How an ACC Unit Releases Iron, a 3-Month Study with Particle Analyzers

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What the Study was outlined to do:

1. Confirm (or further define) the excellent average 3 ppb FW iron results reported through plant testing and repeated lab analysis
2. Determine if FAC or other corrosive mechanisms existed within the ACC and under what conditions
3. Look at alternative technologies to provide timely and accurate iron data in the steam cycle
4. Explore the use of an oxidizing environment in the steam cycle and determine benefits

Plant Design

- Two Siemens SGT-PAC 5000F Gas turbines each capable of 194-220 MW
- One Steam Alstom turbine capable of 305 MW
- Two duct fired 3-drum HRSG's each capable of
  - HP drum @ 11-20 Mpa (1,600-2,900 psi) @ 180 Kkg/hr (408 Klbs/hr)
  - IP drum @ 5.2 Mpa (750 psi) @ 17.5 Kkg/hr (38.5 Klbs/hr)
  - LP drum @ 1.0 Mpa (140 psi) @ 11.5 Kkg/hr (25 Klbs/hr) (feedwater)
- One SPX Air Cooled Condenser, 5 street, 30 - 30' fans
- Vacuum and seal steam are maintained when offline with an Auxiliary boiler
- Makeup is prepared with 2-pass RO's and polishing mixed beds, There is no condensate polishing other than a CUNO 10 µm particle filter
- The plant is operates on 2- hour call from the Power Authority and thereafter adjusts load every 5-minutes
- Average 21 starts per month

Chemistry Parameters

HP and IP Drums

- Do not cascade blowdown
- Suspended and Total Iron consistently less than 10 ppb
- Operate with low level Trisodium Phosphate
- Maintain 1% blowdown

Condensate and Feedwater (LP drum)

- Maintain a pH of 9.5-9.8 average 9.6
- Suspended and Total Iron consistently less than 3 ppb
- ~10 ppb of Carbohydrazide in FW
- Utilize a combination MEA/Ammonia blend for pH buffering

Testing Protocol

1. Installation of a continuously sampling Chemtrac Model PM2500 Particle Monitor on the condensate loop immediately after the Hotwell extraction pumps and before the in-line full flow CUNO condensate filter
2. Installation of a continuously sampling Chemtrac PC3400 Particle Counter on the LP feedwater point
3. Continue plant testing and logging of all chemistry parameters including Millipore iron analysis related to these two sample points
4. Stepped up sampling for lab analysis and ultra low total iron determination as well as periodic review of ultra low organic acid species

Instrumentation

The Chemtrac PM2500 Monitor detects particulate contamination in a flowing liquid sample by Dynamic Light Obscuration (DLO). As particles pass through the illuminated sensing area, they obstruct a portion of the transmitted light. A sensitive photodetector converts these light fluctuations into an RMS signal and a “number is displayed” representative of particle size and concentration.

The Chemtrac PC3400 Counter allows excellent detection and counting of particles in a flowing liquid sample in 6 size segments

2-5 micron, 5-10 micron, 10-15 micron, 15-25 micron, 25-50 micron, 50-100 micron, > 100 microns

The detection is made by Light Obscuration created by the particle passing through a laser light field at a pre-set flow rate.

Testing Time Period and Plant Operation

1. Testing was performed from December 1st, 2011 to March 1st, 2012
2. The plant was operating on dispatch mode in response to the Power market and ran in several modes of operation such as 1 on 1 , 2 on 1 and at various duct burning, steaming and pressure rates
3. The plant saw during this time period ambient temperatures of:
   - Minimum minus 15.3 ºC (4.5ºF)
   - Maximum plus 13.1 ºC (55.6ºF)
   - Average 0.0 ºC (32ºF)

Discussion of Results

Very low levels of iron observed

The following average Total Iron (ICP-MS) values were obtained during the study

- Condensate Pump Discharge 2 ppb
- HRSG-2 LP FW 5 ppb
- HRSG-2 BFP suction 2 ppb
- HRSG-2 HP drum 17 ppb
- HRSG-2 IP drum 15 ppb
- HRSG-1 LP FW 36 ppb* (8 out of 10 samples <2 ppb)
- HRSG-1 BFP suction 13 ppb** (8 out of 10 samples <2 ppb)
- HRSG-1 HP drum 4 ppb
- HRSG-1 IP drum 18 ppb

