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# RESULTS OF EXPERIMENTAL TESTS AND CALIBRATIONS OF THE SURFACE NEUTRON MOISTURE MEASUREMENT PROBE

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Abstract: The surface neutron moisture probe has been tested both to demonstrate that it is able to operate in the expected in-tank temperature and gamma-ray fields and to provide detector responses to known moisture concentration materials. The probe will properly function in a simultaneous high temperature (80 °C) and high gamma radiation field (210 rad/hr) environment. Comparisons between computer model predicted and experimentally measured detector responses to changes in moisture provide a basis for the probe calibration to in-tank moisture concentrations.

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# RESULTS OF EXPERIMENTAL TESTS AND CALIBRATIONS OF THE SURFACE NEUTRON MOISTURE MEASUREMENT PROBE

W. T. Watson
J. H. Bussell

# Results of Experimental Tests and Calibrations of the Surface Neutron Moisture Probe

## 1.0 SUMMARY

Tests have been completed that demonstrate that the surface neutron moisture probe will function properly in expected in-tank conditions and that provide a calibration of the detector responses that will enable moisture measurement data interpretation. Both the probe electronics and the system interface electronics have been shown to be nearly insensitive to expected temperatures changes (-10 to 60 °C). Proper settings of the lower level discriminators have been determined that will allow for the separation of the neutron capture signal from the gamma-ray induced detector signal for exposure rate as high as 210 rad/hr. Accumulated gamma-ray exposure was found to have predictable effects upon probe output. Corrections for these accumulated exposure effects have been identified for exposures up to about $1.5\times10^5$ rad. Tests demonstrate that the probe responses exhibit excellent sensitivity to changes in moisture content. Comparisons between computer model predictions of detector responses and measured responses obtained from known moisture standards show that the model accurately predicts the measured responses. The computer model will now be used to generate predicted responses to best estimate waste containing different moisture concentrations and gradients. These predictions will be used to obtain moisture interpretations from in-tank probe response data. Based upon comparisons between the computer predictions and experimental measurements, in-tank data moisture interpretations are expected to be accurate to within 3 weight percent moisture.

## 2.0 INTRODUCTION

The Surface Moisture Measurement System (SMMS) is designed to measure the moisture concentration near the surface of the wastes located in the Hanford Site tank farms (WHC 1996A). A neutron moisture measurement sensor has been designed, built, and tested for deployment as part of the SMMS. In order to translate the expected in-tank data obtained with this system, the neutron sensor must be calibrated and the calibration results used to benchmark computer model predictions of probe responses to moisture. Other expected in-tank conditions that affect the response of the probe must be characterized to enable accurate interpretations of in-tank probe response/moisture data.

This report documents the experimental tests performed to characterize and calibrate the response of the surface neutron probe to changes in temperature, gamma exposure rates, and the moisture content and neutron absorption properties of surrounding media. These tests were performed by following much of the guidance found in the "Calibration Technique for the Neutron Surface Moisture Measurement System," (Watson and Shreve 1996).

The SMMS neutron probe operates by emitting high energy neutrons that are moderated or slowed in the surrounding waste, primarily through interactions with hydrogen nuclei (Hearst and Carlson 1994). The neutron probe consists of a Cf-252 neutron source and three B-10 lined neutron detectors, some of which are shielded with cadmium and polyethylene. The shielding prevents many of the thermal neutrons that reach the shield from reaching the detector while allowing epithermal or higher energy neutrons to pass through the shield, thermalize, and be detected. All of the detectors are most sensitive to thermal neutrons. These thermal and epithermal detectors absorb fractions of the moderated neutrons at rates related to the hydrogen concentration of the surrounding waste. These detection rates may also be affected by the elemental composition (thermal neutron absorption properties), bulk density, and physical arrangement or geometry of the underlying waste.

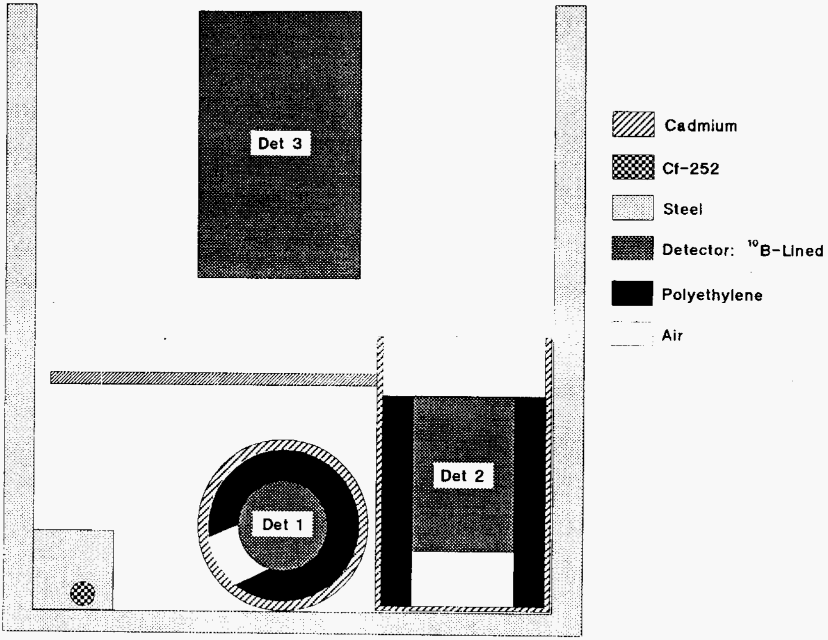
We intend to interpret probe responses by comparing them with computer model predictions of the responses to different moisture concentrations and moisture gradients. In order to use the computer modeling predictions with confidence, we must demonstrate that the modeling can be used to accurately predict the probe responses to controlled, well known media. Computer modeling can then be used to generate reliable predictions of probe responses to many different waste compositions and arrangements.

## 3.0 PROBE DESCRIPTION

The probe is mechanically housed within a nearly cylindrical stainless steel container (WHC 1996B) with an outer diameter in the sensor region of about 3.3 inches. The main sensor portion of the probe consists of three detectors, each of which is at least partially shielded with cadmium and or polyethylene, and a californium-252 neutron source. Figure 3-1 shows a sketch, not to scale, of the sensor portion of the probe with the major components identified. The housing is designed to be deployed upright on the surface being investigated with the flat bottom in firm contact with the material. Detector 1 is positioned horizontally in the bottom of the housing nearest to the neutron source and is surrounded with a thick (0.16 cm) outer cadmium shield and a partial inner layer of polyethylene. This detector is designed to detect epithermal neutrons returning to the probe. Epithermal neutrons will have, on average, undergone fewer collisions than lower energy neutrons and, therefore, will have traveled less deep in the media. Detector 2 is surrounded with a very thin (0.01 cm) cadmium shield and a polyethylene wrap and is vertically positioned near the probe bottom opposite the source. This detector detects a mix of thermal and epithermal neutrons that have, on average, traveled more deeply into the material that those detected by detector 1. Detector 3 is not surrounded with shielding, but rather is placed directly centered above a thick cadmium disk. This detector captures mainly thermalized neutrons that have traveled, on average, most deeply in the waste and exited the waste a short distance outside the probe housing.

The probe also contains two solid state temperature sensors, one placed just inside the cadmium shield surrounding detector 1 and the other mounted in the center of the line driver circuit

Figure 3-1. Sketch of the Sensor/Source Portion of the Neutron Probe (Cross-Sectional View).



board (WHC 1996C). The electronic boards are stacked above the detector 3 within the housing. The temperature sensors provide continuous indication of the probe internal temperature that could be used to apply correction to probe data if the probe responses were sensitive to changes in temperature.

The probe contains considerable signal processing and power supply electronics (WHC 1996C, D, E, F). The probe is supplied with 16 volts DC power and contains a regulator controlled DC to DC converter that converts the low voltage input to the high voltage (650 V) supplied to the three detectors. The pulses produced by each detector are separated from this high voltage and are routed to individual charge sensitive preamplifiers. The value of 650 VDC detector bias voltage was chosen because it was a good compromise between the charge input limitation of the charge amplifiers and minimum bias voltage for the detectors to provide output above the system noise level. Experimental measurements showed that the largest detector bias voltage that could be applied to the detectors without saturating the charge amplifier was about 725 VDC. These experimental measurements also showed that the proportional gas gain of the detectors changed by a factor of 2 to 4 per 100 volts detector bias voltage change. The charge output of the detectors is estimated to be about $2 \times 10^{-13}$ coulombs at a bias of 650 VDC. This number is based on the measurement of maximum pulse height from the Amptek A225 charge amplifier using the nominal gain and the actual value of the charge output may be 50% smaller to 200% larger. The output of these amplifiers is sent to individual line driver circuits that transmit the signal to an interface board located at the top of the deployment mechanism. Voltages proportional to the temperature are generated by the solid state temperature sensors and are AC coupled to the probe signal lines. Appendix A contains detailed information concerning detectors, temperature sensors, assembly and test, and other configuration information.

## 4.0 EXPERIMENTAL TEMPERATURE AND GAMMA EXPOSURE TESTS

Tests were devised and have been performed to characterize expected or likely changes in the responses of the probe detectors to changes in environmental conditions. Changes in the temperature of the probe and or the masthead electronics may affect the signal transmitted to the data acquisition system. It is possible to correct observed signals given that the temperatures of these two systems are known. Subjecting the probe to high gamma exposure rate fields will produce interfering signals that must be electrically or software discriminated from actual neutron capture events. Changing the moisture, or hydrogen, concentration of materials near the probe will significantly affect the response. Measurements of the changes in response to changes in moisture have been used to validate the computer model of the neutron probe.

The performance of the electronics in both the probe and the masthead were characterized with respect to changes in their temperature and gamma exposure rate. Often electronics will exhibit temperature or gamma exposure rate dependencies. These tests were performed to identify any such dependencies, within expected operating conditions, so that measured data could be properly corrected to account for these conditions.

The probe used for these temperature and radiation tests was a prototype version of the final probe. The differences between the prototype probe and the final in-tank probe primarily consist of a few minor mechanical and electrical modifications, such as the addition of a thin steel cylinder around the cadmium plating for detector 2, and the replacement of Teflon standoffs with ceramic ones for the high voltage board contacts. The major components, including the detectors, high voltage transformer, charge sensitive preamplifiers, solid state temperature sensors, signal line drivers, and basic circuitry layouts are identical to the final probes. The differences cause negligible changes in the results found for the prototype probe.

