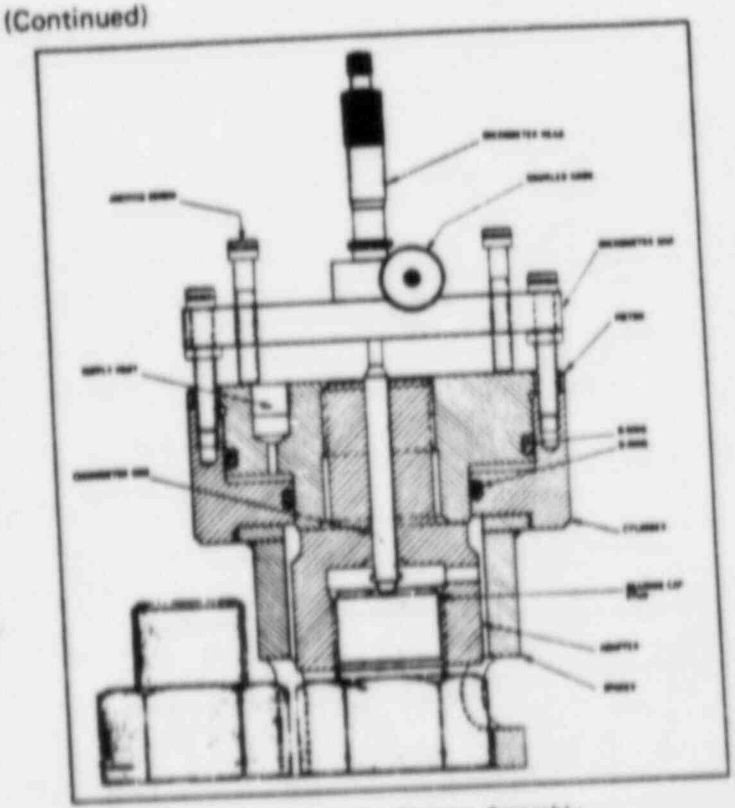


Figure 6-D-3 Pre-Stresser Assembly

BEARING SHELL REPLACEMENT.

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

BEARING CAP INSTALLATION.

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

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

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

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

PART D – CRANKSHAFT AND BEARINGS (Continued)

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

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

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

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

CAUTION

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

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

Note

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

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

WARNING

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

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

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

PART D – CRANKSHAFT AND BEARINGS (Continued)

CRANKSHAFT ALIGNMENT AND THRUST CLEARANCE.

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

CHECKING THRUST CLEARANCE.

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

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

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

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

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

Note

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

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

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

Note

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

PART D – CRANKSHAFT AND BEARINGS (Continued)

CRANKSHAFT WEB DEFLECTION.

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

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

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

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

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

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

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

DEFLECTION STANDARDS.

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

CORRECTIVE ACTION.

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

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.

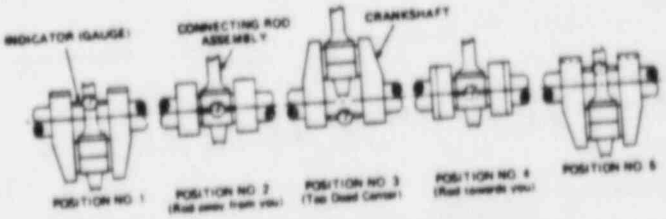
If the deflection in any crank in an engine in service exceeds 3 mils, corrective action must be taken. Also, if the total deflection value in any two adjacent cranks exceeds 3 mils, corrective action must be taken. Example, a +2 mils in any crank with a -2 mils in the next adjacent crank adds up to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

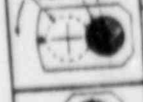
ALL INLINE ENGINES	15° AFTER BOTTOM CENTER
HV, HVA & GVB ENGINES	38° AFTER VERTICAL BOTTOM CENTER
RV ENGINES	52° AFTER VERTICAL BOTTOM CENTER

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-4. Crankshaft Alignment Record, Form D-1063

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

e. Remove idler gear and bracket assemblies.

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

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

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

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

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

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

f. Remove camshaft gear assemblies.

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

PART E – CAMS, CAMSHAFTS AND BEARINGS (Continued)

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

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

g. Remove camshaft gear.

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

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

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

INSPECTION.

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

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

b. Clean gear seat area of crankshaft.

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

ASSEMBLY.

a. Install camshaft gear.

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

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

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

b. Install crankshaft gear.

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

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

PART E – CAMS, CAMSHAFTS AND BEARINGS (Continued)

(3) Set the flywheel to the left bank 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 bears 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 gear and bracket assembly into position with a chainfall and suitable sling. Align with match-marks (if present) and mesh teeth. The camshaft bear 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.

(4) Rotate flywheel in the direction of normal engine rotation to the right bank fuel injection point. (See Engine Data Sheet in front of manual or engine nameplate).

(5) Set right bank camshaft with number one fuel injection pump timing marks matched.

(6) Lift right idler gear and bracket assembly into place and install capscrews. The camshaft gear may be moved part of a tooth to allow the three gears to mesh.

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 assemblies until shims are held tight between gear teeth. This will establish the required backlash between each gear. Tighten idler gear retaining capscrews on each idler assembly.

(3) Rotate the flywheel and check backlash clearance in at least four places around each gear. Refer to the Table of Clearances. If backlash is within tolerances, tighten all idler assembly retaining capscrew 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 camshafts 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 time by the cam key method. Failure to observe the proper camshaft timing sequence can result in an altered firing orde and an incorrectly operating engine.

a. Remove number one fuel injection pump on master rod bank.

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

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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.

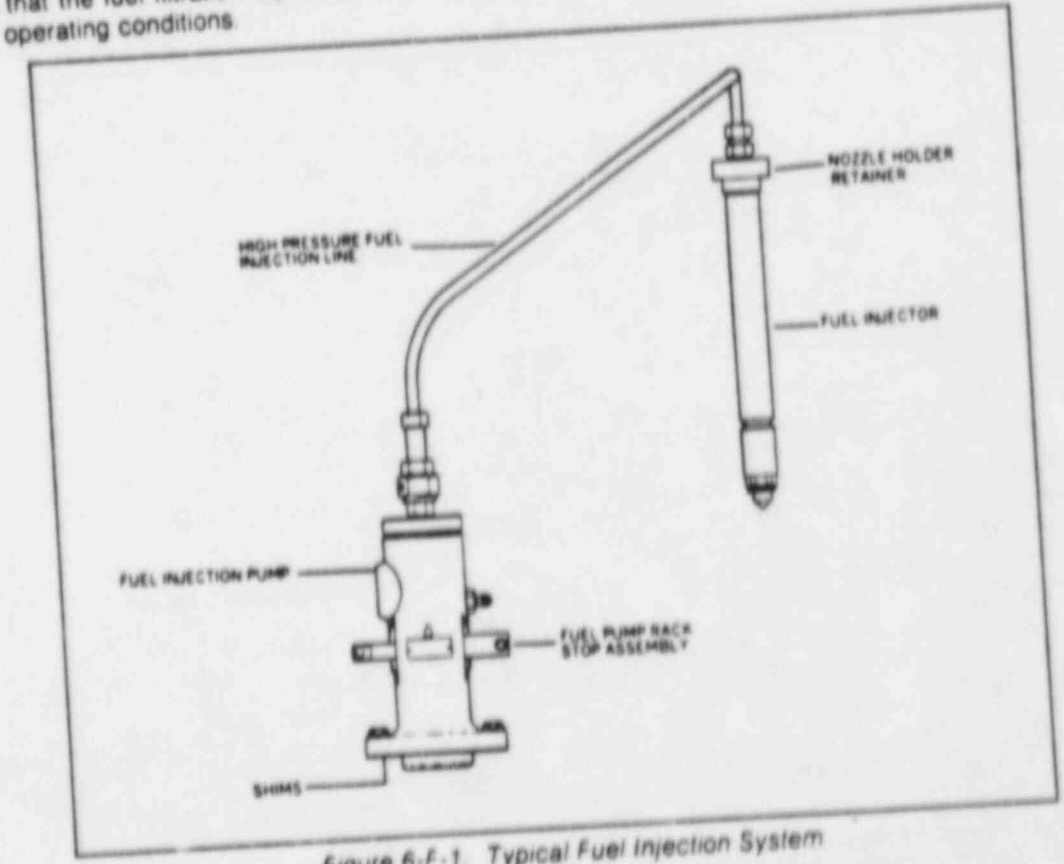


Figure 6-F-1. Typical Fuel Injection System

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 sealing 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)

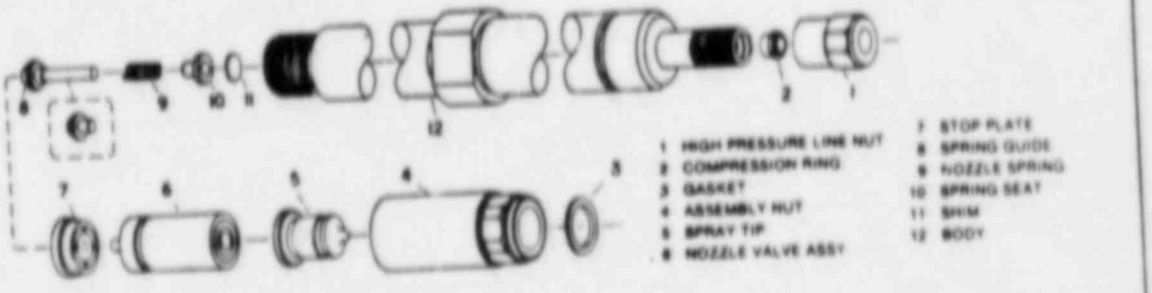


Figure 6-F-2. Fuel Injection Nozzle Assembly

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.

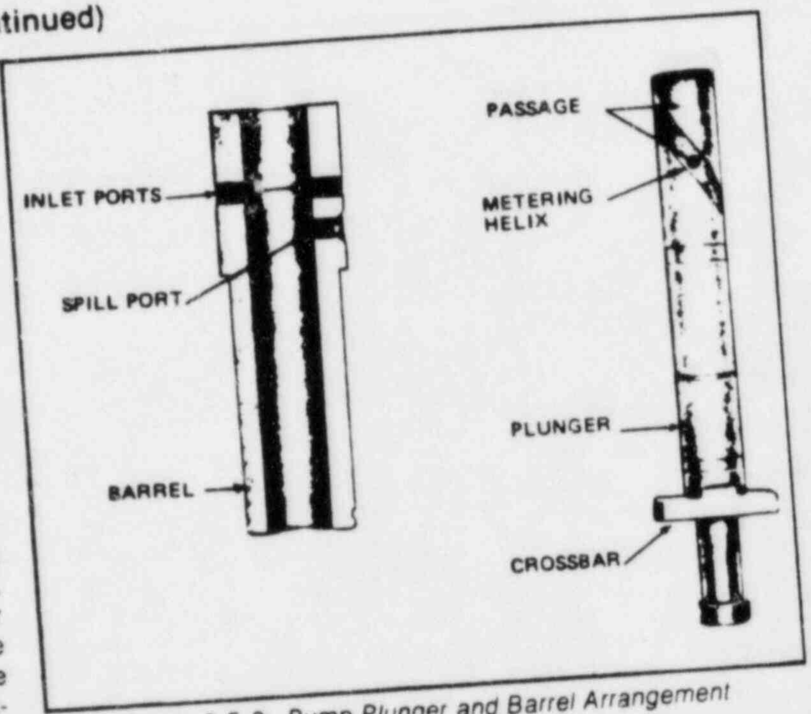


Figure 6-F-3. Pump Plunger and Barrel Arrangement

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.

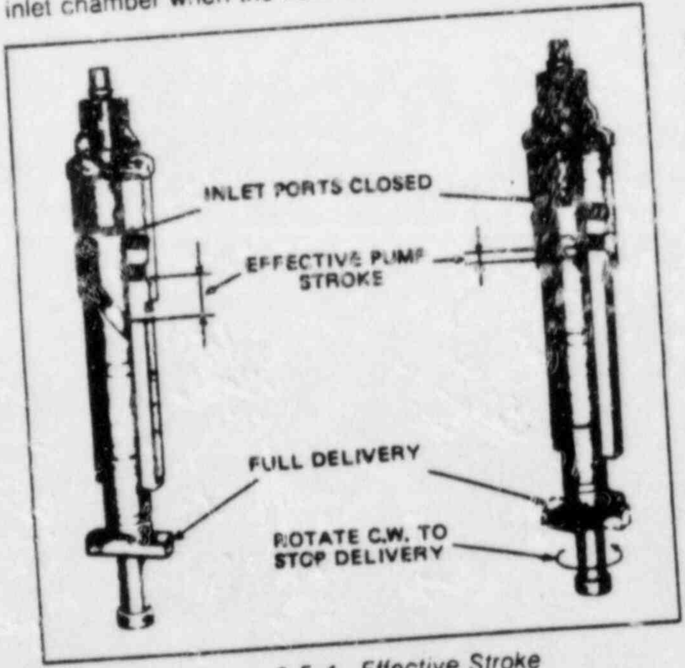


Figure 6-F-4. Effective Stroke

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.

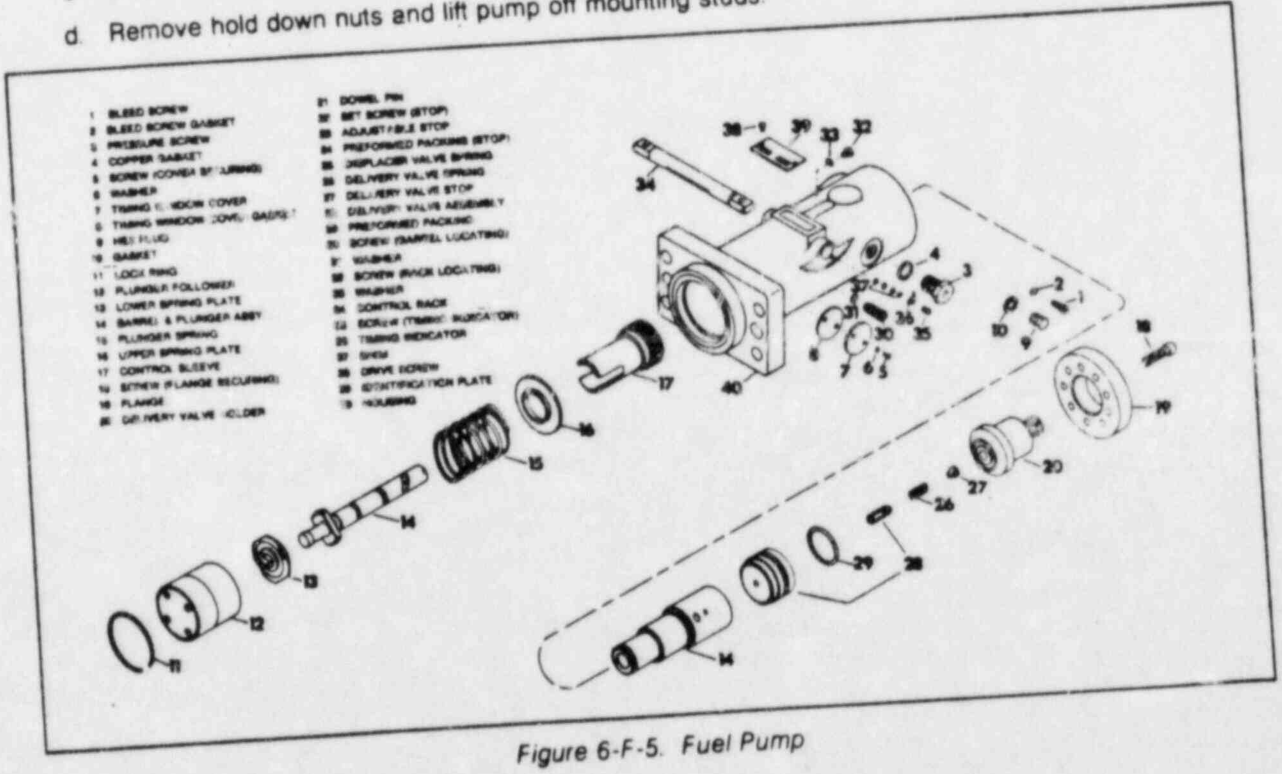


Figure 6-F-5. Fuel Pump

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)

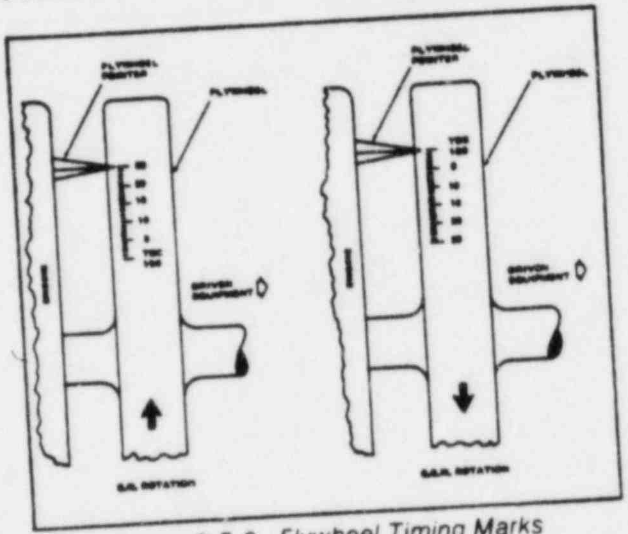


Figure 6-F-6. Flywheel Timing Marks

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.

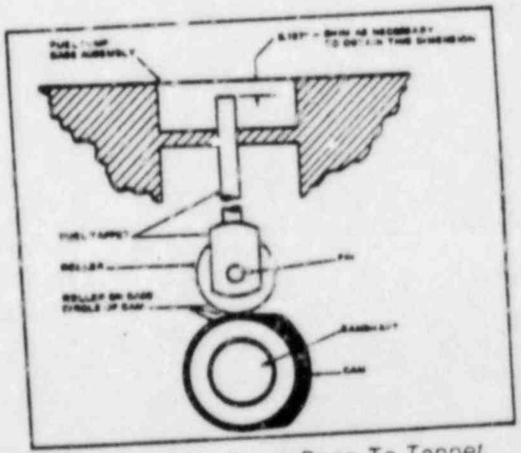


Figure 6-F-7. Pump Base To Tappet Adjustment

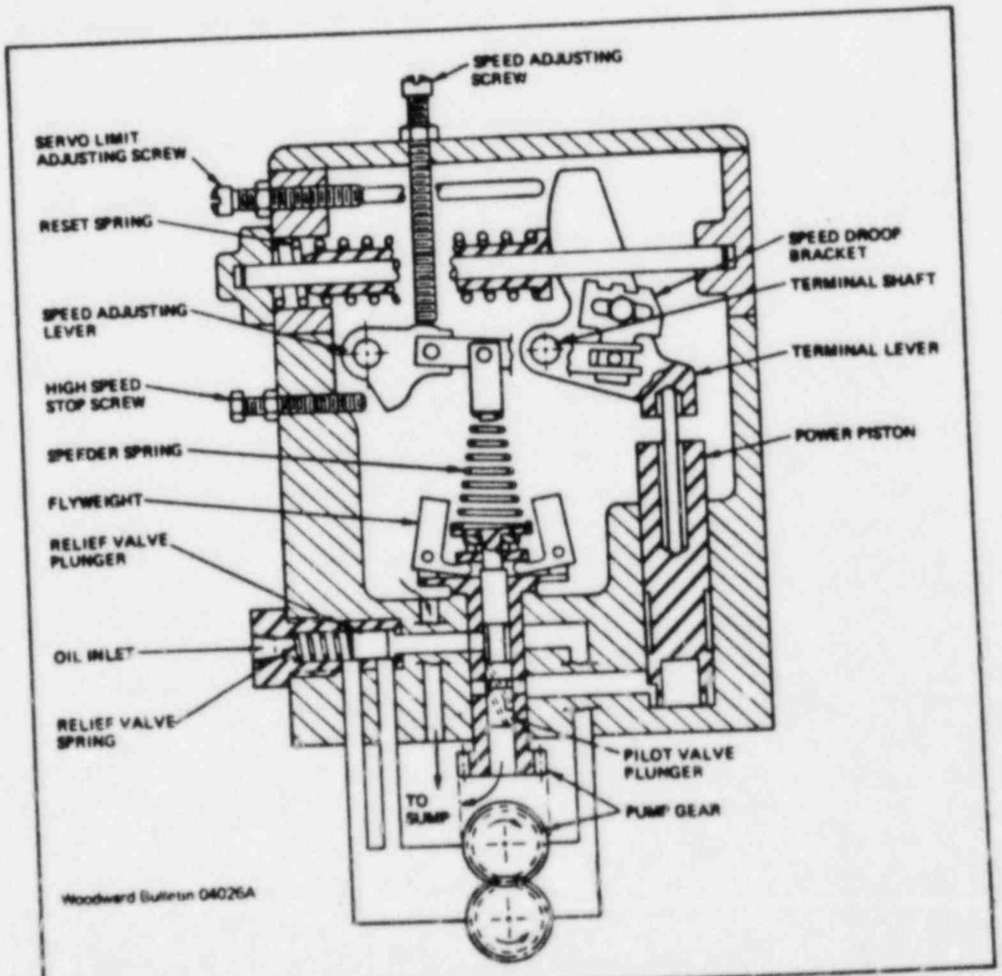
CAUTION

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.



Woodward Bulletin 04026A

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.

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.

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.

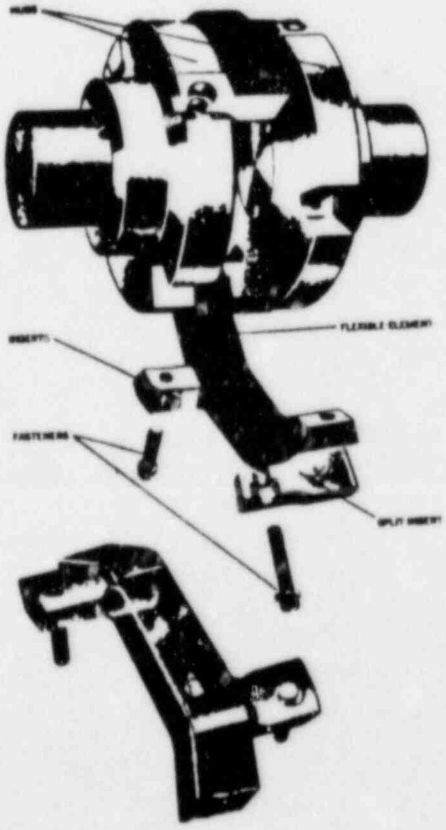


Figure 6-G-2. Governor Drive Coupling

PART G – ENGINE CONTROLS (Continued)

LOGIC BOARD TROUBLE SHOOTING.

Trouble shooting of the logic boards should be approached in a logical manner, eliminating the obvious first. The following steps will assist in the finding of faults in the system.

a. Check that there is proper supply pressure in the system, as specified on the applicable system drawings.

b. Check that all operator controls are in the correct positions for the selected mode of operation.

c. Check the board for the proper output signals. Since the system is designed to provide a predictable series of output signals, the first place to start trouble shooting is to determine if the output signals that should be present are present, and which ones should not be present when the problem occurs. Check out procedures for individual logic boards are shown on the drawing for that board. Also, check to see if the signals come on and off sharply without gradual increases or decreases in pressure unless this is called for in the check out procedures. If the increase or decrease is slow, check for leaks, pinched tubes, etc. If the proper signals are present, then the malfunction may be in one of the power devices.

d. Check for proper input signals to the logic board. Once the determination has been made that the output signals from the board are not on and off at the proper time, check the input signals to the board to make sure they are correct. Once again, return to the control schematic drawings and determine which input signals are to be on and which are supposed to be off when the problem occurs. Of equal importance is the order in which they go on and off.

e. Once the output signal conditions have been checked and found to be incorrect, and after the input signals have been checked and found to be correct, then and only then is the circuit board to be considered for trouble shooting. Make sure the problem is in the circuit board before proceeding.

CHECKING LOGIC ELEMENTS.

If a logic board is not performing properly, the logic elements should be checked for proper installation on the board before removing them. Then, if the functioning of an element is suspect, it may be removed and replaced. Testing and the repair of the elements should be in accordance with the manufacturer's instructions in the ***Associated Publications Manual***.

a. Refer to the layout diagram on the appropriate assembly drawing and check element location on the circuit board to make certain that all elements are in their proper locations.

b. Check for proper rotation of each element. Elements can be rotated 180°, providing two different positions that it can assume on the board. The rotation is selected at the time the circuit is designed and must agree with the circuit pattern layout. Each element has an "a" or a "b" located on its top cover and these letters are to be oriented as shown on the assembly drawing. Any element that is mislocated or rotated should be changed and the circuit rechecked.

PART H – ENGINE BALANCING

GENERAL.

The load on a diesel engine should be evenly divided between all cylinders. If it is not, one or more of the cylinders will be forced to carry more than their share of the load while other cylinders loaf with a resulting loss in operating economy and the possibility of experiencing one or more of the following conditions.

a. Scored pistons and liners.

b. Excessive vibration.

c. Excessive piston, valve, bearing and crankshaft wear.

d. Excessive fuel consumption.

e. Excessive lubricating oil usage.

CYLINDER BALANCE.

The balance between power cylinders on Enterprise diesel engines is obtained by having all the fuel injection pumps read the same millimeter of rack position when the governor is in a position equivalent to full load. In order to accomplish this it is essential that all fuel pumps be calibrated in accordance with the fuel pump manufacturer's specifications. The fuel pump rack levers are adjusted during factory test and the lever clamps are then doweled to the fuel rack shaft.

CAUTION

> This setting should not be changed in the field, nor should shimming ever be used between the fuel rack lever clamp and the fuel rack lever to change fuel rack settings for individual cylinders. Also, the female rod end which connects the fuel rack lever to the fuel rack should not be adjusted. When a variation in cylinder exhaust temperatures indicates on overloaded or an underloaded cylinder, this condition should not be remedied by changing the individual fuel rack settings. Rather, the real cause of the malfunction should be determined and corrected.

FUEL INJECTION EQUIPMENT.

Clean fuel is essential to the operation of a diesel engine. Injection equipment is manufactured with close working tolerances and, therefore, dirt or other impurities in the fuel can cause pumps or spray nozzles to malfunction. Small depressions in injector valve seats, some so small they are not visible to the naked eye, may be caused by small particles of dirt and will affect spray patterns in the combustion chamber. Pumps and valves must be checked and cleaned periodically. The frequency of cleaning can best be determined from experience, however, care must be taken not to wait too long before cleaning. Fuel pumps should deliver exact amounts of fuel according to the millimeter settings of their fuel pump racks. If they do not, obviously the balance of the cylinders will be affected and the problem must be corrected. It is recommended that whenever a fuel pump is disassembled for any reason, it be recalibrated in accordance with the manufacturer's specifications.

ENGINE OUT OF TUNE.

Spray nozzles are usually suspect if an engine is out of tune or smoking. There are other factors which may also contribute to these conditions. All of them should be considered when evaluating engine performance.

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.

PART I – STARTING AIR SYSTEM

GENERAL.

The engine is started by the timed admission of high pressure starting air to the power cylinders during the equivalent of the power strokes of the respective cylinders. The air is admitted at approximately top center of the power stroke, and admission continues until approximately the opening of the exhaust valves. The pressure is then relieved, thereby creating rotation of the engine comparable to the normal power stroke. As the engine accelerates on starting air, the heat of compression of the combustion air plus the starting air develops sufficient temperature to ignite the injected fuel within a few revolutions and the engine then initiates normal combustion and begins to accelerate under its own power without further aid of starting air.

AIR SUPPLY.

There are two separate, independent air supply systems, each consisting of a motor driven air compressor, a refrigerant drier and a storage tank. Each supply is available to the engine, independent of the other. The starting air supply is stored at 250 psig (17.57 kg/cm²), and the full 250 psig pressure is available to the starting air header without reduction to provide maximum acceleration for extremely fast and reliable starting.

OPERATION.

The on-engine portion of the starting air system consists of a remotely controlled, pilot operated diaphragm valve in the air supply line, two camshaft driven starting air distributors, one for each cylinder bank, an air filter for each distributor, and a pilot operated air starting valve (figure 6-I-1) in each cylinder head. When the starting air admission valve in the supply line is opened, 250 psig (17.57 kg/cm²) starting air is admitted into the starting air manifold and, therefore, to the starting air valves in the cylinder heads as well as to the starting air distributors. Individual spool valves in the distributors (one for each cylinder of the bank serviced) are engaged by air pressure and follow the profile of the starting cam attached to the end of the camshaft. The cam profile is such that at least one spool valve is always in position to emit a pilot signal to its respective starting valve in the cylinder, allowing starting air to enter the combustion chamber of that cylinder, rotating the engine. As the engine rotates, the starting air cam will cause the spool valves to emit timed and sequenced pilot air signals to the starting air valves. The starting process will continue until the signal to the starting air admission valve is terminated. The starting air distributors emit a timed pilot air signal that starts five degrees before top dead center and ends at 115 degrees after top dead center on the power stroke.

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.

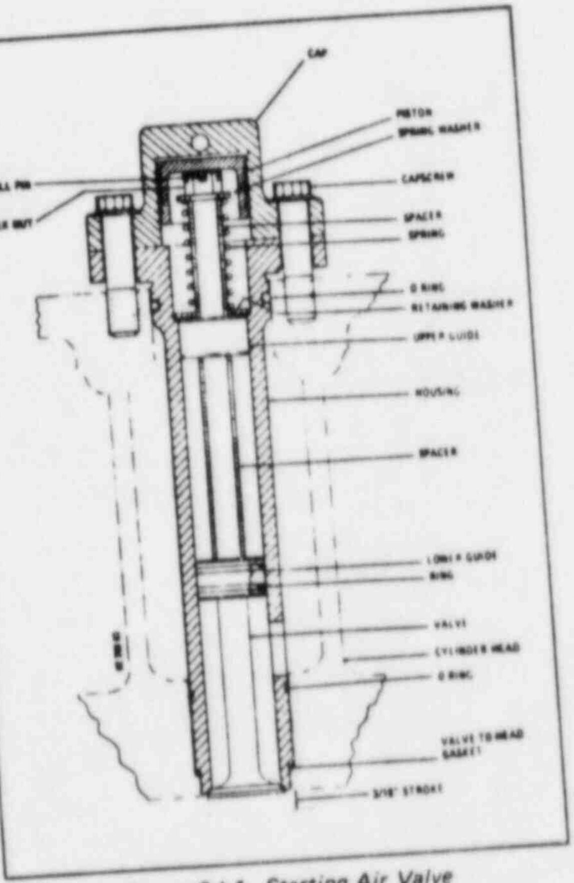


Figure 6-I-1. Starting Air Valve

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 distributors are timed at the factory when they are installed. If it should become necessary to re-time them, the following procedure may be used.

a. Bar engine over in direction of normal rotation until number one cylinder of bank being timed 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 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 gasket, cover and hex head bolts.

h. If timing of the other cylinder bank is necessary, insure that number one cylinder of that bank is on the end of its compression stroke. An error in selecting the correct position will result in a failure of that bank to crank when a starting air signal is applied to the engine.

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.

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

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.

PART K – LUBRICATING OIL SYSTEM

FILTERS AND STRAINERS.

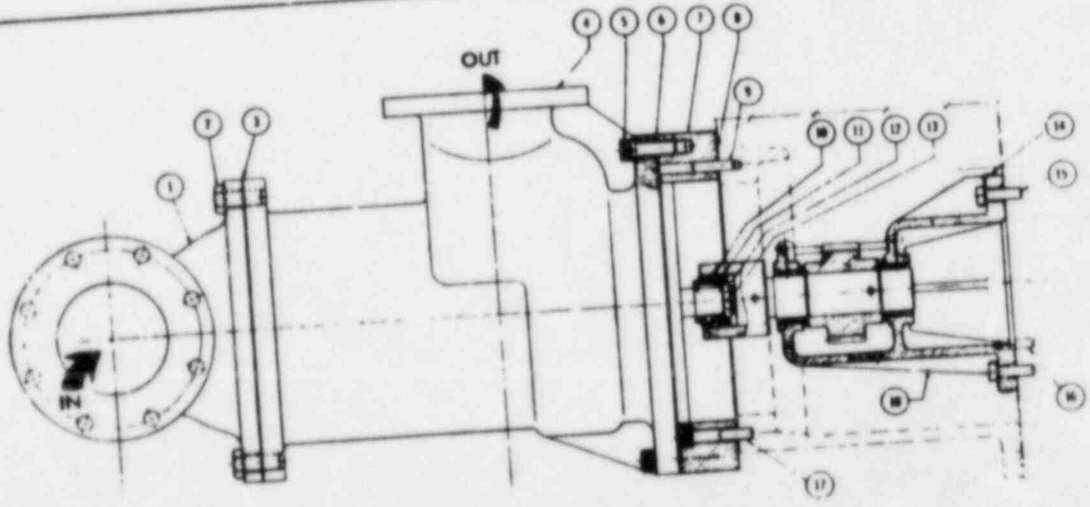
The full flow filter continuously filters all of the lubricating oil from the pump before it passes to the oil strainer. The length of time that the lubricating oil and the filter elements may remain in service can best be determined by carefully watching the result of oil analysis and the pressure drop across the oil filter. Change period will vary with the operating conditions to which each individual engine is subjected. During the first two or three days of engine operation after initial installation, or after a major overhaul, the strainer at the pump suction and the strainer at the oil header inlet should be checked and cleaned as necessary to remove any debris and other foreign matter that may be present. If at any time the oil pressure gauge shows a low reading, the following should be done to the degree necessary to correct the situation.

a. Check the oil level in the sump tank.

b. Inspect strainer, filter and lubricating oil cooler. A leak in the cooler may be detected by a sudden increase in oil consumption, and by the presence of oil in the cooling water system. Leakage may occur in the packing between the tubes and the tube sheet, or may be due to tube erosion, depending on the construction of the cooler.

c. Inspect all external and internal piping for tightness and freedom from obstructions.

d. Dismantle and inspect pump.



1 ELBOW
2 CAPSCREW
3 GASKET
4 L.O. PUMP
5 CAPSCREW
6 GASKET
7 ADAPTER
8 GASKET
9 DOWEL

10 SPLINE – EXTERNAL
11 SQUARE KEY
12 HEX NUT
13 COTTER PIN
14 LOCKING CLIP
15 CAPSCREW
16 DOWEL
17 CAPSCREW
18 GEAR CARRIER

Figure 6-K-1. Lubricating Oil Pump and Gear Carrier Assembly

PART K – LUBRICATING OIL SYSTEM (Continued)

LUBRICATING OIL PUMP.

A Delaval IMO, constant displacement, rotary screw type lubricating oil pump is used. Lubricating oil in the pump is propelled axially in a constant, uniform flow through the action of but three moving parts – a power rotor and two idler rotors. The smooth intermeshing of these rotors propells the lubricating oil in a steady flow without any churning, pocketing or pulsation. There are no timing gears, cams, valves, sliding vanes or reciprocating parts to wear or become noisy. The pump is mounted on the front of the gearcase, and is coupled to a carrier assembly by a splined coupling. The carrier assembly is mounted on the front of the engine base, and is driven by the crankshaft speedup gear. Once the pump has been placed in service it should continue to operate satisfactorily with little attention other than an occasional inspection. Noisy pump operation is usually indicative of excessive suction lift, air in the system, misalignment or, in the case of an oil pump, excessive wear.

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

To remove the pump from the engine, do the following.

a. Remove the inlet and discharge piping as well as any other interfering piping or accessories.

b. Position a sling on the pump and attach to a chainfall and take up the slack.

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

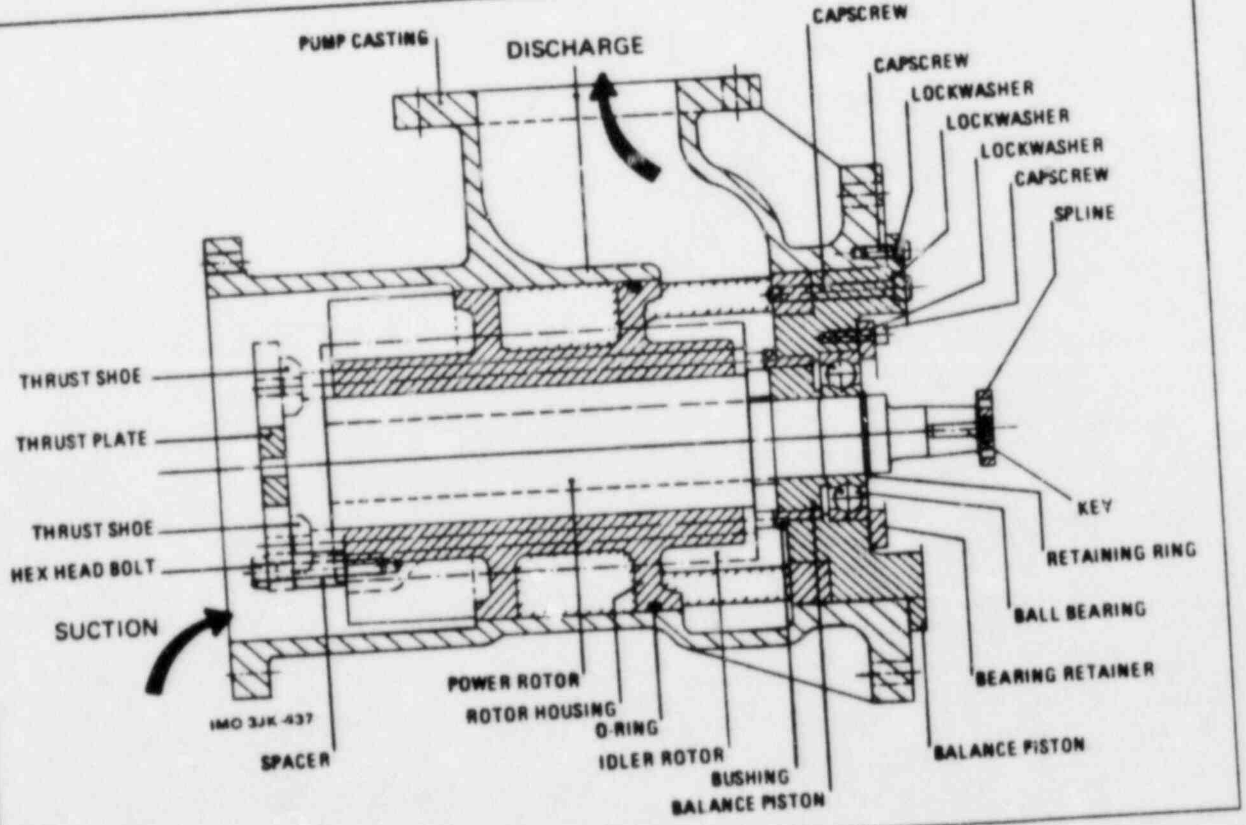


Figure 6-K-2. Lubricating Oil Pump Assembly

R/RV (IMO 3JK-437) 75

PART K – LUBRICATING OIL SYSTEM (Continued)

PUMP DISASSEMBLY (See Figure 6-K-2).

