BRF-8701

SG

DELAVAL

A Transamerica Company

Warren Rhia'dro
Al Lenwey
[illegible] 643

INSTRUCTION MANUAL
Volume I

Model DSRV–16–4
Serial Nos. 76001-2849
76002-2850
76003-2851
76004-2852

TEXAS UTILITIES SERVICES INC.
Comanche Peak Steam Electric Station
Nuclear Units Nos. 1 & 2

097

ENGINE AND COMPRESSOR DIVISION

DELAVAL VOLUME I
CP-0034-001

17½-2 1D1602

DELAVAL ENGINE AND
COMPRESSOR DIVISION
550-85TH AVENUE
OAKLAND, CALIF. 94621

DELAVAL

ENGINE DATA SHEET

Manufactured for:	Sales Order No.
TEXAS UTILITIES SERVICES INC.	76001/76004
For Installation: COMANCHE PEAK STEAM ELECTRIC STATION Nuclear Units Nos. 1 & 2	Purchase Order No.

ENGINE DATA

Model: DSRV-16-4

Serial No(s).: 76001-2849, 76002-2850, 76003-2851, 76004-2852

☒ Stationary ☐ Marine ☒ Diesel ☐ Dual Fuel ☐ Heavy Fuel ☒ V-type ☐ Inline

No. Cylinders	Bore	Stroke	Cycles	Total Displacement	Controls
16	17 in.	21 in.	4	76,266 cu-in.	☒ Right Hand ☐ Left Hand

BMEP	Brake Horsepower	Crankshaft Rotation	Starting System
225 psi	9783 @ 450 rpm	CW, viewed from flywheel end	Pilot air, gear driven distributor

Firing Order: 1L-8R-4L-5R-7L-2R-3L-6R-8L-1R-5L-4R-2L-7R-6L-3R

Fuel Injection Timing: LB = 22°, RB = 21° °BTDC, set Right bank = 13.05, Left bank = 12.46 inches BTDC on a 68 in. diameter flywheel

Fuel Injection Pump Rack at Full Load: DIESEL 38 mm XXXXXX ______

Valve Clearance – Cold Engine: INTAKE NA EXHAUST NA ☒ Equipped with hydraulic valve lifters

FACTORY TEST RESULTS (Average Full Load Data)

Item	Diesel	Dual Fuel	
EXHAUST TEMPERATURE	960° F		
AIR MANIFOLD PRESSURE	49.9 in.-hg		
AIR MANIFOLD TEMPERATURE	127° F		
AMBIENT TEMPERATURE	70° F		
BAROMETRIC PRESSURE	29.90 in.-hg		

NOTE: Exhaust temperatures are the average for all cylinders during factory test under LOCAL AMBIENT CONDITIONS. Temperatures in the field, therefore, may exceed this average temperature. Always include serial numbers when communicating with DELAVAL Engine and Compressor Division concerning engine performance, or when ordering spare or replacement parts.

Power Engines

DELAVAL ENGINE AND
COMPRESSOR DIVISION
550 – 85th AVENUE
OAKLAND, CALIFORNIA 94621

DELAVAL
A Transamerica Company

GUARANTEE

Unless otherwise specifically stated, all machinery and equipment purchased hereunder is subject to the following warranty: DELAVAL TURBINE 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

DELAVAL ENGINE AND COMPRESSOR DIVISION
550 – 85th AVENUE
OAKLAND, CALIFORNIA 94621

DELAVAL
A Transamerica Company

TABLE OF CONTENTS

SECTION 1 – INTRODUCTION

Purpose	1-1
Scope of Manual	1-1
Notes, Cautions and Warnings	1-1
Customer Assistance	1-1
Parts Manual	1-2
Associated Publications Manual	1-2
General Engine Description	1-2

SECTION 2 – INSTALLATION

General	2-1
Foundation Drawing	2-1
Installation Drawing	2-1
System Schematic Drawings	2-1
Handling and Shipment	2-1
Foundation	2-2
Foundation Bolt Assemblies	2-2
Preparation For Installation	2-3
Placing Engine Over Foundation	2-3
Mounting Flywheel and Connecting Shaft	2-5
Grouting	2-5
Piping Systems	2-6
Treatment of Piping	2-6
Jacket Water System	2-7
Cooling Water System	2-8
Fuel System	2-9
Lubricating Oil System	2-10
Intake System	2-11
Exhaust System	2-12
Starting Air System	2-13

SECTION 3 – OPERATING PRINCIPLES

PART A GENERAL

Working Principle	3-A-1
Intake Stroke	3-A-1
Compression Stroke	3-A-1
Power Stroke	3-A-1
Exhaust Stroke	3-A-1

SECTION 3 – OPERATING PRINCIPLES (Continued)

PART B – LUBRICATING OIL SYSTEM

General 3-B-1
Pressure Regulating Valve 3-B-1
Filters and Strainers 3-B-2

PART C - CONTROL SYSTEM

SECTION 4 – ENGINE OPERATION

SECTION 5 – ENGINE MAINTENANCE

General 5-1
Maintenance Concept 5-1
Record Keeping 5-1
Maintenance Schedules 5-3
Preserving Engine For Shipment or Storage 5-5
Specification For Protective Materials 5-5
Preservation Equipment 5-6
Torque Wrench Tightening Procedure and Values 5-6
Procedure 5-6
Torque Values 5-6
Pre-Stressed Studs 5-6

SECTION 6 – DISASSEMBLY, INSPECTION AND REPAIR (Continued)

PART F – FUEL SYSTEM
Fuel Injection Equipment 6-F-1
Fuel Injection Nozzles 6-F-1
Nozzle Adjustment 6-F-2
Fuel Injection Pumps 6-F-2
Description of Operation 6-F-3
Malfunctioning Pump 6-F-4
Pump Removal 6-F-4
Pump Disassembly 6-F-4
Pump Assembly 6-F-5
Pump Installation and Timing 6-F-6

PART G – ENGINE CONTROLS
Overspeed Trip 6-G-1
Overspeed Trip Adjustment 6-G-2
Governor Drive Element Replacement 6-G-3
Logic Board Trouble Shooting 6-G-4
Checking Logic Elements 6-G-4

PART H – ENGINE BALANCING
General 6-H-1
Cylinder Balance 6-H-1
Fuel Injection Equipment 6-H-1
Engine Out Of Tune 6-H-1
Preventive Maintenance 6-H-2
Trouble Shooting 6-H-2

PART I – STARTING AIR SYSTEM
General 6-I-1
Air Supply 6-I-1
Operation 6-I-1
Starting Air Valve Removal 6-I-2
Valve Disassembly 6-I-2
Valve Assembly 6-I-2
Valve Installation 6-I-2
Timing Starting Air Distributor 6-I-3
Air Filter Inspection 6-I-3
Strainers 6-I-3

PART J – COOLING WATER SYSTEMS
General 6-J-1
Jacket Water Treatment 6-J-1
Cleaning Jacket Water System 6-J-1
Environmental Restrictions 6-J-2

PART K – LUBRICATING OIL SYSTEM
Filters and Strainers 6-K-1
Lubricating Oil Pump 6-K-2
Removing Pump 6-K-2
Pump Disassembly 6-K-3
Pump Reassembly 6-K-3
Oil Pump Gear Carrier Assembly 6-K-3
Disassembly and Assembly of Gear Carrier Assembly 6-K-4

PART L – MISCELLANEOUS
Crankcase Pressure 6-L-1
Manometer 6-L-1
Measuring Vacuum 6-L-1
Operation and Maintenance 6-L-1
Crankcase Ventilation System 6-L-2
Crankcase Vacuum 6-L-2

SECTION 6 – DISASSEMBLY, INSPECTION AND REPAIR

PART A – GENERAL

Rotation and Cylinder Designation . . . 6-A-1
Assembly of Parts . . . 6-A-1
Use of Assembly Drawings . . . 6-A-1
Special Tools . . . 6-A-2
Cleanliness . . . 6-A-2
Torquing . . . 6-A-2

PART B – CYLINDER HEADS AND VALVES

Cylinder Head Removal . . . 6-B-1
Inspection . . . 6-B-1
Valves . . . 6-B-2
Valve Spring Replacement . . . 6-B-2
Valve Removal From Cylinder Head . . . 6-B-2
Valve Inspection and Reconditioning . . . 6-B-3
Cylinder Head Installation . . . 6-B-3
Hydraulic Lifters . . . 6-B-4
Valve Lifter Maintenance . . . 6-B-4
Lifter Removal and Disassembly . . . 6-B-4
Assembly and Installation of Lifters . . . 6-B-5
Adjustment . . . 6-B-5

PART C – PISTONS AND RODS

General . . . 6-C-1
Connecting Rod Bearing Shell Replacement . . . 6-C-1
Link Rod and Piston Removal . . . 6-C-2
Piston and Master Rod Removal . . . 6-C-3
Removal of a Seized Stud . . . 6-C-4
Disassembly . . . 6-C-5
Inspection . . . 6-C-5
Piston Ring Replacement . . . 6-C-6
Piston Ring Gap and Side Clearances . . . 6-C-6
Piston Pin Bushing Replacement . . . 6-C-6
Link Pin Bushing Replacement . . . 6-C-7
Piston and Rod Assembly . . . 6-C-7
Piston and Master Rod Installation . . . 6-C-8
Piston and Link Rod Installation . . . 6-C-9

PART D – CRANKSHAFT AND BEARINGS

Main Bearings . . . 6-D-1
Bearing Cap Removal . . . 6-D-1
Bearing Shell Replacement . . . 6-D-2
Bearing Cap Installation . . . 6-D-2

PART E – CAMS, CAMSHAFTS AND BEARINGS

General . . . 6-E-1
Camshaft Bearing Replacement . . . 6-E-1
Cam Replacement . . . 6-E-1
Timing Gears . . . 6-E-3
Inspection . . . 6-E-4
Assembly . . . 6-E-4
Camshaft Timing . . . 6-E-5

SECTION 7 – TROUBLE SHOOTING

General 7-1
Records 7-1

SECTION 8 – APPENDICES

Appendix I – Torsional Stress and Critical Speeds 8-2
Appendix II – Operating Pressures and Temperatures 8-3
Appendix III – Table of Clearances 8-4
Appendix IV – Torque Values 8-5
Appendix V – Timing Diagram 8-6
Appendix VI – Lubricating Oil Recommendations 8-7
Appendix VII – Alarms and Safety Shutdowns 8-8
Appendix VIII – Fuel Oil Specifications 8-9
Appendix IX – Power Engine Factory Test Log 8-10

LIST OF ILLUSTRATIONS

Figure	Title	Page
1-1	Cross Section	1-3
2-1	Suggested Foundation Bolt Template	2-2
2-2	Crankshaft Alignment Record, Form D-1063	2-4
2-3	Flywheel Mounting	2-5
3-A-1	Diagram of Working Principle	3-A-1
3-B-1	Oil Pressure Regulating Valve	3-B-1
6-A-1	Engine Rotation and Cylinder Designation	6-A-1
6-B-1	Cylinder Head Lifting Fixture	6-B-1
6-B-2	Valve Spring Removal Tool	6-B-2
6-B-3	Removing Valve Keepers	6-B-2
6-B-4	Tightening Sequence For Cylinder Head Stud Nuts	6-B-3
6-B-5	Hydraulic Valve Lifter	6-B-4
6-C-1	Pistons and Connecting Rods	6-C-1
6-C-2	Bearing Replacement Tool Arrangement	6-C-1
6-C-3	Tools Installed For Removing Piston and Link Rod	6-C-2
6-C-4	Lifting Piston and Link Rod From Cylinder Liner	6-C-3
6-C-5	Tools Installed For Piston and Master Rod Removal	6-C-3
6-C-6	Lifting Master Rod and Piston From Cylinder Liner	6-C-4
6-C-7	Piston Assembly	6-C-5
6-C-8	Piston and Rod Installation	6-C-8
6-C-9	Liner Sealing Rings	6-C-9
6-D-1	Main Bearing Cap	6-D-1
6-D-2	Crankshaft Thrust Rings	6-D-1
6-D-3	Pre-Stresser Assembly	6-D-2
6-F-1	Sectional View of Typical Nozzle and Holder Assembly	6-F-2
6-F-2	Pump Plunger and Barrel Arrangement	6-F-3
6-F-3	Effective Stroke	6-F-3
6-F-4	Flywheel Timing Marks	6-F-6
6-F-5	Pump Base to Tappet Adjustment	6-F-6
6-G-1	Overspeed Trip Governor	6-G-1
6-G-2	Governor Drive Coupling	6-G-2
6-I-1	Starting Air Valve	6-I-2
6-K-1	Lubricating Oil Pump and Gear Carrier Assembly	6-K-1
6-K-2	Lubricating Oil Pump Assembly	6-K-2
6-K-3	Gear Carrier Assembly	6-K-4
6-L-1	Manometer With Vacuum Pump	6-L-1
6-L-2	Reading Manometer	6-L-1
6-L-3	Crankcase Ventilation System	6-L-2

RECORD OF CHANGES

CHANGE NUMBER	DATE OF CHANGE	VOLUME			DATE CHANGE ENTERED	ENTERED BY
		I	II	III		

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 and repair of the Delaval Engine and Compressor Division equipment described on the data sheet in the front of the manual. The instructions given herein cover generally the operation and maintenance of the subject equipment. Should any questions arise which may not be answered specifically by these instructions, they should be referred to Delaval Turbine Inc., for further detailed information and technical assistance.

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 into the most easily understood wording. 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 Delaval furnished 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.

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 personal injury or possible loss of life if not correctly followed.

CUSTOMER ASSISTANCE.

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

PARTS MANUAL.

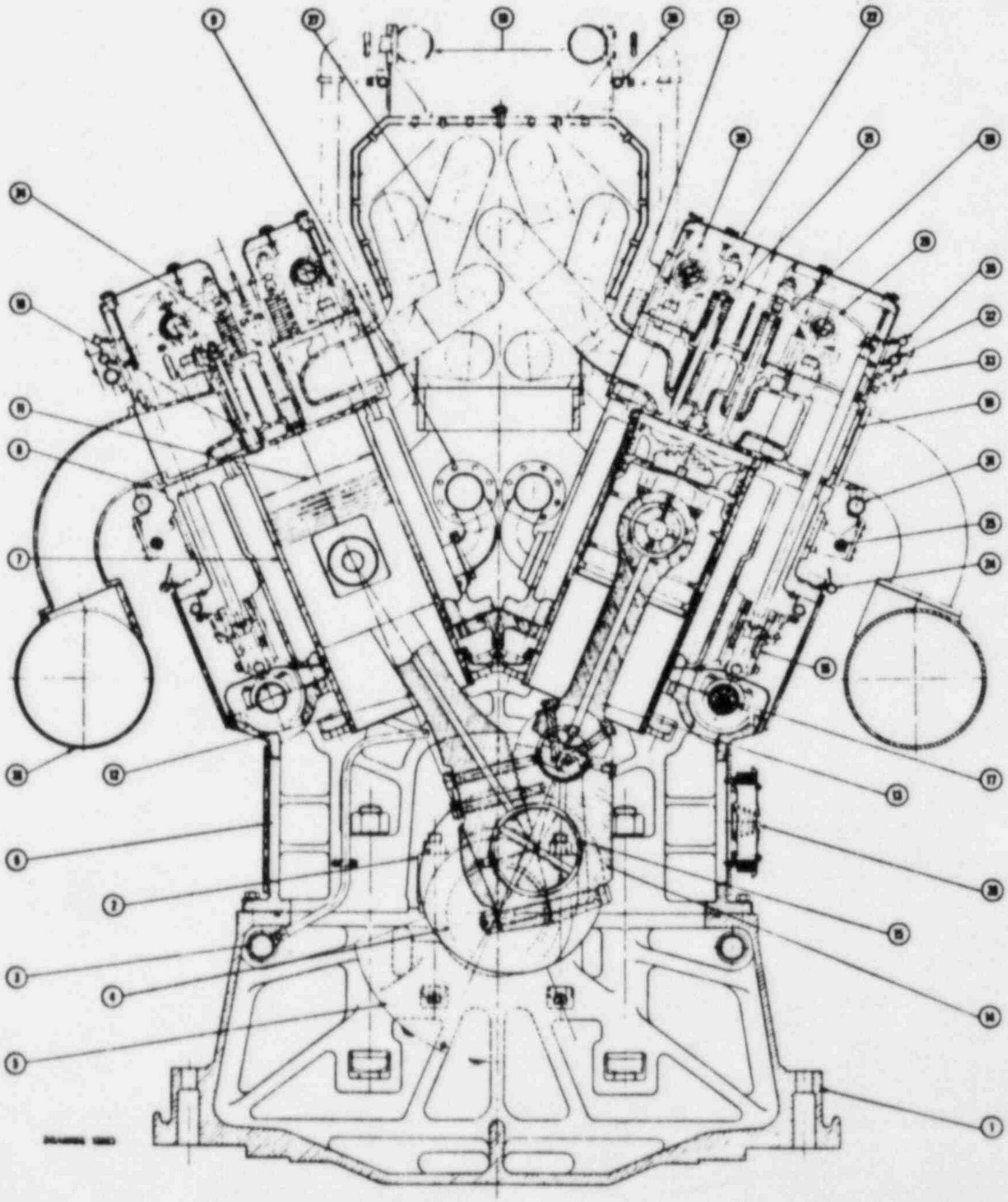
The *Parts Manual* furnished with the engine contains engine specifications, parts lists and part numbers for all furnished equipment together with instructions for ordering spare and replacement parts. Assembly drawings are also included in the manual to assist in the identification of parts, however, part numbers appearing on the assembly drawings should not be used when ordering parts. Always use the part numbers appearing on the appropriate Group Parts List in the *Parts Manual*.

ASSOCIATED PUBLICATIONS MANUAL.

The *Associated Publications Manual* is a companion publication to this instruction manual, and contains manufacturer's instructions, bulletins and parts lists applicable to parts and equipment not manufactured by DELAVAL Engine and Compressor Division, but which are furnished with the engine and which require servicing and/or adjustment.

GENERAL ENGINE DESCRIPTION.

The Model RV engine is a four-stroke-cycle, turbocharged, aftercooled, V-type engine, built in 12, 16 or 20 cylinder arrangements. The engine is available in either diesel or dual fuel versions and may be equipped to operate on heavy (residual) fuel. The angle of the Vee is 45 degrees. Trunk-type pistons, removable wet-type cylinder liners, pressure lubrication and mechanical fuel injection are features of the RV engine. Individual fuel injection pumps are provided for each cylinder, and as they are of standard design, are interchangeable. The fuel lines are of equal length and are relatively short, reducing line surge to a minimum. Fuel pumps, nozzles and orifice size and angle are all carefully matched to the engine and the fuel to be used to give maximum thermal efficiency. Engine rotation and cylinder bank designation are determined while facing the engine at the flywheel end, number one cylinders always being the pair farthest from the flywheel.



Item	Description	Group Parts List
1	Engine Base	305
2	Main Bearing Cap	305
3	Lubricating Oil Header	307
4	Crankshaft & Bearings	310
5	Crankshaft Counterweight	310
6	Crankcase Assembly	311
7	Cylinder Liner	315
8	Engine Block	315
9	Jacket Water Header (In)	315
10	Jacket Water Header (Out)	317
11	Piston	340
12	Master Rod	340
13	Link Rod	340
14	Connecting Rod Box	340
15	Connecting Rod Bearings	340
16	Tappets	345
17	Camshaft & Bearings	350
18	Air Starting Valve	359
19	Cylinder Head	360
20	Intake Valve	360
21	Exhaust Valve	360
22	Cylinder Head Cover	362
23	Cylinder Head Sub Cover	362
24	Fuel Injection Nozzle	365
25	Fuel Pump Linkage	371
26	Intake Manifold	375
27	Exhaust Manifold	380
28	Crankcase Relief Valve	386
29	Rocker Arm, Intake	390
30	Rocker Arm, Exhaust	390
31	Starting Air Manifold	441
32	Fuel Oil Return	450
33	Fuel Oil Header	450
34	Fuel Oil Drain	450
35	Rocker Arm Oil Header	465
36	Pyrometer Conduit	630

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

SECTION 2
INSTALLATION

GENERAL.

The installation of a DELAVAL Engine and Compressor Division "Enterprise" engine may vary from site to site, therefore, 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. It is essential that the foundation be constructed to standards of the highest 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 mechanism.

SYSTEM SCHEMATIC DRAWINGS.

Electrical and flow diagrams are furnished for the various systems. Flow diagrams specify pipe sizes and the type and location of fittings and apparatus. These represent minimum requirements. To insure compatibility, any changes should be approved by DELAVAL Engine and Compressor Division engineers before installation.

HANDLING AND SHIPMENT.

Care must be exercised during the shipment and handling of the engine and associated equipment during installation to avoid damage. 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 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.

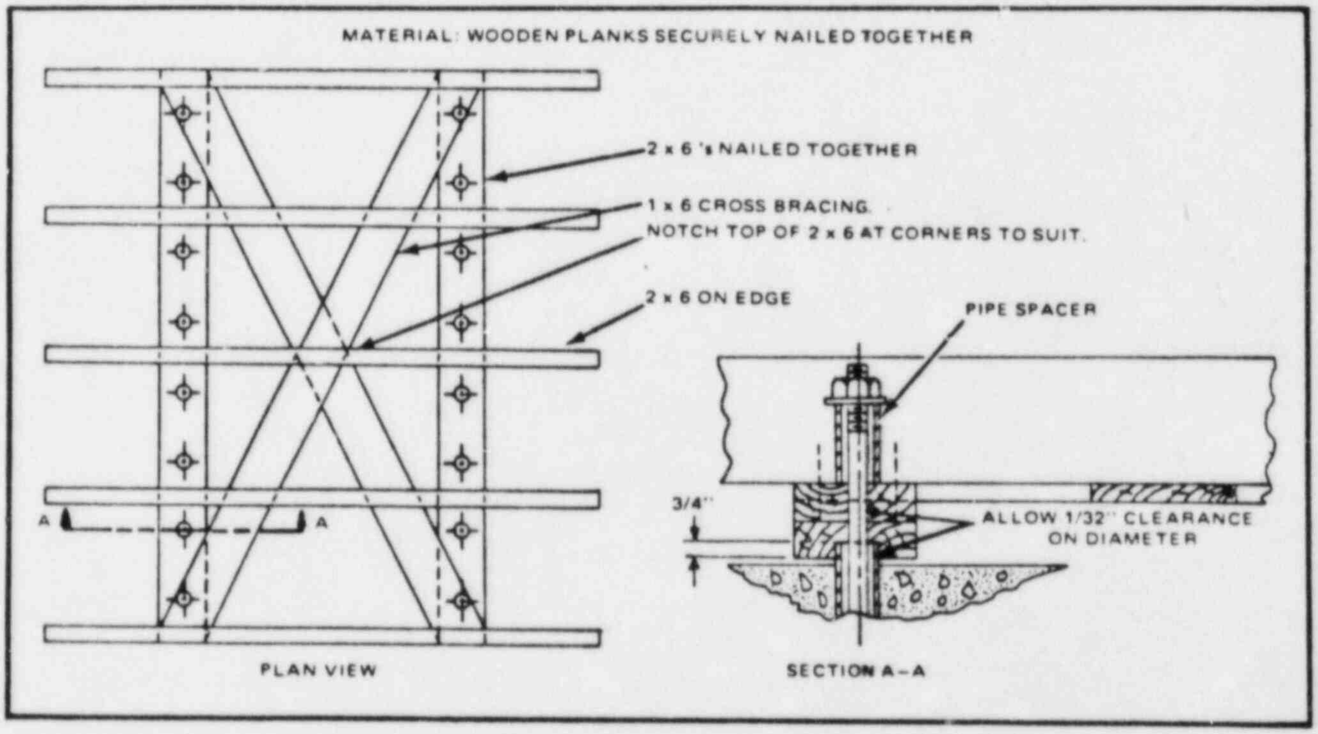


Figure 2-1. Suggested Foundation Bolt Template

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 the 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, following the crankshaft alignment on DELAVAL Engine and Compressor Division Form D-1063. Record deflection readings on the form. 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.

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.

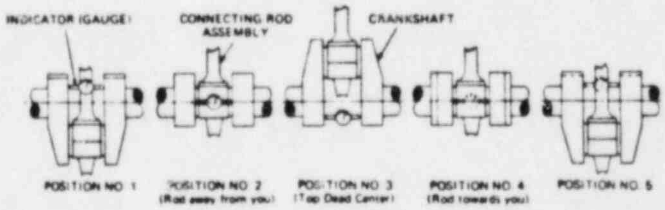
If the deflection in any crank in an engine in service exceeds 3 mils, corrective action must be taken. Also, if the total deflection value in any two adjacent cranks exceeds 3 mils, corrective action must be taken. Example, a +2 mils in any crank with a -2 mils in the next adjacent crank adds up to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

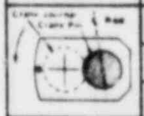
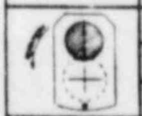
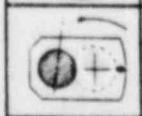
ALL INLINE ENGINES	15° AFTER BOTTOM CENTER
HV, HVA & GVB ENGINES	38° AFTER VERTICAL BOTTOM CENTER
RV ENGINES	52° AFTER VERTICAL BOTTOM CENTER

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 1	2	3	4	5	6	7	8	9	10	DATE
											
											
											
											
											

Form D-1063 (R-2) 1/76

Figure 2-2. Crankshaft Alignment Record, Form D-1063.

MOUNTING FLYWHEEL AND CONNECTING SHAFT.

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

a. Apply a thin coat of anti-seize lubricant such as "Molykote" or "Lubriplate" 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 2-3) and draw the flywheel up on the flange until it is seated.

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

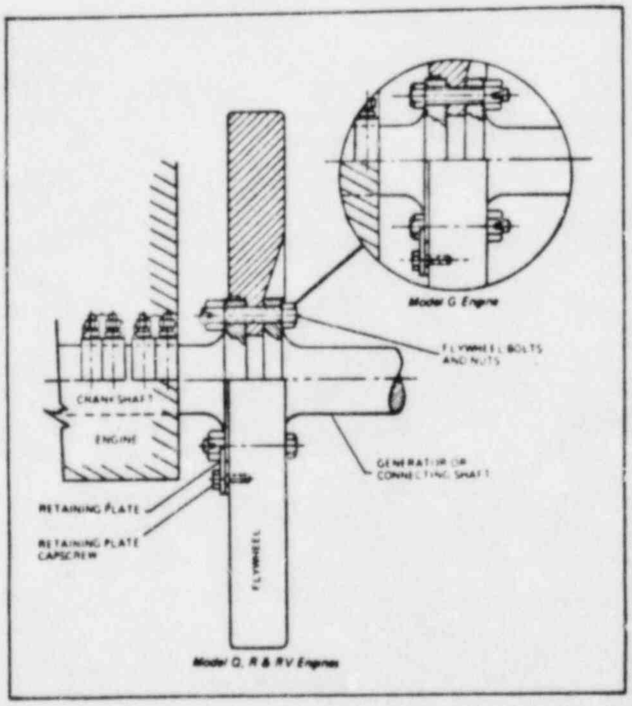


Figure 2-3. Flywheel Mounting

c. Special tapered aligning dowels and a flywheel bolt reamer are available from the 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.

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.* A DELAVAL 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.

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 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 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 suggested method of treatment. The jacket water system is shown in schematic form on Drawing 09-810-76001. Note that the off-engine components are mounted on the auxiliary module and consist of the standpipe, a heater, a keep-warm pump, the jacket water cooler, a thermostatic valve, the lubricating oil cooler and the auxiliary jacket water pump. Connections are provided for raw water flow through the jacket water cooler. Flexible couplings are not recommended at customer connections because of the potential failure hazard during operation. All piping must be properly supported to minimize pipe vibration and flange loading.

COOLING WATER SYSTEM.

There is no separate cooling water system provided with this unit. Rather, raw water from the owner's supply is piped through the jacket cooler to provide the cooling medium for that cooler. Refer to the jacket water piping schematic drawing, 09-810-76001 for connections.

FUEL SYSTEM.

The fuel injection equipment on the engine must be maintained in as clean a condition as possible. Every precaution must be taken to keep water from mixing with the fuel. Fuel injection equipment is hand lapped to extremely close tolerances and, therefore, every precaution must be taken to keep dirt or other contaminents from passing to the fuel injection pumps or nozzles. Filtration equipment must be of the highest quality and carefully maintained. The fuel oil system is shown in schematic form on drawing 09-825-76001.

LUBRICATING OIL SYSTEM.

The lubricating oil system is of the dry sump type, the lubricating oil supply being contained in a separate sump tank. The system is illustrated in schematic form on Drawing 09-820-76001. Observe that all off-engine components are contained in an auxiliary module. All procedures and precautions contained in the drawing notes should be observed during installation.

PLACING LUBRICATING OIL SYSTEM IN SERVICE.

Before the engine is first started, the assembled lubricating oil piping system should be thoroughly flushed with oil. Disconnect the pipe between the duplex filter and the pressure strainer, and arrange a temporary bypass from the filter discharge to the sump tank. This will permit circulation of 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. Likewise, the flushing operation should be done for the "keep warm" portion of the system by disconnecting the pipe between the keep-warm filter and the keep-warm strainer and arranging the same type of bypass back to the sump tank. Although the sump tank and the engine base will have been thoroughly cleaned and sealed at the factory before shipment, the base and tank should be inspected again during installation to ensure cleanliness before filling with oil. The auxiliary lubricating oil pump can be used for pumping oil during flushing operations. The pre-lube pump must be used for the keep-warm circuit. Flushing should continue for at least eight hours if care was exercised during installation and hook up to keep dirt and debris from being introduced into the system. As much as 24 hours of flushing may be needed if the system is dirty. When oil is circulating through the system, the pipes should be pounded thoroughly several times with a heavy hammer to loosen any dirt and debris. Hot flushing oil will clean better than cold oil. Piping around the oil cooler requires special attention to ensure that the pipes and oil cooler are properly flushed. Precautions must be taken to ensure the complete removal of testing fluids, water or other liquids before attempting to flush the cooler.

Note

If it is certain that the connections between the strainers and the main engine oil headers have not been disconnected since the engine left the factory, the following paragraph may be omitted. Consideration should be given, however, as to the conditions and environment to which the unit may have been subjected in determining the advisability of performing the following procedure.

Disconnect jumper tubes between engine lubricating oil header and main bearings, and between main bearings and auxiliary headers. Secure a fine screen such as a nylon stocking over each main header fitting to catch debris that may be washed through the system as it 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.

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

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.

STARTING AIR SYSTEM.

Compressed air from the starting air tanks at 250 psi (17.6 kg-cm^2) is applied to the upstream side of the starting air admit valve where it is blocked until a starting signal is applied to the pilot of the starting air admit valve. When a start signal is applied to the starting air admit valve pilot, the valve opens and admits starting air to the starting air manifold on the engine and to the gear-driven starting air distributor. Timed pilot signals are sent to the air start valves on the engine in the correct sequence, and as each air start valve opens, starting air is admitted to the cylinder, causing that piston to be forced downward, rotating the crankshaft. The starting air tanks are provided with isolating valves and pressure relief valves. Refer to the starting air schematic drawing for the location of filters, strainers, regulators and valves, and for the direction of air flow.

SECTION 3
OPERATING
PRINCIPLES

SECTION 3

OPERATING PRINCIPLES

PART A – GENERAL

WORKING PRINCIPLE.

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.

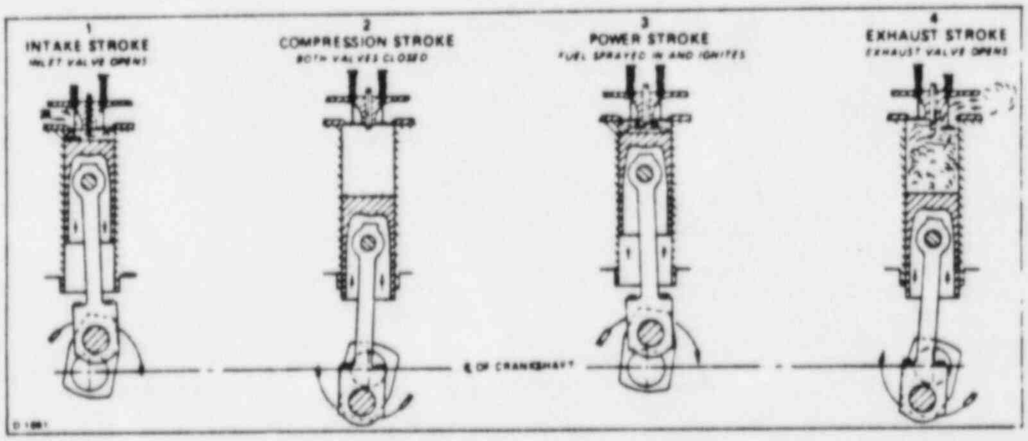


Figure 3-A-1. Diagram of Working Principle

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.

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.

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.

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.

PART B – LUBRICATING OIL SYSTEM

GENERAL.

An engine-driven pump draws oil from the sump through a strainer, and discharges it to a thermostatic valve where, depending on the temperature of the oil, it is either passed through the lubricating oil cooler, or directly to the filter. Filtered oil is then passed through a strainer to the engine lubricating oil header. Oil return to the sump tank is by gravity flow. An integral safety valve on the pump prevents excess discharge pressure, and a pressure regulating valve controls the pressure in the engine lubricating oil header. Refer to the lubricating oil system schematic drawing for the relative location of components and for the direction of flow.

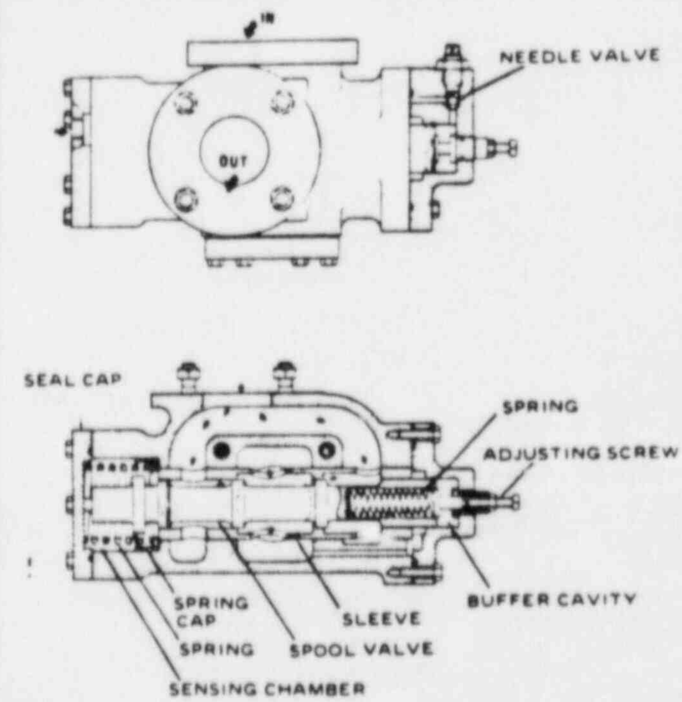


Figure 3-B-1. Oil Pressure Regulating Valve

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.

PART B – LUBRICATING OIL SYSTEM (Continued)

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.

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.

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 periods 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 basket-type strainers at the pump suction and at the oil header inlet should be checked and cleaned as necessary to remove any debris and 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, or engine base.

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 that particular cooler.

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

d. Dismantle and inspect pump. Refer to manufacturer's instructions on the *Associated Publications Manual.*

CP-0034-001

MANUAL CHANGE

DELAVAL ENGINE AND
COMPRESSOR DIVISION
550 - 85th AVENUE
OAKLAND, CALIFORNIA 94621

DELAVAL
A Transamerica Company

No. 76001-1

DATE OCT 26, 1978

THIS MANUAL CHANGE IS APPLICABLE TO THE MANUALS AS INDICATED BELOW. WHEN INCORPORATED INTO THE APPROPRIATE MANUAL(S), THE CHANGE SHOULD BE RECORDED ON THE RECORD OF CHANGES SHEET IN THE FRONT PART OF THE INSTRUCTION MANUAL, VOLUME I.

ENGINE MODEL: DSRV-16-4

SERIAL NO(S): 76001-2849, 76002-2850, 76003-2851, 76004-2852

PURCHASER: TEXAS UTILITIES SERVICES INC.

DISTRIBUTION:
Customer (25); Gibbs & Hill (5); Svc. Dept (2); File (1)

ADD THE FOLLOWING PAGES TO THE INSTRUCTION MANUAL, Volume I FOR THE ABOVE LISTED UNITS.

SECTION 3: REMOVE SHORTAGE NOTICE 76001-1 AND INSERT CONTROL INSTRUCTIONS, PAGES 3-C-1 THROUGH 3-C-13.

SECTION 4: REMOVE SHORTAGE NOTICE 76001-2 AND INSERT OPERATING INSTRUCTIONS, PAGES 4-2 THROUGH 4-5

SECTION 8: REMOVE SHORTAGE NOTICE 76001-3 AND INSERT APPENDIX VII, PAGE 8-8, ALARMS & SAFETY SHUTDOWNS.

PART C – CONTROL SYSTEM.

GENERAL.

The following is a description of the local engine control system and its operation. The system will start, stop, protect 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 manufacturers' literature covering the various components of the system. Of special significance are the Delta Switchboard company's publications, which describes the switchgear and the local generator control panel. Also significant 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 parts for the system, refer to the *Parts Manual* for the correct part numbers.

DRAWINGS.

The drawings provided with these instructions include schematics of the pneumatic and electrical systems, interconnection diagrams, and 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 76001 in the *Parts Manual* for a listing of drawings applicable to the system.

OPERATING MODES.

There are two base modes incorporated into the system, the NORMAL mode and the MAINTENANCE or STANDBY 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 MAINTENANCE mode permits maintenance or repair. The unit will not accept a start signal while it is in the MAINTENANCE mode. A selector switch is present at the Local Engine Control Panel which permits mode selection.

CONTROL OPTIONS - REMOTE AND LOCAL.

All control operations, such as starting, stopping, and running the diesel/generator, as well as loading the unit onto an energized bus, are normally initiated from the owner's remote control room equipment. However, a Local Generator Control Panel is also provided with each unit, which will fulfill these functions in an emergency condition, or whenever local control is desired. Signals generated from either the owner's remote control equipment or from the Local Generator Control Panel are interfaced with the pneumatic and electrical control circuitry at the Local Engine Control Panel. A three position control selector switch is included at the Local Generator Control Panel, which provides *Remote* or *Local* control selection, and also includes a *Maintenance* position for routine maintenance or repairs. Selection of the *Remote* position allows initiation of normal or emergency start signals from the remote location, as well as remote control of voltage regulation and speed/load setpoints. *Local* position on the control selector switch transfers control of these functions to the Local Generator Control Panel, and isolates all remote control. *Local* position provides both normal and emergency start capabilities at the local panel, as well as local control of loading procedures. Selection of *Maintenance* position isolates all remote control and all starting capability, both remote and local. *Maintenance* position on the control selector switch is used in conjunction with MAINTENANCE mode to insure that the unit cannot be started while repair or maintenance procedures are being carried out.

REMOTE NORMAL START.

