Integrated Boiler Management Through Advanced Condition Monitoring and Component Assessment

DE-FE0031683

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Boiler Life & Availability Improvement

Crosscutting Research and Advanced Energy Systems Project Review Meeting – Transformative Power Generation

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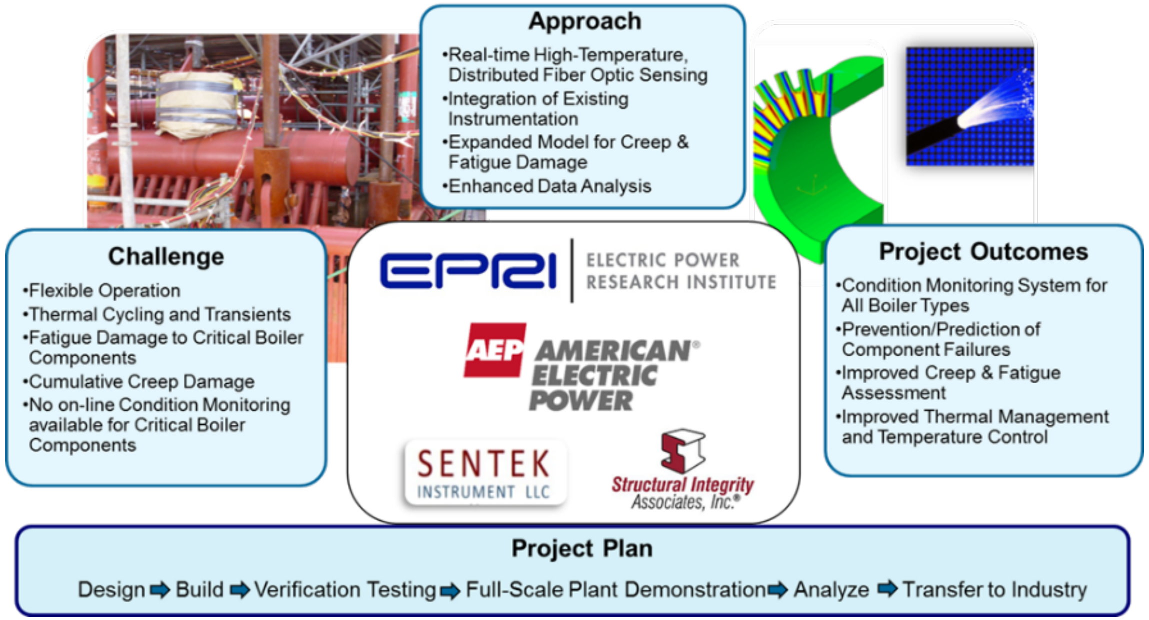
Project Objectives and Status

- Project Objectives
  - Develop, demonstrate, and support technology transfer of an integrated boiler management system to track accumulation of creep and fatigue damage
    - Includes development of high-temperature optical fiber distributed sensing
    - Near real-time assessment of creep and fatigue damage accumulation
  - Improved boiler operation in concert with existing plant data
- Status
  - Development of creep-fatigue management system complete
  - Host-site demonstration of integrated boiler management system in progress
  - Development of optical fiber distributed sensing technology continues; demonstration delayed until late 2021

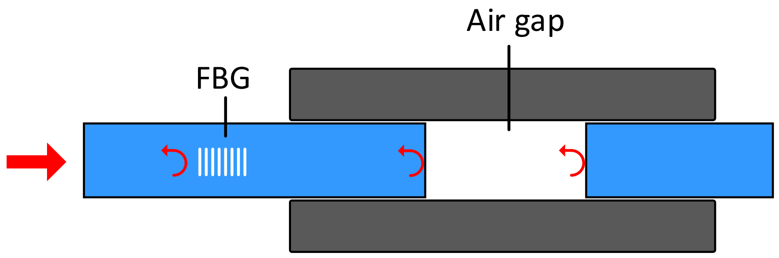
Project Partners

- Project Partners and Responsibilities
  - Project prime (EPRI)
  - High-temperature, distributed optical fiber sensors (Sentek Instrument LLC)
  - Creep-Fatigue Management System (Structural Integrity Associates)
    - Incorporates sensor output
      - Optical fiber sensor
      - Existing plant instrumentation
    - Near real-time assessment
  - Host-site demonstration (AEP)

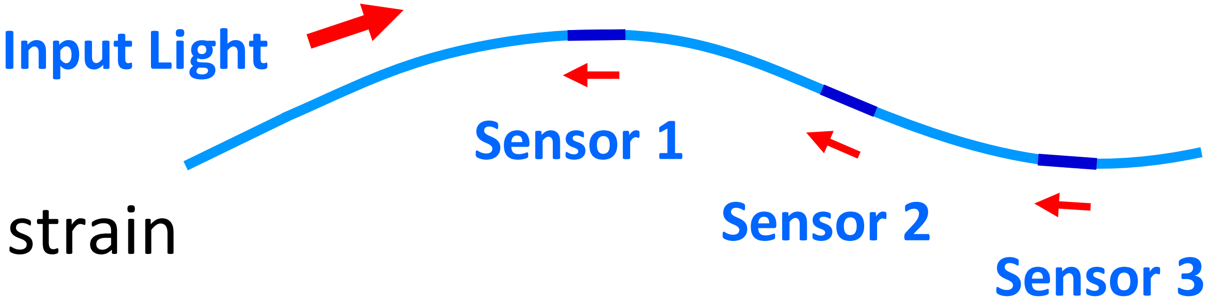


High-Temperature, Distributed Optical Fiber Sensors

Multiplexed Fiber Strain Sensors



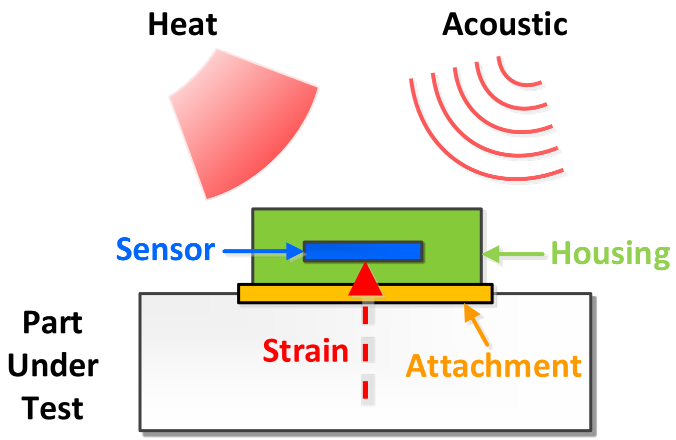
- Sensing principle
  - Air gap optical interferometer
  - Fiber Bragg grating (FBG)
  - Multiplexed sensor link



