ACOUSTIC CLEANING OF REGENERATIVE AIRHEATERS SUBJECTED TO PRB ASH

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Abstract

Acoustic cleaning of fireside deposits has been done for over twenty years. It has been used as a remedial tool for most applications. Infrasound has been shown to be effective in removing ash deposits in applications where large heat exchanger elements are used. It has been particularly effective in removing the aggressive deposits formed by PRB ash from regenerative air heaters. Xcel Energy's Roy Tolk Station has been using infrasound to clean Ljungstrom air heaters subjected to PRB deposits since 1996. Data is presented, showing the effectiveness of infrasound versus sootblowing as measured by pitot tube tests of relative flow rates in two side-by-side air heaters. Criteria for equipment justification, cleaning mechanism, hardware, performance optimization and cleaning results are all discussed.

Conclusion

Proper application of infrasound to regenerative air heaters subjected to aggressive PRB ash can slow down or eliminate the accumulation of ash deposits. The result is reduced fan power consumption, reduced expenses for off-line water washing of regenerative air heater elements, and longer air heater element life expectancy.

Background

Xcel's Roy Tolk Station lies in the panhandle of Texas, about 80 miles northwest of Lubbock. There are two CE 565MWe units firing low sulfur coal from the Powder River Basin of Wyoming (PRB). Unit 1 went on line in 1982, with Unit 2 following in 1985.

The four size 31½ Ljungstrom-type air heaters (two on each unit) were the first in North America to be installed with infrasonic cleaners in the original plant construction. The infrasonic cleaners (one per air heater) were installed on the gas inlet ducting, and were operated along with retractable sootblowers to provide maximum cleaning. The output sound from each horn was at 20 Hz with 800 W (Watt) of acoustic energy.

The effect of the infrasonic cleaners was unknown since they were used in tandem with the sootblowers. Pressure drop across the air heaters remained relatively constant. The original infrasonic cleaners were de-commissioned in 1989.

Within a couple of years the pressure drop across the air heaters started to climb. Because this is typical of general industry experience with PRB ash in air heaters, it is not possible to know whether the removal of the sonic cleaners from service contributed to the degradation in cleanliness.

Summary

A newer, more powerful infrasonic cleaner was installed on the West air heater of Unit 1, and started service in May of 1996. This cleaner was installed on the gas outlet, operated at 22 Hz, and was capable of outputs up to 5000 W acoustic power. Based on experience from the latter 1980s with infrasound on PRB ash deposits in regenerative air heaters, it was felt this would be a much-improved combination.

Because the air heaters are in parallel on the gas side, pressure drop data is not capable of determining the difference in cleanliness between the two. Pitot tube tests were performed to evaluate the performance of the infrasonic cleaner by showing the relative difference in gas flow between the air heaters. Each test comprised a 54-point traverse of the inlet gas duct of both the East and West air heaters.

Figure 1 is a plot of the flow differential between the air heaters. It can be seen that the relative cleanliness of the West air heater steadily increased when compared to the East.

In November of 1996, new hot and intermediate layer elements were put in the Unit 1 air heaters. At that time it was also decided to switch the West air heater sootblower off to get a feel for how much of the cleaning was being done by the infrasonic cleaner. The trend continued as evidenced by Figure 1.

The highest measured difference in flow was experienced in August of 1998, when the West air heater was passing over 22 percent more flow than the East one.

During this period a decision was made to install more infrasonic cleaners to take advantage of the cleaning improvements. New infrasonic cleaners were installed on both air heaters of Unit 2 in the spring of 1999, along with replacement of all three element layers of the air heaters. The infrasonic cleaners were the only cleaning used on these air heaters.

The pressure differential was starting to climb across both air heaters of Unit 1 (because the gas flues are in parallel, the pressure drop across both air heaters is necessarily the same), so a high-pressure wash was done in February of 2000. By December of 2000 the flow difference was back up to almost 10 percent.

To see if any measurable change would register, the sootblowers on Unit 2 air heaters were operated. Since a reduction in pressure drop of about ½ inch resulted, the sootblowers were put back in service along with the infrasonic cleaners. That is how things remain on Unit 2 to the time of this writing. There has been no measurable increase in pressure drop since.

Because of the results on Unit 2, the West air heater sootblower on Unit 1 was placed back into service as well. In addition, a fourth infrasonic cleaner was purchased in 2001, and is scheduled for commissioning in February of 2002. This will complete the complement of cleaning equipment.