If NORMAL mode has been selected, and the control selector switch at the Local Generator Control Panel has been placed in the *Remote* position, the unit will accept a manually injected normal start signal from the remote location, provided the unit's entire protective system is permissive. The unit will start, come up to rated speed and voltage, and a "Ready To Load" signal will be transmitted for use of the owner's synchronizing equipment. Both the speed/load and voltage regulation setpoints are adjustable from the remote location. Note that the unit will respond to a start signal

PART C – CONTROL SYSTEM (Continued)

generated by the owner's equipment in response to a power blackout, if NORMAL mode and *Remote* control have been selected, and provided the unit's entire protective system is permissive. While running in this mode, the unit's safety shutdown system is completely operational, and system malfunctions will be displayed on the owner's annunciation equipment.

REMOTE EMERGENCY START.

If NORMAL mode has been selected, and the control selector switch at the Local Generator Panel has been placed in the Remote position, the unit will accept a maintained remote emergency start signal, injected either manually or in response to a Loss of Cooling Accident (LOCA) signal, provided that d-c power is available, and overspeed and generator/switchgear malfunction protection are permissive. The unit will start, come up to speed and voltage, and transmit a "Ready To Load" signal for use in the sequencing equipment. The governor will automatically be placed in isochronous operation. When the unit is given an emergency start signal, the setpoint of the governor and the automatic setpoint of the voltage regulator are returned to their preset values. Fifteen seconds after going to normal, the preset signal is released to allow the operator to control voltage and load. If the unit is undergoing its periodic "Exercise Test" at the moment an emergency start signal is received, or at the moment a LOCA signal is received, whether the unit is starting, running disconnected, running loaded, tripping on a fault other than overspeed or generator/switchgear malfunction, or coasting to a stop, the control system will cause the unit to return to its rated speed and voltage, and will disarm all protection except overspeed and generator/switchgear malfunction. If the emergency is corrected and the LOCA signal is terminated, the control system will keep the unit running loaded but with full shutdown protection. Once this is done, however, it will require the receipt of another emergency start or LOCA signal to disarm the shutdown system again. This feature prevents an operator from operating the diesel manually without shutdown protection.

LOCAL OPERATION.

In the unlikely event of a Control Room Evacuation, or at any time when local control of the unit is desired, rotation of the control selector switch from the *Remote* position to the *Local* position will permit all control operations to be carried out from the Local Generator Control Panel. Note that selection of local control disarms all remote control, eliminating the possibility of redundant or contradictory control signals. In addition, removal of the control selector switch from the *Remote* position activates an annunciator point in the remote control room, alerting the remote operator that the unit is in local control. If *Local* control has been selected, and the unit is in NORMAL mode, the unit will accept a manually injected start signal from the local panel, provided the entire protective system is permissive. The unit will start and come up to rated speed and voltage. A "Ready To Load" signal will be generated, and both the speed/load and voltage setpoints are adjustable from the local panel. While being operated from the local panel, the unit will not accept a LOCA signal. However, the unit will accept a manually injected Local Emergency Start, provided that overspeed and generator/switchgear differential protection only are permissive, and d-c power is available. A two position switch is present at the Local Generator Control Panel. If an Emergency Start is desired, the switch must be turned from the "AUTO" position to the "START" position. The unit will start, come up to rated speed and voltage, and transmit a "Ready To Load" signal to the synchronizing equipment. When the unit is given an emergency start, the setpoint of the governor and the automatic setpoint of the voltage regulator are returned to their preset values. Fifteen seconds after starting, the preset signal is released to allow the local operator to control voltage and speed. Governor operation is placed in isochronous when the unit is in the emergency condition. If the emergency is corrected, and the owner wishes to keep the unit running, but with full shutdown protection, turning the start switch to the "AUTO" position will restore the protective system to full operation.

STOPPING THE UNIT.

A stop signal must be initiated from the previously selected control location. If remote control has been selected, depressing the Remote Normal Stop pushbutton will cause the unit to shut down, provided the circuit breaker has been opened. Depressing the Remote Emergency Stop pushbutton will stop the unit and automatically trip the breaker. If local control has been selected, depressing the Local Normal Stop pushbutton will stop the unit, provided the circuit breaker has been opened. Actuation of the Local Emergency Stop pushbutton will cause the unit to shut down, and will automatically trip the breaker. In addition, a unit shutdown generaged by the protective system will automatically trip the breaker.

PART C – CONTROL SYSTEM (Continued)

MAINTENANCE LOCKOUT.

Selection of MAINTENANCE mode, for routine maintenance, inspection or repair procedures, is accomplished so as to afford maximum protection for the plant and also for maintenance personnel. Two distinct operations must be carried out to place the system in MAINTENANCE mode. First, the control selector switch at the Local Generator Control Panel must be rotated to the *Maintenance* position. This isolates all remote control and disarms all starting circuitry, remote and local. Second, the mode selector switch at the Local Engine Control Panel must be turned momentarily to the MAINTENANCE position. Note that the mode selector switch is provided with a key interlock, which permits only authorized personnel to change the mode of the unit. While in the MAINTENANCE mode, the unit may be turned over on starting air without starting by means of the Engine Roll pushbutton at the Local Engine Control Panel. The barring device may also be used in MAINTENANCE mode to turn the engine over manually. If a return to NORMAL mode is desired, the barring device must be disengaged and locked out, and the mode selector switch must be turned momentarily to the NORMAL position. In addition, the control selector switch must be removed from the Maintenance position, to either the *Remote* or *Local* position before a start can be accomplished.

STARTING AND PROTECTIVE SYSTEMS.

The engine starting circuits are duplicated in total, and can receive d-c power from two separate conduit entries, if desired. Further, auxiliary 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. 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 or a LOCA 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.

PANEL ELECTRICAL CONTROL (See Drawing 09-500-76001).

The local engine control panel electrical circuitry is shown in schematic form on sheets 3 of 8 through 8 of 8 on the referenced drawing.

a. Starting circuitry is shown on sheet 3. 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-2A, SOL-1B 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 starts, and directly by the emergency start signal during an emergency.

b. The redundant "Remote Emergency Start" and LOCA signal contacts are from the owner's equipment. The "Local Emergency Start" signal contacts are from the Local Generator Control Panel. When any of these contacts closes, an emergency start is initiated provided pressure switches PS-40A and PS-40B are closed, indicating that the unit is in NORMAL mode, and if tachometer relay SS1 is not transferred (i.e., if the unit is not running at 200 rpm), and if pressure switches PS-3A and PS-5B are closed, indicating that at least 150 psi starting air is left in the receivers. These latter pressure switches are present so that, if for some reason the unit does not fire (valve closed in the fuel supply line, for instance), there will be enough starting air left for several manual starts. In addition, the contacts of the Remote/Local/Maintenance control selector switch shown must reflect appropriate control location selection corresponding with the source of the input signal. Refer to section f. below for further discussion of the control selector switch.

PART C – CONTROL SYSTEM (Continued)

c. Note that upon application of an "Emergency Start Signal", or upon receipt of a LOCA signal, solenoid valves SOL-6A and SOL-6B become energized, causing the shutdown system to disarm, except for overspeed and generator/switchgear malfunction protection. SS1 transfer at 200 rpm will cause solenoid valves SOL-7A and SOL-7B to energize, activating pressure switches PS-33A and PS-33B, which cause the starting air solenoids to de-energize. Note that if SS1 fails to open at the prescribed speed, combustion will close the air start valves and no damage is done.

d. At a Normal Manual Start, either of the switch contacts shown (local or remote) will close, which causes relay R4A and R4B to energize for five seconds. A Blackout signal, generated by the owner's equipment, will have the same effect. Solenoid Valves SOL-3A and SOL-3B will be activated by R4A and R4B, arming the shutdown system.

e. Note that the mode selector must be in NORMAL mode for any of the above to take place. If it is in the MAINTENANCE mode, the engine roll button, on the Local Engine Control Panel only, is operative. Pressure switch PS-40A will be closed on the line 9 contact shown, and the unit can be turned over on starting air without starting, a useful maintenance feature.

f. Contacts of the Remote/Local/Maintenance control selector switch comprise permissive which must be satisfied for mode selection, starting, operating and stopping the unit. As shown on sheet 3 of the referenced drawing, *Local* position must be selected at the Local Generator Control Panel in order to arm the Local Emergency Start pushbutton at that location. If Local Manual Normal Starting is desired, the *Local* position must be selected. If the *Remote* position is selected on the control selector switch at the Local Generator Control Panel, the relay RX/1A contacts shown will be in the normally closed position, allowing a start initiated from the remote control equipment. Note that selection of *Remote* position disarms the local starting circuits. Conversely, when either the *Local* or *Maintenance* positions are selected, a relay RX/1A will be energized, opening the normally closed contacts, and remote control is isolated. The mutually exclusive nature of the switch development is designed to prevent contradictory or redundant input signals from separate control locations. The control selector switch must also be placed in the *Maintenance* mode to permit switching of the unit from NORMAL to MAINTENANCE or STANDBY mode for repair purposes. Functional development of the control selector switch is presented in chart form on sheet 3 of the referenced drawing. Use the chart as a convenient cross reference for R/L/M control selector switch development in the control circuitry.

g. When the unit receives a start signal, pressure switch PS-32E closes, latching relays R1 and R1AUX, if pressure switch PS-9D shows the unit not tripped. The field flash solenoid valves, SOL-9A and SOL-9B are energized by pressure switches PS-33A-1 and PS-33B-1, which are activated by SS1 transfer at 200 rpm. Note that as in the start circuits, SS1 failure will not prevent field flashing, due to the presence of time delay relay contacts TD1A and TD1B which are energized by R4A and R4B for a timed period. Time delay TD4 is present to reset the R1 relays should the unit fail to achieve "Ready To Load" status for any reason.

h. The tachometer relay SS2 contacts shown transfer when engine speed reaches 450 rpm. When the undervoltage relays VR1 and VR2 indicate correct voltage levels, the contacts shown will close, energizing relays R11A and R11B, and energizing solenoid valves SOL-8A and SOL-8B. Contacts of the R11 relays are used as permissives in the owner's equipment to close the generator breaker, putting the unit on-line. Signals generated by the actuation of the SOL-8 solenoid valves transmit a "Ready To Load" signal for use of the synchronizing controls.

i. The two R2 relays shown on sheet 4 of the referenced drawing are responsive to the latching of R1, but there is a 60 second time delay (TD3) before R2 latches. Contacts of the R2 relays are used to disarm various alarm functions which are normally in a fault state when the unit is stopped, starting or stopping.

j. Status lights, which allow the operator to monitor the condition of the unit as it proceeds through a start sequence, are shown in schematic form on sheet 4 of the referenced drawing. These status lights are actuated by contacts of the starting relays in some cases, and by pressure switches which function in the pneumatic control system. Status lights are provided at the Local Engine Control Panel, and contacts are provided for use in the owner's remote control equipment.

PART C – CONTROL SYSTEM (Continued)

k. The annunciator system is represented on subsequent sheets of the referenced drawing. Note that an alarm sounds when a contact opens. The annunciator points and alarms are interfaced with pressure switches from the pneumatic system, level switches, control relays, and contacts from the switchgear and generator equipment. For specific details on the annunciator, refer to the manufacturer's publications in the *Associated Publications Manual.*

NUMBER	SETTING	FUNCTION
PS-3A, C	200 psi falling	Starting Air Admission – Left Bank
PS-5B, C	200 psi falling	Starting Air Admission – Right Bank
PS-9AA, A, C, D	25 psi rising	Unit Tripped
PS-10A, B, BB, E, F, G	25 psi rising	LOCA (Loss Of Cooling Accident)
PS-13B, D	25 psi rising	Barring Device Engaged
PS-14C	45 psi falling	Trip – High Temperature Jacket Water
PS-15C	45 psi falling	Trip – High Temperature Bearings
PS-16C	45 psi falling	Trip – High Temperature Lubricating Oil
PS-17C	20 psi rising	High Differential Pressure – Lubricating Oil Filter
PS-18C	20 psi rising	High Differential Pressure – Fuel Oil Filter
PS-19C	45 psi falling	Trip – Low Pressure Turbocharger Oil
PS-20C, D	20 psi falling	Low Pressure Turbocharger Oil
PS-22C, D	15 psi falling	Low Pressure Jacket Water
PS-23D	25 psi rising	Locked Out with Delay
PS-24C	45 psi falling	Trip – Low Pressure Lubricating Oil
PS-25C	45 psi falling	Low Pressure Lubricating Oil
PS-26C	45 psi falling	Trip – Vibration
PS-27C	45 psi falling	Trip – High Pressure Crankcase
PS-28C	20 psi falling	Low Pressure Fuel Oil
PS-29C, D	25 psi rising	Trip – Overspeed
PS-30A, B	25 psi rising	Field Flash
PS-31C	25 psi rising	DC Power Available
PS-32C, D, E	25 psi rising	Starting
PS-33A, B, C, D, E, F, G, A-1, A-2, A-3, B-2, B-1	25 psi rising	200 rpm
PS-34C	25 psi rising	Ready To Load
PS-36C, D	10 psi falling	Fuel Pump/Overspeed Failure
PS-40A, B, BB	25 psi rising	Maintenance/Normal

Table 3-C-1. Pressure Switches

PART C – CONTROL SYSTEM (Continued)

SOLENOID	FUNCTION	OPERATED BY
SOL-1A	Starting Air Admission	R4A or Emergency Start
SOL-1B	Starting Air Admission	R4B or Emergency Start
SOL-2A	Starting Air Admission	R4A or Emergency Start
SOL-2B	Starting Air Admission	R4B or Emergency Start
SOL-3A	Shutdowns Activate	Remote or Local Normal Start pushbutton
SOL-3B	Shutdowns Activate	Remote or Local Normal Start pushbutton
SOL-5B	Maintenance Lockout Mode	Mode Selector Switch
SOL-6A	Shutdowns De-Activate	Emergency Start or LOCA
SOL-6B	Shutdowns De-activate	Emergency Start or LOCA
SOL-7A	Up To Speed	Tach transmitter contact SS1A
SOL-7B	Up To Speed	Tach transmitter contact SS1B
SOL-8A	Ready To Load	SS2A and VR1
SOL-8B	Ready To Load	SS2B and VR2
SOL-9A	Field Flash	PS-33A-1 or TD1A
SOL-9B	Field Flash	PS-33B-1 or TD1B
SOL-10B	Normal Mode	Mode selector switch
SOL-11A	DC Power	Panel Circuit Breaker
SOL-11B	DC Power	Panel Circuit Breaker
SOL-12B	Stop	Stop pushbuttons

Table 3-C-2. Solenoid Valves

RELAY	CONTACTS		TIME	FUNCTION
TD1A	TD1A	N.O.	1 second	Provides power to Field Flash solenoid
TD1B	TD1B	N.O.	1 second	Provides power to Field Flash solenoid
TD2A	TD2A	N.C.	5 seconds	Provides power to R4A
TD2B	TD2B	N.C.	5 seconds	Provides power to R4B
TD3	TD3-1	N.O.	60 seconds	Provides latching power to R2 relays
TD4	TD4-1	N.O.	5 seconds	Provides reset power to R1 relays
	TD4-1	N.C.	5 seconds	Provides latching power to R1 relays
				(Note: TD4-1 is a single pole, double throw relay)
	TD4-3	N.C.	5 seconds	Provides power to Unit Failure To Start alarm

Table 3-C-3. Time Delay Relays

PART C – CONTROL SYSTEM (Continued)

RELAY	CONTACTS		FUNCTION (WHEN ENERGIZED)
R1	R1-1	N.O.	Energizes TD4 at "Unit Failure To Start"
	R1-2	N.O.	Energizes TD3
	R1-3	N.O.	Energizes "Start" remote status lamp
	R1-4	N.C.	Energizes "Stopped" remote and local status lamps*
R1AUX	R1AUX-1	N.C.	Shuts off Jacket Water Pump and Heater in "AUTO"
	R1AUX-2	N.C.	Shuts off Prelube Pump and Heater in "AUTO"
	R1AUX-3	N.C.	Arms High Temperature Lubricating Oil Trip Alarm
	R1AUX-4	N.C.	Arms High Temperature Bearing Trip Alarm
	R1AUX-5	N.O.	Energizes "Shutdown System Active" status lamp
	R1AUX-6	N.C.	Provides reset power to R1 at "Unit Failure To Start" *
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 Trip alarm
	R2-4	N.C.	Arms Low Pressure Lubricating Oil alarm
	R2-5	N.C.	Arms Low Pressure Lubricating Oil Trip alarm
	R2-6	N.C.	Arms High Pressure Crankcase Trip alarm
R2AUX	R2AUX-1	N.C.	Arms Low Pressure Fuel Oil Alarm
	R2AUX-2	N.C.	Arms High Temperature Generator Stator alarm
	R2AUX-3	N.C.	Arms High Temperature Jacket Wager OUT Trip alarm
	R2AUX-4	N.C.	Arms Fuel Pump/Overspeed Drive Failure alarm
	R2AUX-5	N.C.	Arms Governor System Trouble alarm
	R2AUX-6	N.C.	Arms Vibration Trip alarm
R4A	R4A-1	N.C.	Provides power to start circuit at Emergency start *
	R4A-2	N.O.	Provides power to start circuit at Normal start
	R4A-3	N.O.	Provides power to start circuit after start valve released
R4B	R4B-1	N.C.	Provides power to start circuit at Emergency start *
	R4B-2	N.O.	Provides power to start circuit at Normal start
	R4B-3	N.O.	Provides power to start circuit after start valve released
R7	R7-1	N.O.	Provides power to R15 at alarm
R8	R8-1	N.O.	Activates "Loss of a-c power" alarm *
R9	R9-1	N.O.	Activates "Loss of d-c power" alarm *
	R9-2	N.O.	"d-c power available" customer contact
	R9-3	N.C.	"d-c power available" customer contact
R10	R10-1	N.C.	Provides power to Fuel Oil Transfer Pump No. 1 in "AUTO" *
	R10-2	N.C.	Provides power to Fuel Oil Transfer Pump No. 2 in "AUTO" *
	R10-3	N.O.	Provides power to High High Level Fuel Oil Day Tank alarm
	R10-4	N.C.	Provides power to Fuel Oil Transfer Pump No. 1 in "HAND" *
	R10-5	N.C.	Provides power to Fuel Oil Transfer Pump No. 2 in "HAND" *

Table 3-C-4. Relays

*These contacts perform described functions when relay de-energized.

PART C – CONTROL SYSTEM (Continued)

RELAY	CONTACTS		FUNCTION (WHEN ENERGIZED)
R11A	R11A-1	N.O.	"Ready To Load" customer contacts
	R11A-2	N.O.	
	R11A-3	N.O.	
	R11A-4	N.O.	
	R11A-5	N.C.	
	R11A-6	N.C.	
R11B	R11B-1	N.O.	"Ready To Load" customer contacts
	R11B-2	N.C.	
	R11B-3	N.C.	
	R11B-4	N.O.	
	R11B-5	N.O.	
	R11B-6	N.O.	
R14	R14-1	N.O.	"Unit Available Emergency Status" customer contacts
	R14-2	N.C.	
R15	R15-1	N.O.	Provides power to alarm horn on alarm
	R15-2	N.O.	Remote indication "Diesel Engine Trouble"
	R15-3	N.C.	
R16	R16-L	N.C.	Activates Low Temperature Lubricating Oil IN alarm
	R16-H	N.O.	Activates High Temperature Lubricating Oil IN alarm
R17	R17-L	N.C.	Activates Low Temperature Lubricating Oil OUT alarm
	R17-H	N.O.	Activates High Temperature Lubricating 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
R20	R20-H	N.C.	Activates High Temperature Generator Bearing alarm
RX/1A	RX/1A-1	N.C.	Provides power to Remote Emergency Start pushbutton and LOCA *
	RX/1A-2	N.C.	Provides power to Shutdown Deactivating solenoid and start circuit at Remote Emergency Start or LOCA *
	RX/1A-3	N.C.	Provides power to Remote Normal Manual Start and Blackout Start *
	RX/1A-4	N.C.	Provides power to start circuit at Remote Normal Manual Start or Blackout Start *
	RX/1A-5	N.C.	To "Diesel Running" and "Diesel Not Running" remote indicating lights
	RX/1A-6	N.C.	
	RX/1A-7	N.C.	
	RX/1A-8	N.C.	

Table 3-C-4. Relays (Continued)

*These contacts perform described functions when relay de-energized.

PART C – CONTROL SYSTEM (Continued)

RELAY	CONTACTS		FUNCTION (WHEN ENERGIZED)
RX/1B	RX/1B-1	N.C.	Provides power to Remote Emergency Start pushbutton and LOCA *
	RX/1B-2	N.C.	Provides power to Shutdown Deactivating solenoid and start circuit at Remote Emergency Start or LOCA *
	RX/1B-3	N.C.	Provides power to Remote Normal Manual Start and Blackout Start *
	RX/1B-4	N.C.	Provides power to start circuit at Remote Normal Manual Start or Blackout Start *
	RX/1B-5	N.C.	Provides power to Remote Normal and Emergency Stop pushbutton *
	RX/1B-6	N.C.	Provides power to Stop solenoid at Remote Normal Manual Stop *
	RX/1B-7	N.C.	Provides power to Stop solenoid at Remote Emergency Stop *
	RX/1B-8	N.C.	Spare contacts *
RX-1/2B	RX-1/2B-1	N.C	Voltage Adjustment Control customer contacts *
	RX-1/2B-2	N.C.	
	RX-1/2B-3	N.O.	
	RX-1/2B-4	N.C.	
	RX-1/2B-5	N.C.	
	RX-1/2B-6	N.C.	
	RX-1/2B-7	N.C.	
	RX-1/2B-8	N.O.	
RX-2/2B	RX-2/2B-1	N.C.	Governor Adjustment Control customer contacts *
	RX-2/2B-2	N.C.	
	RX-2/2B-3	N.C.	
	RX-2/2B-4	N.C.	
	RX-2/2B-5	N.C.	
	RX-2/2B-6	N.C.	
	RX-2/2B-7	N.C.	
	RX-2/2B-8	N.C.	

Table 3-C-4. Relays (Continued)

*These contacts perform described functions when relay de-energized.

PART C – CONTROL SYSTEM (Continued)

LOCAL ENGINE CONTROL PANEL (See Drawing 00-500-76001).

The local engine control panel houses those control components which are not engine or remotely mounted, or mounted on the generator control panel. 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 jacket water systems.

a. Status lamps are provided as follows in both local and remote locations.

1. Shutdown System Active – lights when relay R1AUX energized.
2. Unit Available Emergency Status – lights when the following conditions have been met.
   (a) Starting Air Pressure Available
   (b) Mode selector in NORMAL
   (c) DC Power Available – sufficient circuits to start
   (d) Overspeed device not tripped
   (e) Generator differential protection permissive
3. Starting – lights when pressure switch PS-32C activated
4. Running – lights when pressure switch PS-33C activated
5. Ready To Load – lights when pressure switch 34C activated
6. Unit Tripped – lights when pressure switch PS-9C activated
7. Stopped – lights if relay R1 is not energized
8. Start (Remote location only) – lights when relay R1 energized

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 R1. 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.

Note

Since overspeed protection and generator fault trippings are the only active trips during an emergency, "two out of three" logic is not used. Overspeed shutdown is inherently safe from nuisance tripping. Generator fault tripping is derived from the owner's own equipment, and the generator control panel circuitry.

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, an AC 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 09-500-76001).

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 of an existing shutdown condition. The logic board functions as follows.

a. If the MAINTENANCE mode is selected (assuming that 60 psi control air is present at all points marked Z▶), solenoid valve SOL-5A is energized momentarily, admitting a 60 psi control air signal to the pilot of valve P_2, which shifts to allow passage of a 60 psi signal. Valve P_2 maintains its actuated position after the momentary pilot signal is terminated. Control air is transmitted to Port 5 of the Shutdown Logic Board where it is applied to port "A" of element NOT-6. This signal acts to inhibit the control air signal from Port 4 from passing through NOT-6, which prevents pressurization of Port 10 of the Board. Since Port 10 normally fills the Group I shutdown line, which must be charged prior to starting, the unit is thereby prevented from accepting a start signal. The control air signal from valve P_2 is also transmitted through a shuttle valve to pressurize line E-89. Referring to Drawing 09-695-76001, note that line E-89 pressure actuates the pilot of a three-way valve (18) causing control air to pass through a shuttle valve to line E-90, where it extends the shutdown cylinder (6), which moves the fuel racks to the "no fuel" position. Referring again to Drawing 09-500-76001, note that the control air signal from valve P_2 is also directed to the pilot of valve P_1, venting the barring device lockout and permitting manual operation of that device. In addition, control air actuates the PS-40 and PS-23 pressure switches, thereby transmitting the MAINTENANCE mode signal to the electrical circuitry.

b. If NORMAL mode is selected, assuming that the barring device is disengaged and locked out, solenoid valve SOL-10B is energized, venting pressure on valve P_2. Port 5 of the Shutdown Logic Board vents back through the valve, and the signal at port "A" of NOT-6 is lost. The control air supply signal at Port 4 is free to pass through NOT-6, as well as pressurizing the "B" ports of elements MEM-15, AND-11 and AND-7. In addition, control air is transmitted to Port 3, and to the "A" ports of elements AND-19 and AND-23. 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. Note that selection of NORMAL mode also vents pressure in line E-89, retracting the shutdown cylinder and allowing movement of the fuel racks. In addition, pressure is lost at the MAINTENANCE mode pressure switches, and the NORMAL mode signal is propagated in the electrical circuitry.

PART C – CONTROL SYSTEM (Continued)

c. A MANUAL TEST START, initiated from either the local or remote location, whichever is in control, will cause solenoid valve SOL-3A and SOL-3B to energize momentarily, transmitting a signal to Port 12 of the Shutdown Logic Board. The PS-32 pressure switches, which transmit the "engine running" signal to the electrical circuitry, are also activated. The signal at Port 12 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 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 element NOT-9, causing an output from port "C" of that element. This output pressurizes Port 9, which locks 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. The Group II sensors are in a venting condition until operating pressures and temperatures are achieved, and therefore will not be able to effect a unit trip at this time.

d. Note that the output of AND-17 is also passed through an orifice/check (21) and an accumulator at Port 1 which delay the signal for approximately 90 seconds. This delay is known as Group II lockout. During this time the engine builds to rated speed and operating temperatures and pressures. As this occurs, the Group II sensors close and the metered signal begins to fill the Group II shutdown lines. After Group II lockout timing is completed, port "A" of NOT-9 is pressurized, terminating the output of that element, causing Port 9 to vent, which reinstates vibration protection. The delayed signal also pressurizes AND-14 and OR-5, allowing Port 2 to be fed through orifice (10), the same orifice that feeds the Group I shutdowns. At this time the Group II shutdowns are fully charged 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 then 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 the "B" port of AND-11, the MEM-15 output transmits through AND-11 and pressurizes Port 8. Port 8 output is conducted through a shuttle valve 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 (18) 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 09-695-76001 which shows the unit 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 (13) will be in the RUN position, blocking the passage of control air. Control air is also fed through an orifice (11) and, if the overspeed trip valve (10) is not tripped, pressure will build on the pilot of a three-way valve (12) which shifts to prevent the passage of control air. When the overspeed trip valve is actuated, the three-way valve vents, allowing the passage of control air through the valve which actuates 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 supply to the engine. Note that control air is also passed through the Stop/Run valve (13) and through a shuttle valve to line E-90 where it activates the "Unit Tripped" sensors, and also extends the shutdown cylinder (6) 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, whichever is in control, if an emergency stop is applied from the appropriate control location, or if a generator/switchgear malfunction occurs, 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, readying the unit for a restart.

i. Upon receipt of a maintained emergency start signal, solenoid valve SOL-6A and SOL-6B will become energized, admitting 60 psi control 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. Since control air from supply is present at the "A" ports of AND-19 and AND-23, these elements transmit a signal to the "A" ports of NOT-20 and NOT-24, inhibiting those elements. The Port 7 signal at OR-4 is conducted through the Group II charging circuitry, and both the Group I and Group II sensors are charged. Note, however, that the normal shutdown path, which passes through elements NOT-20 and NOT-24, is inhibited. So that while the sensors fed through Port 2 and Port 10 are still active and continue to monitor the condition of the unit and display fault indications on the annunciator panel, these sensors will not be able to effect a unit trip. Only the overspeed trip (described in section g. above) and the generator/switchgear malfunction trip (described in section h. above) are active during the emergency condition.

SECTION 4
ENGINE OPERATION

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. Ensure that Three-position Remote/Local/Maintenance Generator Selector Switch at the Generator Control Panel is in Maintenance position.

b. Ensure that MAINTENANCE mode is selected at Local Engine Control Panel.

c. Barring device locked out.

d. Open indicator cocks on all cylinder heads.

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

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

g. Close indicator cocks.

PLACING UNIT IN NORMAL MODE.

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

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

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

CAUTION

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

c. Check Prelube pump and heater, Auxiliary Lubricating Oil Pump, Jacket Water keep-warm pump and heater, Auxiliary Jacket Water Pump, Fuel Oil Booster Pump, and Air Compressors in AUTO.

d. Check a-c and d-c power ON.

e. Check that Barring device is disengaged and locked out.

f. Check starting air pressure.

g. Ensure that emergency shutdown devices which require manual reset (the overspeed trip, for instance) are reset.

h. Rotate mode Selector Switch at Local Control Panel to NORMAL.

i. Check "Unit Available Emergency Status" indicator lamp ON.

STARTING PROCEDURES.

REMOTE NORMAL MANUAL START.

To start the unit manually from the remote location while in the NORMAL mode, perform the following

a. Ensure that Three-Position Remote/Local/Maintenance Control Selector Switch on the Generator Control Panel is in Remote position.

b. Engage the Remote Normal Manual Start pushbutton. As soon as the engine has fired once or twice, release pushbutton.

c. If the unit's entire protective system is permissive, it will start come up to speed and build voltage automatically. A "Ready To Load" indicator light will illuminate for use in the owner's sequencing equipment.

STATION POWER BLACKOUT START.

If a Blackout signal is received from the owner's equipment, a start signal will be automatically transmitted to the Local Engine Control Panel, and the unit will start, if its entire protective system is permissive and if the Remote/Local/Maintenance Control Selector Switch is in the Remote position. The unit will come up to speed automatically, voltage will build up and a "Ready To Load" signal will be generated for use with the owner's loading controls.

REMOTE EMERGENCY START.

In the event of a station emergency, a maintained Remote Emergency Start signal may be applied manually from the owner's remote control room or a Loss Of Cooling Accident signal (LOCA) may be generated by the owner's sensing equipment. If the unit is in the NORMAL mode, and the Three-Position Control Selector Switch is in the Remote position, the unit will start, come up to speed and build voltage automatically, and all shutdowns will be disarmed, except for overspeed and generator/switchgear malfunction.

LOCAL OPERATION.

Although the unit is normally operated from the remote location, a Local Generator Control Panel is provided which is capable of performing all starting, running, loading, and stopping functions. If a Local Normal Manual Start is desired, perform the following

a. Ensure that Three-Position Remote/Local/Maintenance Control Selector Switch on Generator Control Panel is in Local Position.

b. Ensure unit is in NORMAL mode.

c. Engage Local Manual Normal Start pushbutton.

d. If the unit's entire protective system is permissive, the unit will start, come up to speed and build voltage automatically. Loading operations may be performed at the Local Generator Control Panel once "Ready To Load" signal is received.

REMOTE CONTROL ROOM EVACUATION.

In the event of a Remote Control Room evacuation, the unit may be given an emergency start signal from the Local Generator Control Panel. In order to effect a local emergency start in the event of such an emergency, perform the following

a. Ensure that Three-Position Remote/Local/Maintenance Control Selector Switch at Local Generator Control Panel is in Local Position.

b. Ensure unit is in NORMAL mode.

c. Place the Local Emergency Start switch at the Local Generator Control Panel in the START position.

d. The unit will start, come up to speed and voltage, and a "Ready To Load" signal will be generated. All protection will be disarmed, except for generator differential and overspeed. Loading operations may be carried out at the Local Generator Control Panel.

STOPPING PROCEDURES.

LOCAL MANUAL STOP.

If the unit is being operated in the Local Control position for any reason, the unit may be stopped by performing the following:

a. Reduce the load on the diesel-generator gradually to no load.

b. At no load, trip the generator and field breakers, disconnecting the generator from its energized bus.

c. Allow engine temperatures to cool to the desired level, and actuate the Local Normal Stop pushbutton at the Local Generator Control Panel.

REMOTE MANUAL STOP.

If the unit is operating in its normal condition, with the Three-Position Remote/Local/Maintenance Selector Switch in the Remote position, and in NORMAL operating mode, the diesel-generator may be stopped by performing the following:

a. Reduce the load gradually to no load.

b. At no load, trip the generator and field breakers, disconnecting the generator from its energized bus.

c. Allow engine temperatures to cool to the desired level, and actuate the Remote Normal Manual Stop pushbutton.

EMERGENCY STOP.

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

a. Open main circuit breaker and depress stop pushbutton in local or remote location, according to Control Selector Switch position.

b. Actuate "Emergency Stop" pushbutton in remote location if Generator Selector Switch is in Remote position.

c. Actuate "Emergency Stop" pushbutton at Local Generator Control Panel if Control Selector Switch is in Local position.

d. Manually place the Stop-Run valve on the engine to Stop.

e. Place Governor Load Limit Switch to zero load.

f. Manually trip to overspeed device.

g. 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 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 gasses, especially oxygen, may result in a violent explosion.

SECTION 5
ENGINE
MAINTENANCE

SECTION 5

MAINTENANCE

GENERAL.

Units employed as a source of on-site emergency power at nuclear power stations will experience relatively few operating hours during the span of their normal service life, yet the requirement that the unit be able to start, come up to rated speed and assume a load quickly in response to an emergency start signal from the owner's equipment dictates that there must be a maintenance program in use which is designed to ensure the necessary high level of reliability of the engine, generator and associated equipment to accomplish this.

MAINTENANCE CONCEPT.

The precise number of hours a standby diesel-generator unit will be operated in any given time period cannot be known in advance. Under ideal conditions the complete engine-generator installation will be operated only in periodic testing situations, although certain systems such as the lubricating oil and jacket water "keep warm" circuits will be operating all the time when the unit is in standby operation. Operating hours, then, cannot alone be the determining factor. Calendar time is also significant for some systems. As there are few operating hours, many maintenance actions are based on operating hours and/or reactor refueling shutdown, whichever comes first. To formulate an effective schedule, certain assumptions must be made.

a. The diesel-generator will undergo periodic exercise tests, the frequency of which will be determined by regulations issued by the U.S. Nuclear Regulatory Commission and other cognizant authority. The frequency of testing is assumed to be no less than once every thirty-one days.

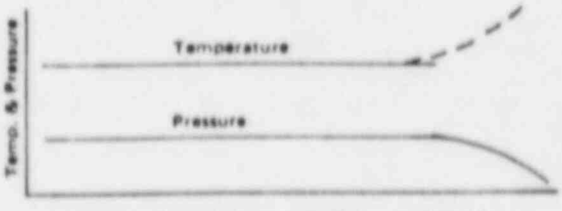
b. The periodic exercise test will involve starting the unit, bringing it to rated speed, applying some load, running under load for a period of time, shedding the load and shutting down. It is assumed that the test will be of a minimum duration of two hours.

c. The plant will be shut down on a periodic basis for refueling of the reactor.

d. The maintenance actions will be performed by personnel who are trained and qualified to do this sort of work.

RECORD KEEPING.

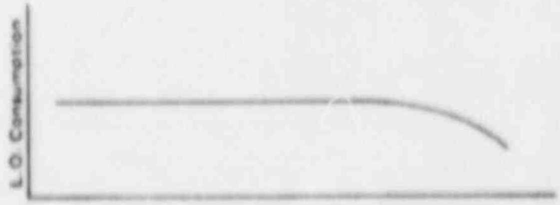
The keeping of records can greatly assist in the evaluation of engine performance and keeping operating personnel informed of the current running condition of the engine. Comparison of present and past log sheets and charts may reveal gradual changes in temperatures, pressures, noise and overall performance, all indicators of the engine's condition which can be of assistance in planning future overhaul and repair schedules. The majority of engine problems are preceeded by signs and indications. Performance trends are not easily detectible, however, unless data is recorded in a manner that makes these trends apparent. Charts and curves can perform this function. Essential to any technique which depends upon the recording of observations is the careful and accurate charting of data. Because of the few operating hours experienced by an engine in nuclear standby service, data should be plotted at frequent intervals during those periods of operation to obtain sufficient data to readily reveal operating trends. The following paragraphs illustrate some of the information that can be obtained from charts and curves.



a. If lubricating oil pressure starts to fall off but the temperature remains constant, it would indicate that the 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 fall off and the lubricating oil temperature rises, it might indicate that the heat exchanger equipment is plugging up.

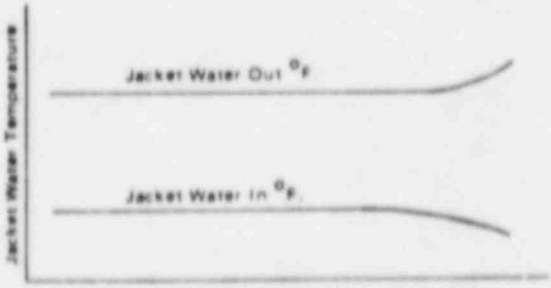
WARNING

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 temperatures 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 water.

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.



TIME – DAILY AND MONTHLY SUMMARY

d. If jacket water temperature starts to rise it could mean that the jacket water cooler is starting to foul. However, it must be remembered that the AMOT temperature 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 weather conditions. If inlet temperature starts to drop, indicating a greater temperature differential across the engine, it could mean one or more of the following.

(1) Poor combustion.

(2) Leaky head gasket(s).

(3) Scuffed piston(s).

(4) Faulty venting of jacket water system.

(5) Faulty water pump.

MAINTENANCE SCHEDULES.

The following maintenance schedules are recommended. Inspection intervals are optimum, however, operating experience must be used to determine the ultimate suitability of the schedule. Where experience indicate more frequent inspection is desirable, the inspection interval should be shortened. Unless otherwise stated, the following inspection intervals are used.

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 periodice 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 to a five year interval.

