Using Thermography to Find a Class of Latent Construction Defects in Drain and Vent Pipes

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ABSTRACT

Certain classes of building defects continue to plague the construction industry despite a variety of defensive techniques put in place to prevent them. The defects occur when a nail, screw or staple penetrates a drain or vent pipe and the problem goes undetected because the pipe doesn't immediately begin to leak. Oxidation of the metal fastener will eventually lead to a hole in the pipe. However, it may take months or years for the leak to develop.

In a previous paper the authors described techniques that we have developed to detect latent defects caused by metal fasteners penetrating copper water pipes. This paper extends these techniques, developed for metal water pipes, to plastic or metal drain pipes.

INTRODUCTION

Latent construction defects continue to be a significant risk for the construction industry. One class of defects is caused when a screw, nail or staple is driven into a pipe during construction, but isn't detected until months

Figure 1. A typical residential construction wall with copper and ABS pipes, wires and protection plates

or years after construction is complete. Figure 1 shows a wall in a typical residential construction project where pipes and wires contained within the wall are protected by nailing plates. The image on the left shows the wall before wallboard is installed. The middle image shows the wall after installation of wallboard. The red ellipse on the wall marks the head of a screw used to install the wallboard. The image on the right shows an “X-ray” view of the wall where the screw in question may have penetrated a copper drainpipe. While nailing plates and other defensive techniques have reduced the number of occurrences of this class of defect, they haven’t completely eliminated them. In a paper given at InfraMation 2005[1], the authors outlined a technique for using infrared thermography to detect this class of latent defects in copper water pipes carrying hot water. A subsequent paper[2] extended the technique to cold water pipes. In this paper we extend the technique to plastic drain and vent pipes.

DETECTING SCREW-INTO-PIPE LATENT DEFECTS

Detection of screw-into-pipe latent defects using thermography relies on the fundamentals of heat transfer via conduction; $q = \frac{kA(T_1-T_2)}{d}$, where q = conduction, k = thermal conductivity of the material, A = surface area, T_1-T_2 = the difference in temperature (ΔT) and d = the thickness of the material. By creating a temperature difference between the screw (steel 45 - 65 k (W/m·K)) and the surrounding wall board or plaster (0.15 - 0.27 k (W/m·K)) or cabinetry where the screw-head resides, heat will flow more rapidly through the high conducting screw-head then the lower conducting wall board or cabinetry. If the point of a screw or nail has penetrated a pipe and come into contact with fluid (gas or liquid) contained in that pipe, then a temperature difference is created between the head of the screw and the surrounding material. The differences in conductivity allow the screw head at or near the wall surface to be detected using a thermal imager. Prior testing in both the laboratory and the real world of residential construction showed that screw-into-pipe defects could be detected in water-carrying pipes within a few minutes of running hot or cold water through the pipe.

ISSUES WITH PLASTIC PIPES

There are two issues involved in extending the techniques developed for copper water pipes to ABS drain or vent pipes. The first issue is that drain and vent pipes are not normally filled with water, although they are tested hydrostatically for leaks during the construction process by filling the entire vent/drain stack with water. The hydrostatic testing is done before wall board is installed. To repeat the test after wallboard installation would take extra time and is an additional expense for the contractor. The second issue is that ABS pipe has a relatively low continuous maximum service temperature of 185 ºF, so filling an ABS pipe with hot fluids for long periods of time could cause premature failure of the piping.

The use of air as a fluid to carry heat (or cold) through plastic pipes addresses these issues, but care must be taken that the air remains below the maximum continuous service temperature or the ABS pipes can be damaged (see Table 1).

		Material			
Property	**Units**	ABS	Nylon	HPDE	PVC-1
Continuous Service Temperature in Air (max)	ºF	185	200-212	180	160
Melting Point	ºF	-	430-491	500	360

Table 1. Selected thermal properties of various plastics.

[1] Using Thermography to find a class of latent construction defects., Ken VanBree and Scott Wood, InfraMation 2005 Proceedings
[2] Using Thermography to find a class of latent construction defects., Scott Wood, Building Science Institute and Ken VanBree, Imaging Perspective, LLC, Thermal Solutions 2006 Proceedings

