

Detect Leaks With Ultrasound

Alan S. Bandes
UE Systems, inc.

Every day, leaks of all shapes and sizes take their toll on the operation of chemical plants. These nuisances negatively affect production, squander energy, and occasionally endanger employees and the environment. Leaks into vacuum systems can damage product runs. Leaks of any type waste money, thereby hurting the bottom line.

Obviously, an ongoing job for plant operators and their maintenance staff is to detect and repair leaks as quickly as possible. All such personnel need procedures, tools and techniques that facilitate detection and repair.

In some facilities, leak detection is a way to keep a system running more efficiently. In other plants, leak detection is part of energy conservation and environmental protection programs. Still other programs use leak detection as a means to controlling fugitive emissions.

Leaks manifest themselves, either internally or externally, in almost any part of a facility. There are different types of leaks, so maintenance departments will use a variety of methods and technologies to locate and document them. Simple methods include the use of soapy bubble-solutions, foam, and smoke bombs; more sophisticated technologies may involve the use of electrochemical and gas-sensitive devices, and infrared and ultrasonic instruments. In this article we will focus on one technology—state-of-the-art ultrasonic instruments and methods—to detect airborne and structure-borne leaks.

What is ultrasound?

Ultrasound is defined as high-frequency sound waves that are above the range of human perception. The lowest point is usually at 20 kilohertz (kHz) and the upper limit is in the

megahertz range. Human beings are able to sense sounds in the range between 20 Hertz and 20 kHz. The portable instruments that measure airborne and structure-borne ultrasound intensity cover frequencies from 20 to 100 kHz.

All operating equipment and most leaks produce a broad range of sounds. The high-frequency, ultrasonic components tend to be concentrated along a narrow pathway. When using ultrasound instruments to detect them, it is relatively easy to separate such signals from background plant noises, and to detect their exact location. In addition, as subtle changes occur in mechanical equipment, ultrasound inspections enable early detection of warning signals before actual failure occurs.

Taken together, the simple formula for wavelength ($Wavelength = velocity/frequency$), and the relative constancy of sonic velocity, show that wavelengths at audible frequencies tend to be much larger than those in the ultrasonic range. Low-frequency sound waves in the audible range are roughly 1.9 cm to 17 m long. By comparison, the lengths of the ultrasound waves that can be sensed by ultrasonic instruments are 0.3 to 1.6 cm.

Because ultrasound wavelengths are far out of the audible range, ultrasonic instruments are more able to locate and isolate the source of problems in loud plant environments. This is a major contributing factor to the popularity of such instruments.

To make these instruments user friendly, internal electronics translate the inaudible ultrasound signals using heterodyning into the audible range. Once this is done, the signals can be heard through headphones or seen as intensity increments on a

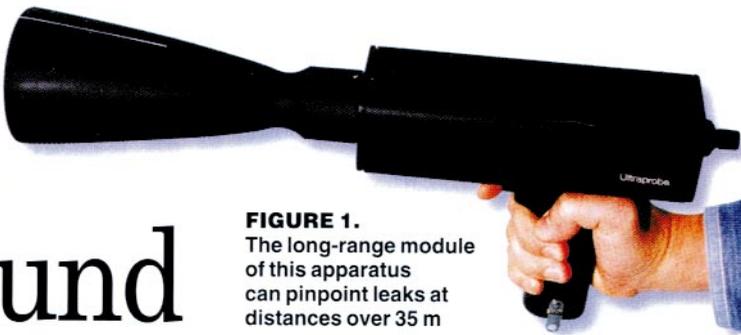


FIGURE 1.
The long-range module of this apparatus can pinpoint leaks at distances over 35 m

Wavelengths are nearly the same size as the fissures, making instruments especially effective

meter or display panel, which is why detectors are also called translators. The ability to both hear and see these translated ultrasounds allows inspectors to confirm a diagnosis on the spot, because users can discriminate between non-relevant equipment noises and sounds associated with leakage.

Applications

Maintenance professionals can use lightweight and portable ultrasonic instruments to inspect potential problems in practically every type of equipment and system in a chemical process plant. Some typical applications include: heat exchangers, chillers, distillation columns, specialty-gas systems, fermentors, pumps, compressors, tanks, pipes, valves, pressure (for instance, compressed air) and vacuum systems, and steam traps.

Ultrasonic instruments have also proven effective for inspection of bearings, detection of valve blow-by, detection of cavitation in pumps, detection of corona in switchgear, compressor valve analysis, and tank levels.* These devices are also used for inspecting the integrity of seals and gaskets in tanks, pipe systems and walk-in boxes.

Meanwhile, in-place monitors can be installed for situations where continuous monitoring for potential leakage or blockage is required. Valves are often monitored using this approach. Most of these monitors are loop-powered at 4-20 mA, and can readily be installed in most plant locations.

