Elimination of Steam Side Scaling on Grade 91 Material, Improving Efficiency, Reliability, and Flexibility of Existing Fossil Fired Power Plants

NETL CROSSCUTTING RESEARCH AND ADVANCED ENERGY SYSTEMS PROJECT REVIEW MEETING

ATC-CES

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Project Description

Purpose:"[To] improve the reliability and efficiency of existing coal-fired power plants under flexible operating conditions by demonstrating a technology to modify the surface chemistry of creep-strength-enhanced steel (Grade 91) tubing to substantially improve its steam- side oxidation resistance (and thereby dramatically reduce scale exfoliation) at a cost and scale that enables its ready acceptance for use by the power generation industry."

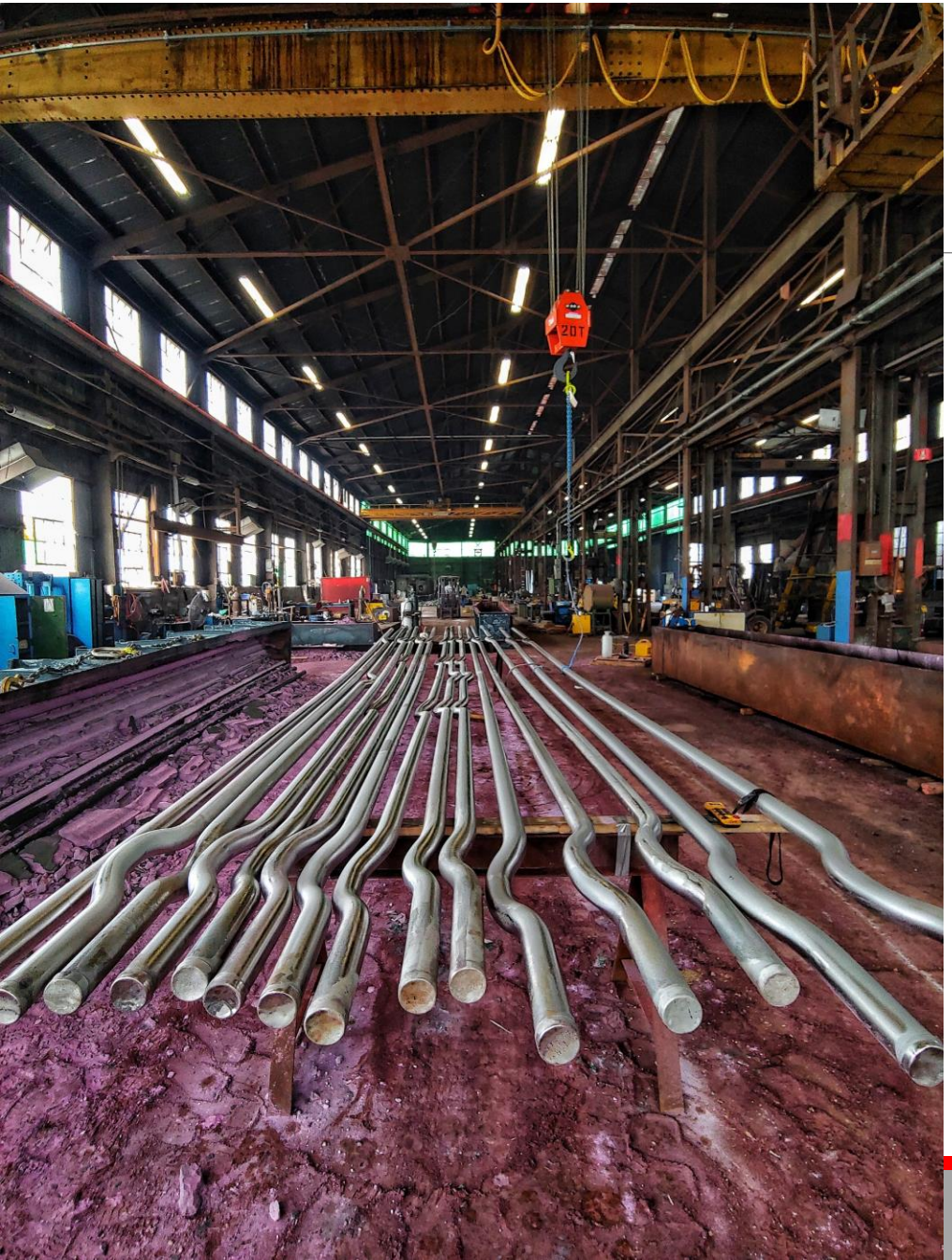
- Chromizing technology has been utilized within the power industry for decades
- Capabilities of eliminating scaling and scale delamination have been proven
  - Never applied to the ID of superheater tubes due to processing restrictions
- ATC set out to not only create a process which would allow for this ID coating to be applied, but also to optimize the coating for performance and provide an alternative for utilities that the current supply chain fails to offer
  - This includes data which provides comparisons between the performance of the coating and existing materials within boiler conditions

