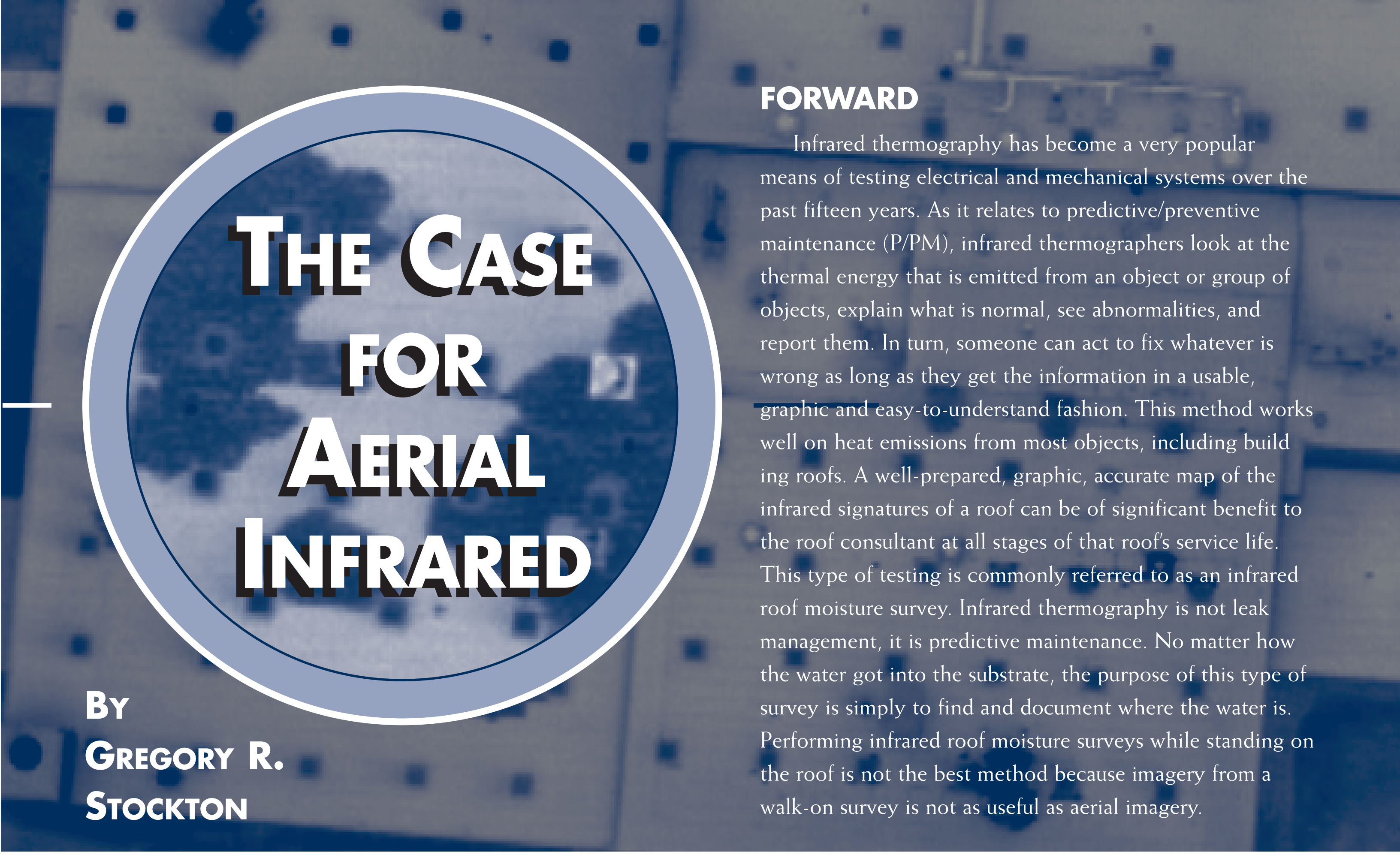

# The Case for Aerial Infrared

By
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## FORWARD

Infrared thermography has become a very popular means of testing electrical and mechanical systems over the past fifteen years. As it relates to predictive/preventive maintenance (P/PM), infrared thermographers look at the thermal energy that is emitted from an object or group of objects, explain what is normal, see abnormalities, and report them. In turn, someone can act to fix whatever is wrong as long as they get the information in a usable, graphic and easy-to-understand fashion. This method works well on heat emissions from most objects, including build ing roofs. A well-prepared, graphic, accurate map of the infrared signatures of a roof can be of significant benefit to the roof consultant at all stages of that roof's service life. This type of testing is commonly referred to as an infrared roof moisture survey. Infrared thermography is not leak management, it is predictive maintenance. 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. 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 school of frozen toes

