Electric Power Conference 2011
May 10-12, 2011 Rosemont, IL
Abstract #SP-6767

PWR2011-6767

Recent Regenerative Airheater Improvements at HECO Kahe Point, Oahu

Section 6D: Innovations of Maintenance Technologies and Practices

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Abstract

Most large electric utility steam generators are equipped with regenerative airheaters which are vitally important for sustained efficient and reliable power generation. Serving as the last heat trap for the boiler system, the airheater typically accounts for ~10% of a plant's thermal efficiency on a common steam generator. The airheater is a regenerative heat exchanger that preheats combustion air allowing for more efficient combustion. If non-optimal performance occurs, not only is unit efficiency in jeopardy but also unit availability. Air heater problems can lead to unit de-rates that result from furnace pressure limits, forced draft supply issues (as a result of leakage), improper combustion temperature, or unacceptable gas temperatures entering the stack.

This paper is to present the performance improvements to the regenerative airheaters at Hawaiian Electric Company (HECO), Kahe Generation Station Unit 2 as a case study. Additionally, the paper will also briefly review the technology and benefits of the innovative nanotechnology tempered vitreous (porcelain) enamel coating which differs from typical industry standard enamel heating element designs. Application of this technology in conjunction with proven mechanical systems design for the regenerative airheaters at Kahe Point is a proven process utilized by Paragon Airheater for optimizing thermal performance and sustainable power generation worldwide.

Introduction

Kahe Generation Station consists of six steam units and is located on the leeward cost of Oahu, HI. Kahe Unit 2 is an 86MWe Babcock & Wilcox oil-fired, forced draft (positive pressure), radiant boiler with reheat and a Westinghouse Steam Turbine/Generator. The unit was commissioned in 1963 and was designed to produce 575Klb/r of main steamflow at 1,005°F at 1,875psig. The boiler is equipped with six front wall fired burners. The draft system consist of one full capacity Forced Draft (FD) fan which takes suction air from atmosphere, pushes it through the air preheater, and supplies heated combustion air to the windbox for combustion. In between air preheater (APH) and windbox is an air flow measuring device.

Data from initial operations indicate that the fan produced 160,000 acfm at 80°F at 17.5 in w.g. while at turbine normal full load. The APH is a Ljungstrom 25-HX-72. The original APH had heat exchange element manufactured with a "generically named" low alloy corrosion resistant" (LACR) steel. The APH configuration prior to Paragon Airheater Technologies work in the summer of 2010 was a four layer design as follows:

Hot End	14" 22 gauge CU element
Hot Intermediate	14" 22 gauge CU element
Cold Intermediate	12", 22 gauge DN7 element
Cold End	12", 22 gauge NF6 element

Historically, Kahe unit 2's FD fan capacity had little margin for APH fouling and degradation. From the period of 2000 to 2010 the unit had several temporary de-rates as a result of airheater fouling. In most cases the limiting factor was furnace pressure. As APH D/P increases so does furnace pressure. To maintain unit capability Kahe2 was routinely taken offline for APH washing and inspection.

During the 2009, Kahe 2 over-haul, the cold end and cold intermediate baskets were replaced while the hot and hot intermediates were cleaned and inspected. It was noted at that time that the hot and hot intermediates were degrading and plans for replacement were put into place. It should be noted that these hot and hot intermediate baskets had been inspected many times over the years and appeared to be in good condition during those inspections.

Photo No. 1

Following the 2009 Overhaul, Kahe Unit 2 had trouble making full load because the FD fan and motor amps were at max capacity. Plant engineers conducted an evaluation of the situation and realized that the APH D/P was very high and that it appeared that there was significant Airheater leakage, which was also having a negative effect on fan capacity. An airheater leakage test was conducted and it was determined that leakage was around 28%. Design airheater leakage was 9%. Therefore, it was planned that the radial and circumferential seals would be replaced during the next Kahe Unit 2 maintenance outage.

June 2010 Project Work

Following the testing and analysis completed after the Kahe Unit 2 overhaul in 2009, HECO engineers put out an RFP for new hot and hot intermediate baskets. After review of bidders HECO selected Paragon Airheater Technologies to supply the new baskets. Paragon worked with HECO to understand long standing problems and to come up with engineered solutions tailored to HECO's specific needs. Rather than propose a "*cookie cutter*" duplicate of the element style that had been installed in the hot intermediate and hot end layers of the air heater, Paragon recommended replacing the CU style element that had been utilized in these layers, with a more appropriate DU design in order to match Kahe Unit 2's operating parameters.