Project Alignment with DOE Objectives

- The overall objective of the project is to produce a method to chromize tubing in order to solve industry based issues
  - Namely ID scaling and the issues accompanying (Discussed later)
- This solution is unique in that it solves the issue with side effects which are beneficial to the utility
  - Allows higher temperature of operation
  - This allows for more energy to be generated
- This benefits DOE in several ways including reliability of units, output increases and potentially reduced cost in generation

Current Status of the Project

- Optimization of the coating process has been completed
  - Overall goals were to achieve a 0.005” Chrome layer
  - Layer having an operating surface with a Cr% of ≥25 wt% Cr
  - Performed in accordance with ORNL
- Development of a method for fabricating longer lengths has been completed
  - The process was designed and has shown results
  - Still being optimized as sample sizes increase
- Quality standards for the product have been set
  - Advancements in quality testing are still being explored to ensure reliability of tubing
  - Similarly, testing to determine effectiveness of coating is ongoing
- Test articles are currently in an HRSG unit
  - Due to a failure in the coal unit planned for insertion

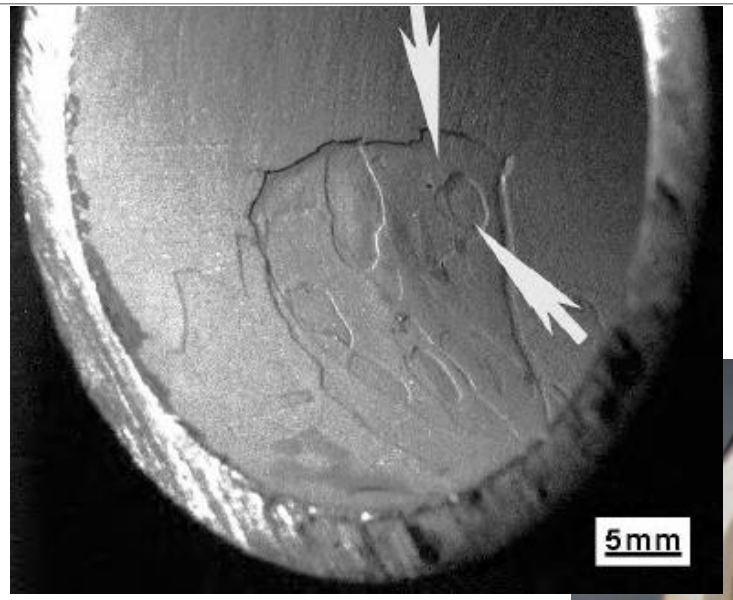


Chromizing

- Chromizing is the process of diffusing elemental Cr into the surface of a material
  - Usually done by vapor deposition
- Common applications of Chromizing consist of:
  - Prevention of flue gas corrosion on waterwall tubing
  - Inhibiting combined-cycle smelt spout failure
  - Applications requiring wear resistance and/or corrosion resistance
    - Especially at elevated temperatures

Steamside Scaling and Energy Generation

- ID scale on superheater tubes has multiple modes of impact on a unit's operating condition
  - Raises tube operating temperature
    - Mode 1: Oxide thickness
    - Mode 2: Turbulent Flow
  - Causes ID exfoliation
  - Can lead to failures via increased hoop stress
    - Especially in bends
- Each of these factors may accelerate the overall creep rate of a superheat assembly
  - Thereby lowering the reliability of the unit overall
  - Forcing utility to replace tubing sooner

