Non-Invasive Roof Leak Detection Using Infrared Thermography

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ABSTRACT

Residential roofs without attics are typically inspected for leaks by installing scaffolding and probing the ceiling for water intrusion with a moisture meter. This paper discusses infrared thermography's ability to probe the ceiling for water intrusion without physical contact with the ceiling. Water was applied to the roof in a controlled manner, starting at the lower sections, then moving to the peak of the roof. During the water application, continuous scanning of the ceiling with a FLIR ThermaCAM® E4 infrared camera allowed instant discovery of the water intrusion.

Keywords: Moisture detection, non-invasive leak detection, roof leak detection, testing criteria, infrared thermography, building diagnostics

INTRODUCTION

Roof leaks are typically discovered by direct observation. If the roof sheathing is not visible from below, such as in an attic, the wallboard or ceiling covering must first be removed. This removal is necessary in order to "visualize" the intrusion point at the underside of the roof sheathing. Before the ceiling is removed, all contents must be removed from the affected area. The floor is then protected from falling debris, and the ceiling is removed, possibly requiring a scaffold system. Infrared thermography is an invaluable tool in the discovery of roof leak intrusion source without the need to remove the ceiling or contents of the room.

The thermal properties of water are unique, allowing water to be observed on the surface of building material or even within the building material being examined. When water evaporates on the surface of building materials, it cools. If the building material is at a different temperature, the water's thermal difference may be detected by conductance through the building material. When infrared thermography is used to observe the ceiling prior to, during, and following water testing, these thermal differences enable moisture to be located on or within the wall or ceiling structures. No portion of the ceiling needs to be removed, allowing for a non-destructive means of finding the roof leak.

BACKGROUND

In April 2003, a leak occurred at the ceiling-wall joint of a residence. Water entered the home at the supply duct register and the windows at the front wall of the living room. Water testing indicated the intrusion might have been the transition between the stucco wall and roof (Fig. 1). Corrective measures were performed in October 2003 that included replacing the roof flashing as well as the stucco siding of this area. On February 25th, 2004, a rainstorm again caused water intrusion within the same area previously noted, before flashing and wall stucco replacement (Fig. 2). Evidence of this intrusion is visible in Figure 2.

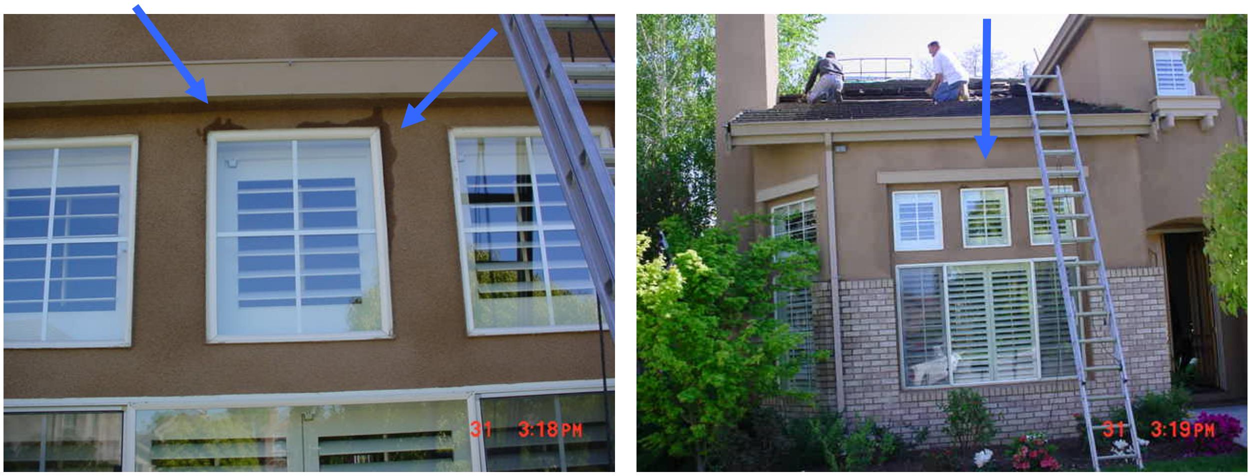

Figure 1. Exterior views of the front of the residence showing the location of water exiting the stucco surrounding the center window (blue arrows), indicating water had entered the wall system above the window.

