TESTING APPLICATION STANDARD (TAS) 126-95

STANDARD PROCEDURES FOR ROOF MOISTURE SURVEYS

1. Scope:

1.1 This Protocol covers the procedures for non-destructive testing for the presence of moisture, and the subsequent destructive testing to confirm moisture content, in Roof System Assemblies; including insulation.

1.2 This Protocol applies to the testing of all Roof Systems Assemblies as required in Section 1521.12 of the *Florida Building Code, Building*.

1.3 All testing and calculations shall be conducted by an approved testing agency and all test reports, including calculations, shall be signed by a Registered Design Professional per F.S., Section 471 or 481.

2. Referenced Documents:

2.1 *The Florida Building Code, Building.*

2.2 *The Roof Consultants Institute*
Standard Practice for the Detection and Location of Latent Moisture in Building Roofing Systems by Nuclear Radioisotopic Thermalization

Glossary of Terms

2.3 *Third International Symposium on Roofing Technology - 1991*
New Wetting Curves for Common Roof Insulations

2.4 *ASTM Standards*

D 1864 Moisture in Mineral Aggregate Used on Built-Up Roofs

D 1079 Standard Definitions and Terms Relating to Roofing, Waterproofing and Bituminous Materials

E 380 Excerpts from Standard Practice for Use of the International System of Units (SI) (the Modernized Metric System)

2.5 *NBS Building Science Series 131*
Laboratory Evaluation and Non-Destructive Methods to Measure Moisture in Built-Up Roofing Systems

3. Terminology & Units:

3.1 Definitions - For definitions of terms used in this Protocol, refer to: ASTM D 1079; Standard Practice for the Detection and Location of Latent Moisture in Building Roofing Systems by Nuclear Radioisotopic Thermalization (noted in Section 2.2, above); the RCI Glossary of Terms; and/or Chapter 2 and Section 1513 of the *Florida Building Code, Building*. Definitions from the *Florida Building Code, Building* shall take precedence.

3.2 Several pertinent definitions specific to this Protocol are listed below for reference.

3.2.1 *Core Cut* - A sample of the roof system extracted from an existing roof system for further analysis, including all elements of the roofing system and deck materials capable of moisture absorption, excluding light weight and structural concrete, light weight insulating concrete, gypsum, and cementious wood fiber roof decks.

3.2.2 *Equilibrium Moisture Content (EMC)* - The percent moisture content in a material after long term exposure to a given temperature and relative humidity. Sometimes referred to as constant weight.

3.2.3 *Film Badge* - A device which must be carried by users of nuclear measuring instruments to measure their total radiation exposure.

3.2.4 *Gravimetric Analysis* - The determination of moisture content by weight of a material by comparing

the wet weight (W_w) to the dry weight (D_w) and applying the formula:

$$\%\,\text{moisture} = \frac{W_w - D_w}{D_w} \times 100$$

3.2.5 *Histogram* - A chart showing a distribution of data, e.g., the number of occurrences of a value plotted versus the value itself.

3.2.6 *Hydroscopic* - The term used to describe a material which attracts, absorbs and retains atmospheric moisture.

3.2.7 *Impedance* - The ratio of effective electromotive force to the effective current in an alternating-current circuit.

3.2.8 *Infrared Camera* - A device which is sensitive to thermal radiation of wavelengths longer than those of visible light.

3.2.9 *Moisture by Weight* - Weight of moisture content of a material compared to the dry weight of the material expressed in percentage.

3.2.10 *Radioisotopic Thermalization* - The process of reducing the energy of a neutron to a level where it is in equilibrium with its environment. Thermalization occurs when the energy of fast neutrons is partially absorbed by moderators of hydrogen atom collisions.

3.2.11 *Relative Moisture* - Moisture content without regard to absolute values (i.e. wet, wetter, wettest).

3.3 Units - For conversion of U.S. customary units to SI units, refer to ASTM E 380.

4. Significance and Use:

4.1 The testing requirements outlined herein provide a means of: 1) establishing the criteria for testing for moisture trapped within Roof System Assemblies; and, 2) determining the percentage of moisture in specific areas and components as required in Section 1521.12 of the *Florida Building Code, Building*.

