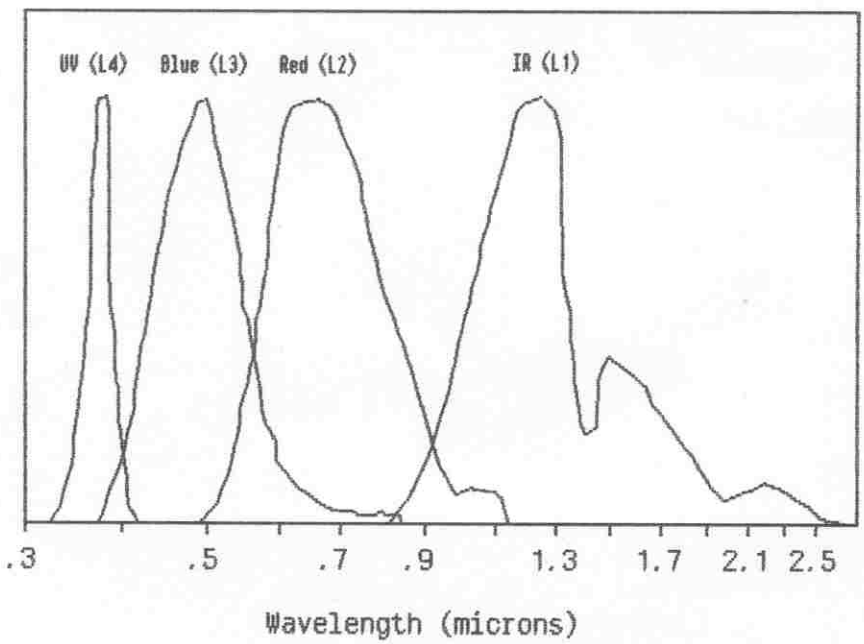
Devices & Services Co.
10024 MONROE DRIVE - DALLAS, TEXAS 75229 - (214) 902-8337

D&S TECHNICAL NOTE 86-1

SOLAR SPECTRUM REFLECTOMETER VERSION 5.0

The Solar Spectrum Reflectometer, Model SSR, is designed to provide an accurate measurement of total solar reflectance. This is accomplished by illuminating the sample with a tungsten lamp source and measuring reflected light with four separate detectors. Color filters tailor the response so that each detector covers a range of wavelengths within the solar spectrum.



By combining the outputs of these four detectors in appropriate proportions, the resulting measurement spectrum can be made to approximate a solar spectrum. Weighting factors are provided to set up the instrument for Air Mass 0, 1 or 2 solar spectrums. Detailed information on the operation of the reflectometer is available in Devices and Services Technical Notes 79-16, 82-1 and 83-1.

Previous versions of the instrument required that the weighting factors be adjusted with an individual gain trimmer for each detector. Reflectance standards were

provided along with a reference card with the appropriate Air Mass 0, 1 and 2 settings. The measurement spectrum settings required periodic adjustment to account for long term drift in the detector outputs. For routine operation of the instrument, a single gain adjustment potentiometer allowed the reflectometer to be calibrated against one of the standards. Occasional adjustment of a zero trimming potentiometer was also required.

The Solar Spectrum Reflectometer Version 5.0, Model SSR-ER, incorporates a microprocessor controlled electronics package to automate set-up and calibration of the instrument. Using a small keyboard located on the front of the electronics package, the operator can quickly elect to display Air Mass 0, 1 or 2 reflectance or absorptance values or display reflectance or absorptance for one of the four individual detectors. Calibration of the reflectometer against a standard is accomplished with a single key stroke and the measurement spectrum is automatically adjusted each time. It is also possible to "record" readings on a sample so that the sample can be used as a working standard. A "Hold" function freezes data from the most recent measurement so that different reflectance or absorptance values can be displayed. The instrument can also be put into a "lock out" mode so that settings cannot be accidentally altered during production or quality control measurements. The settings are retained in battery backed up memory while power is off and are restored on power up.

The new electronics package was designed so that existing reflectometers can be upgraded. The circuit board is identical in size and the edge connector is pin compatible with previous versions. The access cover on the front panel has been replaced by a small keypad. The measurement heads are also compatible, however two new features are added to the new units. The first is a lighted momentary switch that comes on when a measurement is being taken. The switch allows the "Hold" function to be activated remotely so the operator does not have to watch the display while working with the measurement head. The other feature is a thermistor temperature sensor in the head that will be used to stabilize the temperature of the measurement head and minimize drift. A full upgrade of both the electronics and the measurement head will be offered to owners of previous versions of the SSR.

