Nondestructive Evaluation of

[redacted]

Provided by: HurleyIR

HIR INC.

HurleyIR

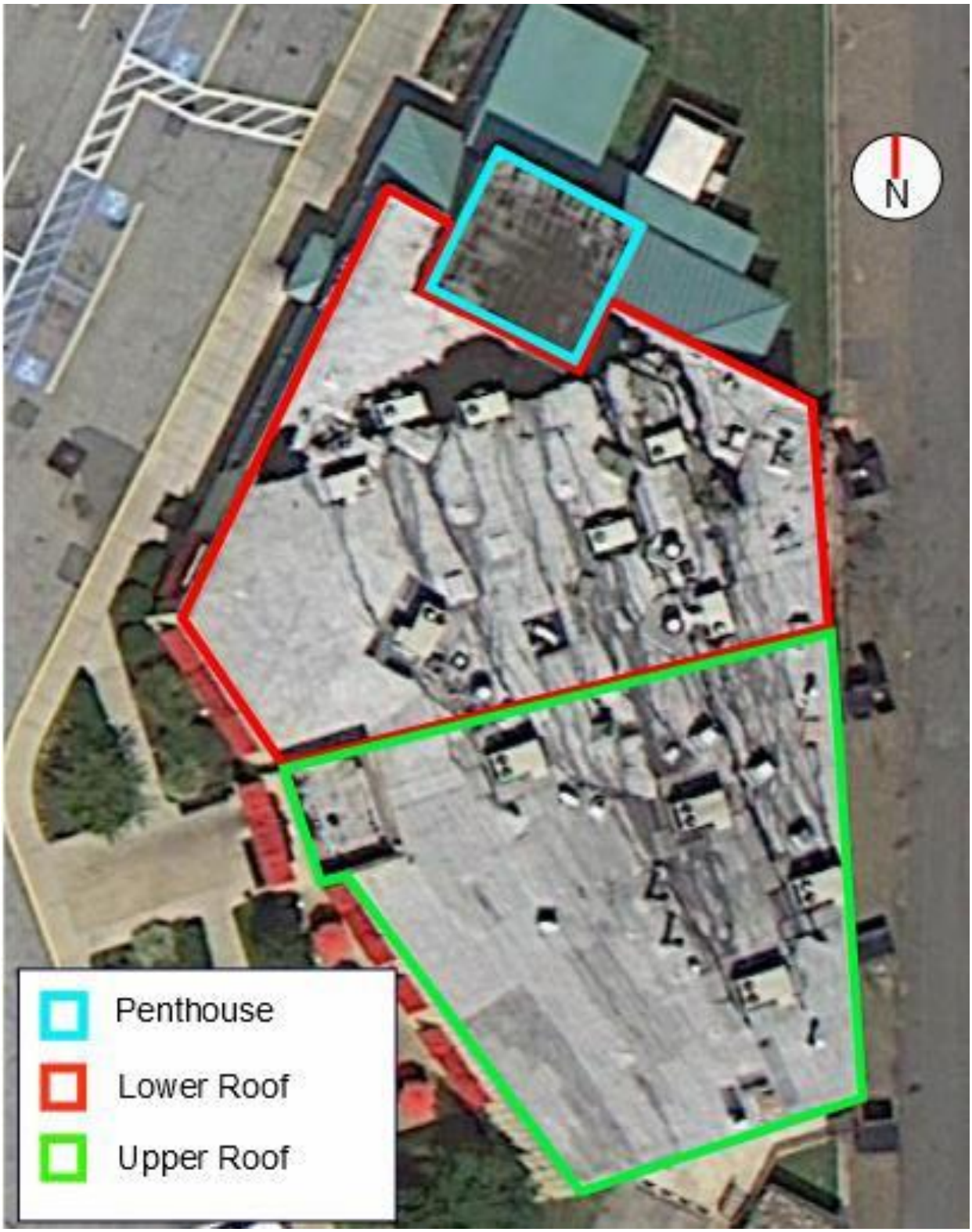
[redacted], HurleyIR provided a nondestructive evaluation for [redacted] The goal of the nondestructive test (NDT) was to successfully map out areas of saturation within the roof's infrastructure; the NDT methods performed Electronic Capacitance Moisture Detection (ECMD) and Infrared Thermography (IRT). The weather conditions were clear, with minimal wind, less than 10 knots. At the time of the ECMD and IRT tests, the roofs were free from any debris, but were crowded with many different heating and cooling units, some of which were discharging condensation drains directly onto roof. There were also vent fans discharging grease onto the roof outside of the collection mats. It is important to understand that while there was some surface moisture from the condensation lines, the surface moisture did not encompass enough of the surface area to affect the NDT evaluations. The penthouse roof and the main roofs (broken into an upper and lower main roof) being tested were collectively measured to be approximately 13,600ft$^2$. The penthouse roof, located at the building's most northern location, is a single-ply Ethylene-Propylene-Diene-Monomer (EPDM), or rubber roof that measured to be 800ft$^2$. The slightly slanted upper roof was the highest portion of the two main roofs, beginning at the building's most southern edge and ending at the transition between the two materials. The upper roof was a modified bituminous, (aluminum painted surface) that measured to be approximately 7000ft$^2$. Beginning at the change of materials and ending at northern edge of the main roof, the lower roof measured to 5,800ft$^2$ and was a modified bituminous (granular surface). Both the lower and the upper main, modified bituminous roofs were reported to be re-covers for an existing built-up roof (BUR) system.