- Sensor response
  - Airgap: sensitive to temperature & strain
  - *Thermal* strain vs. *Mechanical* strain
  - FBG: temperature only (for temperature compensation)
  - Mechanical strain measurement after temperature compensation

Design Considerations of Strain Sensing System

- Unlike temperature or vibration that can easily penetrate sensor housing, mechanical strain is affected by several factors
  - Attachment method, housing design, and materials
  - Application-specific requirements
- Design considerations
  - Minimize sensor dimension and maximize force transfer
  - Increase out-of-plane rigidity and in-plane flexibility
  - Maintain high temperature capabilities



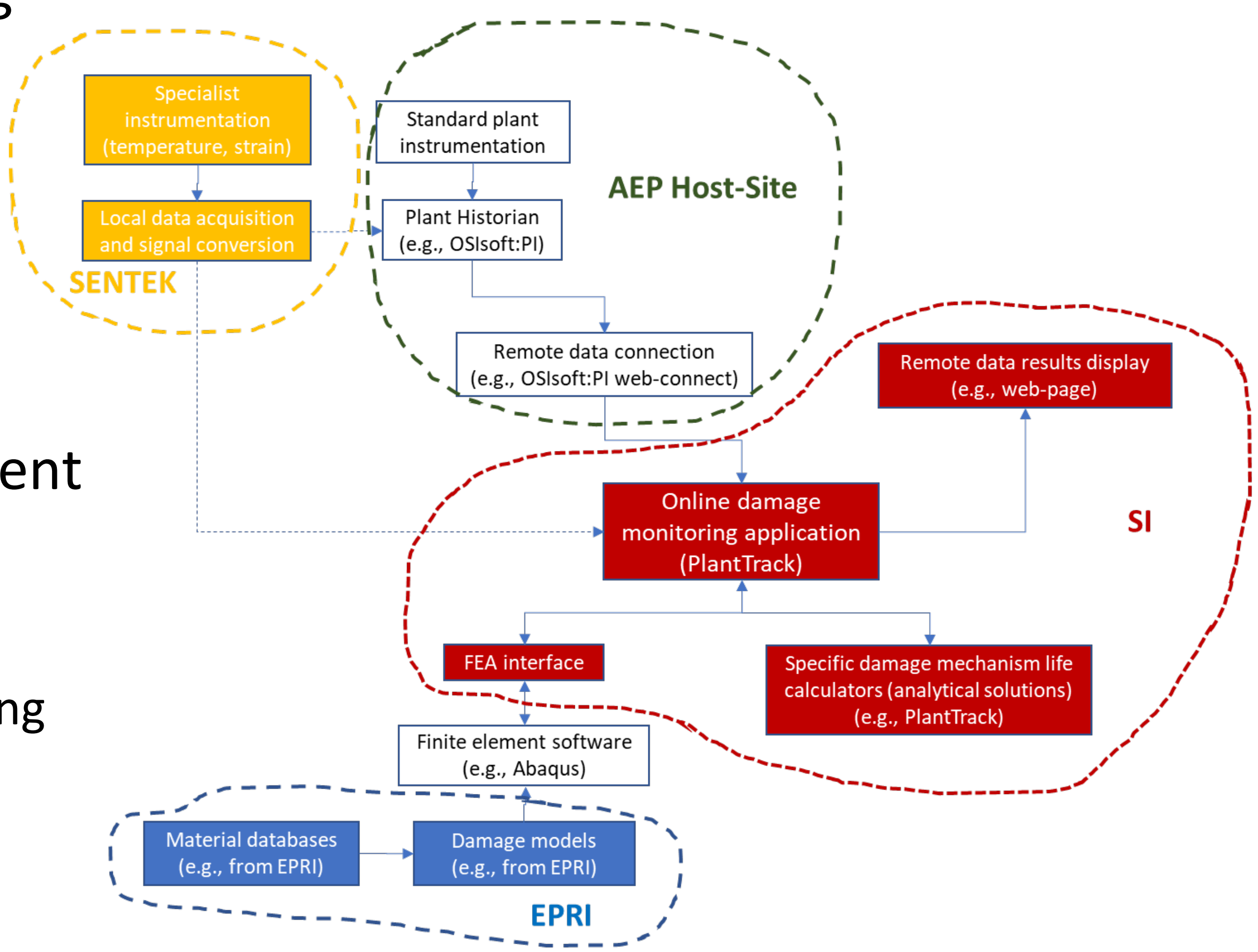
Status and Plan for Strain Sensing System

- Multiple rounds of sensor iterations and testing completed
- Extensive insights gained through testing
- Next-generation design developed and being fabricated
- High-temperature strain test setup being developed
- Sensors to be tested and calibrated individually and as a link
  - EPRI Charlotte laboratories
  - 3Q 2021
- Field demonstration anticipated to begin late 2021/early 2022

Integrated Boiler Management System

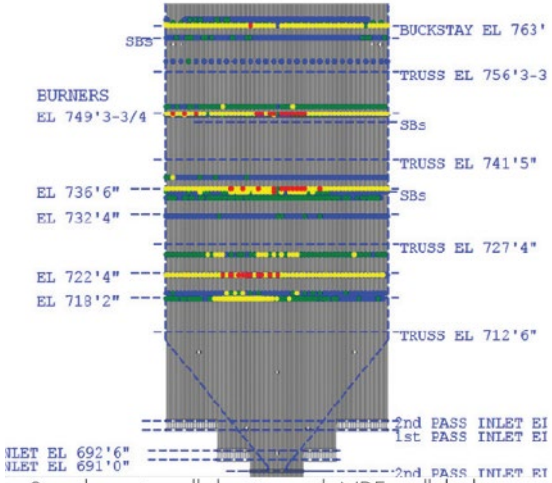
Online Damage Monitoring

- Modular configuration to leverage existing technology
  - Connection to plant historian (OSIsoft:PI)
  - Finite element software (Abaqus)
  - Damage constitutive models (EPRI)
  - Web-based interface (PlantTrack)
- Scalable system adaptable to any component or damage mechanism
  - Python scripting in Abaqus
    - Automation of FE analysis and post-processing
  - Connectivity between applications
    - Data exchange and display

