

Qualitative Infrared Roof Moisture Surveys – Who Performs Them, Who Buys Them, and Why

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Abstract Qualitative infrared thermography is performed on roofs to quantify the extent of roof moisture (water) that is in the roof system. Infrared thermography is *not* leak management. No matter how the water got into the substrate, the purpose of this type of survey is simply to find and document where the water is located. This information is then used to manage roof assets more effectively. By knowing where and how much water is *in* the roof, the owner can make an informed decision regarding maintenance activities that need to take place.

Today, most infrared roof moisture surveys are performed by roofers and/or roof consultants, standing on the roof. As aerial infrared thermographers, we see two problems with this. First, unbiased, trained infrared thermographers should be performing these surveys with state-of-the-art equipment. Second, rooftop or on-roof infrared surveys do not provide the client with the most useful imagery.

This paper discusses problems with infrared surveying of roofs in general, the advantages and disadvantages of on-roof and aerial infrared thermography, as well as market forces driving the product that is available today.

Keywords: *Infrared, thermography, infrared roof moisture survey, roof asset management*

The Need Infrared roof moisture surveys are performed for the sole purpose of finding out whether water has penetrated the roof’s waterproof layer, and if so, where it is located. This is a predictive maintenance activity. The owner of the roof should receive a well-prepared, graphic and accurate map of the infrared signatures from the roof. This information can be of significant benefit to the owner at all stages of that roof’s service life (see Figure 1). Everything wears out and building roofs are no exception. The ravages of sun, wind, rain, snow, chemicals, leakage and time—will eventually cause every roof to fail. Roofs must be maintained. Owners sometimes think that a roof warranty will protect them. Roof warranties are written by roofing manufacturers for the purpose of protecting themselves from liability. For example, often a warranty is written such that if improperly installed or defective roofing materials are used on a roof and water leaks into the electrical switchgear room causing an explosion, the roofing



Figure 1: Aerial infrared thermograph taken from 2000 ft. over the building, showing crystal clear outlines of subsurface roof moisture. Light colored areas contain moisture. Dark areas are dry.

manufacturer will replace the materials, the roofer will reinstall the materials, but the building owner has to pay for the replacement of the switchgear and any downtime that resulted from the failure. The roofer's and roofing manufacturer's liability in the case of roof failure are also reduced by vaguely written roof warranties, which do not define words like "regular" or "routine" maintenance. Not accepting the roof warranty is not the answer, since the roof will not be installed unless the owner agrees to the warranty. To eliminate these problems, the building owner should have an agreement with a qualified roofer or roof consultant to inspect and maintain the roof (in accordance with the terms of the warranty) at least once a year.

Extending the life of a roof will save the owner the expense and aggravation of reroofing or recovering. Re-roofing means that the roof is taken down to the decking and replaced completely. Recovering the roof means that the waterproofing layer(s) are removed, the wet insulation is removed and replaced (usually) and new waterproofing is put down. The cost of an infrared roof moisture survey is usually between one and three cents per square foot, depending mostly on the level of report that is needed. Since it costs an average of five dollars per square foot to repair roofs, knowing the location of the water is extremely useful information because then only those areas that are damaged need to be targeted. Infrared roof moisture surveys are usually per-

formed as part of an overall roof asset management plan. This information is used to plan budgets and when needed, as a bid document for contracting repairs and/or replacement of the roof.

Waterproofing problems manifest themselves in two ways: Leakage and entrained moisture contamination. Leakage is pretty simple, although the leak inside the building rarely directly relates to the exact spot on the roof, since the water flows down the slope of the roof to a spot that is not sealed and into the building at that point. Most leaks occur where the waterproofing is sealed or where there is a penetration of the roof. Since most types of roof systems absorb some amount of water, it is harder to find the exact spot of water contamination in the insulation because it may not leak into the building until it has absorbed all the water it can hold. There are three types of surveys that are used to find water in a roof: nuclear gauges, which count neutrons; capacitance meters, which measure resistance; and infrared, which measures heat. Both nuclear gauges and capacitance meters are used to take spot readings on a 10' × 10' or 20' × 20' grid on the roof. These measurements are used to extrapolate where the water is from the readings obtained from the gauge. They are good for types of roofs that do not gain or lose much solar energy and therefore do not lend themselves to infrared.

