U.S.NRC

United States Nuclear Regulatory Commission

Protecting People and the Environment

Chapter 14

SOME OTHER ENGINES

HRTD
Human Resources
Training & Development

Learning Objectives

As a result of this chapter you will be able to:

1. Recognize basic similarities and differences between the engines that power EDGs at nuclear power plants.
2. Use the tabulation at the end of this chapter to identify EDGs and associated equipment at each nuclear power plant.

EMD EDG Engines

- 2-stroke cycle Vee
- Intake ports, 4 exhaust valves
- Gear-driven turbocharger for scavenging and turbocharging
  - Overriding gear/clutch to disengage from engine drive
- Unit fuel pump/injectors – no high pressure fuel lines from pumps to injector nozzles
- Overhead camshafts – no pushrods
  - Operate exhaust valves and unit fuel pump/injector rocker arm assemblies directly

EMD EDG Engines (con't)

- Cylinders – directly opposite each other via fork-and-blade piston connecting rods
  - Common connecting rod bearing on a single crankshaft journal
- Connecting rods – no drilled oil passage to provide lube oil from journal bearing to wrist pin bearing
- Lubrication and cooling of pistons from frame-mounted aimed jet oil spray into each piston
- Figure 14-1 is an EMD Engine cross-section.

Figure 14-1 is an EMD Engine cross-section.

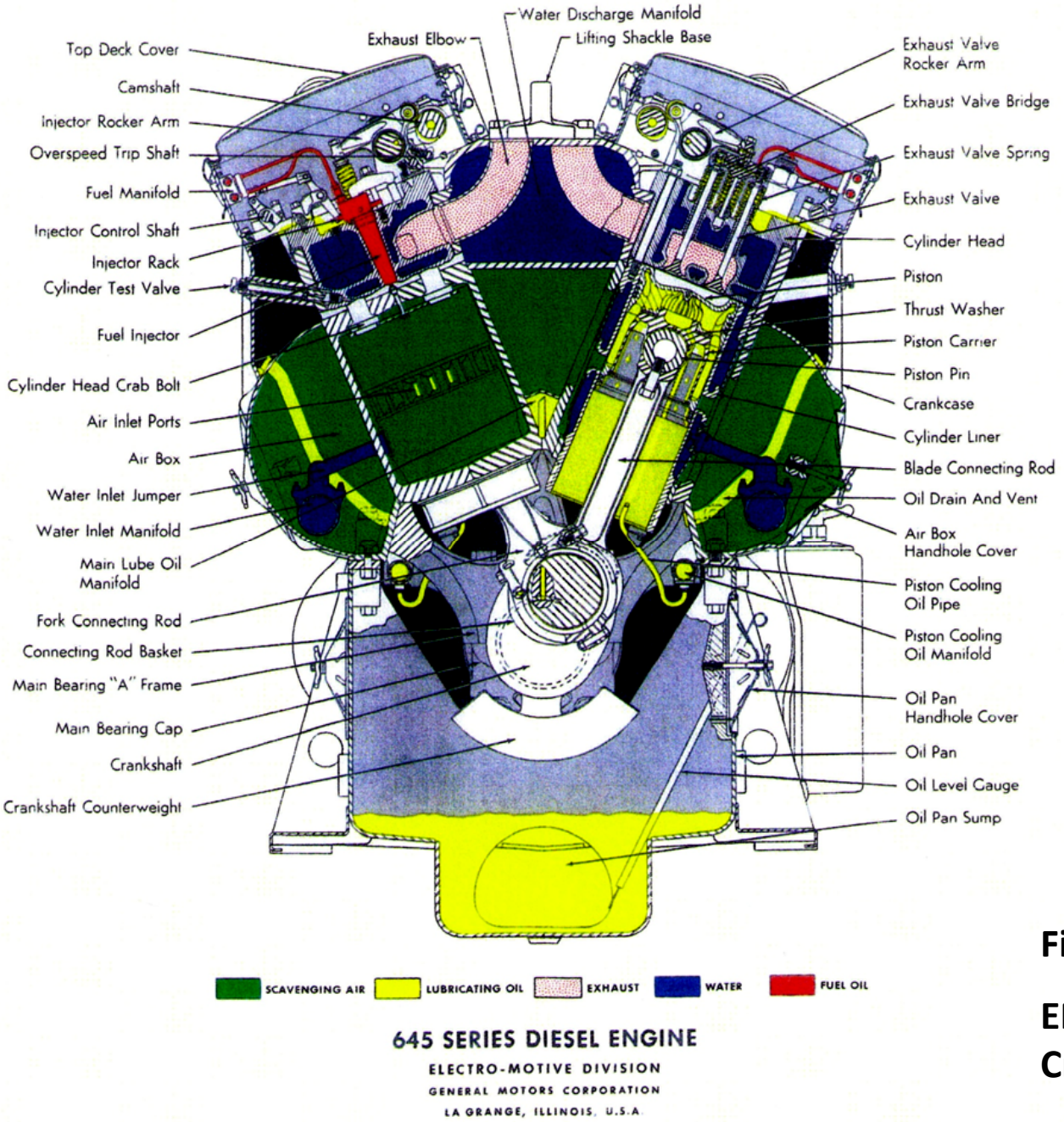


Figure 14-1

EMD Cross-Section

Figure 14-2 is an EMD general service data sheet.