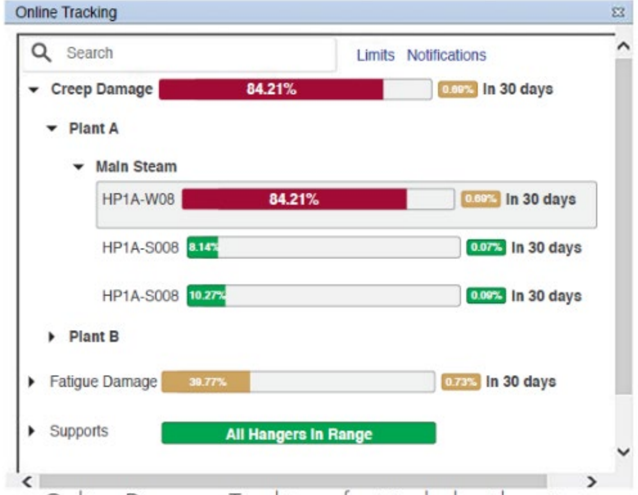


Creep-Fatigue Management System

- Existing web-based data management system which provides a graphical user interface for:
  - Location specific design data
  - Historical inspection results
  - Maintenance and repairs actions
  - Engineering data on either uploaded design drawings or on 3D models
- Used to perform subsequent engineering analyses/calculations to help:
  - Prioritize locations for future inspections
  - Aid in assessments of relevant damage mechanisms
  - Overall life management



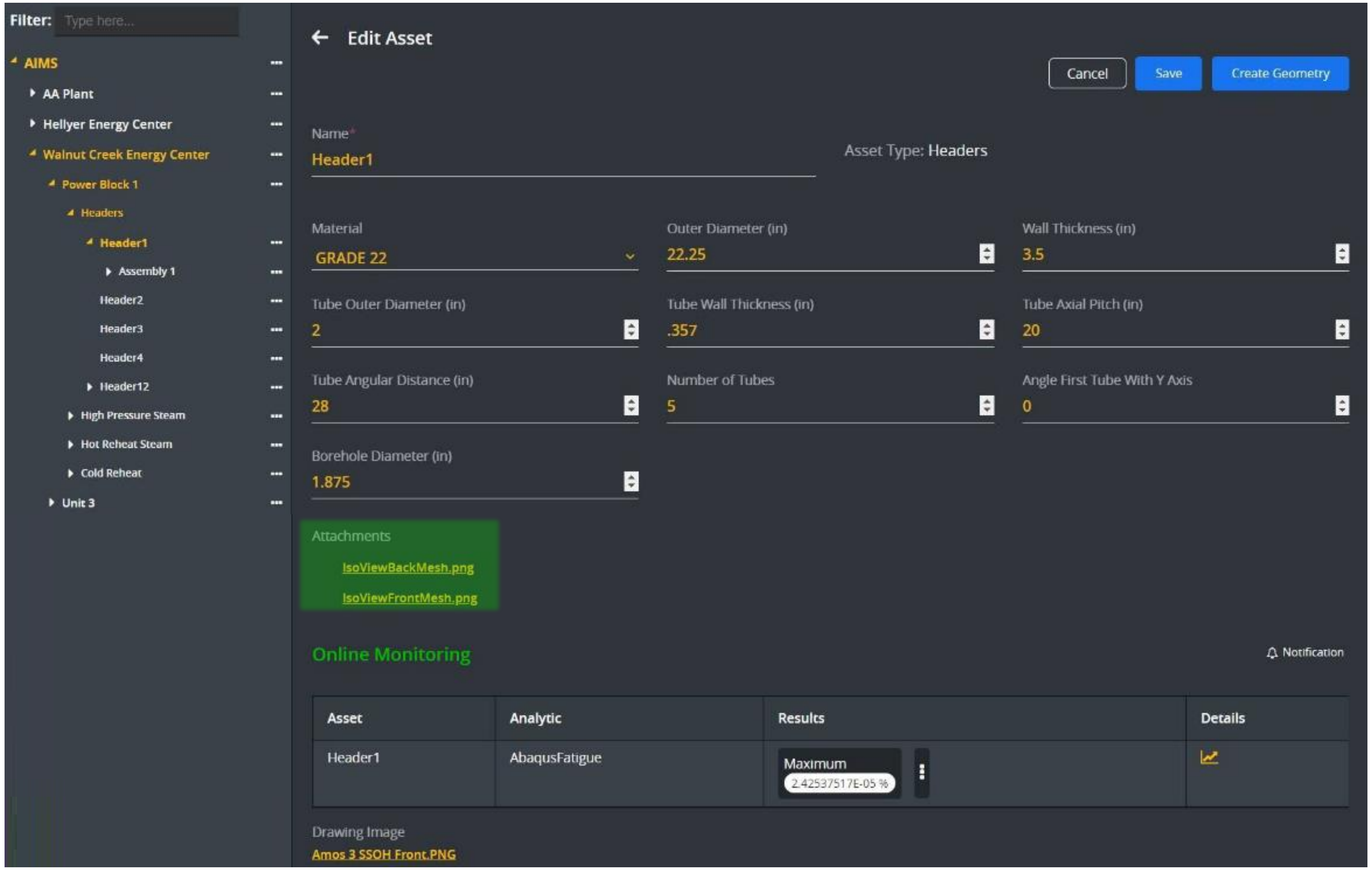
Sample waterwall drawing with NDE wall thickness readings