If it is necessary to disassemble the pump, exercise care to keep the parts clean so that no dirt, grit or other foreign matter will be present when the pump is assembled. Disassemble as follows.

a. Set pump on suction end and remove capscrews and lockwashers holding balance piston housing in pump casing. Remove two capscrews with lockwashers from opposing positions, 180 degrees apart and insert ½ – 13 eyebolts into vacated holes. Lift internal assembly out of pump case and set assembly on its side. *Do not* set it down on thrust plate. Remove eyebolts.

b. Remove bolts, lockwashers, spacers and thrust plate from suction end of rotor housing. Note location of each spacer with respect to the rotor housing. Support and remove each spacer as each bolt is removed. Set parts aside in order of removal.

c. Grasp thrust shoe on end of each idler rotor and unscrew idler rotors from rotor housing. Do not remove thrust shoe from idler rotor.

d. Remove capscrew with lockwashers and bearing retainer. Grasp coupling end of power rotor shaft and pull power rotor out of rotor housing. Avoid hitting bushing with end of power rotor as it is removed. Inspect power rotor and ball bearing.

e. If it is necessary to replace the ball bearing, proceed as follows. Remove retaining ring. Obtain wheel or gear puller and small piece of soft metal. Place soft metal over end of power rotor shaft and use puller to remove the ball bearing from balance piston. Discard bearing.

f. Remove retaining capscrews with lockwasher and separate balance piston housing from rotor housing. Do not disassemble bushing from balance piston housing unless it requires replacement. This completes disassembly necessary for maintenance purposes.

PUMP REASSEMBLY (See Figure 6-K-2).

a. If ball bearing was removed, pressure a new bearing into position on the balance piston. Replace retaining ring. If a new bushing is required, coat outside diameter of new bushing with *Locktite Retaining Compound* and insert bushing into balance piston housing.

b. Set rotor housing on suction end and install new O-ring. Place balance piston housing on discharge end of rotor housing and fasten down with four capscrews and lockwashers, leaving two holes, 180 degrees apart, vacant.

c. Lay rotor housing on its side and insert power rotor into housing from discharge end. Fasten bearing retainer to balance piston housing with capscrews and lockwashers.

d. Insert idler rotors into rotor housing from suction end. Reassemble thrust plate to rotor housing with bolts and washers, making sure that each spacer is assembled to the housing in its original location. Note: *The four spacers have been machined to close tolerances to assure accurate spacing between thrust plate and rotor housing. A minimum torque of 800 in.-lb applied to each bolt should assure proper spacing between thrust plate and rotor housing. Improper spacing will result in accelerated wear of internals.*

e. Insert two ½" x 13 eyebolts into vacated holes in balance piston housing and lift internal assembly into position over pump case. Insert assembly into pump case, being careful not to damage O-ring during process. Fasten internal assembly to pump case with capscrews and lockwashers.

PART K – LUBRICATING OIL SYSTEM (Continued)

f. This completes pump reassembly. Before mounting to gearcase, make sure that pump turns freely. Do not force piping into place as the strain on the casing may cause excessive pump wear.

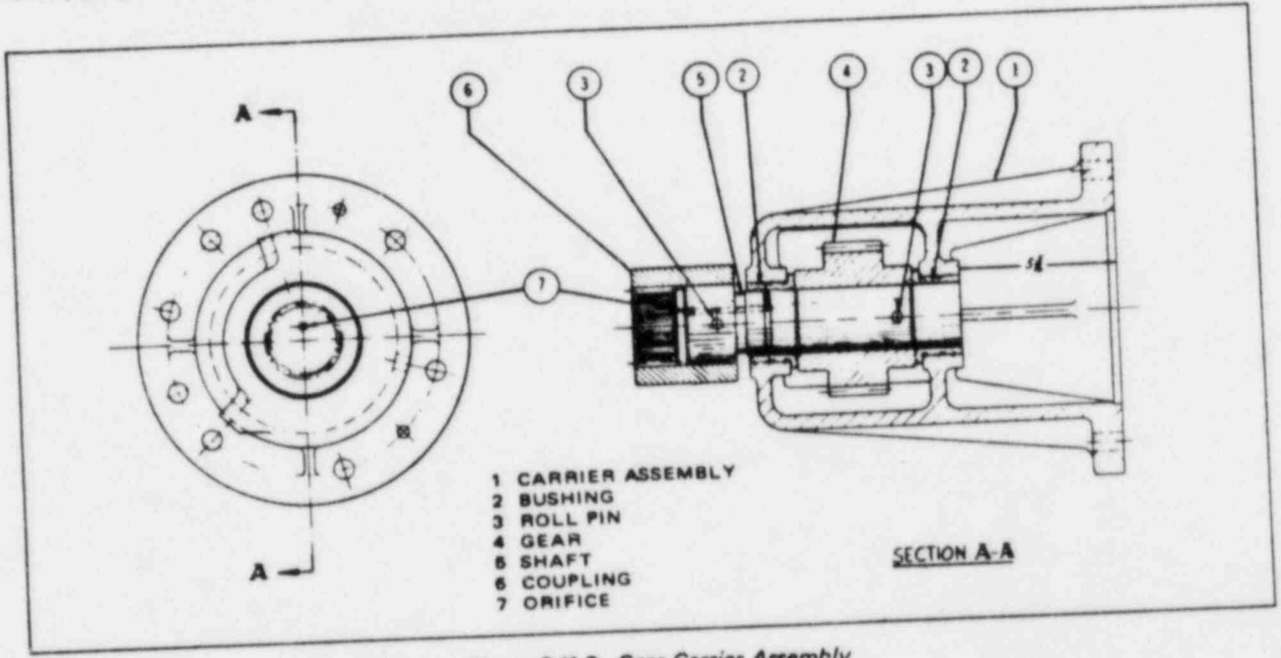


Figure 6-K-3. Gear Carrier Assembly

OIL PUMP GEAR CARRIER ASSEMBLY (See Figure 6-K-3).

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

DISASSEMBLY AND ASSEMBLY OF GEAR CARRIER ASSEMBLY (See Figure 6-K-3).

To remove the pump gear carrier assembly, the pump must be removed as outlined above, then the gearcase removed.

a. Remove lubricating oil lines from carrier assembly.

b. Bend back locking clips and remove capscrews. Remove carrier assembly.

c. To remove gear, shaft and bushings from carrier assembly, remove gear-to-shaft roll pin then press shaft out of gear. With shaft and gear removed, press bushing out of drive bracket.

d. Assembly is the reverse of disassembly. Use new locking clips.

PART K – LUBRICATING OIL SYSTEM (Continued)

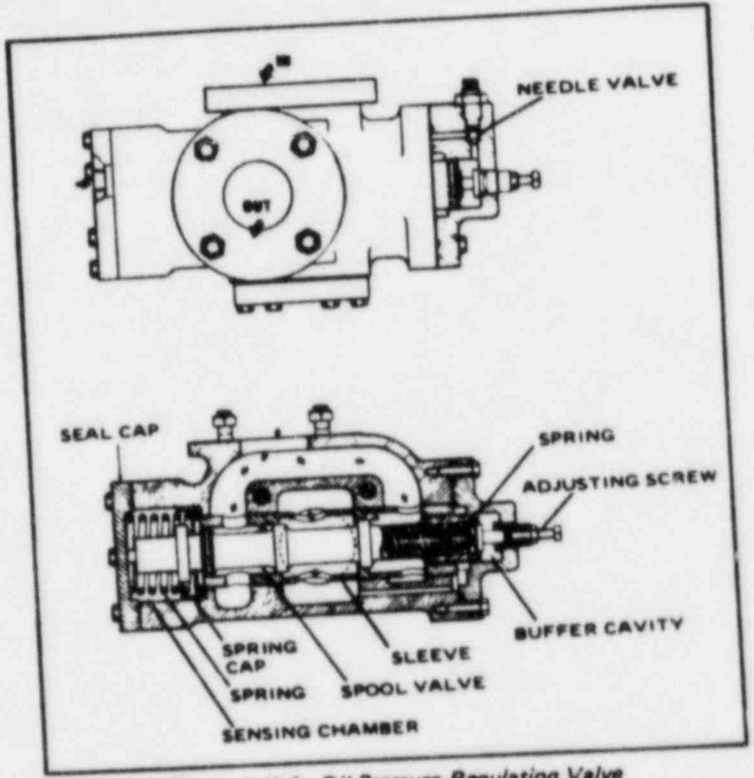


Figure 6-K-4. Oil Pressure Regulating Valve

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 ANS Z11.131. Engine oils are intentionally formulated slightly alkaline so that they are capable of neutralizing the acidi compounds that form from products of combustion and of oil oxidation. Generally this reserve alkalinity is deplete and the weak organic acids that attack bearing surfaces can be destructive. Periodic evaluation of Total Base Numbe (TBN) and Total Acid Number (TAN) are an important measure of oil degradation. As time goes on, TBN is deplete and TAN begins to rise.

d. PENTANE AND BEZINE INSOLUBLES – ASTM D893. This test is a measure of oil insoluble materia oil resinous matter from oil or additive degradation, external contamination, fuel carbon and highly carbonized materia 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 including wear or corrosion metals such as aluminum, chromium, iron, copper, silver, lead and tin. Also, dirt conta nants 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)

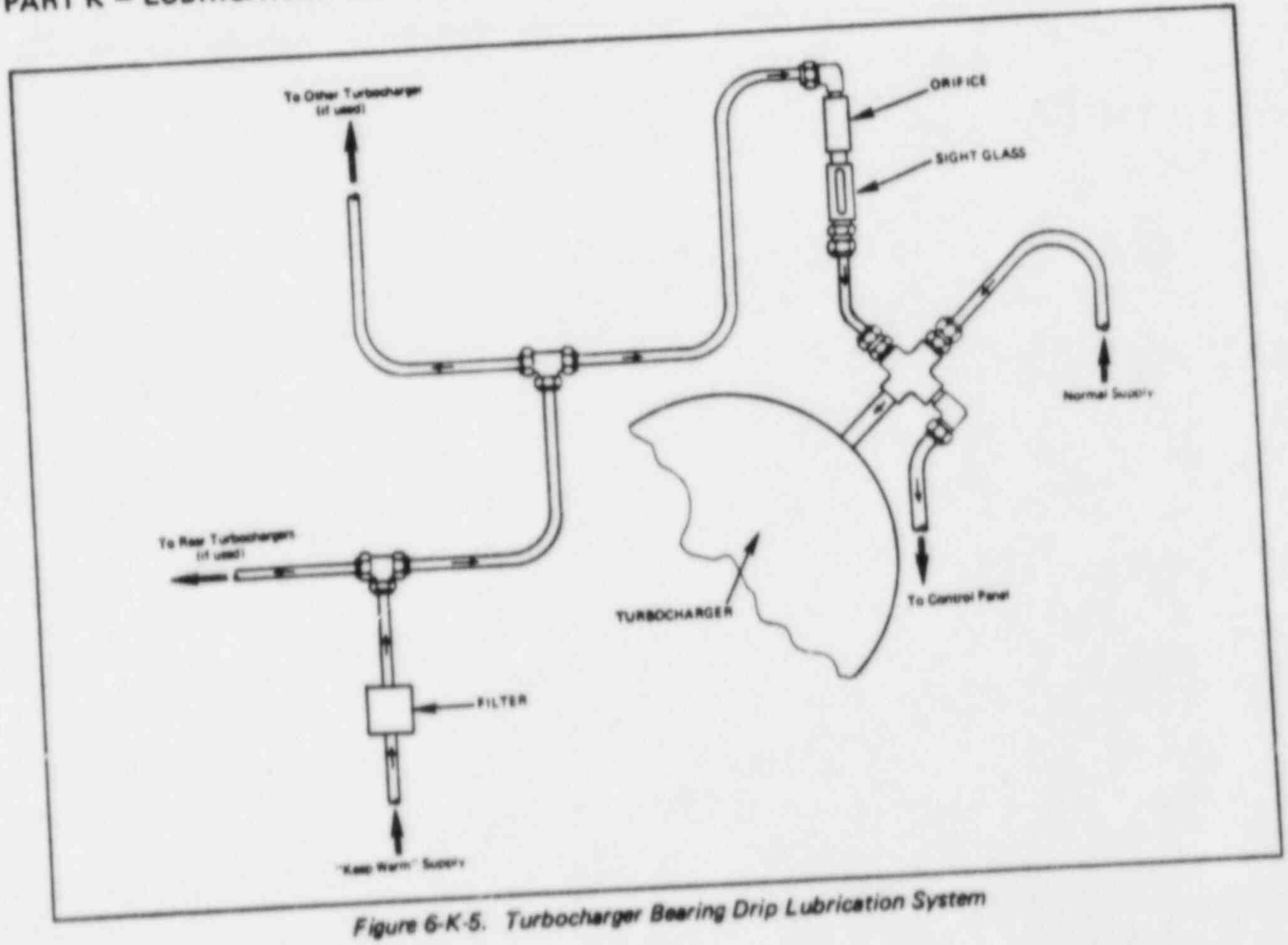


Figure 6-K-5. Turbocharger Bearing Drip Lubrication System

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.

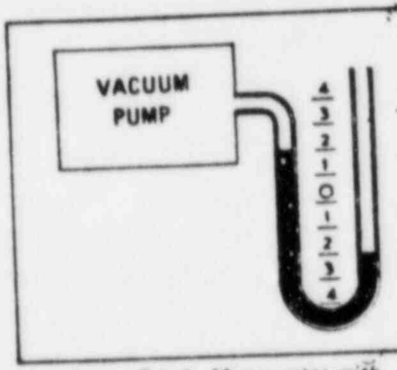


Figure 6-L-1. Manometer with Vacuum Pump

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.

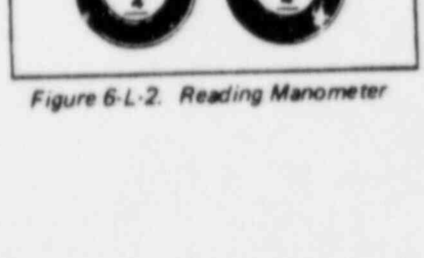


Figure 6-L-2. Reading Manometer

PART L – MISCELLANEOUS

CRANKCASE PRESSURE.

The crankcase is fully enclosed and theoretically air tight. To remove gases and vapors from the crankcase, crankcase pressure is maintained at a level slightly below atmospheric, measured in inches of water by a standard U-type manometer.

CRANKCASE VENTILATION SYSTEM.

The crankcase ventilation system is designed to expel vapors from the crankcase while the engine is running. The system will also assist in determining the general condition of the engine, particularly piston ring and cylinder liner wear. If piston ring and/or liner wear becomes excessive, piston blowby will cause a rise in crankcase pressure and, therefore, will be evidenced by a change in the crankcase pressure towards a positive pressure. Two motor-driven blowers are used to draw directly from the crankcase through an oil separator and discharge directly to atmosphere outside the engine room. Oil particles suspended in the air are removed as the air passes through the separators, and the oil drains back to the engine crankcase. The blower motors are started automatically when the engine is started, and shut down when the engine is stopped.

CRANKCASE VACUUM.

A crankcase vacuum of 0.2 to 0.5 in.-H_2O is normal when the engine is operating at rated load and speed. Crankcase vacuum readings should be taken carefully, and compared with previous readings. In this way gradual changes can be detected and investigated so that minor problems can be corrected before they reach major proportions. Should the readings indicate a loss of crankcase vacuum, the cause should be promptly determined and corrected.

Section 7
Trouble
Shooting

Section 7
Trouble Shooting

GENERAL.

Maintenance trouble shooting, to be effective demands a sound knowledge of the engine in both a theoretical and a practical sense. The mechanic must analyze the causes and effects, and where the cause is not readily apparent, he must employ a fine sense of logic based upon the use of all tools available. Section 1 discussed preventive maintenance. The technique of that program is, to varying degrees, applicable to trouble shooting as well. To assist in determining the causes of improper performance, this section contains a listing of some of the more common engine malfunctions their probable causes and the logical remedies.

RECORDS.

All possible malfunctions and their probable causes cannot be accurately 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.

CHART RECORDERS.

The nuclear application requires fast starting and loading at random intervals, and associated diesel-generator records should reflect the effects of both structural (acceleration) and thermal (temperature change) loading. To accomplish this purpose, two chart recorders are included at the Local Generator Control Panel, which are of special significance in record keeping, and in the entire maintenance/trouble shooting concept. The records provided by the chart recorders offer highly accurate documentation of vital parameters, and should be used in conjunction with records of other system variables and repair and maintenance procedures records to form a complete portrait of unit performance and condition. Capabilities of the respective chart recorders are as follows.

a. The high speed Gould model 2600 (6-channel, 2-event) recorder with a chart speed of 2.5 inches per second will start each time a diesel start is initiated and run for 20 seconds. The following signals are recorded.

(1) Engine start signal (event)

(2) Starting air pressure, system number 1

(3) Starting air pressure, system number 2

(4) Engine speed

(5) Governor position

(6) Generator voltage

(7) Timing mark (1 second interval on recording paper)

(8) Fuel header pressure

(9) Generator breaker close (event) (Owner supplied contract)

b. The slow speed Westronics engine temperature recorder shall run continuously and will be used to monitor standby as well as operating temperatures of the following.

(1) Jacket Water IN

(2) Jacket Water OUT

(3) Lubricating Oil IN

(4) Lubricating Oil OUT

(5) Manifold

(6) Stator (hottest point thermocouple as determined by test will be monitored.)

(7) Ambient Air

c. The chart recorders are an important tool in the total maintenance/trouble shooting program. It must be emphasized, however, that relevant data from all sources must be analyzed and compared before a logical diagnosis of a given problem can be accomplished. The high speed recorder measures simultaneous variation in certain interdependent variables during a start event. If deviation is experienced in one or more variables, comparison with other parameters in the same start event profile may reveal the cause of the problem. For instance, if a low generator voltage condition were experienced, knowledge of governor position and the engine speed would be helpful in isolating the malfunction. In addition, comparison of individual start profiles with those of other units, or comparison of start event profiles over a period of time, will reveal gradual changes in performance and engine condition. The slow speed temperature recorder is used to monitor vital systems temperatures continuously, from the standby condition, through the start event and on to load operation. This recorder documents the effects of thermal loading, and is a good indicator of the performance of the whole system. Again, note that a high temperature reading for any one variable must be compared to other relevant data as a first step in troubleshooting.

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.

TROUBLE	POSSIBLE CAUSE	ACTION
6. Engine has blue smoky exhaust.	a. Piston rings stuck.	Free, clean ring grooves and oil drain holes.
	b. Worn piston rings or liners.	Replace rings as required. If necessary, use oversized rings. Replace liners if scored or worn.
	c. Burning lubricating oil.	Check piston rings, ring grooves and liners.
	d. Crack or hole in piston.	Replace piston.
7. Engine knocks while running.	a. Fuel nozzle stuck, clogged, damaged or worn.	Replace with spare and examine.
	b. Fuel injection pump out of time.	Adjust timing.
	c. Poor fuel oil quality.	Check specifications of fuel being used against standards.
	d. Defective fuel tappet.	Check, replace worn parts.
	e. Piston loose in liner.	Shut off fuel to suspected cylinder. If knock decreases, check piston and ring clearances. Replace worn parts.
	f. Loose piston pin or pin bushing.	Place piston at bottom dead center. With pry bar, check piston for loose fit. Replace pin or bushing as necessary.
	g. Connecting rod bearing defective.	Check clearances.
	h. Defective main bearings.	Check clearances.
8. Low lubricating oil pressure.	a. Low oil level in sump tank.	Add oil.
	b. Lubricating oil suction clogged.	Check strainer and clean.
	c. Loose lubricating oil piping.	Check and retighten as necessary.
	d. Loaded filter elements.	Clean or replace elements.
	e. Sticking relief valve.	Free and clean valve.
	f. Defective lubricating oil pump.	Inspect pump. Repair or replace.
	g. Pressure regulating valve set too low.	Adjust valve.
	h. Loose or worn bearings.	Check bearing clearances.
9. High lubricating oil pressure.	a. Relief valve stuck.	Free and clean.
	b. Dirty lubricating oil cooler or full flow filter.	Clean.
	c. Pressure regulating valve set too high.	Adjust to correct pressure.
10. High jacket water inlet temperature.	a. Jacket water pressure too low.	Check and tighten connections.
	b. Air in water system.	Check water pump — bleed air.
	c. Pump suction or discharge clogged.	Check and clean.
	d. Pump airbound.	Open vents on pump, or on top of suction.
	e. Water passage clogged with scale.	Clean with recognized solvent.
	f. Inadequate heat exchanger coolant.	Inspect and clean as necessary.
	g. Dirty heat exchanger.	Inspect and clean.
	h. Engine overloaded.	Reduce load.
	i. Loose piping.	Check and tighten.
	j. Inadequate raw water supply.	Check.
11. Excessive vibration.	a. Cylinder misfiring.	Check fuel injector nozzles, fuel pump, cylinder fuel cut off.
	b. Stuck valve.	Free, re-face, reseat or replace.
	c. Mechanical problems.	Investigate all systems and auxiliaries, particularly moving or rotating parts.
12. Excessive exhaust temperatures, all cylinders.	a. Engine overloaded.	Reduce load.
	b. Low manifold air pressure.	Increase manifold pressure.
	c. Piston sticking.	Remove, clean, check clearances.
	d. Bearing failure.	Inspect and check clearances.
	e. Dirty intake air filter.	Clean.
13. Unequal exhaust temperatures (wide spread with engine loaded)	a. Valve leakage.	Check valves, grind and reseat.
	b. Fuel injection pump out of adjustment.	Adjust.
14. Rising exhaust temperature in one cylinder.	a. Burned exhaust valve.	Replace valve.
	b. Bad fuel injection nozzle.	Check and replace if necessary.
	c. Faulty pyrometer.	Check thermocouples and pyrometer.
15. High pre-turbine exhaust temperature.	a. Engine overloaded.	Reduce load.
	b. Low manifold air pressure.	Increase pressure.
	c. Sticking piston.	Remove, clean, check clearances.
	d. Bearing failure	Inspect and check clearances.
	e. Dirty intake air filter.	Clean.

TROUBLE	POSSIBLE CAUSE	ACTION
16. Low exhaust temperature in one cylinder.	a. Bad fuel pump. b. Bad fuel pump nozzle. c. Faulty pyrometer.	Check and replace if indicated. Check and replace if indicated. Check thermocouples and pyrometer.
17. Erratic speed variations (hunting)	a. Injection pump improperly timed. b. Injection nozzle tip clogged. c. Injection nozzle improperly adjusted. d. Injection pump plunger stuck. e. Low oil level in governor. f. Low fuel oil pressure. g. Governor or linkage sticking. h. Governor adjustment.	Retime pump. Clean nozzle. Adjust. Free plunger. Fill governor with clean oil. Increase pressure. Lubricate linkage with engine oil. Refer to governor manufacturer's bulletins. Refer to manufacturer's bulletins.
18. Constant engine speed fluctuation.	a. Governor. b. Sticking control linkage. c. Speed signal control air pressure.	Refer to manufacturer's bulletins. Clean and lubricate with engine oil. Check system and supply.
19. Excessive venting and/or vapors from vent holes in each end of starting air header.	a. Leaking starting air valves.	Check valves. Repair or replace.
20. Low jacket water pressure.	a. Defective water pump. b. Water pump airbound.	Check and repair. Bleed air.
21. Low raw water pressure.	a. Defective water pump. b. Air in system. c. Dirty strainer.	Check and repair. Bleed air. Clean.
22. Low compression pressure.	a. Worn piston rings. b. Burned valves. c. Valve tappets improperly adjusted.	Replace. Replace. Adjust valve clearance, or if equipped with hydraulic valve lifters, adjust lifters.
23. Low fuel oil pressure.	a. Dirty filters or strainers. b. Relief valve stuck open. c. Defective booster pump. d. Air leak in suction line.	Check and clean. Free and check. Check and repair or replace. Repair.
24. Excessive lubricating oil consumption.	a. Worn piston rings or liners. b. Leak in sump or piping. c. 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.

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. b. Early injection. c. Malfunctioning nozzle.	Reduce load.
29. Low peak firing pressure.	a. Late ignition.	

Section 8
Appendices

Section 8
Appendices

The purpose of this section of the manual is to provide a single location for data which, if located within the text of the manual, would be more difficult to locate. As a general rule, specific values, such as pressures, clearances, torques, etc., have been omitted from the text and, where appropriate, reference is made to the applicable appendix.

The following appendices are provided in this section:

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)

$$\text{bmep} = \frac{\text{bhp} \times 33{,}000}{L \times A \times N}$$

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 = $\text{Radius}^2 \times 3.1416$

Conversion Factors and Other Useful Information

Areas of Circles
(Diameters in Inches, Area in Square Inches)

Diameters	Area
1/16	.00307
1/8	.01227
3/16	.02761
1/4	.04909
5/16	.07670
1/8	.1104
7/16	.1503
1/2	.1964
9/15	.2485
5/8	.3068
11/16	.3712
3/4	.4418
13/16	.5185
7/8	.6013
15/16	.6903
1	.7854
1/16	.8866
1/8	.9940
3/16	1.1075
1/4	1.2272
5/16	1.3530
1/8	1.4849
7/16	1.6230
1/2	1.7671
9/16	1.9175
5/8	2.0739
11/16	2.2365
3/4	2.4053
13/16	2.5802
7/8	2.7612
15/16	2.9483
2	3.1416
1/16	3.3410
1/8	3.5466
3/16	3.7583
1/4	3.9761
5/16	4.2000
1/8	4.4301
7/16	4.6664
1/2	4.9087
9/16	5.1572
5/8	5.4119
11/16	5.6727
3/4	5.9396
13/16	6.2126
7/8	6.4918
15/16	6.7771
3	7.0686
1/16	7.3662
1/8	7.6699
3/16	7.9798
1/4	8.2958
5/16	8.6179
3/8	8.9462
7/16	9.2806
1/2	9.6211
9/16	9.9678
3	
5/8	10.3206
11/16	10.6783
3/4	11.0447
13/16	11.4158
7/8	11.7933
15/16	12.1767
4	12.5664
1/8	13.3641
1/4	14.1863
1/8	15.0330
1/2	15.9043
5/8	16.8002
3/4	17.7206
7/8	18.6655
5	19.6349
1/8	20.6289
1/4	21.6476
3/8	22.6907
1/2	23.7583
5/8	24.8505
3/4	25.9673
7/8	27.1086
6	28.2744
1/8	29.4648
1/4	30.6797
3/8	31.9191
1/2	33.1831
5/8	34.4717
3/4	35.7848
7/8	37.1224
7	38.4846
1/8	39.8713
1/4	41.2826
3/8	42.7184
1/2	44.1787
5/8	45.6636
3/4	47.1731
7/8	48.7071
8	50.2656
1/8	51.8487
1/4	53.4563
3/8	55.0884
1/2	56.7451
5/8	58.4264
3/4	60.1322
7/8	61.8625
9	63.6174
1/8	65.3968
1/4	67.2008
3/8	69.0293
1/2	70.8823
5/8	72.7599
3/4	74.6621
7/8	76.5888
10	78.5398
1/8	80.5158
10	
1/4	82.5161
3/8	84.5409
1/2	86.5903
5/8	88.6643
3/4	90.7628
7/8	92.8858
11	95.0334
1/8	97.2065
1/4	99.4022
3/8	101.6234
1/2	103.8691
5/8	106.1394
3/4	108.4343
7/8	110.7537
12	113.098
1/4	117.859
1/2	122.719
3/4	127.677
13	132.733
1/4	137.887
1/2	143.139
3/4	148.489
14	153.938
1/4	159.465
1/2	165.122
3/4	170.874
15	176.715
1/4	182.655
1/2	188.692
3/4	194.828
16	201.062
1/4	207.395
1/2	213.825
3/4	220.354
17	226.981
1/4	233.706
1/2	240.529
3/4	247.447
18	254.469
1/4	261.587
1/2	268.803
3/4	276.117
19	283.529
1/4	291.040
1/2	298.648
3/4	306.355
20	314.159
1/4	322.063
1/2	330.064
3/4	338.164
21	346.361
1/4	354.657
1/2	363.051
3/4	371.543
22	380.134
1/4	388.822
22	
1/2	397.609
3/4	406.494
23	415.477
1/4	424.558
1/2	433.737
3/4	443.015
24	452.389
1/4	461.864
1/2	471.436
3/4	481.107
25	490.875
1/4	500.742
1/2	510.706
3/4	520.769
26	530.929
1/4	541.189
1/2	551.547
3/4	562.003
27	572.557
1/4	583.209
1/2	593.959
3/4	604.807
28	615.754
1/4	626.789
1/2	637.941
3/4	649.182
29	660.521
1/4	671.959
1/2	683.494
3/4	695.128
30	706.858
1/4	718.689
1/2	730.618
3/4	742.645
31	754.769
1/4	766.992
1/2	779.313
3/4	791.732
32	804.247
1/4	816.865
1/2	829.579
3/4	842.391
33	855.301
1/4	868.309
1/2	881.415
3/4	894.618
34	907.922
1/4	921.323
1/2	934.822
3/4	948.418
35	962.115
1/4	975.909
1/2	989.789
3/4	1003.788
36	1017.878
1/4	1032.065
1/2	1046.349
3/4	1060.732
37	1075.213
1/4	1089.792
1/2	1104.469
3/4	1119.244
38	1134.118
1/4	1149.089
1/2	1164.159
3/4	1179.327
39	1194.593
1/4	1209.95
1/2	1225.42
3/4	1240.98
40	1256.64
1/4	1272.39
1/2	1288.25
3/4	1304.20
41	1320.25
1/4	1336.40
1/2	1352.65
3/4	1369.00
42	1385.45
1/4	1401.99
1/2	1418.63
3/4	1435.37
43	1452.20
1/4	1469.14
1/2	1486.17
3/4	1503.30
44	1520.53
1/4	1537.86
1/2	1555.29
3/4	1572.81
45	1590.43
1/4	1608.16
1/2	1625.97
3/4	1643.89
46	1661.91
1/4	1680.02
1/2	1698.23
3/4	1716.54
47	1734.95
1/4	1753.45
1/2	1772.06
3/4	1790.76
48	1809.56
1/4	1828.46
1/2	1847.46
3/4	1866.55
49	1885.75
1/4	1905.04
1/2	1924.43
3/4	1943.91
50	1963.49
1/4	1983.18
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	.996
1500		458	54	12	28.33	719.6	13.91	.978
2000		610	52	11	27.82	706.6	13.66	.960
2500		763	50	10	27.32	693.9	13.41	.943
3000		915	48	9	26.82	681.2	13.17	.926
3500		1068	47	8	26.33	668.8	12.93	.909
4000		1220	45	7	25.84	656.3	12.69	.892
4500		1373	43	6	25.37	644.4	12.46	.876
5000	0.95	1526	41	5	24.90	632.5	12.23	.860
6000	1.1	1831	38	3	23.99	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	†8.273^{-1}	21.0	.406	.0285
90,000	17.1	27,459	-57	-50	5.200^{-1}	13.2	.255	.0179
100,000	18.9	30,510	-51	-46	3.290^{-1}	8.36	.162	.0114
120,000	22.8	36,612	-26	-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}	†6.97^{-1}		
180,000	34.2	54,918	19	-7	1.284^{-2}	3.26^{-1}		
200,000	37.9	61,020	-3	-19	5.846^{-3}	1.48^{-1}		
220,000	41.7	67,122	-44	-42	2.523^{-3}	6.41^{-2}		
240,000	45.5	73,224	-86	-66	9.955^{-4}	2.53^{-2}		
260,000	49.3	79,326	-129	-90	3.513^{-4}	8.92^{-3}		
280,000	53.1	85,428	-135	-93	1.143^{-4}	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	342	549,180			1.8^{-10}	4.57^{-9}		
2,000,000	379	610,200			9.2^{-11}	2.34^{-9}		

Data from NASA Standard Atmosphere (1962).

*Temperature and barometer are approximate for negative altitudes.

**Temperatures are average existing at 40° latitude and are rounded to even numbers.

†Negative exponent shows number of spaces the decimal point must be moved to the left.

Conversion Factors and Other Useful Information (cont'd)

Conversion Factors

Multiply	By	To Obtain
Atmospheres	76.0	Cms. of mercury
Atmospheres	29.92	Inches of mercury
Atmospheres	33.90	Feet of water
Atmospheres	10,333	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 (Centares)	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.)

Multiply	By	To Obtain
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

Multiply	By	To Obtain
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
$\frac{\text{Lumber Width (in.)} \times \text{Thickness (in.)}}{12}$	Length (ft.)	Board Feet
Meters	100	Centimeters
Meters	3.781	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	137.5	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
$\frac{1}{\text{Sq. ft./gal./min.}}$	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)	37000	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.
1/64	0.015625	0.3969
1/32	0.031250	0.7938
3/64	0.0467875	1.1906
1/16	0.062500	1.5875
5/64	0.078125	1.9844
3/32	0.093750	2.3812
7/64	0.109375	2.7781
1/8	0.125000	3.1750
9/64	0.140625	3.5719
5/32	0.156250	3.9688
11/64	0.171875	4.3656
3/16	0.187500	4.7625
13/64	0.203125	5.1594
7/32	0.218750	5.5562
15/64	0.234375	5.9531
1/4	0.250000	6.3500
17/64	0.265625	6.7469
9/32	0.281250	7.1438
19/64	0.296875	7.5406
5/16	0.312500	7.9375
21/64	0.328125	8.3344
11/32	0.343750	8.7312
23/64	0.359375	9.1281
3/8	0.375000	9.5250
25/64	0.390625	9.9219
13/32	0.406250	10.3188
27/64	0.421875	10.7156
7/16	0.437500	11.1125
29/64	0.453125	11.5094
15/32	0.468750	11.9062
31/64	0.484375	12.3031
1/2	0.500000	12.7000
33/64	0.515625	13.0969
17/32	0.531250	13.4938
35/64	0.546875	13.8906
9/16	0.562500	14.2875
37/64	0.578125	14.6844
19/32	0.593750	15.0812
39/64	0.609375	15.4781
5/8	0.625000	15.8750
41/64	0.640625	16.2719
21/32	0.656250	16.6688
43/64	0.671875	17.0656
11/16	0.687500	17.4625
45/64	0.703125	17.8594
23/32	0.718750	18.2562
47/64	0.734375	18.6531
3/4	0.750000	19.0500
49/64	0.765625	19.4469
25/32	0.781250	19.8437
51/64	0.796875	20.2406
13/16	0.812500	20.6375
53/64	0.828125	21.0344
27/32	0.843750	21.4312
55/64	0.859375	21.8281
7/8	0.875000	22.2250
57/64	0.890625	22.6219
29/32	0.906250	23.0188
59/64	0.921875	23.4156
15/16	0.937500	23.8125
61/64	0.953125	24.2094
31/32	0.968750	24.6062
63/64	0.984375	25.0031
1	1.000000	25.4000

APPENDIX II

OPERATING PRESSURES AND TEMPERATURES

PRESSURES

The following pressures should be present for starting:

Starting Air Supply	250 psi	17.6 kg/sq cm
Starting Air Header	250 psi	17.6 kg/sq cm

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

	psi	in.-hg	kg/sq cm
Lubricating Oil*	50 — 55	101.8 — 112.0	3.52 — 3.87
Lubricating Oil at Turbocharger Inlet	20 — 25	40.7 — 50.9	1.41 — 1.76
Jacket Water	10 — 30	20.4 — 61.1	0.70 — 2.11
Fuel Oil	20 — 30	40.7 — 61.1	1.41 — 2.11

TEMPERATURES

While running under rated load, the outlet temperatures should be as follows:

Lubricating Oil out of Engine*	170° F — 180° F (76.6° C — 82.2° C)
Jacket Water out of Engine	170° F — 180° F (76.6° C — 82.2° C)

EXHAUST TEMPERATURES.

The exhaust temperatures shown on the "Factory Test Results" page are the average for all cylinders during factory test under *local ambient conditions*. Temperatures in the field, therefore, may exceed this average temperature. Exhaust temperatures may be considered normal if within plus or minus 50° F of the average taken for all cylinders. Temperatures, high or low, exceeding this range should be investigated (see Section 7).

FIRING PRESSURES.

Firing pressures may be considered normal if within plus or minus 75 psi of the average for all cylinders. High or low pressures exceeding this range should be investigated (see Section 7).

NOTES.

Operating pressures and temperatures listed are established as a guide to proper operation. Except as noted for exhaust temperatures and firing pressures, they should be held to within plus or minus 10 percent. Sudden changes in readings require immediate investigation and correction.

When making adjustments as a result of a high or low cylinder exhaust temperature, or firing pressure, both temperature and pressure readings must be taken into account when determining the proper corrective action.

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*When using SAE 40 lubricating oil in engine.

