Devices & Services Co.

D & S TECHNICAL NOTE 83-1

SOLAR SPECTRUM REFLECTOMETER DESIGN MODIFICATIONS: REVISION #4

ABSTRACT

The Solar Spectrum Reflectometer electronics have been modified to sample and hold the reflectance reading once every eight seconds, rather than continuously monitoring reflectance. The change allows the lamp in the measurement head to be turned on for only a fraction of the measurement cycle time minimizing heat build-up during extended operation. Because temperature changes are a major contributor to drift in the detector scale factors, the modification significantly improves short term drift and repeatability. SSR users in the past would have to calibrate more often and might have to select a value if significant drift occurred during the measurement interval. With the modified circuit design the drift is minimized. Additionally, a procedure is described for determining if a lamp needs to be replaced. This procedure corrects that given in the original instructions.

INTRODUCTION

The D & S Model SSR Solar Spectrum Reflectometer provides a single measurement of hemispherical solar reflectance. A tungsten filament lamp illuminates the sample port. Reflected radiation is measured with four filtered detectors covering different wavelength ranges through the solar spectrum. By including gain adjustments for the individual detectors and combining the detector outputs, the reflectometer achieves a reasonable match to a solar spectrum. The light source, detectors, and detector preamplifiers are contained in a measurement head that is connected by a multi-conductor cable to an enclosure that houses the power supply, control electronics, and display for the reflectance values.

The four detectors are designated UV (ultraviolet), Blue, Red and Infrared, indicating the predominant range of wavelength each covers. Spectral distribution curves for the individual detectors can be found in D & S Technical Note 79-16. The first three of these detectors are silicon photovoltaic cells. The UV detector is a blue-enhanced silicon cell with blocking filters to eliminate all but the small amount of radiation emitted by the tungsten lamp in the 0.3 to 0.43 micron range. For the infrared detector, a lead sulfide photo-conductive cell is used along with appropriate filters to limit the range of response. Outputs from the four detectors are added with a summing amplifier to produce the solar reflectance reading.

In order to measure the detector outputs with the desired resolution, it was necessary to implement an autozero/measurement cycle controlled by circuitry within the electronics enclosure. In the original design, approximately once every 25 to 30 seconds, the lamp was turned off for about four seconds during which time two separate circuits made the following adjustments. First, the output of a lead sulfide cell is logarithmic rather than linear, and the cells are subject to changes due to temperature and light history. For this reason an offset adjustment must be made for the lead sulfide cell with no light input. Additional electronics are required to linearize the detector output once the lamp is turned on. Secondly, because of the very high gain required for the UV and Blue detectors, amplifier offsets became significant, and the drift in offset with time and temperature was too great to adjust with a static offset adjustment. Instead, the output of the summing amplifier that adds all four of the detector outputs was nulled out during the period that the lamp was off. In this manner, a stable zero reading was achieved regardless of the offset drifts in the individual detector amplifiers. Figure 1a illustrates the original autozero timing.