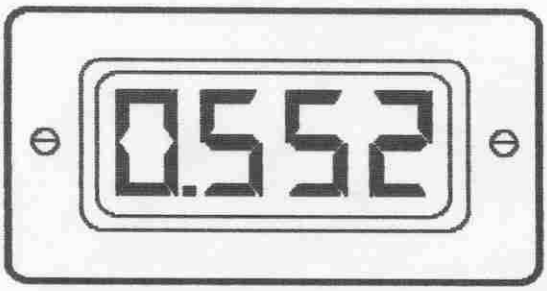
This technical note describes the operation of each feature of the new electronics package. An applications section deals with special measurements on non-flat surfaces and second surface mirrors. Finally, a brief description of several anticipated enhancements to the software is included.

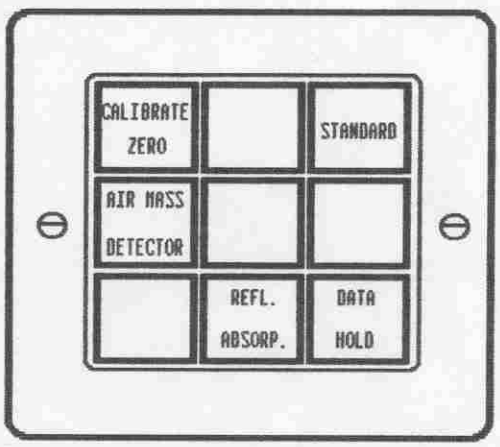
Operation of the SSR Version 5.0

The basic operation and use of the SSR remains unchanged from version 4.0 of the instrument except that the set-up and calibration have been greatly simplfied. Once the instrument is powered up it begins running thru an eight second measurement cycle. During the first six seconds the lamp is off and the electronics package is in an auto-zero mode. Before the lamp comes on, offset voltages are measured for the four detectors. The lamp then comes on for two seconds during which time the lamp output is first stabilized and then the four detector readings are taken. The microprocessor uses this data to calculate the reflectance for the selected Air Mass or for an individual detector and the resulting reflectance value is displayed on the

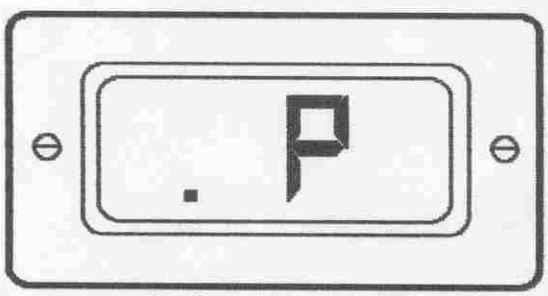
four character LCD. The display is updated with a new value after each cycle. Periodic calibration and zeroing of the instrument is required as before. The instrument zero is set using a blackbody cavity over the measurement port. One of three standards provided with the unit, or a working standard chosen by the user, is used to calibrate the instrument for absolute reflectance. To obtain a reflectance reading from an unknown sample the material is simply held flat over the measurement port until the unit completes a measurement cycle.

The following figure shows the front panel keypad and display. The keys that do not have legends are not currently assigned a separate function.

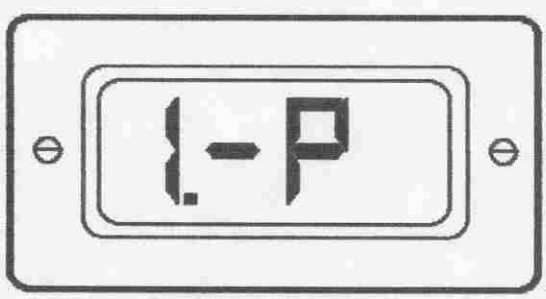




Reflectance / Absorptance — This key allows the operator to toggle between displaying either reflectance or absorptance. Note that we assume that the material is opaque and that the absorptance is simply one minus reflectance. By pressing the key briefly the display will indicate whether the instrument is currently in reflectance or absorptance mode. Holding the key down will toggle between reflectance and absorptance mode. Release the key when the appropriate mode is displayed.



