BWR POWER PLANT TRAINING

Attachment 1

Revision 5

Issued 10/14/74

A. EMERGENCY POWER - DIESEL GENERATORS AND BATTERIES

B. REFERENCES

1. Design Documents

   a. P&ID M-173

   b. Electrical Schematics 12E2430, 12E2350-12E2357, 12E2389

2. Equipment Manual Chapter 10

3. SAR - Section 8.2.3

4. Technical Specifications, Section 3.9.C & 3.9.D

5. Western Engine Company Diesel Manual

6. GM Electro-Motive Power Manual

C. OBJECTIVES

1. Learn design basis for Diesel Generators.

2. Be familiar with auxiliary systems supplying Diesel Generators.

3. Know load requirements for accident and loss of normal power conditions.

4. Be familiar with local manual start procedure and sequence of events.

5. Learn Diesel Generator trips.

6. Learn basic 250V DC power distribution.

7. Learn basic 125V DC power distribution.

8. Learn basic 24/48V DC power distribution.

9. Learn technical specifications associated with the Diesel Generators and the batteries.

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D. BRIEF DESCRIPTION

1. Design basis of diesel generators:

   a. Provides an alternate source of AC electrical power in the event of a loss of all off-site power.

   b. Designed to start and carry the largest vital loads required under postulated accident conditions.

   c. Designed to start automatically within 10 seconds and accept full load within 30 seconds upon loss of all normal power sources.

2. Diesel Generator Description

   a. 20 cylinder, 900 RPM, 2600kw, 4160V, 3Ø, 60 hertz machine.

   b. Either Diesel Generator available to a unit is capable of carrying the ECCS power requirements within the 2 hour, 10% overload rating of the diesel (2860kw).

   c. Either Diesel Generator is capable of carrying all loads necessary for a safe shutdown of the unit.

   d. Auxiliary systems required for Diesel Generator operation

      1) Lubricating oil
      2) Fuel oil
      3) Starting air
      4) Cooling water
      5) Turbocharger

E. COMPONENT DESCRIPTION

1. Diesel Generator Auxiliaries

   a. Lubricating oil (Figure 1)

      1) The scavenging oil pump takes a suction from the engine oil pan, pumps the oil through a filter and cooler, and provides a suction to the piston oil pump and the main oil pump.

      2) The piston oil pump supplies oil for the cooling of the piston and lubrication of the piston pin bearing surfaces.

E. 1. a. Lubricating Oil (Figure 1) (Continued)

3) The main oil pump supplies the other moving engine parts such as the main bearings, gear train, cam shaft, rocker arms, etc.

4) The oil circ pump provides lube oil for the turbocharger. It also provides a small flow back to the main oil system during shutdown operation. This flow, along with the immersion heater in the water system, maintains the main oil system in standby readiness.

b. Fuel Oil System (Figure 2)

1) During start action, the electric driven priming pump supplies fuel oil to the injector system.

2) At > 200 RPM, the electric pump is cut-out and the engine driven fuel pump takes over.

3) The 750 gallon "day" tank provides enough fuel to operate for 4 hours.

4) Fuel must be transferred from the 15,000 gallon Diesel storage tank with the diesel oil transfer pump to continue operation. This is accomplished automatically by level switches on the "day" tank.

5) An emergency fuel cutoff valve is provided in event of a fire or other emergency. It should not be used indiscriminately, as the fuel oil also provides cooling to the injectors, and they may be damaged.

c. Starting Air System (Figure 3)

1) Two air starting motors engage a flywheel ring gear if the starting solenoid valve is energized.

2) Air, supplied by 4 air receiver units, cranks the starting motor.

3) Receiver pressure is maintained at 250# by 2 air compressors.

E. 1. c. Starting Air System (Figure 3) (Continued)

4) At > 200 RPM, the starting solenoid valve is de-energized, interrupting air to the starting motors and venting the pressure off.

5) This causes the air motors to stop and disengage.

6) If system pressure is reduced to 175 psig, sufficient pressure remains to start the Diesel Generator once with no air compressor action.

d. Cooling Water System (Figure 4)

1) Cooling water circulates through cored passages in the cylinder liners and heads. It also supplies the aftercooler on the turbocharger.

2) A constant temperature is maintained by the temperature regulating valve which controls the flow of engine water through the heat exchangers.

3) A bypass line provides fast engine warmup and a constant flow of engine water.

4) Heat exchanger cooling is provided by the Diesel Generator cooling water pumps (located in the crib house).

5) Lube oil is also cooled by the diesel cooling water system.

6) An expansion tank provides a surge volume and makeup capability.

7) Two gear driven centrifugal pumps provide the motive force.

8) A 15 kw immersion heater is provided to maintain the diesel in standby readiness (warmed up).

a) Natural circulation will force the cooling water through the system.
b) The oil cooler now becomes an oil "heater" and the flow from the oil circ pump is warmed to keep the oil system in standby readiness.

E. 1. e. Turbocharger

1) The diesel is turbocharged to force more air into the engine, increasing the power of the engine.

2) The turbocharger is driven by the engine gear train at low loads and by exhaust gas at high loads (>70%).

3) An aftercooler reduces the temperature of the air, increasing its density and allowing more oxygen to be forced into the engine.

F. INSTRUMENTATION

1. Control Room Indications

Instrument	Type	Range
DG 2&2/3 watts	indicator	0 - 3.5 kilowatts
DG 2&2/3 VARS	indicator	-2400 to +2400 kVARS
DG 2&2/3 frequency	indicator	58 to 62 hertz
DG 2 to bus 24-1 current	indicator	0 - 600 amps
DG 2/3 to bus 23-1 current	indicator	0 - 600 amps
DG 2&2/3 voltage	indicator	0 - 5.25 kilovolts

2. Local

Instrument	Type	Range
Starting air pressure	gage	0 - 600#
Lube oil temperature into filter	gage	0 - 250°F.
Cooling water temperature		
engine inlet	gage	50 - 300°F.
engine outlet	gage	0 - 250°F.

F. 2. Local (Continued)

Instrument	Type	Range
Lube oil pressure	gage	0 - 200#
Cooling water pressure	gage	0 - 200#
Fuel oil pressure	gage	100 psig

3. Major Trips & Interlocks

Item	Setpoint	Function
Diesel Generator Hot Engine (High water temperature)	Alarm 190°F. Trip 200°F. (bypassed in ECCS condition)	Shuts down Diesel Generator
Low Water Pressure	<45 psi within 2 min. of reaching 800 RPM (bypassed in ECCS condition)	Shut down Diesel Generator
Low Oil Pressure	<21 psi within 90 seconds after reaching 200 RPM (bypassed in ECCS condition)	Shut down Diesel Generator
High Crankcase Pressure	Causes oil to be dumped to crankcase, Diesel Generator will trip on low oil pressure within 90 seconds. (Bypassed in ECCS condition)	Shut down Diesel Generator and prevent possible fire in crankcase.
Underfrequency when Generator supplying bus	<55 hertz	Shut down Diesel Generator
Engine Overspeed	Flyweight device cuts off fuel injection	Shut down Diesel Generator

F. 3. Major Trips & Interlocks (Continued)

Item	Setpoint	Function
Generator High Differential Current		Shut down Diesel Generator
Diesel Generator Output Breaker		Sequences the starting of ECCS motors to prevent overload.