NUCLEAR EMERGENCY STANDBY ENGINE MAINTENANCE SCHEDULE

COMPONENT GROUP   DIESEL ENGINE

FREQUENCY CODES:
A Daily
B Weekly
C Monthly
D Annual/Each Shutdown
E Bi Annual/Alternate Shutdowns
F Each Five Years

ITEM	MAINTENANCE ACTION	A	B	C	D	E	F		
	Observe and record lubricating oil and jacket water temperatures. (Only if unit operating in standby mode with keep warm pumps on)	XX							
	Drain all low point water collectors, "Y" strainers and air receiver tanks in starting air system.	XX							
	Check engine and auxiliary equipment for oil, water and fuel oil leaks.	XX							
	Check level of lubricating oil in sump tank, governor and pedestal bearing.	XX							
	Check fuel pump racks for freedom of movement through full limit of travel. Do not disconnect from governor.	XX							
	Check operation of air strangulation valve and actuating cylinder.		XX						
	Turn on electrical fuel oil booster pump for a short time and circulate fuel through system. Check strainers for clean fuel.		XX						
	Clean and inspect "Y" strainers in starting air system. Note: if fouling of strainers is such that more frequent inspection is indicated, shorten inspection interval.			XX					
	Check lubricating oil filter pressure differential.			XX					
	Inspect and clean air filter in starting air distributor. If conditions warrant, inspect more frequently.			XX					
	Drain water and/or sludge from lubricating oil full flow filter.			XX					
	If differential pressure indicates, check strainer screens in fuel oil and lubricating oil pressure strainer.			XX					
	Check lubricating oil for fuel dilution with a viscosimeter.			XX					
	Send lubricating oil sample to laboratory for analysis.			XX					
	Drain lubricating oil system. Clean sump and strainers, refill with new oil.				XX				
	Check pH factor of jacket water. Correct as necessary as recommended by chemical supplier. Recommended pH is 8.25 - 9.75.			XX					

NUCLEAR EMERGENCY STANDBY ENGINE MAINTENANCE SCHEDULE

COMPONENT GROUP: DIESEL ENGINE (Continued)

FREQUENCY CODES
A Daily
B Weekly
C Monthly
D Annual/Each Shutdown
E Bi-Annual/Alternate Shutdowns
F Each Five Years

ITEM	MAINTENANCE ACTION	A	B	C	D	E	F	
	Remove alternate left side doors and examine inside of engine for any abnormal conditions.				XX			
	Check hydraulic valve lifters for operation and proper adjustment.				XX			
	Remove fuel injector nozzles, clean, reset and reinstall.				XX			
	Check connecting rods and link rod bearing clearances using the "Bump" method.				XX			
	Check and record crankshaft deflections.				XX			
	Visually inspect foundation for breaks in bond between sole plates and grout.				XX			
	Check foundation bolts for correct torque. Retorque as necessary then recheck crankshaft deflections.				XX			
	Check lubricating oil jets at gears for plugged or broken lines.				XX			
	Remove cam covers and cylinder head covers. Inspect cams, tappets, rollers, rocker arms, push rods, springs and valve guides.				XX			
	Drain governor oil, clean, flush, refill with new oil. If necessary, replace governor drive coupling.				XX			
	Remove turbocharger(s). Disassemble and clean.						XX	
	Check cold compression pressures, maximum firing pressures and take an indicator card. If indicated, remove cylinder heads, grind valves. Check valves and liners.				XX			
	Inspect gears for general condition. Check backlash and replace worn gears exceeding maximum clearance.					XX		
	Remove fuel injection pumps. Disassemble, clean, repair and adjust as necessary.					XX		
	Remove end plates from heat exchangers and intercoolers. Examine and clean as necessary.				XX			
	Check main bearings.					XX		
	Inspect intake air filter oil distribution plate. Change oil in filter.				XX			

PRESERVING ENGINE FOR SHIPMENT OR STORAGE.

The following instructions are for preserving an operable engine for shipment, storage or inactivating for an indefinite period of time.

a. COOLING SYSTEM AND WATER PUMPS – Before shutting an engine down, add a water soluble liquid such as Texaco Soluble Oil "C", to the water system and circulate for about 15 minutes, then drain. Disconnect the water line from its source and seal with a blind flange to prevent water seepage into the system. Remove engine water header and make sure all water has been removed from around the liners. Drain all water lines and when sure the system is dry, reconnect all lines and engine header to form an airtight system.

b. FUEL SYSTEM – To preserve the fuel system, disconnect the fuel line ahead of the engine fuel transfer pump and allow engine to burn about five gallons of Tectyl No. 502-C before shutting down. Cap the fuel line to the engine. Drain all fuel tanks and spray insides with Tectyl No. 502-C. Drain all other fuel lines.

c. LUBRICATING OIL SYSTEM – Using an auxiliary lubricating oil pump, circulate a mixture of 50% lubricating oil and 50% Tectyl No. 502-C, then drain. If the turbocharger has a separate lubricating air system, circulate a 50-50 mixture of lubricating oil and Tectyl No. 502-C, then drain.

d. CRANKCASE, CAM GALLERY, CYLINDER HEADS AND FUEL INJECTION PUMPS – Remove camshaft covers and spray cams, tappets, etc. with 100% Tectyl No. 502-C and replace cam covers. Remove crankcase doors and spray 100% Tectyl No. 502-C all over the inside of the crankcase then replace covers. Remove cylinder head covers and spray 100% Tectyl No. 502-C on rocker arms, etc. Remove fuel injection pumps and spray 100% Tectyl No. 502-C down on the tappet parts and up on the fuel pump cup (plunger follower) then reassemble. For all non-painted parts, such as the fuel rack shaft on the outside of the engine, Tectyl No. 502-C can be sprayed on if protection is required for only a short time, that is two or three months. Be sure the exposed parts are cleaned and dryed before spraying. This makes a good seal for such parts as heim joints. Fuel pump racks require a little grease on the edge of the pump body to prevent the compound from entering the pump body and sticking the pump racks.

e. GOVERNOR – The engine governor lubricating oil should be drained and refilled with new oil.

f. OPENING – Air intake and exhaust openings to the engine should be sealed with gaskets and blind flanges of the metal type. All other such openings to the engine should also be sealed with gaskets and blind flanges.

g. SHIPPING AND STORAGE – In addition to the above instructions, the engine must be stored in a building out of the weather elements. While in shipment the engine must be protected by a tarpaulin or boxed when shipped overseas.

SPECIFICATION FOR PROTECTIVE MATERIALS

MATERIAL	MANUFACTURE
Tectyl No. 502-C	Valvoline Oil Company Freedom, Pennsylvania
Soluble Oil "C" – Use 3 to 5% mixture in the cooling water	Texaco, Inc.

PRESERVATION EQUIPMENT.

In the foregoing instructions it is recognized that many times it is necessary to apply protective materials under difficult field conditions. A common paint brush may be used for applying preservative to accessible parts, and a hand operated pump sprayer with a pointed discharge nozzle of the type commonly used to spray insecticides may be used for inaccessible points. If desired, a small oil pump may be rigged with a motor drive to make a convenient mechanical pressure spray unit. Shop compressor air lines usually carry too much moisture to be safe for this purpose, and should not be used.

TORQUE WRENCH TIGHTENING PROCEDURES AND VALUES.

Torque figures given in this manual are based on the use of a thread lubricant composed of equal parts by volume of engine lubricating oil and Dixon Number 2 powdered medium flake graphite, or equal. They do not apply to dry threads, or to threads lubricated with "Super Lubricants". Dry thread torque readings can be as much as 50 percent in error.

PROCEDURE.

a. Lubricate threads with oil and graphite mixture and tighten nuts hand tight.

b. Tighten all nuts by snugging the first nut, then moving to the one farthest removed and continuing in a crisscross pattern until all nuts are snug.

c. Unless otherwise specified, apply 20 percent of the required torque to each nut in the same sequence as described above, then repeat procedure for 50, 60, 80, and 100 percent of the prescribed torque value.

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

TORQUE VALUES.

See Appendix IV for torque wrench values to be used when torquing the various engine parts.

PRE-STRESSED STUDS.

Cylinder head studs and main bearing cap studs on Model RV engines are pre-stressed when installed rather than torqued with a wrench because of their size, location and high torque requirements. This is accomplished by stretching the studs with a hydraulic tool, then tightening the stud nuts. When the tool is removed a pre-determined stress remains in the stud. For this type application pre-stressing offers certain advantages.

a. Less physical effort is required.

b. It is easier to accomplish in confined areas.

SECTION 6
DISASSEMBLY,
INSPECTION
& REPAIR

APPENDIX IV

TORQUE VALUES
Model RV Engine

The torque values listed below are based upon the use of the lubricant specified on page 5-7 under "Torque Wrench Tightening Procedures". All values are given both in foot pounds and in kilograms per meter. Where applicable, bolt sizes are shown in parenthesis.

Item		Torque ft-lb	Torque kg-m
NUT, Foundation Bolt (heat treated steel*)		3800	525.6
NUT, Main Bearing Cap Stud (1¾")**		3000	415
NUT, Base to Crankcase Thru-Bolt		7000	968
CAPSCREW, Crankcase to Base (1")		285	39.4
NUT, Cylinder Block to Crankcase Thru-Bolt (2½")		4500	622
" " " " " " " (2")		3000	425
NUT, Connecting Rod Bolt (1½")		1200	166
" " " " (1-7/8")		1800	248.9
BOLT, Link Connecting Rod to Link Pin (1¼")		735	101.5
" " " " " " " (1-1/8")		1050	145.2
NUT, Cylinder Head Stud (2-8NC)**		3300	456.4
NUT, Spark Plug Tube Retainer	Minimum	60	8.29
	Maximum	65	8.98
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
NUT, Camshaft Bearing Cap Stud		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

*Heat treated bolts are identified by the figure "4" stamped on end of bolt.
**Not applicable if pre-stressing method is used.

GENERAL TORQUE VALUES

The torque values given on the preceeding 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

SECTION 6

DISASSEMBLY, INSPECTION 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.

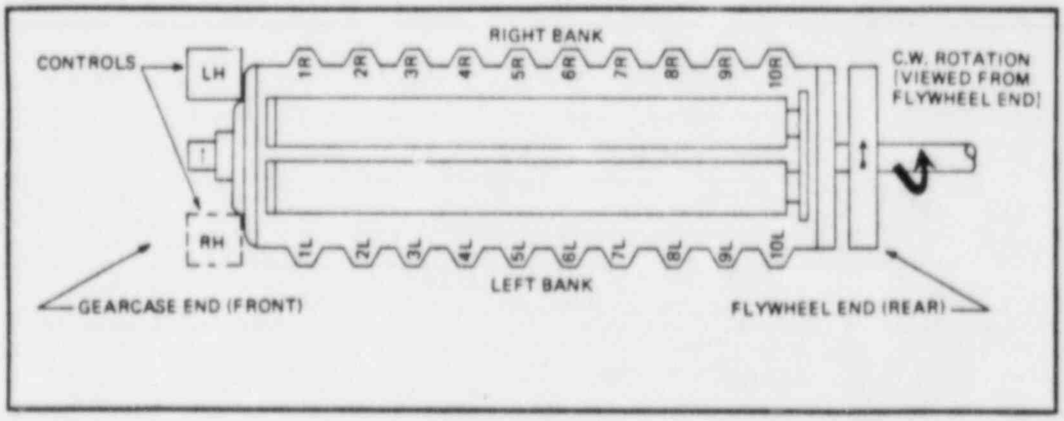


Figure 6-A-1. Engine Rotation and Cylinder Designation

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)

SPECIAL TOOLS.

Refer to the 590 Group Parts List in the *Parts Manual* for a listing of the special maintenance tools and equipment furnished with the engine.

CLEANLINESS.

Care must be exercised to keep dirt, grit or other debris from entering any of the lubricating oil or cooling water system as well as from the bearing surfaces of pistons, shafts, etc.

TORQUING.

Make reference to Section 5 for the correct method of torquing nuts and bolts, and to Appendix V for the specified torque values.

PART B – CYLINDER HEADS AND VALVES (Continued)

VALVES.

Intake and exhaust valves are constructed of alloy steel, however, the steel alloy specifications differ. Valves may be identified by the marking "IN" for intake valves and "EX" for exhaust valves, stamped on the valve stem. The intake valves on dual fuel engines also serve as gas admission valves and are so constructed that an enlarged portion of the valve stem fits into the lower portion of the valve guide to form a gas admission valve. At the proper point of the intake valve opening stroke, gas is admitted through ports in the valve guide to mix with the intake airstream.

VALVE SPRING REPLACEMENT (Cylinder Head Not Removed).

Valve springs may be replaced without removing the cylinder head from the block. Remove rocker arms assemblies then bar engine over until piston of cylinder being worked on is at top dead center. Attach valve spring removal tool to the two fuel injector studs as shown in Figure 6-B-2. Make sure the nuts are rundown far enough on the studs to hold securely. Tighten nut on cross arm, making sure the cross arm is not bearing on the top of the wedges. Tighten nut until valve springs are compressed. Lift the valve by its stem and remove the two keepers from each valve. Back off on compression nut on tool, then remove tool from cylinder head. Springs may be lifted off valve stems. Spring installation is the reverse of removal.

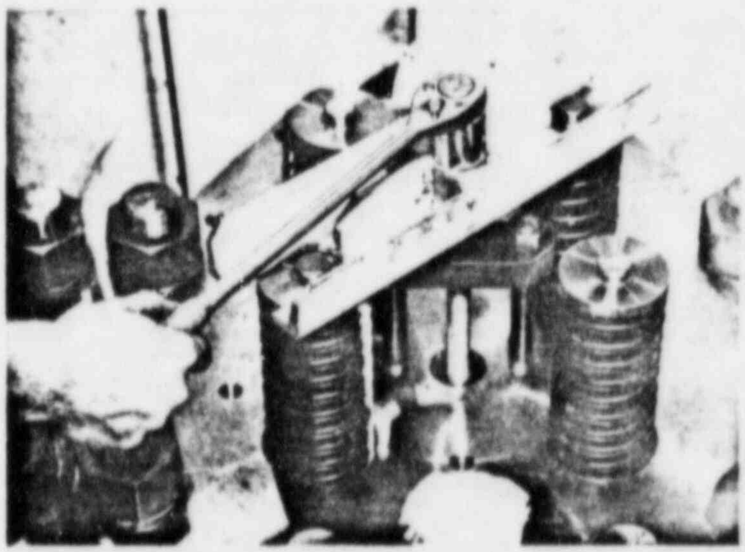


Figure 6-B-2. Valve Spring Removal Tool

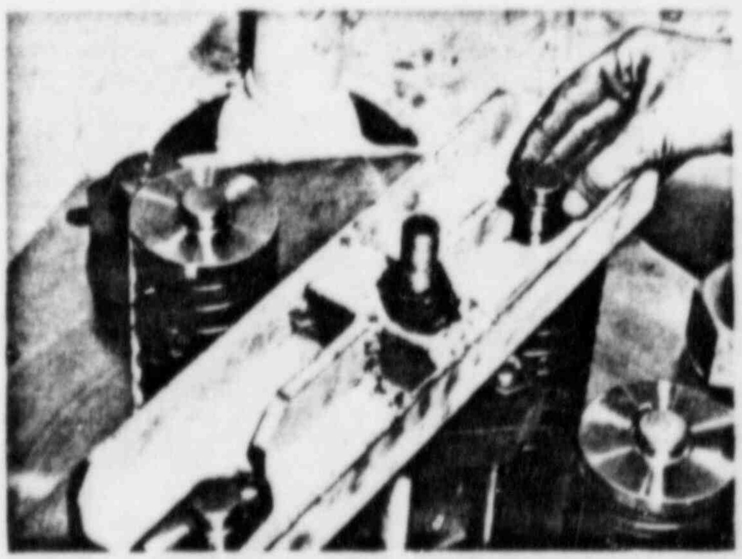


Figure 6-B-3. Removing Valve Keepers.

VALVE REMOVAL FROM CYLINDER HEAD.

With cylinder head removed from engine, install valve spring removal tool as shown above, and remove valve springs. Remove valves from combustion side of cylinder head.

Form E–177a

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)

VALVE INSPECTION AND RECONDITIONING.

The seating surface of valves, particularly exhaust valves, may have the appearance of pitting due to small carbon particles which may have been trapped on the seats and impressed on the metal. This condition has no effect on operation unless there is an indication of blowby, in which case the valves should be reseated. Valves may be re-faced on a standard valve re-facing machine, or on an ordinary lathe. The seating should be exactly 45 degrees. If done on a lathe with a cutting tool, be sure to use very fine feed and a sharp tool for the final cut. If a grinding wheel is used, the wheel should be dressed for exact trueness before the final grinding cut is taken. Remove just enough material to eliminate pits and to make the seat run exactly true with the stem. If the valve guide is worn, a new guide should be installed before re-facing valve seats. Re-seat head with a valve grinder. If a grinder is not available, use a 45 degree hand reamer. Face just enough for trueness and removal of pits. Limit width of valve seat to 19/32 $\pm$ 1/64 inch (1.51 $\pm$ 0.04 cm) with a 45 degree tool. If the engine is equipped with valve rotators, the rotators must be replaced whenever the valves are serviced.

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.

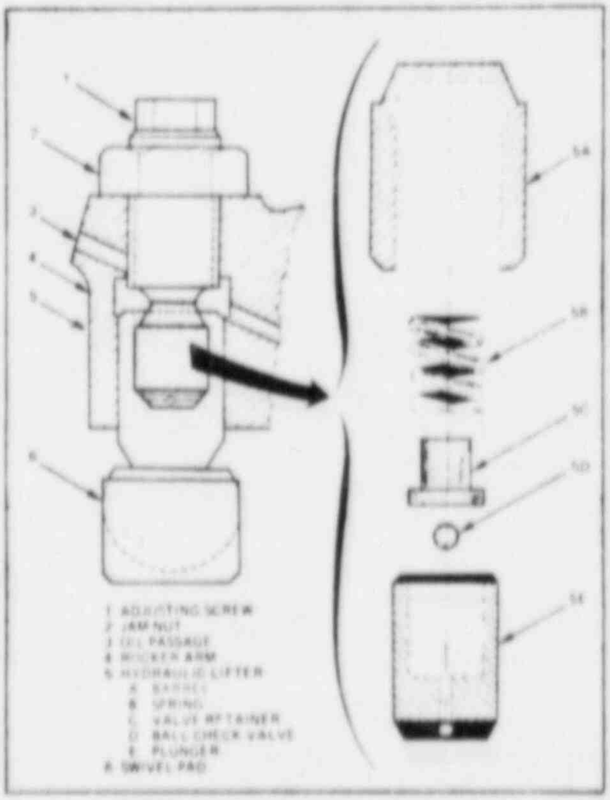


Figure 6-B-5. Hydraulic Valve Lifter

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.

Pistons and their attached rods may be removed from the engine by lifting them straight out of the cylinder liners. To prepare the engine for piston removal, remove the cylinder heads and the engine side doors adjacent to the pistons and rods to be pulled. If, however, it is only desired to remove or inspect the connecting rod bearings, the cylinder heads need not be removed. Follow the procedure in the next paragraph.

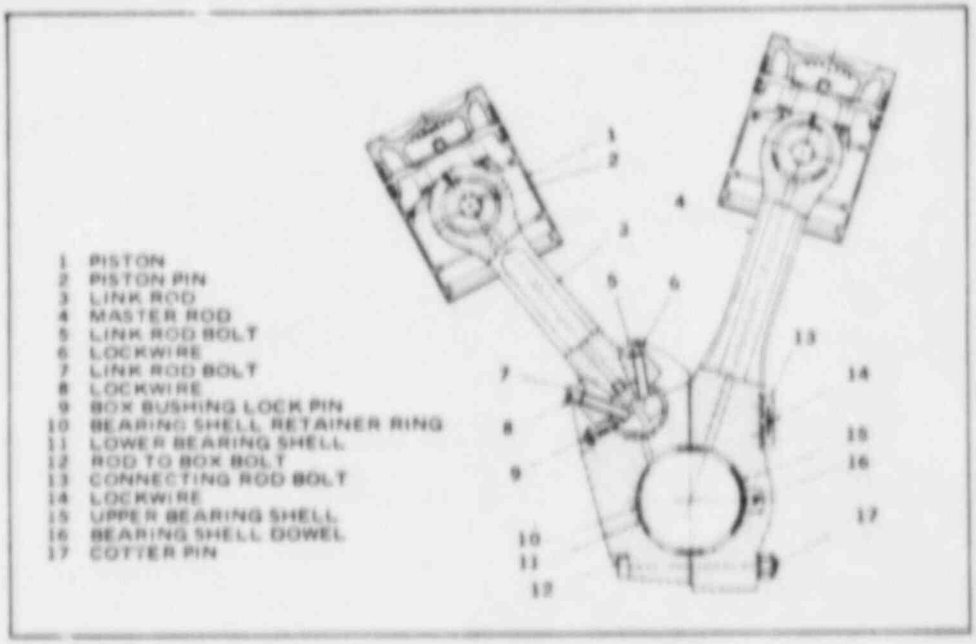


Figure 6-C-1. Pistons and Connecting Rods

CONNECTING ROD BEARING SHELL REPLACEMENT.

With engine side door covers adjacent to the bearing to be replaced removed, proceed as follows.

a. Loosen all connecting rod bolts slightly, but do not remove.

b. Block crankshaft to prevent further movement.

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

d. Attach chain puller bracket to side of crankcase, then attach chain puller.

e. Attach chains to each end of link pin with capscrews. Attach chain puller to chain and take up slack as necessary to hold the link rod firmly against the crankpin.

f. 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.

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

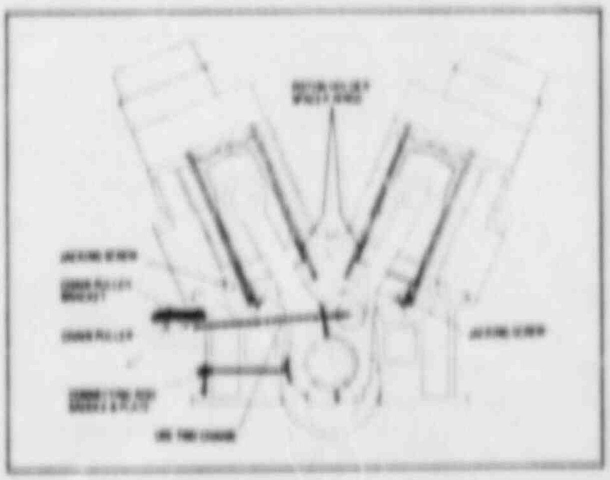


Figure 6-C-2. Bearing Replacement Tool Arrangement

PART C – PISTONS AND RODS (Continued)

h. Remove six bolts which attach link rod box to master rod. Slack off chain puller to allow link rod box to swing clear of bearing shell. Adjust locking ring assembly jacking screw as necessary to prevent binding.

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

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

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

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

m. 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.

n. Tighten chain puller and guide link rod box into engagement with the crankpin and the serrated joint of the master rod.

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

p. Remove all tools and blocking from engine.

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 tool to the crown of the 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 crank hook and attach hook to side lifting hole of pulling tool.

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.

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

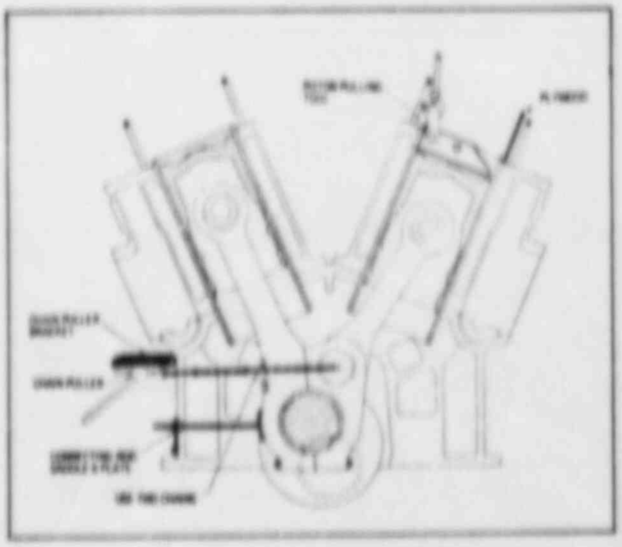


Figure 6-C-3. Tools Installed For Removing Piston and Link Rod.

PART C – PISTONS AND RODS (Continued)

g. Remove six bolts (see figure 6-C-1) which hold link rod box to master rod 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 asbestos 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 1 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.

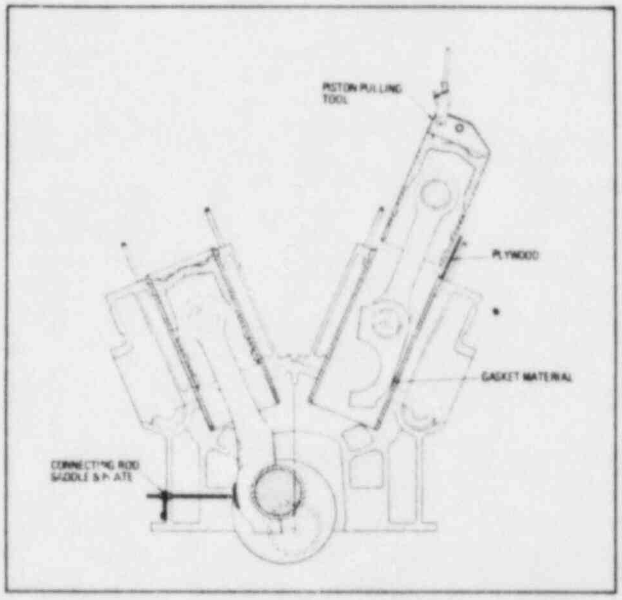


Figure 6-C-4. Lifting Piston and Link Rod From Cylinder Liner.

PISTON AND MASTER ROD REMOVAL.

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).

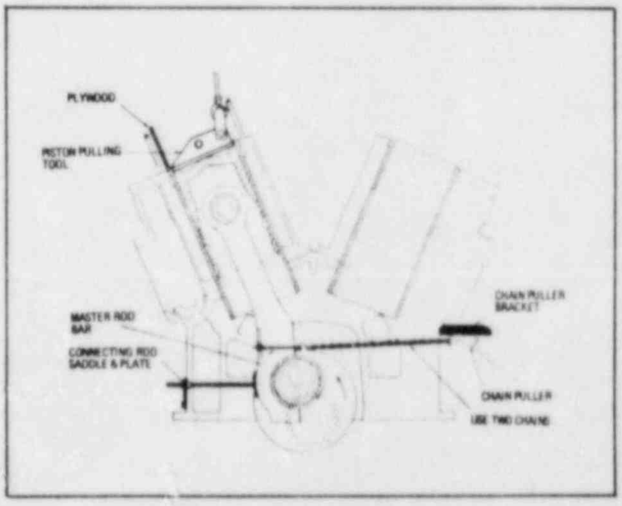


Figure 6-C-5. Tools Installed For Piston and Master Rod Removal.

PART C – PISTONS AND RODS (Continued)

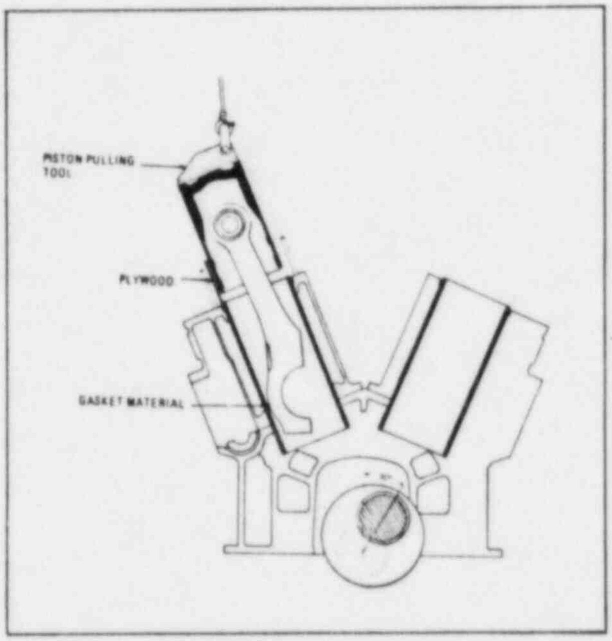


Figure 6-C-6. Lifting Master Rod and Piston From Cylinder Liner.

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

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

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

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

e. Clean out the slag and burned metal and remove the gasket shield.

f. Install a master rod retaining bar and plate assembly to hold the master rod firmly against the connecting rod bearing and crank journal.

g. Install the tools and fixtures necessary to remove the link rod and piston.

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

i. 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.

j. Clean the 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.

k. Set the 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.

l. 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.

m. 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)

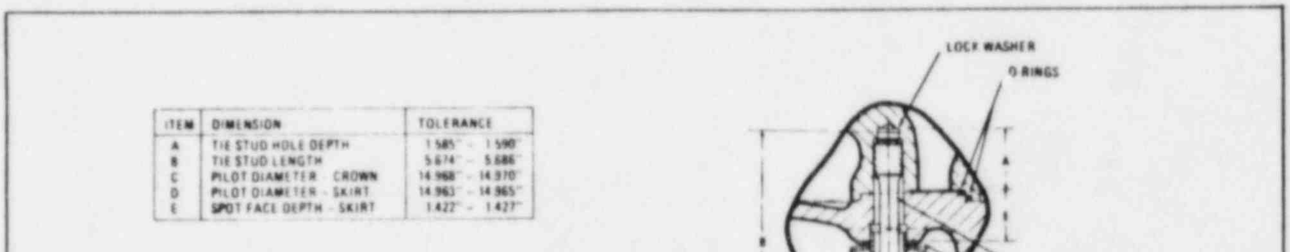
DISASSEMBLY.

With piston and rod suspended from a hoist and with the weight of the assembly resting lightly on the piston crown, remove piston pin retainer rings from grooves on ends of piston pin then slide piston pin out of piston. Lift rod assembly clear of piston.

INSPECTION.

Carefully inspect piston, rod, pin and bushings for wear and/or damage.

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.



ITEM	DIMENSION	TOLERANCE
A	TIE STUD HOLE DEPTH	1.585" – 1.590"
B	TIE STUD LENGTH	5.674" – 5.686"
C	PILOT DIAMETER – CROWN	14.968" – 14.970"
D	PILOT DIAMETER – SKIRT	14.963" – 14.965"
E	SPOT FACE DEPTH – SKIRT	1.422" – 1.427"

Figure 6-C-7. Piston Assembly

c. Reassemble pistons as follows.

(1) Measure depth of crown stud holes. Measure from raised inner ring towards the center of the crown, not from the 0.007" deep relieved area. Must be within tolerances (A, Fig. 6-C-7).

PART C – PISTONS AND RODS (Continued)

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

(3) Measure length of tie stud from lock washer end to centerline of roll pin hole (B, Fig. 6-C-7). Acceptable tie studs must be within tolerances.

(4) Lubricate threads of tie studs (end opposite roll pin hole) with a 50-50 mixture of graphite and engine oil, and thread studs into holes in crown. Torque to 250 ft-lb.

(5) Take a micrometer measurement of crown and skirt pilots (C, D, Fig. 6-C-7). Must be within tolerances to ensure ease of assembly without damage to O-rings.

(6) Measure skirt spot face depth (E, Fig. 6-C-7). Should be within stated tolerances.

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

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

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

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

(11) Install spring collars on each tie stud, then install two lok-straps as shown in Figure 6-C-7.

(12) Lubricate tie stud threads with a 50-50 mixture of graphite and engine oil and assemble hex nuts to studs. Tighten finger tight.

(13) Align each washer stack with fingers so outer edge of washer stack is even. Torque each nut to 95 ft-lb, then back off three-quarter turn.

(14) Retorque each nut to 85 ft-lb and check alignment of tie stud roll pin holes with nut slots. Increase torque as necessary to align roll pin holes with closest nut slot. Do not exceed 100 ft-lb.

(15) Check for proper assembly. Roll pin hole in stud should be even with, or a maximum of 1/32" above base of nut slot. If within this tolerance, clean roll pin hole and install roll pin, using loktite. If not within tolerance, check assembly of parts for proper size and correct number of springs each way.

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

PISTON RING REPLACEMENT.

If piston rings require replacement, remove and install as follows.

a. Starting with top ring, spread and slide piston rings up and off piston. Four brass strips, measuring approximately 1/32" x 1/2" x 8" may be inserted under rings to protect piston during removal and installation of rings.

PART C – PISTONS AND RODS (Continued)

b. Replace piston rings in reverse order of removal. Intermediate compression rings are marked "UP" on the upper sides. Top compression rings may be installed with either side up. The oil cutter rings must be installed with the cutting edge down.

c. Rotate the rings in the grooves so gaps are staggered around circumference of piston.

PISTON RING GAP AND SIDE CLEARANCES.

Piston ring gap may be measured by inserting piston ring into cylinder liner and sliding it down squarely, measuring the gap at various levels in the liner. The gap clearance should be determined at the smallest diameter, usually near the bottom of the liner. Piston ring wear is usually indicated by excessive ring gap clearance. Refer to "Appendix III" in Section 8 for correct gap clearance. If the recommended gap clearance is exceeded by 1/16-inch or more, the bore of the liner should be measured with an inside micrometer. If the bore at any point is worn more than shown in "Appendix III" the liner should be replaced. Liner wear is usually limited to the last few inches of ring travel near the top.

PISTON PIN BUSHING REPLACEMENT.

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

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

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.

LINK PIN BUSHING REPLACEMENT.

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.

PART C – PISTONS AND RODS (Continued)

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 1-1/2 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.

PISTON AND ROD ASSEMBLY.

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. 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.

PART C – PISTONS AND RODS (Continued)

PISTON AND MASTER ROD INSTALLATION.

Install a piston pulling tool on piston crown then suspend piston and rod from an overhead hoist then proceed as follows.

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

b. Install piston ring fixture on top of cylinder liner.

c. Place a piece of one-half inch 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. Position piston and rod over cylinder liner.

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

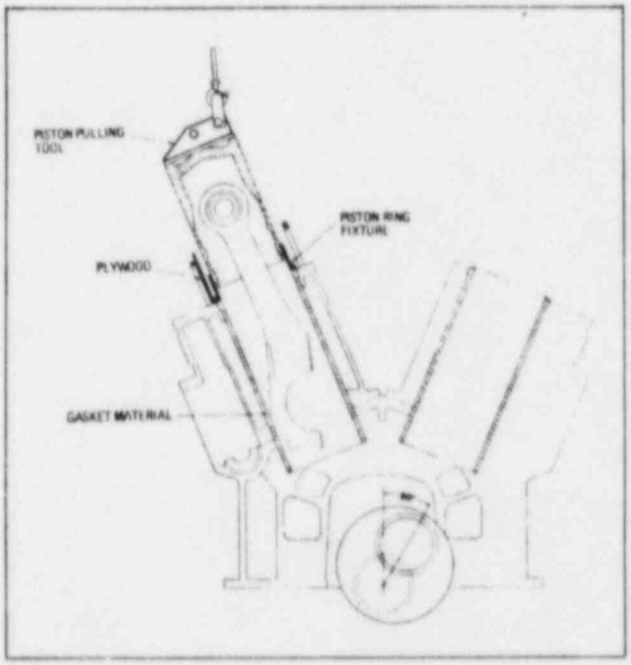


Figure 6-C-8. Piston and Rod Installation

g. Lower rod into cylinder (see figure 6-C-8). Hold piston rings in place as they enter the piston ring fixture. Insure ring gaps are staggered around circumference of 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 shell may be necessary.

j. Install connecting rod saddle and plate on master rod side (see figure 6-C-5) and set 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 movement.

PART C – PISTONS AND RODS (Continued)

PISTON AND LINK ROD INSTALLATION.

Use same procedure used for master rod and piston installation to install link rod, connecting rod box and piston in engine, then use the following procedure to attach connecting rod box to master rod.

a. Attach chain puller bracket to master rod side of crankcase and attach chains in same way as was done for removal (see figure 6-C-3) and draw connecting rod box into engagement with crankpin and master rod. Make sure serrated joints are properly engaged.

b. Apply graphite and lubricating oil mixture to threads of connecting rod bolts and washers and install bolts and washers and tighten bolts to the specified torque. Secure bolt heads with lockwire (see figure 6-C-1).

c. Install connecting rod-to-box bolts in lower holes and assemble washers and nuts that are lubricated with oil and graphite lubricant. Torque nuts as specified and insert cotter pins.

d. Remove all installation tools, brackets, fixtures and other installation equipment.

CYLINDER LINERS.

The water contact type cylinder liners fit into the cylinder block. Three sealing rings are recessed in grooves at the lower end of the liner, preventing water from entering the crankcase. The silicone seal goes into the lower sealing ring groove.

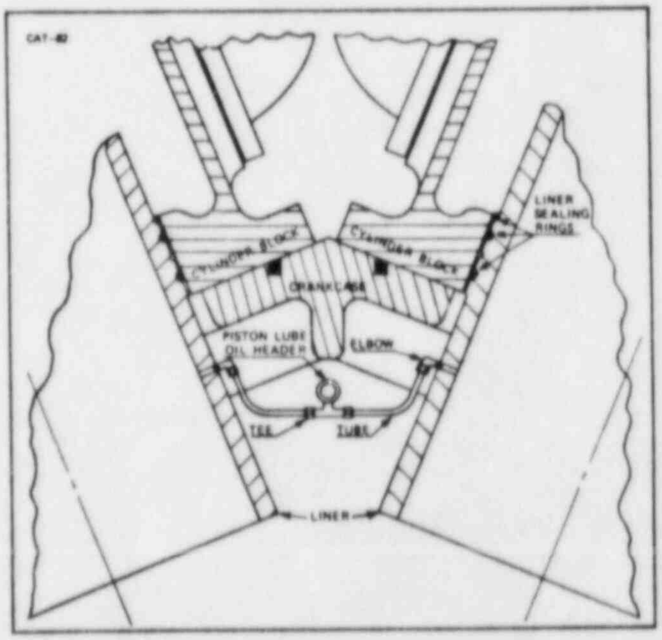


Figure 6-C-9. Liner Sealing Rings

LINER REMOVAL.

Remove the cylinder head, piston and connecting rod, then disconnect lubricating lines from lower end of liner. Install liner pulling tool, Part No. 00-590-01-OV to the bottom of 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.

LINER INSTALLATION.

Installation of the liner is the reverse of removal. To prevent damage to the seals, they should be installed in the grooves after the liner has been lowered approximately two-thirds of the way into the cylinder block. Use new sealing rings and coat them with a liquid dishwashing soap, or a tire installing lubricant before installing. The bottom seal is silicone and should be handled carefully to prevent tearing or nicking. It is essential that liners be replaced in their original positions in the block and that the scribe marks on top of the liner be aligned with the mark on the block.

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).

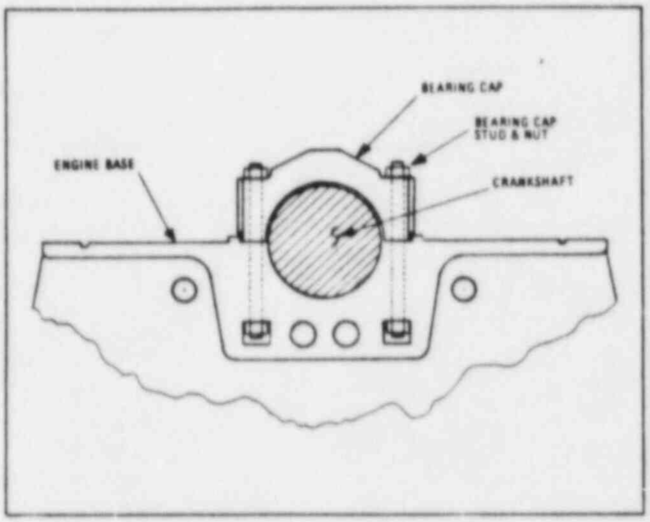


Figure 6-D-1. Main Bearing Cap

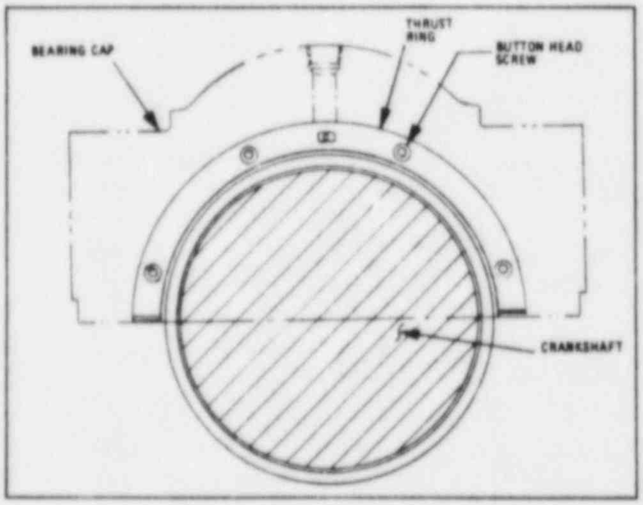


Figure 6-D-2. Crankshaft Thrust Rings

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.

