Air Cooled Condenser Users Group: Corrosion Product Transport Monitoring

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Topics

- Why Monitor Corrosion Product Transport?
- Creating a Monitoring Program
- Sampling and Sample Methods
- Iron Monitoring Methods
- Costs and Time Commitments

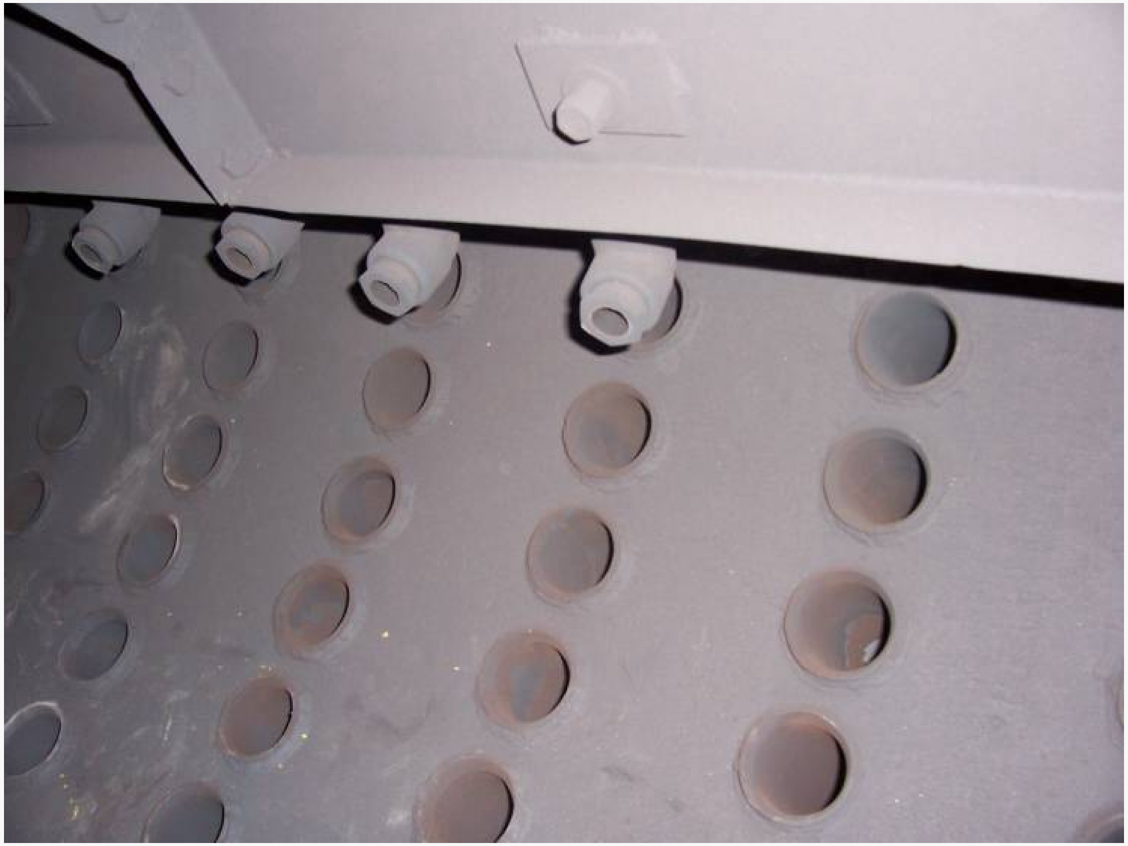
Why Monitor Corrosion Product Transport?

- Protects people
  - Minimizes equipment failures and hazards
- Protects plant equipment
  - FIRST line of defense in problem detection
  - Protects ACC, feedwater, HRSGs and turbines
  - Predicts and minimizes cleaning needs and frequency
- Allows performance monitoring of the steam-condensate-feedwater cycle
  - Provide data to operating & chemistry personnel for detection of any deviations from control specs.
  - Allows corrective action