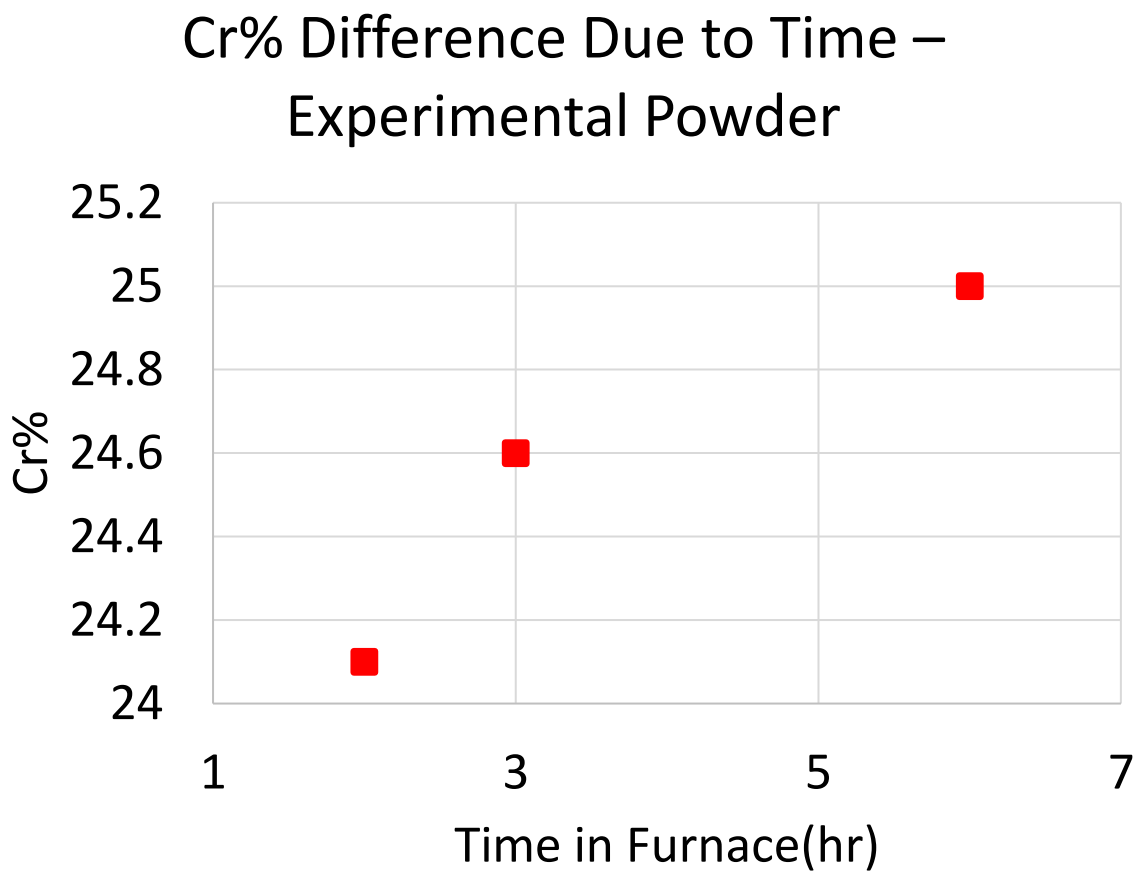


ID Chromizing

- ID chromizing has been researched for more than 20 years
  - Issues remaining in the process itself are the reason for its disuse
  - ATC has solved many of those problems
    - For example, loading a 20’ tube with powder is more complex than it may seem
    - Powder which enters the tube MUST be removed, thus no bending is allowed
- ATC split focus between optimal quality of the coating and price of processing
  - Price point of ID chromizing is most affected by 2 things:
    - Material required
    - Time spent

ID Chromizing (Cont..)

