ACOUSTIC CLEANING OF OIL FIRED DEPOSITS

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Fifth EPRI Intelligent Sootblowing Workshop

Nashville, Tennessee March 16-17, 2004

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ABSTRACT

Acoustic cleaning of fireside surfaces with low frequency sound has been proven to be effective on a wide variety of deposits. One unique property is the sound's ability to remove pre-existing deposits over time. When this is combined with a nearly uniform coverage, tube banks can be restored to an "as- new" condition.

Dynegy Northeast Generation's Roseton Station has been using low frequency sound to clean an extended surface economizer subjected to heavy oil fired deposits since the winter of 2002. Data is examined, showing the effectiveness of acoustic cleaning for removing existing deposits. Boiler profiles are compared from before and after acoustic cleaning, as well as when the units were new.

Criteria for equipment justification, cleaning mechanism, hardware, performance optimization and cleaning results are all discussed.

BACKGROUND

Dynegy Northeast Generation's Roseton station lies on the western bank of the Hudson River, less than ten miles from Newburgh, New York. There are two CE sister units firing heavy oil, each rated at 575 MW net.

Problems with economizer cleanliness have been experienced since early in the plant's life, which started commercial operation in 1974. There have never been conventional sootblowers in the economizer areas of either boiler. Spiral-finned tubes are arranged in a staggered configuration.

Advanced Acoustic Technologies, LLC (AAT) was contracted in phases to engineer and deliver an acoustic cleaning system for the economizer.

RESULTS

The acoustic cleaner entered service early December 2002. The effects of the applied sound were noticed immediately. Opacity spikes occurred during initial operation because of the tramp deposits that were liberated. Operating times were limited until ash clouds diminished.

This is a common occurrence until major deposits have been removed. Once the cleaning system is in a maintenance mode, the AQCS equipment can easily handle the quantities of ash removed during operation.

Outages in the following months showed passages between tubes were opening up. By July of 2003 the pressure drops were as low as plant personnel could remember. Pressure drop at full load was 5.4 to 5.5 inches as measured by plant instrumentation. Available data going back into the 1980s showed 6.4 to 7.8 inches as normal operating pressure drops at full load while firing oil, and Unit 1 records pressure drops in excess of 8 inches across the economizer.

Monetary savings

The majority of realized savings is due to reduced pressure drop and fan power requirements. Figure 1 contains an example from a savings analysis commonly used by AAT. Note that costs of operating the acoustic cleaner are included in the calculation.

On a large utility unit, even small changes in pressure drop have a profound effect on fan power and annual costs. The sample shows an annual savings of about $100K.

The increased thermal performance could not be calculated, as there are not enough instrument readings available to do a heat balance. When these readings are available, an accurate evaluation of cleanliness can be done. This same LMTD method of calculating cleanliness factors is used by automatic cleaning systems to make sootblower operating decisions.

Physical and visual effects

The ash deposits are hiding in the boundary layer of the convective gases as they pass through the exchanger. If they weren't, there would be no need for cleaning methods, as the tube bundles would stay clean by themselves.

Using large, resonant sound fields for cleaning of heat exchangers results in cleaning of those areas that are directly impacted by the convective gases. Ash formations that are hiding in dead areas will often retain their deposits. This is especially true of the last row of tubes in the bundle.

Photos of Unit 2 economizer, which are included in Figures 2 and 3, display evidence of this. The remaining ash has little or no effect on the heat transfer or pressure drop of the bank. For comparison, a photo of Unit 1 economizer (no cleaning equipment) is shown in Figure 4.

This is in contrast to conventional sootblowing, where cleaning is accomplished by direct impingement of high velocity gas jets for a brief time. Cleaning also results, in part, from impingement of deposits removed upstream. Tube banks that are densely packed, without direct gas paths, are difficult to effectively clean with conventional sootblowers.

SELECTION OF ACOUSTIC CLEANING PARAMETERS

Modeling

Three-dimensional acoustic modeling is an available tool for accomplishing resonating field cleaning. Figure 5 shows a 3 Dimensional Sound Pressure mesh output for the subject economizer.

This tool provides precise parameter values for acoustic cleaning, and takes out the guesswork of effectively applying this technology. The model results have been repeatedly verified by their physical application over the last 8 years.

Location

The location of Acoustic Cleaners, while important, has a fair amount of latitude. Prospective areas of convenience are typically chosen for inclusion in the modeling. One of these prospects can usually be used for the point of sound injection.

For the Roseton application, locations around the side of the economizer area were explored. The favored location was immediately below the sidewall header, where a penetration could be made without installing a large waterwall opening. The resulting location was the favored one, with an outlet geometry to accommodate fitting between structural steel straps.

Figure 6 is a photo of the Acoustic Cleaner penetrating the lower sidewall.

Sound Frequency

Sound output profiles are calculated for proposed locations to identify resonating frequencies. The final operating frequency(s) are chosen from these profiles.