G. SYSTEM OPERATIONAL SUMMARY

1. Local Start Procedure & Sequence of Events

Note: The Diesel Generator cannot be synchronized from the diesel room. It can only be started and run.

a. Selector switch (local) in manual.

b. Press "Engine Start" pushbutton.

1) This picks up the engine start relay which:

a) Starts fuel priming pump motor.
b) Opens air starting solenoid valve.
c) Starts 15 second timer for engine start failure relay (ESFR).
(1) ESFR will stop the start sequence if 200 RPM is not reached within 15 seconds.
d) Energizes the speed sensing relays so that it may energize the excitation start relay when the engine reaches 800 RPM.
e) Energizes the engine control relay which has a 5 minute dropout time delay to keep the engine running 5 minutes after unloading.
(1) Provides engine cooling.

2) At 200 RPM:

a) ESFR is removed from the circuit.
b) Stops fuel priming pump motor.
c) Closes air starting solenoid valve.
d) Starts 90 second timer.
(1) If oil pressure is not >21 psig in 90 seconds, the diesel is tripped.
e) De-energizes immersion heater.

G. 1. b. Press "Engine Start" pushbutton. (Continued)

3) Engine speed can be controlled by using the governor. Going to "Raise" increases RPM.

4) At 800 RPM:

a) If bearing oil pressure not >51 psig within 2 minutes, we get "Oil Pressure Fault" indicator (alarm only).
b) If water pressure not >45 psig within 2 minutes, the engine is shut down.

2. Local Stop Procedure

a. Decrease frequency using "lower" on governor control switch.

b. Press "Engine Stop" pushbutton.

c. Engine runs for 5 minutes, then shuts down.

3. Remote Start Sequence

a. Diesel selector switch (local) must be in remote.

b. Place Diesel control switch (Panel 8) to "start".

c. Sequence will be the same as local start until 800 RPM.

d. At 800 RPM

1) Voltage Excitation Start relay picks up.
2) Field flashing relay flashes field with 125V DC.
3) Lines up excitation circuit.
4) Starts 2 minute timer for oil and water pressure as in b.4.a) and b).

e. Field flashing is cut out at ≈3300 volts.

f. Speed and/or voltage may be manually adjusted from the control room.

g. The Diesel Generator must be paralleled if the emergency bus is live. It will automatically close onto the bus if it is dead (after the diesel reaches speed and voltage).

G. SYSTEM OPERATIONAL SUMMARY (Continued)

4. A atic Emergency Start Sequence (Control Switch in Auto)

   a. Caused by:

      1) 2# drywell pressure or
      2) -59" reactor water level or
      3) Undervoltage on its emergency bus(es).

   b. Identical to remote start sequence except:

      1) Fast start relay picks up which:
         a) Prevents engine shutdown due to low oil or water pressure, high water temperature, and positive crankcase pressure.

   c. If the emergency bus is energized, Diesel Generator will start upon receipt of 2# drywell pressure or -59" reactor water level signals and run unloaded.

   d. If the emergency bus is de-energized, Diesel Generator will automatically start and close onto the emergency bus.

      1) Closure of the Diesel Generator output breaker interlocks the ECCS loads on that emergency bus so they start sequentially.
         a) Prevents overloading diesel on starting current inrush.

5. Diesel Generator 2/3 Output Breaker Control

   a. Two keylock switches are provided for the operator to select the preferred unit in the event of simultaneous demand for the 2/3 Diesel Generator.

   b. Both switches are normally left in the "Normal" position.

   c. Referring to Figure 5, assume the following conditions.

      1) Both Unit 2 and Unit 3 are operating at power, no ECCS conditions exist. Both keylock switches in "Normal".

         a) Bus 23 to Bus 23-1 breaker(s) would be closed and the b contact would be open in the closing coil circuit.

G. 5. c. 1) Both Unit 2 and Unit 3 are operating at power, no ECCS conditions exist. Both keylock switches in "Normal". (Continued)

b) There is no loss of coolant in Unit 3 so the contact in the closing coil circuit would be closed and the contact in the trip coil circuit would be open.

c) The keylock switch contact in the closing coil circuit would be open and the contact in the trip coil circuit would be closed.

d) Diesel Generator 2/3 to Bus 33-1 breaker is open so the b contact in the closing coil circuit would be closed.

e) The 2/3 Diesel Generator is not at proper speed and voltage so the closing coil contact is open.

f) The closing coil circuit is not complete and the Diesel Generator 2/3 to Bus 23-1 breaker would not be closed.

2) Now assume a complete loss of normal power occurs and bus 23 is de-energized (not on overcurrent).

a) Bus 23 to Bus 23-1 breaker(s) open, closing the b contact in the closing coil circuit.

b) Diesel Generator 2/3 starts and comes up to speed and voltage.

c) All contacts in the closing coil circuit for Diesel Generator 2/3 to Bus 23-1 are now closed and the breaker will close.

d) When the breaker closes, the b contact in Diesel Generator 2/3 to bus 33-1 closing coil circuit opens, preventing that breaker from closing even if Unit 3 loses normal power.

3) Now assume a simultaneous loss of coolant accident and loss of power occurs in Unit 3. Diesel Generator 2/3 is feeding Bus 23-1, both keylock switches are in "Normal", and Unit 3 bus 33-1 is de-energized.

a) As soon as the LOCA signal is received the following action takes place:

G. 5. c. 3) a) As soon as the LOCA signal is received the following action takes place: (Continued)

(1) Diesel Generator 2/3 to Bus 23-1 trip coil is energized, tripping the breaker.
(2) Diesel Generator 2/3 to Bus 23-1 closing coil circuit is opened.
(3) When Diesel Generator 2/3 to Bus 23-1 breaker trips, the b contact in Diesel Generator 2/3 to Bus 33-1 closing coil circuit closes, completing the circuit and the Diesel Generator 2/3 to Bus 33-1 breaker will close.
(4) When the Diesel Generator 2/3 to Bus 33-1 breaker closes, the b contact in the Diesel Generator 2/3 to Bus 23-1 closing coil circuit opens.
(5) The end result is Diesel Generator 2/3 feeding bus 33-1 and bus 23-1 is de-energized.

Note: Diesel Generator 2 and Diesel Generator 3 should have started and closed onto their respective buses.