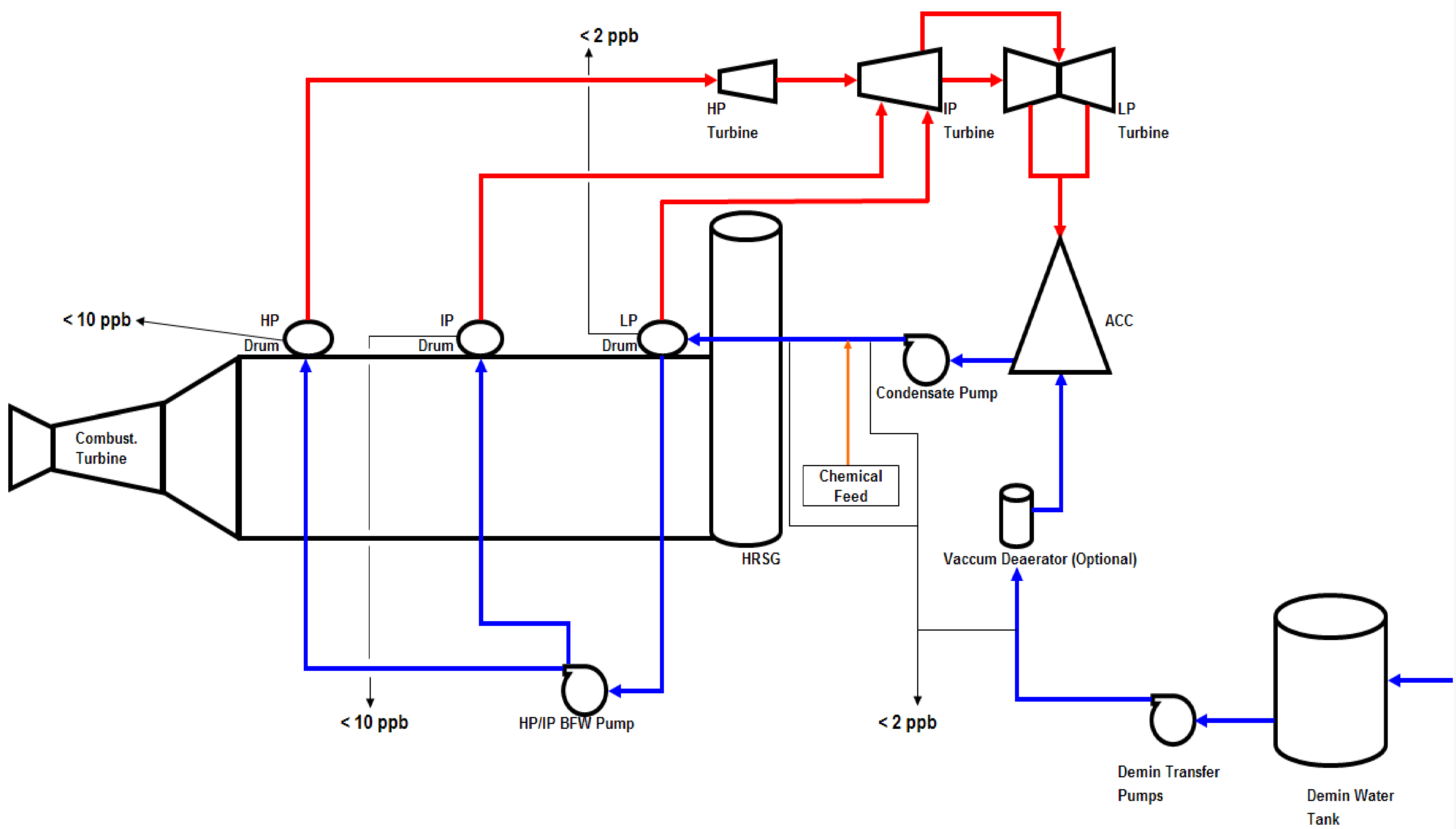

Boiler chemical cleaning tank farm

Creating a Monitoring Program

- Sample Locations and Limits
- Sample Frequency
- Interpreting Data
- Recommended Tests



Creating a Monitoring Program: Sample Locations and Limits



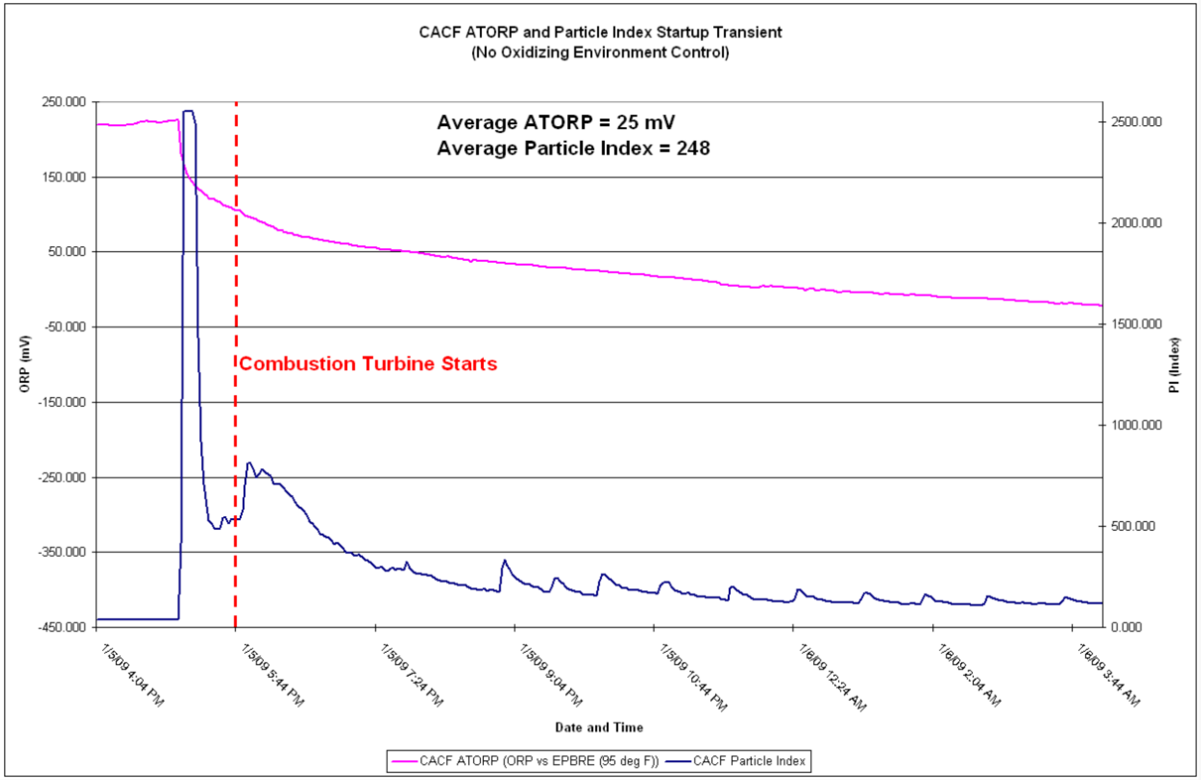
Creating a Monitoring Program: Frequency