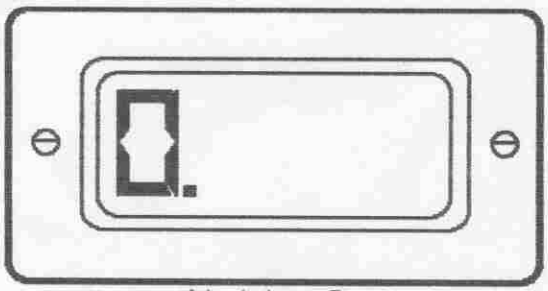
Reflectance Mode



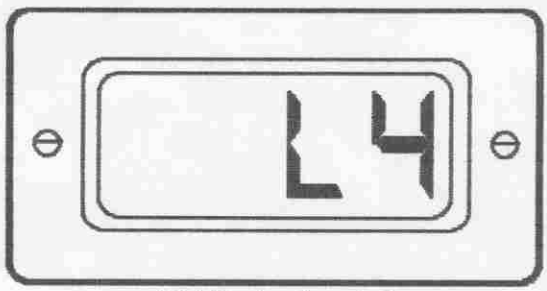
Absorptance Mode

Selection of absorptance mode does not affect calibration of the instrument except that after calibration, the absorptance of the standard is displayed instead of reflectance.

Air Mass / Detector — This key selects the reflectance quantity to be displayed. Pressing the key momentarily displays the current selection. The seven selections currently available are Air Masses 0, 1 and 2 and L1 thru L4. L1 thru L4 represent the four detectors used in the reflectometer. Selecting one of these displays the reflectance of the sample for that detector's measurement spectrum (or response curve) alone.



Air Mass 0

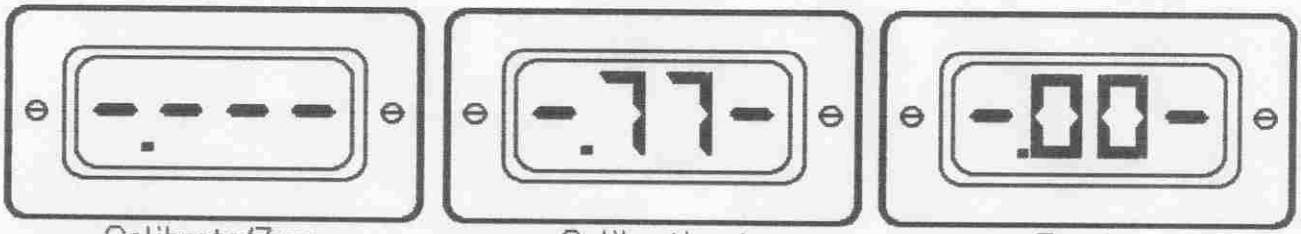


UV Detector L4

Holding the key down will cause the display to toggle through the seven settings. Release the key when the desired selection is displayed.

Standard — This key selects the current working standard. One of the three standards provided with the instrument or one of five user programmable working standards can be selected. Once the standard is selected, the calibration function described below assumes that the selected standard is on the measurement port when calibration is initiated. The display will show the selected standard, as illustrated, in response to momentarily pressing the standard key. Again, holding the key down will toggle through the available selections.

Calibrate / Zero — This key initiates either calibration or zeroing of the instrument. Pressing this key will cause four dashes to be displayed. The unit determines whether a calibration standard or the blackbody is on the port and automatically selects either the calibrate or zero mode. If a reflective material is sensed, the calibration mode is selected and it is assumed that the standard selected with the "Standard" key is on the port. The selected standard is displayed as shown. From the readings obtained on the standard the new weighting factors for the four detectors are calculated. If the reflectance reading for the standard was slightly off before calibration, the correct value will be displayed after the calibration routine is completed.



Calibrate/Zero Initiated | Calibrating to Standard #77 | Zeroing

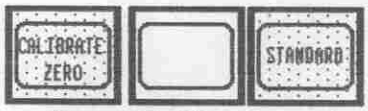
If the blackbody cavity is over the port, the unit will measure a zero offset that is due to light leakage into the detectors from inside the measurement head. This offset is subtracted from every reading thereafter. The display indicates if the zero mode has been selected properly.

Both the zero offset and the calibration should be checked periodically during operation of the instrument and readjusted when necessary.

Data / Hold — The data hold key duplicates the function of the lighted push—button on the measurement head. Currently, both are used for a hold function only. Pressing the key or the push—button on the head will freeze the last sampled set of data. The slight display blink that occurs each time a measurement cycle has been completed and the display is updated, will not occur in the hold mode. The operator can then check the reading obtained or select different reflectance values to display via the Air Mass / Detector key. The hold function is canceled by pressing either the Data / Hold key or the push—button on the head. If the hold is canceled after a new measurement cycle has been completed, the display will be updated immediately upon cancellation of hold.

Other functions are activated by holding down combinations of keys.

