Impact of increased flexibilization on Boiler Tube failures

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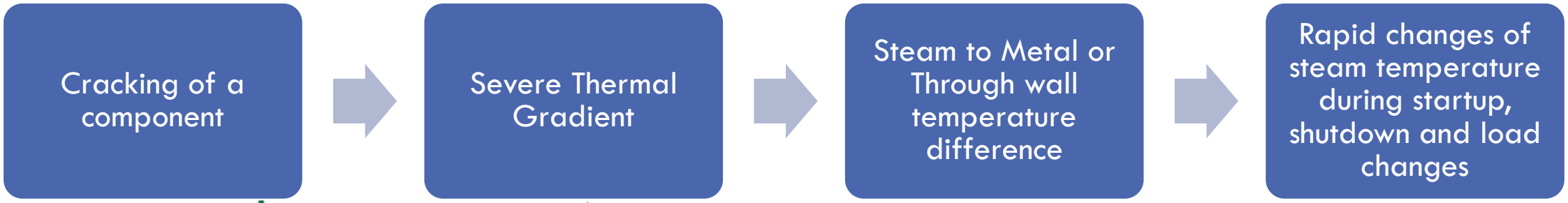
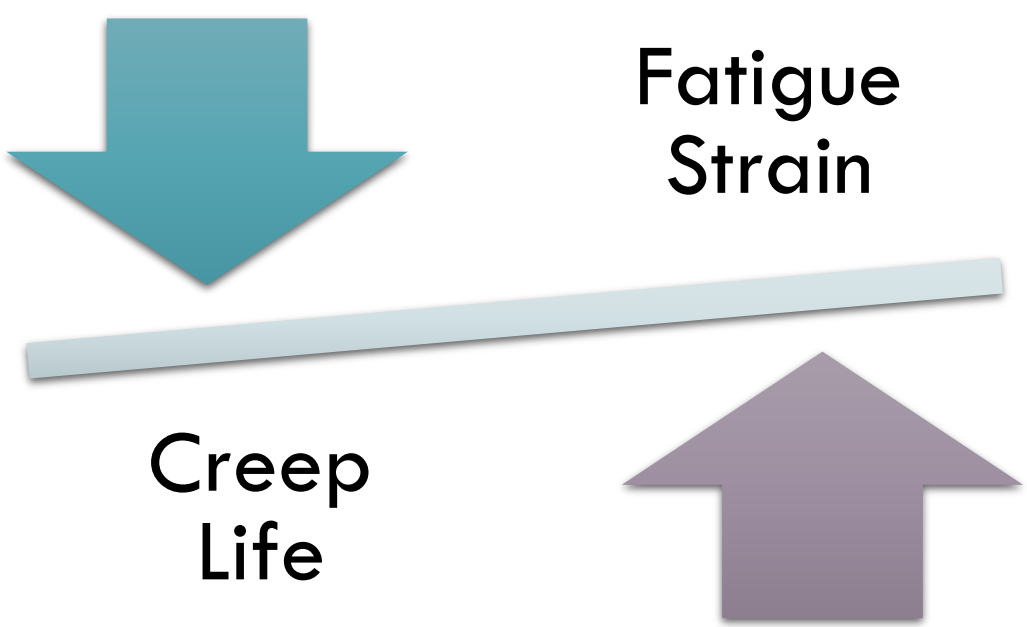
BACKGROUND

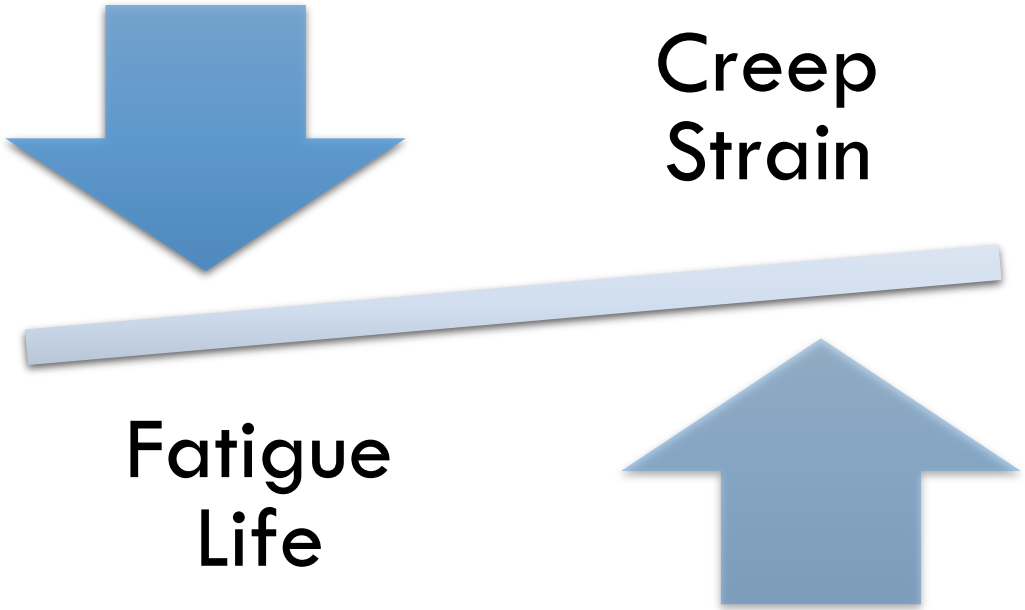
- Older base load plants were designed to operate predominantly under creep conditions.
- Design codes assumed that the effects of fatigue were contained within the conservatism of the design stress.
- Fatigue in conjunction with creep degraded material is now a significant concern.
- Thermal fatigue phenomenon manifest in the form of cracking of an individual component or in the mechanical failure of structures.
- Major components at risk are boiler superheater headers, PCP, Eco inlet headers, tube attachments.



