Boiler Tube Scale Deposit Measurement Program

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Industry Strategies for Cleaning Boilers

- Chemical clean boilers on a regular interval
  - Example; every 5 -10 years
  - Excessive or unnecessary cleaning can cause tube damage
- Remove sample tubes for DWD analysis and chemically clean based on analysis
  - Annual
  - Other interval
- Maintain strict water chemistry controls
  - A delay of one or two years on a dirty boiler can result in major tube damage.
- Type of Boiler (RB vs PB) and use
- Clean following major upgrade or rebuild as required (10% or more replacement)

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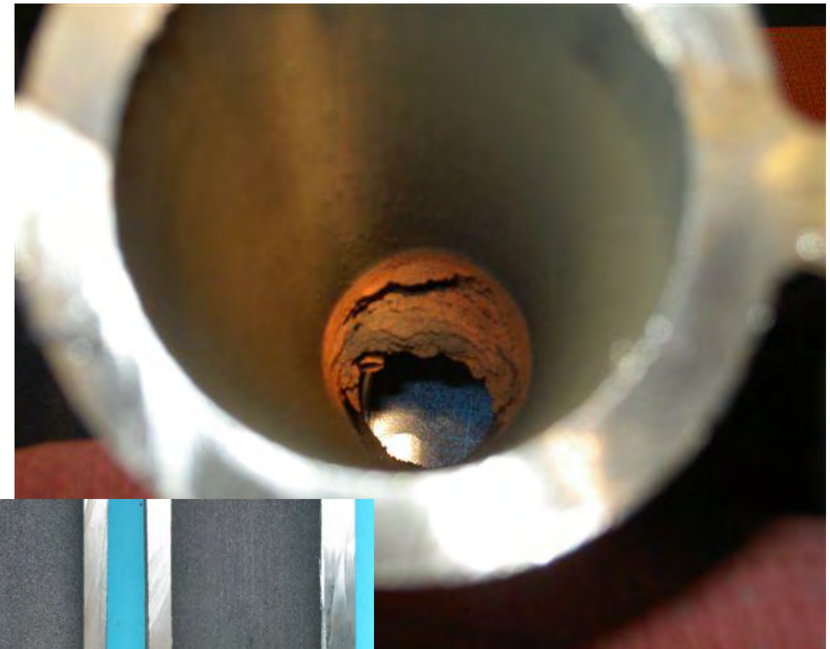
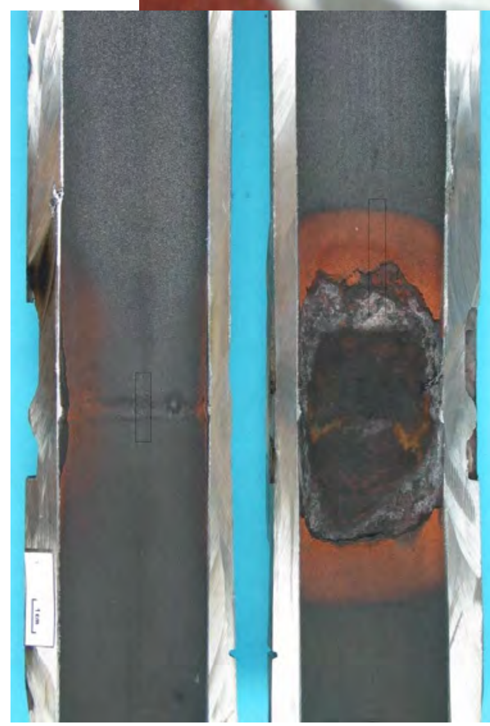
Factors Affecting A Successful Strategy

- Water chemistry incidents between cleaning intervals
  - Major or several small incidents
  - Do your incident corrective actions include a tube sample at next opportunity?
- Water chemistry controls
  - Condensate return fouling
  - Makeup water contamination
- Change in treatment strategy
  - Coordinated PO4 to All-volatile
- Change in fuels or burner design
  - Coal to gas conversion, changes high heat zone
- If chemical cleaning is improperly performed, it can result in
  - Excessive cleaning time
  - Tube wall thinning
- Insufficient cleaning can lead to
  - Possible corrosion damage
  - Loss of heat transfer.