- Normal Operation
  - Daily (to start) – all locations (include RACs if equipped)
  - Adjust schedule based on results
- Startup and Shutdown Profiles
  - Specific schedule important
  - Sample every 15 minutes for first 6 hours (or until levels stabilize)
  - Perform quarterly and after major maintenance
  - Determines “crud burst” duration and magnitude

Creating a Monitoring Program: Interpreting Data

Interpret data carefully

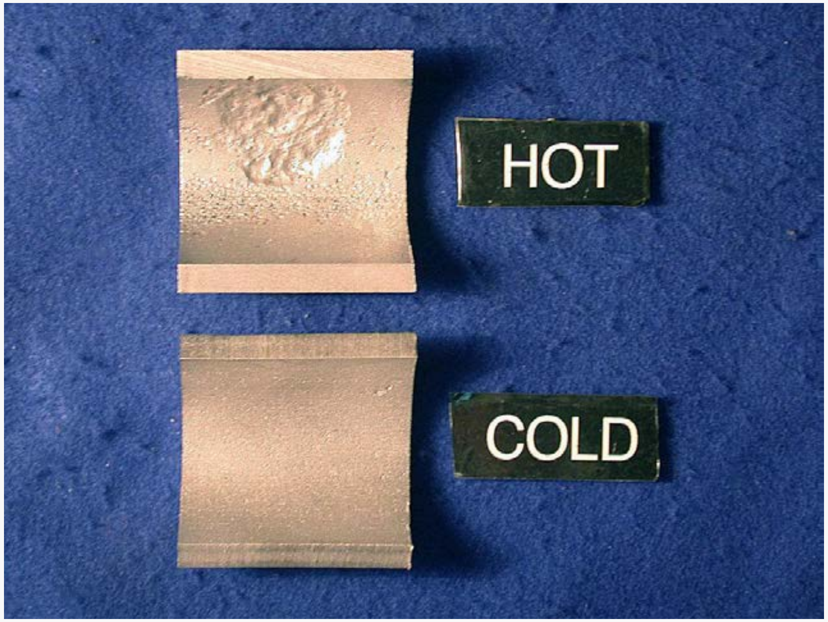
- Most transport occurs during transients
- S/U and S/D important



Particle index (discussed later) and ORP on plant startup

Creating a Monitoring Program: Recommended Tests

- Total, Soluble, and Filtered Tests to start
- Continue for 30-60 data sets (60 preferred)
- Analyze for consistency and trends
- Soluble test frequency decreases to monthly if results consistently non-detect
- Total (wet test) frequency to weekly if consistent with filtered results



Sampling and Sample Methods

- Continuously running
- SS lines, ¼ to ⅜-inch
- Minimize line lengths
  - Minimizes lag time
  - Minimizes iron loss (through sample line deposition)
- Cooled to < 90°F
- Flow rate 4-6 FPS
- Isokinetic samples best, but most plants don’t have them (continuous flow especially important

Sampling and Sample Methods

- Key Monitoring Parameters
  - pH
  - Total Iron (wet test)
  - Soluble Iron (wet test)
  - Suspended Iron (Millipore filter test)
  - Dissolved Oxygen
  - Treatment Chemical (oxygen scavenger, if used)
- Influencing Parameters
  - Na leakage from demineralizers and polishers
  - Alkalinity (CO2 source) and TOC
  - Cation and Specific Conductivity of feedwater, condensate and steam
  - NH3 and dissolved CO2
  - Silica
  - Hardness
  - Na and hydrogen in the steam
  - Flow rates, temperatures and pressures

Iron Monitoring Methods

Method	Soluble Iron	Total Iron	Digestion Required	Test Type	Detection Limit (ppb)
TNTplus		X	X	Grab / Wet	200
FerroVer		X	X	Grab / Wet	20
TPTZ		X	X	Grab / Wet	10
1-10, Phenanthroline	X			Grab / Wet	20
FerroZine		X	X	Grab / Wet	10
Titraver		X		Grab / Titration	10,000
FerroMo		X	X	Grab / Wet	10
Test Strips	X			Grab / Strips	150
Millipore (Suspended Iron)		X		Grab / Filter	10*
Composite Sampler		X		Composite / Filter	1
Off-site Lab	X	X		Grab / Off-site Lab	3
Particle Analysis		X		Continuous / Online	N/A (Particle Index)
Deposit Weight Density		X		Destructive	N/A