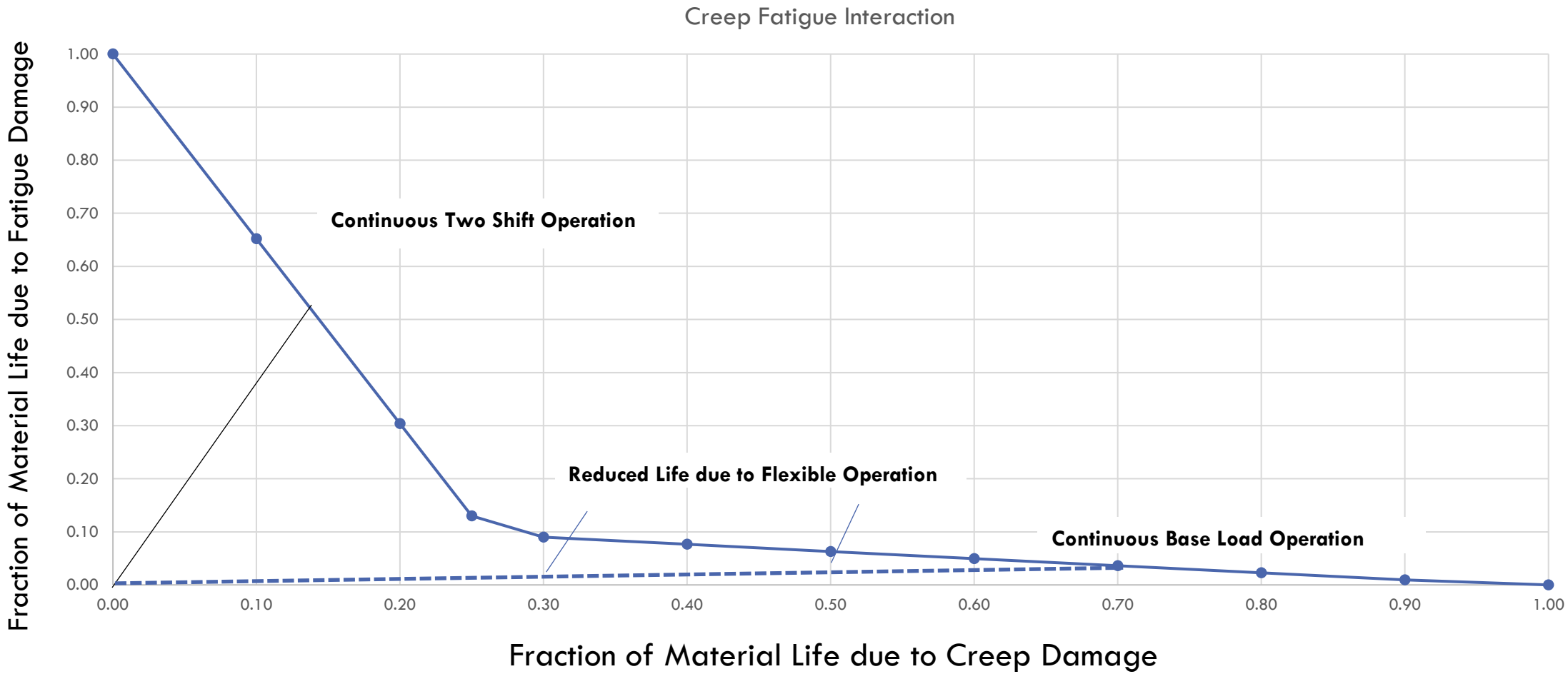
INTERACTION OF CREEP & FATIGUE

- Creep along with Fatigue Interaction acts **synergistically** to cause premature failure.