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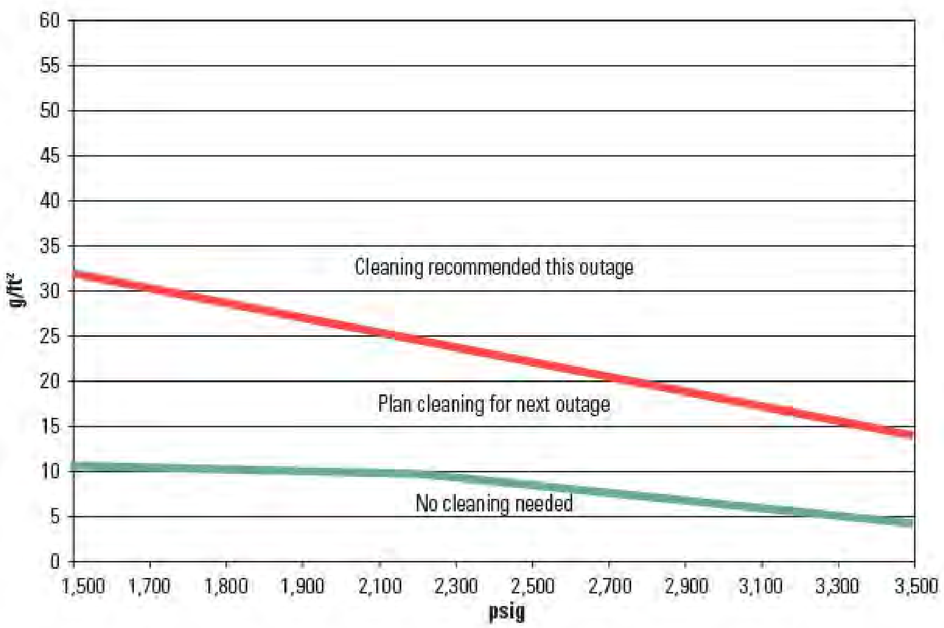
Tube sample for DWD

Deposit Weight Density

- The standard DWD test should not only provide a deposit loading but also an analysis of chemical composition of the deposit on the tube
- Optimally, the tube sample for DWD should be from the highest heat flux area and/or low flow area of the boiler.
- The change in the weight of the tube divided by the water-touched area where the deposit was removed produces the DWD result (g/ft^2)
- What are the best practices for determining correct tube sample location?
- Threshold ~ **25-30 g/ft^2**



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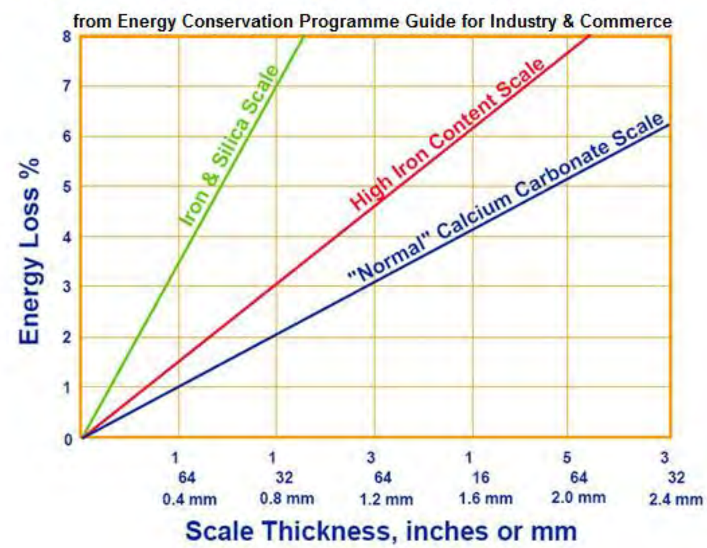
Deposition Effect on Efficiency & Operating Costs

8000 operating hours

- Annual Operating Costs Increase due to high iron deposit layer measuring 0.1 mm.
- 0.1 mm = 3.9 mils ~ 25 g/ft^2 (threshold)
- ~ 0.5% Energy Loss
- 1000 MMBTU/Hr Heat Input
- Fuel cost = $2.50/MMBTU
- = **$100,000 per year**
- An indirect indicator of scale or deposit formation is flue gas temperature. If the flue gas temperature rises (with boiler load and excess air held constant), the effect is possibly due to the presence of scale.

Energy Loss from Scale Deposits



Energy Loss Due to Scale Deposits*			
Scale Thickness, inches	Fuel Loss, % of Total Use		
	Scale Type		
	"Normal"	High Iron	Iron Plus Silica
1/64	1.0	1.6	3.5
1/32	2.0	3.1	7.0
3/64	3.0	4.7	–
1/16	3.9	6.2	–

Note: "Normal" scale is usually encountered in low-pressure applications. The high iron and iron plus silica scale composition results from high-pressure service conditions.

*Extracted from *National Institute of Standards and Technology, Handbook 115, Supplement 1.* On well-designed natural gas-fired systems, an excess air level of 10% is attainable. An often stated rule of thumb is that boiler efficiency can be increased by 1% for each 15% reduction in excess air or 40°F reduction in the stack gas temperature.

