PALO VERDE
NUCLEAR GENERATING STATION

Mechanical Maintenance Training
Turbine Operation and Component Identification
Classroom Lesson

Mechanical Maintenance Training	**Date: 6/16/2010 9:20:50 AM**
LP Number: NMT75C000103	**Rev Author: MARK TAGUE**
Title: Turbine Operation and Component Identification	**Technical Review:** Holladay, James A (Z49490) Digitally signed by Holladay, James A(Z49490) DN: cn=Holladay, James A (Z49490) Reason: I have reviewed this document Date: 2010.06.17 17:22:09 -07'00'
Duration : 2 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: 2010.06.25 10:42:14 -07'00'

INITIATING DOCUMENTS

Task Analysis of Tasks

REQUIRED TOPICS

None

CONTENT REFERENCES

G E Preventive Maintenance Training Manual

M400-0301-00044 & 00045: INSTRUCTION MANUAL-STEAM TURBINE GENERATOR

TCS #99-0031 Revise LSTG Turbine course

TCSAI 2856141 Include standards and expectation into lesson plan.

SOER 84-06 RX trips caused by turbine controls and protection system failures

OE 16299 Turbine rubs and a vibration trip at Clinton Power Station

OE 15274 Turbine blade cracking a South Texas

OE 17436 Plant startup delays due to vibration problems with new nono block low pressure turbine rotors.

LESSON PLAN REVISION DATA

Jun 16, 2010	Mark Tague	TCSAI 3478460 Incorporate Human Performance and Prevent Events strategies TCSAI 3405879 Added system tie-in of the LSTG Turbine

Tasks and Topics Covered

The following tasks are covered in Turbine Operation and Component Identification :

Task or Topic Number*	**Task Statement**

Lesson: Turbine Operation and Component Identification

LSTG027	Inspect and clean reservoir in electrohydraulic turbine control system
LSTG028	Inspect and clean reservoir in turbine oil system
LSTG029	Balance turbine rotor
LSTG017	Remove and install turbine rotors (e.g. for cleaning or blade inspection)
LSTG018	Remove, inspect, and reinstall inner and outer turbine shells
LSTG021	Rework or replace steam seals on turbine shell
LSTG022	Rework diaphragms on turbine shell
LSTG002	Rework turbine bearings
LSTG001	Inspect turbine bearings
LSTG023	Maintain turbine governor on LSTG
LSTG003	Realign turbine
LSTG026	Rework steam nozzles
LSTG004	Remove, inspect, and install LSTG couplings

Total task or topics: 13

TERMINAL OBJECTIVE:

1 Given a maintenance operation, the plant mechanic will , identify turbine components and explain the basic turbine operating principles as demonstrated by passing a written examination with a minimum score of 80% using classroom reference materials

1.1 Explain the basic principles of operation of the Large Steam Turbine Generator

1.2 Identify turbine components

CONTENT	METHODS & 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 (Course Terminal Objective) Given a maintenance operation, the plant mechanic will explain the procedure to rework the turbine as demonstrated by passing a written examination with a minimum score of 80% using classroom reference materials.	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) a. Discuss at least one specific error likely situation	Look at Error Precursors in S&E Book
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. Schedule	Lay out the schedule and expectations for schedule adherence
1. Length of class	
2. Break policy	
a. Two Minute Drill - After lunch at a minimum	At instructor's discretion - not to interrupt class flow
3. Evaluation	
4. Post training critique	Feedback (i.e. Class Climate)

CONTENT	METHODS & ACTIVITIES
D. Qualification	
1. Identify what they will be qualified to do upon completion of the course	
III. Lesson Introduction	
A. Lesson Terminal Objective Given a maintenance operation, the plant mechanic will identify turbine components and explain the basic turbine operating principles as demonstrated by passing a written examination with a minimum score of 80% using classroom reference materials.	Read and/or discuss the lesson objectives
B. Lesson Enabling Objectives	
EO01 Explain the basic principles of operation of the Large Steam Turbine Generator.	
EO02 Identify turbine components.	