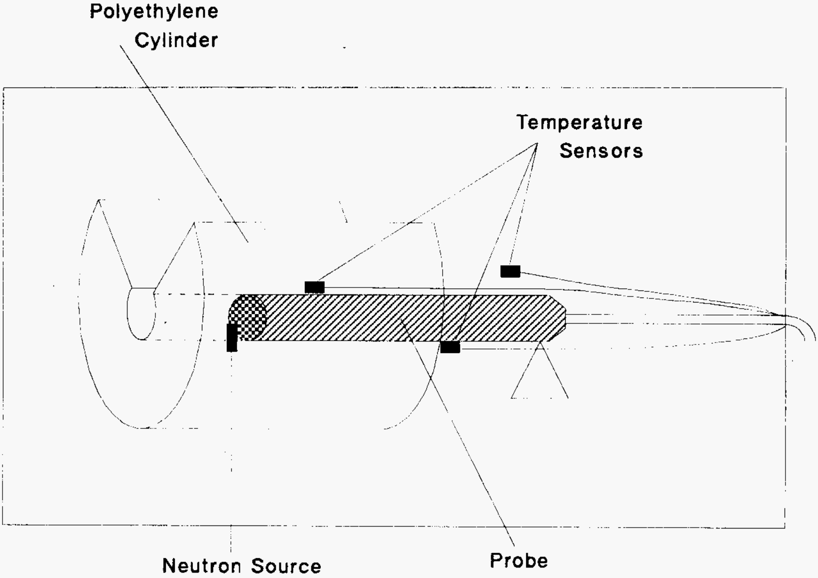
## 4.1 PROBE TEMPERATURE RESPONSE TESTS

Temperature tests of the neutron probe were performed in an environmental chamber located in the 305 building from March 11-15, 1996. This chamber has a large insulated cavity (about 0.8 x 0.8 x 0.8 m) into which objects may be placed and brought to a controlled temperature and humidity. The humidity was not really important to our test, but was set to a maximum value of about 25% to prevent moisture from condensing on the probe at lower temperatures. The temperature controller on the environmental chamber had no current calibration documentation and was only used to set the chamber to a stable temperature near the desired value. Actual temperatures were measured using three calibrated thermocouples outside the probe and the two solid state temperature sensors within the probe.

The probe was placed roughly in the center of the chamber within a large cylindrical piece of polyethylene. The polyethylene had a 3.6 in. diameter hole bored through its center for the probe. The inner wall of this bored hole had a 3/8 in. hole drilled into it that held a neutron source capsule in position. The capsule extended into the hole for the probe so that the probe could be pushed into the polyethylene until it stopped against the source capsule. The neutron source (ID# SR-CF-260C) used contains about 0.03 micrograms of Cf-252. The probe and the polyethylene cylinder were both taped and tied in place so that neither could move during the test. Figure 4-1 shows a sketch of the probe\temperature sensor arrangement in the environment chamber.

The tests were performed by setting the environmental temperature controls to approach the desired temperature and then waiting until the temperature sensors strapped to the outside of the probe case provided temperature readings that indicated that the probe had reached within 1 °C of the temperature measured by the calibrated thermocouple located in the chamber airspace. At that time data collection for the three neutron detectors within the probe was initiated. Analog neutron capture signal data was acquired for each detector for a time interval of 80 minutes at each temperature. The chamber temperature was then incremented by about 10 °C and the process repeated. Data was obtained for temperatures ranging from about 0 to 60 °C.

Figure 4-1. Sketch of Probe, Source, and Temperature Sensor Arrangement used in the Environmental Temperature Test.



The analog data collected for each detector at each temperature was converted to detector count rates using the data post processing Curvecut code (Finfrock 1996). Because there were no changes in the geometry or hydrogen concentration, any changes in the detector count rates could be attributed to temperature effects. Figure 4-2 shows the analog neutron capture signal spectrum (somewhat smoothed for clarity) for three selected temperatures. Only a small difference can be seen between these spectra: the signal gain is slightly reduced with increasing temperature. The count rate is simply the integrated number of counts for each curve (above a Curvecut chosen lower level discriminator cutoff) divided by the total live time for data collection. Figure 4-3 shows the Curvecut determined count rates for all three detectors at each measured temperature. The error bars on the points represent the statistical uncertainty in each count rate based upon Poisson counting statistics. These results show that, within the measured uncertainties, changes in temperature ranging from 0 to 60 °C have no measured effect upon any of the detector count rates. Based upon these results, we do not plan any temperature corrections to the data based upon probe temperatures within this range.

## 4.2 COMBINED PROBE GAMMA RAY EXPOSURE RATE AND TEMPERATURE TESTS

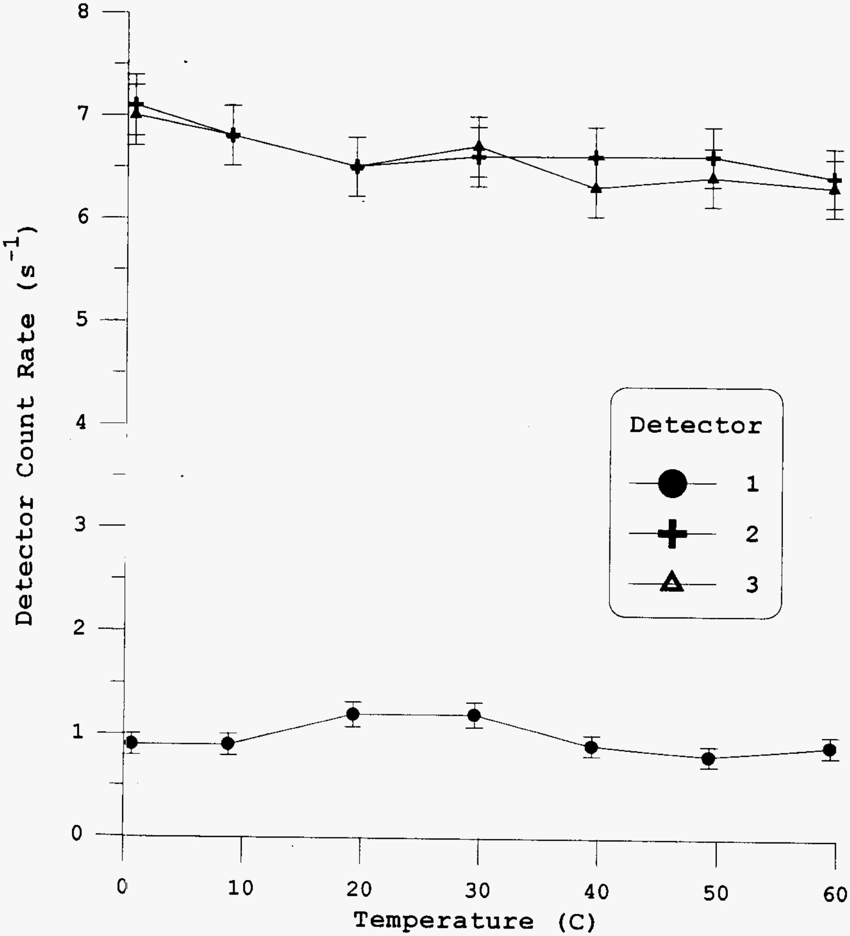
These tests were performed at the 318 building High Exposure Facility on March 25 and 26, 1996. Appendix B contains the current calibration information for the facility. During these tests, the probe was simultaneously subjected to changes in both temperature and incident gamma-ray exposure rate while a neutron source was used to provide a reference neutron capture signal. Gamma-rays were produced by Cobalt-60 sources exposed in air.

The probe temperature was controlled by wrapping it with an inner heating mat and an outer insulating blanket. Thermocouples strapped to the exterior of the probe housing provided feedback to the heating mat temperature controller.

The probe was placed perpendicular to the gamma irradiation beam on a remote positioning platform. The positioning platform moves to a calibrated, computer controlled distance from the source during irradiation to achieve the desired exposure rate for the probe. The location of the center of the probe housing was set to be at the reference exposure rate. For all exposure rates the probe was positioned sufficiently far from the gamma source to ensure that the entire probe was subtended by the collimated gamma-ray beam. The neutron source, about 1Ci of $^{241}$Am-Be, was positioned behind the probe housing and in front of a small block of polyethylene.

Figure 4-4 shows the neutron capture signal spectra produced from detector 3 for 0, 50, 100, and 210 rad/hr incident gamma field at ambient room temperature (25 °C). The feature of interest is the gradual increase in the number of low pulse height events (seen in the lower channels of the spectra). These events result from gamma-ray pile-up in the detector. Each gamma-ray will produce a small pulse in the detector as it ionizes gas molecules with which it interacts. At high exposure rates, many gamma-rays will often interact with the gas at nearly the same instant (within the resolving time of the detector) and will produce essentially a single pulse that is the approximately

Figure 4-3. The Measured Detector Responses to a Constant Neutron Field as a Function of Probe Temperature.



the sum of their contributions. Such a pulse is indistinguishable from low pulse height neutron capture signal pulses. To only count neutron capture induced pulses, a lower level discriminator (hardware and/or software controlled) must be used to eliminate these gamma pile-up pulses.

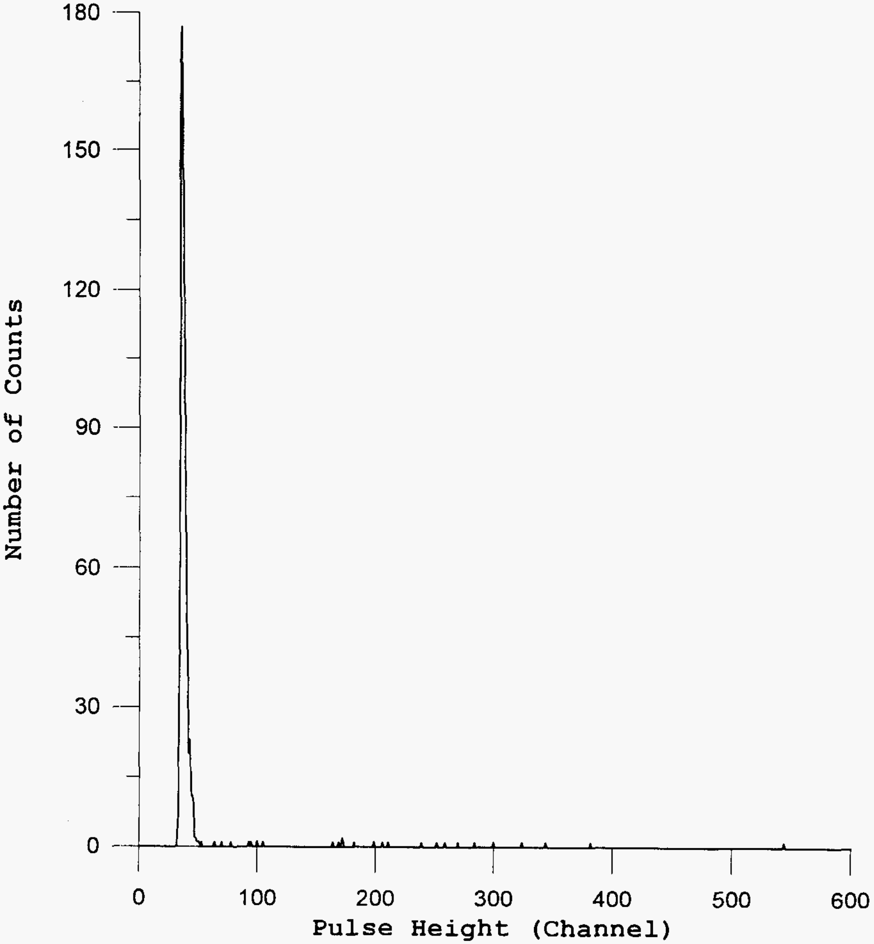
After the exposure rate tests at room temperature were completed, the probe heating blanket was turned on and allowed to heat for about an hour, until the probe housing temperature was within about 2 °C of the detector 1 temperature. The gain settings of the signal amplifiers located in the data acquisition van were increased over those used during the ambient temperature tests. Figure 4-5 shows the neutron capture signal spectra produced from detector 3 for 50, 100, and 210 rad/hr incident gamma field at an elevated temperature (82 °C measured at detector 1). Figure 4-6 shows the all three detector spectra obtained at 210 rad/hr and 82 C. Figure 4-7 shows the detector 3 spectrum collected at 210 rad/hr and 82 C with the neutron source removed. The gamma pile-up signal, at more than the maximum expected in-tank exposure rate, is clearly seen in this figure. A few counts did accumulate with pulse heights in the neutron capture signal portion of the spectrum. These are likely from actual neutron capture events because the neutron source was placed in a nearby shielded cask during this test and some neutron leakage would have allowed neutrons to reach the detectors.