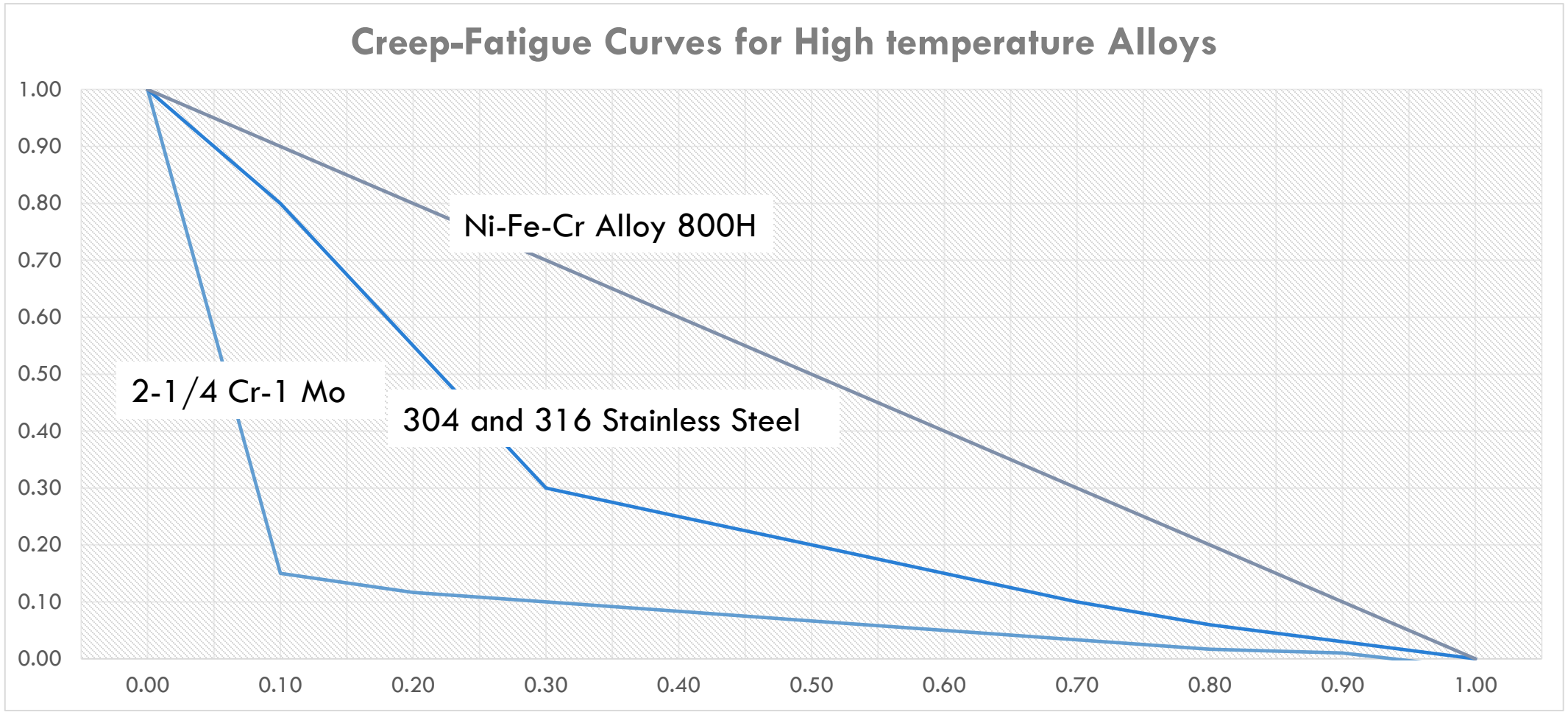




CREEP FATIGUE INTERACTION



CREEP FATIGUE CURVE



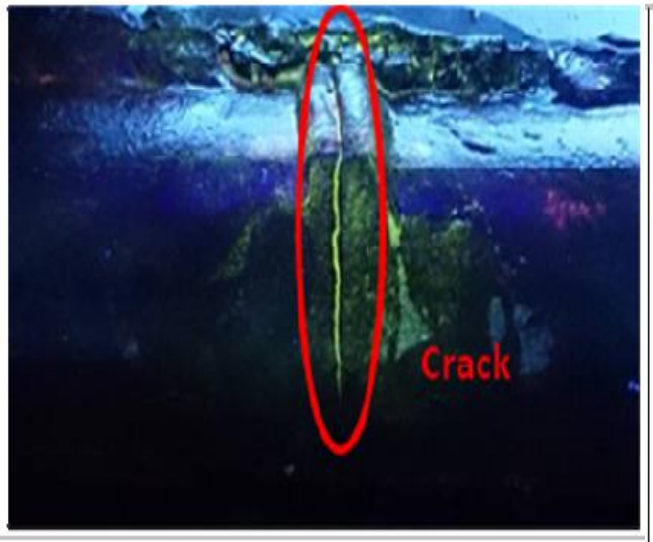
ISSUES IN BOILER

- Cracking of Thick Wall Components
- Superheater and Reheater Header Ligament Cracking
- Evaporator Header Stub Cracking
- Economizer Headers
- Feed Water Headers
- **Attachment Failures**
- **Condensate blockade issues at part load**
- **Exfoliation related failures due to frequent startups/ flexible operation**
- Furnace disturbance at part load due to soot blowing
- Economizer outlet feed water near saturation (eco steaming) risk at part loads

Boiler Tube Failure-Thermal Fatigue Failure

Failure in Platen SH stubs

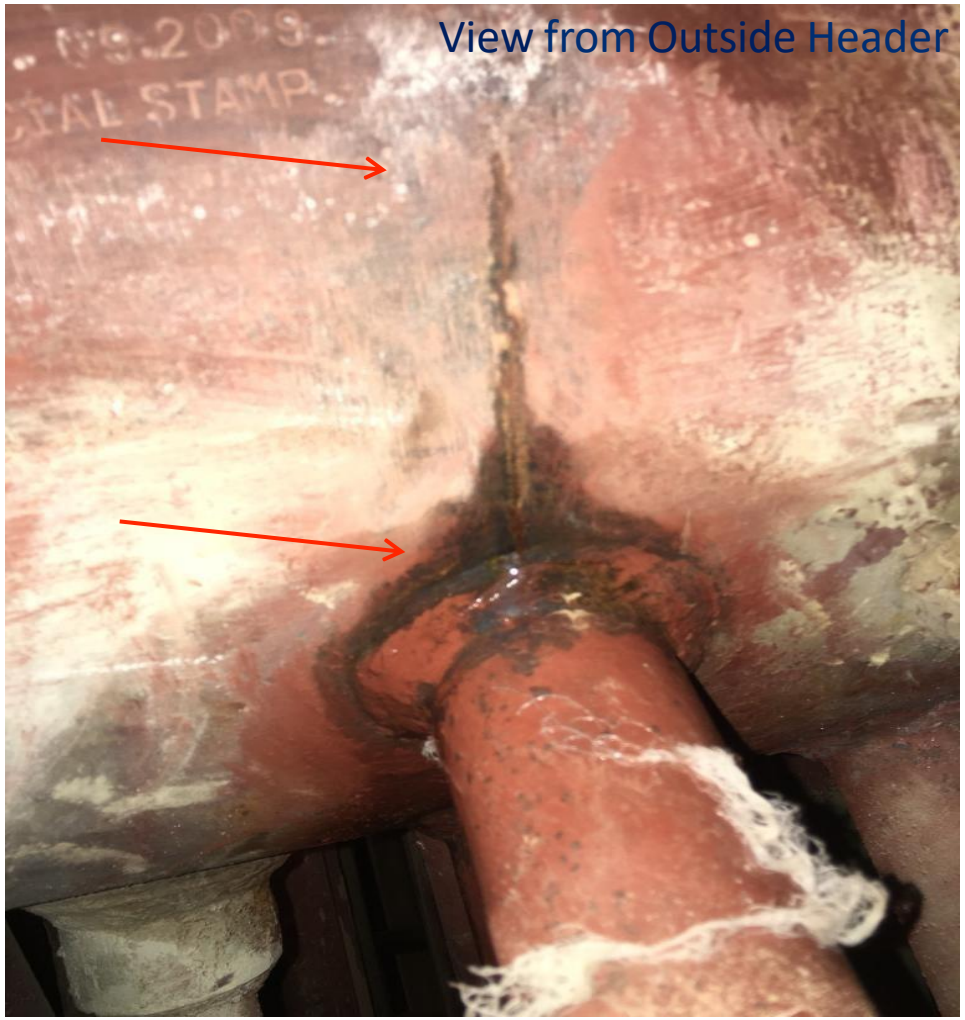
Boiler Tube Failure-Stub joint and Attachment Failure