4) Now assume a LOCA occurs in Unit 2. Both keylock switches are still in "Normal".

a) Upon receipt of the LOCA in Unit 2, the trip coil for Diesel Generator 2/3 to Bus 33-1 is energized, tripping the breaker.

b) Diesel Generator 2/3 to Bus 23-1 closing coil circuit cannot be energized however, and the end result is both Bus 23-1 and Bus 33-1 are de-energized and the Diesel Generator 2/3 is running unloaded.

c) To prevent this, the operator could have placed Unit 3 keylock switch in "Bypass", opening the Diesel Generator 2/3 to Bus 33-1 trip coil circuit and bypassing the Unit 2 LOCA signal. Diesel Generator 2/3 would stay on Bus 33-1. Bus 23-1 would remain de-energized.

d) The operator could also transfer Diesel Generator 2/3 to Unit 2, by placing the Unit 2 keylock switch in "Bypass" and returning Unit 3 keylock switch to "Normal".

(1) As soon as Unit 3 switch was placed in "Normal", the Diesel Generator 2/3 to Bus 33-1 trip coil circuit would be completed and the breaker would trip.
(2) When Diesel Generator 2/3 to Bus 33-1 breaker opened, the closing coil circuit on Diesel Generator 2/3 to Bus 23-1 would be completed, and the Diesel Generator 2/3 would close onto Bus 23-1.

G. 5. c. 4) Now assume a LOCA occurs in Unit 2. Both keylock switches are still in "Normal". (Continued)

e) By following the above procedure, the operator could alternately energize Bus 23-1 and 33-1 as necessary.

d. Refer to the Electrical Distribution Lesson Plan for more information on the keylock switches.

6. Remote Stop Sequence (From Control Room)

a. Reduce generator load with governor.

b. Open Diesel Generator output breaker.

c. Place control switch in "Auto".

d. Diesel Generator will continue to run for 5 minutes, then shutdown.

1) This allows cooling water to cool the turbocharger and engine.

7. Local Stop Sequence

a. Press the "Stop" button.

1) Engine will continue to run for 5 minutes for cooling purposes.

b. In the event of a fire or other emergency situation, the diesel can be stopped immediately by

1) Pulling the fuel injector rack handle. (Preferred method)

2) Closing the emergency fuel shutoff valve. (Can cause overheating of injector tips)

G. 8. Loads supplied by the Diesel Generator are grouped into two main categories as follows:

a. Loads which are required for loss of coolant accident conditions. These loads start automatically upon restoration of emergency bus voltage by the Diesel Generator. (Table 1)

b. Loads required to safely shutdown the plant without equipment damage following a complete loss of normal power from 100% power situation. (Table 2)

In addition to supplying the loads listed, the Diesel Generator System is available on a manual basis, to feed other loads including essentially all of the equipment on buses 23, 24, 23-1, 24-1 of the 4160V system, and lower systems connected to the 4160V system.

H. RELATIONSHIPS WITH OTHER SYSTEMS

1. The Diesel Generators supply backup electrical power to 4kv buses 23, 24, 23-1, 24-1 and 34-1.

2. The Diesel Generator cooling water system utilizes part of the service water piping for return of cooling water.

3. 125V DC supplies field flashing power and the air start solenoid. The Unit 2/3 diesel is supplied by both batteries via an auto transfer switch.

I. TECHNICAL SPECIFICATIONS

1. See Electrical Distribution Lesson Plan.

J. BRIEF DESCRIPTION OF BATTERIES

1. Design Basis of Batteries

a. Designed to supply DC power for various pumps, valves and control power during normal and emergency conditions.

J. BRIEF DESCRIPTION OF BATTERIES (Continued)

2. 250V DC Battery (Figure 6)

   a. Sized to carry its required load for eight hours without recharging.

   b. Consists of 120 individual glass enclosed cells connected in series. A control panel, normal and standby battery chargers, and a distribution network complete the system.

   c. All the loads normally powered by the 250V DC system can be supplied by battery chargers.

   d. Battery chargers can be powered from multiple sources, including the Diesel Generator.

   e. Removable copper links have been provided such that the power supply to the reactor building bus can be manually transferred from the Unit 2 battery (normal source) to the Unit 3 battery (reserve source).

   f. A ground detection device annunciates and records the first ground, making multiple faults unlikely.

   g. Loss of 250V DC would pose no immediate threat to the plant if it is in a normal operating or shutdown condition. However, many backup or emergency systems would be unavailable in an emergency situation.

   h. Both the HPCI and the Isolation Condenser systems would be out of service and the plant would have to be shut down and depressurized to $<$90 psig within 24 hours.

   i. Major loads are listed in Table 3.

3. 125V DC Battery (Figure 7)

   a. Sized with a capacity to supply emergency power for a time deemed adequate to safeguard the plant until normal sources of power are restored.

   b. Consists of 60 individual glass enclosed cells connected in series. A control panel, normal and standby battery charger, and a distribution network complete the system.

J. 3. 125V DC Battery (Figure 7) (Continued)

c. All the loads normally powered by the 250V DC system can be supplied by battery chargers.

d. Battery chargers can be powered from multiple sources, including the Diesel Generators.

e. The Unit 2 turbine building reserve bus is normally supplied from Unit 3 battery and the Unit 3 reserve bus is normally supplied from Unit 2 battery.

f. Copper disconnect links allow the reactor building distribution panels to be fed from either turbine building panel. (Normally turbine building main bus)

g. A ground detection device annunciates and records the first ground, making multiple faults unlikely.

   1) A single fault probably will not render the battery inoperable.

h. The 125V DC system is vital to plant operation as it supplies control power to all 4 kv breakers in the plant. Therefore, all 4160V breakers will fail "as is".

i. Since ECCS logic is DC and energize to function, all ECCS systems will will be disabled. They will not start automatically, and cannot be started manually from the control room.

j. The auto depressurization logic and solenoid valves are 125V DC and would not function to control pressure.

k. The unit diesel (either Diesel Generator 2 or Diesel Generator 3) would not start automatically and the operator could not start it because starting controls, including the solenoid operated air start valve, are DC and energize to function.

   Note: The 2/3 diesel would still be operable because its control power is supplied by either Unit 2 or Unit 3 battery through an auto-transfer switch.

l. The turbine would trip and the reactor would scram, but the generator would not trip. This could cause the generator to motorize, windmilling the turbine.

m. Major loads are listed in Table 4.

J. 4. 24/48V DC Nuclear Instrument Supply System (Figure 8)

a. Provides electrical power for Source and Intermediate Range monitoring systems and some Process Radiation monitors.

b. Consists of two duplicate 24/48V DC systems. Each system consists of two 24 volt batteries connected in series to a distribution panel.

c. Four battery chargers supply the batteries. (Two normally on standby.)

d. Loss of 24/48V DC would cause SRM and IRM Inoperative trips. Loss of both batteries would cause a scram if the mode switch was in Startup.

e. Operator would lose all indication on SRM's and IRMs.