Recording a programmable standard — This function allows the user to select up to five working standards of his own choosing and record the reflectance values as measured against the standards provided with the instrument. The reflectance values are recorded as one of the five programmable standards P01 — P05. Once the readings are recorded, the working standard can be used to calibrate the instrument during operation. First the instrument should have recently been calibrated against one of the three standards provided with the instrument. Note that the current release of the software will not allow one programmable standard to be calibrated against another. Select one of the three standards and calibrate as described above. Do not attempt to select the programmable standard as the working standard at this time. The working standard must remain the one used to make the initial calibration. Place the material to be used as a working standard on the port. Simultaneously press and hold the Calibrate / Zero and Standard keys. The display will slowly step through the designated numbers for the programmable standards to the one to be used. Release the keys at that point and the reflectance values will be recorded. After the values are recorded, the reflectance of the working standard will be redisplayed.

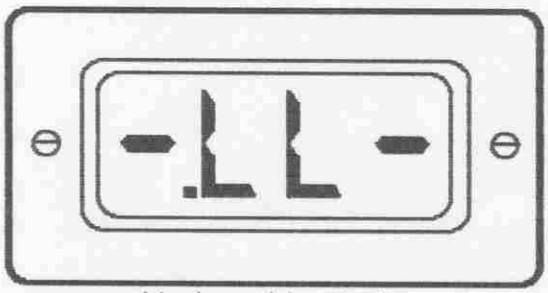


Press Calibrate and
Standard Keys

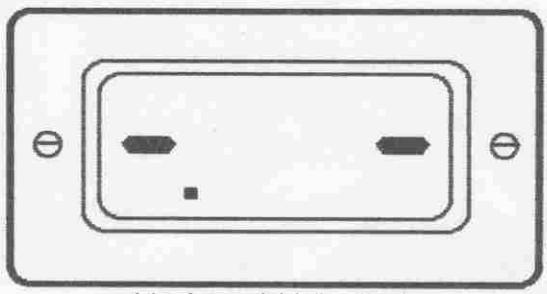
Recording programable
Standard 01

Check by using the Standard key to select this programmable standard as the current working standard. Press the calibrate key with the working standard on the port. The calibration routine should display the standard number (01 – 05) and after completion should display the same reflectance value that was recorded.

Lock–out – A multiple key lockout feature is provided so that if desired, particular settings can be locked into the instrument and cannot be changed accidentally during operation. All of the functions are disabled except the Calibrate / Zero, Hold and Cold Start functions (see below). Press the three corner keys excluding the Data / Hold key to toggle into the locked mode. Press again to unlock.



Keyboard Locked



Keyboard Unlocked

Cold Start – A cold start procedure is provided just in case the microprocessor loses initial set–up data that is stored in battery backed up memory. Other data such as programmed standards, current working standard, selection of reflectance value displayed and reflectance or absorptance mode, are retained in this memory and are restored on power up. If the instrument seems to be hopelessly hung up, a Cold Start may solve the problem. Pressing the top three keys simultaneously will initiate a cold start. During the first measurement cycle the processor extends the lamp on time to set the lamp current. The display will flash until the unit is zeroed and calibrated. Perform the zero operation first so that the correct leakage readings will be subtracted when the instrument is calibrated.

Special Applications

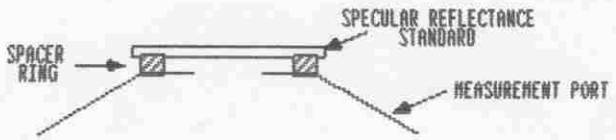
The new features of the reflectometer enhance the use of the instrument in certain applications that normally would require correction factors applied to the readings or complicated calibration procedures. Two of these are measurements on second surface reflectors and measurements on non-flat surface geometries.

The difficulty with measurements of second surface reflectors is described in D&S Technical Note 82-1 which also describes a previous revision to the measurement head that improves the accuracy for these measurements. The problem occurs because of the fact that the primary reflective surface is displaced from the port by the thickness of the transparent material.

The reflectance measurement is accomplished by providing diffuse illumination of the sample and measuring reflected energy at an angle of 20 degrees. This is equivalent to measuring total reflectance for beam radiation incident at the same 20 degrees. In the case of the SSR, the property of interest is the total reflectance for direct (beam) solar radiation. For these two measurements to be exactly equivalent, the incident radiation in the first case must be perfectly uniform in all directions. This is impossible to achieve in a practical instrument, so some compromise between the size of the diffusing chamber and the level of diffussivity must be accepted. There will be some variation of light intensity as a function of direction reaching the sample port.

