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D&S Technical Note 10-2

EMISSOMETER MODEL AE1 – Slide Method for High Emittance Materials with Low Thermal Conductivity

Introduction

The model AE1 Emissometer is designed to measure total hemispherical emittance of materials by comparison with high and low emittance standards. The measurement requires that the standards and the surface to be measured be maintained at the same temperature. A heat sink is provided with the instrument upon which the standards and small thermally conductive samples can be mounted. The heat sink maintains a uniform temperature close to room or ambient temperature for the samples while the detector surface, which is positioned close to the sample, is maintained at about 75C. For metallic samples or thin materials the heat sink is sufficient to keep the sample and the standards at the same temperature. For thicker materials with low thermal conductivity or materials that cannot be applied to the heat sink, significant errors can result due to heating of the surface during the time required for the detector to come to a steady reading (about 90 seconds).

Where emittance measurements need to be made on materials that cannot be placed on the heat sink to control the temperature, a method is proposed in D&S Technical Note 04-1, Slide Method for AE Measurements. With the slide method, the idea is to sequentially move the detector to an unheated portion of a larger sample area as the detector transient response approaches the correct emittance value for the sample. The detector is "slid" or only lifted off of the surface slightly to avoid disturbing the conduction/convection between the detector and the sample and thus prolonging the transient response of the detector. It is similar to having the sample on a conveyor belt running underneath the detector, continuously exposing a sample area that is at the correct temperature.

This technical bulletin describes testing of the slide method for high emittance materials that may have both low thermal conductance and low thermal capacitance and are either too thick or too large to be applied to the heat sink to control the surface temperature. Verification of the slide method could lead to the development of a standard test method for these materials.

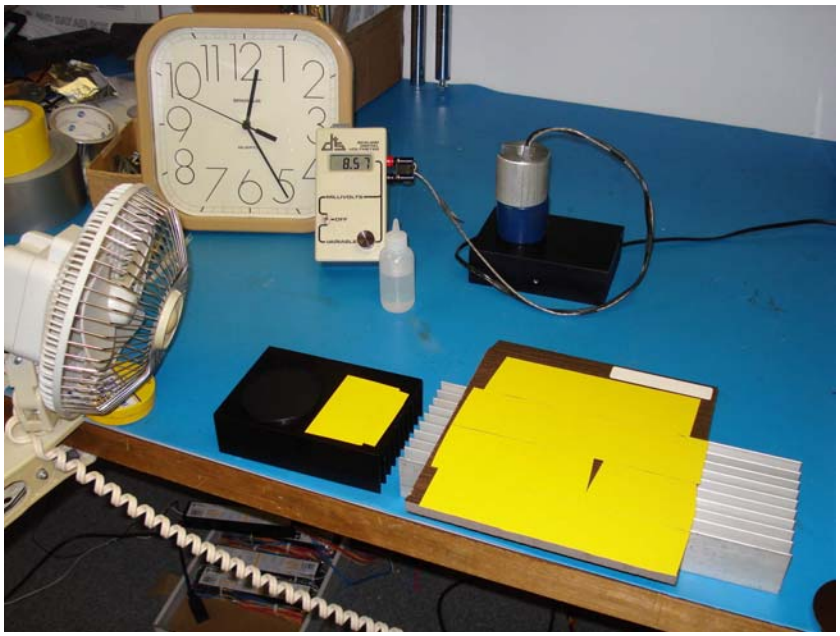
Slide Method Testing

As proposed in D&S Technical Note 04-1, a test of the slide method can be conducted to ensure that the emittance values obtained are close to the correct value. This was done by measuring the emittance of a wide vinyl tape that can be applied flat to the heat sink as well as to various samples of materials that cannot be applied to the heat sink. First the "correct" emittance value of the tape is determined by measuring the tape as applied directly to the heat sink alongside the calibration standards. Then the tape is applied to the surface of a test material such as a flat concrete tile and the "slide" method is used to measure the tape as applied to the surface. It should be possible to obtain roughly the same "correct" emittance reading on the tape as applied to the test material if the sample area is large enough.

Test Procedure

The slide method test procedure is outlined below.

1. Setup – As shown in the photo below, a small fan is set up to provide for cooling of the AE1 heat sink that is supplied with the instrument and the sample to be measured. Here the sample is a concrete tile with the vinyl tape applied and it is resting on a finned heat sink that will allow air flow beneath the tile. In order to prevent a slow temperature rise of the heat sink, the emissometer detector is placed on a separate heat sink while measurements are not being made. Note that in the photo, the high emittance standard is installed on the left hand side of the heat sink but it cannot be seen because it is black anodized.