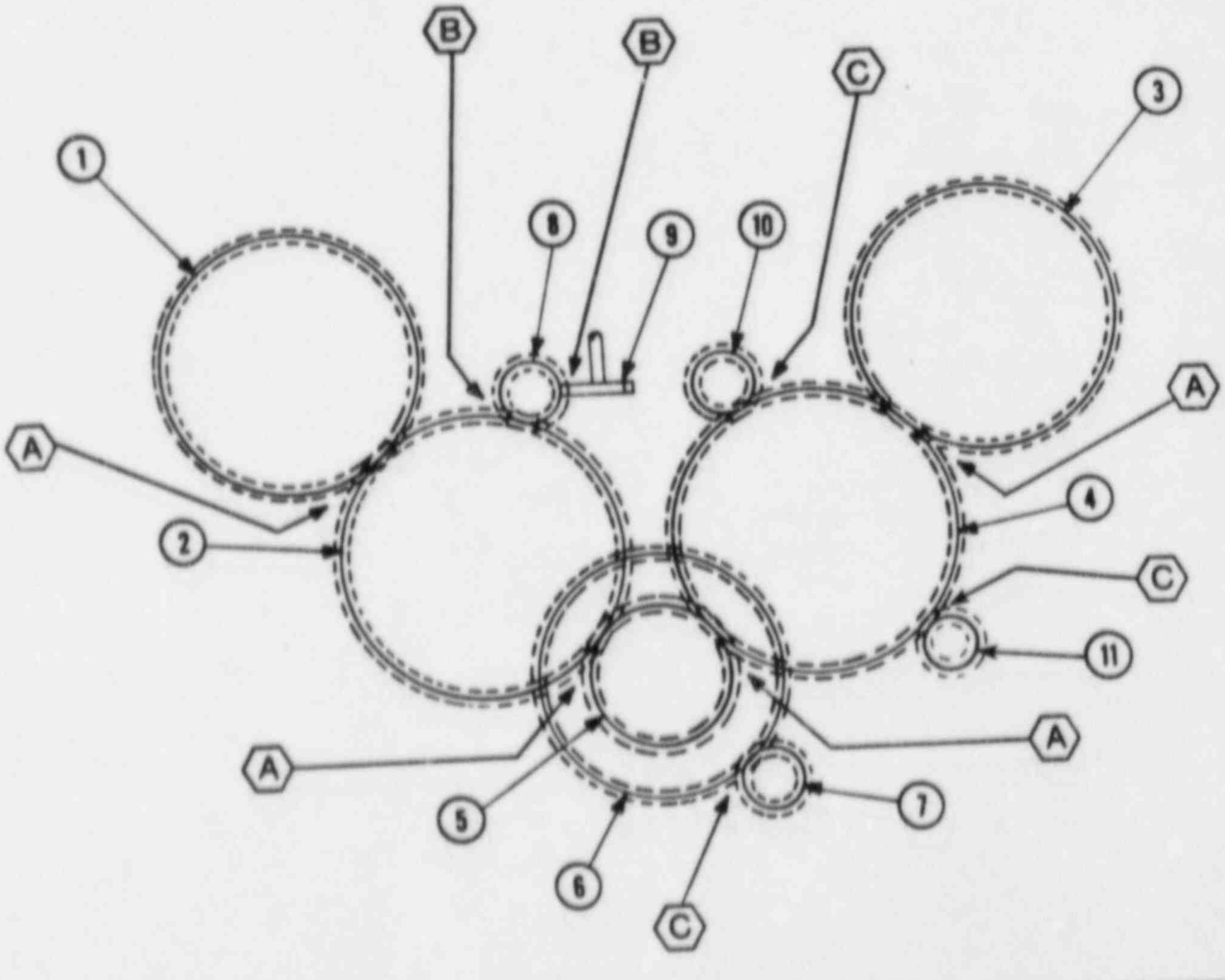
APPENDIX III

TABLE OF CLEARANCES
MODEL RV-4 ENGINE

	Clearance When New		Replace When Over		
Item	Inches	Millimeters	Inches	Millimeters	Notes
Crankshaft to Main Bearings	0.010/0.014	0.254/0.356	— — —	— — —	See bearing shell thickness figures
Crankshaft to Thrust Ring	0.022/0.030	0.559/0.762	0.040	0.016	Replace at least one
Connecting Rod Bearing to Crankshaft	0.010/0.014	0.254/0.356	— — —	— — —	See bearing shell thickness figures
Camshaft Bearings to Camshaft (intermediate)	0.004/0.008	0.102/0.203	— — —	— — —	See bearing shell thickness figures
Camshaft Thrust Adjustment	0.004/0.007	0.102/0.178	— — —	— — —	Adjust at 0.012" or over
Connecting Rod Link Pin to Bushing	0.006/0.011	0.152/0.279	0.015	0.381	
Piston Pin to Rod Bushing	0.010/0.015	0.254/0.381	0.020	0.508	
Piston Pin to Piston	0.002/0.004	0.051/0.102	0.005	0.127	
Idler Gear Bushings to Shaft	0.003/0.005	0.076/0.127	0.010	0.254	
Idler Gear Thrust to Bracket	0.005/0.009	0.127/0.229	0.015	0.381	
Rocker Arm Bushing to Shaft	0.004/0.006	0.102/0.152	0.012	0.305	
Intake Rocker Arm Assy. to Sub Cover (end clearance)	0.010/0.025	0.254/0.635	0.045	1.143	
Exhaust Rocker Arm Assy. to Sub Cover (end clearance)	0.005/0.015	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 1st Ring	0.030/0.050	0.762/1.270	— — —	— — —	Radial Clearance
Skirt — Bearing Surface	0.017/0.019	0.432/0.483	— — —	— — —	See liner replacement figures
Piston Ring End Gap					
Top Compression Ring (No. 1)	0.075/0.090	1.905/2.286	0.200	5.080	
Compression Ring (No. 2)	0.075/0.090	1.905/2.286	0.200	5.080	
Compression Ring (No. 3)	0.050/0.065	1.270/1.651	0.200	5.080	
Compression Ring (No. 4)	0.050/0.065	1.270/1.651	0.200	5.080	
Oil Control Ring (Upper)	0.035/0.060	0.889/1.524	0.200	5.080	
Oil Control Ring (Lower)	0.035/0.060	0.889/1.524	0.200	5.080	
Piston Ring Side Clearance in Groove					
Top Compression Ring (No. 1)	0.007/0.011	0.178/0.279	0.020	0.508	
Compression Ring (No. 2)	0.005/0.009	0.127/0.229	0.020	0.508	
Compression Ring (No. 3)	0.005/0.009	0.127/0.229	0.020	0.508	
Compression Ring (No. 4)	0.012/0.019	0.305/0.483	0.030	0.762	
Oil Control Ring (Upper)	0.003/0.007	0.076/0.178	0.020	0.508	
Oil Control Ring (Lower)	0.003/0.007	0.076/0.178	0.020	0.508	
Intake Valve Stem to Guide	0.005/0.007	0.127/0.178	0.012	0.305	
Intake Valve Guide Inlet Diameter to Guide	0.007/0.011	0.178/0.279	0.016	0.406	Dual fuel engines only
Gas Injection Piston Ring End Gap	0.0018/0.015	0.046/0.381	0.040 @ 1.500 dia.	1.016 @ 38.10 dia.	Dual fuel engines only
Exhaust Valve Stem to Guide (Upper)	0.006/0.008	0.152/0.203	— — —	— — —	See valve rocking test
Exhaust Valve Stem to Guide (Lower)	0.058/0.080	1.473/2.032	— — —	— — —	See valve rocking test
Exhaust Valve Rocking (movement) Test	0.012/0.017	0.305/0.432	0.045	1.143	See Section 6, Part 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	0.619/0.618	15.723/15.697	0.613	15.570	Lower shell
Main Bearing Thrust Rings	0.616/0.614	15.646/15.596	— — —	— — —	See: Crankshaft to Thrust Rings
Connecting Rod Bearing Shells	0.619/0.618	15.723/15.697	0.613	15.570	Upper shell
Camshaft Bearing Shells (intermediate)	0.208/0.207	5.283/5.258	0.202	5.131	Lower shell
Camshaft Bearing Thrust Flange	0.211/0.208	5.359/5.283	— — —	— — —	See: Camshaft Thrust Adjustment

APPENDIX III-1

GEAR SET AND BACKLASH CLEARANCES
MODEL RV ENGINE



ITEM	DESCRIPTION	GPL
1	CAMSHAFT GEAR, LEFT HAND	350
2	IDLER GEAR, LEFT HAND	355
3	CAMSHAFT GEAR, RIGHT HAND	350
4	IDLER GEAR, RIGHT HAND	355
5	CRANKSHAFT GEAR	310
6	LUBRICATING OIL PUMP DRIVE GEAR	355
7	LUBRICATING OIL PUMP DRIVEN GEAR	420
8	GOVERNOR & TACHOMETER DRIVE GEAR	411
9	GOVERNOR DRIVEN AND DRIVEN GEAR	411
10	FUEL OIL PUMP & OVERSPEED TRIP DRIVE GEAR	410
11	JACKET WATER PUMP DRIVE GEAR	425

POS.	BACKLASH	
	INCHES	CENTIMETERS
A	0.008 — 0.010	0.020 — 0.025
B	0.004 — 0.006	0.010 — 0.015
C	0.005 — 0.008	0.013 — 0.025

RV 74 Fuel Oil Booster Pump L.O. Pump Drive Gear

APPENDIX III-2
VALVE SPRINGS

Part Number: 03-360-02-OM

Direction of coils	Right hand
Active coils	10
Total coils	12
Load Rate	163.5 lbs/in.
Load at maximum working length	281/310 lbs.
Load at minimum working length	475/525 lbs.
Free length	9.060 in.
Maximum working length	7.250 in.
Minimum working length	6.000 in.
Solid length (ref.)	4.872 in.
Inside diameter	2-15/32 in.
Outside diameter	3-9/32 in.
Wire diameter	0.409/0.403 in.

APPENDIX IV

TORQUE TABLES
Model RV-4 Engine

The first portion of this torque table, Special Torque Values, applies to those nuts, bolts, capscrews and other threaded fasteners for which a specific torque value has been assigned. If no specific torque value is listed for a fastener, refer to the General Torque Values portion of the table, using the torque listed for the thread size of the item in question. All torque values are based upon the use of a thread lubricant consisting of a 50-50 mixture by volume of powdered graphite and engine lubricating oil. All torques are listed in both foot pounds and in kilograms per meter. Where applicable, bolt sizes in the special torque section are shown in parenthesis.

SPECIAL TORQUE VALUES

		Torque	
Item		ft-lb	kg-m
NUT, Foundation Bolt (heat treated steel)		3000*	415
NUT, Main Bearing Cap Stud (1¾")		3000**	415
NUT, Base to Crankcase Thru-Bolt		8000	1106
CAPSCREW, Crankcase to Base (1")		425	58.8
NUT, Cylinder Block to Crankcase Thru-Bolt (2½")		4500	622
NUT, Cylinder Block to Crankcase Thru-Bolt (2")		3000	425
NUT, Connecting Rod Bolt (1½")		1700	235
NUT, Connecting Rod Bolt (1⅞")		2600	359.5
BOLT, Link Connecting Rod to Link Pin (1¼")		1050	145.2
NUT, Cylinder Head Stud (2-8NC)		3600**	497.7
NUT, Fuel Injection Nozzle Retainer	Minimum	75***	10.37
	Maximum	80	11
NUT, Fuel Pump Stud		80	11
CAPSCREW, Fuel Pump Base (Allen)		120	16.6
CAPSCREW, Camshaft Bearing Cap		200	27.6
CAPSCREW, Idler Gear Mount Bracket		120	16.6
NUT, Flywheel Bolt		4500	622.3
NUT, Crankshaft Counter Weight (13" Crankpin)		2450	338.7
CAPSCREW, Rocker Shaft		365	50.5
CAPSCREW, Sub-Cover to Cylinder Head		120	16.6
Camshaft Gear Retainer Nut		1800	248.9
CAPSCREW, Air Start Valve to Cylinder Head		150***	20.74

*Heat treated bolts are identified by the figure "4" stamped on end of bolt.

**Not applicable if pre-stressing method is used.

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

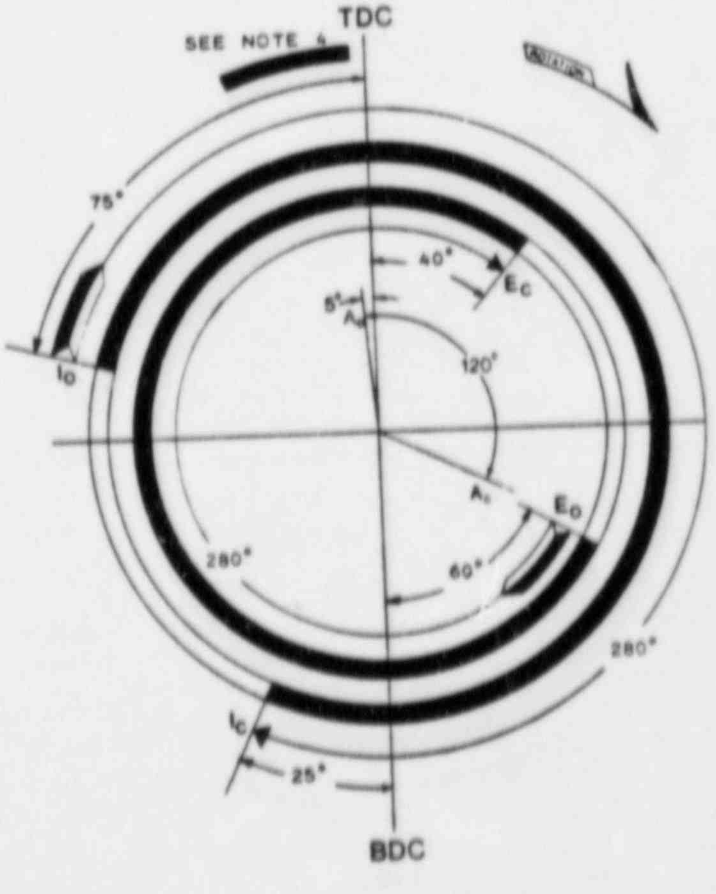
GENERAL TORQUE VALUES

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

Appendix V
Timing Diagram

ENGINE MODEL:	R/RV
ENGINE TYPE:	STATIONARY
FUEL:	DIESEL
ROTATION:	CLOCKWISE
INTAKE CAM:	02-350-04-OT
EXHAUST CAM:	02-350-06-AH



TDC	TOP DEAD CENTER
BDC	BOTTOM DEAD CENTER
I_O	INTAKE VALVE OPENS
I_C	INTAKE VALVE CLOSES
E_O	EXHAUST VALVE OPENS
E_C	EXHAUST VALVE CLOSES
A_O	AIR STARTING VALVE OPENS
A_C	AIR STARTING VALVE CLOSES

NOTES:
1. Diagram is in crankshaft degrees.
2. See engine data sheet in front of manual, or engine nameplate for firing order.
3. See engine nameplate for cylinder and bank designation.
4. See engine data sheet for diesel fuel injection point.

APPENDIX VI

LUBRICATING OIL RECOMMENDATIONS

The Transamerica Delaval Engine and Compressor Division does not recommend lubricants by brand name. The final measure of the quality of an oil is its performance in service. The lubricant supplier must work with the fuel oil supplier to insure the use of the proper lubricant. *The consistent quality and performance of a suitable heavy duty oil must, therefore, be the responsibility of the company making the lubricant.*

CAUTION

> It must be the concern of the operator to consult with the oil supplier concerning the proper selection of a lubricant which will perform compatibly with the type of fuel to be used in order to insure the most satisfactory performance and life with overall economical operation. In the case of unresolved questions, the Transamerica Delaval Engine and Compressor Division should be consulted.

To determine the condemning limits for oil in service, have the oil supplier take representative samples at regular intervals for oil analysis. His recommendations, then, for either further service or for condemnation will be based on qualitative factors. The following applies to new oil only.

RECOMMENDED LUBRICATING OIL CHARACTERISTICS

SAE GRADE 40 OIL

	Maximum	Minimum
Viscosity Index (ASTM D567)	–	70
Gravity, A.P.I. at 60°F (25.6°C) (ASTM D287)	30	20
Flash Point °F (ASTM D92)	–	425 (218° C)
Pour Point °F (ASTM D97)	–	10 (5.6° C) below coldest oil starting temperature

OIL RECOMMENDATIONS

DIESEL ENGINES (Using fuel oil with less than 1.05% sulfur):

Engines rated 205 bmep and below – API/SAE Classification "CC" or better.

Engines rated 206 bmep and above – API/SAE Classification "CD" or better.

APPENDIX VII

ALARMS AND SAFETY SHUTDOWNS

The following conditions are monitored by the systems protective network. Those items identified as shutdowns will stop the unit and open the generators circuit breaker in the EXERCISE or TESTING state only. Those items marked * will stop the unit even if running in response to a LOCA signal.

	FUNCTION	ALARM (Setting)	SHUTDOWN (Setting)
TEMPERATURES	High temperature Bearings	190° F	228° F
	High Temperature Jacket Water	190° F	200° F
	High Temperature Lubricating Oil	140° F	
	Low Temperature Lubricating Oil – IN	140° F	
	Low Temperature Lubricating Oil – OUT	175° F	
	High Temperature Lubricating Oil – IN	190° F	
	High Temperature Lubricating Oil – OUT	140° F	
	Low Temperature Jacket Water – IN	140° F	
	Low Temperature Jacket Water – OUT	175° F	
	High Temperature Jacket Water – IN	190° F	
	High Temperature Jacket Water – OUT		
PRESSURES	High Pressure Crankcase	.3 – .5 psir	3 psir
	Left Bank Turbocharger Oil Pressure Low	20 psif	15 psif
	Right Bank Turbocharger Oil Pressure Low	20 psif	15 psif
	Low Pressure Jacket Water	15 psif	10 psif
	Low Pressure Lubricating Oil	45 psif	30 psif
	Low Pressure Fuel Oil	20 psif	
	Control Air Pressure Low	60 psif	
	Starting Air Pressure Low	160 psif	
	High Differential Pressure – F.O. Filter	20 psir	
	High Differential Pressure – F.O. Strainer	20 psir	
	High Differential Pressure – Booster Pump Str.	20 psir	
	High Differential Pressure – L.O. Filter	20 psir	
	High Differential Pressure – L.O. Strainer	20 psir	

APPENDIX VII (Continued)

FUNCTION		ALARM (Setting)	SHUTDOWN (Setting)
MISCELLANEOUS	Voltage Regulation System	Trouble	
	Any Control Switch	Not in AUTO	
	Barring Device	Engaged	
	Fuel Day Tank Level	High/Low	
	Fuel Transfer Pump No. 2	Running	
	Generator Field Ground	Existing	
	Fuel Storage Tank Level (7 Day)	Low	
	Fuel Storage Tank Level (1 Day)	Low	
	Field Flash 125 VDC	Power Loss	
	Generator Stator Temperature	High	
	Jacket Water Standpipe Level	Low	
	Diesel Generator	Failure to Start	
	Fuel Pump/Overspeed Drive	Failure	
	Emergency Start Signal	Received	
	Diesel Generator Differential Relay	Trip	Trip
	Overspeed (115% above rated speed)	517.5 RPM	517.5 RPM
	Engine Vibration	Excessive	Excessive

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.

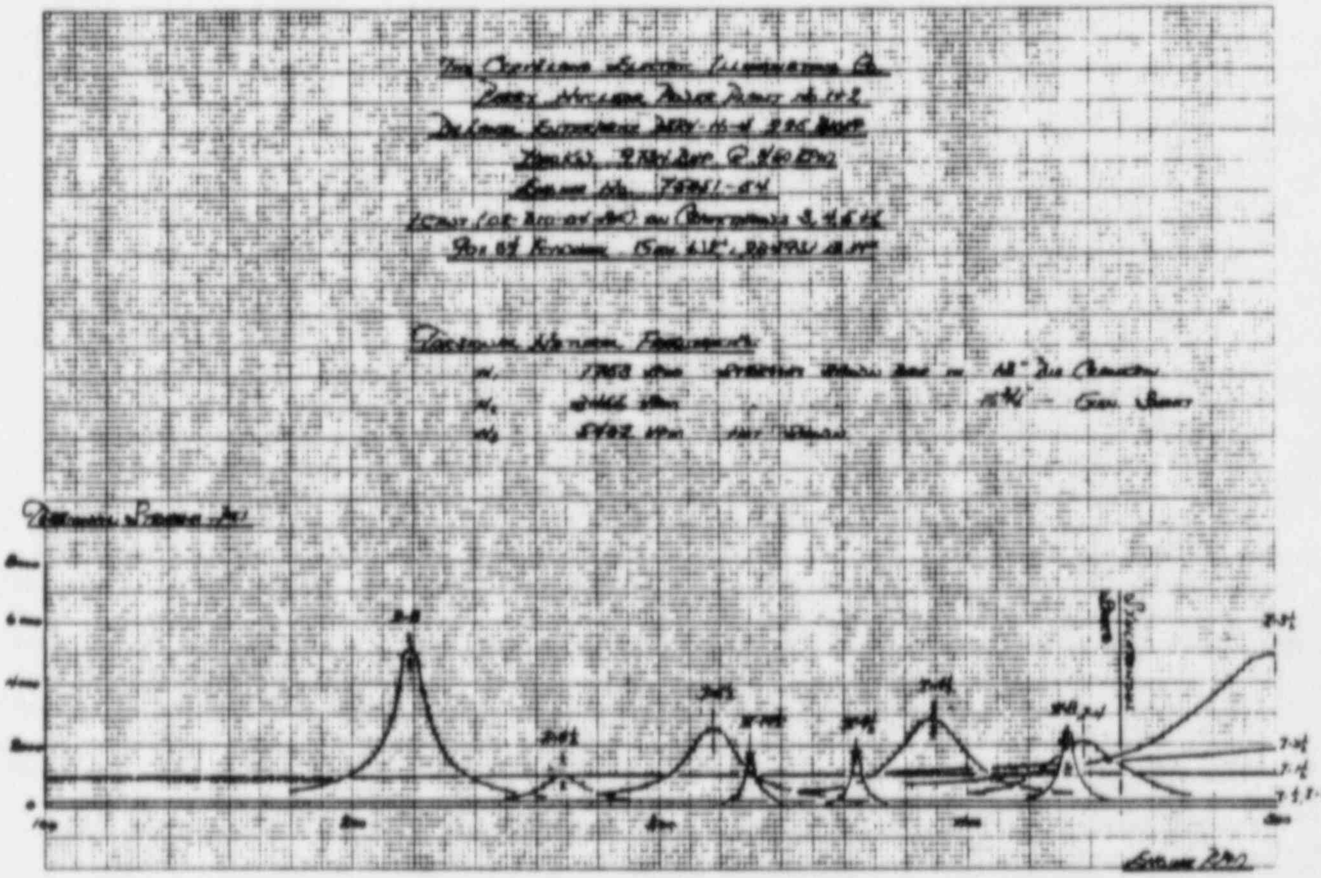
The above specification covers fuel oils classed as Grade F.S. No. 2.

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

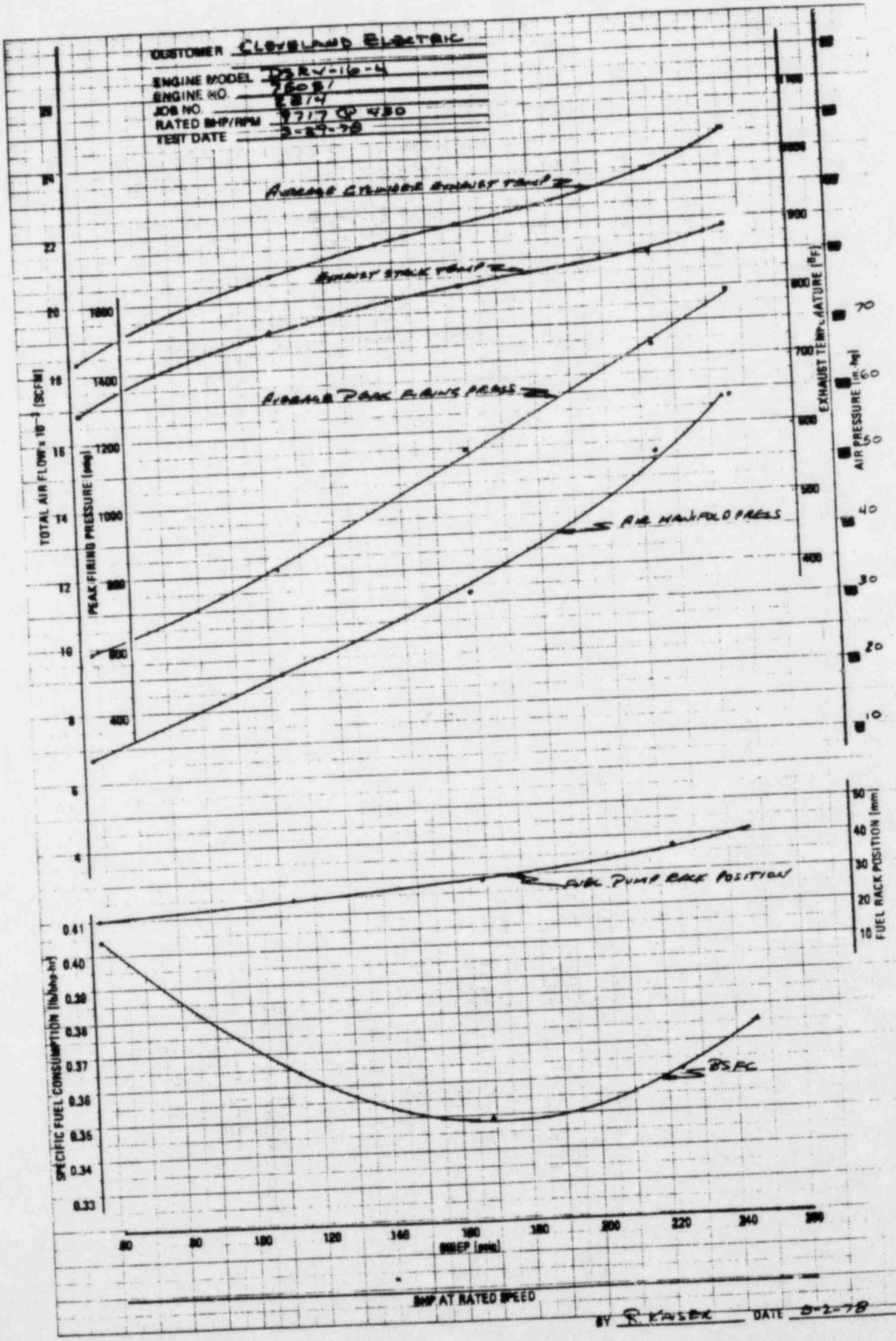
Copies of the Power Engine Factory Test Logs and a summary of the tests are provided in this appendix to assist operating personnel in becoming familiar with the operating characteristics of the engine(s). The data included is that recorded during the actual factory test of the engine. For ready reference, 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.)
75051-2814	51.0 IN.-HG	---	29.82 IN.-HG	74°F	974°F
75052-2815	49.5 IN.-HG	133°F	29.83 IN.-HG	71°F	973°F
75053-2816	48.0 IN.-HG	125°F	29.75 IN.-HG	75°F	982°F
75054-2817	49.4 IN.-HG	129°F	29.85 IN.-HG	62°F	958°F

47 1513



CUSTOMER Cleveland Electric

ENGINE MODEL DSRV-16-4

ENGINE NO. 76081

JOB NO. E814

RATED BHP/RPM 9717 @ 450

TEST DATE 3-29-78

BY R. Kaiser DATE 8-2-78

Form D-4261 (Diesel) (R-1) 8/76

DELAVAL ENGINE AND COMPRESSOR DIVISION, OAKLAND, CALIFORNIA

POWER ENGINE FACTORY TEST LOG

LOG 1 A

CUSTOMER CLEVELAND ELECTRIC MODEL DSRV-16-4 TEST STAND NUCLEAR JOB NO. 2814 ENGINE NO. 75051 FULL LOAD RATING 9717 BHP @ 450 RPM 224 BMEP

LINE	DATE	WALL CLOCK TIME ON LOAD	WALL CLOCK TIME THIS LOG	% LOAD (Rem.)	DYNAMOMETER LOAD DATA DYNA CONST RPM	SCALE (ft-lb)	BHP (Corr.)	BMEP	A.C. GENERATOR LOAD DATA KWHR METER CONST = DISC REVS	TIME (sec)	POWER FACTOR	A.C. VOLTS	A.C. AMPS	KW	GEN EFF	BHP (Corr.)	BMEP	GOV LOAD LIMIT
1	3-29	1900	2000	50	450						1.0	4160	485.7	3500	.955	4915	118.4	
2	3-29	2020	2120	75	450						1.0	4160	728.6	5250	.963	7311	169	
3	3-30	0300	0400	100	450						1.0	4160	971.5	7000	.966	9717	224	
4	3-30	0400	0500	100	450						1.0	4160	971.5	7000	.966	9717	224	
5	3-30	0505	0605	25	450						1.0	4[illegible]	242.9	1750	.943	2488	57.4	
6	3-30	0610	0710	110	450						1.0	4160	1068.7	7700	.966	10689	246	
7																		
8																		
9																		
10																		

FUEL PUMP RACK POSITION (MM)

LINE	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R
1	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5			24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5		
2	29.0	29.0	29.0	29.0	29.0	29.0	29.0	29.0			29.0	29.0	29.0	29.0	29.0	29.0	29.0	29.0		
3	37.0	37.0	37.0	37.0	37.0	37.0	37.0	37.0			37.0	37.0	37.0	37.0	37.0	37.0	37.0	37.0		
4	37.0	37.0	37.0	37.0	37.0	37.0	37.0	37.0			37.0	37.0	37.0	37.0	37.0	37.0	37.0	37.0		
5	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0			20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0		
6	41.0	41.0	41.0	41.0	41.0	41.0	41.0	41.0			41.0	41.0	41.0	41.0	41.0	41.0	41.0	41.0		
7																				
8																				
9																				
10																				

TURBOCHARGER PRESSURES

LINE	BLOWER INLET (in. H₂O) LF	RF	LR	RR	BLOWER DISCHARGE (in. hg) LF	RF	LR	RR	AIR MANIF. in. hg LB	RB	TURBINE INLET (in. hg) LF	RF	LR	RR	TURBINE EXHAUST (in. H₂O) LF	RF	LR	RR
1									20	20								
2									31.5	31.5								
3									50	50								
4									51	51								
5									8.5	8.5								
6									59	59								
7																		
8																		
9																		
10																		

TURBOCHARGER TEMPERATURES

LINE	BLOWER INLET (°F) LF	RF	LR	RR	BLOWER DISCHARGE (°F) LF	RF	LR	RR	AIR MANIF. (°F) LB	RB	AIR FLOW NOZZLE SIZE ► TURBOCHARGER RPM LF	RF	LR	RR	NOZZLE Δh (in. H₂O) LF	RF	LR	RR	AIR FLOW SCFM TOTAL	AMBIENT BARO (Corr.) in. hg	AMBIENT AIR (°F)
1																				29.82	
2																				29.82	
3																				29.82	
4																				29.82	
5																				29.82	
6																				29.82	
7																					
8																					
9																					
10																					

FUEL OIL DATA / DIESEL BSFC

LINE	MANIF. (psig)	API GRAVITY AS READ @ °F		API Corrected To 60°F	LHV (Btu/lb)	LBS MEAS	TIME (sec)	lb/hr	(Corr) gal/hr	(Corr) lb/bhp-hr
1	32.5	34.2	78	32.5	18535	1270	2574	1770.2	247.2	.364
2	30.8	34.9	79	32.8	18350	1020	1452	2528.9	352.7	.349
3	28.5	35.0	80	32.8	18350	1150	1187	3487.8	486.4	.362
4	28.5	35.3	82	32.8	18350	1100	1142	3467.6	483.6	.360
5	35.0	35.3	82	32.8	18350	360	1302	995.4	138.8	.404
6	27.5	35.5	82.5	32.8	18350	1100	997	3971.9	554.0	.375
7										
8										
9										
10										

FUEL GAS DATA / GAS BSFC / DUAL FUEL BSFC

LINE	MANIF. (psig or in. hg)	LHV Btu/ft³	TO GAS METER mfg (psi) in. hg	TO GAS METER °F	CORR. FACTOR	ft³ MEAS	TIME (sec)	ft³/hr (Corr.)	Btu/bhp-hr	PILOT Btu/bhp-hr	GAS Btu/bhp-hr	TOTAL Btu/bhp-hr	REMARKS
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													

INJECTION/IGNITION TIMING °BTDC 22 LB 21 RB

FUEL OIL SPEC MOBIL #2 DIESEL

LUBE OIL SPEC SHELL x 100 SAE 40

Form D 4173 (R 1) 9-74

AIR FLOW NOZZLE COEFFICIENT

LF ______ RF ______

LR ______ RR ______

(FLYWHEEL END)

OPERATOR G LEVERING

ENGINEER M. ESHELMAN

WITNESS

DATE 3-29-78

LOG NO 1 A

JOB NO 2814

Rx 5278

DELAVAL ENGINE AND COMPRESSOR DIVISION, OAKLAND, CALIFORNIA

POWER ENGINE FACTORY TEST LOG

LOG 1 8

CUSTOMER CLEVELAND ELECTRIC MODEL DSRV-16-4 TYPE SERVICE NUC. STBY. GEN JOB NO 2814 ENGINE NO 75051

DIRECTION OF ROTATION (AS VIEWED FROM FLYWHEEL END) CW

EXHAUST TEMPERATURES °F

LINE	TURBINE INLET (T - TOP, B - BOTTOM) LFTL	LFTR	LFB	RFT	RFB	LRT	LRB	RRTL	RRTR	RRB	TURBINE EXHAUST LF	RF	LR	RR	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	EXHAUST ELBOW 1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVE	LINE
1											720	790			800	797	818	867	774	735	761	784			835	898	892	941	763	943	830	962			838	1
2											781	842			875	903	906	974	837	799	797	826			880	998	952	1010	807	973	870	1033			903	2
3											842	864			960	1018	1009	995	949	731	928	953			941	1036	996	1004	913	986	971	1016			975	3
4											840	861			958	1015	1004	989	944	928	929	962			942	1032	994	1005	915	988	969	1016			974	4
5											634	647			723	705	722	731	700	673	720	695			713	705	743	687	764	720	721	769			718	5
6											877	899			1020	1070	1063	1039	1013	992	981	1025			1005	1084	1043	1053	956	1030	1017	1062			1028	6
7																																				7
8																																				8
9																																				9
10																																				10

FIRING PRESSURES - PSIG

LINE	ENGINE WATER PSIG TO ENGINE	TO ENGINE (°F)	FROM ENGINE (°F)	TURBOCHARGER WATER OUTLET (°F) LF	RF	LR	RR	AFTERCOOLER WATER INLET (°F) F	R	OUTLET (°F) F	R	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVE	LINE
1	12	153	162									820	830	820	820	830	800	780	820			800	800	770	890	800	820	790	860			816	1
2	11.5	161	178									1130	1150	1140	1150	1140	1140	1150	1130			1130	1140	1100	1240	1120	1160	1100	1220			1146	2
3	11.5	153	161									1430	1470	1460	1440	1500	1420	1430	1450			1470	1440	1390	1490	1470	1410	1420	1460			1447	3
4	11.5	160	166									1430	1460	1450	1440	1480	1400	1420	1440			1455	1480	1380	1475	1460	1390	1400	1400			1432	4
5	11.5	158	163									580	580	590	580	630	550	560	570			580	570	590	600	600	560	570	580			581	5
6	11.5	156	166									1570	1580	1570	1590	1620	1550	1560	1570			1610	1580	1520	1640	1615	1560	1580	1620			1583	6
7																																	7
8																																	8
9																																	9
10																																	10

LINE	LUBRICATING OIL PRESSURE - PSIG FROM PUMP	TO ENGINE	CAM HEADER	TO TURBOCHARGER LF	RF	LR	RR	LUBRICATING OIL TEMPERATURE °F TO ENGINE	FROM ENGINE	TURBOCHARGER DRAIN LF	RF	LR	RR	CRANK CASE PRESS " in H2O	REMARKS
1		51.5		28	25			157	175						
2		52.0		26.5	24.5			162	176						
3		52.0		26.5	28.5			158	177						
4		50.5		26.0	23.5			157	178						
5		50.0		28.0	25.0			165	172						
6		51.0		26.0	23.0			153	179						
7															
8															
9															
10															

LEGEND L, LB - LEFT BANK F - ENGINE FRONT AT NO. 1 CYLINDER
R, RB - RIGHT BANK R - ENGINE REAR, FLYWHEEL END
(WHEN VIEWED FROM FLYWHEEL END)

TURBOCHARGER MAKE & MODEL
LF EL BC090 RF EL BC090
LR RR

OPERATOR G. LEVERING
ENGINEER M. ESHELMAN
WITNESS

DATE 3-29-78
LOG 1 8
JOB NO 2814

RK 5278

Form D-4174 (R 1) 9-74

DELAVAL ENGINE AND COMPRESSOR DIVISION, OAKLAND, CALIFORNIA

POWER ENGINE FACTORY TEST LOG

LOG 1 A

CUSTOMER CLEVELAND ELECTRIC MODEL DSAV-16-4 TEST STAND NUCLEAR JOB NO. 2815 ENGINE NO. 75052 FULL LOAD RATING 9687 BHP @ 450 RPM 223 BMEP

LINE	DATE	WALL CLOCK TIME ON LOAD	WALL CLOCK TIME THIS LOG	% LOAD (Nom.)	DYNAMOMETER LOAD DATA DYNA CONST RPM	SCALE (ft lb)	BHP (Corr.)	BMEP	A.C. GENERATOR LOAD DATA KWHR METER CONST - DISC REVS	TIME (sec)	POWER FACTOR	A.C. VOLTS	A.C. AMPS	KW	GEN EFF	BHP (Corr.)	BMEP	GOV LOAD LIMIT
1	3-29	0110	0200	50	450	57364	4915	113										
2	3-29	0940	1040	75	450	85162	7296	168										
3	3-29	1115	1215	100	450	113058	9687	223										
4	3-29	1215	1315	100	450	113058	9687	223										
5	3-29	1320	1420	25	450	29143	2497	58										
6	3-29	1425	1525	110	450	124367	10656	245.8										
7																		
8																		
9																		
10																		

FUEL PUMP RACK POSITION (mm)

LINE	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R
1	26.5	26.5	26.5	26.5	26.5	26.5	26.5	26.5			26.5	26.5	26.5	26.5	26.5	26.5	26.5	26.5		
2	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5			30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5		
3	37	37	37	37	37	37	37	37			37	37	37	37	37	37	37	37		
4	37	37	37	37	37	37	37	37			37	37	37	37	37	37	37	37		
5	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5			20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5		
6	43.0	43.0	43.0	43.0	43.0	42.0	43.0	43.0			43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0		
7																				
8																				
9																				
10																				

TURBOCHARGER PRESSURES

LINE	BLOWER INLET (in. H2O) LF	RF	LR	RR	BLOWER DISCHARGE (in. hg) LF	RF	LR	RR	AIR MANIF in. hg LB	RB	TURBINE INLET (in. hg) LF	RF	LR	RR	TURBINE EXHAUST (in. H2O) LF	RF	LR	RR
1	5.7	6.2			20.0	20.2			20.1	20.1								
2	10.0	10.4			33.1	33.4			32.8	32.9								
3	16.9	17.4			49.9	50.0			49.2	49.8								
4	16.2	16.8			49.9	49.9			49.2	49.8								
5	3.1	3.1			8.5	8.5			8.4	8.4								
6	19.2	20.3			56.0	54.9			55.8	55.9								
7																		
8																		
9																		
10																		

TURBOCHARGER TEMPERATURES · AIR FLOW NOZZLE SIZE ▶

LINE	BLOWER INLET (°F) LF	RF	LR	RR	BLOWER DISCHARGE (°F) LF	RF	LR	RR	AIR MANIF (°F) LB	RB	TURBOCHARGER RPM LF	RF	LR	RR	NOZZLE Δh (in. H2O) LF	RF	LR	RR	AIR FLOW SCFM TOTAL	AMBIENT BARO (Corr) in hg	AIR (°F)
1	72	68			186	187			128	129					5.9	6.0			14177	29.78	72
2	68	66			221	237			129	129					10.1	10.7			18828	29.83	68
3	71	67			305	303			128	129					16.1	17.2			23759	29.84	71
4	72	69			309	306			133	133					15.8	16.8			23505	29.83	71
5	73	71			133	136			131	131					3.0	3.0			5033	29.83	73
6	75	71			334	338			129	131					18.4	20.0			25412	29.83	75
7																					
8																					
9																					
10																					

LINE	FUEL OIL DATA MANIF (psig)	API GRAVITY AS READ @ °F		API Corrected To 60°F	LHV (Btu/lb)	DIESEL BSFC LBS MEAS	TIME (sec)	lb/hr	(Corr) gal/hr	(Corr) lb/bhp hr	FUEL GAS DATA MANIF (psig or in. hg)	LHV Btu/ft³	TO GAS METER psig (or) in. hg	°F	CORR FACTOR	GAS BSFC ft³ MEAS	TIME (sec)	ft³/hr (Corr)	Btu/bhp-hr	DUAL FUEL BSFC PILOT Btu/bhp-hr	GAS Btu/bhp-hr	TOTAL Btu/bhp-hr
1	36.0	34.5	72	33.7	18350	610	1206	1821	255.4	.374												
2	38.5	34.8	76	33.7	18350	1700	2425	2524	340.1	.349												
3	36.5	34.6	73	33.7	18350	1700	1775	3448	483.6	.359												
4	36.5	34.7	75	33.6	18345	1700	1779	3440	482.1	.358												
5	42.5	34.7	75	33.6	18345	670	2443	987	138.4	.399												
6	35.5	35.3	82	33.8	18355	1700	1591	3847	539.9	.364												
7																						
8																						
9																						
10																						

REMARKS

INJECTION/IGNITION TIMING °BTDC 22° LB 21° RB

FUEL OIL SPEC #2 DIESEL - STANDARD

LUBE OIL SPEC X-100 - 40wt SHELL

Form D-4173 (R 1) 8-74

AIR FLOW NOZZLE COEFFICIENT

LF 12283 RF 12283

LR RR

(FLYWHEEL END)

OPERATOR G. MEIER / R. VITAL

ENGINEER R. KAISER

WITNESS R. Holler - GILBERT ASSOCIATES INC.