Figure 7 shows the profile for Roseton. An operating frequency of about 37.5 Hz was chosen because of its resonating properties, and the relatively high resonance of neighboring frequencies. Operating experience showed that the airflow could be reduced about 30 percent and still maintain conservative sound levels for cleaning.

As of the writing of this paper, the subject application is operating at the highest frequency AAT has used to date. Lower frequencies (infrasound) were previously favored, but the frequency spectrum of Figure 7 was a strong incentive to try a higher one.

AAT is currently the only domestic supplier that can supply these “intermediate” frequencies (between infrasound and about 60 Hz) with output powers up to 5000 watts and beyond, tailored to induce resonating sound fields.

Operating Parameters

An aggressive operating sequence was initially used to try to remove deposits that had been in place for an extended period of time. A 50 percent duty cycle was used for the first several weeks. Continuous operation, 24/7/364.5 is possible, if necessary.

Full output power was also initially used to aid in the “clean up”. As the tube bundle cleared out, the resonance increased because of the reduced impedance to the standing waves. The output was lowered to about 70 percent to bring the sound levels more in line. Currently, a reduced airflow rate is used for a 60 second cleaning cycle every 10 minutes.

HARDWARE

Roseton Acoustic Cleaner

The Acoustic Cleaner uses low pressure air at about 10 psig to produce the sound energy. The system at Roseton utilizes a PD blower capable of delivering over 1200 SCFM of air. This results in a substantial cost savings over plant compressed air. Currently the airflow is about 800 SCFM during the 30 second cleaning cycle, and about 150 SCFM during the 4 minute purge cycle.

Physical Characteristics

The Acoustic Cleaner at Roseton is shown in Figure 8. Low pressure air is supplied at about 10 psig to the reservoir tank on the generator's Pulser.

The output power capability of an Acoustic Cleaner is, in general, proportional to the third power of its diameter at the closed end. The diameter of this generator's resonating tube is 24 inches.

Cost Savings with WaveMaster™ Acoustic Cleaning

COSTS OF SOOTBLOWING AND DEPOSITS

Boiler Net Rating (MWe)		450
Number of Sootblowers		0
No. of Operations per day		3
No. of Annual Operating Days		300
Sootblower Air Flow (SCFM)		2000
Travel Length (ft)		20
Travel Speed (inches/min)		100
Cost per kwhr ($)		0.05
Annual Maintenance per Sootblower ($)	$	500
Total Annual Sootblowing Cost ($)	$	-
Annual Cost of Off-Line Cleaning ($)	$	-
Number of Annual Off-Line Cleanings		
Add'l Press Drop before off-line cleaning (in H_2O)		1.5
Average Additional ID Fan Power (HP)		318
Fan Efficiency		0.85
Motor Efficiency		0.95
Annual Cost of Additional Fan Power	$	105,583
Total Annual Reduced Costs	$	105,583

COST OF ACOUSTIC CLEANER OPERATION

Air Flow Operate (SCFM)		800
Air Flow Purge (SCFM)		100
Operate Time (Sec.)		30
Purge Time (Sec.)		240
Annual Maintenance	$	2,000
Annual Cost of Operation	$	5,711.99