Ultrasonic detection methods

The generalized method of leak detection is straightforward. An inspector equipped with an ultrasonic instrument scans an area, and listens for a

* See pp. 29-31 for using ultrasonics in level measurement

distinct rushing sound. With continued adjustments of a volume control, the leak sound is followed until the loudest point is heard. In the ultrasound range, the inspector is able to discriminate between irrelevant background noises and the leak signal.

Some instruments include a rubber focusing probe that narrows the area of reception. This shields against competing ultrasounds and helps pinpoint the location of small leaks.

The greatest advantage of ultrasonic detection is that it can be used in a variety of environments since it is sound-sensitive and not gas-specific. When a leak occurs, the fluid (liquid or gas) moves from the high-pressure side of a leak, through the hole to the lower-pressure side, where it expands rapidly and produces a turbulent flow. This turbulence has strong ultrasonic components that are detected by the instrument. The intensity of the ultrasonic signal falls off rapidly from the source, which has the effect of localizing the signal, thereby enabling an inspector to isolate the exact leak site.

For systems that are offline, a specialized test, called a tone test, uses an ultrasonic transmitter to produce an ultrasonic sound source. The tone test is conducted by placing an ultrasonic transmitter inside, or on one side of, the piece of equipment being tested. A warble-pulse signal floods the test item, and penetrates any existing leak site. Even thin spots in certain metals will be vibrated by the imposed signal. A scan for sonic penetration using an ultrasonic instrument will pinpoint a leak. The tone generator is versatile enough to perform any leak inspection procedure; on such components as seals, gaskets, welds, tanks and pipes. It is especially well-suited for heat exchangers.

Probes and horns

The only difference in detecting pressurized- or vacuum-system leaks is where to look for the greatest amount of turbulence. In a pressurized system, turbulence will occur externally. In a vacuum leak it will be produced internally. Be aware that since leak scans are typically performed externally, the intensity of the sound in a vacuum leak under the same flow con-

ditions will be less than that of a pressurized leak.

Commonly, a standard scanning probe is used to locate a leak. This probe contains a piezoelectric transducer which, when exposed to ultrasound pressure, flexes and produces an electrical charge. The airborne leak sounds are converted from mechanical energy to electrical energy, whereupon they are amplified and translated into the audible range. The scanning-probe can be supplemented by a rubber focusing-probe, whose narrow opening facilitates pinpointing the exact location rapidly.

There are times when the signal may either be difficult to reach or too subtle to detect with standard scanning probes. Specialized probes have been developed to help locate leaks at a distance, and to detect low-energy leaks. For leaks that are out of range, such as those emanating from sources that are high up or far away, parabolic dishes are used. These probes are designed to collect far-off sounds on a parabolic surface and focus them into an array of transducers, where the sound is amplified (Figure 1, p. 67). Depending on the size and shape of the parabola, the focal range can be as tight as 5 deg, allowing a user to pinpoint the location of a leak from distances greater than 35 m.

Low-level leaks, such as vacuum leaks in a distillation column, or leaks in pipe and flange fittings, may be difficult to locate with conventional scanning modules. A scanning probe with an internal "horn" shape, often referred to as a close-focus module, may be used to scan such a leak site closely. The subtle leak sound is amplified and carried via the funnel-shaped collecting cone to the sensing transducer, enabling users to identify the leak site.

For low-level pressure or vacuum leaks, where turbulent flow is low or nonexistent, a unique method that combines a liquid "bubble test" with ultrasound can be used. A bubble solution that has a low surface tension is applied to the suspected leak area. Bubbles form quickly and burst in the presence of a leak, producing a detectable ultrasound. The basic instrument is augmented with a scanning probe for both pressure and vacuum conditions.



FIGURE 2. A simple contact of the probe will test a steam trap

However, there will be instances in vacuum service where the scanning probe will not work due to the signal being low level and internally generated. In those situations, combine a contact probe and a liquid. The contact probe has a metal rod that serves as a wave guide. Touch the test surface with this probe and apply the liquid to the surface. You can hear a leak sound when the liquid is "sucked in" and sputters against the internal walls. Any liquid that is compatible with the vacuum side can be incorporated.

Testing steam traps

To perform an accurate test of steam traps, it is important to understand the way each specific type of trap functions. Acoustically, there are two types of traps: those with continuous flow and those with intermittent flow. Poorly operating traps can lead to complete blow-through, leakage, or plugging. Plugged steam traps will be cool, whereas operating traps and leaking traps will be hot. Before testing, we recommend that the temperature of the trap be taken with a non-contact infrared thermometer to determine whether a trap is hot or cold.