	Equipment	Estimated bhp Required
1.	One Core Spray Pump	860
2.	Two Low Pressure Coolant Injection Pumps	1200 (600 each)
3.	Standby Gas Treatment Equipment	55
4.	AC Powered Valves Required for Emergency Conditions	80
5.	Emergency AC Lighting	35
6.	Diesel Generator Auxiliaries (Cooling Water Pump and Starting Air Compressor)	37
		2267 total bhp

$$\text{kw required} = \frac{2267 \text{ bhp} \times .746}{\text{motor efficiency of } .93} = 1818 \text{ kw}$$

TABLE 1 - LOADS RESTARTING (OR STARTING) AUTOMATICALLY FOLLOWING A LOSS OF COOLANT ACCIDENT

Equipment	Estimated bhp Required
1. One Low Pressure Coolant Injection Pump	600
2. One Containment Cooling Service Water Pump	480
3. Reactor Building Closed Cooling Water Pump	300
4. Three Drywell Cooling Blowers	90 (30 each)
5. Service Water Pump	1000 Hp.
6. Emergency AC Lighting	35
7. Demineralized Water Pump (For Isolation Condenser)	20
8. Essential Instrumentation and Battery Charger	60
9. Diesel Auxiliaries (Cooling Water Pump and Starting Air Compressor)	37
	2632 bhp total

$$\text{kw required} = \frac{2632 \times .746}{\text{motor efficiency of } .93} = 2104 \text{ kw}$$

TABLE 2 - LOADS REQUIRED FOR SAFE SHUTDOWN OF PLANT WITHOUT EQUIPMENT DAMAGE FOLLOWING A COMPLETE LOSS OF NORMAL POWER

TURBINE BUILDING BUS

1. Main Turbine Emergency Bearing Oil Pump - 40 Hp.
2. Emergency Hodrogen Seal Oil Pump - 7.5 Hp.
3. Essential Service System MG Set D-C Drive Motor - 50 Hp.
4. Recirculation MG Set Coastdown Lube Oil Pump - .5 Hp.

REACTOR BUILDING BUS

1. HPCI Turbine Auxiliary Oil Pump - 40 Hp.
2. HPCI Turbine Emergency Bearing Oil Pump - 7.5 Hp.
3. HPCI Turning Gear - 1.5 Hp.
4. Various other valves and components on the HPCI System
5. DC primary containment isolation valves on main steam line drains, shutdown cooling system, cleanup system and isolation condenser

TABLE 3 - MAJOR 250V DC LOADS

TURBINE BUILDING MAIN BUS

1. 4160V Breaker Control (Main feeder breakers to buses 21, 22, 23, 24)
2. 480V Breaker Control (Main feeder breaker to buses 25, 26, 27)
3. DG 2 and DG 2/3 Controls
4. Turbine EHC System
5. Main Generator Controls
6. 345 kv Breaker Control
7. Turbine Building and Control Room DC Lighting

TURBINE BUILDING RESERVE BUS

1. 4160V Breaker Control (Reserve feeder breakers to buses 21, 22, 23, 24)
2. 480V Breaker Control (Reserve feeder breakers to buses 25, 26, 27, 28, 29)
3. 345 kv Breaker Control
4. Turbine EHC System
5. Main Generator Controls

REACTOR BUILDING BUS

1. 4160V Breaker Control (Feeder breakers to buses 23-1, 24-1)
2. 480V Breaker Control (Main feeder breakers to buses 28, 29)
3. Electromatic Relief Valve Controls and Solenoid
4. Reactor Building DC Lighting
5. TIP System Shear Valve Controls
6. HPCI Turbine Controls

