Technical Paper

Operating Experience Using Acoustic Leak Detection at Gaston Station

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Unit Description

Alabama Power Company's B.C. Gaston Plant is located in Wilsonville, Alabama and has five units totalling 1,880 MW.

Unit 5 is a Combustion Engineering (CE) supercritical, combined circulation, Radiant reheat boiler. The furnace is divided into two halves by a center water wall and is fired under positive pressure. Each furnace half is fired by four tilting tangential burner assemblies. The coal can be admitted through seven elevations of pulverized coal nozzles in each assembly.

The unit is designed to deliver superheated steam at a rate of 6,351,470 Ib/h (maximum continuous), at 1000F, and 3625 psig (superheater outlet) to an 850 MW turbogenerator. The reheater is designed to deliver reheated steam at 5,691,821 Ib/h reheated from 586 to 1000F.

The steam/turbogenerator is operated with a full load of 884 MW gross output.

History of Leak Detection on Unit 5

Because of the size of the boiler and the positive operating pressure, the methods of boiler leak detection on Unit 5 were limited to audio inspection from outside the boiler, temperature indications and makeup water use. More often than not, increased makeup water use was the first indication to plant operations personnel that a leak may be present. Unfortunately, to be detected audibly or by makeup water use, the leak had to be of significant size. This usually meant that additional damage to boiler tubing was occurring through steam washing and cutting or overheating until the leak was finally detected and the unit could be brought off-line for repairs. This was especially true for leaks in the reheat section, due to the lower operating pressure of the reheater.

Early Leak Detection System Cost Justified

The amount of unit downtime to repair damage from a leak is affected by the number of tubes to be repaired and the type of repairneeded. In most cases, early leak detection can minimize the number of tubes to be repaired, the type of tube repairs needed, and also the outage hours the unit would be off-line and unavailable.

The cost savings generated by an early leak detection system is dependent on the frequency of leaks occurring and the cost of replacement power at the time the leaks occurred. Given the historical data on Unit 5 leaks, together with an average replacement power cost of approximately $90,0007 day, an early leak detection system was found to be cost justified on Unit 5. In fact, only three leaks on the unit would cost justify the purchase of a detection system using the vendors' approximate budget numbers. After all factors were evaluated, Alabama Power chose the Babcock & Wilcox Acoustic Leak Locator (ALL®) to provide early leak detection.

16 Channel System Required for Complete Boiler Coverage

Alabama Power and Babcock & Wilcox (B&W) determined that Unit 5 needed a 16 channel leak detection system to properly cover all areas susceptible to leaks. However, at that time, the ALL system processor box could only handle eight channels. In order to handle 16 channels, two processor boxes were required. However, a new processor box that could handle 16 channels was being developed. Alabama Power decided to install and use an eight channel system until the 16 channel system was ready. This system would provide leak detection during the months of June through August, which is the crucial peak season for Alabama Power. Unit 5 would then become a beta-test site for the 16 channel system when it became available.

The ALL system is a leak detection and warning system designed for on-line monitoring of pressurized systems and valves in the industrial environment. The technology is based on high frequency acoustic emissions emanating from gas or fluid leaks through cracks or corrosion in pressurized systems. Sensitive piezoelectric sensors mounted to the structure transform these acoustic waves into electronic voltage signals which are amplified, filtered and processed to determine energy content. The signal output is monitored continuously on each channel, and two alarm levels (high and low) can be defined independently by the channel for system response.

The main components of the system are:

- airborne waveguide,
- airborne sensor/low noise cable,
- preamplifier,
- dual signal processor and relay input/output modules,
- control unit,
- power unit, and
- enclosure and bus.

The system has the option of being connected to either a personal computer with proprietary software which will display signal strength for each channel, a chart recorder, the existing plant computer or an annunciator panel. At Gaston station the choice was made to connect the system to an L&N chart recorder with a common annunciator panel for boiler leaks. The annunciator panel also indicates low alarm conditions to alert personnel to a possible channel failure or plugged waveguide.

