Water Quality for Supercritical Plants

Objectives and other details of modules

Duration – 75 minutes

Training aids

Power point Presentations

Objective

At the end of the session participants will be able to:

- **Explain metallurgical restriction and requirement in supercritical boilers**
- **Develop capability to take action to maintain chemical parameters**
- **List out chemical parameters – condensate limits, feed water limits and main steam limits**
- **Illustrate the process of cycling online chemical instrumentation**
- **Indicate water chemistry influence on boiler tube failure in supercritical units**
- **Introduce operators' best practices relating to water chemistry for supercritical units**

What is Supercritical

- As the fluid pressure increases, Latent Heat reduces.
- At critical points it becomes zero
- In physical terms at this pressure water transformers to steam spontaneously
- Supercritical Parameters:
  - Steam Pressure > 221.2 BAR
  - Steam Temperature > 374.15ºC

Metallurgical restrictions and requirements

☐ Do not allow for the use of any copper or copper alloys in feed water cycle.

☐ Copper and copper alloy condensers are acceptable

☐ 100% full flow deep bed condensate polishing with external regeneration is required

- Cycle chemistry should be oxygenated feedwater treatment.
- Makeup water plant should be capable of producing water with a conductivity of less than 0.1 mmho, with chlorides, sulfates and sodium less than 3 ppb and silica less than 10 ppb.

Chemical Parameters

Action Levels

- **Action Level 1**
  - Parameter is to be returned to normal values within 72 hours. If parameter does not return to normal in 72 hours, parameter moves to Action Level 2.

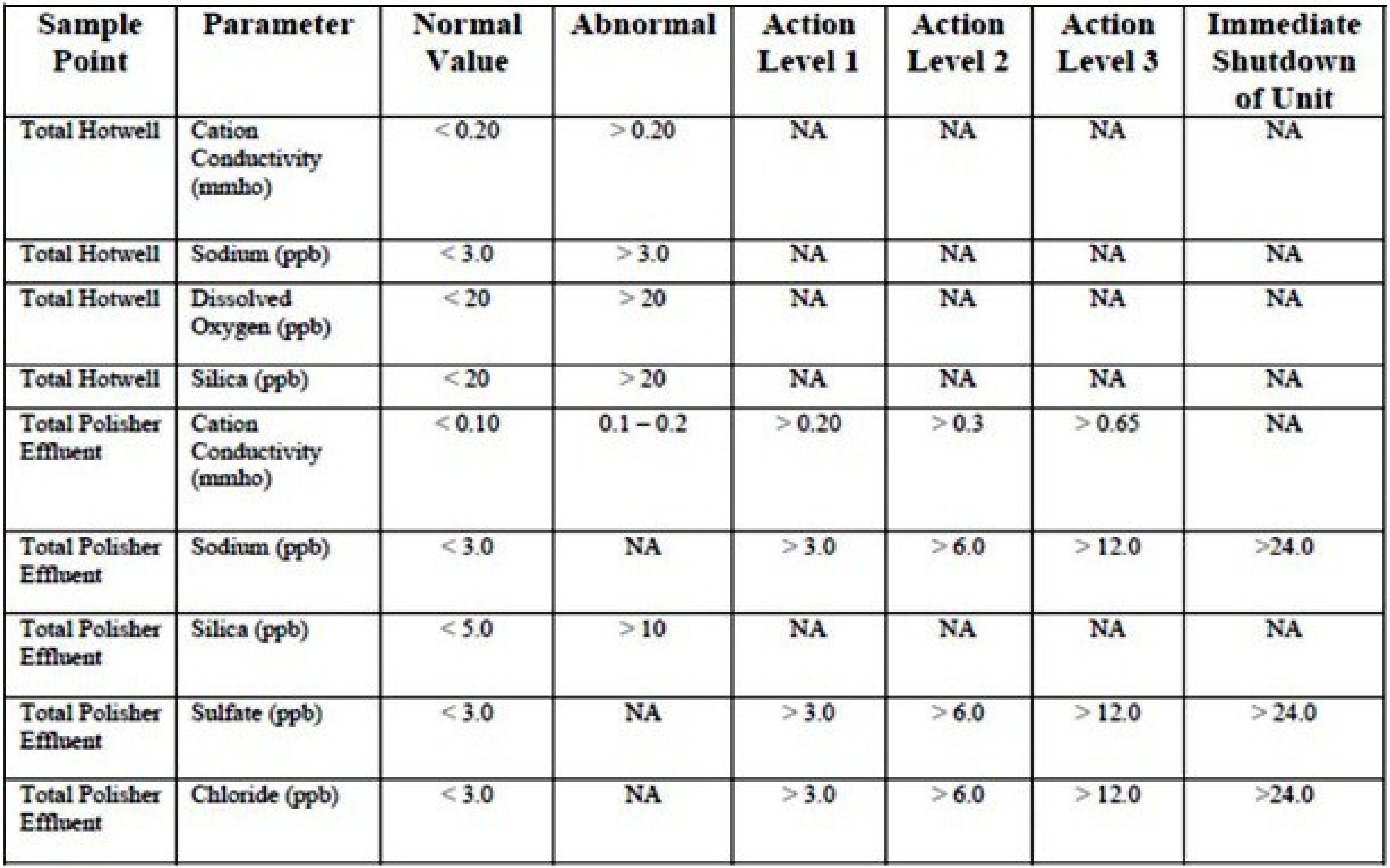
- **Action Level 2**
  - Parameter is to be returned to normal values within 24 hours. If parameter does not return to normal in 24 hours, parameter moves to Action Level 3.