Evaluation

Pressure Drop

The cost of increased pressure drop through a regenerative air heater is substantial. Fan power requirements increase through both the ID and FD circuits.

Depending on the criteria used for cost evaluations, the actual cost figures can vary substantially. Fuel costs have been used historically for such evaluations, but the cost of replacement power has been used by some in recent years due to the competitive nature of the market

At the point where 17.3 percent more gas flow was going through the West air heater on Unit 1, this corresponded to about 1½ inches of increased pressure drop through the air heaters if neither air heater had infrasonic cleaning, versus both having it. On the Tolk boilers that corresponded to a 700 kW increase in fan power consumption. In the worst case this could be an annual loss of margin of $ 140,000, based on a gross margin of 3.5 ct / kWh.

Reduction in Water Washing

Water washing in itself is an expensive proposition. Forced outages to recover lost generating capacity because of excessive pressure drop through regenerative air heaters are significantly more costly. Now that there is more experience with PRB ash in regenerative air heaters, air heater washing has become an accepted maintenance expense. This doesn't necessarily have to be the case.

PRB ash contains a high percentage of CaO, which makes gypsum after reacting with sulfur in the flu gas, mixing with water and then being allowed to dry in place. This happens to a certain degree every time a regenerative air heater is washed that has PRB ash residing in it. No water washing that is done with the air heater elements in place will remove all ash, but all ash that is not removed will be hydrated and will harden into a deposit that is all but impossible to remove.

Experience with inadequate washings has led to practices where extremely conservative washing schedules are used. Unfortunately even these practices cannot remove all deposits. Channeling occurs that takes water in the intermediate elements through open paths and leaves deposits behind. Without being able to force water through all points of all passages, this cannot be avoided. This is espescially true for some of the high thermal efficiency element designs currently in use.

Even when water washes are avoided at all costs, if there is PRB ash in the elements, it will eventually turn hard during an outage. As the air heater cools, water condenses out that mixes with the ash. This dries and hardens into the same cement.

The only way to avoid these deposits, which eventually force replacement of the elements, is to keep the deposits from forming in the first place. If the PRB ash is not allowed to accumulate, the cement cannot form.

One thing that can be said of the experience at Tolk is that there has never been a need to wash the air heaters when infrasonic cleaning and sootblowers were used in tandem. Whether you consider the first 7 years or so of operation, or Unit 2 since installation of the infrasonic cleaners in 1999, there has not been a degradation of air heater pressure drop that required water washing.

Air Heater Element Replacement

With fuels other than PRB, air heater element replacement has generally come when the metal has been eroded by sootblowing, or when the temperature cycles on the elements are numerous enough to cause failure. With PRB ash, however, the elements become unusable when they have accumulated enough "cement". This phenomenae is clearly demonstrated by plant data, see **Figure 2** for details.

Elements have been redesigned to allow the plates to shift, sometimes referred to as "loose pack", to allow scale to break up and be removed. These improve the situation, but not allowing the ash to form in the first place is a preferred solution.

The cleaning result at Tolk Station using infrasound and sootblowers in tandem is not an isolated case. There are other stations that are using this technology to remedy their PRB cleaning problems.

Application of Infrasound

Infrasound has properties that separate it from higher frequencies. The most significant of these is its ability to fill large enclosures with resonant sound. This allows one infrasonic generator to provide enough sound intensity to clean large areas. The technology has matured and application is now based on three-dimensional acoustic modeling to determine operating frequency and optimum location of the infrasonic cleaner.

The acoustic modeling has not only provided more consistent results of applied infrasonic cleaners, it has also explained why past installations did not work. In some instances, infrasonic cleaners were changed to produce different frequencies, and / or moved to a more preferred location.

Figure 3 shows a three-dimensional mesh of the inlet and outlet duct areas of Unit 1 air heaters at Tolk Station. The model uses this mesh to calculate the sound levels within the boundaries. Physical obstructions (such as the heating elements) and structures within the volume are considered, along with temperature, gas velocity, and the location of the sound sources.

Figure 4 shows the sound levels for different frequencies of injected sound energy. The sound frequency that provides the most efficient utilization of energy to produce the required cleaning is the one that is chosen. Because of these results, the original location and frequency chosen for the first three infrasonic cleaners were retained for the fourth and final application.