Photo 2, CU element

Photo 3, DU element

There are many different options when it comes to choosing a heat exchange element design for an airheater. Each configuration has its own unique pressure drop and heat transfer characteristics. For example, an element configuration that is designed to achieve maximum heat transfer in a limited amount of space (depth) may also have a higher overall pressure drop than an element design that requires a greater depth to achieve the equivalent heat transfer. Typically, the configurations with the lowest pressure drop per inch of depth also have a lower heat transfer rate per inch and require a greater depth of element for equal thermal performance. While the end result of some element configurations can be an overall lower pressure drop while achieving the same amount of heat transfer, not all airheaters can accommodate the additional element depth that may be required without extensive modifications to the rotor.

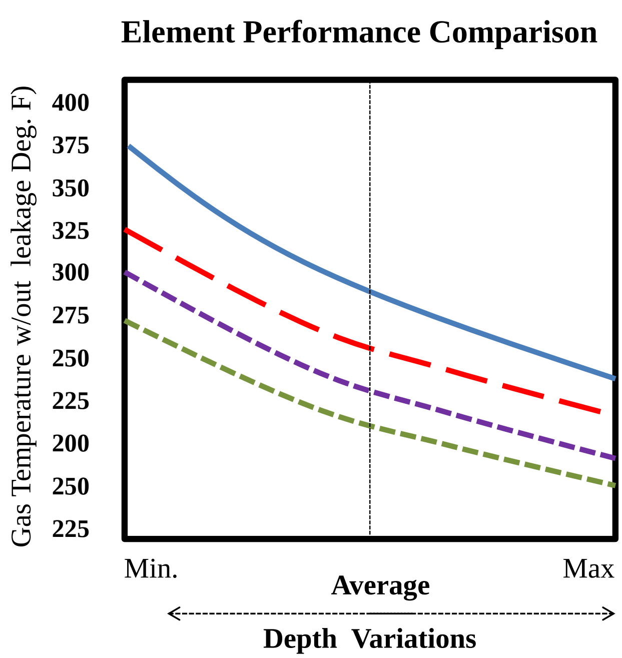


Figure No. 1, varying element configurations (*for example only*)

To achieve Kahe Unit 2's operational needs within the physical constraints of the current rotor, Paragon examined a variety of options. Figure No.1 represents the depth requirements of different element configurations that would be required to meet a specific gas outlet temperature (efficiency) parameter. The thermal performance and pressure drop characteristics of the various element configurations were used to determine the optimum configuration for Kahe Unit 2.

In the case of Kahe Unit 2, Paragon's recommendation was to change the element to a more robust DU profile that would result in less pressure drop and plugging. The new baskets and element were equivalent in depth to CU configuration that was replaced, so the installation was straightforward and no rotor modifications were required. To provide an extended lifespan for the new baskets, the Paragon DU element was manufactured with an actual Cor-Ten grade steel, which is ASTM grade A606-04 -High Strength, Low Alloy (HSLA) steel with Improved Corrosion Resistances certified using the ASTM G 101 – 04 Standard for Measuring the Corrosion Resistance of Low Alloy Steels.

Paragon also proposed the use of their high performance DuraPlus seals to reduce leakage, which would also substantially reduce the volume loading on the FD fan. HECO agreed to test these seals on the Kahe 2 while Paragon worked with HECO to ensure that baskets and seals were properly installed and the results met their expectations.

Air Leakage and Performance

The main advantage of the regenerative air heater is that it is probably the least expensive heat recovery device that is able to operate reasonably well in the harsh environment of the flue gas exhaust stream from a fossil fired boiler. A major drawback of the regenerative air heater is the undesired leakages that are inherent to the design of the device.

It's extremely difficult to seal these types of heaters due to the large temperature difference between their hot and cold ends (about 400 degrees F), coupled with the large diameter of the rotors. These opposing temperature gradients work together to produce a significant radial thermal expansion difference between the hot and cold sides of the air heater's rotor after unit start up. Due to this inherent thermal distortion, it's not uncommon for the outer edges of a large air heater at operating temperature to experience a significant "droop" (or "*turn down*"). The distortion caused by this thermal turndown (which can be as much as 4 inches on some rotors) changes the gaps between the seals and the sealing surfaces as the rotor warms to operating temperature, and is the most significant contributor to air heater leakage. This phenomenon must be accounted for when setting the seals at a cold state.

