



# Listen Closely

## Latest ultrasonic technology reduces equipment failure

By Douglas Waetjen

**V**eteran maintenance managers will offer a common response about their experiences with the use of ultrasonic technology. They talk about how the technology has resulted in increased production, reduced maintenance costs and energy consumption, as well as made more efficient use of personnel. Companies are then able to generate greater profitability.

For more than a generation, ultrasonic instruments have been employed for their leak-detecting capabilities. Their ability to pinpoint miniscule pressure and vacuum leaks in tanks, pipes, heat exchangers, valves and steam traps have saved companies thousands of dollars annually. These compact, portable instruments are also now commonly used to trend bearing failure, detect conditions (i.e. lack of lubrication and rubbing, as well as inspect high-voltage apparatus for arcing, tracking and corona).

### Spotting and confirming problems

All operating equipment produces a broad range of sound. The high-frequency ultrasonic components of these sounds are extremely short-wave and tend to be fairly directional and localized. As a result, it's easy to isolate these signals from back-



Ultrasonic technology can be used by maintainers to find pressure and vacuum leaks.

ground plant noises and detect their exact location. In addition, as changes begin to occur in mechanical equipment, the subtle nature of ultrasound allows these potential warning signals to be detected early, before actual failure.

Air and structure-borne ultrasound instruments, often referred to as “ultrasonic translators,” provide information through multiple paths: qualitatively through their ability to hear ultrasounds through a noise-isolating headphone, and quantitatively via incremental readings on a meter/display panel. Digital instruments provide on-board storage for data logging and for viewing baseline information. Some newer versions of the instruments also include on-board sound recording for spectral analysis.

The instruments allow inspectors to confirm a diagnosis on the spot because they clearly discriminate among various equipment sounds. An electronic process called “heterodyning” accurately converts ultra-

sounds that are sensed by the instrument into the audible range, where users can hear and recognize them through headphones. This process enables users to record sound events through conventional recording devices.

Most of the sounds sensed by humans range between 20 Hertz and 20 kHz (20 cycles per second to 20,000 cycles per second). (The average high-end human threshold is 16.5 kHz.) When compared with the sizes of sound waves sensed by ultrasonic translators, the wavelength sizes of these frequencies tend to be relatively gross. The wavelength of low-frequency sounds in the audible range is approximately 3/4 inch (1.9 centimetres) up to 56 inches (17 metres) in length (when using the high-frequency average of 16.5 kHz). On the other hand, ultrasounds sensed by ultrasonic translators are only 1/8 inch (0.3 centimetres) up to 5/8 inch (1.6 centimetres) long.

Since ultrasound wavelengths are magnitudes smaller than those in the audible

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range, they have characteristics that are conducive to condition analysis. One advantage is that the amplitude of a generated ultrasound falls off exponentially from the source, making the emission localized and easily isolated for detection and analysis.

### Handy, precise instruments

Airborne ultrasound translators consist of hand-held units with a meter (or display panel and sensitivity adjustment, headphones, as well as interchangeable modules that are used in either a scanning or contact mode.

Some instruments have the ability to tune the frequency response from between 20 to 100 kHz. An ultrasonic transmitter, often referred to as a tone generator, is usually included.

Many of these features are useful in helping a user adapt to a specific test situation. For example, should an ultrasound source be too difficult to locate due to an intense signal, a downward adjustment of the sensitivity will help focus in on the exact site. In another instance, should a water or compressed gas leak occur behind a wall or underground, the frequency can be adjusted to help a user “tune in” to the leak.

The interchangeable modules allow users to adjust for different types of inspection problems. The scanning mode is used to detect ultrasounds that travel in the atmosphere (i.e. pressure leak or a corona discharge), while the contact mode is used to detect ultrasounds generated within a casing, such as in a bearing, pump, valve or steam-trap housing.

### Variety of application uses

Applications for ultrasonic translators fall into three categories: leak detection, mechanical inspection and electrical inspection.

### Leak detection

Because the technology is sound-sensitive and not gas-specific, a great advantage is

that it can be used in a number of leak situations, including steam traps, valves and pressurized systems (i.e. pipes and tanks).

When a fluid (liquid or gas) leaks, it moves from the high-pressure side through the leak site to the low-pressure side, where it expands rapidly and produces a turbulent flow. This turbulence has strong ultrasonic components. The intensity of the ultrasonic signal falls off rapidly from the source. For this reason, an inspector can locate the exact spot of a leak. Applications include pressure leaks (i.e. compressed air and other gases, vacuum leaks, condensers, heat exchangers and leaks behind walls or underground).

For faulty seals and gaskets, air infiltration and leaks in systems that are too difficult to locate using standard pressure or vacuum testing, a unique ultrasonic tone test is employed. An ultrasonic transmitter is placed on one side or inside the test subject, while an inspector scans on the opposite side with an ultrasonic translator. Then he/she listens for the point of sonic penetration, which will indicate a leak.

According to Alan Urwick, director of U.S.-based Anovotek Energy, air leaks are easily detected with ultrasonic technology and the exact cost of the wastage can be measured. Using an industry standard to

calculate the loss, he says that a plant spending more than U.S.\$1 million annually on compressed air can lose anywhere from U.S.\$75,000 to \$100,000 in wasted air through leaks, if it doesn't have a leak management program. Urwick bases these figures on the energy standard number for the cost of compressed air (19 cents per thousand cubic feet and four cents per kilowatt-hour of electricity).