- **Action Level 3**
  - Parameter is to be returned to normal values within 4 hours. If parameter does not return to normal in 4 hours, a controlled shutdown of the unit shall be initiated.

Abnormal

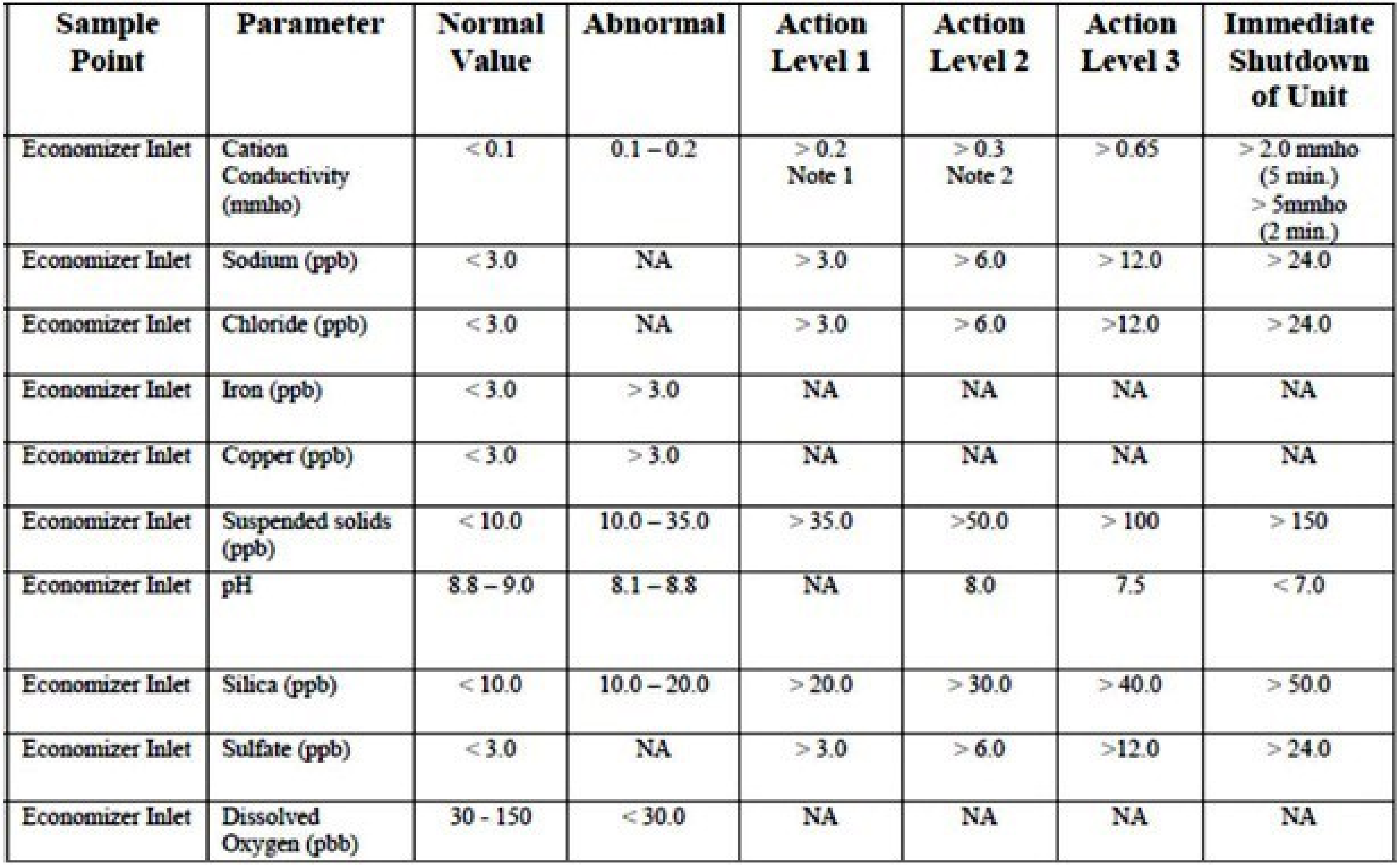
- ❑ Abnormal is condition between what is considered normal cycle water chemistry and action level 1.
- ❑ Operation of unit is limited to two weeks before moving into action level 1 unless an extension is granted