EMD 645 ENGINE
GENERAL DATA

Engine Type	Two-Stroke Cycle, Vee
Bore & Stroke	9 1/16 by 10 inches
Angle between Banks	45 degrees
Compression Ratio	14.5:1
Displacement per Cylinder	645 cu. inches
Rotation (facing rear end)	Counterclockwise
Firing Order (20-cylinder)	1, 19, 8, 11, 5, 18, 7, 15, 2, 17, 10, 12, 3, 20, 6, 13, 4, 16, 9, 14
Main Bearings	4
Scavenging	Turbo-Centrifugal
Cooling System	Pressurized
Water pumps	Centrifugal
Lubricating oil system	Full Pressure
Main Oil Pump & Piston Cooling Pump	2 Positive Displacement Pumps in 1 Housing; Siamesed Inlet; Double Discharge
Scavenging Oil Pump	Helical Gear Type
Fuel Pump/Injector	Unit Pump/Injector with Needle Valve
Engine Starting	Air or Electric Motors
Rating at 900 rpm	2500 KW
Idle/Rated Speed	450/900 rpm

Figure 14-2

EMD Engine Data Sheet

Cooper EDG Engines

- 4-stroke cycle Enterprise "KSV" V16 and V20 cylinder engines
- Figure 14-3 is a diagram of the Cooper engine articulating connecting rods and bearings.

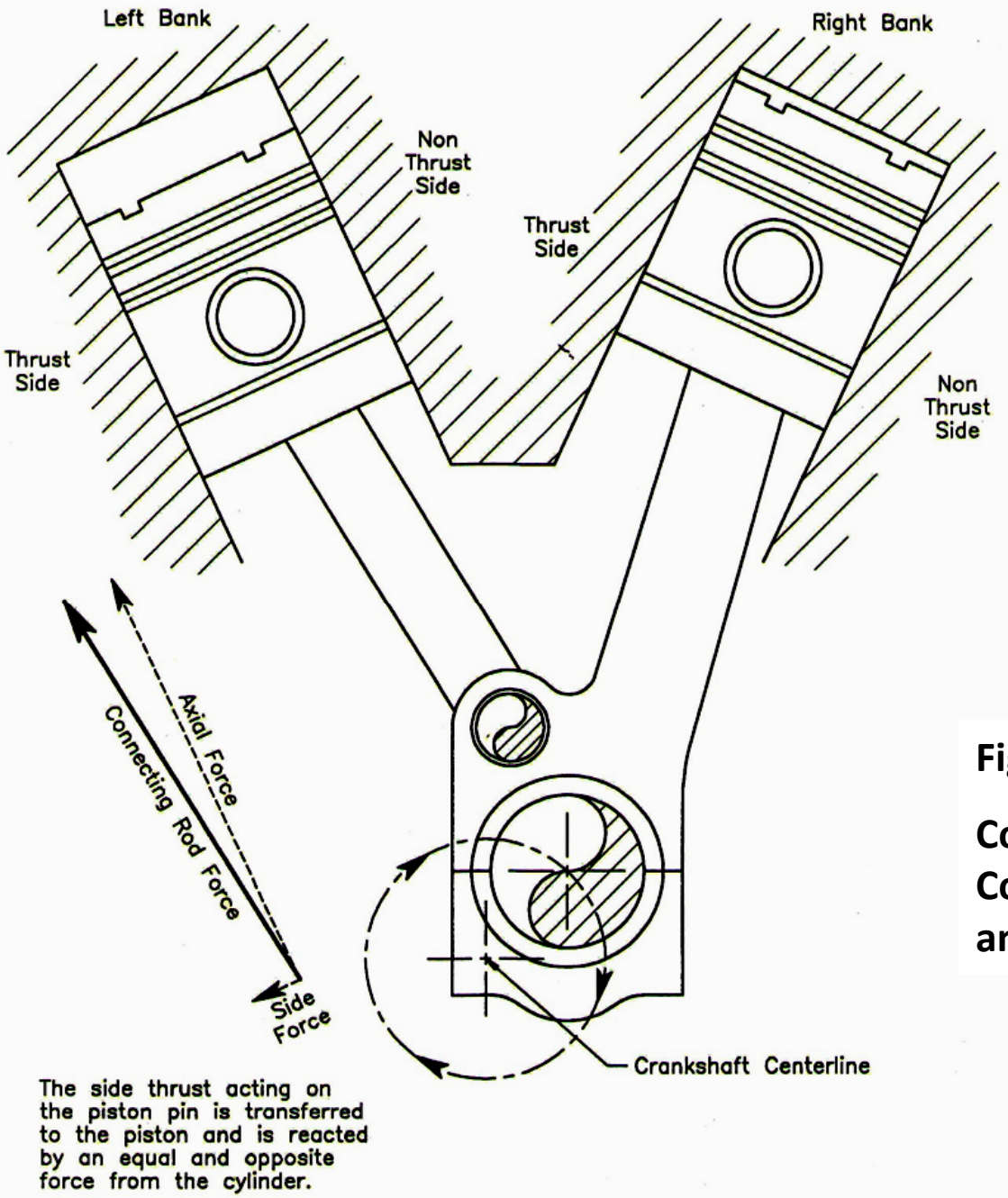


Figure 14-3

Cooper Engine Connecting Rods and Bearings

Cooper crankcase explosion events (see 12.6)

Figure 14-4 is a copy of the Cooper engine service data sheet.

