



Using an IR-InSight™ to do an infrared roof inspection

Introduction

Flat roof structures are the standard in industrial applications within the USA. Of the millions of square feet of roof installed each year it has been estimated that up to 40% will develop problems within the first year of service. The average life span of these roofs is seven years, but it is estimated that they could last as long as twenty years if correctly installed and maintained. Replacement roofs can cost as much as \$8 to \$10 per square foot when disposal costs of the old roof are included. Billions of dollars are lost every year due to premature roof failure. By simply maintaining the roof, a great deal of money that is being lost could be put to better use. This is where infrared roof inspection stands above all other methods in prolonging the life of a flat roof structure.

Thermal infrared inspections are non-contact and non-destructive testing procedures. The infrared camera allows the user to quickly scan large areas of the roof. Traditional roof inspection requires a grid type contact search, is very time-consuming and requires use of heavy equipment e.g. in the case of capacitance testing. It also requires invasive testing (e.g. core sampling) of several different parts of the roof that may or may not be affected.

Moisture is the number one enemy of built up roofs. Undetected wet insulation is the primary cause of premature roof failures and high maintenance costs. The advantage for infrared thermography is the ability to provide a fast, accurate and inexpensive way to locate areas of wet insulation and potential leaks that give maintenance personnel the opportunity to limit their roof problems before they become costly. In addition, infrared imaging can be carried out from an elevated vantage point, which precludes the need to climb down to the various lower elevations of the roof.

Flat Roof Basics

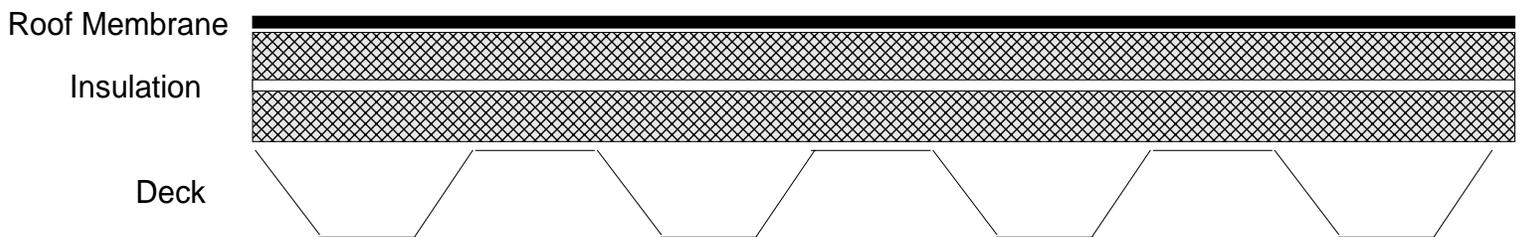


Figure 1: Cross section of a typical Flat Roof



The roof deck supports the roof and the roof load. The types of roof deck whether it is steel, wood, tectum (wood fiber in cement mixture) or concrete has no bearing on the infrared inspection.

Insulation is installed on top of the structural decking. Roof insulation is manufactured in boards of varying thickness and can be categorized as either absorbent or nonabsorbent. Perlite, wood fiber, cork and fiberglass are examples of absorbent insulation. Extruded polystyrene, foam glass, lightweight concrete, closed-cell polyisocyanurate, closed-cell polyethylene, urethane, and expanded polystyrene are examples of nonabsorbent insulation. It is important to note that different types of insulation will result in different thermal patterns. Identifying the type of insulation and the thermal pattern it will create is crucial before starting an infrared roof inspection.

The roof membrane is the waterproof barrier between the outside elements and the interior of the building. An effective roof membrane has to be waterproof, durable, able to expand/contract with the materials it is adhered to, resist forces of high winds, and support external loads. Hence, it is easy to see why roofs leak. Even though a variety of roof membrane materials are available, they can usually be classified as either built-up or single ply. Built-up roof membranes consist of layers of roofing felts that are adhered to each other with hot asphalt or coal tar pitch. Single ply membranes are large sheets of thick rubber or plastic material (e.g. neoprene, EPDM, PVC) that are usually glued down or held down with heavy stone ballast.