DATE 3-29-78

LOG NO. 1 A

JOB NO. 2815

DELAVAL ENGINE AND COMPRESSOR DIVISION OAKLAND, CALIFORNIA

POWER ENGINE FACTORY TEST LOG

LOG 1 B

CUSTOMER CLEVELAND ELECTRIC MODEL DSRV-16-4 TYPE SERVICE NUCLEAR STANDBY JOB NO 2815 ENGINE NO 75052 DIRECTION OF ROTATION (AS VIEWED FROM FLYWHEEL END) CW

EXHAUST TEMPERATURES - °F

LINE	TURBINE INLET (T - TOP, B - BOTTOM)										TURBINE EXHAUST			
	LFTL	LFTR	LFB	RFT	RFB	LRT	LRB	RRTL	RRTR	RRB	LF	RF	LR	RR
1											640	638		
2											662	668		
3											701	711		
4												718		
5												501		
6												748		
7														
8														
9														
10														

LINE	EXHAUST ELBOWS																				
	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1	802	780	791	854	835	811	842	839			809	809	810	835	827	875	806	862			829
2	887	872	883	929	847	870	847	894			830	907	880	957	824	943	801	946			883
3	956	992	1005	984	918	963	919	946			926	1012	970	1036	954	1009	939	979			969
4	961	1004	1012	990	922	959	921	951			932	1013	974	1035	956	1012	941	982			973
5	694	691	674	707	720	709	722	713			676	669	715	666	742	693	694	675			698
6	1002	1047	1054	1023	960	1005	956	992			979	1060	1024	1080	1004	1047	995	1019			1015
7																					
8																					
9																					
10																					

LINE	ENGINE WATER			TURBOCHARGER WATER OUTLET (°F)				AFTERCOOLER WATER			
								INLET (°F)		OUTLET (°F)	
	PSIG TO ENGINE	TO ENGINE (°F)	FROM ENGINE (°F)	LF	RF	LR	RR	F	R	F	R
1	26	163	166	168	168			141		143	
2	24	161	166		168			139		141	
3	24	167	173		176			138		140	
4	24	170	176		178			133		145	
5	24	158	161		161			100		103	
6	24	169	176		178			141		145	
7											
8											
9											
10											

LINE	FIRING PRESSURES - PSIG																				
	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1	880	880	880	875	880	870	870	880			870	840	850	820	850	890	840	890			870
2	1180	1180	1150	1140	1170	1170	1150	1170			1160	1160	1160	1190	1120	1210	1120	1220			1170
3	1480	1510	1480	1490	1490	1510	1490	1480			1610	1510	1530	1520	1520	1530	1590	1620			1500
4	1480	1510	1480	1440	1490	1510	1490	1480			1510	1510	1530	1620	1520	1530	1590	1520			1500
5	600	610	590	580	620	620	600	590			590	590	610	600	600	600	600	590			600
6	1580	1620	1590	1580	1600	1600	1560	1580			1620	1610	1620	1610	1630	1620	1630	1640			1610
7																					
8																					
9																					
10																					

LINE	LUBRICATING OIL PRESSURE - PSIG							LUBRICATING OIL TEMPERATURE °F						CRANK CASE PRESS	REMARKS
				TO TURBOCHARGER						TURBOCHARGER DRAIN					
	FROM PUMP	TO ENGINE	CAM HEADER	LF	RF	LR	RR	TO ENGINE	FROM ENGINE	LF	RF	LR	RR	" in H2O	
1	58	65		35.5	33.0			158	173					-1.9	
2	57.5	54		34.0	32.0			159	173					-1.5	
3	57.5	64		33.5	31.8			159	177					-1.5	
4	57	64		33.0	32.0			161	181					-1.5	
5	58	55		35.5	33.7			158	169					-1.9	
6	57	54		33.0	31.5			160	180					-1.2	
7															
8															
9															
10															

LEGEND: L, LB - LEFT BANK; F - ENGINE FRONT AT NO. 1 CYLINDER
R, RB - RIGHT BANK; R - ENGINE REAR FLYWHEEL END
(WHEN VIEWED FROM FLYWHEEL END)

TURBOCHARGER MAKE & MODEL
LF EL BC090 RF EL BC090
LR RR

OPERATOR G. MEIER / R. VITAL
ENGINEER R. KAISER
WITNESS R. Holler - GILBERT ASSOCIATES INC.

DATE 3-29-78
LOG 1 B
JOB NO 2815

ME 5/12/78

Form D-8174 (R-1) 9-74

DELAVAL ENGINE AND COMPRESSOR DIVISION, OAKLAND, CALIFORNIA

POWER ENGINE FACTORY TEST LOG

LOG 1 A

CUSTOMER CLEVELAND ELECTRIC MODEL DSRV-16-4 TEST STAND 23 JOB NO. 2816 ENGINE NO 75053

FULL LOAD RATING 9687 BHP @ 450 RPM 223 BMEP

LINE	DATE	WALL CLOCK TIME ON LOAD	WALL CLOCK TIME THIS LOG	% LOAD (Nom.)	DYNAMOMETER LOAD DATA (DYNA CONST) RPM	SCALE (lb)	BHP (Corr.)	BMEP	A.C. GENERATOR LOAD DATA (KWHR METER CONST -) DISC REVS	TIME (sec)	POWER FACTOR	A.C. VOLTS	A.C. AMPS	KW	GEN EFF	BHP (Corr.)	BMEP	GOV LOAD LIMIT
1	5/3	1350	1450	25	210	29143	1165	58										
2	5/4	1035	1135	25	270	29143	1498	58										
3	5/4	1140	1240	25	380	29143	2109	58										
4	5/4	1245	1345	50	400	57368	4369	113										
5	5/4	1350	1450	50	450	57368	4915	113										
6																		
7	5/4	1455	1555	75	450	85152	7296	168										
8	5/4	1600	1700	100	450	113058	9687	223										
9	5/4	1700	1800	100	450	113058	9687	223										
10	5/5	0810	0910	25	450	29143	2492	58										

FUEL PUMP RACK POSITION (MM)

LINE	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R
1	19	19	19	19	19	19	19	19			19	19	19	19	19	19	19	19		
2	19	19	19	19	19	19	19	19			19	19	19	19	19	19	19	19		
3	20	20	20	20	20	20	20	20			20	20	20	20	20	20	20	20		
4	26	26	26	26	26	26	26	26			26	26	26	26	26	26	26	26		
5	26.5	26.5	26.5	26.5	26.5	26.5	26.5	26.5			26.5	26.5	26.5	26.5	26.5	26.5	26.5	26.5		
6																				
7	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5			30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5		
8	38	38	38	38	38	38	38	38			38	38	38	38	38	38	38	38		
9	38	38	38	38	38	38	38	38			38	38	38	38	38	38	38	38		
10	21	21	21	21	21	21	21	21			21	21	21	21	21	21	21	21		

TURBOCHARGER PRESSURES

LINE	BLOWER INLET (in. H₂O) LF	RF	LR	RR	BLOWER DISCHARGE (in. hg) LF	RF	LR	RR	AIR MANIF in. hg LB	RB	TURBINE INLET (in. hg) LF	RF	LR	RR	TURBINE EXHAUST (in. H₂O) LF	RF	LR	RR
1	.5	.6			.7	.7			.8	.8								
2	1.1	1.1			2.3	2.3			2.2	2.2								
3	2.0	2.0			5.6	5.6			5.3	5.3								
4	4.4	4.9			15.7	15.8			15.2	15.2								
5	5.9	6.1			19.3	20.0			19.0	19.0								
6	10.0 ↓	10.6 ↓			32.1 ↓	32.3 ↓			32.3 ↓	32.2 ↓								
7																		
8	16.5	16.9			47.2	49.9			47.9	49.9								
9	16.5	16.9			47.2	48.8			48.0	48.0								
10	2.7	3.0			8.1	8.5			8.0	8.0								

TURBOCHARGER TEMPERATURES

AIR FLOW NOZZLE SIZE ▶ 12" 12"

LINE	BLOWER INLET (°F) LF	RF	LR	RR	BLOWER DISCHARGE (°F) LF	RF	LR	RR	AIR MANIF (°F) LB	RB	TURBOCHARGER RPM LF	RF	LR	RR	NOZZLE Δh (in. H₂O) LF	RF	LR	RR	AIR FLOW SCFM TOTAL	AMBIENT BARO (Corr.) in. hg	AMBIENT AIR (°F)
1	75	75			84	85			83	82					.6	.5			4344	29.85	~~[illegible]~~
2	72	71			94	94			93	92					1.1	1.0			5964	29.83	72
3	73	73			116	115			110	112					2.8	2.0			8219	29.83	73
4	75	75			169	172			124	125					4.3	4.7			12303	29.82	75
5	76	76			190	193			130	133					5.6	6.0			13950	29.80	76
6	75 ↓	75 ↓			248 ↓	251 ↓			130 ↓	136 ↓					10.0 ↓	10.5 ↓				29.80 ↓	75 ↓
7																			18562		
8	76	76			315	316			118	133					16.0	16.6			23366	29.75	76
9	75	75			310	313			117	132					16.1	16.7			22403	29.75	75
10	68	68			124	128			119	125					2.7	2.8			9686	29.85	68

FUEL OIL DATA / DIESEL BSFC

LINE	MANIF. (psig)	API GRAVITY AS READ @ °F		API Corrected To 60°F	LHV (Btu/lb)	LBS MEAS	TIME (sec)	lb/hr	Btu/bhp-hr	(Corr) lb/bhp-hr
1	47.5									
2	46.0									
3	42.0									
4	37.5									
5	36.5	35.2	86	18140	18360	1310	2713	1738		.357 = 236.8 Gals HR.
6	37.0			18140						
7	37.0	35.2	86	18140	18360	1520	2160	2533		.350 = 345.1 Gals HR
8	34.5	35.	84	18190	18360	1500	1580	3416		.356 = 465.6 Gals HR.
9	34.5	35	84	18190	18360	1520	1593	3435		.358 467.9 Gals HR.
10	43.0	34.5	74	18190	18365	720	2690	964		.390 135.7 Gals HR.

FUEL GAS DATA: MANIF. (psig or in. hg) | LHV Btu/ft³ | TO GAS METER psig (or) in. hg | °F | CORR FACTOR | ft³ MEAS

GAS BSFC: TIME (sec) | ft³/hr (Corr.) | Btu/bhp-hr

DUAL FUEL BSFC: PILOT Btu/bhp-hr | GAS Btu/bhp-hr | TOTAL Btu/bhp-hr

REMARKS

2255-2310 15 MIN HT CHECK OK.

Dyno watermotor burn out - install A new motor-

Drop SPEED + LOAD FOR cold compression-

INJECTION/IGNITION TIMING °BTDC 22° LB 21° RB

FUEL OIL SPEC #2 DIESEL

LUBE OIL SPEC SHELL V100 40 WT

AIR FLOW NOZZLE COEFFICIENT LF 12283 RF 12283 LR RR (FLYWHEEL END)

OPERATOR

ENGINEER

WITNESS 5/5/78

DATE 5-2-78

LOG NO 1 A

JOB NO 2816

Form D-173 (R 1) 4/74

DELAVAL ENGINE AND COMPRESSOR DIVISION, OAKLAND, CALIFORNIA

POWER ENGINE FACTORY TEST LOG

LOG 1 B

CUSTOMER CLEVELAND, ELECTRIC MODEL DSRV-16-4 TYPE SERVICE GEN. JOB NO 2816 ENGINE NO 75053 DIRECTION OF ROTATION (AS VIEWED FROM FLYWHEEL END) CW

EXHAUST TEMPERATURES - °F

LINE	TURBINE INLET (T - TOP, B - BOTTOM) LFTL	LFTR	LFB	RFT	RFB	LRT	LRB	RRTL	RRTR	RRB	TURBINE EXHAUST LF	RF	LR	RR	EXHAUST ELBOWS 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1												427			493	493	514	489	503	505	456	487			550	528	502	525	501	499	498	485			502
2											468	479			502	513	529	508	537	528	477	510			560	536	521	556	523	530	539	521			523
3											541	550			575	601	618	602	614	622	562	600			648	621	606	646	601	620	612	622			611
4											691	711			703	956	775	748	756	786	710	740			771	770	757	846	713	790	753	767			757
5											726	747			714	805	859	845	844	842	789	816			860	839	792	882	817	882	788	822			827
6											788	801			817	900	945	940	891	915	845	883			904	927	864	927	845	966	829	907			890
7											↓	↓			↓	↓	↓	↓	↓	↓	↓	↓			↓	↓	↓	↓	↓	↓	↓	↓			↓
8											839	845			995	1014	1048	1002	958	989	933	965			943	1003	959	1053	951	1023	928	982			981
9											832	838			935	1004	1036	996	950	976	987	959			938	990	955	1045	937	1017	917	975			972
10											589	602			617	662	693	669	696	688	632	663			714	690	668	717	686	698	678	677			678

LINE	ENGINE WATER PSIG TO ENGINE	TO ENGINE (°F)	FROM ENGINE (°F)	TURBOCHARGER WATER OUTLET (°F) LF	RF	LR	RR	AFTERCOOLER WATER INLET (°F) F	R	OUTLET (°F) F	R
1	8	98	99	100	101						
2	9	150	151	152	152			75		84	
3	23	159	161	161	161			75		84	
4	235	159	162	162	163			118		128	
5	25	160	163	163	164			130		144	↑
6	25	160	165	165	166			11			
7	25	160	165	165	166			118		157	
8	25	163	169	169	170			104		158	
9	25	160	166	166	167			104		157	
10	24	158	160	159	161			74		83	

FIRING PRESSURES - PSIG

LINE	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1	620	600	610	600	590	420	580	610			600	600	560	590	570	570	560	590			579
2	630	590	590	590	545	590	600	600			600	590	580	560	580	580	580	600			592
3	600	595	605	590	590	580	580	600			600	580	560	600	560	580	560	580			585
4	820	800	800	810	820	800	800	820			830	840	820	820	820	840	840	830			819
5	~~900~~	~~880~~	~~880~~	~~880~~	~~840~~	~~840~~	~~820~~	~~840~~			~~820~~	~~840~~	~~840~~	~~840~~	~~840~~	~~880~~	~~820~~	~~840~~			
6	820	840	840	840	840	800	820	840		↑	840	840	840	800	840	840	820	840			831
7	1180	1160	1170	1160	1160	1140	1140	1140			1180	1120	1120	1140	1140	1120	1140	1140			1147
8	1520	1500	1500	1490	1480	1470	1470	1480			1440	1480	1440	1460	1460	1460	1440	1460			1476
9	1500	1480	1470	1470	1470	1480	1470	1480			1440	1480	1440	1460	1470	1460	1440	1460			1470
10	560	580	560	560	560	560	580	580			580	580	540	560	560	560	540	560			564

LINE	LUBRICATING OIL PRESSURE - PSIG FROM PUMP	TO ENGINE	CAM HEADER	TO TURBOCHARGER LF	RF	LR	RR	LUBRICATING OIL TEMPERATURE °F TO ENGINE	FROM ENGINE	TURBOCHARGER DRAIN LF	RF	LR	RR	CRANK CASE PRESS " in H2O
1	62	57.5		32.5	32.5			95	96					2.0
2	55	52		32.5	32.0			147	198					-3.1
3	57.5	54		34.0	33.0			159	166					-3.0
4	56.5	53		32.5	31.5			159	170					-2.8
5	55.0	52.5		31.5	31.0			159	174					-2.8
6														
7	55	52		30.5	30.0			159	176					2.4
8	57.5	54		31	31			159	180					-2.1
9	56.5	55		31.5	31.5			158	178					-2.1
10	58.5	55		34.5	33.0			155	159					-2.8

REMARKS

2 #6LR Firing press. has been corrected

10 1815 SHUT DOWN UNIT TO CHECK NOISY VALVES Cyl 2+3RB + 2L.B. CHANGING VALVE SPRINGS AS PER. HAL HENDRICKS.

LEGEND L, LB - LEFT BANK F - ENGINE FRONT AT NO. 1 CYLINDER
R, RB - RIGHT BANK R - ENGINE REAR FLYWHEEL END
(WHEN VIEWED FROM FLYWHEEL END)

TURBOCHARGER MAKE & MODEL
LF ______ RF ______
LR ______ RR ______
BB - Brown Boveri [illegible]

OPERATOR ______
ENGINEER ______
WITNESS 5/3/78

DATE 5-2-78
LOG 1 B
JOB NO 2816

Form D-4174 (R-1) 8/74

DELAVAL ENGINE AND COMPRESSOR DIVISION, OAKLAND, CALIFORNIA

POWER ENGINE FACTORY TEST LOG

LOG 2 A

CUSTOMER CLEVELAND

MODEL DSRV-16-4

TEST STAND 23

JOB NO 2816

ENGINE NO 75053

FULL LOAD RATING 9687 BHP @ 450 RPM 223 BMEP

LINE	DATE	WALL CLOCK TIME ON LOAD	WALL CLOCK TIME THIS LOG	% LOAD (Nom.)	DYNAMOMETER LOAD DATA RPM	SCALE (ft-lb)	BHP (Corr.)	BMEP	A.C. GENERATOR LOAD DATA DISC REVS	TIME (sec)	POWER FACTOR	A.C. VOLTS	A.C. AMPS	KW	GEN EFF	BHP (Corr.)	BMEP	GOV LOAD LIMIT
1	5/5	0920	0945	110	450	124367	10656	245.8										
2	5/5	1000	1100	110	450	124367	10656	245.8										
3	5/5	1110		0	450	0	0	0										
4																		
5																		
6																		
7																		
8																		
9																		
10																		

FUEL PUMP RACK POSITION (MM)

LINE	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R
1											44	44	44	44	44	44	44	44		
2	44	44	44	44	44	44	44	44			44	44	44	44	44	44	44	44		
3	44	44	44	44	44	44	44	44			11	11	11	11	11	11	11	11		
4	11	11	11	11	11	11	11	11												
5																				
6																				
7																				
8																				
9																				
10																				

END OF SHOP Test

TURBOCHARGER PRESSURES

LINE	BLOWER INLET (in. H2O) LF	RF	LR	RR	BLOWER DISCHARGE (in. Hg) LF	RF	LR	RR	AIR MANIF. in. Hg LB	RB	TURBINE INLET (in. Hg) LF	RF	LR	RR	TURBINE EXHAUST (in. H2O) LF	RF	LR	RR
1	20.0	20.5			58.4	58.7			57.2	57.1								
2	20.1	20.6			58.4	58.6			57.2	57.1								
3	1.4	1.4			2.3	2.3			2.2	2.2								
4																		
5																		
6																		
7																		
8																		
9																		
10																		

TURBOCHARGER TEMPERATURES / AIR FLOW NOZZLE SIZE ▶

LINE	BLOWER INLET (°F) LF	RF	LR	RR	BLOWER DISCHARGE (°F) LF	RF	LR	RR	AIR MANIF. (°F) LB	RB	TURBOCHARGER RPM LF	RF	LR	RR	NOZZLE Δh (in. H2O) LF	RF	LR	RR	AIR FLOW SCFM TOTAL	AMBIENT BARO (Corr.) in. Hg	AIR (°F)
1	71	73			341	345			134	135					19.5	20.1			25889	29.84	71
2	69	70			342	346			129	142					19.6	20.4			26015	29.83	69
3	70	71			103	104			112	114					1.3	1.2			6641	29.82	70
4																					
5																					
6																					
7																					
8																					
9																					
10																					

LINE	FUEL OIL DATA [illegible]	API GRAVITY AS READ @ °F		API Corrected To 60°F	LHV (Btu/lb)	DIESEL BSFC LBS MEAS	TIME (sec)	lb/hr	lbs/bhp-hr	(Corr.) lb/bhp-hr	FUEL GAS DATA [illegible]	LHV	TO GAS METER [illegible]	°F	CORR. FACTOR	GAS BSFC ft³ MEAS	TIME (sec)	ft³/hr (Corr.)	Btu/bhp-hr	DUAL FUEL BSFC PILOT Btu/bhp-hr	GAS Btu/bhp-hr	TOTAL Btu/bhp-hr
1	34.0	35.0	83	18190	18360																	
2	34.0	35.0	84	18190	18360	1600	1601	3398		.341	=	508.8	Gal HR.									
3	44.5	34.7	76	18190	18350	70	1155															
4																						
5																						
6																						
7																						
8																						
9																						
10																						

REMARKS

Unit shut Down High J.W. Trip
SET GOV - Got OVERSPEED
517-516-507
Check ALL 4 Air start Valves
OK [illegible]
Ran tycle in Fuel System

INJECTION/IGNITION TIMING °BTDC 22° LB 20° RB
FUEL OIL SPEC #2 Diesel standard
LUBE OIL SPEC X-100 40wt Shell

AIR FLOW NOZZLE COEFFICIENT
LF 12283 RF 12253
LR RR
(FLYWHEEL END)

OPERATOR Gurmeurz
ENGINEER Henrichs
WITNESS Roy Bolling 5/5/78

DATE 5-5-78
LOG NO 2 A
JOB NO 2816

Form D-4173 (R-1) 8/74

DELAVAL ENGINE AND COMPRESSOR DIVISION, OAKLAND, CALIFORNIA

POWER ENGINE FACTORY TEST LOG LOG R B

CUSTOMER CLEVELAND MODEL DSRV-16-4 TYPE SERVICE GEN JOB NO 2816 ENGINE NO 75053 DIRECTION OF ROTATION (AS VIEWED FROM FLYWHEEL END) CCW

EXHAUST TEMPERATURES - °F

LINE	TURBINE INLET (T - TOP, B - BOTTOM) LFTL	LFTR	LFB	RFT	RFB	LRT	LRB	RRTL	RRTR	RRB	TURBINE EXHAUST LF	RF	LR	RR
1											856	865		
2											856	863		
3											381	380		
4														
5														
6														
7														
8														
9														
10														

LINE	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	EXHAUST ELBOW 1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1	972	1063	1083	1022	990	1024	973	990			963	1079	1018	1080	990	1058	975	997			1016
2	907	1063	1082	1019	983	1020	970	987			967	1074	1016	1086	974	1058	977	1000			1015
3	339	360	358	384	359	360	301	326			381	360	343	361	335	339	324	312			346
4																					
5																					
6																					
7																					
8																					
9																					
10																					

LINE	ENGINE WATER PSIG TO ENGINE	TO ENGINE (°F)	FROM ENGINE (°F)	TURBOCHARGER WATER OUTLET (°F) LF	RF	LR	RR	AFTERCOOLER WATER INLET (°F) F	R	OUTLET (°F) F	R
1	25	166	172	172	173			104		167	
2	25	166	173	173	174			104		169	
3	25	159	160	160	160			100		106	
4											
5											
6											
7											
8											
9											
10											

FIRING PRESSURES - PSIG

LINE	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1	1580	1580	1600	1580	1560	1560	1580	1580			1600	1580	1580	1560	1570	1570	1560	1570			1578
2	400	410	400	420	400	400	410	400			440	420	420	420	420	420	420	420			414
3																					
4																					
5																					
6																					
7																					
8																					
9																					
10																					

LINE	LUBRICATING OIL PRESSURE - PSIG FROM PUMP	TO ENGINE	CAM HEADER	TO TURBOCHARGER LF	RF	LR	RR	LUBRICATING OIL TEMPERATURE °F TO ENGINE	FROM ENGINE	TURBOCHARGER DRAIN LF	RF	LR	RR	CRANK CASE PRESS " in. H₂O	REMARKS
1	58	54		31.2	31.5			158	178					-1.6	
2	58.5	55		32.0	31.0			158	178					-1.6	
3	61.5	58		36.5	35.5			158	167					-3.2	
4															
5															
6															
7															
8															
9															
10															

LEGEND L, LB - LEFT BANK F - ENGINE FRONT AT NO. 1 CYLINDER
R, RB - RIGHT BANK R - ENGINE REAR FLYWHEEL END
(WHEN VIEWED FROM FLYWHEEL END)

TURBOCHARGER MAKE & MODEL
LF ___ RF ___
LR ___ RR ___

OPERATOR
ENGINEER
WITNESS 5/5/78

DATE 5-5-78
LOG R B
JOB NO 2816

Form D-4174 (R 1) 9-74

DELAVAL ENGINE AND COMPRESSOR DIVISION, OAKLAND, CALIFORNIA

POWER ENGINE FACTORY TEST LOG LOG 1 A

CUSTOMER CLEVELAND MODEL DSRV-16-4 TEST STAND 23 JOB NO 2817 ENGINE NO 75054 FULL LOAD RATING 9687 BHP @ 450 RPM 223 BMEP

LINE	DATE	WALL CLOCK TIME ON LOAD	WALL CLOCK TIME THIS LOG	% LOAD (Rated)	DYNAMOMETER LOAD DATA RPM	SCALE (lb)	BHP (Corr)	BMEP	A.C. GENERATOR LOAD DATA DISC REVS	TIME (sec)	POWER FACTOR	A.C. VOLTS	A.C. AMPS	KW	GEN EFF	BHP (Corr)	BMEP	GOV LOAD LIMIT	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	LINE
1	5/19	1430	1530	25	210	29143	1165	58											19	19	19	19	19	19	19	19			19	19	19	19	19	19	19	19			1
2	5/19	2215	2315	25	270	29143	1498	58											19	19	19	19	19	19	19	19			19	19	19	19	19	19	19	19			2
3	5/19	2345	2415	25	380	29143	2109	58											19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5			19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5			3
4	5/20	2415	0115	50	400	57364	4367	113											25	25	25	25	25	25	25	25			25	25	25	25	25	25	25	25			4
5	5/20	0120	0220	50	450	573[illegible]	4915	113											26	26	26	26	26	26	26	26			26	26	26	26	26	26	26	26			5
6	5/20	0225	0325	75	450	85132	7296	168											30	30	30	30	30	30	30	30			30	30	30	30	30	30	30	30			6
7	5/20	0330		100	450	113058	9687	223																															7
8	5/20	0705	0805	100	450	113058	9687	223											38	38	38	38	38	38	38	38			38	38	38	38	38	38	38	38			8
9	5/20	0805	0905	100	450	113058	9687	223											38	38	38	38	38	38	38	38			38	38	38	38	38	38	38	38			9
10	5/20	0910	1010	25	450	29143	2492	58											21	21	21	21	21	21	21	21			21	21	21	21	21	21	21	21			10

FUEL PUMP RACK POSITION (MM)

TURBOCHARGER PRESSURES / TURBOCHARGER TEMPERATURES — AIR FLOW NOZZLE SIZE ▶ 12 in.

LINE	BLOWER INLET (in. H2O) LF	RF	LR	RR	BLOWER DISCHARGE (in. Hg) LF	RF	LR	RR	AIR MANIF in. Hg LB	RB	TURBINE INLET (in. Hg) LF	RF	LR	RR	TURBINE EXHAUST (in. H2O) LF	RF	LR	RR	BLOWER INLET (°F) LF	RF	LR	RR	BLOWER DISCHARGE (°F) LF	RF	LR	RR	AIR MANIF. (°F) LB	RB	TURBOCHARGER RPM LF	RF	LR	RR	NOZZLE Δh (in. H2O) LF	RF	LR	RR	AIR FLOW SCFM TOTAL	AMBIENT BARO (Corr) in. Hg	AIR (°F)	LINE
1	.7	1.1			.9	.9			.9	.9									87				97	97			95	96					.7					29.77	87	1
2	1.0	.9			2.0	2.0			2.0	2.0									72	72			94	94			92	92					1.0	.9			5665	29.80	72	2
3	2.1	2.0			5.1	5.1			5.2	4.9									69	69			113	112			[illegible]	112					2.1	1.9			8243	29.80	69	3
4	4.6	4.4			15.3	15.1			15.2	14.7									69	69			164	162			128	128					4.6	4.2			12228	29.80	69	4
5	5.9	5.6			19.7	19.1			19.2	18.4									68	68			183	181			131	131					5.8	5.3			13748	29.81	68	5
6	10.1	9.6			32.6	31.6			32.2	31.0									69	69			239	238			128	128					10	9.5			18207	29.81	69	6
7	17.4	16.5			50.9	49.8			49.8	49.0									62	61			309	307			132	127					17.0	16.0			23860	29.85	62	7
8	↓	↓			↓	↓			↓	↓									↓	↓			↓	↓			↓	↓					↓	↓			↓	↓	↓	8
9	17.5	16.9			50.9	50.1			49.9	49.0									63	63			308	307			130	132					17.1	16.1			23909	29.85	63	9
10	2.9	2.9			8.5	8.1			8.2	7.8									67	67			137	136			126	125					2.9	2.9			9958	29.86	67	10

LINE	FUEL OIL DATA MANIF	API GRAVITY AS READ @ °F		API Corrected To 60°F	LHV (Btu/lb)	LBS MEAS	DIESEL BSFC TIME (sec)	lb/hr	Btu/bhp-hr	(Corr) lb/bhp-hr	FUEL GAS DATA MANIF	LHV Btu/ft³	TO GAS METER in. Hg	°F	CORR FACTOR	GAS BSFC ft³ MEAS	TIME (sec)	ft³/hr (Corr)	Btu/bhp-hr	DUAL FUEL BSFC PILOT Btu/bhp-hr	GAS Btu/bhp-hr	TOTAL Btu/bhp-hr
1	49.5																					
2	49																					
3	46																					
4	42																					
5	41.5	34.4	76	[illegible]	18345	750	1545	1747.5		.359		246.4	Gal HR									
6	38.5	34.4	75	18190	18345	850	1212	2524.8		.349		355.5	Gal HR									
7	37.5	34.6	75	18190	18345	1150	1232	3360		.350		473.2	Gal HR									
8	↓	↓	↓	↓	↓	↓	↓	↓		↓												
9	37.5	35.4	74	18190	18360	1500	1543	3500		.365		492.9	Gal HR									
10	44	35.8	78	18190	18355	710	2608	980		.396		139.4	Gal HR									

REMARKS

RAW 15 MIN 1320-1335

Heat check - OK -

Drop LOAD + SPEED FOR cold compres

0335 Intercooler in hose started to

expand. 0355 shut down restarted

at 0645 changed hose and #6R2

fuel pump

INJECTION/IGNITION TIMING °BTDC 22° LB 21° RB

FUEL OIL SPEC #2 DIESEL STANDARD

LUBE OIL SPEC R-100 wt40 SHELL

AIR FLOW NOZZLE COEFFICIENT

LF 12283 RF 12283

LR RR

(FLYWHEEL END)

OPERATOR Germain

ENGINEER

WITNESS

DATE 5-19-78

LOG NO 1 A

JOB NO 2817

DELAVAL ENGINE AND COMPRESSOR DIVISION, OAKLAND, CALIFORNIA

POWER ENGINE FACTORY TEST LOG

LOG 1 B

CUSTOMER Cleveland

MODEL DSRV-16-4 TYPE SERVICE GEN JOB NO 2817 ENGINE NO 75054

DIRECTION OF ROTATION (AS VIEWED FROM FLYWHEEL END) CW

EXHAUST TEMPERATURES - °F

LINE	TURBINE INLET (T - TOP, B - BOTTOM) LFTL	LFTR	LFB	RFT	RFB	LRT	LRB	RRTL	RRTR	RRB	TURBINE EXHAUST LF	RF	LR	RR	EXHAUST ELBOW 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG	LINE
1											463	447			501	544	507	508	500	527	500	490			544	503	468	503	494	513	511	506			507	1
2											501	474			511	569	549	519	523	538	535	519			544	512	484	509	516	530	529	511			531	2
3											570	541			597	657	630	609	602	629	618	608			621	580	627	586	602	609	618	586			617	3
4											730	688			731	841	760	756	746	784	759	753			725	695	747	726	759	740	761	700			747	4
5											747	715			766	896	831	831	821	840	848	796			785	757	809	796	794	826	819	784			818	5
6											797	764			859	962	910	915	890	895	870	899			852	807	861	901	854	921	845	~~[illegible]~~ 787			877	6
7											833	808			991	1021	996	972	942	956	981	974			899	960	950	998	934	969	912	898			958	7
8											↓	↓			↓	↓	↓	↓	↓	↓	↓	↓			↓	↓	↓	↓	↓	↓	↓	↓			↓	8
9											839	810			964	1038	995	977	960	935	978	977			902	963	951	989	933	968	920	889			960	9
10											629	590			688	735	684	693	693	706	710	675			681	683	700	663	660	677	702	652			683	10

LINE	ENGINE WATER PSIG TO ENGINE	TO ENGINE (°F)	FROM ENGINE (°F)	TURBOCHARGER WATER OUTLET (°F) LF	RF	LR	RR	AFTERCOOLER WATER INLET (°F) F	R	OUTLET (°F) F	R	FIRING PRESSURES - PSIG 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG	LINE
1	85	122	123	124	124							600	600	580	600	570	570	580	570			600	580	570	570	570	576	580	580			580	1
2	20	160	161	161	–																												2
3	85	159	161	160	←																												3
4	23	158	161	161	–							785	810	800	800	790	790	780	785			790	720	790	790	710	770	780	770			790	4
5	25	158	162	162	–							785	805	800	795	795	800	795	800			810	785	790	750	795	808	790	780			840	5
6	25	158	163	163	–							1040	1070	1045	1050	1045	1050	1035	1050			1060	1040	1030	1060	1035	1070	1050	1035			1050	6
7	23	140	166	166																													7
8	↓	↓	↓	↓								1460	1440	1490	1460	1440	1490	1450	1460			1440	1440	1450	1450	1440	1460	1460	1450			1450	8
9	24	160	166	167								1465	1440	1445	1455	1440	1440	1460	1470			1440	1450	1460	1440	1440	1450	1460	1450			1450	9
10	25	158	160	159								560	590	570	580	590	590	570	580			590	560	560	570	560	580	570	560			570	10

LINE	LUBRICATING OIL PRESSURE - PSIG FROM PUMP	TO ENGINE	CAM HEADER	TO TURBOCHARGER LF	RF	LR	RR	LUBRICATING OIL TEMPERATURE °F TO ENGINE	FROM ENGINE	TURBOCHARGER DRAIN LF	RF	LR	RR	CRANK CASE PRESS " in H2O	REMARKS	LINE
1	53	50		30	30			114	116					-1.0		1
2	57	53		33	33			138	140					-2.6		2
3	55	51		32	31			159	165					-2.5		3
4	58	54		33.5	33			158	169					-2.5		4
5	58.5	55		33.5	33			158	171					-2.4		5
6	58	54.5		32.5	32			158	174					-2.1		6
7	56.5	53.0		31.0	30.5			157	177					-1.8		7
8	↓	↓		↓	↓			↓	↓					↓		8
9	56.5	53.0		31.0	31.0			186	177					1.8		9
10	55	51.8		32.5	31.5			185	167					2.9		10

LEGEND L, LB - LEFT BANK F - ENGINE FRONT AT NO. 1 CYLINDER
R, RB - RIGHT BANK R - ENGINE REAR FLYWHEEL END
(WHEN VIEWED FROM FLYWHEEL END)

Form D-4174 (R 1) 9-74

TURBOCHARGER MAKE & MODEL
LF EL BC090 RF EL BC090
LR ____ RR ____
BB - Brown Boveri DI - Delaval EL - Elliott

OPERATOR Gurmeer
ENGINEER
WITNESS

DATE 5-19-74
LOG 1 B
JOB NO 2817

Section 9
Drawings

SECTION 4
DRAWINGS

SECTION 9
DRAWINGS

The drawings listed below apply to this installation, and are intended to assist in the installation operation, overhaul and repair of the engine. In addition, the pages in the front part of this section contain information to assist in the use of the drawings as well as other information of a general nature intended to provide ready reference data to the user.