A considerable amount of additional air heater leakage can occur around the perimeter of the air heater through the bypass/circumferential seals. The following 3-D diagram (Figure 2) is a good representation of the various leakage paths through the air heater. In this diagram, the leakage through the circumferential seals (*also may be referred to as peripheral seals or bypass seals*) is depicted at the bottom.

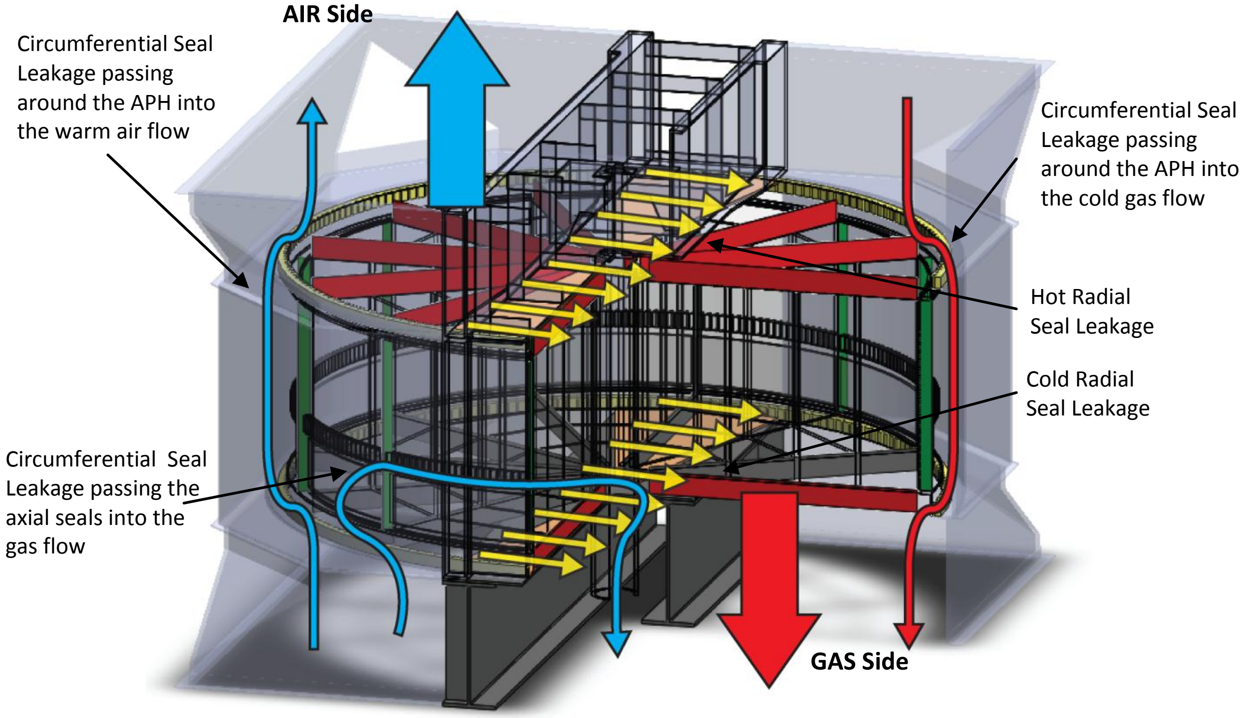


Figure 2 –Circumferential leakage through an air heater

Circumferential seals are located on the entire circumference of the air heater rotor, on both the hot end and cold end of the air heater. On the flue gas side of the air heater, all of the leakage through the inlet side circumferential seals will short circuit around the air heater (*bypassing the heat transfer element*) and exit through the downstream circumferential seals. This leakage results in a loss of enthalpy transfer into the element bundle, and increases the temperature (*and therefore the actual volume*) of gas entering the ID fans. On the air side of the air heater the volume of leakage through the first set of circumferential seals, will enter the annulus around the perimeter of the rotor, where the leakage will split in two directions. The volume in each direction depends on the differential pressures between points of exit. A portion of the flow will continue in a straight path and exit through the second set of circumferential seals. The remainder of the flow will be directed around the perimeter of the rotor and exit into the exhaust gas stream (*through the axial seals*) and that volume will, in turn, exit the air heater through the gas side-cold end circumferential seals.

