NUCLEAR REGULATORY COMMISSION
EXTENDED POWER UPRATE
PRE-SUBMITTAL MEETING

SUSQUEHANNA STEAM ELECTRIC STATION

FLOW INDUCED VIBRATION (FIV) EVALUATION
&
REACTOR PRESSURE VESSEL STEAM DRYER ANALYSIS

11/15/2005

PPL SUSQUEHANNA
EXTENDED POWER UPRATE

Plant Overview / Uprate History & Plans

PLANT OVERVIEW

- Two Unit Site - Berwick, Pa. (Northeast Pa.)
- BWR-4, 251" Vessel, Variable Speed Reactor Recirculation Pumps
- Mark II Pressure Suppression Containment
- Natural Draft (Closed Loop) Cooling Towers
- Commercial Operation: Unit 1 – July 1983
  Unit 2 – February 1985

SUSQUEHANNA STEAM ELECTRIC STATION (SSES) POWER UPRATE HISTORY / PLANNED

- Original Licensed Thermal Power: **3293 MWth** (OLTP)
- Stretch Uprate: ~ 4.5% Thermal Increase To **3441 MWth** / 1993 – 1994 Timeframe
- Feedwater Measurement Uncertainty Recapture (MUR) Uprate: ~ 1.6% Thermal Increase To **3489 MWth** - Current Licensed Thermal Power (CLTP) / 2002 – 2003 Timeframe
- Turbine Retrofit Project (TRP): No Thermal Power Increase - ~ 50 Mwe Increase / 2003 – 2004 Timeframe
- Extended Power Uprate (EPU) Project Current Plan
  - Currently At ~ 106% Of OLTP
  - Planning On Licensing Up To The Full 120% Of OLTP
  - Each Unit's Uprate To Be Implemented Over 2 Fuel Cycles
    - Unit 2 1st Step (~ 7% Thermal) - Spring 2007
    - Unit 1 1st Step (~ 7% Thermal) - Spring 2008
    - Unit 2 2nd Step (Generator Limited To 1300 MWe) - Spring 2009
    - Unit 1 2nd Step (Generator Limited To 1300 MWe) - Spring 2010
  - Normal Anticipated Power Level For Most Of The Year: ~ 116 – 117 % OLTP

PPL SUSQUEHANNA
EXTENDED POWER UPRATE

Flow Induced Vibration (FIV) Evaluation

- Overall approach outlined below & analysis results to-date will be provided in an attachment to the SSES EPU submittal

- BWROG EPU Lessons Learned and Recommendations Report (NEDC-33159) has been used as the starting point for PPL's FIV evaluation effort

  - NRC RAIs have also considered
  - Plant Performance Assessment (PPA) completed during EPU feasibility study phase

- EPU Review of the Extent Of Condition (EOC) for vibration-related issues

  - EXTERNAL: Review of industry events (INPO OE EPU data base) regarding piping & component vibration problems
  - INTERNAL: Comprehensive document review of SSES piping & components vibration history (calculations, maintenance documents, corrective action items)
  - INTERNAL: Plant personnel input to aid in defining existing vibration sensitive equipment

- Evaluate the potential for increased FIV effects due to EPU increased flows, focusing on:

  - Main Steam & attached piping
  - Condensate/Feedwater
  - Extraction Steam
  - Feedwater Heater Drains

- Installation of vibration instrumentation on EPU affected piping which will be inaccessible during operation

  - Instrumented locations/directions are based on nodal analyses of the most susceptible locations
  - To date, piping instrumentation has been installed, or is planned to be installed:

System	Unit 1		Unit 2	
	# Locations	# Accelerometers	# Locations	# Accelerometers
Main Steam	6	18	**6**	**16**
Feedwater	5	11	5	11
Recirculation	18	27	**11** (7 more to be Installed	**16** (11 more to be installed)
RHR (Outside Containment)	4	20	**4**	**20**
Ext. Steam (4th Stage)	**3**	**8**	Under Assessment	
Bold items are currently installed				

