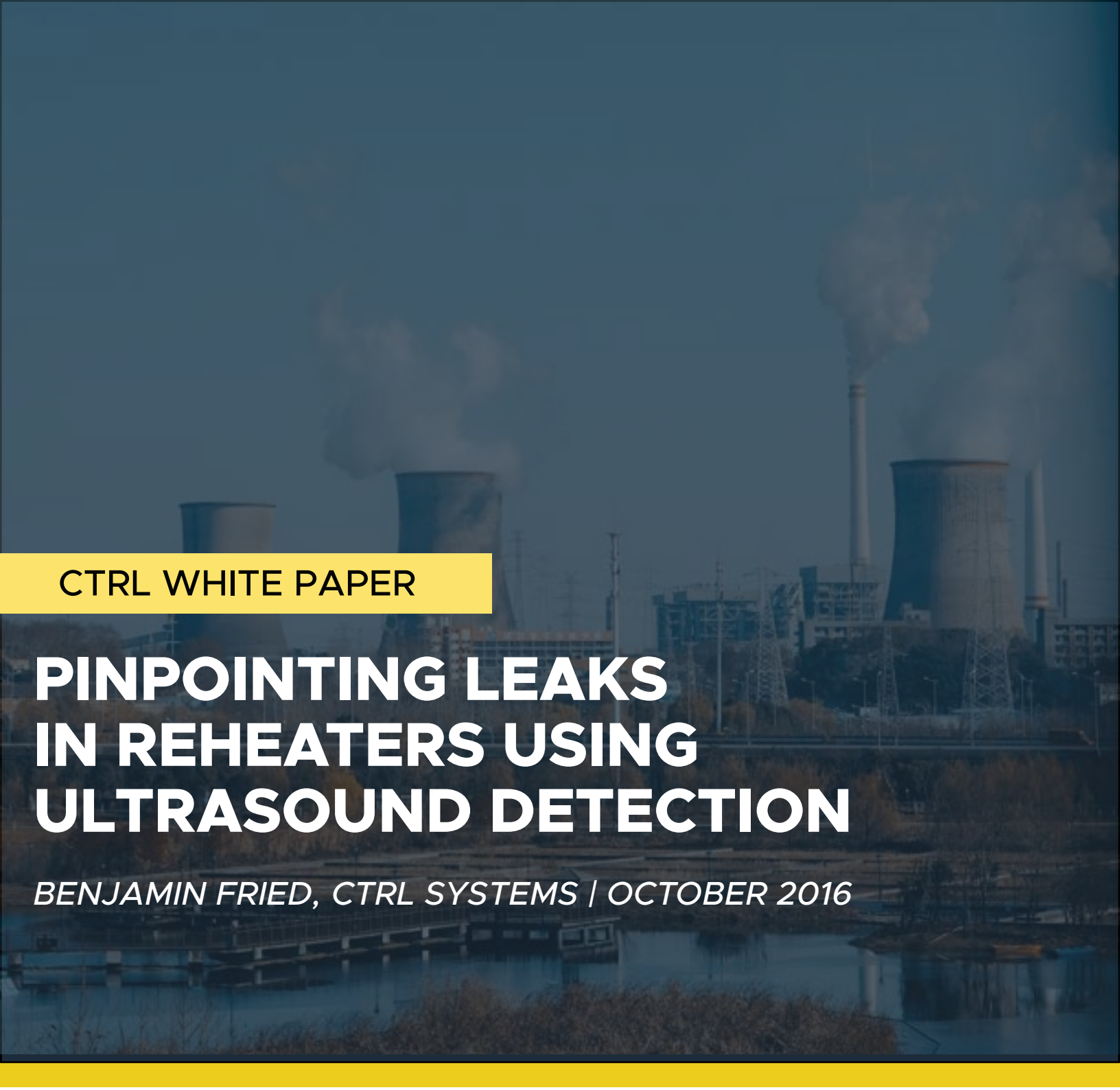

CTRL WHITE PAPER

PINPOINTING LEAKS IN REHEATERS USING ULTRASOUND DETECTION

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Application

Tube failure continues to be the leading cause of unplanned downtime in thermal power plants. Leaks occur in the tubes due to the failures including bending, cracking, bulging, or wear. There are many reasons for the failures including ash, overheating, corrosion, erosion, etc.