Component Descriptions

Waveguide

The system uses acoustic sensors mounted on the ends of waveguides to sense the sound in a boiler. The waveguides are mounted on boiler access doors, observation doors, unused sootblower ports, or other offset tubes. The waveguide provides a smooth continuous acoustic path to the sensor and also provides thermal protection by eliminating the direct radiant heat of combustion. A secondary purpose of the waveguide is to prevent flyash or wash water from directly contacting the sensor diaphragm. The waveguides are either welded directly to a door or attached with a special fixture and oriented to place the acoustic sensors in as nearly a vertical position as possible.

The standard waveguide is fabricated from stainless steel pipe with a nipple welded on the tangent of the bend for admission of compressed air for purging. This purge connection is also used to rod out solid blockage. B&W recommends that purging should be done as required by operating conditions. On the pressurized unit at Gaston, a timer initiated 10 second purge is repeated every six minutes on each channel.

Airborne Sensor

The sensor is a specially designed pressure transducer for detection of leaks in high pressure and/or high temperature environments on the gas side of furnaces and convection passes of boilers. An operating boiler has a characteristic low frequency (1 kHz) rumbling sound due to combustion noise; the sound level is typically quite loud. When a pressurized fluid such as steam or water escapes through a hole in a tube, it generates sound in the 3 kHz range due to the interaction of a high velocity stream mixing with a surrounding medium such as flue gas. The onset and growth of a leak can be slow or rapid depending on the failure mechanism involved. In either case, the sound level in a characteristic range of frequencies increases by a factor of 2 to 500, or more, as the leak grows.

Preamplifier

The preamplifiers perform the first stage of signal conditioning for the raw acoustic signal. It amplifies the sensor's low level electrical signals and filters out the unwanted sounds from the combustion noise prior to transmitting the signal to the ALL system. Up to 90% of the extraneous noise is eliminated. This allows the system to be set to higher sensitivities for leak detection. The preamplifiers are protected from the boiler atmosphere by mounting them in NEMA 4 enclosures.

ALL System Dual Signal Processing Unit and Control Unit

The Dual Signal Processing Unit (DSPU) contains two identical signal paths and a microcontroller to set channel gain levels, provide alarm functions and communicate with the control unit. The front panel features signal output connectors and LED indicator lights for alarm status. Each channel has two BNC outputs, one for the unamplified signal, and one for the amplified and filtered signal. These are useful for system checkout and signal spectral analyses for choosing the proper frequency bandpass values. LED's for each channel show high, low and normal alarm status. The high alarm indicates a leak condition. The low alarm typically indicates a sensor or amplifier failure or a plugged waveguide.

The control unit has the only front panel controls in the system. The keypad on the control unit allows the user to view and change channel settings and to reset all system alarms. It also indicates the relative signal strength (in volts) of the selected channel.