Condensate Limits



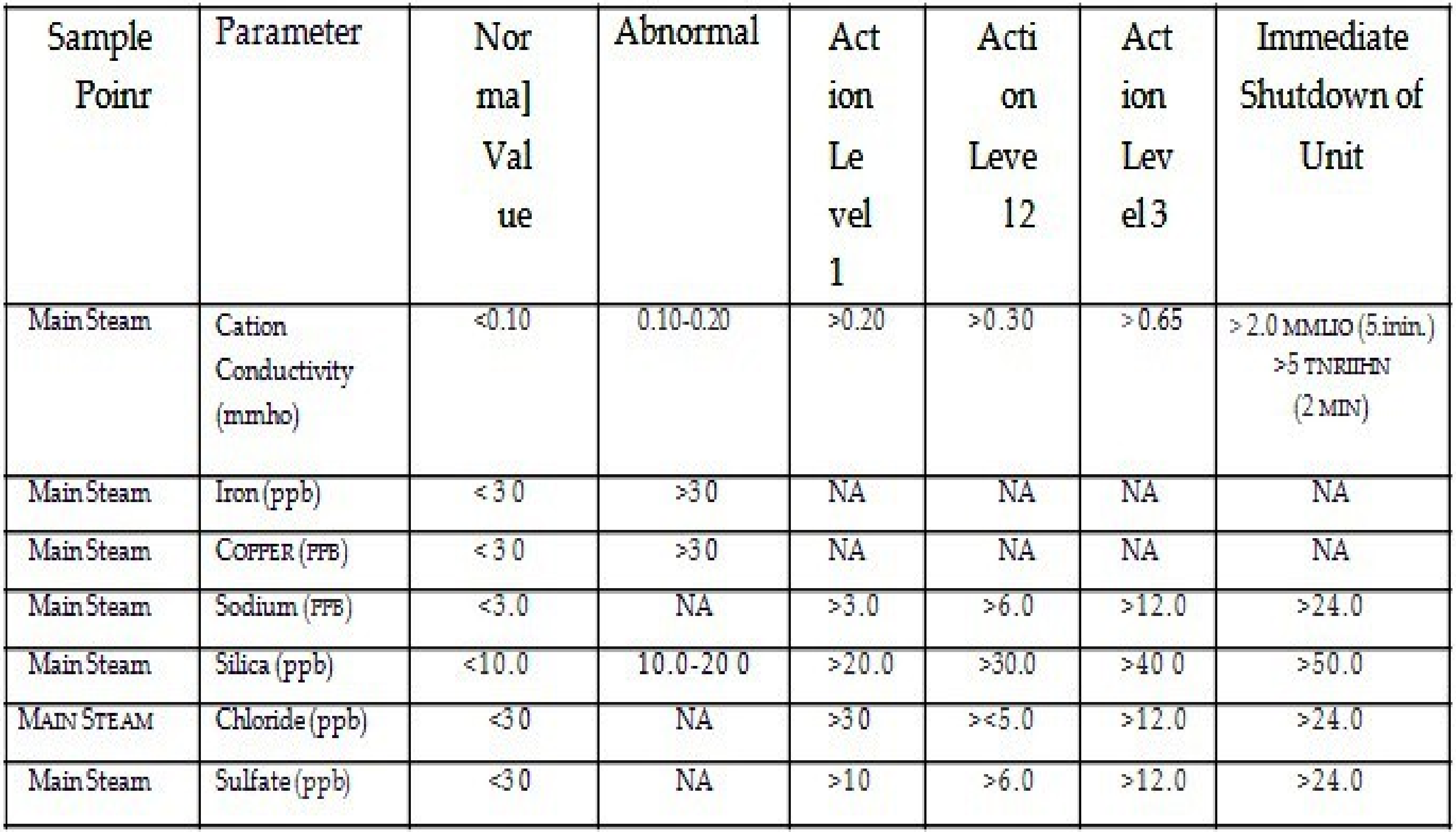
Sample Point	Parameter	Normal Value	Abnormal	Action Level 1	Action Level 2	Action Level 3	Immediate Shutdown of Unit
Total Hotwell	Cation Conductivity (mmho)	< 0.20	> 0.20	NA	NA	NA	NA
Total Hotwell	Sodium (ppb)	< 3.0	> 3.0	NA	NA	NA	NA
Total Hotwell	Dissolved Oxygen (ppb)	< 20	> 20	NA	NA	NA	NA
Total Hotwell	Silica (ppb)	< 20	> 20	NA	NA	NA	NA
Total Polisher Effluent	Cation Conductivity (mmho)	< 0.10	0.1 – 0.2	> 0.20	> 0.3	> 0.65	NA
Total Polisher Effluent	Sodium (ppb)	< 3.0	NA	> 3.0	> 6.0	> 12.0	>24.0
Total Polisher Effluent	Silica (ppb)	< 5.0	> 10	NA	NA	NA	NA
Total Polisher Effluent	Sulfate (ppb)	< 3.0	NA	> 3.0	> 6.0	> 12.0	> 24.0
Total Polisher Effluent	Chloride (ppb)	< 3.0	NA	> 3.0	> 6.0	> 12.0	>24.0