After performing two NDT tests, HurleyIR found a total of only two regions on the roof that did **not** have patterns and/or measurements indicative of entrapped moisture. Of the three areas marked with red marking paint on the roof, two are showing good areas, while one is showing a bad area. The good area of the upper roof measured to be nearly 3,500ft$^2$, while the other good areas on the lower roof and penthouse collectively measured approximately 1,100ft$^2$. The marked bad area, located between the two good areas contains a marked "x", representing a good place for a core/cut verification test to be taken in order to verify the NDT and determine the magnitude of saturation and types of materials. Both the ECMD and the IRT tests' results correlated revealing the same areas of moisture readings throughout the main elevation; both NDT methods detected a total of 9,000ft$^2$ of saturated material, or approximately 66% of the entire roof.

In conclusion, the results of the NDT evaluations make it clear that attempting another recover or patching would not prove to be a cogent solution. The magnitude of entrapped moisture would dictate this roof is unsalvageable. Any continued patching or recovering will likely prove to be ineffective. Leaving the moisture entrapped in the current system and taking only as needed remedial measures also exasperates the probable deterioration to the roof deck system. The next step is the core/cut verification tests to substantiate these findings, verify types

of materials to be removed and inspect the deck system. Presuming verification samples substantiate the NDT findings it is our recommendation for a total roof tear off and replacement.

**<u>This image lays out the different sections of the entire roof.</u>**



**This image shows the percentages detected by the ECMD during the NDT evaluation.**

**These images were taken during the IRT portion of the NDT evaluation. Images on the left are in the visual spectrum, while the images on the right are in the Infrared spectrum. Lighter areas represent the saturated materials detected, while dark images represent unsaturated materials.**

