

## Conducting a Whole House Inspection for Latent Fastener-into-Pipe Defects Using Visual and Thermal Information

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### ABSTRACT

A certain class of building defects continues to plague the construction industry, despite a variety of defensive techniques put in place to prevent them. The defects occur when a nail or screw comes into contact with a copper pipe or penetrates a plastic pipe carrying fluids. If these defects are not caught during construction, they can turn into leaks that can go undetected for years. The resulting leaks can result in mold growth, dry rot or even structural damage in extreme cases. Contractors in California have a ten-year liability window for these types of defects. Finding cost-effective ways to eliminate these defects during construction can lower builders overall warranty costs *and* improve overall customer satisfaction.

### INTRODUCTION

In a 2005 Inframation paper, we introduced techniques that we developed to detect this class of latent construction defects in copper water pipes carrying either hot or cold water. In a 2006, paper we extended those techniques to include PVC or copper drain and vent pipes where the use of water to heat the pipes is not a viable approach.

The thermographic techniques we have developed are straightforward to apply, however in a large construction project the search for potential defects can be like looking for a needle in a haystack. In this paper we discuss a systematic process for searching for latent defects in a new home. The process uses visible light images of a home under construction to narrow the search for potential latent fastener-into-pipe defects. Thermal images of the areas in question are then used to check that no latent defects are present.

### USING VISUAL INFORMATION

Prior work has shown that thermography can be used to quickly and easily confirm that a fastener has penetrated a pipe. Systematically applying these techniques to a newly completed custom home entails heating or cooling every pipe in the home and looking for the thermal signature of fastener-into-pipe type defects. The challenge when going into a newly completed home is finding exactly where every pipe in the home is located. This is where visual information becomes critical.

The advent of digital cameras has made it easy for contractors and others to record details of construction projects that can be used for diagnosis later on. Imaging Perspective has developed a service that organizes as-built construction photographs into an intuitive interface that can be used to quickly locate images of specific areas of a home under construction. Imaging Perspective's thru-view as-built imaging service was used to photograph the house analyzed in this paper. Figure 1 is a typical screen-shot from Imaging Perspective's viewer that shows the piping details in one of the bathrooms. Two sides of the same wall of the bathroom are shown. The image on the right shows the piping in the wall of the bathroom above the sink. The image on the left shows the same piping from the master hall. The cursor in the leftmost image points to the ABS drain pipe. To the left of the drain/vent pipe is the cold-water feed for the sink, and to the left of that is the insulated hot-water pipe. The background between the two photographs is the floor plan of the area of the house in question. The red dots are locations where images have been taken. The small red fan toward the top of the floor plan is the camera indicator showing the direction of the photograph of the master hall that appears on the left in the viewer. The black bar beneath each photograph gives information about when and where the image was taken.



Figure 1. Screen shot of Imaging Perspective's viewer showing piping in bathroom from both sides of wall.

After locating the pipe runs using visual images such as the ones in Figure 1, we turned on the hot water to the sink in the bathroom. Figure 2 shows our computer sitting next to the sink with the hot-water tap turned on. Although not visible in the photograph, the screen of the laptop in Figure 2 shows images of the piping in the wall behind the sink. The thermogram at the right of Figure 2 shows the temperature of the water running from the tap. After running the hot water for several minutes we took the thermogram in Figure 3. We were prepared to force hot air through the vent pipe in order to make it visible in IR, but we were delighted to see that the hot air given off by the hot water going down the drain was sufficient to make the pipe stand out.