TABLE 4 - MAJOR 125V DC LOADS

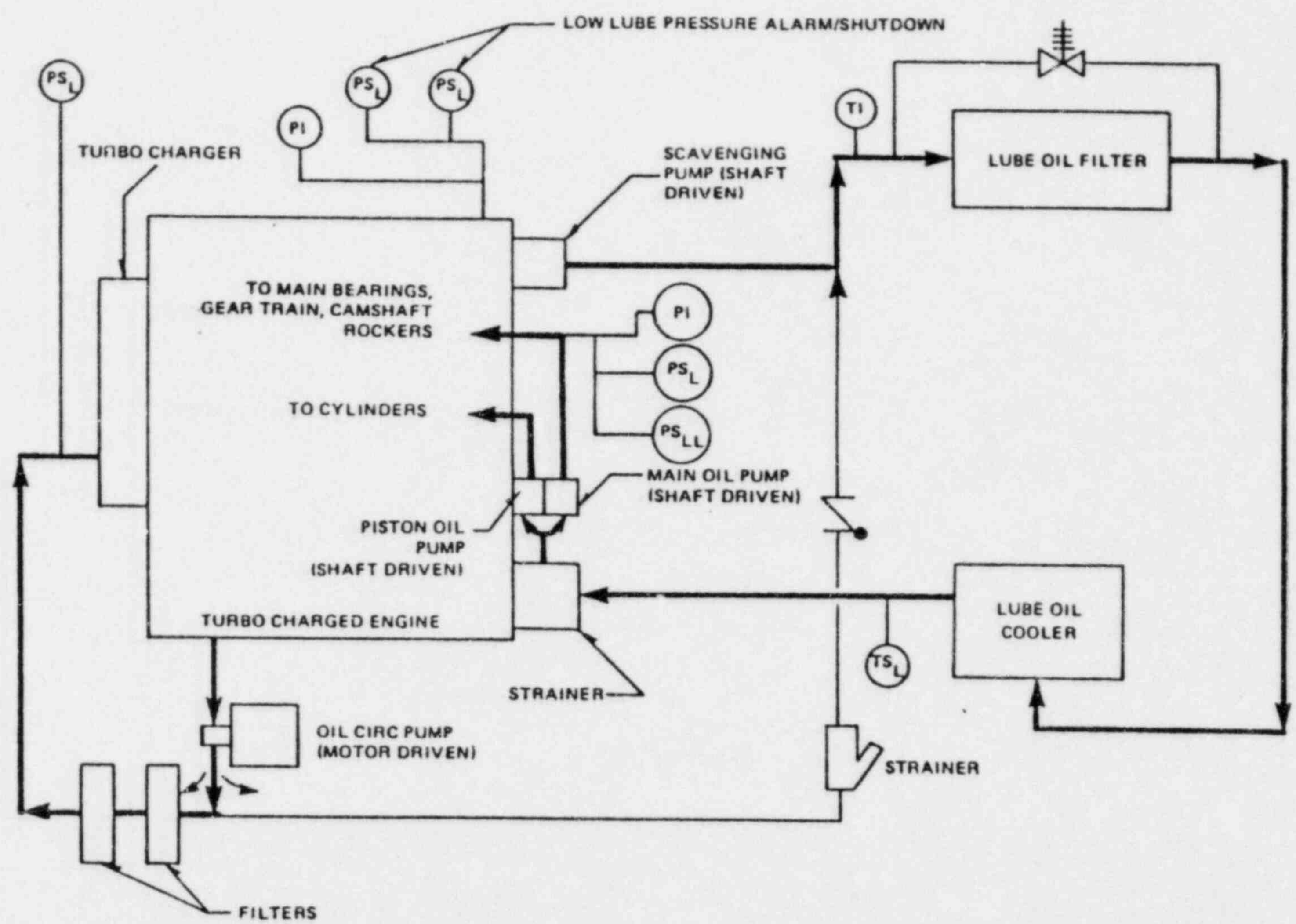

FIGURE 1. ENGINE LUBRICATING OIL SYSTEM

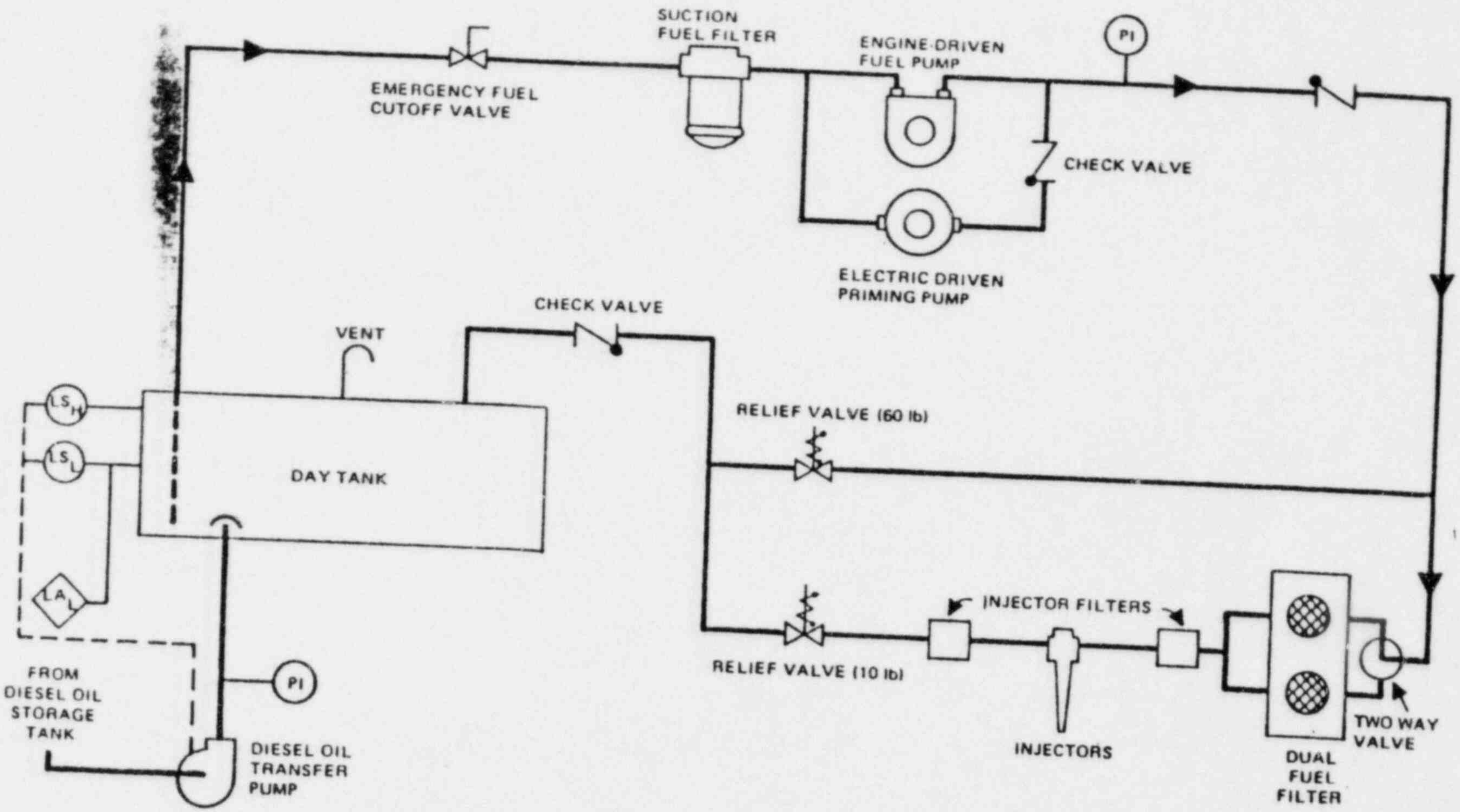

FIGURE 2. DIESEL GENERATOR FUEL OIL SYSTEM