*Can lower detection limit with larger sample

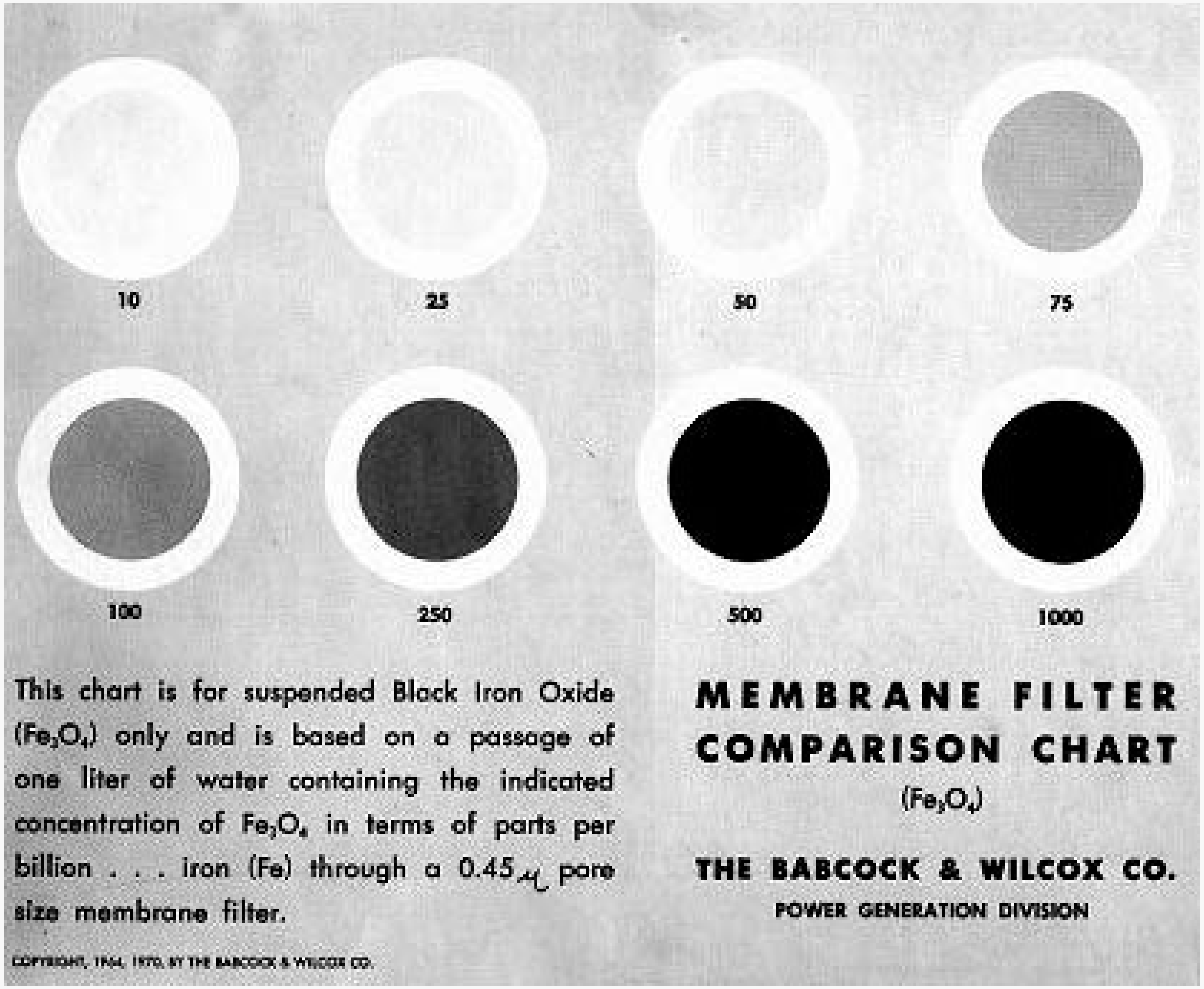
Iron Monitoring Methods – Wet Tests

- Hach tests shown (typical)
- Specialty chemical suppliers may have their own
- Detection limit usually too high (minimum is 10 ppb)
- Require digestion (complicated and time consuming)
- Requires spectrophotometer
- Suspended iron test is better, but early testing should include wet tests

Iron Monitoring Methods – Suspended Iron

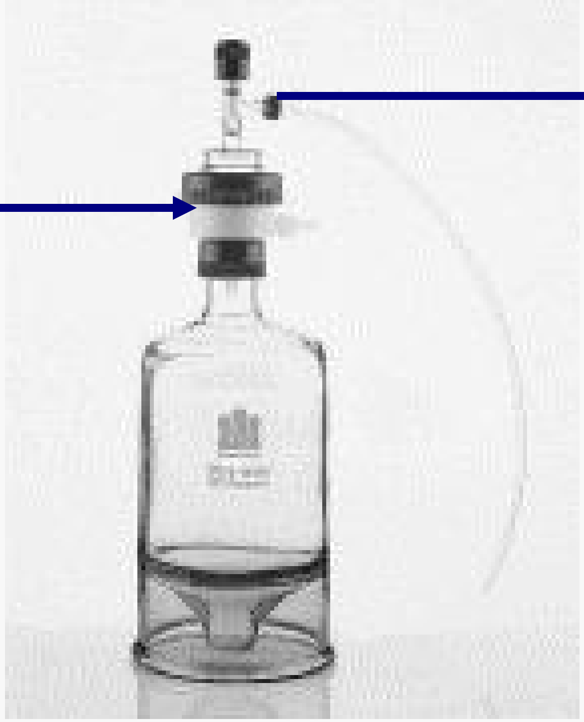
- Millipore filter test (filter through 0.45 micron filter)
- More accurate than wet tests
  - Wet test methods don't accurately measure total iron in drums
  - Iron changes form and does not show up on the traditional wet tests unless digested
- Uses B&W comparison chart
- Detection limit of 10 ppb for 1L sample
- Lower detection limit by increasing sample size
- 5L sample lowers detection limit to 2 ppb
- Manual filtering of 5L of sample impossible
  - Use a vacuum pump and filter assembly to accomplish this task

