Manual reactor scram and AP-913 failure event due to preliminary report of failure of tube in *Rctr Clnt Steam Generator S31301ME088.

Status: OE - Equipment Failure - Event Tentative Complete Last Updated: 2012-10-29 4:09 PM

Significance: Significant
This event is SIGNIFICANT because the unexpected wear discovered has resulted in a lengthy outage to address the degradation of a major piece of equipment with high importance. Also, eight tubes did not meet design performance criteria per technical specifications for tube integrity, which resulted in a principal safety barrier being seriously degraded.

Abstract:
Manual reactor scram and AP-913 failure event due to preliminary report of failure of tube in *Rctr Clnt Steam Generator S31301ME088.

Recommended for Review By:
Mechanical Maintenance Staff

Lessons Learned Summary:
Reactors Coolant System - Key - Heat exchanger, condenser, steam generator - Mitsubishi Heavy Industry - 116TT1 - S31301ME088
None lessons learned were reported
Unspecified or Not Listed - Unspecified or Not Listed

Event Summary:
Steam Generator Tube Leak during First Cycle after Steam Generator Replacement (OE35393 updated by OE36028) During normal full power operation, a high radiation alarm from the condenser air ejector line revealed a primary to secondary leak from a steam generator tube. Operations responded by rapidly reducing power at approximately 1% per minute to 35% power and then removed the unit from service. The tube leak resulted from flow induced wear from "in-plane" tube to tube interaction in the tube u-bend region. The cause of the tube to tube interaction was fluid elastic instability (FEI) due to high steam velocity, high void fraction, and possibly less than expected contact forces between the tubes and the anti-vibration bars.

Event Date: 1/31/2012

Station Name/Unit Number: San Onofre Unit 3

Significance/Consequences: Consequential

Lessons Learned for the Industry:
Since full scale testing of new steam generators is not feasible prior to installation and operation in a plant, the potential for tube vibration problems must be assessed during the design phase, and the design must be robust enough to ensure that if tube vibration occurs, it will not compromise the design and operational objectives. The standard industry methods (state-of-practice) for flow induced vibration analysis assume that anti-vibration bars provide
effective support for restraining "in-plane" motion with the result that "in-plane" motion is not likely to occur because of the higher frequency of "in-plane" motion than for "out-of-plane" motion. This assumption might be incorrect for large steam generators with local regions of high steam velocity and/or high void fraction. Long term corrective actions might include operational restrictions (e.g., reduced power operations), increased steam generator tube inspection frequency (e.g., mid-cycle inspection outages), additional tube plugging, and/or installation of additional tube supports.

Applicability: Operations, Component Engineering, Systems Engineering, Design Engineering, Radiological Protection, Work Management,

Description:
During normal full power operation, a high radiation alarm from the condenser air ejector line revealed a primary to secondary leak from a steam generator tube. The leak rate increased from approximately 30 gallons per day to approximately 82 gallons per day within 65 minutes compared to a Technical Specifications limit of 150 gallons per day. Operations responded by rapidly reducing power at approximately 1% per minute to 35% power and then removed the unit from service.

After cooling to mode 5 and draining the primary coolant system to midloop, the leaking tube was located by filling the secondary side of the steam generator and pressurizing to 80 psig with nitrogen. The leak location was confirmed by eddy current testing. Subsequent eddy current testing of the tubing in both steam generators revealed wear indications on a number of tubes.

The tube leak occurred in Unit 3 while Unit 2 was in a planned refueling outage.

In-situ pressure testing to three times the normal operating differential pressure was subsequently performed on 129 steam generator tubes, including the leaking tube that caused the shutdown. Eight of the tubes failed the test with three failing the leak rate criteria of 0.5 gpm and five not maintaining structural integrity. The tube failures were in the u-bend region of the tube bundle in the tube freespan. These results did not meet the performance criteria for steam generator tube integrity.

Causes:
The tube leak resulted from flow induced wear from "in-plane" tube to tube interaction in the u-bend region. Wear had also occurred on the anti-vibration bars, tube support plates, and retainer bars. There was no evidence of foreign material at the tube leak site. The cause of the tube to tube interaction was "in-plane" tube vibration as a result of fluid elastic instability (FEI) due to high steam velocity, high void fraction, and possibly less than expected contact forces between the tubes and the anti-vibration bars.

Two adjacent Unit 2 tubes also had minor tube to tube wear. The Unit 2 tubes met the steam generator performance criteria. The Unit 2 tube wear from retainer bar vibration (OE35357) that was recently detected during eddy current testing is a separate problem from the Unit 3 tube to tube wear problem.

Corrective Actions:
Eddy current testing was performed in both Unit 3 steam generators to determine what portions of the tube bundle were susceptible to the wear mechanism. Secondary side
inspections and in-situ pressure testing in accordance with EPRI guidelines were also performed. Degraded tubes, per the steam generator program repair criteria, were removed from service by plugging. The specific tubes that were potentially susceptible to this mechanism were preventively plugged and stabilized. Repair plans will be developed to mitigate the wear mechanism.

Long term corrective actions might include operational restrictions (e.g., reduced power operations), increased steam generator tube inspection frequency (e.g., mid-cycle inspection outages), additional tube plugging, and/or installation of additional tube supports. Startup of either unit is contingent upon completion of the actions in response to the NRC Confirmatory Action Letter of March 27, 2012 and subsequent NRC review of required actions.

The procedures/instructions for the plant to respond to the tube leak were appropriately followed. However, the Steam Generator Tube Rupture Emergency Operating Instruction (EOI) is being resequenced to initiate lowering the reactor coolant system (RCS) temperature, lowering the RCS pressure, and then isolating the affected steam generator. This change is consistent with CEN-152, "Combustion Engineering Emergency Procedure Guidelines."