TO: 1 **Given a maintenance operation, the plant mechanic will , identify turbine components and explain the basic turbine operating principles as demonstrated by passing a written examination with a minimum score of 80% using classroom reference materials**

EO: 1.1 Explain the basic principles of operation of the Large Steam Turbine Generator

Main Idea

CONTENT	METHODS & ACTIVITIES
I Turbine operating principles	
A. A steam turbine converts the potential energy of steam into useful work in two distinct steps:	
NOTE: Potential energy is the energy that any body or substance possesses due to elevation or pressure	Ask if anyone can define potential energy.
1. First, the potential energy is converted into kinetic energy by the expansion in a nozzle or suitable passage	Power Point Slide 10 Hero's turbine
The steam will emerge from the passage or nozzle at a high velocity	
2. Second, the kinetic energy is converted into mechanical energy or work by:	Power Point Slide11
a. **IMPULSE** - Directing the steam against blades mounted on a revolving rotor	Power Point Slide 12
b. **REACTION** - The jet-like action of the steam expanding in the passage between the blades	
B. Turbine Classification	
1. According to the method of steam expansion	
a. Impulse	
b. Reaction	
c. Compounding	
1) <u>Velocity</u> - More than one set of moving blades in a stage	Power Point Slide 13

CONTENT	METHODS & ACTIVITIES
2) <u>Pressure</u> - More than one simple impulse stage in a casing	Power Point Slide 14
3) <u>Pressure-Velocity</u> - 1st stage velocity compounded, remainder pressure	Power Point Slide15
2. Direction of steam flow	
a. With relation to the shaft	Draw examples on the board of each type of flow.
1) Axial flow	Power Point Slide 16
Steam flows in a direction parallel to the rotor.	
2) Radial flow	Power Point Slide 17
Steam enters in such a way that it flows radially toward the rotor.	
3) Tangential flow	Power Point Slide 18
Steam enters at a tangent to the periphery of the rotor.	
b. With respect to sequence	
1) Single flow	Power Point Slide 19
Steam flow once through the blading in an axial direction.	
2) Double flow	Power Point Slide 20
Steam enters in the center and flows to the ends of two single flow units on the same shaft.	Show flow through only one side.
3. Drive connection	Ask what is meant by type of drive connection and have them name some.
a. Direct connected (coupled)	This is ours, so the other two are info only

CONTENT	METHODS & ACTIVITIES
b. Gear connected (a gear between the turbine and the generator)	
c. Indirect connected (electric)	
C. Two types of turbines	
	Have someone explain the difference between impulse and reaction turbines.
	Impulse: steam expands in nozzle only. Reaction: steam expands as it passes across both the moving and the fixed blades.
1. Impulse turbines	Power Point Slide 21
a. In an impulse turbine the steam expands through the nozzle only. As the steam leaves the nozzle it is at a very high velocity.	
b. This high velocity steam then strikes the moving blade and imparts energy to the blade, making it move.	
c. When the steam leaves the moving blade it:	Power Point Slide 22
1) Gets redirected by a set of fixed blades and then hits another set of moving blades, or	
2) Enters another set of nozzles	
d. This process continues until the steam leaves the last set of blades	
2. Impulse Compounding	
a. Velocity compounded	Power Point Slide 23
1) Defined as more than one velocity decrease without a velocity increase	

CONTENT	METHODS & ACTIVITIES
2) A single stage starting with one row of nozzles followed by a row of moving blades	
3) A row of stationary blades and another row of moving blades follows	
b. Pressure compounded	Power Point Slide 24
1) Defined as more than one pressure decrease without a pressure increase	
2) Consists of multiple impulse stages in a single casing	
c. Pressure/Velocity compounded	Power Point Slide 25
1) The use of both pressure and velocity configurations for maximum turbine efficiency.	Usually the first stage is velocity compounded and the rest are not in the pressure compounded turbine
3. Reaction turbines	Power Point Slide 26
a. The steam pressure drops and expands as it passes across both the moving and the fixed blades	
b. Both fixed and moving blades act as nozzles.	

CONTENT	**METHODS & ACTIVITIES**

II. System Tie

A. The process of using steam to make electricity is pretty basic.

1. The reactor is used to make water hot enough to turn into high pressure steam.

2. The steam is used to turn the Main Turbine starting with the High Pressure turbine and then steam flows on through the Low Pressure Turbines.

3. These turbines are coupled in tandem to the Electrical Generator which in turn spins to produce electricity.

B. At Palo Verde Main steam from the steam generators is supplied to the main turbine through four 28" steam lines.

1. The Main Turbine system (MT) begins at the stop valves of which there are four.

2. Steam flows through the stop valves and is throttled through the control valves of which there are four.

3. Steam is then directed into the high pressure turbine through four inlet pipes. Two in the center of the lower shell casing and two in the center of the upper shell section.