Online Damage Tracking of critical plant locations

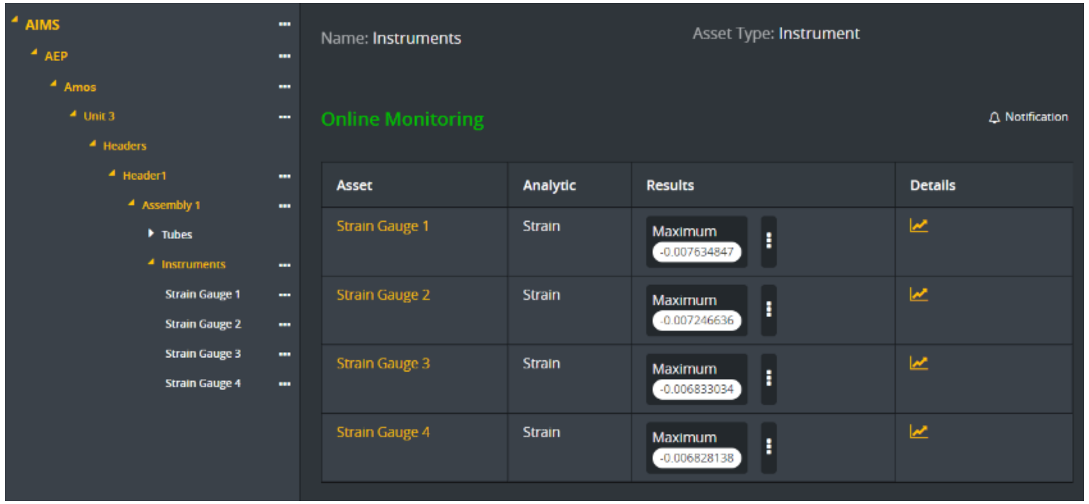
Geometry Creation

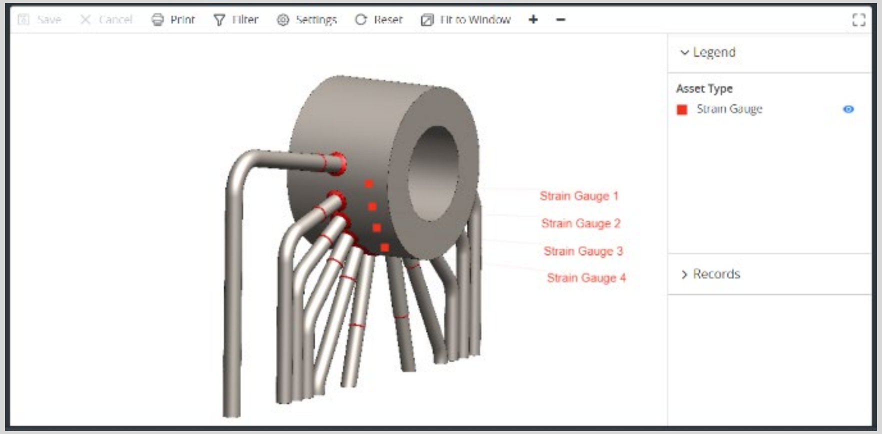
- Developed under this project - initial header geometry creation page
- User completes input and selects “Create Geometry”
  - Scripts launch Abaqus CAE
  - Generates the model
  - Creates PNG picture files for verification

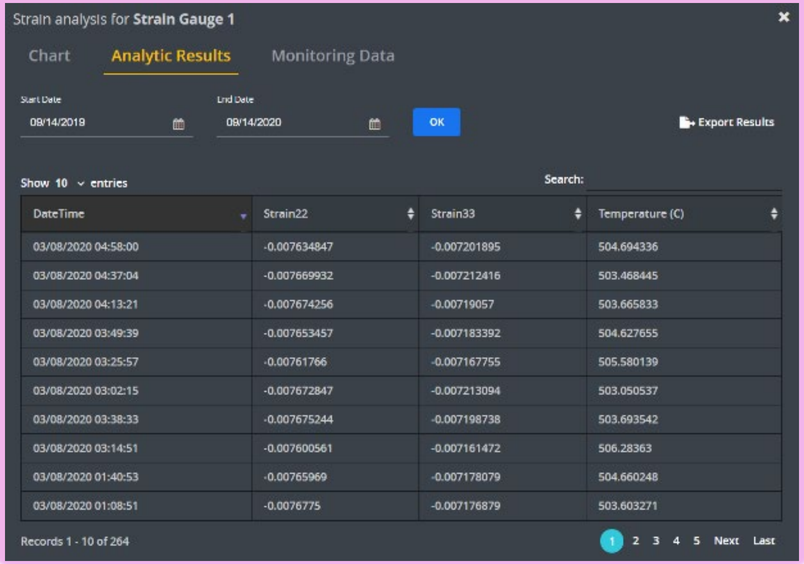


Strain Gauge Measurements

- Strain Gages can be observed separately
  - Show gage locations on header
  - Show calculated strain output from the Finite Element Model
  - Show the measured strain output from the installed gauges
  - Plot the comparison







DateTime	Strain22	Strain33	Temperature (C)
03/08/2020 04:58:00	-0.007634847	-0.007201895	504.694336
03/08/2020 04:37:04	-0.007669932	-0.007212416	503.468445
03/08/2020 04:13:21	-0.007674256	-0.00719057	503.665833
03/08/2020 03:49:39	-0.007653457	-0.007183392	504.627655
03/08/2020 03:25:57	-0.00761766	-0.007167755	505.580139
03/08/2020 03:02:15	-0.007672847	-0.007213094	503.050537
03/08/2020 03:38:33	-0.007675244	-0.007198738	503.693542
03/08/2020 03:14:51	-0.007600561	-0.007161472	506.28363
03/08/2020 01:40:53	-0.00765969	-0.007178079	504.660248
03/08/2020 01:08:51	-0.0076775	-0.007176879	503.603271

Demonstration Host Site

Demonstration – AEP Host Site

- Front Secondary Superheat Outlet Header (SSOH) selected, focus on assemblies with steam cooled spacer tubes (SCSTs)
- Background
  - B&W Plant Service Bulletin PSB-49, January 1994
  - Possible condensate entering SSOH from the SCST
  - Additional thermocouples added to assess temperature response

B&W babcock & wilcox power generation group

Plant Service Bulletin

Steam-Cooled Spacer Tube Related Cracking of Secondary Superheater Outlet Headers

Purpose

To advise owners and operators of B&W drum and once-through coal-fired design boilers, equipped with secondary superheater steam-cooled spacer tubes, to inspect the secondary superheater outlet header internal surfaces for cracks in the vicinity of the steam-cooled spacer tube entries. The steam-cooled spacer tube design (see Figure 1) is used on many units to maintain superheater section side spacing.

Problem

Internal, longitudinal cracks may develop on the inside of the outlet header in the vicinity of the steam-cooled spacer tube entries. These cracks are caused by thermal quenching from water that clears the spacer tube during startup and impinges on the higher temperature outlet header internal surface. Longitudinal-type cracking may also develop in the spacer tube bore holes because of this thermal quenching.

Recommendations

To avoid the quenching and prevent header damage, the spacer tube should be boiled out simultaneously with the secondary superheater before the startup gas temperature limit is released. The following recommendations are provided to determine if header damage is developing on a unit, and to identify the corrective measures to help prevent further damage.