Dwg. No.	Rev.	Title
R-3951	G	INSTALLATION DRAWING
R-3952	D	FOUNDATION DRAWING
00-500-75051	F	CONTROL PANEL INSTALLATION
09-500-75051	L	CONTROL PANEL SCHEMATIC (10 SHEETS)
09-688-75051	E	ENGINE & SKID ELECTRICAL SCHEMATIC
09-695-75051	D	ENGINE PNEUMATIC SCHEMATIC
09-805-75051	B	EXHAUST, INTAKE & CRANKCASE PIPING SCHEMATIC
09-810-75051	E	JACKET WATER PIPING SCHEMATIC
09-820-75051	E	LUBE OIL PIPING SCHEMATIC
09-827-75051	D	FUEL OIL PIPING SCHEMATIC
09-835-75051	D	STARTING AIR PIPING SCHEMATIC
61-560-6147	E	PNEUMATIC LOGIC BOARD ASSEMBLY
52433	–	INTERCONNECT DIAGRAM
52434	A	ELECTRICAL INTERCONNECT DIAGRAM

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

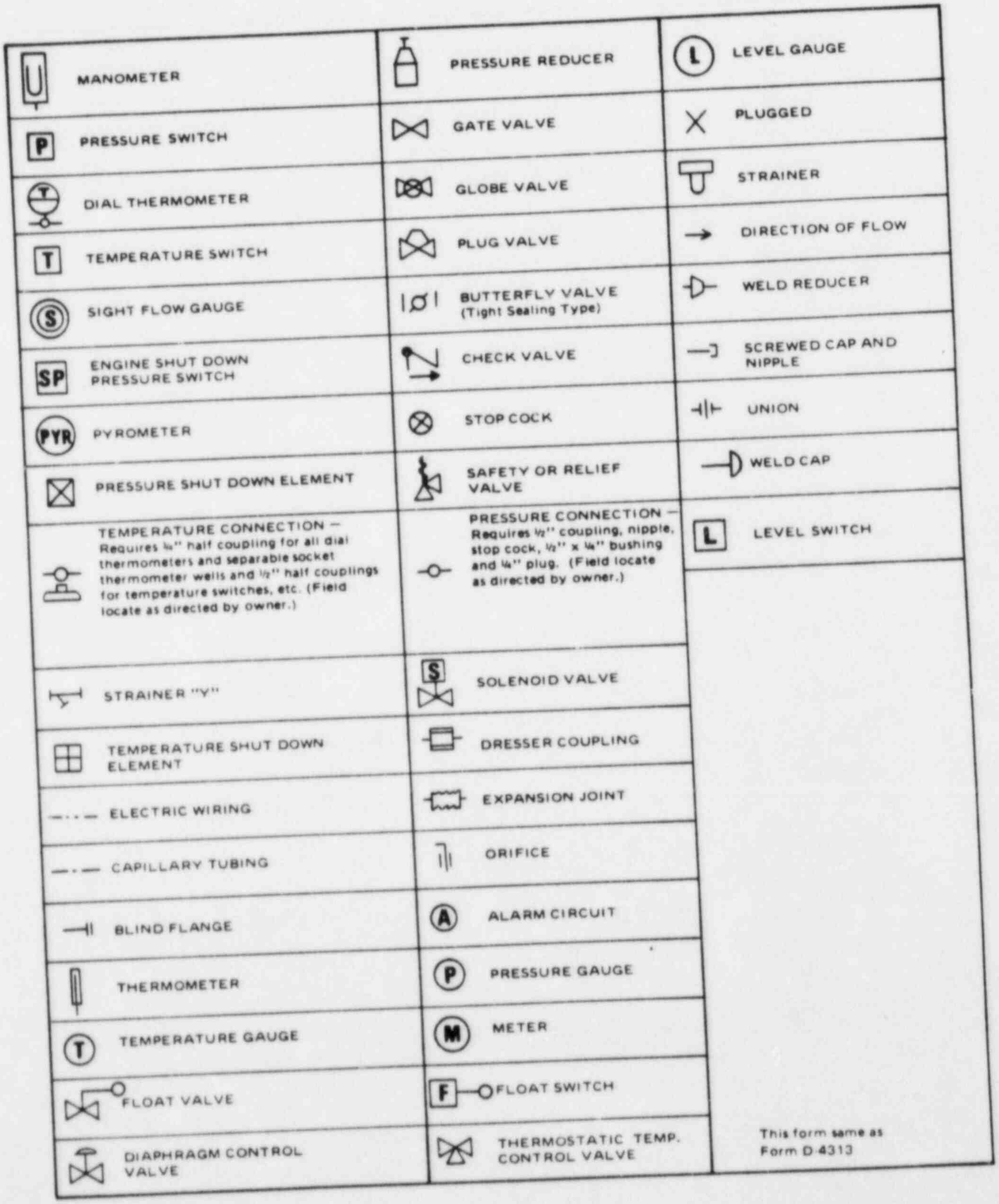
ITEM POWER GAS CONNECTIONS

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

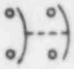
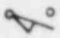
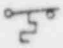
Piping Symbols

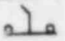
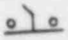
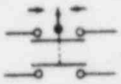
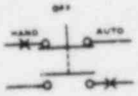
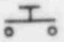
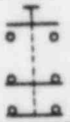
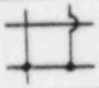
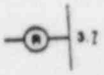
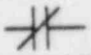
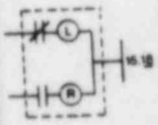


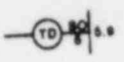
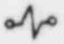
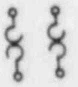
MANOMETER	PRESSURE REDUCER	LEVEL GAUGE
PRESSURE SWITCH	GATE VALVE	PLUGGED
DIAL THERMOMETER	GLOBE VALVE	STRAINER
TEMPERATURE SWITCH	PLUG VALVE	DIRECTION OF FLOW
SIGHT FLOW GAUGE	BUTTERFLY VALVE (Tight Sealing Type)	WELD REDUCER
ENGINE SHUT DOWN PRESSURE SWITCH	CHECK VALVE	SCREWED CAP AND NIPPLE
PYROMETER	STOP COCK	UNION
PRESSURE SHUT DOWN ELEMENT	SAFETY OR RELIEF VALVE	WELD CAP
TEMPERATURE CONNECTION — Requires ¼" half coupling for all dial thermometers and separable socket thermometer wells and ½" half couplings for temperature switches, etc. (Field locate as directed by owner.)	PRESSURE CONNECTION — Requires ½" coupling, nipple, stop cock, ½" x ¼" bushing and ¼" plug. (Field locate as directed by owner.)	LEVEL SWITCH
STRAINER "Y"	SOLENOID VALVE	
TEMPERATURE SHUT DOWN ELEMENT	DRESSER COUPLING	
ELECTRIC WIRING	EXPANSION JOINT	
CAPILLARY TUBING	ORIFICE	
BLIND FLANGE	ALARM CIRCUIT	
THERMOMETER	PRESSURE GAUGE	
TEMPERATURE GAUGE	METER	
FLOAT VALVE	FLOAT SWITCH	
DIAPHRAGM CONTROL VALVE	THERMOSTATIC TEMP. CONTROL VALVE	

This form same as Form D 4313

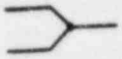
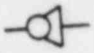
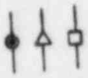
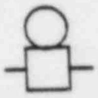
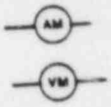
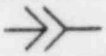
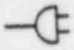
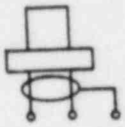
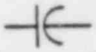
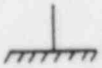
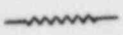
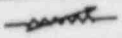
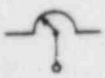
Electrical Schematic Symbols

Symbol	Device
SWITCHES – General	
	Disconnect (2 pole)
	Circuit Breaker (2 pole)
	Normally Open Limit
	Normally Closed Limit
	Held Closed Limit
	Held Open Limit
	Normally Open Liquid Level
	Normally Closed Liquid Level
	Normally Open Pressure
	Normally Closed Pressure
	Normally Open Differential Pressure
	Normally Closed Differential Pressure
	Dual Contact Differential Pressure
	Normally Open Temperature
	Normally Closed Temperature
	Normally Open Thermostatic – Adjustable
	Normally Closed Thermostatic – Adjustable
	Normally Open Flow
	Normally Closed Flow

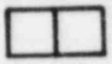
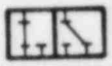
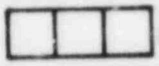
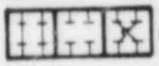
Symbol	Device
SELECTORS	
	Normally Closed Manual
	Normally Open Manual
	Normally Open Held Closed
	Normally Closed Held Open
	Three Position Spring Return to Center
	Three Position Maintained Position (shown in Hand position)
PUSHBUTTONS	
	Normally Open
	Normally Closed
	Normally Closed, Held Open
	Multiple 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

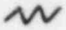
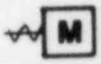
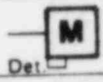
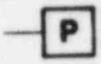
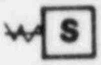
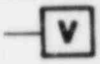
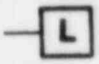
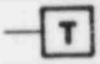
Symbol	Device
	Time Delay Relay Coil - Slow Operating Type - On energization, contacts change state after delay and reset immediately on de-energization. (5 sec. shown)
	Time Delay Relay Coil - Slow Release Type - on energization, contacts change state immediately and reset after delay on de-energization
	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			Rheostat		
	Fuse		Thermocouple		
	Horn		Terminals		
	Alarm Bell		Meters		
	Plug & Receptacle		Transformer		
	Line Plug		Magnetic Pick Up With Shield		
	Receptacle		Motor, AC		
	Fixed Capacitor				
	Adjustable Capacitor				
	Diode				
	SCR				
	Earth Ground				
	Chassis Ground				
	Lamp				
	Motor Starter or Contactor				
	Motor, DC				
	Remote Location				
	Resistor				
	Adjustable Resistor				
	Potentiometer				

Valve Symbols

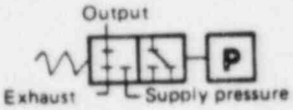
TWO POSITION VALVE (W/O ACTUATOR)	
	Basic two position
	Two way, two position
	Three way, two position
	Four way, two position
	Five way, two position
THREE POSITION VALVE (W/O ACTUATOR)	
	Basic three position
	Three way, closed center, three position
	Three way, open center, three position
	Four way, closed center, three position
	Four way, open center, three position
	Five way, open center, three position
	Five way, closed center, three position

ACTUATORS	
	Spring return
	Manual push actuator
	Manual pull actuator
	Detented manual actuator
	Pressure actuator
	Solenoid actuator
	Vibration actuator
	Flow actuator
	Liquid level actuator
	Temperature actuator

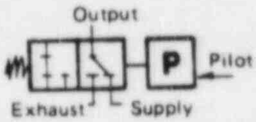
1. Actuators (there may be one or two) are shown attached to either end of valve symbol.
2. Valve symbols are always shown in non-actuated, i.e., "Normal, relaxed" condition.
3. The tube or pipe connections to the valve are considered to be immoveable, while the internal passage blocks are mentally shifted between the external connections to visualize valve action.

EXAMPLES

Three-way valve, two position, pressure actuated, spring return

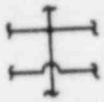
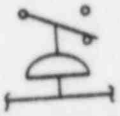
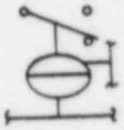
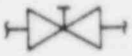
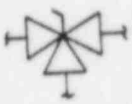
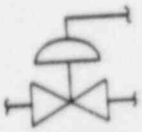
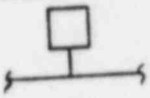
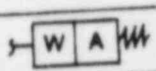
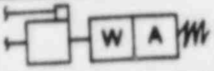
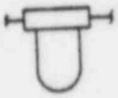
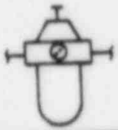
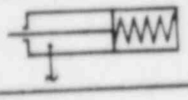
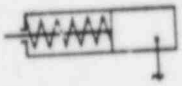
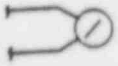
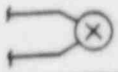


Valve connected normally closed (supply shut off when no pilot pressure exists). Note output is connected to exhaust.

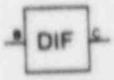


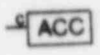
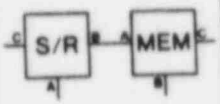
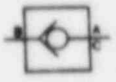
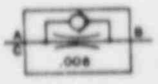
Valve shown with pilot pressure applied (actuated). Supply is now connected to output, and exhaust is blocked. Note that connections have not moved, and valve body is shifted to the left, causing the right passage block to come beneath the connections. Also note, this view will not show up on drawings.

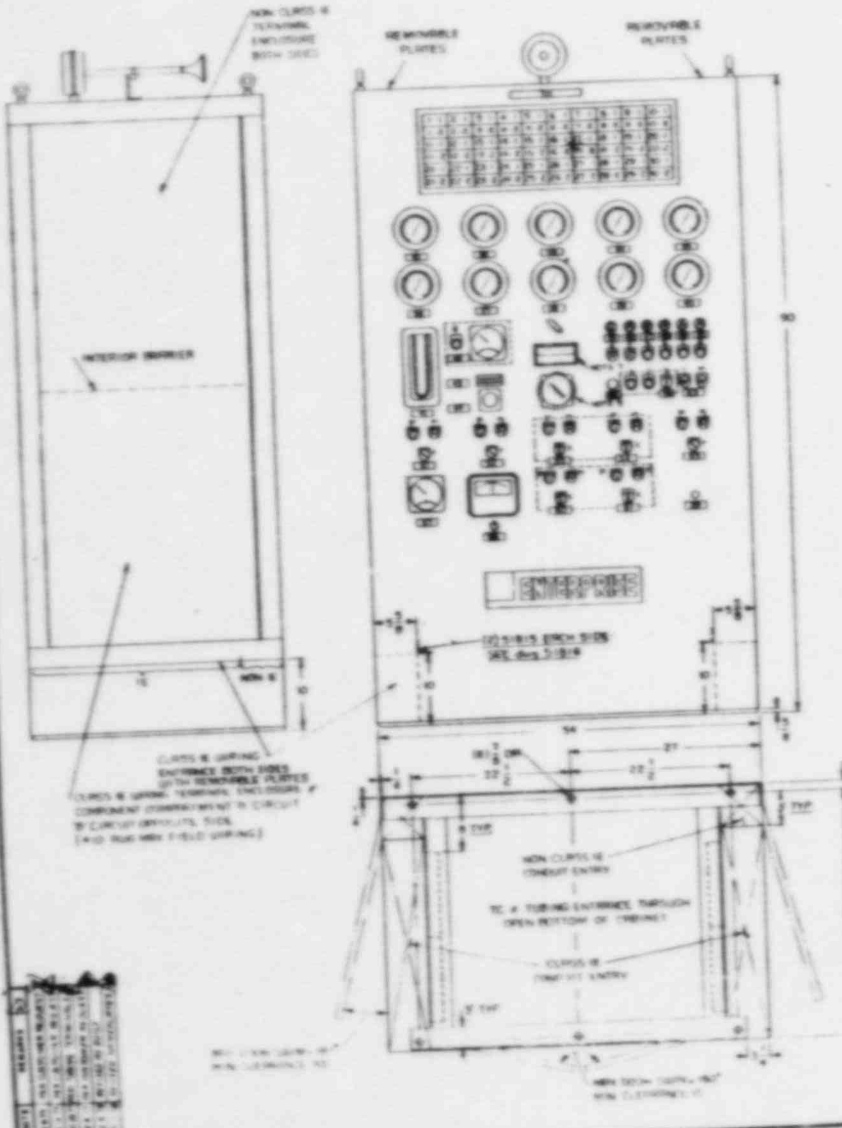
Pneumatic Control Device Symbols

Symbol	Device
	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
	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 Plugged Exhaust Performs NOT function as above, but exhaust port is blocked. Pressure flows from B to C except when there is pressure at A. With pressure at A, pressure flow from B to C stops, but C does not vent. Pressure retained downstream of C.
	**TIMER** Provides timing with slow pressure rise, from 0.08 to 7.5 seconds adjustable. With supply pressure at A, slow rising pressure at C, reaching full pressure when delay completed. Without pressure at A, C vents through internal exhaust port.
	**DELAY** With pressure at B only, no pressure flow from B to C. When pressure applied to A, flow permitted from B to C after time delay. Output delay adjustable from 0.08 to 7.5 seconds. Ports A and B sometimes connected to common source for time delay output functions.
	**TIMER/NOT** With pressure at port B only, pressure flows from port B to port C. When pressure is applied to port A, pressure flow from port B to port C is terminated after delay. Output termination time adjustable from 0.08 to 7.5 seconds. Ports A and B sometimes connected to common source for single shot pulse output.
	**DIFFERENTIATOR** With pressure at input port B, there is a single shot output pulse from port C. Pulse output duration is 80 msec.
	**SET/RESET** Pressure flow from port C to port B will set element. Pressure output at port B remains trapped when input at port C is removed. Pressure applied at port A causes pressure at port B to exhaust through port C. Pressure at port C overrides pressure at port A if both pressures present at the same time.

Symbol	Device
	**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.



1-1

2-1 BY SWITCH NOT IN AUTO
3-1 JACKING DEVICE ENGAGED
4-1 FO BOOSTER PUMP STRAIN Δ P HIGH
5-1 FUEL DAY TANK LEVEL LOW
6-1 FUEL TRANS PUMP 2 RUNNING
7-1 LUBE OIL FILTER Δ P HIGH
8-1 LUBE OIL INLET TEMP LOW
9-1 JACKET WATER PRESS LOW
10-1 JACKET WATER INLET TEMP LOW
1-2
2-2
3-2 CONTROL AIR PRESS LOW
4-2 FUEL TRANS PUMP 1 FLTR Δ P HIGH
5-2 FUEL DAY TANK LEVEL HIGH
6-2
7-2 LUBE OIL STRAINER Δ P HIGH
8-2 LUBE OIL INLET TEMP HIGH
9-2
10-2 JACKET WATER INLET TEMP HIGH

11-1 GENERATOR FIELD GROUND
12-1
13-1 STARTING AIR PRESS LOW
14-1 FUEL TRANS PUMP 2 FLTR Δ P HIGH
15-1 FUEL STRG TANK LEVEL LOW (1 DAY)
16-1
17-1 FUEL PUMP STRAINER Δ P HIGH
18-1
19-1
20-1
11-2 FIELD FLASH 125 VDC POWER LOSS
12-2 GENERATOR STATOR TEMP HIGH
13-2
14-2 FUEL FILTER Δ P HIGH
15-2 FUEL STRG TANK LEVEL LOW (1 DAY)
16-2 TURBO OIL LEFT BANK PRESS LOW
17-2 LUBE OIL LOW LEVEL
18-2 LUBE OIL OUTLET TEMP LOW
19-2 J.W. STANDPIPE LEVEL LOW
20-2 JACKET WATER OUT TEMP LOW

21-1
22-1
23-1 DIESEL GEN FAILURE TO START
24-1 FUEL OIL PRESS LOW
25-1 FUEL PUMP/ OS DRIVE FAILURE
26-1 TURBO OIL RIGHT BANK PRESS LOW
27-1 LUBE OIL PRESS LOW
28-1 LUBE OIL OUTLET TEMP HIGH
29-1
30-1 J.W. OUTLET TEMP HIGH
21-2 DIESEL GEN EMG START SIGNAL RCVD
22-2 DIESEL GEN Δ RELAY TRIP
23-2 DIESEL GEN OVERSPEED TRIP
24-2 ENGINE VIBRATION TRIP
25-2 CRANKCASE PRESS HIGH TRIP
26-2 TURBO OIL PRESS LOW TRIP
27-2 LUBE OIL PRESS LOW TRIP
28-2 LUBE OIL TEMP HIGH TRIP
29-2 ENGINE BRG TEMP HIGH TRIP
30-2 J.W. OUTLET TEMP HIGH TRIP

31 STARTING AIR PRESS LEFT BANK
32 STARTING AIR PRESS RIGHT BANK
33 LUBE OIL PRESS
34 TURBO OIL PRESS LEFT FRONT
35 TURBO OIL PRESS RIGHT FRONT
36 FUEL OIL PRESS
37 FUEL OIL FILTER DIFFERENTIAL PRESS
38 COMBUSTION AIR PRESS LB TEST RB
39 LUBE OIL FILTER DIFFERENTIAL PRESS
40 JACKET WATER PRESS
41 CRANKCASE PRESS
42 ENGINE SPEED
43 ENGINE STARTS
44 ENGINE HOURS
45 UNIT TRIPPED
46 SHUTDOWN SYSTEM ACTIVE
47 READY TO LOAD
48 ABOVE 200 RPM
49 STARTING
50 UNIT AVAIL EMERGENCY STATUS
51 STARTING AIR COMP #1
52 STARTING AIR COMP #2
53 DC FUEL OIL BOOSTER PUMP
54 LUBE OIL CIRCULATING PUMP & HEATER
55 JACKET WATER CIRCULATING PUMP & HEATER
56 LUBE TANK LEVEL PUSH TO READ
57 DAY TANK LEVEL
58 MODE SELECT
59 PHONE JACK
60 FUEL OIL TRANSFER PUMP #1
61 FUEL OIL TRANSFER PUMP #2
62 PULL TO START
63 PANEL POWER

a SILENCE
b ACKNOWLEDGE
c TEST
d FLTET
e START
f ENGINE STOPPED
g
h NORMAL STOP
i EMERGENCY STOP
j INOP NORMAL
k AC
l DC
m ON
n OFF
o
p OFF AUTO ON
q ENGINE ROLL
s STOP AUTO START

10 ENGINE CONTROL PANEL DIVISION 1 UNIT 1 1H51P054A

ENGINE CONTROL PANEL DIVISION 1 UNIT 2 2H51P054A

ENGINE CONTROL PANEL DIVISION 2 UNIT 1 1H51P054B

ENGINE CONTROL PANEL DIVISION 2 UNIT 2 2H51P054B

1. ALL ANNUNCIATOR LENSES ARE WHITE TRANSLUCENT & ENGRAVED WITH 1/4" BLACK LETTERING AS SHOWN. THE FOLLOWING POSITIONS HAVE RED AMBER LENSES FOR TRIP INDICATIONS. 5-1, 5-2, 13-1, 15-1, 15-2, 21-2, 22-2, 23-2, 24-2, 25-2, 26-2, 27-2, 28-2, 29-2, 30-2.
2. NAMEPLATES 45, 50, 58 & 62 ARE ENGRAVED WITH 1/8 BLACK LETTERING ON 3/4" x 2" WHITE LAMACOID. a-s ARE STANDARD FURNAS NAMEPLATES AS SHOWN. #10 IS AS INDICATED. ALL OTHER NAMEPLATES ARE 3/4" x 2 3/4" WHITE LAMACOID WITH 1/8" BLACK LETTERING. CLASS IE EQUIPMENT NAMEPLATES ARE COLOR CODED AS PER NAMEPLATE 10.
3. TC SELECTOR SW: CYL 1-8LB, CYL 1-8RB, STACK LB, STACK RB, LO IN & OUT, JW IN & OUT, OFF
4. PAINT SPECIFICATION: PANEL EXTERIOR TO BE A HIGH GLOSS FINISH, ANSI #61 GRAY. INTERIOR TO BE A NON-REFLECTIVE WHITE. SEE D 4849 FOR GENERAL CONTROL CABINET SPEC.
5. ALL CABINET DOORS LOCKABLE
6. TAG: 1H51P054A,B
2H51P054A,B
7. DIGITAL TEMP INDICATOR.

DO NOT SCALE DRAWING

WEIGHT = 2500 LBS

NUCLEAR
SAFETY
RELATED

CLEVELAND ELECTRIC
ILLUMINATING CO.
PERRY NUCLEAR POWER PLANT
UNIT 1 #1 & #2

DELAVAL

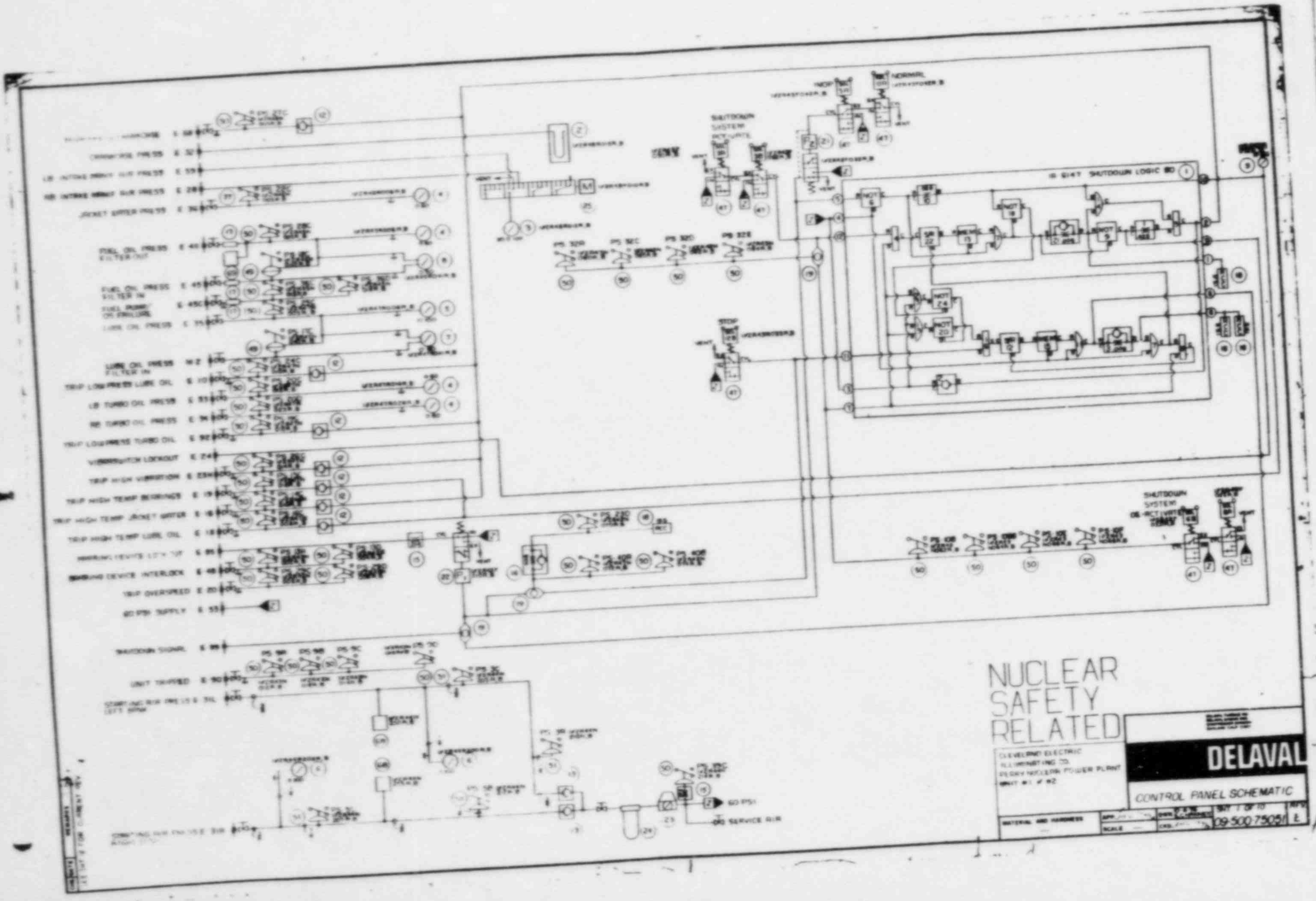
CONTROL PANEL INSTALLATION

MATERIAL AND HARDNESS

SCALE

00-500-75051

REV F



NUCLEAR
SAFETY
RELATED

CLEVELAND ELECTRIC
ILLUMINATING CO.
PERRY NUCLEAR POWER PLANT
UNIT #1 & #2

DELAVAL

CONTROL PANEL SCHEMATIC

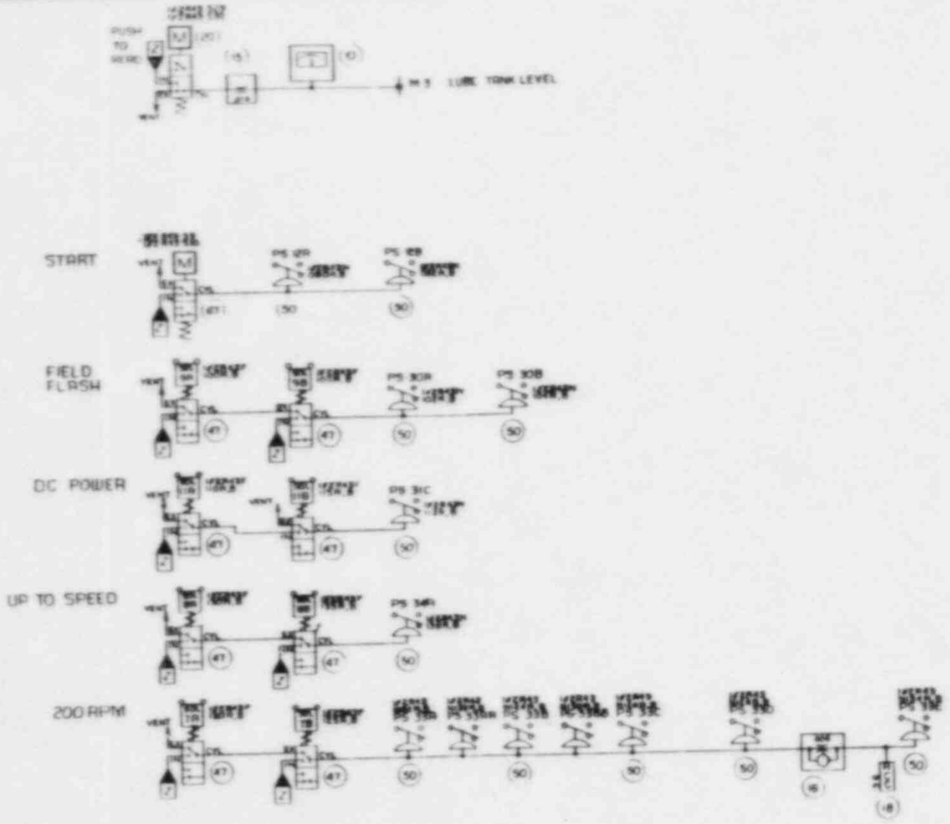
MATERIAL AND HARDNESS

SCALE

SHT 1 OF 10

09-500-75051

REV



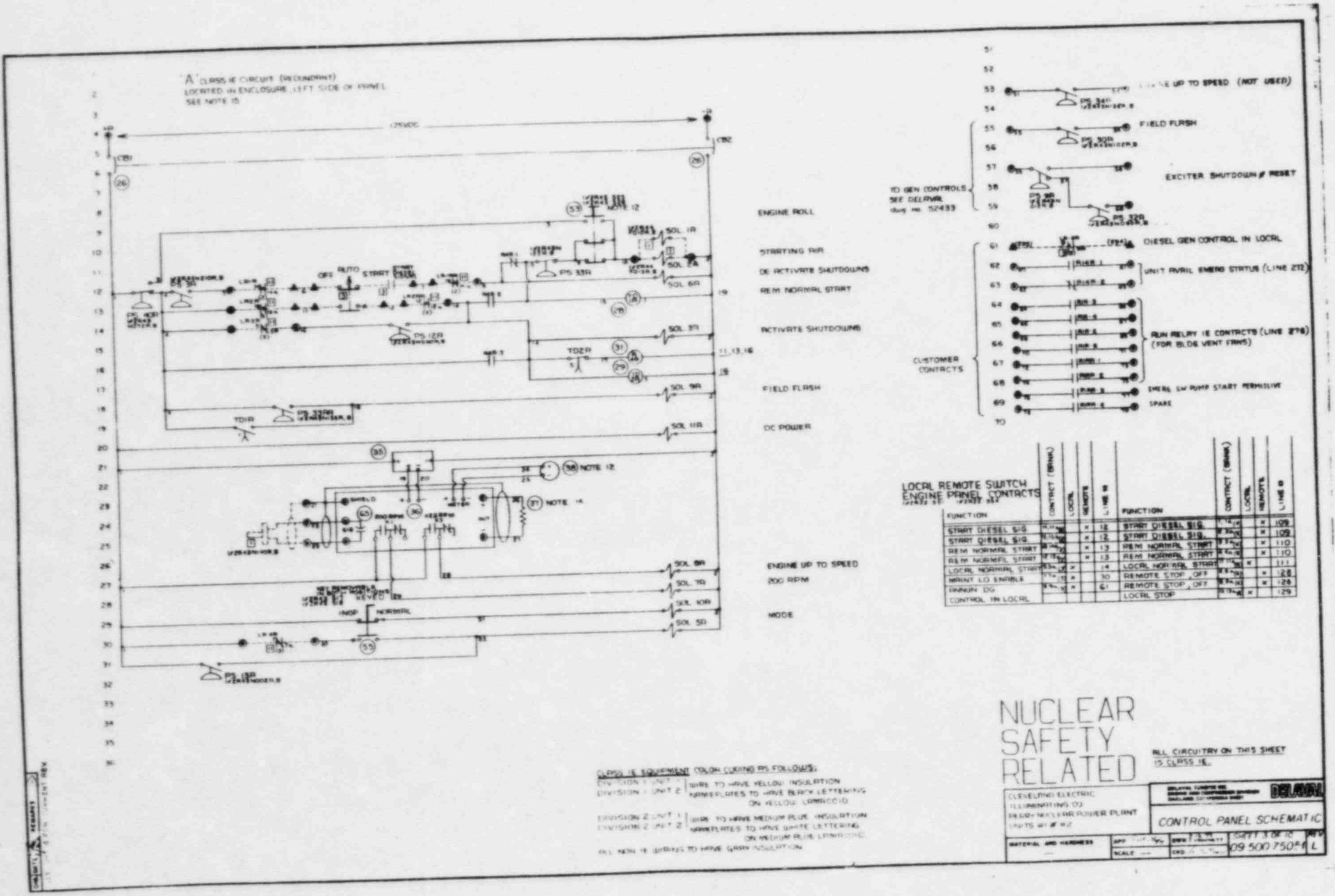
NUCLEAR
SAFETY
RELATED

CLEVELAND ELECTRIC
ILLUMINATING CO
PERRY NUCLEAR POWER PLANT
UNITS #1 & #2

DELAVAL

CONTROL PANEL SCHEMATIC

MATERIAL AND HARDNESS	APP	DWN	SHT 2 OF 15	REV
—	SCALE —	CKD	09 500 75051	L



LOCAL REMOTE SWITCH ENGINE PANEL CONTACTS

FUNCTION	CONTACT (BANK)	LOCAL	REMOTE	LINE #	FUNCTION	CONTACT (BANK)	LOCAL	REMOTE	LINE #
START DIESEL SIG.	[illegible]		×	12	START DIESEL SIG.	[illegible]		×	109
START DIESEL SIG.	[illegible]		×	12	START DIESEL SIG.	[illegible]		×	109
REM NORMAL START	[illegible]		×	13	REM NORMAL START	[illegible]		×	110
REM NORMAL START	[illegible]		×	13	REM NORMAL START	[illegible]		×	110
LOCAL NORMAL START	[illegible]	×		14	LOCAL NORMAL START	[illegible]	×		111
MAINT LO ENABLE	[illegible]	×		30	REMOTE STOP, OFF	[illegible]		×	128
ANNUN DG CONTROL IN LOCAL	[illegible]	×		61	REMOTE STOP, OFF	[illegible]		×	128
					LOCAL STOP	[illegible]	×		129

NUCLEAR
SAFETY
RELATED

ALL CIRCUITRY ON THIS SHEET IS CLASS IE.