Boiler Tube Scale Deposit Measurement

Equipment

- Hardware and Software System:
  - Package combining the advanced UT hardware and software package developed to measure and record thicknesses of the internal deposit layer and remaining tube wall in waterwall tubing.
- Equipment Operates Using Ultrasonic Testing (UT) Technology
  - The tube thickness and deposit layer can be accurately measured by measuring the change in wave forms through the material
  - Requires cleaned smooth inspection surface
  - Minimum detectable scale capability less than 1 mil

Inspection Technique

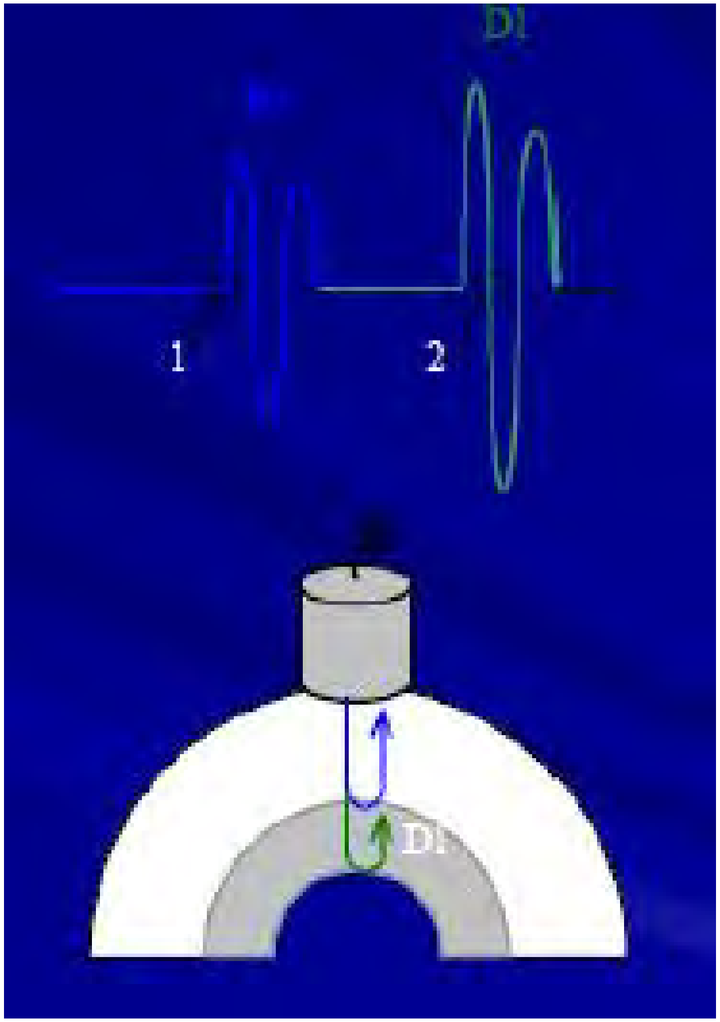
Preparation

- Transducer probes are prepared beforehand using the inspection tube size as a reference. The probe needs to be profiled to match the tube.
- Boiler tubes are prepared by cleaning an area of 1x1 inch near the crown area in a way which does not damage the metal surface itself.
- A wire wheel and buffing pad may be used to polish the surface without removing any base metal.

Inspection Technique

Wave form measurement

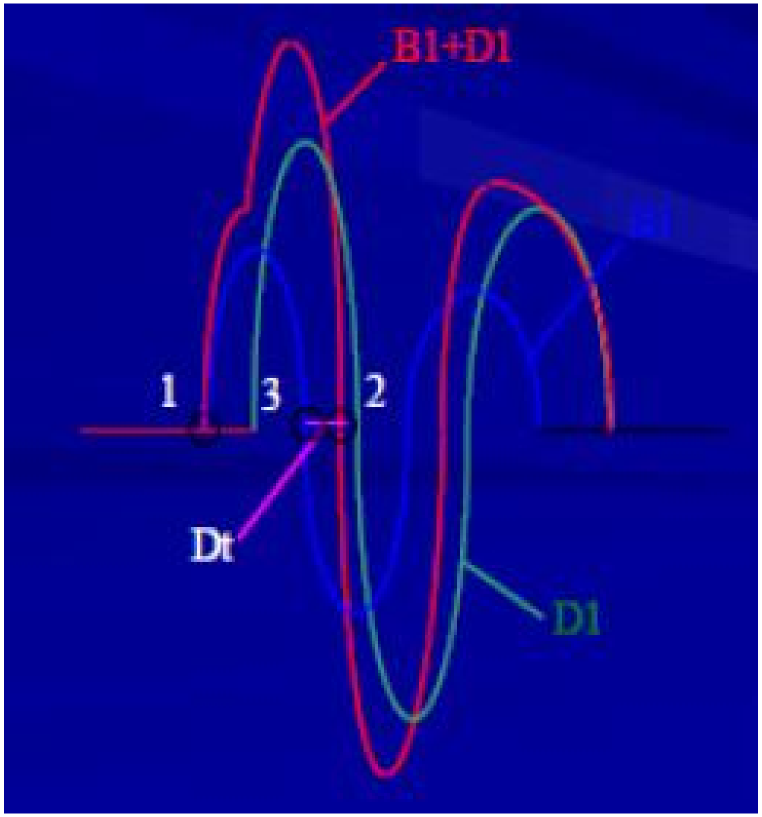
- Scale thickness measurement is based on reflection of longitudinal ultrasonic waves from different interfaces.
- Sound is reflected from both metal/deposit and deposit/water/air interfaces
- Deposit thickness can be calculated directly from the distance of separate waves reflected from different interfaces and from sound propagation speed in the scale.



