PALO VERDE
NUCLEAR GENERATING STATION

Mechanical Maintenance Training

Classroom Lesson

Mechanical Maintenance Training	**Date: 7/23/2010 6:20:31 AM**
LP Number: NMC61C000503	**Rev Author: LEE BAKER**
Title: Fuel System	**Technical Review:** Martin J. Sullivan Digitally signed by Martin J. Sullivan DN: cn=Martin J. Sullivan, o=Mechanical Planning, ou=8561, email=Martin.Sullivan@apc.com, c=US Date: 2010.07.27 06:13:01 -07'00'
Duration : 3 HOURS	**Teaching Approval:** Steinmetz, Tim P(Z99348) Digitally signed by Steinmetz, Tim P(Z99348) DN: cn=Steinmetz, Tim P(Z99348) Reason: I am approving this document Date: 2010.07.27 09:26:47 -07'00'

INITIATING DOCUMENTS

Task Analysis of Tasks

REQUIRED TOPICS

None

CONTENT REFERENCES

IS 879: Operating Experience Information, No. 13, Perry/ General Electric

PM Task # 008603

VTM-C628-002: Diesel Generator Auxiliaries

LESSON PLAN REVISION DATA

Jul 23, 2010	Lee Baker	Revised Lesson Plan to: Incorporate Human Performance and Prevent Events strategies [TCSAI 3478459] Add systems training tie-in of the Class Electrical systems [TCSAI 3260637] Include OE from IN 07-27 [TCSAI 3319710]

Tasks and Topics Covered

The following tasks are covered in Fuel System :

Task or Topic Number*	**Task Statement**
Lesson:	Fuel System
EDG006	Inspect, Test, Rework fuel injectors
EDG008	Test fuel injectors
EDG010	Troubleshoot emergency diesel engine
EDG004	Perform routine maintenance on emergency diesel engine

Total task or topics: 5

TERMINAL OBJECTIVE:

1 Given applicable maintenance instructions the Maintenance Mechanic will, state the function of and explain the preventive maintenance performed on the EDG Fuel System, demonstrated by passing a written exam with a score of 80% or better.

1.1 Describe the function of the EDG Fuel System

1.2 Describe the EDG Low Pressure Fuel System Components

1.3 Describe the EDG High Pressure Fuel System Components

1.4 Explain the routine preventive maintenance performed on the EDG Fuel System

CONTENT	METHODS AND ACTIVITIES
I. Motivation	Focus student attention on "What's In It For Me".
II. Pre-Job Brief	
A. Pre-job briefing on the day's activities modeling the use of the Palo Verde Standards & Expectations, Preventing Events	
B. Focus On Five (Task Preview)	
Familiarize worker with the scope of work, task sequence, and critical steps.	
1. Critical Steps (Terminal Objectives)	
Given applicable maintenance instructions the Maintenance Mechanic will, state the function of and explain the preventive maintenance performed on the EDG Fuel System, demonstrated by passing a written exam with a score of 80% or better	PVNGS Standards & Expectation book (Focus on five) Highlight the critical steps (Terminal Objectives) on the power point presentation.
2. Identify error likely situations (error traps)	Look at Error Precursors in S&E book
a. Discuss at least one specific error likely situation.	
3. Identify the Worst thing that can happen.	Apply to the setting you're in. (Lab versus Classroom)
4. Identify specific error prevention defenses to be used.	What defenses can we employ to prevent the "Worst thing that could happen"
5. Identify actions to assure proper configuration control.	This may not be applicable in every training setting.
C. Break policy	
1. Two Minute Drill – After lunch at a minimum	At Instructor's discretion, not to interrupt class flow.

CONTENT	METHODS AND ACTIVITIES
III. Lesson Enabling Objectives	Read and/or discuss the lesson objectives
EO01 Describe the functions of the EDG Fuel System	
EO02 Describe the EDG Low Pressure Fuel System Components	
EO03 Describe the EDG High Pressure Fuel System Components	
EO04 Explain the routine preventive maintenance performed on the EDG Fuel System	

TO: 1	**Given applicable maintenance instructions the Maintenance Mechanic will, state the function of and explain the preventive maintenance performed on the EDG Fuel System, demonstrated by passing a written exam with a score of 80% or better.**