*One high peak (immediately after break of vacuum)

** Two moderate peaks (immediately after break of vacuum)

Note HRSG #1 always started first and the iron would be preferential to that unit

Discussion of Results

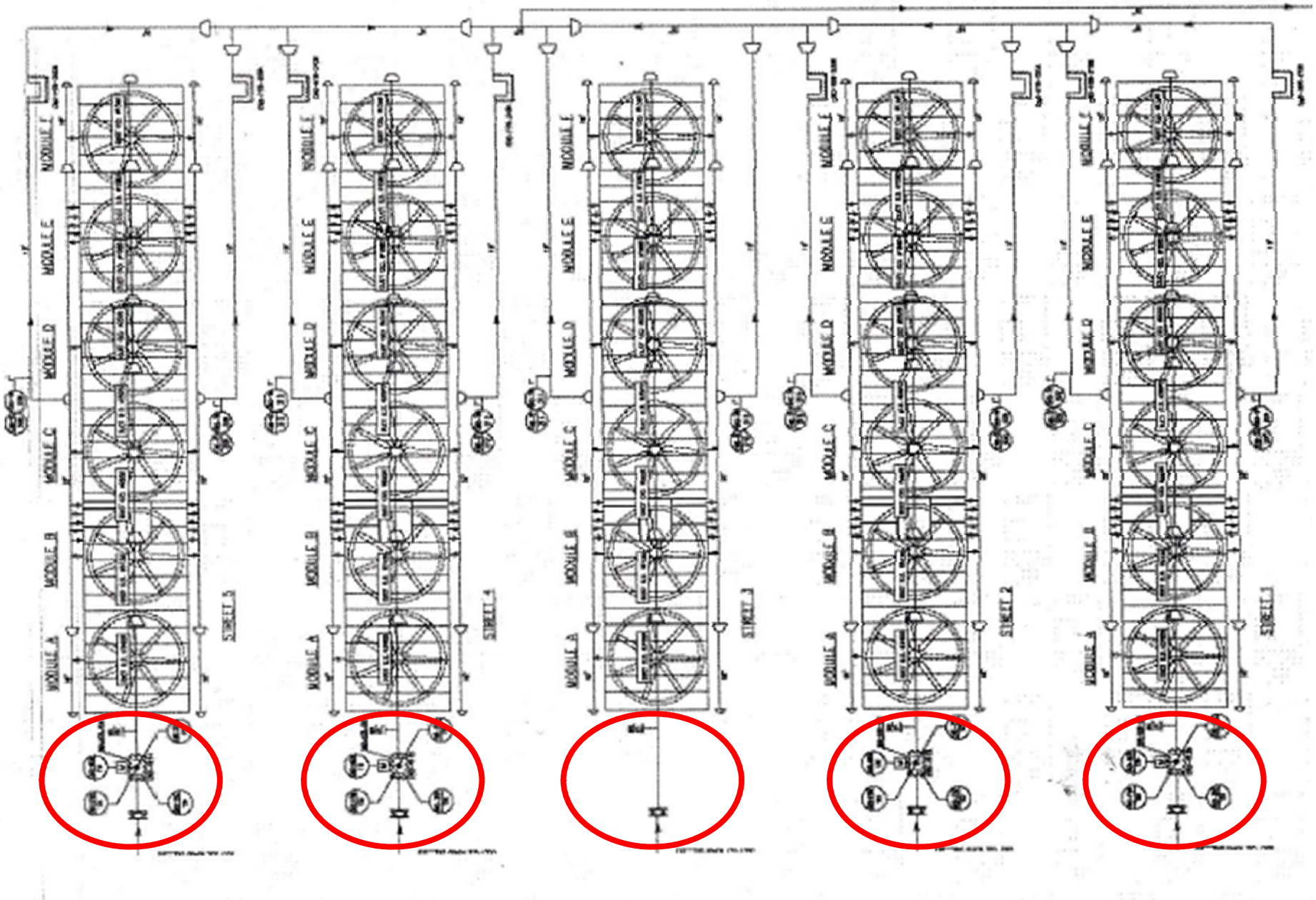
Pattern of when Particle Bursts occurred

We had expected the particle burst were related to the startup/shutdown sequences of the facility but there was a very poor correlation to this effect

We did find an excellent agreement with the particle bursts coinciding with the opening and closing of the street valves on the ACC

Each week the data from the particle analyzers, steam flows, valve positions were charted to look for relationships. Data was gathered every 15 minutes.