Given similar detector gain setups (see appendix B), the data obtained in these gamma exposure rate tests enable us to appropriately set lower level discriminator (LLD) settings for each detector so that only neutron capture events will be counted. The bottom most portion of all of the spectra will always be deleted with a hardware LLD cutoff. The hardware LLD will remove all electrical noise from the spectrum and will remove much of the gamma-ray pile-up signal. A software LLD setting will be established in the Curvecut post processing code that ensures that gamma-ray induced signals are not used in making the moisture interpretations.

## 4.3 ACCUMULATED GAMMA EXPOSURE PROBE TEST

Tests were completed to assess the effects of accumulated gamma exposure of the probe upon probe performance. The results of these tests allow a probe maintenance schedule to be anticipated and allow probe responses to be corrected for observed effects. The complete SMMS neutron probe was irradiated at the 3730 $^{60}$Co Facility for a total of $2.8 \times 10^5$ rad. While the probe continued to function throughout the irradiation, the signal gain from the neutron detectors gradually changed in a way that interfered with the probe calibration to moisture content. Analyses of the data show that it is possible to correct for this effect up to at least $1.5 \times 10^5$ rad total accumulated exposure. Inspection of the probe electrical components revealed that the shift in the signal gain was primarily caused by the gradual degradation of the voltage regulator for the probe high voltage supply. The preferred solution to this problem is to simply limit the amount of exposure the probe receives, especially in any one tank deployment, by minimizing the time the probe is deployed in the tank. Information about the total accumulated exposure should be obtained by the use of thermoluminescent dosimeters placed within the probe housing before each deployment.

**Figure 4-7. The Analog Signal Spectrum Produced from Detector 3 for an Incident Gamma Field of 210 rad/hr (82 C) with the Neutron Source Removed. (channels 600-1023 not displayed)**



### 4.3.1 Irradiation Conditions

The SMMS neutron probe was irradiated at the 3730 $^{60}$Co Facility from April 22 to 29, 1996. This facility contains multiple encapsulated $^{60}$Co source arrays that are submerged near the bottom of a tank filled with water. More than 30 access tubes are installed in the tank to provide irradiation locations that receive different gamma-ray exposure rates depending upon their distance from the sources. These access tubes are 4-inch or larger diameter pipes that are sealed on the bottom end. The exposure rate as a function of height in each access tube was calibrated in 1984 (see appendix C). Current values of the exposure rates are accurately obtained by applying the decay constant for $^{60}$Co to the original calibrated rates.

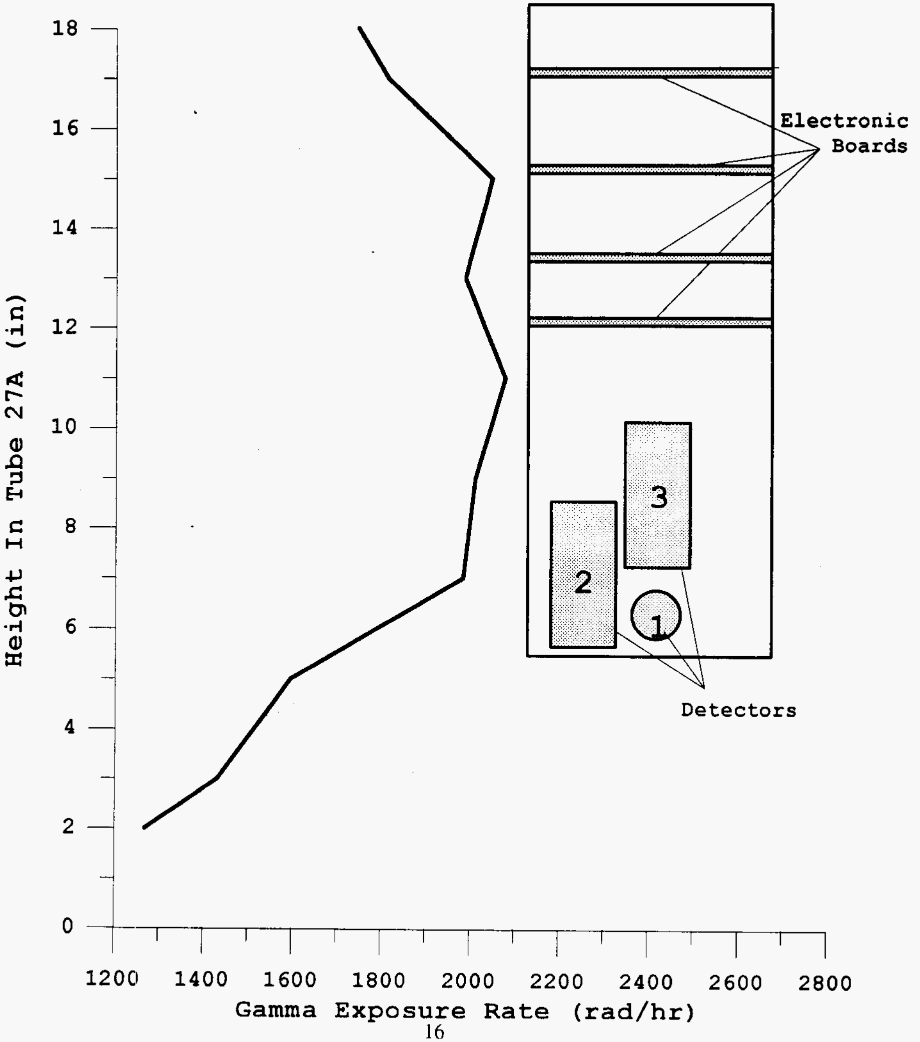
Expected in-tank exposure rates range from about 10 to 200 rad/hr at the waste surface and in the tank headspace (Parra and Watson 1994). The design goal for the total accumulated exposure that the probe should be able to receive before failure was about $1 \times 10^5$ rad. We wanted to accelerate the rate at which the probe exposure accumulated during the test compared with that expected for in the in-tank environment. We did not want to subject the probe to an exposure rate that would cause significant heating or processes other than gamma irradiation to degrade or otherwise change the test results from expected in-tank results. The region of the probe housing that contains components to be irradiated is about 13 inches long. We desired an access tube that would provide a relatively uniform exposure rate along the full 13 inches of probe requiring irradiation. Access tube number 27A was chosen for our irradiation based upon these criteria.

In order to place the probe in the most uniform irradiation field, a stand 5.5 inches tall was taped beneath the probe bottom. This stand provides an appropriate offset from the tube bottom, so that the probe and stand could be lowered completely to rest on the bottom of the tube. Figure 4-8 shows a sketch of the approximate placement of key probe components superimposed upon a graph of the gamma exposure rate in tube 27A. The average exposure rate incident upon the probe region of interest was about $1.96 \times 10^3$ rad/hr and the rates ranged from about $1.75 \times 10^3$ to $2.05 \times 10^3$ rad/hr. Cobalt-60 has a half life of 5.27 years, leading to negligible decay of the source intensity over the one week irradiation time period.

### 4.3.2 Test Arrangement And Procedure

The probe was energized (supplied with 20 volts) during the irradiation and several output signals were monitored. The gamma-ray pile-up signal from each detector and the current supplied to the probe were monitored continuously. The detector outputs were routed through the masthead electronics prototype board to individual Nuclear Instrument Module (NIM) bin amplifiers and then on to analog logarithmic count rate meters. Initially two EG&G Ortec 408A and one EG&G Ortec 575 amplifier were used because of availability. Later in the test, the EG&G Ortec 408A amplifiers were replaced with Tennelec 242 amplifiers because more gain was needed to provided pulses to count rate meters above their discriminator levels. An output from each count rate meter (0-10 volts corresponding to zero to full scale) was connected to a strip chart recorder that continuously

Figure 4-8. Graph of the Exposure Rate Profile in Tube 27A with a Sketch Showing the Placement of the Neutron Probe and Internal Electronics.



recorded each relative count rate. The current required by the probe was monitored by measuring the voltage drop across a 1 Ohm resistor placed in series with the input supply voltages to the probe. The measured voltage drops were recorded by a strip chart recorder. The chart recorders were calibrated with a voltage standard and a calibrated voltmeter, Keithley 2000, Standards Code 804-45-08-010. See Appendix G for standards laboratory calibration records.

Immediately before the probe was first placed in the irradiation facility, the neutron source was installed in the probe and the probe was placed in operation check standard 2A (WHC 1996C). Using the SMMS data acquisition van, data from the detector was collected for 5 minutes to provide baseline count rates for each detector. The probe was removed from the irradiation facility 6 times during the irradiation. Each time the probe was removed the above described test in check standard 2A was repeated in order to assess the status of the probe calibration as a function of accumulated exposure. The functioning of the probe temperature sensors was qualitatively assessed during each of these tests, by noting whether or not their readings were consistent with the expected temperatures (between 15 and 30°C). The board mounted temperature sensor is usually a few degrees warmer than the detector 1 mounted sensor and they both should be between the temperature of the irradiation facility water tank (about 15.5 °C) and their normal room operating temperatures of about 25/30 °C (detector1/board mount).