CLASS IE EQUIPMENT COLOR CODING AS FOLLOWS:

DIVISION 1 UNIT 1
DIVISION 1 UNIT 2 — WIRE TO HAVE YELLOW INSULATION
NAMEPLATES TO HAVE BLACK LETTERING ON YELLOW LAMACOID

DIVISION 2 UNIT 1
DIVISION 2 UNIT 2 — WIRE TO HAVE MEDIUM BLUE INSULATION
NAMEPLATES TO HAVE WHITE LETTERING ON MEDIUM BLUE LAMACOID

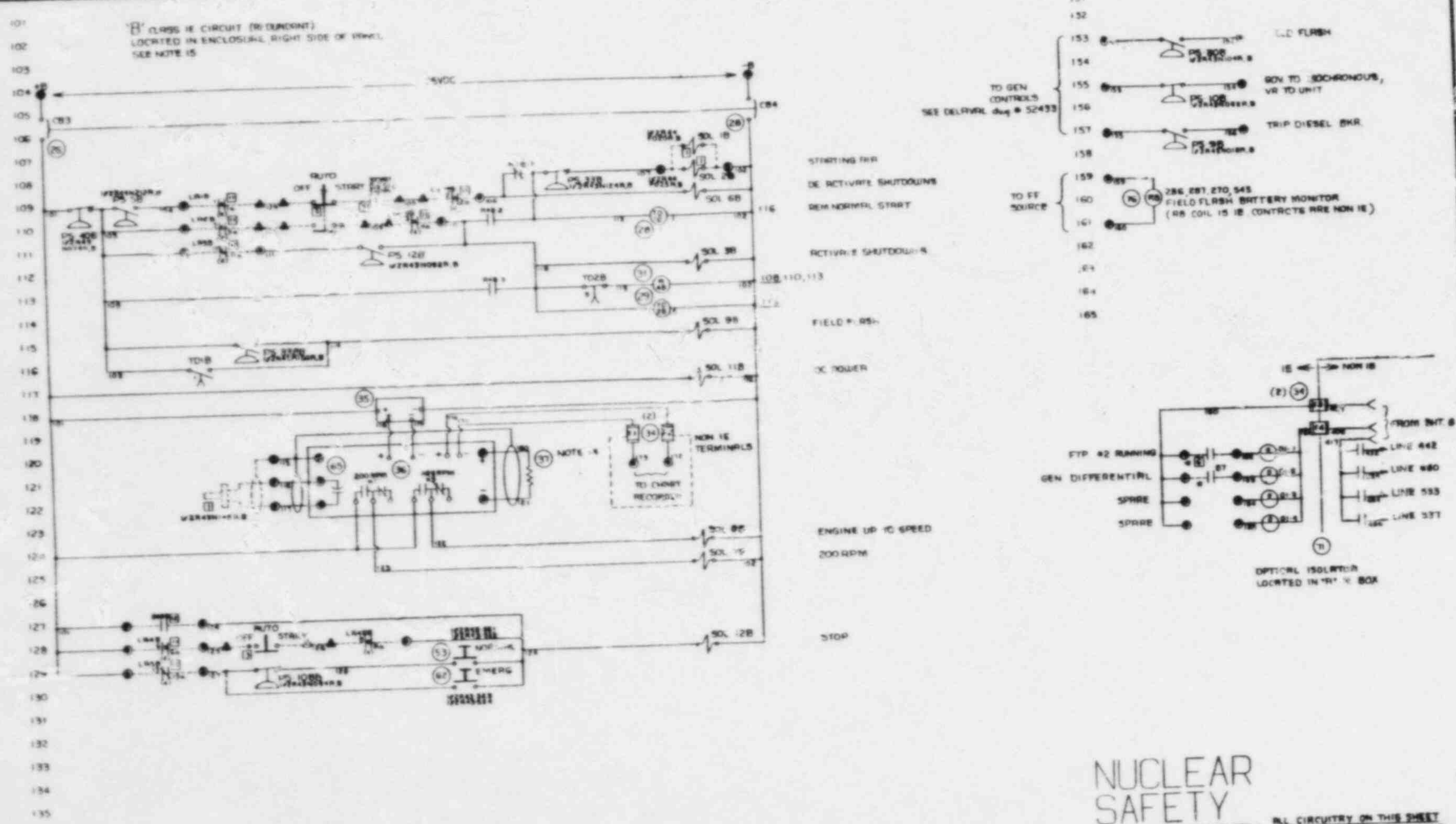
ALL NON IE WIRING TO HAVE GRAY INSULATION

CLEVELAND ELECTRIC
ILLUMINATING CO
PERRY NUCLEAR POWER PLANT
UNITS #1 & #2

DELAVAL

CONTROL PANEL SCHEMATIC

MATERIAL AND HARDNESS
SCALE —
SHEET 3 OF 12
09 500 750
REV L



NUCLEAR
SAFETY
RELATED

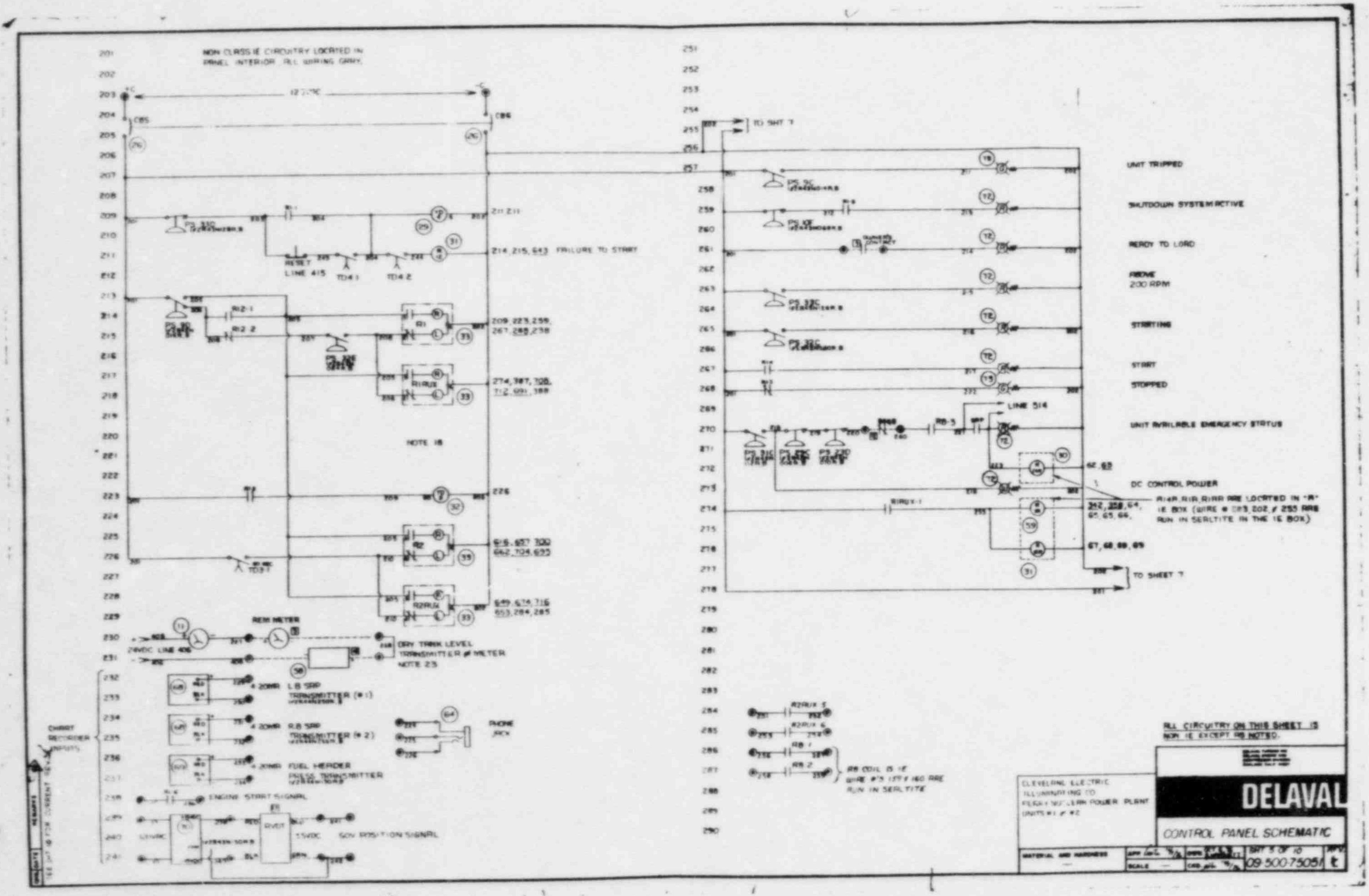
ALL CIRCUITRY ON THIS SHEET
IS CLASS IE, EXCEPT AS NOTED

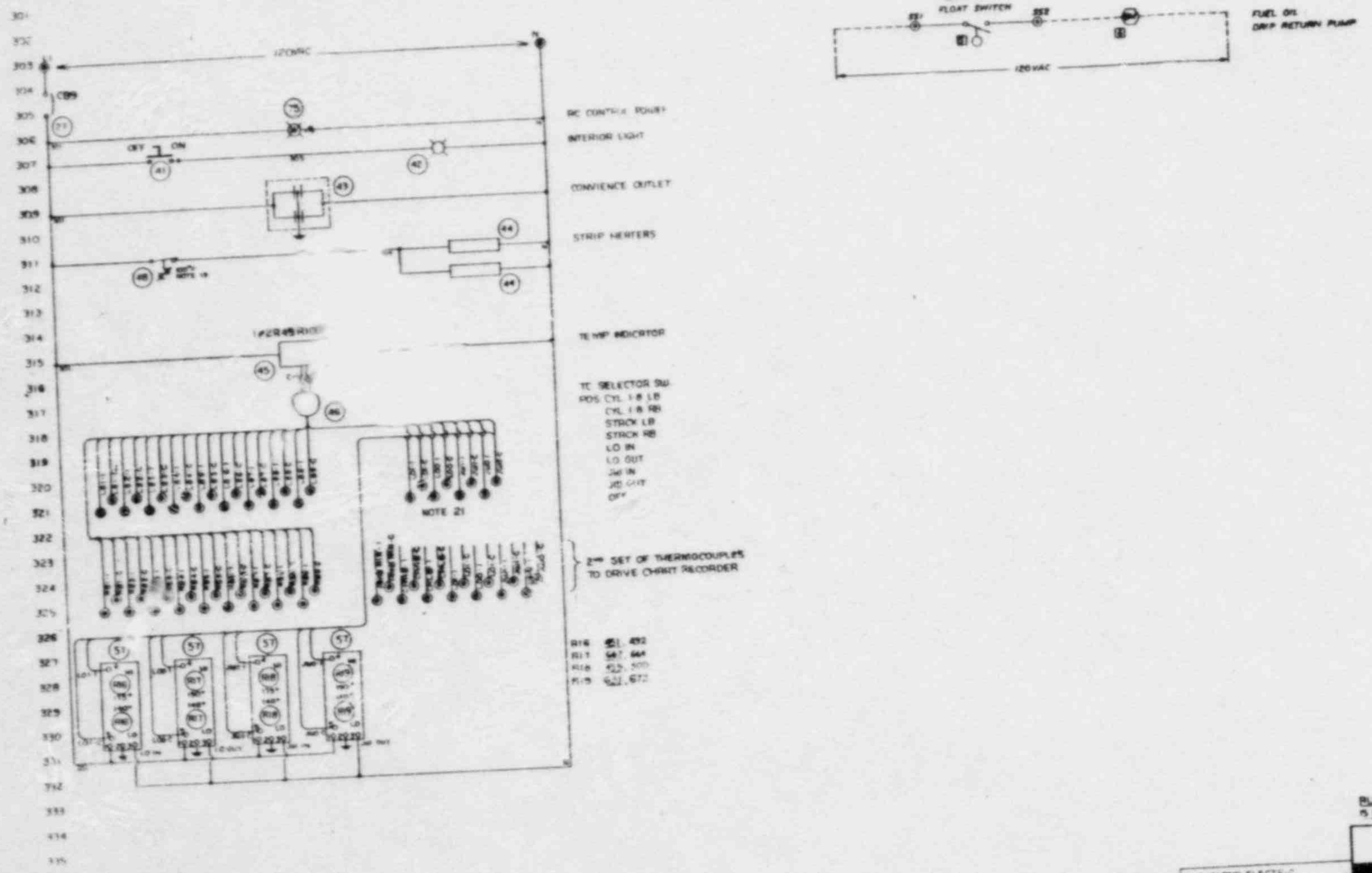
CLEVELAND ELECTRIC
ILLUMINATING CO
PERRY NUCLEAR POWER PLANT
UNITS #1 & #2

DELAVAL

CONTROL PANEL SCHEMATIC

MATERIAL AND HARDNESS —	APP	DWG	SHEET 4 OF 10 09 500 75051	REV L
	SCALE —	CHK		


NON CLASS IE CIRCUITRY LOCATED IN PANEL INTERIOR. ALL WIRING GRAY.
+C
-C
CB5
CB6
211,211
214, 215, 643 FAILURE TO START
RESET LINE 415
TD4.1
TD4.2
R12-1
R12-2
R1
R1AUX
209, 223, 259, 267, 288, 238
274, 387, 108, 112, 691, 188
NOTE 18
226
R2
R2AUX
TD3T
616, 657, 700, 662, 704, 695
649, 674, 716, 653, 284, 285
REM METER
24VDC LINE 406
DAY TANK LEVEL TRANSMITTER & METER NOTE 23
4-20MA L.B. SRP TRANSMITTER (#1)
4-20MA R.B. SRP TRANSMITTER (#2)
4-20MA FUEL HEADER PRESS TRANSMITTER
CHART RECORDER INPUTS
PHONE JACK
ENGINE START SIGNAL
15VDC
SOV POSITION SIGNAL
TO SHT 7
UNIT TRIPPED
SHUTDOWN SYSTEM ACTIVE
READY TO LOAD
ABOVE 200 RPM
STARTING
START
STOPPED
LINE 514
RB-3
UNIT AVAILABLE EMERGENCY STATUS
R1AUX-1
62, 63
DC CONTROL POWER
R1AR, R1R, R1RR ARE LOCATED IN "R" IE BOX (WIRE # 283, 202 & 255 ARE RUN IN SEALTITE IN THE IE BOX)
242, 258, 64, 6?, 65, 66,
67, 68, 69, 69
TO SHEET 7
R2AUX 5
R2AUX 6
RB-1
RB-2
RB COIL IS IE WIRE #'S 177 & 180 ARE RUN IN SEALTITE
ALL CIRCUITRY ON THIS SHEET IS NON IE EXCEPT AS NOTED.
CLEVELAND ELECTRIC ILLUMINATING CO. PERRY NUCLEAR POWER PLANT UNITS #1 & #2
DELAVAL
CONTROL PANEL SCHEMATIC
MATERIAL AND HARDNESS
SCALE
SHT 5 OF 10
09-500-75051
t



ALL CIRCUITRY ON THIS SHEET
IS NON IE

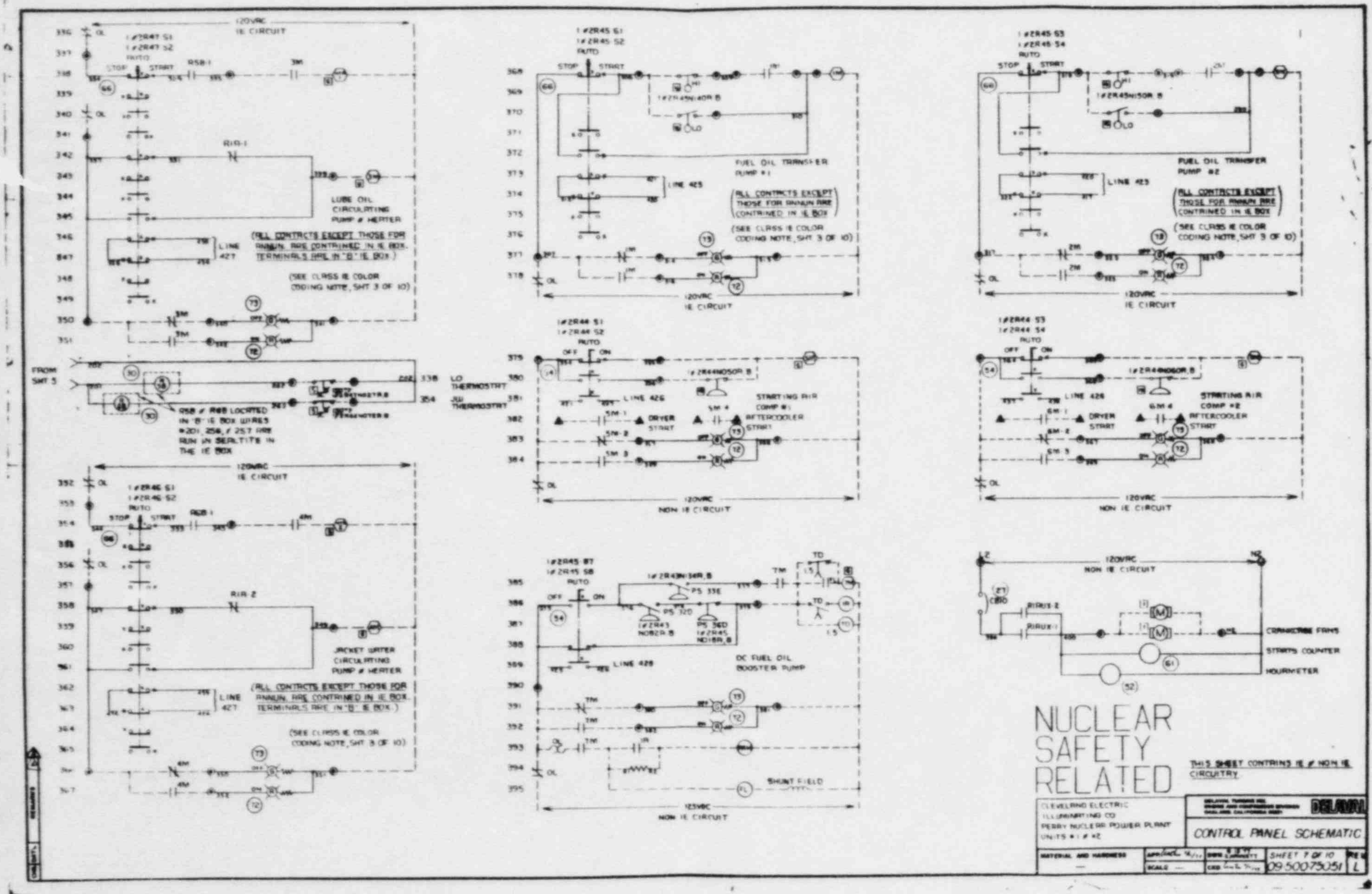
NUCLEAR
SAFETY
RELATED

CLEVELAND ELECTRIC
ILLUMINATING CO.
PERRY NUCLEAR POWER PLANT
UNITS #1 & #2

DELAVAL

CONTROL PANEL SCHEMATIC

MATERIAL AND HARDNESS	APP	DWN	SHT 6 OF 10	REV
—	SCALE —	CKD	09-500-75051	L



NUCLEAR
SAFETY
RELATED

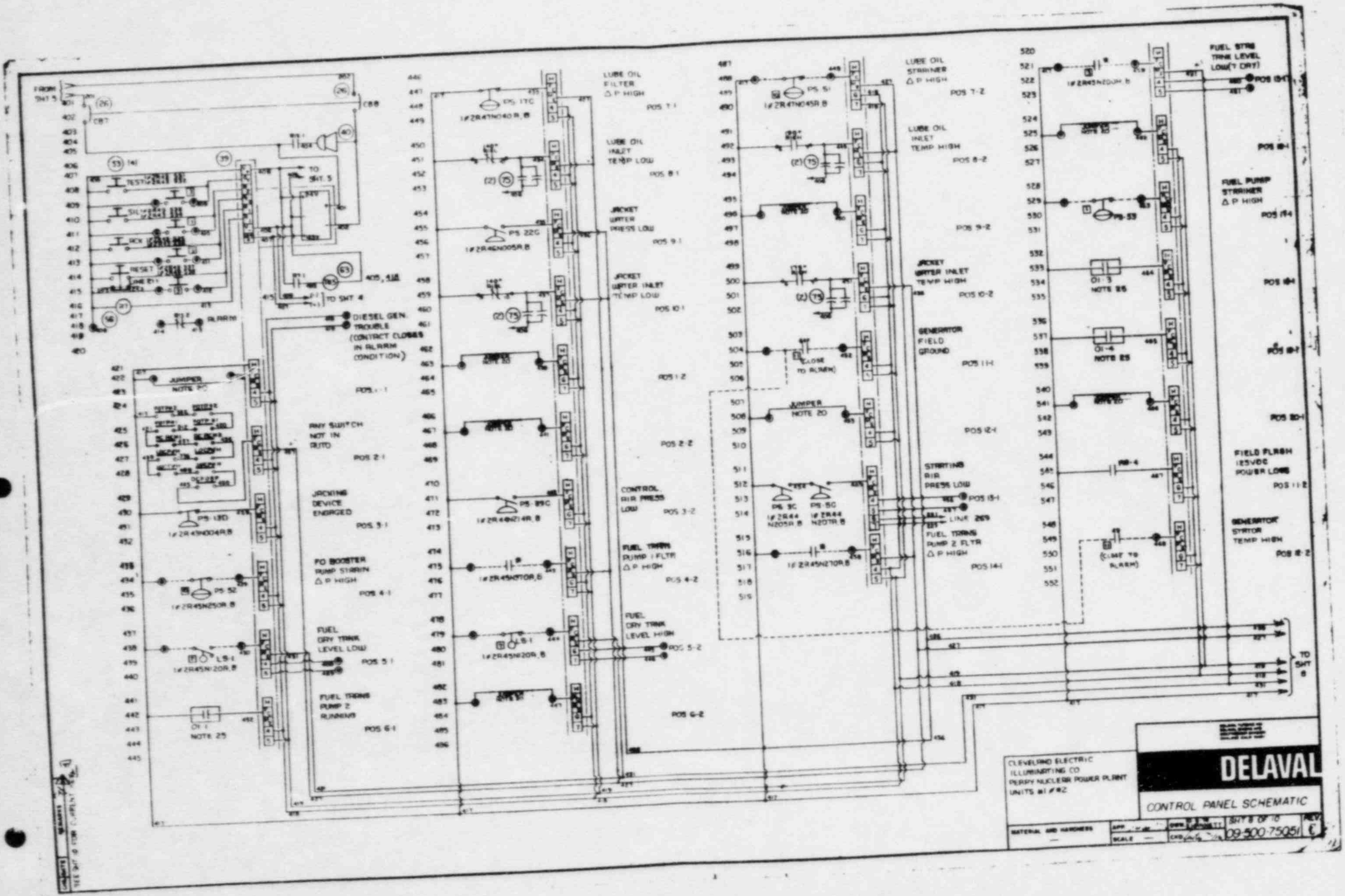
THIS SHEET CONTAINS IE & NON IE CIRCUITRY

CLEVELAND ELECTRIC
ILLUMINATING CO
PERRY NUCLEAR POWER PLANT
UNITS #1 & #2

DELAVAL

CONTROL PANEL SCHEMATIC

MATERIAL AND HARDNESS	APP	DWN	SHEET 7 OF 10	REV
—	SCALE —	CKD	09 50075051	L

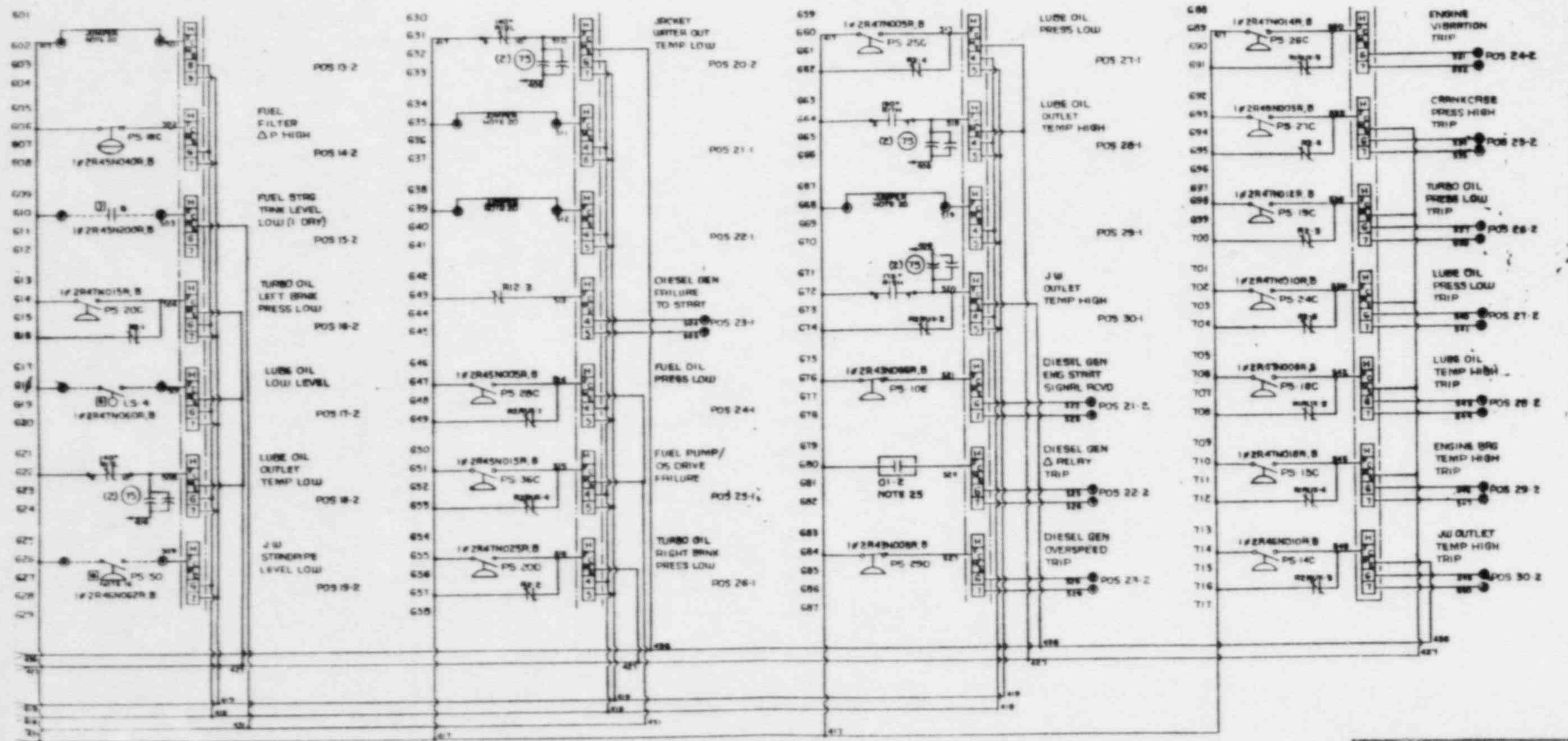


CLEVELAND ELECTRIC
ILLUMINATING CO
PERRY NUCLEAR POWER PLANT
UNITS #1 & #2

DELAVAL

CONTROL PANEL SCHEMATIC

SHT 8 OF 10
09-500-75051
REV C



CLEVELAND ELECTRIC
ILLUMINATING CO.
PERRY NUCLEAR POWER PLANT
UNITS 1 & 2

DELAVAL

CONTROL PANEL SCHEMATIC

MATERIAL AND HARDNESS —
SCALE —
SHT 9 OF 10
09-500-75051
REV. 6

	SETTING	FUNCTION
A,C 1	150PSIF	STARTING AIR LEFT BANK
A,C 3	150PSIF	STARTING AIR RIGHT BANK
A,B,C,D 9	45PSIR	UNIT TRIPPED
A,9B,E,F 10	45PSIR	LOCA
A,B 12	45PSIR	LOCAL MANUAL START
A,D 13	45PSIR	BARRING DEVICE ENGAGED
C 14	45PSIF	HIGH TEMP JW TRIP
C 15	45PSIF	HIGH TEMP BEARING TRIP
C 16	45PSIF	HIGH TEMP LO TRIP
C 17	20PSIR	ΔP LO FILTER
C 18	20PSIR	ΔP FUEL FILTER
C 19	45PSIF	TURBO OIL PRESS TRIP
C,D 20	20PSIF	TURBO OIL PRESS
C 22	15PSIF	LOW PRESS JW
D 23	45PSIR	LOCKED OUT W/DELAY
C 24	45PSIF	LO PRESS TRIP
C 25	45PSIF	LOW PRESS LO
C 26	45PSIF	VIBRATION TRIP
C 27	45PSIF	HIGH PRESS CC TRIP
C 28	20PSIF	LOW PRESS FO
C,D 29	45PSIR	OVERSPEED TRIP
A,B 30	45PSIR	FIELD FLASH
C 31	45PSIR	DC POWER AVAILABLE
A,C,D,E 32	45PSIR	STARTING
9B,9B,A,B,C,D,E 33	45PSIR	200 RPM
A 34	45PSIR	UP TO SPEED
C,D 36	10PSIF	FUEL PUMP / DB FAILURE
C 39	50PSIF	CONTROL AIR PRESS
A,B 40	45PSIR	INOP/NORMAL

1. PNEUMATIC CONTROL MEDIUM IS AIR.
2. 2▶ INDICATES 60PSI CONTROL AIR
3. SYSTEM SHOWN SHUTDOWN, DE-PRESSURIZED & DE-ENERGIZED
4. SET, TEST & TAG ALL SAFETY SENSORS
5. PSIF INDICATES ACTUATION AT SETTING ON FALLING PRESSURE
   PSIR INDICATES ACTUATION AT SETTING ON RISING PRESSURE
6. SEE D-4908 FOR VALVE SYMBOLS
7. ◆ DENOTES SWAGELOK BULKHEAD TUBE TERMINATION NEAR BOTTOM OF CABINET, IDENTIFY TERMINALS
8. TUBING IS 1/4" OD COPPER EXCEPT AS NOTED, FITTINGS ARE BRASS.
9. FOR 3/8" EXTERNAL CONNECTIONS, SEE DWG NO 51816.
   ALL LUBE OIL LINES ARE 3/8" EXTERNAL CONNECTIONS
10. 1/4" TUBING IS RECOMMENDED FOR CONNECTION TO PANEL, EXCEPT WHERE TERMINATION ON THIS DWG IS SHOWN 3/8"
11. IDENTIFY BOTH ENDS OF WIRES.
12. DEVICE IS ENCLOSED, CONNECTED BY CONDUIT TO CLASS 1E ENCLOSURE, LEFT SIDE OF PANEL.
13. DEVICE IS ENCLOSED, CONNECTED BY CONDUIT TO CLASS 1E ENCLOSURE, RIGHT SIDE OF PANEL.
14. REMOVE RESISTOR IF REMOTE TACH IS USED.
15. LIKE CONTACTS TO BE OPERATED SIMULTANEOUSLY IN A & B CIRCUITS
16. JW LL SENSOR TO BE 35" BELOW ℄ OF JW INLET FLANGE ON STANDPIPE
17. WIRING TO BE #14GA STRANDED, TINNED COPPER, LOCA QUALIFIED, IEEE 323 & 383
18. RELAY R1 TRANSFERS WITH A START OR AT A STOP SIGNAL
    RELAY R2 TRANSFERS 60 SEC AFTER A START OR AT A STOP
19. MOUNT HIGH IN CABINET, CENTRALIZED.
20. REMOVE JUMPER IF SPARE IS USED.
21. THERMOCOUPLE LEADS TO BE IRON CONSTANTAN.
22. DASHED LINES (------) INDICATE WIRES RUN OUTSIDE THE PANEL.
23. JUMPER WIRE #227 TO WIRE #228 FOR SHOP TEST.
24. TAG NUMBERS SHOWN REPRESENT ALL FOUR PANELS (2 UNITS 2 DIVISIONS)
    FOR EXAMPLE: 1&2R43N001A,B = 1R43N001A (UNIT 1, DIV 1)
    1R43N001B (UNIT 1, DIV 2)
    2R43N001A (UNIT 2, DIV 1)
    2R43N001B (UNIT 2, DIV 2)
    1&2R43-S21 = 1R43-S21 (UNIT 1, DIV 1)
    1&2R43-S22 1R43-S22 (UNIT 1, DIV 2)
    2R43-S21 (UNIT 2, DIV 1)
    2R43-S22 (UNIT 2, DIV 2)
25. ◆ SIGNALS CONNECTED TO ANNUNCIATOR THROUGH OPTICAL ISOLATOR.

ITEM	DESCRIPTION	PART NO	QTY	MFG
1	SHUTDOWN LOGIC	IR-6147	1	DELAVAL
2	MANOMETER	F 562 001	1	MERIAM
3	PRESSURE GAUGE 30-0-100	F 530 400	1	ROYLYN
4	↓ 0-60	F 530 478	4	ASHCROFT
5	0-100	F 530 479	1	↓
6	0-300	F 530 482	2	
7	0-60 DIFF	F 530 489	1	
8	0-30 DIFF	F 530 488	1	
9	0-100	F 530 370	1	MOORE
10	LEVEL GAUGE	F 530 469	1	SIMMONS
11	METER, DAY TANK	F 561 093	1	GE
12	CHECK VALVE	F 573 121	7	CALCON
13	CHECK VALVE	F 573 375	2	M & M
14				
15	ORIFICE .014	F 575 133	5	CALCON
16	PARALLEL ORIFICE CHECK .006	F 573 144	2	↓
17	SNUBBER	F 535 375	3	ASHCROFT
18	ACCUMULATOR 19.6 CU IN	F 573 326	5	TIMBRA
19	SHUTTLE VALVE	F 573 126	3	HUMPHREY
20	3 WAY VALVE MAN	F 573 589	1	↓
21	↓ NC	F 573 587	1	
22	NO	F 573 132	1	
23	REGULATOR	F 579 061	1	BELLOFRAM
24	FILTER	F 527 002	1	NORGREN
25	MANO TEST VALVE	F 573 298	1	WHITEY
26	CIRCUIT BREAKER 10AMP DC	F 511 085	8	HEINEMANN
27	CIRCUIT BREAKER 10AMP AC	F 511 001	2	HEINEMANN
28	TIME DELAY .5 TO 5 SEC	F 590 208	2	AGASTAT
29	TIME DELAY 1.5 TO 15 SEC	F 590 220	3	AGASTAT
30	RELAY 2 POLE DC	F 580 076	3	A B
31	RELAY 4 POLE DC	F 580 078	4	A B
32	TIME DELAY 20 TO 200 SEC	F 590 221	1	AGASTAT
33	RELAY 6 POLE DC LR	F 580 088	4	A B
34	FUSE 3AMP	F 525 032	4	BUSS
35	POWER SUPPLY	F 596 010	2	AIRPAX
36	TACH TRANSMITTER	F 594 041	2	AIRPAX
37	RESISTOR	F 583 019	2	OHMITE
38	TACHOMETER	F 594 043	1	GE
39	ANNUNCIATOR	75051-127	1	RONAN
40	HORN	F 596 013	1	FEDERAL

ITEM	DESCRIPTION	PART NO	QTY	MFG
41	TOGGLE SW 2 POS	F 585 129	1	HUBBLE
42	INTERIOR LIGHT	F 555 039	1	CROUSE HINDS
43	CONVENIENCE OUTLET	F 191 024	1	HUBBLE
44	STRIP HEATER	[illegible]35 395	2	GE
45	TEMP INDICATOR	F 578 047	1	DORIC
46	TC SEL SWITCH	F 585 119	1	OMEGA
47	SOL VALVE 3 WAY 125VDC	F 586 061	15	HUMPHREY
48	TEMP SWITCH	F 593 012	1	FENWAL
49	PRESS SWITCH DIFF.	F 577 027	2	BARKSDALE
50	↓	F 577 046	4	↓
51	↓	F 577 045	4	
52	HOURMETER	F 561 014	1	WESTINGHOUSE
53	PUSHBUTTON BLACK	F 576 001	6	GE
54	SEL SW 3 POS	F 585 059	3	GE
55	SEL SW 2 POS KEYED	F 585 008	1	GE
56	RELAY 24VDC	F 580 021	1	P B
57	RELAY TC SETPOINT DUAL	F 540 105	4	ACTION PAK
58	LIQUID LEVEL TRANSMITTER	F 540 117	1	ROSEMOUNT
59	RELAY 6 POLE DC	F 580 080	1	AB
60	PUSHBUTTON GUARD	F 576 012	1	G E
61	STARTS COUNTER	F 513 009	1	DURANT
62	PUSHBUTTON RED	F 576 002	1	G E
63	RELAY 24VDC	F 580 094	1	AB
64	PHONE JACK	F 555 405	1	ALLIED
65	CAPACITOR	F 514 006	2	SPRAGUE
66	SEL SW 2 POS SPG RET TO CTR.	F 585 139	4	GE
67	3 WAY VALVE	F 180 002	1	VALVAIR
68	PRESS TRANS 0-400 PSI	F 540 119	2	BOURNS
69	PRESS TRANS 0-100 PSI	F 540 118	1	BOURNS
70	AVDT & POWER SUPPLY	F 540 120	1	SCHAEVITZ
71	OPTICAL ISOLATOR	IR-6478	1	DELAVAL
72	PILOT LIGHT W/RESISTOR RED	F 575 148	14	RUNDEL
73	↓ GREEN	F 575 147	9	↓
74	WHITE	F 575 149	1	
75	CAPACITOR 28 MFD	F 514 008	16	SPRAGUE
76	RELAY 7 POLE DC	F 580 081	1	AB
77	PRESSURE SWITCH	F 577 014	1	BARKSDALE

☐ INDICATES LOCATION
\# PROVIDED BY OWNER
1 ON ENGINE
2 ON GENERATOR
3 IN CONTROL ROOM PANEL
4 ON HEAT EXCHANGER
5 ON HEATER
6 IN MCC
7 PART OF DAY TANK LEVEL SW
8 PART OF DC STARTER, AUX SKID
9 PART OF LUBE TANK SW
10 ON AUX MODULE
11 IN GENERATOR PANEL
12 IN SWITCHGEAR
13 IN PANEL
14 ON STARTING AIR TANK
15 IN STANDPIPE
16 ON DAY TANK
17 ON FUEL RACK
18 MAIN FUEL TANK
19 ON STARTING AIR COMPRESSOR
▲ INDICATES TERMINAL OUTSIDE OF ENGINE CONTROL PANEL

SOL			FUNCTION
5	A	B	ACTIVATE SHUTDOWNS
5	A	-	MODE INOP
6	A	B	DE ACTIVATE SHUTDOWNS
7	A	B	200 RPM
8	A	B	UP TO SPEED
9	A	B	FIELD FLASH
10	A	-	MODE NORMAL
11	A	B	DC POWER
12	-	B	STOP

NUCLEAR
SAFETY
RELATED

CLEVELAND ELECTRIC
ILLUMINATING CO
PERRY NUCLEAR POWER PLANT
UNITS #1 & #2

MATERIAL AND HARDNESS —

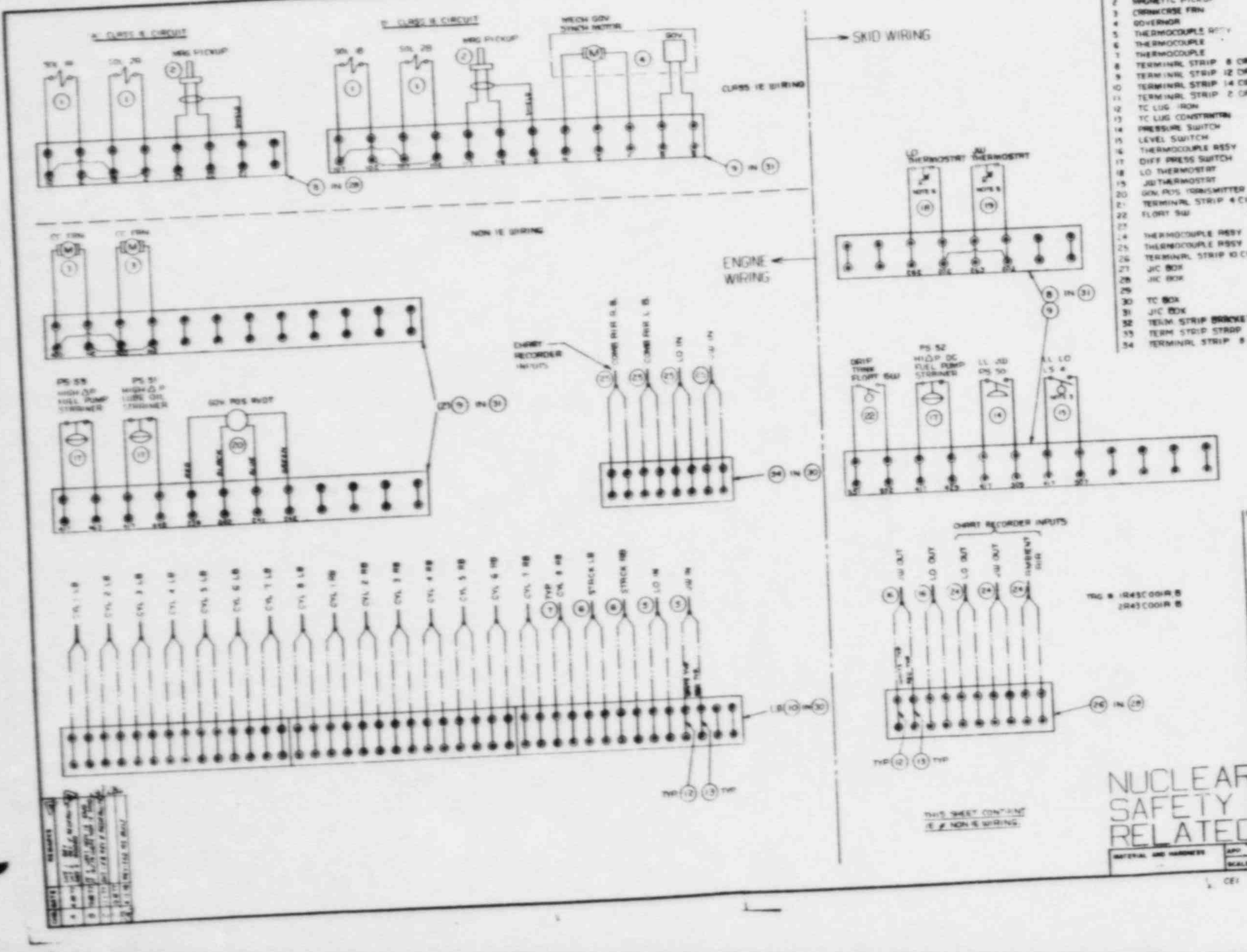
DELAVAL

CONTROL PANEL SCHEMATIC

SHT 11 OF 18

09-500-75064

REV E



ITEM	DESCRIPTION	PART NO	QTY	P.L.
1	STARTING AIR SOLENOID	SEE SPEC	4	441
2	MAGNETIC PICKUP	FA 008 000	2	888
3	CRANKCASE FAN	SEE SPEC	2	387
4	GOVERNOR	SEE SPEC	1	415
5	THERMOCOUPLE ASSY	F 540 050	2	890
6	THERMOCOUPLE	SEE SPEC	2	650
7	THERMOCOUPLE	SEE SPEC	16	630
8	TERMINAL STRIP 8 CIRCUIT	F 591 114	2	688
9	TERMINAL STRIP 12 CIRCUIT	F 591 105	4	688
10	TERMINAL STRIP 14 CIRCUIT	F 591 107	3	888
11	TERMINAL STRIP 2 CIRCUIT	F 591 005	6	688
12	TC LUG IRON	F 591 090	29	888
13	TC LUG CONSTANTAN	F 591 091	29	688
14	PRESSURE SWITCH	F 577 088	1	091
15	LEVEL SWITCH	F 528 027	1	091
16	THERMOCOUPLE ASSY	F 540 050	2	091
17	DIFF PRESS SWITCH	F 577 027	3	090
18	LO THERMOSTAT	SEE SPEC	1	717
19	JW THERMOSTAT	SEE SPEC	1	717
20	GOV POS TRANSMITTER	F 540 120	1	500
21	TERMINAL STRIP 4 CIRCUIT	F 591 007	2	688
22	FLOAT SW	SEE SPEC	1	021
23				
24	THERMOCOUPLE ASSY	F 540 050	3	689
25	THERMOCOUPLE ASSY	F 540 050	4	688
26	TERMINAL STRIP 10 CIRCUIT	F 591 013	1	688
27	JIC BOX	F 510 027	8	
28	JIC BOX	F 510 114	2	
29				
30	TC BOX	F 510 025	1	
31	JIC BOX	F 510 015	3	
32	TERM STRIP BRACKET	F 510 142	1	
33	TERM STRIP STRAP	F 510 147	9	↓
34	TERMINAL STRIP 8 CIRCUIT	F 591 011	1	688

13 75051 & 75052: ALL IE WIRING TO BE YELLOW. 75053 & 75054: ALL IE WIRING TO BE MEDIUM BLUE. ALL NON IE WIRING TO BE GRAY, F 509 401.