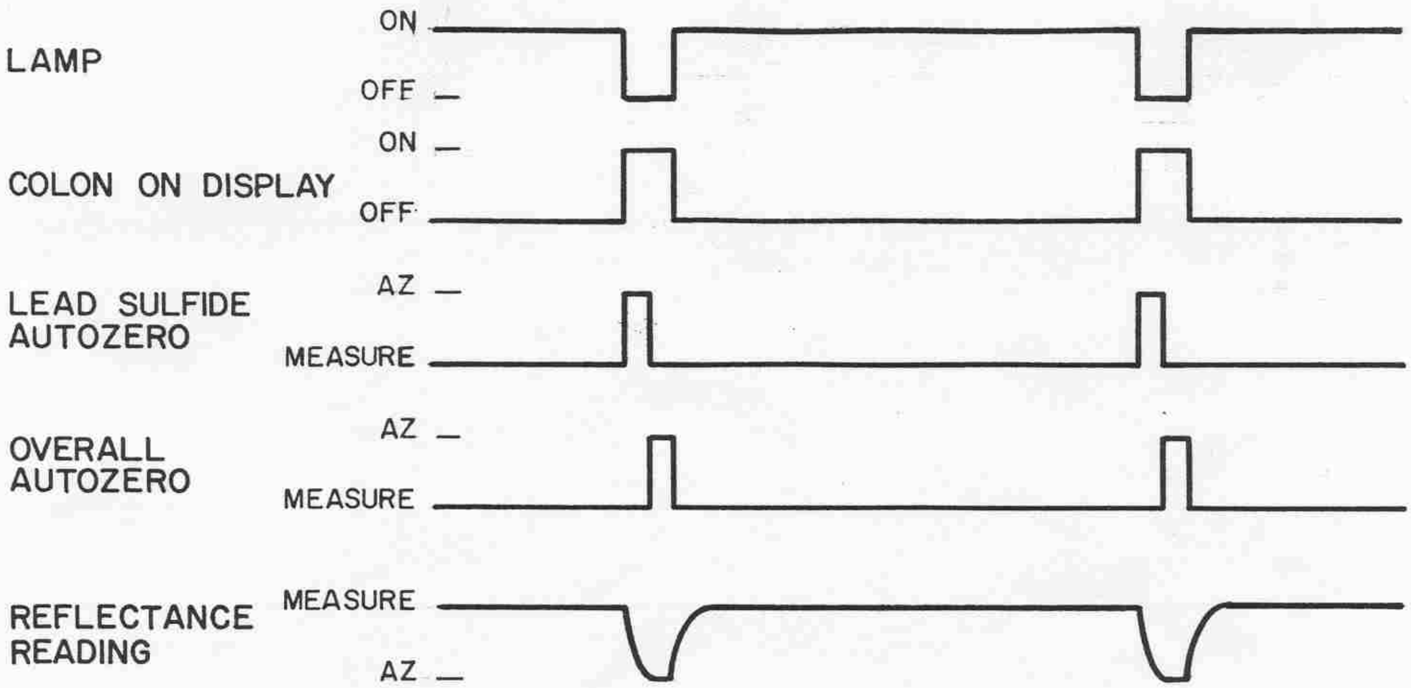

FIGURE IA. Measurement cycle timing for the original SSR design.

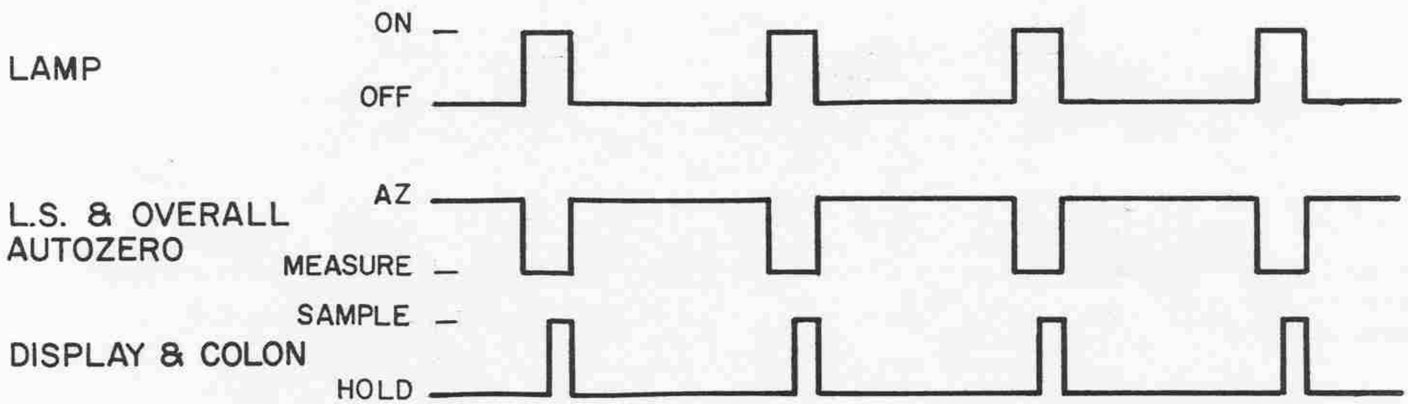

FIGURE IB. Modified SSR measurement cycle timing.

DESIGN MODIFICATIONS

Timing for the autozero cycle has been modified as shown in Figure 1b. The lamp is turned on for about two seconds once every eight seconds. The reflectance at the port is sampled when the detector outputs have stabilized, just before the lamp is turned off, and the reading on the display is held until the next measurement period. While the lamp is off the autozero operates as described above. This modification improves the performance of the SSR in several areas.