Our company began looking at roofs by walking them with infrared cameras early in 1990. A couple of facts became clear rather quickly:

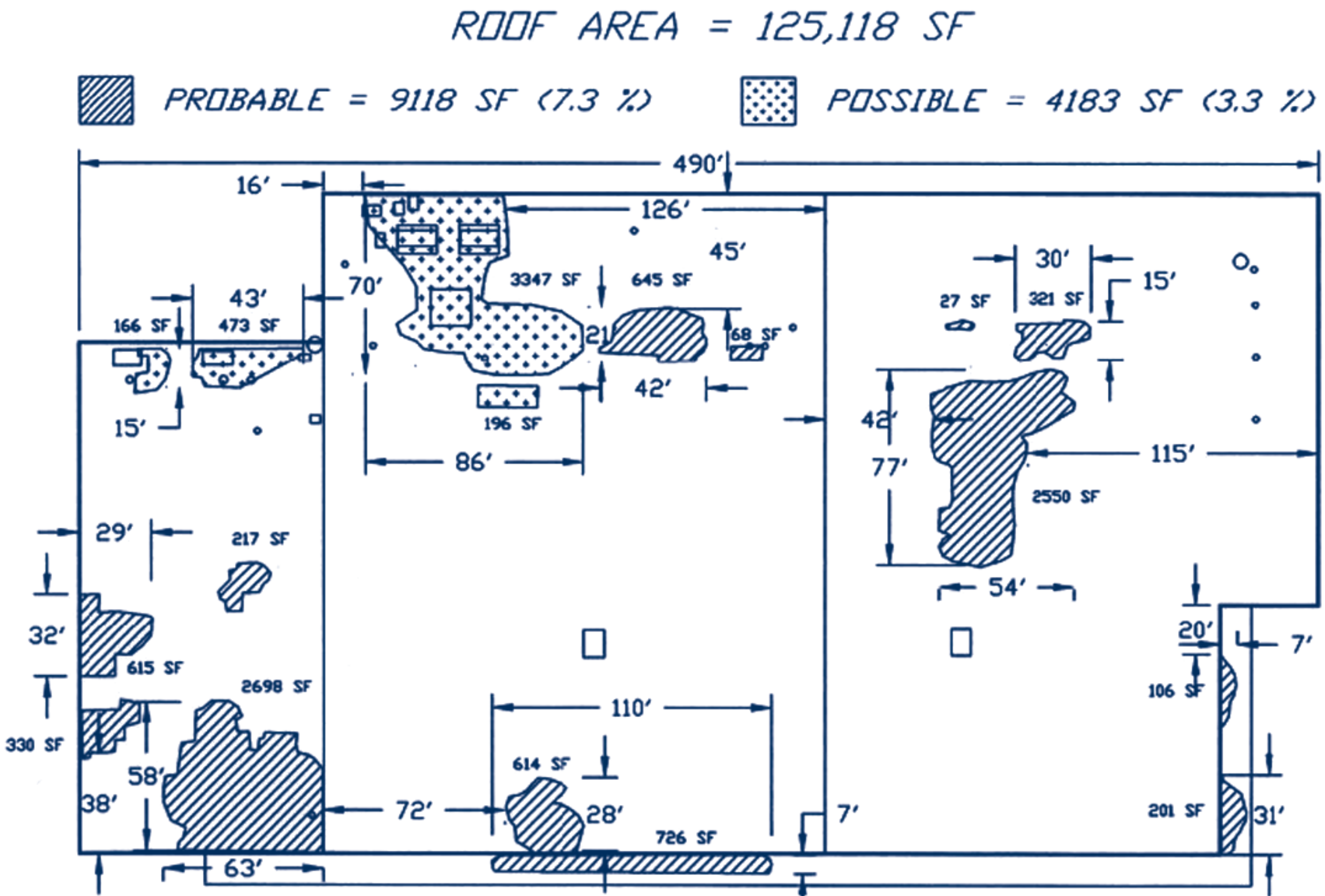
a) Since there are so many types of roof systems in use, one standard testing plan for performing all roof moisture surveys was not going to work. Each roof system has different thermal properties: that is, it may absorb and emit heat at different rates.
b) Sometimes a roof cannot be successfully surveyed under any circumstances.
c) We did not know enough about the roofs we were surveying. The thermal patterns were sometimes fantastic. Clear outlines of subsurface moisture in one roof would be followed by very mottled and almost unreadable imagery on another. Conditions could and would change radically over the course of the night, sometimes before our very eyes when a cloud came over or dew formed on the roof.
d) The infrared camera's wavelength, filters, windows, and lenses could dramatically affect the quality of the imagery.
e) Even with a strong infrared signal, factors on the roof could affect the analysis and interpretation of the data. Some of these factors: 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 on the roof, ponding, heavy build-up of ballast at parapet walls and along edges, etc.
f) Surveying roofs was a labor-intensive, time-consuming, and at times, dangerous undertaking, requiring a great deal of planning and preparation.
g) Information on the target roofs was, at best, sparse; and at worst, non-existent, especially the drawings. Often, information on the roof types, repair history, and as-built drawings was simply not available. Many times the drawings were not to scale and were incomplete, lacking many of the objects that we saw when we climbed up on the roof.