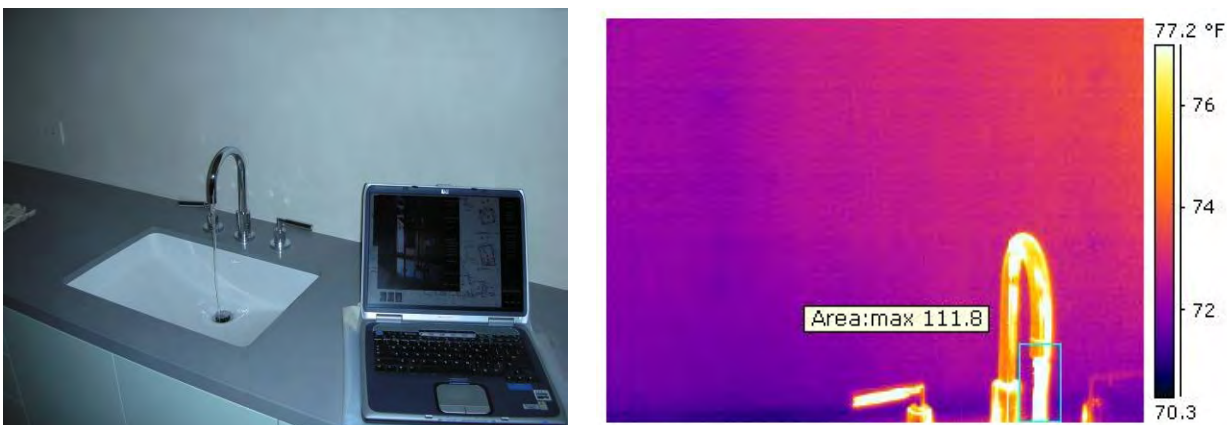


Figure 2. Test setup with visual images on laptop and thermogram of hot water running from tap in bathroom sink

Figure 3 shows three views of the backside of the bathroom wall. The first view is the existing piping shot before insulation and dry wall was installed. The middle view is the stitched thermal image of the same area, and the right-hand view shows the stitched thermal image layered on a picture of the thermal camera taking one of the thermograms used in the stitched image.



*Figure 3. Visual and thermal images of vent pipe (leftmost pipe in stud bay) and hot-water pipe (rightmost pipe)*

We continued through the house running the hot water tap in each bathroom, laundry room, kitchen, and powder room. In some rooms, glass tile, mirrors or stainless steel had been installed. In these situations we were only able to test for defects in the un-covered portions of the wall. Figure 4 shows one such area where a stainless steel backsplash and cabinetry blocked acquisition of thermal images in parts of the wall. Although the visual and thermal images in Figure 4 aren't from exactly the same perspective, you can see that the stainless steel backsplash below the window acts as a mirror to reflect both the hot-water tap and the hot water stream exiting the tap. In the upper right of the thermal image in Figure 4 you can see the hot water pipes exiting through the ceiling. Figure 5 shows the pipes above the refrigerator in the kitchen in more detail. Notice that there are hot pipes on both sides of the stud bay above the refrigerator. The pipes on the left are the hot water and vent pipes for the kitchen sink, while the pipe on the right is a radiant heat pipe that feeds a distribution panel that can be seen below the window at the far right of the rightmost image in Figure 5.

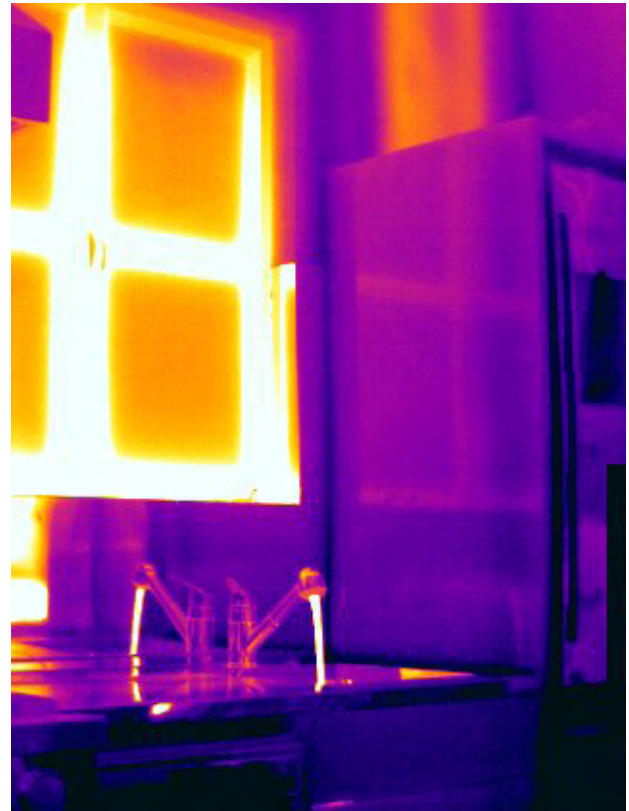


Figure 4. Hot water feed to kitchen blocked in some areas by cabinetry and stainless steel backsplash.