Figure 2. Visual image of the living room ceiling showing the water staining caused by the roof leak. The blue arrows show the staining along the ceiling-wall joint directly under the supply register. Black marks (pieces of tape indicated by red arrows) are reference points for the wallboard separation, only visible upon close examination between the tape marks.

VISUAL INSPECTION PROCESS

On March 31, 2004, an inspection of the affected area, including a water test of the roof, was performed. The vaulted ceiling did not allow direct access to the underside of the roof sheathing. In the absence of infrared thermography, the ceiling would have been removed to inspect the roof sheathing for the water intrusion points. A non-infrared inspection is accomplished by removing the room's contents, protecting the floor, and installing scaffolding to reach and remove the ceiling wallboard. With infrared thermography, it was not necessary to remove contents and wallboard or erect scaffolding; nor was floor protection necessary.

Visual inspection of the roof exposed two potential water intrusion points, the gutter and chimney areas as shown in Figures 3-5. Foam had been installed at the upper slope of the gutter (Fig. 4). Since this was an unusual use of foam, it may have hidden imperfections or water entry points behind the gutter. Water testing was directed as described later in this paper at the gutter area to determine if it was a leak site.

Figure 3. Visual images of the roof showing the cement roofing tiles intact (without cracking, separation or missing tiles). The gutter system at the right (see blue arrow) did have unusual construction, as shown in Figure 4.

Figure 4. Visual images showing a close-up of the gutter system (Fig. 3) where foam was applied. The foamed area (blue arrows) may be covering a possible water intrusion point.

Figure 5. No flashing is visible at the chimney's top and side but may be incorporated within the chimney's cladding, which is stucco. This is apparent in the visible flashing of the chimney's lower edge, as shown on the image at the left (see blue arrow).

BASELINE DETERMINATION

Following the visual inspection, a complete infrared thermographic inspection of the interior of the affected area was performed (Fig. 6). This was to provide a reference point of the thermal characteristics of the walls and ceiling of the affected area. Areas that were cooler or showed temperature abnormalities were examined more closely with moisture survey equipment consisting of conductive and dielectric meters. No moisture differences were found in the cooler areas visible in the infrared thermograms.

The temperature differences of the lower sections of the ceiling (indicated with green arrows in Figure 6) were due to the condition of the insulation within the ceiling. It is unclear what may have caused the cooler areas indicated by the red arrows shown in Figure 6. These unknown cooler areas are located near where the first water intrusion points were discovered and may be related to past water intrusions or missing insulation.