TESTING IN THE LABORATORY

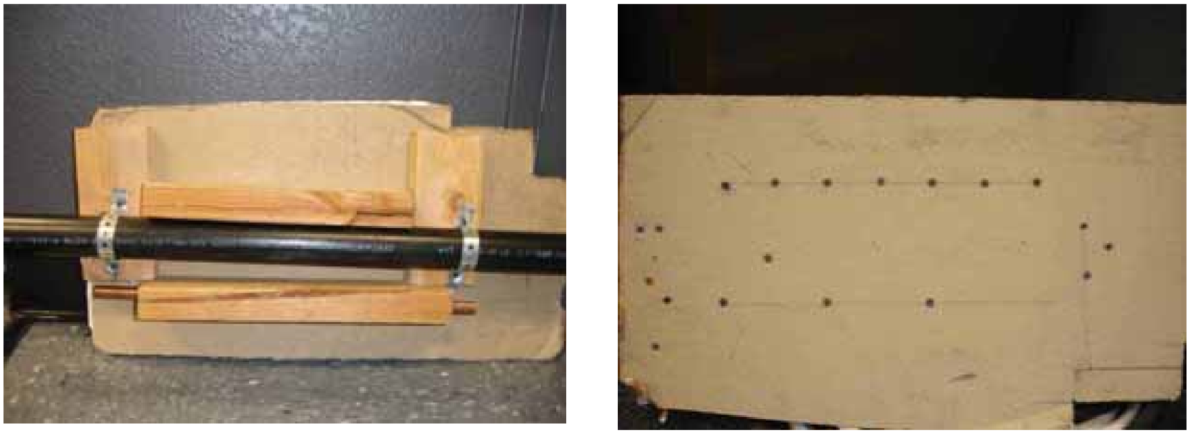

Figure 2. The back and front of a test jig for screw-into-pipe defects.

Figure 2 shows the back and front respectively of a jig we developed to test for screw-into-pipe defects in both copper and ABS pipes. The top line of seven screws in Figure 2 front view is used for water pipe testing. The bottom line of 3 screws attach to a stud that supports the wall board. The single screw between the top and bottom line of screws penetrates the wall board and the ABS pipe behind it. Heated air was applied to the ABS pipe by a Conair 1875-watt hair drier. Figure 3 shows the infrared thermograms of the test jig at the beginning and end of a test where hot air was blown through the ABS pipe. As you can see from the thermogram on the left, the pipe and all of the screws begin the test at around room temperature of 22.1 ºC. The thermogram on the right shows both the pipe and the center screw have been heated to 26.4 ºC after 7 min of passing hot air through the ABS pipe. The other screws in the test jig are still at their starting temperatures.

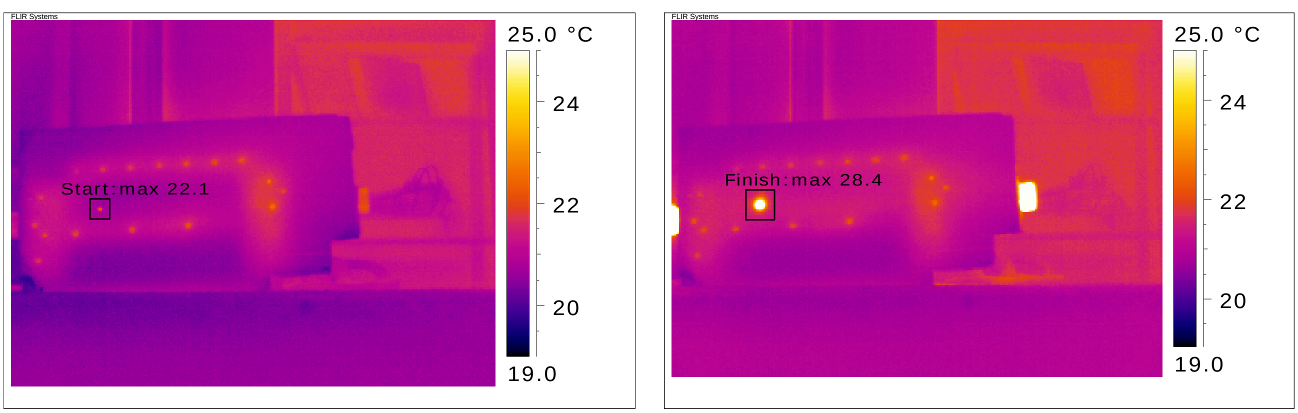

Figure 3. Initial (left) and final (right) infrared thermograms of wall board screws in and near an ABS vent pipe.

TESTING IN THE REAL WORLD

In order to test this technique in a real world construction setting we contacted a friendly contractor who agreed to help us devise a realistic test. Figure 4 shows the positioning of the infrared camera used during the test. The left hand image in Figure 5 shows a portion of a bathroom under construction. The wall board has been installed and taped but the bathroom cabinetry has not yet been installed. Three screws have been inserted in the wall board above the water pipes and drain at the level where bathroom cabinetry would typically be installed. The image on the right is a composite image where a series of infrared thermograms have been overlaid on the original photograph. The infrared thermograms were taken after the conclusion of a test in which the authors forced hot air from a heat gun through the vanity drain. The infrared thermograms show that the topmost of the three screws heated above the temperatures of the lower screws inserted into the wallboard. This upper screw demonstrates a latent defect because it has penetrated the vent pipe while the other two screws have not. The thermograms also show the outline of the vent stack between the studs behind the wallboard.

Figure 4 Image of wall under test and the positioning of the infrared camera.

Figure 5 Image of wall under test (left) and an overlay of the final infrared thermogram of the wall under test.