TOTAL SAVINGS

Total Annual Reduced Costs less Annual Cost of Operation	$	99,871

Fig. 1 – Cost Savings Calculation

Fig. 2 – Unit 1 Economizer

Fig. 3 – Unit 1 Economizer

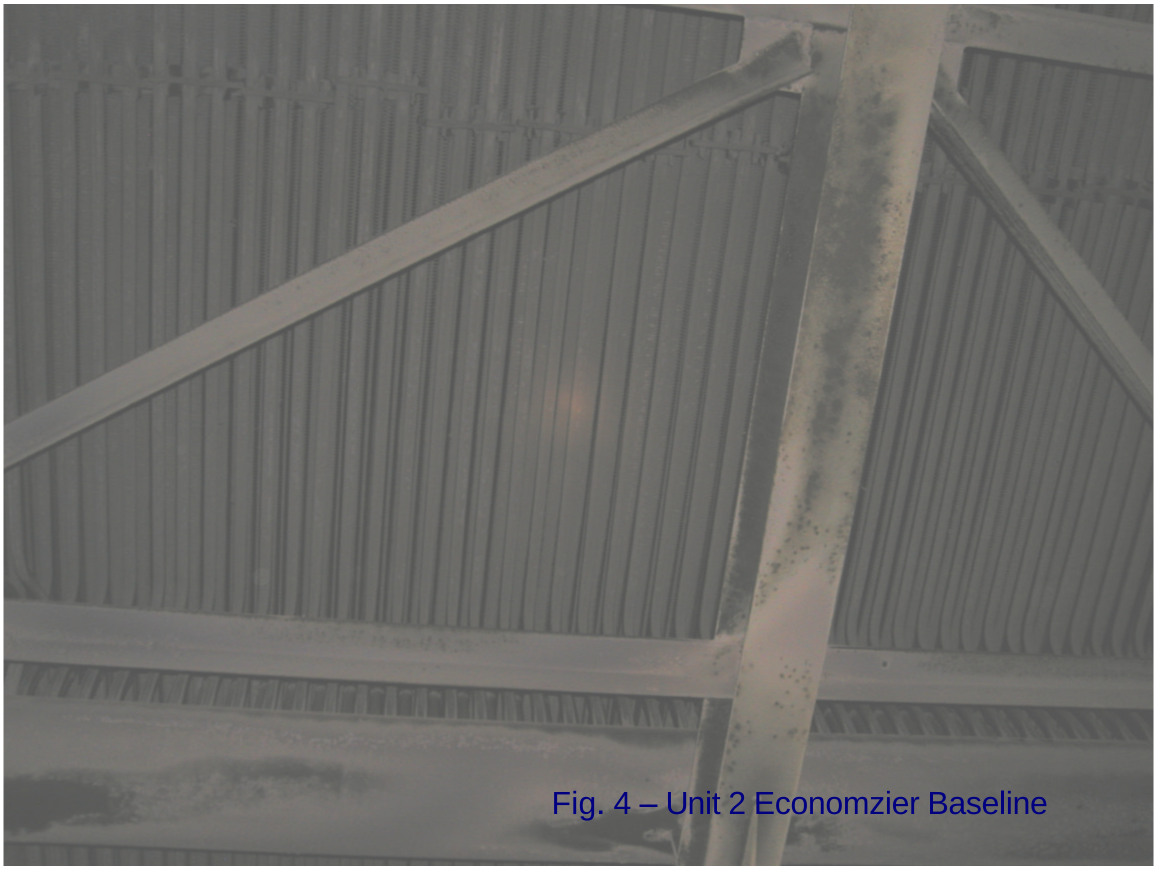

Fig. 4 – Unit 2 Economzier Baseline

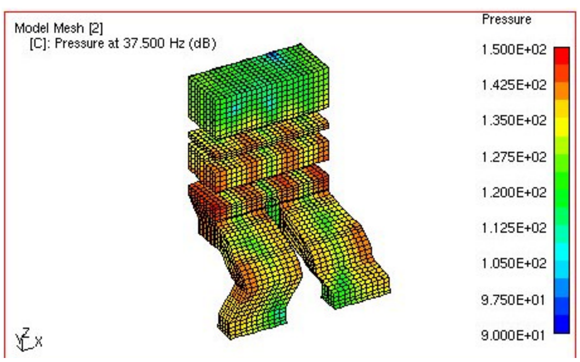

Fig. 5 – Modeling Mesh

Fig. 6 – Corner Location

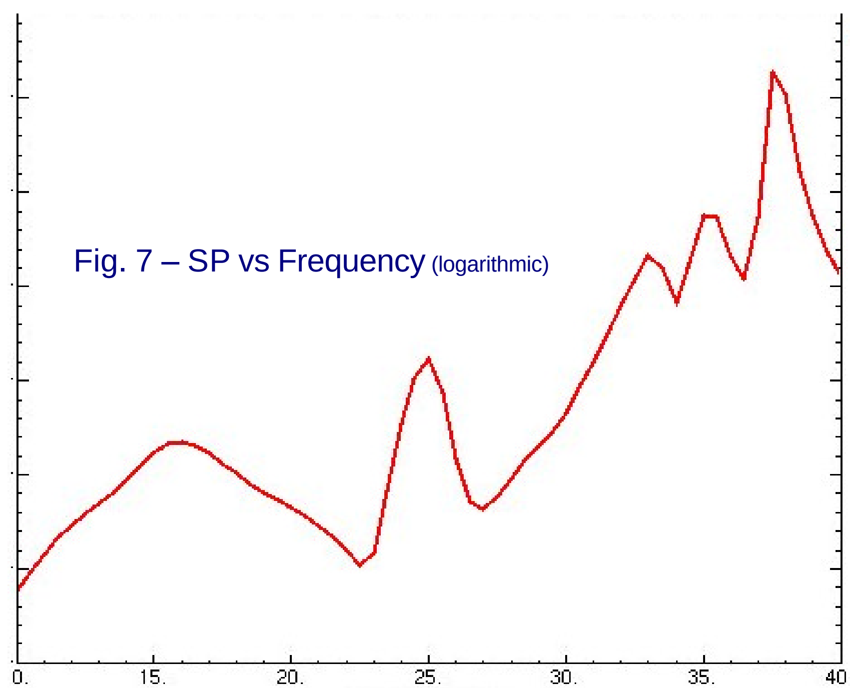

Fig. 7 – SP vs Frequency (logarithmic)

Fig. 8 – WaveMaster™ Acoustic Cleaner