1. If the spacer tube outlet legs are not instrumented with thermocouples to monitor boil-out during startup, install thermocouples near the outlet header. Collect data during several startups to determine if the tubes are cleared of water prior to releasing the startup gas temperature limit.
2. A problem is indicated if a spacer tube temperature rises rapidly, some time after release of the startup gas temperature limit. If this delay in clearing is evident, then the header could possibly have existing damage. The spacer tube could also be damaged from overheat, caused by trapped water restricting steam flow.
3. Inspect the internal header surfaces in the vicinity of the spacer tube entries and the spacer tube bore holes for cracking damage. Normally, cracking is oriented with the longitudinal axis of the header. This damage should not be confused with tube ligament cracking, which can occur in the same area and is radially oriented around the tube holes.
4. Inspect the spacer tubes along their lengths for overheat damage as evidenced by warping, swelling, or support tie misalignment.

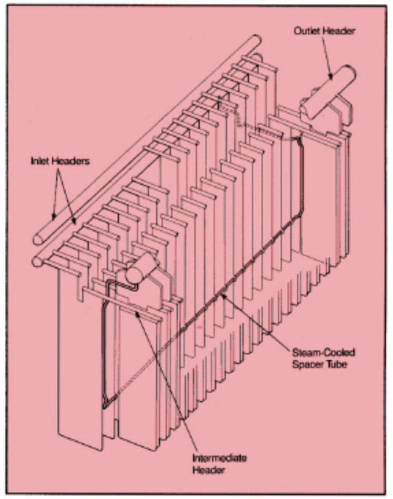


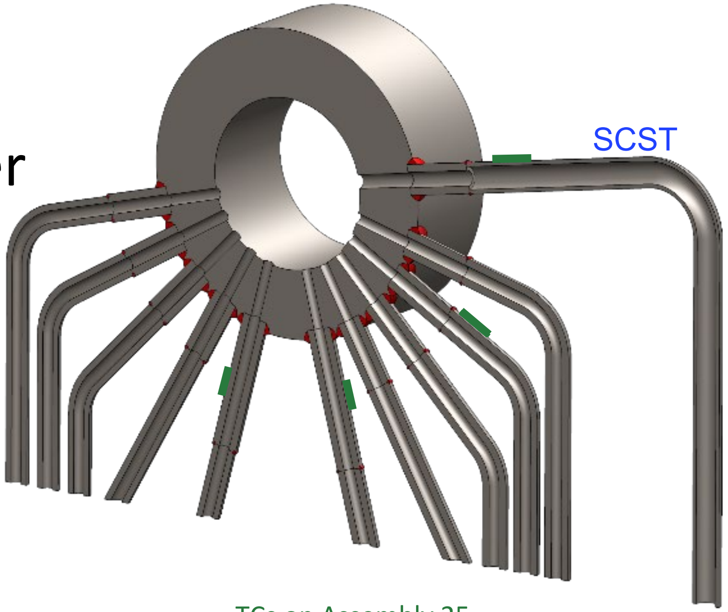
Figure 1 Pendant superheated with steam-cooled spacer tube.

(continued on reverse side)