First, the linearization circuit for the lead sulfide infrared detector requires the use of two matched cells (matched for dark resistance), one for the measurement and one for a reference. Within the measurement head the cells are kept in close thermal contact, and are subjected to the same incident radiation. This minimizes detector drift due to temperature changes and light history. As long as the cells remain matched, the electronics provide a linear output with a reasonably stable gain. Recently, however, a batch of lead sulfide cells had become badly mismatched after only a few weeks of operation. The dark resistances of the two cells which were initially matched to +/- 5% were found to be as much as 100% off. The problem was specific to the particular batch of cells and is apparently related to the temperature level reached in the measurement head during extended operating periods. With the modified autozero timing, the lamp is only on for 20% of the time compared to about 85% for the original design. This results in a much lower operating temperature which should eliminate any chance that the cells will degrade. In addition, a new supplier has been found for the lead sulfide cells. Two of the new cells have been operated continuously for a month in a measurement head using the original autozero cycle (at approximately 75% duty cycle for the lamp), with less than two percent drift in the detector gain.

The problem of mismatch between the two lead sulfide cells can cause not only the long term drift in the infrared detector gain and short term thermal drift, but it can also cause the two cells to exhibit differences in light history response. Typically, the response of a lead sulfide cell to a sudden change in light intensity will depend on the light intensity prior to the change. Over several minutes time, the cell will then slowly reach a steady resistance at the new intensity level. Because the cells never reach a steady condition during operation of the SSR, the cells light history response must also match. If a mismatch developes, it will appear as a drift in gain during the measurement interval. Some of the older SSR's have exhibited this problem. The lead sulfide reading will show a small upward or downward drift during the time that the lamp is on. In addition, after the unit has been on or off for some time, the autozero point may have drifted enough to fall outside the autozero range of the electronics. This requires a trimmer adjustment to bring the autozero circuit back into range. The modified autozero cycle eliminates any problems related to light history. Because the lamp is off most of the time and only on for a short time, the cells show very little light history response even with a highly reflective material over the port. In addition, the reflectance is sampled at the same time during each measurement cycle, just before the lamp goes off, improving the repeatability. The reading is held on the display, removing the difficulty caused by taking a reading as the value drifts several counts during the measurement cycle. Finally, since the measurement head now runs within a tighter temperature range, the gain stability of all of the detectors is improved. After 30 minutes warm-up, a test unit, modified for the improved autozero cycle, consistently maintained a drift of less than 0.5% of reflectance per hour of operation. As a side benefit of the lower temperatures, the water filter positioned in the collimator is expected to last longer before developing air bubbles.

OPERATIONAL CHANGES

Some operational changes have resulted from the modifications. These are described below.

Colon on Display - The colon on the display is now used as a visual indication that the reflectance is being sampled. The lamp comes on for about one second before the colon appears on the display. This allows time for the reading to approach a steady state value. The colon then comes on and the display is updated. The last reading on the display as the colon goes off is held until the next measurement interval.

Setting Gain or Zero - Because the reading is held rather than displayed continuously, the gain and zero adjustments must be made incrementally. For example, set the gain adjust in appropriate direction and then wait for the colon to appear on the display, when the reflectance is sampled. This is repeated until the gain is properly adjusted.

Autozero Diagnostics - A diagnostic circuit on the SSR electronics board senses if either of two zeroing circuits goes out of range of adjustment. There is a two-color LED and a trimmer for each zeroing circuit. These are located beneath the cover on the front panel. If either of the circuits goes out-of-range, the associated LED will light up green or red indicating that a clockwise or counter-clockwise adjustment of the trimmer is required. No light indicates that adjustment is not required. In addition, an arrow in the upper left hand corner of the display comes on when either light comes on, indicating that one of the trimmers needs adjustment. The timing associated with the autozero diagnostic circuit is illustrated in Figure 2.

