Understanding Evaporation: Why Don't Leaks Always Appear on my Thermal Images?

By Terry Carson, B.Sc., MBA, B.S.S.O., R.H.I., C. Tech.

Infrared thermal imagers are often touted as an easy to operate, sure-fire moisture detector that can quickly scan large areas and pinpoint moisture with CSI accuracy. This claim, unfortunately, is only true in specific situations. The objective of this article is to describe 1) the conditions necessary for capturing thermal images of interior water leaks, and 2) the use of non-invasive moisture meters, and air temperature and relative humidity (RH) measurements to verify the presence of sub-surface moisture. The leaks discussed are restricted to wall and ceiling surfaces viewed from the interior, and do not include exterior leak detection, such as for flat roofs or EIFS which would be viewed from the exterior.

Thermal imagers as a moisture detection tool

Modern thermal imagers produce colour images of surface temperatures, with an amazing sensitivity of 0.06°C. Imagers used by building investigators today typically cost between $7,000 and $25,000. They can be useful diagnostic tools for finding building envelope air and water leaks, but require considerable training in building science and thermography to avoid misinterpretation.

Thermal imagers do not actually detect or measure moisture. Instead, they show a composite image of surface temperatures that may be the result of evaporation, air leakage or other anomalies in the building assembly. Every leak detection situation is unique since there are many types of building assemblies, potential leak sources, seasonal factors and ambient conditions interacting. Not all situations will result in sufficient evaporation for useful thermal images.

Quick Review of Evaporation

To understand if evaporation will highlight leaks on thermal images, we must first know if ambient conditions are favourable for evaporation. Evaporation is the process by which water changes from a liquid to water vapour at the water-air surface. It is the same as drying and requires 2250 Joules of heat for every gram of water that evaporates. The heat required for evaporation results in a cooler surface temperature, which explains why we feel cold stepping out of the shower.

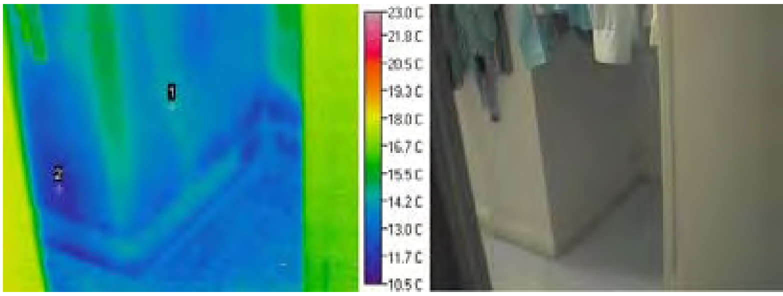
The rate of evaporation or drying will be greater when the amount of moisture in the air is low. The Psychrographic chart can help us identify the difference in vapour pressure (amount of moisture in the air) between the wet building surface and the air in the room (ambient conditions). We can measure the surface temperature with a thermal imager or infrared thermometer, and the air temperature and relative humidity of the air in the room with a thermal hygrometer.

Let us first consider the ideal ambient conditions for evaporation. In the summer of 2008, I travelled to Bodrum in the south of Turkey. The fruit markets and pedestrian malls have water misters that lower the temperature by evaporative cooling. You can wash a shirt and dry it on a clothesline in less than 30 minutes in 40°C, 43 percent relative humidity conditions. Air movement or wind speeds up the drying process, the same as in a clothes dryer. Clearly, evaporation (drying) is faster when the ambient temperature is hot; the relative humidity low and there is air movement.

These same principles are applied by the water restoration industry to quickly dry flooded interior areas and save interior drywall finishes before mould germinates, to help minimize the costs for insurers. Water restoration technicians pump out and vacuum the liquid water and then install air movers and high capacity dehumidifiers to draw moisture from the building finishes by evaporation (see IICRC Standard S-500 for details).

Thermal imagers excel at determining the extent of wet building finishes under such conditions. Investigators will encounter a variety of leak situations and evaporation conditions, as illustrated by the following cases.