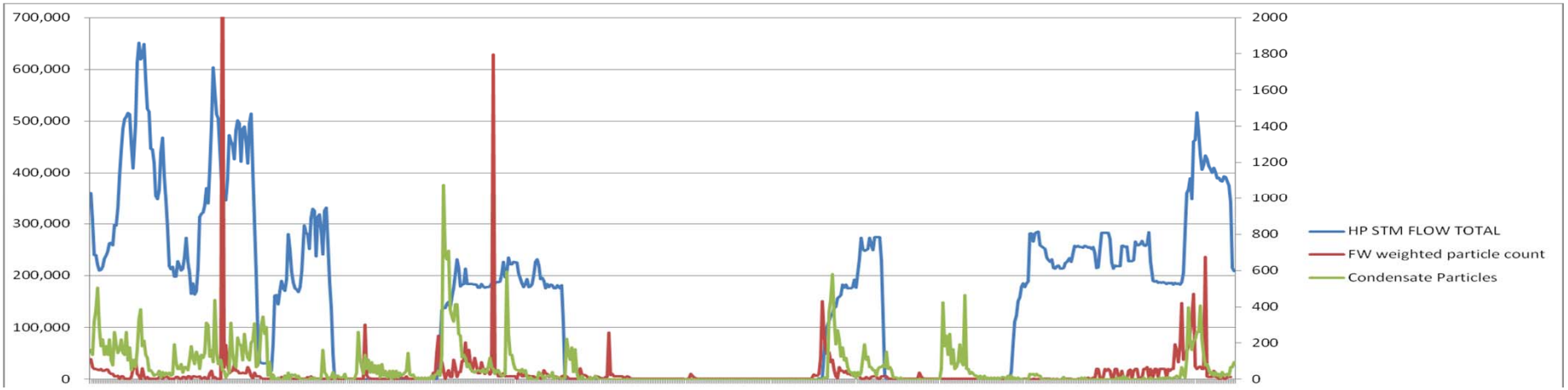
The following are example charts in one week segments which are representative of all the data