Radial seal leakage is expressed as a percentage and basically represents the percentage of the gas flow downstream from the airheater that is the result of the mass of inlet air that leaks through the airheater seals into the gas outlet stream. It is the experience of the authors that radial leakage rates over 40% have been measured in some air heaters, and leakage rates around 20% are often accepted as a "normal" condition especially in older air heaters that have experienced physical distortion, wear, and erosion over time leakage at this level places a significant extra burden on the boiler fans in order to move gas and air that serves no useful purpose. The burden placed on the fans is often exacerbated by the fact that, in many plants, changes in fuels and operating conditions over the years have resulted in induced draft fans operating at near capacity. Because fans become much less efficient when they operate near full capacity, a 1% increase in fan volume can actually result in as much as a 3% increase in required fan horsepower (refer to Figure 3). So, in these cases, even a small reduction in radial seal leakage can yield very large benefits considering that fan motors are one of the largest electricity users in the entire plant.

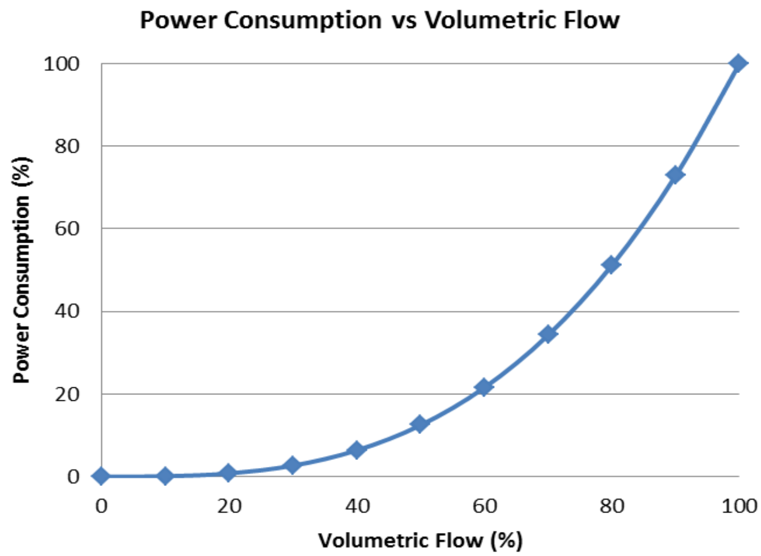


Figure 3, Flow Volume vs. Power Consumption (*Speed Control Theoretical*)

Leakage Solutions

A cost effective and simple method for reducing air heater leakage is replacement of the original equipment type air heater seals with newer design high performance full contact radial seals and progressively interlaced circumferential/bypass seals- also designed for flexibility under contact - such as those shown here (*supplied by Paragon Air Heater Technologies).* Full contact seals have demonstrated the ability to reduce air heater leakage by 50% or more in many airheaters when they have replaced original equipment type seals commonly found today on most air heaters. An example of a high performance full contact radial seal (DuraPlus™) is shown in Figure 4.

In comparison with an original design seal, which is really a rigid "proximity" air dam, the full contact seal is constructed to maintain a continuous, but flexible contact with the sealing plate at all times, effectively eliminating the main path for radial seal leakage. These seals provide additional leakage reduction benefits because they are capable of maintaining full contact even when there is unevenness and distortion in the sealing surfaces (sector plates), as is commonly found in older air heaters. These "distortion gaps" can be a significant contributor to the high leakage rates found in most old air heaters.

The high performance circumferential seals (DuraFlex™) shown in Figure 5 have progressively interlaced structural design that provides both flexibility and resistance to tearing, which allows the seals to operate in contact with the perimeter sealing surface without being damaged, thus minimizing the gaps and leakage openings in comparison to original style seals.