Figure 14-5 is a Cooper engine cross-section.

COOPER ENGINES
GENERAL DATA

	KSV-16-T	KSV-20-7
Engine Type	4-stroke cycle	4-stroke cycle
Cylinders	16	20
Bore	13.5 inches	13.5 inches
Stroke	16.5 inches	16.5 inches
RPM	600	600
KW	4000	5000
BHP	5580	6948
Max. PFP (PSI) Average	1690	1690/1850
Max Exhaust Temperature	980°F	905°F

Figure 14-4 Cooper Engine Data Sheet

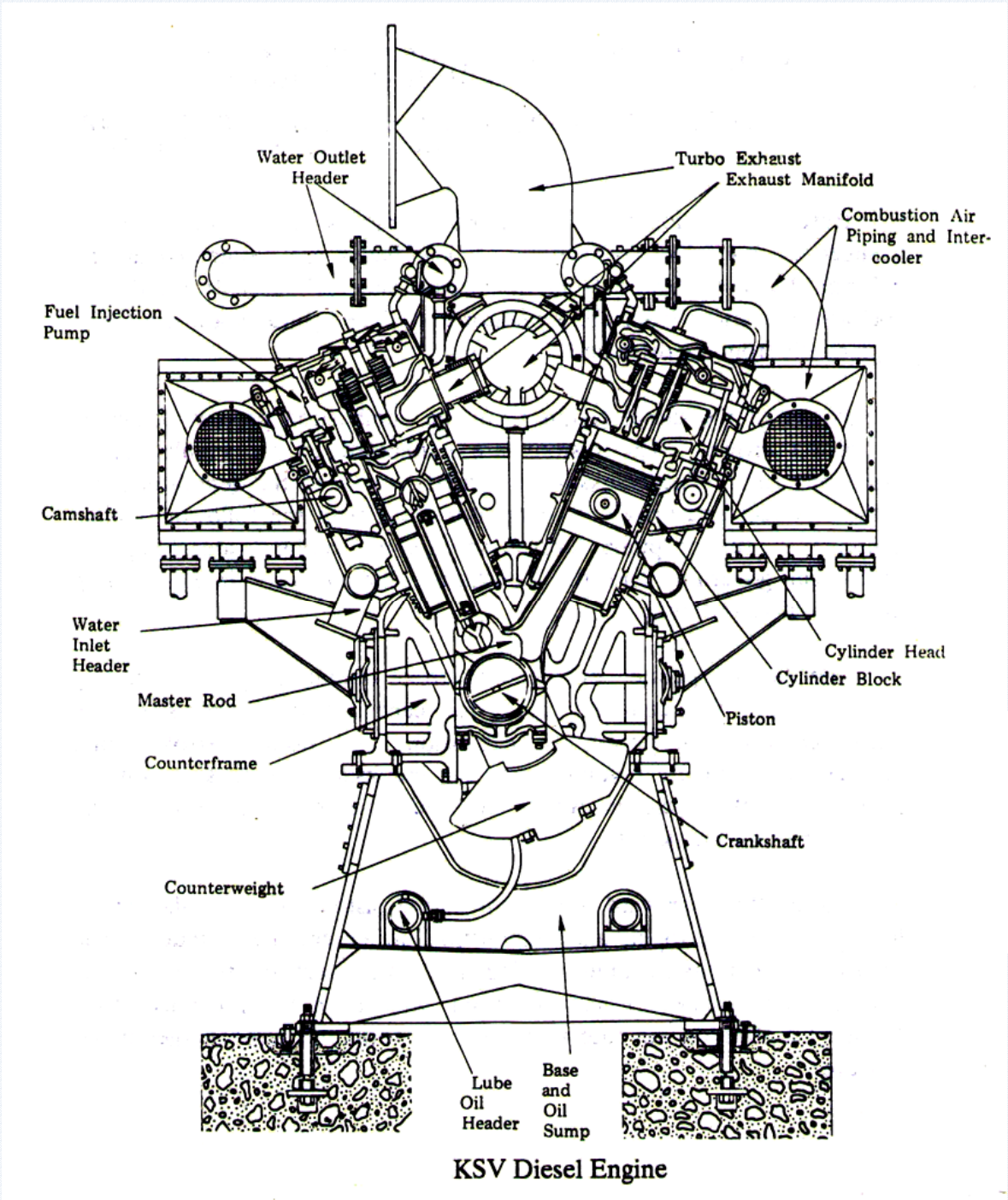


Figure 14-5

Cooper KSV Engine Cross-Section

Figure 14-7 is a Cooper engine timing bar graph. This is typical for all 4-stroke cycle engines.