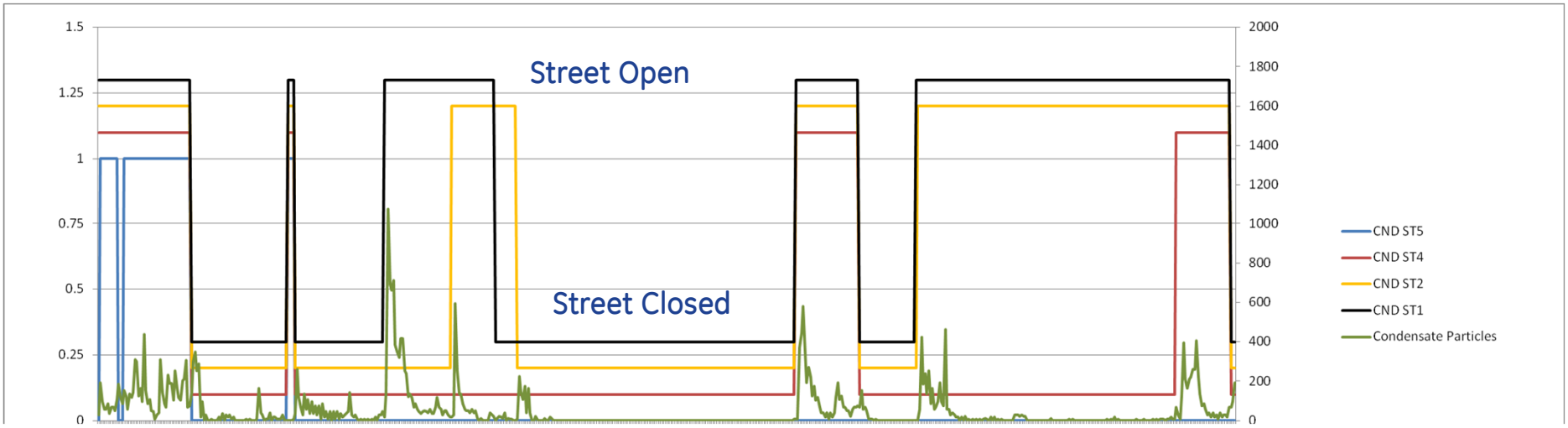
imagination at work

Street Valves

Particle Burst Timing



7-days



7-days

Discussion of Results

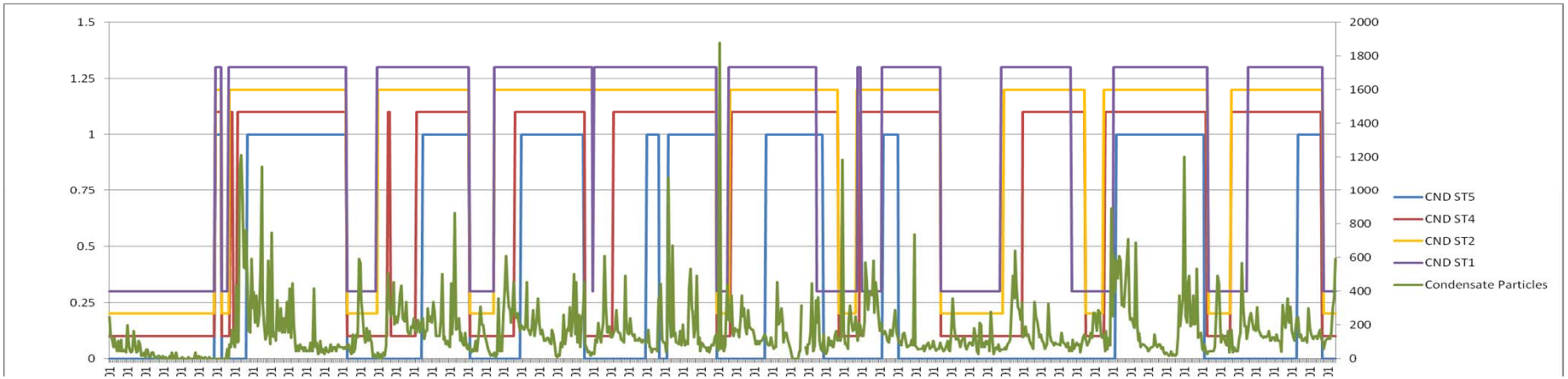
Degree and Longevity of the Particle Burst

The following graphs look at not only the timing of the bursts but the number of streets that are on-line to accept the steam flow

We saw that steam flow per street varied significantly and the higher the volume per street the more intense the particle burst was and it lasted longer

The street valve position is >1=open and <0.5=closed. To show clarity between each street the values have been staggered by 0.1 of a unit between each street. Street 3 in the center of the ACC is constantly open

Particle Burst Intensity and Longevity



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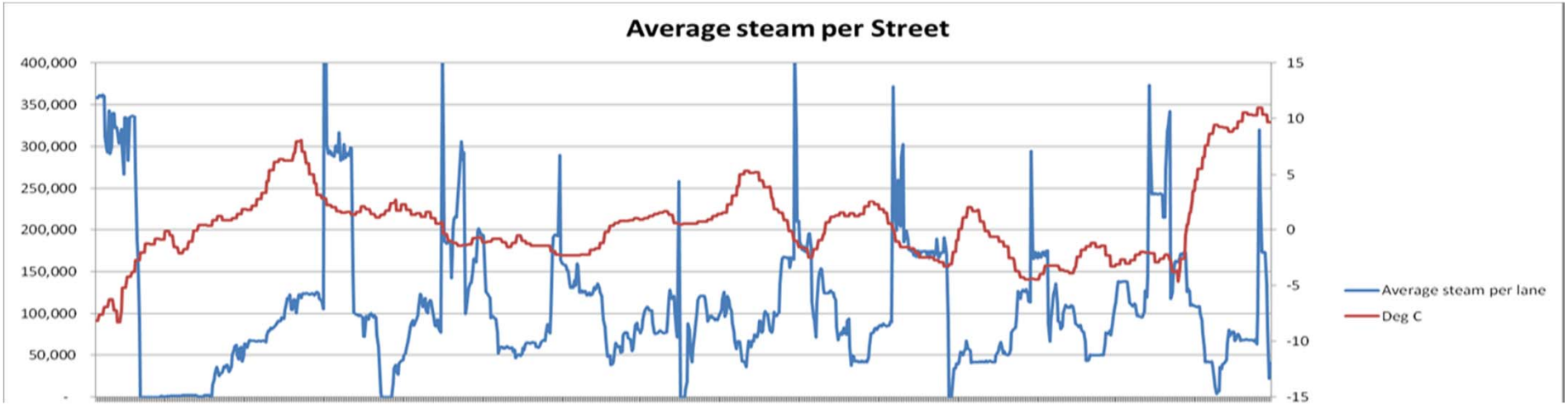


