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Steam Trap Performance Assessment

Advanced technologies for evaluating the performance of steam traps

Approximately 20% of the steam leaving a central boiler plant is lost via leaking traps in typical space heating systems without proactive assessment programs. Losses can be significantly and easily reduced by implementing a program using portable test equipment. Fixed test equipment, allowing continuous monitoring and evaluation, can reduce losses to less than 1%. The potential impact in the Federal sector is enormous; annual savings associated with implementing an assessment program using portable equipment is estimated to be about $80 million, with an average payback period of less than half a year.

This *Federal Technology Alert*, one in a series on new technologies, describes the various techniques and technologies for evaluating steam traps, with a focus on more advanced technologies utilizing ultrasonic sound or fluid conductivity measurement. A methodology for estimating the costs and benefits of implementing a proactive steam trap maintenance program is also presented along with the results of a site-specific Federal application.

Photo courtesy of TLV CORPORATION

Computerized steam trap management system.

Steam Trap Function

Steam traps are automatic valves used in every steam system to remove condensate, air, and other non-condensable gases while preventing or minimizing the passing of steam. If condensate is allowed to collect, it reduces the flow capacity of steam lines and the thermal capacity of heat transfer equipment. In addition, excess condensate can lead to "water hammer," with potentially destructive and dangerous results. Air that remains after system startup reduces steam pressure and temperature and may also reduce the thermal capacity of heat transfer equipment.

Non-condensable gases, such as oxygen and carbon dioxide, cause corrosion. Steam that passes through the trap provides no heating service. This effectively reduces the heating capacity of the steam system or increases the amount of steam that must be generated to meet the heating demand. Where condensate is not returned to the boiler, water losses will be proportional to the energy losses associated with leaking steam. Feedwater treatment costs will be proportionately increased. In turn, an increase in make-up water increases the blowdown requirement and associated energy and water losses. Even where condensate is returned to the boiler, steam bypassing a trap may not condense prior to arriving at the deaerator, where it may be vented along with the non-condensable gases.

Performance Assessment Methods

Steam trap performance assessment is basically concerned with answering the following two questions:

1) Is the trap working correctly or not?
2) If not, has the trap failed in the open or closed position?

Federal Technology Alert

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Sight, sound, and temperature measurements have been used to assess the performance of steam traps since steam traps were invented, but the measuring technology has evolved over the years. In particular, sound measurement has progressed to include ultrasonic devices that compare measured sounds with the expected sounds of working and nonworking traps to render a judgment on trap condition. Equipment using a fourth method, based on the conductivity of the fluid at a specific point in the pipeline, has also been developed in recent years. These advanced technologies are often coupled with temperature-measuring capability to increase diagnostic accuracy.

Where to Apply

Steam trap performance assessment equipment varies significantly in initial cost and moderately in operating cost and assessment effectiveness. For smaller steam systems with relatively few traps and/or for energy managers with exceptionally small budgets, a simple ultrasonic gun (without built-in diagnostics) is probably the best investment. However, where many different staff may be called upon to conduct tests, the incremental investment in an ultrasonic gun with built-in diagnostics makes the most sense. The built-in diagnostic capability practically eliminates the need for training, which is essential to achieving good results without built-in diagnostics, but would be expensive if a large group had to be trained.

Conductivity-based assessment equipment offers the best performance improvement and lowest operating costs via continuous, remote monitoring, but installation of the sensing chambers and wiring make this the most capital-intensive steam trap assessment system. The extra investment is most likely to be cost-effective in steam systems serving heating equipment with relatively large loads and, hence, relatively large steam traps. Larger steam traps, when failed open, result in larger, more expensive leaks. Industrial process heating applications would be most attractive for this type of assessment system, but space-heating applications should not be excluded from consideration.

What to Avoid

The retrofit of sight glasses or test valves allowing a visual assessment of steam trap performance should be carefully considered. While visual assessment is judged by the majority of steam trap experts to be the best assessment technique, the cost of retrofitting this type of equipment is significantly greater than any portable temperature or sonic test equipment and comparable to conductivity-based test equipment. The latter has the advantage of being wired for continuous, remote monitoring, however, which should reduce operating costs and improve steam system efficiency for a relatively modest incremental investment, compared with sight glasses or test valves.

Bottom Line

The widespread cost-effectiveness of proactive steam trap maintenance is well documented in the literature. ***Thus, implementing almost any type of steam trap maintenance program will be beneficial; selecting the specific type of assessment equipment is of secondary importance.***

Steam Trap Performance Assessment

Advanced technologies for evaluating the performance of steam traps

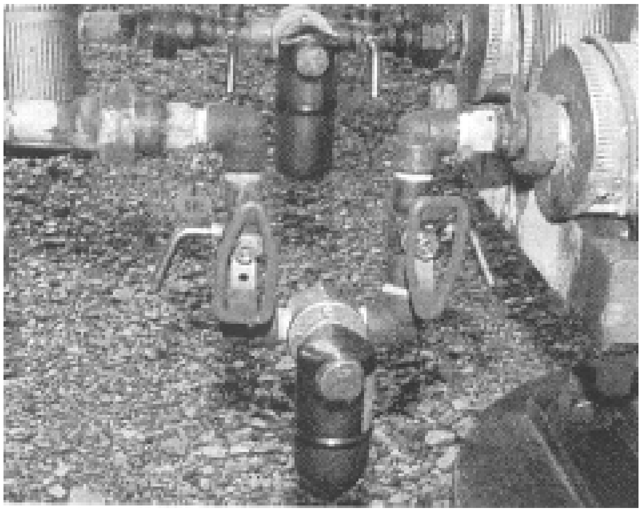

Photo courtesy of Armstrong International, Inc.

Three-way valves on either side a steam trap comprise a trap test station. They make it easy to test traps and to check on back pressure in the system.

Federal Technology Alert

Abstract

Various types of performance assessment equipment can be used as part of a proactive steam trap maintenance program to significantly reduce energy losses in steam distribution systems. Approximately 20% of the steam leaving a central boiler plant is lost via leaking traps in typical space heating systems without proactive maintenance programs.1 Relatively simple equipment and programs can easily cut losses in half. Intermediate equipment and programs can cut losses in half again. The best equipment and programs can reduce losses to less than 1%.2

The potential impact in the Federal sector is enormous. In the Army alone, the annual savings associated with implementing intermediate steam trap performance assessment equipment and programs are estimated to be about $20 million. Based on investment costs of only $8 million, the average payback period is less than half a year. The total present value of savings over a 25-year period was estimated to be about $200 million. Department of Defense (DoD) and Federal sector impacts are probably about three and four times as great, respectively, as the Army impacts.

Steam trap performance assessment has traditionally been based on three basic methods: sight, sound, and temperature. This *Federal Technology Alert* focuses on ultrasonic sound measurement equipment and equipment utilizing a fourth method based on conductivity. A sight glass specifically designed for steam trap performance assessment is also included.

The first two sections present background material that describes the basic types of steam traps and performance assessment methods. The next section describes the technologies included in this *Federal Technology Alert* in more detail. Subsequent sections describe how to use the technologies and the experiences of Federal sector users. Details regarding development of the Army impacts noted above and the results of a specific program initiated at three Veterans Administration hospitals are also documented. Finally, Appendix A provides detailed information on manufacturers and their products, and Appendix B gives Federal life-cycle costing procedures.

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[1] Estimated based on data presented in Pychewicz (1985), Vallery (1981), and Johnson and Lawlor (1985).

[2] A "simple" program would use rudimentary portable test equipment once a year. An "intermediate" program would use more sophisticated portable test equipment twice year. The "best" program would use permanently installed test equipment allowing continuous monitoring and evaluation.

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About the Technology

The focus of this *Federal Technology Alert* (FTA) is on advanced technologies for evaluating the performance or working condition of steam traps. However, prior to discussing techniques and equipment for evaluating steam traps, a brief overview of steam trap functions, designs, and operating characteristics is provided. At least a rudimentary understanding of steam trap principles is necessary to understand how the various evaluation approaches work and why some are more likely to produce a better evaluation than others. Those not familiar with steam traps are also referred to several references listed at the end of this FTA that provide a more detailed discussion.

Steam Trap Overview

Steam traps are automatic valves used in every steam system to remove condensate, air, and other non-condensable gases while preventing or minimizing the passing of steam. If condensate is allowed to collect, it reduces the flow capacity of steam lines and the thermal capacity of heat transfer equipment. In addition, excess condensate can lead to "water hammer," with potentially destructive and dangerous results. Air that remains after system startup reduces steam pressure and temperature and may also reduce the thermal capacity of heat transfer equipment. Non-condensable gases, such as oxygen and carbon dioxide, cause corrosion. Finally, steam that passes through the trap provides no heating service. This effectively reduces the heating capacity of the steam system or increases the amount of steam that must be generated to meet the heating demand.

The objective of the steam trap is not an easy task and condensate pressures and flow rates vary significantly at various points in a steam distribution system. As a result, many different types of steam traps have been developed. Steam traps are commonly classified by the physical process causing them to open and close. The three major categories of steam traps are 1) mechanical, 2) thermostatic, and 3) thermodynamic. In addition, some steam traps combine characteristics of more than one of these basic categories.

The operation of a mechanical steam trap is driven by the difference in density between condensate and steam. The denser condensate rests on the bottom of any vessel containing the two fluids. As additional condensate is generated, its level in the vessel will rise. This action is transmitted to a valve via either a "free float" or a float and connecting levers in a mechanical steam trap. One common type of mechanical steam trap is the inverted bucket trap, shown in Figure 1. Steam entering the submerged bucket causes it to rise upward and seal the valve against the valve seat. As the steam condenses inside the bucket or if condensate is predominately entering the bucket, the weight of the bucket will cause it to sink and pull the valve away from the valve seat. Any air or other non-condensable gases entering the bucket will cause it to float and the valve to close. Thus, the top of the bucket has a small hole to allow non-condensable gases to escape. The hole must be relatively small to avoid excessive steam loss.

As the name implies, the operation of a thermostatic steam trap is driven by the difference in temperature between steam and sub-cooled condensate. Valve actuation is achieved via expansion and contraction of a bimetallic element or a liquid-filled bellows. Bimetallic and bellows thermostatic traps are shown in Figures 2 and 3. Although both types of thermostatic traps close when exposure to steam expands the bimetallic element or bellows, there are important differences in design and operating characteristics. Upstream pressure works to open the valve in a bimetallic trap, while expansion of the bimetallic element works in the opposite direction. Note that changes in the downstream pressure will affect the temperature at which the valve opens or closes. In addition, the nonlinear relationship between steam pressure and temperature requires careful design of the bimetallic element for proper response at different operating pressures. Upstream and downstream pressures have the opposite effect in a bellows trap; an increase in upstream pressure tends to close the valve and vice versa. While higher temperatures still work to close the valve, the relationship between temperature and bellows expansion can be made to vary significantly by changing the fluid inside the bellows. Using water within

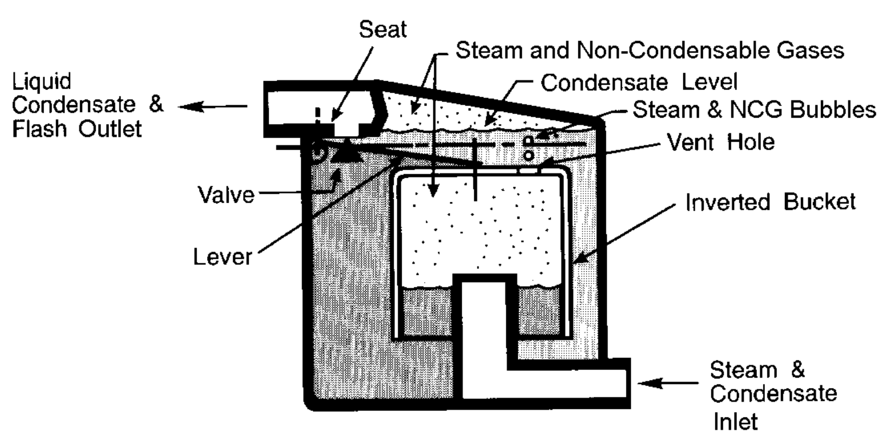

Illustration courtesy of Yarway Corporation

Figure 1. *Inverted bucket steam trap.*

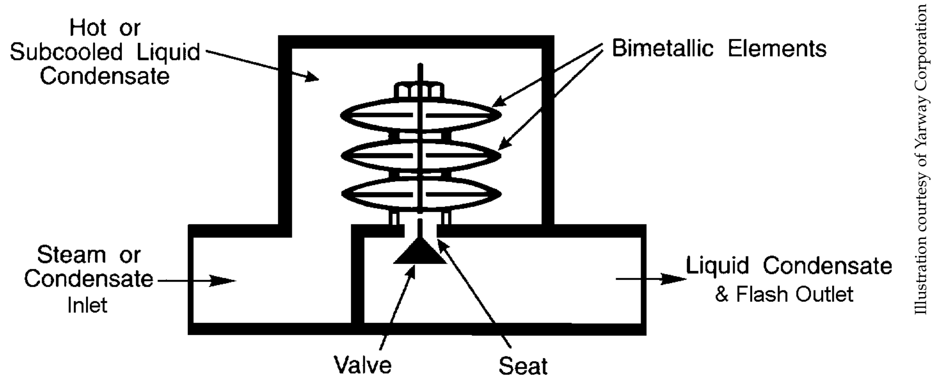

***Figure 2**. Bimetallic steam trap*

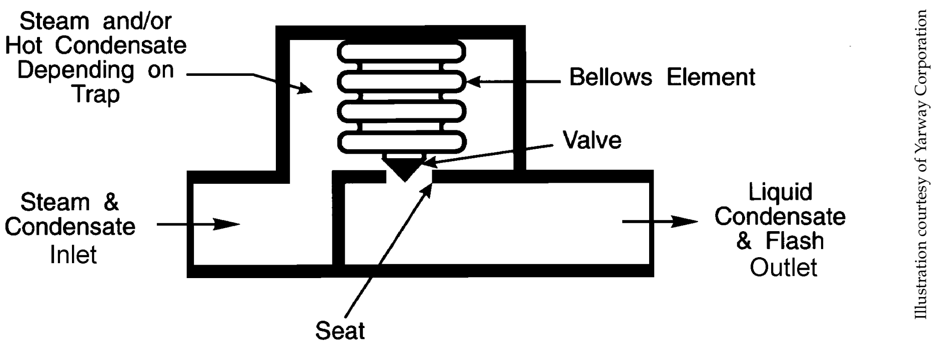

***Figure 3**. Bellows steam trap.*

the bellows results in nearly identical expansion as steam temperature and pressure increase, because pressure inside and outside the bellows is nearly balanced.

