# Mechanical Maintenance Training

## Turbine Operation and Component Identification

### Classroom Lesson

**Title:** Turbine Operation and Component Identification  
**Date:** 6/16/2010 9:20:50 AM  
**LP Number:** NMT75C000103  
**Rev Author:** MARK TAGUE

**Technical Review:** Digitally signed by Holladay, James A (Z49490)  
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<table>
<thead>
<tr>
<th>Description</th>
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<tr>
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INITIATING DOCUMENTS
Task Analysis of Tasks

REQUIRED TOPICS
None

CONTENT REFERENCES
GE 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:

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

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

I. Motivation

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.
      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
      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

#### D. Qualification

1. Identify what they will be qualified to do upon completion of the course

### METHODS & ACTIVITIES

#### 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.

#### B. Lesson Enabling Objectives

<table>
<thead>
<tr>
<th>EO01</th>
<th>Explain the basic principles of operation of the Large Steam Turbine Generator.</th>
</tr>
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<tbody>
<tr>
<td>EO02</td>
<td>Identify turbine components.</td>
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**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

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

   1. First, the potential energy is converted into kinetic energy by the expansion in a nozzle or suitable passage

   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:

   a. **IMPULSE** - Directing the steam against blades mounted on a revolving rotor

   Power Point Slide 11

   b. **REACTION** - The jet-like action of the steam expanding in the passage between the blades

   Power Point Slide 12

B. Turbine Classification

1. According to the method of steam expansion

   a. Impulse

   b. Reaction

   c. Compounding

   1) **Velocity** - More than one set of moving blades in a stage

   Power Point Slide 13
<table>
<thead>
<tr>
<th>CONTENT</th>
<th>METHODS &amp; ACTIVITIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>2) Pressure - More than one simple impulse stage in a casing</td>
<td>Power Point Slide 14</td>
</tr>
<tr>
<td>3) Pressure-Velocity - 1st stage velocity compounded, remainder pressure</td>
<td>Power Point Slide 15</td>
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2. Direction of steam flow

a. With relation to the shaft

1) Axial flow

Steam flows in a direction parallel to the rotor.

Power Point Slide 16

2) Radial flow

Steam enters in such a way that it flows radially toward the rotor.

Power Point Slide 17

3) Tangential flow

Steam enters at a tangent to the periphery of the rotor.

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b. With respect to sequence

1) Single flow

Steam flow once through the blading in an axial direction.

Power Point Slide 19

2) Double flow

Steam enters in the center and flows to the ends of two single flow units on the same shaft.

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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.
b. Gear connected (a gear between the turbine and the generator)

c. Indirect connected (electric)

C. Two types of turbines

1. Impulse turbines

   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:

      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

      1) Defined as more than one velocity decrease without a velocity increase
CONTENT

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

   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

   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

   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.

METHODS & ACTIVITIES

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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)
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

I Components of Palo Verde Turbine

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.

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.

   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.

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   Power Point Slide 28
3) Exhaust hood contains blowout diaphragms

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
   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).
   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.
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

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.
4. OE16299 Turbine Rubs and A Vibration Trip at Clinton Power Station

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.

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.
D. Diaphragms

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.

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

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.

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.
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

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.

METHODS & ACTIVITIES
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.