Figure 5 shows the sound levels at the boundaries of the different element layers within the air heaters. One of the benefits of Ljungstrom type air heaters is that small areas of low sound levels will not adversely affect cleaning. Because the elements are constantly moving, if the sound level is low one moment, it will increase the next moment.

Infrasonic Hardware

To generate lower tones efficiently, the equipment must get longer, like musical wind instruments. Infrasonic generators are about 14 feet long and can have outlet openings about 40 inches in diameter. They typically operate in the 15 – 35 Hz range. Only one device is required per air heater, and since low-pressure air is adequate, a positive displacement blower can supply the air. This significantly reduces the electric energy required, eliminates the need for a receiver tank, and reduces the length of piping runs.

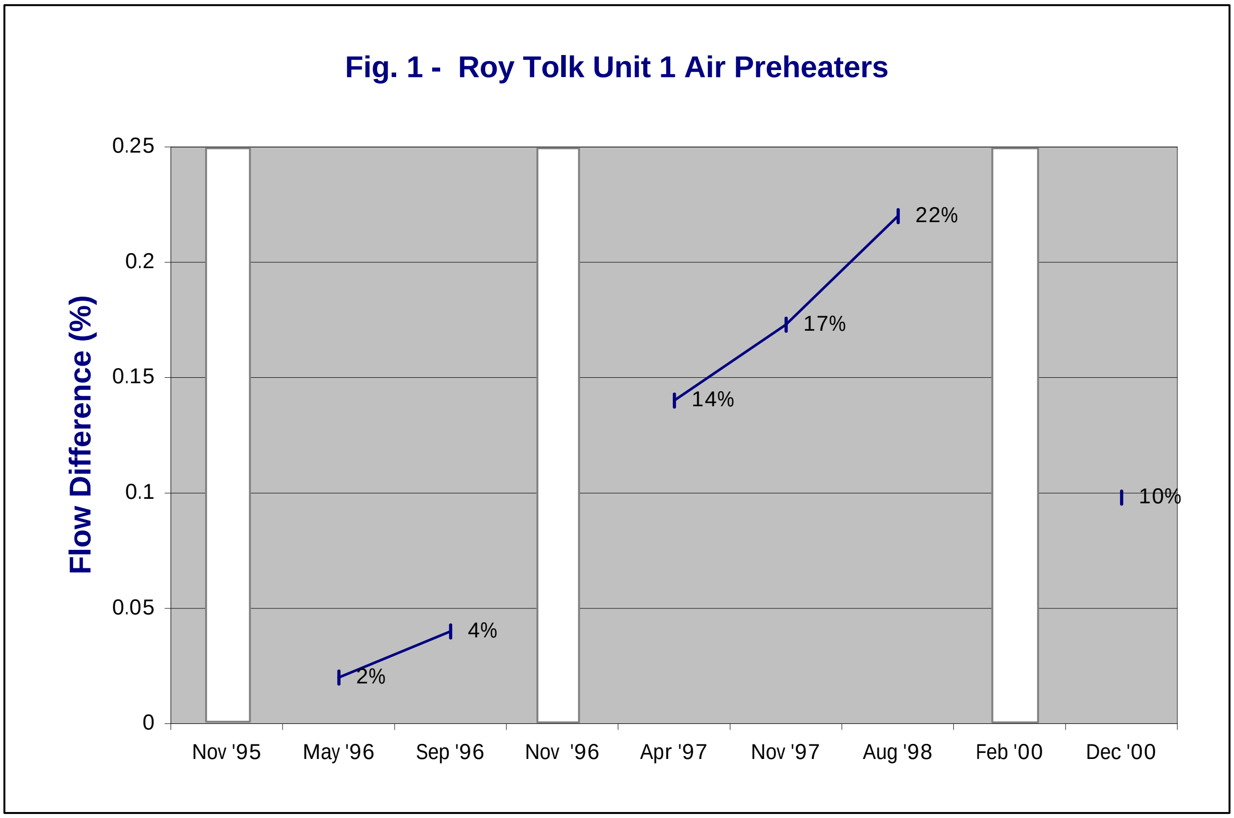


Fig. 1 - Roy Tolk Unit 1 Air Preheaters
Flow Difference (%)
0.25
0.2
0.15
0.1
0.05
0
2%
4%
14%
17%
22%
10%
Nov '95
May '96
Sep '96
Nov '96
Apr '97
Nov '97
Aug '98
Feb '00
Dec '00