Boiler tube leakage-Stub joint crack

Boiler tube leakage-Fatigue Crack

Thermal Fatigue Failure in Header – Passing of Drains in HRH Hdr

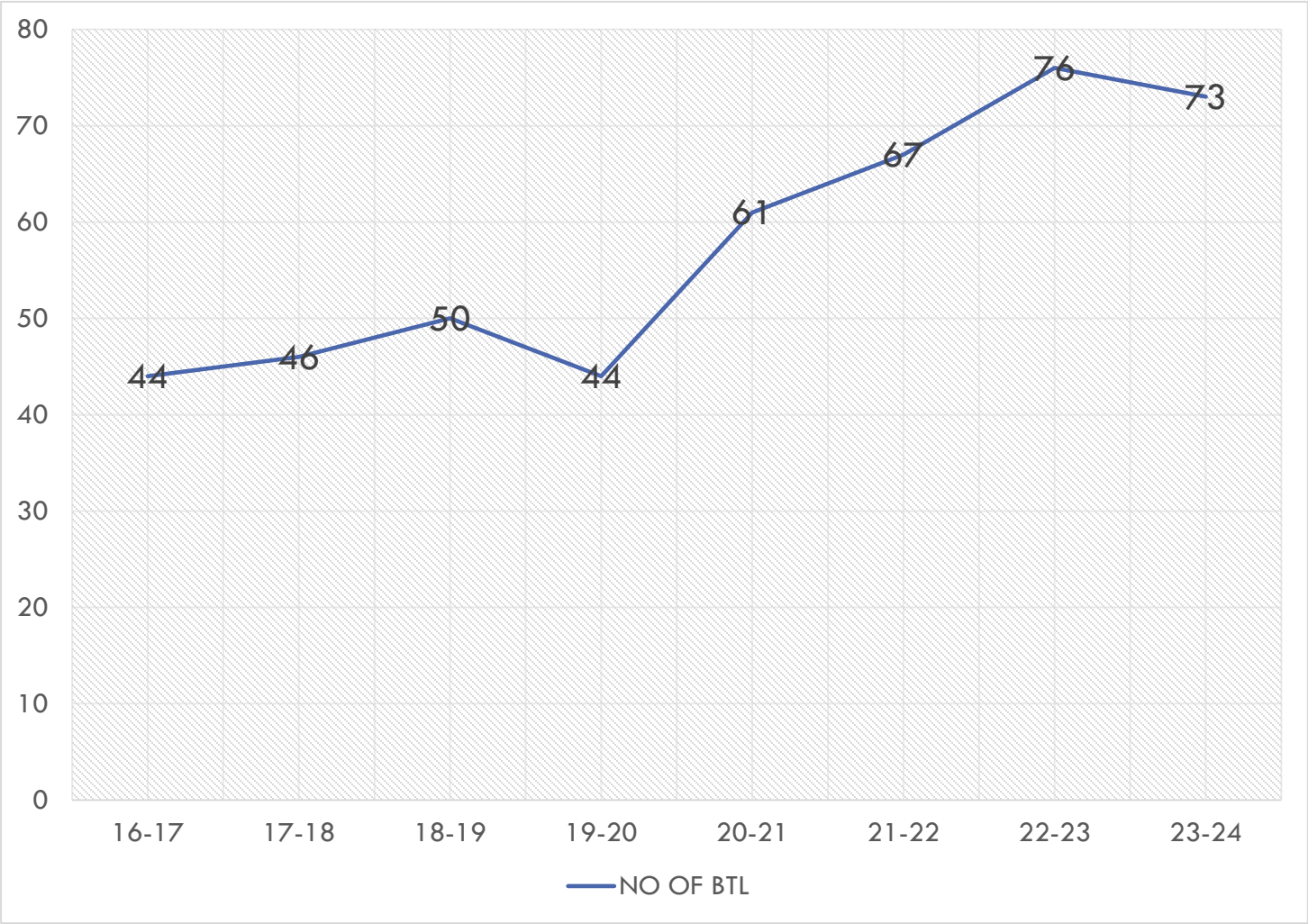


Failure in HRH Header(Ligament Cracks)

Innermost bend Crack

Failure of Innermost Bend of Final RH Pendent Coils Due to Fatigue

FATIGUE BTL TREND



During checking of Stubs in opportunity shut down cracks were observed in stubs in Water Wall and Steam Cooled Wall area as per following details:

Opportunity	Station & Unit	Area	No of stubs crack observed
Dec'21	NTPC	SCW	(Front: 66, Rear: 23, LHS: 2 no)
Feb'22	NTPC	SCW	94
May'22	NTPC	WW O/L Stub	10
June'22	NTPC	SCW	22
Aug'22	NTPC	SCW	123
Nov'22	NTPC	WW	1
Dec'22	NTPC	WW O/L Stub	3
Jan'23	NTPC	WW O/L Stub	3
Feb'23	NTPC	SCW	37 (Front: 10 no, Rear: 20, LHS: 5, RHS: 2 no)
Mar'23	NTPC	SCW	143

Exfoliation Process

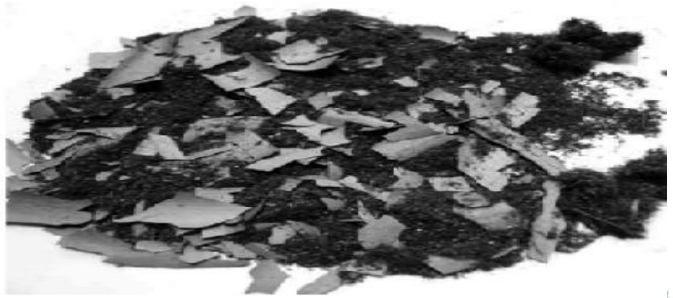
During start up or load ramp Oxide scale is subjected to Tensile stress and During shutdown or ramp down the Oxide scale is subjected Compressive stress.

Cyclic stress facilitates the crack at the metallurgically weak bond between the Austenitic structure of base metal and Feritic structure of magnetite layer.

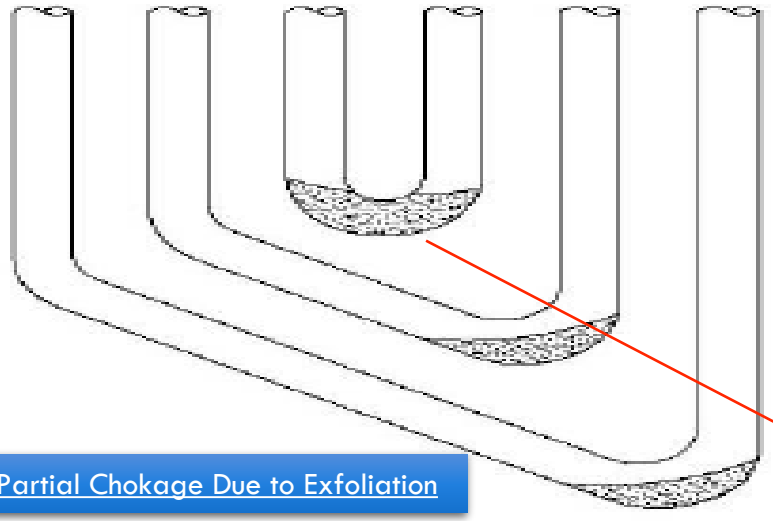
Phenomenon of differential expansion is leading to Spallation. The film gets detached and falls off to bottom bend and gets accumulated there.

Thickness of oxide films in the range of 100 micron only but the huge volume mixed with water at the bottom bends of pendant SH & RH leads to choking & subsequent overheating and failure.