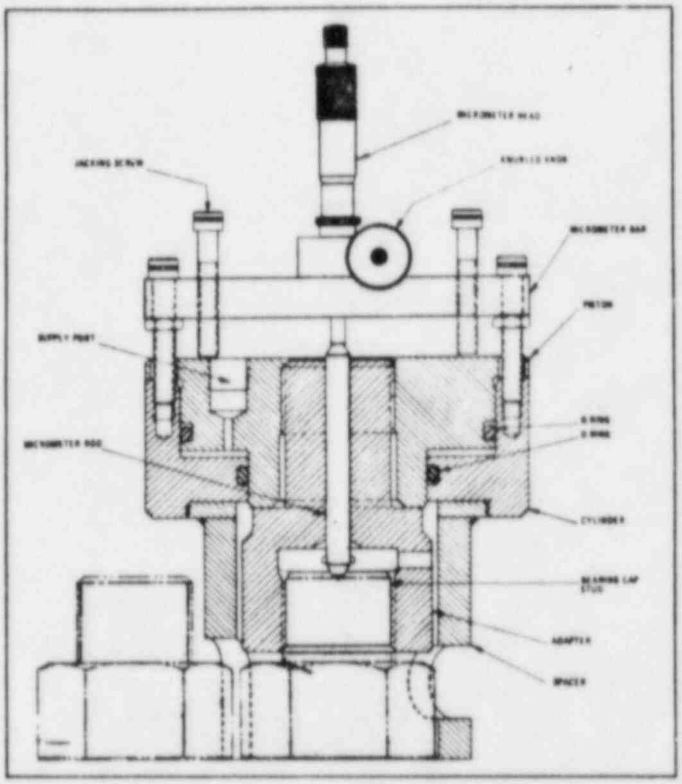


Figure 6-D-3. Pre-Stresser Assembly

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 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 or 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 timed by the cam key method. Failure to observe the proper camshaft timing sequence can result in an altered firing order 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 on the base circle of its cam.

PART E – CAMS, CAMSHAFTS AND BEARINGS (Continued)

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

PART F – FUEL SYSTEM

FUEL INJECTION EQUIPMENT.

Each cylinder is fitted with an individual fuel injection pump and nozzle. The fuel supply to the pumps is from a common header, and a separate high pressure line connects each pump to its respective nozzle. As was stated in Section 2, fuel injection equipment is built to extremely close tolerances and, therefore, requires a great deal of care when being worked on to avoid damage to the parts. Only trained fuel injection equipment mechanics should be allowed to perform this work.

FUEL INJECTION NOZZLES.

Because nozzles and tips are subjected to extremes in pressure and temperature, they normally are the first source 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.

d. Close 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.

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

(2) Raise pressure slowly to determine pressure at which valve opens. The valve should open at 3000 psi (211 kg-cm^2) pressure. The opening pressure is adjusted by means of shims in the valve assembly, requiring disassembly of the unit. See figure 6-F-1 and "Nozzle Adjustment" instructions.

(3) Dry off spray tip and raise pressure to within 100 psi of the opening pressure and observe tip for dribbling 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* for overhaul instructions.

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)

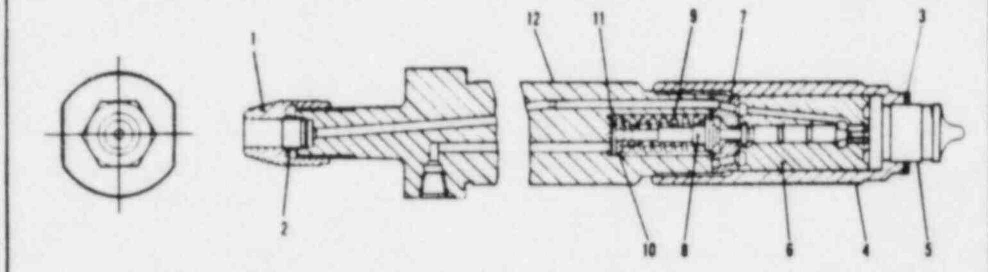


Figure 6-F-1. Sectional View of Typical Nozzle and Holder Assembly

NOZZLE ADJUSTMENT (See Figure 6-F-1).

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 (211 kg-cm^2), 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 needle to seat properly. Pump the pressure up to the point where the pressure gauge needle 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.

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 and timed fuel injection pumps. Refer to the manufacturer's instructions in the *Associated Publications Manual* for complete details of the fuel injection pump 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-2). On some pumps there is a second helix to retard the point of delivery at low fuel settings.

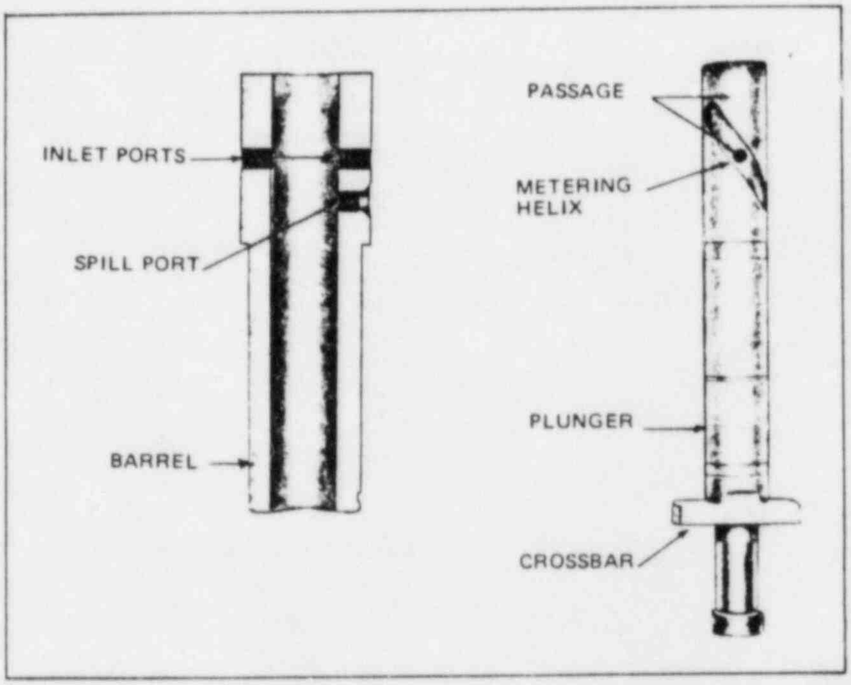


Figure 6-F-2. Pump Plunger and Barrel Arrangement

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.

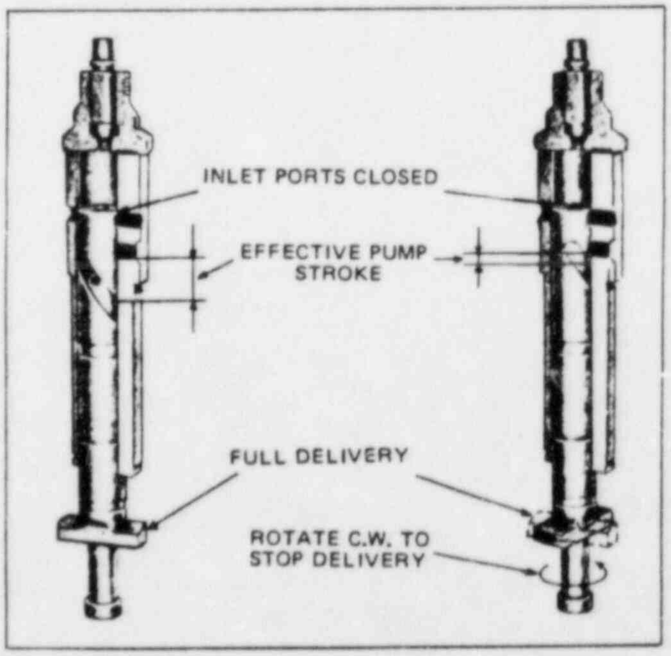


Figure 6-F-3. Effective Stroke

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 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 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.

PUMP DISASSEMBLY.

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 be disassembled as follows.

a. Secure pump in the inverted position in a soft jawed vise. Depress the plunger follower and insert a 1/8 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 1/8 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.

PART F – FUEL SYSTEM (Continued)

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.

PUMP ASSEMBLY.

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)

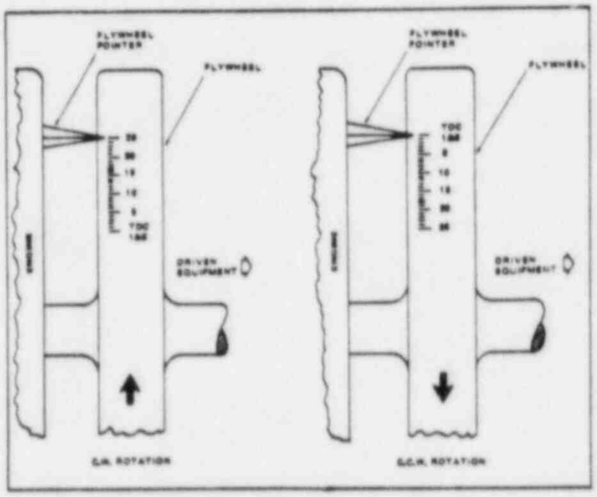


Figure 6-F-4. Flywheel Timing Marks

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-4). 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-5), 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 pointer is aligned with the fuel injection point (degrees BTDC specified on Engine Data Sheet) 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.

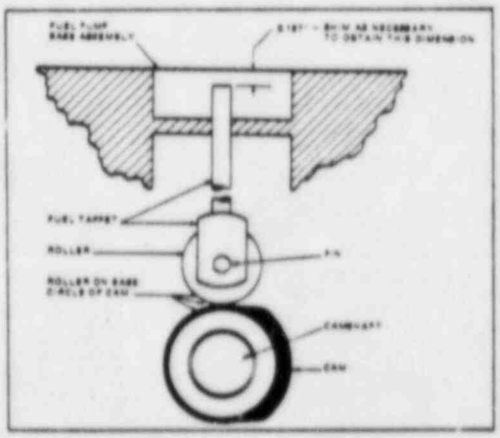


Figure 6-F-5. Pump Base To Tappet Adjustment.

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 (10% above rated speed) it will initiate positive engine shutdown by tripping a dump valve which vents the automatic safety shutdown system. Operation of the overspeed trip governor is as follows.

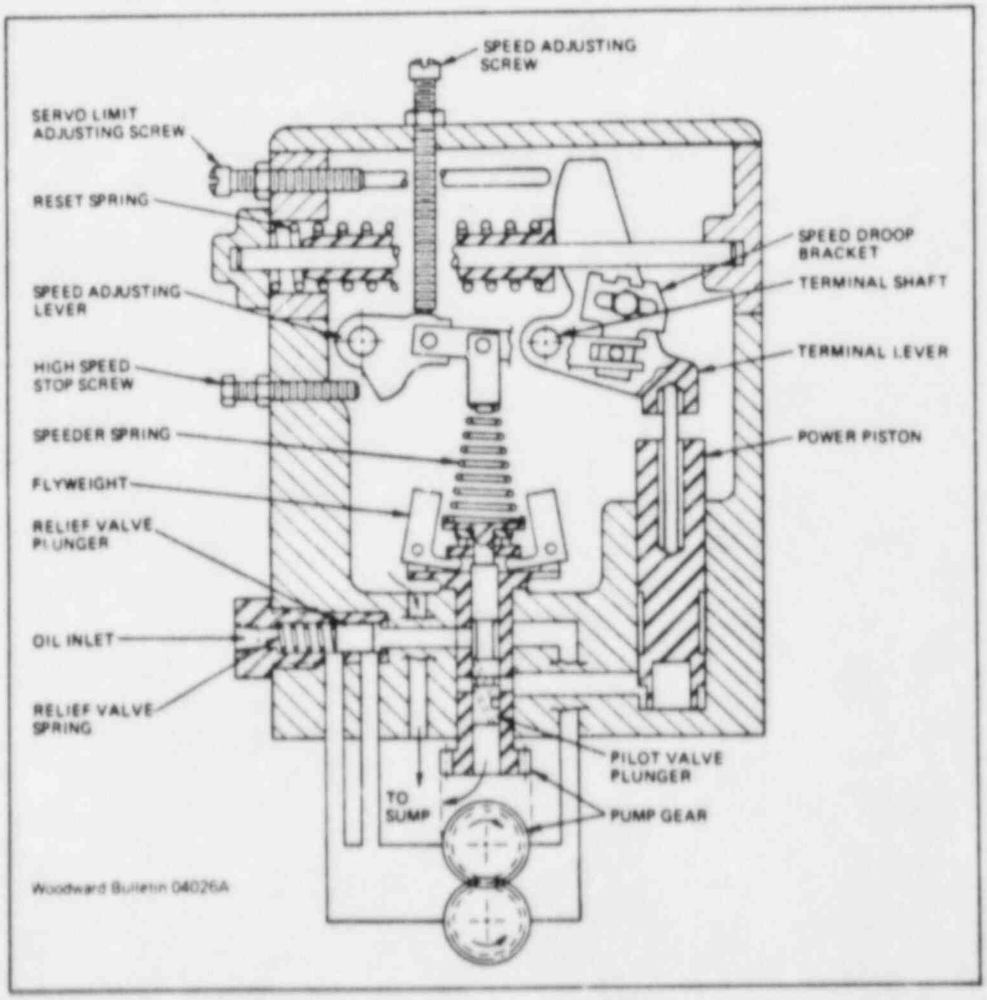


Figure 6-G-1. Overspeed Trip Governor

a. Oil enters the overspeed trip at the oil inlet, drops down into the cavity on the suction side of the pump gears, then around to the pressure side of the pump. If the supply of pressure oil is greater than required, the pump builds up pressure until the relief valve plunger is pushed to the left against the force of the relief valve spring. This uncovers the bypass hole in the relief valve sleeve and oil is recirculated through the pump. If the overspeed trip requires more oil than is being recirculated, pressure will be reduced and the spring will move the relief valve to the right, blocking the recirculating passage to maintain operating pressure. Additional oil, as needed, will enter the pump through the inlet port.

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.

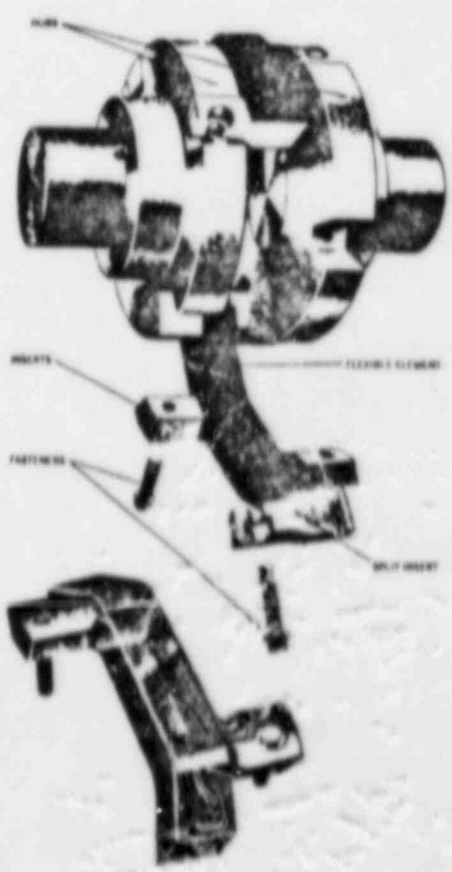


Figure 6-G-2. Governor Drive Coupling

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^{0}, 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 stroke 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 causing 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 that of the starting air develops a sufficiently high temperature to ignite the injected fuel within a few revolutions. The engine then initiates normal combustion and begins to accelerate under its own power without further aid of starting air.

AIR SUPPLY.

The starting air supply is produced and stored in the starting air module at 250 psig (17.57 kg/cm^2). The storage tanks are provided with relief valves set at 275 psig (19.53 kg/cm^2).

OPERATION.

The on-engine portion of the starting air system consists of a remotely controlled, pilot operated diaphragm valve in the air supply line, two camshaft driven starting air distributors, one for each cylinder bank, an air filter for each distributor, and a pilot operated air starting valve (figure 6-I-1) in each cylinder head. When the starting air admission valve in the supply line is opened, 250 psig (17.57 kg/cm^2) starting air is admitted into the starting air manifold and, therefore, to the starting air valves in the cylinder heads as well as to the starting air distributors. Individual spool valves in the distributors (one for each cylinder of the bank serviced) are engaged by air pressure and follow the profile of the starting cam attached to the end of the camshaft. The cam profile is such that at least one spool valve is always in position to emit a pilot signal to its respective starting valve in the cylinder, allowing starting air to enter the combustion chamber of that cylinder, rotating the engine. As the engine rotates, the starting air cam will cause the spool valves to emit timed and sequenced pilot air signals to the starting air valves. The starting process will continue until the signal to the starting air admission valve is terminated. The starting air distributors emit a timed pilot air signal that starts five degrees before top dead center and ends at 115 degrees after top dead center on the power stroke.

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.

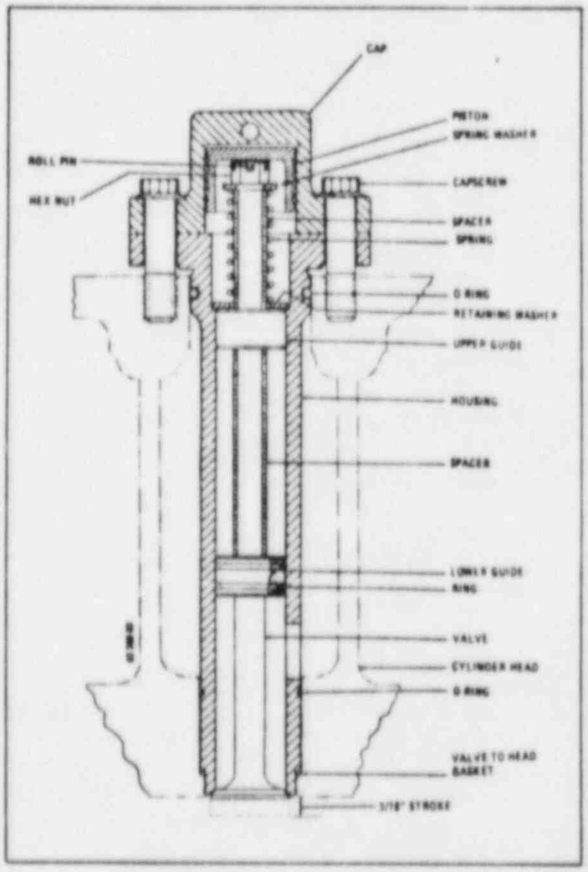


Figure 6-I-1. Starting Air Valve

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).

PART I – STARTING AIR SYSTEM (Continued)

TIMING STARTING AIR DISTRIBUTOR.

The timing of the starting air distributor should be checked if the distributor is replaced, or if the engine camshaft has been replaced or re-timed.

a. Position engine flywheel with number one cylinder (bank on which distributor is mounted) five degrees before top dead center (BTDC) on the compression stroke.

b. Remove cover plate from distributor and loosen capscrews in elongated holes.

c. Rotate distributor assembly to position centerline of spool valve for number one cylinder in line with the TDC scribe mark on the opening ramp of the starting air distributor. Note direction of engine rotation. The spool valve for number one cylinder is now in position to just start emitting an air signal.

d. Shop air at 125 psig (9.79 kg/cm^2) can be connected to the distributor supply port to verify the valve position.

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 are such that more frequent inspections are warranted, then shorten the inspection interval.

PART J – COOLING WATER SYSTEMS

GENERAL.

If, for any reason, there is a disruption in 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 cooling system until the temperature of the cooling surfaces in the engine have dropped to approximately that of the inlet water. All cooling surfaces must be kept free of scale or other deposits as any such accumulation will degrade the cooling capability of the system and, therefore, cooling water temperatures will not accurately indicate the extent of cooling. Any coating of the cooling surfaces will act as an insulating material and will prevent transfer of heat. A check of the pressure differential between the inlet and outlet of coolers will indicate the need for cleaning of the tubes.

JACKET WATER TREATMENT.

It may be advisable to consult a commercial water treatment company concerning the treatment of jacket water to insure that local conditions are taken fully into account. A suggested water treatment material for jacket water systems is sodium dichromate and boiler compound. Sodium dichromate is an inexpensive source of alkaline chromate (CrO_4) which has been found to form a protective film on metallic surfaces that prevents attack by the corrosive elements found in the jacket water. Sodium dichromate is an acid compound which must have an alkaline compound such as boiler compound added to convert the dichromate to an effective alkaline chromate form. The alkaline chromate concentration must be maintained between 700 and 1700 parts per million (ppm). Less than 700 ppm can result in accelerated corrosion while more than 1700 ppm serves no useful purpose and is a waste of material. The pH value of the water must be maintained within a range of 8.25 and 9.75. The minimum pH value is necessary to prevent acid attack on the metallic surfaces, and the 9.75 maximum value will prevent corrosion due to high alkaline content in the water. The chloride content must not be allowed to exceed 100 ppm as the effectiveness of alkaline chromate decreases as the chloride content increases. When initiating alkaline chromate water treatment for the first time, or after the system has been refilled, the water should be tested daily for alkaline chromate concentration and pH value. When the treatment becomes stable, the test interval can be extended to weekly tests. After each addition of chemicals, the water should be circulated through the system then tested to insure that the required limits are met. Where necessary, an anti-freeze coolant solution such as ethylene glycol or similar may be used.

CLEANING JACKET WATER SYSTEM.

Rust can be removed from the jacket water system by filling the system with a solution of 75 pounds of ammonium nitrate in enough fresh water to make 100 gallons of solution. Make enough solution to fill the jacket water system then operate the engine for two hours. The jacket water system must then be flushed with fresh water and neutralized. Scale can be removed from the system by using a scale solvent solution composed of 7 gallons of 20° Baume muriatic (hydrochloric) acid, one-half gallon of liquid inhibitor and 92½ gallons of fresh water at 160° F. Make enough solution to fill the system. Circulate the acid solution through the system for one or two hours, depending on the extent of the scale deposit. The temperature of the acid solution must be maintained at 160° F during circulation. After circulating the acid solution, drain the jacket water system and then fill with clean fresh water and flush it thoroughly. After flushing, neutralize the system with a solution composed of 20 pounds of soda ash (sodium carbonate) and enough fresh water at 160° F to make 100 gallons of neutralizing solution. Fill the jacket water system with the neutralizing solution and circulate it through the system for one-half hour. Maintain the temperature of the solution during circulation.

CAUTION

The above methods of cleaning must not be used for systems which have components containing aluminum.

PART J – COOLING WATER SYSTEMS (Continued)

ENVIRONMENTAL RESTRICTIONS.

Alkaline chromate water treatment compounds, such as sodium dichromate, may be considered environmentally objectionable in some locations, or may be prohibited. In these instances, nitrate compounds such as sodium nitrate ($NaNO_2$) are suggested as adequate substitutes. When using $NaNO_2$, the concentration must be 500 ppm with a pH of 7.5 to 8.5 to achieve effective corrosion control. Nitrate compounds for treating engine jacket water systems are available from most commercial chemical supply houses, and instructions for their use are available from the chemical supplier.

PART K – LUBRICATING OIL SYSTEM

FILTERS AND STRAINERS.

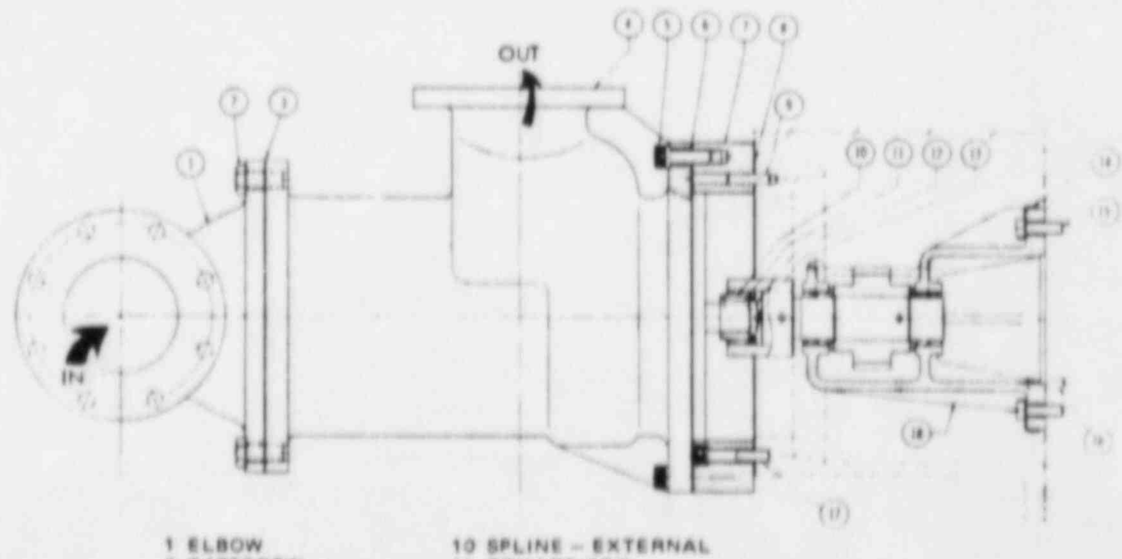
The full flow filter continuously filters all of the lubricating oil from the pump before it passes to the oil strainer. The length of time that the lubricating oil and the filter elements may remain in service can best be determined by carefully watching the result of oil analysis and the pressure drop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

a. Check the oil level in the sump tank.

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

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

d. Dismantle and inspect pump.



1 ELBOW
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.

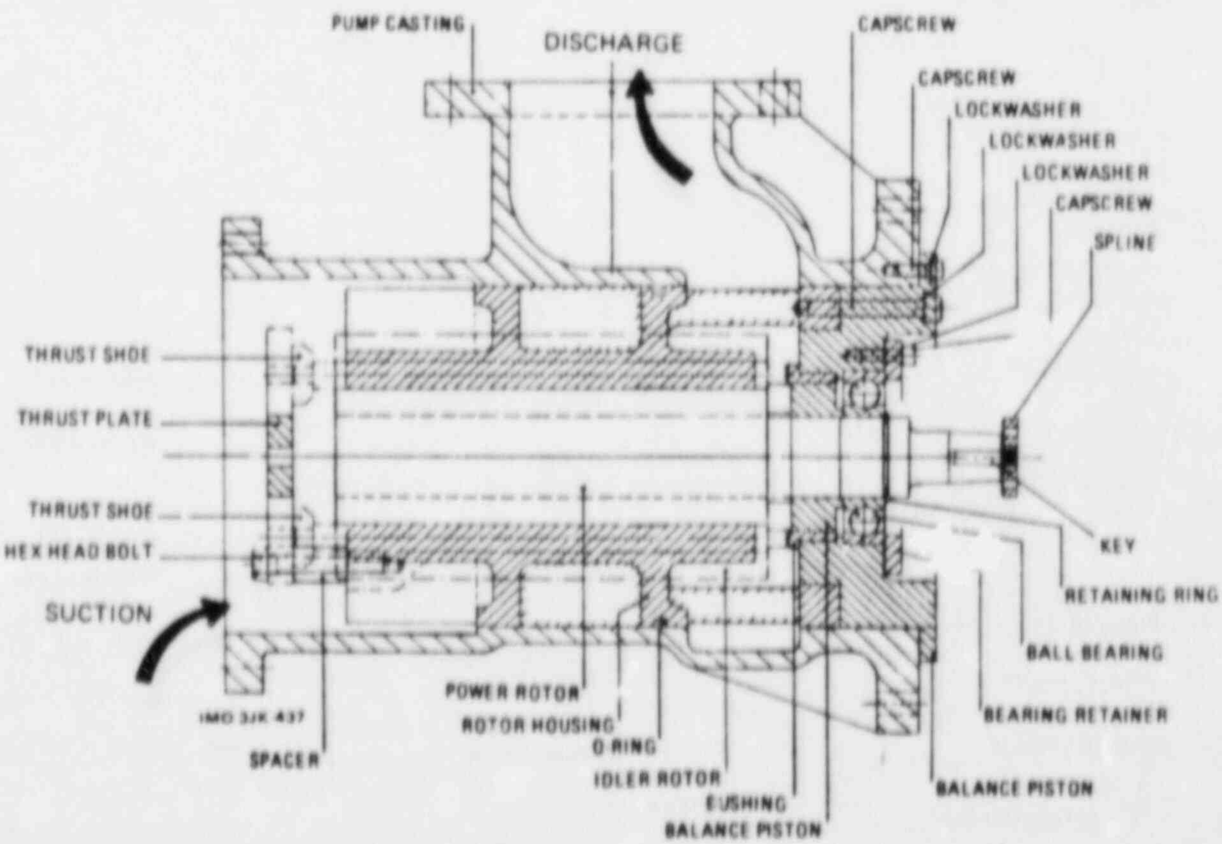


Figure 6-K-2. Lubricating Oil Pump Assembly

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.

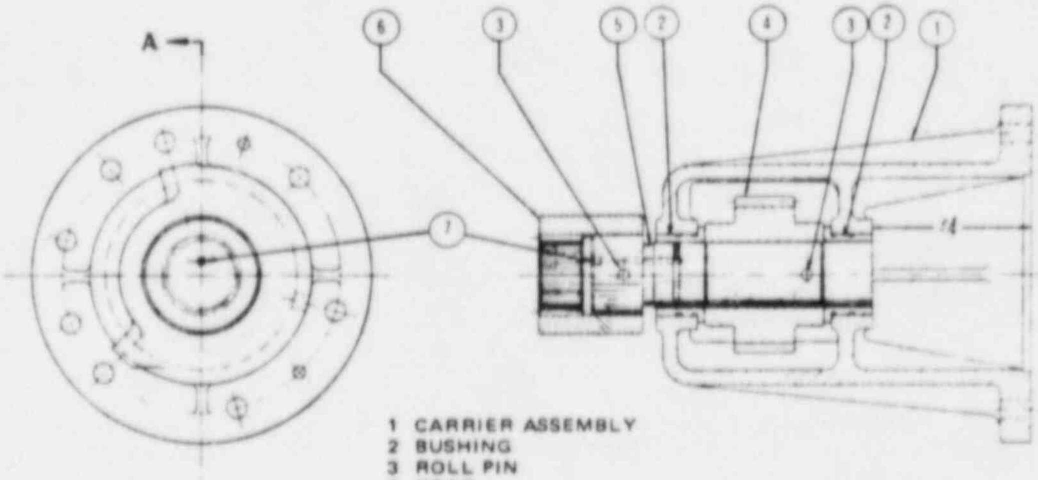


Figure 6-K-3. Gear Carrier Assembly

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 L – MISCELLANEOUS

CRANKCASE PRESSURE.

The crankcase is fully enclosed and theoretically air tight. To remove gases and vapors from the crankcase and to reduce the possibility of fresh air or oxygen being present, crankcase pressure is maintained at a level slightly below atmospheric, measured in inches H_2O by a standard U-type manometer.

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.

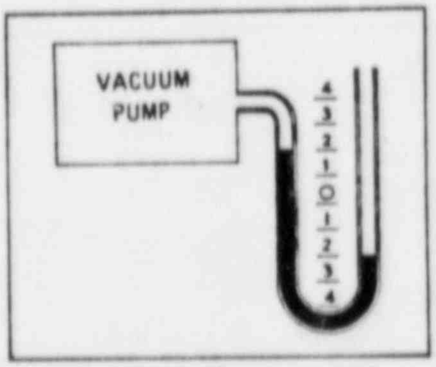


Figure 6-L-1. Manometer with Vacuum Pump

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.

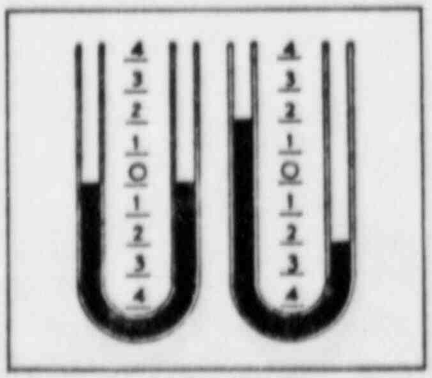


Figure 6-L-2. Reading Manometer

No C/C Ventilator Blower

PART L – MISCELLANEOUS (Continued)

CRANKCASE VENTILATION SYSTEM.

The crankcase ventilation system is designed to reduce the amount of fresh air and oxygen present in the crankcase while the engine is running. The system will also assist in indicating the general condition of the engine, particularly piston ring and 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 manometer reading towards a positive pressure. A motor driven blower is used to draw directly from the crankcase and discharges through an oil separator where oil vapors are removed. The discharge should be piped outside the building, or otherwise disposed of to prevent the presence of vapors in the atmosphere surrounding the engine.

a. Air flowing through the separator passes through the filter element where any oil particles are trapped. The oil then drains down the side walls of the filter element to the bottom of the separator where it then drains back to the engine crankcase.

b. The blower motor is normally controlled by a pressure switch, actuated by lubricating oil pressure. The switch, sensitive to rising lubricating oil pressure, reaches a preset pressure during starts and the system is turned on. Refer to the control system drawings for the pressure at which the switch closes.

c. The filter element in the oil separator should be removed periodically and washed in a solvent. After washing, allow the element to dry before placing it back in the separator. Under normal conditions, the filter element should require cleaning no oftener than 1500 hours of engine operation.

d. Crankcase vacuum is controlled by an orifice in the discharge line. The orifice size is determined in the field at the time of installation to suit the specific conditions at the site by the Service Representative.

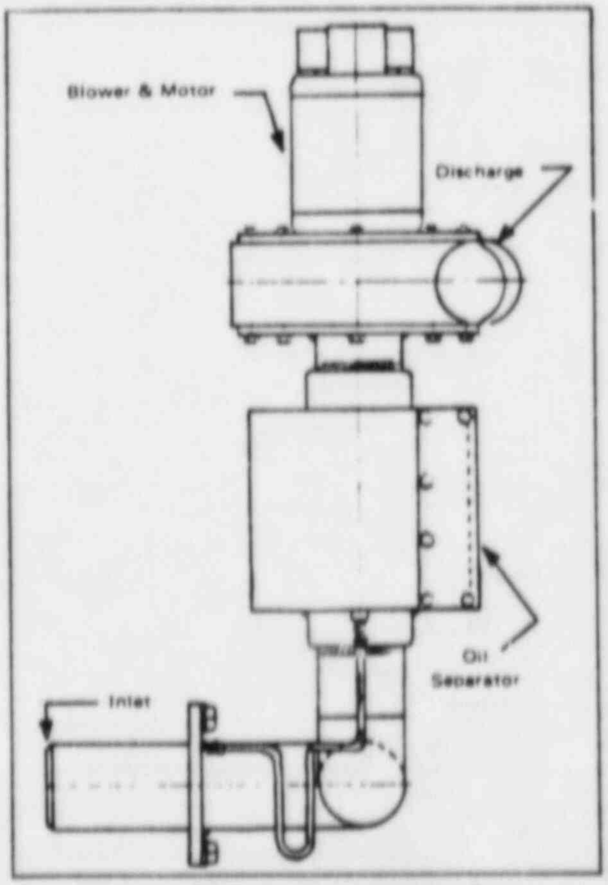


Figure 6-L-3. Crankcase Ventilation System

CRANKCASE VACUUM.

a. While operated at rated load and speed, crankcase vacuum of 0.2 to 0.5 in.-H_2O (0.508 to 1.27 cm-H_2O) should be maintained.

b. Crankcase vacuum readings must be carefully taken, logged hourly, and compared with past 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 logged readings indicate a loss in crankcase vacuum, the cause should be promptly determined and corrected.

PART L – MISCELLANEOUS (Continued)

c. Crankcase vacuum readings should be carefully observed during heavy load operations. Should the pressure go from a vacuum to a positive reading, the engine should be shut down immediately. The engine should never be operated with a positive pressure inside the crankcase as this indicates that the suction source for purging the crankshaft has been plugged and/or otherwise obstructed, or that some condition exists that is creating abnormal heat. If a hot spot develops in the engine and the oil flows or splashes over it a considerable amount of oil vapor will be formed. This vapor is explosive and the engine must be stopped immediately. Allow engine to rest for fifteen minutes to allow fumes and vapors to dissipate before removing any engine covers. Determine the cause and correct before continuing operation.

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.

TROUBLE	POSSIBLE CAUSE	ACTION
1. Engine fails to turn over when air start valve turned ON.	a. Air line valves closed. b. Air pressure too low. c. Air start valve leaking or stuck. d. Air distributor timing (if so equipped). e. Power to control system OFF. f. Camshaft not fully shifted.	Check air line valves. Check pressure. Check for clogged strainer. Release cylinder pressure by opening indicator cocks. Remove air start valve and examine. Adjust timing. Turn ON. Check and correct controls.
2. Engine turns on air but will not start.	a. Fuel line valve closed. b. Fuel low in day tank. c. Air in fuel system. d. Fuel lines clogged. e. Fuel filters plugged or dirty. f. Water in fuel oil. g. Fuel control linkage sticking. h. Fuel oil relief valve stuck open. i. Fuel oil shutdown cylinder not retracting. j. Stuck valve k. Air intake blocked. l. Valves riding open. m. Valve seats worn. n. Cylinder head gaskets leaking. o. Piston rings stuck.	Open all fuel valves. Fill tank. Vent system by opening fuel pump bleeder screws. Clean lines. Clean filters. Drain and fill system with clean oil. Free and lubricate. Free valve. One of the shutdown elements leaking air, or pneutrol orifice upstream of accumulator tank open — open and hold reset valve (if so equipped). Free, clean and lubricate. Check and clean line. Adjust valve clearance. Reseat valves. Replace with new gaskets. Replace rings as required, using oversized rings if necessary. Replace liners if scored or worn.
3. Running engine slows or stops.	a. Fuel low in day tank. b. Water in fuel oil. c. Fuel filters plugged and dirty. d. Engine overloaded. e. Exhaust line restricted. f. Intake air blocked. g. Piston seized. h. Safety shutdown system.	Fill tank. Drain and fill with clean oil. Clean filters. Reduce load. Clear obstruction. Check and clear line. Actual piston seizure makes a high pitched, squeaking noise. *Stop engine immediately.* Check pistons, liners and cooling system. Check indicators and investigate.
4. Engine fires irregularly when running.	a. Low fuel in day tank. b. Air in fuel system. c. Water in fuel oil. d. Fuel lines clogged. e. Fuel filters plugged and dirty. f. Fuel nozzle stuck, clogged, damaged or worn. g. Injection tube connectings leaking. h. Fuel nozzle bleeder valve open. i. Injection pump dirty, damaged or worn. j. Injection pump out of time. k. Injection pump delivery out of balance with others. l. Lack of compression. m. Excessive manifold air pressure.	Fill tank. Vent system by opening fuel pump bleeder screws. Drain and fill with clean oil. Clean lines. Clean filters. Replace with spare and examine. Clean joints and tighten. Close valve. Replace with spare and examine. Adjust timing. Check exhaust temperatures of all cylinders until temperatures are within 50° F of one another. See paragraph 2 above. Reduce pressure.