### Mechanical inspection

According to NASA research, ultrasonic monitoring of bearings provides the earliest warning of bearing wear, detecting imminent failure long before it's indicated by changes in vibration or temperature. The study showed that an increase in amplitude of a monitored ultrasonic frequency of 12 to 50 times over baseline will indicate the initial stages of bearing failure.

All mechanical equipment produces a sound signature that can be used to determine an effective or normal operating condition. As components begin to fail, however, there's a change in the sonic signature. An inspector can note this as a change in sound quality through the headphones, as a change in amplitude (or dB) on a meter or viewed as a fault in an FFT sound spectrum. The sound samples may be recorded directly to a vibration analyzer or captured on a mini-disc recorder, tape recorder or directly to a laptop computer with a sound card.

There are three distinct phases of bearing failure. In the pre-failure phase (lubrication starvation), lubrication levels diminish and levels of ultrasound increase without any dramatic change in the quality of the heterodyned signal. The amplitude increases and is accompanied by a recognizable shift in sound quality, as conditions worsen and a bearing enters the early stages of failure. In phase two, the onset of failure, a bearing begins to emit a



Ultrasonic technology is sound-sensitive and can spot numerous leaks.

variety of tell-tale sounds that often can be confirmed when viewed on a spectral or vibration analyzer. As that condition exacerbates, sound levels rise quickly and heat begins to build. Unfortunately, if a bearing is allowed to reach this stage, the result can be catastrophic (phase three).

To determine whether a bearing is in good or failed mode, an inspector touches a reference point on the bearing housing using the instrument's contact probe. He/she adjusts the sensitivity/volume to get a specific intensity reading. The next step is to compare this reading at the same sensitivity setting to a similar reference point on a bearing which is operating under the same conditions. The amplitude reading and sound quality should be similar. An inspector then can use this baseline reading to trend each bearing over time to determine lack of lubrication or failure mode.

"We first used ultrasonics technology to inspect bearings 20 years ago and we've been delighted with the results. From 1984 to 1991, for example, we operated without losing a single motor because of either motor-bearing or pump-bearing failure. We also didn't have any unscheduled emergency (and costly) downtime," says Terry Harris, facility maintenance manager, with Cargill Foods in Sidney, OH. "It has been an enormous boon for the plant and has contributed significantly to the company's profitability and growth."

## Electrical inspection

Changes in ultrasonic patterns produced by potentially damaging faults in electrical apparatus, such as switchgear, transformers, insulators or potheads and splices, are easily recognized acoustically as either arcing, partial discharge, tracking or corona (corona doesn't occur under 1,000 volts), loose connections, low insulating levels, faulty equipment or wear on components.

When an electrical disturbance occurs, the electricity ionizes air molecules, producing a distinct, detectable ultrasound signal. An ultrasonic detector senses these subtle changes in the acoustic signature of a component and can pinpoint potential sources of failure before they cause costly

damage. High-frequency sounds tend not to penetrate solids, but instead will slip through the smallest openings. Therefore, ultrasonic detectors are an ideal way to safely troubleshoot electrical emissions through enclosed compartments by scanning door seals and air vents. Totally enclosed systems can be inspected using the contact module.

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Normally, electrical equipment should be silent, although some transformers may produce a constant 60-cycle hum or steady mechanical noises. These shouldn't be confused with the erratic, sizzling, frying, uneven and popping sounds of an electrical discharge. Some manufacturers of ultrasonic equipment offer sound samples either via their Web sites or on a disk to help users learn how to recognize problematic sounds.

Often in electrical inspections, technicians use both infrared and ultrasound. Ultrasonic devices detect acoustic events, while infrared instruments detect problems related to heat. There are times, however, when it may be difficult to access electrical equipment with infrared, especially if the equipment is enclosed or if lighting conditions might affect results. Ultrasound provides an alternative when these conditions arise.

For high-voltage inspections, such as substations, where an inspector might not wish to get too close for safety reasons, a technician uses an ultrasonic detector with a parabolic microphone. These devices have a narrow field of view (10 to five degrees) and can detect problems at more than double the distance of standard scanners.

Don Barker, electrical service specialist with U.S.-based Suburban Electric (a full-service, employee-owned electrical contractor), handles everything from data-processing assignments and machine moves to comprehensive inspections of electrical distribution systems. The company inspects all types of electrical problems, including hot spots, loose connections with switchgear and other power-quality issues.

Citing one dramatic case, Barker says that early detection of a simple 10-cent cracked washer in a low-voltage 225-amp panel box saved a client approximately U.S.\$1,226 per year. "The problem was causing a constant load on the disconnect, which would've developed into a 'hot spot' down the line," says Barker. "Within minutes, technicians using an ultrasonics instrument spotted the damaged disk, averting a potentially dangerous situation that might have resulted in a catastrophic fire."

Over the years, air and structure-borne ultrasound instruments have become an important part of predictive maintenance, fugitive emissions and energy conservation programs. Their versatility, ease-of-use and portability enable managers to effectively plan and implement inspection procedures. By locating leaks, detecting high-voltage electrical emissions and sensing the early warning of mechanical failure, these instruments contribute to cost reductions, improve system efficiencies and reduce downtime. For optimum effectiveness, it's recommended that all major technologies (i.e. ultrasound, infrared and vibration) be used as part of a company's comprehensive inspection program. **PEM**

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