TP 347 H material is most susceptible to Exfoliation.

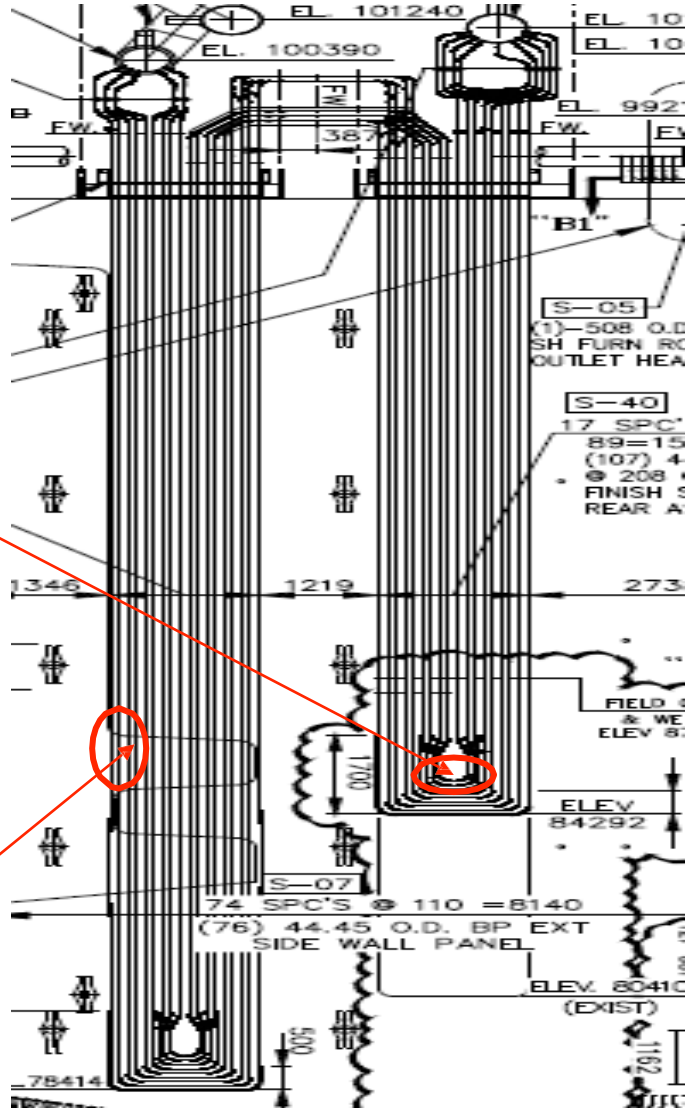


Overheating STOH due to Chokage in Pendent Coil (Exfoliation

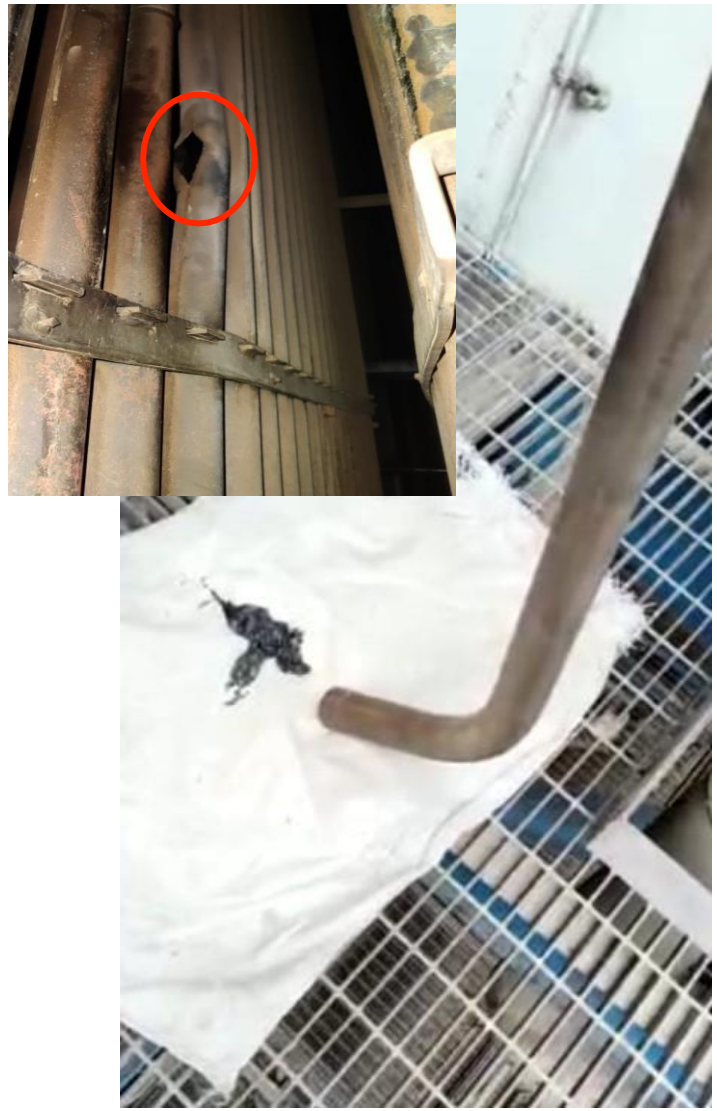


Full & Partial Chokage Due to Exfoliation

Source: EPRI



Boiler tube leakage

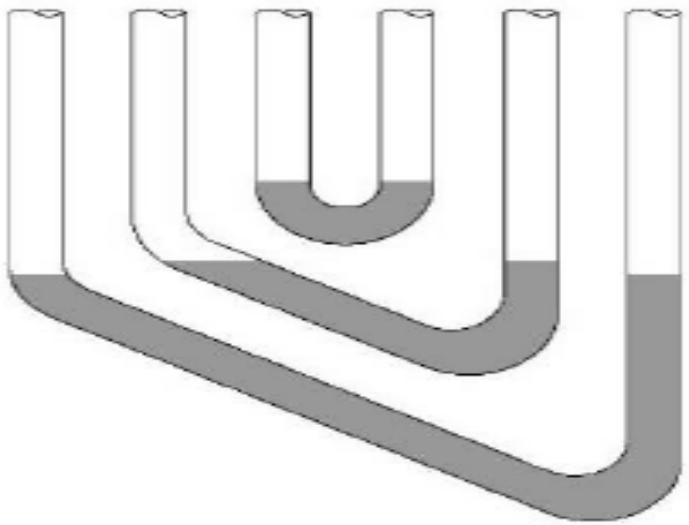


Final SH Panel

Remedies of STOH due to exfoliation…

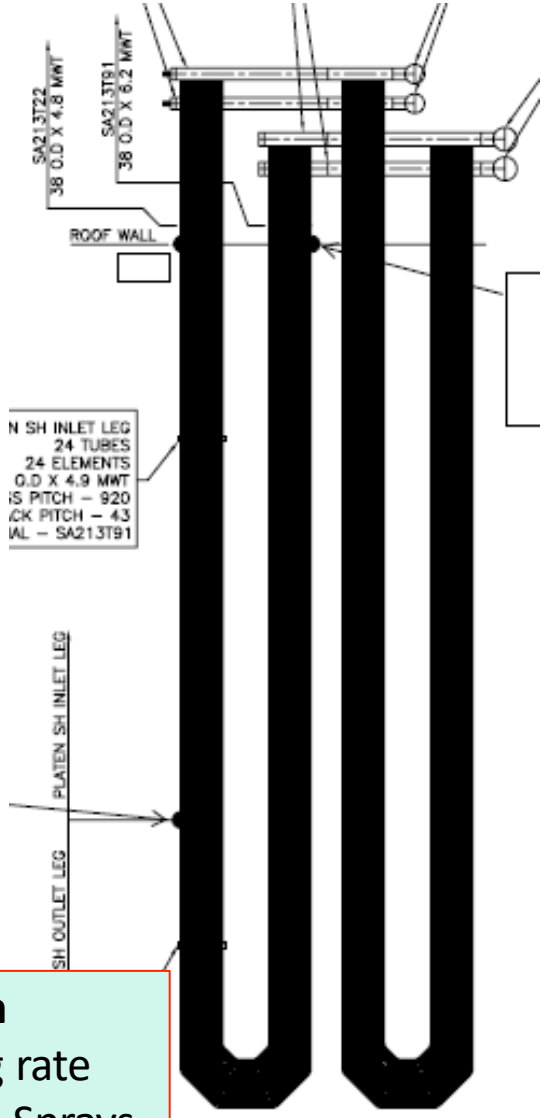
- No use of TP 347 H grade material and other stainless steel of HFG grade only to be used- change in engineering spec.
- Avoid metal temperature excursions.
- Minimise load ramp up and ramp down rate.
- Vent out the exfoliation outside the boiler tubes.