Iron Monitoring Methods – Suspended Iron



Iron Monitoring Methods – Suspended Iron

5L Sample Reservoir



Filter Assembly and 5L Receiver

Vacuum Pump

Iron Monitoring Methods – Composite Sampling

- Millipore test uses visual comparison
- Composite sampling uses same filter, but off-site analysis provides greater accuracy
- Known volume of water passes through filter
- Corrosion products accumulate
- Filter removed and weighed after exposure
- Weight of iron (in mg) divided by total flow (in L) to provide result in mg/L or ug/L
- Additional analyses (like X-ray diffraction) can provide data on oxide composition

Iron Monitoring Methods – Composite Sampling

Iron Monitoring Methods – Off-site Lab

- Field test accuracy not the best (high detection limits)
- Off-site samples confirm field test results
- Should be obtained quarterly for all streams of interest (see diagram)
- Include soluble and total iron
- Samples must be preserved to ensure accuracy
- Pull samples when field grab samples are pulled
- Compare results to confirm accuracy
- Costly ($250-$400 per sample)

Iron Monitoring Methods – Particle Analysis

- Traditional monitoring of metal transport and generation in the steam cycle relies primarily on periodic wet tests
- Wet tests valuable, but leave significant holes in the data stream
- Every thermal, chemical, or hydraulic event liberates or generates metal oxides in the steam cycle
- These events occur often and cannot be scheduled - they occur as the plant operates

Iron Monitoring Methods – Particle Analysis

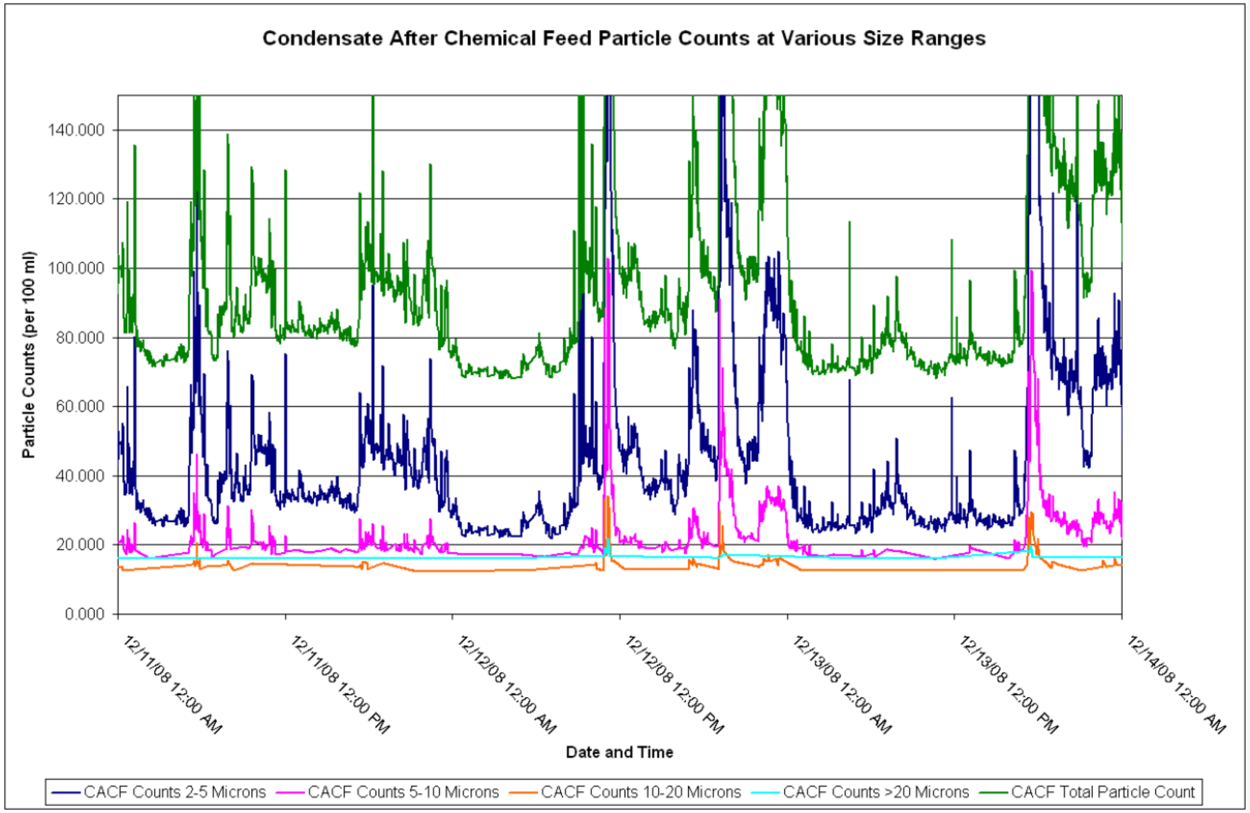
- Time-based testing (iron sampling at a specific frequency) important, but it cannot detect the majority of these events
- Particle analysis provides a window into metal liberation and transport as it occurs
- Two different technologies that can be used - particle size analysis and particle counts