EO: 1.1 Describe the function of the EDG Fuel System

CONTENT **METHODS AND ACTIVITIES**

I. Functions

A. Provides for fuel storage

B. Provides for fuel transfer

C. Injects fuel under high pressure into engine cylinders

II. System Description (Low and High Pressure)

A. General

1. The diesel fuel oil and transfer system provides on-site storage and transfer of diesel fuel oil for the operation of the diesel generators.
2. The fuel oil and transfer system is comprised of two storage tanks, each with a capacity of 84,000 gallons, a transfer pump for each tank and associated piping to provide fuel to each diesel generator system
3. All components in the system can be categorized into one of two systems, the “Low Pressure” or the “High Pressure” system

B. Description of Low pressure system

1. Motor driven transfer pump supplies fuel from underground storage tanks to a day tank
2. Day tank (one for each engine) supplies fuel to engine driven booster pump via a four element duplex strainer
3. Relief valve in booster pump discharge regulates supply (35 psig) to injection pumps via a four element duplex filter

CONTENT	METHODS AND ACTIVITIES

4. Small head tank is located on generator end of engine, above and between cylinder banks

5. A small shell-tube cooler cools fuel oil that is by-passed by booster pump discharge relief valve

6. A low pressure alarm switch set at 10 psig, in supply header, announces a low supply pressure

C. High pressure system

1. The high pressure fuel sub-system delivers fuel to the cylinders according to governor demand and cam shaft rotation.

2. It consists of the following major components:

   a. Injection pump

      1) Cam operated off main camshaft through crosshead and pushrod assemblies

      2) Pump meters fuel according to engine load and delivers high pressure fuel to fuel injection nozzle in timed relation with engine firing order

   b. Fuel injector

      1) High pressure fuel from the pump is injected into the cylinder combustion chamber by the nozzle

      2) Spray holes in the nozzle tip atomize the fuel into a fine mist where it is ignited by the heat of compression

EO: 1.2 Describe the EDG Low Pressure Fuel System Components

CONTENT	METHODS AND ACTIVITIES

IS 879 Industry Operating Experience Information

I.

II. Low Pressure Fuel System Components

- A. Fuel Oil Storage Tank
  - 1. Location
    - a. In the ground, plant southwest of "A" train diesel generator
    - b. Unit 3 has one tank on either side of the DG building
  - 2. Function
    - a. Store fuel oil for extended EDG operation
      - 1) Tech. Spec. requires minimum of 71,500 gal. (85% capacity) in tanks
      - 2) This should be sufficient for 7 days of continuous operation
  - 3. Construction
    - a. Carbon Steel
    - b. 13’ x 86'
    - c. 84,000 gal
    - d. Connections
      - 1) Fill line
      - 2) Vent line with a flame arrestor
      - 3) Return line from day tank
      - 4) Water drain line

CONTENT **METHODS AND ACTIVITIES**

4. Operation
    a. When level in the day tank drops to a preset low level, the associated level switch initiates a signal to start the transfer pump
    b. When day tank preset high level is achieved, the pump stops
    c. Storage tanks are refilled by tanker trucks
    d. Storage tanks are equipped with low level alarms and fuel level is checked every 31 days

B. Fuel Oil Transfer Pump

1. Location
    a. Inside of Fuel Oil Storage Tank

2. Function
    a. Transfer fuel oil with a capacity of twice the consumption rate of the diesel at full power from the fuel oil storage tanks to the fuel oil tank

3. Construction
    a. Horizontal, centrifugal type with an integral motor
    b. Pump and motor are hermetically sealed in a casing and are designed to operate submerged in storage tank
    c. Pump bearings are cooled by recirculation of pumped fluid. An integral filter on pump discharge traps suspended contaminants in the recirculation fluid
        1) Entire assembly is suspended from a cover plate which is bolted to a nozzle on the tank. Assembly can be lifted out of the tank for maintenance and inspection

C. Duplex Fuel Strainer

CONTENT	METHODS AND ACTIVITIES

1. Location
    a. On base of the engine at cylinder # 1L
2. Function
    a. Remove any foreign materials
3. Construction
    a. Four shells with cleanable type wire mesh elements attached to a common manifold
    b. A control valve in center of manifold permits flow to two elements on either side of valve, or to all four elements
        1) This requires switching strainers and cleaning the dirty elements

D. Duplex Fuel Filter

1. Location
    a. Beside the Fuel Oil Strainers on the engine base
2. Function
    a. Filter fuel oil just prior to entering the engine supply header
3. Construction
    a. Four shells with replaceable filter cartridges attached to a common manifold
    b. A control valve in center of manifold permits flow to two elements on either side of valve, or to all four elements

CONTENT **METHODS AND ACTIVITIES**

4. Operation
    a. Two elements in operation with other two clean and ready for operation
    b. A differential pressure alarm occurs at 10 psi across the filters
        1) This requires switching filter and replacing the dirty cartridges