Inspection Technique

Wave form measurement

- With a deposit the waves reflected from the deposit and water/air interface widen noticeably. The waves are combined (B1+D1).
- B1+D1 is gain adjusted and compared to the known metal material wave.
- The change in wave width (Dt) is the scale thickness.
- Calibration is by checking the zero point from a scale free tube. If a tube sample containing scale is available, the measurement can be fine tuned.



Factors Affecting Accuracy

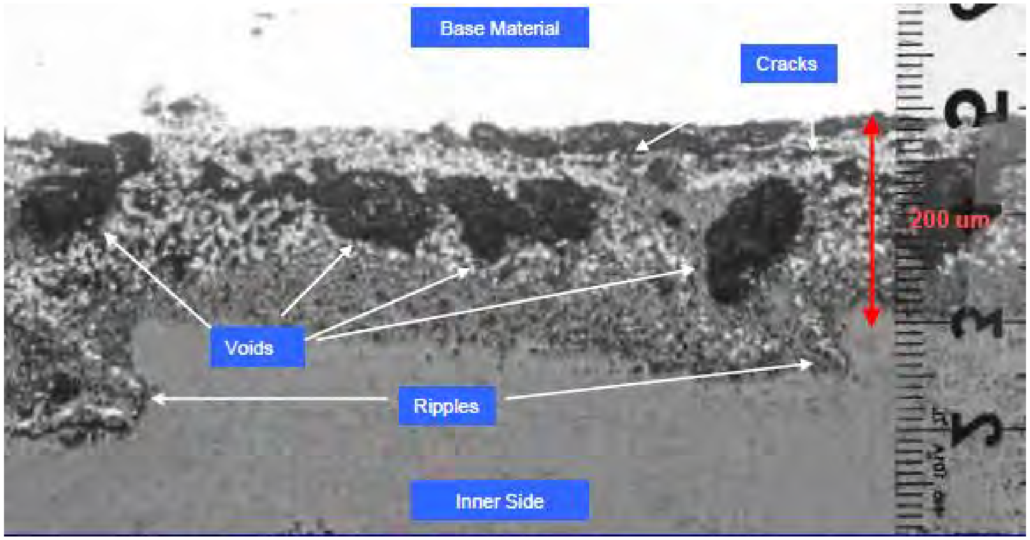
Deposit voids would attenuate the sound transmission and in the larger quantities provide “false” UT interface

Ripples in deposit would significantly increase the measured thickness value or decrease it (in the case of the “reversed ripples”)

Cracks would provide a “false” UT interface

Exfoliation, in places, would prevent any readings

Riffled tubes (floor tubes) cannot accurately be measured



Benefits

- Measures tube scale deposit thickness with direct correlation to standard Deposit Weight Density (DWD) method using advanced UT method.
- Internal scales in furnace tubes can be measured in hundreds of points.
- Tube samples are taken only <u>when</u> needed <u>where</u> needed.
- When scale growth is monitored frequently, corrective actions can be carried out in time (before corrosion risks increase).
- The impacts of water treatment become clearly visible: water treatment can be optimized so that acid cleaning interval can be extended or acid cleanings can be completely prevented.
- On-line monitoring of acid cleaning: acid treatment phase can be extended or terminated as needed. Cleaning results can be verified (vs. guarantees).
- Results can be used to replace a few “problem” tubes instead of acid cleaning entire boiler.