- Shot peening the existing SS tubes or replacing the same.

STOH due to Chokage in Pendent Coil by Condensate



Source: EPRI

Chokage Due to Condensate Pooling



Generally Occur During Cold Startup and low load:
a) Avoid Sudden increase in Fuel Flow during startup.
b) Care must be exercised so as not to spray down below a minimum of 20°C above the saturation temperature at the existing operating pressure.

The primary methods for controlling steam temperature during startup should be firing rate and airflow adjustment. Requirement of SH Sprays is an indication of overfiring.

Inspection technique

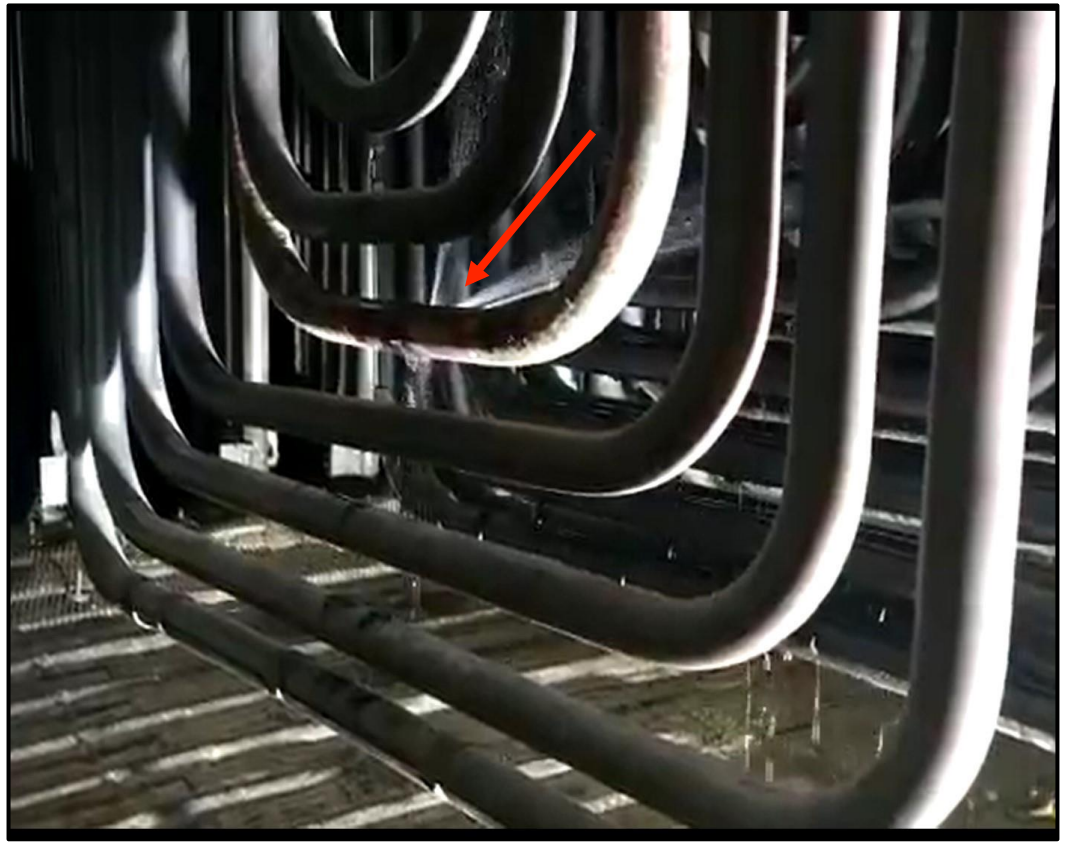
Condensate accumulation can be checked by