5. Applicable Roof System Assemblies:

5.1 All types of low slope Roof System Assemblies may be tested by one or more of the methods noted in Section 7.

5.2 Type of testing equipment may vary depending on the type of roof membrane. The equipment manufacturer shall be consulted for a listing of suitable membrane type for each type and model of testing equipment.

6. Precautions:

6.1 This Protocol may involve hazardous materials, operations, and equipment. While several safety issues are addressed in Section 9, this Protocol does not purport to address all of the safety problems associated with its use. It is the responsibility of the user to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

7. Equipment Types - Non-Destructive Testing:

7.1 Infrared Thermography

7.1.1 An infrared camera is used to detect the temperature of areas within a Roof System Assembly. As the air temperature decreases at sunset, dry insulation allows the roof surface above to cool quickly, while areas where moisture is present, either in the insulation or between membrane plys, have a large thermal mass and take much longer to cool.

7.1.2 The infrared camera is calibrated to an appropriate wavelength and is used to detect and record the difference in infrared radiation emitted from the roof surface.

7.1.3 Infrared scanning may be conducted on the roof surface or from the air. Aerial infrared photography is generally used to locate

"hot spots" for subsequent roof top scanning.

7.1.4 Infrared equipment can be a simple roof top scanner which records relative moisture or can record by film or video.

7.1.5 While infrared scanning provides accurate moisture content within a Roof System Assembly, a thorough examination of the structure should be conducted prior to scanning to determine whether one or more of the following conditions exist. These conditions could create inaccuracies during an infrared scan.

- underdeck heating or cooling units that may affect a limited area of the roofing above;
- venting of hot fumes which can cause "hot trails";
- daytime shading caused by sunlight obstructions (i.e. trees, billboards, adjacent building, or intermittent clouds) of the roof surface causing uneven heat conduction;
- moisture on the roof surface;
- heavy gravel on the roof surface which may be obstructing roof top moisture; and
- windy conditions at the roof top level potentially causing irregular infrared readings due to convection across the roof surface.

7.1.6 Infrared scanning is most effective at sunset or at night.

7.2 Nuclear Thermography

7.2.1 A nuclear scanning meter emits neutrons from a radiation source within the scanning meter downward to the Roof System Assembly. Neutrons which encounter hydrogen atoms are slowed down; a portion of which "bounce back" to be counted by a detector within the scanning meter. Since water contains significant hydrogen atoms, areas of moisture within the roofing plys and/or insulation record high levels of slowed neutrons. The nuclear scanning meter provides accurate results to a depth of 7 in.

7.2.2 Nuclear testing is generally conducted on a 5' x 5' grid pattern over the entire roof surface. If moisture is detected within a particular 5' x 5' grid area, the area is reduced to 2' x 2' grid areas for greater accuracy in determining areas of moisture.

7.2.3 Varying types and thickness of membrane, and other roofing components, also contain varying quantities of hydrogen atoms and; therefore, higher levels can be detected at different areas. For this reason, operator skill and experience is important.

7.2.4 Ponded water will result in increased readings; however, the quantity of water below the scanning meter in these areas is generally constant. For this reason, areas of ponded water can be tested and compared separately.

7.2.5 Operators of nuclear equipment shall be licensed by the United States Nuclear Regulatory Commission (USNRC), or a State Agency which has entered into an agreement with the USNRC to assume control over distribution and use of equipment containing a radioactive element, to transport and operate nuclear testing equipment. Licensing requirements can differ depending on the radioactive element being used in the equipment.

7.2.5.1 Changes in State and Federal regulations pertaining to the purchase, distribution and use of equipment containing radioactive elements are common. It shall be the obligation of the user to keep up-to-date with all cur-

rent regulations. The final responsibility for State and Federal compliance shall rest with the owner of the equipment.

7.2.6 The operator of any equipment containing an isotopic radioactive source consisting of Americium 241, Radium 226, or Cesium 137 with a Beryllium target shall be familiar with the device manufacturer's instruction manual and shall have completed an approved training program provided by the device manufacturer or other party acceptable to the appropriate licensing authority.

7.2.7 The device shall be stored in a locked area, base down, and in contact with shielding material such as concrete. Transportation shall be in a DOT approved shipping container, secured against removal by unauthorized personnel, and be accompanied by a current "Shipper's Certification For Radioactive Materials." During cleaning and use of the device, the operator shall avoid direct contact with the base of the instrument and shall make sure others do likewise.