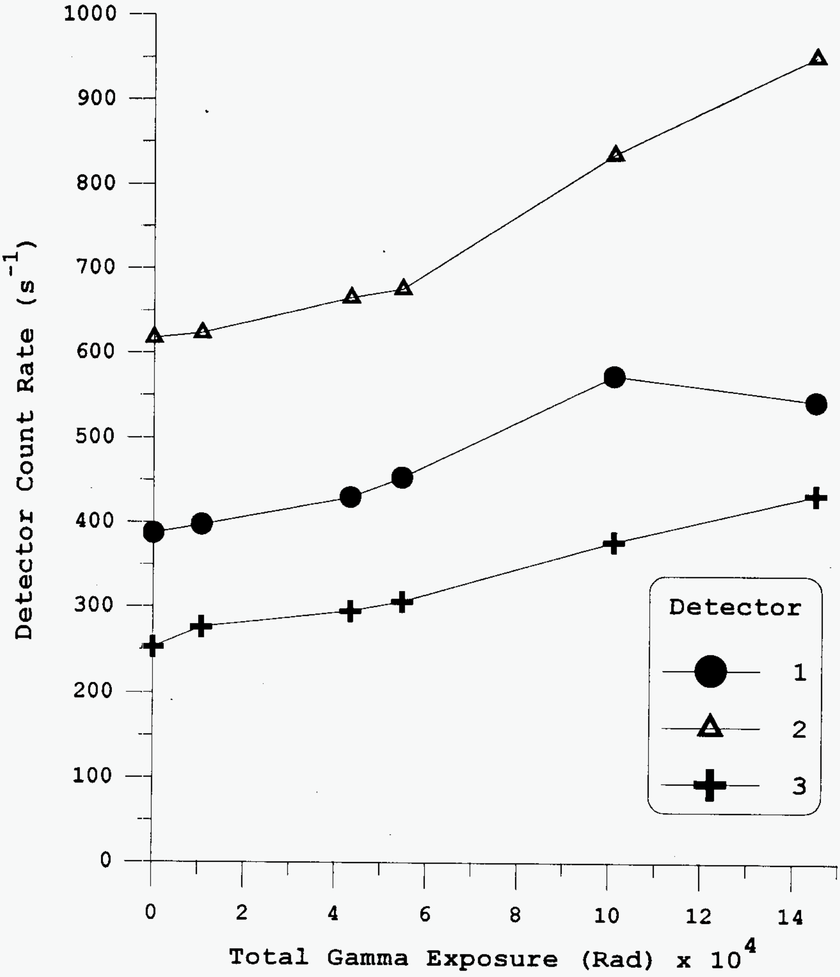
### 4.4.3 Test Results

For the probe to provide data that may be interpreted into moisture concentration profile information, the probe must remain calibrated for the duration of the in-tank tests. Calibrations, performed in the 306E building with known moisture standards, are known to still be valid in the field by using operational check standards both before and after tank deployment. Ideally, the probe detector responses to the check standard would remain, within counting statistics and accounting for source decay, identical to those obtained at the time of the calibration measurements.

Figure 4-9 shows the measured response rates for each of the three detectors as a function of integrated gamma exposure. The count rate for each detector is seen to nearly linearly increase with increasing total exposure. At about $14x10^4$ rad, the response of detector 1 appears to decrease only because hardware lower level discriminator (LLD) setting was too high to count all interesting counts because of the large reduction in signal gain. This same effect occurs for detectors 2 and 3 at the final measured accumulated exposure of $2.8x10^5$ rad (not plotted). The accumulated effect of gamma exposure is significant. Once the probe has reached an exposure of only about $4x10^4$ rad, each of the detector count rates has increased by on the order of 10 percent, which is significant enough to invalidate the calibration if no correction is possible.

Figures 4-10, 4-11, and 4-12 show the neutron capture signal spectra (smoothed for clarity), one for each of the three detectors, for increasing total exposure. Data begins between about channel 40 or 70, depending upon the hardware LLD setting for each detector. As the total exposure increases, the spectrum is compressed toward lower channels, most likely because the supply voltage and corresponding tube amplification is reduced (see section 5). The data post

Figure 4-9. The Measured Detector Count Rates in Operational Check Standard 2A as a Function of Accumulated Gamma Exposure.



processing code, Curvecut, determines the detector count rate by integrating the total number of counts under the curve above a software chosen LLD channel. This LLD channel is a constant number of channels below a software determined reference point on each spectrum curve. The reference point is the channel at which the maximum slope occurs in the spectrum to the right of the initial steep slope region found in each spectrum, indicated on each curve in Figure 4-10 with a black dot. This software chosen LLD method is designed to remove the effects of simple linear shifts in the signal offset/gain from the count rate determinations. The Curvecut code would need to be modified to correct for changes in the spectrum like those seen in these tests.

The probe was irradiated for a total of $2.8 \times 10^5$ rad at which time a final measurement was made in the calibration fixture. The probe continued to function, but the signal gain had dropped so significantly that it was not possible to collect a significant portion of the neutron capture spectrum without increasing the main amplifier gains for each detector in the SMMS van data acquisition system. Adjustment of these main gains is a possible step that could be used to obtain viable data from the probe, but this change does complicate the interpretation of the data. Proper correction for the gain change could be made by characterizing the signal amplification as a function of gain setting for these amplifiers. This work was not done for this report, so the calibration standard data taken after the total irradiation was completed is not analyzed in detail.

The in-probe temperature sensors produced temperature readings completely consistent with those expected until the final measurements were taken after $2.8 \times 10^5$ rad. Table 4-1 shows the measured temperature results for increasing total probe exposure. The results are all consistent with expectation except the final readings, where the detector 1 sensor reports a reading that is several degrees colder than the ambient temperatures to which the probe was exposed. It is clear that between $1.5 \times 10^5$ rad and $2.8 \times 10^5$ rad, the temperature sensors function, but the calibration of at least the detector 1 mounted one is no longer valid. Tests show that the temperature sensors remain responsive to temperature changes even after receiving $2.8 \times 10^5$ rad exposure, but the responses show a shift in the calibration. Other variations in the temperature readings are likely related to the length of time that the probe was removed from the gamma facility, the ambient room temperature, and the length of time that the probe boards were energized. Table 4-2 lists the gamma irradiation periods and summarizes phenomena observed on the strip chart recorders.

Table 4-1. Internal Probe Temperatures Measured with Irradiated Probe Solid State Temperature Sensors.

| | Measured Temperatures (°C) | |
|---|---|---|
| Total Exposure (rad) | Detector 1 Mounted | Electronic Board Mounted |
| 0 | 23 | 27 |
| 10500 | 18 | 22 |
| 43300 | 17 | 20 |
| 54600 | 22 | 30 |
| 101000 | 15 | 16 |
| 145000 | 18 | 19 |
| 279000 | 11 | 16 |

**Table 4-2**
**Gamma Irradiation Test Record Sheet**

| Period No. | In/Out | Date | Time | Exposure Time (hours) | Comments/Anomalies Noted |
|---|---|---|---|---|---|
| 1 | IN | 4/22 | 0922 | | 1. High Voltage Power Supply (HVPS) current dropped and then increased during first 75 minutes after placement in irradiation facility<br>2 Temperature sensors are functional at the end of period 1 |
| | OUT | 4/22 | 1442 | 5.33 | 3. Count rate from gamma radiation is fairly constant over period for all three detectors. The chart paper for detector #3 count rate ran out during this period |
| 2 | IN | 4/22 | 1524 | | 1 HVPS current dropped and then increased during first 75 minutes after placement in irradiation facility.<br>2 Temperature sensors are functional at the end of period 2. |
| | OUT | 4/23 | 0806 | 16.70 | 3 The count rate for all three detectors decreased over period. The gain of NIM Bin amplifiers had be increased prior to start of test to increase count rate, count pulses of higher amplitude |
| 3 | IN | 4/23 | 0844 | | 1 HVPS current dropped and then increased during first 75 minutes after placement in irradiation facility<br>2 Temperature sensors are functional at the end of period 3. |
| | OUT | 4/23 | 1428 | 5.73 | 3 The count rate for all three detectors decreased over the period. The gain of NIM Bin amplifiers had to be increased prior to start of test to increase count rate; count pulses of higher amplitude. |
| 4 | IN | 4/24 | 0831 | | 1. HVPS current dropped and then increased during first 75 minutes after placement in irradiation facility. There is a abrupt drop in HVPS current during this period, about 0.25 mA<br>2 Temperature sensors were functional at the end of period 4<br>3 The count rate for all three detectors decreased over the period The gain of NIM Bin amplifiers had be increased prior to start of test to increase count rate, count pulses of higher amplitude |
| | OUT | 4/25 | 0800 | 23.48 | 4 Nim Module Settings<br>Det#1 Amplifier (EG&G Ortec 408A): 15<br>Count Rate Meter Full Scale Setting: 100 counts per second<br>Det#2: Amplifier (EG&G Ortec 408A) 15<br>Count Rate Meter Full Scale Setting 30 counts per second<br>Det#3 Amplifier (EG&G Ortec 575): Coarse: 4 Fine: 5.16 (Net Gain: 20.48)<br>Count Rate Meter Full Scale Setting: $10^4$ counts per second |

**Table 4-2**
**Gamma Irradiation Test Record Sheet**

| Period No. | In/Out | Date | Time | Exposure Time (hours) | Comments/Anomalies Noted |
|---|---|---|---|---|---|
| 5 | IN | 4/25 | 0922 | | 1 HVPS Current dropped and then increased during first 75 minutes after placement in irradiation facility.<br>2 Temperature sensors were functional at the end of period 5.<br>3 The count rate for all three detectors decreased over the period. The gain of NIM Bin amplifiers had be increased prior to start of test to increase count rate, count pulses of higher amplitude.<br>4 Nim Module Settings:<br>Det#1. Amplifier (Tennelec 242): Coarse: 100 Fine: 1.18 (Net Gain 118)<br>Count Rate Meter Full Scale Setting: $10^4$ count per second<br>Det#2: Amplifier (Tennelec 242): Coarse: 100 Fine: 0.722 (Net Gain 72.2)<br>Count Rate Meter Full Scale Setting: $10^4$ counts per second<br>Det#3: Amplifier (EG&G 575): Coarse: 40 Fine: .874 (Net Gain 34.7)<br>Count Rate Meter Full Scale Setting: 3 x $10^4$ counts per second |
| | OUT | 4/26 | 0800 | 22.63 | |
| 6 | IN | 4/26 | 1150 | | 1. HVPS Current dropped and then increased during first 75 minutes after placement in irradiation facility.<br>2 Temperature sensors, while functional at the end of period 6, appear to no longer be calibrated.<br>3 The count rate for all three detectors decreased over the period. The gain of NIM Bin amplifiers had be increased prior to start of test to increase count rate; count pulses of higher amplitude<br>4 Nim Module Settings:<br>Det#1. Amplifier (Tennelec 242): Coarse: 100 Fine: 1.118 (Net Gain 118)<br>Count Rate Meter Full Scale Setting: $10^4$ count per second<br>Det#2. Amplifier (Tennelec 242). Coarse: 100 Fine: 0.77 (Net Gain 77)<br>Count Rate Meter Full Scale Setting: $10^4$ counts per second<br>Det#3. Amplifier (EG&G 575). Coarse. 40 Fine: 1.25 (Net Gain 34.7)<br>Count Rate Meter Full Scale Setting 3 x $10^4$ counts per second |
| | OUT | 4/29 | 0809 | 68.32 | |
| Total | | | | 142.19 | |

### 4.3.4 Identification of Electronic Component Degradations

### 4.3.4.1 Physical Changes Noted by Visual Inspection

The physical appearance of probe components did not change, except as noted below, during the irradiation test. The glass ceramic seals of the detector tubes were browned from the gamma radiation. The surface of the polyolefin tubing and the polyvinyl chloride insulated wiring did not have the surface sheen that they had prior to irradiation. The Teflon[1] (Polytetrafluoroethylene) terminals used for standoffs for high voltage components did not visually appear to be damaged. It should be noted that the Teflon terminals have been replaced with an alkyd phthalate insulated terminal on the final assemblies. Available radiation damage literature indicates that the Teflon terminals should have been severely damaged at 2 x $10^4$ rad while the replacement terminals insulated with the alkyd phthalate insulated terminals do not show damage until $10^8$ rad.

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[1] Teflon is DuPont's registered trademark.