Iron Monitoring Methods – Particle Analysis – Particle Counter or Particle Monitor

- PC reports counts in different size ranges
  - Requires 4 DCS inputs for each sample
  - Provides more data than PM, but requires more storage and data infrastructure
- PM provides only one reading – “index”
  - Only 1 DCS input/PI tag per sample
  - Index represents the total surface area of all particles passing through the sensor

Iron Monitoring Methods – Particle Analysis – Particle Counter or Particle Monitor

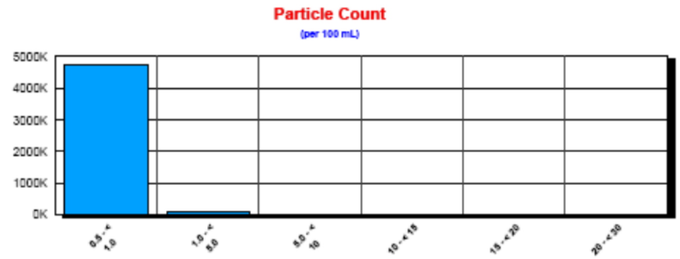
- Both may be useful
- Testing indicates that the majority of iron transport occurs as particles < 5 microns in size
- Most iron transport occurs as particles of similar and smaller size

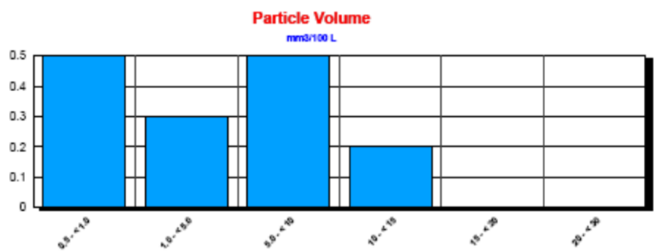


Iron Monitoring Methods – Particle Analysis – Particle Counter or Particle Monitor

Particle Size Analysis

Micron Range	Particle Count per 100 ml	Particle Count Range %	Particle Count Cum %	Particle Volume mm3/100 L	Particle Volume Range %	Particle Volume Cum %
0.5 - < 1.0	4,742,494	97.6	97.6	0.5	33.3	33.3
1.0 - < 5.0	110,891	2.3	99.9	0.3	20.0	53.3
5.0 - < 10	4,337	0.1	100.0	0.5	33.3	86.6
10 - < 15	310	0.0	100.0	0.2	13.3	99.9
15 - < 20	0.0	0.0	100.0	0.0	0.0	99.9
20 - < 30	0.0	0.0	100.0	0.0	0.0	99.9
Total	4,858,032			2		





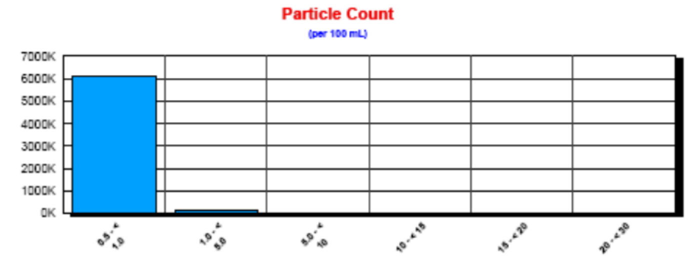
Other(s)

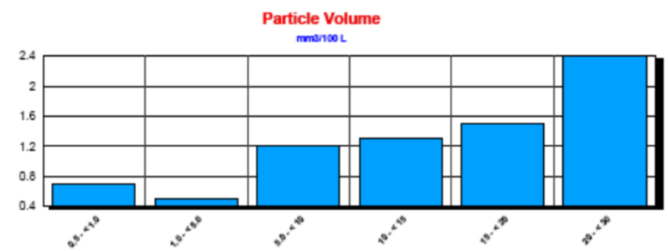
Turbidity 0.12 NTU

Condensate After Chemical Feed Particle Distribution

Particle Size Analysis

Micron Range	Particle Count per 100 ml	Particle Count Range %	Particle Count Cum %	Particle Volume mm3/100 L	Particle Volume Range %	Particle Volume Cum %
0.5 - < 1.0	6,089,431	97.3	97.3	0.7	9.2	9.2
1.0 - < 5.0	158,244	2.5	99.8	0.5	6.6	15.8
5.0 - < 10	10,544	0.2	100.0	1	15.8	31.6
10 - < 15	1,881	0.0	100.0	1	17.1	48.7
15 - < 20	700	0.0	100.0	2	19.7	68.4
20 - < 30	438	0.0	100.0	2	31.6	100.0
Total	6,261,238			8		