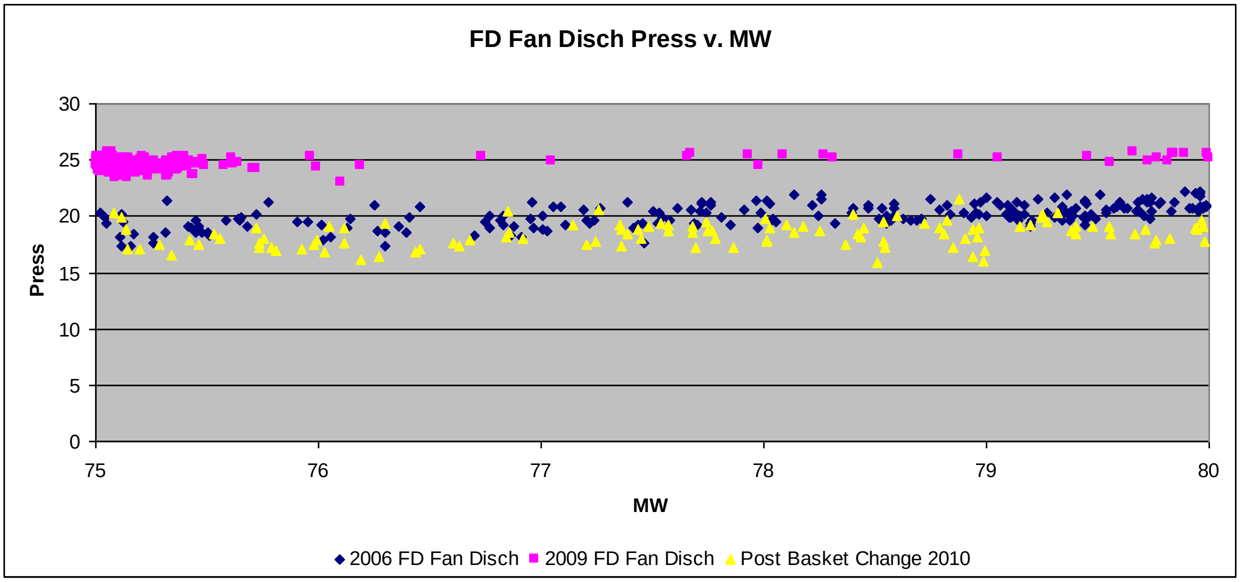
Figure 4, DuraPlus™ High Performance Seal

Figure 5, Circumferential Seal

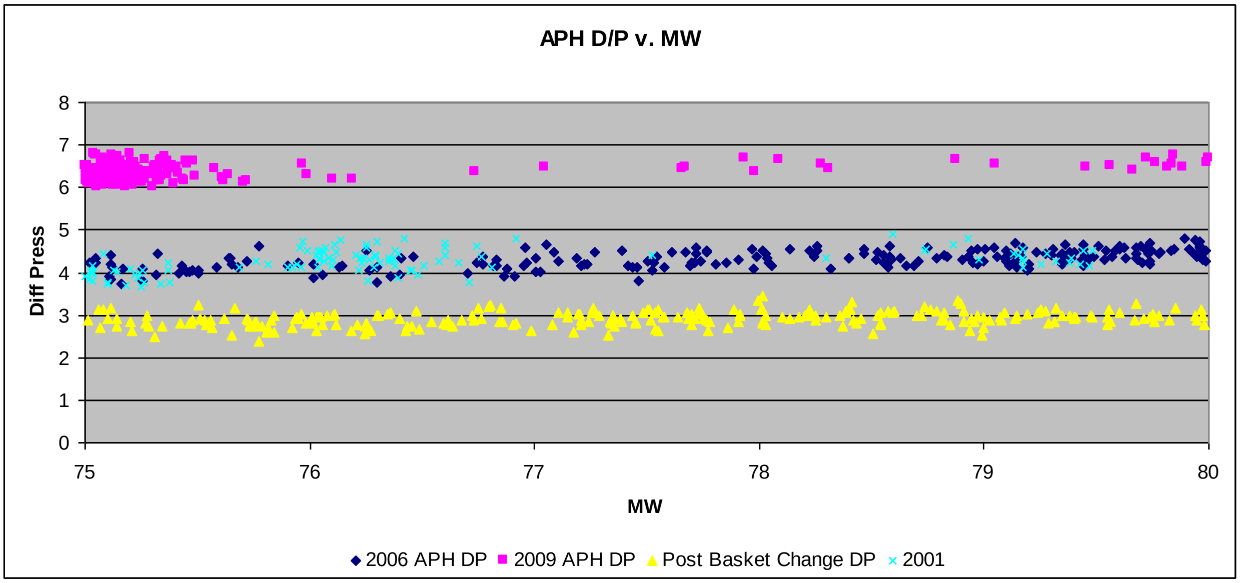
Performance Results

After the installation of the new air heater baskets with the Paragon DU element configuration as well as the Paragon high performance seals, Kahe unit 2 can now reliably make its full load of 86 MW. There was a dramatic drop in APH D/P while thermal performance remained consistent. Likewise there is a dramatic difference in FD fan amps which resulted in significant auxiliary energy savings. HECO conducted post maintenance airheater leakage testing and found that the leakage to be less than 8% (a level that is normally seen only in new or near-new air heaters prior to experiencing the inevitable distortion and physical changes that result in increased leakage over time).