TROUBLE	POSSIBLE CAUSE	ACTION
5. When running, engine has black exhaust.	a. Fuel nozzle stuck, clogged, damaged or worn.	Replace with spare and examine.
	b. Injection pump out of time.	Adjust timing.
	c. Injection pump delivery out of balance with others.	Check exhaust temperatures of all cylinders. Adjust control linkage until temperatures are within 50° F of each other.
	d. Air intake blocked.	Clear.
	e. Engine overloaded.	Check load. Reduce if necessary.
6. Engine has smoky (blue) exhaust.	a. Piston rings stuck.	Free, clean ring grooves and oil drain holes.
	b. Piston rings or liners worn.	Replace rings as required. If necessary, use oversized rings. Replace liners if scored or worn.
	c. Loss of lubricating oil.	Check piston rings, ring grooves and liner.
	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. Injection pump out of time.	Adjust timing.
	c. Poor grade of fuel being used.	Check specifications of fuel being used against standard.
	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. Bad connecting rod bearing.	Check clearances.
	h. Defective main bearings.	Check clearances.
8. Low lubricating oil pressure.	a. Low oil level in sump.	Add oil.
	b. Lubricating oil suction clogged.	Check and clean.
	c. Loose piping.	Check and tighten as necessary.
	d. Loaded filter elements.	Clean or replace.
	e. Sticking relief valve.	Free and clean valve.
	f. Defective lubricating oil pump.	Inspect pump. Repair or replace.
	g. Relief valve set too low.	Adjust.
	h. Loose or worn bearings.	Check clearances.
9. Excessive lubricating oil pressure.	a. Relief valve stuck.	Free and clean.
	b. Dirty lubricating oil cooler or filter.	Clean.
	c. Relief valve improperly adjusted.	Adjust.
10. High jacket water inlet temperature.	a. Jacket water pressure 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.
	k. Vapor phase system (if so equipped) defective.	See Manufacturer's Instructions in *Associated Publications Manual*.
11. Excess vibration.	a. Cylinder misfiring.	Check fuel injector nozzles, fuel pump, gas admission valve, cylinder fuel cutoff.
	b. Stuck valve.	Free, re-face and re-seat, or replace.
	c. Mechanical problems.	Investigate all systems and auxiliaries.
12. Excessive exhaust temperatures, all cylinders.	a. Engine overloaded.	Reduce load.
	b. Low manifold air pressure.	Increase pressure.
	c. Piston sticking.	Remove, clean, check clearances.
	d. Bearing failure.	Inspect and check clearances.
	e. Dirty air cleaner.	Clean.
13. Unequal exhaust temperatures (wide spread with engine loaded).	a. High air manifold air pressure.	Reduce pressure.
	b. Valve leakage.	Check valves, grind and re-seat.
	c. Fuel injection pump out of adjustment.	Adjust.

TROUBLE	POSSIBLE CAUSE	ACTION
14. Rising exhaust temperature in one cylinder.	a. Gas admission valve. b. Burned exhaust valve.	Check and adjust valve. Replace valve.
15. High pre-turbine exhaust temperature.	a. Engine overloaded. b. Low manifold air pressure. c. Piston sticking. d. Bearing failure. e. Dirty air cleaner.	Reduce load. Increase pressure. Remove, clean, check clearances. Inspect and check clearances. Clean.
16. Low exhaust temperature in one cylinder.	a. Obstruction in gas supply. b. Gas cutoff in header closed.	Check lines and clear. Open cutoff.
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. Oil level in governor low. f. Fuel oil pressure low. g. Fuel control regulator. h. Governor or linkage sticking.	Time pump. Clean nozzle. Adjust. Free plunger. Fill governor. Increase pressure. Check and adjust regulator. Refer to manufacturer's instructions. Lubricate linkage with engine oil.
18. Constant engine speed fluctuation.	a. Governor. b. Linkage. c. Speed signal air pressure.	See manufacturer's bulletins. Clean and lubricate with engine oil. Check system and air supply.
19. Excessive venting and/or vapors from vent holes in each end of starting air header.	a. Leaking air start 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.
23. Low fuel oil pressure	a. Dirty filters or strainers. b. Relief valve stuck open. c. Defective pump. d. Air leak in suction line.	Check and clean. Free and check. Check and repair. Repair.
24. Excessive lubricating oil consumption.	a. Worn piston rings or liners. b. Leak in sump or piping.	Check clearance – Replace if clearance is excessive. Repair.
25. Loss of crankcase vacuum.	a. Faulty manometer indications. b. Blower motor defective c. Defective pressure switch. d. Loose electrical connection. e. Air leak around cylinder head covers. f. Air leak at fuel line entrance to cylinder head sub covers. g. Air leak past valve guides. h. Piston blowing by. i. Lubricating oil fuming. **WARNING** This heavy vapor is 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 for gasket condition and that cover is tightened evenly. Check grommet and fuel line gaskets. Check clearances. Check for stuck piston rings. Check for excessive piston ring wear. Check for hot spots.

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. Check whether transfer pump delivers fuel to tank. Open all valves in line.
	b. Fuel inlet pipe clogged or third stage filter element dirty.	Clear 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. Plunger spring broken.	Replace with spare.
	f. Delivery valve does not seat properly.	Clean delivery valve and seating. If either are damaged, replace with spares.
	g. Delivery valve spring broken.	Replace with spare.
	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 causes pump plunger to jam, or control rod rack is coated with dirt.	Dismantle and clean.
	k. Supply connection leaks.	Install new gasket or replace connection if damaged.
	l. Leakage past spring guide caused by worn plunger or improper seal of barrel in main body.	Replace defective parts with spares.
	m. 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 qualities in fuel oil.	*Change to fuel or proper specifications.
	c. Nozzle body and valve corroded or eroded due to acid, water or dirt in fuel oil.	Replace nozzle body and valve with spares. Check fuel and filters.
	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.

SECTION 8
APPENDICES

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		228° F
	High Temperature Jacket Water	190° F	200° F
	High Temperature Lubricating Oil	190° F	200° F
	Low Temperature Lubricating Oil – IN	140° F	
	Low Temperature Lubricating Oil – OUT	140° F	
	High Temperature Lubricating Oil – IN	175° F	
	High Temperature Lubricating Oil – OUT	190° F	
	Low Temperature Jacket Water – IN	140° F	
	Low Temperature Jacket Water – OUT	140° F	
	High Temperature Jacket Water – IN	175° F	
	High Temperature Jacket Water – OUT	190° F	
PRESSURES	High Pressure Crankcase	.3 - .5 psir	3 psir
	L.B. Turbocharger Oil Pressure Low	20 psif	15 psif
	R.B. Turbocharger Oil Pressure Low	20 psif	15 psif
	Low Jacket Water Pressure	15 psif	10 psif
	High Differential Pressure – Fuel Oil Filter	20 psir	
	High Differential Pressure – Fuel Oil Strainer	20 psir	
	High Differential Pressure – Lube Oil Filter	20 psir	
	High Differential Pressure – Lube Oil Strainer	20 psir	
	Low Pressure Fuel Oil	20 psif	
	Low Pressure Lubricating Oil	20 psif	30 psif

APPENDIX VII (Continued)

	FUNCTION	ALARM (Setting)	SHUTDOWN (Setting)
MISCELLANEOUS	Overspeed (115% above rated speed)		517.5 rpm
	Barring Device	Engaged	
	Fuel pump/overspeed Governor	Failure	
	Local-Remote-Maintenance Switch	Not in Remote	
	Lube Oil Level	Low	
	Fuel Oil Storage Tank Level	High/Low	
	Fuel Oil Storage Tank Level	High-High/Low-Low	
	Any pump switch	Not in AUTO	
	Jacket Water Level	Low	
	Voltage Regulator Transfer	Trouble	
	Governor System	Over/under frequency	
	Generator		Ground
	Generator		Field Ground
	Generator		Reverse Power
	Generator		Differential
	Generator		Loss of Field
	Generator		Negative Sequence
	Generator		Overcurrent
	Generator Stator		High Temperature
	Generator Bearings		High Temperature
	DC Control Power	Loss of	
	AC Control Power	Loss of	
	Voltage Balance Relay	Operated	
	Blackout Start	Owner's signal	
	LOCA	Owner's signal	
	Vibration		Excessive
	Unit Failure To Start	Failure	

SECTION 8

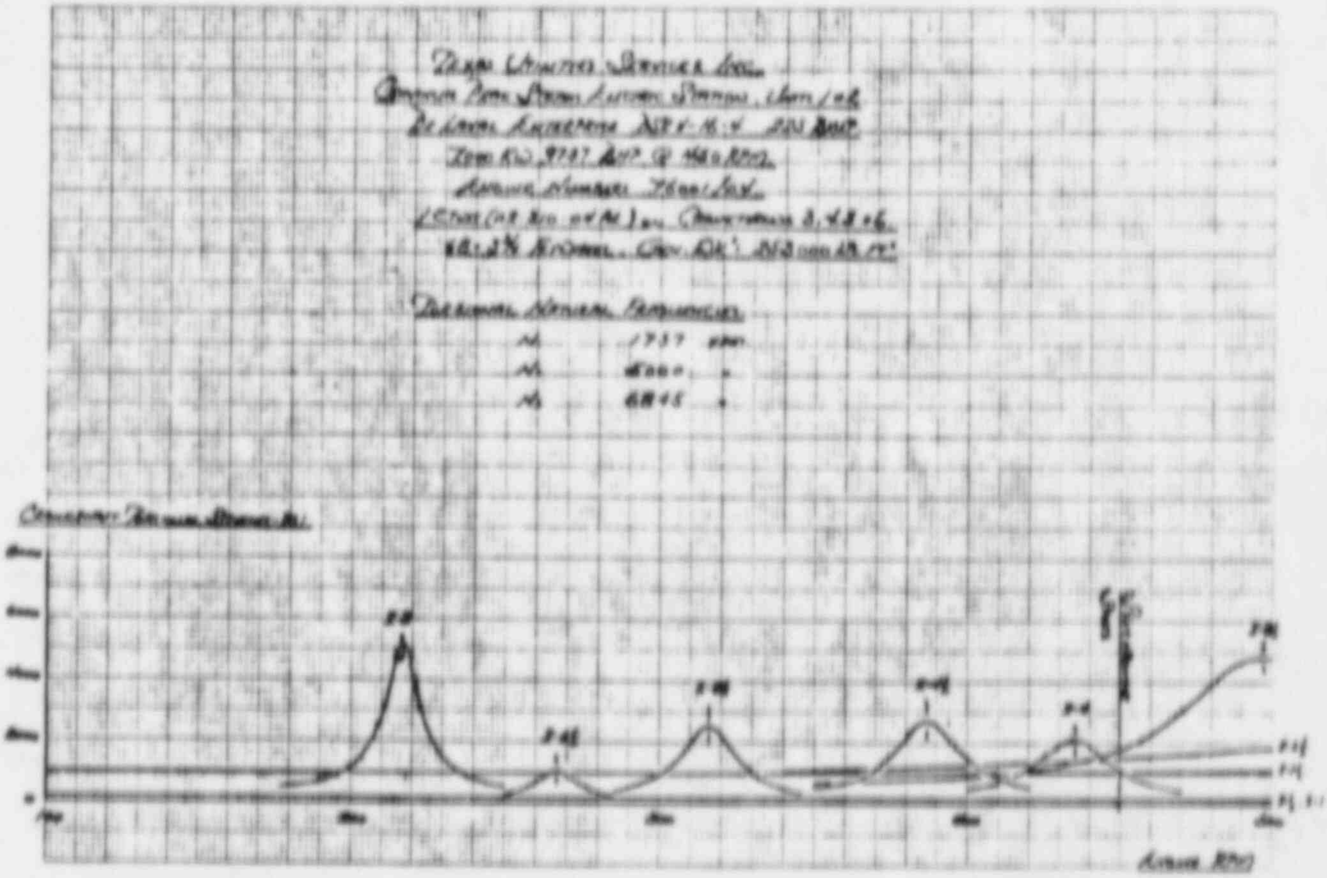
APPENDICES

The purpose of this section of the manual is to provide a single location for specific data which, if located within the body of the manual, would be more difficult to locate. As a general rule, specific values have been omitted from the text and, where appropriate, reference is made to the applicable appendix. The following appendices are contained in this section.

Appendix I	Torsional Stress and Critical Speeds
Appendix II	Operating Temperatures and Pressures
Appendix III	Table of Clearances
Appendix IV	Torque Values
Appendix V	Timing Diagram
Appendix VI	Lubricating Oil Recommendations
Appendix VII	Alarms and Safety Shutdowns
Appendix VIII	Fuel Oil Recommendations
Appendix IX	Power Engine Factory Test Logs

APPENDIX I

TORSIONAL STRESS AND CRITICAL SPEEDS



APPENDIX II

OPERATING PRESSURES AND TEMPERATURES

PRESSURES

The following pressures should be present for starting:

Starting Air Supply	150 – 250 psi	10.55 – 17.6 kg/sq cm
Starting Air Header	150 psi	10.55 kg/sq cm

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

	psi	in. hg	kg/sq cm
Lubricating Oil*	40 – 50	81.4 – 101.8	2.81 – 3.51
Lubricating Oil at Turbocharger Inlet	25 – 35	50.9 – 71.26	1.76 – 2.46
Jacket Water	10 – 30	20.4 – 61.1	0.70 – 2.11
Fuel Oil	20 – 30	40.7 – 61.1	1.40 – 2.11
FOR DUAL FUEL ENGINES (Pressure Before Regulator)			
Gas**	40 – 45	81.4 – 91.6	2.81 – 3.16

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)

TEMPERATURES

The exhaust temperatures shown on the title page are the average for all cylinders during factory test under local ambient conditions. Temperatures in the field, therefore, may exceed this average temperature.

On dual fuel engines, individual cylinder exhaust temperature is normal if within plus or minus 50 degrees of the average taken from all cylinders.

Pressures and temperatures listed are established as a guide to proper operation. They should be held within plus or minus 10 percent. Sudden changes in reading require immediate investigation and correction.

* With SAE 40 lubricating oil in engine.

** With gas flow nozzle lower pressures may be used under special conditions.

APPENDIX III

TABLE OF CLEARANCES MODEL RV ENGINE

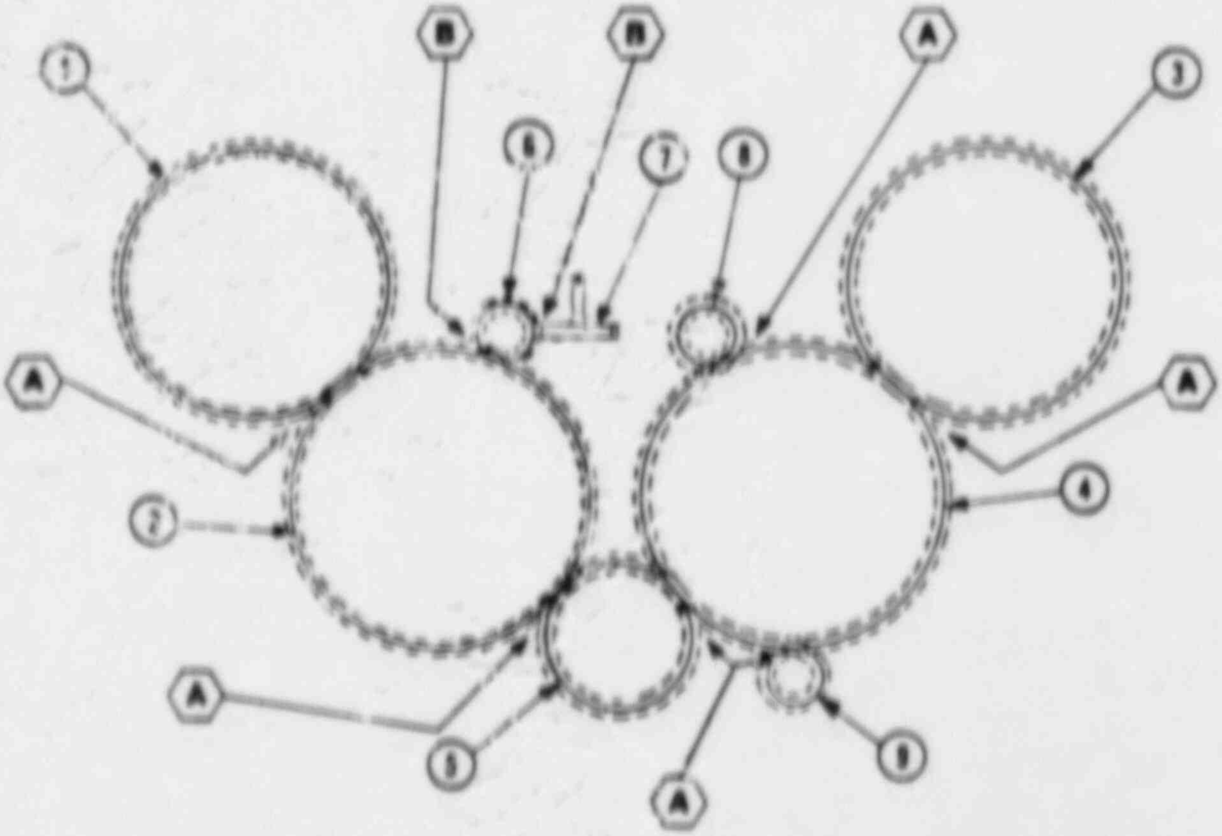
Position		Clearance When New				Replace When Over		Notes
		Minimum		Maximum				
		Inches	Centimeters	Inches	Centimeters	Inches	Centimeters	
Exhaust Valve Guide Bore Dia.	Upper	0.997	2.532	0.998	2.534	1.010	2.565	(7)
	Lower	1.002	2.545	1.003	2.548	1.020	2.591	(8)
Air valve piston		0.0055	0.014	0.0075	0.019	- - - -	- - - -	(1)
Rocker arm bushing on shaft		0.002	0.005	0.0035	0.009	0.010	0.025	(1)
Tappet in guide		0.002	0.005	0.004	0.010	0.015	0.038	(1)
Tappet roller on pin		0.0015	0.004	0.0030	0.008	0.005	0.013	(1)
Conrod link pin to bushing		0.0039	0.010	0.0085	0.022	0.012	0.031	(1)
Idler gear bushing on shaft		0.003	0.008	0.005	0.013	0.010	0.025	(2)
Idler gear bushing to bracket thrust face		0.005	0.013	0.009	0.023	0.012	0.031	(2)
Piston pin in piston		Push fit at 70° F (21.1° C)				0.002	0.005	(1) or (2)
Piston pin in bushing		0.0095	0.024	0.0105	0.027	0.020	0.051	(1) or (2)
BEARING SHELLS*								
Main bearing to crankshaft		0.012	0.031	0.0164	0.042	0.614	1.559	(1)(4)(5)
Rear main thrust bearing		0.022	0.056	0.030	0.076	0.611	1.552	(2)
Conrod bearing to crankshaft		0.011	0.028	0.0154	0.039	0.616	1.565	(3) (6)
Camshaft bearing to camshaft		0.0035	0.009	0.0065	0.017	0.193	0.490	(1)(4)(5)
SKIRT CLEARANCE IN LINER								
Top (land tapered)		0.120-0.074	0.305-0.188	0.126-0.077	0.320-0.196	- - - -	- - - -	(1) or (2)
Bottom (skirt)		0.018	0.046	0.021	0.053			(1) or (2)
Liner bore		- - - -	- - - -	- - - -	- - - -	17.060	43.332	(1)
PISTON RING GAP CLEARANCES								
Top compression ring		0.075	0.191	0.090	0.229	0.200	0.508	(2)
Compression ring – Groove No. 2		0.075	0.191	0.090	0.229	0.200	0.508	(2)
Compression ring – Grooves 3 & 4		0.050	0.127	0.065	0.170	0.200	0.508	(2)
Oil control ring – Grooves 5 & 6		0.035	0.089	0.060	0.152	0.200	0.508	(2)
PISTON RING SIDE CLEARANCE IN GROOVE								
Top compression ring		0.007	0.018	0.011	0.028	0.020	0.051	(2)
Compression ring – Groove No. 2		0.005	0.013	0.009	0.023	0.020	0.051	(2)
Compression ring – Grooves 3 & 4		0.005	0.013	0.009	0.023	0.020	0.051	(2)
Oil control ring – Grooves 5 & 6		0.003	0.008	0.007	0.018	0.020	0.051	(2)

Notes:
(1) Use micrometer and snap gauges.
(2) Use feeler gauge.
(3) Use dial indicator (bump test).
(4) Use plasta gauge.
(5) Measure at bottom of lower shell.
(6) Measure at top of upper shell.
(7) Diameter of bore, measured ½ inch from top of guide.
(8) Diameter of bore, measured 3 inches from bottom of guide.

*Bearing replacement figures are based upon wall thickness, measured as indicated by note.

APPENDIX V-1

GEAR SET AND BACKLASH CLEARANCES
MODEL RV ENGINE



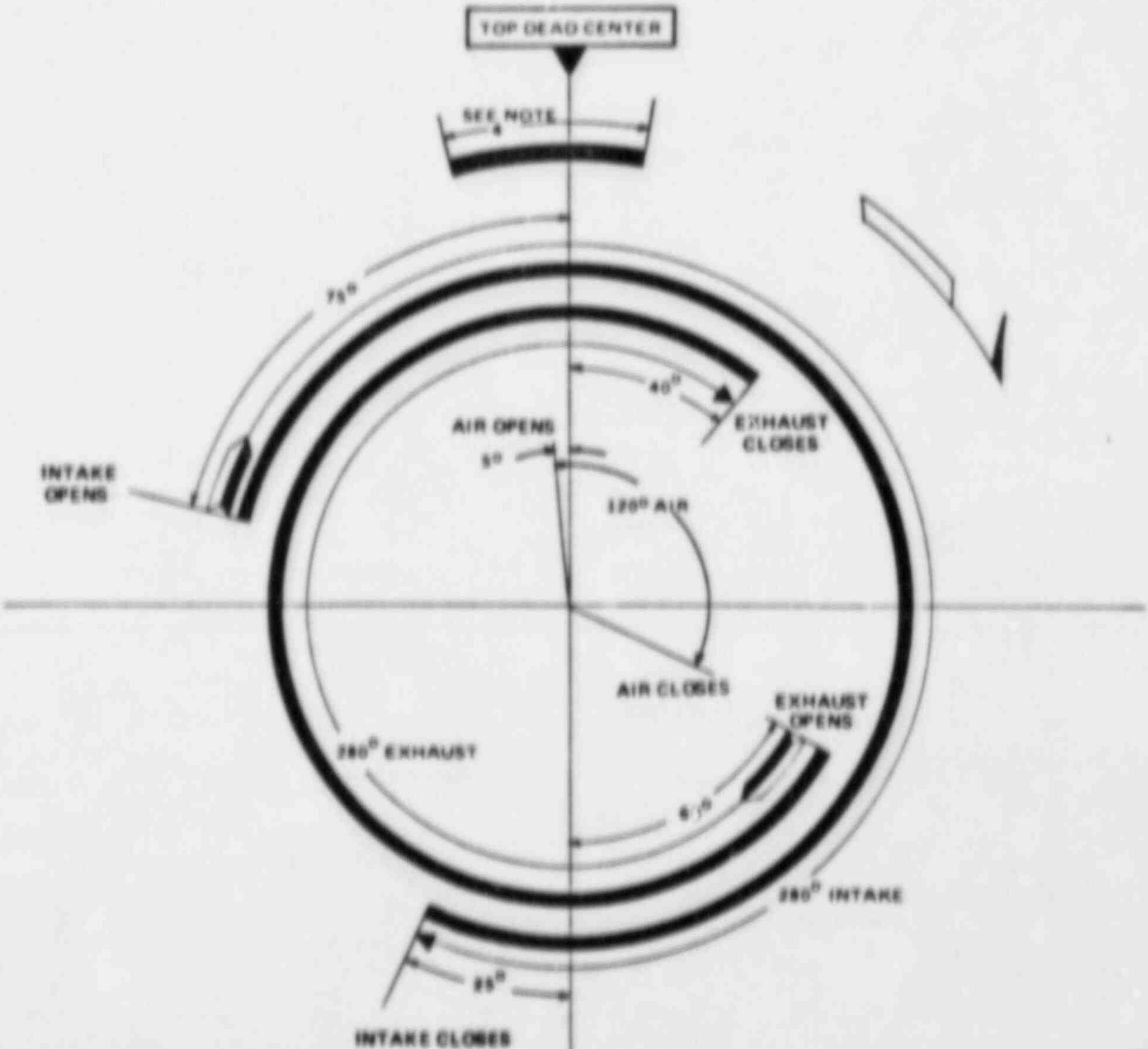
ITEM	DESCRIPTION
1	CAMSHAFT GEAR, LEFT HAND
2	IDLER GEAR, LEFT HAND
3	CAMSHAFT GEAR, RIGHT HAND
4	IDLER GEAR, RIGHT HAND
5	CRANKSHAFT GEAR
6	GOVERNOR & TACHOMETER DRIVE GEAR
7	GOVERNOR DRIVE AND DRIVEN GEAR
8	OVERSPEED TRIP DRIVE GEAR
9	FUEL TRANSFER PUMP GEAR

POS	BACKLASH	
	INCHES	CENTIMETERS
A	0.006 – 0.010	0.015 – 0.025
B	0.004 – 0.006	0.010 – 0.015

APPENDIX V

TIMING DIAGRAM

MODEL	TYPE	FUEL
RV	STATIONARY	DIESEL
INTAKE CAM	**EXHAUST CAM**	**ROTATION**
02-350-04-OT	02-350-06-AH	CLOCKWISE



NOTES

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

APPENDIX VI

LUBRICATING OIL RECOMMENDATIONS

The 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 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 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.

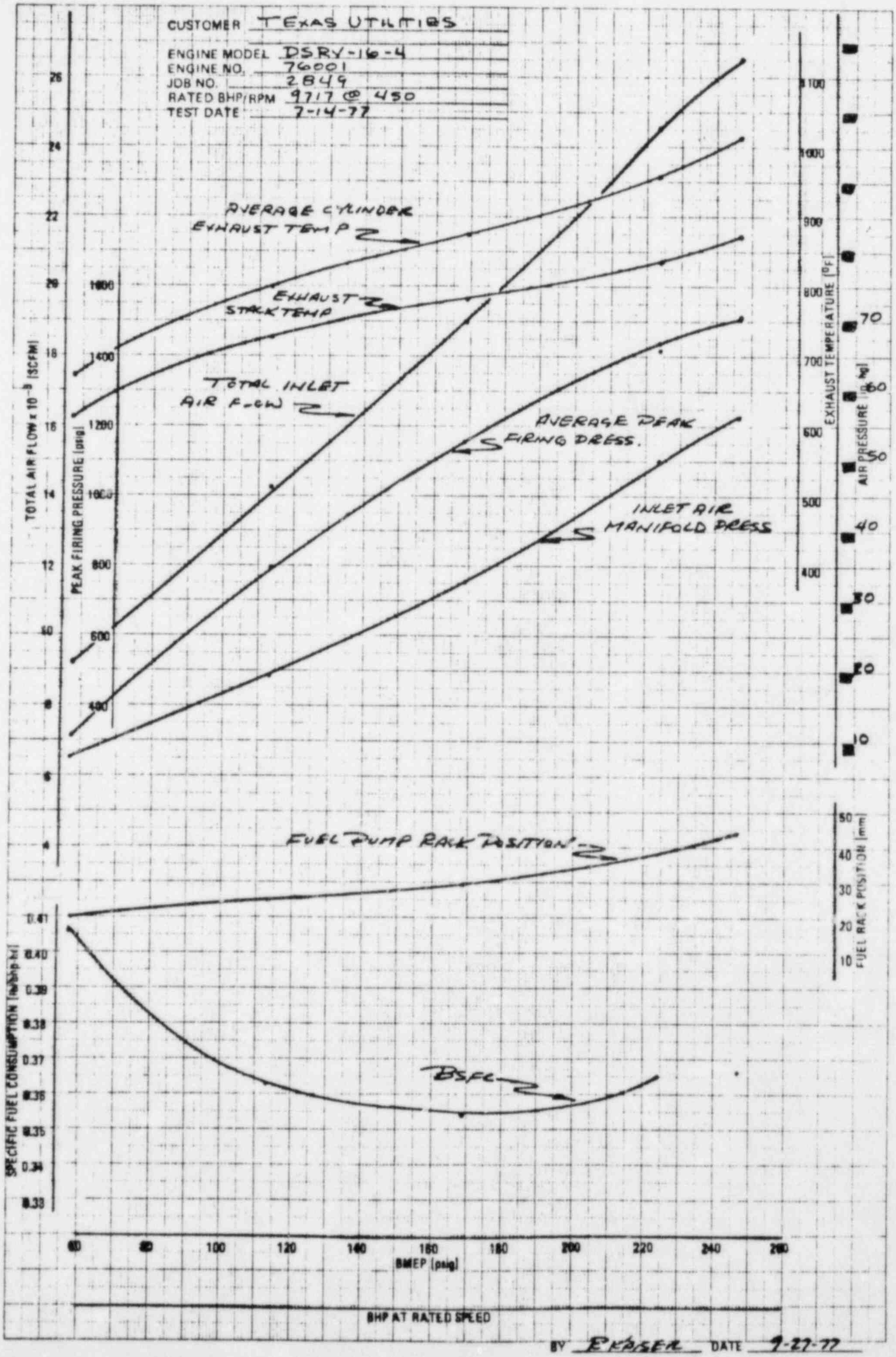
Fuels heavier than the above can be burned in Enterprise engines provided proper treating and pre-heating facilities are available. In the event it is desirable to use such fuels, DELAVAL Engine and Compressor Division should be consulted for advice as to the arrangements that need to be made. An analysis of the particular fuel to be used must be provided.

For lubricating oil recommendations, refer to Section 2, Page 5.

APPENDIX IX

POWER ENGINE FACTORY TEST LOGS

Copies of the Power Engine Factory Test Logs are provided in this appendix to assist operating personnel in becoming familiar with the operating characteristics of the engine. The data included is that recorded during actual factory test of the engine.



BY R KAISER DATE 9-27-77

ENGINE AND COMPRESSOR DIVISION OAKLAND CALIFORNIA

POWER ENGINE FACTORY TEST LOG — LOG 1 A

CUSTOMER: TEXAS UTILITIES — MODEL: DSRV-16-4 — TEST STAND: 23 — JOB NO: 2849 — ENGINE NO: 76001 — FULL LOAD RATING: 9717 BHP @ 450 RPM 224 BMEP

	Date	Wall clock time On	Off	% Load	RPM	Dyna scale	BHP	BMEP	Fuel pump rack position 1L	2L	3L	4L	5L	6L	7L	8L	1R	2R	3R	4R	5R	6R	7R	8R
1	7-14	0715	0815	60	450	57365	4915	134	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
2	7-14	0820	0920	75	450	85325	7311	169	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	7-14	0930	1030	100	450	113408	9717	224	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
4	7-14	1030	1130	100	450	113408	9717	224	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
5	7-14	1135	1235	25	450	29043	2488	57.4	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	7-14	1240	1340	110	450	124762	10689	247	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0
7	7-14	1350	1405	0	450	0	0	0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0

TURBOCHARGER PRESSURES / TURBOCHARGER TEMPERATURES / AIR FLOW NOZZLE 18" 18"

	Blower inlet LF	RF	Blower discharge LF	RF	LB	RB	Blower inlet °F LF	RF	Blower discharge °F LF	RF	Air manifold °F LB	RB	Nozzle LF	RF	Air flow total	Ambient baro	Amb °F
1	6.1	5.8	19.3	19.7	19.2	19.2	66	67	181	181	125	123	6.1	5.8	14.77	29.89	66
2	10.8	10.4	33.1	33.5	32.8	32.7	67	68	239	241	125	126	10.7	10.4	18993	29.89	67
3	18.3	17.1	50.0	50.9	50.0	49.8	68	68	315	318	127	127	18.3	17.1	24591	29.90	68
4	18.4	17.2	50.2	49.8	49.7	49.9	72	73	311	314	126	126	18.2	17.3	24523	29.90	72
5	2.6	2.4	7.9	7.9	7.9	7.9	73	74	132	135	106	106	2.6	2.4	9192	29.89	73
6	22.0	21.0	56.7	56.4	56.1	56.0	76	78	349	352	126	123	21.4	20.7	26586	29.88	76
7	1.5	1.4	1.9	1.9	1.9	1.9	76	76	109	110	106	106	1.5	1.4	6982	29.87	76

FUEL OIL DATA / FUEL GAS DATA / GAS BTU / FUEL BTU

	Basis	API gravity	at °F	LHV	Lbs	Time	%	lb/BHP-hr
1	36.5	38.0	78	18430	1400	2862	1761.0	.363
2	36.0	38.0	78	18430	1400	1975	2551.9	.364
3	38.0	38.2	78	18430	1674	1725	3493.6	.364
4	38.0	38.0	77	18430	1540	1582	3504.4	.365
5	47.0	38.0	79	18430	668	2411	997.4	.406
6	36.5	38.2	84	18420	700	653	3859.1	.366
7	49.0	38.2	84	18420	64	1084	212.6	—

REMARKS

INJECTION / IGNITION TIMING °BTDC: 22 LB 21 RB
FUEL OIL SPEC: STANDARD #2 DIESEL
LUBE OIL SPEC: SHELL X-100 30 BWD

AIR FLOW NOZZLE COEFFICIENT: LF 12283 RF 12283

OPERATOR: H F M — ENGINEER: R KAISER — WITNESS:

DATE: 7-14-77 — LOG NO: 1 A — JOB NO: 2849

RK 92777

ENGINE AND COMPRESSOR DIVISION OAKLAND CALIFORNIA

POWER ENGINE FACTORY TEST LOG — LOG 1 B

CUSTOMER: TEXAS UTILITIES — MODEL: DSR-16-4 — TYPE SERVICE: NUC STBY GEN — JOB NO: 2849 — ENGINE NO: 76001 — DIRECTION OF ROTATION: CW

EXHAUST TEMPERATURES °F

	Turbine exhaust LF	RF	Exhaust elbow 1L	2L	3L	4L	5L	6L	7L	8L	1R	2R	3R	4R	5R	6R	7R	8R	Avg
1	738	716	802	813	784	795	810	823	817	804	795	797	777	784	798	804	779	801	799
2	783	781	862	889	845	848	868	879	876	860	904	907	879	879	881	880	863	886	874
3	844	826	977	996	955	930	927	965	984	929	988	1005	963	950	945	943	963	962	960
4	846	825	981	995	955	932	928	965	984	929	984	996	960	948	943	941	946	960	959
5	620	601	669	656	672	677	690	687	689	668	683	675	663	661	670	674	655	677	673
6	882	867	1041	1060	1012	987	982	1002	1037	980	1045	1059	1006	998	985	982	995	1014	1012
7	401	399	385	343	360	357	384	355	361	314	364	370	362	355	363	366	3[illegible]6	334	349

JACKET WATER / TURBOCHARGER WATER OUTLET / AFTERCOOLER WATER / FIRING PRESSURE PSIG

	Jacket water PSIG	To engine	From engine	Turbo water LF	RF	Aftercooler inlet	Aftercooler outlet	1L	2L	3L	4L	5L	6L	7L	8L	1R	2R	3R	4R	5R	6R	7R	8R	Avg
1	27.5	157	161	159	161	124	126	780	780	800	800	800	790	790	800	790	800	790	810	790	813	780	820	796
2	23.5	161	167	165	168	126	132	1180	1150	1150	1150	1150	1150	1150	1160	1180	1150	1140	1200	1150	1180	1150	1160	1159
3	29	165	173	172		125	138	1440	1430	1430	1430	1440	1440	1440	1440	1440	1450	1430	1450	1440	1450	1450	1440	1440
4	29	165	173	173		122	136	1430	1425	1415	1430	1430	1420	1415	1420	1420	1430	1420	1425	1415	1430	1420	1415	1422
5	26	161	154	162		105	106	560	560	560	560	560	560	570	560	560	560	560	570	560	570	570	570	563
6	27	166	174	176		114	133	1530	1500	1520	1500	1520	1500	1500	1500	1520	1530	1480	1520	1500	1540	1540	1530	1515
7	27	149	151	151		104	104	340	340	340	320	340	340	320	340	340	340	340	320	360	340	320	340	330

LUBRICATING OIL PRESSURE PSIG / LUBRICATING OIL TEMPERATURE °F / CRANKCASE PRESS

	From pump	To engine	To turbocharger LF	RF	To engine °F	From engine °F	Crankcase press
1	68	55.5	25	23.5	168	169	-3.4
2	67	65	23.5	22.5	168	174	-3.1
3	67	65	22.5	21.5	168	178	-2.4
4	67	95	22.5	21.5	169	179	-2.4
5	69	56.5	27	25	167	168	-3.7
6	67	65	22	21	168	178	-2.2
7	60	57.5	28.5	25.5	156	167	-3.7