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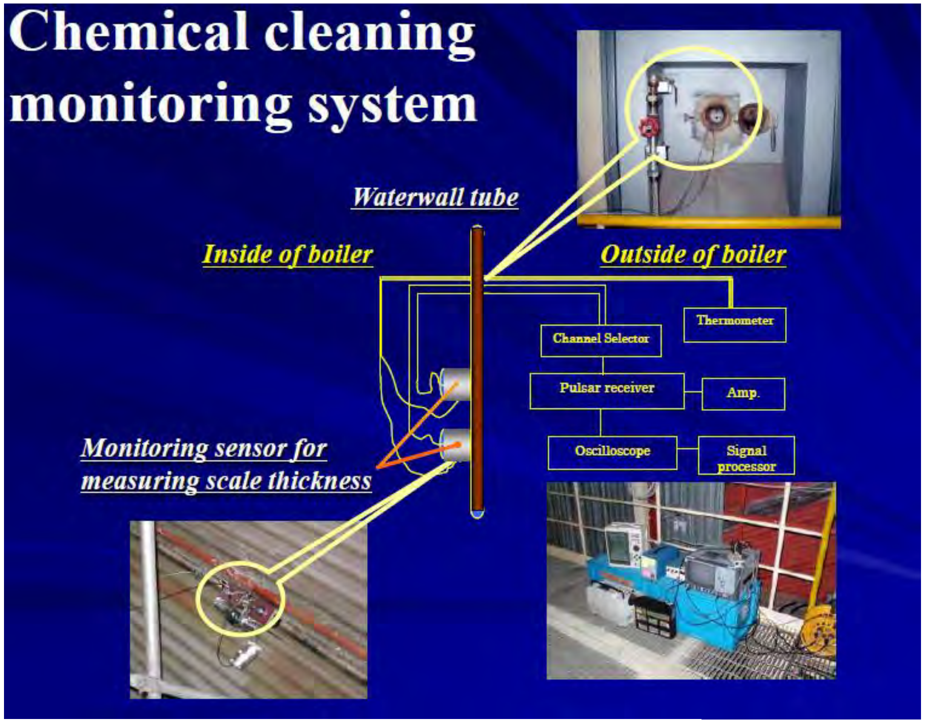
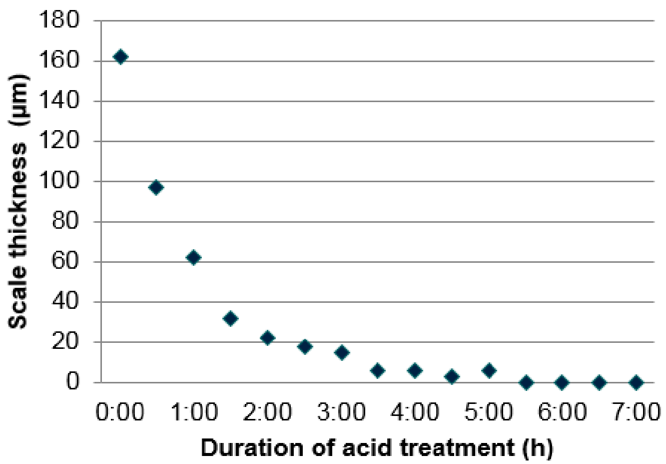
Technology Enhances Chemical Cleaning

Equipment can be used to monitor effectiveness of cleaning

- Minimizes potential for tube damage due to excessive cleaning
- Cleaning time is optimized to improve boiler availability





Internal Scale In Furnace Wall Tubes

Sample Tubes

Sample Scale thickness on the average ≈ 6 mils
maximum 8 – 12 mils
3 – 4 mils consider cleaning
(20-25 g/ft^2) DWD
Thick scales are not detectable by endoscopy

Damaged tube

Detectable by endoscopy

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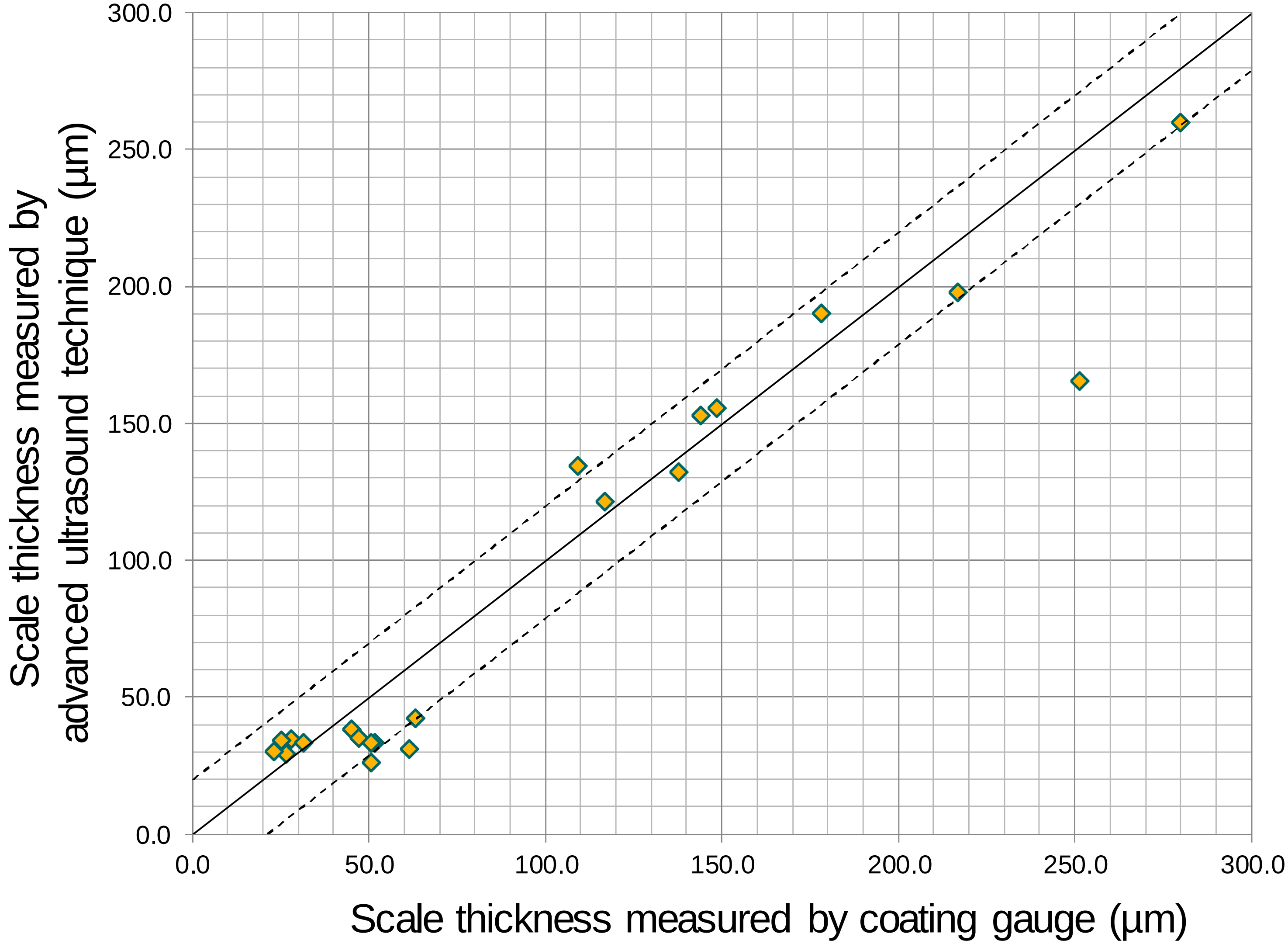
Validation Results