- Powder Optimization:
  - ATC's conventional powder is designed for a pack type system
  - For ID chromizing ATC wanted to push speed of deposition
  - Worked with ORNL to form a thermodynamic model in order to predict the optimal mixture
    - This mixture is part of the IP gained by ATC
  - As an example, this is one part of a matrix used to determine the appropriate time-temperature to apply to one of the experimental powder blends

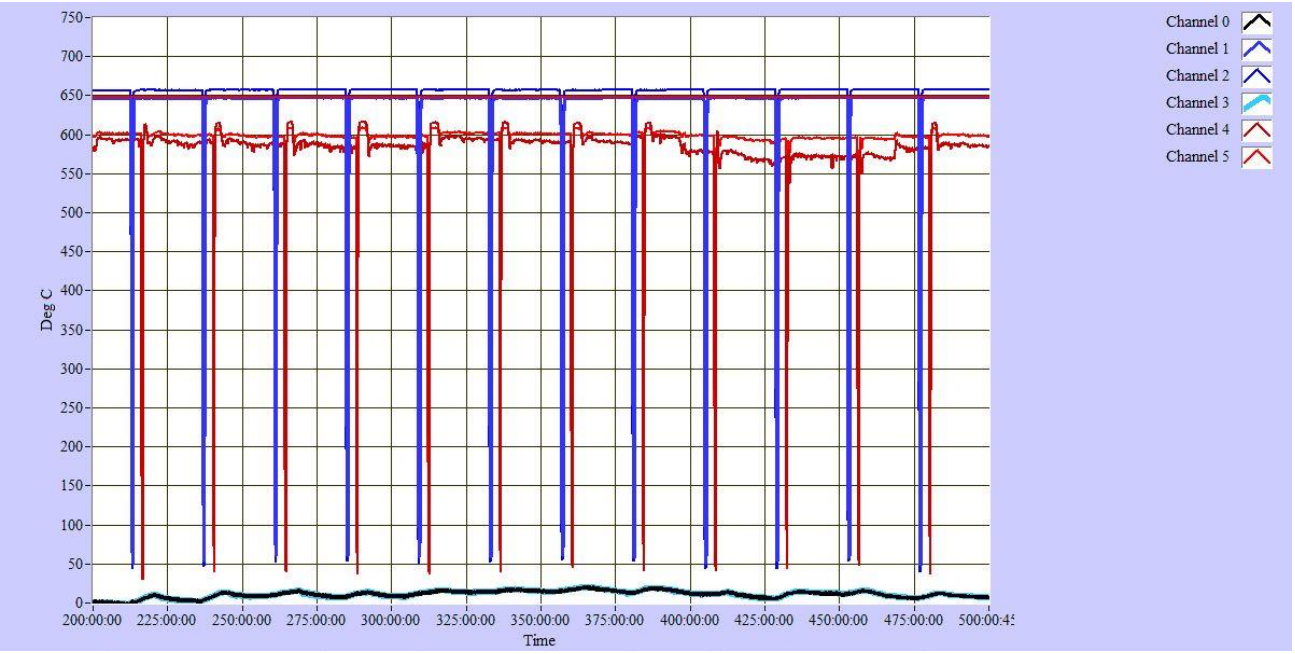


Coating Efficacy

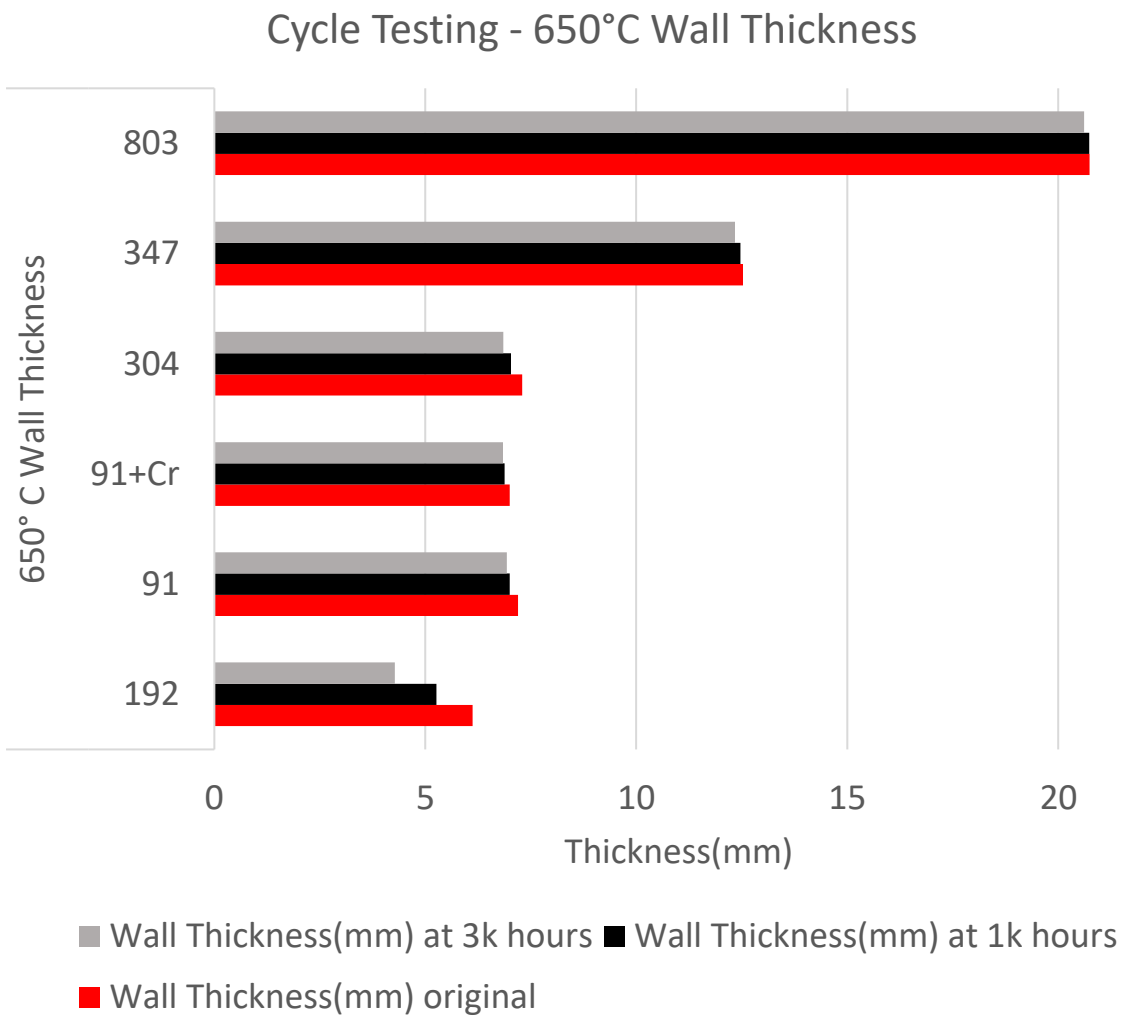
- To compare the performance of the coating, several tests have began
  - Steam-Oxidation Testing
  - Steam-Cycle-Oxidation Testing
  - Creep Testing
- This testing will compare the coated Grade 91 specimen to uncoated Grade 91, Austenitic stainless steels and lower grade carbon steels
  - This should provide an answer to the margin of difference the coating will provide