REMARKS

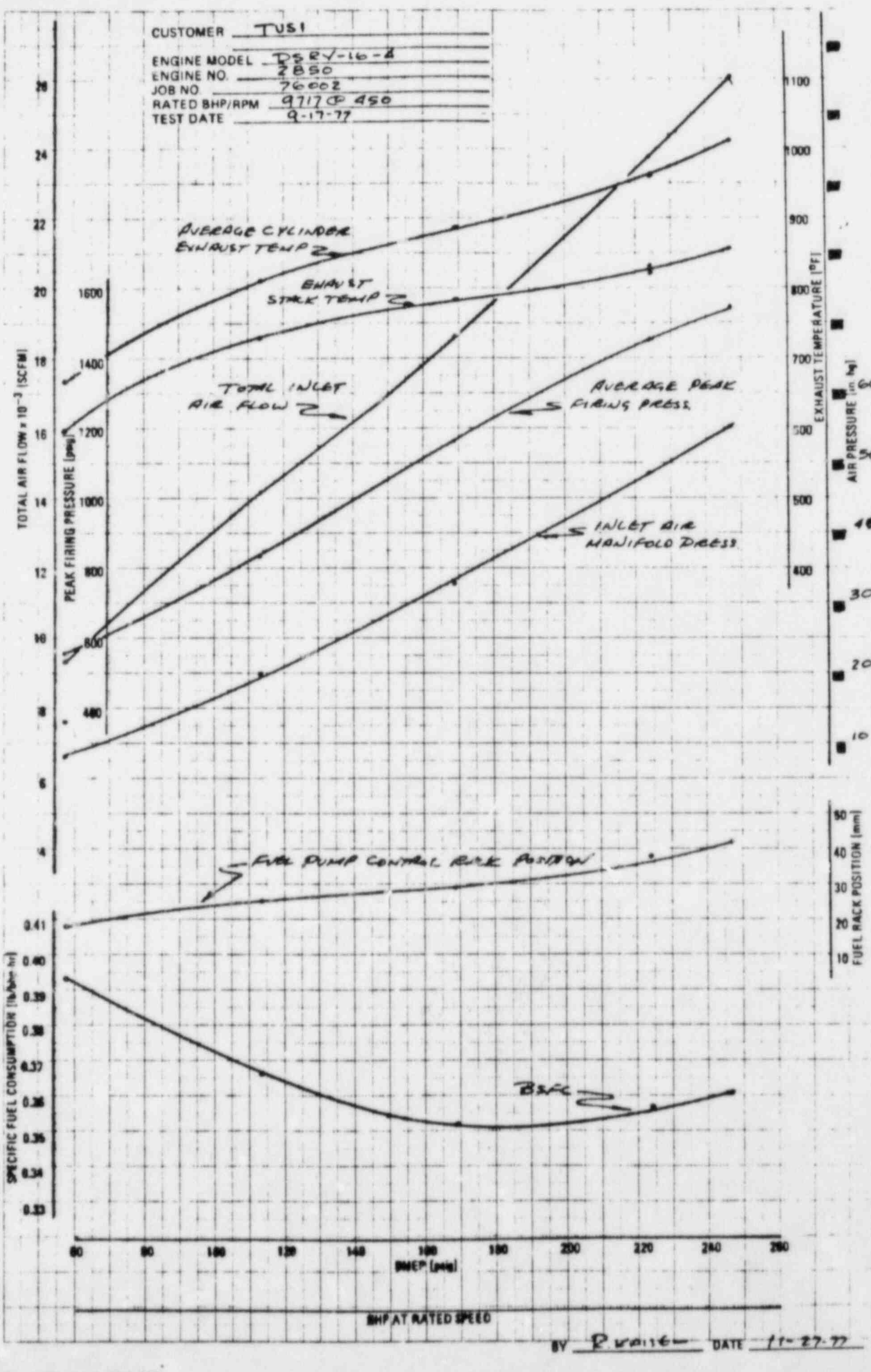
LEGEND: L LB LEFT BANK; R RB RIGHT BANK

TURBOCHARGER MAKE & MODEL: LF EL BOROG RF EL BOROG

OPERATOR: H F M — ENGINEER: R KAISER — WITNESS:

DATE: 7-14-77 — LOG: 1 B — JOB NO: 2849

RK 92777



Form D-4351 (Diesel) (R-1) 8/76

ENGINE AND COMPRESSOR DIVISION OAKLAND CALIFORNIA — POWER ENGINE FACTORY TEST LOG — LOG 1 A

CUSTOMER TUSI — MODEL DSRV-16-4 — TEST STAND 23 — JOB NO. 2850 — ENGINE NO. 76002 — FULL LOAD RATING 9717 BHP 450 RPM 224 BMEP

No.	Date	Wall clock time (on)	Wall clock time (take)	% Load	RPM	Scale	BHP	BMEP	Fuel pump rack position (1–8)	Fuel pump rack position (9–16)
1	9-16	2145	2245	50	450	57365	4916	113.4	25.0 29.0 25.0 18.0 15.0 25.0 26.0 18.0	26.0 15.0 15.0 25.0 15.0 26.0 15.0 25.0
2	9-16	2305	2400	75	450	85629	7311	169	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	9-17	2410	0110	100	450	113408	9717	224	38.0 38.0 38.0 38.0 38.0 38.0 38.0 38.0	38.0 38.0 38.0 38.0 38.0 38.0 38.0 38.0
4	9-17	0110	0210	100	450	113408	9717	224	38.0 38.0 38.0 38.0 38.0 38.0 38.0 38.0	38.0 38.0 38.0 38.0 38.0 38.0 38.0 38.0
5	9-17	0215	0315	25	450	29045	2488	57.4	18.0 18.0 18.0 18.0 18.0 18.0 18.0 18.0	18.0 18.0 18.0 18.0 18.0 18.0 18.0 18.0
6	9-17	0320	0420	110	450	124762	10689	247	42.0 42.0 42.0 42.0 41.0 41.0 42.0 42.0	42.0 41.0 42.0 42.0 41.0 42.0 41.0 42.0
7	9-17	0420		0	450	0	0	0	10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0	10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0
8										
9										
10										

AIR FLOW NOZZLE 72 72

No.	Blower inlet (in. H_2O)	Blower discharge	Intake	Blower inlet temp. °F	Blower discharge temp. °F	Air manif. °F	Nozzle	Air flow	Barom./Amb.
1	56 62	207 204	199 200	69 70	188 186	127 127	56 62	14156	2982 70
2	98 110	331 33.5	329 329	72 71	246 244	133 133	98 108	18670	2982 72
3	16.0 17.6	48.8 49.0	48.5 48.5	71 71	307 305	125 126	16.0 17.4	23789	2983 71
4	16.1 17.7	48.7 49.0	48.5 48.5	71 71	312 311	127 128	16.1 17.5	23864	2984 71
5	2.7 3.0	8.2 8.4	8.2 8.2	71 73	130 131	104 104	2.7 3.0	9519	2984 73
6	21.0 21.1	56.3 55.9	56.1 55.1	72 72	340 337	125 125	19.6 20.8	26182	2984 72
7	1.3 1.3	2.1 2.1	2.1 2.1	71 72	102 103	104 104	1.3 1.3	6637	2984 72
8									
9									
10									

FUEL OIL DATA / DIESEL BSFC

No.	Wght	API gravity	Temp	LHV	LB	Time		BHP-hr	Corr
1	29.5	37.0	77	18410	1200	2435	1776.6		.366
2	35.5	36.7	72	18410	1500	2125	2541.1		.362
3	35.0	36.7	72	18410	1950	2627	3427.6		.357
4	35.0	36.7	72	18410	1500	1972	3495.1		.368
5	41.5	36.7	72	18410	650	2425	964.9		.373
6	31.0	36.7	72	18410	1600	1510	3814.6		.361
7	44.0	36.7	72	18410	64	910	213.6		—
8									
9									
10									

FUEL: STANDARD #2 DIESEL
LUBE OIL: SHELL X-100 SAE 40

AIR FLOW NOZZLE COEFFICIENT LF 12283 RF 12283

OPERATOR P. VITAL / G. MEYER — ENGINEER P. KOISER — DATE 9-17-77 — JOB 2850 — A

RX 112777

ENGINE AND COMPRESSOR DIVISION OAKLAND CALIFORNIA — POWER ENGINE FACTORY TEST LOG — LOG 1 B

CUSTOMER TUSI — MODEL DSRV-16-4 TYPE SERVICE NUC STBY GEN — JOB NO. 2850 — ENGINE NO. 76002 — DIRECTION OF ROTATION CW

EXHAUST TEMPERATURES °F

No.	Turbine exhaust	Exhaust temperatures (cyl. 1–8)	Exhaust elbow (cyl. 9–16)	Avg
1	730 731	777 826 797 814 833 822 814 830	783 837 766 838 784 815 811 825	811
2	781 789	852 902 885 914 892 879 887 902	848 911 848 930 863 896 857 917	886
3	821 820	968 1005 994 978 959 982 974 961	937 990 915 1013 923 952 914 972	964
4	832 829	950 1009 991 982 965 989 991 961	937 989 923 1000 946 940 935 963	967
5	596 596	658 673 642 675 680 670 677 660	641 661 672 665 718 647 708 680	668
6	860 865	1007 1058 1041 1032 1010 1030 1055 1018	980 1043 971 1047 986 980 973 1005	1015
7	363 368	329 357 333 346 335 347 316 319	327 343 341 318 381 335 344 319	337
8				
9				
10				

FIRING PRESSURES PSIG

No.	Jacket water	Turbocharger water	Aftercooler water	Firing pressures (1–8)	Firing pressures (9–16)	Avg
1	225 161 166	169 166	112 130	850 860 820 860 850 810 810 820	820 840 810 850 840 840 820 840	833
2	21 163 169	169 171	118 137	1180 1180 1160 1180 1180 1130 1130 1180	1160 1180 1130 1180 1160 1180 1160 1180	1165
3	26 163 176	170 172	113 126	1470 1460 1450 1460 1470 1450 1450 1440	1470 1470 1470 1470 1470 1440 1440 1430	1454
4	26 166 179	180 182	120 136	1490 1480 1440 1460 1470 1460 1460 1440	1470 1470 1460 1480 1460 1440 1450 1480	1466
5	26 150 162	162 153	99 106	560 540 540 560 580 560 560 570	560 560 550 550 550 550 530 540	554
6	26 168 176	175 177	116 138	1560 1530 1520 1560 1580 1520 1530 1560	1580 1520 1530 1530 1560 1540 1560 1540	1547
7	12 147 150	149 160	99 104			
8						
9						
10						

LUBRICATING OIL PRESSURE PSIG / LUBRICATING OIL TEMPERATURE °F

No.	From pump	To gauge	To turbocharger	Temperatures	Crank case press.
1	58	66	31.5 31	159 178	-2.8
2	58	65	31 31	159 176	-2.6
3	58	65	31 31	159 177	-2.0
4	58	65	31 31	161 180	-2.0
5	58	66	33 33	157 168	-3.2
6	58	65	30 30	160 179	-1.8
7	59	66	33 33	157 166	-2.4
8					
9					
10					

LEGEND: L LEFT BANK, R RIGHT BANK, F ENGINE FRONT, B ENGINE REAR

TURBOCHARGER MAKE & MODEL: LF ELLIOTT 90G4, RF ELLIOTT 90G4

OPERATOR P. VITAL / G. MEYER — ENGINEER P. KOISER — DATE 9-17-77 — LOG 1 B — JOB 2850

RX 112777

DRAWINGS

DRAWINGS

The drawings provided in this manual are intended for the customer's use in the installation and operation of the unit. They include installation, foundation (where applicable) and system piping schematic drawings. Control system drawings are also included. Assembly drawings may be found in the Parts Manual, Volume II.

INSTRUCTION MANUAL

DELAVAL ENGINE AND
COMPRESSOR DIVISION
550 – 85th AVENUE
OAKLAND, CALIFORNIA 94621

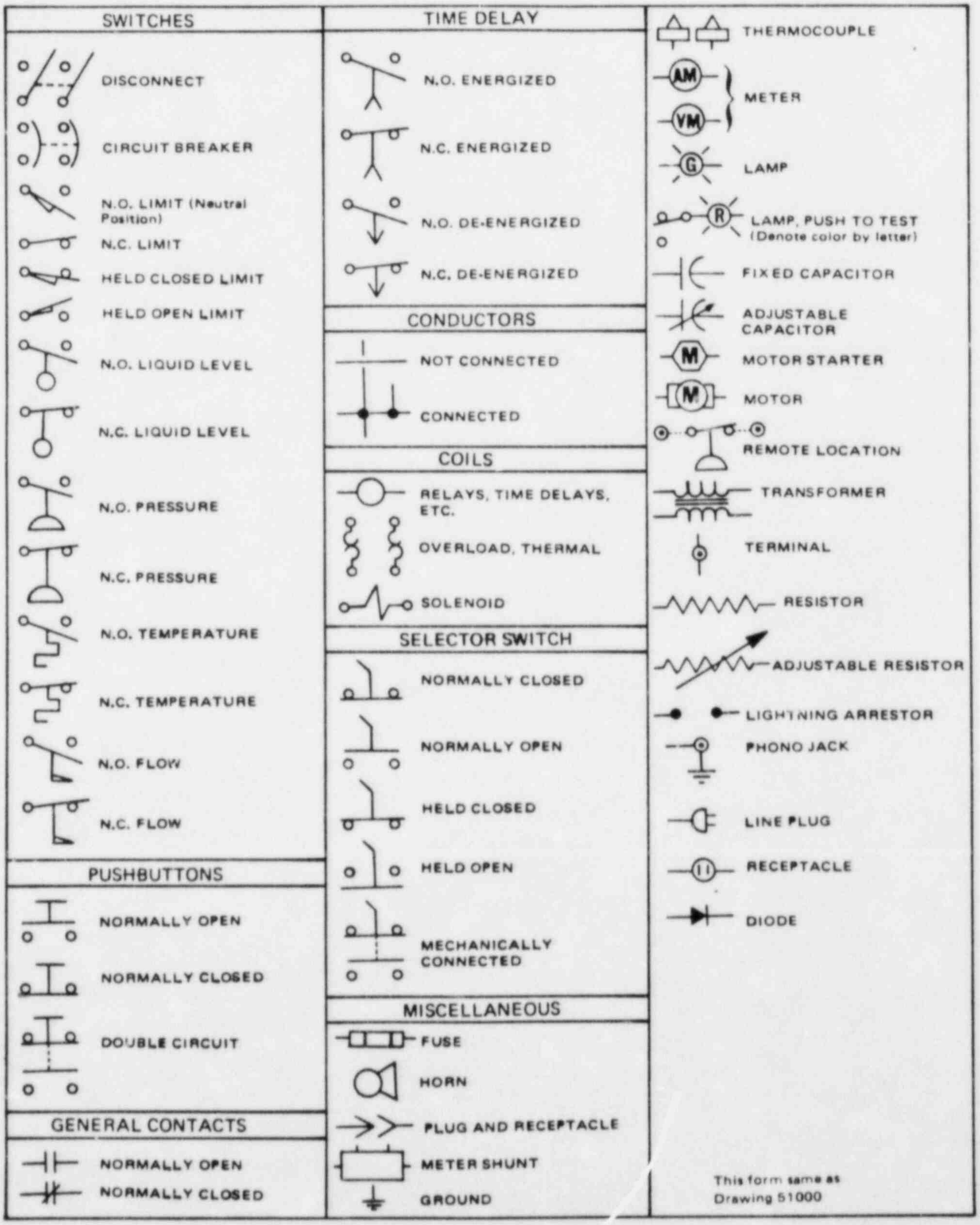
DELAVAL
A Transamerica Company

PIPING SYMBOLS

	MANOMETER		PRESSURE REDUCER	L	LEVEL GAUGE
P	PRESSURE SWITCH		GATE VALVE	X	PLUGGED
T	DIAL THERMOMETER		GLOBE VALVE		STRAINER
T	TEMPERATURE SWITCH		PLUG VALVE	→	DIRECTION OF FLOW
S	SIGHT FLOW GAUGE		BUTTERFLY VALVE (Tight Sealing Type)		WELD REDUCER
SP	ENGINE SHUT DOWN PRESSURE SWITCH		CHECK VALVE		SCREWED CAP AND NIPPLE
PYR	PYROMETER	⊗	STOP COCK		UNION
	PRESSURE SHUT DOWN ELEMENT		SAFETY OR RELIEF VALVE		WELD CAP
	TEMPERATURE CONNECTION — Requires ¾" half coupling for all dial thermometers and separable socket thermometer wells and ½" half couplings for temperature switches, etc. (Field locate as directed by owner.)		PRESSURE CONNECTION — Requires ½" coupling, nipple, stop cock, ½" x ¼" bushing and ¼" plug. (Field locate as directed by owner.)	L	LEVEL SWITCH
	STRAINER "Y"	S	SOLENOID VALVE		
	TEMPERATURE SHUT DOWN ELEMENT		DRESSER COUPLING		
	ELECTRIC WIRING		EXPANSION JOINT		
	CAPILLARY TUBING		ORIFICE		
	BLIND FLANGE	A	ALARM CIRCUIT		
	THERMOMETER	P	PRESSURE GAUGE		
T	TEMPERATURE GAUGE	M	METER		
	FLOAT VALVE	F	FLOAT SWITCH		
	DIAPHRAGM CONTROL VALVE		THERMOSTATIC TEMP. CONTROL VALVE		This form same as Form D-4313

DELAVAL ENGINE AND
COMPRESSOR DIVISION
550 – 85th AVENUE
OAKLAND, CALIFORNIA 94621

ELECTRICAL SCHEMATIC SYMBOLS

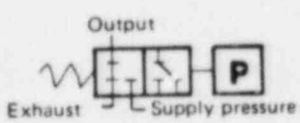


VALVE SYMBOLS

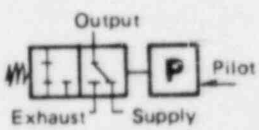
TWO POSITION VALVE (W/O ACTUATOR)	ACTUATORS
Basic two position	Spring return
Two way, two position	M — Manual push actuator
Three way, two position	M — Manual pull actuator
Four way, two position	M (Det.) — Detented manual actuator
Five way, two position	P — Pressure actuator
THREE POSITION VALVE (W/O ACTUATOR)	S — Solenoid actuator
Basic three position	V — Vibration actuator
Three way, closed center, three position	F — Flow actuator
Three way, open center, three position	L — Liquid level actuator
Four way, closed center, three position	T — Temperature actuator
Four way, open center, three position	1. Actuators (there may be one or two) are shown attached to either end of valve symbol.
Five way, open center, three position	2. Valve symbols are always shown in non-actuated, i.e., "Normal, relaxed" condition.
Five way, closed center, three position	3. The tube or pipe connections to the valve are considered to be immoveable, while the internal passage blocks are mentally shifted between the external connections to visualize valve action.

EXAMPLES:

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

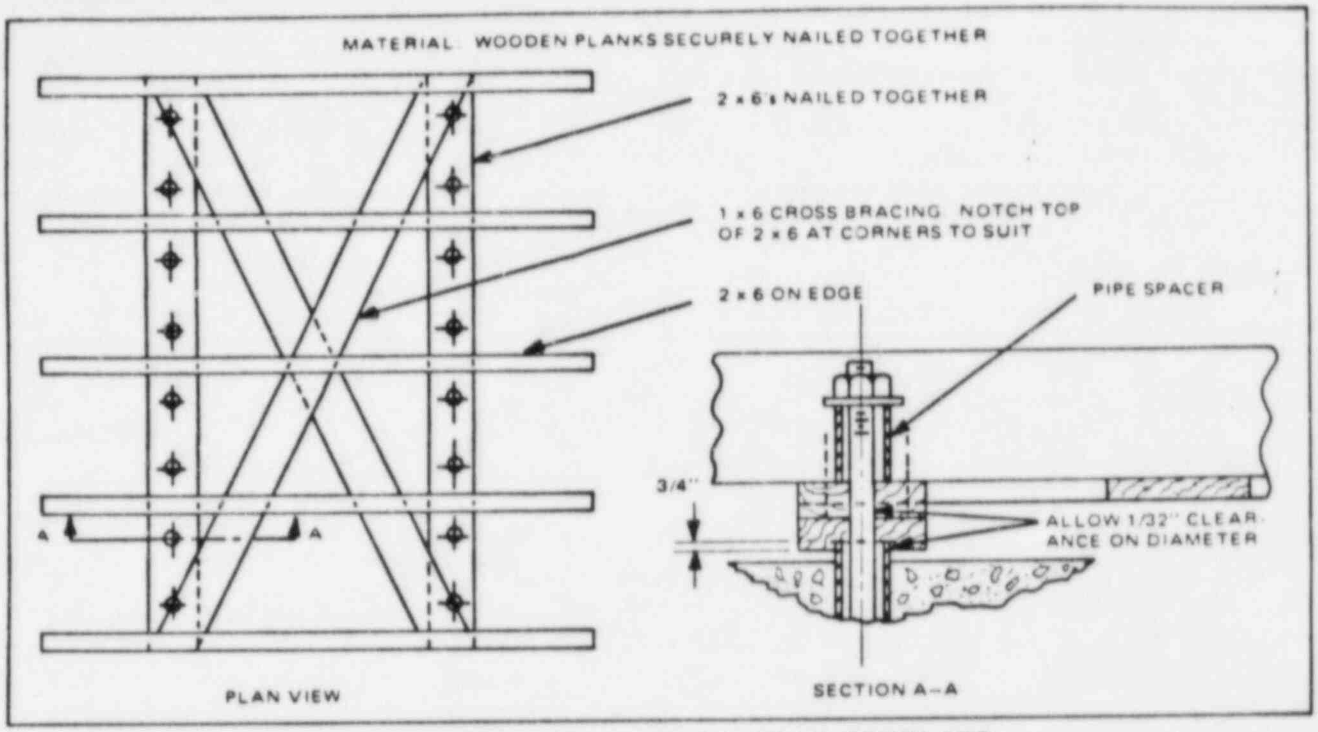


Valve connected normally closed (supply shut off when no pilot pressure exists). Note output is connected to exhaust.



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

PROCEDURE NOTES FOR MOUNTING ENTERPRISE ENGINES ON CONCRETE FOUNDATIONS



SUGGESTED FOUNDATION BOLT TEMPLATE

OBSERVE THE FOLLOWING SEQUENCE OF OPERATION:

1. Construct a foundation bolt template, using certified foundation drawing to determine positioning of foundation bolt holes. See sketch for a suggested template design. Exercise great care in locating bolt centers.

2. Position and support template from foundation forms, securely anchoring it to prevent movement.

3. Thread foundation bolt into lower nut in shield assembly, being careful not to damage cap at bottom of nut. Insert foundation bolts and shields in holes provided in template, then tighten upper nut. Shields must be securely held in correct position to prevent any movement during pouring of 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 then adding "X" bracing between the two rows of bolts. Another method is to tie the bolt assemblies to other reinforcing rods already in the foundation.

4. *Recheck template positioning, alignment and elevation before pouring concrete.* It is recommended that a DELAVAL Engine and Compressor Division Service Representative be present to check bolt layout.

5. Foundation is to be poured monolithic and must suitably reinforced with reinforcing steel. Let concrete set for 10 days before installing equipment and 30 days before running equipment.

6. Top surface of foundation must be roughened wherever grout is to be applied to remove laitance, oil stains, etc., and to provide a rough, dry surface for good bonding of epoxy grout to foundation.

7. Remove engine foundation bolts from shields and set aside where they will not be damaged. Place jacking screw plates in position at each jacking screw location. Plates should either be imbedded in foundation before concrete sets, or grouted in place.

8. Bring engine into position over foundation. If engine is rolled into position, ends of foundation bolt shields must be protected to prevent damage.

9. Insert toe jacks at four corners of engine, just inboard of shipping skids to support engine while skids are being removed. *CAUTION: To avoid damage to base casting, do not locate jacks at center of engine.* Remove shipping skids, clean engine mounting rails and lower engine to grade. Be sure foundation bolt holes in engine base are correctly aligned with foundation bolt sleeves in foundation for easy installation of foundation bolts.

10. Clean sole plates and chocks with a degreasing type solvent. After cleaning, it is recommended that sole plates be primed with a primer recommended by grout manufacturer. Lubricate threads of jacking screws with a mixture of powdered graphite and engine lubricating oil. Lower end of jacking screws should be coated with wax to prevent epoxy grout material from binding to screws.

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

73029–30

mounting rails (The front and rear sole plates at each side of the engine are designed to make contact with the mounting rail shoulder and are intended to restrain side movement of the engine.)

12. Lubricate threads at lower end of foundation bolts with standard mixture of engine oil and powdered graphite, then replace bolts in sleeves and screw firmly into threads at bottom of sleeve. Lubricate upper threads with oil and graphite mixture then place washers and nuts on bolts.

13. Level and align engine, following crankshaft alignment instructions on DELAVAL Engine and Compressor Division Form D-1063 (Revised 12/71). Record deflection readings on form. 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 foundation bolts to prevent movement of engine during generator installation and grouting.

14. Attach sole plates to generator and outboard pedestal bearing, using approximately 1/8 inch of shimming material between each sole plate and generator or pedestal. To provide insulation protection against circulating currents, 1/16 inch of the shimming between the sole plates and the pedestal bearing must be insulation material.

15. A DELAVAL Engine and Compressor Division Service Representative *must be present to supervise the alignment of the engine.* See Instruction Manual, Section 2, Page 1, Paragraph B, "Placing and Aligning Engine on the Foundation".

16. If not already installed, attach flywheel to crankshaft. Carefully clean and de-burr all mating surfaces of flywheel, crankshaft coupling flange and driven equipment coupling flange, including bolt holes. Lubricate crankshaft flange and flywheel counter bore with a light coat of anti-seize lubricant such as "Molykote" or "Lubriplate" and mount flywheel on crankshaft flange. Insure one-half inch locating holes are aligned. Make sure no dirt or other foreign matter is present between mating surfaces. Attach three retainer plates to flywheel and draw flywheel up on crankshaft flange until seated.

17. Bring generator and pedestal into position and attach generator shaft to flywheel. Lubricate bore in flywheel and connecting shaft flange with a light coat of anti-seize lubricant. Align half inch locating hole in flange with hole in flywheel and bring connecting shaft into engagement with flywheel. Be sure no dirt is allowed to get between mating surfaces. Insert two long 1 or 1¼ inch diameter bolts through two opposite flywheel bolt holes and draw connecting shaft flange until flange is seated. Check with feeler gauges between face of connecting shaft flange and flywheel to be sure flange is fully seated and square with flywheel. Lubricate two special aligning dowels with a thin coat of anti-seize lubricant (dowels and special flywheel bolt reamers are available from DELAVAL Engine and Compressor Division Service Department), and tap them into two opposite flywheel bolt holes. *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. 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. Flywheel bolts *must not* be driven with a sledge, jack or "Porto-Power". Fit bolts into two reamed holes, screw nuts on bolts and draw up tight. Use anti-seize lubricant on bolts and powdered graphite and engine oil on threads. Remove two temporary bolts and aligning dowels, ream holes and fit remaining bolts. Torque all bolts to the specified torque.

18. Check crankshaft alignment, then align outboard pedestal bearing. Line stator up with rotor and moderately tighten stator and pedestal foundation bolts with jacking screws in place. Check entire alignment, including crankshaft alignment. Record crankshaft deflections on Form D-1063.

19. Pour and vibrate grout under engine, generator and pedestal bearing. Carter Waters No. 604 or Ceilote No. 648 grout may be used. It is recommended that a representative of the grout supplier be present at the installation to be sure the grout is prepared and place in accordance with manufacturer's specifications. Do not fill bolt shields with grout. If a ramming strap is used, its movement should be slow so as not to entrain excess air in the grout.

20. After grout has cured, back off sole plate jacking screws one turn each and torque foundation bolts to recommended torque 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 final torque value is reached. Foundation bolts should be torqued to the following values:

Engine Model	*Torque (ft-lb)*
G	650
HV, HVA, HA	480
Q, R	1400
RV	3800

21. If foundation bolts are re-tightened at a later date, the nuts must be removed and re-lubricated in order to get accurate torque values. Dry thread torque readings can be as much as 50 percent in error.

22. Recheck entire alignment of equipment and check crankshaft deflections (record readings on Form D-1063). Remove or add shims to pedestal bearing and generator as necessary. Dowel generator and pedestal bearing to sole plates when alignment is necessary.

23. Crankshaft alignment should be rechecked after engine start up when engine and concrete foundation are at their normal operating temperatures. Record deflection on Form D-1063.

73029—30

ENGINE LUBRICATING OIL PIPING PROCEDURE

1. PRECAUTIONS TO BE OBSERVED DURING CONSTRUCTION OF THE LUBRICATING OIL SYSTEM, AND BEFORE STARTING ENGINE

1.1. Chill rings should not be used in welded pipe joints because of their tendency to retain scale, welding slag and beads which can come loose as the pipe becomes hot during operation of the engine.

1.2. *All* lubricating oil system piping *must* be pickled after fabrication to remove varnish, mill scale, welding debris, dirt and grease. The pickled surfaces of the pipe must be coated with a rust preventive compound immediately after pickling to protect them from rust. The compound must be soluble in the lubricating oil that will be used in the engine, and compatible with it so as not to contaminate the oil. Apply the compound by spraying or flooding the pipes – swabbing with rags or mops will leave lint. Ordinary lubricating oil will not prevent rust in the pipes.

1.3. Mechanical cleaning will not completely clean the pipes, therefore, this method is not acceptable.

1.4. Before the engine is started, the assembled lubricating oil piping system must be thoroughly flushed with oil. Disconnect the pipe at the pressure strainer inlet, (item 168 on installation drawing) and arrange a temporary bypass line from this pipe to the sump tank, or engine base as appropriate. The bypass will permit oil circulation through the piping system without filling the internal lubricating oil system of the engine. Several thicknesses of cloth sack should be secured to the outlet end of the bypass line to catch debris as it is flushed out of the system.

1.5. The piping around the lubricating oil cooler requires special attention to insure that the pipes and the cooler are properly flushed. Precautions must be taken to insure the complete removal of testing fluids, water, or other liquids before attemping to flush the cooler.

1.6. The oil sump tank and engine base must be carefully cleaned before being filled with oil.

1.7. The auxiliary lubricating oil pump, or any continuous duty pump of sufficient capacity, can be used to pump oil during flushing operations. If care was exercised during fabrication of the piping system it should be flushed for at least eight hours. As much as 24 hours of flushing may be required for a dirty system. While the oil is circulating through the system the pipes must be thoroughly pounded several times with a heavy hammer to loosen dirt and debris. Hot flushing oil is recommended as it does a better job of cleaning.

1.8. After flushing is completed, reconnect the piping system for normal operation. Examine all strainers, and filters for cleanliness and for proper assembly.

1.9. Disconnect the jumper tubes between the engine lubricating oil header and the main bearings, and between the main headers and the auxiliary headers. Secure a nylon stocking over each main header fitting to catch debris that may pass through the system as it is flushed. Cover the main bearing fittings and the open ends of the auxiliary header feeders to prevent entry of dirt. *Engine oil* should be pumped through the open system for at lease four hours to be sure of removing any foreign material that may have entered the headers during construction.

1.10. Reassemble the internal tubes and brackets as required.

1.11. The pressure strainer at the engine oil inlet will catch any debris that may remain in the piping system. It may require several cleanings during the first few hours of engine operation.

1.12. The utmost caution must be observed in the fabrication and preparation of the lubricating oil system for service. Foreign material of any kind can do a great deal of damage to the crankshaft, bearings, pistons, and cylinder liners.

1.13. NOTE. There may be instances where an engine is shipped with the pressure strainer mounted on the engine and connected to the engine lubricating oil header. If it is certain that the pipe connection between the pressure strainer and the engine lubricating oil header has not been disconnected since the engine left the factory, steps 9 and 10 above may be omitted.

2. PIPE PICKLING

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

2.2. The entire surface, including the interior, shall be wire brushed, using boiler tube brushes or commercial pipe cleaning apparatus, it shall then be blasted thoroughly with air to remove loose particles.

2.3. The parts shall be submerged for 15 minutes or longer, depending upon the degrees of contamination, in a solution containing 7 to 10 ounces of anhydrous trisodium phosphate or sodium hydroxide and one ounce of detergent, Mil. Spec. MIL-D-16791, to one gallon of water at 200°F. to insure complete removal of paint.and grease.

2.4. Parts shall then be rinsed in warm fresh water at 120°F. to prepare them for acid treatment.

2.5. Fabricated carbon steel pipe and fittings shall be pickled by submerging them for 30 to 45 minutes in an acid bath contained one part of sulphuric acid, 66 deg. Baume, to 15 parts of fresh water and supplemented by an inhibitor. The acid bath shall be maintained at temperatures between 160 and 180 degrees F. While the parts are submerged, the bath shall be agitated. At the end of the pickling procedure the parts shall be rinsed in warm fresh water. After the rinse, the parts shall then be momentarily submerged in a boiling solution containing 4 ounces of sodium carbonate per gallon of water, and then rinsed in cold fresh water and dried by air blast.

2.6. Immediately following pickling and rinsing procedures, fabricated steel pipe and fittings shall be coated inside and outside with rust and corrosion preventive compound, and the ends sealed to prevent the entry of dirt.

2.7. The foregoing is minimum requirement to produce an acceptable cleaning of lubricating oil piping systems. Substitute methods must produce pipe and fittings of equal or better cleanliness.

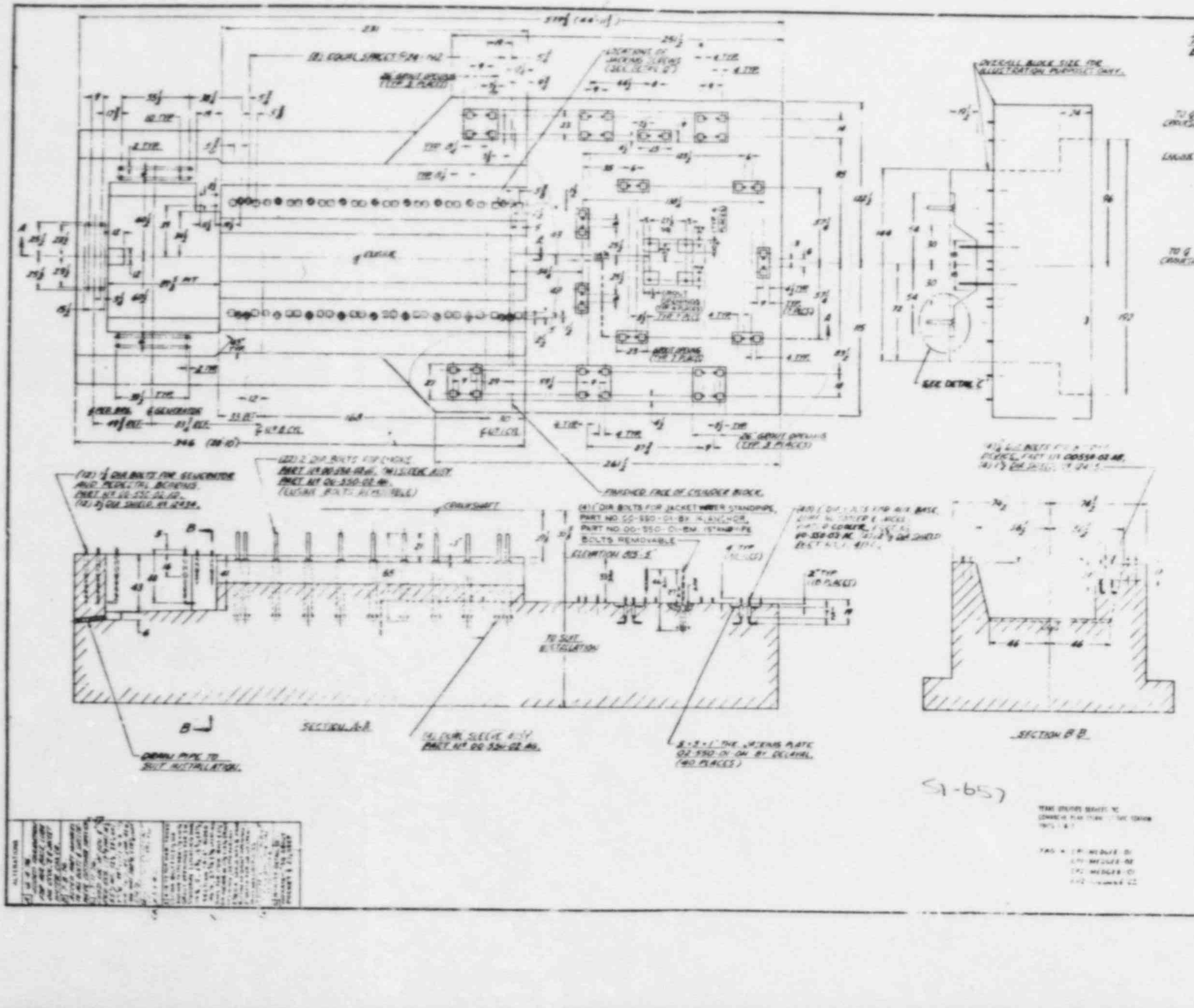
2.8. The practice of fastening the sections of pipe together to form a system through which pickling acid is pumped should be discouraged. The difficulty of producing an acceptable job with this method is great.

2.9. DE LAVAL – ENTERPRISE recommends strongly that lubricating oil system piping should be pickled by a company which is equipped to do this kind of work. Such a company will have tanks and vats and the technical knowledge to completely clean and prepare the pipe for service.

2.10. It will be necessary to completely fabricate and finish weld all pipe prior to pickling. Remove all valves and non-ferrous fittings.

2.11. Make sure that the rust and corrosion preventive compound will mix with engine lubricating oil without causing contamination.