#### 4.3.4.2 Electrical Changes Observed in the High Voltage/Low Voltage Power Supply Board

Shifts in the pulse gains, observed in neutron capture spectrum (collected spectrum) of the neutron detectors, were traced to the high voltage power supply since the gains of the pulse amplifiers, charge sensitive amplifiers and line driver amplifiers, had not significantly changed. The high voltage power supply voltage was measured at the beginning and the end of the test. The high voltage power supply voltage, detector bias voltage, dropped from 650 V to 560 V. A downward shift in the collected spectrum is only observable evidence of decreasing detector bias voltage. The downward shift in the collected spectrum was first observed starting at about $10^4$ rad and continued gradually to the end of the test. The proportional gas gain of the Boron-10 lined neutron detectors decreases by a factor of 2 to 4 per 100 volts of bias voltage change. The peak in the collected spectrum decreased by more than a factor of two from the beginning to the end of the gamma irradiation test. Crude proportional gas gain measurements made in January, 1996 show that the detector pulse shapes became non-linear (ugly shaped) in the region of 500 to 550 V of tube bias (Bussell 1995). The decrease in pulse amplitude or spectrum shift appears to be caused from the decrease in the internal reference voltage in the voltage regulator integrated circuit and the increase in bias current from the feedback pin. Table 4-3 shows the results of the pre-test and post-test measurements for the high voltage/low voltage power supply board and the line driver board. Analysis of the data shows that the internal reference voltage, voltage at U1-Pin 7, of the voltage regulator integrated circuit (National Semiconductor LP2951ACM) dropped about 8% while the high voltage output voltage dropped 14%. NASA has performed radiation testing on this integrated circuit and the test results are in appendix D. Their testing results are similar to our results with the exception that the increase in ground current (internal regulator supply current, $I_q$ and $I_Q$) did not increase to the levels shown in NASA's test data. The other 6% of voltage drop can be attributed to changes in bias current for the feedback pin of the voltage regulator and possibly changes in the resistance of voltage divider network. The output voltage of the regulator is given by:

$$V_{out} = V_{ref} * \frac{(R_2 + R_1)}{R_1} - I_{bias} * R_2$$

where $R_2$ is the resistor (100 Megohms) connected between the high voltage power supply output and the feedback pin, pin 7, and $R_1$ is the resistor (approximately 200 kilohms) connected between the feedback pin and ground or circuit common. $V_{ref}$ is the voltage (nominally 1.23 V) of the voltage regulator internal reference. $I_{bias}$ is the bias current (nominally 60 nanoamperes) of the feedback pin. This equation can be derived by assuming that the voltage regulator and the DC-DC converter comprise a non-inverting operational amplifier with an input bias current that flows out of an inverting terminal. Normally the feedback pin bias current is 60 nanoamperes out of the pin. The voltage divider network for the high voltage supply bleeds about 7 to 10 microamperes from the high voltage power supply output to ground or circuit common. If the feedback pin bias current increased by 6 to 7 microamperes then the remaining 6% voltage drop may be attributed to it. The input circuit at the feedback pin in the voltage regulator integrated circuit is the base of a PNP transistor. Changes in the required base current of PNP transistors of this order of magnitude for a given collector current are not uncommon with the gamma radiation dose that the neutron moisture probe received. It is unlikely that resistance values of voltage divider network changed because of gamma radiation. The resistance of the resistors in the voltage divider network was not measured. Prior to this test the DC-DC converter, model K-15 which is manufactured by Eldec Corporation, has not been tested for functionality or parameter shifts as a function of radiation dose. The DC-DC converter contains discrete transistors, transformer, capacitors, and high voltage rectifier diodes. As a result of the use discrete components the DC-DC converter will continue operate with transistor gains, betas, over a wide range. The DC-DC converter will degrade in the same manner with increasing gamma radiation dose as it did during the test. The other components on this board, described above, will also degrade in a predictable fashion since each component is manufactured using the same processes within a production lot. Over time, as improvements are made to a particular integrated circuit, such as process improvements to improve yields, the radiation dose degradation mode or rate will change. The parts from the same production lot will in general degrade in the same manner with radiation exposure within statistical limits.

The low voltage power supply voltage dropped about 10%. The same voltage regulator integrated circuit is used for the high voltage power supply and the low voltage power supply. As discussed above, the output voltage drop between pre-test and post-test can be attributed to a decrease in the internal reference voltage and an increase in the feedback pin bias current. A voltage drop of 10% is tolerable for continued operation of the neutron moisture probe.

## Table 4-3
## High Voltage/Low Voltage Power Supply Board and Line Driver Board Pre-Test and Post-Test Measurements

| Parameter | Pre-Test | Post-Test |
|---|---|---|
| | High Voltage Power Supply (HVPS) | |
| High Voltage Output as Set | 650 V | 560 V |
| HVPS Current Draw as Set | 12.24 mA[1] | 11.45 mA |
| Input Voltage to Eldec K-15 DC-DC Converter (red to black wires) at as Set | 6.088 V[2]<br>(interpolated value from previous measurements) | 5.701 V<br>(measured value after irradiation)<br>5.335 V<br>(interpolated value from measurements) |
| Eldec K-15 DC-DC Converter Current Draw as Set | 9.2 mA[2]<br>(interpolated value from previous measurements) | 7.7 mA<br>(interpolated value from measurements) |
| Maximum High Voltage Output (adj. full ccw) | 730 V[1] | 650 V |
| Input Voltage to Eldec K-15 DC-DC Converter (red to black wires) at Maximum Output | 6.756 V[2]<br>(interpolated value from previous measurements) | 6.541 V<br>(measured value after irradiation)<br>6.088 V[2]<br>(interpolated from previous measurements) |
| HVPS Current Draw at Maximum Output | 13.88 mA[1] | 13.693 mA |
| Eldec K-15 DC-DC Converter Current Draw at Maximum Output | 10.5 mA[2]<br>(interpolated value from previous measurements) | 9.7 mA[2]<br>(interpolated value from previous measurements) |
| Minimum High Voltage Output (adj. full cw) | 565 V[1] | 500 V |
| Input Voltage to Eldec K-15 DC-DC Converter (red to black wires) at Minimum Output | 5.376 V[2]<br>(interpolated value from previous measurements) | 5.156 V<br>(measured value after irradiation)<br>4.836 V[2]<br>(interpolated value from previous measurements) |
| HVPS Current Draw at Minimum Output | 9.72 mA[1] | 9.959 mA |
| Eldec K-15 DC-DC Converter Current Draw at Minimum Output | 7.8 mA[2]<br>(interpolated value from previous measurements) | 6.66 mA[2]<br>(interpolated value from previous measurements) |
| U1-Pin 7 Feed Back Voltage to Ground at Minimum Output | 1.2335 V[1] | 1.1334 V |

**Table 4-3**
**High Voltage/Low Voltage Power Supply Board and Line Driver Board Pre-Test and Post-Test Measurements**

| Parameter | Pre-Test | Post-Test |
|---|---|---|
| | Low Voltage Power Supply (LVPS) | |
| Output Voltage | 11.879 V[1] | 10.735 V |
| U2-Pin 7 Feed Back Voltage to Ground | 1.2335[1] | 1.1368 V |
| | Line Driver Board Measurements | |
| Temperature +5 V Reference Voltage | 5.001 V[1] | 4.961 V |

Notes

[1] Voltage measurements obtained from assembled production probe. Electronic circuit and layout are nearly identical.

[2] Interpolated values are calculated from laboratory measurements made on Eldec K-15 DC-DC converter with 100 Megohms load on output. Values were interpolated between measurements points using a simple two point interpolation. Measurements are for information only as instruments used did not have calibration that is traceable to NIST standards. Measurements were made on 12/12/95 and are recorded in WHC-N-1237, pp. 51 to 52.

### 4.3.4.3 Electrical Changes Observed in the Preamplifier and Line Driver Boards

Very little change was observed in the pulse amplifier circuits in the neutron moisture probe. The measurement results are shown in Table 4-4. Although there seems to be systematic error present in the pre-test measurements, the pre-test and post-test measurements show that no major degradation took place in the neutron probe preamplifiers and line drivers with respect to pulse amplification. Appendix E contains a plot of the gain and noise performance for the charge sensitive amplifiers, Amptek A225, as a function of gamma radiation dose. This plot was furnished by the manufacturer of the charge sensitive amplifiers. The plot shows that the Amptek A225 charge sensitive amplifiers are fully functional to about $10^7$ Rad with some increase in noise. The solid state temperature sensors lost calibration during the test. Table 4-3 shows the temperature +5 V reference voltage output change decreased about 0.8%.

## Table 4-4
## Preamplifier and Line Driver Board Pre-Test and Post-Test Measurements

| Charge Sensitive Amplifier Input | 50 mV | | 100 mV | | 200 mV | | 250 mV | |
|---|---|---|---|---|---|---|---|---|
| | Charge Sensitive Amplifier Output | Probe Output (line driver) | Charge Sensitive Amplifier Output | Probe Output (line driver) | Charge Sensitive Amplifier Output | Probe Output (line driver) | Charge Sensitive Amplifier Output | Probe Output (line driver) |
| Detector #1 Irradiation Test Pre-Test Value (1/27/96) | 1.5 V | 0.6 V | 2.8 V | 1.4 V | 5.6 V | 2.5 V | 7.2 V | 2.9 V |
| Detector #1 Irradiation Test Post-Test Value (5/2/96) | 1.7 V | 0.7 V | 3.4 V | 1.5 V | 7.0 V | 2.8 V | 8.0 V | 3.5 V |
| Detector #2 Irradiation Test Pre-Test Value (1/27/96) | 1.2 V | 0.7 V | 3.1 V | 1.4 V | 6.1 V | 2.7 V | 7.6 V | 3.4 V |
| Detector #2 Irradiation Test Post-Test Value (5/2/96) | 1.6 V | 0.7 V | 3.3 V | 1.4 V | 6.7 V | 2.8 V | 8.4 V | 3.5 V |
| Detector #3 Irradiation Test Pre-Test Value (1/27/96) | 1.3 V | 0.6 V | 2.7 V | 1.3 V | 5.5 V | 2.5 V | 6.7 V | 3.2 V |
| Detector #3 Irradiation Test Post-Test Value (5/2/96) | 1.6 V | 0.7 V | 3.1 V | 1.4 V | 6.2 V | 2.9 V | 7.8 V | 3.7 V |

Notes

1 Measurements made on 1/27/96 are information only. The oscilloscope used to make these measurement did not have a calibration that is traceable to NIST standards

2 The input voltage was applied to high voltage coupling capacitor through a 5 ± 0.5 picofarad capacitor. The pulse had a 1 microsecond or faster rise time and a fall time greater than 500 microseconds. The pulse were negative-going and set with an oscilloscope. Test pulses were applied where the detector tube is connected to the charge sensitive amplifier.

3 The accuracy of the pulse measurements is about 5 to 10% as the measurement were made by reading the pulse height on the graticule of an oscilloscope.