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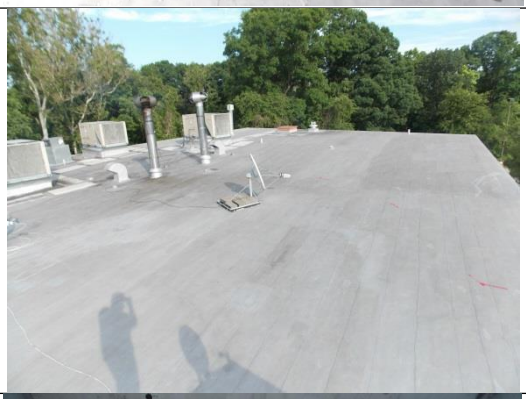
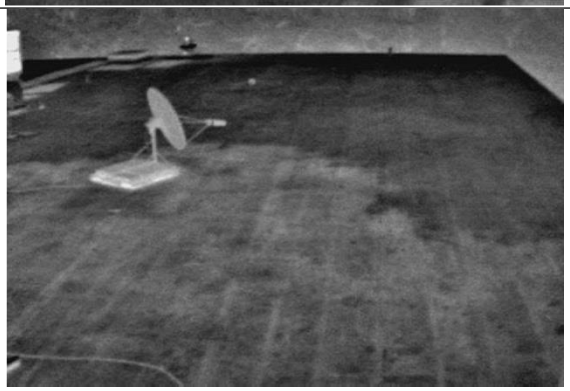
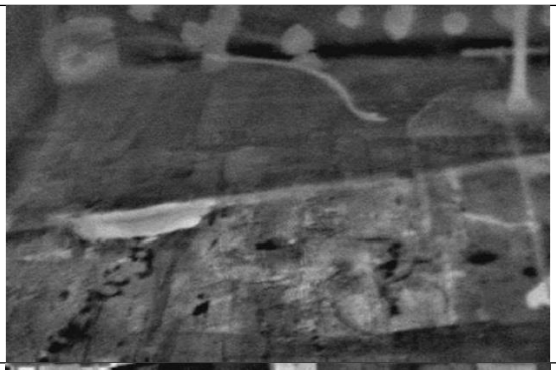
| 2 |  |  |
| 3 |  |  |
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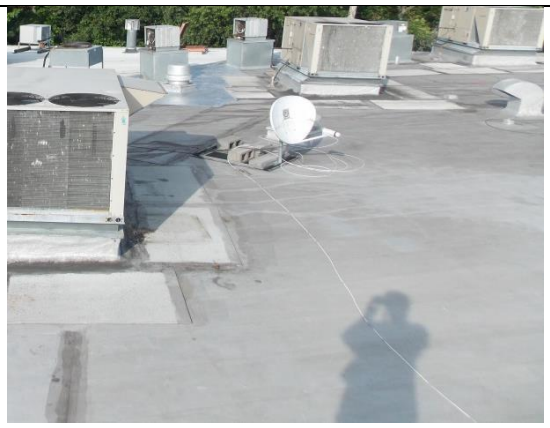
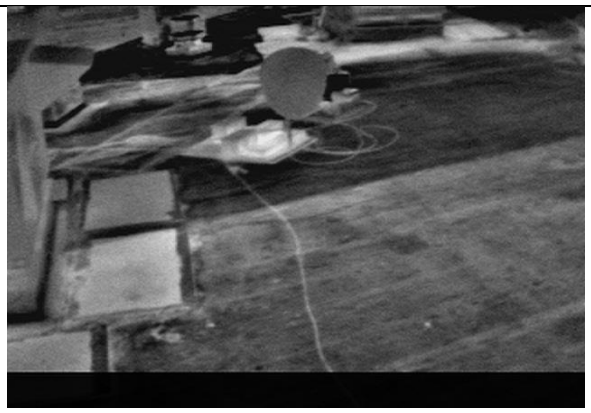
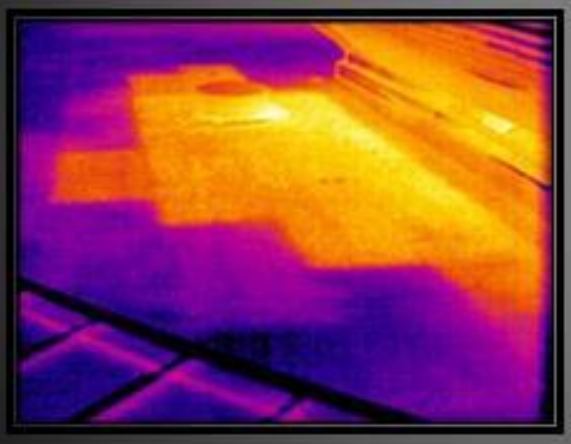
| 5 |  |  |

**End of Report**

# Hurley IR

## Aerial and Ground Base

## Roof Surveys



# NDT ROOF METHODOLOGY©

The roof has always been one of the most important structural functions of the building envelope. It is however, one of the most overlooked areas for major consideration in building maintenance. As long as the roof is not leaking into the building it is thought to be functioning properly. This is an erroneous assumption because many problems occur long before they are evident as leaks into the building. Early location and repair of roof problems can save a facility thousands of dollars in costly roof tear-off and replacement.