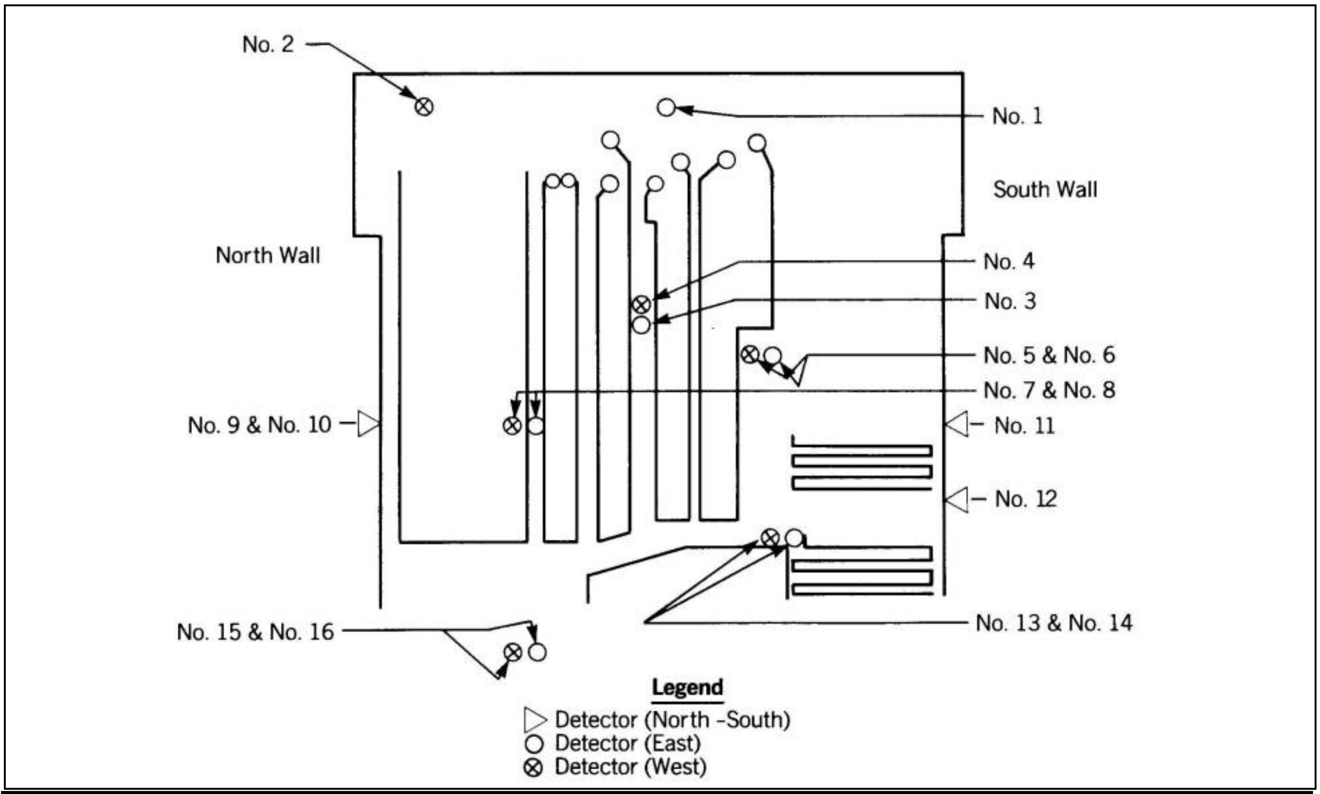

Figure 1 Location of ALL® acoustic sensors.

Installation of the ALL System

Installation of the leak detection system began during the spring outage of 1990 on Unit 5. During this outage *six* bent tube openings were installed in the furnace. The tube membrane was of sufficient width (1-7/8 in. and 3-3/4 in.) in the backpass to allow installation of the waveguides (1-1/4 in. opening required) without requiring new bent tube openings.

All 16 of the waveguides were installed during this outage. *Six* were located in the furnace, eight in the backpass, and two in the penthouse (see Figure 1). After the outage, cable runs from the waveguides to the control room were completed and an L&N 25000 Speedomax Recorder was installed in the control room. Piping runs from existing service air headers were made to each waveguide, and solenoid valves were installed to control purge air to the waveguide. The purge air is required to prevent flyash buildup within the waveguide which would isolate the sensor from the boiler. In addition, manual valves for aspirating air were installed to permit manual cleaning of the waveguide and sensor removal while the unit is operating.

In June 1990, the eight channel ALL system was installed. The 16 channel ALL system was scheduled for summer testing, with delivery to follow. In October 1990, this system was received and installed to monitor all 16 points. Between June and October 1990, the eight channel system detected four leaks on Unit 5.

The Gaston installation was the first commercial installation of the 16 channel ALL system, as well as only the second installation of a leak detection system on a pressurized unit by B& W. Therefore, some troubleshooting was needed to identify and solve the problems associated with this type of unit and the new system.