PPL SUSQUEHANNA
EXTENDED POWER UPRATE

Flow Induced Vibration (FIV) Evaluation

- Results to date:
  - Main Steam: Results are about 10% of initial screening criteria established by Structural Integrity (SI)
  - Feedwater: No results to date - Expected to be consistent with Main Steam results
  - Recirculation & RHR: Results are well within initial screening criteria. Maximum location is 60% of initial criteria
  - Ext. Steam: Results are about 40% of initial screening criteria - Modifications installed to support the SSES TRP Project have addressed concerns - Evaluation is ongoing
- Operational and outage walk-downs to inspect areas for evidence of unacceptable vibration
  - Inspection plan & locations being developed
  - EPRI guidelines exist for continued monitoring
  - Continuous monitoring via SSES Station Engineering system monitoring health program
- Completed modifications to address vibration examples:
  - PPL's ongoing initiative to address Reactor Recirculation small branch pipes
  - Replacement of vibration degraded snubbers on Steam Seal & Feedwater Heater Drain Systems with energy absorbing restraints
- Planned additional modifications to address expected unacceptable vibration on Main Turbine Electro Hydraulic Control (EHC) system
- Potential for additional modifications to address high vibration detected by installed instrumentation and walk downs is acknowledged

PPL SUSQUEHANNA
EXTENDED POWER UPRATE

Flow Induced Vibration (FIV) Evaluation

SUMMARY

- PPL's strategy accounts for the BWROG recommendations, and both industry and plant specific experience
- Systems of primary EPU focus are those that are most impacted by EPU, with emphasis on most likely problematic locations:
  - Main Steam
  - Condensate/Feedwater
  - Extraction Steam
  - Feedwater Heater Drains
- Additional system under consideration:
  - Reactor Recirculation
- To-date results:
  - Low responses have been observed at the most susceptible locations
  - Recirculation System exhibits a moderate response, but still well within acceptable levels
  - Data observed provides ongoing inputs for future monitoring locations & strategy

PPL SUSQUEHANNA
EXTENDED POWER UPRATE

RPV Steam Dryer Analysis

- Overall approach outlined below & analysis results to-date will be provided in an attachment to the SSES EPU submittal

- BWROG EPU Lessons Learned and Recommendations Report (NEDC-33159) has been used as the starting point for PPL's steam dryer evaluations
  - NRC RAIs have also considered
  - PPL continues to monitor industry developments

- SSES has curved hood dryers: 3rd generation dryer design which has been carried through to BWR 5's & 6's - Examples of structural enhancements:
  - Outer hoods – ½" plate
  - Tie bars – 2" x 2" bar stock connecting top pd dryer banks, increased # of bars
  - PPL Modification: 2nd bank hood to end panel welds – 3/16" thick reinforcement strips

- SSES Operational Experience
  - Unit 1 1st Refueling Outage (1986): Identified a crack on one of the 2nd bank hood to end panel welds & cracking of dryer support lug
    - Modified the location with a – 3/16" thick reinforcement strip (common modification is shown in BWRVIP-139) & removed/replaced the support lug
    - Cracking attributed to possible dryer "rocking"
    - Performed an instrumented test to verify the validity of the repair
    - **Results from the SSES instrumented test will be benchmarked against Acoustic Circuit (AC) Monitoring & Scale Model Testing (SMT)**
  - As a result of this crack, PPL has performed augmented dryer inspections every refueling outage (both units)
  - Other structural repairs: Drain channel horizontal repair & steam dam repair SSES dryer condition is comparable to the industry
  - Minor IGSCC in weld heat affected zones & cold worked surfaces – similar to that found throughout the BWR fleet
  - SSES dryer condition is comparable to the industry: IGSCC is monitored – structural issues are repaired

- EPU Experience
  - BWR 3s have experienced hood and cover plate failures attributed to acoustic loads due to very high main steam velocities
  - Vortex shedding occurring at branch line connections excites resonant frequencies in critical length branch lines (SRV stand pipes)

RPV Steam Dryer Analysis

- SSES-specific design considerations
  - SSES dryers are the curved hood design: No failures have been reported from slanted or curved hood dryers at EPU levels
  - SSES main steam velocities at EPU will be about 75% of Quad Cities
  - SSES SRV configuration: Only 6 of 16 SRVs are on "live legs"
  - SSES has data from an instrumented dryer test for benchmarking purposes