These revelations did not discourage us from performing roof moisture surveys. We knew that it worked well on most roofs. We just had to figure out a better way to perform the inspections. In the case of roofs, infrared thermographers should see their role as providers of infrared imagery—nothing more, nothing less: the mappers of heat. We do not profess to know everything about roofs or how to fix them. Our role is to obtain and provide information that will help experts at roof construction, installation, and repair.

## Once Upon a Roof

Many consultants have been on a roof when an infrared roof moisture survey was being performed.Those who have can relate to the following:

When we started conducting walk-on infrared inspections of roofs, we had no idea what nightmares these surveys could be.




*Aerial infrared thermograph showing a roof with extensive rooftop equipment. It would take 20 infrared images to completely document all the areas of suspect roof moisture on this one roof section.*

First, nighttime conditions have to be right. Having low winds, clear skies, and some sunshine during the preceding daylight hours is usually not too much of a problem. However, mobilizing a certified infrared thermographer, a helper, a building owner's representative, and a roof consultant to meet at a site on a specific scheduled date when the weather is just right takes much more flexibility and some luck. Also, some roofs do not exhibit a good infrared signal, primarily for two reasons: 1) The surface is too reflective, and 2) the roof's ballast is so thick (or dense), that daylight radiation is not absorbed into the substrate (insulation), therefore it cannot be emitted back into the atmosphere at night. There are other reasons why infrared thermography is of little value on certain other roof types.

Suppose we have a roof that lends itself to infrared (other than metal, most roofs do). We have scheduled the job, everyone is in attendance, and the weather is favorable. The biggest problems then become logistical in nature.

Again, the infrared thermographer's job is to make a graphic, accurate, and easy-to-understand report. For legitimate results, you need excellent imagery. To get excellent imagery, a high angle of view and high resolution are needed. When standing on the roof, eye-level is at best six feet over the surface. If you are looking out over a roof with large areas of moisture contamination (even if you have a good infrared camera), there is virtually no way, without taking multiple shots, that you can get a 900-square foot amoeba-shaped blob, or an 80-foot long striation of subsurface moisture resolved on the screen in one infrared shot. If you take multiple shots, the report starts to become confusing, and the visual images that you have to take the next day are going to be hard to reconcile with the infrared images. J.P. "Sonny" Ledoux, an infrared thermographer with over twenty years experience, describes the problem best, saying, "When performing walk-on roof surveys, many times you can't see the forest for the trees."

Marking the roof is not difficult if you are able to yell out the commands well, and your helper with the marking paint is adept at his task. But then there are the drawings. Many times I was faxed a photocopied fire plan of the building (without any rooftop equipment indicated) for use as my roof drawing. We really struggled with the drawings, especially on the night of the survey.

Consider the costs, scheduling woes, logistical problems, and danger (from tripping, poking yourself in the eye, falling off the roof or dropping $80,000 worth of your livelihood), together with how much trouble the report is going to be to produce, and it's no wonder that infrared thermographers survey comparatively few roofs... It is a lot easier to make a living checking electrical switchgear!

## Imagery vs. paint

Those who have infrared cameras or a favorite infrared thermographer to perform on-roof inspections do not need me to explain how a survey should be done.

Some may be thinking at this moment that:

1. Good imagery is not all that important. What is important is finding and marking the water under the roof.
2. Printed infrared and/or visual images of the roof are not necessary if you mark the outline of the water directly on the roof with marking paint.
3. Two people can do the job just as good as four. The owner leaves the keys to the roof hatch and a helper who can spray the paint.
4. We can go back on the roof during the day and measure the paint-marked blobs with a tape measure. I have AutoCAD 2000™ and know how to use it!