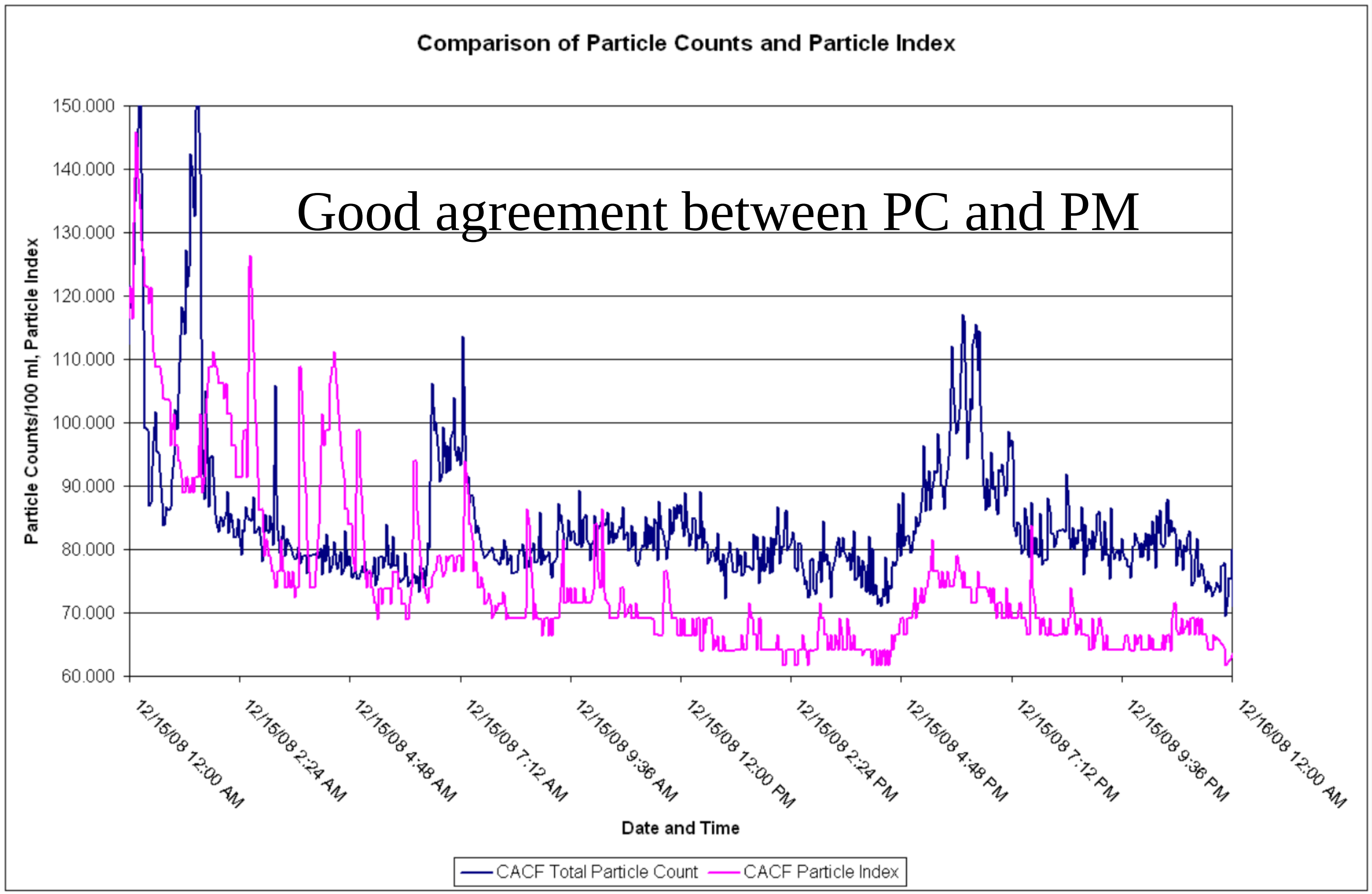


Other(s)

Turbidity 0.20 NTU

LP Economizer Outlet Particle Distribution

Iron Monitoring Methods – Particle Analysis – Particle Counter or Particle Monitor