The **re-heater** is critical to the performance and efficiency of the power generation process in a thermal power plant. A typical thermal power plant uses the *Rankine Cycle Model*, which describes how steam-operated heat engines generate power by converting heat into mechanical work. In short, fuel such as coal, is put into a boiler furnace to heat water (i.e. steam) to the right temperature and pressure. The steam is heated further with an economizer and put into a furnace where the radiant energy is absorbed into the firewalls. By this point, the temperature of the steam has been raised from 700° F to 800° F.

Figure 1. Inside view of the re-heater. The tube bundles are stacked more than 20 feet below.

The steam goes into a superheater at just about the critical point in order to heat up to 1000° F. If the steam pressure and temperature is higher, there is greater efficiency bythe engine for converting the steam's heat into mechanical work. The steam then goes through the turbine where it loses energy and therefore, temperature and pressure. Enthalpy is a measurement of energy, typically represented in Joules = sum of internal energy and product of pressure and volume).

From the turbine, a vast majority of the steam is exhausted to a re-heater to be used again for a second, lower pressure series of turbines. The re-heater pressure is just one fourth of the original boiler pressure but the temperatures are the same. This prevents the vapor from condensing during expansion and improves efficiency because the combination of turbines (high pressure/high temperature and low pressure/high temperature) are more efficient than reheating through burning fuel.

Steam is then exhausted from the Low Pressure Turbines into the condenser where cooling water is used to condense the steam into water. The phase change from steam to water creates a natural vacuum in the condenser which is also aided by vacuum pumps. The condensed steam (referred to at this point as condensate water) is cleaned and sent back through the heating process to be converted to from water to a supercritical fluid which will continue the once through cycle over again. Cooling water (referred to as circulating water) is sent from the condenser to the cooling tower where the water is air cooling using evaporative cooling to lower the temperature before being pumped backthrough the condenser again.

Leaks Threaten Plant Efficiency

Vacuum can be lost in the turbine due to condenser air-in-leakage. If left unchecked, there will be a strain on the turbine blades, leading to erosion, eventual blade cracking or even blade liberation due to the strain caused by condenser back pressure (low vacuum caused by air leaks and inadequate cooling). For more on condenser leaks check out the article *http://www.process-cooling.com/articles/88004-comparing-leak-detectionmethods-for-power-generation-condensers?v=preview*

Re-heater leaks are another problem. When the re-heater is online, the boiler tube pressure is positive. When offline, valves are closed to keep water out of the system. The steam cools and condenses, creating a natural vacuum. A vacuum is further created by a vacuum pump. The typical vacuum level should be equal to the optimum condenser vacuum level (~ 25” Hg).

Power plants remain diligent about indication and location of leaks in boiler tubes because they are the major cause for outage and generation loss. An estimated 60% of boiler outages are due to tube leaks. The cost of repair, replacement, and maintenance are extremely high. Re-heater materials are typically replaced every 15-20 years at an estimated cost of $20 million.

Whenever the re-heater is offline, personnel will perform a leak check using ultrasound in order to prevent possible minute leaks getting worse. A gross leak will cause the gas temperatures and water level to drop. The gas temperatures should be in the range of 2000° F. When the water level drops, more water needs to be added. In the case of a leak, about 100 – 500 gallons of water can be added per hour to make up for the loss.

Ultrasonic Leak Testing Method

An ultrasound leak detector (with appropriate sensitivity) is used to indicate and locate leaks whenever there is a scheduled shutdown of the re-heater and whenever there is an indication of a leak by the drop in gas temperatures and water level.

1. The boiler is shut down.
2. Valves are automatically closed in order to stop steam from flowing.
3. The boiler goes into a cool down process that requires about 6-10 hours, depending upon the ambient temperature. In order to mitigate other problems from occurring, a 200° F / hour cooling rate is maintained.
4. Once the cool down process is complete, a “lock out / tag out” of the re-heater is performed in order for the technician to walk or crawl into the confined spaces.
5. At the same time, a vacuum is pulled from the condenser through the turbines to the re-heater, caused by the condensing of steam and vacuum pumps. Anything connected to the turbines is under vacuum when offline. The vacuum level is verified to be a minimum 20” Hg, but thedesired vacuum is 25” Hg.
6. The ultrasound leak detector is used by the technician to sweep the re-heater. A re-heater can be more than 70 feet long and 20 feet deep. If there are no leaks, the entire leak detection sweep will take just 3 minutes.