In contrast to the inverted bucket trap, both types of thermostatic traps allow rapid purging of air at startup. The inverted bucket trap relies on fluid density differences to actuate its valve. Therefore, it cannot distinguish between air and steam and must purge air (and some steam) through a small hole. A thermostatic trap, on the other hand, relies on temperature differences to actuate its valve. Until warmed by steam, its valve will remain wide open, allowing the air to easily leave. After the trap warms up, its valve will close, and no continuous loss of steam through a purge hole occurs. Recognition of this deficiency with inverted bucket traps or other simple mechanical traps led to the development of float and thermostatic traps. The condensate release valve is driven by the level of condensate inside the trap, while an air release valve is driven by the temperature of the trap. A float and thermostatic trap is shown in Figure 4.

Thermodynamic trap valves are driven by differences in the pressure applied by steam and condensate, with the presence of steam or condensate within the trap being affected by the design of the trap and its impact on local flow velocity and pressure. Disc, piston, and lever designs are three types of thermodynamic traps with similar operating principles; a disc trap is shown in Figure 5. When subcooled condensate enters the trap, the increase in pressure lifts the disc off its valve seat and allows the condensate to flow into the chamber and out of the trap. The narrow inlet port results in a localized increase in velocity and decrease in pressure as the condensate flows through the trap, following the 1st law of thermodynamics and the Bernoulli equation. As the condensate entering the trap increases in temperature it will eventually flash to steam because of the localized pressure drop just described. This increases the velocity and decreases the pressure even further, causing the disc to snap closed against the seating surface. The moderate pressure of the flash steam on top of the disc acts on the entire disc surface, creating a greater force than the higher pressure steam and condensate at the inlet, which acts on a much smaller portion of the opposite side of the disc. Eventually, the disc chamber will cool, the flash steam will condense, and inlet condensate will again have adequate pressure to lift the disc and repeat the cycle.

Performance Assessment Methods

Steam trap performance assessment is basically concerned with answering the following two questions:

1) Is the trap working correctly or not?
2) If not, has the trap failed in the open or closed position?

Traps that fail open result in a loss of steam and its energy. Where condensate is not returned, the water is lost as well. The result is significant economic loss, directly via increased boiler plant costs, and potentially indirectly, via decreased steam heating capacity. Traps that fail closed do not result in energy or water losses, but can result in significantly reduced heating capacity and/or damage to steam heating equipment.

There are three basic methods for evaluating a steam trap that are commonly discussed in the literature: sight, sound, and temperature. The three are discussed below in the general order of reliability. At least two of the three methods should be used to increase the chances of correctly identifying the condition of a steam trap. ***A less commonly discussed***

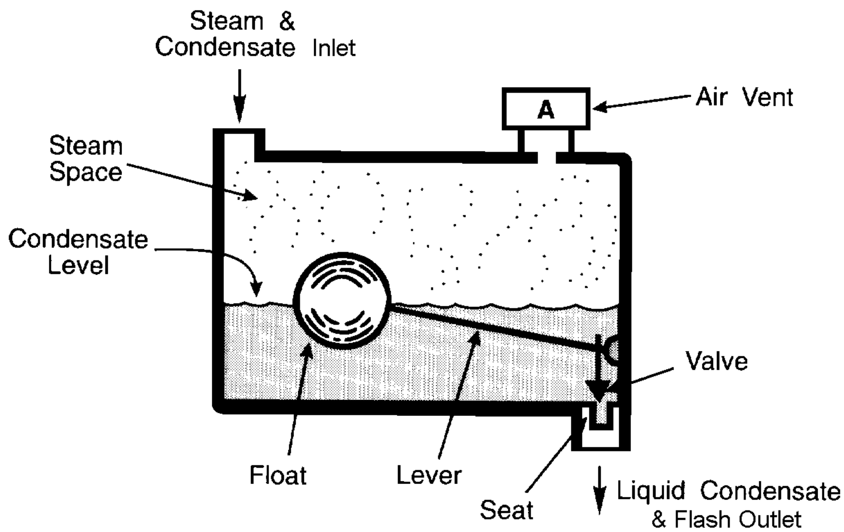

Illustration courtesy of Yarway Corporation

Figure 4. *Float and thermostatic steam trap*

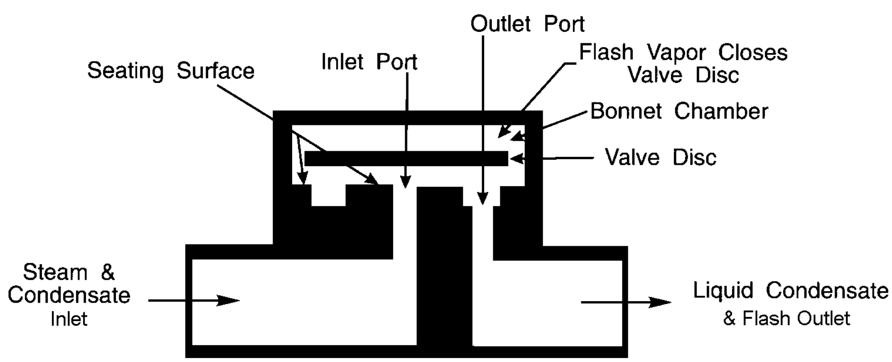

Illustration courtesy of Yarway Corporation

Figure 5. *Disc steam trap.*

method is based on fluid conductivity. Although this method should be at least as reliable as sonic-based methods, it is discussed less frequently in the literature, and no general consensus on its relative reliability was evident.

Sight Method

The sight method is usually based on a visual observation of the fluid downstream of the trap. This is possible if there is no condensate recovery system or if test valves have been installed to allow a momentary discharge of the downstream fluid from the condensate recovery system. In either case, the steam trap evaluator must be able to distinguish between "flash" steam, which is characteristic of a properly working trap, and "live" steam, which is characteristic of a trap that has failed open and is leaking or blowing a significant amount of steam. Flash steam is created when a portion of the condensate flashes to vapor upon expansion to atmospheric pressure. Flash steam is characterized by a relatively lazy, billowy plume. Live steam, on the other hand, will form a much sharper, higher velocity plume that may not be immediately visible as it exits the test valve or steam trap. The difference between live steam and flash steam is illustrated in Figure 6.

Sight glasses can also be used for a visual observation, but have some drawbacks that must be overcome or avoided. First, steam and condensate are both expected to exist upstream and downstream of the trap (live steam on the upstream side and flash steam on the downstream side). Second, the view through a sight glass tends to deteriorate over time because of internal or external fouling. Third, both steam and condensate will appear as clear fluids within the pipe. In response to the first and third concerns, sight glasses have been developed with internal features that allow the proportion of steam and condensate to be identified. Incorporation of a sight glass into a pipe is shown in Figure 7a. Normal and abnormal operating conditions viewed through a sight glass are illustrated in Figures 7b, 7c, and 7d for a sight glass installed on the upstream side of the trap. In Figure 7b normal operation results in a condensate level that is just above the internal flow baffle. Moderate to high rates of steam flow past the baffle (indicating a leaking or blowing steam trap) will sweep out most of the condensate, as shown in Figure 7c. A completely flooded baffle, shown in Figure 7d, could be caused by excess condensate formed during startup, a steam trap that is undersized for normal condensate loads, blockage in the condensate return system, or a steam trap that has failed closed or nearly so. Additional investigation is required to determine which of the alternative causes is the likely source of the problem.

Sound Method

Mechanisms within steam traps and the flow of steam and condensate through steam traps generate sonic (audible to the human ear) and supersonic sounds. Proper listening equipment, coupled with the knowledge of normal and abnormal sounds, can yield reliable assessments of steam trap working condition. Listening devices range from a screwdriver or simple mechanic's stethoscope that allow listening to sonic sounds to more sophisticated electronic devices that allow "listening" to sonic or

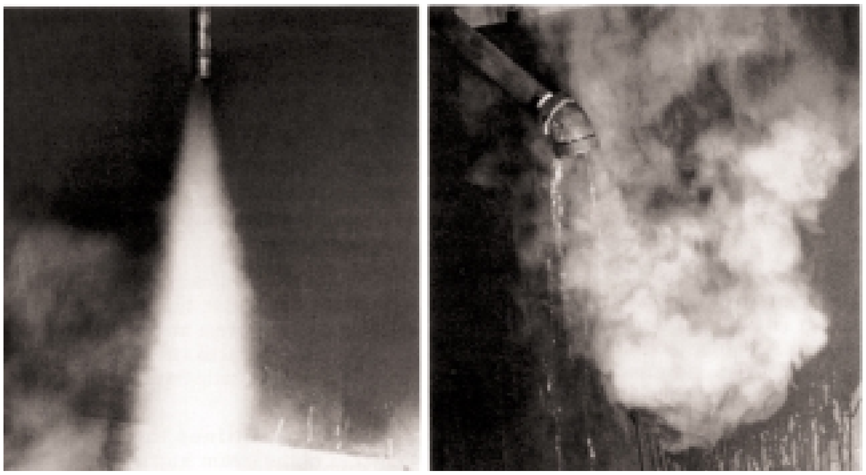

Photo courtesy of Yarway Corporation

Figure 6. *Live steam versus flash steam.*

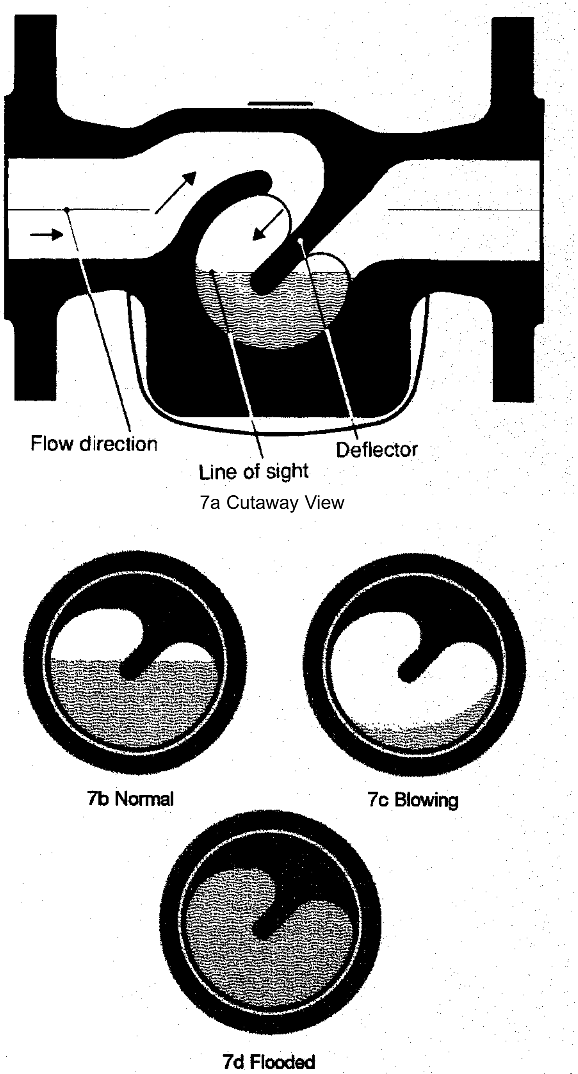

Illustration courtesy of GESTRA, Inc.

Figure 7. *Sight glass evaluation.*

sonic and ultrasonic sounds at selected frequencies. The most sophisticated devices compare measured sounds with the expected sounds of working and non-working traps to render a judgment on trap condition. A typical ultrasonic test kit is shown in Figure 8.

Temperature Method

Measuring the temperature of the steam trap is generally regarded as the least reliable of the three basic evaluation techniques. Saturated steam and condensate exist at the same temperature, of course, so it's not possible to distinguish between the two based on temperature. Still, temperature measurement provides important information for evaluation purposes. A cold trap (i.e., one that is significantly cooler than the expected saturated steam temperature) indicates that the trap is flooded with condensate, assuming the trap is in service. As described above for the visual test via a sight glass, a flooded trap could mean several things, but barring measurement during startup, when flooding can be expected, generally indicates a problem that needs to be addressed. Downstream temperature measurement may also yield useful clues in certain circumstances. For example, the temperature downstream of a trap should drop off

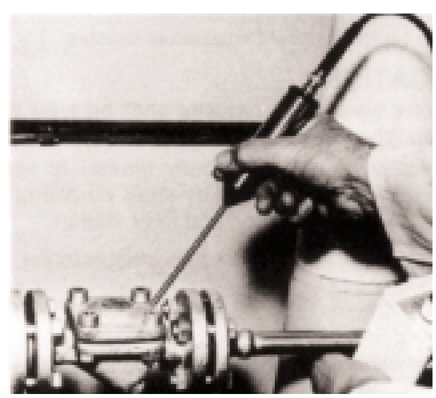

Photo courtesy of GESTRA, Inc.

Figure 8. *Ultrasonic test kit.*

relatively quickly if the trap is working properly (mostly condensate immediately past the trap). On the other hand, the temperature downstream of the trap will be nearly constant if significant steam is getting past the trap. Care must be taken not to use this technique where other traps could affect downstream conditions, however.