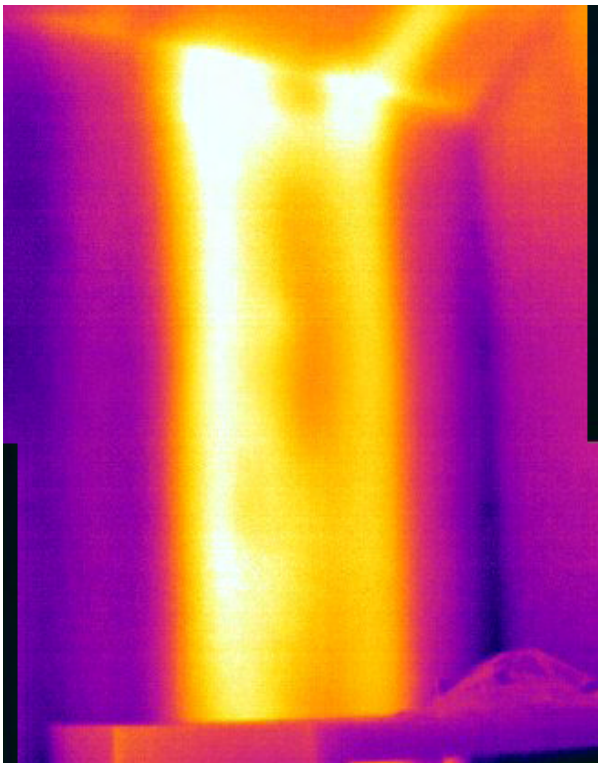
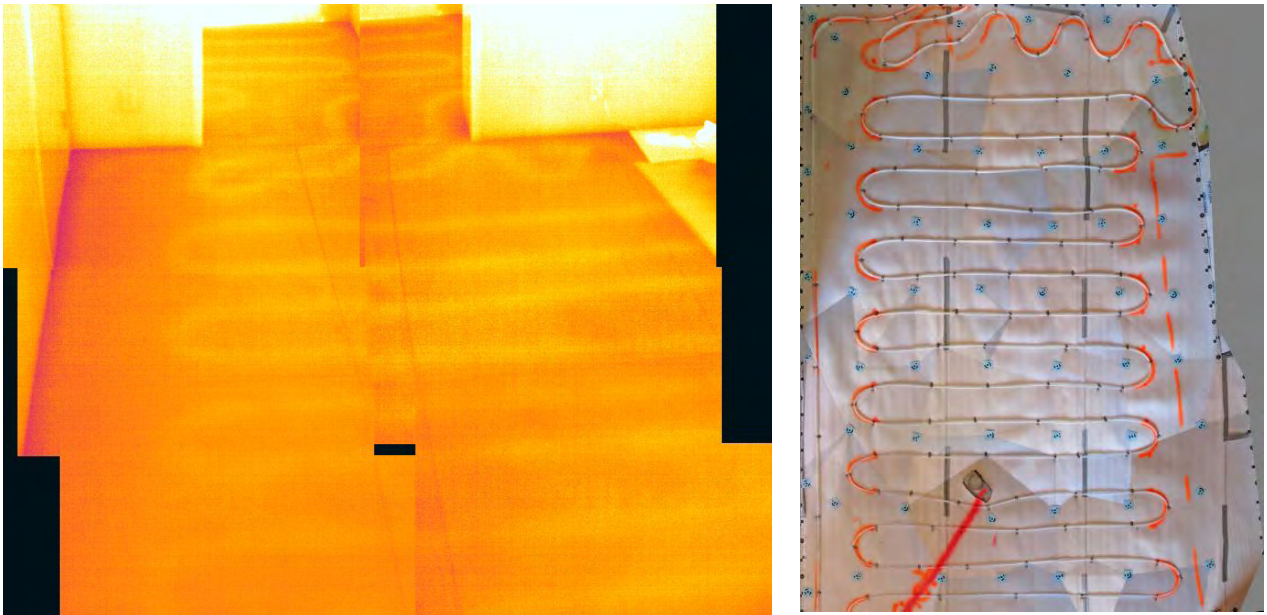


Figure 5. Detail of piping above refrigerator in kitchen. Hot water and vent exit on left. Right pipe is radiant heat.