2.12. Make sure that cleanliness is maintained when the sections of pipe are reassembled to form the system.

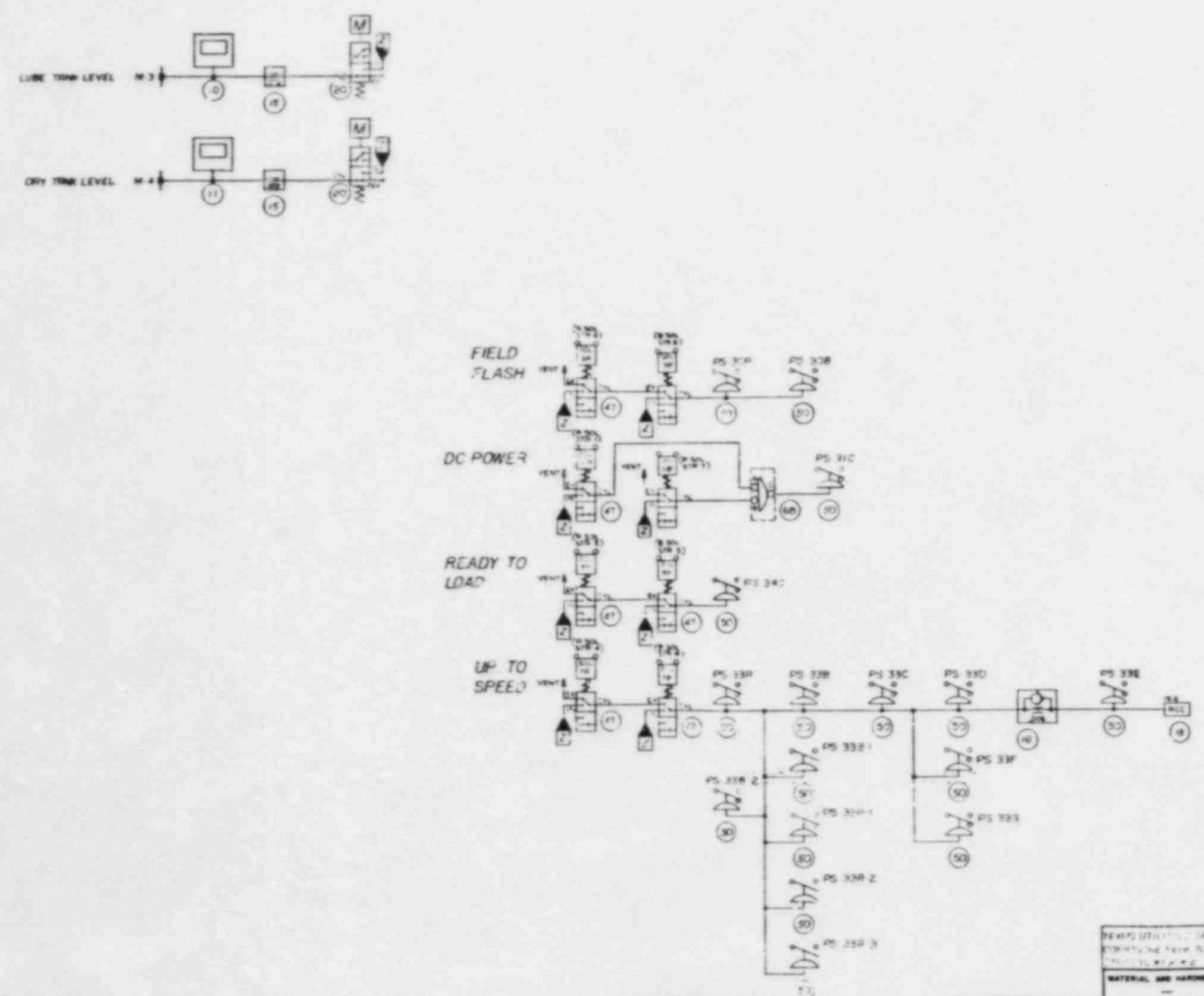


12. FOR ENGINE MTG LAYOUT SEE 02-550-03.
11. FINAL DESIGN AND DIMENSIONS OF ENGINE FOUNDATION MUST BE DETERMINED BY CUSTOMER'S REGISTERED ENGINEER TO SUIT INSTALLATION & SOIL CONDITIONS.
10. CONCRETE MUST BE DRY & CHIPPED CLEAR OF ALL LAITANCE IN AREA TO BE GROUTED.
9. SEE DWG. 100232 FOR SUGGESTED CONCRETE FOUNDATION & ENGINE INSTALLATION PROCEDURE.
8. CEILCOTE #648 GROUT OR CARTER-WATERS #604 MAY BE USED. WE RECOMMEND THAT A REPRESENTATIVE OF THE GROUT SUPPLIER BE PRESENT AT INSTALLATION TO BE SURE THAT GROUT IS PREPARED & PLACED ACCORDING TO SPECIFICATIONS.
7.
6. FOUNDATION MUST BE SUITABLY REINFORCED.
5. 1" OF GROUT UNDER GENERATOR & PED BRG. 1½" GROUT UNDER OTHER EQUIPMENT.
4. ALL FOUNDATION BOLTS ARE FURNISHED BY DELAVAL.
3. IT IS RECOMMENDED THAT THE FOUNDATION BE POURED MONOLITHIC IF POSSIBLE.
2. FOR INSTALLATION SEE DWG. R-3944.
1. TOLERANCE OF MOUNTING TO BE ± 1/8"

51-657

FOUNDATION DRAWING

R-3943 G

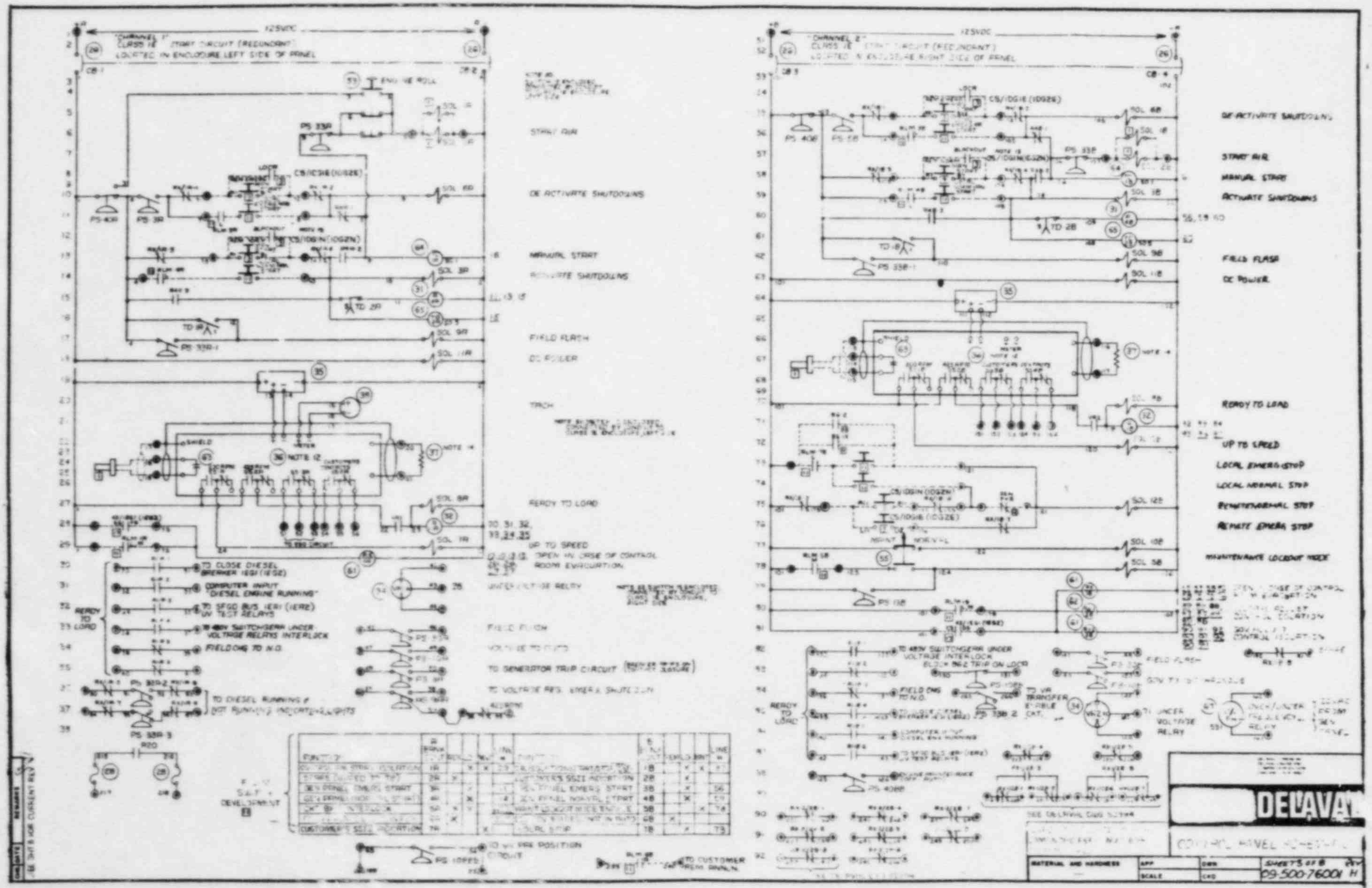


DELAVAL

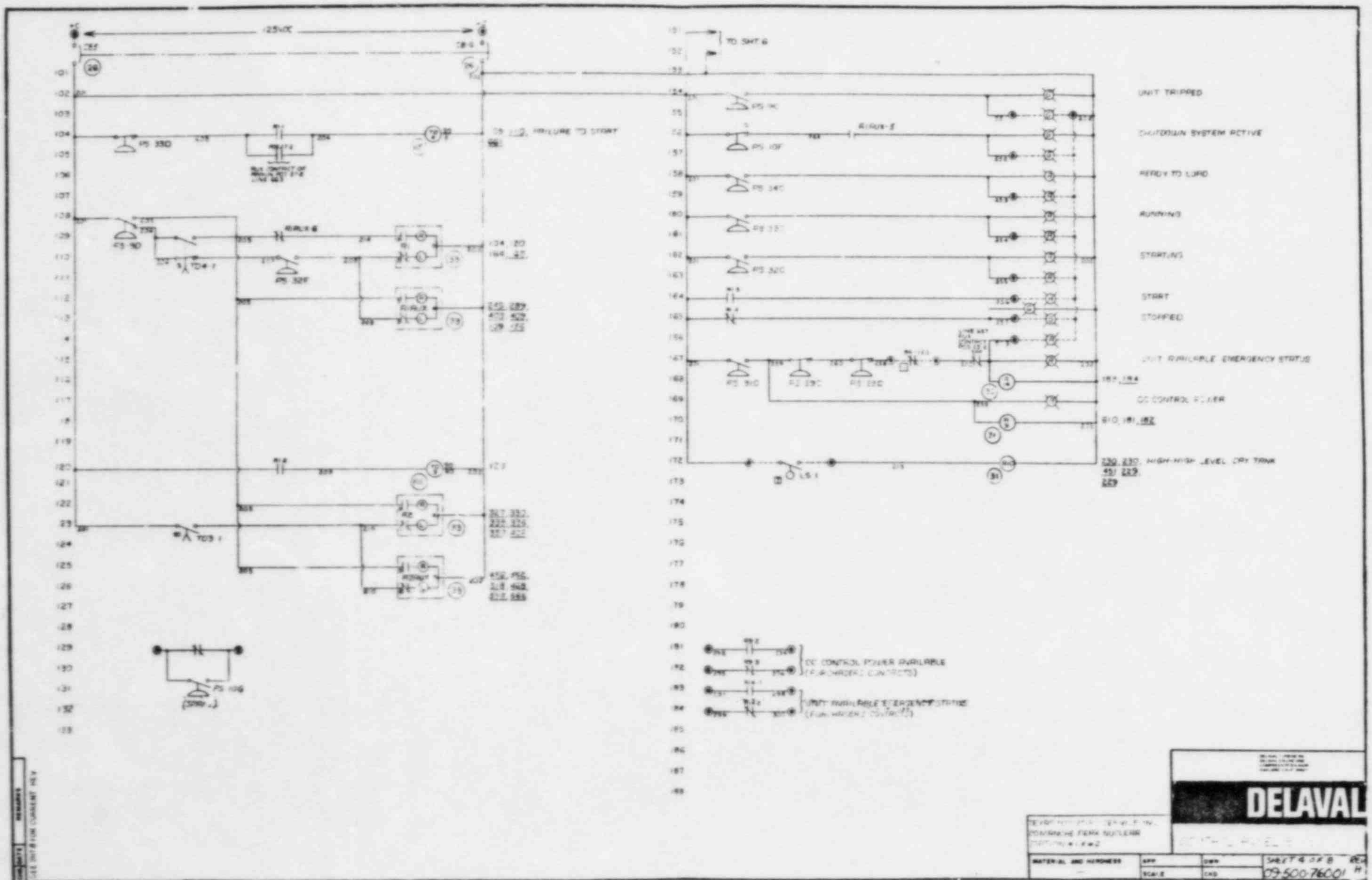
CONTROL PANEL SCHEMATIC

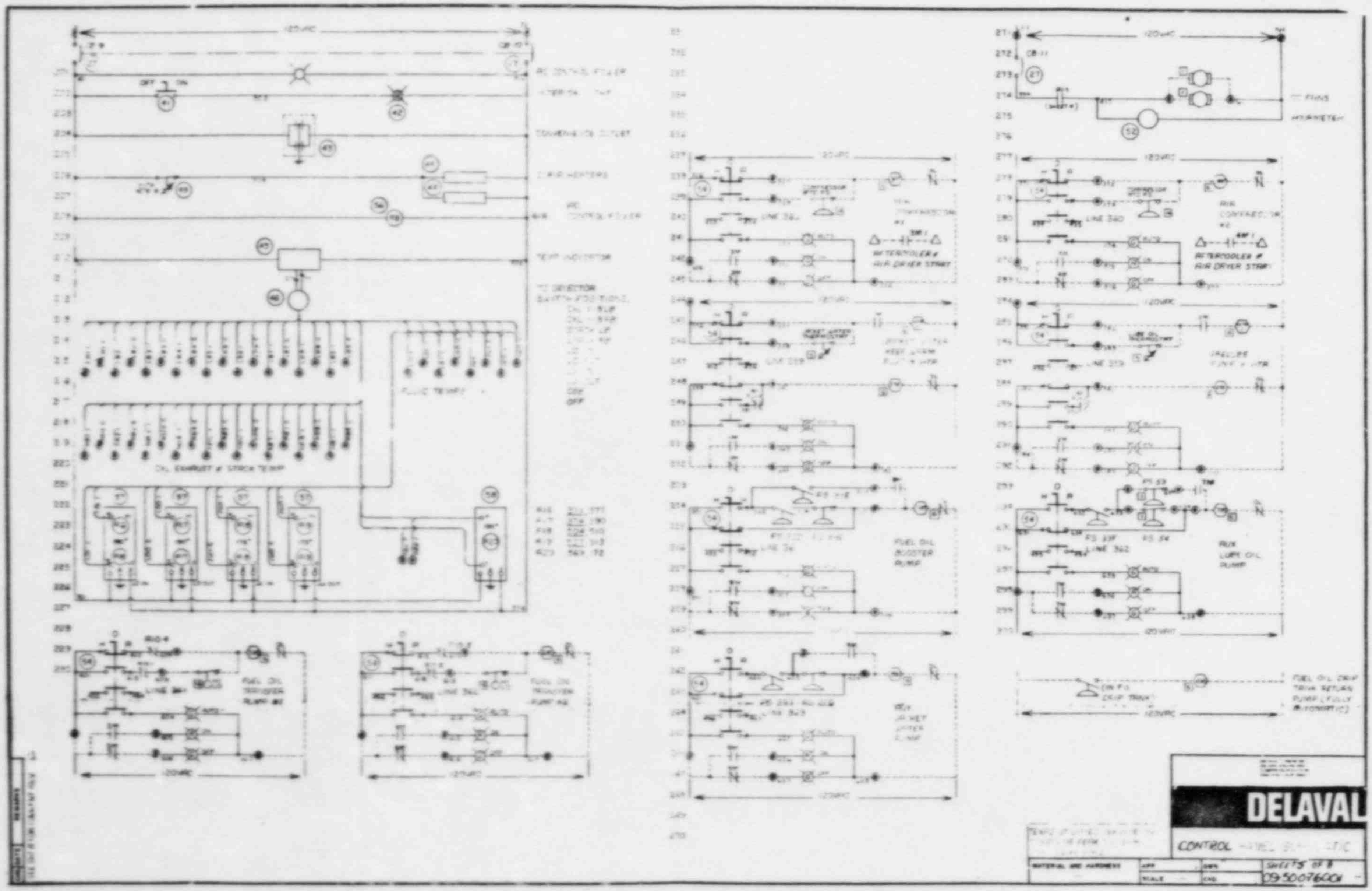
MATERIAL AND HARDNESS	APP	DWN	SHEET 2 OF 8	
—	SCALE	CHKD	09500760001	H

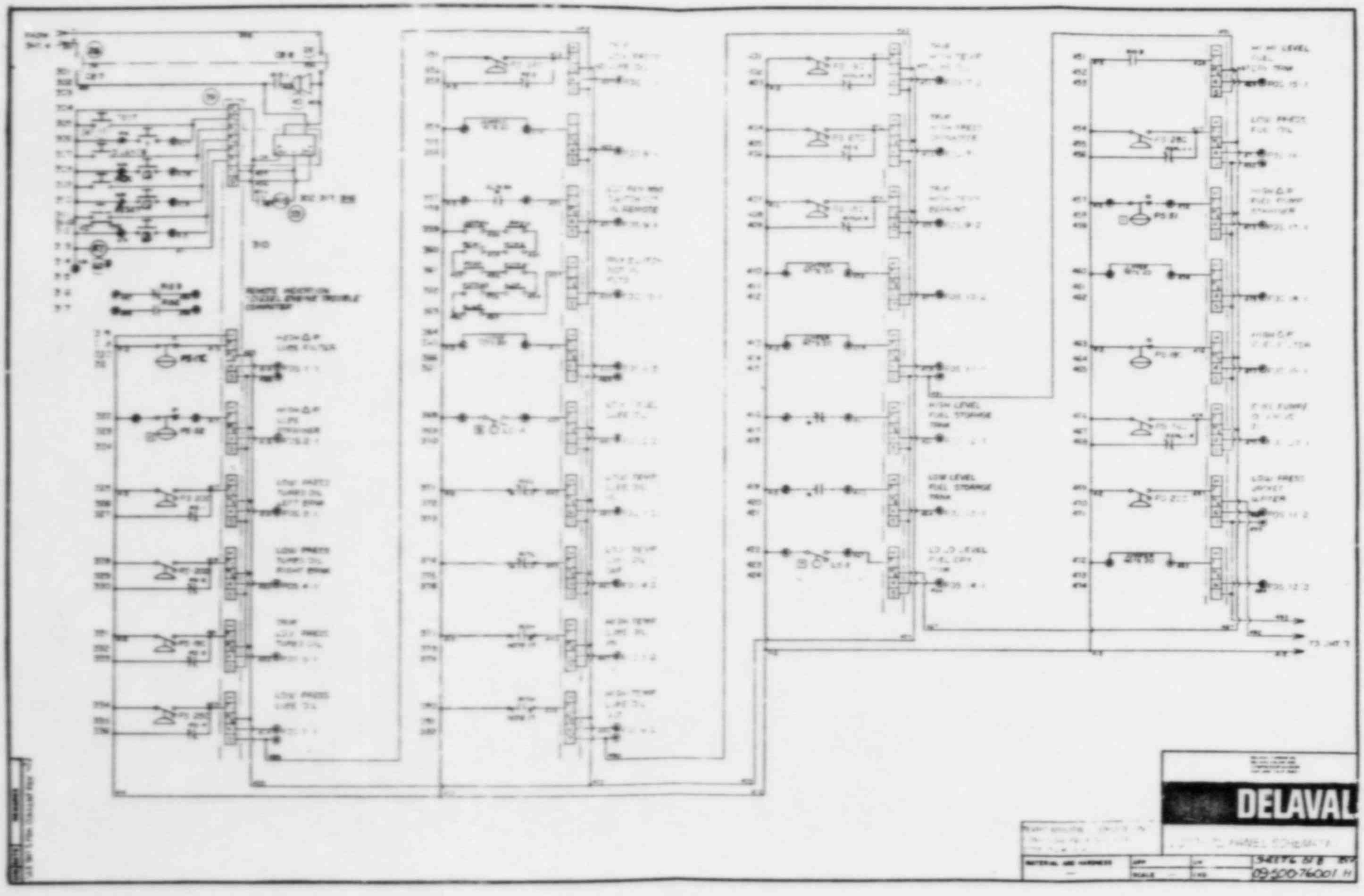
SEE SHT 8 FOR CURRENT REV

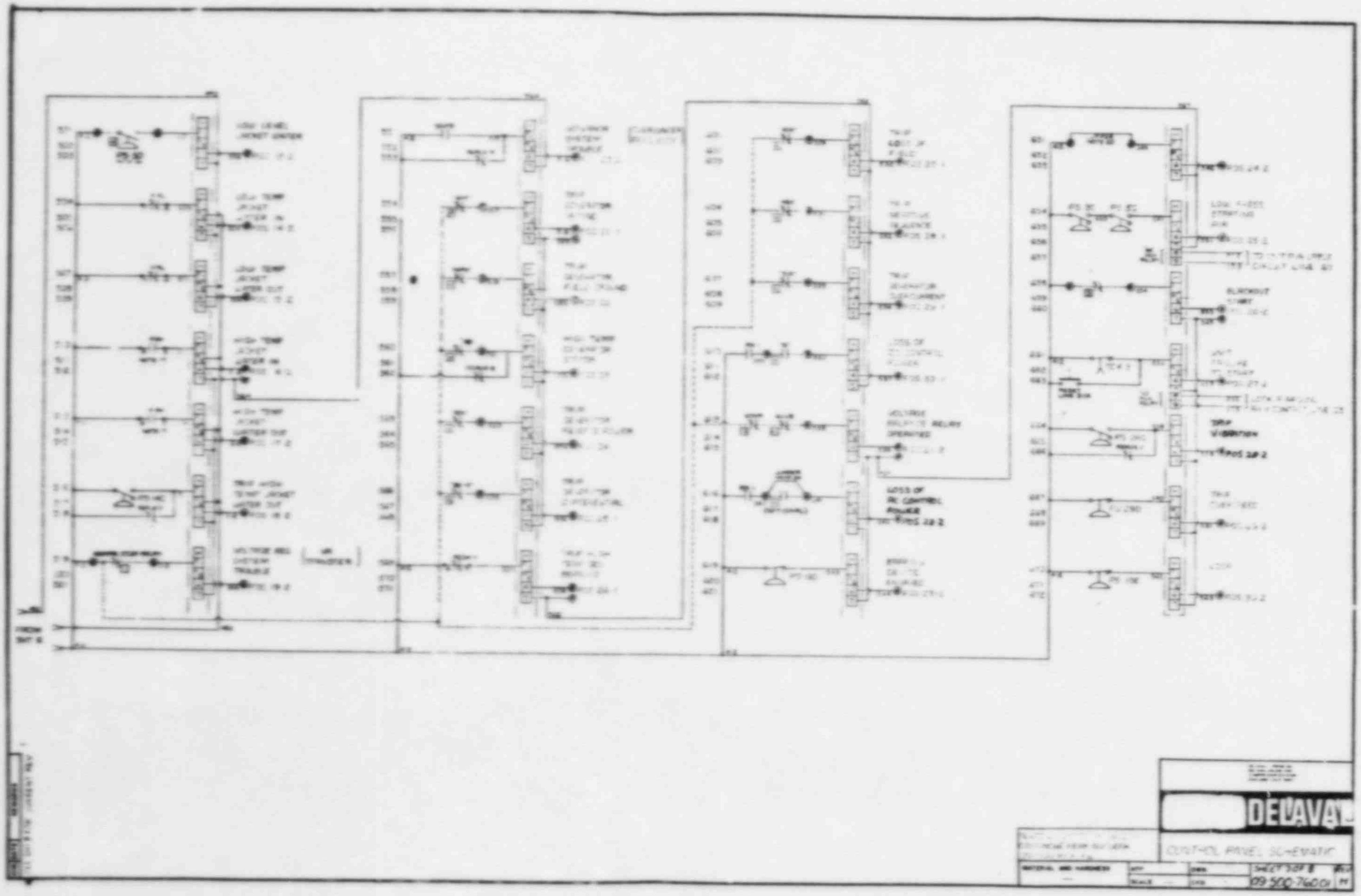


125VDC
"CHANNEL 1" CLASS 1E START CIRCUIT (REDUNDANT)
LOCATED IN ENCLOSURE LEFT SIDE OF PANEL
"CHANNEL 2" CLASS 1E START CIRCUIT (REDUNDANT)
LOCATED IN ENCLOSURE RIGHT SIDE OF PANEL
ENGINE ROLL
START AIR
DE ACTIVATE SHUTDOWNS
MANUAL START
ACTIVATE SHUTDOWNS
FIELD FLASH
DC POWER
TACH
READY TO LOAD
UP TO SPEED
OPEN IN CASE OF CONTROL ROOM EVACUATION
UNDERVOLTAGE RELAY
TO CLOSE DIESEL BREAKER
COMPUTER INPUT "DIESEL ENGINE RUNNING"
TO 480V SWITCHGEAR UNDER VOLTAGE RELAYS INTERLOCK
FIELD DHG TO N.O.
TO GENERATOR TRIP CIRCUIT
TO DIESEL RUNNING
TO VR PRE POSITION CIRCUIT
TO CUSTOMER
LOCAL EMERG STOP
LOCAL NORMAL STOP
REMOTE NORMAL STOP
REMOTE EMERG STOP
MAINTENANCE LOCKOUT MODE
TO VR TRANSFER ENABLE CKT
UNDER VOLTAGE RELAY
SEE DELAVAL DWG
DELAVAL
CONTROL PANEL SCHEMATIC
SHEET 5 OF 8
09-500-76001 H


125VDC
TO SHT 8
PS 33D
PS 9D
PS 32F
TD4-1
TD3-1
RR(AUX-6)
R(AUX)
R2
PS 10G
FAILURE TO START
UNIT TRIPPED
SHUTDOWN SYSTEM ACTIVE
READY TO LOAD
RUNNING
STARTING
START
STOPPED
UNIT AVAILABLE EMERGENCY STATUS
DC CONTROL POWER
HIGH-HIGH LEVEL DRY TANK
LS 1
PS 31C
PS 10F
PS 34C
PS 32C
DC CONTROL POWER AVAILABLE
(PURCHASERS CONTACTS)
UNIT AVAILABLE EMERGENCY STATUS
DELAVAL
09-500-76001


120VAC
AIR COMPRESSOR #1
AFTERCOOLER & AIR DRIVER START
FUEL OIL BOOSTER PUMP
AIR COMPRESSOR #2
AFTERCOOLER & AIR DRYER START
AUX LUBE OIL PUMP
FUEL OIL TRANSFER PUMP #2
FUEL OIL TRANSFER PUMP #1
OIL EXHAUST & STACK TEMP
FUEL OIL DRIP TANK RETURN PUMP (FULLY AUTOMATIC)
DELAVAL
CONTROL
SHEETS OF 8
09-500-7600I


HIGH ΔP
LUBE FILTER
LOW PRESS
LUBE OIL
HIGH LEVEL
FUEL STORAGE
TANK
LOW LEVEL
FUEL STORAGE
TANK
LOW PRESS
FUEL OIL
HI HI LEVEL
FUEL
TO UNIT 2
DELAVAL
PANEL SCHEMATIC
MATERIAL AND HARDNESS
SCALE
SHEET 8 OF 8
09500-76001 H


LOW LEVEL JACKET WATER
LOSS OF DC CONTROL POWER
TRIP VIBRATION
DELAVAL
CONTROL PANEL SCHEMATIC
09-500-76001

	SETTING	FUNCTION
[illegible]	[illegible]	[illegible]

NOTES

1. PNEUMATIC CONTROL MEDIUM IS AIR.
2. [illegible] INDICATES ADJ... CONTROL AIR.
3. SYSTEM SHOWN SHUTDOWN DE-PRESSURIZED & DE-ENERGIZED.
4. SET, TEST & [illegible] ALL SAFETY DEVICES.
5. PS/# INDICATES ACTUATION AT SETTING ON FALLING PRESS. PS/# INDICATES ACTUATION AT SETTING ON RISING PRESS.
6. SEE [illegible] FOR VALVE [illegible]
7. [illegible] DENOTES [illegible] TERMINATION WITH BOTTOM OF CABINET. IDENTIFY [illegible]
8. TUBING IS [illegible] COPPER EXCEPT [illegible] FITTINGS ARE BRASS.
9. FOR [illegible] EXTERNAL CONNECTIONS [illegible] ALL LUBE OIL LINES [illegible] EXTERNAL CONNECTIONS.
10. [illegible] TO PANEL, EXCEPT WHERE TERMINATION IS [illegible]
11. IDENTIFY BOTH ENDS OF WIRES.
12. WHEN POWER IS APPLIED, [illegible] RELAY CONTACTS TRANSFER [illegible]
13. WIRING TO BE [illegible] STRANDED, TINNED COPPER, [illegible] QUALIFIED, [illegible]
14. REMOVE RESISTOR IF [illegible]
15. [illegible] CONTACTS TO BE [illegible] CIRCUITS.
16. [illegible]
17. NO CONTACTS CLOSE TO ALARM. ALL OTHER [illegible] OPEN TO ALARM.
18. RELAY [illegible] TRANSFERS [illegible] START [illegible] STOP [illegible] RELAY [illegible] TRANSFERS [illegible] SEC AFTER A START OR AT A STOP.
19. MOUNT [illegible] IN CABINET [illegible]
20. REMOVE JUMPER IF [illegible]
21. THERMOCOUPLE LEADS TO BE [illegible]
22. APPROPRIATE COLOR CODE

TS[illegible] & TS[illegible] (CHROMEL OR ORANGE [illegible])

TS[illegible] & TS[illegible] (CHROMEL OR GREEN [illegible])

ITEM	DESCRIPTION	PART NO.	QTY	MFR
1	SHUTDOWN LOGIC BD	[illegible]	1	DELAVAL
2	MANOMETER	F 132 001	1	[illegible]
3	PRESS. GAUGE 20-0-100 Hg	F 530 400	1	[illegible]
4	↓ 0-60	F 530 478	3	ASHCROFT
5	0-100	F 530 479	1	↓
6	0-300	F 530 482	2	
7	0-60 [illegible]	F 530 485	1	
8	0-30 [illegible]	F 530 486	1	↓
9	0-100	F 530 510	1	MOORE
10	LEVEL GAUGE LUBE OIL	F 530 468	1	[illegible]
11	LEVEL GAUGE FUEL OIL	F 530 547	1	[illegible]
12	CHECK VALVE	F 573 127	1	[illegible]
13	CHECK VALVE	F 573 275	2	[illegible]
14				
15	ORIFICE [illegible]	F 573 135	3	CALCON
16	[illegible] CHECK [illegible]	F 573 144	2	CALCON
17	SNUBBER	F 573 275	4	ASHCROFT
18	ACCUMULATOR [illegible]	F 573 226	5	[illegible]
19	SHUTTLE VALVE	F 573 [illegible]	1	HUMPHREY
20	3 WAY VALVE [illegible]	F 573 385	2	↓
21	↓ NC	F 573 387	1	
22	NO	F 573 132	1	↓
23	REGULATOR	F 573 061	1	[illegible]
24	FILTER	F 527 002	1	NORGREN
25	MANOMETER VALVE	F 573 239	1	[illegible]
26	CIRCUIT BREAKER [illegible]	F 511 [illegible]	5	HEINEMANN
27	CIRCUIT BREAKER [illegible]	F 511 001	5	HEINEMANN
28	PRESS GAUGE [illegible] DUPLEX	F 230 [illegible]	1	ASHCROFT
29				
30	RELAY 2 POLE DC	F [illegible]	1	A-B
31	↓ 4	F [illegible]	4	↓
32	4	F 580 [illegible]	2	
33	4 ↓ ↓ [illegible]	F 580 [illegible]	4	↓
34	↓ UNDERVOLTAGE	F 580 [illegible]	2	[illegible]
35	POWER SUPPLY	F [illegible]	2	[illegible]
36	TACH TRANSMITTER	F 594 [illegible]	2	[illegible]
37	RESISTOR [illegible]	F 591 [illegible]	2	[illegible]
38	TACHOMETER	F 594 [illegible]	1	GE
39	ANNUNCIATOR	[illegible]	1	[illegible]
40	HORN	F 596 [illegible]	1	FEDERAL

ITEM	DESCRIPTION	PART NO.	QTY	MFR
41	TOGGLE SW. 2 POS	F 585 123	1	HUBBLE
42	INTERIOR LIGHT	F 559 259	1	CROUSE HINDS
43	CONVENIENCE OUTLET	F 581 024	1	HUBBLE
44	STRIP HEATER	F 535 395	2	GE
45	TEMP. INDICATOR	F 578 047	1	[illegible]
46	TC SELECTOR SW.	F 585 [illegible]	1	OMEGA
47	TCL VALVE 3 WAY [illegible]	F 586 [illegible]	[illegible]	HUMPHREY
48	TEMP SWITCH	F 593 [illegible]	1	FENWAL
49	PRESS SWITCH DIFF	F 577 027	2	BARKSDALE
50	↓ 3 [illegible] 90 PSI	F 577 [illegible]	[illegible]	↓
51	[illegible] PSI	F 577 [illegible]	4	
52	HOURMETER	F [illegible]	1	WESTINGHOUSE
53	PUSHBUTTON BLACK	F 578 005	5	FURNAS
54	SEL. SWITCH 3 POS	F 585 104	5	↓
55	SEL. SW. 3 POS [illegible]	F 585 [illegible]	1	
56	RELAY 2 POLE AC	F 590 [illegible]	1	AB
57	↓ TC SETPOINT DUAL	F 540 [illegible]	4	ACTION PAK
58	TC SETPOINT	F 540 [illegible]	1	ACTION PAK
59	24 VDC 2 POLE	F 580 054	1	A-B
60	24 VDC	F 580 021	1	A-B
61	125VDC [illegible]	F [illegible]	3	A-B
62	125VDC [illegible] 2 NO	F [illegible]	1	A-B
63	CAPACITOR	F 514 006	2	SPRAGUE
64	TIME DELAY .5 TO 5 SEC	F 590 [illegible]	2	[illegible]
65	↓ .5 TO 15 SEC	F 590 [illegible]	3	↓
66	1.2 TO 120 SEC	F 590 [illegible]	1	
67	OVER/UNDER FREQUENCY RELAY	F 590 [illegible]	1	[illegible]
68	AND ELEMENT, BASE MOUNT	F 575 [illegible]	1	[illegible]
69	FUSE [illegible]	F [illegible]	2	BUSS

☐ INDICATES LOCATION
* PROVIDED BY OWNER
1. ON ENGINE
2. ON GENERATOR
3. IN CONTROL ROOM PANEL
4. ON [illegible] EXCHANGER
5. ON HEATER
6. IN [illegible]
7. PART OF DAY TANK LEVEL SW.
8. PART OF DC STARTER FOR [illegible]
9. PART OF LUBE TANK SW.
10. ON [illegible] NOZZLE
11. IN GENERATOR PANEL
12. ON SWITCHGEAR
13. IN PANEL
14. ON STARTING AIR TANK
15. IN [illegible]
16. IN FUEL OIL TANK
17. IN [illegible] SHUTDOWN PANEL

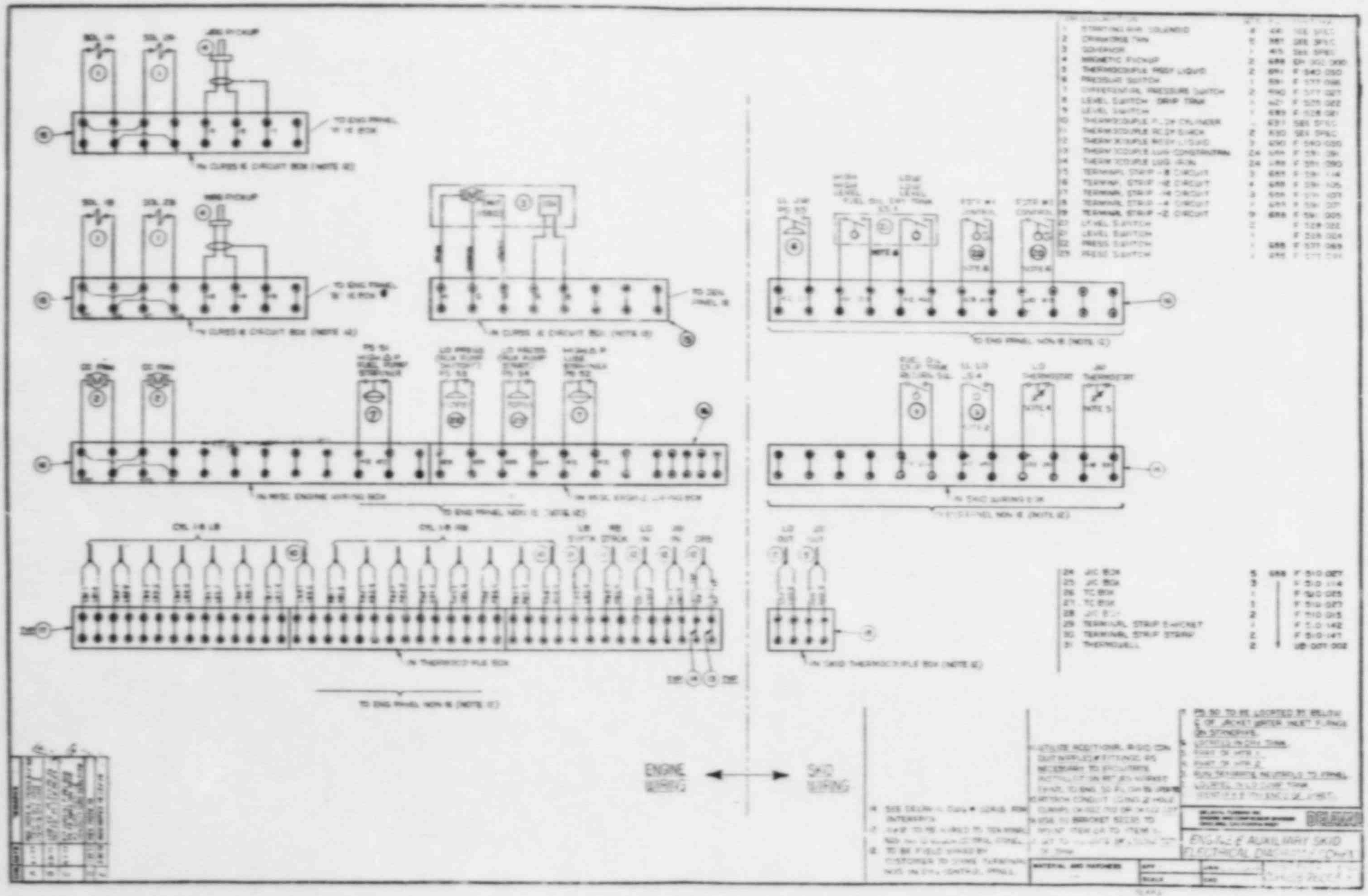
DELAVAL

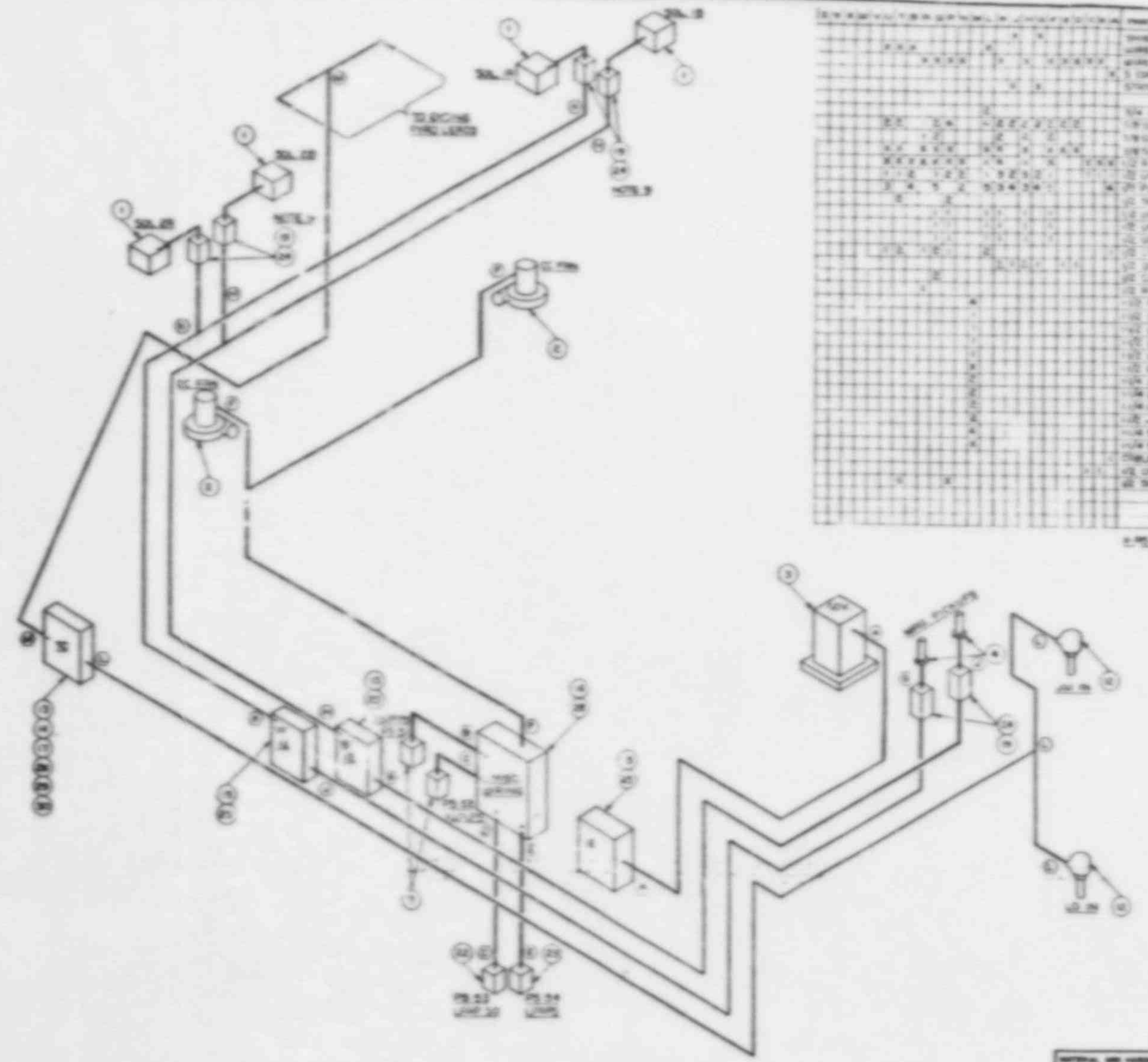
TEXAS UTILITIES SERVICE INC. COMANCHE PEAK NUCLEAR [illegible]