Temperature measurement methods, like sound measurement, vary tremendously in the degree of sophistication. At the low-end, spitting on the trap and watching the sizzle provides a general indication of temperature. For the more genteel, a squirt bottle filled with water will serve the same purpose. Alternatively, a glove-covered hand can provide a similar level of accuracy. More sophisticated are various types of temperature-sensitive crayons or tapes designed to change color in different temperature ranges. Thermometers, thermocouples, and other devices requiring contact with the trap offer better precision. Finally, non-contact (i.e., infrared) temperature measuring devices provide the precision of thermometers and thermocouples without requiring physical contact. Non-contact temperature measurement makes it easier to evaluate traps that are relatively difficult or dangerous to access closely. An infrared temperature measuring "gun" is shown in Figure 9.

Conductivity Method

Conductivity-based diagnostics are based on the difference in conductivity between steam and condensate. A conductivity probe is integrated with the steam trap or just upstream of the steam trap in a sensing chamber. Under normal operation, the tip of the conductivity probe is immersed in condensate. If the steam trap leaks excessively or is blowing, steam flow will sweep away the condensate from the test probe tip and conductivity corresponding to steam will be measured. Thus, the sensing chamber and the existence of steam and condensate under normal and leaking or blowing conditions are similar to that described above and shown in Figure 7 for the sight glass.

Photo courtesy of Raytek Corporation

Figure 9. *Infrared temperature gun.*

Conductivity measurement must be accompanied by temperature measurement to ensure a correct diagnosis. For example, an indication of steam and a trap that has failed open could occur if a trap has not been used recently and has filled with air. The conductivity of air is similar to steam, but a trap filled with air would be close to ambient temperature, in contrast to a trap filled with steam. Similarly, the presence of condensate could mean the trap is working properly, but could also mean that 1) the trap has flooded, either because the trap has failed closed or something else is blocking the line, 2) the trap is undersized, or 3) the heat transfer equipment served by the trap is warming up to its normal operating temperature and generating an unusually large amount of condensate for a short period. These alternative conditions would be indicated by low temperature in conjunction with the presence of condensate.

Application Domain

Steam trap monitoring equipment should be employed wherever steam heating systems and steam traps are used. Steam can be used for space and process heating. Space-heating with steam is more common in the Federal sector than other sectors, which can be attributed to a tendency for Federal buildings to be larger, grouped closely together in campus-like arrangements, or constructed in an era when central boiler systems were the preferred heating system. The Department of Defense has about 5,000 miles of steam distribution systems, not including piping within buildings. Larger forts or bases can easily have more than 10,000 steam traps. Proactive steam trap maintenance programs are believed to be the exception, rather than the rule, in the Federal sector due to a shortage of maintenance staff. On the other hand, essentially all studies of steam trap maintenance programs reported in the literature suggest that energy savings far exceed implementation costs. Thus, the potential incremental application of steam trap performance evaluation equipment is significant when measured by either the size or fraction of the market.

Energy-Saving Mechanism

Monitoring and evaluation equipment does not save any energy directly, but identifies traps that have failed and whether failure has occurred in an open or closed position. Traps failing in an open position allow steam to pass continuously, as long as the system is energized. The rate of energy loss can be estimated based on the size of the orifice and system steam pressure using the relationship illustrated in Figure 10. This figure is derived from Grashof's equation for steam discharge through an orifice (Avallone and Baumeister 1986) and assumes the trap is energized (leaks) the entire year, all steam leak energy is lost, and that makeup water is available at an average temperature of 60°F. Boiler losses are not included in Figure 10, so must be accounted for separately. Thus, adjustments from the raw estimate read from this figure must be made to account for less than full time steam supply and for boiler losses.

The principal uncertainty in using the Figure 10 energy loss rates is estimating the equivalent hole diameter for a trap suspected of leaking or blowing steam. Vendor advice can be solicited to identify the orifice size for a trap when fully open. However, not all traps fail in this mode. Rather than being stuck open, the trap valve may no longer seal properly, resulting in a smaller hole. Intermediate failure modes are also possible. Whether a trap has lost its seal or is stuck fully open, the flow of condensate through the orifice reduces the area available for steam flow. Fischer (1995) estimates that condensate flow reduces steam flow by 1/3 to 1/2 of that expected without condensate. The variation depends on the sizing of the trap relative to expected condensate load. In addition, steam trap internals create flow restrictions that reduce losses relative to unimpeded flow through an orifice.

The maximum steam loss rate occurs when a trap fails with its valve stuck in a fully opened position. While this failure mode is relatively common, the actual orifice size could be any fraction of the fully opened position. Therefore, judgment must be applied to estimate the orifice size associated with a specific malfunctioning trap. Lacking better data, assuming a trap has failed with an orifice size equivalent to one-half of its fully-opened condition is probably prudent. Additional advice on estimating losses from individual traps can be found in Pychewicz (1985), David (1981), and Tuma and Kramer (1988).

The use of Figure 10 is illustrated via the following example. Inspection and observation of a trap led to the judgment that it had failed in the fully open position and was blowing steam. Manufacturer data indicated that the actual orifice diameter was 3/8 inch. The trap operated at 60 psia and was energized for 50% of the year. Boiler efficiency was estimated to be 75%. Calculation of annual energy loss for this example is illustrated in the sidebar on page 11.

Other Benefits

Where condensate is not returned to the boiler, water losses will be proportional to the energy losses noted above. Feedwater treatment costs will also be proportionately increased. In turn, an increase in make-up water increases the

Steam Leaks

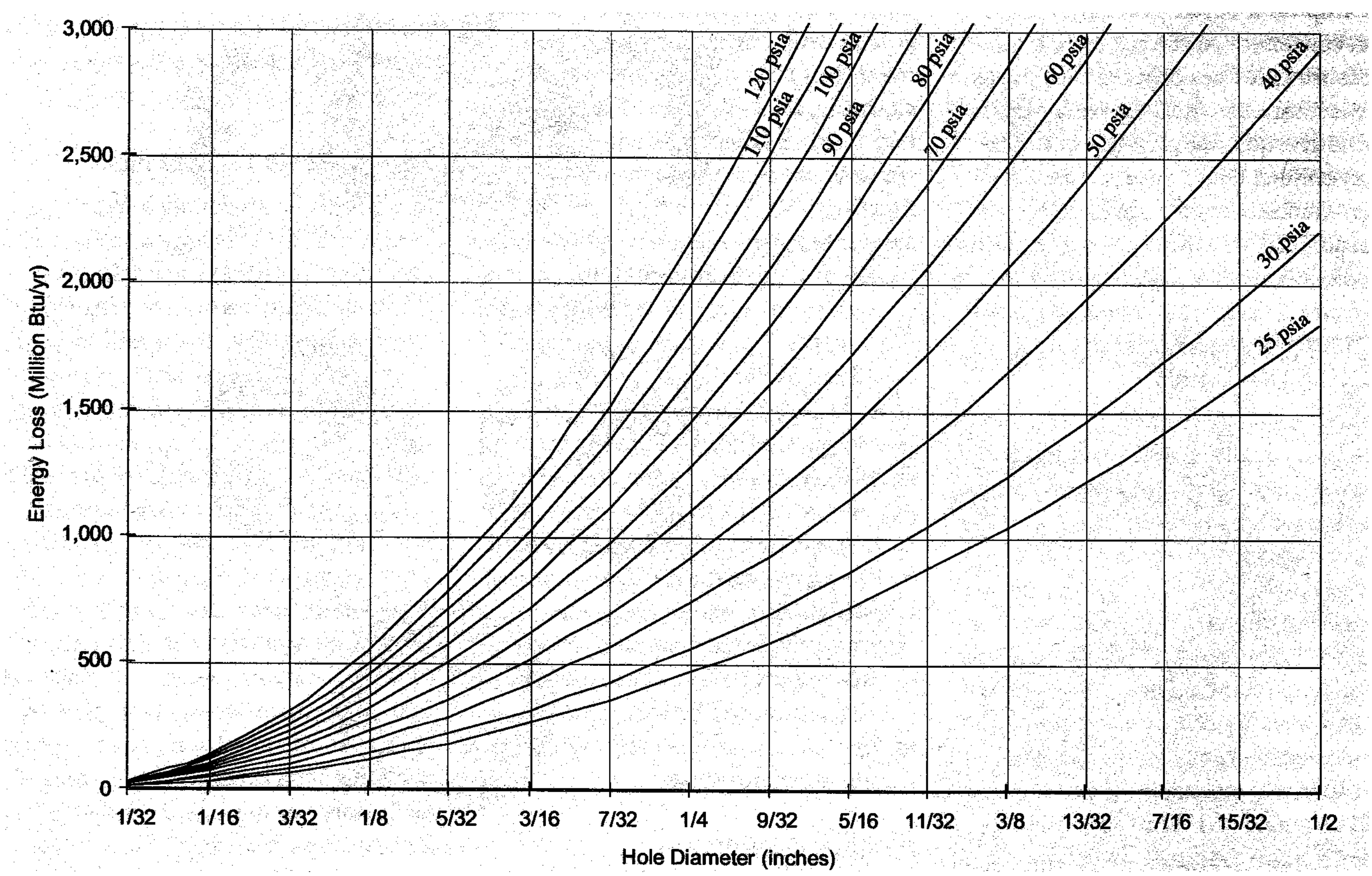

Figure 10*. Energy loss from leaking steam traps.*

Estimating steam loss using Figure 10

Assume: 3/8-inch-diameter orifice steam trap, 50% blocked, 60 psia saturated steam system, steam system energized 4,380 h/yr (50% of year), boiler efficiency 75%.

- Using Figure 10 for 3/8 inch orifice and 60 psia steam, steam loss = 2,500 million Btu/yr
- Assuming trap is 50% blocked, annual steam loss estimate = 1,250 million Btu/yr
- Assuming steam system is energized 50% of the year, energy loss = 625 million Btu/yr
- Annual fuel loss including boiler losses = [(625 million Btu/yr)/(75% efficiency)] = 833 million Btu/yr

blowdown requirement and associated energy and water losses. Even where condensate is returned to the boiler, steam bypassing a trap may not condense prior to arriving at the deaerator, where it may be vented along with the non-condensable gases. Steam losses also represent a loss in steam-heating capacity, which could result in an inability to maintain the indoor design temperature on winter days or reduce production capacity in process heating applications. Traps that fail closed do not result in energy or water losses, but can also result in significant capacity reduction (as the condensate takes up pipe cross-sectional area that otherwise would be available for steam flow). Of generally more critical concern is the physical damage that can result from the irregular movement of condensate in a two-phase system, a problem commonly referred to as "water hammer."

Installation

Installation requirements are essentially nil for portable test equipment, which includes ultrasonic systems with or without built-in diagnostic capability. Some training will be required for the ultrasonic systems without built-in diagnostics, however, for the user to correctly interpret the signals received. The conductivity-based systems generally require a test chamber plumbed into the pipeline just upstream from the steam trap, although some steam traps have an integrated test chamber. Continuous monitoring requires the installation of power and control wiring to connect individual test probes to a central monitoring terminal. Otherwise, a portable monitoring device can be periodically connected to each test probe. Sight glasses must also be plumbed into the pipeline just upstream from the steam trap.

Federal Sector Potential

Steam heating systems are relatively common in the Federal sector. Total boiler capacity, boiler energy consumption, steam piping length, and the number of traps in the Federal sector are not directly available from databases, but can be estimated from related data and rules-of-thumb.

Estimated Savings and Market Potential

Implementation of a proactive steam trap program (i.e., a program based on regular maintenance checks rather than only replacing steam traps when failure creates an intolerable operating condition) can save significant energy. The results of several steam trap programs described in the literature suggest that failed steam traps leak approximately 20% of the steam leaving the boiler in predominately space-heating systems lacking a proactive maintenance program. The same sources suggest that the loss rate would be reduced to about 6% by the average proactive maintenance program. If the average loss rate for a proactive program is 6%, then a minimal program (using rudimentary test equipment) might reduce losses to about 8% and an intermediate program (using good portable equipment and more frequent testing) should yield better results, reducing losses to perhaps 4%. With an advanced program (using hard-plumbed and wired equipment allowing continuous monitoring), the loss rate should approach 0%.

In general, each increment of improvement in the steam trap loss rate requires an increased investment in labor and equipment. Equipment costs are negligible for either the minimal or intermediate programs, but would increase significantly for the advanced program, which requires the installation of new hardware, including retrofit of the existing steam piping. The significant investment associated with the advanced program is probably not justified in most Federal applications, which are predominately for building space heating. Compared to typical industrial process heating applications, end-use heat exchanger condensate loads are small for typical space heating applications. Thus, smaller steam traps are used, and the potential loss from a single trap probably does not warrant the expense of an advanced program. This generalization should be revisited in any site-specific analysis, however.

The estimated savings and market potential were estimated by evaluating the cost-effectiveness of implementing either a minimal or intermediate proactive steam trap maintenance program. 80% of Federal sites were assumed not to have a proactive maintenance program. 15% were assumed to have a minimal program and 5% an intermediate program. No Federal sites were presumed to have an advanced program.

The costs of implementing a minimal or intermediate program, or upgrading from a minimal program to an intermediate program, were estimated from rules-of-thumb provided in publications describing proactive steam trap maintenance programs. Program requirements include an initial identification of all steam trap locations, purchase of test equipment, training, trap testing, trap replacement, and engineering management.

Estimated costs for the two programs, as a function of the total trap population, are shown in Table 1. The minimal program is presumed to use whatever testing equipment is already available, so no expenditure for equipment or equipment-use training is required. Traps are presumed to be tested once a year for the minimal program and twice a year for the intermediate program, which explains the difference in trap testing and engineering management costs for the two programs. The intermediate program is presumed to do a better job of assessing trap condition; a higher percentage of traps that have failed are identified as having failed and a lower percentage of traps that are working correctly are misidentified as having failed. Thus, a lower percentage of steam traps are still leaking after completing a test and repair cycle with the intermediate program. In addition, subsequent failures accumulate for only six months for the intermediate program compared to a year for the minimal program. The combined effect is presumed to cut energy losses for the intermediate program in half compared to the minimal program.