Figure 2. Ultrasound Detector with parabolic dish is used to indicate and locate partial discharge from distances up to 300 feet.

7. If a leak is indicated by the hissing sound within the headset, the location of the leak must be determined by using the principles of ultrasound (i.e. directionality, sensitivity adjustments, shielding, different acoustic attachments, etc.) to pinpoint the exact location within the tube bundles. This process may take up to one hour due, depending upon the location of the leak. In some cases, a solid probe attachment is used to indicate the tube that is leaking. The location of the leak can be traced by moving along the tube bundle toward the loudest sound.
8. Repairs are completed as soon as possible. A code repair is performed; documentation of the repair must be submitted to the insurance provider. Confirmation of repair is indicated by a vacuum test or, in rare cases, a hydrostatic test.
9. The ultrasound leak detector is used to confirm there is no sound coming from the leak location and no leaks were created during the welding or installation of a new tube.

Case Study: Ultrasound Finds Leaks in Re-heater in Power Plant

A power plant in West Virginia has several generators. Whenever there is an indication of a leak or during normal shutdown, an ultrasound leak detector is used to scan the re-heater for leaks. A shutdown can occur just one time every three months, but leaks have caused shutdowns to occur as much as once per month. The ultrasound leak detector is used to scan the entire tube area of the re-heater, and other areas including the turbine and steam piping. The Boiler Engineer indicated that there are times when leaks can be heard with just the ear, but it is impossible to locate the source of the leak in a reasonable time.

They have been doing ultrasound leak detection for the past 10 years and cannot imagine performing the test any other way.

More than 100 leaks have been found with the ultrasound leak detector in the past ten years at just one of the generating facilities. The repair of a single tube can require about twelve hours getting access. It takes six to eight hours to repair or replace the tube. If a tube is replaced, there are twelve welds to be performed. Each weld takes approximately three hours.

The cost of a leak is as follows:

- $50,000 in material and labor
- $90,000 in start-up related costs
- $500,000 in lost revenue due to 36 – 48 hours downtime

Using the ultrasound leak detector saves $100's thousands annually by maximizing the efficiency of each of the turbines. Additionally, catastrophic failures are prevented to the turbine, turbine blades, parts deterioration, and even explosion.[1]

Taking Advantage of Ultrasound Detection Technology

Power plants can take advantage of owning ultrasound technology by applying it to a variety of departments and systems when the detector is not in use for re-heater leak detection. Ultrasound is produced by a variety of sources and can be used for steam traps and valves, condition based monitoring, and electrical inspection.

[1] November 6, 2007: Boiler Tube Leak Caused Explosion and Loss of 3 Lives; Report available: https://www.dli.mn.gov/ccld/PDF/boiler_massachusetts_explosion.pdf

Condition based monitoring of critical bearings, motors and gearboxes for indicating under lubrication, over lubrication, and excessive wear is a compliment to infrared and vibration analysis. Ultrasound has an advantage over other predictive technologies due to the fact that faults appear first in the ultrasound range (about 40 kHz) before any indication of audible vibration, acceleration, or heat. Additionally, ultrasound attenuates very rapidly allowing the user to pinpoint the exact source.

Figure 3. Ultrasound Detector being used to locate leak in transformer at substation

Ultrasound is also used to diagnose valves and steam traps. Contact the housing of the valve with the ultrasound receiver and a solid probe attachment. If the valve or steam trap is closed, there should be no ultrasound heard through the headset. If sound is heard, there is an internal by-pass leak.

Electrical systems can also be tested for ultrasound produced by arcing, tracking, or corona discharge. Infrared is used to indicate excessive resistance and load anomalies, but ultrasound is used to indicate leaking voltage, which can be nuisance by creating Radio Frequency Interference (RFI) or even causing catastrophic failure to transformers, relays, and switchgear.

Conclusion

Re-heater and boiler tube failures continue to be the leading cause of unplanned downtime in power plants. A routine leak detection program using ultrasound can be implemented to prevent catastrophic failure and improve the overall efficiency of the power generation process. Purchase of a robust, intrinsically safe ultrasound detector can pay for itself withthe detection of just one leak.