Coating Performance

Steam-cycle-oxidation Temp-Time Chart



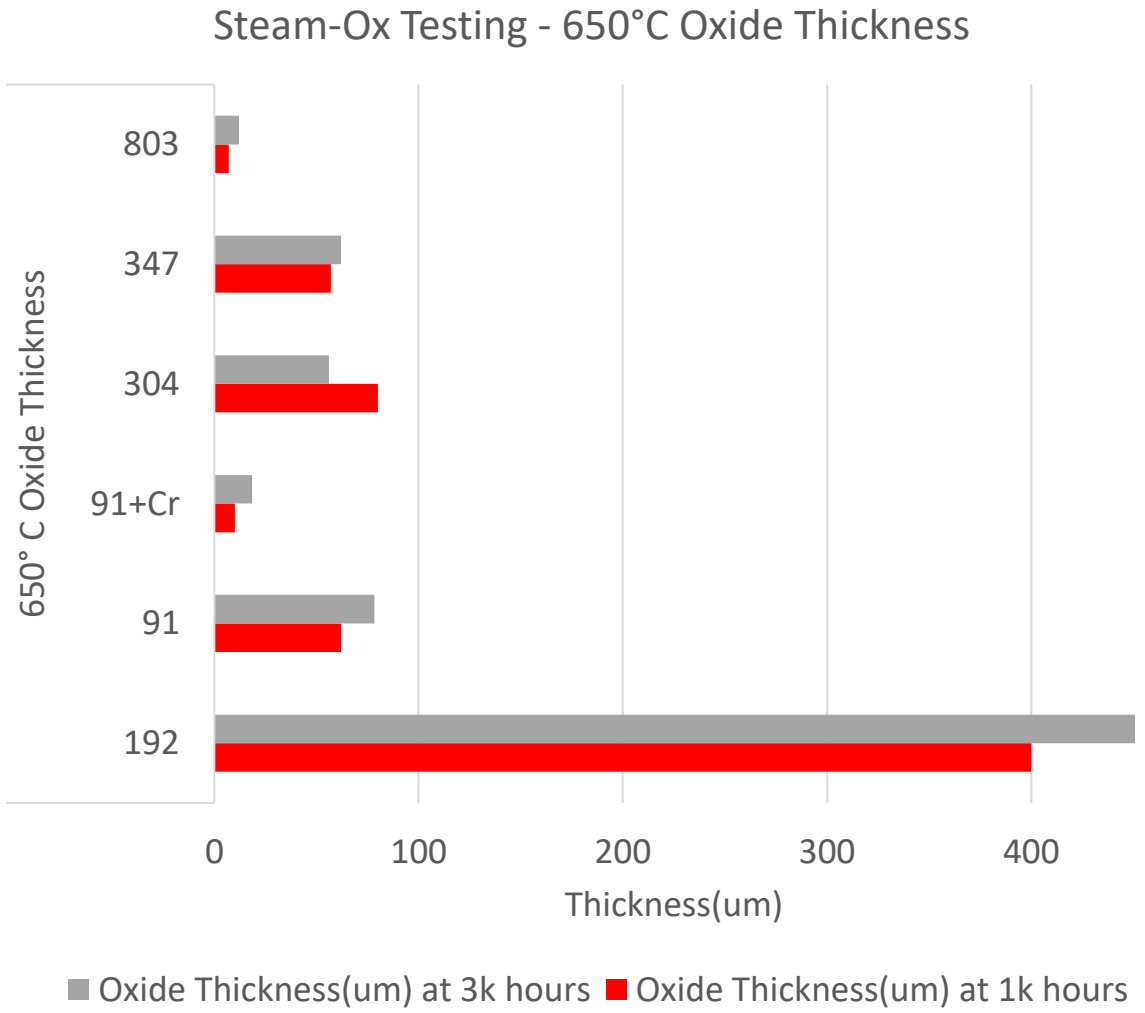
Results – 650°C



Coating Performance

- The current outlook on coating performance in all manner of testing is promising
  - Results have been consistent with OD chromized articles
- Some of the results recorded have shown evidence that the coating is outperforming 803 Incoloy
  - There were locations on the Incoloy sample with more than 20 um of oxide growth, with the maximum of 15 um on the coating surface
  - This is due to the protective ceramic layer which forms on the face of the coating inhibiting oxidation

Results – 650°C



Remaining Work

- Tube bend characterization
  - Bent articles at the most severe degree applied in SH tubing have been made
  - Characterization of these bends is ongoing, with indications that there will be no issue with performing these bends cold
- Continued materials testing
  - Both types of oxidation testing will be run with varying samples to compare directly to the coated specimens
    - 10K testing
  - Creep testing to explore the process effect on creep life

Remaining Work

- Continued improvement on chromizing process
  - Corrections to the overall process have been made throughout the project
  - Oxidation of tubing during chromizing
  - Tube straightness in longer sections (20'+)
  - Best cleaning practices are still being optimized
- Test sample characterization
  - Once the samples have been returned to ATC they will be assessed for the operating losses expected
  - This will provide ATC the best predictive evidence for predicting the life and performance benefit of the tubing to the utility

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