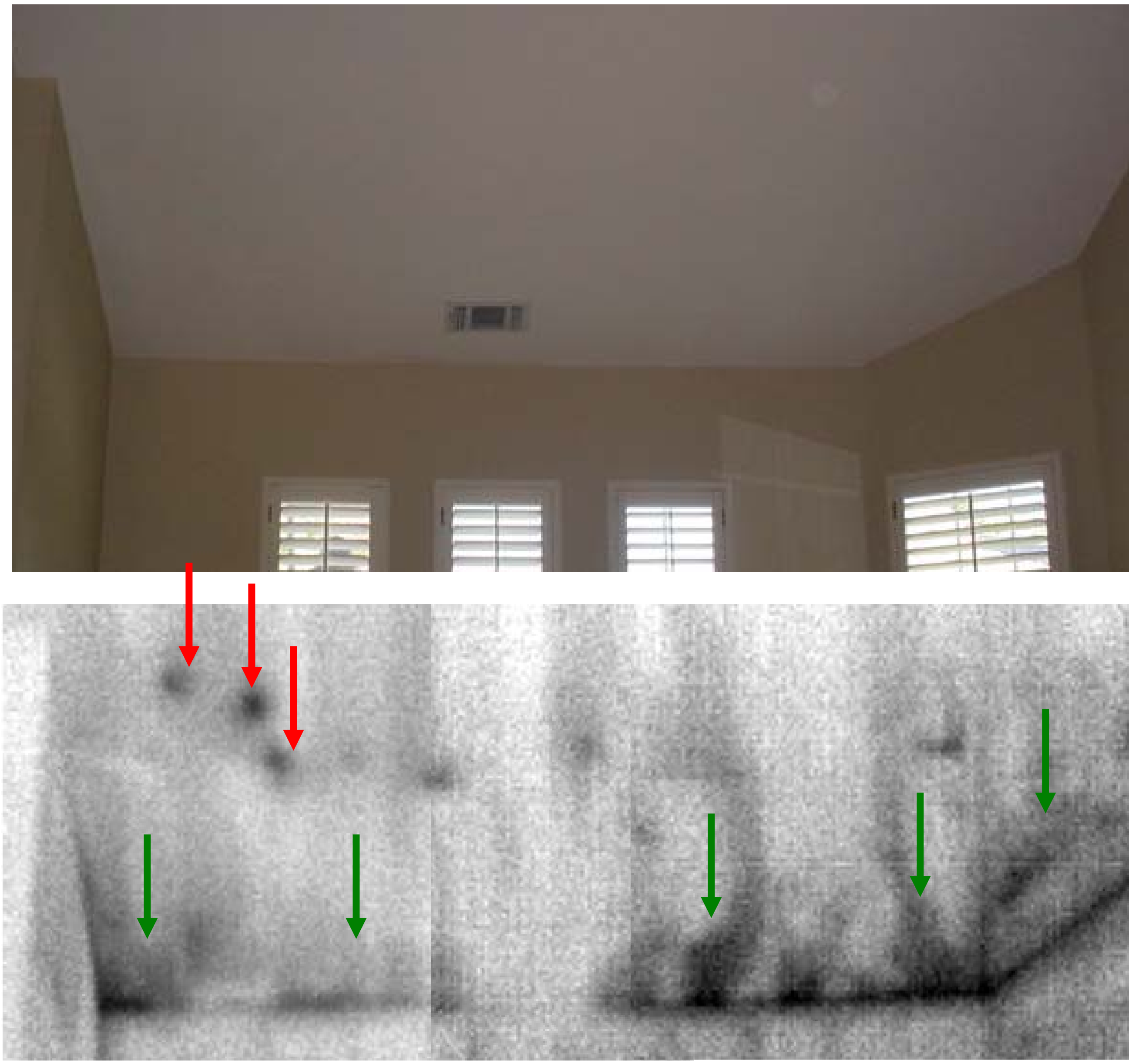

Figure 6. Visual image of the ceiling as well as infrared thermograms showing a thermo baseline of the ceiling where the water leak should be visible. The cooler areas indicated by the green arrows are due to insulation gaps. It is unclear why the areas indicated by the red arrows were cooler than the surrounding wallboard. Moisture readings show no moisture differences in all the areas visible in this image.

WATER TESTING

Water was applied to the roof from a spray rack system for 30 minutes at each location or for 15 minutes using the hand-held spray applicator (Fig. 7). Figure 9 shows the positions of the rack system for each 30-minute test. Soon after the spray rack system was moved into Position 8, water intrusion was found in the ceiling of the residence. The first water intrusion point was the cool area visible in Figure 10. This area was tested for moisture using a moisture meter, which confirmed the presence of a leak.

To test the suspect gutter area, the hand-held applicator was used (Fig. 8). During this test no water intrusion was found, indicating no water intrusion points for this area of the roof.