7.2.8 Leak tests must be performed in accordance with the manufacturer's specifications, at prescribed intervals and in compliance with the procedures designated by the licensing authority.

7.2.9 All maintenance of the radioactive source or source holder, or other actions which entail removal of the source, shall be performed by the device manufacturer or other persons specifically trained to perform these operations.

7.2.10 All users shall be provided with film badge type dosimeters to be worn when handling or using the equipment. Authorized personnel shall see to it that other persons are kept away from the instrument during use, transportation or storage.

7.2.11 The device containing licensed material may be disposed of by either:

- transfer to another specifically licensed user or disposal agency, or
- return to the device manufacturer.

7.3 Impedance Testing

7.3.1 An impedance meter emits low frequency electronic signals from rubber electrodes located on the base of the instrument. Over a dry substrate, the electrodes are insulated from one another, no complete circuit exists and little or no reading is recorded. Over a wet substrate, the electrical conductance is greater, which leads to a complete electrical circuit and readings are recorded. Greater amounts of moisture result in higher readings.

7.3.2 Meters are available in small, hand-held units and large, mobile units.

7.3.3 The impedance method of testing can only be used over a dry roof surface.

7.3.4 Modified instruments may be necessary for testing of EPDM Roof System Assemblies.

7.4 Selection of the type of nondestructive moisture testing to be conducted (infrared, nuclear or impedance) should be based on the parameters involved for the particular project. Regardless of which nondestructive test equipment is utilized, the results shall be confirmed through core sampling, as noted in Section 12, of both "dry" and "wet" areas.

8. Test Personnel:

8.1 All testing and core sampling shall be conducted under supervision of a Test Director who shall be thoroughly trained in

the operation of the nondestructive moisture testing device used and who shall have a complete understanding of modern roofing technology, including the following:

- types of roofing membrane material, insulations, and decks and the effects of moisture in materials;
- construction procedures;
- equilibrium moisture contents;
- the effects of structural building components on testing results; and
- moisture migration in building structures.

8.2 The Test Director shall have completed the following minimum training requirements:

- a recognized training program addressing radiological safety;
- operational training conducted by the manufacturer of the equipment being used;
- a formal training course addressing basic roofing technology offered by a recognized school or facility specializing in this course, evidence of the successful completion of which, via a certificate, diploma, or certification, shall be maintained by either that Test Director or his/her employer; and
- previous field experience in this testing discipline with "hands on application," for a period of not less than five (5) years.

8.3 All other personnel involved in the survey shall have at least been instructed in radiological safety and basic roofing technology.

9. Safety:

9.1 Roof top testing requires constant monitoring of equipment in combination with movement on the roof top. All appropriate safety precautions shall be taken to provide a safe work area. It shall be the responsibility of the Test Director to establish a safety plan and convey the plan, in writing, to all roof top personnel. The safety plan shall include, but shall not be limited to the following:

9.1.1 Not less than two personnel shall be present on a roof top during testing. One person shall be designated as a "spotter" to watch the operator and advise the operator of potential hazards.

9.1.2 All overhead wires, hot stacks or areas designated "unsafe" shall be marked prior to testing.

9.1.3 All electric powered equipment shall be protected with "in-line" ground fault interrupters not greater than 50 feet from the equipment.

9.1.4 Proper safety equipment and clothing shall be worn by all roof top personnel.

9.1.5 All roof top personnel operating nuclear measuring instruments shall carry a film badge to measure total radiation exposure.

10. Preparatory Procedures:

10.1 Prior to commencement of non-destructive testing, the user shall visit the job site to: 1) visually determine potential problem areas; 2) secure structural and roof plan drawings, if available; 3) verify composition of existing Roof System Assembly and associated Roofing Components; and, 4) solicit historical data pertaining to the Roof System Assembly and its performance. This information may be collected concurrently with the initial stages of the nondestructive testing.

10.2 Under no circumstances shall rooftop traffic be permitted until adequate data has been obtained to ensure the safety of the survey personnel.

10.3 A checklist shall be utilized to ensure that all necessary equipment, supplies and documentation are available and operational for the moisture survey.