Roof Infrared Basics

During the day, the sun radiates energy onto the roof and into the roof substrate; at night, the roof radiates the heat back into outer space. This is called radiational cooling. Areas of the roof that are of a higher mass (wet) retain this heat longer than that of the lower mass (dry) areas. Infrared imagers can detect this heat and “see” the warmer, higher mass areas during the “window” of uneven heat dissipation.

Problems With Roof Infrared in General

Some roofs and insulation types or combinations do not absorb water. These roofs should be inspected by other methods, as described above. Even among roofs having insulation types that do absorb water, some do not exhibit a good infrared signal, primarily for two reasons: 1) The surface is too reflective, and/or 2) the roof’s ballast is so thick (or dense), that daylight radiation is not absorbed into the substrate (insulation), and therefore cannot be emitted back into the atmosphere at night. Even with a strong infrared signal, factors on the roof can affect the analysis and interpretation of the data. Some of these factors are: water between multiple layers, old patches, heavy flood coats, reflective coatings, heat-producing equipment under the roof –or heat blowing down onto the roof, stains, ponding, heavy build-up of ballast at parapet walls and along edges, etc.

On-Roof Infrared

To perform an on-roof survey properly, a crew of three to four people is needed: an experienced infrared thermographer and helper, an experienced roof consultant or roofer, and the building owners’ representative for access and security. The crew needs

authorization and access to all areas and levels of the roof(s) from either ladders or roof hatches and plenty of time to collect data. Depending on how many problems are found (very dependent), a crew can survey 50,000–200,000 square feet building roof(s) in one night. Areas that contain subsurface moisture are verified wet by the roof consultant and then outlined with marking paint directly on the roof. The infrared images are stored on videotape or flashcards and printed so that the photos can be lined-up in the report. The next day, the thermographer goes back on the roof(s) to take visual photographs of the areas that contain subsurface moisture.

Disadvantages and Advantages of On-Roof Infrared

When one is standing on the roof, eye-level is at best six feet over the surface. Even with the best infrared camera available, there is virtually no way to get large areas (800 sq. ft. blobs or 100' long striations) of moisture contamination on the screen in one infrared shot. Taking multiple shots is labor-intensive and makes the report confusing. When performing walk-on roof surveys, many times “you can’t see the forest for the trees.” Marking the roof is fairly easy, but it is very difficult/time-consuming to produce accurate drawings of the wet areas from painted lines on the roof. Often the drawing supplied by the owner is outdated, incorrect or even non-existent.

There are two distinct advantages to on-roof surveys:

- Verification of wet areas can be performed before marking a suspect area.
- Verified wet areas can be marked directly on the roof.

Aerial Roof Infrared

Performing infrared roof moisture surveys while standing on the roof is not the best method because *imagery* from a walk-on survey is not as useful as aerial imagery. The same laws of physics apply to both aerial IR and on-roof IR. A dry roof, low winds and no rain are needed on the night of the survey. However, the “window” when the roof is radiating heat differently from wet and dry areas is longer with aerial infrared, because slight nuances of temperatures over large areas are recognizable. A high angle of view and high resolution are needed to produce usable imagery. The cameras that are used for on-roof surveys are not of sufficient spatial resolution to obtain good imagery from flight altitudes of 1,200 – 1,500 feet above the roof. Almost all modern infrared cameras have $\sim 256 \times 256$ pixels, a total of 65,536 pixels. The resolution with this type of detectors from this distance is generally unacceptable, so a helicopter is required to fly at a nominal 500 feet over the target roof. This will work, but high vibration levels, high costs of operation, slow ferry speeds and other logistic problems make fixed-wing a much better option for us. Fixed-wing aircraft must fly at higher altitudes, which means that more pixels are required. We use a Mitsubishi M-600, which has a 512×512 staring array detector (262,144 pixels) with a 50mm lens. From an altitude of 1,200–1,500 feet above the roof with over a quarter of a million pixels, the ground resolution element is about six inches square (see Figure 2).