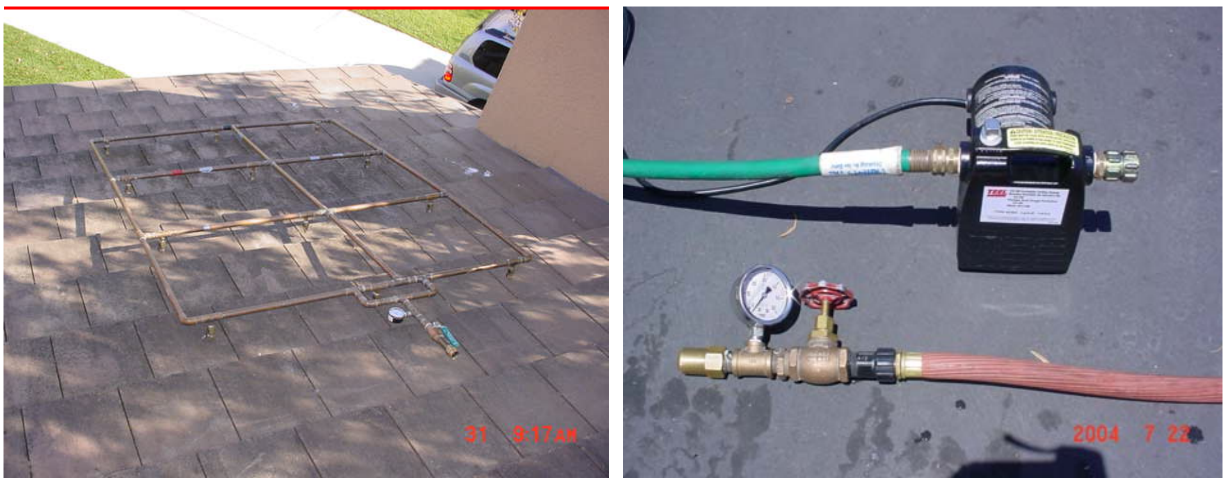

Figure 7. Images of the spray rack system (left) and the hand-held spray applicator (right) used to apply water to the roof. The hand-held sprayer was used to apply water to the suspect area located at the gutter.

Figure 8. Image of the hand held applicator and its position during the water test of the gutter area, as well as the positioning of the spray rack system.