CASE 1 – CONDOMINIUM APARTMENT LEAK



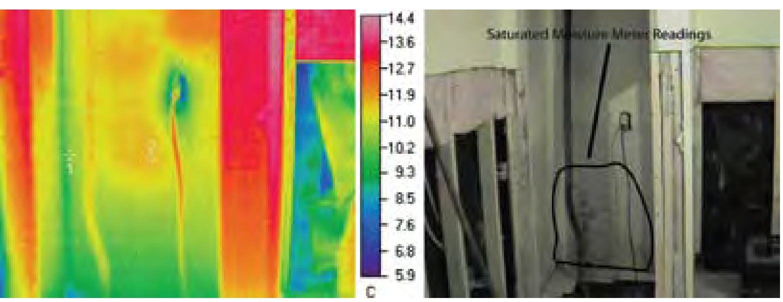
This first case shows ideal conditions for evaporation and good thermal images. Water from a burst pipe migrated to a number of apartment suites below. The leak occurred 48 hours before my visit and restoration crews had vacuumed up water the previous day, and installed air movers and dehumidifiers.

The thermal image shows water-saturated wall and carpet finishes in a bedroom closet. The dark blue patterns indicate where water appears to have wicked up the wall and where the carpet was wet. Moisture meter readings confirmed thermal image results.

Why conditions resulted in a good thermal image

1. The wall assembly consisted of drywall on steel frame studs. There was no insulation or wood studs to absorb or store excess water. The drywall was porous and had considerable surface area where evaporation could take place on both sides of the wall cavity. For this reason, water restoration technicians will often create ventilation holes in wall cavities to speed up drying inside wet wall and ceiling cavities.
2. The air movers and dehumidifiers created ideal drying conditions. Ambient conditions were 19°C with a low relative humidity (RH) of 22 percent (compared to a typical interior 40 percent RH in winter), resulting in a vapour pressure decrease between the wet wall finish and ambient air of 68 percent.

CASE 2 – BASEMENT WINTER SUMP PUMP FAILURE

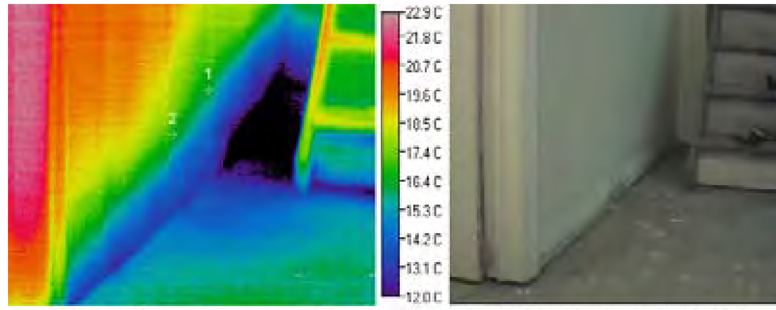


Sudden freezing conditions resulted in a discharge hose obstruction, pump failure and standing water on the floor in this finished basement. The owner removed the water and lower wall drywall according to my suggestion, but not behind the sump pump. This thermal image was taken eight days later and did not pinpoint areas of saturation identified by the moisture meter, where mould was also visible. I could not determine whether the cooler temperature was moisture or simply a cooler outside wall.

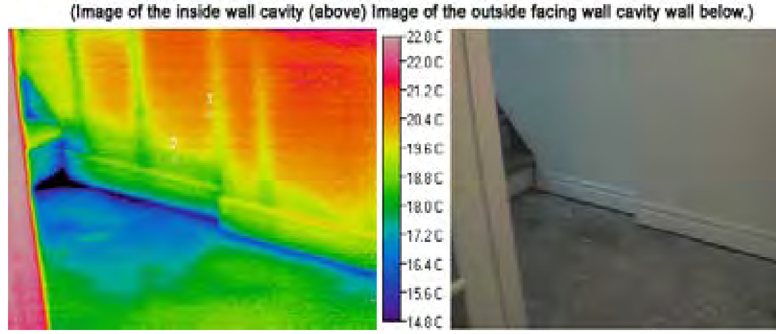
Why conditions resulted in a poor moisture image

1. The wall assembly consisted of a stud wall cavity on an exterior basement foundation wall. The outside temperature was well below freezing. The fiberglass insulation was acting like a sponge holding in water while the polyethylene vapour barrier was retarding evaporation, like plastic pants over a baby's wet cloth diaper.
2. The room was poorly heated and there was little air movement. The wall studs in the foreground had a temperature of only 12°C while the wet drywall surface temperature was 9°C. The vapour pressure drop between the wet wall finish and ambient air was estimated to be 21 percent, compared with 68 percent in Case 1.