Once the aircraft is over a building, very little time (five minutes per 200,000 square

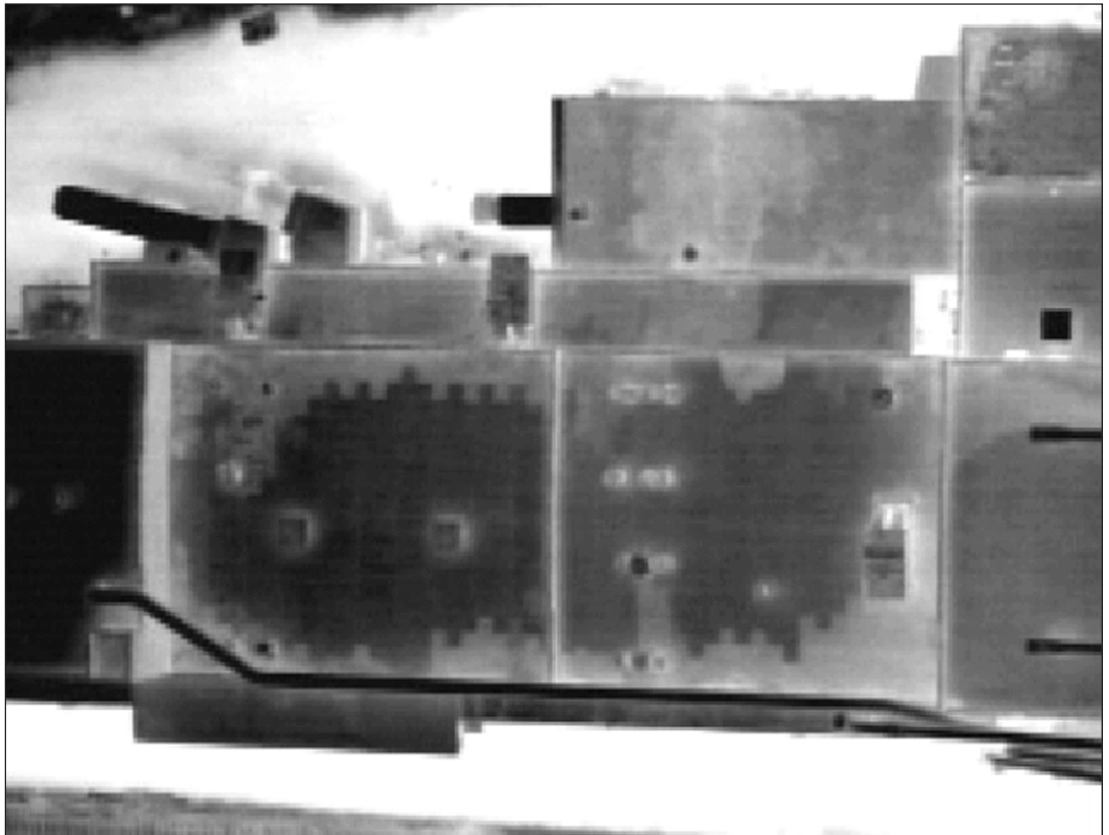


Figure 2: Aerial infrared thermograph from 1,800 ft. AGL (above ground level) clearly shows 4' x 8' wet insulation boards.

feet, about 25 minutes for two million square feet) is required to fly over making multiple passes (see Figure 3). The imagery is recorded on digital videotape. Visual photographs are taken earlier in the day or the next day. After returning to the office, the photos are printed and the thermographs are saved on the computer. The raw video imagery, thermographs and photographs are used to make an edited videotape copy of the passes over the building. Both visual and infrared images are used to do the analysis by overlaying the AutoCAD drawing of the roof “over” the digitized photographs and thermographs. The drawings always need to be corrected, because rooftop equipment has been removed, moved or added since the last update of the drawings. We then draw in the areas of suspected moisture contamination. The result is a report where visual, infrared and AutoCAD components (printed and video) are well matched and lined up.