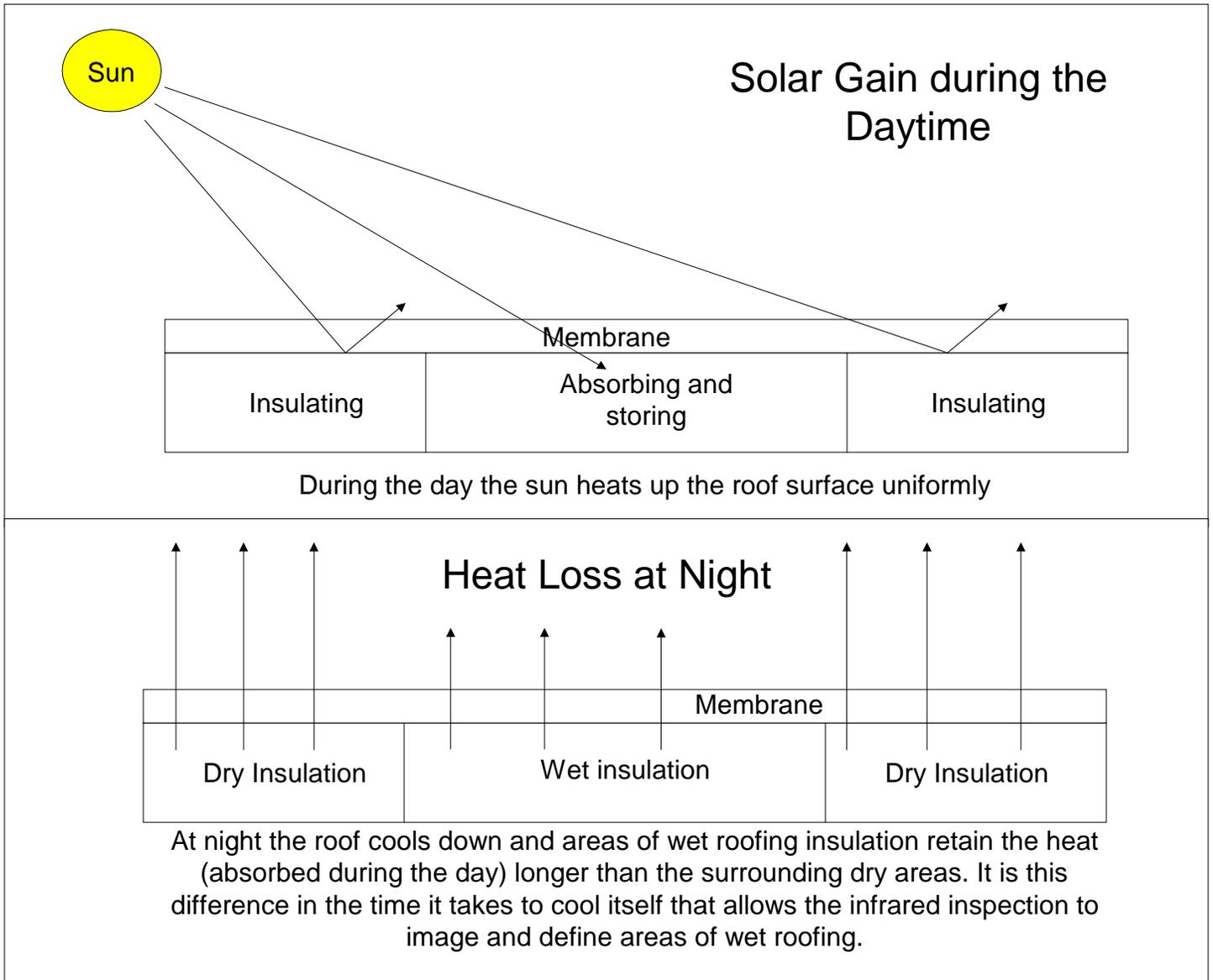
Theory behind infrared roof inspections

Normally there is little or no water within a flat roof assembly. When a leak develops, water enters the assembly and, depending on the type of insulation system, is either absorbed by the insulation or runs to the cracks between the nonabsorbent insulation. When water enters the roof assembly it is there for a long time, sometimes the life of the roof.

Thermal capacitance is the physical property of a material's ability to store heat. The materials in roof assemblies have relatively low thermal capacitance, especially when compared to water. Water requires a lot of energy to raise its temperature and likewise must release a lot of energy to cool.

The physics used for thermal roof inspections is that dry roof insulation heats up and cools down faster than wet roof insulation. Infrared inspection goes beyond simply finding a leak by locating the extent of the moisture invasion of the insulation. However, it first requires solar heating of a sunny day. Then at dusk, after the sun goes down and the roof surface begins to cool, the dry roof insulation cools faster than wet roof insulation. This temperature difference can be detected by the IR-InSight™. Hence, the wet areas can be seen as warmer than the dry areas. By the same rationale, the

inspection could be carried out at dawn too because it takes longer for the water saturated part of the roof to heat up than the dry part and the wet areas could be seen as cooler than the dry parts. However, industry norm is for the inspections to be carried out around dusk.