One major difference between the old eight channel system and the new 16 channel ALL system is the sensors. The old system used sensors with integrated preamplifiers, which were susceptible to damage from the high gas temperatures immediately outside the boiler casing. They were rated to an ambient temperature of 200F; the integral preamplifier incorporated in the design was also rated at 200F. Because plant personnel were concerned that ambient temperatures on Unit 5 might exceed this rating, temperature strips were mounted near several waveguides. These strips were scaled from 100 to 250F. Several of the strips indicated temperatures in excess of 250F.

The temperature problem was addressed during the installation of the 16 channel ALL system by replacing the integrated sensors with a 400F sensor which did not include an integral preamplifier. The new system uses nonintegrated sensors with the preamplifiers located safely away from the high temperatures. Instead, the preamps for the ALL system were mounted approximately 15 to 25 ft from each waveguide to reduce exposure to hot boiler gases. This alleviated any concerns regarding high temperatures. These new sensors are also more rugged than the old sensors. The other major difference is the fact that the new system has a greater range of listening sensitivity while monitoring for leaks. The eight channel system was unable to completely span the width of the Unit 5 boiler.

Initial Operation

Several problems were observed during the first few weeks of operation of the 16 channel system. At times, the ALL system would alarm, indicating a boiler leak. However, the unit operator had no indication that a boiler leak had actually occurred. After monitoring unit makeup and listening to the boiler, it would be determined that a false alarm had occurred. At other times it was noted that some channels would not respond to sootblowers or to the purge air, indicating that the sensor had failed. An intensive effort to determine the cause of these problems was initiated.

The first step was to ensure that proper preventive maintenance procedures were being followed. In the event a channel failed to respond to known noises, operations personnel would inspect the waveguide to ensure that it was not plugged or, if plugged, clean it. A schedule was developed and implemented to clean each waveguide assembly three times per week. If a channel did not respond after cleaning, plant personnel would plug in a set of headphones and monitor the channel during the purge cycle. If there was no noise, the problem most likely was a faulty sensor, cable and/or connection, preamplifier or ALL system input/output card. Plant personnel would then identify which component had failed and it would be replaced. Since the installation and initial checkout of the system in October 1990, only one input/output card and one preamplifier have failed. However, even after extensive work by both B&W and plant personnel, the problem with channels not responding continued to plague the system.

In January 1991, extensive testing of the ALL system was conducted to determine why some channels did not respond. Spectral data was recorded on channels 7,8,10,13 and 14. Three tests were performed on these channels with filters in and filters out and at different sensitivity settings. After analysis of the data, it was determined that there was no problem with the equipment; the unit had an uncharacteristically quiet background noise level. The existing 40 db preamplifiers were replaced with 60 db preamplifiers to increase the system gain, thus resolving the problem.

Prior to the testing, plant personnel reported that channels 4and6werein high alarm with no indication of a boiler leak. Plant engineering personnel inspected the system and noticed that the Delrin isolators had evidently melted due to the unusually high temperatures outside the casing and had failed. These isolators are designed to prevent a ground loop from occurring and causing an alarm. The ground loop problem can be identified by a ringing noise heard with the headphones or by analysis with an oscilloscope. This was confirmed during testing and two teflon coated sensors were provided for channels 4 and 6 until teflon isolators could be procured for all 16 channels. These isolators are rated at 450F and have not failed.

Leaks Found by 16 Channel System

Because the new 16 channel system was in beta-testing, plant operators did not have the same confidence in it as in the old. After the problems mentioned above were corrected, only successful leak detection could restore their confidence. The system was responding to purge air and sootblowers because they generate enough acoustic energy to exceed the alarm threshold. Therefore, the system requires that an individual channel remain above the alarm point for 30 minutes before an audible alarm is given to the operator. This provides ample time for a sootblower to cycle and will provide an alarm in the event the blower is hung up in the boiler.

Also of note is the fact that each channel receives a 10 second blast of air for purging every six minutes. This air also generates enough energy to move the recorder to the maximum value. To alleviate this problem, the plant instrument department programmed the recorder to print an eight minute average of the channel signal levels. This effectively removed the unwanted spikes from the chart and made it much easier to interpret.