## TESTING COLD WATER PIPES AND RADIANT HEATING

The technique that we developed for testing for fastener-into-pipe defects in cold water pipes relies on a thermal difference between the temperature of the cold water and the temperature of the walls. Checking the cold-water tap temperature in the house showed that it was the same as the ambient air temperature, around 78° Fahrenheit. This made it impossible to “see” the cold-water runs as we had in other settings. There are several approaches to increasing the temperature differential between the walls and the cold water supply. One approach is to schedule the inspection on a day when the ambient temperature is in the 90s, and allow the walls to come up to the outside air temperature. A second approach is to turn on the heat in the house to bring the wall temperature up to 88°F and provide the needed differential. Neither of these approaches was ideal for this inspection. Coming back another day would require coordinating multiple schedules based on un-reliable weather forecasts. We tried turning on the hydronic heating system, but discovered that the system wasn't yet functional in the areas we needed to test cold water pipes. Figure 6 shows a stitched thermal image of a portion of the hydronic heating system along with a photograph of the heating pipes before pouring the concrete floors. The thermal image of the heating pipes was taken about 5 minutes after the heat was turned on in the room.



*Figure 6 Thermal and visible-light images of a portion of the hydronic heating system of the home*

We were unable to test cold water pipes in this visit because of the ambient air temperature and the lack of a fully functional hydronic heating system. On future tests we will need to coordinate with the builder or homeowner to insure that we could raise the wall temperature at least 10 degrees above the cold water inlet temperature in order to coordinate the testing. It occurred to us that it may be possible to use the heat generated within the wall cavity by our hot water pipe tests to facilitate a cold water pipe test. The hot water pipe and vent pipe tests we ran increased the wall temperature in the areas around the route of the hot pipes. If the cold water pipes ran through the walls near to the hot pipes we may be able to “see” any fastener-into-pipe defects in the cold water pipes which penetrated the walls pre-heated by the hot water tests. The procedure would be to run the hot water test first, then run a cold-water test on the same sink. This procedure could be applied anywhere, with the visual images showing hot and cold water pipes running through the same stud bay.

## OUR FINDINGS

We were able to inspect all hot water feed lines and ABS vent pipes in 6 bathrooms, a laundry room and a kitchen. In most cases we were able to observe the pipes on both sides of the walls they were routed through. We found no evidence of fastener-into-pipe defects in any of the pipes tested. However, we did locate a leak in a cold-water feed to a sink in one bathroom. Figure 7 shows a thermal and visual image of the leak in question.



*Figure 7 Visual and Thermal images of leak at angle stop of cold water line feeding bathroom sink.*

## SUMMARY

Techniques developed to test for fastener-into-pipe defects in water and drain pipes can be systematically applied to do a whole-house inspection. The key to effectively interpreting the thermal images is to have a comprehensive set of as-built images of the piping in the home to guide the inspection. Hot water pipes and ABS drain/vent pipes can be tested together because the hot air generated by the hot water flowing through drain pipes is sufficient to make the ABS vent pipes visible. Any fastener-into-pipe defect will show up as a point on the wall that is hotter (for hot water testing) or cooler (for cold water testing) than the surrounding wall. Fastener-into-pipe defects show up within a few minutes of applying hot or cold water to the piping system under test. We were able to test 6 bathrooms, a laundry room, and a kitchen in a period of 6 hours. Testing in future projects could be simplified by turning on multiple hot-water taps simultaneously and by coming prepared with a set of printed images of the piping in each room that could be taped to the corresponding walls to guide the thermographer.

## REFERENCES

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## **ABOUT THE AUTHORS**

Ken VanBree is the founder and owner of Imaging Perspective, LLC, a San Francisco Bay Area firm that specializes in as-built photography and thermography for the construction industry. Imaging Perspective's innovative approach to as-built photography produces layered images of construction details that can be used to find defects and to simplify change orders and long term maintenance. For more information visit [www.imagingperspective.com](http://www.imagingperspective.com) or e-mail the author at [kvanbree@imagingperspective.com](mailto:kvanbree@imagingperspective.com)

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