12

11 ALL WIRING TO BE RUN IN RIGID CONDUIT. SHORT LENGTHS OF SEALTITE BETWEEN DEVICES & CONDUIT ARE PERMISSIBLE.

10 ALLOW CONDUIT & WIRE TO REACH ENGINE

9 MOUNT 35 BELOW ℄ OF INLET FLANGE ON STANDPIPE.

8 USE BRACKET 52235 TO HOLD ITEM 48 TO START AIR ADMISSION VALVE.

7 RUN UNDER CAMSHAFT GALLERY

6 PART OF HTR 2

5 PART OF HTR 6

4 RUN SEPARATE NEUTRALS TO PANEL

3 LOCATED IN LO SUMP TANK

2 IDENTIFY BOTH ENDS OF WIRE

1

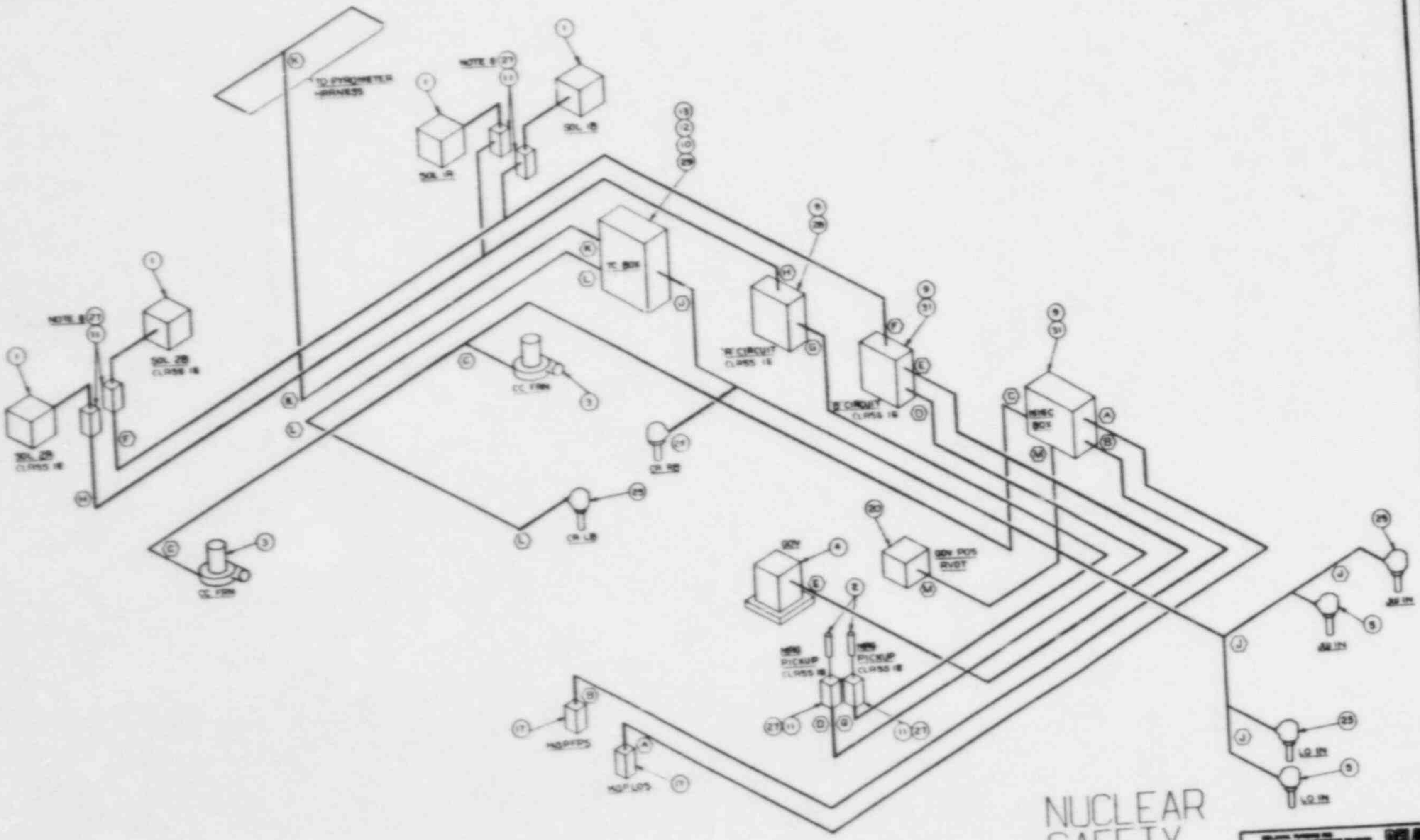
NUCLEAR SAFETY RELATED

DELAVAL

ENGINE & SKID ELECTRICAL SCHEMATIC

MATERIAL AND HARDNESS	APP	DWN	SHEET 1 OF 3	REV
	SCALE	CKD	09-688-75051	E

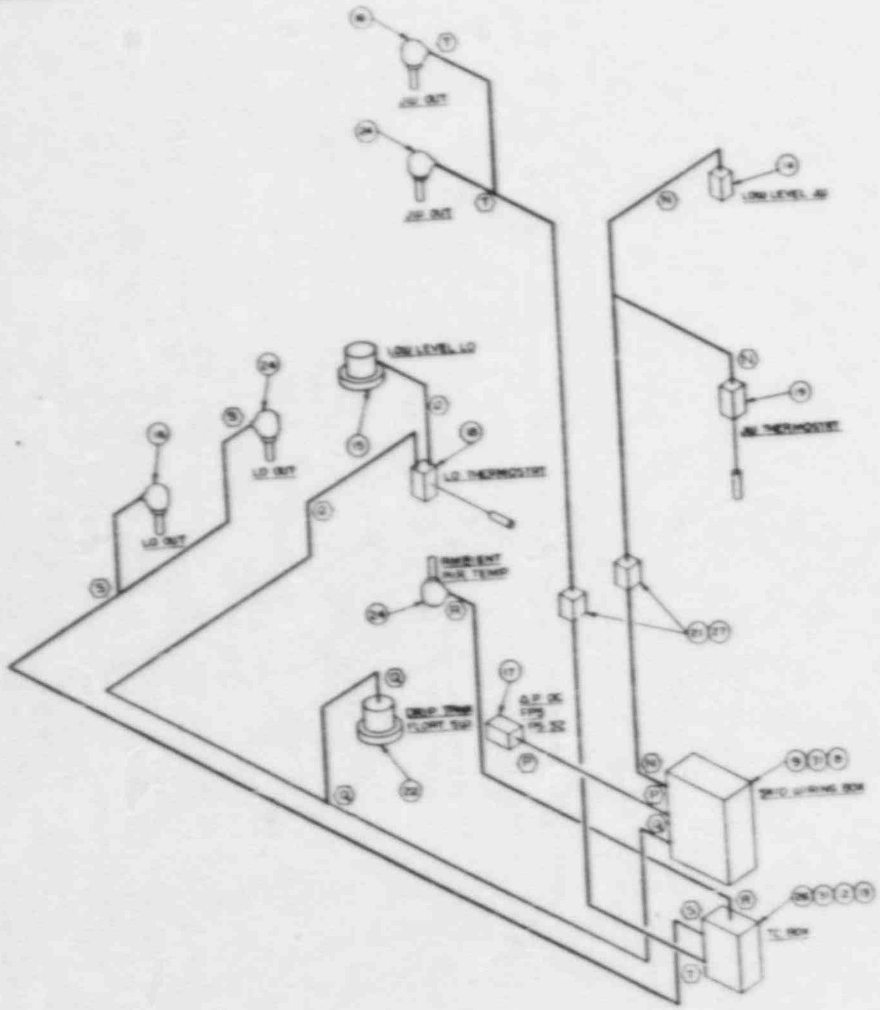
CE1



NUCLEAR
SAFETY
RELATED

THIS SHEET CONTAINS
1E & NON 1E CIRCUITRY

DELAVAL
ENGINE & SKID
ELECTRICAL SCHEMATIC
MATERIAL AND HARDNESS —
SCALE —
SHEET 2 OF 3
09-688-7505
REV E



PART NAME	PART NO.	REMARKS	QTY
SHIELDED CABLE	F 509 031		34'
WIRE, THERMOCOUPLE	F 509 355		300'
WIRE, 14 GR	F 509 107		[illegible]
3 CONDUCTOR CABLE	F 509 212		18'
STRYCO SEAL WASHER	F 118 056		8
3/4 x 1/2 REDUCER	F 509 087		14
3/8 SEALTITE CONNECTOR	F 509 118		22
3/8 90° ELBOW	F 509 123		17
3/8 CONDUIT	F 509 113		30
1/2 RIGID CONDUIT	F 509 080		300'
1/2 UNI SEAL HUB	F 509 408		27
1/2 PULL ELBOW	F 509 394		[illegible]
1/2 LB UNILET	F 509 035		2
1/2 UNILET TEE	F 509 081		8
1/2 COVER	F 509 037		10
1/2 GASKET	F 509 041		10
1/2 UNION COUPLING	F 509 026		27
1/2 GASKET ASSY	F 509 079		6
1/2 CLOSE NIPPLE	F 509 013		30
1/2 ELBOW CONN	F 509 051		2
1-1/2 PULL ELBOW	F 509 417		7
1-1/2 CLOSE NIPPLE	F 509 380		3
1-1/2 UNILET TEE	F 509 413		1
1-1/2 COVER	F 509 040		1
1-1/2 GASKET	F 509 044		1
1-1/2 RIGID CONDUIT	F 509 308		30'
1-1/2 SLEEVE	F 509 41[illegible]		3
1-1/2 FACTORY ELBOW	F 509 431		3
1-1/2 UNION	F 509 415		2
1-1/2 x 1-1/4 BUSHING	F 509 413		3
1-1/4 SEALTITE CONNECTOR	F 509 122		4
1-1/4 SEALTITE CONDUIT	F 509 11[illegible]		8
CABLE CONNECTOR	F 509 395		1
1-1/2 HUB	F 509 412		1

X - AS REQUIRED

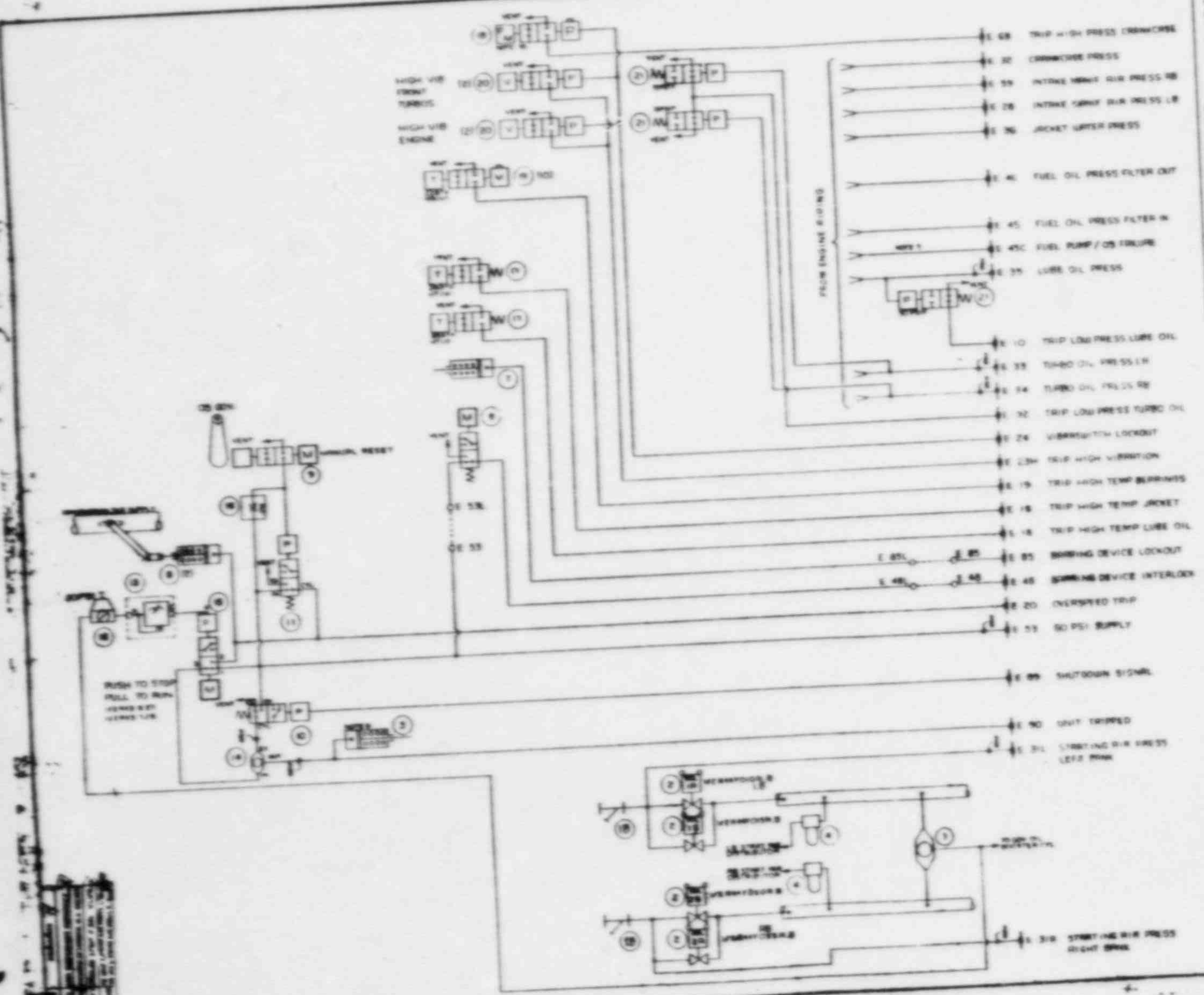
NUCLEAR
SAFETY
RELATED

ALL CIRCUITRY ON THIS SHEET IS NON 1E

DELAVAL

ENGINE & SKID
ELECTRICAL SCHEMATIC

SHEET 3 OF 3
09-688-75051
REV E



ITEM	DESCRIPTION	PART NO.	QTY	P.L.	MFR
1	START AIR STRAINER	SEE SPEC	2	441	–
2	START AIR ADMISSION VLV		4	441	–
3	SHUTTLE VALVE		1	441	–
4	FILTER, AIR DISTRIBUTOR		2	442	–
5	SHUTDOWN CYL		1	413	–
6	AIR SHUTOFF CYL		2	415	–
7	BARRING DEVICE LOCKOUT CYL		1	525	–
8	BARRING DEVICE INTERLOCK		1	525	–
9	OVERSPEED TRIP VALVE	F 153 009	1	410	PRATT
10	3 WAY VALVE NC	F 573 123	1	695	HUMPHREY
11	3 WAY VALVE NO	F 573 132	1		HUMPHREY
12	PRESS REGULATOR	F 579 013	1		NORGREN
13	TIMER NOT ELEMENT	F 573 307	1		BRO
14	SHUTTLE VLV QUICK	F 573 126	1		HUMPHREY
15	STOP RUN VLV	F 573 212	1		CALCON
16	ORIFICE .014	F 573 133	1		
17	TRIP HIGH TEMP	F 573 330	2		
18	HIGH PRESS	F 578 359	1		
19	MAIN BRG TEMP	F 573 271	10		
20	VIBRATION	F 573 171	4		
21	LOW PRESS	F 573 156	3		

10. MOUNTS INTO CRANKCASE USING 3/4" HYDRAULIC NIPPLE CONNECT DRAIN TO SUMP
9. KEEP TUBES BETWEEN CYL & FEED DEVICES SHORT.
8. ALL VENTS MUST FACE DOWN OR BE SPLASH SHIELDED
7. THIS TUBE CONNECTS BETWEEN FUEL PUMP DISCH & DISCH CHECK VALVE
6. SET, TEST & TAG ALL SAFETY SENSORS DURING SHOP TEST.
5. 1/4" OD TUBING IS RECOMMENDED FOR CONNECTION TO PANEL EXCEPT AS SHOWN 3/8 ON THIS DWG
4. TUBING IS SEAMLESS STL 1/4" OD EXCEPT AS NOTED. FITTINGS ARE CAD PLATE STL
3. SYSTEM SHOWN SHUTDOWN & DEPRESSURIZED
2. ⦶ DENOTES TUBE TERMINATION AT ENG TERMINAL BRCK. IDENTIFY TERMINALS
1. CONTROL MEDIUM IS AIR

NUCLEAR
SAFETY
RELATED

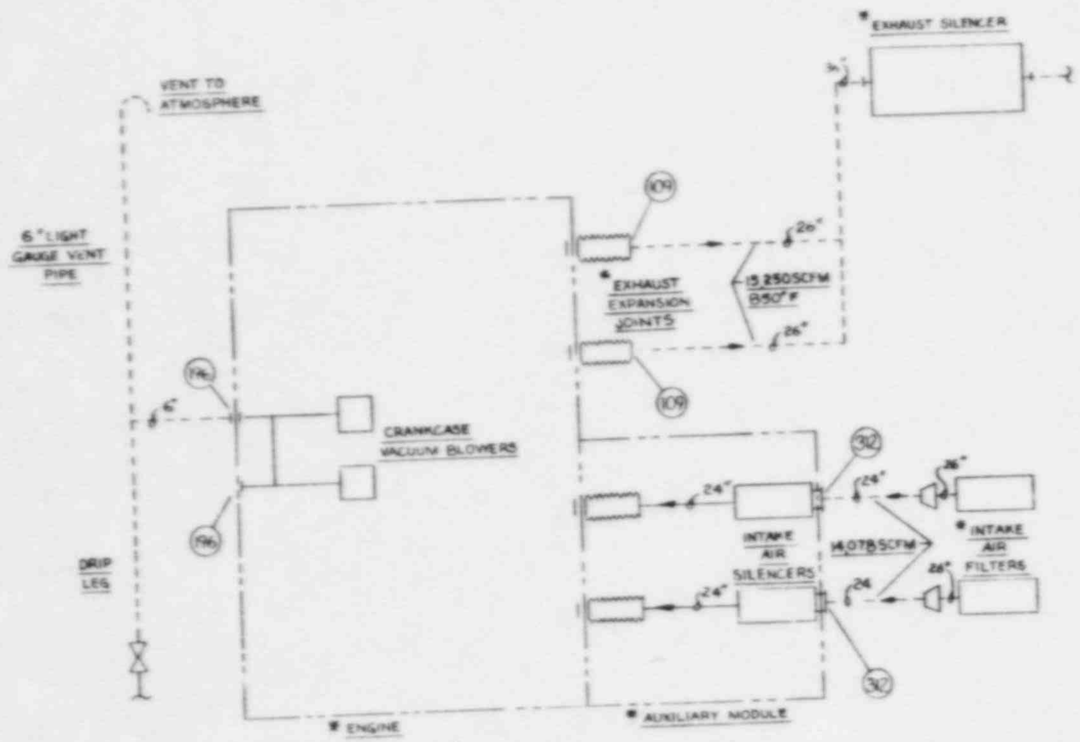
CLEVELAND ELECTRIC
ILLUMINATING CO.
PERRY NUCLEAR POWER PLANT
UNITS #1 & #2

DELAVAL

ENGINE PNEUMATIC SCHEMATIC

MATERIAL AND HARDNESS —
SCALE —

D-695-7305
REV D



1. ALL ITEMS MARKED * ARE SUPPLIED BY DELAVAL.
2. (100) - (300) SERIES NUMBERS CORRESPOND TO NUMBERED PIPE CONNECTIONS BY CUSTOMER.
3. SOLID LINES INSIDE OF (100) - (300) SERIES NUMBERED CONNECTIONS REPRESENT PIPING & FITTINGS SUPPLIED BY DELAVAL.
4. FOR PIPING SYMBOLS SEE DRAWING D-4313.
5. FLEXIBLE COUPLINGS ARE NOT RECOMMENDED AT CUSTOMER CONNECTIONS BECAUSE OF POTENTIAL FAILURE HAZARD DURING OPERATION, EXCEPT FOR FLEXIBLE CONNECTIONS AT CONNECTION 109.
6. ALL PIPING TO BE PROPERLY SUPPORTED TO MINIMIZE PIPE VIBRATION & FLANGE LOADING. INTAKE & EXHAUST PIPES MUST NOT BE SUPPORTED BY THE TURBOCHARGER.
7. CONTROLS ARE NOT SHOWN, BUT RATHER SEE CONTROL SCHEMATIC FOR SIZE & LOCATION.
8. CUSTOMER TO SUPPLY AND INSTALL ALL PIPING SHOWN IN DOTTED LINES (---).
9. INLET AIR PRESSURE DROP MUST BE NO MORE THAN 9 INCHES H_2O AT CONNECTION 312.
10. EXHAUST GAS BACK PRESSURE MUST BE NO MORE THAN 10 IN. H_2O AT CONNECTION 109.
11. PIPE SIZES SHOWN FOR INTAKE & EXHAUST ARE MINIMUM FOR 30 FT. PIPE RUNS.
12. LOCATE THE INTAKE & EXHAUST SO THAT EXHAUST HEAT DOES NOT ENTER INTAKE.
13. SOUND INSULATE PIPE BETWEEN TURBO & INTAKE SILENCER FOR FREQUENCIES BETWEEN 2000 & 8000 HZ.
14. PREPARE & PAINT INSIDE OF INTAKE PIPE WITH RUST-OLEUM OR EQUIVALENT COATING SYSTEM IN ACCORDANCE WITH THEIR DIRECTIONS FOR INTAKE PIPES.
15. EXHAUST MUFFLER TAIL PIPE IS TO BE EXTENDED TO AN OUTLET LEVEL ABOVE EAVES.
16. CLEAN PIPES AFTER WELDING & PRIOR TO ASSEMBLING.

System # R-48

CERTIFIED PRINT MUST BE USED FOR CONSTRUCTION

CERTIFICATION

PROJECT ENGINEER C. W. Dawson

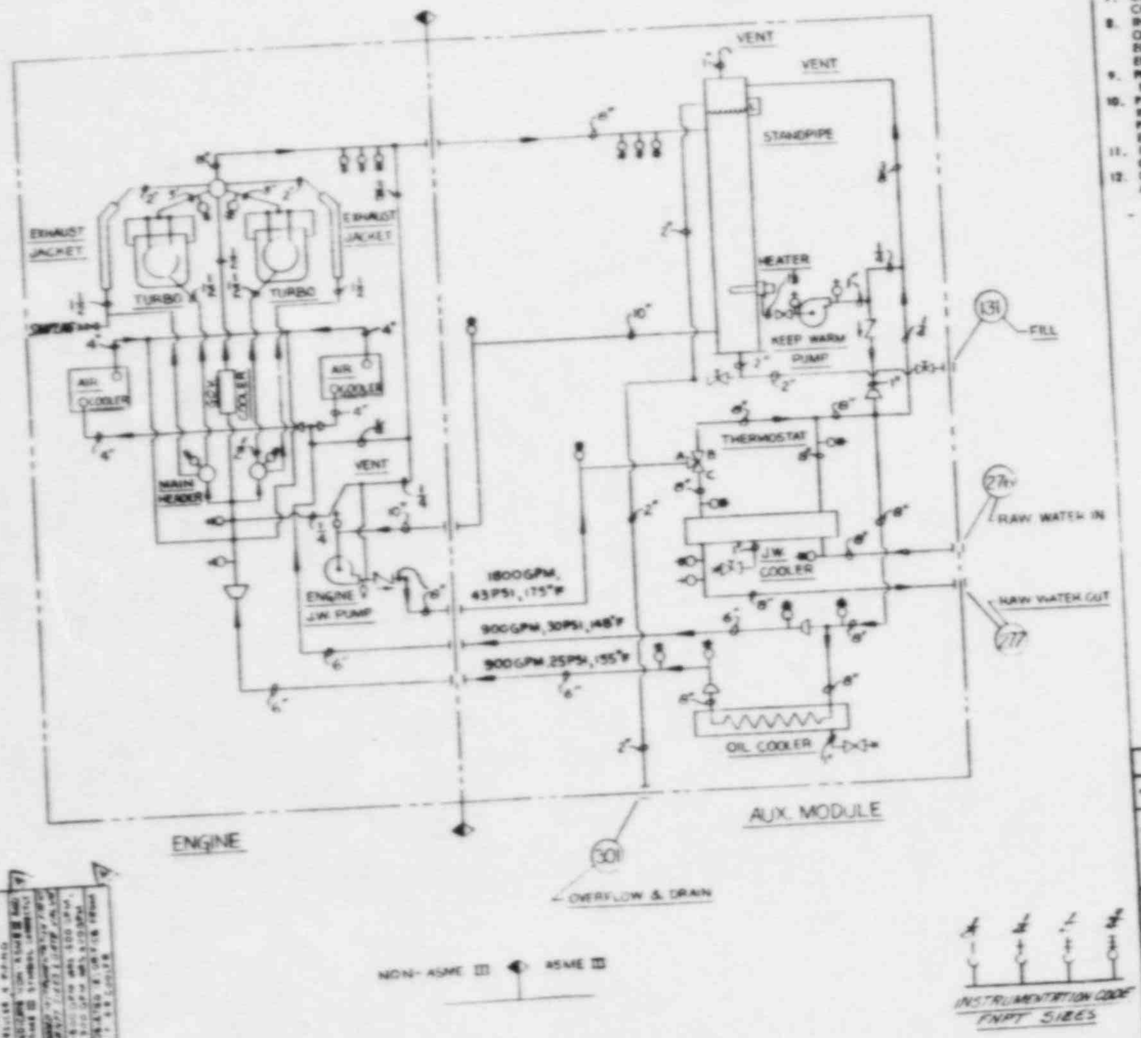
CUSTOMER CLEVELAND ELECTRIC ILLUMINATING CO.
CUSTOMER REF PERRY NUCLEAR UNITS 1&2
ENGINE NO. 75051-54

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

EXHAUST, INTAKE & CRANK-CASE PIPING SCHEMATIC

DRAWN S.K. 10-6-76	09-805-75051	B
CHECKED JEL 10-7-76		
APPROVED 21E		
SCALE NONE	DRAWING NUMBER	ALT

CHG	DATE	REMARKS
A	[illegible]	[illegible]
B	[illegible]	[illegible]



1. ALL ITEMS AND PIPING SHOWN ARE SUPPLIED BY DELAVAL.
2. (100) - (300) NUMBERS CORRESPOND TO NUMBERED PIPE CONNECTIONS BY CUSTOMER.
3. SOLID LINES INSIDE OF (100) - (300) SERIES NUMBERED CONNECTIONS REPRESENT PIPING & FITTINGS SUPPLIED BY DELAVAL.
4. FOR PIPING SYMBOLS, SEE DRAWING D-4313.
5. FLEXIBLE COUPLINGS ARE NOT RECOMMENDED AT CUSTOMER CONNECTIONS BECAUSE OF POTENTIAL FAILURE HAZARD DURING OPERATION.
6. ALL PIPING TO BE PROPERLY SUPPORTED TO MINIMIZE PIPE VIBRATION & FLANGE LOADING.
7. CONTROLS ARE NOT SHOWN, BUT RATHER SEE CONTROL SCHEMATIC FOR SIZE & LOCATION.
8. INSTALLATION CONTRACTOR(S) TO SUPPLY ALL OFF-ENGINE PIPING, PIPING FITTINGS, EQUIPMENT & VALVES NOT SUPPLIED WITH ENGINE-MODULE.
9. PROVIDE SUCH DRAINS AND VENTS AS DEEMED NECESSARY BY DELAVAL ENGINEERING.
10. PIPE SIZES SHOWN ARE MINIMUM FOR MOST INSTALLATIONS BUT MAY VARY WHEN LENGTH OF PIPE, NUMBER OF FITTINGS & VALVES PRODUCE EXCESSIVE PRESSURE DROP.
11. 10 PSI PRESSURE DROP IS AVAILABLE FOR OFF-ENGINE PIPING CIRCUIT.
12. CLEAN PIPES AFTER WELDING AND PRIOR TO ASSEMBLING.

System # R-46

CERTIFIED PRINT MUST BE USED FOR CONSTRUCTION

CERTIFICATION

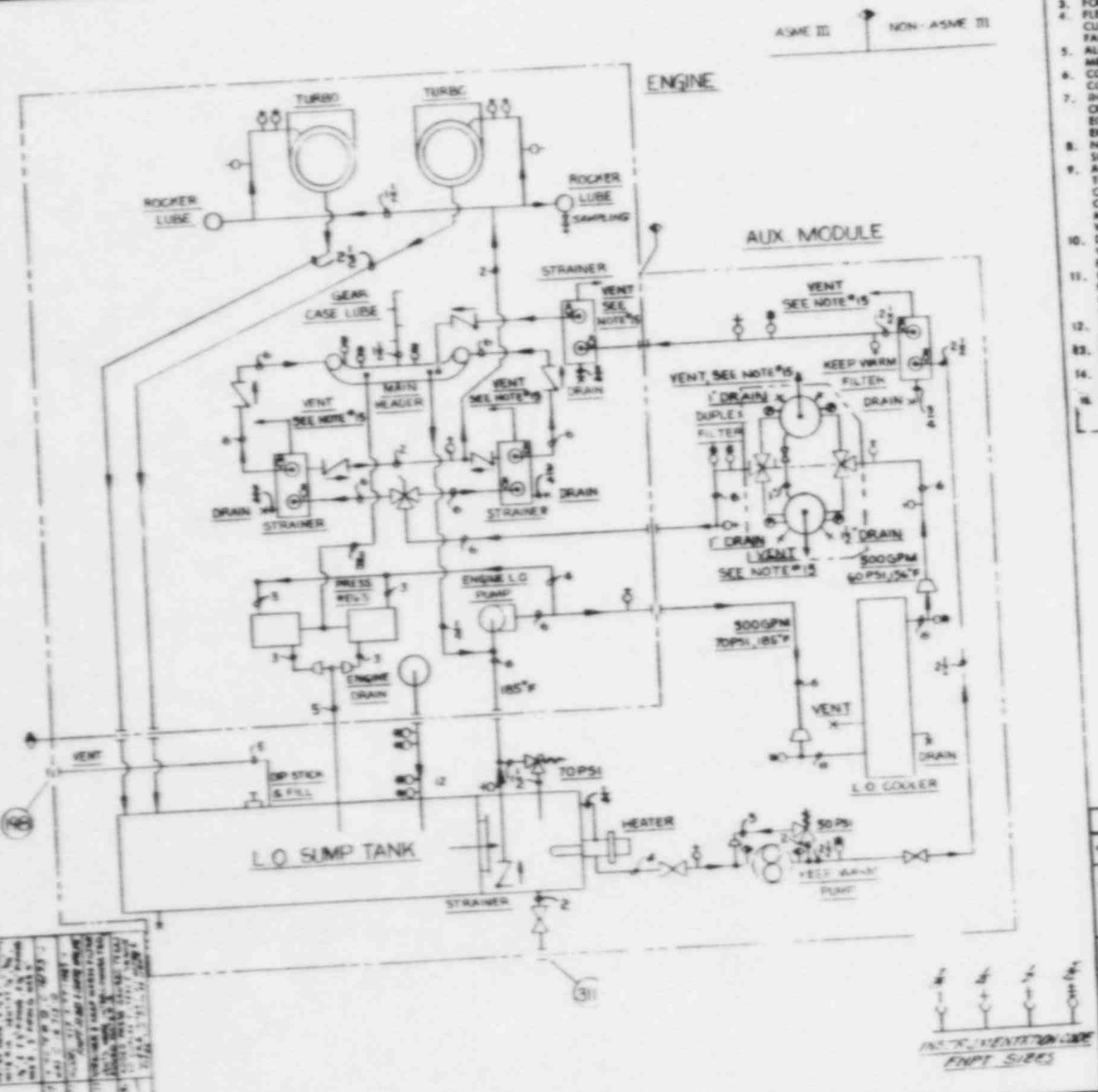
PROJECT ENGINEER C W [illegible]

CUSTOMER CLEVLAND ELECTRIC ILLUMINATING CO.
CUSTOMER REF PERRY NUCLEAR - UNIT'S 1&2
ENGINE NO. 75051-54

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

JACKET WATER
PIPING SCHEMATIC

DRAWN S.K. 10-7-76	09-810-75051	E
CHECKED FEK 10-7-76		
APPROVED RJB	DRAWING NUMBER	ALT
SCALE NONE		



1. ALL ITEMS AND PIPING SHOWN ARE SUPPLIED BY DELAVAL.
2. (100) - (300) SERIES NUMBERS CORRESPOND TO NUMBERED PIPE CONNECTIONS BY CUSTOMER.
3. FOR PIPING SYMBOLS, SEE DRAWING D-4313.
4. FLEXIBLE COUPLINGS ARE NOT RECOMMENDED AT CUSTOMER CONNECTIONS BECAUSE OF POTENTIAL FAILURE HAZARD DURING OPERATION.
5. ALL PIPING TO BE PROPERLY SUPPORTED TO MINIMIZE PIPE VIBRATION & FLANGE LOADING.
6. CONTROLS ARE NOT SHOWN, BUT RATHER SEE CONTROL SCHEMATIC FOR SIZE & LOCATION.
7. INSTALLATION CONTRACTOR(S) TO SUPPLY ALL OFF-ENGINE PIPING, PIPING FITTINGS, EQUIPMENT & VALVES NOT SUPPLIED WITH ENGINE-MODULE.
8. NO BACK-UP RINGS OR CAST IRON FITTINGS SHALL BE USED IN THE SYSTEM.
9. ALL PIPE TO BE HOT PICKLED AFTER FABRICATION AND PRESERVED WITH MIL SPECIFICATION C-23411 OR C-16173C TO PREVENT RUST. COMMERCIALLY, THIS IS MET BY LPS NO. 3 MANUFACTURED BY LPS RESEARCH LABORATORIES, WEST LOS ANGELES, CALIF.
10. DELAVAL RECOMMENDS THAT NO ISOLATING VALVES BE INSTALLED IN THE MAIN LUBE OIL PIPING.
11. OPEN ENDS OF SECTIONS OF PIPE ARE TO BE PROTECTED WITH STEEL BLIND FLANGES & GASKETS, IN ORDER TO PROTECT AGAINST CONTAMINATION.
12. PROVIDE SUCH DRAINS & VENTS AS DEEMED NECESSARY BY DELAVAL ENGINEERING.
13. PRECAUTIONS FOR LUBE OIL SYSTEM, DELAVAL FORM D-4597 ARE TO BE COMPLIED WITH.
14. CLEAN PIPES AFTER WELDING AND PRIOR TO ASSEMBLING.
15. FILTER AND STRAINER VENTS 1" O.D. CONNECT INDIVIDUALLY ON LUBE TANK TOP. DO NOT COMBINE VENTS. DO NOT USE VALVES.