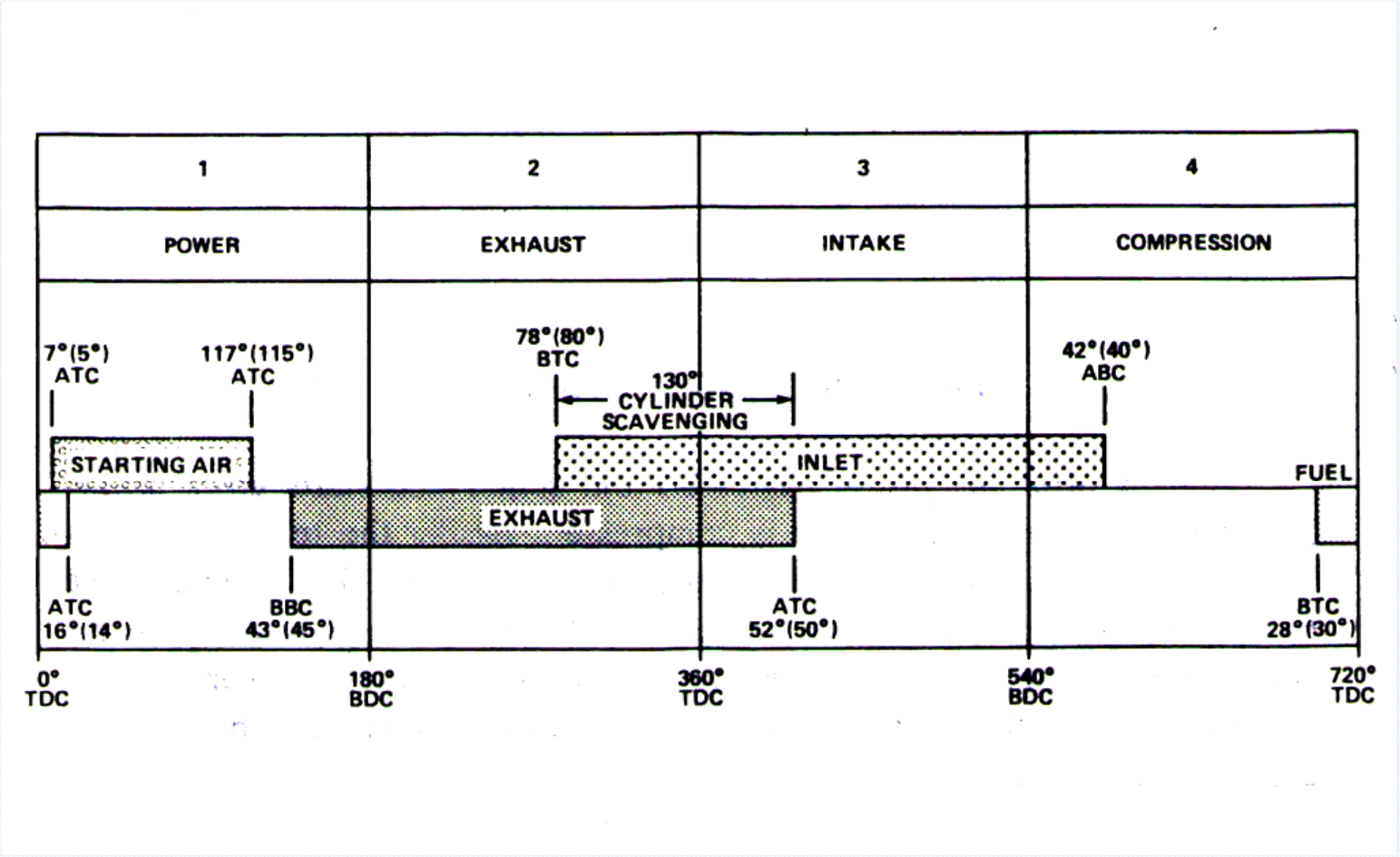


Figure 14-7 Cooper Engine Timing Bar Graph

Nordberg EDG Engines

- 4-stroke cycle Vee
- Unique linkshaft cam shifting mechanism
  - Advances fuel injection timing
  - Advances air inlet valve closure
  - Illustrated in Figure 14-8