*An aerial infrared thermograph showing clear outlines of subsurface moisture contamination from 2,000 ft. AGL (Above Ground Level).*

No matter which method or style you currently use to perform these surveys, the end product will benefit from high quality imagery and drawings. The end product is not only a printed document but also the knowledge of where the moisture is in the roof so that precise, cost-effective repairs can be accomplished.

As stated earlier, excellent imagery demands a high angle of view and high resolution. In order to get excellent infrared and visual imagery of that 900-square foot blob onto a printed page, a lot of costly work has to be done with an infrared and visual camera on the roof and then with a computer in the office to create the report. To avoid reflections and to image a large area at the same time, we used to climb rickety ladders with very expensive infrared cameras so we could get as high above and as close as possible to a 90-degree angle over a particular area. This was done by looking down from a higher roof to a lower one or climbing on air washes and other rooftop equipment. All this takes time and can be dangerous. Some roofs have only package air conditioning units, allowing for maybe 12 feet over the surface at best. So, we decided to try a helicopter.

## Why aerial infrared?

The problem with the helicopter was that even as close as 500 feet above the building, we could not resolve (to our satisfaction) the infrared images of the blobs. We had to deal with the vibrations. Also, the slow ferrying speeds and $575/hour for the aircraft and the pilot dissuaded us. By the time we got high enough to get a large area in the image, we lost our resolution. Even though we were using state-of-the-art infrared cameras, they just did not have the thermal and/or spatial resolution required for obtaining good imagery from high above. Most infrared cameras are built to resolve images a short distance away from the detector. These cameras, including the modern 2000 model focal plane arrays, have only 256x256 pixels–a total of 65,536 pixels. They work fine for looking at switchgear, electric motors, or boilers (which is what they were designed to do). They were not designed to image objects a half-mile away.

The breakthrough came in the form of the 5122 focal plane staring array chip. These cameras can be used for aerial infrared because they have 512x512 pixels–a total of 262,144 pixels, which is four times the resolution of the 2562. That's four times farther away at the same resolution. Because of the high resolution, this type of camera can be mounted in a fixed-wing aircraft allowing the infrared thermographer to quickly fly over buildings, obtaining great imagery of large areas of roofs. What used to take a four-man crew six hours can be done better and less expensively in 60 seconds.

## Fixed-wing aerial infrared imaging provides:

- High-angle, straight down infrared images which lessen reflections.
- High-resolution images that capture large areas at once, making the report easier and less expensive to produce.
- A more cost-effective platform to obtain infrared imagery than rotor-wing, while reducing ferry times and vibrations.

## More advantages:

- 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.
- Plan view imaging allows accurate marking of areas of suspect roof moisture contamination. AutoCAD drawings can be made by drawing "over" the captured visual and infrared images on the screen. Hatch marked areas indicate probable and possible wet areas. The infrared, visual,


*Example of a scaled AutoCAD drawing of roof moisture.*

and AutoCAD components can then be separated. If dimensional information is available, this creates a quantitative, scale quality AutoCAD drawing of the suspect roof moisture contamination on the roof. If dimensional information is not available, the drawings become scaleable and easily updated at any time in the future, once quantitative data are obtained.

- The printed AutoCAD drawings can be used on the roof to paint areas of moisture contamination directly on the roof, if desired.
- The aerial infrared thermographer can wait for a good night for imaging, surveying many roofs under good conditions. If the image quality is not acceptable on a particular building roof early in the night, he can return at different times during the night in order to image the building under the best possible conditions.
- Instead of inefficiently using four people for a night to perform a survey, an airplane crew of two can do many times as much data collection and then process the data (not in a hurry on a freezing cold night) under comfortable conditions at a consistent pace in the office.



- Instead of imaging 200,000 square feet in a night, up to ten million square feet can be imaged!
- Access to multiple levels of the roof is never a problem.

## Flexible Reporting

The owner of a roof and his roof consultant should be given as much latitude as possible with respect to the level of detail in the infrared roof moisture survey report. Here are the different levels of reporting, in ascending order of costs:

**Unedited videotape.** If scheduled in an area where the plane will be operating on a particular night, a building roof can be imaged (recorded on digital videotape and VHS) and the unedited VHS videotape can be delivered to a local airport that night. The owners' roof consultant can review the videotape the next morning.