Consider a hypothetical facility with 100,000 lb/hr of steam generating capacity, 500 traps, annual steam production of 219,000,000 lb, and a marginal cost of steam production of $5/thousand pounds. Implementation of the minimal program would save 26,280,000 lb of steam valued at $134,000 every year for an initial cost of $27,500 plus annually recurring costs of $16,000. Implementation of the intermediate program would save 35,040,000 lb of steam valued at $175,200 every year for an initial cost of $31,500 plus annually recurring costs of $19,500. The payback periods for the minimal and intermediate programs are 0.23 and 0.20 years, respectively.

The calculations in the previous paragraph provide the economic justification to proceed with trap identification and testing, resulting in a more accurate assessment of trap conditions and steam losses, hence trap replacement costs and energy savings. The life-cycle cost calculations should be repeated once this additional information is available to determine if trap replacement is still economically justified. Note that money already spent for trap identification and initial testing are "sunk" and should not be included in the subsequent calculation.

The potential economic and environmental impacts of implementing cost-effective steam trap maintenance programs in the Army are shown in Table 2. The results are quite impressive. Annual energy savings could be about 5 trillion btu, with the present value of annual savings (annual energy savings less annual program costs) and the net present value (after paying for initial program investment costs) both in excess of $200 million. The data required for accurate estimates were not available, but DoD and Federal sector impacts are probably about three and four times as great, respectively, as the Army impacts.

***Table 1**. Steam trap proactive maintenance program cost estimates.*[3]

Cost Element	Minimal Program	Intermediate Program
Trap Identification	$15/trap once	$15/trap once
Equipment and Training	$0 total once	$4000 total once
Trap Testing	$5/trap per year	$10/trap per year
Trap Replacement	$40/trap first year	$40/trap first year
	$15/trap thereafter	$15/trap thereafter
Engineering Management	$5000 + $2/trap/year	$5000 + $4/trap/year
Total Initial Cost	$55/trap	$4000 + $55/trap
Total Annual Cost	$5000 + $22/trap	$5000 + $29/trap

[3] Estimates were developed from information presented in Hooper and Gillette (1997), Garcia Gaggioloi (1986), Miller (1985), Johnson and Lawlor (1985), Lane (1983), Vallery (1981), and FEMP (1996).

Laboratory Perspective

The cost-effectiveness of proactive steam trap maintenance is well documented in the literature. In general, it's far more important to ensure that steam traps are evaluated on a regular basis than to worry about which specific type of testing equipment is used. A more careful analysis of the costs and benefits is justified, however, if some of the more expensive options requiring hardware installation are considered. Still, the efficiency improvement offered by these more sophisticated systems may be justified for systems with larger steam traps that lose much more steam upon failure. The pervasive existence of steam heating systems coupled with relatively few proactive steam trap maintenance programs in the Federal sector presents a substantial opportunity for energy savings and related benefits.

Application

This section describes in more detail the technical considerations regarding implementation of a proactive steam trap maintenance program and selection of steam trap testing equipment. The first few paragraphs describe the conditions and characteristics where a maintenance program and specific types of equipment should be applied and situations that should probably be avoided. Subsequent sections focus on equipment integration impacts, including installation requirements, equipment and installation costs, and maintenance requirements.

Application Screening

Some type of steam trap performance assessment program should be implemented anywhere steam heating systems and steam traps are used. Even for smaller systems with only a handful of traps, some type of steam trap program will be cost-effective. The use of temperature and sound measurement equipment currently available in your maintenance shop, even if limited to a gloved hand and a screwdriver, is better than having no regular assessment program at all. The most important decision is to implement a steam trap performance assessment program. Selection of the specific performance assessment equipment is a secondary consideration.

Table 2. *Potential Army impacts of proactive steam trap maintenance programs*

Criteria	Result
Net Present Value ($)	203,991,245
Installed Cost ($)	7,850,779
Present Value of Savings ($)	211,841,024
Energy Savings (million Btu/year)	5,197,636
SO_2 Emissions Reduction (lb/year)	3,624,870
NO_x Emissions Reduction (lb/year)	1,215,219
Particulate Emissions Reduction (lb/year)	68,721
CO Emissions Reduction (lb/year)	354,341
CO_2 Emissions Reduction (tons/year)	368,695
Hydrocarbon Emissions Reduction (lb/year)	8,163

Where to Apply

The steam trap performance assessment equipment described in this FTA varies significantly in initial cost and moderately in operating cost and assessment effectiveness. For smaller steam systems with relatively few traps and/or for energy managers with exceptionally small budgets, a simple ultrasonic gun (without built-in diagnostics) is probably the best investment. However, where many different staff may be called upon to conduct tests, the incremental investment in an ultrasonic gun with built-in diagnostics makes the most sense. The built-in diagnostic capability practically eliminates the need for training, which is essential to achieving good results without built-in diagnostics, but would be expensive if a large group had to be trained. Conductivity-based assessment equipment offers the best performance improvement and lowest operating costs via continuous, remote monitoring, but installation of the sensing chambers and wiring make this the most capital-intensive steam trap assessment system. The extra investment is most likely to be cost-effective in steam systems serving heating equipment with relatively large loads and, hence, relatively large steam traps. Larger steam traps, when failed open, result in larger, more expensive leaks. Industrial process heating applications would be most attractive for this type of assessment system, but space-heating applications should not be excluded from consideration.

What to Avoid

The retrofit of sight glasses or test valves allowing a visual assessment of steam trap performance should be carefully considered. While visual assessment is judged by the majority of steam trap experts to be the best assessment technique, the cost of retrofitting this type of equipment is significantly greater than any portable temperature or sonic test equipment and comparable to conductivity-based test equipment. The latter has the advantage of being wired for continuous, remote monitoring, however, which should reduce operating costs and improve steam system efficiency for a relatively modest incremental investment, compared to sight glasses or test valves.

Equipment Integration

Portable steam trap test equipment, which includes all of the ultrasonic devices described in this FTA as well as most temperature-measuring equipment, requires no integration with the steam distribution system. On the other hand, conductivity-based and visual-based test equipment must be plumbed into the distribution system. Some steam traps have built-in conductivity sensor chambers, but most utilize a separate sensor chamber. Either approach requires isolation of the steam trap and surrounding piping and insertion of a new device (either a new steam trap with a sensing chamber or a separate sensing chamber). Sight glasses and test valves require a similar retrofit. Conductivity chambers, sight glasses, and test valves are generally available in models allowing threaded, flanged, or welded connections to suit pipeline-specific requirements, but all require at least a moderate amount of pipefitting labor to install.

Maintenance Impact

All steam trap performance assessment equipment will require incremental labor to collect and evaluate test data. Much of this incremental labor is associated with walking from one trap to another with portable test equipment. This requirement can be eliminated with hard-wired, remotely accessed, conductivity-based systems, however, with incremental labor limited to periodic review and evaluation of the centrally collected data. Steam trap replacement costs will increase, of course, compared to not having a proactive steam trap maintenance program. Otherwise, maintenance of the performance assessment equipment itself is generally expected to be negligible. A notable exception would be sight glasses, which may require periodic removal and cleaning to maintain clarity.

Equipment Warranties

A one-year warranty is standard for most steam trap performance equipment and manufacturers covered in this FTA. An exception to this generalization is the Ultraprobe' ultrasonic system manufactured by UE Systems, Inc., which is warranted for five years.

Costs

The costs of steam trap performance-assessment equipment vary significantly, depending on the type, its features, and its size (for sight glasses and conductivity-based equipment that must be plumbed into the existing pipeline). Fixed frequency ultrasonic meters can be purchased for $600 or less up to about $2,000. Tunable ultrasonic test systems can usually be purchased for $3,000 to $5,000. The purchase cost of conductivity-sensing chambers and sight glasses varies from less than $100 to more than $1,000 per trap, depending on pipe diameter, pipe material, and the type of connection (welded, flanged, or threaded). Installation costs for conductivity test chambers and sight glasses are also significant and variable, although not generally as expensive or variable. Depending on pipe size and connection type, an additional $50–200 per trap can be expected.

Rough estimates of other costs associated with a proactive steam trap maintenance program are shown in Table 1.

Technology Performance

Ultrasonic testing equipment, applicable to a wide-range of technologies besides steam traps, has been used extensively in the Federal and private sectors. Conductivity-based test equipment and sight glasses, both more peculiar to steam trap assessment, have been used less frequently, but have still seen significant use. All of the steam trap performance assessment equipment included in this FTA could be described as mature. In all cases, hundreds or thousands of units or systems have been sold. In general, a substantial fraction of sales have been to the Federal sector, but specific sales data for Federal and non-Federal sectors and customer references were not always available. The specific experiences of available references are documented in this section. Contact information is provided in Appendix A.

Ted Tomaliwski of the National Institute of Standards and Technology (NIST) in Gaithersburg, Maryland, uses the CTRL Ultraphonic' ultrasonic tester. Ted works at the central steam, chilled water, and compressed air plant at the NIST facility. Steam produced at the central plant is primarily used for space heating. Ted uses the Ultraphonic to check for air leaks and malfunctioning steam traps. Ted told us the Ultraphonic "works well and is easy to use." Ted also uses a contact temperature probe to evaluate steam trap performance.

Charles McMullin has responsibility for exterior steam lines at Whiteman Air Force Base in Knobnoster, Missouri. Charles has used TLV's TrapMan' (an integrated ultrasonic and temperature measurement system with built-in diagnostics) for about 4 years, and considers it an improvement over temperature measurement devices that were previously used to evaluate steam traps. Charles notes that performance data are recorded by the system, so it takes very little time to conduct the tests. Overall, Charles says that he is "well satisfied" with the TrapMan system.

CIS Services operates the Electric Power Research Institute's Monitoring and Diagnostics Center. CIS provides instruction on the inspection of transformers, valves, and steam traps. They use Triple 5 Industries' ultrasonic leak detector for all of these applications. George Spencer of CIS says that Triple 5 Industries' ultrasonic leak detector is "the best system you can buy." In particular, George likes the battery-powered portability of the system, and claims the system is substantially faster than using temperature systems for assessing steam traps.

Peter Palamidis is the Preventive Maintenance Coordinator at Brookhaven National Laboratory in Upton, New York. Peter uses UE Systems' Ultraprobe™ 2000 to survey approximately 2,500 steam traps at his facility. Peter says the Ultraprobe is a "good system," and he was especially enthusiastic about the support that UE Systems provides its customers.

Case Study

Steam trap management programs were recently initiated at three Veterans Administration (VA) medical centers in the Northeast with the help of FEMP's SAVEnergy Program. The three VA hospitals were located in Providence, Rhode Island, and Brockton and West Roxbury, Massachusetts. Steam trap inspection and evaluation was included as part of broader audit of the steam generation, distribution, and end-use equipment at these three facilities. Steam traps were identified and evaluated to determine their performance and the value of steam losses from malfunctioning traps. Malfunctioning traps were designated for either repair or replacement. In addition, VA maintenance crews received trap-testing training as part of the continuing steam trap management program.

Facility Description

The key facility-level characteristics for a steam trap management program are the steam system pressure or pressures, the hours per year that the steam system is energized, and the marginal cost of producing steam that is lost in faulty traps. The steam pressure affects the rate of steam loss through a leaking trap as shown in Figure 10. Losses occur continuously at a constant rate (independent of end-use demand) whenever the steam system in energized, so care must be taken to estimate this factor correctly. Individual pieces of steam-heated equipment or sections of a system may be energized for different portions of the year. For example, space-heating lines may be shut off during the summer while domestic water heating is required year round. In addition, the use of automated control valves (or not) will significantly affect the fraction of time that a steam trap is energized. The marginal cost of steam will equal fuel cost divided by boiler efficiency at a minimum. Makeup water treatment costs should also be included for that fraction of the leaking steam that fails to return to the boiler feed water tank.

Multiple steam pressures were found at each of the three medical centers. The specific pressures were 110, 80, 40, and 15 psig at Providence; 120, 40 and 5 psig at Brockton; and 100, 55 and 5 psig at West Roxbury. Steam uses at all three facilities include space heating, water heating, food preparation, equipment sterilization, and laundry. Steam usage ranged from 12–52 weeks per year for the various processes. Steam losses were valued at $5.25 per 1,000 pounds of steam at Providence and $4.25 per 1,000 pounds of steam at Brockton and West Roxbury.

Existing Technology Description

Trap-specific characteristics must be collected via inspection and evaluation to accurately estimate annual steam loss. The size, type, manufacturer, and model should be identified. This information is used to identify the effective orifice size if the trap has failed in a fully open condition. Interpretation of trap operating condition via one of the methods previously described is required to judge whether a trap is operating correctly or not, if it has failed in an open or closed position, and the degree of failure if less than fully open. Accurately determining the effective orifice size for a trap determined to have failed in an open or partly open position requires detailed knowledge of the trap design (acquired from the trap vendor) and experience evaluating traps. Thus, it may be more cost-effective to hire the services of a company that specializes in trap testing and evaluation than to conduct the assessment with in-house personnel. Sites with larger steam systems and more traps are more likely candidates for developing their own capabilities, but availability of maintenance staff is often the limiting factor.

The trap inspection and evaluation company contracted for the VA assessment identified the trap location, manufacturer, type, model (in some cases), nominal pipe diameter, inlet and outlet pressure, steam supply control, and steam service for each steam trap. Again, knowledge of steam service (e.g., water heating, space heating, equipment sterilization, main and header drip legs, etc.) and steam supply control to the service is essential for estimating the number of hours a year that each trap will be energized and potentially leaking. The balance of the information collected is oriented toward determining the leak rate.