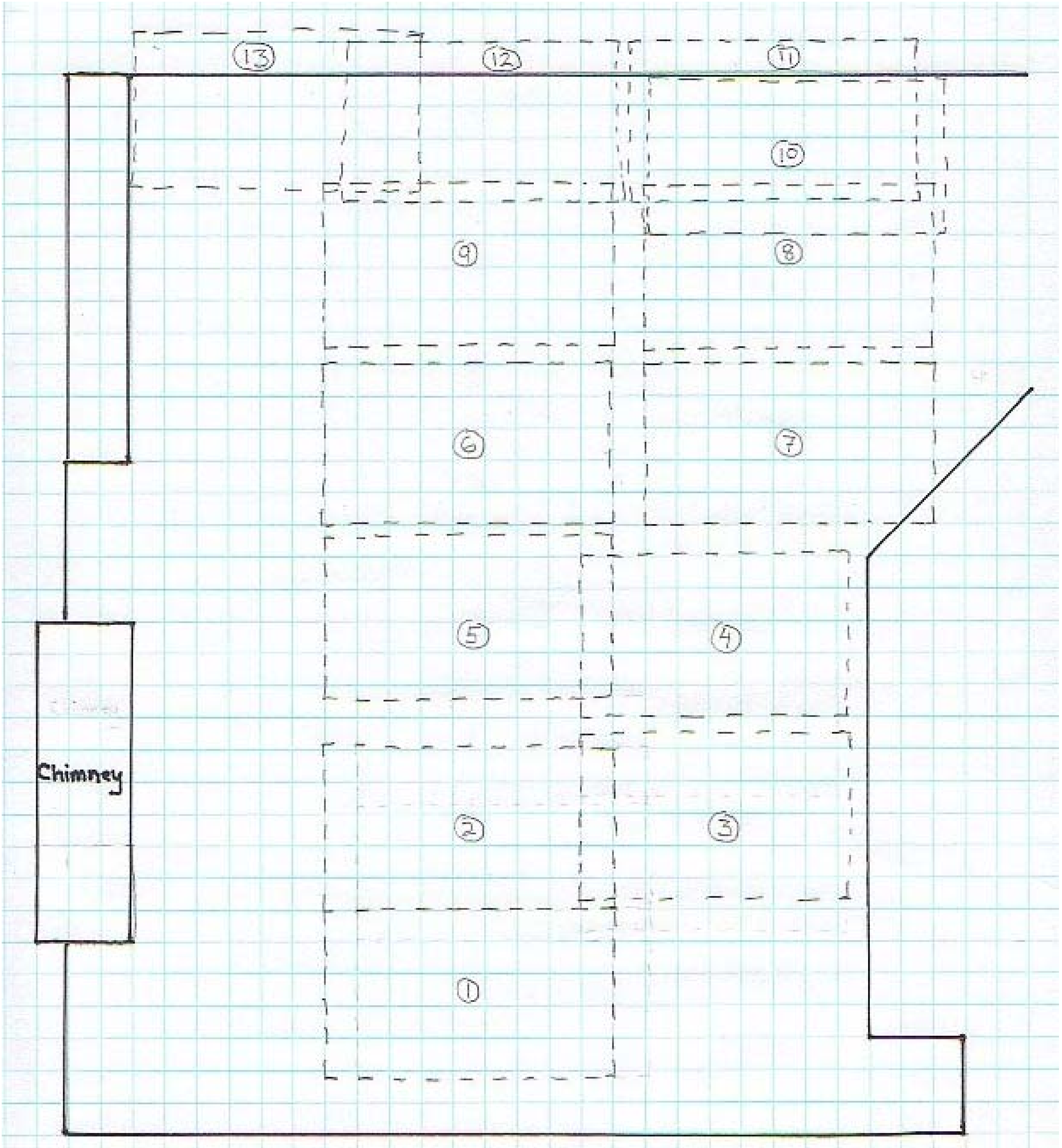

Figure 9. Diagram of the roof showing the positions, 1-13, of the location of the spray rack

MOISTURE DISCOVERY

During the water application process, infrared thermography was used to scan the ceiling surface of the living room. No moisture was detected until the spray rack system reached Position 8 (Fig. 9). Figure 10 shows the beginnings of the water intrusion as indicated by the cool spot marked by the arrow.

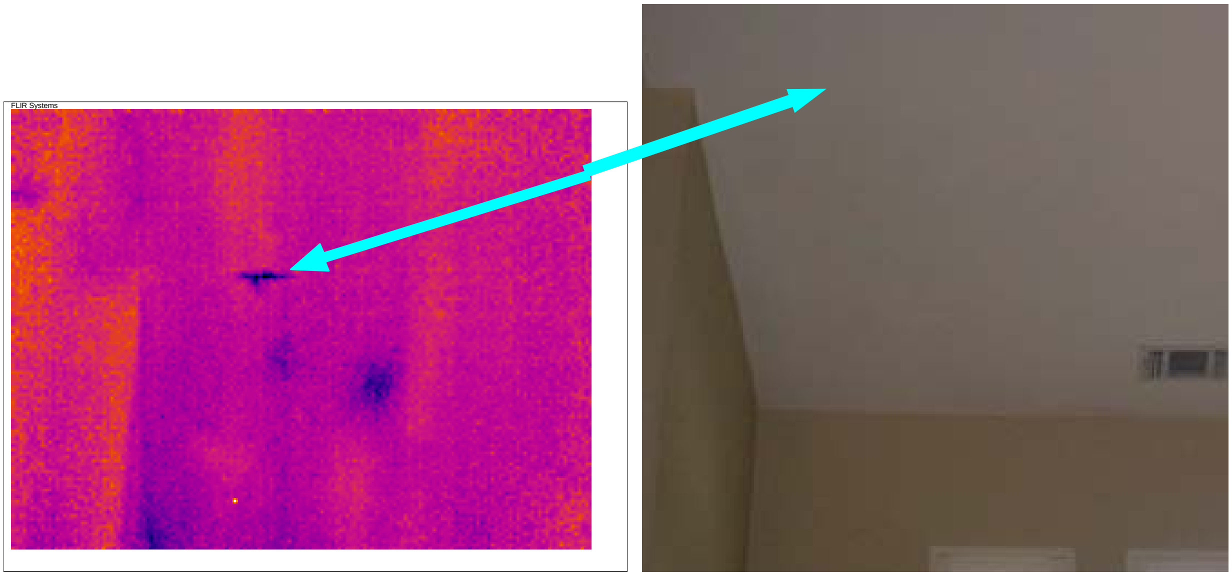

Figure 10. Thermogram/photo pair showing the beginnings of the water intrusion. Cool spot indicated by the arrow was tested for moisture with a moisture meter to confirm the presence of moisture.