Feedwater Limits



Sample Point	Parameter	Normal Value	Abnormal	Action Level 1	Action Level 2	Action Level 3	Immediate Shutdown of Unit
Economizer Inlet	Cation Conductivity (mmho)	< 0.1	0.1 – 0.2	> 0.2 Note 1	> 0.3 Note 2	> 0.65	> 2.0 mmho (5 min.) > 5mmho (2 min.)
Economizer Inlet	Sodium (ppb)	< 3.0	NA	> 3.0	> 6.0	> 12.0	> 24.0
Economizer Inlet	Chloride (ppb)	< 3.0	NA	> 3.0	> 6.0	>12.0	> 24.0
Economizer Inlet	Iron (ppb)	< 3.0	> 3.0	NA	NA	NA	NA
Economizer Inlet	Copper (ppb)	< 3.0	> 3.0	NA	NA	NA	NA
Economizer Inlet	Suspended solids (ppb)	< 10.0	10.0 – 35.0	> 35.0	>50.0	> 100	> 150
Economizer Inlet	pH	8.8 – 9.0	8.1 – 8.8	NA	8.0	7.5	< 7.0
Economizer Inlet	Silica (ppb)	< 10.0	10.0 – 20.0	> 20.0	> 30.0	> 40.0	> 50.0
Economizer Inlet	Sulfate (ppb)	< 3.0	NA	> 3.0	> 6.0	>12.0	> 24.0
Economizer Inlet	Dissolved Oxygen (pbb)	30 - 150	< 30.0	NA	NA	NA	NA

Main Steam Limits



Sample Poinr	Parameter	Normal Value	Abnormal	Action Level 1	Action Level 2	Action Level 3	Immediate Shutdown of Unit
Main Steam	Cation Conductivity (mmho)	<0.10	0.10-0.20	>0.20	>0.30	> 0.65	> 2.0 MMLIO (5.inin.) >5 TNRIIHN (2 MIN)
Main Steam	Iron (ppb)	< 3 0	>3 0	NA	NA	NA	NA
Main Steam	COFFER (FFB)	< 3 0	>3 0	NA	NA	NA	NA
Main Steam	Sodium (FFB)	<3.0	NA	>3.0	>6.0	>12.0	>24.0
Main Steam	Silica (ppb)	<10.0	10.0-20 0	>20.0	>30.0	>40 0	>50.0
MAIN STEAM	Chloride (ppb)	<3 0	NA	>3 0	><5.0	>12.0	>24.0
Main Steam	Sulfate (ppb)	<3 0	NA	>10	>6.0	>12.0	>24.0

Cycle On-line Chemical Instrumentation

Cycle Instrumentation

- All chemical instrumentation needs to be alarmed and displayed in the main control room
- A temperature control unit should be supplied for secondary cooling of the sample lines to ensure cycle samples are maintained at 25 C

Cycle Instrumentation

- Hot well cation conductivity mounted locally on each condenser half
- Condensate - cation conductivity, sodium
- Common condensate outlet - sodium, silica,specific conductivity