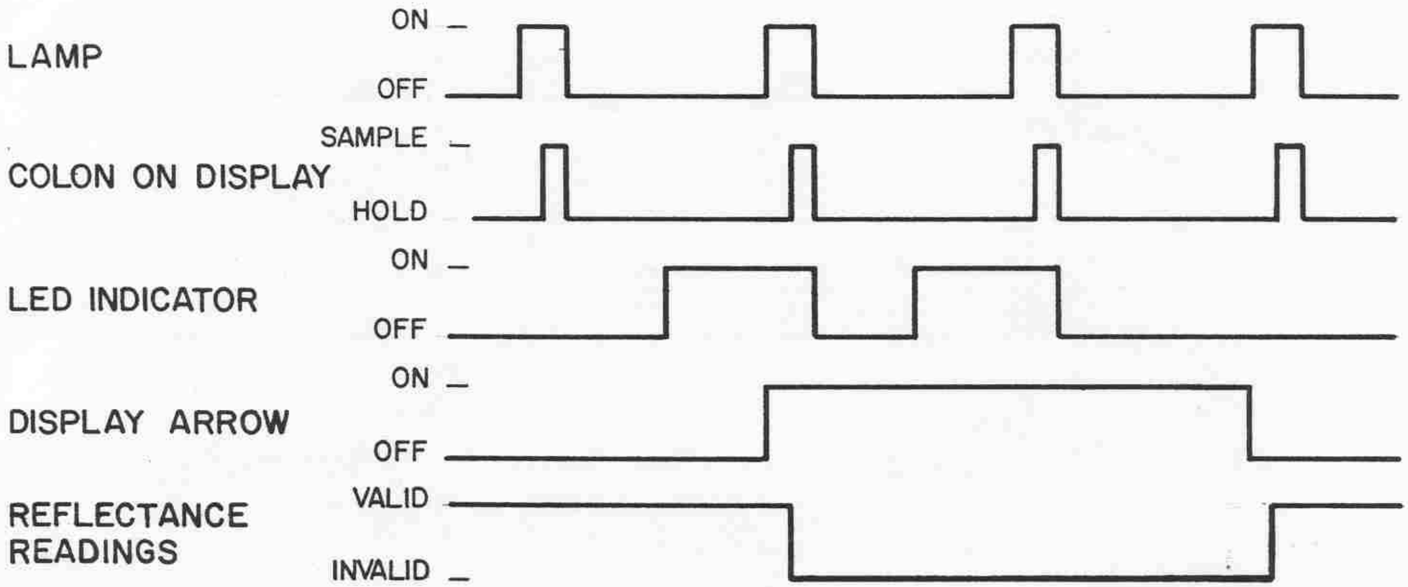

FIGURE 2.

The diagnostic LED's do not remain on continuously. The error condition can occur any time during the autozero cycle at which point the LED will come on. The LED remains on until the lamp goes off, the error condition is cleared and the circuit enters the autozero cycle again. If one of the LED's comes on at any time during the cycle, the trimmer needs adjusting. Note that this adjustment must also be made incrementally, waiting for a complete measurement/autozero cycle between adjustments.

Optional Output Package - The optional outputs have also been modified. Figure 3 illustrates the timing. If an external device is to monitor the SSR operation, the falling edge of the "sample" output should be used to hold or latch the analog output. If Auto Zero Fail goes high, operator attention is required to adjust the unit.