7-days

Discussion of Results

Nature of the Particles in the Feedwater

The particle counter provided data like this over the 3-month testing period

2-5 micron, 103,690 counts	weight basis* 103,630
5-10 microns, 8,849 counts	weight basis* 86,720
10-15 microns, 596 counts	weight basis* 27,718
15-25 microns, 51 counts	weight basis* 9,537

25+ microns, zero

*Based on a particle size of 3.5 micron

It is postulated that since the 10-micron CUNO filter doesn't build a pressure drop and that upon inspection the filters rarely show much iron that the majority of particles are less than 10-micron in size

Discussion of Results

The Impact of Breaking Vacuum

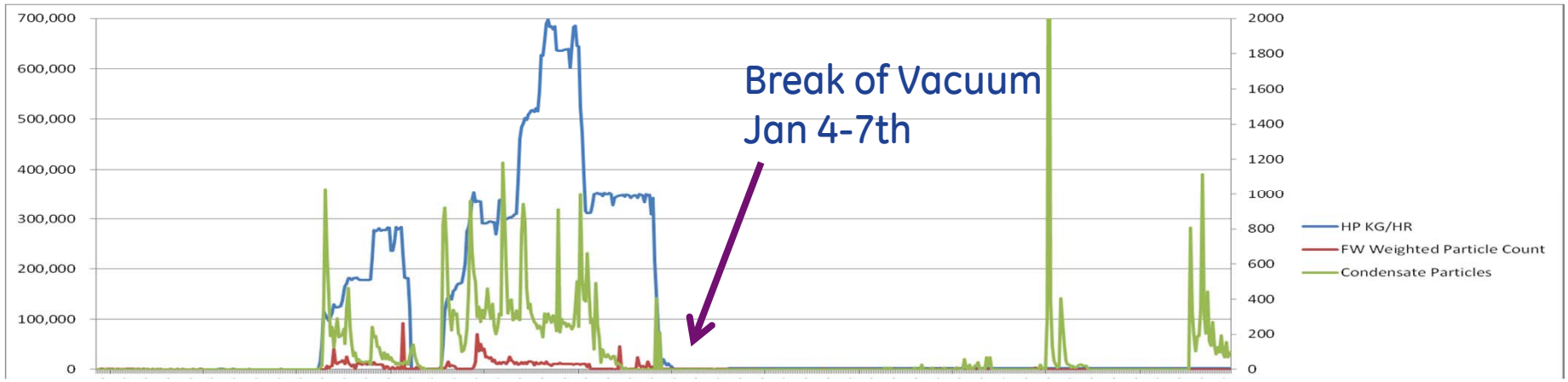
The plant was taken down for a short period Jan 4th-7th and vacuum broken. The effects were seen immediately upon startup with elevated irons on a continual basis with peaks still being observed with respect to the ACC street valve operation.

The purging of iron took approximately 10 days with particle counts steadily decreasing during this time period.