This poses a problem when measuring specular (mirror like) materials in comparison with diffuse materials because the light reaching the detector from a specular material comes from a small area of the diffusing chamber that is located in the specular direction from the detector. In order for both specular and diffuse materials to read correctly, the intensity coming from the specular direction must be equal to the average intensity reaching the port from all directions. This is even further complicated by the fact that each detector views a slightly different portion of the chamber wall. When a second surface reflector is placed on the port it displaces the viewing area from that of a front surface reflector because of the 20 degree angle of incidence. In addition some of the reflected energy escapes through the transparent material. Technical Note 82-1 describes how the detector head was modified to minimize errors for these measurements. Basically the measurement port was enlarged and the alignment of the detector adjusted to prevent "clipping" of the direct reflection from the sample by the port itself. In addition, a new method of adjusting the intensity incident from the specular direction was devised. This involves adjusting the position of the source lamp within the chamber to produce a large area of nearly uniform intensity that provides the best agreement possible between specular and diffuse standards. Even with these adjustments, some error remains. To address the remaining error, both specular and diffuse materials are provided as reflectance standards. The values for the specular standard provided are corrected to an NBS specular reflectance standard. It is recommended that for measurements on mostly specular materials the specular standard (or a specular working standard) be used instead of the diffuse tile materials. Because of these small corrections, the reading obtained on the specular standard will not agree precisely with the value specified if the reflectometer is calibrated with the diffuse standard.

With this somewhat involved introduction to the problem of measuring second surface reflectors, the capabilities of the microprocessor controlled electronics provide a simple method of making these measurements. The error introduced by a second surface reflector can be estimated by displacing a first surface mirror away from the measurement port by a distance equal to the thickness of the first surface reflector divided by the index of refraction of the material. This is illustrated in Technical Note 82—1. The specular standard provided with the instrument can be used in this manner by making a support ring to space the mirror away from the port by this amount. The ring should be as large as possible and still remain on the flat front end of the measurement port and it should be blackened to reduce reflections. You will notice a small decrease in the reflectance reading when the standard is displaced from the port. However, calibrating the instrument for this standard with it displaced from the port will automatically make the required adjustments in the weighting factors for each detector. This will produce accurate measurements for second surface reflectors since the correction will be reasonably small for mirror thicknesses up to 0.25 inches.



A similar problem occurs when attempting to measure surfaces that are not flat. Adapters have been made at D&S and by a few customers for measuring cylindrical surfaces from 0.5 inches to several inches in diameter. The idea of the adapter is to position the surface close to and with a repeatable orientation relative to the measurement port. In order to calibrate the instrument for these measurements, film materials have been supplied that can be measured flat and then applied to the cylindrical surfaces and measured with the adapter. This requires lengthy measurement procedures and some care to get good results. With the microprocessor based electronics, all that is required is to record the film material as measured in a flat condition, as one of the programmable working standards. This material is then applied to the cylindrical surface, and measured with the adapter. The instrument is then recalibrated using the values previously recorded for the flat film material. We have also found that for the smaller cylindrical surface adapters, that the support hardware itself will reflect enough light into the detectors to produce an offset (even though the adapter hardware is usually blackened). The zeroing procedure easily eliminates the offset.

Software Enhancements

Several software enhancements are anticipated but are not implemented in the current release of the software (version 5.0). These are listed here to provide an idea as to what can be accomplished with the current hardware configuration.

Temperature Stabilization — A thermistor is installed in the new (and upgraded) measurement heads. This will allow the temperature of the head to be monitored during operation, and stabilized using the lamp duty cycle. This will minimize drift in detector outputs with temperature.

Correction of Substitution Error — Technical Note 82—1 also describes a phenomenon known as the substitution error that results from the fact that changing the reflectance of the sample on the port changes the amount of light within the diffusing chamber. It will be possible to make an adjustment for this error in software.

Diagnostic error reporting — Many aspects of the operation of the instrument can be monitored by the microprocessor. These include:

Monitoring lamp performance over time.

Checking the lamp control range during each cycle.

Monitoring detector degradation over time.

Flagging inconsistent data due to movement of the head, etc.

Tracking the IR detector to report a faulty water filter.

Statistical Analysis — An average and standard deviation can be maintained for a set of data as entered by the operator from the push—button switch on the measurement head or the keypad.

Serial Port — A bi—directional serial port is included on the board and the connector is installed in the case but no software is written for the port at this time. It will be used to help automate the procedure used to set up the instrument at the factory. It will also enable the instrument to dump data to a serial printer. A user interface may be added to enable the instrument to be programmed from a terminal or computer.