Providence has by far the greatest number of traps of the three facilities with 1109 units. Brockton and West Roxbury have 202 and 95 traps, respectively. Unfortunately, the trap inspection was conducted in the spring at Providence and summer at Brockton and West Roxbury when most, if not all of the traps servicing space-heating equipment were not in use. Thus, it was not possible to test approximately 70% of the traps at Providence and approximately 40% of the traps at Brockton and West Roxbury. Of the remaining traps, 51, 47, and 5 were found to have failed in the open position at Providence, Brockton, and West Roxbury, respectively. Among those determined to have failed opened, each was classified as leaking at a low, medium, or high rate relative to the leak rate for each trap if it failed fully open. Thus, the estimated annual leak rate is a function of the trap orifice if fully open, the degree of openness of the failure, the differential pressure across the trap, and the number of hours the trap is energized.

New Technology Equipment Selection

The energy savings in this case study come from repairing and replacing steam traps that have failed in a fully or partly open position and were leaking steam into the condensate system. No change in steam trap technology was considered. Instead, a change in maintenance practice was recommended. Selection of the steam trap testing equipment is not nearly as important as the decision to conduct testing. Using the most rudimentary trap testing equipment will probably cut trap-related steam losses by more than 50%. Using any of the testing equipment described in this Federal Technology Alert will probably cut trap-related steam losses by at least 75%. In general, more sophisticated testing equipment and more frequent testing is warranted for larger traps operating at higher pressures, where the potential steam loss rate is the highest.

Savings Potential

The savings potential for each trap can be calculated from an estimate of the orifice size associated with a leaking trap (i.e., the size of the hole that steam is leaking through, which will be less than or equal to its orifice size when a trap is fully open), the steam pressure, the fraction of the year that the trap is energized, and the boiler efficiency. Figure 10 shows how annual energy losses vary with equivalent hole (orifice) diameter and steam pressure.

Annual steam losses were estimated to be 3,561, 16,591, and 733 thousand pounds per year at the Providence, Brockton, and West Roxbury medical centers, respectively. Steam was valued at $5.25 per thousand pounds at Providence and $4.25 per thousand pounds at Brockton and West Roxbury. Thus, the total annual costs of the losses (and the expected annual savings if fixed) were estimated to be $18,695 at Providence, $70,511 at Brockton, and $3,117 at West Roxbury.

Life-Cycle Costs

Trap inspection and evaluation at the VA medical centers was included as part of broader energy audits addressing other components of the steam generation and distribution systems. The trap-related portion of the energy audit costs were estimated by the contractor to average $9.70 per trap, while trap replacement was estimated to cost $94 each.[4] Thus, total trap replacement costs were estimated to be $5076, $4512, and $470 at Providence, Brockton, and West Roxbury, respectively. Combining these investment costs with the annual savings estimates noted above yields payback periods of 0.27, 0.06, and 0.15 years for the three medical centers in the same order. Note that "sunk" cost associated with trap testing does not figure into the economic assessment affecting the decision to replace the traps or not. Also note that this assessment focuses on the costs and savings of the traps identified as failed and needing replacement. The estimated savings for these traps will continue until these traps start to fail. The average trap lasts for about 5 years, with some lasting longer and some failing sooner.

The Technology in Perspective

Proactive steam trap management programs have proven themselves to be cost-effective. The most important decision is making a commitment to implement a program; the specific testing equipment chosen is of lesser importance. Still, site-specific steam system and maintenance resource characteristics (e.g., number and size of traps, availability of capital and labor) will affect the preferred testing technology. In the future, continued improvement of performance assessment technologies should allow even greater cost-effective energy savings.

The Technology's Development

Sight, sound, and temperature measurements have been used to assess the performance of steam traps since steam traps were invented, but the measuring technology has evolved over the years. Equipment using a fourth method, based on the conductivity of the fluid at a specific point in the pipeline, has been developed in recent years.

In steam systems without condensate return, steam leaking past a trap is directly visible. With condensate return, a test tee and two valves (one to isolate the trap being tested from the influence of other traps, the other to provide an outlet for viewing the fluid downstream of the trap being tested) are all that's required. Thus, the standard technology for conducting a visual test has remained unchanged since steam traps were invented. Sight glasses provide an alternative approach to visual assessment that can be used without affecting system operation, but are prone to fouling in some service conditions.

Sound measurement has progressed from a screwdriver to a more comfortable mechanic's stethoscope to ultrasonic listening devices. The former two assist with hearing sounds in the normal audible range of the human ear, while the latter detects normally inaudible sounds of higher frequency and converts the signal into audible sounds. Simpler ultrasonic listening devices are tuned to a fixed frequency or frequency range, while more advanced models allow tuning to a specific frequency or frequency range. More recently, acoustic signatures representative of properly working and failed traps have been stored in the memory of ultrasonic listening devices for comparison with current readings. This allows the ultrasonic instrument to provide a diagnosis of trap condition without relying on the experience of the instrument user.

Temperature measurement tools have also progressed significantly over the years. Although a gloved-hand or squirt bottle may be adequate in some situations, much better accuracy can be easily achieved. Temperature measurement has progressed from these original "ballpark" approaches to temperature-sensitive materials that change color with temperature to several types of contact and non-contact devices. Earlier instruments were generally thermometers (i.e., devices that measure temperature based on the thermal expansion of various materials). More advanced contact devices are now based on either the thermoelectric potential of two dissimilar metals (thermocouple) or the variation in electrical resistance of a metal with temperature (thermistor). Contact temperature measurement is often coupled with ultrasonic measurement to provide an integrated steam trap testing unit. Non-contact devices allow the freedom and comfort of measuring temperature from a distance based on the thermal radiation emitted from an object's surface. The radiation entering a non-contact pyrometer is either focused on a heat-sensitive element such as a

[4] Note that $94 was estimated per trap replaced, while the figures in Table 1 are based on the total trap population. Thus, the figure of $40/trap in Table 1 incorporates assumptions about the fraction of traps initially needing replacement and the cost per replacement.

thermocouple or thermistor (radiation or infrared pyrometer) or its intensity is compared to that of reference element (optical pyrometer).

Conductivity measurement is a relatively new approach for evaluating steam traps. A probe inserted into the pipeline can easily distinguish between the conductivity of steam or condensate. The probe must be positioned at a location where normally it would be covered by condensate, but failure would cover it with steam or vice versa. Special sensing chambers create a flow path and precise point for inserting a probe. Conductivity probes, also often coupled with contact temperature measurement devices, can be wired to a central, remote monitoring device that receives signals from many probes. This minimizes subsequent data collection efforts, but does cost more to purchase and install than ultrasonic test equipment, which is portable.

Technology Outlook

Steam trap testing equipment is relatively mature, but evolutionary progress is expected to continue. Advances in electronics have spurred the development of new steam trap testing equipment and reduced the cost of basic ultrasonic and temperature measurement instruments. This trend is expected to continue. Future advances in ultrasonic measurement might reduce costs enough to allow meters to be permanently attached to individual steam traps like conductivity probes and sensing chambers. This would allow central, remote monitoring of ultrasonic measurements.

Manufacturers

The number of technologies that could potentially be applied to the evaluation of steam trap performance is extensive. In general, the manufacturer list that follows was limited to those making technologies that are peculiar to the evaluation of steam traps. This excluded, for example, all temperature-measuring devices. An exception to this general exclusion was made for ultrasonic testing equipment, however.

Steam trap evaluation technologies and associated manufacturers were identified by contacting steam trap and ultrasonic testing equipment manufacturers listed in product directories published by *Thomas Register, Chemical Engineering, Energy Products, Heating/Piping/Air-Conditioning, Energy User News,* and *Consulting Specifying Engineer.* We also conducted searches of Internet web sites and library databases. Despite our efforts, it is practically impossible to ensure that all manufacturers of steam trap performance assessment equipment have been identified. In fact, given the broad scope of potentially applicable equipment, some manufacturers have surely been missed. To those, we extend our apologies.

The search process identified 13 products offered by 10 companies in four generic categories. The four categories were 1) ultrasonic listening devices (with or without accompanying temperature-measuring devices) with built-in diagnostic capability, 2) conductivity measuring devices (with or without accompanying temperature-measuring devices) with built-in diagnostic capability, 3) ultrasonic listening devices (tunable or fixed frequency bandwidth, with or without accompanying temperature-measuring devices) without built-in diagnostic capability, and 4) a sight glass for visual determination of steam trap condition. A detailed description of each product, including manufacturer contact information, is presented in Appendix A.

The 10 companies offering these steam trap products are:

– Armstrong International, Inc.
– CTRL Systems, Inc.
– Electronics For Industry, Inc.
– GESTRA, Inc.
– Mitchell Instrument Co.
– Spirax Sarco, Inc.
– Superior Signal Company, Inc.
– TLV CORPORATION
– Triple 5 Industries, LLC.
– UE Systems, Inc.

Who is Using the Technology

Thousands of ultrasonic listening devices (without built-in steam trap diagnostics) have been sold to Federal and non-Federal customers. However, these devices can be used for evaluating an extremely broad range of other equipment, so the number used for evaluating steam traps is unknown. Approximately 150 ultrasonic testing systems with built-in steam trap diagnostics also have been sold. Again, the specific number of Federal applications is unknown. Sales data for sight glasses and conductivity-based testing systems were unavailable. The following Federal contacts were identified by the manufacturers listed above as users of one or more of the steam trap monitoring technologies described in this *Federal Technology Alert*.

Ted Tomaliwski
National Institute of Standards and Technology
Quince Orchard and Clopper Road
Gaithersburg, Maryland
301-975-6983

George Spencer
CIS Services
440 Baldwin
Eddystone, Pennsylvania
800-745-9981

Charles McMullin
Whiteman Air Force Base
Building 410
Knobnoster, Missouri
660-687-5095

Peter Palamidis
Brookhaven National Laboratory
Building 097
Upton, New York
516-344-2462

For Further Information

Associations

International District Energy Association
1200 19th Street, N.W. Suite 300
Washington, DC 20036-2412
Tel: 202-429-5111
Fax: 202-429-5113
www.energy.rochester.edu/idea/

American Boiler Manufacturers Association
950 N. Glebe Road
Suite 160
Arlington, VA 22203-1824
Tel: 703-522-7350
Fax: 703-522-2665
www.abma.com

Council of Industrial Boiler Owners
6035 Burke Centre Parkway
Suite 360
Burke, VA 22015
Tel: 703-250-9042
Fax: 703-239-9042
www.cibo.org

Clearinghouse

Steam Challenge Clearinghouse
P.O. Box 43171
925 Plum Street, SE
Olympia, WA 98504-3171
Tel: 800-862-2086
Fax: 360-586-8303
Steamline@energy.wsu.edu

Other Web Sites

U.S. Department of Energy, Office of Industrial Technologies Steam Challenge Program
www.oit.gov/steam

Alliance to Save Energy
www.ase.org

Armstrong Steam Library
www.armstrong-intl.com/university/su.html

Guides and Handbooks

Armstrong International, Inc. 1995. *Steam Conservation Guidelines for Condensate Drainage*. Three Rivers, Michigan.

McCauley, J.F. 1995. *The Steam Trap Handbook*. The Fairmont Press, Inc. Lilburn, Georgia.

Naval Facilities Engineering Service Center. 1998. *Steam Traps—An Overview.* Port Hueneme, California.

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Pychewicz, F.S. 1985. "Steam Traps—The Oft Forgotten Energy Conservation Treasure." Published in the *Proceedings of the 1985 Industrial Energy Technology Conference and Exhibition.* Public Utility Commission of Texas, Austin, Texas.

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Vallery, S.J. 1982. " Are your steam traps wasting energy?" *Process Energy Conservation.* McGraw-Hill Publications Co, New York.

Appendixes

Appendix A: Steam Trap Monitoring Equipment Information

Appendix B: Federal Life-Cycle Costing Procedures and the BLCC Software

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Appendix A
Steam Trap Monitoring Equipment Information

Manufacturer: Armstrong International, Inc.
Address: 816 Maple Street, PO Box 408, Three Rivers, MI 49093
Phone: 616-273-1415
Fax: 616-278-6555
Contact: Scott French

Product Name: Trap Scan™/Trap Alert™

Description: Trap Scan is a remotely operated steam trap testing system with probes that are integrated with the body of the steam trap. Signals from individual traps/probes are communicated via wire to zone modules and from there to a single central processing unit (CPU) provided by Armstrong or a programmable logic controller (PLC) provided by the user. Trap Alert uses the same probe as the Trap Scan, but does not forward a signal to a central processing unit. Instead, the external portion of the probe is integrated with a visual signaling device.

Operating Mechanism: The probe measures the temperature and conductivity within the steam trap at a location near the bottom of an inverted bucket. The conductivity measurement indicates whether the measurement point is within steam or condensate. During normal operation, the probe should be covered with condensate, indicating that steam is not leaking or blowing through the trap. If the temperature is also within an acceptable preset range, normal operation would be indicated. If the probe is covered with condensate, but the temperature is below the preset range, the trap is presumed to have failed closed or be otherwise blocked. If the probe indicates it is covered by steam, the trap is presumed to be leaking or failed open, unless the trap is also cold. In this latter combination, the trap is probably serving an inactive device and has lost its prime.

How Applied: Trap Scan data collection is initiated by pressing a button on the CPU/PLC. The CPU/PLC polls steam traps by zone to determine temperature and conductivity at the probe tip. One zone module can take signals from up to eight traps, and up to 25 zones can feed into one CPU. The CPU processes the data and interprets each steam trap's condition. The CPU comes with an RS-232 serial communications port (for connection to a computer), and either a parallel communications port for use with an external printer or an optional integrated printer. Alternatively, the output could be viewed on a PLC monitor. Trap Alert for indoor service is activated by focusing a flashlight beam on the unit's photodetector. The beam activates the unit's batteries, which power three small indicator lights. A green light indicates a good condition; yellow means the trap is cold; red signals a leaking or blowing trap. Trap Alert for outdoor service is activated by a magnetic field (almost any type of magnet can be used). When activated, a bulb lights for 1-2 seconds if the trap is okay, for 10-15 seconds if the trap has lost its prime or is leaking or blowing steam, or flashes on and off for 10-15 seconds if the trap is cold.