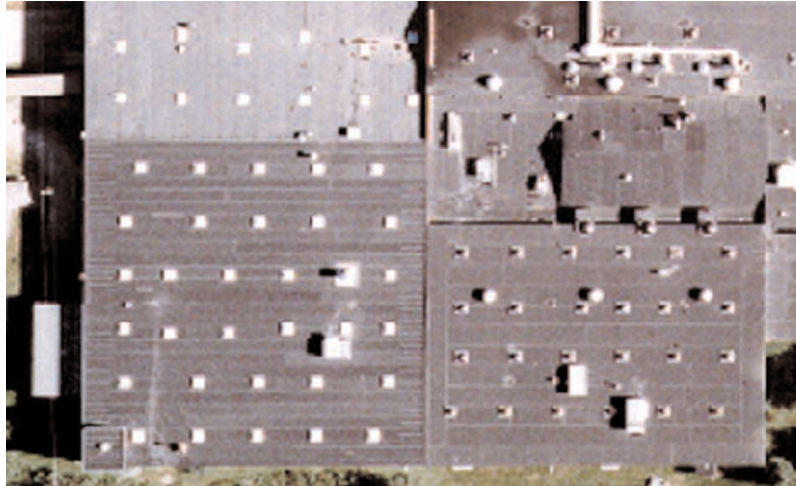
Fixed-wing aerial infrared imaging provides many advantages over on-roof infrared imaging:

- Access to multiple levels of the roof is not a problem.
- High-angle, straight-down infrared images lessen reflection problems.
- High-resolution images capture large areas at once, making report writing easier and less expensive to produce.

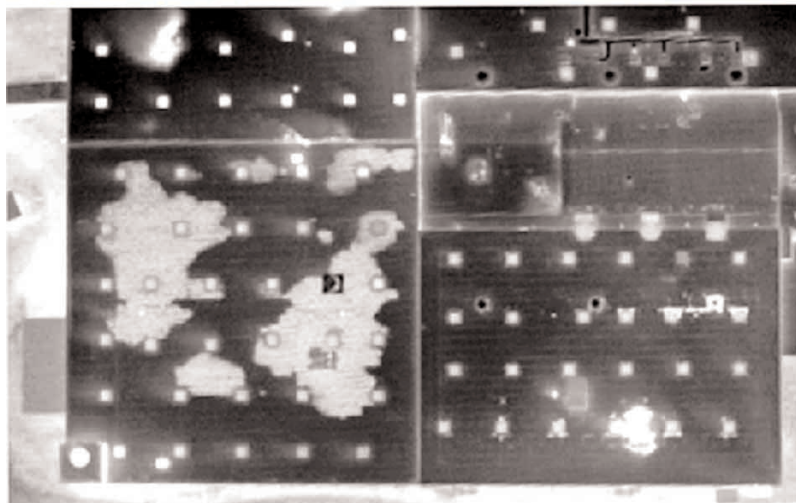


Figure 3: Aerial photograph of a 2.2 million sq.ft. building that took 25 minutes to infrared survey from the air. We calculate a crew of three would have taken 5–7 nights to infrared survey from the roof.

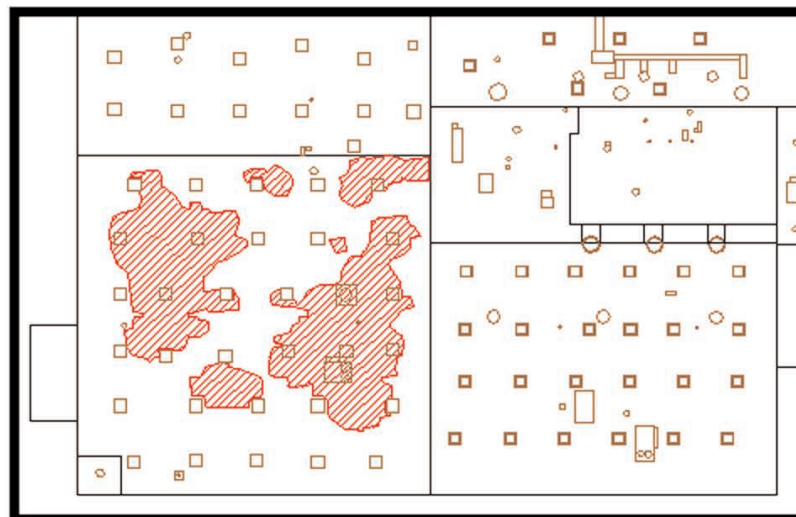
- Plan view allows for infrared images, visual images and AutoCAD drawings to be reconciled closely. As a result, the report is clear, concise and easy to understand (see Figures 4, 5, & 6).
- Plan view imaging allows accurate marking of areas of suspect roof moisture contamination.
- The printed AutoCAD drawings can be used on the roof to paint areas of moisture contamination directly on the roof (after verification), if desired.
- The aerial infrared thermographer can wait for a good night for imaging, surveying many roofs under good conditions.
- The trending of roof moisture becomes possible.
- An air crew of two can easily survey many millions of square feet in a single night.
- Processing the data is done in the office, not on the roof.