E. Engine Driven Booster Pump

1. Location
    a. On forward left side of engine
2. Function
    a. Provide Net Positive Suction Head (NPSH) to the Injector Pumps
3. Construction
    a. Horizontally mounted gear type pump
4. Operation
    a. Driven off back of jacket water pump drive at 1750 rpm
    b. Discharge pressure maintained at 35 psi by a relief valve that relieves back to the day tank via a cooler

F. Fuel Oil Cooler

1. Location
    a. On front of engine above engine driven fuel booster pump
2. Function
    a. Cooler prevents fuel oil in the Day Tank from heating up due to energy imparted to fuel oil from the Engine Driven Fuel Oil Pump by-passing to the day tank through the relief valve when engine is running at idle speed

CONTENT	METHODS AND ACTIVITIES
3. Construction a. Shell and tube type	
4. Operation a. Cooler will handle 6 gpm of fuel on shell side and 11 gpm of cooling pond water on tube side	
G. Fuel Drains	
1. Location a. Oil compartments located in pedestal of every fuel injection pump which are connected to fuel drain header	
2. Function a. Collect fuel oil leakage from fuel nozzles and injector pumps and return it to the storage tank	
3. Construction a. Drip plate connected to fuel drain header	
4. Operation a. There is normally some leakage of fuel oil from 1) Fuel nozzle valve and its body which acts as a lubricant for these parts 2) Fuel injection pump plunger and its barrel which acts as a lubricant for these parts b. This fuel enters drain compartment in fuel pump pedestal via return passages	
5. Fuel drain header is connected to all fuel pump pedestals of each cylinder bank and returns the fuel, by gravity to storage tank	
III. Palo Verde 2008	
A. Recently, after an injector pump change out, the fuel system was not properly vented	*What Happend*

CONTENT	METHODS AND ACTIVITIES
1. The engine did not start when it received the start signal for the maintenance run	*Why Did This Happen*
2. The engine was then tagged out again and troubleshooting for I & C, Electrical, and Mechanical Maintenance was initiated. It was discovered that the fuel system had not been completely vented, which was the cause of engine failure	
B. Time and effort could have been saved if the fuel system had been thoroughly vented	
C. The venting can be accomplished by coordinating with Operations to open the Day Tank valve	
D. Place the handles for the fuel oil filters and strainers to the “BOTH” position	
E. Open the head tank valve and, with gooseneck fitting installed, drain approximately five gallons of fuel into a bucket or until air is no longer present	
F. NOTE: It is a good practice to roll the engine while venting using the turning gear for a more complete venting. Also, vent all 20 injector pumps at the bleed screw and be sure to clean all fuel from injector pumps with IPCO or Spotcheck to prevent mistakes in leak detection	

EO: 1.3 Describe the EDG High Pressure Fuel System Components

CONTENT **METHODS AND ACTIVITIES**

I. Components

A. Injection Pump Linkage

1. Location
   a. One between each injection pump fuel rack and the control shaft
2. Function
   a. Permits governor, or fuel control cylinder, to shut off fuel to all pumps even if one pump should become stuck in the "on" position
3. Construction
   a. Torsion spring connects control shaft to fuel pump control rack
4. Operation
   a. When clutch lever moves toward fuel "on" position it acts as if it were solid
   b. When moving toward off position, torsion spring causes control lever to follow movement of control shaft and shut-off the fuel

B. Injection Pump

1. Location
   a. One each located just outside and to the left side of each cylinder (as you face the center of the engine) on the Intake end of the head
2. Function
   a. Meters fuel according to engine load

CONTENT	METHODS AND ACTIVITIES
3. Construction a. Positive displacement plunger type pump b. Plunger has a metering helix machined into it for fuel metering 1) Quantity of fuel delivered to the cylinder is controlled by rotating pump plunger so that the helical groove uncovers bypass port earlier or later during the up-stroke c. Cam-operated off main camshaft through crosshead and pushrod assemblies d. Flowing vent connection allows a constant flow of fuel oil through injection pump to day tank to cool injection pump	
4. Operation a. Plunger is rotated by the control rack to set the effective stroke of the plunger 1) Control rack is connected to engine controls and governor and is positioned according to demand of the engine for fuel b. As push rod raises plunger, inlet ports are covered and fuel injection begins the instant line pressure exceeds pressure setting of the nozzle c. Fuel injection continues until leading edge of metering helix reaches by-pass d. At this instant the fuel pressure in barrel, plunger center and cross holder, and metering helix is released through by-pass into inlet chamber e. This stops fuel injection because fuel line pressure drops and allows nozzle valve to close	**IS THIS NOTE STILL APPLICABLE** NOTE: Palo Verde is in the process of changing out the injection pumps due to issues of non-compatibility of the ultra low sulfur diesel fuel and the Buna o-rings that the injection pumps contain.
C. Fuel Line 1. Connects the injector pump to the injection nozzle	