Cycle Instrumentation

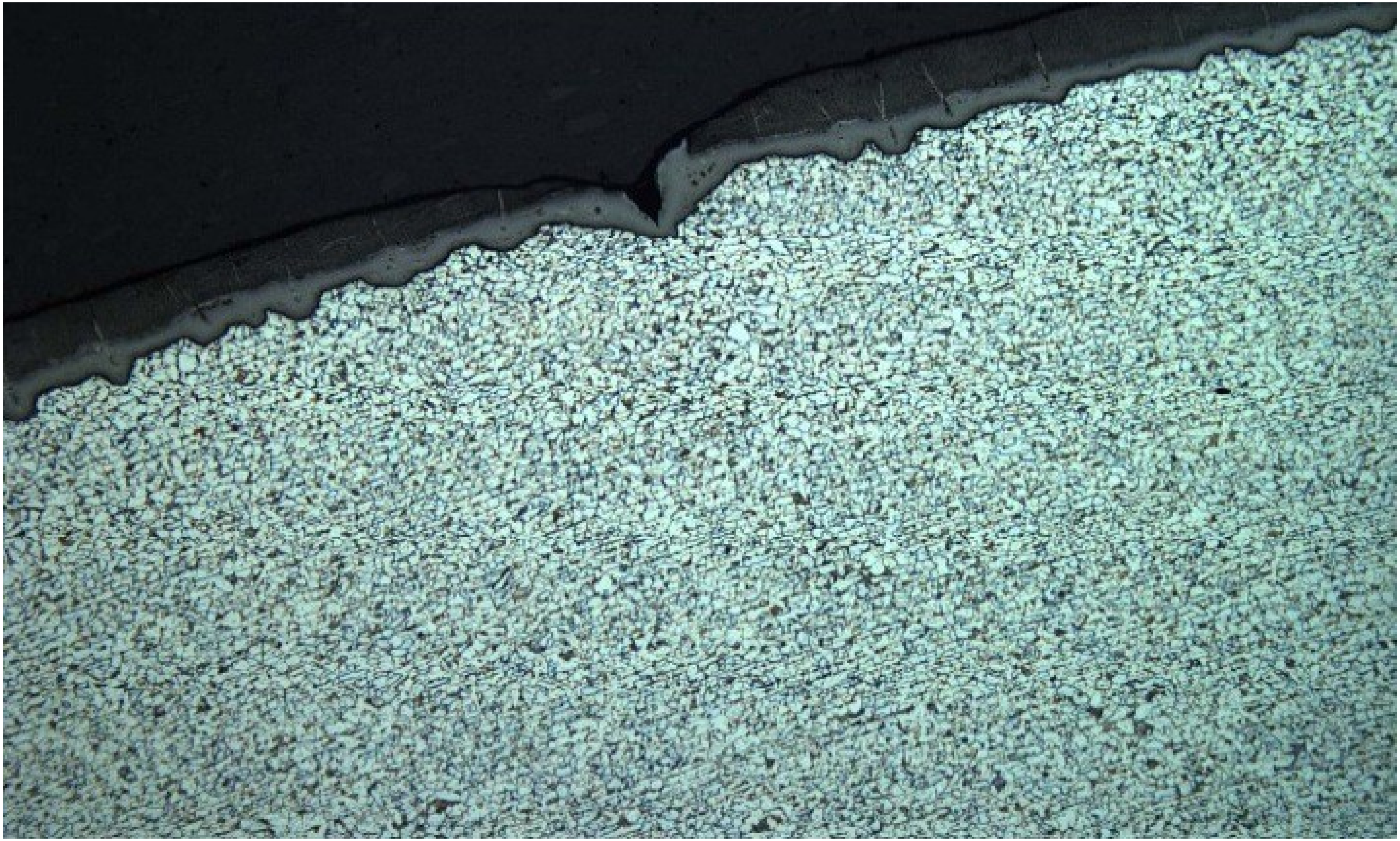
- Deaerator Inlet - Dissolved oxygen
- Deaerator Outlet - Dissolved oxygen
- Economizer Inlet - Cation conductivity, specific conductivity, pH
- Main Steam - Cation conductivity, specific conductivity
- High Pressure Heater Drain - Dissolved oxygen or ORP (only need to monitor one of the drains)
- Reclaim/Miscellaneous Drain Tank - cation conductivity mounted locally

Chemistry Program

The Basis for Cycle Chemistry Control

- To form the proper protective passive layer.
- To protect this passive protective layer during operation.
- To protect this passive protective layer during shutdown.