Although the bottom right screw shown in Figure 5 is in direct line with the vent pipe it does not show up as a heated object (defect) like the upper screw. This is because it only touches but does not penetrate the ABS pipe, which is not an efficient conductor of heat (plastics 0.2-0.5 k (W/m·K)). If the vent pipe were copper rather than ABS, this bottom right screw would have shown up as a defect as well, since copper is a good heat conductor (401 k (W/m·K)). In the case of a copper vent pipe a steel screw in contact with a copper pipe would eventually lead to corrosion through galvanic action between the different metals. ABS pipe will not corrode in the same way, so a screw that touches but does not penetrate the pipe will not compromise the integrity of the pipe.

We used several pieces of spare ABS pipe to couple the heat gun we were using to the drain in the bathroom that we were testing. Our attempts to use a low temperature heat gun were foiled by a safety switch that shut the gun off after it had run for several minutes. We substituted a higher temperature heat gun and built a cardboard funnel to couple the gun into the ABS pipe. At the conclusion of the test, the pipe closest to the gun had expanded internally due to the excessive heat from the gun. We recommend using a hair dryer, such as that used for the test jig, with a low temperature setting for doing this type of testing rather than a high temperature heat gun. Infrared thermography can be used to determine the output air temperature from the hair dryer confirming that it will not heat the material above the maximum continuous operating temperature. This should prevent potential leaks due to excessive expansion and contraction (or melting) of the plastic pipe under test.

Figure 6 shows the initial and final infrared thermograms of the area of the bathroom wall where the test screws were inserted. In the image on the left the three screws as indicated by the arrows can be seen as warm spots between the cooler studs. Because the screws are metal and have a low emissivity, they reflect the temperature of the objects around them. The apparent temperature of the screws in the thermogram on the left in Figure 6 is due in part to the reflection of the thermographer standing directly in front of the wall. The image on the right in Figure 6 shows the infrared thermogram at the end of the test, 13 minutes after the initial infrared thermogram was taken. In this final image the topmost of the three screws is significantly warmer than the other two screws indicating that it has penetrated the ABS vent pipe behind the wallboard whereas the other two screws have not penetrated the pipe.

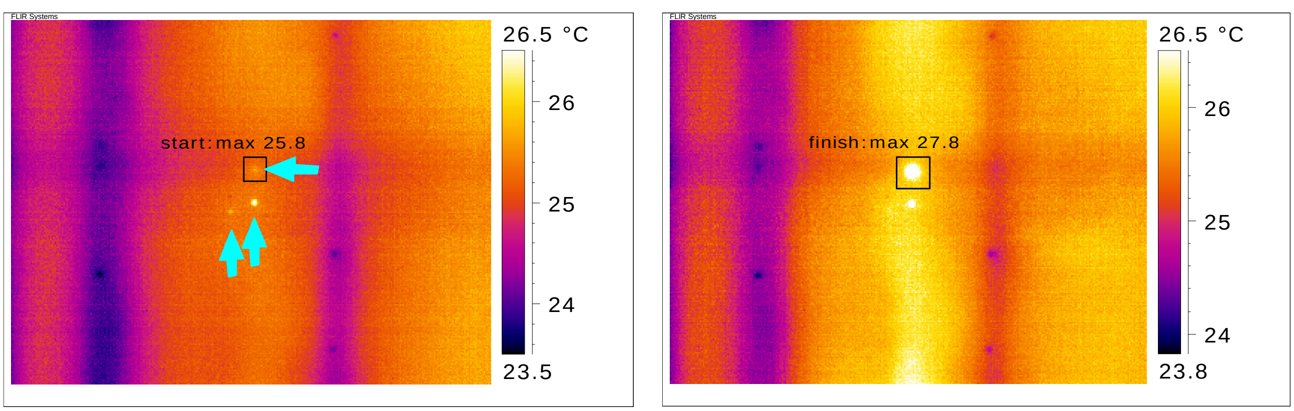

Figure 6. Initial (left) and final (right) thermograms of wall board screws in and near an ABS vent pipe.

SUMMARY

In summary, infrared thermography has been shown to be an effective technique for finding latent screw-into-pipe defects in plastic drain and vent pipes. Forcing warm air through a vent stack will heat any metal screw, nail or staple that has penetrated the plastic pipe and make them stand out in an infrared thermogram of the wallboard where the screw, nail or staple is lodged. The technique is easy to apply, and defective nails, screws or staples can be identified within 10 to 15 minutes of heat application to the vent stack. Care must be taken to keep the temperature of the heated air used for testing below the maximum continuous operating temperature for the plastic pipes that are being testing. For ABS pipes this temperature is 185 ºF (see Table 1).

REFERENCES

VanBree, Ken; Wood, Scott; "Using Thermography to find a class of latent construction defects."; pp. 69-74, InfraMation 2005 Proceedings, Volume 6, October, 2002.

Scott Wood, Building Science Institute and Ken VanBree, Imaging Perspective, LLC, "Using Thermography to find a class of latent construction defects.", pp. 85-91 Thermal Solutions 2006 Proceedings, January 2006.

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