4. Steam exiting the HP turbine is directed to several places for heating purposes.

   a. Extraction steam at various stages inside the HP Turbine is used to provide heating for the HP Feed water heaters.

   b. Some HP extraction steam is also used to reheat steam in the Moisture Separator Re-heaters. (MSR's)

CONTENT	METHODS & ACTIVITIES

5. Steam exiting the MSR's is then directed to the Combined Intermediate Valves (Two for each Low Pressure Turbine) for entry into the Low Pressure Turbines.

6. After steam enters the LP Turbine; extraction steam is tapped off to provide heat for the LP Feed water heaters.

   a. The remaining steam is exhausted downward into the main condenser.

7. Every effort has been made through design to squeeze as much use out of the steam as possible for efficiency before it is condensed back into water.

EO: 1.2 Identify turbine components

Main Idea

CONTENT	METHODS & ACTIVITIES
I Components of Palo Verde Turbine	Ask someone to explain the term six flow. three double flow low pressure units.
A. **Casings**-Our turbine is a tandem-compound six flow unit consisting of four sections	
1. One double flow high pressure section and three double flow low pressure sections	
2. The high pressure section is a single shell unit with four integral 90° nozzle box segments which direct the steam into the first stage buckets.	Power Point Slide 27
3. Each low-pressure section has an inner casing and an exhaust hood.	
a. The inner casing is supported in the exhaust hood by four support pads and is also keyed to the exhaust hood to maintain alignment.	Power Point Slide 28
b. These casing elements provide support for the rotating parts, contain steam within the designed steam paths	
c. The inner casing has three primary functions.	
1) A transition structure between the last stage exhaust and the condenser.	
2) Sustain various external forces imposed upon it.	

CONTENT	METHODS & ACTIVITIES
3) Exhaust hood contains blowout diaphragms	Power Point Slide 29
4. Inner Casing internals	
a. Supports for the stationary nozzle diaphragms	
b. Incorporates the inlet steam "crossover" bowl.	
c. Contains the extraction pockets which divert steam to heat the feed water.	
B. Bearings	
1. Journal bearings	Power Point Slide 30-strongback liner
a. These are an elliptical split bearing with a babbitt liner.	
b. The outer diameter of the bearing ring sits in a machined surface in the support pedestal, which is part of the lower exhaust hood structure	
c. The bearings are located at each end of the rotor.	
2. Thrust bearing	
a. A Tapered Land Thrust bearing is installed between the high and low pressure turbines (between #2 & 3 journal bearings).	Power Point Slide 31-32
b. The bearing consists of two stationary thrust plates and two rotating thrust collars on the turbine shaft which provide the front and back faces to the bearing.	

CONTENT	**METHODS & ACTIVITIES**
c. The surface of the two thrust plates are babbitted and have tapered lands of fixed converging surfaces, permitting a wedge of oil to exist between the rotating thrust collars and the thrust plates.	
d. The thrust plates are constructed as split copper rings, with babbitt faces divided into lands by radial oil-feed groves.	
e. The stationary portion of the thrust bearing carries both the front and back thrust plates in one casing.	
f. The outside diameter of the casing is machined to a spherical surface, seating inside the bearing ring. this allows the thrust plates to align relative to the thrust collars.	
g. An adjusting shim is provided between each thrust plate and the casing. These shims are used to adjust the axial position of the rotor and thrust bearing clearance.	
C. Shaft Seal Packing	Power Point Slide 33
1. The packing is a steam throttling device consisting of stationary and rotating teeth arranged concentrically with small radial clearance.	
2. The rotating element consists of step recesses machined directly into the rotor.	
3. The stationary elements are segment rings provided with teeth.	