Previous Industry OE:
1. OE35357 - Steam Generator Tube Wear after First Cycle of Operation (San Onofre 2)
2. OE35359 - (Update to OE29131) Large Number of Anti-Vibration Bar Wear Indications Reported in the Unit 2 Replacement Steam Generators (St Lucie)
3. OE35393 - Steam Generator Tube Leak during First Cycle after Steam Generator Replacement (San Onofre 3)

Equipment Information:
NSSS/A-E: Combustion Engineering/Bechtel
Reactor Type: PWR
Affected System: Primary Coolant System
Component Manufacturer: Mitsubishi
Component Model Number: 116TT1 (drawing L5-04FU001)
Component Part Number: Alloy 690TT tubes of 0.750 diameter and 0.043 inch wall thickness
Component Type: Steam Generator

Information Contact:
Name: David Calhoun
Title: Senior Nuclear Engineer
Telephone: 949-368-7168
E-mail: David.Calhoun@SCE.com

Corrective Action Program Documents:
201836127, LER 362-2012-002

Attachments (Pictures, Root Cause, and so forth):
None

This event is NOTEWORTHY-CONSEQUENTIAL because the unit was removed from service because of a primary to secondary leak.

**Cause Summary:**
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Long term corrective actions might include operational restrictions (e.g., reduced power operations), increased steam generator tube inspection frequency (e.g., mid-cycle inspection outages), additional tube plugging, and/or installation of additional tube supports. Startup of either unit is contingent upon completion of the actions in response to the NRC Confirmatory Action Letter of March 27, 2012 and subsequent NRC review of required actions. The procedures/instructions for the plant to respond to the tube leak were appropriately followed. However, the Steam Generator Tube Rupture Emergency Operating Instruction (EOI) is being resequenced to initiate lowering the reactor coolant system (RCS) temperature, lowering the RCS pressure, and then isolating the affected steam generator. This change is consistent with CEN-152, "Combustion Engineering Emergency Procedure Guidelines."

**Event Type:**
- Operational Consequence - Scram or Plant Transient
- Maintenance Rule Program Consequence - Functional Failure
- Maintenance Rule Program Consequence - Exceeded Plant Level Monitoring Criteria
- International Severity - 0. No Safety Significance
- Regulatory Reporting Consequence - Preliminary Event Notification (PEN)
- Operational Consequence - Non-Transient Shutdown, Generation Loss or Outage

**Impact**

**Unit Consequence:**
- Location Name: San Onofre Unit 3
- Unit Effect Start Date: 2012-01-31 4:30 PM
- Unit Effect: Manual Reactor Scram
- Scram Signal: N/A
- Initial Plant Mode: Power Operation
- Final Plant Mode:
- Initial unit Power:
- Final Unit Power:
Industrial Safety Consequence:  
None

Radiological Consequence:  
None

Level of Investigation: Root Cause Evaluation

Unit Description: 
San Onofre Unit 3  USA  Combustion Engineering    CE-2 Loop

Equipment Affected: 
Initiating Components:

Key Component:  
Heat exchanger, condenser, steam generator - S31301ME088 - INPO947702 Ap-913)

System:  
Reactant Coolant System

Performance Description:  
Internal Leakage

Discovered During:  
Operational (Non-Test) Demand

Age at failure:  
1 Years, 30 Days

Industry Common Name:  
*Rctr Clnt Steam Generator

Site Common Name:  

Manufacturer:  
Mitsubishi Heavy Industry

Specific Model:  
116TT1

Generic Model:  
116TT1

Required Engineering Characteristics: 

Location/Nature:  
Permanently installed site equipment

Subcategory (Parts List) :  
Steam Generator

Type :  
Vertical Shell and Tube

Optional Engineering Characteristics: 

Configuration :  
U-Tube

Tube Material :  
Iron-Chrome-Nickel Alloys

Parts:  
Tube

Cause:  
Component / Equipment Specific Cause(s):

Design:

Failure to Consider Design Inputs
(AP-913) Design Change Less Than Adequate - Component Not Appropriate for its Configuration / Application

Excessive Vibration
Other Trend Codes:

Process/ Program Codes (General Area - Does Not Imply Cause):
- Equipment Reliability
  - System Monitoring Program and System Health
- Configuration Management
  - Design Change Program - Staff Design Change
- Equipment Reliability
  - Maintenance Rule Program

Repeat Of:

Complicated By:

User Defined Tags:

Technical Contact:
Matheny, Al  -  al.matheny@sce.com  -  949-368-9011
Senior Nuclear Engineer

Former Report Numbers:
OE:OE35393, OE36028 EPIX:804

Former Database IDs:
PED Event: 362-120131-1 EPIX Failure: 57032

Start Date/ Time: 2012-01-31 4:10 PM
End Date/ Time: 

Attachments:
I0045006 - STEAM GENERATOR TUBE LEAKAGE (OPERATIONAL CONSIDERATIONS)
OE35393.doc - OE35393 - Steam Generator Tube Leak during First Cycle after Steam Generator Replacement (San Onofre 3)
PEN47628.doc - MANUAL TRIP DUE TO A PRIMARY TO SECONDARY LEAK GREATER THAN 30 GAL/HR
83-02.txt - STEAM GENERATOR TUBE RUPTURES
0018.txt - STEAM GENERATOR TUBE LEAKAGE (OPERATIONAL CONSIDERATIONS)
OE36028.doc - OE36028 - (Update to OE35393) Steam Generator Tube Leak during First Cycle after Steam Generator Replacement (San Onofre 3)
0018-1.doc - STEAM GENERATOR TUBE LEAKAGE
17-82.txt - STEAM GENERATOR TUBE LEAKS
NN 201836127 - Unit shutdown due to apparent steam generator tube leak