11. Test Procedure:

11.1 A reference point and two dimensional axis system (x-axis and y-axis) shall be established on a field recording sheet for each roof deck. The field recording sheet shall include a sketch of the roof deck being surveyed. All measurements relating to grid markings (as noted in Section 11.2) and the location of roof top structures and equipment; roof penetrations; and/or membrane defects shall be made in accordance with this established reference point and axis system with horizontal distances measured along the x-axis and vertical distances measured along the y-axis.

11.2 The horizontal axis (x-axis) and vertical axis (y-axis) shall be broken into distance increments, creating an intersecting grid pattern for each roof deck to be surveyed. The distance between grid lines shall be determined by the Test Director to best provide an adequate number of readings for a thorough evaluation. Grid size will be influenced by the size and configuration of the roof deck and the material make up of the Roof System Assembly.

11.2.1 The distance between grid lines shall not exceed ten (10) feet.

11.2.2 The intersecting grid pattern shall only encompass the "field" area of the roof, as noted in Section 11.3.

11.3 The reference point, axis system and associated grid pattern noted on the field recording sheet shall be marked on the roof surface and on wall flashings around the perimeter of the roof deck being surveyed for future reference. Ensure that the material used for marking is compatible with the surface material being marked.

11.4 All roof top structures, equipment, penetrations and obvious patched areas shall be noted on the field recording sheet.

11.5 All areas of ponded water shall be marked on the field recording sheet and all testing and analysis of these areas shall be conducted separately from other areas.

11.6 Areas where additional materials such as tapered edge insulation, cant strips and flashing materials are present shall be tested and analyzed separately to avoid unfounded comparisons of survey results. These areas of increased thickness will have differing results to those in the "field" area of the roof and therefore shall be considered separately. These areas shall be marked on the field recording sheet.

11.7 Readings shall be taken at each grid intersection point or at regular, logical intervals and recorded on the field recording sheet. Additional readings shall be taken in areas adjacent to grid intersection points which exhibit elevated moisture content readings and at other locations as determined by the Test Director to provide a thorough examination of the roof deck being surveyed.

11.7.1 A smaller scale grid pattern may be created within an original grid area to accurately record the location of elevated moisture readings. The smaller scale grid pattern shall be noted on the data recording sheet and marked on the roof surface.

11.8 The following field conditions shall be considered when recording data.

11.8.1 Areas of increased material thickness due to extra bitumen or insulation materials, flashings and/or gravel may alter any established reference level.

11.8.2 A change in substrate material (e.g., metal vs. concrete decking; or, polyisocyanurate vs. fiberboard insulation) may alter any established reference level.

11.8.3 Heavy, moist, and/or dirty gravel may alter any established reference level.

11.8.4 Ponded water shall be avoided, if possible. If the device utilized is an impedance moisture meter, any ponded water shall be removed and the area allowed to dry prior to testing. All ponded areas shall be treated as separate roof areas and all testing and analysis of results

shall be conducted separately, including separate core sampling.

11.8.5 Large grid sizes may result in undetected moisture. Grid sizes shall be established as small as possible.

12. Verification and Quantification:

12.1 All field data collected from non-destructive moisture testing is relative and must be quantified by core cuts.

12.2 Subsequent to non-destructive moisture testing, as noted in Sections 7 and 11, core samples, of minimum 2 in. diameter, shall be taken from: 1) those areas determined to be "dry"; and, 2) those areas found to have varying levels of moisture present (i.e., "low", "medium" and "high" levels) during non-destructive testing.

12.2.1 Sampling shall include cores from "low level", "medium level" and "high level" readings taken during non-destructive testing for calibration purposes.

12.3 All samples shall be placed immediately into separate, watertight containers, such as plastic containers with airtight lids or plastic bags with sealable openings.

12.4 Each sample and the area on the roof from which it was taken shall be labeled for clear identification. Each area from which a core sample was taken shall be noted on the field recording sheet using the identification noted on the sample itself.

12.5 All roof areas from which core sample were taken shall be immediately repaired upon completion of the destructive testing.

12.6 Samples, in their watertight containers, shall be immediately transported to an Approved Testing Facility for gravimetric analysis (moisture by weight testing) in compliance with ASTM Test Method D 1864.