CONTENT	METHODS AND ACTIVITIES

D. Fuel Injection Nozzle

1. Location
   a. Installed in top center of every cylinder
2. Function
   a. Atomizes the fuel
   b. Sprays the fuel into the cylinder combustion chamber where it is ignited by heat of compression
3. Construction
   a. Holder body with a fuel inlet duct and a drain duct, a valve and valve body, nozzle tip, valve loading spring, stop plate, spring pressure adjusting shims and assembly nut

CONTENT	METHODS AND ACTIVITIES

4. Operation
    a. Fuel enters nozzle holder through connection at top and passes down through holder to valve
        1) Loading spring keeps the valve closed
    b. When pressure of fuel in chamber between valve seat and valve, exceeds valve spring pressure (3500 psig), valve is forced open
    c. Fuel oil at high pressure flows from chamber between valve and valve seat, down to nozzle tip where it sprays into cylinder through spray holes in the tip
    d. Atomized fuel injected into cylinder now mixes with air in cylinder to form a combustible mixture
    e. Mixture is ignited by heat of compression
    f. A small quantity of fuel leaks upward between valve stem and valve bore to lubricate these parts
        1) This fuel leakage drains from holder body through a flexible line to fuel drains via pump pedestal

EO: 1.4 Explain the routine preventive maintenance performed on the EDG Fuel System

CONTENT	METHODS AND ACTIVITIES
I. OE28380 Diesel Generator Slow Start	Facilitate a discussion on the importance of this event and maintaining proper maintenance practices

A. **What Happened**

1. On February 4, 2009, the PVNGS Unit 3 'A' diesel generator (DG) experienced two slow start times (>10 sec) during surveillance testing (ST). The diesel was run three times resulting in the following start times: 10.7 sec, 8.4 sec, and 18.7 sec. position
2. Following the third start, mechanics walked down the fuel racks and fuel injection pumps and discovered that the 7R fuel injection pump metering rod/control rack did not move freely and was stuck at approximately the 1 mm
3. The pump was removed from the generator and sent to an offsite laboratory for disassembly and inspection.

CONTENT **METHODS AND ACTIVITIES**

B. **Why Did It Happen**

1. Root Cause
    a. Foreign material was found between the control sleeve and the barrel which restricted free movement of the pump internal parts. Small amounts of the same foreign material were also found on the plunger (T-portion), the spring and the lower and upper spring plates
    b. The specific material type and specific source of the material introduction in the pump has not been fully determined at this time, but is believed it may have been introduced during refurbishment of this pump in 2008
    c. Final Disposition of source determined to be from a hand soap that was used introduced by the vendor during final assembly
2. Corrective Actions
    a. The 7R injection pump was removed from service and replaced.
    b. The other DG fuel injection pumps on the 3A DG and the other 5 PVNGS DGs were manually exercised to verify their freedom of movement.
    c. An interim action to manually exercise the DG fuel injection pumps metering rod to verify freedom of movement is being implemented on a weekly basis until the source of the foreign material can be determined

C. **What is the significance to PVNGS**

a. Consequences of an unplanned safety system unavailability
b. 10 Day LCO (Tech Spec 3.8.1)

CONTENT	METHODS AND ACTIVITIES
D. **How can PVNGS Mitigate this event**	What are the preventative measures or barriers we have at our site (FME, gloves, ect..)

II. Preventive Maintenance

A. Remove sludge and water from the bottom of the storage tank

1. Use 2" water drain valve

a. Goes to sump area (lowest point in storage tank)

2. Using air pump (no sparks) pump fuel oil into a 55 gal. drum(s) until fuel is clean with no water

B. Reset and Rebuild Fuel Nozzle

1. This P.M. is to be performed for Nozzles that fail the Pop-Test

2. Basic Procedure: DISASSEMBLY OF NOZZLES

a. Clean nozzle in clean fuel oil before disassembly

<u>NOTE:</u> Keep valve and valve body of each nozzle together. They are hand fitted, mated parts and should never be mixed

b. Place nozzle assembly in soft jaw vise with tip up

c. Remove stop plate and nozzle valve assembly

d. Place threaded end of assembly nut on a wooden block and using tool LS-44-CC (Punch), Drive out nozzle tip