As the roof water test continued, the water intrusion increased, moving to the front wall of the living room. Figure 11 indicates the location of the water within the wall as it moves behind the wall, surfacing at the top and bottom of the window. At this point of the test, water was dripping from the window header onto the floor of the living room. Water testing continued with the spray rack positions 9 through 13. As the rack moved away from the valley of the roof, the water intrusion decreased, finally stopping with the completion of the water testing.

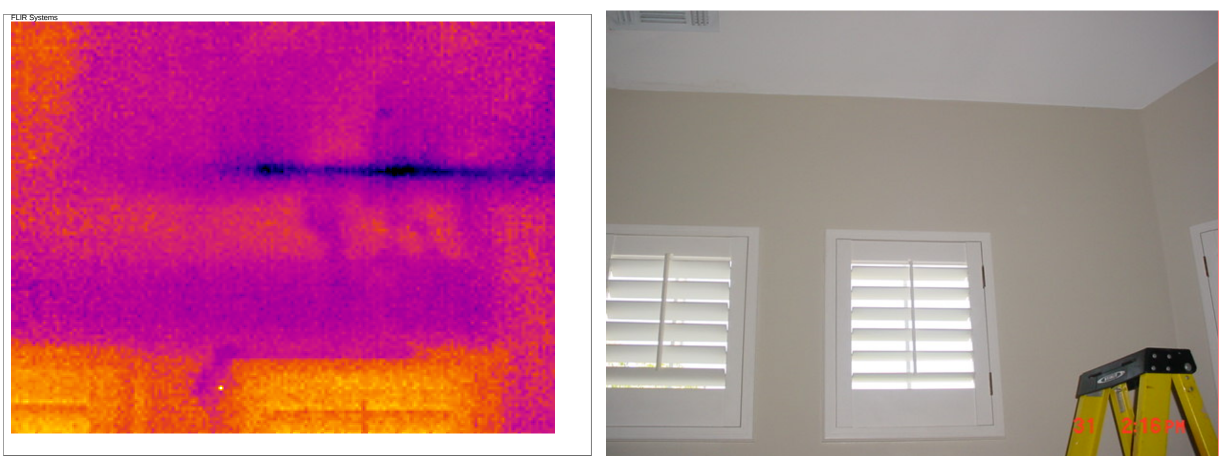

Figure 11. Thermogram/photo pair showing the water intrusion moving to the front living room wall

INTRUSION DISCOVERY

Once it was determined through water testing where the approximate location of the roof leak was, roof tiles were removed to examine the underlayment and roof sheathing.

Figure 12. Images showing water under the tiles (left) and under the roof's underlayment (right). Note the location of the area in reference to the gutter at the upper left side of the left image.

Figure 13. Image (left) showing the underlayment and roof sheathing, as well as two nails (red arrows) found lying on the roof sheathing. The heads of the nails penetrated the underlayment, causing water to flow onto the roof sheathing and then into the residence. The image on the right shows remains of the debris dam and the edge of the flashing (green arrow) where the water spilled over (blue arrow).

Figure 14. Image showing the debris dam at the roof valley before the tile was removed.

By following the water visible below the underlayment, the source of the intrusion was found. Two nails were discovered that had been dropped onto the roof sheathing, then covered by the underlayment. The nails had punctured the underlayment (Fig. 13).

Since the roofing tiles prevent water from entering the underlayment, it was important to determine how the water got under the roofing tiles to begin with. Further exploration of the roof revealed a debris dam at the valley of the roof. Roofing codes in the area required the tiles to be installed without a gap at the roof valley. This allowed debris to accumulate in the valley, eventually damming the valley and causing water to spill over onto the underlayment (Fig. 13-14).

SUMMARY

Infrared thermography was able to save the customer time and reconstruction costs during a water intrusion study. It allowed the water test to be performed without inconveniencing the homeowner with a destructive tear-out, typical of most water testing when no infrared thermography is used. By viewing the ceiling of the living room with an infrared camera, the approximate roof location was determined. Once located, a small section of the roofing system was removed, and the punctures to the underlayment, as well as the debris in the roof valley, were discovered.

REFERENCES

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