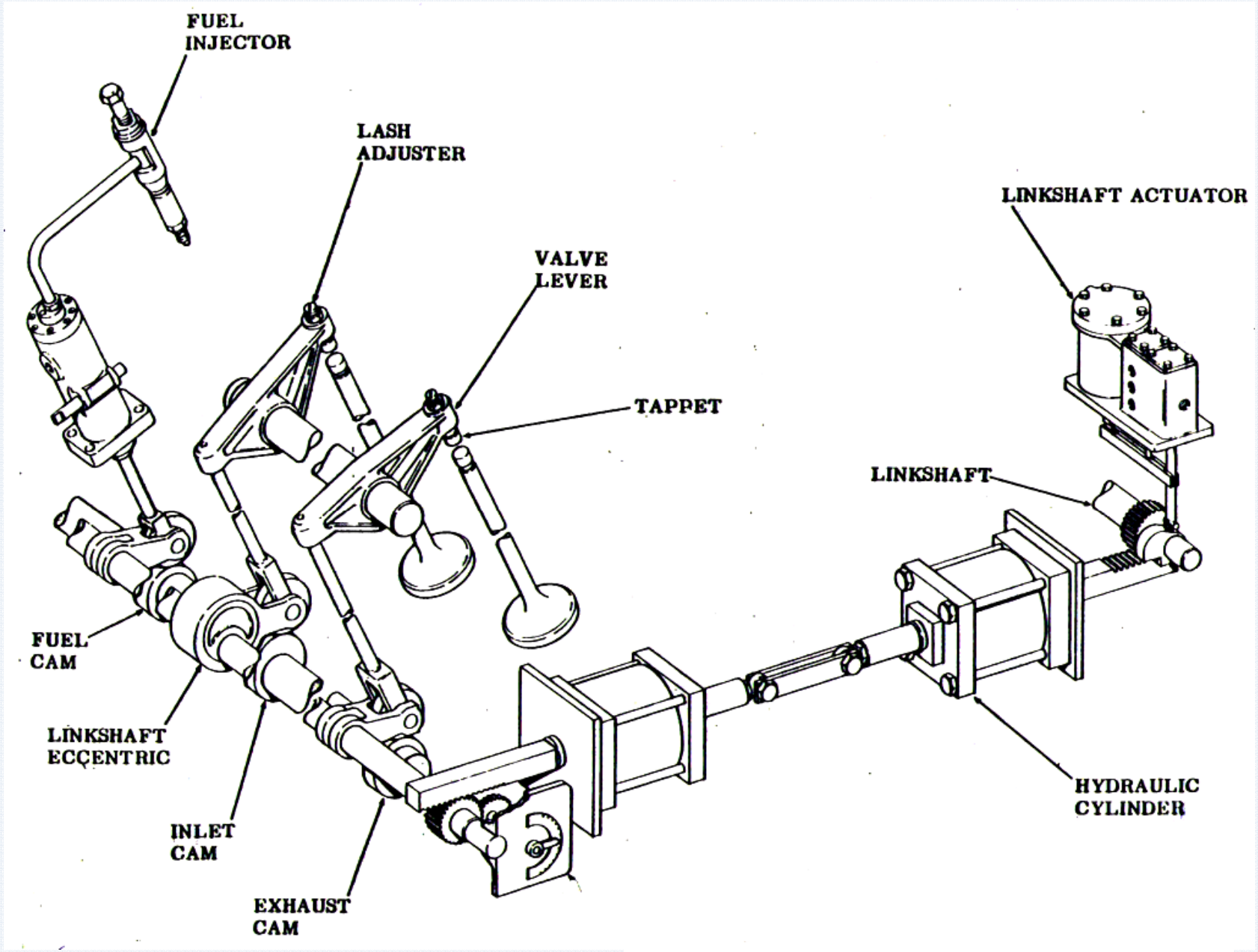


Figure 14-8 Nordberg Engine Linkshaft

Nordberg engine service data is illustrated in Figure 14-9.

Nordberg operating pressures and temperatures are illustrated in Figure 14-10.

NORDBERG ENGINES

GENERAL DATA

Engine Type	Four-Stroke Cycle, Vee
Rated and Idling Speed	514 RPM
Number of Cylinders	16
Bore	13 ½ inches
Stroke	16 ½ inches
Rated Horsepower	4900 BHP
Rotation	Counterclockwise
Firing Order	1r-8l-6r-2r-7l-5r-4l-8r-1l-3r-6l-7r-2l-4r-5l
Electrical Ratings	4812 KVA at 0.8 Power Factor 3850 KW
Flywheel Markings	One Degree Equals 0.593 inch

Note: A torsional critical speed analysis has been made for this engine. This analysis shows the engine to be free from harmful torsional criticals throughout normal operation. Engine idle speed should be at 514 rpm.

Should it become necessary for minor repairs of maintenance work to operate the engine with the fuel is out from any given cylinder, this may be done provided the fuel out from no more than one cylinder at a time.

Figure 14-9

Nordberg Data Sheet

NORDBERG ENGINES
Recommended Operating Temperatures and Pressures
for Straight Oil Engines Rated at 200 BMEP

Temperatures (Degrees Fahrenheit)	Minimum	Maximum
Inlet Manifold Air	120	150
Jacket Water from Engine	165	175
Lubricating Oil from Engine	160	170
Cooling Water from Turbocharger		190
Exhaust (Pre-turbine)	940	1020
Exhaust (Individual)	675	775
Pressures (psi)		
Compression	830	880
Maximum Firing	1200	1250
Lubricating Oil to Engine	36	42
Fuel to Header	36	42
Jacket Water to Engine	**	35
Starting Air	150	250

** As required to maintain normal 10 to 12° temperature rise across the engine.

Pressures (Inches of Water)		
Crankcase Vacuum	0.2	1.0
Suction before Turbocharger		8
Exhaust Back Pressure		10
Air Inlet Manifold Pressure at 514 rpm (psig) Approximate		
100 percent load		23.5
75 percent load		13.5
50 percent load		7.8

Figure 14-10

Nordberg Data Sheet

Worthington EDG Engines

- 4-stroke cycle
- Opposite side connecting rods offset on single crankshaft journal
- Design problems with high pressure fuel lines
  - 90 degree bends
  - Cavitation erosion leaks
- Intended corrective action
  - Replace with double-wall, high pressure flex tubing
  - Route the fuel line tubing so as to avoid sharp bends

Figure 14-12 is a Worthington engine cutaway.