1)

CONTENT	METHODS AND ACTIVITIES
e. Remove valve spring, spring seat and pressure adjusting shims from nozzle body ***NOTE: Use only a hex box wrench to remove assembly nut. Do Not use a 12 point box wrench*** ***NOTE: If nozzle needs adjustment of opening pressure only add or remove shims as necessary at this time. Reassemble and retest on stand at this time***	*Point out valve spring, spring seat & press. adjusting shims*
3. Cleaning and inspecting nozzle tips and assembly nuts	
a. Inspect nozzle tips for clogged spray holes under a magnifying glass. Clean with orifice cleaning needle as necessary	
b. Inspect nozzle tips for the following	
1) Worn spray holes	
2) Elliptical holes	
3) Bell mouthed holes	
c. Clean nozzle tip bore in assembly nut until the nozzle tip will enter this bore freely and bottoms metal-to-metal in bore shoulder	
C. Lubricate and Adjust Fuel Control Linkage	
D. Replace Fuel Supply and Drain Line Hoses	
E. Check Fuel Nozzle Lift Pressure on Test Stand	
1. Remove Fuel Injector nozzle from cylinder	
a. Remove hold down clamp	
b. Use special knocker tool to remove nozzle (part # LS-44-DD)	
c. Use special tool to remove nozzle copper gasket (part # LSV-44-1B)	

CONTENT	METHODS AND ACTIVITIES

2. Test Stand Basic Operating Procedure

   CAUTION: ***NEVER PLACE HANDS IN THE PATH OF THE SPRAY AS THE FORCE WILL PUNCTURE THE SKIN, POSSIBLY RESULTING IN BLOOD POISONING!!***
   WEAR SAFETY GLASSES AND GLOVES ***WHEN WORKING WITH DIESEL FUEL***

   a. Fill Supply Cup with clean fuel oil

   b. Open Gage Valve

   c. Attach nozzle and connector to Discharge Block Fitting, using lower connection pop tests; use upper connection for leakage rate measurements

   d. Install plug on connection not in use and tighten all connections

   e. Install Pump Handle on Handle Shoe in base of Nozzle Tester and pump the unit for desired test

   f. Using Test Stand check nozzle for the following

      NOTE: ***always use new, clean #2 diesel fuel oil in the test stand***

      1) OPENING PRESSURE

         a) Pump handle slowly and note pressure when nozzle opens

         b) Normal opening pressure is 3500 psi

         c) New nozzles are set 200-300 psi higher, since after a short period of engine operation, the opening pressure will drop 200-300 psi

CONTENT	METHODS AND ACTIVITIES

2) SPRAY CHARACTERISTICS

Note Pump test handle about 20-25 strokes per minute

a) All holes in nozzle should be open and injecting same quantity of fuel

b) Spray pattern must be uniform

3) SEAT TIGHTNESS

a) Pump rapidly then wipe end of nozzle with a clean dry cloth

b) Slowly raise pressure to within 100psi of opening pressure

c) Hold this pressure for 10 seconds

d) If it drips while the test handle is being rapidly pumped the valve is leaking

e) If it drips while being held, the seat is leaking

4) NOZZLE VALVE CHATTER

a) Pop the nozzle valve

b) Movement of nozzle valve returning to its seat is accomplished by a sharp staccato noise

c) Good nozzle will make almost a "chirping" sound

d) Worn valve will make a "dull" sound

g. Replace any nozzle that fails the test with a new nozzle then rebuild the failed nozzle

SUMMARY OF MAIN PRINCIPLES

The following items are things to consider in your lesson summary. They are not mandatory. You should develop your own summary.,

Objectives Review

Review the Lesson Objectives

Topic Review

Restate the main principles or ideas covered in the lesson. Relate key points to the objectives. Use a question and answer session with the objectives.

Questions and Answers

Oral questioning

Ask questions that implement the objectives. Discuss students answers as needed to ensure the objectives are being met.

Problem Areas

Review any problem areas discovered during the oral questioning, quiz, or previous tests, if applicable. Use this opportunity to solicit final questions from the students (last chance).

Concluding Statement

If not done in the previous step, review the motivational points that apply this lesson to students needs. If applicable, end with a statement leading to the next lesson.

You may also use this opportunity to address an impending exam or practical exercise.

Should be used as a transitional function to tie the relationship of this lesson to the next lesson. Should provide a note of finality.