The low slope built-up roof (B.U.R.) system was the answer to the need for rapid and economical building construction. Initially, B.U.R. systems consisted of shingled layers of several plies of felt (roofing paper), held together by bitumen (asphalt of coal tar pitch), which were fastened to the structural main medium (deck). As energy concerns increased, the use of insulation between the deck and roof membrane became widespread. The use of a non-porous insulation on top of the membrane has been utilized, although this type of roof is not as cost effective. The traditional visible roof inspection methods are not as effective on insulated roof systems as they are on uninsulated roof systems. When the B.U.R. systems were first constructed they were predominately uninsulated. An experienced roofer or consultant could perform accurate visible inspections of an uninsulated roof system, by examining the surface of the roof system. These uninsulated deck systems did not tend to promote subsurface water migration. Therefore, when water entered the building through the roof it was relatively easy to determine the source of the leaks. Since no insulation was present there was little medium for water retention or diffusion. Consequently, leaks manifested themselves almost immediately.

Larger roof areas that are typical of modern low-rise industrial facilities led to the increased usage of roof insulation. Roof insulation reduced energy costs and increased energy efficiency. This low-rise construction method increased the importance of roof maintenance, because roof problems could compound before becoming visibly evident. This necessitates a more effective and accurate form of roof system analysis.

# IR METHODOLOGY

Locating entrapped moisture within insulated roof systems is achieved through proper application and evaluation of infrared imagery. In order to understand the methodology for infrared roof scanning, it is important to first understand how thermal differences are detected and diagnosed when applied to areas of wet and dry insulation.

During the day, the sun heats the entire roof surface (solar loading). Late in the day, the wet insulation has the capability to store vast quantities of energy (high heat capacity), with little temperature change into the early nighttime hours. In turn, the dry insulation remains cool. This phenomenon coupled with the insulation's reduced thermal resistance, (which will permit interior-exterior heat flow) will cause the roof over the wet insulation to hold a different temperature then that over the dry. For the most optimum results it is necessary to do the infrared testing at night when solar loading is not a factor. During the night the energy stored in the roof system is lost through radiant, convective and conductive effects. The areas over the dry insulation though warmer during the day have less energy stored then the wet insulation area. Therefore the areas of dry insulation will cool rapidly. The poor thermal resistance of the wet insulation will cause a greater energy conductance in the wet areas, which keeps the roof surface warmer. These two effects coupled make the roof over the wet insulation areas warmer at night than those over dry insulation. On your black and white (monochrome) thermographs, the lighter tones will delineate the warmer areas or "probable moisture damage", and the constant darker tones will represent good roof. There may be color imagery as part of your report and the colors representing probable moisture damage are easily discerned.

Standard infrared roof evaluation procedure calls for systematic survey of the entire roof surface using a high-resolution infrared imager. The nighttime period in which the infrared survey must be done (survey window) begins when the wet and dry insulation's temperature differential is detectable to the infrared imaging system. The infrared imager utilized by Hurley and Associates resolves temperature differences as small as a fraction of one degree. Knowing the type of insulation in the roof system will assist the technician in choosing the proper thermal window for obtaining the best results.

# ECMD METHODOLOGY

Though IR is the most comprehensive and cost effective method of roof system evaluation, there is another quality method of non-destructive test (NDT) called Electronic Capacitance Moisture Detection (ECMD). This method is also very effective in locating water permeation and saturation of roof materials.