4 Post-test measurements were made with a Tektronix model 485 oscilloscope, Standard Code 013-51-01-012.

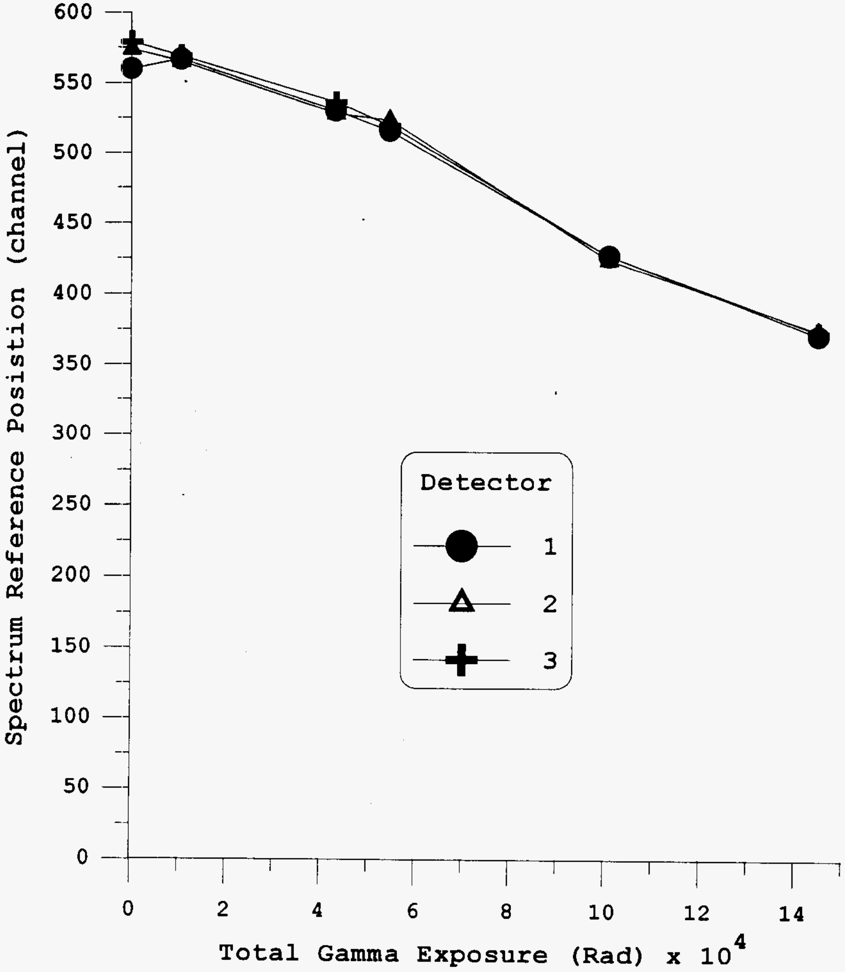
### 4.3.5 Accumulated Gamma Exposure Test Conclusions and Recommendations

It is clear that the accumulated gamma exposure received by the probe does have a gradual and predictable effect upon the probe calibration over at least the first 1.5x$10^5$ rad. There are several ways that this effect may be accounted for in the data analyses. Figure 4-13 shows a graph of the data processing software spectrum reference point (channel) plotted as a function of the accumulated exposure. This graph is proportional to plotting the position of the spectrum peak (or signal gain) as a function of the accumulated exposure. The change in the spectrum reference point with increasing exposure is linear for all three detectors. This graph essentially provides a calibration relating the change in the reference point value with the total accumulated exposure. This calibration can be used in conjunction with the results from Figure 4-9 to provide a correction to the data that allows for moisture interpretations based upon the original moisture calibration. This technique should be applicable for at least the first 1.5x$10^5$ rad gamma exposure accumulated by the probe. Although it is expected that the voltage drop as a function of exposure will be somewhat repeatable, since all three detectors responded in such a consistent manner to the drop in voltage, the repeatability of the voltage drop as a function of exposure may be unimportant. Figure 4-9 provides a correction to the data as function of peak shift, assuming that the shift is due to a decrease in supplied high voltage. Knowing the accumulated exposure could provide additional confirmation that the proper correction to the data was determined. In order to confirm the accumulated exposure information derived from this method, it would be highly desirable to have multiple thermoluminescent or other small gamma dosimeters placed in the probe to measure the total exposure received by the probe during deployment. The exposure rate could be assumed to be constant and the exposure calculated for the time of each measurement for comparison with this technique.

Obviously, the most desirable solution for reducing the effects of probe gamma exposure is to deploy the probe, obtain measurements, and remove the probe from the tank in as short of a period of time as possible. Current plans make it possible to complete this work so that the probe is actually in the tank for less than a week. For most tanks, such as BY-110, a week of gamma exposure on the surface of the waste will amount to less than 1x$10^4$ rad. This low of an accumulated exposure would require negligible corrections be made to the data.

Increasing the detector bias voltage will prolong the radiation exposure life of the probe by increasing the time for the bias supply to decrease past 600 V. The gain of the charge sensitive amplifier will not permit the bias voltage from being increased beyond 725 V because of reaching the end of its linear range. The detector bias voltage can be increased past 725 V with addition of a charge divider network, consisting of three components, to the front end of each of the three charge sensitive amplifiers. The charge divider divides the charge. The existing preamplifier board has provision for adding these three charge divider networks. However with the addition of the charge divider networks, the preamplifier as seen from its detector is no longer a true charge sensitive but a voltage sensitive amplifier. Voltage sensitive amplifier gains, as contrasted to charge sensitive amplifier, are sensitive to changes in cable or detector capacitance. The loss in pulse amplitude as a result of detector bias voltage decrease can be eliminated by increasing the gain of the amplifiers in the instrumentation van if the detector tubes are operating in their proportional gas gain region.

Figure 4-13. The Spectrum Software Lower Level Discriminator Reference Position for Each Detector as a Function of Accumulated Gamma Exposure.



It might be advisable to change out the voltage regulator integrated circuit prior to each use in a tank. Surface mount dual-in-line package sockets may be available that will allow changing the voltage regulator chip without de-soldering and soldering operations. Inquiry should be made with National Semiconductor about obtaining a radiation hardened version of the integrated circuit.

## 4.4 ENCLOSURE INTERFACE BOARD TEMPERATURE TESTS

In the field, signals from the probe are routed up a signal wire bundle to a group of electronics in the deployment system enclosure or masthead before being transmitted to the data acquisition system (WHC 1996D). The purposes of these masthead electronics are to 1) provide an electrical intrinsic safety barrier between the potentially flammable gas atmosphere of the tank head space and potential electrical ignitors, and 2) condition and amplify the signal pulses to send them down another long cable to the data acquisition system. This masthead will rest on top of the deployment riser and will be exposed to ambient weather conditions. Tests were performed to assess the effects of changes in temperature upon the signals output from these electronics.

The temperature test were performed from March 26 to 29, 1996. The interface board was connected as shown in Figure 4-14. A prototype line driver board combined simulated nuclear counting pulses with simulated temperature signals to provide input pulses to the interface board. The board was tested over the temperature range of -20°C. to +60°C. The board functioned normally over the temperature range. No observable trends were noted in pulse amplifier gains and temperature signal conversions. Tables 4-5, 4-6, and 4-7 show the results of temperature tests in a tabular form. Raw data recorded during the test is given in Appendix F.

### 4.4.1 Test Article Description

The interface board is located in the mast head enclosure of the SMMS. The interior temperature of the mast head enclosure is expected to range from -20 °C to +60 °C. The board is mounted vertically in the mast head enclosure. An interface board was selected at random from the three assembled boards. The interface board with serial number 01 was selected for testing. The board was calibrated per informal procedures developed during assembly. The calibration procedure consists of setting the offset and gain adjustments of the two temperature conversion circuits. The procedure is an iterative process of adjusting the gain and zero until the output at the minimum temperature input signal, 4.0 V which is equivalent to -100 °C, is -10 V (-10.003 to -9.997 V) and the output at the maximum temperature input signal, 6.0 V which is equivalent to +100 °C, is +10 V (+9.997 to +10.003 V). The zero adjustment is not uncoupled from the gain adjustment.

The pulse gain of the amplifiers for the four detector channels is fixed. The interface boards were modified after this temperature test to increase the gain of the pulse amplifiers. The gain was increased from four to eighteen to accommodate a new final stage amplifier in the data acquisition van, an EG&G Ortec 444 amplifier. Resistors were the only component replaced during this modification. The changed resistor will not effect the temperature coefficient of amplifier gains as the temperature of the resistors will track with each other. The temperature coefficients, fractional change in resistance per degree of temperature change, of the resistors are very small, approximately 200 ppm/°C. The time constant of the pulse amplifier feedback networks were not changed in this modification.

### 4.4.2 Test Procedure and Test Setup

The interface board was placed in the center of the environmental chamber, an approximate 1 meter cube, and was secured to the mesh shelf with magnet wire. Type K thermocouples, 28 AWG wire, were bonded to the cases of the -15 voltage regulator (U13), +15 voltage regulator (U12), switching regulator (U11), TEMP1 Line Driver (U4), and Detector 4 Line Driver (U8). These thermocouples were not calibrated by the standards laboratory. The data acquisition system monitored the output of -15 volt regulator and +15 volt regulator during the test. The environmental chamber was manually cycled between -20 °C and +60 °C. Measurements were made at -20 °C, -5 °C, +5 °C, +15 °C, +25 °C, +35 °C, +45°C, and +60 °C. Ambient temperatures in the Surface Moisture Monitor System mast head enclosure are expected to range from -20 °C to +60 °C. when it is deployed in the tank farm. Figure 4-15 shows the block diagram of the test setup.

When temperature equilibrium was reached, a simulated temperature signal was set to three test points, -100 °C, 0 °C, and +100 °C, and the two temperature output voltages, TEMP1 (J3-1,3) and TEMP2 (J3-3,4), from the interface board were recorded. Likewise the simulated nuclear counting pulses were applied to the interface board from two tail pulse generators. One of the tail pulse generators provided the trigger to the other tail pulse generator to delay its output pulse by 50 microseconds. The delayed pulses were connected to the DET1 input and the DET3 input of the prototype line driver board. The non-delayed pulses were connected to the DET2 input of the prototype line driver board. Figure 4-15 shows the output pulses, measured at -20 °C, from the prototype line driver board, COUNT1, on channel 1, and DET1 (J5) and DET2 (J4) from interface board on channels 2 and 3 respectively. Figure 4-16 shows the output pulses, measured at -20 °C, from the prototype line driver board, COUNT2, on channel 1, and DET3 (J7) and DET4 (J6) from interface board on channels 2 and 3 respectively. Channel 4, shown on Figures 4-15 and 4-16, is the trigger used to synchronize the two tail pulse generators. DET4 (J6) is not used for the current neutron surface moisture probe, but is available for future use.

### 4.4.3 Test Anomalies Observed During the Test

- When the environmental chamber reached 25 °C, the chamber was opened and a prototype high voltage board identical to the one used in the probe was placed in the chamber. The output of a voltage divider network was connected to the Hewlett Packard 3497A scanner. After the high voltage divider was connected to the scanner, the voltage signal for input voltage for TEMP2 was lost. In the data recorded, the input voltage for TEMP2 is recorded as 5.7 to 5.9 VDC. Both temperature channels are connected together and the output voltage should be identical and is nearly identical during the first part of the test. Appendix F shows the data recorded during the test.

- The pulse amplitude at 35 °C was not recorded on the data sheet.
- The measured case temperature of the +15 V regulator, shown in Figure 4-17, may be in error. The measured temperature is less than the chamber temperature. The thermocouple must have come loose from the +15 V regulator case.