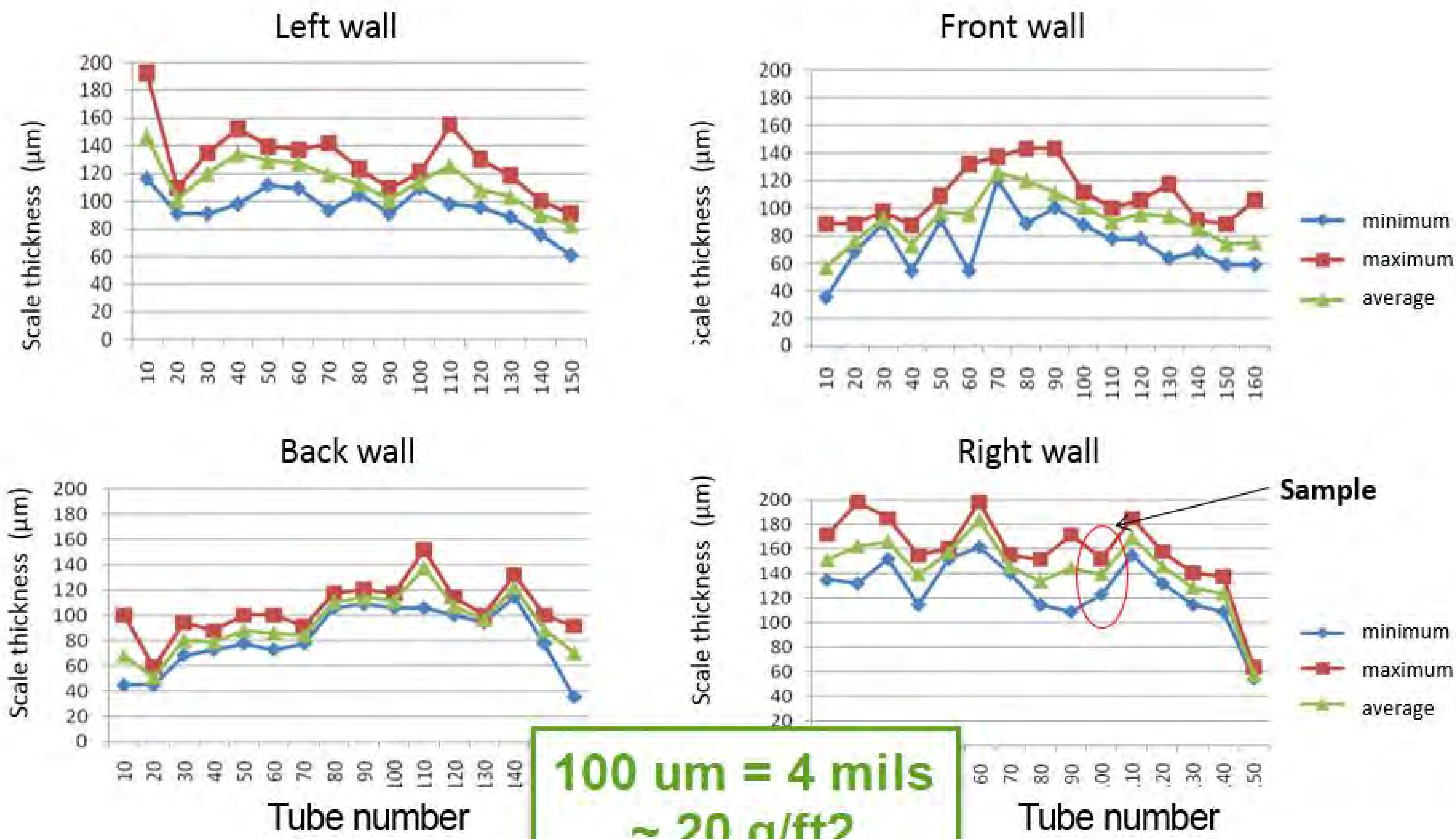


Difference ± 20 µm

20µm = 0.8 mils

Actual Data from Inspection

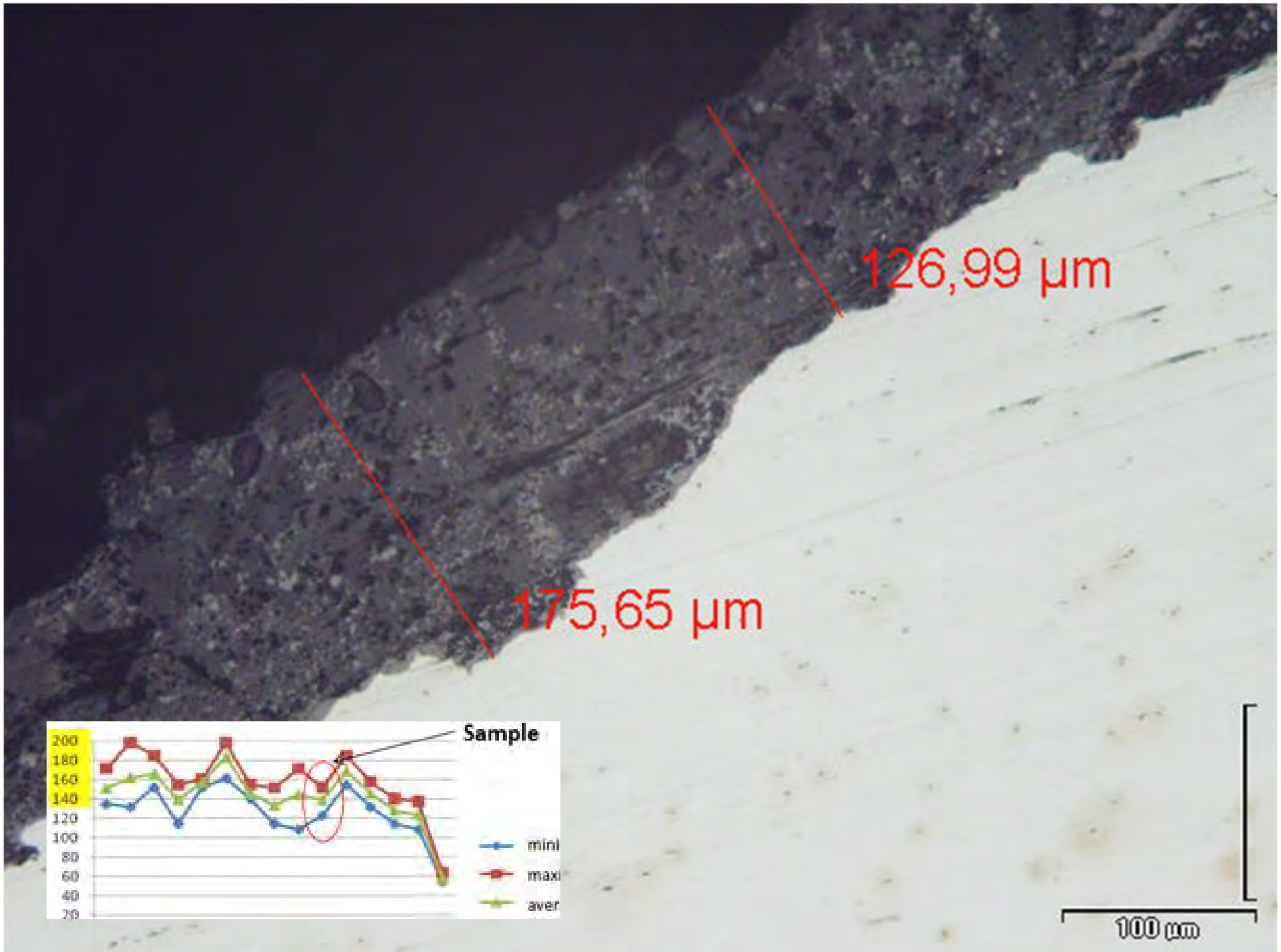
Recovery Boiler 10 feet above floor



100 um = 4 mils
~ 20 g/ft2

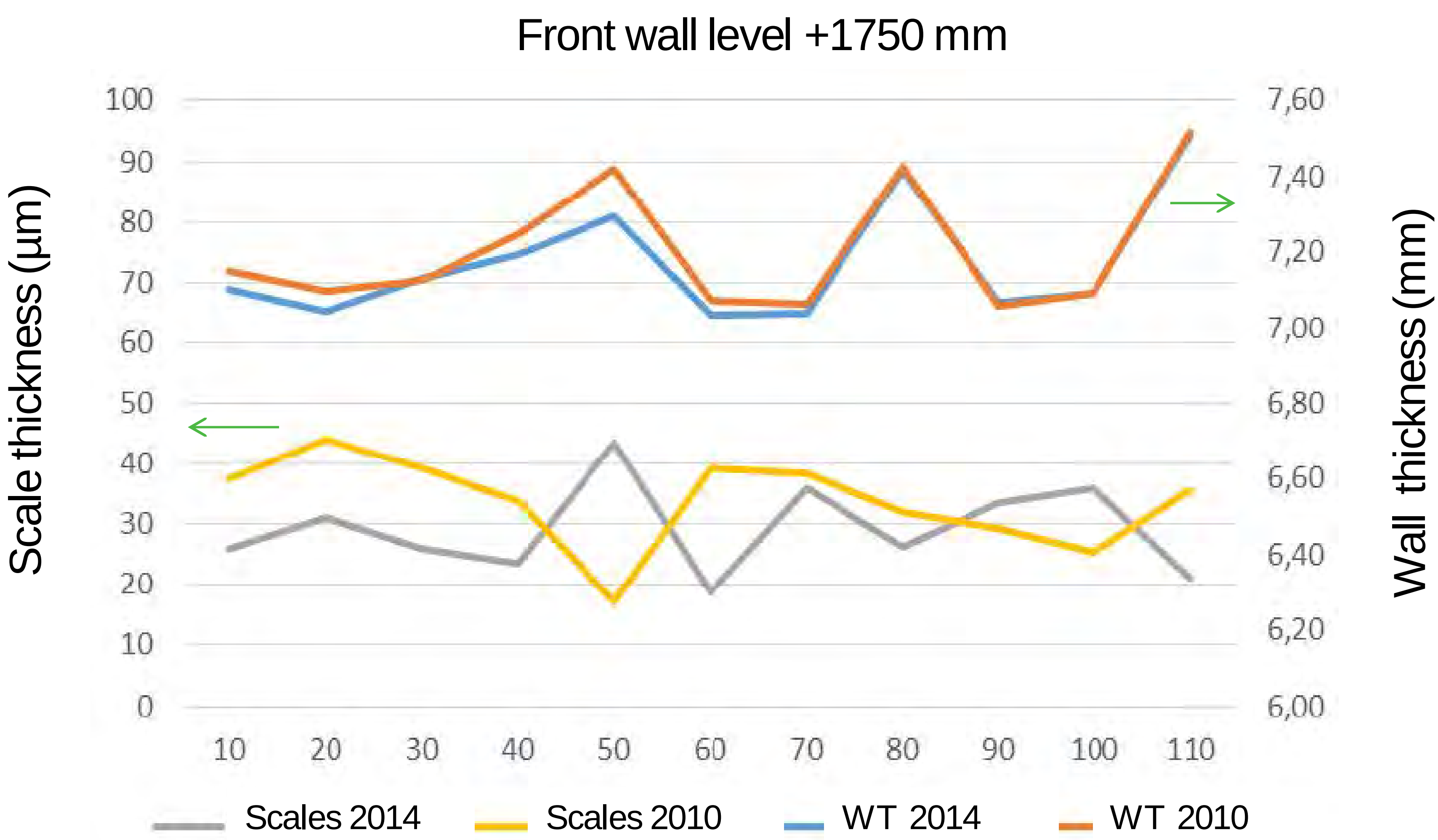
Sample Tube Cross Section

Readings compared to actual cross section measurement



Inspection Results for a Recovery Boiler

Operated 26 years without acid cleaning



No change in internal scale thickness: water quality and water chemistry OK

Reference List (39 Inspections)

- **Finland**
  - Alholmens Kraft 2010
  - April Kerinci 2014
  - Fortum Joensuu 2013
  - Fortum Kauttua 2011
  - Fortum Nokia 2010