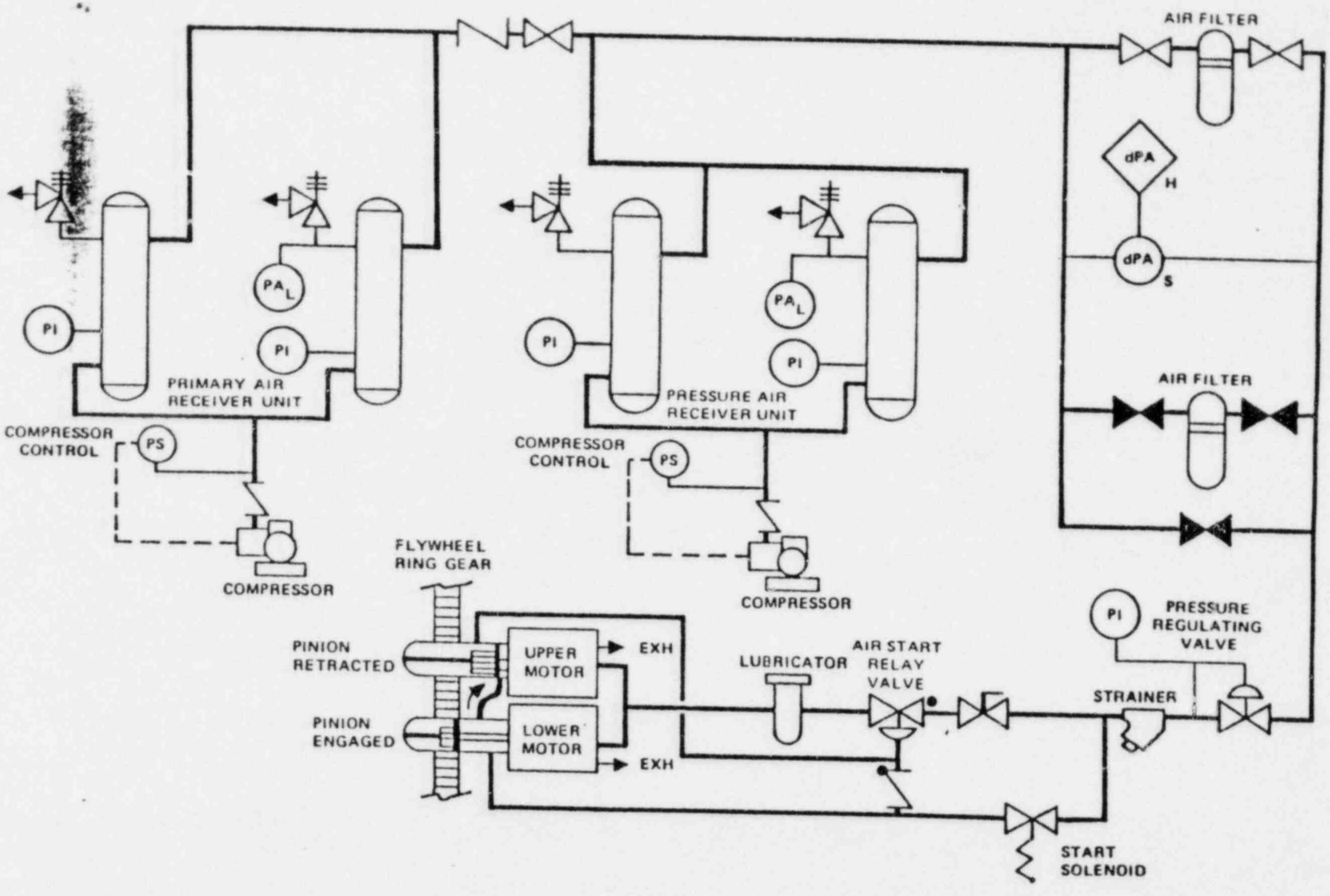

FIGURE 3. DIESEL START-UP AIR PIPING

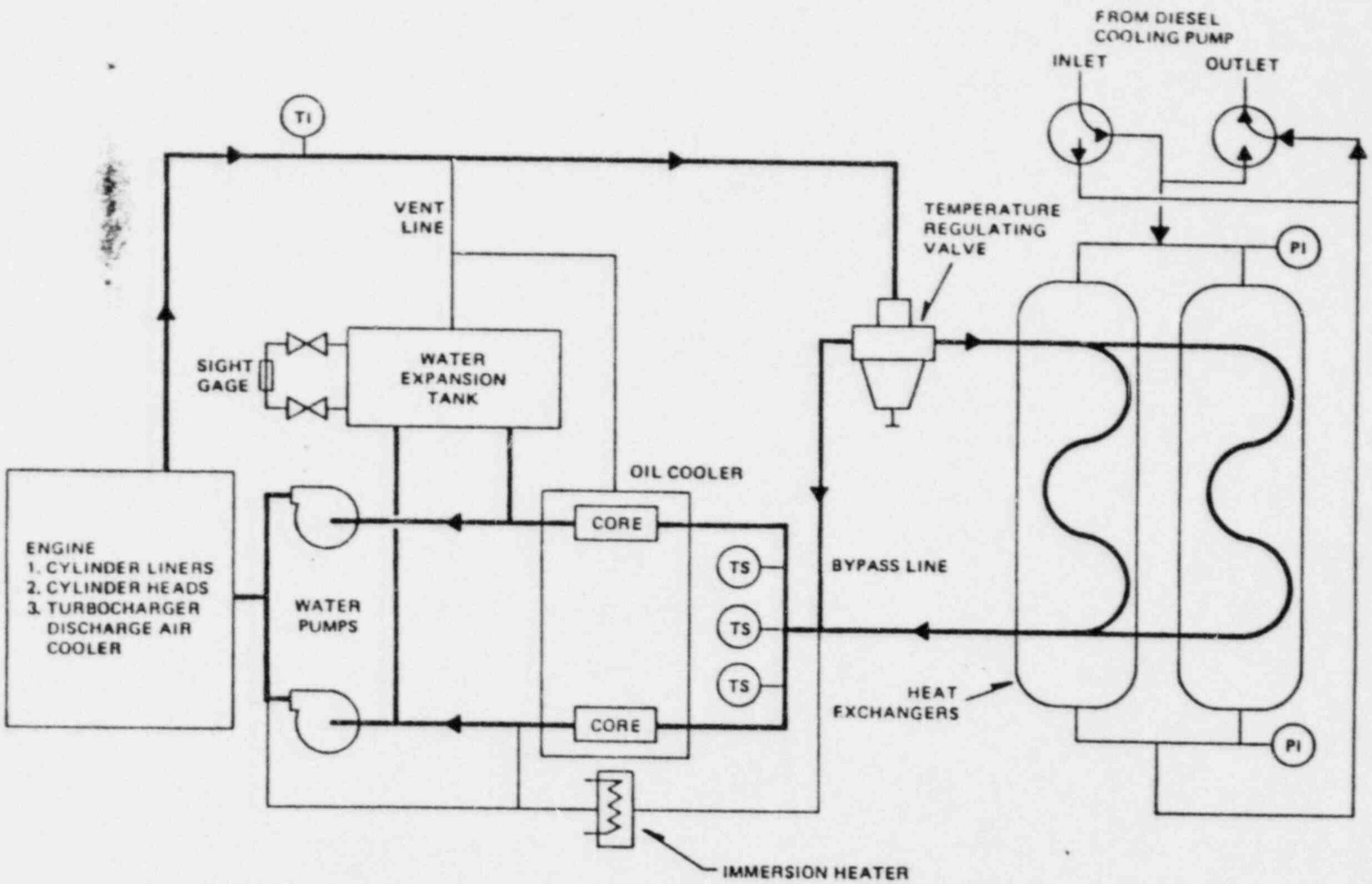

FIGURE 4. DIESEL GENERATOR COOLING WATER SYSTEMS