Protective Passive Layer



Protective Passive Layer

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- All boiler tube and turbine blade failures influenced by cycle water chemistry have the breakdown of the passive protective layer as part of the failure mechanism.
- If you protect your protective layer 24/7 seven days a week 365 days a year, you will not have boiler or turbine blade failures due to cycle chemistry.

Water Chemistry Influence on Boiler Tube Failures of Supercritical Units

- Corrosion Fatigue
- Pitting
- Stress Corrosion Cracking
- Supercritical Water wall Cracking

Corrosion Fatigue

Cracking mechanism in which cracks initiate and propagate due to combination of cycle tensile stress and environmental which is corrosive metal

➢ **Process of developing cracks**

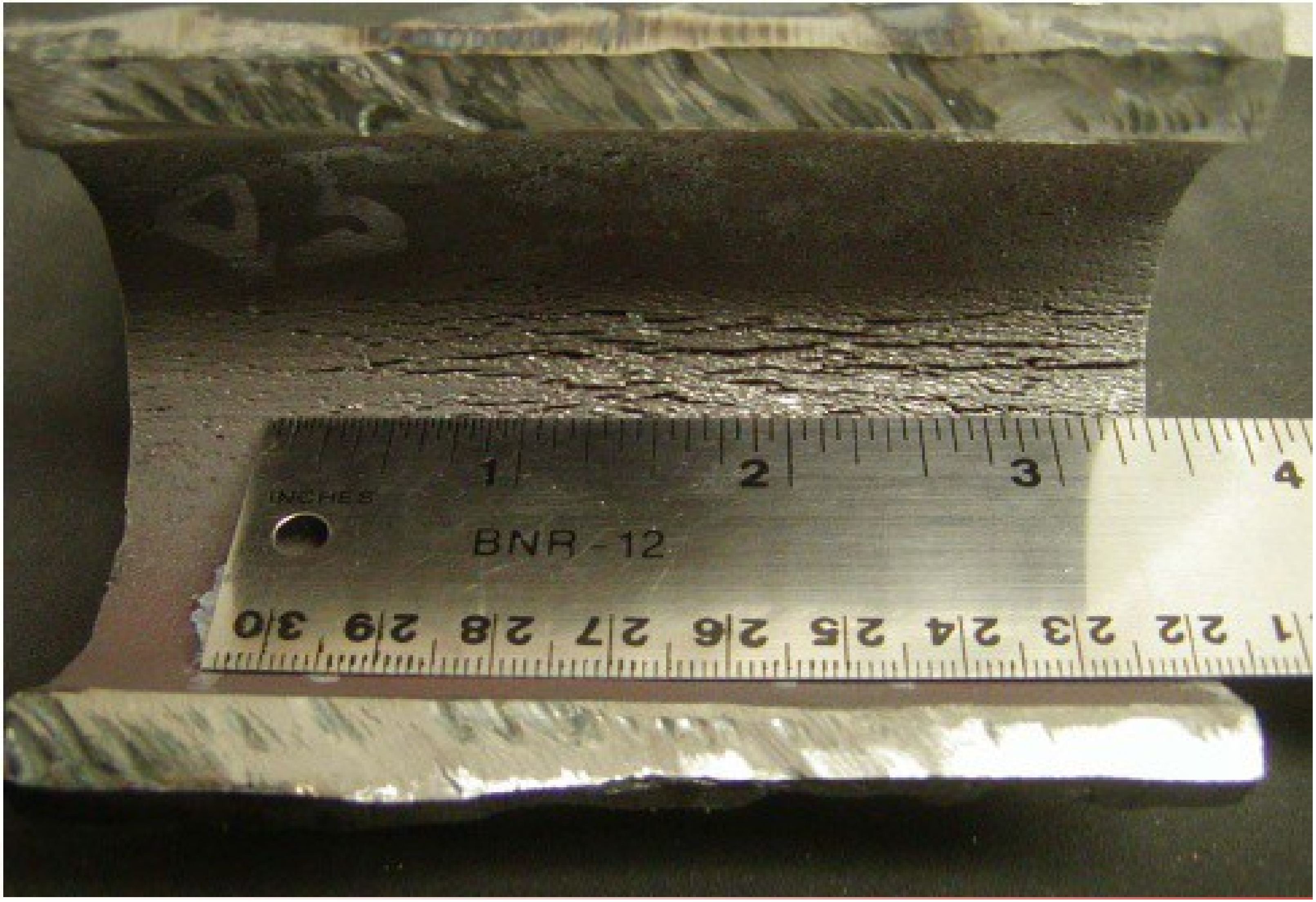
- Bretel iron oxide layers fractures, opening microsocopic cracks through metal surface
- Exposed metal at the root of crack oxide forms a notch
- During cycle of tensile stress, the oxide fractures at the notch, and cracks are depend
- The cycle continuous a wedge shaped cracks propagate through the metal