### 4.4.4 Test Results

The pulse gain measured from the output of the prototype line driver to the output of the interface board varied from 1.0 to 1.1 for the four pulse amplifiers. The pulse amplitudes were measured on an oscilloscope at a range of 0.2 V/div to 0.5 V/div with a resolution of 0.1 division. This implies that the precision of this measurement is about ±5%. Within that measurement accuracy, no pulse gain changes were observed. Table 4-5 shows the gain measurements made during the test.

The rise of case temperature of the "power" semiconductor parts did not exceed 10 °C. Figures 4-18, 4-19, 4-20, and 4-21 show the case temperature plots for the selected "power" semiconductors. These temperature measurements are approximate because a big "blob" of epoxy was used to bond the thermocouple to the semiconductor part case. The test results show that improvements made between the prototype and the production printed circuit boards solved the problem of heat dissipation of the positive voltage regulator, +12 V in the prototype printed circuit board and +15 V in the production printed circuit board.

The voltage output from the -15 V and +15 V regulators remained stable during the test. The output voltage of the -15 V regulator remained within a 50 mV band and the output voltage of +15 V regulator remained within a 35 mV band. No indication of significant voltage drop or thermal shutdown was observed during the 20 hours the interface board was operated at 60 °C Figures 4-22 and 4-23 show the output voltage plots for these two voltage regulators. The line driver for the temperature signals, TEMP1 (J3-1,2) and TEMP2 (J3-3,4), did not show any indication of overheating or thermal shutdown. The line driver outputs (J3, J4, J5, J6, and J7) for the detectors were not continuously monitored but they were fully functional when intermittent pulse measurements were made. Pulses were applied to the interface board at a frequency of 1 kilohertz. The expected count rate when the SMMS probe is deployed in a waste tank is about 100 counts per second.

**Table 4-5**
**Input to and Output from Interface Board Pulse Amplifiers**

| | COUNT1 Input (J1) | | | | COUNT2 Input (J2) | |
|---|---|---|---|---|---|---|
| Chamber Temperature (°C) | DET1 Input (negative-going pulses) | DET1 Output (positive-going pulses) on J5 | DET2 Input (positive-going pulses) | DET2 Output (positive-going pulses) on J4 | DET3 Input (negative-going pulses) | DET3 Output (positive-going pulses) on J7 |
| -20 | 2.0 | 2.2 | 2.0 | 2.2 | 2.0 | 2.0 |
| -5 | 2.0 | 2.2 | 2.0 | 2.0 | 2.0 | 2.0 |
| 5 | 2.0 | 2.1 | 2.0 | 2.0 | 2.0 | 2 .0 |
| 15 | 1.9 | 2.1 | 2.0 | 2.0 | 1.8 | 2 .0 |
| 25 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2 .0 |
| 35 | 2.0 | 2.0 | 2.0 | note 1 | 2.0 | 2 .0 |
| 45 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2 .0 |
| 60 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2 .0 |

Notes:
[1] Data was not recorded on data sheet. DET3 output voltage is the same magnitude since gain of pulse amplifier is the same within manufacturing tolerances.

**Table 4-6**
**Interface Board TEMP1 Temperature Signal Response as a Function of Temperature**

| | -Full Scale (-100 °C) | | Mid Scale (0 °C) | | +Full Scale (+100 °C) | |
|---|---|---|---|---|---|---|
| Chamber Temperature (°C) | Input (J1) | Output (J3-1,2) | Input (J1) | Output (J3-1,2) | Input (J1) | Output (J3-1,2) |
| -20 | 3.9998 | -10.0458 | 5.0002 | -0.0516 | 6.0006 | 9.9428 |
| -5 | 9.9996 | -10.0537 | 4.9999 | -0.058 | 6.0002 | 9.9366 |
| 5 | 3.9996 | -10.0567 | 4.9999 | -0.0595 | 6.0005 | 9.9426 |
| 15 | 3.9998 | -10.0569 | 5.0001 | -0.0569 | 6.0005 | 9.9416 |
| 25 | 3.9995 | -10.0617 | 4.9999 | -0.0586 | 6.0004 | 9.9448 |
| 35 | 3.9994 | -10.0619 | 4.9998 | -0.0562 | 6.0005 | 9.9501 |
| 45 | 3.9995 | -10.0614 | 4.9998 | -0.0547 | 6.0004 | 9.9550 |
| 60 | 3.9995 | -10.0544 | 4.9998 | -0.0449 | 6.0003 | 9.9688 |

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**Table 4-7**
**Interface Board TEMP2 Temperature Signal Response as a Function of Temperature**

| | -Full Scale (-100 °C) | | Mid Scale (0 °C) | | +Full Scale (+100 °C) | |
|---|---|---|---|---|---|---|
| Chamber Temperature (°C) | Input (J2) | Output (J3-3,4) | Input (J2) | Output (J3-3,4) | +FS In (J2) | +FS Out (J3-3,4) |
| -20 | 4.0004 | -10.041 | 5.0007 | -0.0417 | 6.011 | 9.9582 |
| -5 | 4.0005 | -10.0465 | 5.0007 | -0.0463 | 6.001 | 9.9537 |
| 5 | 4.0007 | -10.0469 | 5.0007 | -0.0447 | 6.001 | 9.9531 |
| 15 | 4.0003 | -10.0507 | 5.0012 | -0.048 | 6.001 | 9.9529 |
| 25 | note 1 | -10.0514 | note 1 | -0.046 | note 1 | 9.9558 |
| 35 | note 1 | -10.0515 | note 1 | -0.045 | note 1 | 9.9545 |
| 45 | note 1 | -10.0532 | note 1 | -0.0483 | note 1 | 9.9525 |
| 60 | note 1 | -10.0558 | note 1 | -0.0509 | note 1 | 9.9512 |

Notes
[1] Data recorded for these values is not correct and is not shown.

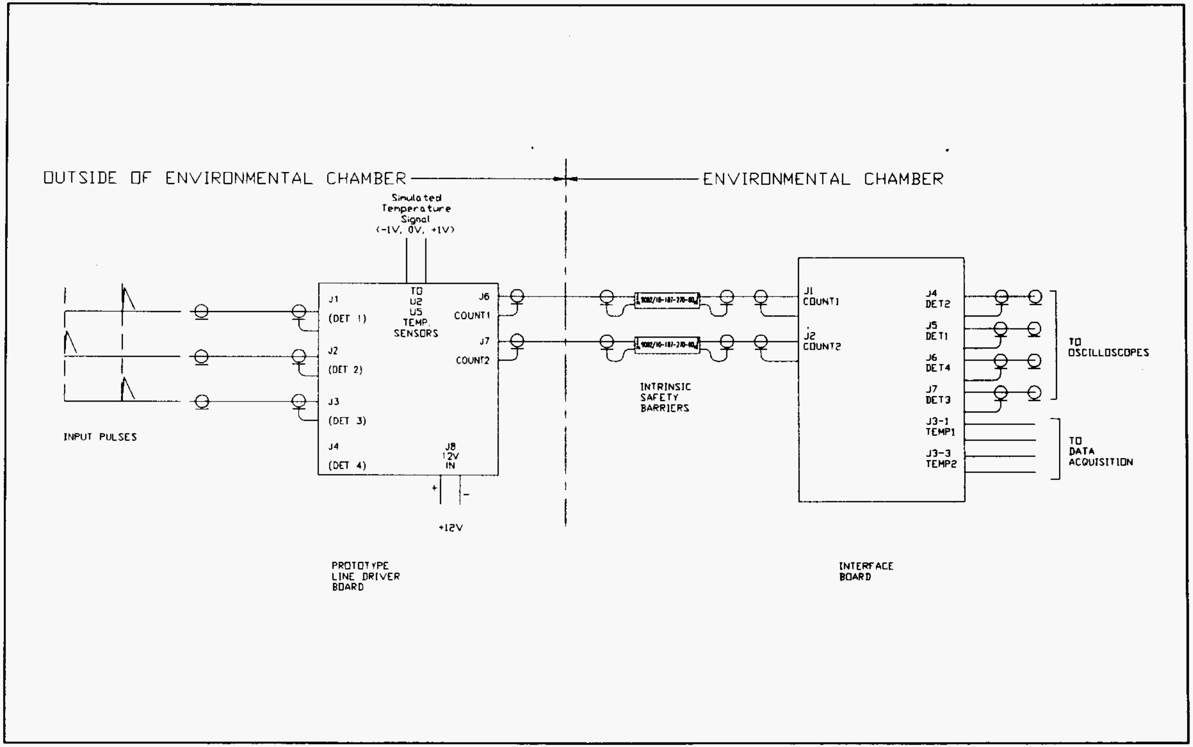


Figure 4-14. **Block Diagram of Test Setup.**

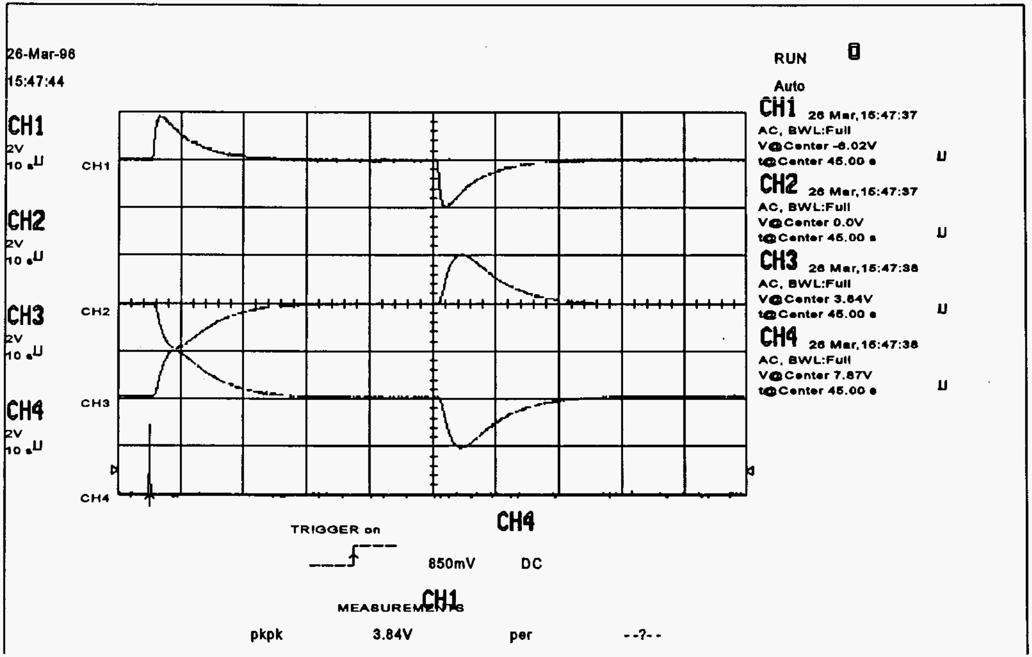


Figure 4-15. Input and output pulses to and from Interface Board measured at -20° C CH1: COUNT1 Input (J1). CH2: DET1 Output(J5). DET2 Output (J4). CH4: Trigger pulse for tail pulse generators.