CONTENT	METHODS & ACTIVITIES
4. OE16299 Turbine Rubs and A Vibration Trip at Clinton Power Station	Operating Experience
a. Following the replacement of the GE Low Pressure Turbine Rotors at the Clinton Power Station with newer designed mono-block rotors, a power reduction for a planned outage was in progress. During the power reduction, the MSRs were manually removed from service, as was the normal practice at Clinton. As the MSRs were removed, turbine vibrations increased and a high vibration trip occurred.	
b. Personnel from GE and Palo Verde reviewed this and other events associated with monoblock rotors. The conclusions are that while the heatup and cooldown rates of the PV existing turbines and monoblock rotors are identical,	
c. the monoblock rotors, being of a stiffer construction, are thought to be less “thermally forgiving” than the existing PV rotors. Heatup and cooldown rates, temperature guidelines associated with hood spray, and SBCS equalization guidelines prior to turbine synchronization, all need to be strictly complied with, in order to minimize the possibility of turbine rubs, and resultant high vibration trips.	While operations controls the turbine during heat up and cool down this is still a good example of ensuring we employ the use of PE Tools Procedure use & adherence
d. The event at Clinton appeared to have been caused by a side-to-side temperature differential that occurred as the MSRs were removed from operation in the manual mode, for which there are strict temperature restrictions. It is typical PV practice to maintain the MSRs reheating in the automatic mode, but caution should still be utilized.	

CONTENT	**METHODS & ACTIVITIES**
e. However, this illustrates the sensitivity of the monoblock rotors to not following turbine temperature limitations.	
D. Diaphragms	Power Point Slide 34
1. Interstage diaphragms direct steam flow at the proper angles and velocities against the buckets of the wheels from stage to stage along the rotor.	
2. Each diaphragm is in two halves bolted together, which sit on support keys in the lower half shell or casing	
3. **NOTE:** The diaphragms for stage #8 are bolted together.	
4. Assembled in the bore of the diaphragm are the segmented shaft seal packing rings.	
E. Rotor	
1. There are three low pressure rotors, one high pressure rotor.	Power Point Slide 35 – HP rotor Power Point Slide 36 – LP Rotor
2. The High pressure rotor is of the mono-block construction, meaning the rotor and the wheels for the dovetails are machined from one block of steel.	
a. The Low Pressure rotors are of the mono-block construction as well. There is no longer a separate wheel shrunk on the rotor at each stage with dove tails machined for attaching buckets.	
3. OE15274 Turbine Blade Cracking at South Texas	Operating Experience

CONTENT	METHODS & ACTIVITIES
a. Following the replacement of steam generators and the generator portion of the main turbine South Texas experienced several turbine problems.	
b. The first was a turbine blade ejection event. Then, after the damaged rotor was replaced, high turbine torsional vibrations were experienced during power ascension.	
c. The unit was taken off line and cracks were discovered in and around the dovetail portion of the blades.	
d. It was concluded that the new generator rotor resulted in a super synchronous resonance condition, with the natural harmonic frequency at 120 Hz. This caused the torsional vibration and subsequent blade damage.	
4. OE17436 Plant startup delays due to vibration problems with new mono block low pressure turbine rotors.	Operating Experience
a. Between November 27 and 30, 2003, during startup from a refueling outage with the new mono block turbine rotors installed, Millstone Unit 2 experienced seven turbine trips and two reactor trips.	
b. One turbine trip was the result of a human error (i.e., operator inadvertently secured the turning gear oil pump during turbine startup), while six turbine trips resulted from high vibration of the new mono block rotors.	
c. These startup difficulties occurred despite extensive mono block rotor replacement operating experience that was identified and incorporated into the Low Pressure Turbine Replacement project.	

CONTENT	METHODS & ACTIVITIES
F. Governor	Power Point Slide 37

F. Governor

1. A mechanical protection device designed to limit turbine speed by tripping the control oil system and securing steam to the turbine.

G. Stop, Control, and Intercept Valves.

1. Stop Valve(s)

    a. The main stop valves are located in the main steam piping directly ahead of the control valves.

    b. Each stop valve has one inlet and one outlet which is welded to the inlet of a separate control valve casing.

    c. The four stop valves are welded together through the below seat equalizers.

    d. The stop valve below seat chambers are all interconnected by means of a below seat equalizer.

2. Control Valves

    a. Steam is supplied from each of the stop valves to the control valves, the individual steam leads from each control valve are provided to the inlet bowl of the high pressure turbine.

    b. Due to the valve size it requires a partial balance. This is accomplished by a small internal valve which opens to decrease the pressure in the balance chamber.

    c. Further lifting of the stem opens the main disk.

3. Combined Intermediate Valve

CONTENT	METHODS & ACTIVITIES
a. Two combined intermediate valves are provided, one in each line supplying steam to the LP turbine.	
b. The combination is actually two valves, the intercept valve (IV) and the intermediate stop valve.	
c. The valves are designed to protect the turbine from overspeeding due to stored steam in the crossaround system.	

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.