CASE 3 – OLD HOUSE BASEMENT LEAK AT BOTH EXTERIOR AND INTERIOR WALLS



(Image of the inside wall cavity (above) Image of the outside facing wall cavity wall below.)



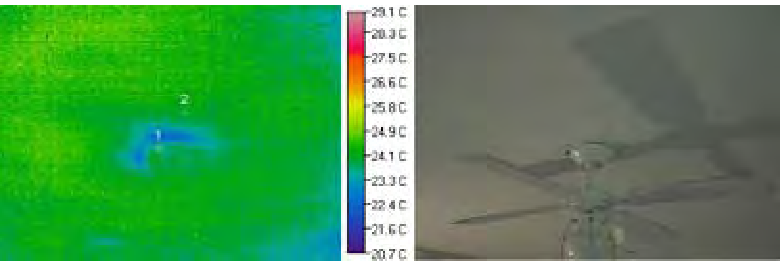
3. A winter leak occurred along the back wall under the basement stairs of a 90 year old house with a stone foundation. An interior and exterior wall cavity were affected by the same leak, allowing a good comparison of evaporation of both an insulated exterior foundation wall and an interior uninsulated wall cavity. The outside wall consists of a stone foundation, wood studs, fiberglass insulation, 6 mil poly and half inch drywall. The inside partition wall consists of half inch drywall on both sides of 2x4 wood studs. The baseboard trim was removed from the interior wall. The owner in this situation installed air movers and provided heat to speed up drying.

Comparing thermal images of interior and exterior insulated wall cavities

1. It is easier to distinguish cool temperatures that result from evaporating moisture on a void interior wall cavity wall, than an insulated exterior wall. The reason is that the inside wall is only undergoing evaporative cooling, while the exterior wall cavity will be influenced by a number of thermal events, in addition to evaporative cooling. There will usually be cooler temperatures at the bottom due to convective air currents, conductive heat loss to the exterior, as well as air infiltration. The outline of the wall studs shows differences in thermal conductivity of wood studs and fiberglass insulation.
2. The surface temperature of the wet exterior wall surface is 18°C, compared to 15°C on the interior side. A temperature drop of two to three degrees Celcius was noted on the interior wall, as well as in Case 1, and suggests that evaporation was occurring to a greater rate at the interior wall, compared with the exterior wall. Both drywall surfaces tested as saturated with a moisture meter.
3. Remember that the blue colour on the floor and walls is cooler temperature and not water.

CASE 4 – SUMMER ROOF LEAK

A roofer was in a hurry and proceeded to strip the shingles from this 1955 home with 1x12 plank sheathing just before a mid-summer downpour. There was no attic access, so I had to rely on a moisture meter and my thermal imager to detect the extent of water damage. The moisture meter showed saturated ceiling moisture levels, but the thermal image suggested the moisture was limited to the area around the base of the ceiling fan. The ceiling collapsed two days later under the weight of the water soaked cellulose insulation.



Why conditions resulted in a poor moisture image

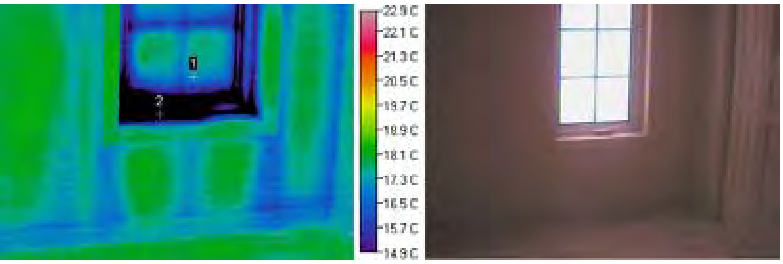
1. The ceilings and walls consisted of a skim coat of plaster with oil-based paint over an underlying plaster lath board, which slowed the passage of moisture. The cellulose insulation acted as a sponge soaking up excess water.
2. The indoor temperature was 25°C and the relative humidity was 63 percent, a 29 percent difference in vapour pressure, which likely resulted in some evaporation. The ceiling temperature variation (green to dark yellow range) of approximately 1°C is difficult to note in the thermal image. Altering the level and span did not improve the image.

CASE 5 – LEAK IN PREFABRICATED CEILINGS AND WALLS

Prefabricated houses are built as complete wall and ceiling sections in a factory and are erected on site in a few days. Snow filled the insulated attic before the roof sheathing was installed, wetting the interior and some exterior wall cavities. We know there was water in the exterior wall, but was the cooler blue colour in the thermal image due to evaporation?