Corrosion Fatigue

Cause:

- Rapid cycle cooling
- Rapid startup and shutdown
- Operation at low pH and excessive high O2 promote pitting. This pit serve as stress concentration to initiate corrosive fatigue cracks

This is Corrosion Fatigue



This is Corrosion Fatigue – How Operators Make a Difference

- Control of dissolved oxygen - Ensure unit has been paralleled for a minimum of 2 hours prior to closing DA vent.

- Control of economizer inlet pH - trip unit when EI pH drops below 7.0

- Stress, heat up and cool down rate do not exceed OEM recommendations

Pitting and Stress Corrosion Cracking

Pitting

- Sulfate and/or Oxygen + water
- Happens when unit is shutdown
  - Operation at low pH level or excessive high O2 promotes pitting

Pitting - How Operators Make a Difference

- Ensure deaerator vent is open and cycle pH is increased on removal of unit from service
- Trip unit if EI cation conductivity is 2.0 m mho for 5 minutes or 5.0 mmho for two minutes.
- Trip unit if EI pH drops below 7.0.

Stress Corrosion Cracking

- Metal failure resulting from a combination static tensile stress and a specific corrodant to which metal is sensitive

- Chlorides + Water

- Initiated on shutdown

- Propagates during operation

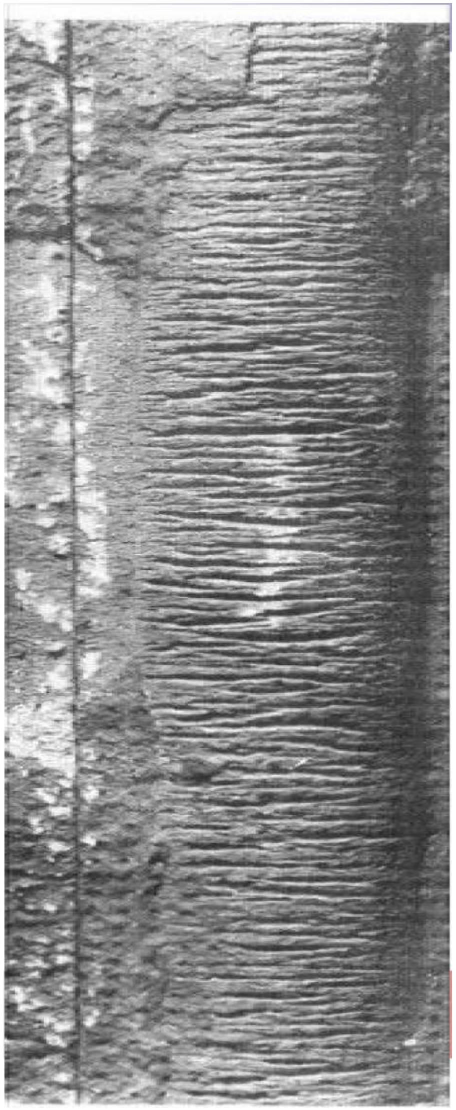
Stress Corrosion Cracking - How Operators Make a Difference

- Ensure deaerator vent is open and cycle pH is increased on removal of unit from service
- Trip unit if EI cation conductivity is 2.0 mmho for 5 minutes or 5.0 mmho for two minutes.
- Trip unit if EI pH drops below 7.0.

Supercritical Water Wall Cracking

- Damage generally forms as regular, parallel cracking, typically oriented circumferentially.
- The primary root cause is the buildup of excessive internal deposits in the tubes.
- Thermal or stress cycles with heavy internal deposits leads to supercritical waterwall cracking