  - Fortum Suomenoja 2011
  - Iggesund Workington 2013, 2015
  - Jyväskylän Energia 2011, 2015
  - Järvisuomen Voima 2009
  - Kainuun Voima 2012
  - Kotkamills 2012
  - Kotkan Energia 2012
  - Laanilan Voima 2012
  - Lahti Energia 2014
  - Metsä Fibre Joutseno 2010, 2012, 2015
  - Metsä Fibre Kemi 2009, 2010, 2011, 2014
  - Metsä Fibre Äänekoski 2010, 2013
  - M-real Kaskinen 2011
  - Oulun Energia 2014
  - Stora Enso Oulu 2010, 2014
  - Stora Enso Varkaus 2014
  - Stora Enso Veitsiluoto 2010, 2011, 2014
  - Tervakoski 2011
  - UPM Kymi 2013
  - UPM Tervasaari 2014
  - UPM Wisa 2014
  - Vantaan Energia 2014
- **North America**
  - MWV, Covington, VA 2015, PB9

Summary

Successful program

The best results are achieved when inspections are made at regular intervals so that fast deposit growth rates can be detected at an early stage.

Value

Method would provide more data to support chemical cleaning strategy. Mills could extend their chemical clean cycle and/or this technology could be used to determine where best to take a tube sample –or-not take a tube sample and instead rely on this technology.

To draw a direct correlation to DWD would require deposit analysis, so at least one sample is recommended. Then shift to annual (or greater) deposit UT method.

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FORWARD