*Visual
Photograph*



*Infrared
Thermograph*



*AutoCAD™
Drawing*

Figures 4,5,6: Three components – Aerial photograph, infrared thermograph, and AutoCAD drawing all match well.

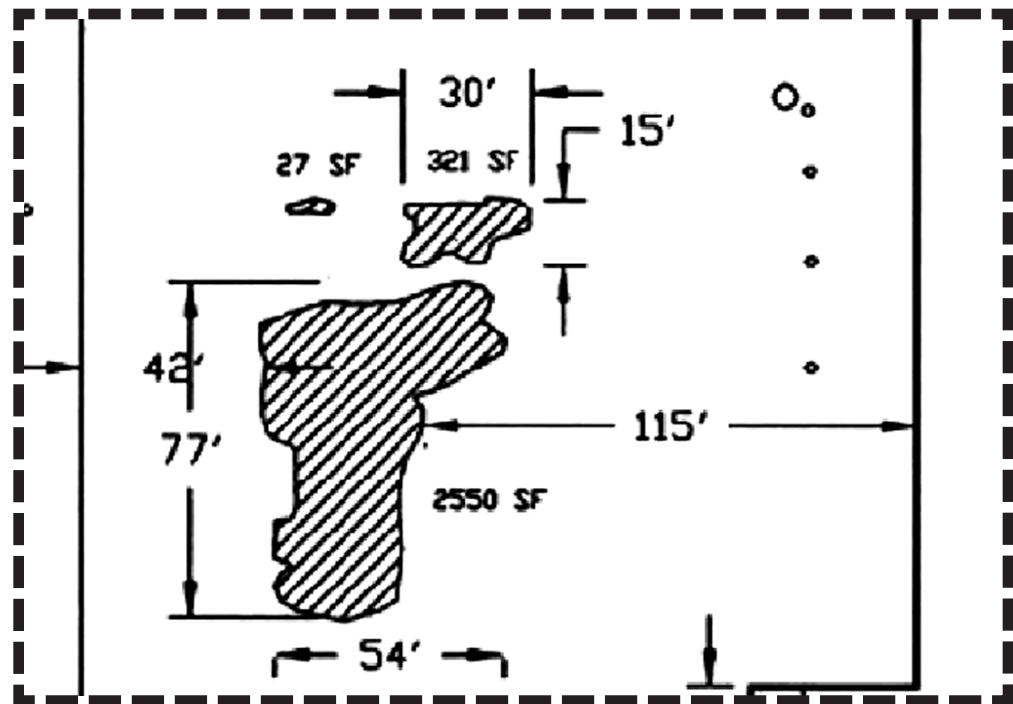


Figure 7A: Scaled AutoCAD drawing showing exact dimensions of probable roof moisture. (Expanded area from Figure 7.)

The biggest advantage of aerial infrared is on roofs that are the most difficult to image from any distance or angle—for example, roofs that have a lot of ballast, are covered with reflective coatings, or for whatever reason are *impossible* to image from the roof (see Figure 8). With high-resolution, plan-view aerial imagery, slight nuances of temperature can be seen from far enough away to actually see the pattern of heat and make a determination of where the problems are.

Who Performs Infrared Roof Moisture Surveys...and Why

In preparation for this paper, I interviewed more than thirty roofing and infrared professionals and asked them to relay their experiences and react to thoughts that I had written. The results of these interviews are in the next two sections. The fact is that in the United States, roofers or roof consultants perform most of the infrared roof moisture surveys. Basically, there are two reasons for this: 1) Roofers and roof consultants want to do the infrared surveys, and 2) infrared thermographers do *not* want to do the surveys:

1. Roofers and roof consultants want to do the surveys.
 - In order to protect a future contract for roofing/roof consulting work, they do not want to let anyone know that their potential client has a need.