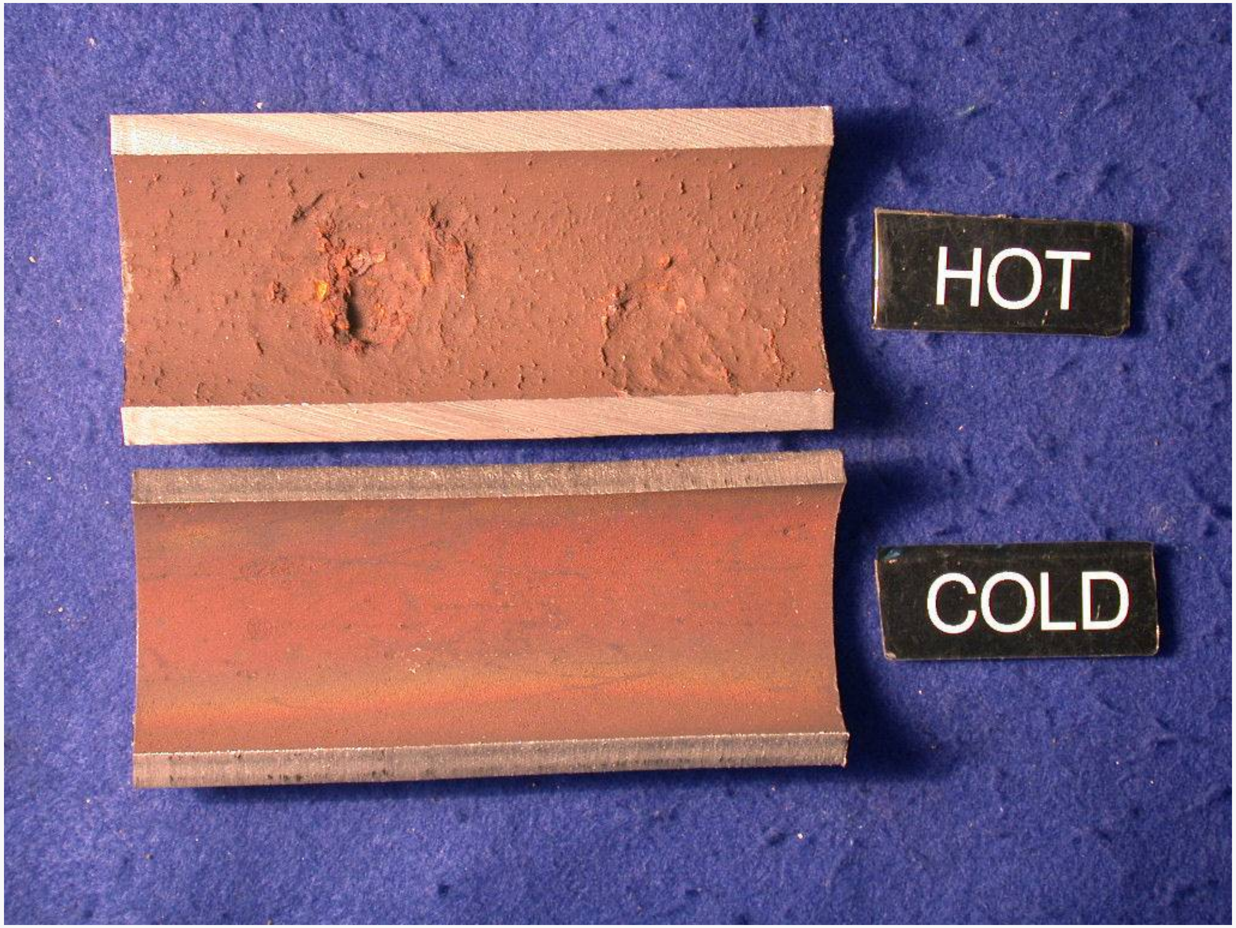
Iron Monitoring Methods: Deposit Weight Density (DWD)

- Measures the amount of deposit on both the hot and cold side of a boiler tube.
  - NACE TM0199-99: Bead Blasting Method
  - Mechanical method, so follow B&W Cleaning Guidelines
- Sample from high heat release zone
  - Conventional unit: water wall approximately the centerline of the highest burner elevation
  - HRSG: HP evaporator, first row
- Used to determine need to clean boiler
  - Need to clean will be unit specific, as heat release and circulation play an important role in deposition on ,and cooling of, the boiler tubes

Iron Monitoring Methods: Deposit Weight Density (DWD)

DWD tube Sample (before cleaning)

- Weigh each side
- Clean
- Reweigh each side
- Difference is DWD



Iron Monitoring Methods: Deposit Weight Density - Chemical Cleaning Guidelines

US Units		Metric Units	
psi	g/ft^2	Bar	g/dm^2
< 1000	10 – 40	< 70	2.1 – 4.3
1000 – 2000	12 – 20	70 – 140	1.3 – 2.2
> 2000	10 - 12	> 140	1.1 – 1.3

- Follows B&W Guidelines
- Based on mechanical cleaning (bead blasting or scraping)
- Need to clean will be unit specific.

Iron Monitoring Methods – Using the Tools

- Conventional testing and DWD provide quantification
- Particle analysis technology provides visibility to previously undetectable events.
- The two approaches can be used to correlate particle index to metal transport (iron) test results
- Combining particle counts with wet test results "closes the loop" on steam cycle metal transport. The combination offers three windows into the process
  - Wet tests correlate particle index to iron transport
  - Particle index provides real-time, continuous indication of amount of iron moving through the system
  - DWD confirms amount of deposition on tubes

Costs and Time Commitments (Approximate)

Method	Cost (per test)	Cost (initial setup)	Time Required	Notes
Wet Tests	$1.00	$0 (assumes existing spectro-photometer and glassware)	Approximately 1 hour per day (concurrent with other sampling)	3 minutes per test, but 3-5 tests per day (condensate, FW, drums)
Millipore Filtered Iron Test	$0.40-$0.50	$1,500 (Reservoir, vacuum pump, tubing, filter, etc.)	Approximately 2 hours per day (concurrent with other sampling)	Operators fill reservoir with sample, start vacuum pump, read result later
Off-site Lab	$250-$400	$0	Approximately 4 hours per quarter	Performed quarterly and only on select samples
Particle Analysis	$0	$15,000	None – online analyzer with input to DCS	Assumes 2 particle monitors, 2 sample streams to each
Deposit Weight Density	$15,000 every 3 years	$0	Approximately 2 days every 3 years	Includes cost to cut and reweld sample.

Questions?

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What a good iron monitoring program can prevent