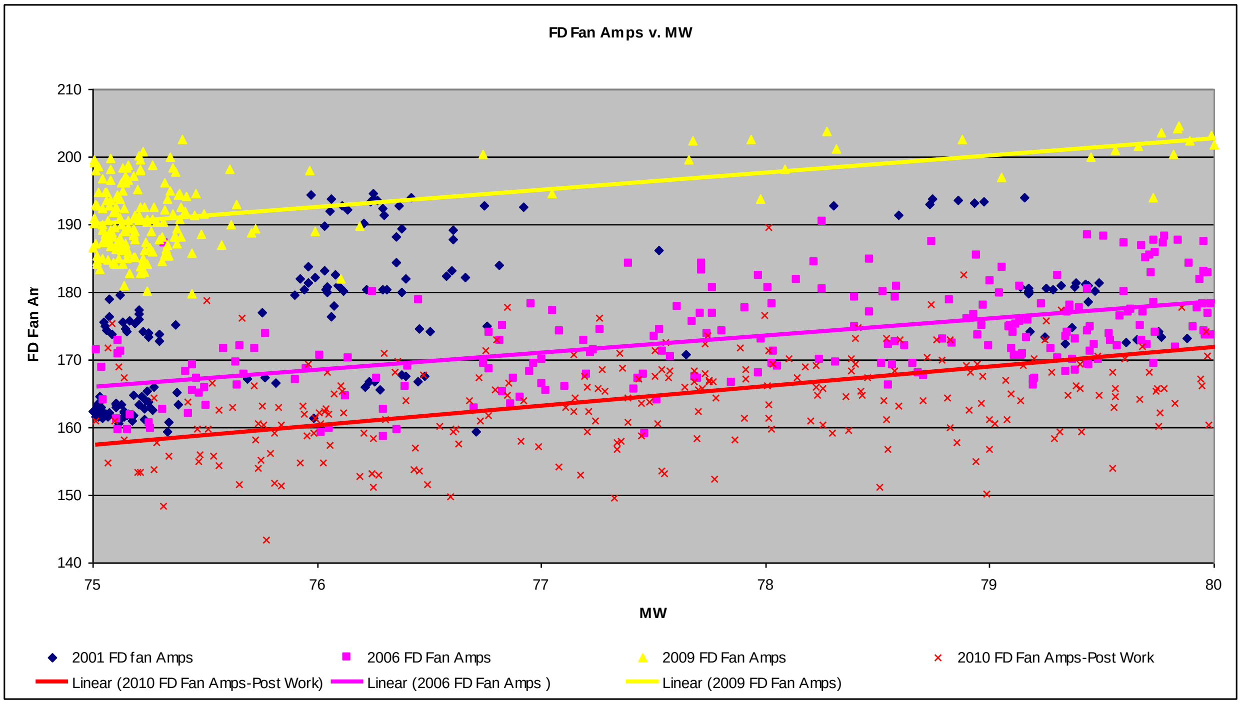
As for lessons learned during this project, it was noted that the Hot End low alloy steel baskets can look good but actual "*swell*" over time causing restrictions and higher pressure drop. The HE and HI baskets likely caused D/P issues from around the time they were ten years old. Secondly, the use of Paragon's high performance seals adds significant benefit in terms of airheater efficiency and reduction of unit's auxiliary load. Airheater air side D/P at full load dropped to about 3.5" from a high of 6.5" and an historic average of 4.5". Likewise FD fan discharge pressure dropped as did fan amps. Other parameters remained consistent demonstrating no change in normal plant operations and control.