CONTROL PANEL SCHEMATIC

SHEET 6 OF 8

09-500-76001


ENGINE WIRING
SKID WIRING
TO ENG PANEL NON IE (NOTE 2)
IN THERMOCOUPLE BOX
IN SKID THERMOCOUPLE BOX (NOTE 2)
IN SKID WIRING BOX
ENGINE & AUXILIARY SKID
ELECTRICAL DIAGRAM

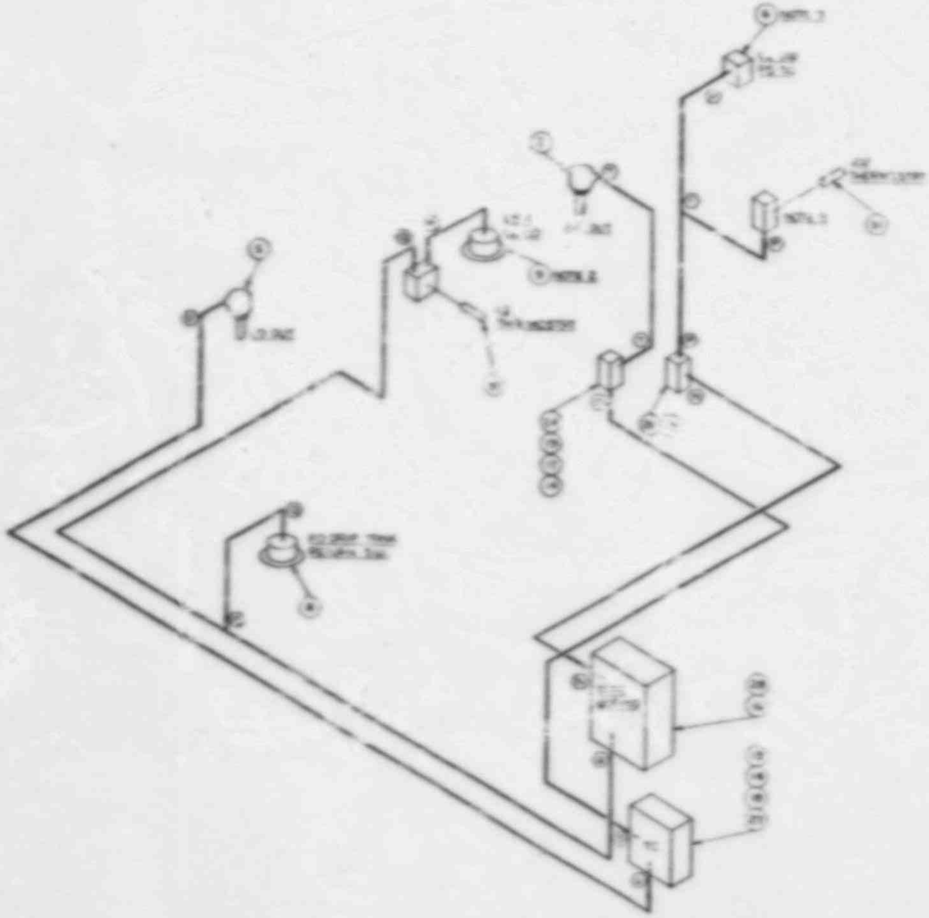


PART NAME	PART NO.	REQUIREMENTS	QTY
SHIELDED CABLE	Y 509 231		36
WIRE THERMOCOUPLE	Y 509 265		150
WIRE, 14 GA.	Y 509 217		850
5 CONDUCTOR CABLE	Y 509 212		8
STATIC SEAL WASHER	Y 1-9 088		2
3/4 - 1/2 REDUCER	Y 509 027		2
1/2 SEALTITE CONNECTOR	Y 509 118		[illegible]
1/2 SEALTITE ELBOW 90°	Y 509 123		9
1/2 SEALTITE CONDUIT	Y 509 113		22'
1/2 RIGID CONDUIT	Y 509 240		216'
1/2 UNI. SEAL HUB	Y 509 408		24
1/2 PULL ELBOW	Y 509 265		10
1/2 SEALTITE CONNECTOR	Y 509 119		[illegible]
1/2 UNILET TEE	Y 509 [illegible]		4
1/2 UNILET COVER	Y 509 037		8
1/2 UNILET GASKET	Y 509 141		4
1/2 UNION COUPLING	Y 509 270		10
1/2 GASKET [illegible]	Y 509 078		[illegible]
1/2 CLOSE NIPPLE	Y 509 079		[illegible]
1/2 RIGID CONDUIT ELBOW 90°	Y 509 036		[illegible]
1 1/2 PULL ELBOW	Y 509 417		4
1 1/2 CLOSE NIPPLE	Y 509 520		[illegible]
1 1/2 UNILET TEE	Y 509 417		[illegible]
1 1/2 UNILET COVER	Y 509 140		[illegible]
1 1/2 UNILET GASKET	Y 509 144		[illegible]
1 1/2 RIGID CONDUIT	Y 509 1[illegible]4		20'
1 1/4 UNILET ELBOW LB	Y 509 [illegible]		2
1 1/4 UNILET COVER	Y 509 240		2
1 1/4 UNILET GASKET	Y 509 244		2
1 1/2 [illegible] BUSHING	Y 509 405		2
1 1/4 SEALTITE CONNECTOR	Y 509 122		4
1 1/4 SEALTITE CONDUIT	Y 509 117		2'
CABLE CONNECTOR	Y 509 083		1
1/2 CONDUIT ELBOW	Y 509 081		8
1/2 SEALTITE CONDUIT	Y 509 114		2'

* AS REQUIRED

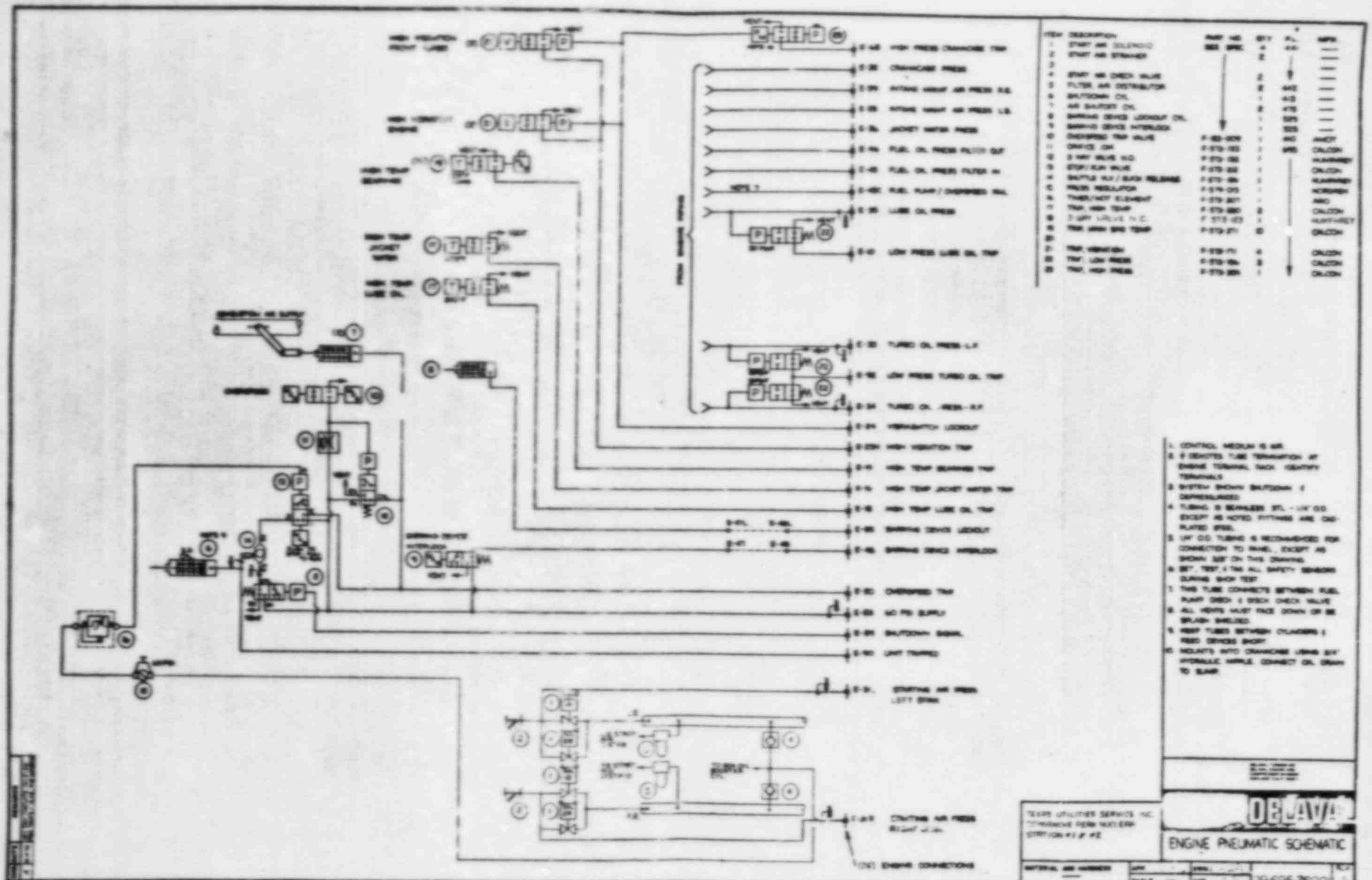
ENGINE & AUXILIARY SKID
ELECTRICAL DIAGRAM & SCHEM

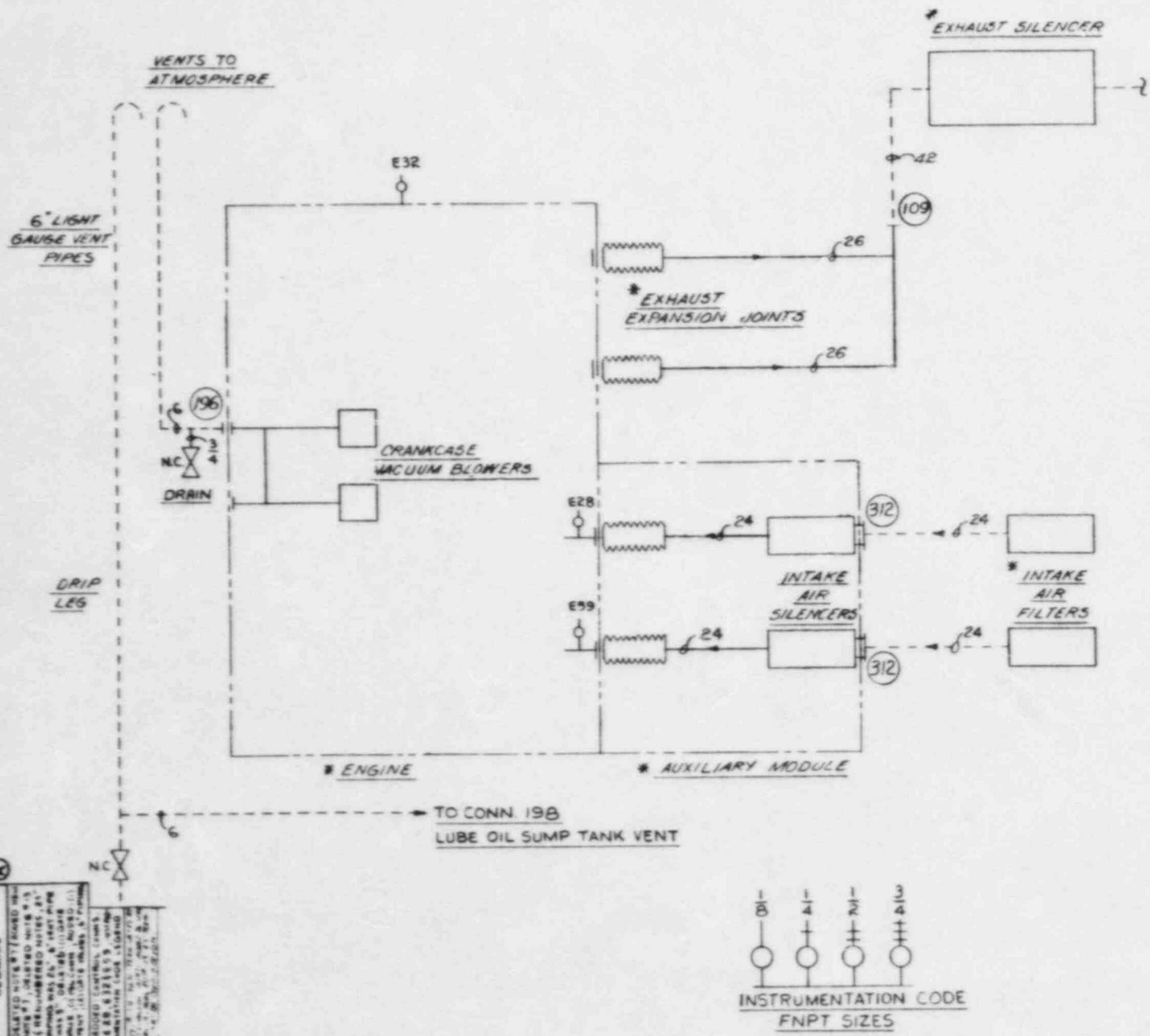
MATERIAL AND HARDNESS —
SCALE —
SHEET 2 OF 3
19478-75004
REV F



ENGINE & AUXILIARY SKID
ELECTRICAL DIAGRAM & SCHEM

MATERIAL AND HARDNESS	APP	DWN	SHEET 3 OF 3
	SCALE	CHK	03-688-7600


TEXAS UTILITIES SERVICES INC.
ENGINE PNEUMATIC SCHEMATIC
79-695 7800



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. PROVIDE SUCH VENTS AND DRAINS AS DEEMED NECESSARY BY DELAVAL ENGINEERING.
8. CUSTOMER TO SUPPLY AND INSTALL ALL PIPING SHOWN IN DOTTED LINE (----).
9. INLET AIR PRESSURE DROP MUST BE NO MORE THAN 10 INCHES H_2O AT CONNECTION 1[illegible].
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 50 FT. PIPE RUNS.
12. LOCATE THE INTAKE & EXHAUST SO THAT EXHAUST HEAT DOES NOT ENTER INTAKE.
13. PREPARE & PAINT INSIDE OF INTAKE PIPE WITH RUST-OLEUM OR EQUIVALENT COATING SYSTEM IN ACCORDANCE WITH THEIR DIRECTIONS FOR INTAKE PIPES.
14. EXHAUST MUFFLER TAIL PIPE IS TO BE EXTENDED TO AN OUTLET LEVEL ABOVE EAVES.
15. CLEAN PIPES AFTER WELDING & PRIOR TO ASSEMBLING.

PROJECT ENGR. A. R. [illegible]

CUSTOMER TEXAS UTILITES SERVICES INC.

CUSTOMER REF. COMANCHE PEAK UNITS 1 & 2

ENGINE NO. 76001-04

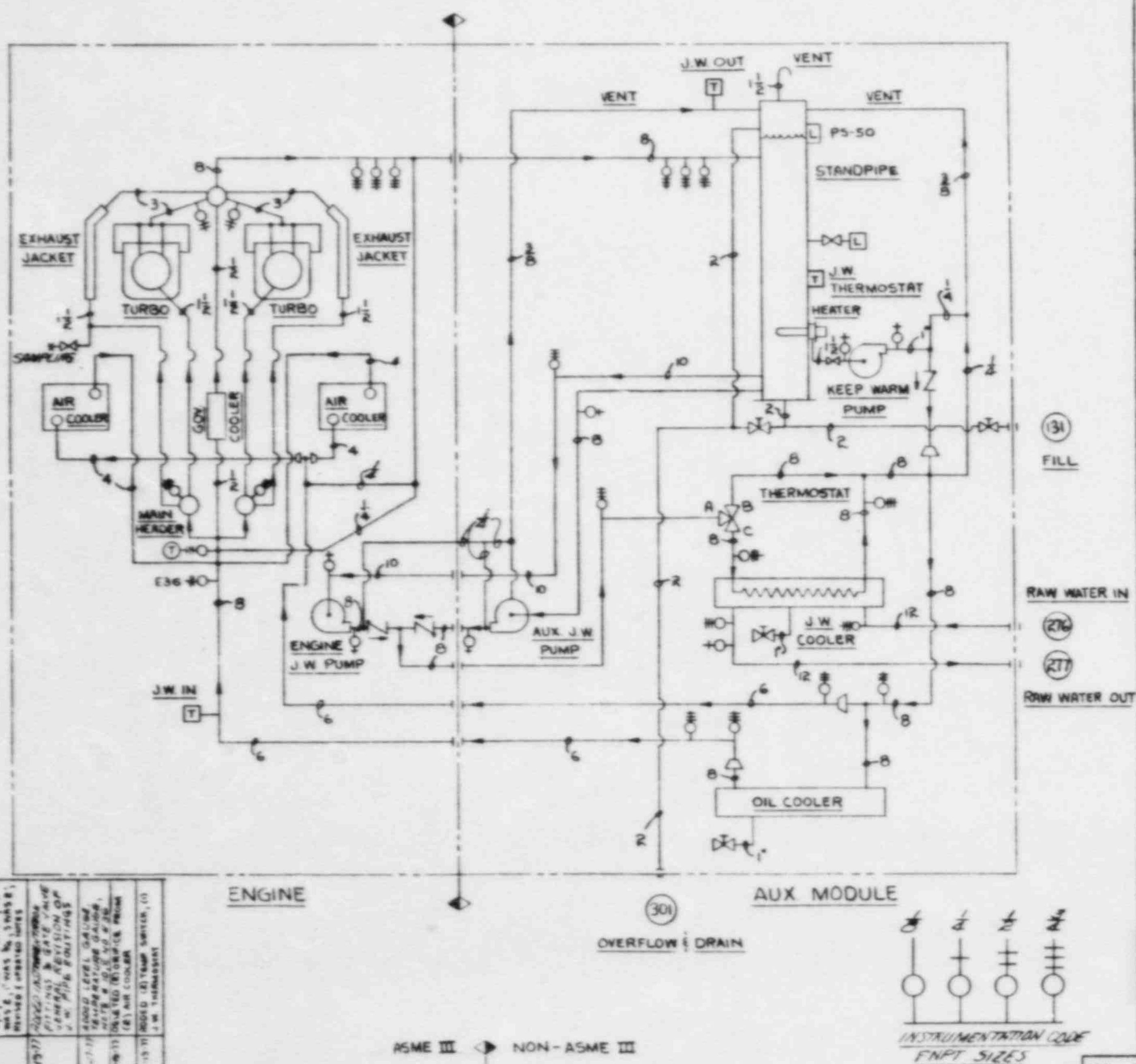
DELAVAL

EXHAUST, INTAKE & CRANKCASE PIPING SCHEMATIC

APP [illegible]	DWN [illegible]	09-805-76001	C
SCALE NONE	CKD [illegible]		

CHG	DATE	REMARKS
A	[illegible]	[illegible]
	[illegible]	ADDED CONTROL [illegible] E28, E32, E59 [illegible]
	[illegible]	[illegible]

1. ALL ITEMS AND PIPING SH[illegible] 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. PROVIDE SUCH VENTS AND DRAINS AS DEEMED NECESSARY BY DELAVAL ENGINEERING.
8. INSTALLATION CONTRACTOR(S) TO SUPPLY ALL OFF-ENGINE PIPING, PIPING FITTINGS, EQUIPMENT & VALVES NOT SUPPLIED WITH ENGINE-MODULE.
9. CLEAN PIPES AFTER WELDING AND PRIOR TO ASSEMBLING.
10. UNLABELED INSTRUMENTATION CONNECTIONS ARE NOT USED AND ARE PLUGGED. THESE ARE STANDARD ON DELAVAL ENGINES FOR USE AS REQUIRED.



CHG	DATE	REMARKS
A	[illegible]	[illegible] REVISED & UPDATED NOTES
B	[illegible]-77	ADDED INSTRUMENTATION FITTINGS & GATE VALVE GENERAL REVISION OF J.W. PIPE ROUTINGS
C	8-[illegible]-77	ADDED LEVEL GAUGE, TEMPERATURE GAUGE, NOTE # 10 & NOTE # 3
D	9-6-77	DELETED (2) ORIFICE FROM (2) AIR COOLER
E	11-15-77	ADDED (2) TEMP SWITCH, (1) J.W. THERMOSTAT

PROJECT ENGR. [signature]

CUSTOMER TEXAS UTILITES SERVICES, INC.

CUSTOMER REF. COMANCHE PEAK UNIT 1 & 2

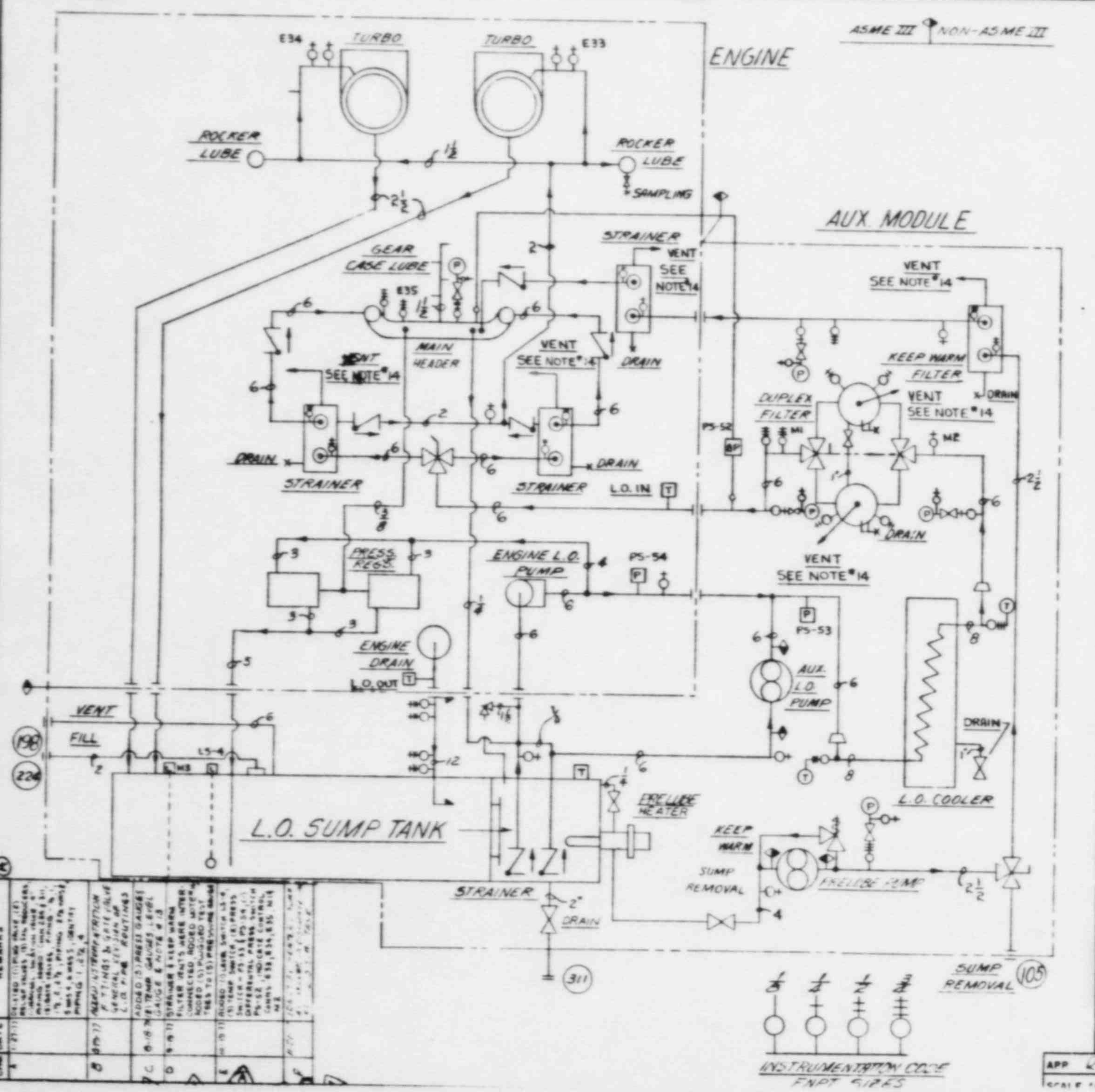
ENGINE NO. 76001-04

DELAVAL

JACKET WATER PIPING SCHEMATIC

APP [illegible] | DWN [illegible] | SCALE NONE | CKD [illegible]

09-810-76001 E



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. PROVIDE SUCH VENTS AND DRAINS AS DEEMED NECESSARY BY DELAVAL ENGINEERING.
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 PIPING TO BE MECHANICALLY CLEANED AFTER WELDING AND PRIOR TO ASSEMBLING.
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. PRECAUTIONS FOR LUBE OIL SYSTEM, DELAVAL FORM D-4597 ARE TO BE COMPLIED WITH.
13. UNLABELED INSTRUMENTATION CONNECTIONS ARE NOT USED AND ARE PLUGGED. THESE ARE STANDARD ON DELAVAL ENGINES FOR USE AS REQUIRED.
14. FILTER AND STRAINER VENTS, & O.D. CONNECT INDIVIDUALLY ON LUBE TANK TOP. DO NOT COMBINE VENTS. DO NOT USE VALVES.

PROJECT ENGINEER: A. P. Falk
CUSTOMER: TEXAS UTILITIES SERVICES, INC.
CUSTOMER REF.: COMANCHE PEAK UNITS 1 & 2
ENGINE NO.: 76001-04

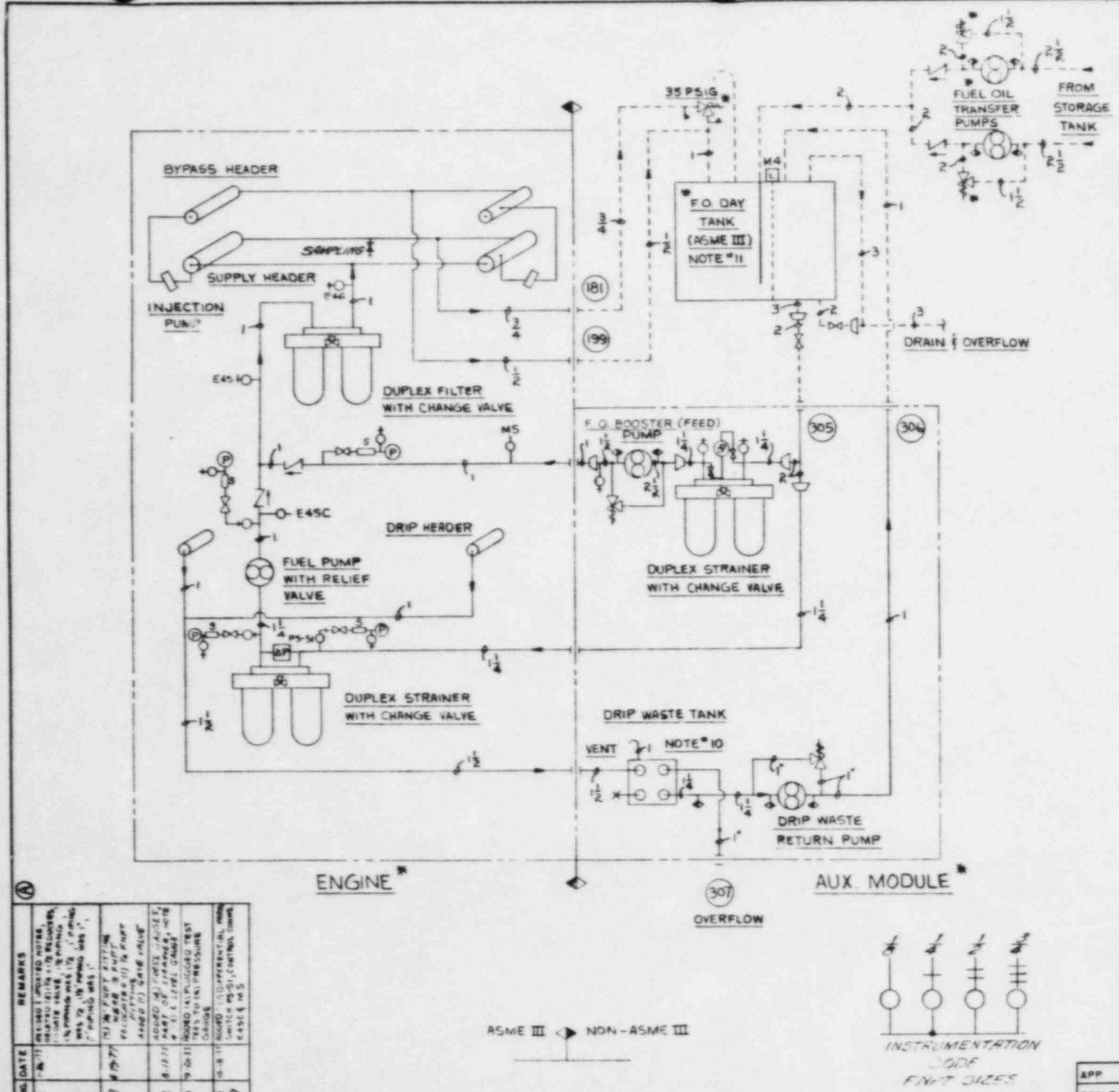
DELAVAL TURBINE INC.
DELAVAL ENGINE AND COMPRESSOR DIVISION
OAKLAND, CALIF. 94621

DELAVAL

LUBE OIL PIPING SCHEMATIC

APP: QBB | DWN | CKD

09-820-76001 | F



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.
6. ALL PIPING TO BE PROPERLY SUPPORTED TO MINIMIZE PIPE VIBRATION & FLANGE LOADING.
7. CUSTOMER TO SUPPLY AND INSTALL ALL PIPING SHOWN IN DOTTED LINE (----).
8. ALL PIPING TO BE MECHANICALLY CLEANED AFTER WELDING AND PRIOR TO ASSEMBLING.
9. 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. VENT MUST NOT BE PIPED: TANK TO BE WELL BELOW DRIP HEADERS.
11. TANK TO BE AT ELEVATION TO PROVIDE FLOODED SUCTION AT BOTH FEED PUMPS.
12. PROVIDE SUCH VENTS AND DRAINS AS DEEMED NECESSARY BY DELAVAL ENGINEERING.
13. UNLABELED INSTRUMENTATION CONNECTIONS ARE NOT USED AND ARE PLUGGED. THESE ARE STANDARD ON DELAVAL ENGINES FOR USE AS REQUIRED.

PROJECT ENGR. A. Rafalk

CUSTOMER TEXAS UTILITIES SERVICES, INC.

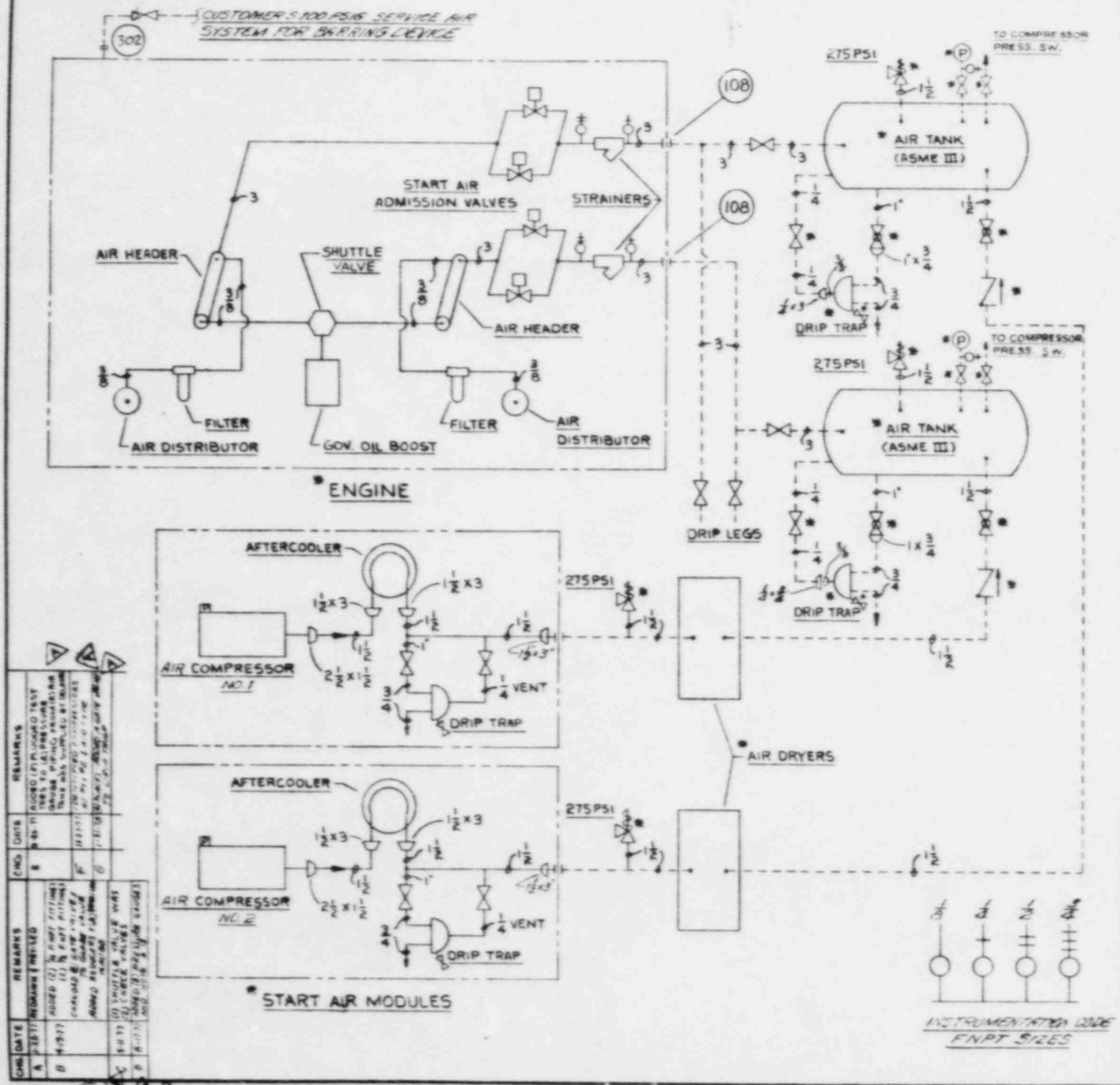
CUSTOMER REF. COMANCHE PEAK UNITS 1 & 2

ENGINE NO. 76001-04

DELAVAL

FUEL OIL PIPING SCHEMATIC

APP	DWN		
APP	DWN RL	09-825-76001	E
SCALE NONE	CKD		



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.
6. ALL PIPING TO BE PROPERLY SUPPORTED TO MINIMIZE PIPE VIBRATION & FLANGE LOADING.
7. CUSTOMER TO SUPPLY AND INSTALL ALL PIPING SHOWN IN DOTTED LINE (---).
8. ALL PIPING TO BE CLEANED INTERNALLY & BLOWN CLEAN PRIOR TO START UP.
9. CUSTOMER PIPING SHOULD BE RUN AT A LOWER LEVEL THAN ENGINE INLET CONNECTION NO. (108). INSTALL MOISTURE COLLECTORS AND DRAINS IN PIPING, AT LOW POINTS NEAR INLET CONNECTION & ANY OTHER LOW POINTS IN SYSTEM.
10. CUSTOMER PIPE SIZES ARE MINIMUM FOR MOST INSTALLATIONS, BUT MAY VARY IF LENGTH OF PIPING, NUMBER OF FITTINGS & VALVES RESULT IN EXCESSIVE PRESSURE DROP. 10 PSI MAX. PRESSURE DROP FROM AIR TANK TO ENGINE HEADER.
11. ALL PIPING TO BE SCHEDULE 80 & PIPE FITTINGS TO BE "300 LBS. ASA" FOR 275 PSI WORKING PRESSURE.
12. "Y" STRAINERS MUST BE INSTALLED IN A HORIZONTAL RUN OF PIPE.
13. UNLABELED INSTRUMENTATION CONNECTIONS ARE NOT USED AND ARE PLUGGED. THESE ARE STANDARD ON DELAVAL ENGINES FOR USE AS REQUIRED.

CERTIFIED PRINT MUST BE USED FOR CONSTRUCTION

CERTIFICATION

PROJECT ENGINEER A Rafalk

CUSTOMER TEXAS UTILITIES SERVICES INC

CUSTOMER REF COMANCHE PEAK UNITS 1 & 2

ENGINE NO 76001-04

DELAVAL TURBINE INC
ENGINE AND COMPRESSOR DIVISION
OAKLAND, CALIFORNIA 94621

DELAVAL

STARTING AIR PIPING SCHEMATIC

DRAWN RL 1-28-77	09-835-76001	G
CHECKED C.P. 2/7/77		
APPROVED		
SCALE NONE	DRAWING NUMBER	ALT

LILCO

LONG ISLAND LIGHTING COMPANY

SHOREHAM NUCLEAR POWER STATION

P.O. BOX 618, NORTH COUNTRY ROAD • WADING RIVER, N.Y. 11792

Direct Dial Number

April 27, 1984 TDI-20

H. R. Denton, Director
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

50-445/446

Dear Mr. Denton:

Your letter of February 28, 1984 requested certain information relating to the TDI Diesels from the TDI Owners' Group, the majority of which have been responded to. The last request outstanding from this letter is for a copy of the Engine Instruction Manual for each of the TDI Owners' Group Diesel Engines.

Accordingly, enclosed please find one copy each of the TDI Engine Instruction Manual for all TDI Owners' Group Diesel Engines with the exception of River Bend (Gulf States Utilities). We are attempting to obtain the Instruction Manual for this plant and will forward it to NRC on receipt. This manual is presently under revision and the copy which will be forwarded to NRC will not incorporate all changes.

As indicated on the cover of the Shoreham Instruction Manual, that document is also being revised and does not incorporate all changes. Please note that these engine manuals are continually revised to incorporate TDI recommended changes as well as utility modifications.

Very truly yours,

W. J. Museler FOR

W. J. Museler
Technical Program Director
TDI Diesel Generator Owners' Group

enclosure

RA/vf

cc: C. Berlinger
R. Caruso
W. Laity (Battelle Pacific
Northwest Lab.)

B031
1/1

8405020029