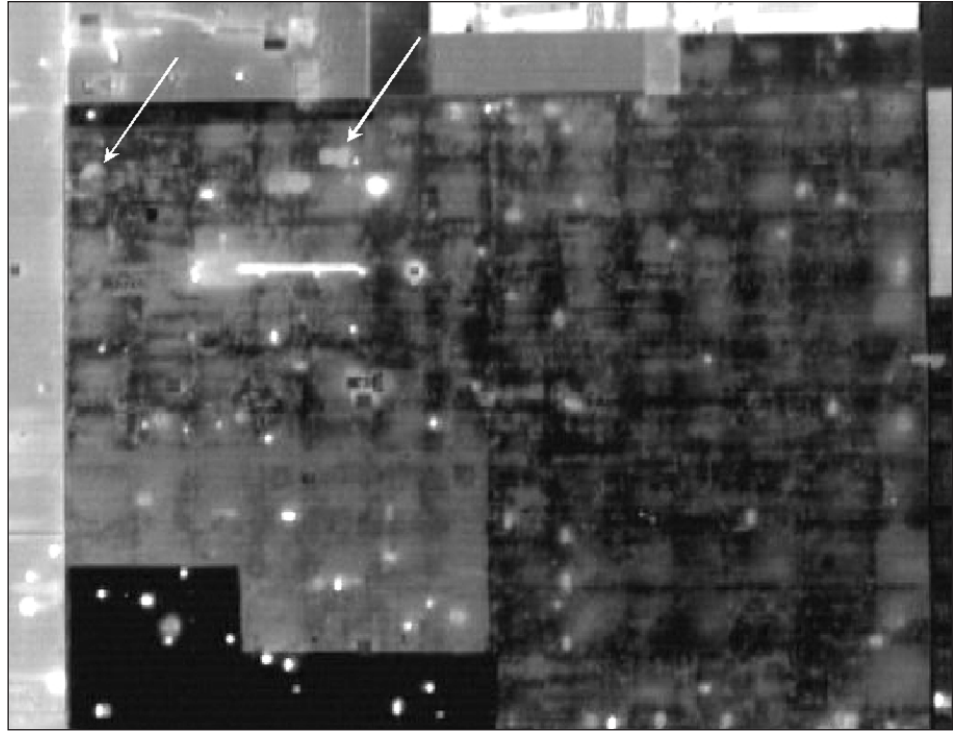


Figure 8: Aerial infrared thermograph showing a heavily stained roof that is impossible to image from the roof. Arrows indicate the only two areas that contain subsurface moisture.

- Roofers and roof consultants are experts on roofs, and to them this is more important than being an expert on infrared.
- They want to do the work themselves for these reasons:
 - They may consider infrared thermography to be a way to make a profit.
 - It may lead to additional work.
 - The cost of a basic, used or antiquated piece of infrared equipment is low enough that the return on investment looks good. Most roofing professionals do not understand the difference between roof infrared of 20 years ago and the state-of-the-art products that are available today. They think that they do not necessarily need a state-of-the-art infrared imager and know they do not need a radiometric camera.
- The quality of the imagery in the report is not of great concern, since they are the ones who will be using the information anyway. They think that printed infrared and/or visual images of the roof are not necessary if the outline of the water is marked directly on the roof with paint. The areas of roof moisture contamination can be measured with a tape measure and later converted to AutoCAD—which they get paid to do.

- Roofers and roof consultants know that there are many reflections and false reading problems, (as shown in figure 8) so they think they need to be there on the roof during the survey anyway. Someone has to test the roof whenever and wherever a suspect warm spot is found, or the number of suspect areas could be so numerous, that the owner could lose faith in the survey results and/or their judgment.
2. Infrared thermographers do not want to do the surveys.
- Often contract infrared thermographers are not comfortable performing surveys on roofs because they have never been trained and have no experience on roof infrared.
 - The work is not easy. On-roof surveying is a labor intensive, time-consuming and, at times, dangerous undertaking, requiring a great deal of planning and preparation.
 - Considering the costs, scheduling problems, logistical problems and danger, together with how much trouble the report is going to be to produce, checking electrical switchgear is a much easier way to make a living.
 - Some of the larger corporations have infrared thermographers on staff. They usually belong to the engineering/maintenance groups and are busy checking electrical switchgear. Often they have received little or no training on roof infrared, primarily because the camera was bought and the program set up for a specific purpose and that is what it is used for.
 - It takes more effort to sell roof infrared. Roofers and roof consultants understand roofs and the market for roofs/roofing services much better than infrared thermographers.