ECMD tests are performed utilizing pre-established grid patterns that provide a qualitative measurement of moisture intrusion. These moisture readings reflect the level of moisture of all components within the roof system, at an approximate maximum depth of 4" to 6". If there is a heavily saturated membrane with dry insulation, the test reading may be high. Inversely, wet insulation and a relatively dry membrane can also yield high moisture readings. Either problem is serious. However, these tests are not easily discerned to distinguish the location of moisture (i.e. membrane, insulation, or both). It is for this reason ECMD is usually used in conjunction with IR evaluation.

Although the ECMD supplies instantaneous and continuous moisture readings, they can only be documented on grid pattern. The ECMD system sends a calibrated low frequency signal into the roof components. Based on the impedance of moisture, the detector yields a numerical level of water intrusion that is documented by its location in the grid.

IR evaluation allows for a defined comprehensive perspective of roof conditions. A skilled roof-testing technician can with great reliability, characterize thermal signatures of subsurface leaks, identify their various levels of saturation, and differentiate which components are water infused. IR evaluation must rely on either a greater conductive heat transfer from interior to exterior, or the solar loading of wet roof components. Both occurrences create substantial thermal signatures delineating internally water damaged roof components. However, minimal temperature difference from the building interior to exterior or an overcast day can create less than optimum IR testing conditions in which case ECMD could serve as the primary test method.

Both procedures of NDT (IR and ECMD) are excellent methods for obtaining information on the operational integrity of the roof system. Either one can be performed with tremendous accuracy. Unfortunately, both are NDT methods and are subject to certain variables, yet used together are very accurate for delineating the true roof conditions. A quality NDT service for roof inspections will always involve at least two reliable methods of evaluation in developing a report.

# VERIFICATION METHODOLOGY

IR evaluation and ECMD are best utilized when proceeded by a thorough visible inspection for the roof system, and then final verification testing. NDT should be substantiated with verification test samples by your NDT technician and the qualified roof contractor licensed to do so, in order to confirm the NDT findings. Verification testing requires a 2" core, or 4” cut and / or two 1/8" probe tests. The core and cut test is used to physically extract a sample of damaged roof, confirming the infrared and electronic test results. This procedure is also used to qualify the type of roof material within the system. The extractions also provide an on-site examination of the deck form the topside.

Probe testing performs verifying by electronic quantitative measurement of moisture. The moisture probe test can also indicate which material has become the most water saturated, by testing at differing levels of penetration through the roof components.

Once saturation is confirmed, water damaged areas on the roof minimally needs full material extraction repairs - removing all confirmed water permeated insulation and membrane materials and replacing them with unsaturated like materials. The main reason for removing water infused roof materials is to avoid the significant damage to surrounding components, particularly the waterproofing membrane, as a result of the vapor pressure manifested from entrapped water.

# NDE Predictive Maintenance Programs

ROOF RE-COVER is a commonly used method to obtain a new roof with a cost that is usually higher than sectional repairs and less costly than that of total replacement. Re-cover roofing should never be considered unless all existing moisture laden substrate is dried or removed, and then replaced with like materials.

Re-cover roofing can be cost effective when placed over an existing roof that has utilized non-absorbent insulation such as polystyrene or many other foam insulators. Yet this "Band-Aid" approach to roofing should never be used over an existing roof that incorporates insulating materials that have existing water retention. Leaks in a re-cover roof will migrate into the pre-existing roof and retain vast quantities of moisture. Inevitably, entrapped moisture in an underlying roof system will destroy the roof deck and could deteriorate the mechanical fasteners that attach the new re-cover roof, in turn, creating extreme danger of wind up-lift damage.

The re-cover roof can save some initial dollars, however it is a method to new roofing that should only be used under limited circumstances. To incorporate a re-cover roof varying from the recommendations stated in this report is almost certainly destined to early failure and financial remedial action many times that of the original roof problems. Re-cover roofing is a method of postponing the disposal of the old roof system, and upon failure of the re-cover roof, the owner will then be faced with costly tear-off and disposal of two roof systems.

Roof system service life can be increased through periodic NDE; proper and prompt repairs based on the predictive maintenance inspections. Roof systems should be non-destructively evaluated, utilizing infrared imagery, every one to three years.