Installation Requirements: The Trap Scan probe is screwed into the bottom of an inverted bucket steam trap. Wires are run from the external tip of each probe to the zone module and from each zone module to the CPU/PLC. Additional wiring or other communication hardware would be required to connect the Trap Scan CPU to a personal computer. 120 VAC power must also be provided to the CPU/PLC. The CPU, zone modules, probes, and probe interfaces are provided by Armstrong. The user supplies communication and power wiring, and any additional communication hardware for connecting to a computer. If the user chooses, they can provide their own PLC in lieu of the Trap Scan CPU, but would need a Trap Scan power supply module instead.

Application Limitations: Trap Scan is compatible with Armstrong Series 800 cast iron and Models 1811 and 2011 stainless steel inverted bucket traps. The unit is designed for services up to 400 psig and temperatures up to 450°F, indoors or outdoors.

Experience: Units sold/installed: About 75 Trap Scan systems are in use, ranging from 10 to 200 probes, as well as thousands of Trap Alerts.

Federal customers: Army

Federal references: None identified.

Purchase Cost: $150 for Trap Alert.

Warranty: Trap Scan and Trap Alert are covered by a 1-year warranty.

Installation Labor/Material/Cost: The incremental costs to install a Trap Alert steam trap are negligible compared to a standard steam trap. The total installed costs (purchase plus installation) for Trap Scan systems (including the trap) range from $400-700 per trap.

Operating Labor/Material/Cost: A single Trap Scan system can check the condition of up to 200 steam traps in a few minutes. No routine maintenance is required.

Manufacturer: CTRL Systems, Inc.
Address: 1902 Twin House Road, Oxford, PA 19363
Phone: 610-932-7006
Fax: 610-998-0588
Contact: Dean Smith

Product Name: Ultraphonic™ Detector Model 101

Description: The Ultraphonic is a portable, hand-held instrument for detecting and measuring ultrasonic sounds. Optional software allows collection and subsequent analysis of historical measurements.

Operating Mechanism: The flow of steam or condensate through a steam trap creates turbulence, which results in ultrasound. Ultrasonic frequencies between 20 and 100 kHz are detected, measured, and converted to audible frequencies between 100 Hz and 3 kHz. By converting the ultrasonic frequencies generated by an operating steam trap into the audible range, the Ultraphonic allows users to hear through a headphone and see on a meter sound characteristics that allow an assessment of a steam trap's condition.

How Applied: The tip of the Ultraphonic stethoscope is held on the steam trap, allowing ultrasonic frequencies to be measured and converted to audible sounds. The unit operates in a fixed frequency range. The user must be trained to identify and differentiate between the sounds expected from a properly functioning trap and the sounds from a trap that has failed close, failed open, or is leaking steam.

Installation Requirements: The Ultraphonic stethoscope and headphones are portable. No installation is required.

Application Limitations: Although the Ultraphonic can be applied to any type of trap, the sounds associated with properly working and failed traps vary with the type of trap, so training on the different types of traps installed at the user's facility is required. One user estimated the training time at as little as 1-2 hours. In addition, the tip of the stethoscope must be placed in direct contact with the steam trap, which may not always be possible.

Experience: Units sold/installed: Approximately 800 units have been sold.

Federal customers: Approximately 25-30% of the 800 units have been sold to military customers.

Federal reference: Ted Tomaliwski works at the central steam, chilled water, and compressed air plant for the National Institute of Standards and Technology in Gaithersburg, Maryland. Steam is produced primarily for facility heating. The Ultraphonic 101 is used to check for air leaks and malfunctioning steam traps, primarily low-pressure traps in the plant. He says the unit "works well and is easy to use." They also use a surface temperature probe to evaluate trap performance.

Ted Tomaliwski, National Institute of Science and Technology, Quince Orchard and Clopper Road, Gaithersburg, MD 20899, 301-975-6983.

Purchase Cost: $1995 for Model 101, not including optional software.

Warranty: The Model 101 is covered by a 1-year warranty.

Installation Labor/Material/Cost: There are no costs associated with installing the equipment, but users will need to be trained to distinguish the sounds of properly functioning traps from the sounds of different failure modes. The length of training depends on the user's familiarity with steam trap principles, but should require no more than 2-3 hours of classroom instruction, plus a hands on field session testing actual steam traps. CTRL has created a CD-ROM training tool for the system. They estimate 1-2 hours training plus 1-2 days of field tests to become familiar with steam trap testing.

Operating Labor/Material/Cost: Mostly the time required to walk from one steam trap location to the next and record the test results; sound measurement is instantaneous.

Manufacturer: Electronics For Industry, Inc.
Address: 18633 S.W. 105th Ave. Miami, FL 33157
Phone: 305-233-1640
Fax: 305-233-1776
Contact: George Harris

Product Name: W-7 Microsonic Detector

Description: The Microsonic Detector is a portable, hand-held instrument for detecting and measuring ultrasonic sounds. The W-7 model is a hand-held "gun" that incorporates a meter indicating the strength of the noise. The EL-300 microsonic stethoscope is also offered, but does not incorporate the visual meter reading.

Operating Mechanism: The flow of steam or condensate through a steam trap creates turbulence, which results in ultrasound. Ultrasonic frequencies between 20 and 100 kHz are detected, measured, and converted to audible frequencies between 100 Hz and 3 kHz. By converting the ultrasonic frequencies generated by an operating steam trap into the audible range, the W-7 allows users to hear through a headphone and see on a meter sound characteristics that allow an assessment of a steam trap's condition.

How Applied: The tip of the W-7 gun is held on the steam trap, allowing ultrasonic frequencies to be measured and converted to audible sounds. The W-7 listens for noise in the 40 kHz region. The user must be trained to identify and differentiate between the sounds expected from a properly functioning trap and the sounds from a trap that has failed close, failed open, or is leaking steam.

Installation Requirements: The W-7 gun and headphones are portable. No installation is required.

Application Limitations: Although the W-7 can be applied to any type of trap, the sounds associated with properly working and failed traps varies with the type of trap, so training on the different types of traps installed at the user's facility is required. In addition, the most accurate results will be achieved when the tip of the gun can be placed in direct contact with the steam trap, which may not always be possible. Although an attachment will allow measurement of airborne signals, it's often difficult to distinguish the source of the signal when operating in this mode, especially in a process plant environment where there are many signal sources.

Experience: Units sold/installed: Manufactured since 1967, with sales to many DoD sites.
Federal customers: None identified.
Federal references: None identified.

Purchase Cost: $699 for W-7 Microsonic Detection Kit, which includes detector body, leak and stethoscope plug-in modules, rubber focusing extension, ultrasonic tone generator, headset, and carrying case.

Warranty: The W-7 is covered by a 1-year warranty.

Installation Labor/Material/Cost: There are no costs associated with installing the equipment, but users will need to be trained to distinguish the sounds of properly functioning traps from the sounds of different failure modes. The length of training depends on the user's familiarity with steam trap principles, but should require no more than 2-3 hours of classroom instruction, plus a hands on field session testing actual steam traps.

Operating Labor/Material/Cost: Mostly the time required to walk from one steam trap location to the next and record the test results; sound measurement is instantaneous.

Manufacturer: GESTRA, Inc.
Address: 10 York Avenue; W. Caldwell, NJ 07006
Phone: 973-403-1556
Fax: 973-403-1557
Contact: Ed Ilg

Product Name: Vaposcope VK

Description: A Vaposcope is a double-sided sight glass that allows visual supervision of flow conditions in pipelines.

Operating Mechanism: Where steam and condensate are present, the steam will pass over the top of the condensate because of its lower density. The internals of the Vaposcope include a flow deflector and condensate basin to aid recognition of the mixture of steam and condensate within the pipe (see Figure 7 in the main text). Steam and condensate are forced through the basin by the deflector. Normal operation is indicated by slight turbulence and a condensate level that just covers the bottom of the deflector. Higher steam flow rates, indicating a leaking or blowing trap, will create more turbulence and depress the condensate level below the deflector. If no turbulence is seen and the deflector is completely covered with condensate, a downstream blockage has occurred, potentially by a failed or undersized steam trap.

How Applied: The Vaposcope is installed directly in a pipeline like a valve. Flow conditions are manually observed through the site glass as described above to judge the condition of nearby steam traps.

Installation Requirements: An existing pipeline would have to be cut open and a short section taken out to allow the Vaposcope to be inserted. Flanges would have to be welded to the two pipe ends or the Vaposcope would have to be welded directly into the pipeline. A threaded version is also available.

Application Limitations: Vaposcopes are available for application at pressures up to 580 psig in nominal pipe diameters of 0.5-2 inches. Applications will be limited to locations where space exists to insert the Vaposcope into the pipe and where physical access allows visual inspection.

Experience: Units sold/installed: Thousands of Vaposcopes have been sold.

Federal customers: None identified.

Federal references: None identified.

Purchase Cost: $518-946.

Warranty: The Vaposcope is covered by a 1-year warranty.

Installation Labor/Material/Cost: Same as installing a steam trap.

Operating Labor/Material/Cost: The time required to walk from one Vaposcope location to the next and record the observation/condition assessment.

Manufacturer: GESTRA, Inc.
Address: 10 York Avenue; W. Caldwell, NJ 07006
Phone: 973-403-1556
Fax: 973-403-1557
Contact: Ed Ilg

Product Name: Test Set VKE

Description: The Test Set is a conductivity measuring device mounted in its own test chamber.

Operating Mechanism: The difference in steam and condensate conductivity is used to identify the presence of steam or condensate at the sensor.

How Applied: The test set is installed upstream of a steam trap. During normal operation, the sensor is immersed in condensate. If the steam trap is leaking sufficient steam, the increased steam flow will result in steam covering the sensor. The sensor is read by temporary electrical connection to a portable test unit or permanent connection to a remote test unit. The remote unit is capable of monitoring up to 18 sensors. The portable test unit shows a green light if condensate is detected and a red light if steam is detected. The remote unit also shows a red light if steam is detected, but no light if condensate is detected. Note that the steam trap could be failed shut, flooding the sensor with condensate, but indicating that operation is normal. Therefore, this device must be used in conjunction with a temperature measurement to make sure that flooding has not occurred. Condensate backup is indicated by a temperature that is lower than expected for normal saturated steam conditions.

Installation Requirements: An existing pipeline would have to be cut open and a short section taken out to allow the Test Set to be inserted. Flanges would have to be welded to the two pipe ends or the Test Set would have to be welded directly into the pipeline. The remote unit would require installation of connecting wiring.

Application Limitations: Test Sets are available for application at pressures up to 465 psig. Applications will be limited to locations where space exists to insert the Test Sets into the pipe. Relatively easy physical access is desirable for manual inspection.

Experience: Units sold/installed: Hundreds of Test Sets have been sold.

Federal customers: None identified.

Federal references: None identified.

Purchase Cost: $3200-3800 for remote test unit. The manual test unit costs $400 and the test chambers range from $350–400, depending on the fitting size.

Warranty: The Test Set VKE is covered by a 1-year warranty.

Installation Labor/Material/Cost: Chamber installation is about the same as installing a steam trap. Add wire and conduit costs of about $0.15 per foot each, plus labor to lay conduit.

Operating Labor/Material/Cost: Manual testing will require time to walk from one Test Set location to the next and record the observation/condition assessment. Even with the remote unit, a complete assessment of steam trap condition will require walking from trap to trap to collect temperature data, so labor savings with the remote unit appear minimal.

Manufacturer: GESTRA, Inc.
Address: 10 York Avenue; W. Caldwell, NJ 07006
Phone: 973-403-1556
Fax: 973-403-1557
Contact: Ed Ilg

Product Name: Trap Test VKP 30 – Available in spring 1999

Description: Trap Test is a computerized steam trap management system. The system consists of a hand-held measuring transducer, a portable computer, and Trap Test software. This is an updated version of the Trap Test VKP 20, with added features such as a weather/shock proof case, audio output, and compatibility with a Windows™ operating system (previously DOS).

Operating Mechanism: Ultrasonic measurements are compared to expected measurements stored in the computer for the specific trap being tested. The computer judges whether the steam trap is operating correctly or not, rather than relying on the judgment of the testing personnel. Data collected by Trap Test can be downloaded later to a personal computer via an accessory cable if desired.

How Applied: Data are collected by placing the transducer tip on the steam trap. The specific point depends on the trap type and make. Ultrasonic vibrations are converted by the transducer to electrical pulses and transmitted as digital pulses to the computer. The signal is presented on a screen and can be printed or stored electronically for future comparisons with additional tests. Data collection requires about 10-25 seconds. Based on the ultrasonic signal recorded, the computer determines whether the steam trap is leaking steam or not. Data can be stored for up to 1100 traps per removable data storage cards. In addition to diagnostic results, survey dates, trap characteristics, location information, and tester comments can be stored. The software will also automatically prepare repair orders. Universal application with all trap types and makes is possible.

Installation Requirements: The Trap Test hardware is portable. No installation is required.

Application Limitations: The Trap Test measuring transducer must be placed on the steam trap, so immediate physical access to the trap being tested is required. Training time for the Trap Test is estimated by the vendor to be about 10 hours.

Experience: Lab tests: The VKP 30 is currently in lab testing. Since most of the components are adapted from the VKP 20, or are purchased components used in other systems (i.e. computer and case) the system is expected to require little additional field testing.

Units sold/installed: About 100 Trap Test VKP 20 systems were installed.

Federal customers: None Identified.

Federal references: None Identified.

Purchase Cost: $5,000 – 7,000.

Warranty: The Trap Test VKP is covered by a 1-year warranty.

Installation Labor/Material/Cost: None**.**

Operating Labor/Material/Cost: The time required to walk from one steam trap to the next and record the observation/condition assessment.