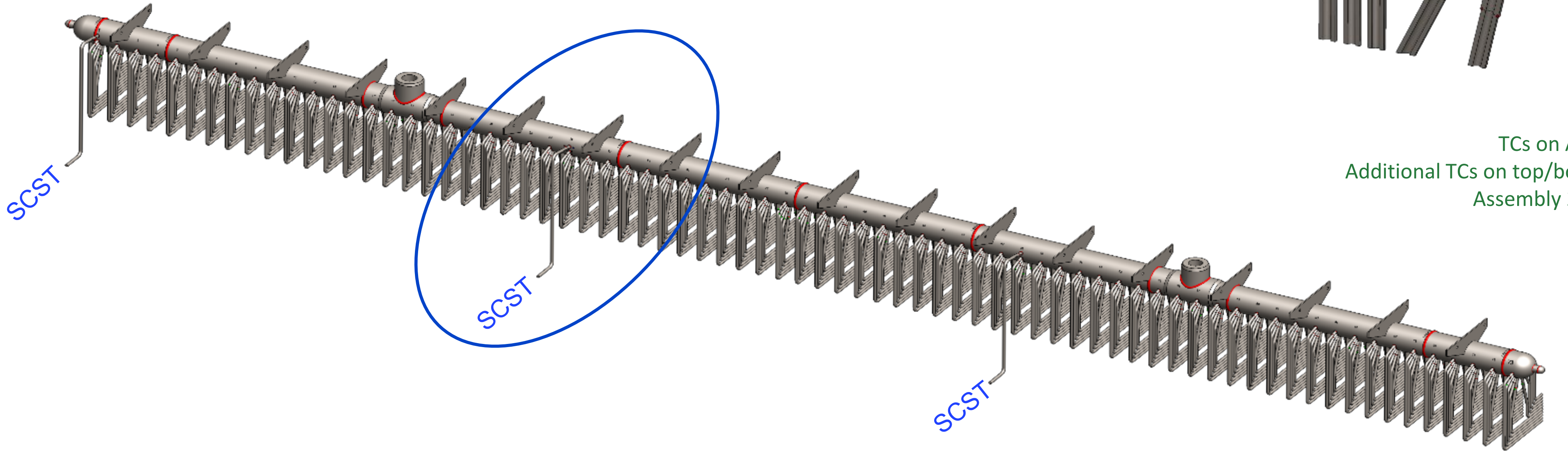
EPRI ELECTRIC POWER RESEARCH INSTITUTE

Demonstration – AEP Host Site

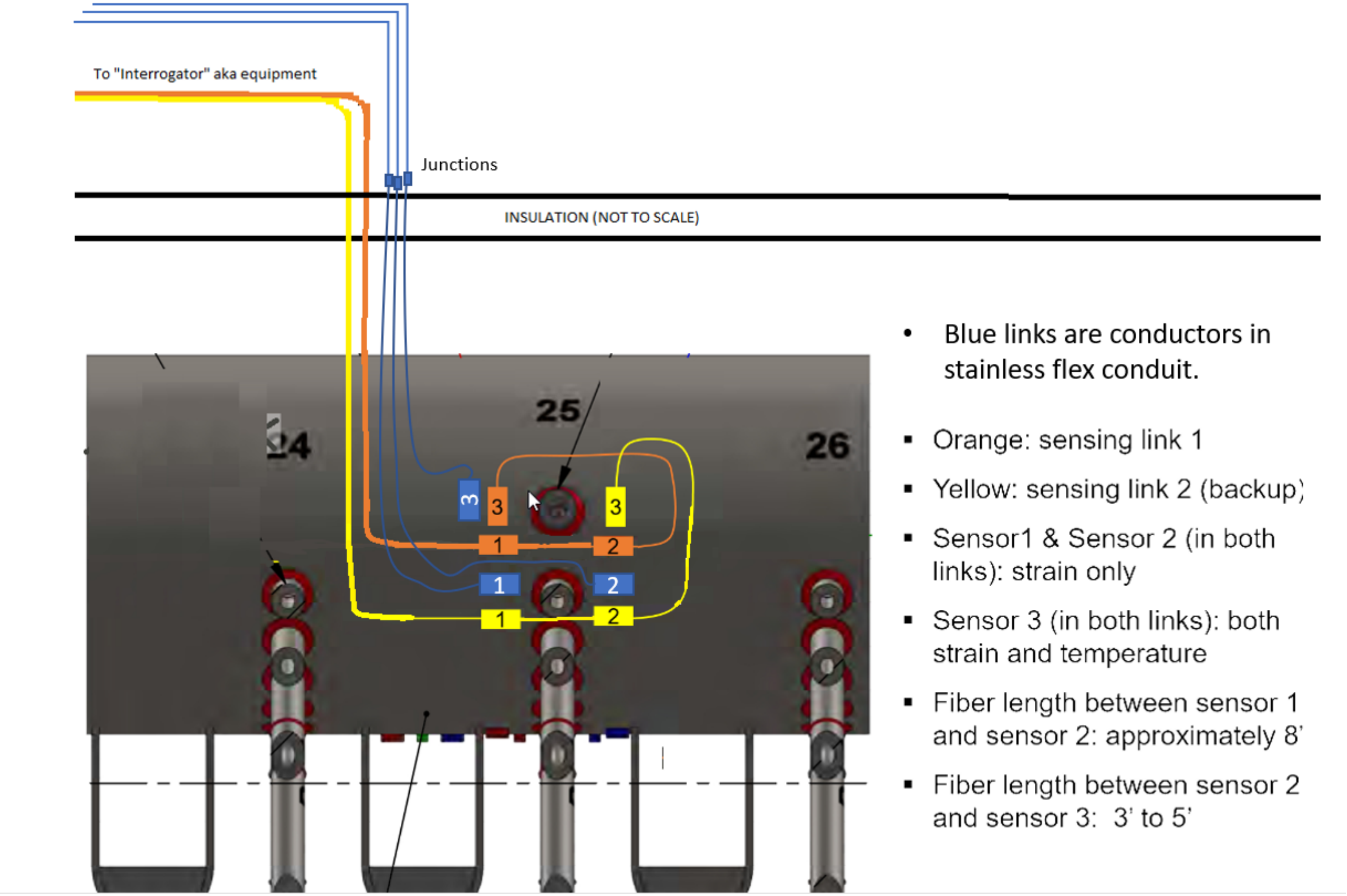
- 73 tube assemblies across the length of each SSOH
- Each assembly has 10 tube penetrations
- Three steam cooled spacer tubes (SCST) along the front header length and 1 SCST on the rear SSOH
- TCs previously added in multiple locations along SSOH



TCs on Assembly 25
Additional TCs on top/bottom of header in vicinity of Assembly 25 (not shown)



Strain Gage Instrumentation – Original Plan