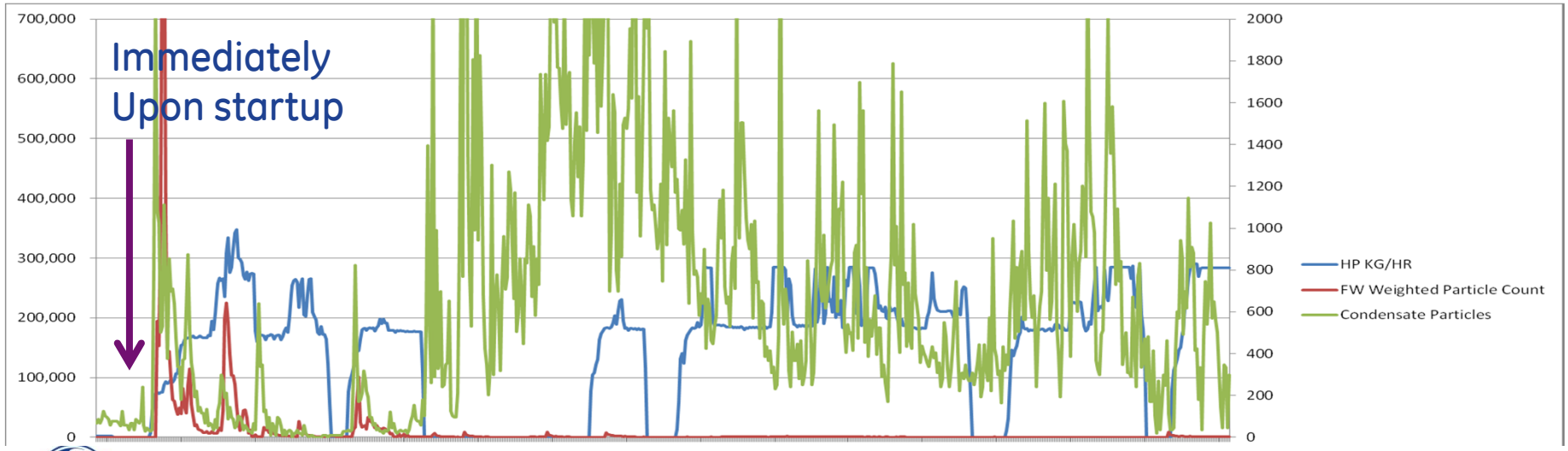
The importance of maintaining the seal steam and vacuum is quite apparent in maintaining the lowest iron transport possible.

Even with the crude bursts observed during a break of vacuum the full-flow CUNO condensate filter with 10 micron cartridges would typically last 6+ months between changes. The plant changes the filters approximately 2 days after a major outage startup simply as a precaution

Break of Vacuum



7-days



7-days

Discussion of Results

Slightly reducing versus slightly oxidizing

This test was performed over a 10-day period and no discernible difference was seen in the amount of iron or particles during this time period

Since the system is virtually all mild steel and vacuum and seal steam is maintained we believe there would be little if any risk in conducting a longer test with oxygen values between 5-15 ppb

There is appreciable data from plants around the world that a slightly oxidizing environment will provide further benefit from FAC conditions

Inspection of the main steam duct has indicated excellent passivation and virtually no damage. Inspection of the ACC will take place 2014

Discussion of Results

The use of a Particle Counter and/or a Particle Monitor is an extremely worthwhile tool in providing rapid and accurate feedback on a continuous basis of iron movement in the steam system

Lab or Millipore testing which are simply grab samples in a point of time provide far less of a picture of how a plant is operating

Summary of Results

1. Very low iron values were observed through lab analysis, and Millipore testing and this was supported through observation of the very low feedwater and condensate particle counts and trends
2. A distinct pattern of when particle bursts was observed whenever the street valves were opened or closed
3. The degree and longevity of these particle bursts show some relationship with the average steam flow per street. The higher the steam flow the more intense the burst (This may also be impacted by turning fans on/off for freeze protection)
4. The Feedwater particles were predominately less than 5 micron in size and the Particle Counter provided data that more closely resembled lab total iron analyses
5. The plant had one occasion where vacuum was broken for a short period The effects of this were seen for approximately 10 days afterwards with high iron values until the system was purged clean
6. Operation with a very slight reducing environment versus a slight oxidizing environment was inconclusive. More long term testing is required

Thanks

Our appreciation goes out to Joseph Zimmermann of CHEMTRAC Inc. in providing these instruments and his support for this study

Thank You for your Attention
Questions?