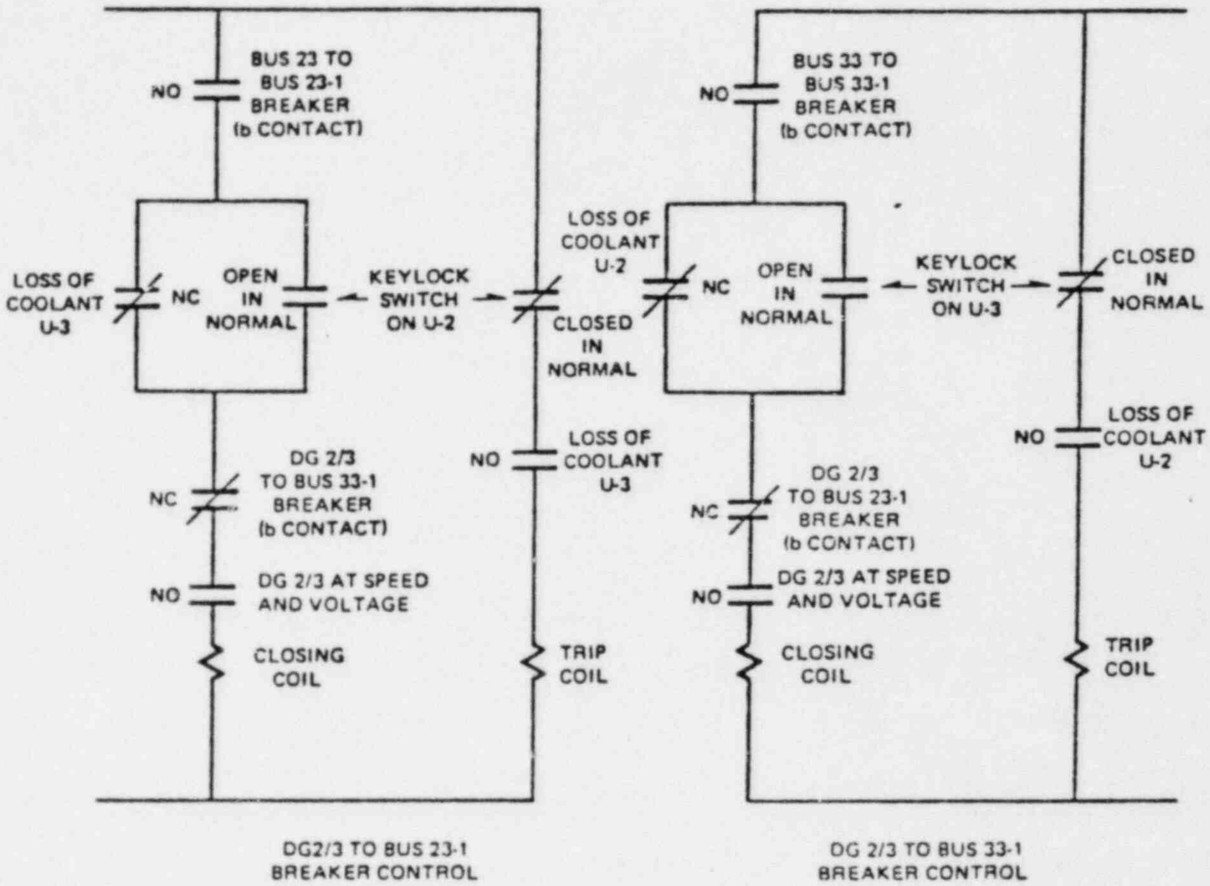

FIGURE 5. SIMPLIFIED DG 2/3 OUTPUT BREAKER CONTROL

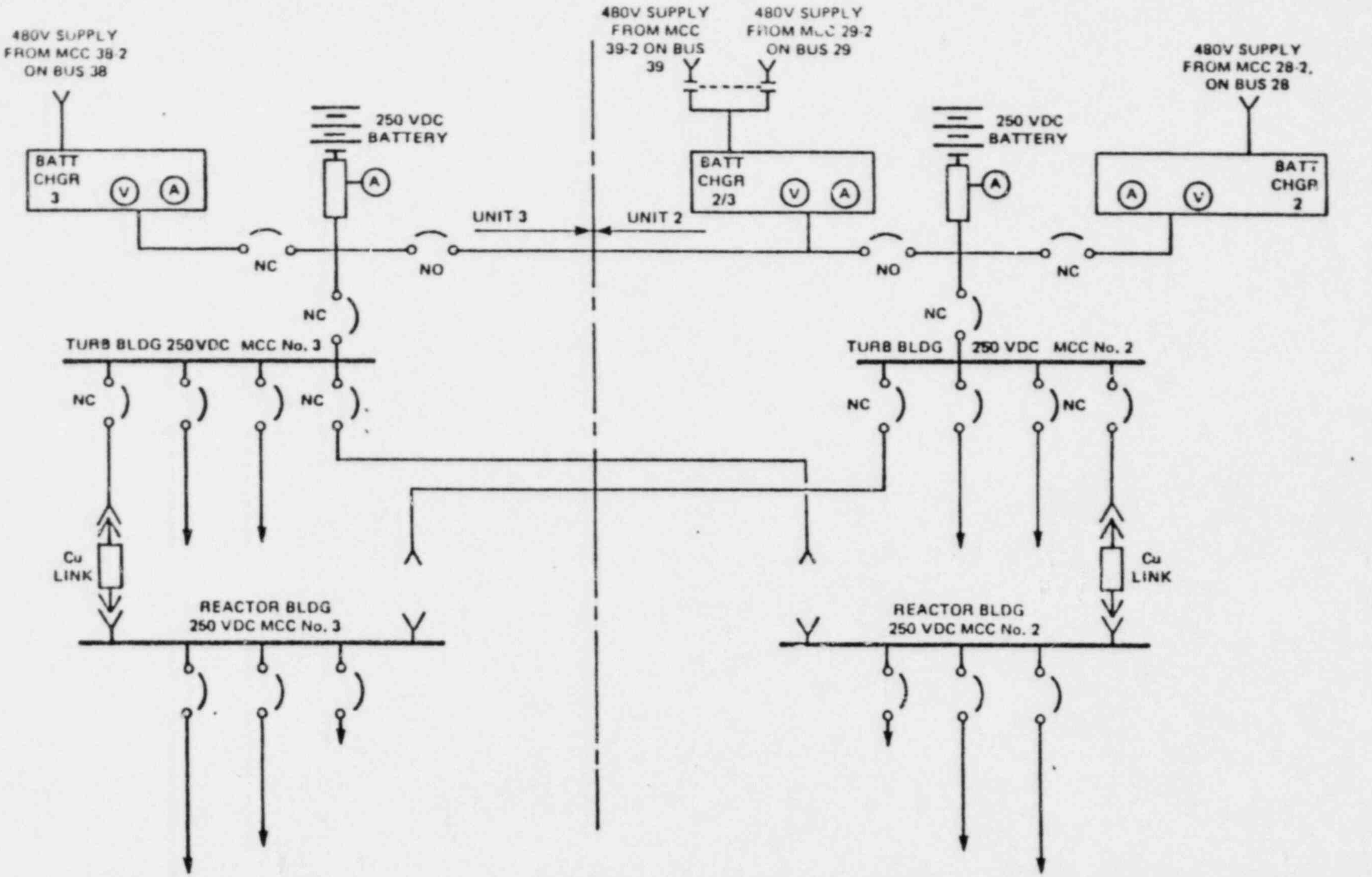

FIGURE 6. 250 Vdc STATION BATTERY SYSTEM

