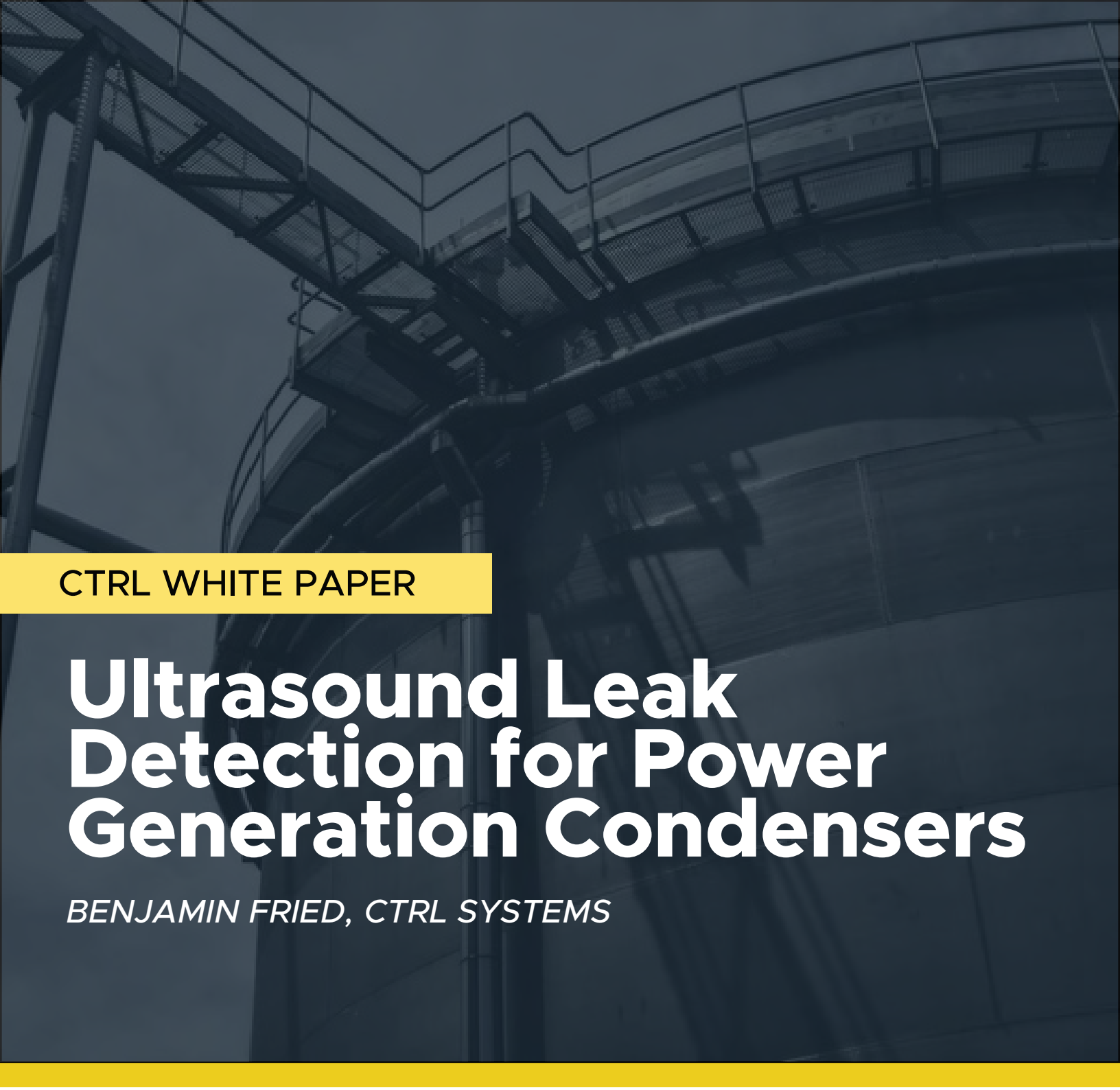

CTRL WHITE PAPER

Ultrasound Leak Detection for Power Generation Condensers

BENJAMIN FRIED, CTRL SYSTEMS

CTRL Systems
1004 Littlestown Pike, Suite H Westminster, MD 21157 USA
+1 (877) 287.5797 | +1 (410) 876.5676 | www.ctrlsys.com

Application

Ninety percent of the power plants in the United States are fueled by coal, nuclear materials, natural gas, and oil. These thermoelectric plants use the different types of fuel to boil water and create steam, which turns the turbines to generate the electricity. Once the steam has passed through the turbine, it must be cooled back into water for reuse by the condenser. The exhaust steam from the turbine is condensed back into water by transferring the heat to the condenser coolant, typically cold water. A common condenser is the surface condenser, also called a water-cooled shell and tube heat exchanger.