2. Calibration – Prior to calibration the fan should be turned on for several minutes to ensure that the heat sink is at or very near room temperature. Turn the fan off and perform calibration of the instrument with the high and low emittance calibration standards. This involves setting the offset with the trimmer on the measurement head and the gain on the voltmeter to get both the high and low emittance standards to read the correct emittance value. This calibration is required primarily to set the offset since all subsequent measurements will be made at room temperature. The offset on the measurement head is insensitive to small changes in the temperature of the samples and thus need only be rechecked occasionally. Additionally, a small error in offset has a negligible affect on emittance measurements for high emittance materials.
3. Bring Standard and Sample to room temperature – Set the AE1 detector aside (in this case on the alternate heat sink) and be sure that the high emittance standard has a few drops of water under it so that there is good thermal contact to the heat sink. The low emittance standard is not needed after calibration. Turn on the fan for some time to bring the heat sink and the sample to be measured to room temperature. For the measurements reported below at least 10 minutes of cooling time was allowed before making each measurement.
4. High Emittance adjustment – Turn off the fan and move the AE1 detector to the high emittance standard on the heat sink. Allow 90 to 120 seconds for the detector output to become completely stable. Adjust the gain on the Scaling Digital Voltmeter to read the emittance value of the high emittance standard. Note that heating of the heat sink and the calibration standard over a period

of 120 seconds is less than 0.003 emittance units as confirmed by measurement of drift over longer periods of time.

5. Measurement – Immediately move the detector to one corner or end of the sample. Leave the detector in place for 20 to 30 seconds. The voltmeter output will usually approach but fall below the correct emittance value of the sample due to heating of the surface. Slide the detector a few inches to another spot on the sample. The emittance reading will begin to rise and then stop or fall back. This may take from a few seconds to 15 seconds depending on the sample. At that time slide the detector again to an unheated area. Continue to slide the detector to new unheated areas for at least 90 seconds.

For this testing the Scaling Digital Voltmeter gain was increased by 10X to read emittance to three digits. This is typically beyond the level of repeatability of the instrument however it is useful in monitoring the direction of movement of the emittance value.

Test data

Measurements were made on an 8" x 9" x 0.4 inch thick concrete tile using two different vinyl tapes. Following the procedure as described above it was found that the tile could be measured with five locations on the sample. That is, moving the detector each time the emittance value peaks, after four moves from the initial location the 90 second time limit was achieved and the reading no longer rises significantly with a subsequent move. Test results for these measurements are given below.

Yellow vinyl tape "correct" emittance = 0.908 (average of four measurements)

Yellow vinyl tape applied to concrete tile: 17 measurements, 0.905 average, 0.004 standard deviation

0.907	0.900	0.911
0.906	0.910	0.905
0.911	0.904	0.905
0.898	0.901	0.902
0.910	0.904	0.905
0.897	0.906	

Gray vinyl tape "correct" emittance = 0.787 (average of four measurements)

Gray vinyl tape applied to concrete tile: 7 measurements, 0.787 average, 0.002 standard deviation

0.784	0.787	0.788
0.785	0.786	
0.787	0.789	

Additional measurements were made on a light weight fiberboard samples 5" x 14" x 0.5 inches thick. Due to the low thermal conductivity and low density of the material it was determined by testing that a larger sample was required. Adding another piece 4.5" x 16" x 0.5 inches provided sufficient surface area to move the detector to 12 or 13 locations and achieve a near steady reading after 90 seconds.

Gray vinyl tape "correct" emittance = 0.787 (average of four measurements)

Gray vinyl tape applied to fiberboard: 12 measurements, 0.784 average. 0.005 standard deviation

0.784	0.775	0.789
0.788	0.789	0.782
0.789	0.782	
0.785	0.785	
0.787	0.778	

Discussion

The slide method as outlined here can be used to measure the emittance of materials with low thermal conductivity and low thermal capacitance within practical limits if a large enough sample area is available. Some additional testing should enable the method to be specified more precisely and possibly used as a standard measurement technique. For example, it may be possible to run a transient response test with the AE1 detector, on a particular sample type, to determine a minimum sample area and a fixed measurement timing sequence. Other test parameters such as cooling time, spacing of measurement locations and averaging could be specified.

Some sample transient test data is shown below. This data was taken using the same test configuration described above, with the yellow vinyl tape applied to the samples. The samples with lower thermal conductivity and/or lower thermal capacitance show a greater drop in reading with time and thus would require a larger sample area and shorter time intervals between detector moves.