AERIAL INFRARED SURVEYS: PREDICTIVE TESTING FOR STEAM DISTRIBUTION

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Abstract: Predictive testing of high temperature hot water and steam distribution systems permits early identification of developing leaks. The inspection information can be used to prevent catastrophic failures and plan for capital improvements. Timely leak identification can reduce wasted energy, minimize repair costs and avoid system outages. Aerial infrared surveys are the primary tool for steam system predictive testing. New developments in infrared instruments have resulted in dramatically improved image quality along with enhanced surface temperature measurement accuracy. Of critical importance, surface temperature measurements allow steam system performance to be trended so that degradation or improvements can be accurately documented.

The call came into the dispatcher at 7:05 AM. The facilities engineer from the National Bank Center reported that temperatures in their basement computer room were up to 85°F and climbing and would soon force a shut down. He suspected a steam line break in front of the building.

Predictive testing of the steam distribution system would have permitted the distribution utility to find this problem before the facilities engineer's call.

Predictive testing is a maintenance concept that is now firmly embraced by many industries. Predictive maintenance emphasizes the use of test instrumentation to provide early warning of developing failures in production equipment. Early identification enables a maintenance response before production is lost through a catastrophic failure.

District heating systems are a highly efficient means of delivering heat energy from central plants to remote locations. However, mechanical failures will occur in the underground piping systems that carry steam from the plant to the end user. Mechanical failures typically start as small leaks. The leaks can grow, wasting substantial amounts of energy and ultimately evolving into catastrophic failures that cause property damage and interrupt steam system operation.

The application of predictive testing concepts to steam distribution utilities enables developing leaks to be identified long before catastrophic failure occurs. The benefits are early fault detection are substantial: Reduced energy losses, reduced repair costs, and enhanced system security. The tools of predictive testing can help prioritize problem severity and act as a system maintenance planning and budgeting tool.

Predictive Testing of Steam Lines: The Tools

The objective of Predictive Testing of steam and high temperature hot water lines is to identify, quantify and prioritize developing faults in underground lines. There are several tools available for predictive testing. The primary tool is the infrared imager. Problem verification can be conducted using seismic vibration measurements and subsurface thermocouple probes.

The infrared imager is a device that converts surface temperature differences into a video image. Developing steam system faults produce steam leaks. Steam leaks produce elevated ground surface temperatures. These elevated temperatures are readily identified using an infrared imager.

Infrared surveys are typically conducted from a helicopter flying at 500 to 1,000 feet of altitude. The procedure is highly efficient, covering 20-100 miles of steam line per hour.

Infrared surveys of steam systems have been conducted for nearly 20 years. Naturally, infrared equipment has evolved over this time period. Figure 1 shows a hot expansion loop at a manufacturing facility. This image was acquired in 1983. The image is qualitative—it contains no absolute temperature measurement capability. The thermal imager that produced this image could resolve a hot spot four feet across at 1,000 feet of altitude.

Temperature measurement is critical in steam line evaluations. The accurate measurement of temperature permits the relative severity of steam leaks to be evaluated. By quantifying problem severity, system planners can prioritize their capital improvement expenditures for maximum return. Further, temperature measurement permits the progress of a problem area to be tracked over time—both deterioration and improvement, before and after repairs are made.

Figure 1:1983 Image

Figure 2:1991 Image with Temperature Measurement

Figure 2 shows a steam line defect acquired in 1991. This image displays on-screen temperature measurement, which was a major advance in instrumentation. The instrument provided absolute temperature measurements of any point in the image. The ground surface temperature at the cross hair is 71.8^{o}F. The measurement capability of this instrument provided the basic data required for predictive testing. The thermal imager that produced this image could resolve a hot spot of two feet across at 1,000 feet of altitude. An accurate temperature measurement at 1,000 feet of altitude required a hot spot greater than 10 feet across.

A critical element of the predictive testing approach is the ability to spot changes by trending surface temperature data. This can be done only if this year's hot spots can be quantitatively compared with last year's system temperatures. Thus, an important element of thermal imaging arrived in 1995: relatively low cost, computer aided post-processing of videotaped infrared images. At least one infrared equipment manufacturer encodes all temperature measurement parameters in the VIR line of each frame of video. When the videotape is played back through a dedicated post-processor, the original temperature measurement for any point on the image is available. With this capability, the present temperature performance of any point on the steam distribution system can be compared with past performance. The appearance of a new problem area can be easily and accurately documented.

Figure 3 shows a post-processed image acquired in 1996. Post processing permits the measureemnt and annotation of actual temperatures right on the image.

Thermal imaging instruments prior to 1996 required a trade-off: instruments that measured temperature did not produce the highest quality images. Thus, temperature measurements were obtained at the price of reduced image quality. The analytical value of temperature data made this trade-off acceptable. This trade-off was eliminated in 1996 with the introduction of radiometric focal plane array imagers. (Radiometric means that a real temperature measurement can be obtained for each pixel in the image.)