A secondary function of the condenser is to maximize turbine efficiency by maintaining a proper vacuum. Decreasing the operating pressure of the condenser (i.e. increasing the vacuum) therefore, increases the electric output of the turbine by increasing the enthalpy drop[1] of the expanding steam. Operating the condenser at the highest vacuum increases plant efficiency allowing the plant to produce more electricity.

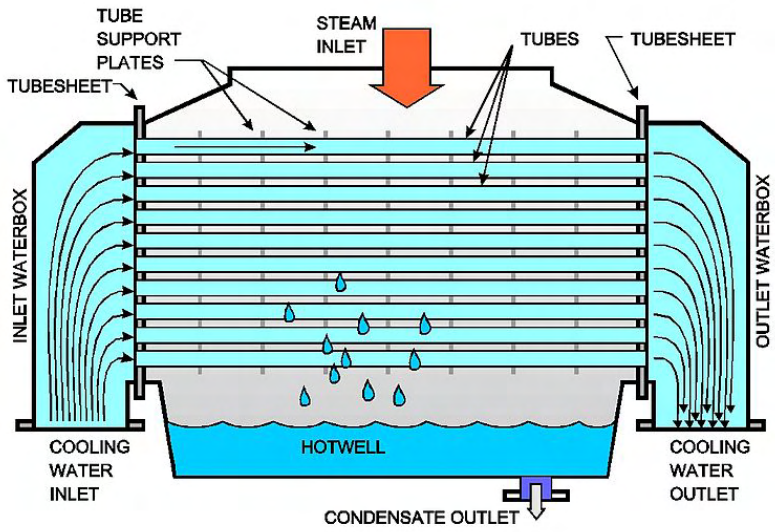

Figure 1. Power Plant Surface Condenser

1 Also called total heat, is a thermodynamic property of a system equal to the sum of its internal energy and the product of its pressure and volume (enthalpy. (n.d.). Dictionary.com Unabridged. Retrieved July 15, 2014, fromDictionary.com website: http://dictionary.reference.com/browse/enthalpy)

When a vacuum leak occurs in the condenser, non-condensable gases are introduced that must be vented. The gases increase the operating pressure, thereby reducing the turbine output and efficiency. The gases also decrease the heat transfer of the steam to the coolant and can cause corrosion in the generator.

Current Test Methods

Several methods for leak testing are used in the power plant, but the most common method is Helium Leak Testing. For vacuum testing, a high vacuum pump and backing pump is used to evacuate the system of most gases. This creates the right condition for a mass spectrometer. Gases are ionized and accelerated through a magnetic field in the mass spectrometer, which isolates gas molecules by mass. This separation allows for the extremely small amounts of Helium to be detected. Helium is introduced to the condenser system by spraying around the vacuum portions of the condenser. The mass spectrometeris placed at the gas outlet of the extractor or at other sites within the vacuum region of the condenser. For pressure testing, Helium is introduced into the system and a sniffer probe is used on the outside to detect escaping Helium gas.

Helium Leak Testing offers several advantages including sensitivity (10^{-5} to 10^{-7} cc/sec), leak rate measurement, ability to seal leaks as soon as identified, and leak test during normal plant operation. However, there are several disadvantages to Helium Leak Testing:

- The results are operator dependent.
- Equipment needs to be calibrated frequently.
- The mass spectrometer is easily damaged in caustic environments.
- Use of one or more pumps, along with the mass spectrometer or sniffer may require two persons.
- Multiple leaks can be masked by one another if they are too close together.
- The Helium may be blocked internally by a membrane or leak through an open valve before reaching the sniffer.