Infrared inspections should be done under the right conditions to obtain the best infrared images. A thermographer needs to make sure that the sun has supplied enough energy during the day and that the roof has cooled off to an adequate extent at dusk for the warm wet insulation to be evident.



The same rules apply during winter. Moreover, if the outside temperature is significantly cooler than the inside temperature, the added heat flow from the building through the wet insulation will enhance the thermal pattern. This is because the water saturated insulation will be more “thermally conductive” than the dry insulation. Hence, it will conduct the heat from inside the building better allowing vivid thermal differentials to be detected.

Thermal Patterns associated with different insulation systems

Different insulation materials interact with water in differing ways. The thermal pattern that is associated with each insulation type depends on this interaction. Following are some insulation systems and the thermal patterns they result in:

- Absorbent roof insulation behaves like a sponge. Water will fill up a complete board before it jumps to an adjacent board. This results in a checker board pattern.
- Nonabsorbent roof insulation does not allow water to be absorbed and, hence, the water tends to run to the edges of the board. Water collects on the edges of the board, resulting in window frame patterns.
- Foamglass Block will only allow the water to fill in surface pores. However, when the water freezes, it will expand and cause the insulation to crack. This results in fractured patterns.
- Monolithic insulations such as lightweight concrete, gypsum, or foamed-in-place polyurethane will result in amorphous anomalies that are irregular in shape.
- Aluminum coated roofs are reflective to solar energy. This makes it hard to detect thermal differentials.

Factors to consider before performing an infrared roof inspection

There are several things that one must consider in order to ensure accurate data collection.

- A built-up roof (BUR) with polyisocyanurate insulation is one of the most common roof assemblies in the industry. These roofs are good candidates for infrared roof inspections. Other applicable constructions include membrane systems containing any of the commercially available rigid insulation boards. This includes boards made of organic fibers, perlite, cork, fibrous glass, cellular glass, polystyrene, polyurethane, isocyanurate, and phenolic. Composite boards and tapered systems made from these materials can also be inspected, as can roofs insulated with foamed-in-place polyurethane.
- Inverted roof membrane assemblies (IRMA roofs) where extruded polystyrene insulation is placed under ballast and above a protected membrane are not good candidates for infrared inspection. However, IRMA roofs are not in widespread use, and are thus not a big problem generally.



- Roofs covered with concrete pavers or river washed ballast (walnut sized rock) usually take longer for thermal patterns to be observable because of the extra layer above the roof membrane. Also the extra layer causes the patterns to be diminished. However, one can even the rocks out in order to facilitate the inspection.
- Roofs with thick insulation systems may be difficult to image when moisture is present only at the bottom of the insulation, but the insulation towards the top has dried up.
- Some materials are more difficult to inspect than others. Roofs having lightweight concrete or gypsum can be more difficult to inspect because they can retain significant quantities of moisture either left over from construction or due to building usage.
- The wetting rates of roof insulations vary according to the type of insulation and the environmental exposure. New roofs with insulations that wet slowly, such as cellular plastics or cellular glass, usually should not be surveyed until they are at least 8 months old.
- Metal roofs are reflective and because of their conductivity tend to dissipate heat rapidly and more uniformly across the entire surface than other roofs do. This makes detection of distinct thermal patterns more challenging. However, if inspected carefully from different angles, thermal anomalies can be observed.
- In general infrared inspections are best performed at night after a sunny day. However, there are several environmental factors, which will influence the ability to collect accurate data. Minimum weather requirements are as follows:
 - Dry roof surface at sunrise. No ice, snow, dew, frost or standing water.
 - Mostly sunny day.
 - Daytime highs above 40 F (unless it is winter in which case internal heat from the building enhances thermal patterns).
 - Nighttime winds of less than 15 mph at the rooftop during the IR inspection.
 - No rain during the day of the inspection
- The amount of moisture within the roofing system will have a direct impact on the images observed.
- During a roof moisture survey, many thermal patterns are seen that are not related to wet insulation. Following are some examples of situations that where an infrared inspection may identify something other than a moisture problem:
 - Insulation with different R-values or different absorption characteristics which are commonly found in repaired areas
 - Different internal building temperatures
 - Extra gravel or bituminous left from construction
 - Warm or cold air exhausting onto roof
 - Re-radiation of heat from south or west facing walls
 - Wind
 - Internal sources of heat or cold such as lights, heaters, and steam pipes
 - Dirt, vegetation and debris
 - Walkway pads and buried steel plates