- SSES Methods of Analysis
  - Overall approach is based industry experience / lessons learned
    - Consideration has been given to the staff's RAIs from other submittals
  - Acoustic Circuit Analysis (AC): Measurements of steam line pressure fluctuations are utilized by Continuum Dynamics Incorporated (CDI) to project pressure loading on the dryer
  - Finite Element Analysis (FEA): General Electric (GE) applies the loads generated by various analytical or testing methodologies to an ANSYS model of the steam dryer to generate stress profiles. These profiles are compared to conservative acceptance criteria
  - Strouhal calculations (CDI, GE, PPL): Generally accepted methodology for determining resonant frequencies of branch lines and relative probability of exciting those resonances due to critical steam line velocities
  - SRV Scale Model Testing (SMT): CDI to perform a 6 to 1 (approximate) SMT of a single SRV branch line to confirm Strouhal calculations
  - Main Steam system SMT: GE to perform a 17 to 1 (approximate) SMT of the SSES main steam lines from the dryer to the turbine inlets

- SSES Analysis (Current Loads)
  - 1986 Unit 1 Instrumented Dryer Data: The Unit 1 steam dryer was instrumented in 1986 and vibration, stress and pressure data at conditions up to 3293 MWth (OLTP) was compiled
    - **Measured dryer response data will be compared to in-plant Main Steam Line (MSL) results for confirmatory purposes**
  - Unit 2 MSL flow venturis have been instrumented to generate pressure data for use in the AC analysis - CDI loads are being used as input to CLTP FEA
  - Unit 1 MSLs will be instrumented in the Spring of 2006 with staring gauges to generate data for use in a more accurate AC analysis
    - **Installation (location & orientation) will be similar to Quad Cities** and will be input to a supplemental FEA
  - Unit 2 MSLs to be instrumented with strain gauges during the initial EPU implementation outage to monitor acoustic loads during power ascension

RPV Steam Dryer Analysis

- SSES Analysis (EPU Predictive Loads)
  - GE SMT results: 17 to 1 scale model of the SSES main steam lines from the dryer to the turbine inlets
    - This model to be used to generate a set of acoustic loads at EPU conditions for input into an FEA model of the SSES steam dryer
  - Strouhal calculations (CDI, GE, PPL): Expected acoustic response at EPU levels based on generally accepted methodology
  - CDI SMT results: The 6 to 1 scale model of a single SRV/MSL section will be used to confirm the Strouhal calculations at EPU conditions
  - 1986 Unit 1 Instrumented Dryer Data
    - **Measured dryer response data will be compared to the SMT results for confirmatory purposes**

RPV Steam Dryer Analysis

SUMMARY

- **Submittal Plan**
  - Information will be provided in a timely manner, as the best data becomes available
  - SSES EPU Submittal (RPV dryer-related content will be provided in an attachment to the SSES EPU submittal)
    - Analysis plan
    - Summary of 1986 instrumented test data
    - Expected acoustic response from SRV/MSL branch lines at EPU levels based on CDI, GE & PPL Strouhal calculations
    - Results of CDI 6 to 1 SMT of the single SRV/MSL branch line (verification of Strouhal calculations)
    - Power ascension dryer test plan (AC analysis using strain gages for confirming dryer loads at hold points)
  - RPV Dryer Supplement 1 (CLTP dryer load definition)
    - CLTP FEA stresses / margins based upon Unit 2 instrument leg AC monitoring
  - RPV Dryer Supplement 2 (EPU projected load definition)
    - CLTP FEA based upon Unit 1 strain gage acoustic monitoring - Increased margin to allowable stress levels over instrument leg measurements is expected
    - EPU FEA based upon GE 17 to 1 SMT results - Predictive analysis at EPU power levels including uncertainty analysis
    - Power Ascension Acceptance Criteria
      - Predictive results from SMT will be monitored via acoustic circuit analysis (strain gage measurements)
      - AC analysis will be utilized to confirm that no unpredicted frequency response is present
      - Acceptance criteria will be determined based upon SMT predictions, Strouhal calculations & FEA margins
      - Vibration monitoring accelerometers on SRVs can identify resonances in real time if they occur