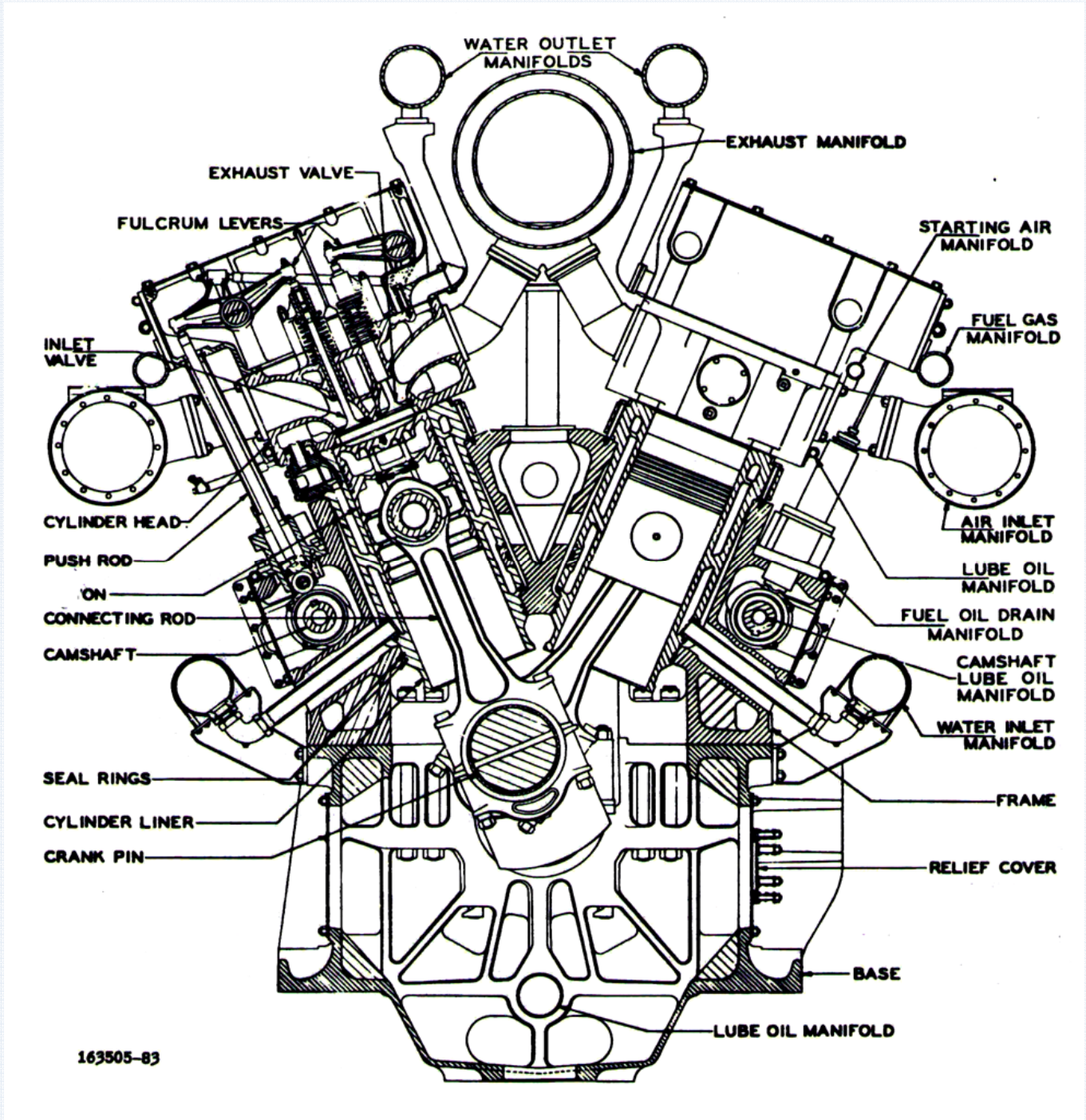
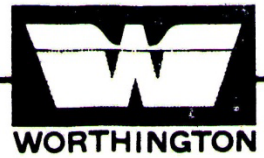


Figure 14-12

Worthington Engine Cross-Section

Figure 14-13 is a Worthington engine general service data sheet.

Figure14-14 is a Worthington engine circle timing diagram. Typical for 4-stroke cycle engines.



ENGINE SPECIFICATION

P. O. #0233-821-9

TYPE SWB VEE DIESEL ENGINE

BORE 14½ STROKE 18

NO. OF CYLINDERS 12

STANDARD RATING

BRAKE HORSEPOWER 4900

RPM 514

BMEP 211 PSI

ELEVATION SEA LEVEL

ROTATION COUNTERCLOCKWISE WHEN VIEWING FLYWHEEL FROM FLYWHEEL END

FIRING ORDER 1F-6R-5F-2R-3F-4R
6F-1R-2F-5R-4F-3R

SERIAL NUMBER VO-3669-70-71-72

DRIVEN EQUIPMENT DIRECT DRIVE GENERAL ELECTRIC ENGINE TYPE 4375 KVA, 3500KW, 3 PHASE, 0.8 P.F., 60 CYCLE, 4160 VOLT GENERATOR AND A SUITABLY RATED BRUSHLESS EXCITER.