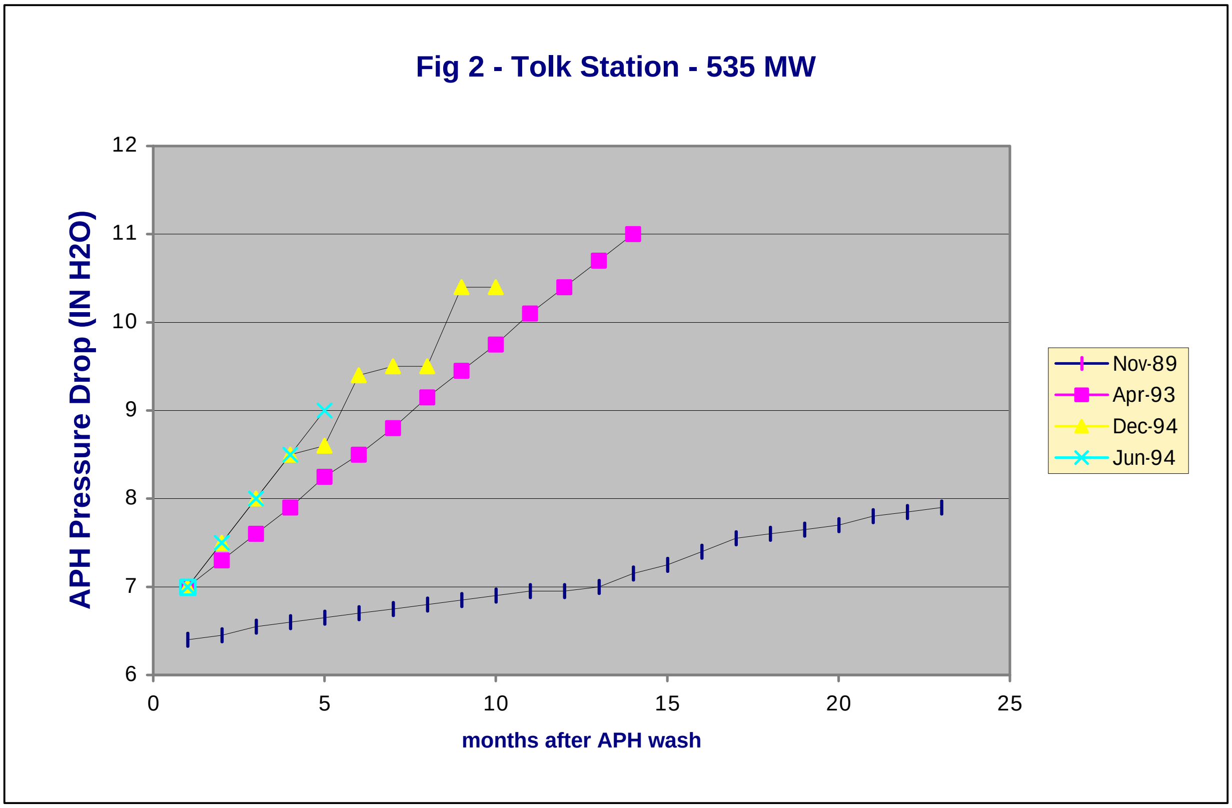


Fig 2 - Tolk Station - 535 MW
APH Pressure Drop (IN H2O)
12
11
10
9
8
7
6
0
5
10
15
20
25
months after APH wash
Nov-89
Apr-93
Dec-94
Jun-94