Graph-1



Graph-2



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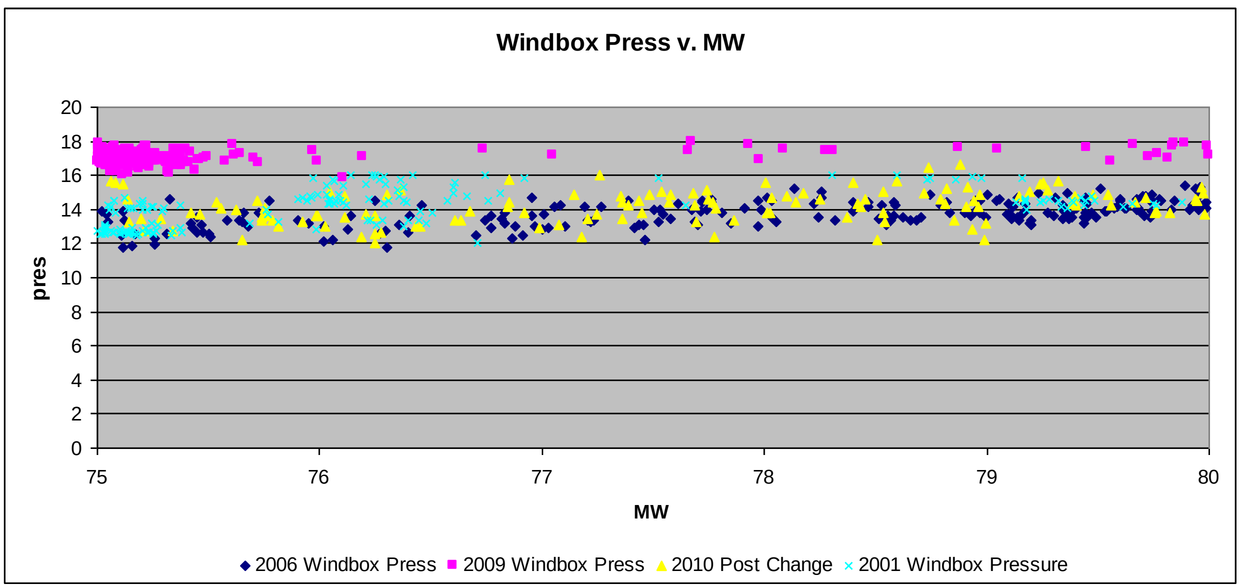
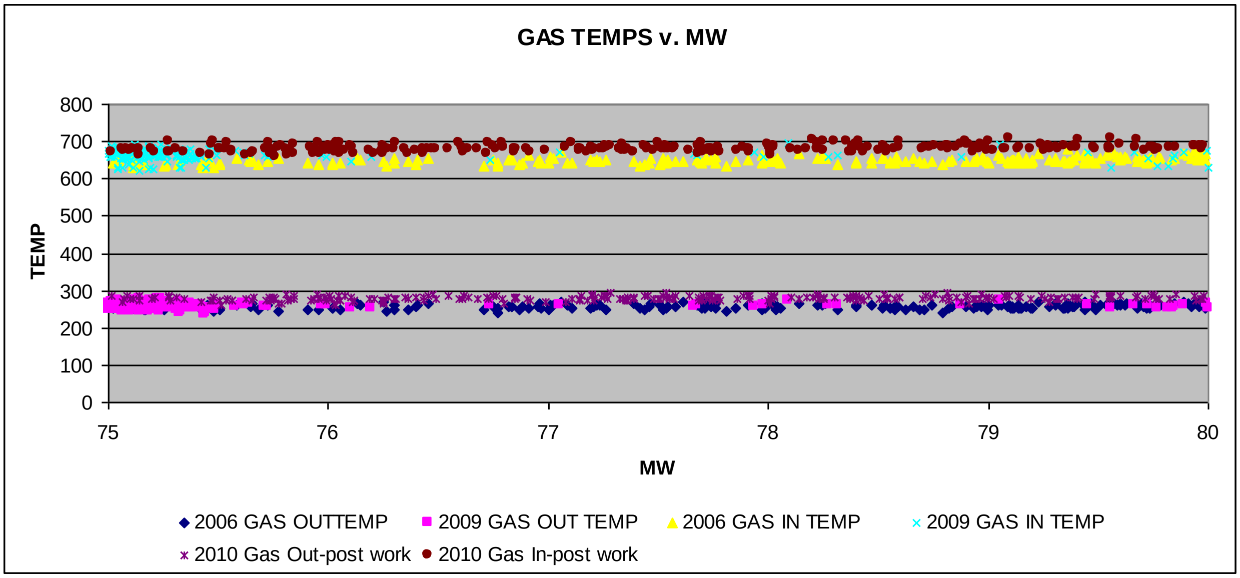