Ultrasound: An Alternative Test Method

Due to technological improvements, ultrasound detection has become an alternative approach for vacuum leak detection. As tested and used by NASA on the International Space Station[2], ultrasound detection technology is now capable to detect all turbulent flow gas and vacuum leaks. Ultrasound is used by many power plants for condenser leak detection.

In China's power plants, for example, ultrasound was tested through a three-year pilot program for its performance to find condenser leaks, thereby improving plant efficiency and power generation output. Twenty-five percent of the Chinese power plants participated in the test with favorable results. The decision was made to institute a permanent program with the opportunity for all of the Chinese power plants to participate going forward.[3]

An ultrasound detector works by detecting ultrasound produced by the turbulent flow of a pressure or vacuum leak. As a gas or liquid escapes from one higher pressure system to the lower pressure side, the molecules become agitated.

2 https://www.ctrlsys.com/nasa
3 https://www.pr.com/press-release/396287

The turbulence produces sound pressure variations at frequencies all along the spectrum from about 20 Hz up to 100 kHz. The amplitude or intensity of the sound at the source of the leak is dependent upon a number of factors including pressure differential, directional radiation pattern, humidity, temperature, and the physical characteristics of the crack.

The ultrasound detector uses a transducer that is most sensitive to pressure changes around 40 kHz. The detected ultrasound is converted into the audible range of hearing (nominally 20 Hz – 20 kHz) and output to a headset. The converted, amplified, filtered sound of the leak can be distinctly heard by a technician. Any sounds outside of 40 kHz produced by the manufacturing environment or power generation plant are inherently ignored by the ultrasound detector. Leaks can, therefore, be easily located in any noisy environment.

Figure 2. Ultrasound Leak Detection of Condenser

Other advantages of ultrasound for leak detection include the following:

- Ease-of-use – simply adjust the sensitivity on a small, handheld receiver up or down to locate and pinpoint the leak; quickly scan areas from distances up to 300 feet
- Directionality – due to low amplitudes and short wavelengths, ultrasound travels in linear paths and does not tend to travel around corners or reflect; leaks are not easily masked
- No calibration – ultrasound is used for indication and location, not measurement ofleaks. The detectors are ruggedized for use in the most caustic of environments including power plants
- Sensitivity – improvements to the technology have given the capability to find leaksfaster and with greater confidence in order for condenser systems to run at normal and even improved vacuum levels to improve power turbine efficiency
- Costs – the cost of the high end ultrasound detector required for condenser leak detection is three to five times less than the cost of a Helium leak detection system, requires less training, and is much faster to use. In many power plants where ultrasound is deployed, a technician is used full time to scan the condenser, exchanger, and multiple other systems for ultrasound. A 0.01% improvement in power generation pays for the integration and manpower of the technology in a matter of days.

Case Study: Ultrasound Finds Leaks in Air-Cooled Condenser in Power Plant

A team of engineers was trained to use ultrasound for leak detection in a power plant with an air cooled condenser. A single day inspection found several vacuum leaks in the top of the tubes, inner tubes and tube junctions. The leaks were repaired; improving the vacuum system back pressure from 27 kPa to 9 kPA (power plant condenser design value is 13.7 kPa).

The increased vacuum pressure not only improved the operational efficiency of thecondenser system, but also reduced coal consumption by 17,000 tons per year. The coalsavings alone were $2.2 million USD. The power plant also saw an increase in electrical generation output.

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 condenser vacuum 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. The detector does not detect only leaks; it is an ultrasound detector.

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 exactly which component is producing the bad ultrasound.

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. Hissing or buzzing through the headset is an early indication of failure. A sound like frying eggs is an indication of imminent catastrophic failure.

Figure 3. Ultrasound Detector with Parabolic Attachment for Detection of Corona Discharge

Conclusion

Improving power generation efficiency and output is necessary to keep up with the growing demands of electricity usage. Leak detection in condensers can have a positive effect on the amount of electricity being generated. Helium Leak Detection is a very sensitive method of finding the smallest vacuum or pressurized leaks in the condenser system. However, technological improvements to the sensitivity and signal-to-noise ratio of ultrasound detectors offer a faster, much more portable alternative. Ultrasound technology should beconsidered for integration into the day-to-day maintenance and reliability tasks to improve power plant generation output.