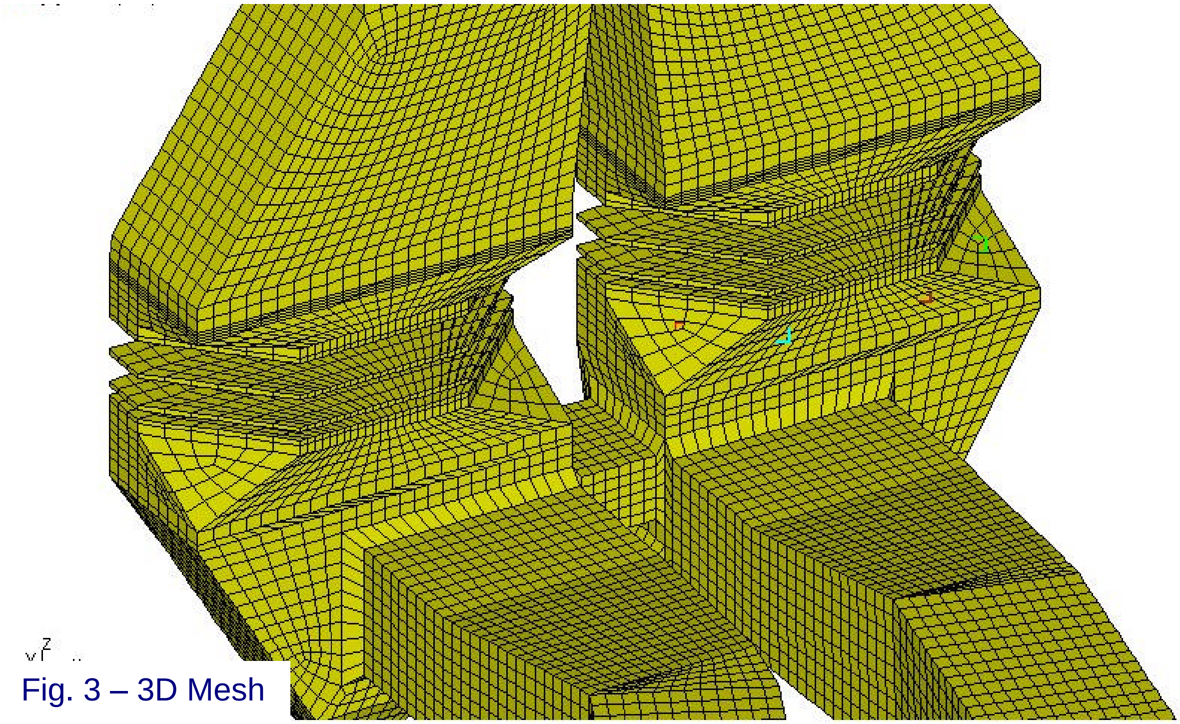
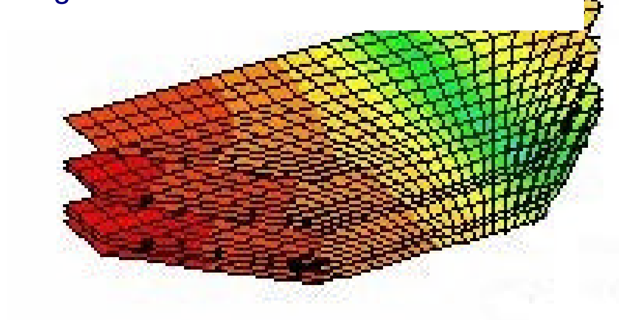


Fig. 3 – 3D Mesh

Fig. 4 – Sound Field East APH



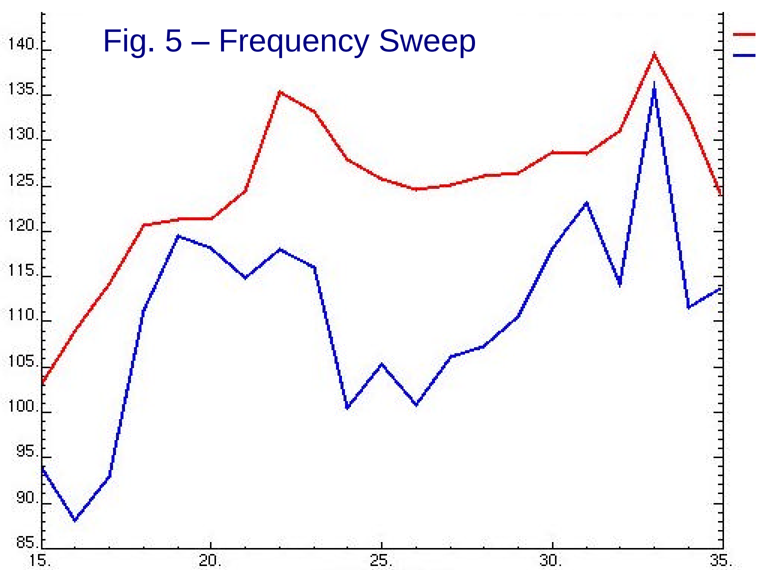


Fig. 5 – Frequency Sweep