(a) Installing & Monitoring MTMs

(b) Heating bends by flame torch

Condensate blockade-Inspection technique

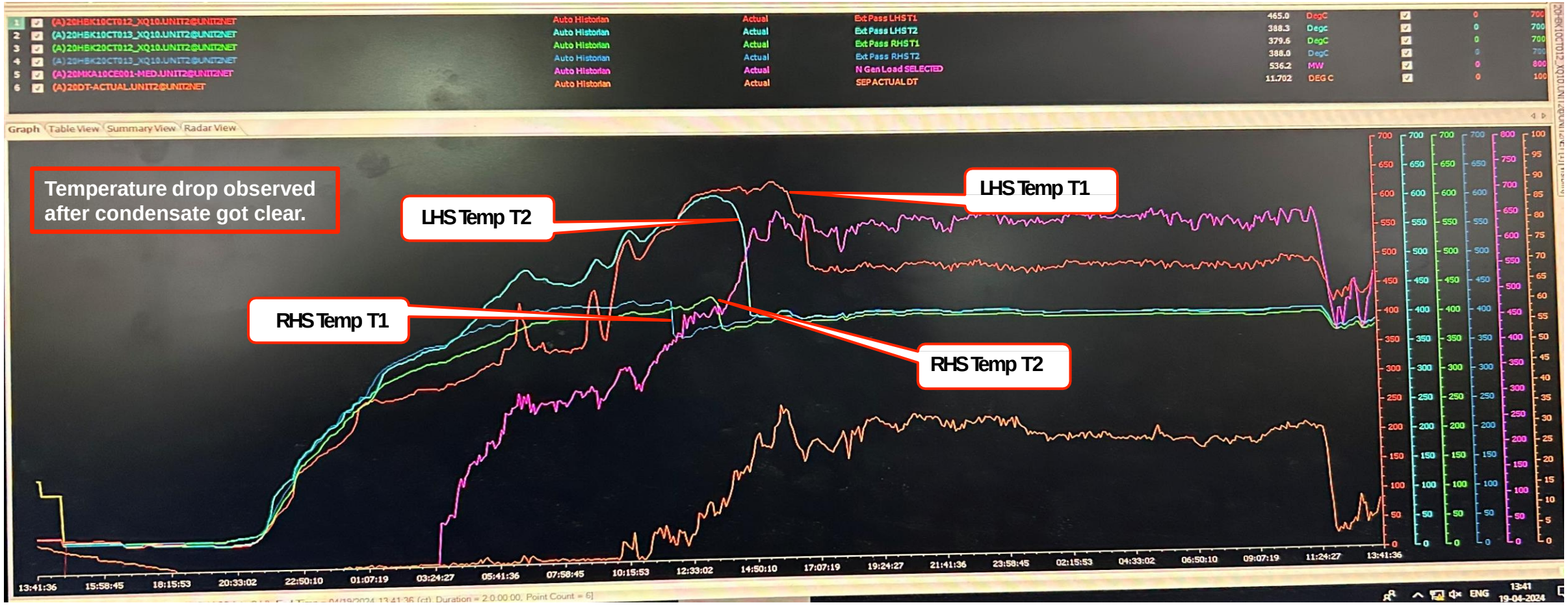
(c) Radiography of bends



(d) Cutting of bend in approachable location

Measures to eliminate the root cause-During Start-up

- **Monitoring of MTMs. Additional MTMs** to be provided for STOH failure prone circuits / based on failure history.

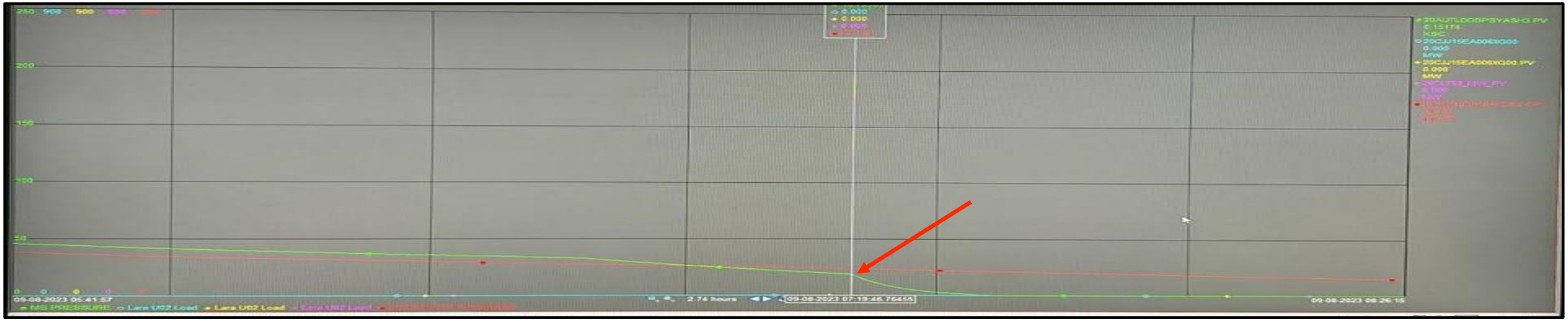


Measures to eliminate the root cause-During Start-up

- Steam blowing to be done through of MS & HRH through ERVs/steam blowing valves.
- Availability of all oil guns to be ensured.
- Rate of increase of fuel firing to be controlled. Logic for rate of rise of MTMs to be incorporated with the help C&I for better monitoring and timely action by operators.
- Increasing MTM density so as to able to detect any one loop condensate blockage from trends.
- Rate of firing to be reduced in case of any sharp increase in MTM and acromats.
- Furnace exit gas temperature should be closely monitored during startups
- No abrupt rise in sprays

Measures to eliminate the root cause-During shutdown

- Steam blowing to be done through of MS & HRH through ERVs/steam blowing valves.
- Opening of all SH vents at 10-12 ksc and Separator vents also to be opened at same pressure to avoid moisture carry-over to SH circuit.
- Fast cooling of boiler to be strictly avoided. Boiler cooling procedure to be followed.
- Opening of boiler vents & drains to be cross-checked by temperature mapping. For operator convenience, MTM installation for all boiler vents & drains can be taken up.
- Boiler to be put under preservation as per shutdown duration.