After the testing was completed, the first leak was detected on March 21, 1991. The leak was detected by channels 4, 6 and 8 which were located in an arc above the leak location. When these channels alarmed, operating personnel used the headphones to listen to internal boiler noise and heard sounds consistent with those of a boiler leak.

Typically, operating personnel will first isolate sensor purge air to determine if the alarms are caused by stuck or leaking solenoid valves. Then, the seal air system to the sootblowers is momentarily isolated to determine if leakage there could be causing the alarm. Finally, the unit is checked

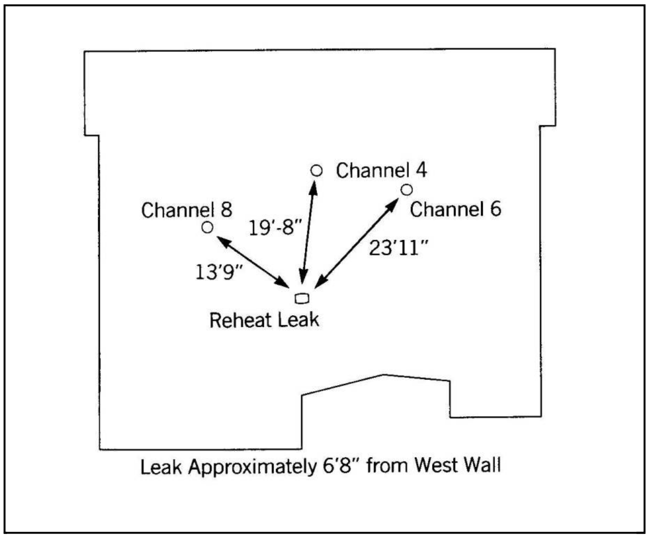

Figure 2 Locations of sensors that detected leak.

to determine if any other items such as stuck sootblowers are present. All of these items were checked on this occasion and nothing abnormal was noted. The ALL system still indicated a leak while unit conditions remained stable.

Due to the lack of successful operating experience with the system, the decision was made to monitor the unit and the ALL system to determine if a leak existed before removing the unit from service for repairs. The chart recorder continued to indicate an increasing signal from channels 4, 6 and 8 (Figure 2), while plant personnel continued to monitorunit makeup and temperatures. Finally, makeup water began to increase as the ALL system signals continued to climb. The decision was made to remove the unit from service for inspection.

The leak was in the final reheat section and occurred in the ninth element from the right side wall. In addition, the original leak washed the fourth and fifth tubes from the rear in the tenth element which also required the installation of 42 in. dutchmen for repair. Two additional tubes were eroded to the point that pad welding was required before the unit could be returned to service. The unit was off for 39 hours and 35 minutes for repairs, with approximately 72 manhours expended. Plant personnel estimate that approximately 12 hours of downtime and 24 manhours (approximate savings of $45,000) could have been saved had the unit been removed from service as soon as the initial operational checks on the ALL system were completed.

The time saved by early leak detection is highly dependent on the location of the leak as well as the number and type of repairs required. In this case, the leak was located where no scaffolding or other access problems existed. In cases where problems are encountered due to access, minimizing the number of tubes damaged becomes more critical.

On November 8,1991, at 11:00 p.m., channels 9 and 13 began to move up the chart, but remained below the alarm level. By 12:20 a.m. on November 9, channels 7, 9 and 13 moved into alarm and makeup had increased to 25%. At 2:42 a.m. the decision was made to remove the unit from service. The leak was repaired and the unit returned to service November 11. Approximately four hours after the unit was placed on-line, channels 5, 9, 7 and 15 went into alarm and the unit was again removed from service. Two leaks were found on the front water wall and repairs were made. Even though these leaks were located in the furnace, it should be noted that in addition to sensors located in the furnace, some of the backpass sensors also picked up the leak. Plant experience has been that sometimes leaks are first detected by channels downstream of the leak location since the noise follows the gas path. In addition, the direction of the escaping fluid from the leak will determine which channels go into alarm. Experience such as this has enabled plant personnel to more accurately pinpoint leak locations before coming off-line.