Also, before beginning a survey, be sure to take a trap map along with you to plan your route, and to be sure the traps are tagged and identified accurately. If you do not have an accurate map of the traps you are to inspect, either make one or take photos (using a digital camera) of the trap locations and label them. You should create a method of identifying your traps with tags so that any problem found can be easily referenced and located for followup action. Always note the type of trap you are testing.

Checking a steam trap with an ultrasonic translator is straightforward.

ward. (Figure 2). The downstream side is used to determine leakage. First, touch a pipe directly upstream of the trap and adjust the meter's sensitivity to a midpoint level where flow conditions can be observed without overloading the display. Then touch the trap on the downstream side with the instrument's contact probe and adjust the sensitivity to better hear flow conditions. Listen to the trap operation and observe the meter. An intermittent trap should have an intermittent sound; a continuous flow trap will produce a modulating "continuous~ flow signal.

If one is not sure of the type of trap being tested, refer to the manufacturer's guide or check with your local trap supplier. Some ultrasound equipment manufacturers and steam trap manufacturers have sound samples available. (For more about steam traps, see [1]).

Note the tag number of all faulty traps and produce a non-compliance report or a work order for repair. Test the traps after they have been repaired or replaced because sometimes a new problem can be inadvertently created.

For valves: easy as ABC

There is an interesting method to determine the leakage condition of a valve. Inspectors have dubbed it the "A, B, C, D and sometimes E" method. They touch the instrument's contact probe at two equidistant points, upstream of the valve to create a baseline reading (the data readings are dubbed A and B), and compare these to two equidistant points downstream (the data readings are dubbed C and D). If A and B are equal, and C is louder than A and B, one can assume there is a leak. However, if there are interfering noises further downstream, e.g., if one records D as louder than C, this might indicate that the valve is not leaking, but that some other pipe or structure is producing a ultrasound signal that could interfere with the survey. One then moves the probe to point E further downstream to confirm this. If E is louder, one can assume that the sound is not related to the valve but is caused by a competing structure-borne ultrasound.

Inspecting heat exchangers

In chemical plants, ultrasound inspection is often employed on two major types of heat exchangers: straight shell-in-tube and U-tube. Tubes in heat exchangers, either under pressure or in a vacuum, are easily assessed using ultrasonic translators. The headers are removed so inspectors have access to the tube sheets. Under vacuum and pressure conditions, inspectors will listen to the tubes that are producing a loud, rushing sound as fluid flows from the high-pressure to the low-pressure side in a tube.

Should multiple heat exchangers of the same type need to be inspected while online, a contact method may be employed. Contact zones along the length of the external shell are created. An operator touches each zone and compares them to similar zones on other heat exchangers at the same test point. When there are leaks, there will be a change in the acoustic properties of one zone when compared to the acoustic properties in a similar zone. This is often heard as a loud, popping or crackling sound (Figure 3).

Inspectors also can conduct tests when the heat exchanger is offline. The preferred inspection method is pressure or vacuum, but the tone test technique described above is a good backup for unique situations. Tone generators are placed to produce a uniform ultrasound field around the tube bundle, and operators scan both ends of the tube listening for an increase in sound level, which will indicate a leak or, in some cases, a tube that is thinning.

Does plant type matter?

So far, we have discussed ultrasonic Leak detection methods in general terms for all chemical process plants. But of course, every process plant is unique, and leak-detection methodologies should be tailored to the specific needs of each facility. A pharmaceutical facility, for example, has fermentors, generic pipe runs, and vacuum dryers among its equipment, while a manufacturer using natural-gas liquids to produce ethylene and propy-



FIGURE 3. Fluid leaking from tubes of a heat exchanger can be heard from the outside without interrupting operation

lene has distillation columns and catalytic chemical-producing processes, and, as a result, engenders different environmental and safety issues.

Our best advice is to research the variety of preventive and predictive technologies, instruments and accessories that are available, and then talk with manufacturers and service providers regarding what best suits your needs.

We have a comment on an alternate technology. Any number of gases present may affect chemical "sniffer" devices. A key advantage of ultrasound, as already noted, is that it is not gas specific, so it may be used to locate a number of different types of leaks in any kind of environment.

Ultrasonic leak detection should be an investment in the future of your facility. When you make the right choices, it provides you with valuable opportunities to conserve energy, maintain product quality, cut unscheduled downtime and ensure a safer environment. ■

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Reference

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Author



Alan S. Bandes is vice-president of marketing for UE Systems, Inc. (14 Hayes Street, Elmsford, NY 10523; Phone: 914-592-1220, Fax: 914-347-2181; Email: abandes@att.net). During his 29 years with this company, he has lectured hundreds of times on the principles and applications of airborne and structure-borne ultrasound technology. He has

prepared instructional manuals for courses for inspectors covering Level I and Level II, as defined by the American Soc. of Nondestructive Testing (Columbus, Ohio). He has a B.A. and an M.A. in marketing management from Hofstra University