12.6.1 The different components of the core sample shall be separated and tested separately. Each component shall be cleaned of debris and weighed immediately after removal from the watertight container and separation from other components of the sample. "Wet" weights shall be recorded and tabulated in accordance with their respective labeling.

12.6.2 Samples shall be chamber dried for 24 hours at 230°F (114°C) and reweighed and the results recorded. After the second weight measurement, the samples shall be placed back into the drying chamber for one additional hour. At the completion of this one hour drying time, the samples shall be reweighed and the results recorded. This procedure shall be continued until no weight loss is recorded.

Note: Closed cell foam and expanded polystyrene insulation tend to dry slowly. The drying procedure, noted in Section 12.6.2, may require repeated cycles until a constant dry weight is recorded. Expanded polystyrene may required an oven temperature of 150°F (66°C) to avoid deterioration of the insulation.

12.6.3 Moisture by weight shall be determined for each tested component using the equation noted in Section 3.2.4.

12.7 Results from gravimetric analysis shall be used to calibrate the moisture readings taken during non-destructive testing, as noted in Section 13.2.

13. Analysis of Collected Data:

13.1 The interpretation of field recorded moisture levels and their correlation to moisture by weight of core sample results shall be accomplished by an individual trained in both the principles of roof system moisture surveys and the type of roof system being surveyed.

13.2 Once the actual moisture levels have been determined for the "low", "medium" and "high" readings, a straight line graph shall be generated relating these field readings to actual moisture levels. This graph shall

be used to convert field readings to quantitative measurements, such as percent moisture by weight.

13.3 Histogram

13.3.1 All quantitative data taken from the line graph shall be compiled in a histogram which groups the data points by defining intervals and combining all data points which fall within a particular interval.

13.3.2 Interval sizes shall be large enough to ease the computational task, but small enough to easily distinguish the normal distribution by the dry sections of the roof area.

13.4 Graphic Plot (Moisture Map)

13.4.1 Once wet and dry areas are defined in the histogram, a graph of the roof plan shall be drawn to summarize the survey. The moisture map shall be prepared depicting a minimum of three moisture levels, the lowest of which shall be the maximum allowable amount of moisture in a Roof System Assembly, as defined in Section 1521.12 of the *Florida Building Code, Building*. The moisture map may be prepared by a dedicated computer program or by hand contouring.

13.5 Statistic Analysis of Data

13.5.1 Statistically, the histogram will result in a bell curve, typically referred to as a "normal distribution." Two conditions must be met to produce a statistically meaningful curve:

- the material being tested (including deck type) must be of the same physical make-up, and
- enough data must be recorded to allow for normal distribution to appear.

13.5.2 The width of a normal distribution is determined by the "standard deviation." The importance of the standard deviation is that once the mean (average) and the standard deviation are known, the "end points" of the normal distribution and; therefore, the count rate range for dry areas of the roof can be defined. Statistically, 99.7% of the measurement counts for the dry areas of the roof will fall between the three (3) standard deviation limits.

13.5.3 The normal distribution curve shall be overlaid on the measurement data histogram. To verify the end points for the overlay process, the mean and standard deviation shall be determined using the following equations:

$$Mean = \frac{(X_i \times F_i)}{N}$$ and,

$$S_x = \sqrt{\frac{\left(X^2{}_i \times F_i\right) - \frac{\left(X_i \times F_i\right)^2}{N}}{N-1}}$$

where,

X_i = the midpoint of the histogram interval;

F_i = frequency of occurrence;

N = total number of points; and

S_x = standard deviation.

These equations are easily implemented with a programmable calculator or a small computer.

14. Report

14.1 The final moisture survey report shall include the following:

14.1.1 The job name, job site address and a description of the Roof System Assembly being tested. A description shall be provided for each roof deck tested.

14.1.2 The type of non-destructive testing conducted, including the type and manufacturer of the testing equipment.

14.1.3 A copy of the field recording sheet.

14.1.4 A copy of the core sample test report provided by the testing laboratory, including gravimetric results.

14.1.5 Analysis of data, including a histogram summarizing all data collected; a scaled graphic plot (moisture map) of the roof area depicting at least three (3) distinct moisture levels and including all roof top structures, equipment, drains, penetrations, areas of ponded water and precise locations of core cuts; and, the statistical analysis of data.