The detection of these leaks helped build operator confidence in the new 16 channel ALL system. Since that time, three additional leaks have been detected in the penthouse where the plant has experienced problems with the dissimilar welds in the final superheat section. Another leak in the furnace in July 1991 and a reheater leak in October 1991 were also detected by the ALL system.

Conclusion

With the experience gained in the initial system troubleshooting and the performance of the system in actual operation, plant personnel are now confident in the system. In fact, there is so much faith that the ALL system is reporting leaks, the boiler has recently been taken off-line before a leak shows up in the makeup water.

Plant personnel's confidence in the system has also been bolstered by the proven savings resulting from finding leaks early. The first leak detected by the ALL system resulted in an approximate savings of $45,000 due to reduced downtime and fewer required maintenance manhours and materials. Leaks found since have produced savings of similar magnitude.

Even though the location of a leak has a dramatic impact on the time required for tube repair, early detection will decrease the amount of repairs to be made and the unit downtime. On large, pressurized units an acoustic leak detection system is an excellent method of minimizing downtime and improving reliability.

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KEY FEATURES

- Airborne, structure-borne, and combined applications are possible
- Modular design - 2 to 16 channels per enclosure
- Dual Signal Processing Modules
- Microprocessor Control in each module
- Programmable gain of 60dB in 2dB steps
- Bandwidth from 1KHz to 500KHz, unfiltered
- Jumper-selectable airborne/structure-borne filter range
- Continuous root-mean-square (RMS) signal processing on each channel
- Programmable HI and LO alarm thresholds and delays for each channel
- Solid-state alarm output relays (optional)
- 4-20 mA or 0-5 VDC analog outputs for each channel. For use on plant DCS
- All microprocessor boards are durable yet designed for easy replacement in minutes
- Local keypad or remote Personal Computer (PC) control of parameter settings
- Key-lock protection of parameter settings
- Parameter settings are retained after power loss
- RS-232 or RS-422 serial I/O communication option
- TCP/IP converter optional
- All modules are bus-connected for ease of troubleshooting
- Rackmount or benchtop enclosure option


ALL microprocessor boards are durable yet designed for easy replacement in minutes


ALL™ sensors are rugged, reliable, and proven. In more than 2,000 installations, less than 0.5% have failed in normal operation.


Self-contained and ready to plug in, ALL goes to work providing you with crucial data in your required format.


ALL is the total system--
and all the reliability that comes with it.
Dating back to the original system installed in 1991, ALL units all over the world are running with no problems due to unit or component failure.

The story of ***Acoustic Monitoring International*** began in 1982, when *Babcock and Wilcox* developed sensors for leak detection for high-pressure boilers. After unsatisfactory results in trying to re-apply existing technologies to steam boilers, *B&W* contracted with *Hartford Steam Boiler Inspection Technologies* to design a special system to their particular specifications. *HSBIT's* Micheal R. Shaw was given the task of designing the system—the ***ALL™ Acoustic Leak Locator***.

After the initial installation of the ALL™ system at Alabama Power's Gaston Station in 1991, B&W purchased *HSBIT*, and created *TotalSCOPE* Products and Services for boiler operating efficiency.

In 1997, *B&W* sold the assets of the ALL™ System to Micheal R. Shaw, and ***Acoustic Monitoring International, Inc.*** was born.

AMI immediately began servicing units all over the world that were under *B&W's* warranty, and continues to provide parts for all existing systems.

Since its inception, ***Acoustic Monitoring International*** has established over 35 new installations of the ALL™ system. With over 2,000 sensors in service in over 10 different countries, ***AMI's*** ALL™ system has been thoroughly field-tested and is extremely reliable. ***AMI*** is constantly improving the system; the ***Acoustic Leak Locator*** is in its fourth generation.

***Acoustic Monitoring International, Inc.*--Listening is our business.**