WORTHINGTON CORPORATION
COMPRESSOR and ENGINE DIVISION • BUFFALO 5, NEW YORK

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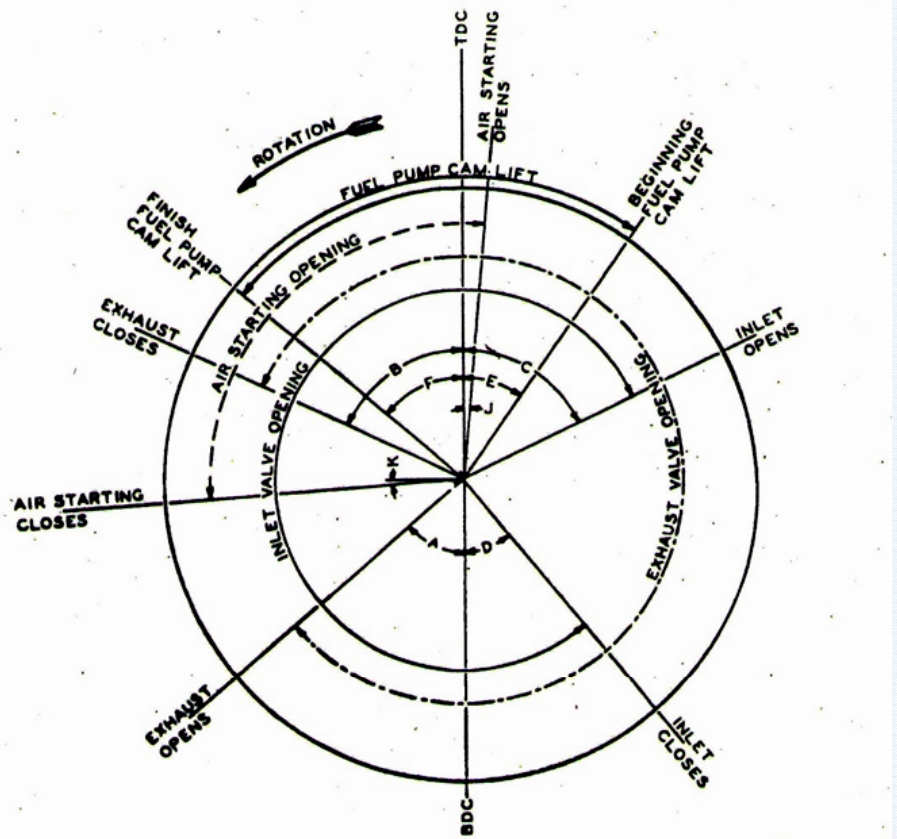
Figure 14-13

Worthington Data Sheet



TIMING DIAGRAM

A.	Exhaust Valve opens	50	Deg. B.B.D.C.
B.	Exhaust Valve closes	65	Deg. A.T.D.C.
C.	Inlet Valve opens	65	Deg. B.T.D.C.
D.	Inlet Valve closes	40	Deg. A.B.D.C.
E.	Fuel Pump Lift begins	35° - 30'	Deg. B.T.D.C.
F.	Fuel Pump Lift ends	50° - 04'	Deg. A.T.D.C.
J.	Starting Air opens	6° - 30'	Deg. B.T.D.C.
K.	Starting Air closes	116° - 30'	Deg. A.T.D.C.
	Fuel Pump Port Closing	16.5	Deg. B.T.D.C.

Figure 14-14

Worthington Timing Diagram

SACM EDG Engines

- 4-stroke cycle
- 2 engines connected in tandem to power a single generator
  - Governors permit load sharing
- Synthetic lube oil incompatibility with water in blowby gases
  - Hard deposits behind piston rings
  - Scuffing scoring of pistons & cylinder liners
- Rebuilt engines and used mineral-based lube oil to correct problem

Figure 14-15 is a SACM engine general service data sheet.

Figure 14-16 is a SACM generator general service data sheet.

EMERGENCY DIESEL GENERATOR DESIGN DATA

DIESEL ENGINE

MANUFACTURER	SACM DIESEL
MODEL/TYPE	UD 45 V16 S5D
QUANTITY	TWO PER GENERATOR SET
CYCLE	FOUR
CONTINUOUS FULL-LOAD RATING	2,785 KW PER ENGINE (GROSS LOADS)
SHORT-TIME RATING	3,064 KW PER ENGINE (GROSS LOADS)
RATED ENGINE SPEED	1,200 RPM
CYLINDER ARRANGEMENT	VEE AT 50°
NUMBER OF CYLINDERS	16

Figure 14-15 SACM Data Sheet

EMERGENCY DIESEL GENERATOR DESIGN DATA

DIESEL GENERATOR

MANUFACTURER	JEUMONT-SCHNEIDER
TYPE	SAT 100/100/6
CONTINUOUS FULL-LOAD RATING	5,400 kW (NET ELECTRICAL OUTPUT)
SHORT-TIME RATING	5,940 kW (NET ELECTRICAL OUTPUT)
POWER FACTOR (AT CONTINUOUS RATING)	0.8
RATED VOLTAGE	4,160 V
FREQUENCY	60 Hz
kVA (AT CONTINUOUS RATING)	6,750
LINE CURRENT (AT CONTINUOUS RATING)	938 AMPS

Figure 14-16 Data Sheet

DeLaval EDG Engines

- 4-stroke cycle Enterprise RSV 16 cylinder
- Same design as Cooper engines, but much larger
- Largest engine in EDG service
- Each piston at peak loading:
  - 340,000 lbs. 225 times/minute
  - These forces are resolved within the engine structure and output shaft as follows:
    - Power output
    - Friction Losses
    - Compression and exhaust expulsion for other cylinders

DeLaval engine service data is in Figure 14-17.