**Edited videotape.** An edited videotape can be made from the original digital videotape and copied onto VHS.

**Printed thermographs**. Printed infrared thermographs (infrared pictures) of each roof section can be captured and printed in high resolution.

**Aerial photographs.** Printed photographs of the roof (straight down) and building site photographs (lower angle "beauty shots" of the building and property) can be developed and printed. Photographs, of course, must be taken during daylight hours, requiring a second flight over the building. The costs increase, but a straight down photograph of a roof section aids significantly in the infrared analysis, showing stains, equipment, and roof boundaries.

**AutoCAD drawings.** AutoCAD drawings, printed and saved to disk, can be made by analyzing all the infrared, photographic, and drawing information. Often, the roof's old drawings are outdated and inaccurate. The old drawings can be corrected by using the new photographs as a reference.

**Digital and printed report.** A complete quantitative infrared roof moisture survey report would include all of the above, printed in high resolution and saved to a CD, put on the Internet with a password to access, and/or e-mailed to all the interested parties.

A roof consultant must verify all infrared data and analyses. The infrared report should be reviewed and the printed data taken on the roof to aid in visual, destructive, and non-destructive testing. I cannot overstress this point! Infrared images of the roof, no matter how spectacular, are only signatures of heat. As stated earlier, there are many causes of heat (or apparent heat) on a roof. Professional verification is a required part of the survey, without which the information is not and should not be considered reliable. I believe this is one of the reasons that this type of infrared survey is not performed more frequently.

## Other Considerations

The main use for aerial infrared thermography is predictive maintenance for existing roofs; however, the prospective owner of a building could have the roof flown over before he buys it. If the roof looks good, he would not have spent much money to find out. If it looks bad, he can ask for a more detailed analysis and use this information as a "bargaining chip" to negotiate the price of the building.

After installation, a new roof that can be imaged effectively should have a survey performed to verify that no wet insulation boards were installed during construction. Also, aerial infrared images taken soon after installation become very important documentation later as the roof ages, since they can be used for comparison. Subsurface fasteners are also evident (in the infrared) on certain roof systems.

Designers could have a roof flown over in order to furnish a quantitative document to all bidders, in the form of verified AutoCAD drawings, for the localized removal and replacement of all wet insulation.

Aerial infrared has a big advantage over walk-on infrared in the ability to trend areas of a certain roof system. A one-year-old aerial thermograph can easily be superimposed over a new aerial thermograph, producing a three-part composite: the area of moisture one year ago, the area of moisture now, and the difference (growth). Using this information, the rate of growth for that particular roof system can be reasonably extrapolated.

Permission to fly over any building in the US is not required. The airspace over a few sensitive federal buildings may be restricted, but even in this rare case, permission is usually granted to fly over.

Soon, the insurance industry will discover the potential benefits of aerial infrared thermography on their insureds' roofs. Highly insured facilities in one area can be surveyed from the air in a matter of minutes. If problems are discovered, the insured can be informed that a more effective roof maintenance program needs to be started at that facility or, for instance, their rate and/or deductible will be increased, or coverage discontinued. Also, if a particular area is prone to hurricanes, tornadoes, or severe storms, the insured roofs in that area can be flown over on an annual basis, thereby limiting the insurance company's liability, in case of roof damage, to the pre-storm condition, as compared to post-storm. Aerial infrared and visual imaging can also be used to quickly assess roof damage after a disaster when security and/or automobile road conditions make on-roof surveys impossible for the purpose of determining which roofs should receive top priority.

## Conclusions

Once a roof consultant has determined that a particular type of flat- or low-slope insulated roof lends itself well to infrared inspection, it should be considered an integral part of the roof asset management program. Regular infrared surveys will help the roof consultant to assess the roof's condition at all stages of its service life. Whether performed on-roof or aerial, infrared imaging only provides a picture of the heat. Infrared analyses must be professionally verified on the roof in order to be reliable. Infrared heat signatures are most efficiently gathered from the air. In order to get a graphic, usable report, the infrared thermographer must obtain high-resolution infrared images of large areas from high above. Therefore, the infrared camera used must have a detector with enough pixels to achieve the desired resolution from the maximum desired altitude. ■

## About the Author

**Gregory R. Stockton** is President of Stockton Infrared Thermographic Services, Inc. Based in Randleman, NC, the corporation operates six complete infrared systems in four divisions. Greg has twenty years experience in the con struction industry, specializing in energy-related technologies. He is an Infraspection Institute Certified Infrared Thermographer (#3583) and publishes technical papers for the infrared industry.

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