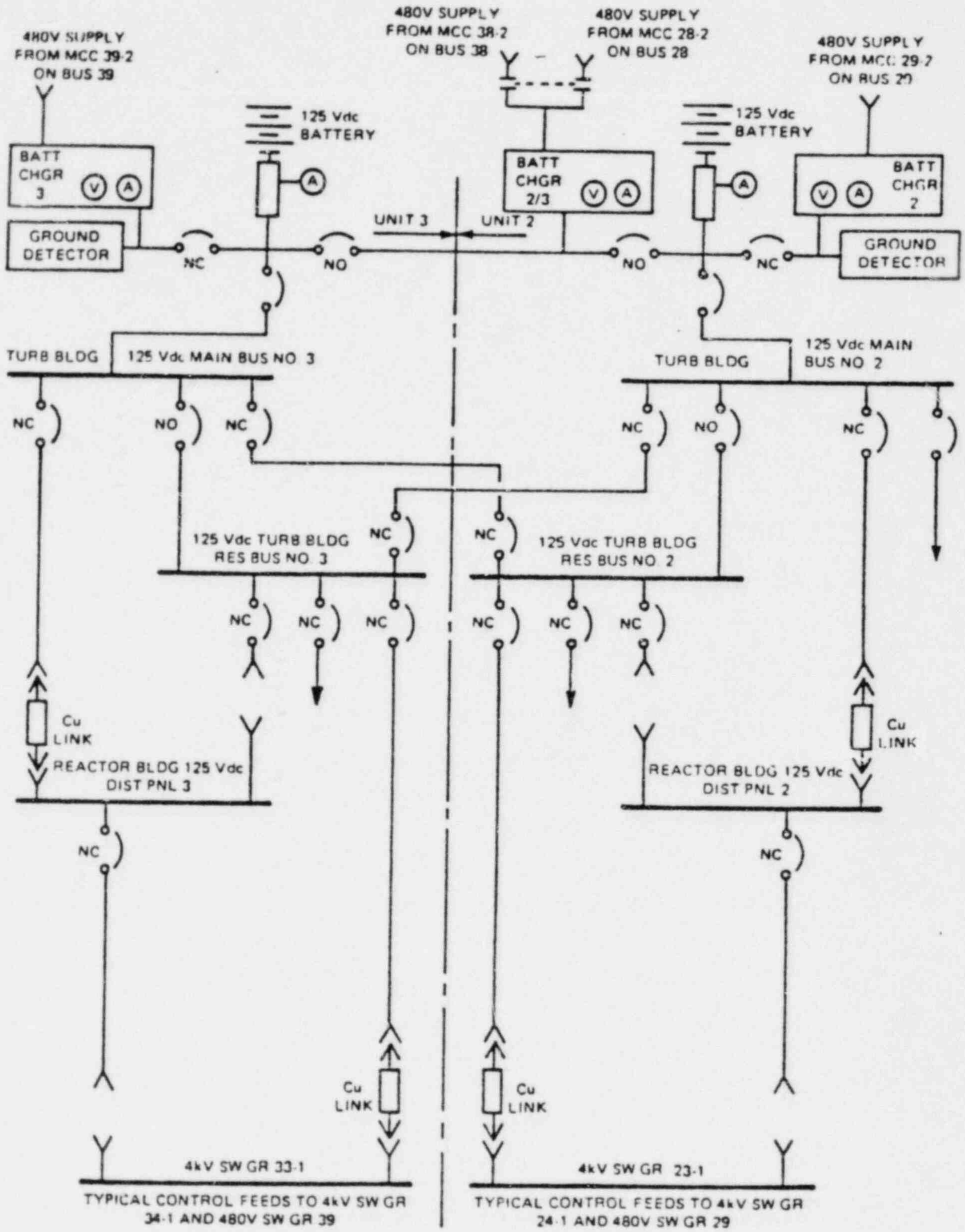

FIGURE 7. 125 Vdc STATION BATTERY SYSTEM

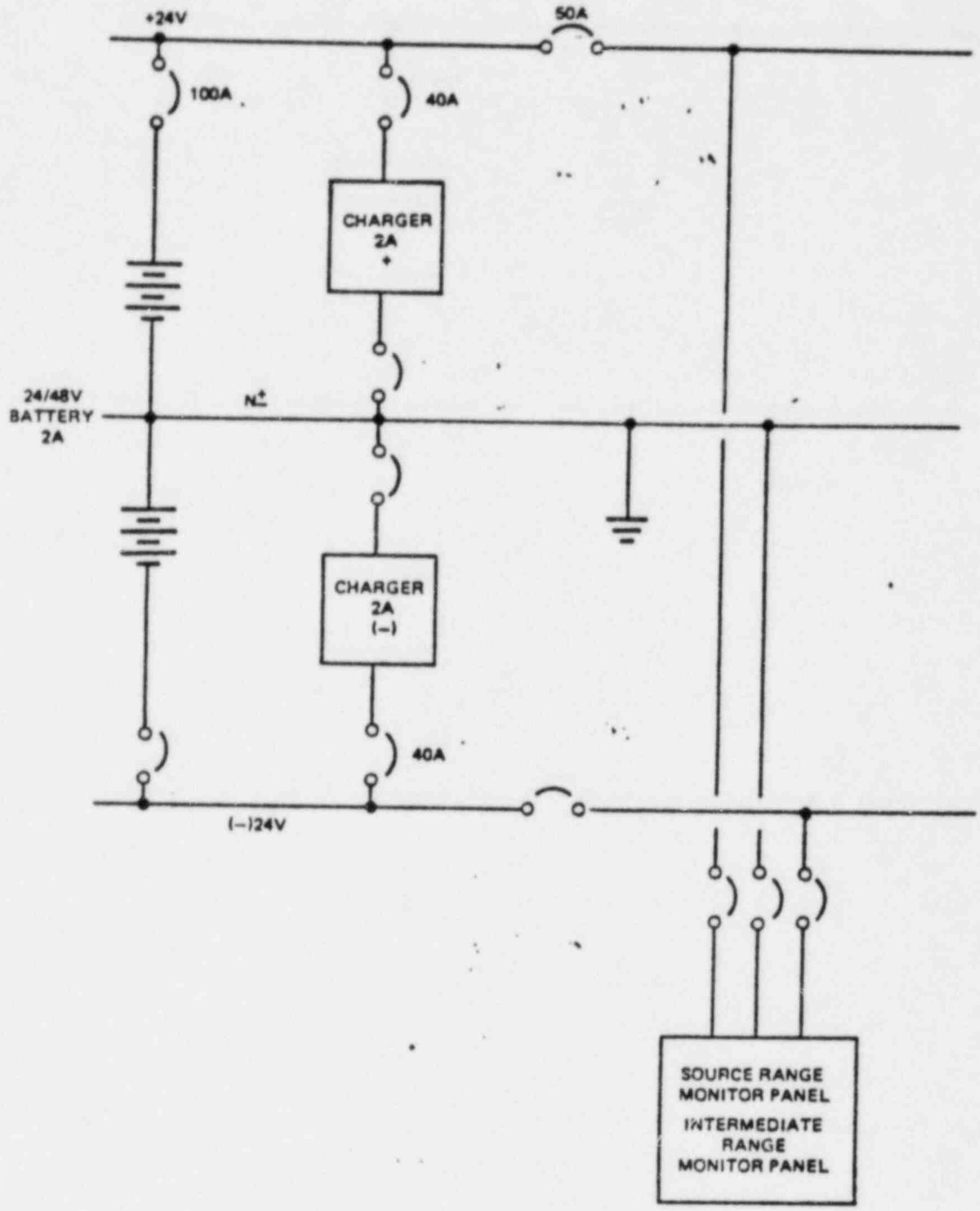

FIGURE 8. 2A 24/48 Vdc NUCLEAR INSTRUMENT SUPPLY SYSTEM