Case	CASE 1: Interior wall leak	CASE 2: Basement sump failure exterior wall	CASE 3: Winter foundation leak interior wall	CASE 4: Winter foundation leak exterior wall	CASE 5: Summer Roof Leak	CASE 6: Pre-fab roof leak into Exterior wall
Indoor Ambient						
Ambient Air Temp C. (Dry Bulb Temp)	19	12	16	16	25	17
Ambient Relative Humidity RH (%)	22%	65% estimated	67%	67	63%	69%
Ambient Vapour Pressure *(mm Hg)	3.63	6.8	9	9	14.98	10.03
Surface						
Surface Temp IR measured	13	9	15	18	23	17
Surface RH **	100	100	100	100	100	100
Surface Vap Press *	11.23	8.61	12.79	14.53	21.08	14.54
Delta Vap-Press Surface-ambient	7.6	1.81	3.79	5.53	6.1	4.51
% Change in Vapour Pressure	**68%**	**21%**	**30%**	**38%**	**29%**	**31%**
Sub-surface moisture reading at drywall	100%	100%	100%	100%	100%	100%
IR/Moisture meter correlation	Good	Poor	Good	Poor	Poor	Good

* Vapour Pressure is calculated from a Psychrographic chart or a calculation program.
**Surface RH is assumed to be 100 percent for comparison purposes and is based on saturated moisture meter readings of wet surfaces. RH of the air close to the surface can also be measured with a small chamber, such as a GE Protimeter Humidity Box placed against the surface.



Recognizing the thermal events

The visual image on the right side of the thermal image is overexposed from the sunlight shining through the window. Solar heating of the exterior wall is affecting the wall cavity and our thermal image. Thermal conductivity differences of the various materials in this wall cavity (such as wood studs and insulation), and between wet and dry insulation seem to be dominating this image. Matted insulation, voids, air leakage, other anomalies and other factors may also contribute to these temperature variations. Evaporation may be happening but is difficult to detect. This case shows the complexity of thermal events that may occur in images of above grade exterior walls. We should also remember that evaporation may occur between the interior cavity and the exterior.

Determining the depth of the water with multiple moisture meters.

Moisture meters were placed on the wall, approximately one foot to the left of the window. The yellow moisture meter has one green light lit on the bottom of the scale, indicating no

elevated moisture. This unit only senses to ~3/4 inch depth, suggesting the drywall and insulation close to the vapour barrier was dry. The moisture meter on the right however shows 11.9 percent, which is near saturation, somewhere within 1.5 inches of the wall surface. This case demonstrates the importance of understanding the sensing range and limitations of moisture meters and the benefits of using more than one moisture meter for non-invasive moisture verification.

Conclusions

1. Thermal imagers can be valuable tools for identifying water leaks and establishing the extent of water damage, provided there is sufficient evaporation. Ambient conditions and building assembly characteristics will affect the rate of

evaporation. In many cases, there will not be sufficient evaporation for satisfactory thermal images of wet finishes or underlying materials in the building assembly.

2. Thermal images of leaks are more reliable and better defined if cavity walls and ceilings are void. Exterior wall cavities with insulation often have interfering thermal patterns from outside temperatures, thermal conductivity of the insulation and other anomalies. The person analyzing the image should always account for cool temperature patterns due to a cause other than evaporation.
3. The greater the difference in vapour pressure between the wet surface and the ambient air, the better the thermal image of the wet finishes should be, due to higher evaporation. According to my anecdotal observation, a minimum 30 percent difference in vapour pressure between the wet surface and interior air under normal interior ambient temperatures generally results in a satisfactory thermal image, if the cavity is void. This correlation however is not reliable for insulated wall and ceiling cavities or surfaces which resist moisture flow.
4. Moisture meters and thermal hygrometers should always be used for verification, but moisture meters may not be accurate if the moisture is not within the sensing depth range. ■

Terry Carson, B.Sc., MBA, BSSO, R.H.I., C. Tech. has over 25 years of experience investigating building leaks and is the principal of Guardian Home Inspectors Inc. in Toronto. He provides building inspection, thermographic interpretation, moisture detection, litigation support and course development services. He is an ASNT Level 3 trained Thermographer. Terry can be reached at info@guardianhomeinspectors.com.