Supercritical WaterWall Cracking



Supercritical WaterWall Cracking – How Operators Make a Difference

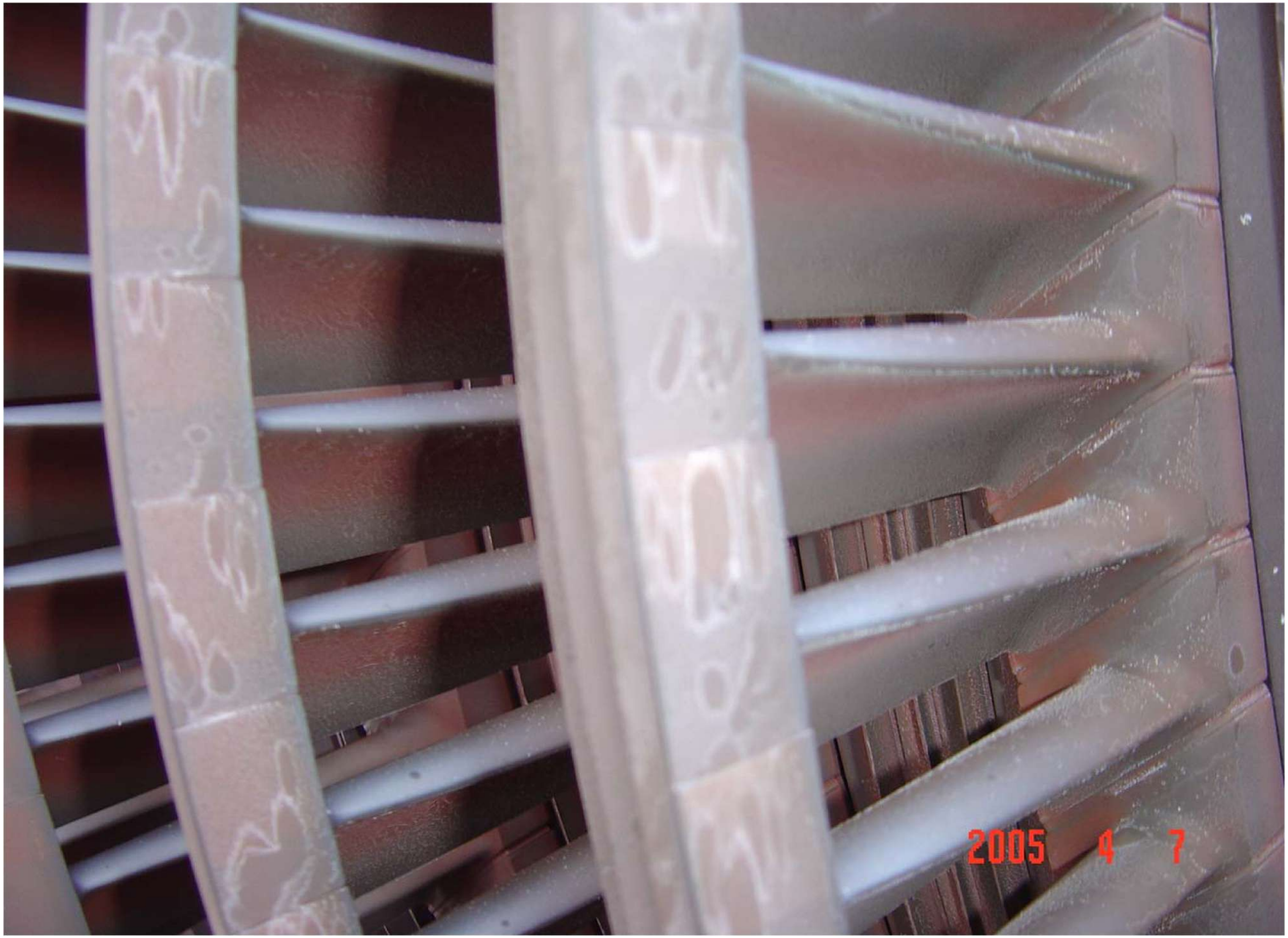
- Trip unit if EI cation conductivity is 2.0 mmho for 5 minutes

  or 5.0 mmho for two minutes.

- Trip unit if EI pH drops below 7.0.

Turbine Deposition

LP Turbine Rotating Blade



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Deposition caused by Steam Chemistry

- Causes include sodium (EI sodium analyzer), chlorides (EI cation conductivity analyzer), and sulfates (EI cation conductivity analyzer) within a moist environment.
- These contaminants can lead to pitting which can turn into stress corrosion cracking or corrosion fatigue turbine blade failures.

Steam Chemistry

- Silica contamination will deposit on the back end of the LP turbine. Silica will cause some efficiency loss of the LP turbine.
- Silica needs to be maintained below 10 ppb in steam. (Silica Analyzers)

Steam Chemistry -
How Operators Make a Difference

- Trip unit if Eco inlet cation conductivity is 2.0 mmho for 5 minutes or 5.0 mmho for two minutes.
- Trip unit if EI pH drops below 7.0.
- Trip unit if EI sodium increases above 24 ppb (action level 1 starts at sodium > 3ppb)
- Analyzer alarms