- Blisters
- Water ponding, steam plumes and water spray
- Shaded sections of roofs

Performing the inspection

Preliminary survey

- Inspect the roof before the day of the survey in order to anticipate the roof's condition with regard to the weather.
- Talk to the building manager and find out the history, design and composition of the roof, its previous problems and discuss your needs during the survey. Line up someone familiar with the roof and with access to it to accompany you during your inspection.
- Pay attention to flashing and penetration details. Observe the condition of the membrane and its drainage characteristics. If possible, make a rough map of the roof indicating roof levels, leak information, problems etc. Use a tape recorder to take notes if needed.
- Do not perform a roof inspection without being 100% sure of the type of insulation
- Walk the inside of the building and study the leaks. Also note objects such as ceiling mounted heaters and lights that may skew the infrared reading.
- Monitor the weather closely as it gets nearer to the day of the inspection. In the event of a storm, try to ascertain how many days it would take for the roof to be totally dry before an inspection is feasible.
- At this time, it would also be prudent to secure permission in writing from the building owner to make core samples for certain sections of the roof.
- **DO NOT CORE A ROOF UNLESS YOU ARE CERTIFIED AND AUTHORIZED TO REPAIR IT.**

The survey

- Never inspect a roof alone.
- Arrive on site at sunset or shortly thereafter.
- Grid off the roof in suitable increments such as 20 feet by 20 feet and record grid on the roof plan.
- Survey roof with IR-InSight sweeping back and forth grid by grid covering the entire roof.
- Once the patterns begin to show themselves, work as quickly as required; e.g. patterns in lightweight concrete and closed cell insulation tend to come and go very quickly. Patterns in absorbent insulation, however, get better with time.
- Lower levels can be scanned from an upper level



- Have your assistant outline the ‘suspect areas’ with permanent paint and record grid location on roof plan. Figure out if this is a known leak.
- Snap infrared images of these spots with the IR-InSight and record number of photo taken and grid location in the survey log.
- After completing the initial sweep, return to suspect areas for further study.
- Re-sweep the suspect areas with the IR-InSight.
- Select location for a Moisture Meter Test, take a second infrared photo and record photo number in the survey log.
- Record grid location and sequence number of the Moisture Meter Test on the roof plan.
- Record results of the Moisture Meter Test in the survey log.
- If moisture is detected, then select an appropriate location for a core of the roof in the area where it was detected. (Get permission to core the roof in writing from the owner)
- Record grid location and location of the core within the grid and also record the core sequence number in the survey log.
- Core the roof and describe condition of the roof system in the log.
- Patch roof core.
- Inform security upon leaving.

Post Survey

- A post survey may be necessary in order to do follow-up work during daylight hours such as taking pictures of suspect areas and completing a map of the roof showing locations of all the wet spots.
- This is also a good occasion to perform a detailed visual inspection in order to locate the point of entry of the water during daylight hours.

Tools Required

- Roof plan of the roof being surveyed
- IR-InSight
- Moisture meter
- Coring Tools (NP-1 for repairs to roof, backer rod to fill roof cores if samples are to be retained from the core, sample bags for core samples)
- Paint (Red for second suspect location tests and moisture meter tests. Yellow for grid making and initial suspect location marking)
- 300 foot tape
- 25-foot power tape
- Flashlights



- Thermometers for ambient temperature
- Camera (preferably digital) with a flash to record necessary attributes, including core sample locations

Report

A written report should contain general administrative details such as building identification, location and use. It should also include all findings, including general conditions of the roof, date and time of survey, composition and condition of roof (as determined from cores), identification of problems and leaks, description of all the wet insulation, amount of moisture detected and correlation with existing leaks. It may also include recommendations for repair of the roof and any relevant photographs and thermograms. Optionally, details of wind velocity, ambient temperature, cloud cover, and roof surface conditions at time of survey can also be provided.

A detailed map of the roof indicating all the protrusions and details is required. Outline areas of wet insulation on this map. This map can then also be used in follow-up surveys.

Sources consulted

- ASTM C1153-97, Standard Practice for Location of Wet Insulation in Roofing Systems Using Infrared Imaging. Available from:
American Society for Testing and Materials (ASTM)
100 Bar Harbor Drive
West Conshohocken, PA 19428
- Thermographic Applications for Predictive Maintenance, A Level I Course. Presented by Snell Infrared.
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