Market Forces and Other Considerations

Facility managers (corporate and in-plant) buy infrared surveys because they are the ones in charge of roofs. Even though it is one of the largest that a company owns, the roof is often an unseen and forgotten asset—until it leaks. Roofs are expensive to maintain. If the owner can put off replacement or even repairs, it will save a lot of money. Production issues take precedence over building maintenance issues. Facility managers usually have some engineering savvy, but almost never have much experience with roof maintenance. They depend on roofing experts outside the company and are convinced that once a “good” roofing guy is found, the relationship should be protected. The relationship could be jeopardized if the manager schedules an infrared survey when his roof “guru” disagrees.

Roofing is a competitive market. In the United States there are 14,000 roofing contractors, over 2,000 roof consultants and 250 roofing materials manufactures, all vying for a limited roof owner market. These figures make them all insecure. This is why

they desperately want to control consulting, testing and the purchase of roofing materials. Roofers and roof consultants perceive infrared thermographers as competition. They market themselves as roof experts. They do not want to have to bring in someone that knows more about anything on a roof than they do.

In their attempt to control roofing purchases, some companies may be willing to perform infrared surveys for free so that they can position themselves for the sale. A 'free' infrared survey will eventually be paid for by the owner and can be worth what is paid for it.

Every contractor knows that even if they try hard, some of their work will not be perfect. They certainly do not want someone outside the 'family' pointing out these problems.

To roofers and roof consultants, it is important just to know where and how much water is in the roof. Infrared roof moisture surveys are only one method for testing to find water, one part of the big picture. They [correctly] perceive infrared thermographers as picture-takers, interested primarily in the end product—a thermographic photo album of sorts.

There may be a conflict of interest associated with a roofer performing infrared roof moisture surveys. A roofer will likely be biased by what he is in the business of selling...roofing and roofing services. He may not recommend an infrared survey even when one is indicated, because there may be the chance of losing a large contract as a direct result. He may have the owner—and himself—truly convinced that replacement is the best option. He might consider that the owner could be swayed too easily by the results of an infrared survey. If the results of the survey show only a small percentage of the roof as damaged (see Figure 9), the owner may opt to repair (patch) the roof instead of replacing it. They know that leaks are going to come back if a roof is patched. They don't like patching because their experience is that if the roof leaks near their patchwork, it reflects on their work, whether or not the patch or an area close to the patch ends up leaking. The owner might lose faith in the roofer's work.

A roofer, roof consultant, and/or owner may have had a bad experience with roof moisture infrared surveys. Remembering the unsuccessful results of a past plant that he had surveyed, he may be unwilling to try infrared again even though his current roof lends itself very well to infrared. Aerial IR is even more difficult to sell if an amateurish attempt to fly a roof has been made. High-vibrations and low-resolution cameras do not produce great results.

There are independent roof consultants that do not hold allegiance to any roofing contractor or roof materials manufacturing company. These consultants often see the need for IR and recommend a survey, but they still may not hire an infrared thermographer because they think it would be better if they did it. Mobilizing and paying a third party does not make sense to them, especially if the roof is small and/or in remote area.