Graph-4



Graph-5

Next Steps for long-term Reliability Improvement

To further pursue innovative advancements in air heater performance, HECO has recently installed another innovative Paragon product on Kahe Unit 4 with a second installation scheduled for Waiau 8 in 2011. The cold end layers on both of these units are being retrofitted with Paragon DU element that is coated with state of the art enamel that is formulated with nanoparticle additives that provide unique attributes. This nanotechnology is the result of a joint 8 year development project by the University of Bologna and SMALTIFLEX S.p.A., Modena, Italy, a Paragon Air Heater Technologies partner.

The unique attributes include not only a self-healing property that effectively addresses the cracking issues associated with traditional enamels but also a unique nanoparticle surface texturing that provides a near immunity to deposition and fouling in extremely adverse environments such as ABS from SCR installations and from sulfuric acid attack on the cold end air heater layers of oil fired boilers. In addition to the acid resistance provided by the enamel outer surface, this unique enamel is manufactured using a proprietary enamel to metal amorphous bonding process that provides a corrosion barrier at the metal to enamel interface to extend the life of the element in these severe corrosion environments.

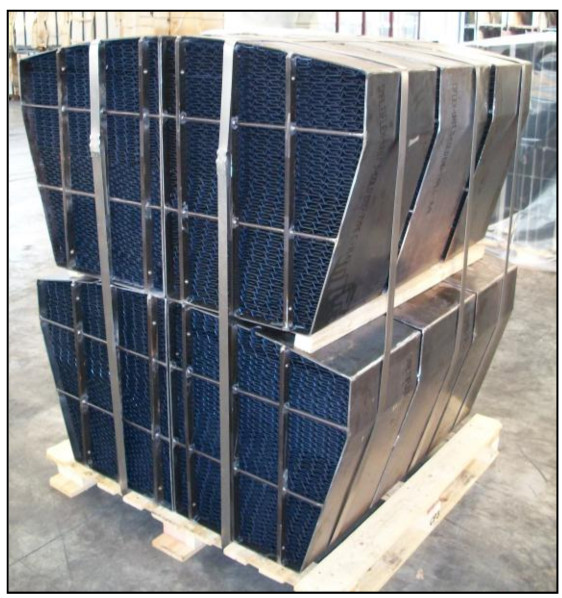


Photo No. 4

It is anticipated that this innovation will result in further operational improvements at Kahe 4 and Waiau 8 (*NF-6 element*) in the form of fewer outages for water washing the element, lower long term pressure drop in the air heater, and extended element life.

Conclusions

From the standpoint of the thermal efficiency of a power plant, the air heater is a critical piece of equipment. Even a small deterioration in air heater performance can result in efficiency losses resulting wasted fuel and unnecessary CO_2 emissions, not to mention the load limitations due to fan losses associated with air heater leakage. This case study validates the magnitude of the potential economic and environmental gains that are potential with a small investment of time, money and consideration at the existing airheater. As with any improvement, the key is to understand, evaluate, optimize and consistently improve the process through lessons learned and consistently attending to the details when working to sustain performance for the long-term.

After the installation of the new air heater baskets with the Paragon solutions implemented, Kahe unit 2 can now reliably make its full load of 86 MW. There was a dramatic drop in APH D/P, the plant's thermal performance requirements were met with w a more robust element configuration using highly corrosion resistant steel, and air heater leakage was dramatically reduced (from ~30% to 8%). Furthermore, the dramatic difference in FD fan amps has resulted in significant auxiliary energy savings.

Acknowledgements

Stephen Storm would like to acknowledge and commend the efforts from Paragon's technical services division as well as HECO for their professional commitment to success and willingness to share their experiences at Kahe Point, Unit-2.

References

[1] "***Experiences with Regenerative Air Heater Performance Evaluations & Optimization***"
POWER-GEN Europe 2010, RAI, Amsterdam, Holland
Stephen K. Storm, John Guffre.

[2] "***Air Preheater Seal Upgrades Renew Plant Efficiency*,**" Power Magazine, October 2010.
Stephen K. Storm, John Guffre