- Blue links are conductors in stainless flex conduit.

- Orange: sensing link 1
- Yellow: sensing link 2 (backup)
- Sensor1 & Sensor 2 (in both links): strain only
- Sensor 3 (in both links): both strain and temperature
- Fiber length between sensor 1 and sensor 2: approximately 8'
- Fiber length between sensor 2 and sensor 3: 3' to 5'

Orange - Sentek Sensing Link 1
Yellow - Sentek Sensing Link 2
Blue - Suprock Technologies Strain Gauges

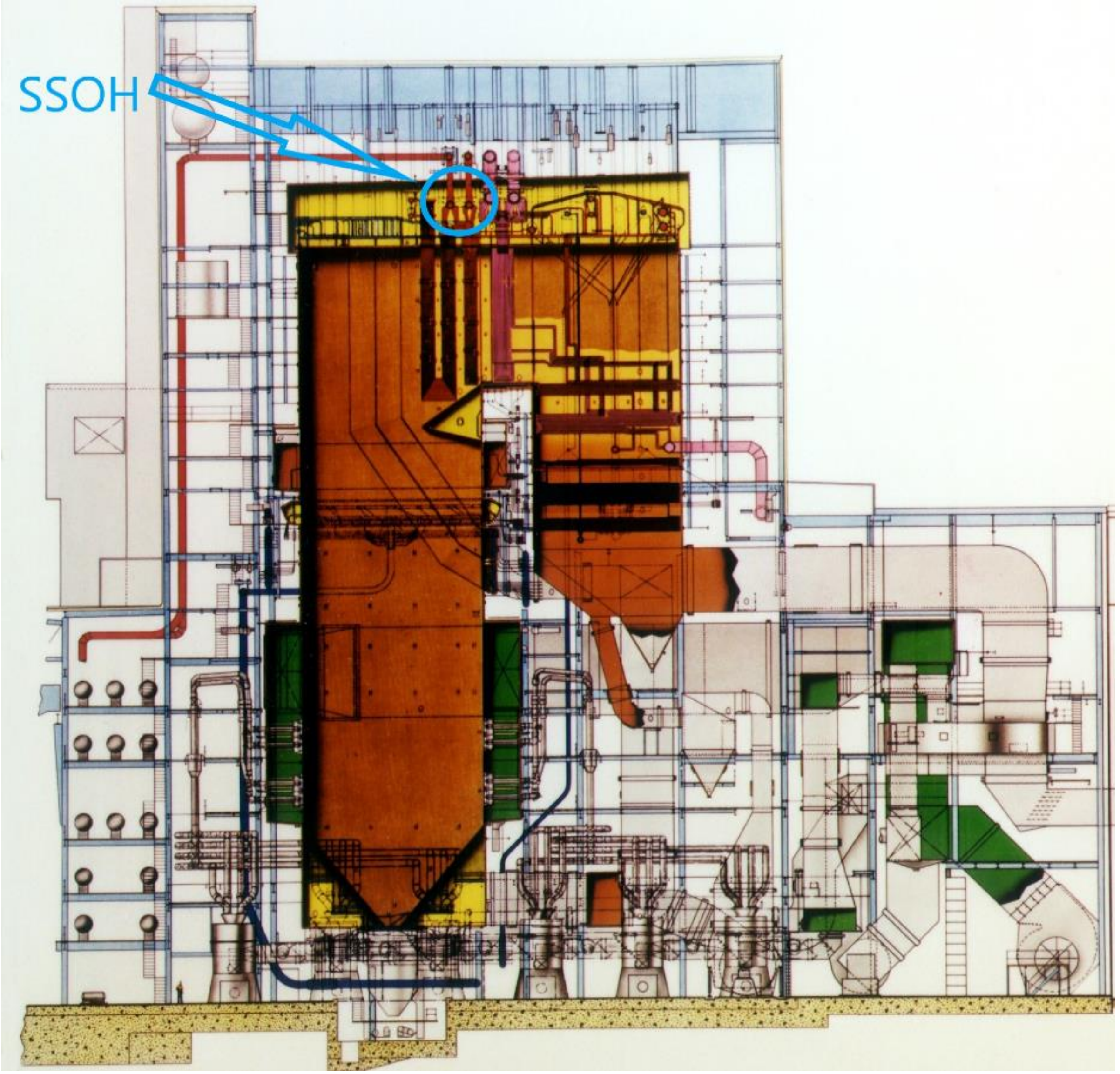
Not Shown:
- Existing plant thermocouples
- SI strain gages installed to complement Suprock gauges