System # R-47

CERTIFIED PRINT MUST BE USED FOR CONSTRUCTION

CERTIFICATION

PROJECT ENGINEER C.W. [illegible]

CUSTOMER CLEVELAND ELECTRIC ILLUMINATING CO.
CUSTOMER REF. PERRY NUCLEAR UNITS 1 & 2
ENGINE NO. 75051-54

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

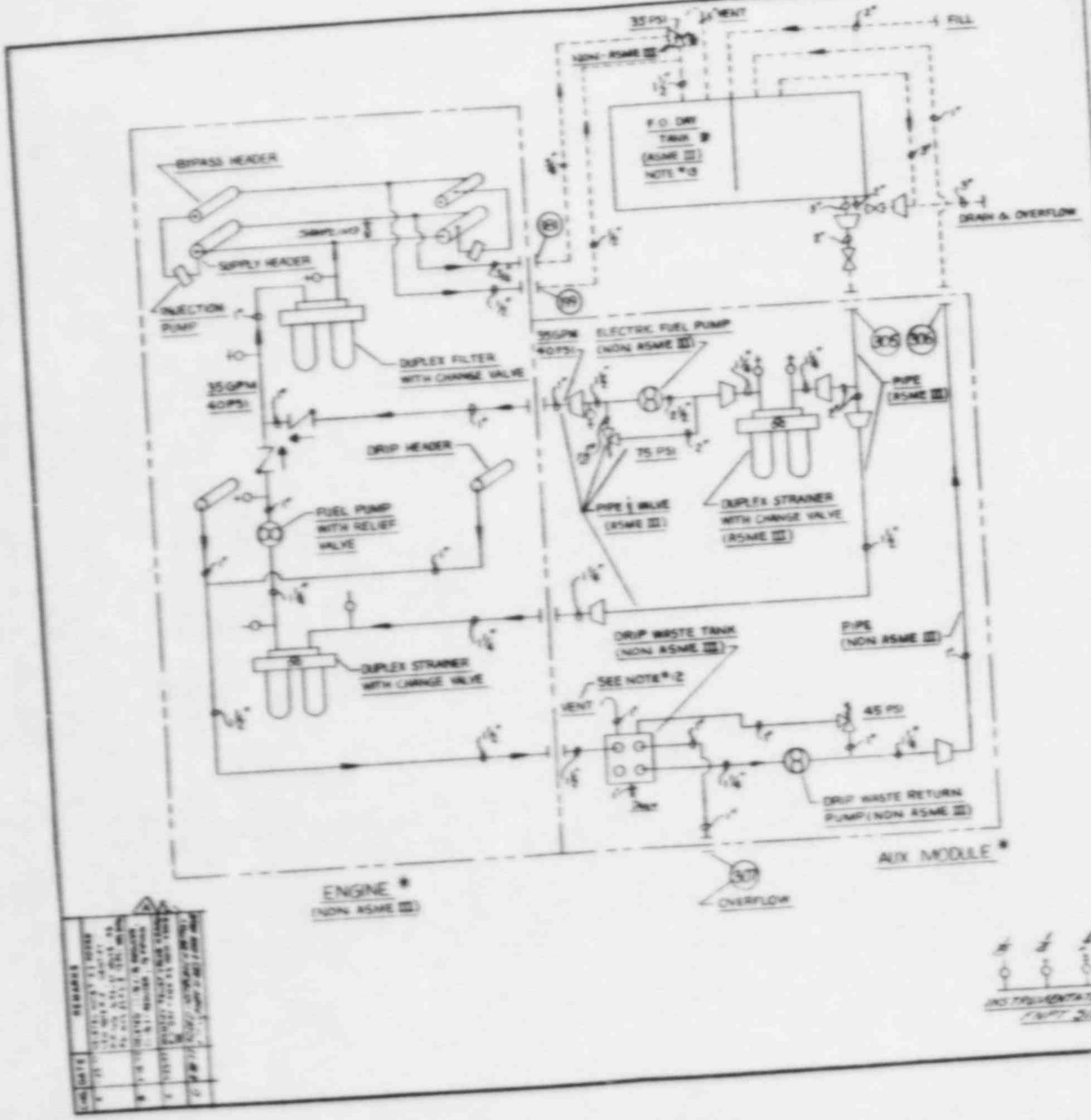
LUBE OIL PIPING SCHEMATIC

DRAWN S.K. 10-11-76
CHECKED [illegible] 10-[illegible]-76
APPROVED [illegible]
SCALE NONE

09-820-75051 E

DRAWING NUMBER ALT

CHG	DATE	REMARKS	APP
E	[illegible]	[illegible]	[illegible]
D	[illegible]	[illegible]	[illegible]
C	[illegible]	[illegible]	[illegible]
B	[illegible]	[illegible]	[illegible]
A	[illegible]	[illegible]	[illegible]



1. ALL ITEMS MARKED * ARE SUPPLIED BY TRANSAMERICA DELAVAL.
2. (100) – (300) SERIES NUMBERS CORRESPOND TO NUMBERED PIPE CONNECTIONS BY CUSTOMER.
3. SOLID LINES INSIDE OF (100) – (300) SERIES NUMBERED CONNECTIONS REPRESENT PIPING & FITTINGS SUPPLIED BY TRANSAMERICA DELAVAL.
4. FOR PIPING SYMBOLS, SEE DRAWING D-4365.
5. FLEXIBLE COUPLINGS ARE NOT RECOMMENDED AT CUSTOMER CONNECTIONS BECAUSE OF POTENTIAL FAILURE HAZARD DURING OPERATION.
6. ALL PIPING TO BE PROPERLY SUPPORTED TO MINIMIZE PIPE VIBRATION & FLANGE LOADING.
7. CONTROLS ARE NOT SHOWN, BUT RATHER SEE CONTROL SCHEMATIC FOR SIZE & LOCATION.
8. CUSTOMER TO SUPPLY AND INSTALL ALL PIPING SHOWN IN DOTTED LINE (---).
9. ALL PIPING TO BE MECHANICALLY CLEANED & PRESERVED WITH MIL SPEC C-23411 OR C-16173-D TO PREVENT RUST. COMMERCIALLY, THIS IS MET BY LPS NO. 3 MANUFACTURED BY LPS RESEARCH LABORATORIES OF WEST LOS ANGELES, CALIFORNIA.
10. CLEAN PIPES AFTER WELDING AND PRIOR TO ASSEMBLING.
11. PIPE SIZES SHOWN ARE MINIMUM FOR MOST INSTALLATIONS, BUT MAY VARY IF LENGTH OF PIPING, NUMBER OF FITTINGS & VALVES RESULT IN EXCESSIVE PRESSURE DROP.
12. VENT MUST NOT BE PIPED HIGHER THAN ONE FOOT ABOVE THE TOP OF THE DRIP TANK.
13. TANK TO BE AT ELEVATION TO PROVIDE FLOODED SUCTION AT BOTH FEED PUMPS.
14. THE PIPE, VALVES, STRAINER ON THE AUX. MODULE ARE ASME SECTION III TO THE ENGINE BOUNDARIES, EXCEPT FOR THE ELECTRIC FUEL PUMP WHICH IS NON ASME III, BUT HAS MATERIAL TRACEABILITY AND SEISMIC QUALIFICATION. THE DRIP RETURN SYSTEM ON THE AUX. MODULE IS NON ASME III.

System # R-45

CERTIFIED PRINT MUST BE USED FOR CONSTRUCTION

CERTIFICATION

PROJECT ENGINEER

CUSTOMER CLEVELAND ELECTRIC ILLUMINATING CO.
CUSTOMER REF. PERRY NUCLEAR UNITS 1 & 2
ENGINE NO. 75051-54

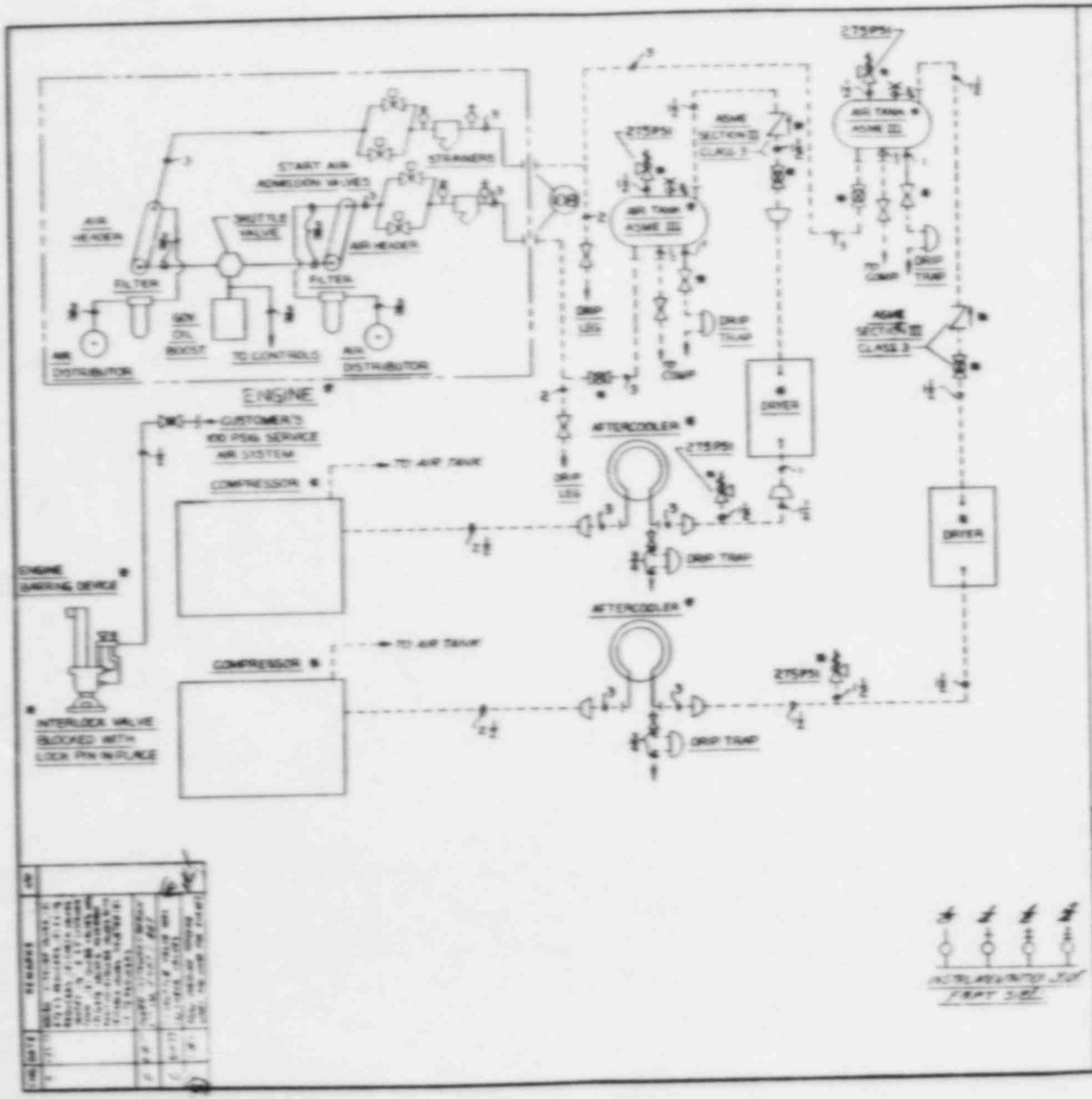
DELAVAL TURBINE INC.
ENGINE AND COMPRESSOR DIVISION
OAKLAND, CALIFORNIA 94621
DELAVAL

FUEL OIL
PIPING SCHEMATIC

DRAWN S.K. 9-15-76
CHECKED HES 5-21-76
APPROVED DRB
SCALE NONE

09-827-75051 D

DRAWING NUMBER
ALT



1. ALL ITEMS MARKED * ARE SUPPLIED BY TRANSAMERICA DELAVAL.
2. (100) - (300) SERIES NUMBERS CORRESPOND TO NUMBERED PIPE CONNECTIONS BY CUSTOMER.
3. SOLID LINES INSIDE OF (100) - (300) SERIES NUMBERED CONNECTIONS REPRESENT PIPING & FITTINGS SUPPLIED BY TRANSAMERICA DELAVAL.
4. FOR PIPING SYMBOLS, SEE DRAWING D-4515.
5. FLEXIBLE COUPLINGS ARE NOT RECOMMENDED AT CUSTOMER CONNECTIONS BECAUSE OF POTENTIAL FAILURE HAZARD DURING OPERATION.
6. ALL PIPING TO BE PROPERLY SUPPORTED TO MINIMIZE PIPE VIBRATION & FLANGE LOADING.
7. CONTROLS ARE NOT SHOWN, BUT RATHER SEE CONTROL SCHEMATIC FOR SIZE & LOCATION.
8. CUSTOMER TO SUPPLY AND INSTALL ALL PIPING SHOWN IN DOTTED LINE (----).
9. ALL PIPING TO BE CLEANED INTERNALLY & BLOWN CLEAN PRIOR TO START UP.
10. PIPING SHOULD BE RUN AT A LOWER LEVEL THAN ENGINE INLET CONNECTION # 108. INSTALL MOISTURE COLLECTORS AND DRAINS IN PIPING AT LOW POINTS NEAR INLET CONNECTION & ANY OTHER LOW POINT IN THE SYSTEM.
11. PIPE SIZES SHOWN ARE MINIMUM FOR MOST INSTALLATIONS, BUT MAY VARY IF LENGTH OF PIPING, NUMBER OF FITTINGS & VALVES RESULT IN EXCESSIVE PRESSURE DROP. 10 PSI MAXIMUM PRESSURE DROP FROM AIR TANK TO ENGINE HEADER.
12. ALL PIPING TO BE SCHEDULE 80, & PIPE FITTINGS TO BE "300 LBS. ASA" FOR 275 PSI WORKING PRESSURE.
13. "Y" STRAINERS MUST BE INSTALLED IN A HORIZONTAL RUN OF PIPE.

System #R-44

CERTIFIED PRINT MUST BE USED FOR CONSTRUCTION

CERTIFICATION

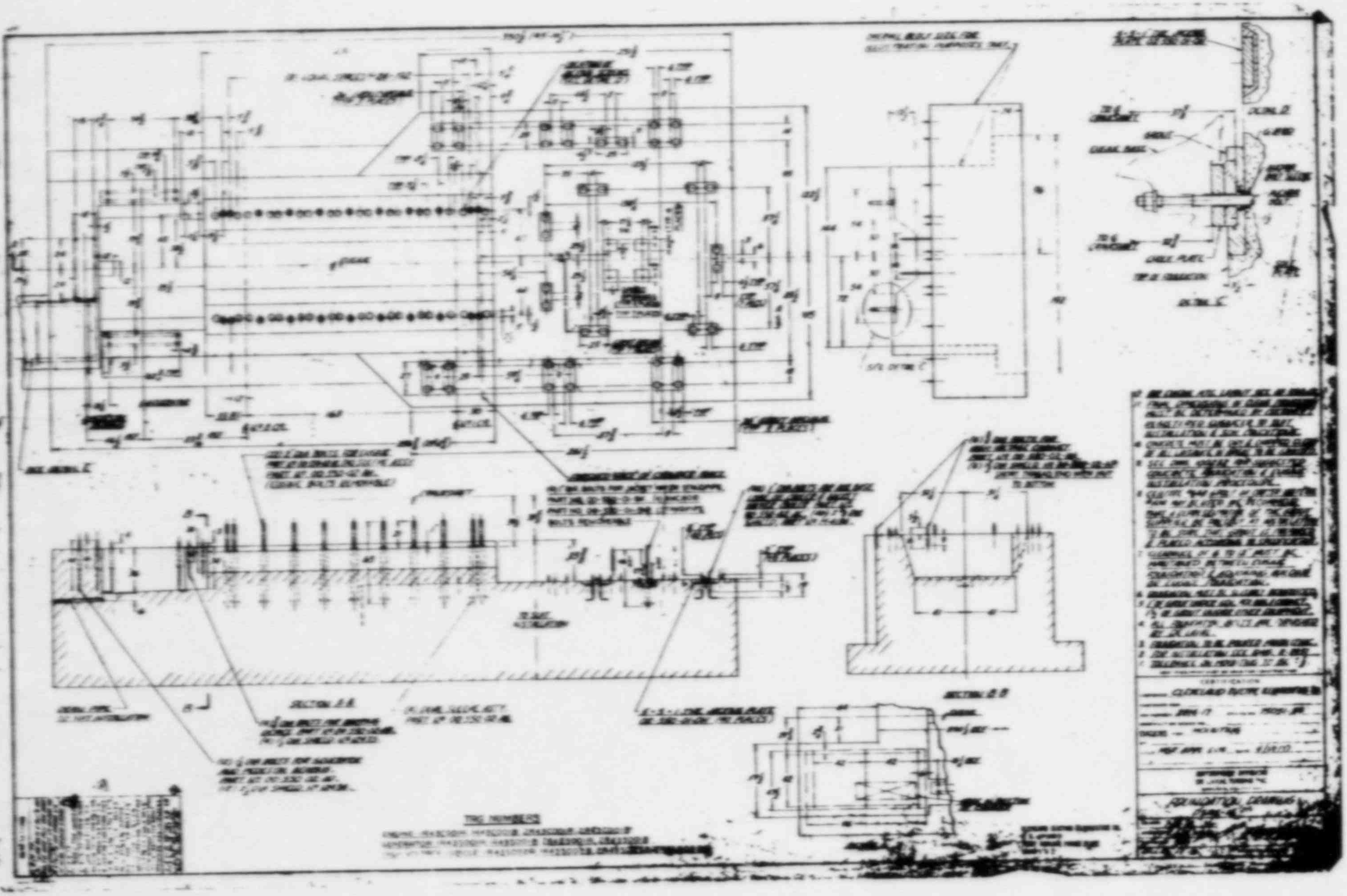
PROJECT ENGINEER

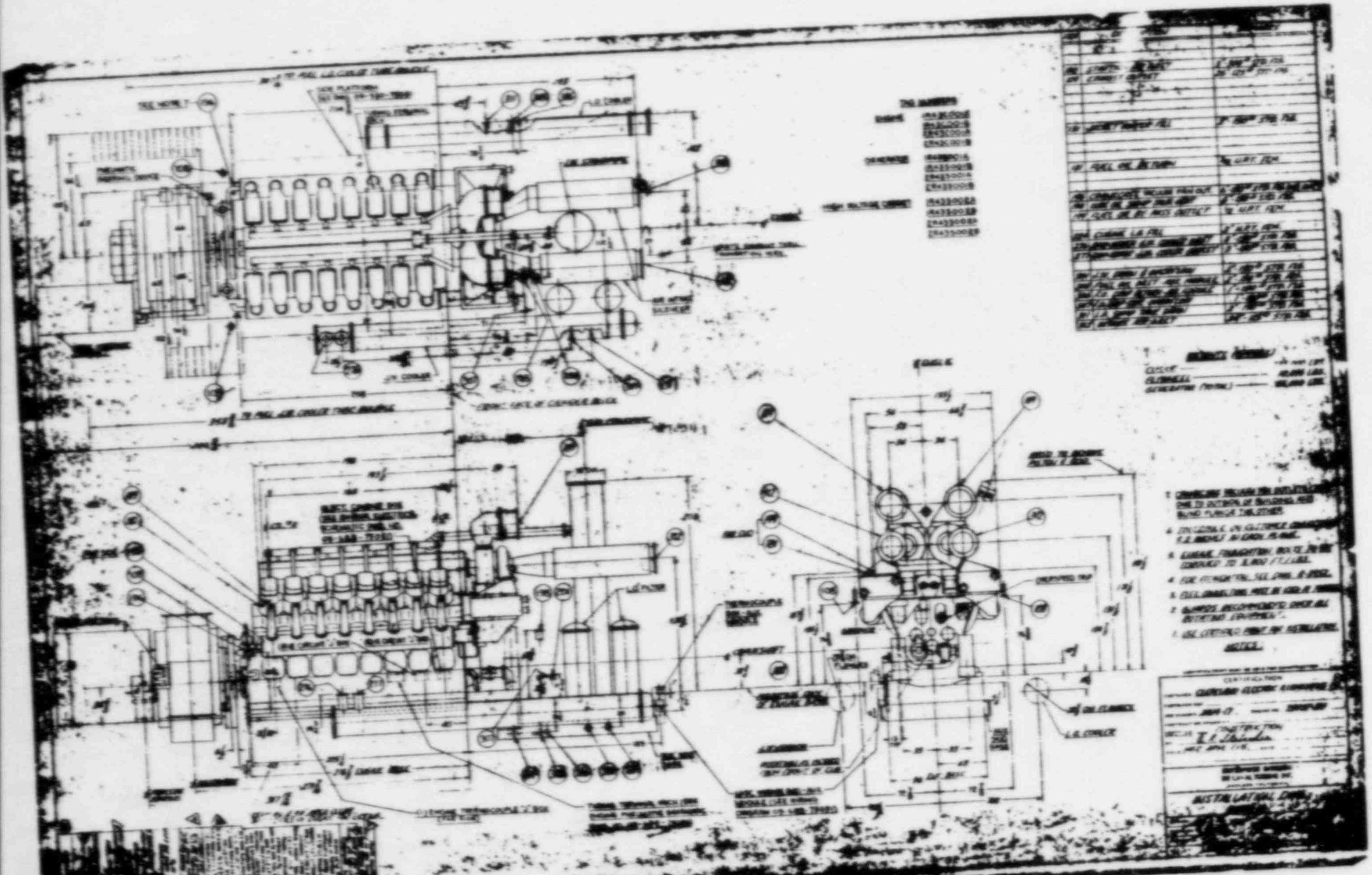
CUSTOMER CLEVELAND ELECTRIC ILLUMINATING CO.
CUSTOMER REF PERRY NUCLEAR UNITS 1 & 2
ENGINE NO. 75081-84

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

STARTING AIR PIPING SCHEMATIC

DRAWN S.K. 10-13-78
CHECKED
APPROVED
SCALE NONE
09-835-75051 D
DRAWING NUMBER
REV


SECTION B-B
SECTION D-D
DETAIL C
TAG NUMBERS
CERTIFICATION
CLEVELAND ELECTRIC ILLUMINATING CO
FOUNDATION DRAWING


NOTES.
CERTIFICATION
CONSTRUCTION
INSTALLATION DWG.

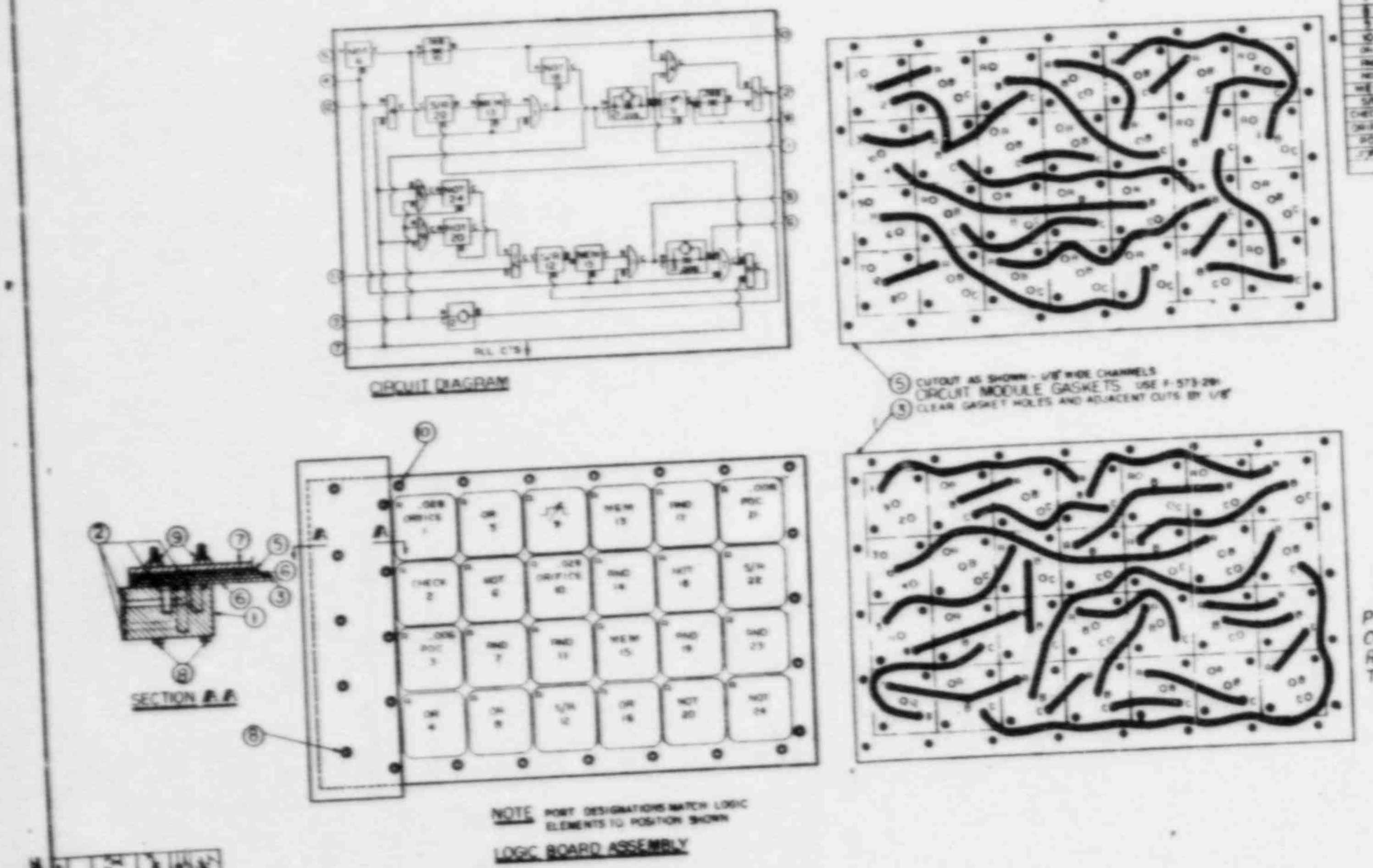
MATERIAL LIST

ITEM	QTY	DESCRIPTION	PART NO.
1	1	CONNECTOR 12 PORT	[illegible]
2	24	O-RING	[illegible]
3	1	CIRCUIT MODULE GASKET	
4			[illegible]
5	1	CIRCUIT MODULE GASKET	[illegible]
6	2	CIRCUIT BASE PLATE	[illegible]
7	1	CIRCUIT COVER PLATE	[illegible]
8	20	SCREW, ALLEN HEAD [illegible]	[illegible]
9	[illegible]	NUT, HEX LIGHT #6-32 UNC [illegible]	[illegible]
10	[illegible]	SCREW, ALLEN HEAD #6-32 [illegible]	[illegible]
OR	4	OR LOGIC ELEMENT	[illegible]
AND	5	AND LOGIC ELEMENT	[illegible]
NOT	4	NOT LOGIC ELEMENT	[illegible]
MEM	2	MEMORY LOGIC ELEMENT	[illegible]
S/R	2	SET/RESET LOGIC ELEMENT	[illegible]
CHECK	1	CHECK VALVE	[illegible]
ORIFICE	[illegible]	ORIFICE .028	[illegible]
POC	[illegible]	PARALLEL ORIFICE CHECK .006	[illegible]
[illegible]	1	TIMER NOT (DIFFERENT[illegible])	

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

TEST PROCEDURE

[illegible]



NOTE PORT DESIGNATIONS MATCH LOGIC ELEMENTS TO POSITION SHOWN

LOGIC BOARD ASSEMBLY

STEP

PORT

DO NOT SCALE DRAWING

NO PRESSURE
PRESSURE
[illegible]
[illegible]
[illegible]

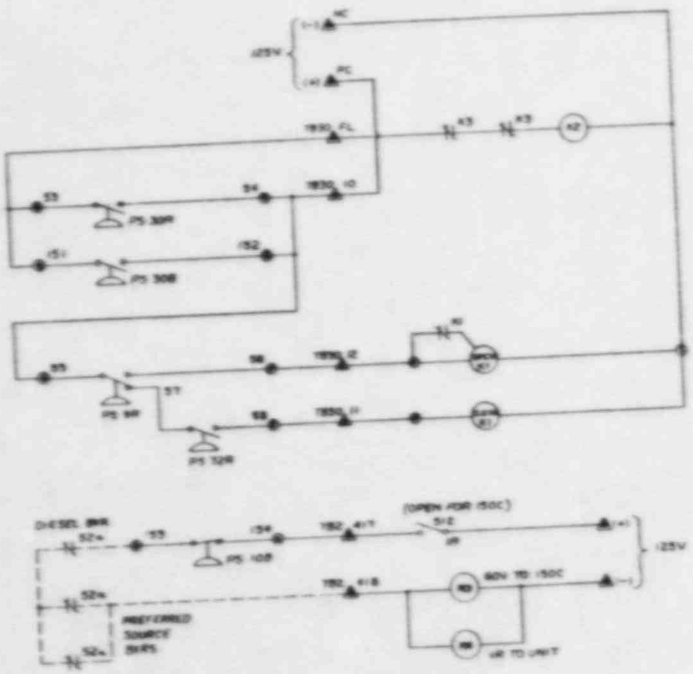
DELAV

PNEUMATIC LOGIC BOARD

61-580-3-[illegible]

SCALE FULL

MATERIAL AND HARDNESS



▲ TERMINALS IN BASLER PANEL

● TERMINALS IN DELAVAL PANEL

INTERCONNECT DIAGRAM

MATERIAL AND HARDNESS —	QTY SCALE —	DWN CKD	52433	REV

10-77

Page 1 of 7

Diesel Local	Engine	Gen. Local	VR	Day Tank	Skid	Gen.	Gen. Remote	Air Comp.	MCC	Swgr.	Control Room	
A+												125 VDC Batteries
A-												
5		325										
		324									X	
		323									X	Start Circuits
8		322										
4		321										
		320									X	
		327									X	
14		326										
4		299										
16		298										
10	10											Start Air Solenoid
2	2											
21	21											Mag. P.U.
22	22											
23	23											
1		297										Mode Sel. Permissive
30		296										
53,151		TB 30 FL										Field Flash, Exciter Trip and Reset
54, 55, 152		TB 30 10										
56		TB 30 12										
58		TB 30 11										

DELAVAL

ELECTRICAL INTERCONNECT DIAGRAM

CLEVELAND ELECTRIC 75051-59	52434	REV. A

Page 2 of 7

Diesel Local	Engine	Gen. Local	VR	Day Tank	Skid	Gen.	Gen. Remote	Air C mp.	MCC	Swgr.	Control Room	
B+												125 VDC
B-												Batteries
104		247										Start Circuits
		246									X	
		245									X	
106		244										
103		243										
		242									X	
		241									X	
110		240										
103		270										
111		271										
107	107											Start Air Solenoids
102	102											
115	115											Mag P.U.
116	116											
117	117											
101										X		Stop
124										X		
101		239										
		238									X	
		237									X	
124		236										
101		272										
127		273										
154		417										Gov to Isoc VR to Unit
153										X		
		418								X		
159		TB 31 P										FF BVM
160		TB 31 N										

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[illegible]

CLEVELAND ELECTRIC
15051-54

52434

REV.
A

Page 3 of 7

Diesel Local	Engine	Gen. Local	VR	Day Tank	Skid	Gen.	Gen. Remote	Air Comp.	MCC	Swgr.	Control Room	
+C												125 VDC Batteries
-C											X	Ready-to-Load
201											X	
214										X		86GB Unit Available
220										X		
260											X	Day Tank Level Transmitter
227											X	
228				X								
406				X								
				Engine Chart Recorder								SAP #1
229		TB1 50										
230		TB1 44										SAP #2
231		TB1 42										
232		TB1 44										Fuel Press
233		TB1 39										
234		TB1 44										Start Sig
235		TB1 53										
236		TB1 54										L1 120 VAC
237												N
239												
238	238											Gov Pos
240	240											Transducer
241	241	TB1 47										
242	242	TB1 46										Engine Speed
172		TB1 48										
173		TB1 49								X		Bkr Closure
		TB1 52								X		
		TB1 51										
											X	
224											X	Phone Jack
225											X	
226												

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ELECTRICAL INTERCONNECT DIAGRAM

CLEVELAND ELECTRIC
75051-54

52434

REV. A

9-9

Diesel Local	Engine	Gen. Local	VR	Day Tank	Skid	Gen.	Gen. Remote	Air Comp.	MCC	Swgr.	Control Room	
L1												120 VAC
N												
LB1-1	LB1-1											Thermocouples
thru RB5-C	thru RB5-C											
				Temperature chart recorder								
Amb Air 1		TB1 16										
Amb Air C		17										
CARB-1		12										
CARB-C		13										
CALB-1		8										
CALB-C		9										
LO1-1		26										
LO1-C		27										
JW1-1		34										
JW1-C		35										
JWO-1		30										
JWO-C		31										
LOO-1		22										
LOO-C		23										
		19				Gen Stator RTD +						
		20				Gen Stator RTD -						
		6 5				RTD + RTD -						
334									X			Lube Oil Circulating Pump & Heater
335									X			
337									X			
339									X			
340									X			
341									X			
342									X			
344									X			Jacket Water Circulating Pump and Heater
345									X			
347									X			
349									X			
350									X			
351									X			
352									X			

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ELECTRICAL INTERCONNECT [illegible]

CLEVELAND ELECTRIC
75051-54

52434

REV. A

Diesel Local	Engine	Gen. Local	VR	Day Tank	Skid	Gen.	Gen. Remote	Air Comp.	MCC	Swgr.	Control Room	
256	256											Lube Oil and Jacket Water Thermostat
257	257											
202	202											
									X			
307												
308				308					X			Fuel Oil Transfer Pump #1
				309					X			
310				310					X			
314									X			
315									X			
316												
									X			
317												
318				318					X			Fuel Oil Transfer Pump #2
				319					X			
320				320					X			
323									X			
324									X			
325												
									X			
354								X	X			Start Air Compressor #1
355								X				
356									X			
357									X			
358									X			
359												
									X			
364								X	X			
365								X				
366									X			Start Air Compressor #2
367									X			
368									X			
369												
L2												Crankcase Fans
N2		N2										
400		400										

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ELECTRICAL INTERCONNECT DIAGRAM

CLEVELAND ELECTRIC
75051-54

52434

8-9

Diesel Local	Engine	Gen. Local	VR	Day Tank	Skid	Gen.	Gen. Remote	Air Comp.	MCC	Swgr.	Control Room	
375									X			DC Fuel Oil Booster Pump
377									X			
379									X			
380									X			
381									X			
382									X			
408											X	Remote Annunciator Controls
409											X	
410											X	
411											X	
412											X	
414											X	
415											X	
417					417							HI ΔP FOBPS
429					429							
417				417								Day Tank Level HI-Lo
430				430								
444				444								
448					448							HI ΔP LOS
417					417							Low Level L.O.
507					507							
509				509								L.L.J.W.
452		TB2 58										Gen. Field Ground Gen. Stator Temp HI
417		TB2 59 TB1 2										
468		TB1 1										
463	463											Fuel Pump Strainer ΔP High
417	417											
417											X	FTP #1 Filter HI ΔP
443											X	
458											X	FTP #2 Fltr HI ΔP
417											X	Tank Level 7 Day 1 Day
459											X	
503											X	

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ELECTRICAL INTERCONNECTION DIAGRAM

CLEVELAND ELECTRIC 75051-54	52434	REV. A

Diesel Local	Engine	Gen. Local	VR	Day Tank	Skid	Gen.	Gen. Remote	Air Comp.	MCC	Swgr.	Control Room	
418											X	Annunciator:
419											X	D-G Trouble
488											X	POS 5-1
489											X	Handoff
445											X	POS 5-2
446											X	Handoff
456											X	POS 13-1
457											X	Handoff
460											X	POS 15-1
461											X	Handoff
504											X	POS 15-2
505											X	Handoff
522											X	POS 21-2
523											X	Handoff
525											X	POS 22-2
526											X	Handoff
528											X	POS 23-2
529											X	Handoff
531											X	POS 24-2
532											X	Handoff
534											X	POS 25-2
535											X	Handoff
537											X	POS 26-2
538											X	Handoff
540											X	POS 27-2
541											X	Handoff
543											X	POS 28-2
544											X	Handoff
546											X	POS 29-2
547											X	Handoff
549											X	POS 30-2
550											X	Handoff

DELAVAL

ELECTRICAL INTERCONNECT DIAGRAM

CLEVELAND ELECTRIC 75051/54	52434	REV. A

LILCO LONG ISLAND LIGHTING

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

50-440/441

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.)

B051
1/1

~~8405020029~~