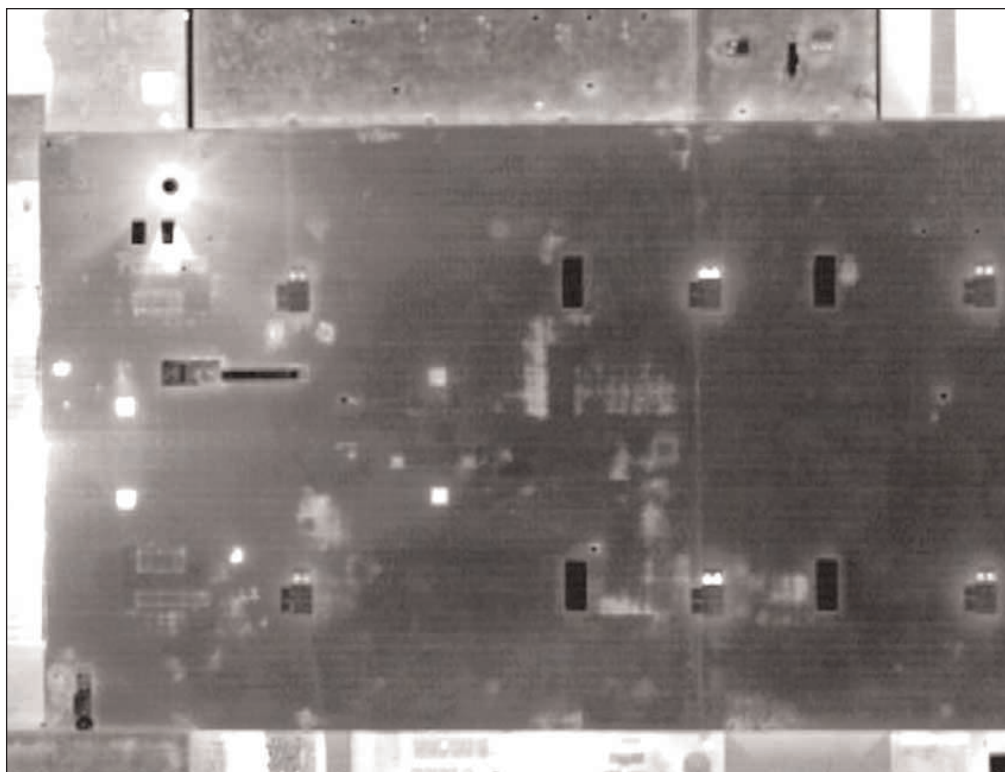


Figure 9: Aerial infrared thermograph showing a roof with numerous leaks, but only a small percentage of wet insulation

Conclusions

Building roofs must be maintained. Roof moisture surveys indicate that roof moisture problems exist and where they are located. This knowledge is valuable because cost-effective repairs can be accomplished with near-surgical precision. Once an IR thermographer determines that a flat or low-slope insulated roof lends itself well to infrared inspection, annual infrared roof moisture surveys should be considered an integral part of the roof asset management program. This will help the owner to assess the roof's condition at all stages of its service life. The [thermographic] end product is a printed and digital document of images and drawings. The images are most efficiently and effectively gathered from straight above the roof. In order to get a usable, accurate graphic report, the infrared thermographer must obtain infrared images of large areas from as high above as possible without losing the needed resolution.

Infrared roof images, no matter how spectacular, are only signatures of heat. Because there are many causes of heat (or apparent heat) on a roof, infrared analyses must be professionally verified on the roof in order to be reliable. The infrared report should be reviewed and the printed data taken on the roof to aid in visual, destructive and non-destructive testing. This professional verification is the duty of roofers and roof con-

sultants, which is a task that they do well. Competently gathering infrared imagery and making infrared reports is the duty of infrared thermographers, which is a task that they do well.

Currently, infrared roof moisture surveys are most often bought by facilities managers and performed by roofers and roof consultants. By and large, these roofing contractors are biased, are not trained experts in infrared thermography, do not use state-of-the-art imaging systems and, therefore, their infrared reports are substandard. In fairness to roofing professionals, part of the reason that they perform most of the IR roof surveys is that infrared thermographers are not approaching them to perform the surveys.

Most infrared thermographers are missing out on the financial rewards and professional satisfaction of performing qualitative infrared roof moisture surveys. If you work in a plant, take your camera (it does not matter which) out on the roof(s) 1 hour, 3 hours, 6 hours, and 9 hours after sunset to see if you find subsurface moisture. If you do, approach the roof “czar” of the plant and show him your imagery. Even if your company has a roof consultant, you can help him. Do surveys from the air or from a higher adjacent roof if you can. Always try to look straight down. But no matter what, get trained, get some experience and go after this market.

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