Manufacturer: GESTRA, Inc.
Address: 10 York Avenue; W. Caldwell, NJ 07006
Phone: 973-403-1556
Fax: 973-403-1557
Contact: Ed Ilg

Product Name: Vapophone VKP-Ex

Description: The Vapophone is a portable, hand-held instrument for detecting and measuring ultrasonic sounds.

Operating Mechanism: The flow of steam through a steam trap creates turbulence, which results in ultrasound. Steam flow ultrasonic frequencies between 40 and 60 kHz are detected, measured, converted to an electronic signal, and displayed on an analog meter. The meter reading is used to make an assessment of a steam trap's condition.

How Applied: The tip of the Vapophone probe is held on the steam trap, allowing ultrasonic frequencies to be measured and converted to an analog meter reading. The unit operates at a fixed frequency range. The magnitude of the analog meter reading is proportional to steam leakage. The user must first calibrate the Vapophone against a steam trap that is known to leak, preferably one that is similar to others to be tested.

Installation Requirements: The Vapophone is portable. No installation is required.

Application Limitations: Although the Vapophone can be applied to any type of trap, the sounds associated with properly working and failed traps varies with the type of trap, so calibration of the meter for the different types of traps installed at the user's facility is required. Training the operator to recognize failures in different types of traps is estimated by the manufacturer to require from 5-8 hours. In addition, the probe must be placed in direct contact with the steam trap, which may not always be possible.

Experience: Units sold/installed: Hundreds of Vapophones have been sold.

Federal customers: None identified.

Federal references: None identified.

Purchase Cost: $1545.

Warranty: The Vapophone VKP-Ex is covered by a 1-year warranty.

Installation Labor/Material/Cost: There are no costs associated with installing the equipment, but users will need to be trained to distinguish the sounds of properly functioning traps from the sounds of different failure modes. The length of training depends on the user's familiarity with steam trap principles, but should require no more than 2-3 hours of classroom instruction, plus a hands-on field session testing actual steam traps.

Operating Labor/Material/Cost: Mostly the time required to walk from one steam trap location to the next and record the test results; sound measurement is instantaneous.

Manufacturer: Mitchell Instrument Co.
Address: 1570 Cherokee Street, San Marcos CA 92069
Phone: 760-744-2690
Fax: 760-744-0083
Contact: Chris

Product Name: Ultrasonic Noise Detector

Description: The Ultrasonic Noise Detector (UND) is a portable, hand-held instrument for detecting and measuring ultrasonic sounds, and measuring surface temperature.

Operating Mechanism: The flow of steam or condensate through a steam trap creates turbulence, which results in ultrasound. Ultrasonic frequencies between 20 and 200 kHz are detected, measured, and converted to audible frequencies between 100 Hz and 3 kHz. By converting the ultrasonic frequencies generated by an operating steam trap into the audible range, the UND allows users to hear through a headphone and see on a meter sound characteristics that allow an assessment of a steam trap's condition. The contact sensor incorporates a thermocouple that allows simultaneous temperature measurement. Digital readings of the monitoring frequency (kHz), sound level, (dB), and temperature are provided. An analog measure of sound level is also displayed.

How Applied: The tip of the UND "gun" is held on the steam trap, allowing ultrasonic frequencies to be measured and converted to audible sounds and temperature measurement via a thermocouple. The UND can be tuned in the full-range mode to any frequency within 20-200 kHz. For better results, the instrument would be more commonly operated in the limited-range mode, which allows tuning to frequencies within 36-44 kHz. This allows differentiation between steam and condensate flows while reducing interference from other ultrasonic signals and ignoring frequencies outside of this range. The user must be trained to identify and differentiate between the sounds expected from a properly functioning trap and the sounds from a trap that has failed close, failed open, or is leaking steam.

Installation Requirements: The UND gun and headphones are portable. No installation is required.

Application Limitations: Although the UND can be applied to any type of trap, the sounds associated with properly working and failed traps varies with the type of trap, so training on the different types of traps installed at the user's facility is required. In addition, the most accurate results will be achieved when the tip of the gun can be placed in direct contact with the steam trap, which may not always be possible. Although an attachment will allow measurement of airborne signals, it's often difficult to distinguish the source of the signal when operating in this mode, especially in a process plant environment where there are many signal sources. The contact sensor may be exposed to 500°F conditions continuously or up to 800°F intermittently.

Experience: Units sold/installed: Several hundred Ultrasonic Noise Detectors are sold each year.

Federal customers: None identified.

Federal references: None identified.

Purchase Cost: The complete package, including ultrasonic gun, airborne sensor, contact sensor with temperature capability, test tone generator, battery charger, soundproof headphones, flexible focus sensor adapter, and carrying case costs $4200. The cost for individual components of the package are: ultrasonic gun: $2900; airborne sensor: $150; contact sensor: $450; test tone generator: $105; battery charger: $60; headphones: $395; flexible focus sensor adapter: $10.

Warranty: The Ultrasonic Noise Detector is covered by a 1-year warranty.

Installation Labor/Material/Cost: There are no costs associated with installing the equipment, but users will need to be trained to distinguish the sounds of properly functioning traps from the sounds of different failure modes. The length of training depends on the user's familiarity with steam trap principles, but should require no more than 2-3 hours of classroom instruction, plus a hands on field session testing actual steam traps.

Operating Labor/Material/Cost: Mostly the time required to walk from one steam trap location to the next and record the test results; sound measurement is instantaneous.

Manufacturer: Spirax Sarco, Inc.
Address: 1150 Northpoint Boulevard, Blythewood, SC 29016
Phone: 803-714-2000
Fax: 803-714-2200
Contact: Dennis Kacsur

Product Name: Spira-Tec™

Description: The Spira-Tec steam trap fault detection system consists of a sensing chamber, sensor, and a portable or remotely installed monitor connected by cable for determining temperature and the presence of steam or condensate. Manual or automatic remote units are available that are able to serve up to 12 and 16 steam traps, respectively.

Operating Mechanism: The Spira-Tec sensor measures the temperature and conductivity of the fluid present at the measuring point in the sensing chamber. Differences in conductivity identify the fluid as steam or condensate. Under normal operation, the sensing point is covered with condensate near the temperature of saturated steam at the local line pressure. Increased steam flow resulting from a leaky trap will bathe the sensing point in steam rather than condensate. A drop in temperature indicates a trap that has failed closed, is blocked, or is not in service.

How Applied: The sensing chamber with sensor is installed directly in the pipeline, just upstream from the steam trap. A portable testing instrument is connected to the sensor. Normal operating conditions are indicated by a green light. A yellow light indicates a trap that has failed closed or is blocked, or is out of service. A red light indicates a trap that has failed open. Up to 12 sensors may be connected to single remote test point for more convenient testing with a portable monitor. Alternatively, an automatic monitor that combines the functions of a remote test point and portable monitor can be connected to as many as 16 sensors. The automatic monitor may also be connected to external building operating and control systems.

Installation Requirements: An existing pipeline would have to be cut open and a short section taken out to allow the sensing chamber to be installed. Sensing chambers accommodating screwed, flanged, or welded connections are available. The manual or automatic remote units require mounting and installation of connecting wiring. The portable monitor is battery-powered, while the automatic monitor must be connected to an external power supply

Application Limitations: Stainless steel and ductile iron sensor chamber models are available in 1/2-, 3/4-, and 1-inch diameter sizes; steel models are also available in 1- and 2-inch diameter sizes. The maximum operating pressure is 464 psig and the maximum operating temperature is the saturated steam temperature corresponding to the operating pressure.

Experience: Spira-Tec has been available in the U.S. for about 15 years.

Units sold/installed: There are thousands of Spira-Tec customers, some with thousands of sensors.

Federal customers: None identified.

Federal references: None identified.

Purchase Cost: Sensor chambers vary from $61.50 for 1/2-inch threaded ductile iron up to $1384.60 for 1-inch flanged stainless steel. Sensors for measuring conductivity only cost $61.50. Combination conductivity and temperature sensors cost $170 for reading with the portable monitor and $195 for reading with the automatic monitor. The portable monitor costs $311.75. The automatic monitor costs $1770. Remote test points cost $155.40 and $398.85, respectively, for single-sensor and 12-sensor capacity models.

Warranty: The Spira-Tec system and components are covered by a 1-year warranty.

Installation Labor/Material/Cost: The user must provide cabling connecting the sensors to remote test points or an automatic monitor. Power wiring to the automatic monitor must also be supplied. Labor is required to install these materials as well as the sensor chambers, sensors, remote test points, and automatic monitor. Installation costs are highly site specific.

Operating Labor/Material/Cost: The time required to walk from one steam trap to the next and record the observation/condition assessment. The time required can be reduced through the use of remote test points or an automatic monitor.

Manufacturer: Superior Signal Company, Inc.
Address: P.O. Box 96, Spotswood, NJ 08884
Phone: 732-251-0800
Fax: 732-251-9442
Contact: Paul Tashian

Product Name: AccuTrak® VPE-1000

Description: The AccuTrak VPE-1000 is a portable, hand-held instrument for detecting and measuring ultrasonic sounds.

Operating Mechanism: The flow of steam or condensate through a steam trap creates turbulence, which results in ultrasound. Ultrasonic frequencies between 20 and 100 kHz are detected, measured, and converted to audible frequencies between 100 Hz and 3 kHz. By converting the ultrasonic frequencies generated by an operating steam trap into the audible range, the AccuTrak allows users to hear through a headphone and see on a meter sound characteristics that allow an assessment of a steam trap's condition.

How Applied: The tip of the AccuTrak "gun" is held on the steam trap, allowing ultrasonic frequencies to be measured and converted to audible sounds. The AccuTrak can be tuned to any frequency within 20-100 kHz, which allows differentiation between steam and condensate flows while reducing interference from other ultrasonic signals and ignoring frequencies outside of this range. The user must be trained to identify and differentiate between the sounds expected from a properly functioning trap and the sounds from a trap that has failed close, failed open, or is leaking steam.

Installation Requirements: The AccuTrak gun and headphones are portable. No installation is required.

Application Limitations: Although the AccuTrak can be applied to any type of trap, the sounds associated with properly working and failed traps varies with the type of trap, so training on the different types of traps installed at the user's facility is required. In addition, the most accurate results will be achieved when the tip of the gun can be placed in direct contact with the steam trap, which may not always be possible. Although an attachment will allow measurement of airborne signals, it's often difficult to distinguish the source of the signal when operating in this mode, especially in a process plant environment where there are many signal sources.

Experience: Units sold/installed: The AccuTrak has been sold to hundreds of customers.

Federal customers: None identified.

Federal references: None identified.

Purchase Cost: $600.

Warranty: The AccuTrak VPE-1000 is covered by a 1-year warranty.

Installation Labor/Material/Cost: There are no costs associated with installing the equipment, but users will need to be trained to distinguish the sounds of properly functioning traps from the sounds of different failure modes. The length of training depends on the user's familiarity with steam trap principles, but should require no more than 2-3 hours of classroom instruction, plus a hands on field session testing actual steam traps.

Operating Labor/Material/Cost: Mostly the time required to walk from one steam trap location to the next and record the test results; sound measurement is instantaneous.

Manufacturer: TLV CORPORATION
Address: 6701-K NorthPark Blvd.; Charlotte, NC 28216
Phone: 704-597-9070; 1-800-858-8727
Fax: 704-597-9082
Contact: Ottmar Hedemus
Product Name: TrapMan™

Description: TrapMan is a computerized steam trap management system. The system includes hand-held TM5, hardware that incorporates ultrasonic and temperature testing equipment with TLV diagnostic logic. Accompanying TrapManager™ software completes the system.

Operating Mechanism: Ultrasonic and temperature measurements are compared to expected measurements stored in the TM5 hardware for the specific trap being tested. The hardware judges whether the steam trap is operating correctly or not, rather than relying on the judgment of the testing personnel. Data collected by the TM5 unit can be downloaded later to the TrapManager software.

How Applied: Data are collected by placing the test probe tip on the inlet side of the steam trap. Data collection requires about 15 seconds. The TM5 unit compares measured conditions with stored conditions and returns one of the following diagnoses: good; small, medium, or large leak; blowing; blocked; low temperature; and temperature adjustment failure. Automatically diagnosed performance results can be modified manually, if necessary. Data can be stored for up to 2000 traps. In addition to the diagnostic result, survey date and time, surface temperature, identification number, and model can be stored. Expected operating characteristics for most traps available on the market can be accessed, including units made by Armstrong, Yarway, Spirax-Sarco, Gestra, Nicholson, Bestobell, Velan, Clark-Reliance, Erwell, Dunham-Bush, Hoffman, Trane, Illinois, and Wright-Austin, as well as TLV. Data are transferred from the TM5 to the TrapManager software via a communications cable supplied with the system.

Installation Requirements: The TM5 hardware is portable. No installation is required. TrapManager software is installed on the user's PC. Minimum PC system requirements are a Pentium™ 90 CPU with 16 MB of RAM, 20 MB of hard drive capacity, a CD-ROM drive, and a VGA monitor. TrapManager is Windows 95™, Windows 98™, and Windows NT™ compatible.

Application Limitations: The test probe must be placed on the steam trap, so immediate physical access to the trap being tested is required. The hardware is designed to work on steam pressures ranging from 7-570 psig and surface temperatures ranging from 32-662°F.

Experience: Units sold/installed: TrapMan systems are being used by over 150 private and public organizations.

Federal customers: Federal users include the Army, Navy, Air Force, Veterans Administration, and Brookhaven National Laboratory.

Federal reference: Charles McMullin has responsibility for exterior steam lines at Whiteman Air Force Base. He has used TrapMan for about 4 years, and considers it an improvement over temperature devices that were previously used to assess steam trap condition. Since trap data is stored in the system it takes very little time to enter the trap I.D. number and carry out the test. Charles says that he is "well satisfied" with TrapMan.