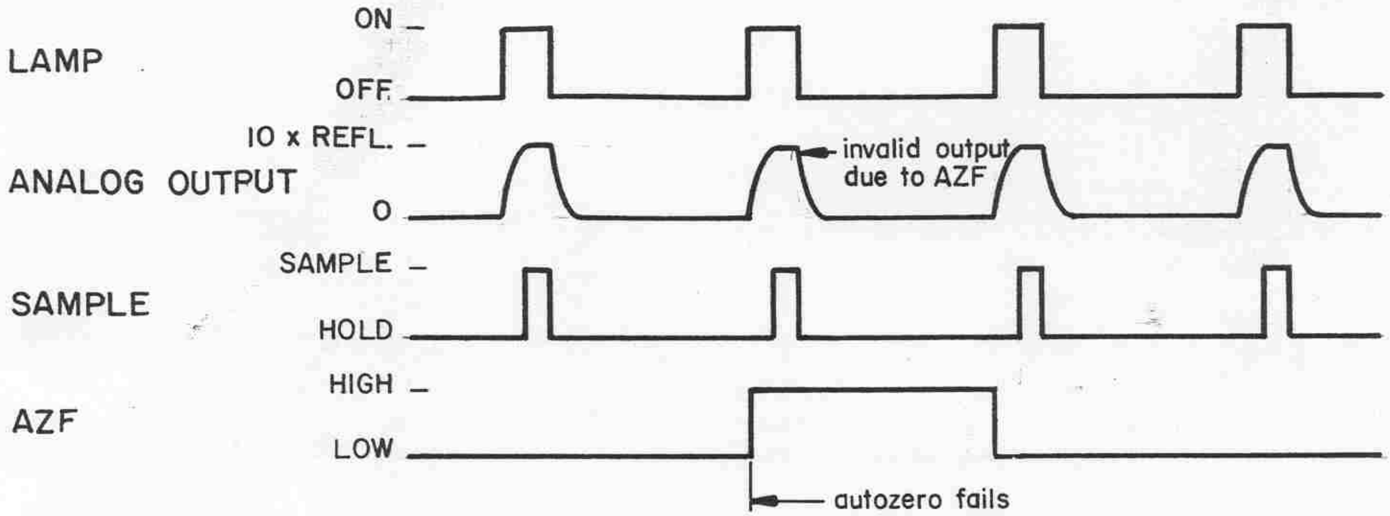

FIGURE 3.

LAMP REPLACEMENT

An error was made in the SSR Instructions concerning adjusting the lamp current. The original SSR Instructions indicated that the lamp current should be checked and if different than 1.08 amps by more than +/- 0.03 amps, the current should be adjusted using a trimmer on the electronics board. However, it is not the lamp current, but the light level inside the chamber that should remain constant.

For a new lamp, the current reading should be 1.08 amps with the blackbody in place over the measurement port. This establishes the appropriate filament temperature and ensures a long life for the bulb. The current should vary slightly with the reflectance of the material placed over the port as the control circuitry attempts to maintain a constant light level inside the measurement head. As the lamp ages, the current level will increase to keep the light level constant. The increase in current level is normal and should happen slowly over many months of operation. The lamp current may even continue to increase up to the point where it is no longer possible for the control circuitry to maintain the same light level. At this point the lamp needs to be replaced.

If the lamp current increases in this manner it should not be set back to 1.08 amps as suggested in the SSR Instructions. This would reduce the light level in the chamber and decrease the outputs from all of the detectors. Instead, the lamp current should only be adjusted to 1.08 amps after the lamp is inspected and found to be free of deposits or when replacing a lamp. Compare the old lamp with a new one to make certain there is no subtle discoloration of the bulb. The following test procedure will determine if the lamp is still putting out enough light for the intensity in the measurement head to be controlled properly.

1. Set up the SSR to display current as described in the Instructions.
2. Place the blackbody over the port and measure the lamp current.
3. Place a material with a reflectance of about 0.20 over the port.
The lamp current should change noticeably. If it does not change, and the lamp current is reading higher than 1.08 amps, the lamp then needs to be replaced. If the lamp current does not vary with reflectance and the current reading is low, there may be a problem with the lamp control circuitry.

CONCLUSIONS

During operation of the SSR in its original form, recalibration with a standard would normally be required after a few minutes of operation due to the possibility of a slow drift in the detector outputs. In some cases, if significant drift occurred during the measurement interval the operator would have to select a value, for example, at the very beginning of the measurement interval to improve the repeatability of the reflectance readings. This problem complicates the operation of the reflectometer and can introduce small errors in the readings.

The Revision #4 design modification described above improves the performance of the SSR by decreasing the operating temperature of the measurement head. This results in more stable detector gains and ensures that the lead sulfide detectors will not be under risk of thermal degradation. In addition, the low duty cycle of the lamp minimizes light history problems with the lead sulfide cells. The reflectance at the measurement port is now sampled about once every eight seconds and held on the display rather than measured continuously. This feature simplifies the measurement procedures for the instrument's operator. To make a measurement, place the sample over the port and wait for the colon to appear on the display indicating that the reflectance is being sampled.

The modification will be made available to owners of Solar Spectrum Reflectometers with Serial Numbers 029 and lower, excluding Serial Number 024 which has already been modified.

NOTE: The revision #4 modifications will be offered on Devices & Services Co. Instrumentation price list. The modification will include installation of a connector receptacle on the back of the electronics enclosure in place of the strain relief for the signal cable. A mating plug will be installed on the cable making the cable a separate part from the enclosure.