Note: Installation of Sentek gauges postponed

Installation of Suprock and SI strain gages supported outside of DOE project (EPRI-funded)

Installation
November 16-18, 2020

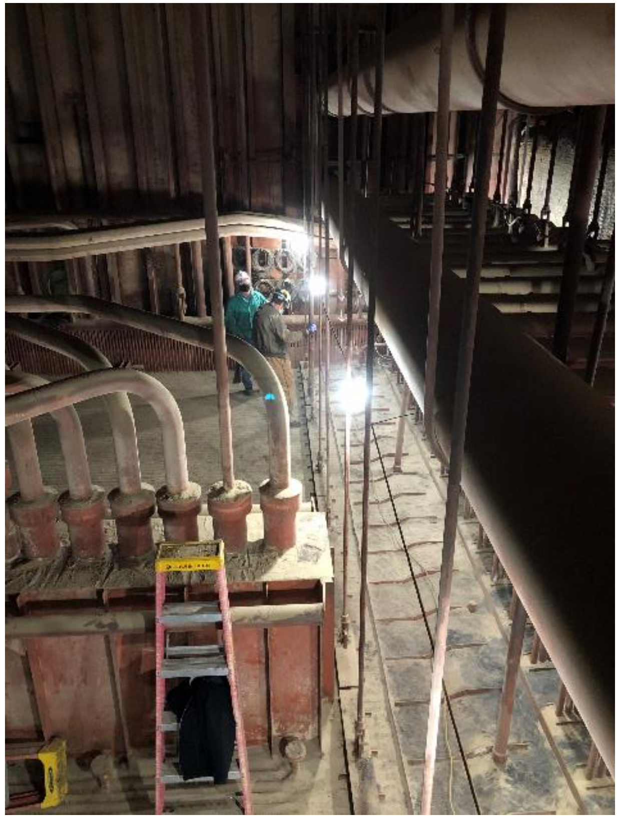
Location of Demonstration – Level 18



SSOH – Penthouse on Level 18

Access to Front SSOH

Prep Work for Gage Installation



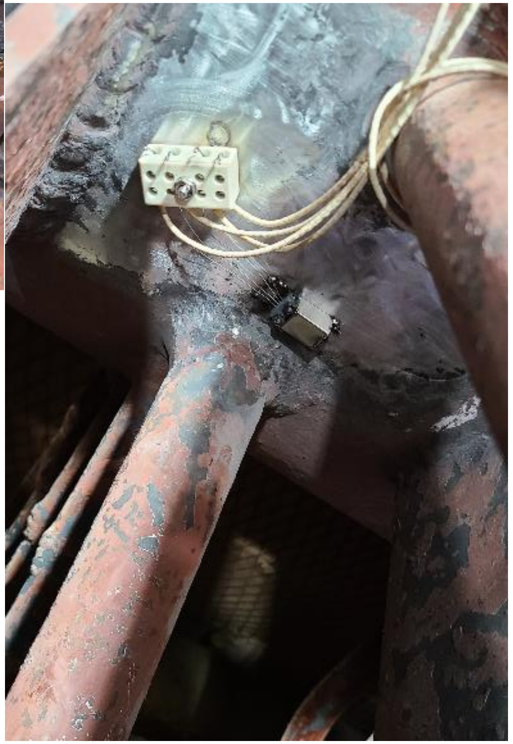
View Towards Penthouse Casing

Low-Capacity Discharge Welder

SSOH – Penthouse on Level 18

Strain Gage Installation
Near Assembly 25 SCST

Strain Gage Installation
SSOH Header Bottom



Cable Routing

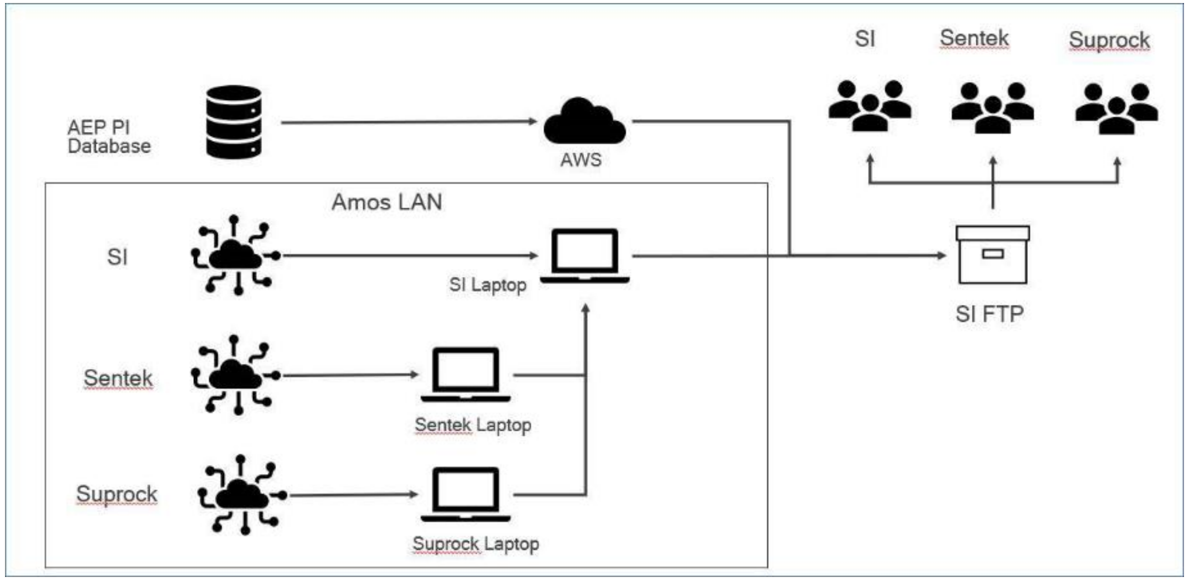
Penthouse Casing
Penetration

Data Acquisition System
Cabinet Outside Penthouse

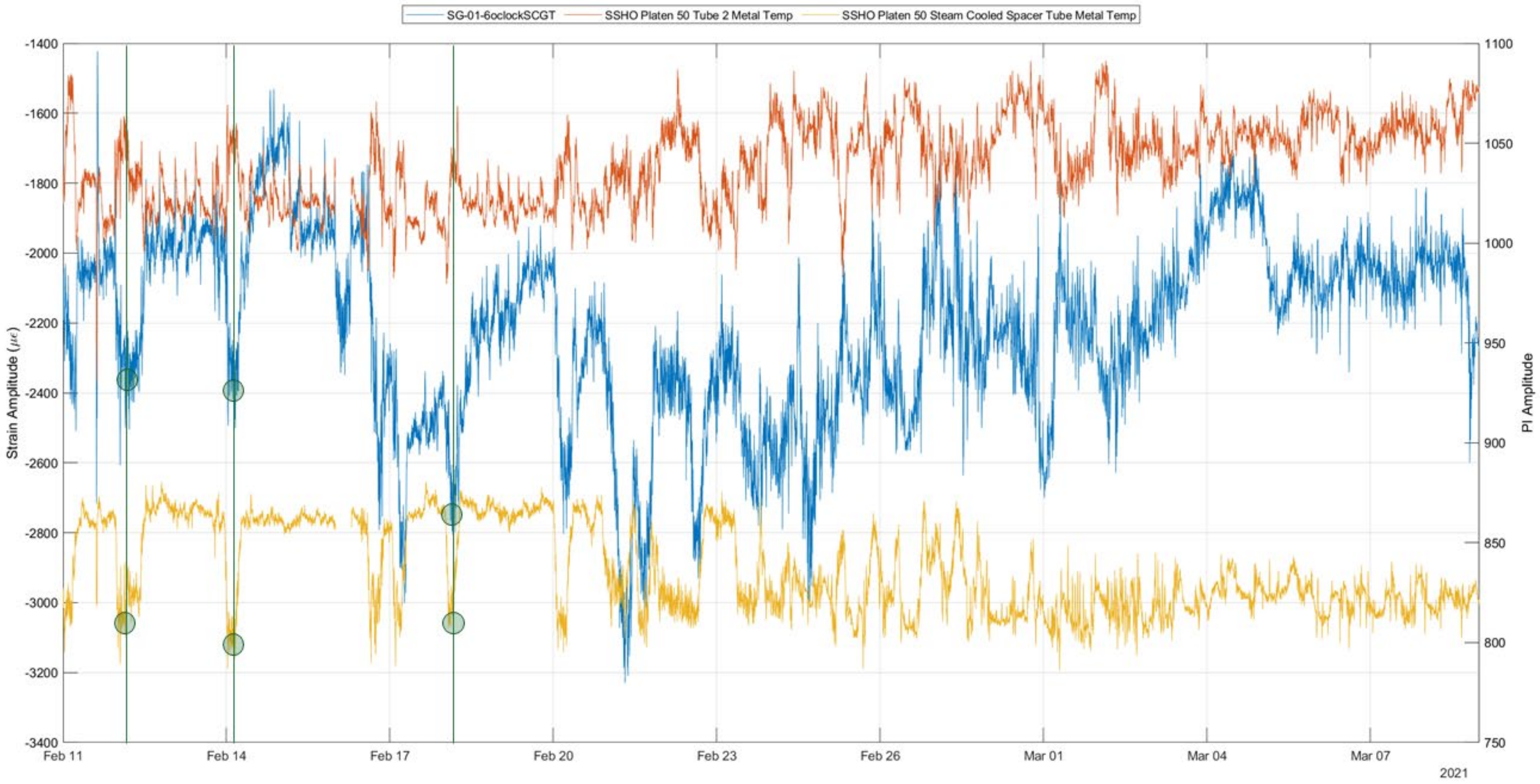
DCS Room – Level 4
Data Recording Laptops

Data Monitoring

- Project plan is to monitor operation for up to one year
  - Time needed to demonstrate creep-fatigue management system
    - Optimize time-steps for recording of strain, temperature
    - Optimize automation of creep-fatigue analysis
  - Time to study various operating profiles
- Data laptops connected through Plant LAN
  - Instrumentation data files written to shared folder
  - Files output to external ftp site
  - Files available to project team
- AEP providing onsite IT support



Independent Temperature Provides Good Agreement with Measured Dynamic Strain



Status

- Host site restarted in early January
- Installed strain gages operational
- Efforts underway to flow data into Creep-Fatigue Management System
  - Plant operating data (PI)
  - Prior installed thermocouples
  - Supplemental strain gages
- Optimization of creep-fatigue management system in progress
  - Verifying strain gage accuracy
  - Optimizing time-step for data recording
  - Automating creep-fatigue analysis

What's Next in 2021

- Process real-time operating data and include strain data in creep-fatigue system
  - Compare actual strain data to values calculated through finite element model
  - Trend damage development and make adjustments/refinements to the FE model and scripts, if needed
  - Complete automation for near real-time assessment
- Continue to develop crack growth algorithms
  - Improve remaining life assessment functionality
- Continue development of optical fiber strain gages (Sentek)
  - Laboratory testing in EPRI Charlotte facilities
  - Field testing at Amos Unit 3, if appropriate

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