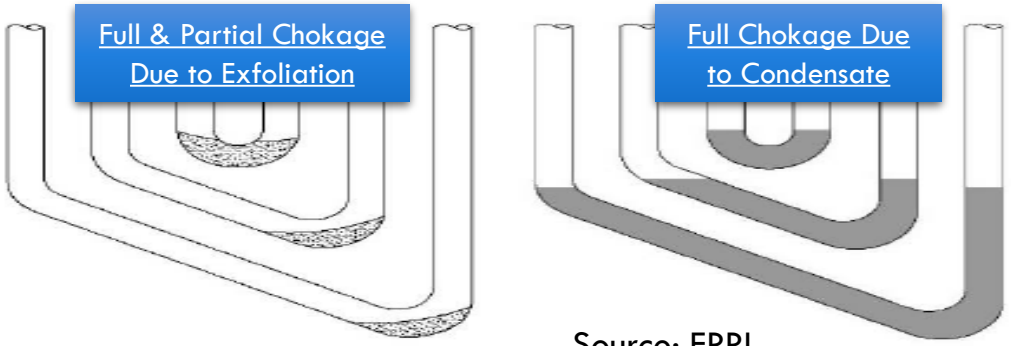
Boiler Fatigue Failure Control

DURING UNIT OPERATION: *(Damage Mechanism due to large variation in Steam temperatures)*

a) During ramping large variation in Steam Temperature in Indian coal observed (25 to 40 °C) : Tuning to minimize variation in existing system.
b) Primary methods for controlling steam temperature during startup should be firing rate and airflow adjustment. Requirement of SH Sprays is an indication of overfiring.

DURING UNIT SHUT DOWN:

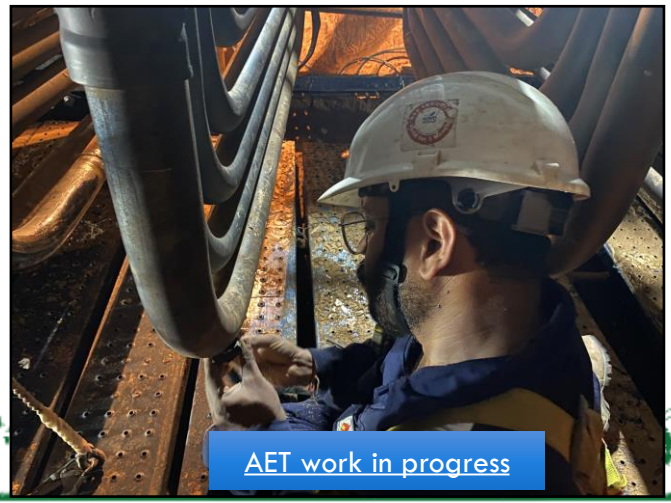
a) Identifying Incipient Defects by Cyclic Hydro.
b) Dry air preservation to prevent tube pitting.



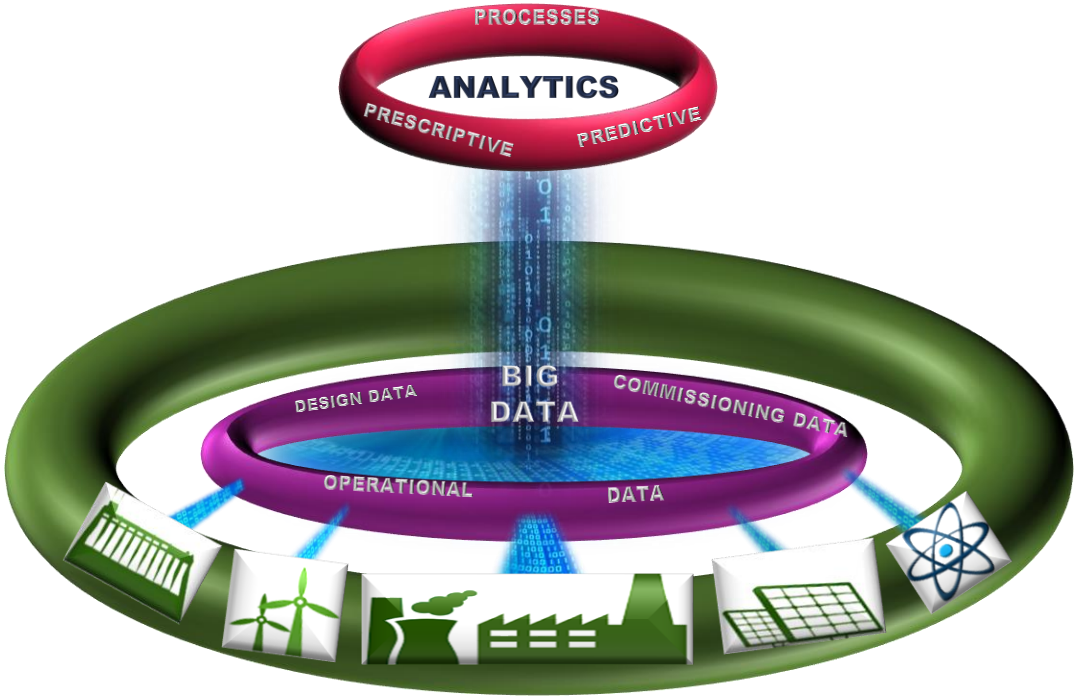
Source: EPRI

DURING UNIT OVERHAUL

a) Attachment modifications as per EPRI guidelines.
b) Both Side Fin Welding earlier only one side.
c) Extensive checking of attachments by NDT during OH.
d) Checking of innermost bend during Overhaul for cracks.
e) Extensive adoption of RFET, AET, Exfoliation, Thermal Flow, Thermovision tests during overhaul.


AET work in progress

Use of AI/ML implementation for mitigating fatigue



ROAD MAP

Defining of Business Problem

- Understanding and defining specific type of BTL.
- Selected: Complex failure of Fatigue related failure caused by high fatigue Operation

Data Collection and Data Preparation

- Collection of all tags available in OS PI related to this process
- Preparation of data – Removing bad data, fixing data type issues, handling missing data, marking out of bounds, identifying unit down.
- Identification of data related to relevant BTL type which is to be modeled.
- Further Handling of Outliers – Standard techniques not effective. Custom logic to identify outlier (bad sudden change in sensor values)

Feature Engineering

- Identifying relevant features (tags) for the current business problem
- Creation of calculated tags for fatigue aberration

Steps in Model Building

Model Building and Evaluation

- Splitting data set into train and test
- Testing different model supervised and unsupervised (Support Vector Machine (SVM), Random Forest, K-means clustering) etc.
- Evaluation of model

Finalization of Modeling Approach

- Cumulative accumulation of Boiler Tube Health Damage due to Aberration in Fatigue associated with high Temp/Pressure Operation
- Correlating this with estimated Boiler tube health at different O/H and post Failures
- Model Tuning to match the cumulative damage to Boiler Health estimates

Dashboard

- Preparation of User and Admin Dashboard showing trends, BTL predictions, tag contributions etc.

Pipelines

- Fetching Raw data from PI
- Cleaning and processing
- Calculation on processed data

Migratory Birds at NTPC Dadri

THANK YOU

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