Charles McMullin, Whiteman Air Force Base, Building 140, Knobnoster, MO, 660-687-5095.

Purchase Cost: The cost of the complete TrapMan system is $17,500. This includes two days of training for two people (with hotel and meal expenses), one-year of unlimited software support, and rebates on TLV traps.

Warranty: TrapMan is covered by a 1-year warranty.

Installation Labor/Material/Cost: Trivial installation costs for software, no installation costs for hardware; 2-4 person-days of training.

Operating Labor/Material/Cost: Mostly the time required to walk from one steam trap location to the next; data recording takes only 15 seconds.

Manufacturer: Triple 5 Industries, LLC
Address: 213 Chesterfield Crosswicks Road; Trenton, New Jersey 08620
Phone: 609-298-5544
Fax: 609-298-5594
Contact: Trudy Bryson

Product Name: Sonic/Ultrasonic Leak Detectors

Description: The Triple 5 leak detectors are portable, hand-held instruments for detecting and measuring sonic and ultrasonic sounds. Optional equipment allows collection and subsequent transfer of data to a personal computer.

Operating Mechanism: The flow of steam or condensate through a steam trap creates turbulence, which results in ultrasound. Additional audible noise is also created by trap operation. Two frequency bands are monitored: 2-11 kHz in the sonic range and 20-180 kHz in the ultrasonic range. Ultrasonic frequencies are converted to audible frequencies for the human ear. The magnitude of the sound is also indicated via an LED display. By converting the ultrasonic frequencies generated by an operating steam trap into the audible range, the Leak Detectors allow users to hear through a headphone and see on the LED display sound characteristics that allow an assessment of a steam trap's condition.

How Applied: The tip of the Leak Detector probe is held on the steam trap, allowing sonic and ultrasonic frequencies to be measured, with the latter converted to audible sounds. The user must be trained to identify and differentiate between the sounds expected from a properly functioning trap and the sounds from a trap that has failed close, failed open, or is leaking steam.

Installation Requirements: The Leak Detectors are portable. No installation is required.

Application Limitations: Although the Leak Detector can be applied to any type of trap, the sounds associated with properly working and failed traps vary with the type of trap, so training on the different types of traps installed at the user's facility is required. In addition, the most accurate results will be achieved when the tip of the gun can be placed in direct contact with the steam trap, which may not always be possible. Although an attachment will allow measurement of airborne signals, it's often difficult to distinguish the source of the signal when operating in this mode, especially in a process plant environment where there are many signal sources. The contact probe is limited to a maximum temperature of 350°F.

Experience: Units sold/installed: About 100.

Federal customers: None identified.

Federal references: None identified.

Commercial reference: CIS Services operates EPRI's Monitoring and Diagnostics Center. They provide courses, including utility training, on inspecting transformers, valves, and steam traps. The 5550 Sonic/Ultrasonic Leak Detector and 5551 Data Logging Leak Detector work for all of these applications. For steam traps, CIS uses a 2-hour class followed by a field trip, for a 1-day course. George Spencer of CIS says that these are "the best system you can buy." The 10-180 kHz band is the best for checking steam traps, but he uses both this and the lower frequency range. He likes the battery-powered portability of the system, and claims that they are substantially faster than thermograph/temperature systems for assessing steam traps.

George Spencer, CIS Services, 440 Baldwin, Eddystone, PA, 800-745-9981

Purchase Cost: $3414-5114. This price is for a test unit and all accessories. The low end of the range is for ultrasonic measurement only. The high end is for sonic and ultrasonic measurement with a data logger. An intermediate model that measures, but does not record sonic and ultrasonic sounds is also available.

Warranty: The systems are covered by a 1-year warranty.

Installation Labor/Material/Cost: There are no costs associated with installing the equipment, but users will need to be trained to distinguish the sounds of properly functioning traps from the sounds of different failure modes. The length of training depends on the user's familiarity with steam trap principles, but should require no more than 2-3 hours of classroom instruction, plus a hands on field session testing actual steam traps.

Operating Labor/Material/Cost: Mostly the time required to walk from one steam trap location to the next and record the test results; sound measurement is instantaneous.

Manufacturer: UE Systems, Inc.
Address: 14 Hayes Street; Elmsford, New York 10523
Phone: 914-592-1220
Fax: 914-347-2181
Contact: Terry O'Hanlon

Product Name: Ultraprobe™ 2000

Description: The Ultraprobe 2000 is a portable, hand-held instrument for detecting and measuring ultrasonic sounds.

Operating Mechanism: The flow of steam or condensate through a steam trap creates turbulence, which results in ultrasound. Ultrasonic frequencies between 20 and 100 kHz are detected, measured, and converted to audible frequencies between 100 Hz and 3 kHz. By converting the ultrasonic frequencies generated by an operating steam trap into the audible range, the Ultraprobe allows users to hear through a headphone and see on a meter sound characteristics that allow an assessment of a steam trap's condition.

How Applied: The tip of the Ultraprobe "gun" is held on the steam trap, allowing ultrasonic frequencies to be measured and converted to audible sounds. The Ultraprobe can be tuned to any frequency within 20-100 kHz, which allows differentiation between steam and condensate flows while reducing interference from other ultrasonic signals and ignoring frequencies outside of this range. The user must be trained to identify and differentiate between the sounds expected from a properly functioning trap and the sounds from a trap that has failed close, failed open, or is leaking steam.

Installation Requirements: The Ultraprobe gun and headphones are portable. No installation is required.

Application Limitations: Although the Ultraprobe can be applied to any type of trap, the sounds associated with properly working and failed traps vary with the type of trap, so training on the different types of traps installed at the user's facility is required. Training may take as little as 15 minutes according to UE Systems, however. In addition, the most accurate results will be achieved when the tip of the gun can be placed in direct contact with the steam trap, which may not always be possible. Although an attachment will allow measurement of airborne signals, it's often difficult to distinguish the source of the signal when operating in this mode, especially in a process plant environment where there are many signal sources.

Experience: Units sold/installed: The Ultraprobe has been sold to thousands of customers.

Federal customers: Includes the Navy, Coast Guard, NASA, Westinghouse Hanford, and several Department of Energy National Laboratories.

Federal reference: Peter Palamidis, Preventative Maintenance Coordinator at Brookhaven National Laboratory, uses the Ultraprobe 2000 to survey the approximately 2,500 traps at their facility. He says that the Ultraprobe is a "good system," and was especially enthusiastic about the support that UE provides to their customers. Formal training is accomplished with a short video, but Peter feels that a day in the field is required to become comfortable with use of the device.

Peter Palamidis, Preventive Maintenance Coordinator, Brookhaven National Laboratory, Building 097, Upton, New York 11973, 516-344-2462

Purchase Cost: Ranges from $3500 to $4900, depending on the specific accessories ordered.

Warranty: The Ultraprobe is covered by a 5-year warranty.

Installation Labor/Material/Cost: There are no costs associated with installing the equipment, but users will need to be trained to distinguish the sounds of properly functioning traps from the sounds of different failure modes. The length of training depends on the user's familiarity with steam trap principles, but should require no more than 2-3 hours of classroom instruction, plus a hands on field session testing actual steam traps.

Operating Labor/Material/Cost: Mostly the time required to walk from one steam trap location to the next and record the test results; sound measurement is instantaneous.

Appendix B
Federal Life-Cycle Costing Procedures and the BLCC Software

Federal agencies are required to evaluate energy-related investments on the basis of minimum life-cycle costs (10 CFR Part 436). A life-cycle cost evaluation computes the total long-run costs of a number of potential actions, and selects the action that minimizes the long-run costs. When considering retrofits, sticking with the existing equipment is one potential action, often called the *baseline* condition. The life-cycle cost (LCC) of a potential investment is the present value of all of the costs associated with the investment over time.

The first step in calculating the LCC is the identification of the costs. *Installed Cost* includes cost of materials purchased and the labor required to install them (for example, the price of an energy-efficient lighting fixture, plus cost of labor to install it). *Energy Cost* includes annual expenditures on energy to operate equipment. (For example, a lighting fixture that draws 100 watts and operates 2,000 hours annually requires 200,000 watt-hours (200 kWh) annually. At an electricity price of $0.10 per kWh, this fixture has an annual energy cost of $20.) *Nonfuel Operations and Maintenance* includes annual expenditures on parts and activities required to operate equipment (for example, replacing burned out light bulbs). *Replacement Costs* include expenditures to replace equipment upon failure (for example, replacing an oil furnace when it is no longer usable).

Because LCC includes the cost of money, periodic and aperiodic maintenance (O&M) and equipment replacement costs, energy escalation rates, and salvage value, it is usually expressed as a present value, which is evaluated by

$$LCC = PV(IC) + PV(EC) + PV(OM) + PV(REP)$$

where PV(x) denotes "present value of cost stream x,"
IC is the installed cost,
EC is the annual energy cost,
OM is the annual nonenergy O&M cost, and
REP is the future replacement cost.

Net present value (NPV) is the difference between the LCCs of two investment alternatives, e.g., the LCC of an energy-saving or energy-cost-reducing alternative and the LCC of the existing, or baseline, equipment. If the alternative's LCC is less than the baseline's LCC, the alternative is said to have a positive NPV, i.e., it is cost-effective. NPV is thus given by

$$NPV = PV(EC_0) - PV(EC_1)) + PV(OM_0) - PV(OM_1)) + PV(REP_0) - PV(REP_1)) - PV(IC)$$

or

$$NPV = PV(ECS) + PV(OMS) + PV(REPS) - PV(IC)$$

where subscript 0 denotes the existing or baseline condition,
subscript 1 denotes the energy cost saving measure,
IC is the installation cost of the alternative (note that the IC of the baseline is assumed zero),
ECS is the annual energy cost savings,
OMS is the annual nonenergy O&M savings, and
REPS is the future replacement savings.

Levelized energy cost (LEC) is the break-even energy price (blended) at which a conservation, efficiency, renewable, or fuel-switching measure becomes cost-effective (NPV >= 0). Thus, a project's LEC is given by

$$PV(LEC*EUS) = PV(OMS) + PV(REPS) - PV(IC)$$

where EUS is the annual energy use savings (energy units/yr). Savings-to-investment ratio (SIR) is the total (PV) savings of a measure divided by its installation cost:

$$SIR = (PV(ECS) + PV(OMS) + PV(REPS))/PV(IC).$$

Some of the tedious effort of life-cycle cost calculations can be avoided by using the Building Life-Cycle Cost software, BLCC, developed by NIST. For copies of BLCC, call the FEMP Help Desk at (800) 363-3732.

About the Federal Technology Alerts

The Energy Policy Act of 1992, and subsequent Executive Orders, mandate that energy consumption in the Federal sector be reduced by 35% from 1985 levels by the year 2010. To achieve this goal, the U.S. Department of Energy's Federal Energy Management Program (FEMP) is sponsoring a series of programs to reduce energy consumption at Federal installations nationwide. One of these programs, the New Technology Demonstration Program (NTDP), is tasked to accelerate the introduction of energy-efficient and renewable technologies into the Federal sector and to improve the rate of technology transfer.

As part of this effort FEMP is sponsoring a series of Federal Technology Alerts (FTAs) that provide summary information on candidate energy-saving technologies developed and manufactured in the United States. The technologies featured in the FTAs have already entered the market and have some experience but are not in general use in the Federal sector. Based on their potential for energy, cost, and environmental benefits to the Federal sector, the technologies are considered to be leading candidates for immediate Federal application.

The goal of the FTAs is to improve the rate of technology transfer of new energy-saving technologies within the Federal sector and to provide the right people in the field with accurate, up-to-date information on the new technologies so that they can make educated judgments on whether the technologies are suitable for their Federal sites.

Because the FTAs are cost-effective and timely to produce (compared with awaiting the results of field demonstrations), they meet the short-term need of disseminating information to a target audience in a timeframe that allows the rapid deployment of the technologies—and ultimately the saving of energy in the Federal sector.

The information in the FTAs typically includes a description of the candidate technology; the results of its screening tests; a description of its performance, applications and field experience to date; a list of potential suppliers; and important contact information. Attached appendixes provide supplemental information and example worksheets on the technology.

FEMP sponsors publication of the FTAs to facilitate information-sharing between manufacturers and government staff. While the technology featured promises significant Federal-sector savings, the Technology Alerts do not constitute FEMP's endorsement of a particular product, as FEMP has not independently verified performance data provided by manufacturers. Nor do the FTAs attempt to chart market activity vis-a-vis the technology featured. Readers should note the publication date on the back cover, and consider the FTAs as an accurate picture of the technology and its performance at the time of publication. Product innovations and the entrance of new manufacturers or suppliers should be anticipated since the date of publication. FEMP encourages interested Federal energy and facility managers to contact the manufacturers and other Federal sites directly, and to use the worksheets in the FTAs to aid in their purchasing decisions.

Federal Energy Management Program

The Federal Government is the largest energy consumer in the nation. Annually, in its 500,000 buildings and 8,000 locations worldwide, it uses nearly two quadrillion Btu (quads) of energy, costing over $8 billion. This represents 2.5% of all primary energy consumption in the United States. The Federal Energy Management Program was established in 1974 to provide direction, guidance, and assistance to Federal agencies in planning and implementing energy management programs that will improve the energy efficiency and fuel flexibility of the Federal infrastructure.

Over the years several Federal laws and Executive Orders have shaped FEMP's mission. These include the Energy Policy and Conservation Act of 1975; the National Energy Conservation and Policy Act of 1978; the Federal Energy Management Improvement Act of 1988; and, most recently, Executive Order 12759 in 1991, the National Energy Policy Act of 1992 (EPACT), Executive Order 12902 in 1994, and Executive Order 13123 in 1999.

FEMP is currently involved in a wide range of energy-assessment activities, including conducting New Technology Demonstrations, to hasten the penetration of energy-efficient technologies into the Federal marketplace.

For More Information

FEMP Help Desk

(800) 363-3732
International callers please use
(703) 287-8391
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