Figure 4 was produced in 1998 using newest focal plane array infrared imager. This instrument eliminates the trade-off between image quality and temperature measurement—it provides excellent image quality and accurate temperature measurements. The thermal imager that produced this image can resolve a hot spot of one foot across at 1,000 feet of altitude. An accurate temperature measurement at 1,000 feet of altitude requires a hot spot of one foot across.

Figures 3 and 4 show the same location, and demonstrate temperature trending over time. Changes may be evaluated by comparing the temperature rise above ground temperature and each hot spot. The ground temperature in Figure 3 is 20.7^{o}F. The ground temperature in Figure 4 is 29.7^{o}F. The comparison is as follows:

Hot Spot	**'96 Temp Rise (^{o}F)**	**98 Temp Rise (^{o}F)**	**Comments**
1	38.5	42.6	No change
2	57.8	103.7	Severe degradation
3	48.9	23.1	Problem repaired

Figure 3:1996 Image, computer post processed

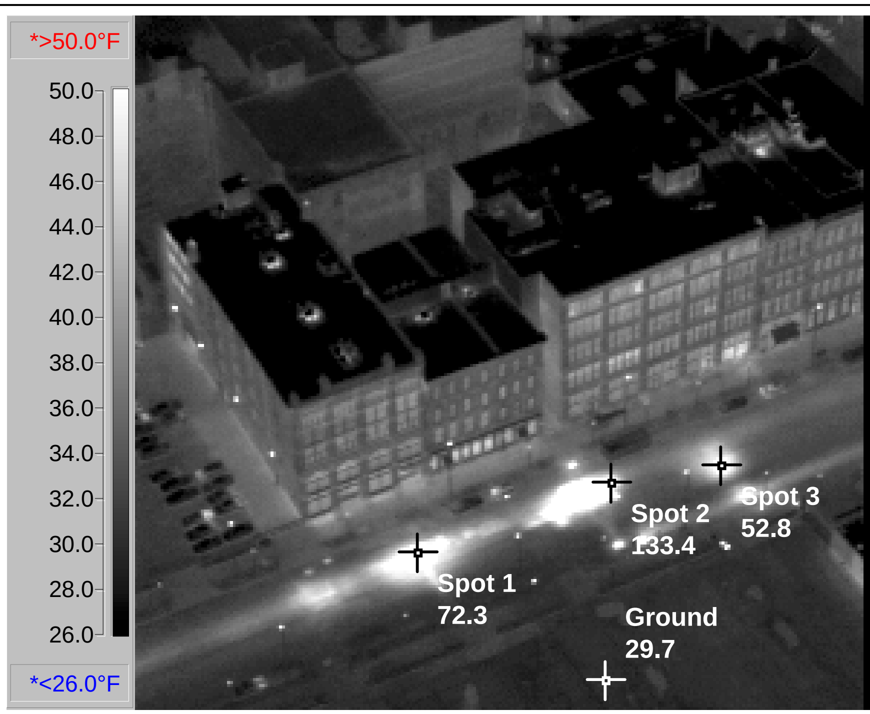

Figure 4:1998 Image

Verification—The Essential Final Step

Identifying the suspected problem is the first step of the analysis. Hot spots can be produced by leaks or defective insulation. Hot spots can also result from manholes, valve boxes, line anchors, changes in pipe depth and other physical structures. A useful assessment of system performance requires accurate evaluation of hot spot causes. Several verification tests are necessary.

The presence of manholes and valves can generally be determined from the thermal image and also from system drawings. Distinguishing between leaks and defective insulation requires further testing. Several methods are available. The simplest method is “sounding”. There are several commercially available instruments to “hear” the sounds produced by a steam leak. These systems utilize a microphone that is set on the pavement surface. The microphone detects vibration in the ground produced by a steam leak and converts it to sound. Mid Atlantic Infrared uses seismic accelerometers mounted on a plate to measure ground vibrations. In heavy traffic areas or in leaks on conduit type systems, ground microphones may be ineffective. In these situations we drive rods into the ground and mount accelerometers on the rod. We then process the vibration signal for listening or display on a spectrum analyzer.

Thermocouple probes can also be a useful verification technique. At times, hot spots on the ground will be unrelated to line performance. This can result from solar loading or the influence of overhanging trees or changes in ground cover (grass to dirt or pavement). The thermocouple probes are driven several feet into the soil to measure subsurface temperatures. Comparative readings at two or more locations along the line will readily distinguish real problems from unrelated surface temperature rises.

Conclusion

Predictive testing of steam distribution systems using aerial infrared surveys provides an economical means of identifying developing failures. The benefits of early detection of developing faults include reduced repair and operating costs, improved system availability and most importantly, satisfied customers and citizens.