Figure 14-18 is a DeLaval engine cross section.

DELAVAL ENGINES

GENERAL DATA

Engine Type	Four-Stroke Cycle, Enterprise DRS Vee
Rated Speed	450 RPM
Number of Cylinders	16 (2 banks of 8 cylinders in a Vee)
Bore	17 inches
Stroke	21 inches
Piston Speed	575 fpm
Rated Horsepower	667 BHP per cylinder (515 kw)
BMEP	250 psig
Engine Peak Firing Temperature (rated load)	1750^{O} F.
Engine Peak Firing Pressure (rated load)	1500 psig*

*This 1500 psi peak firing pressure acting on the pistons top surface area loads the piston with 340,000 pounds 225 times each minute.

Figure 14-17

DeLaval Data Sheet

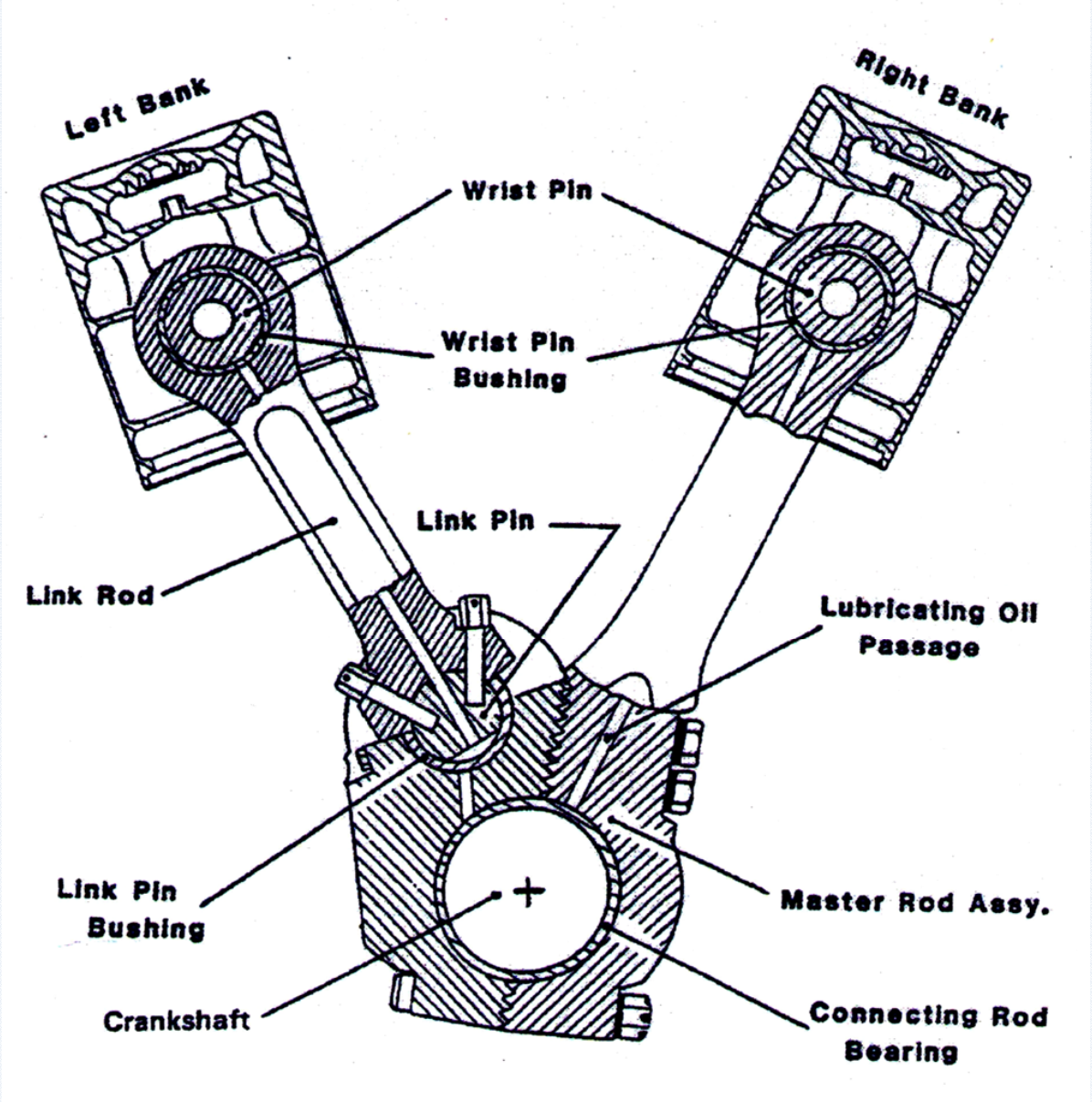


Figure 14-18 DeLaval Engine Articulating Connecting Rod Assembly

Note the tabulation at the end of this chapter identifying the EDGs and associated equipment at most nuclear power plants.

END OF CHAPTER 14