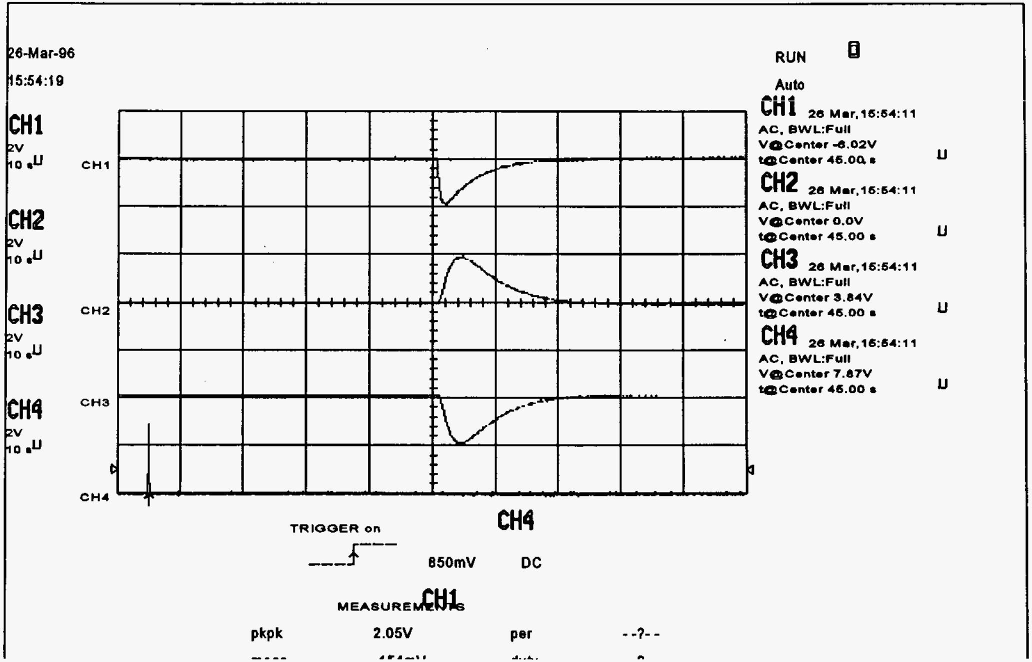


Figure 4-16. Input and output pulses to and from Interface Board measured at -20° C CH1: COUNT2 Input (J2). CH2: DET3 Output(J2). CH3: DET4 Output (J4). CH4: Trigger Pulse for tail pulse generators.

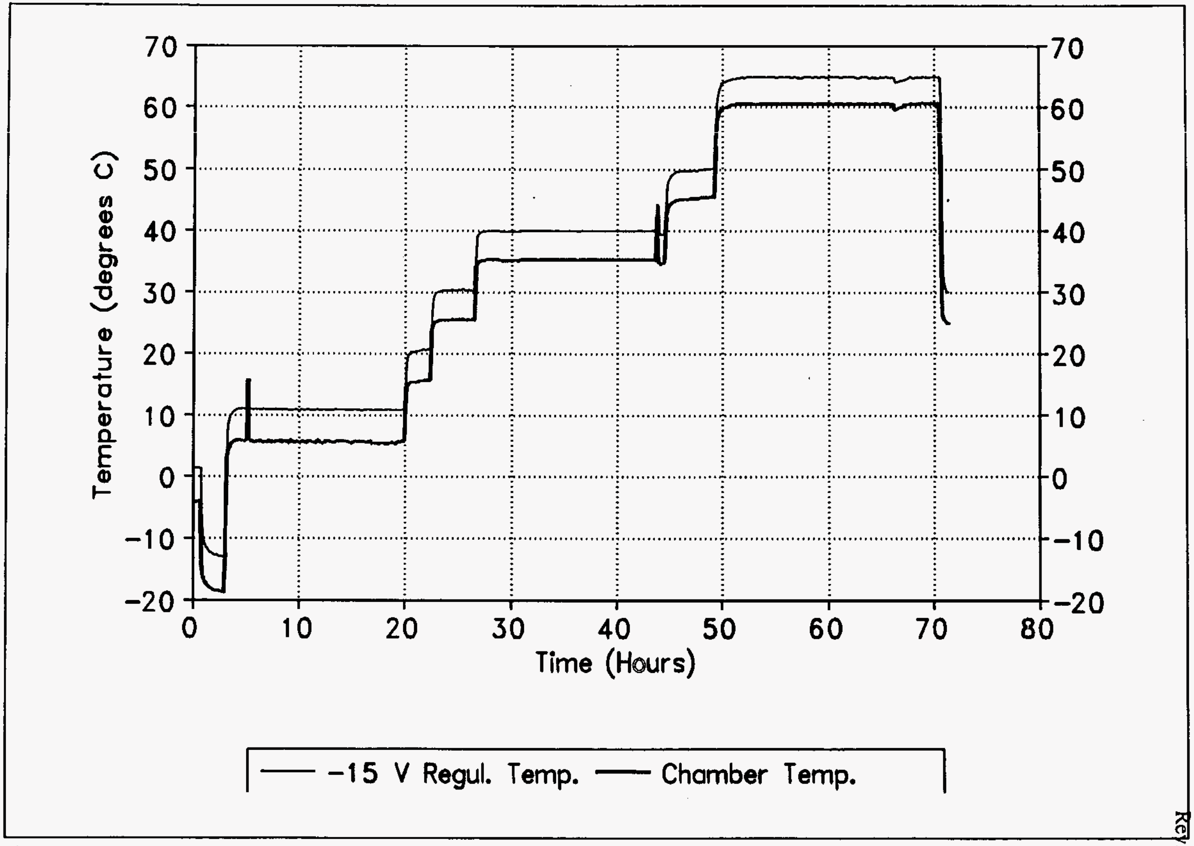


Figure 4-17. **-15 V Regulator Case Temperature.**

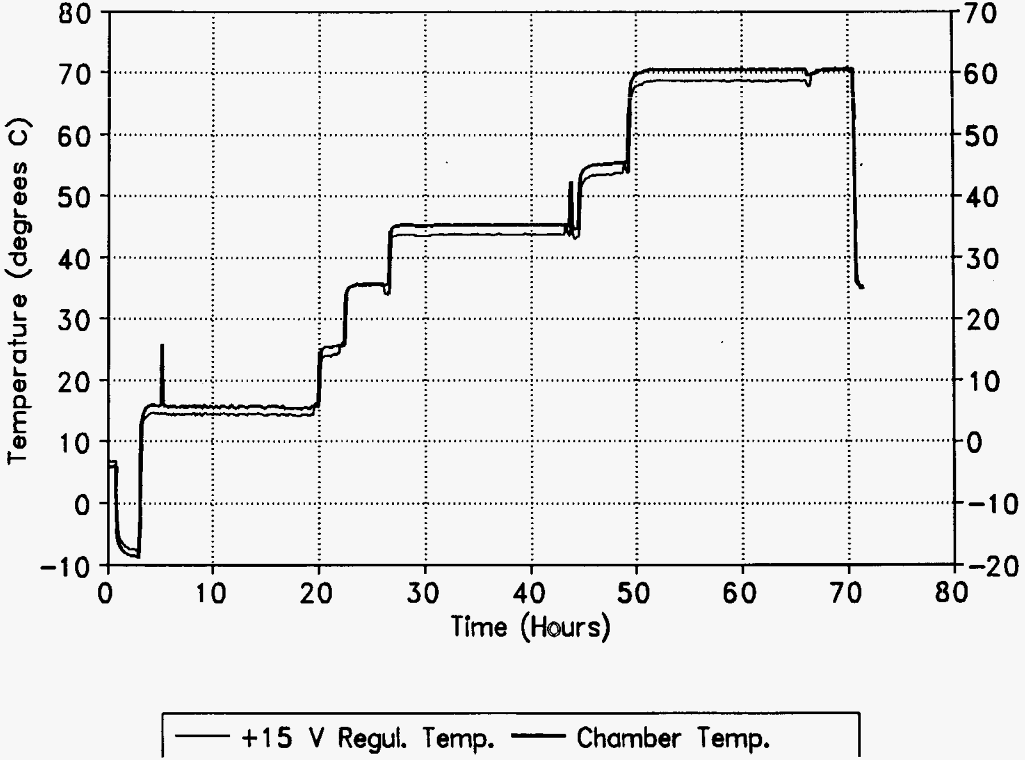


Figure 4-18. **+15 V Regulator Case Temperature.**

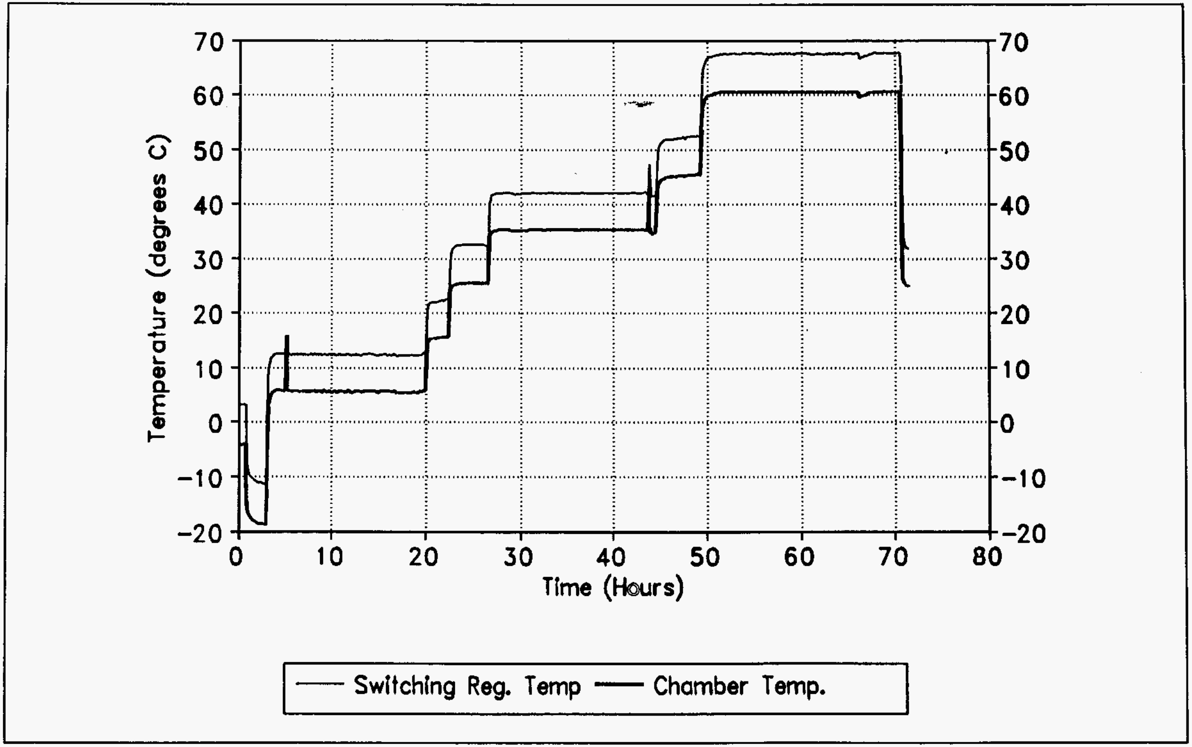


Figure 4-19. **Switching Regulator Case Temperature.**

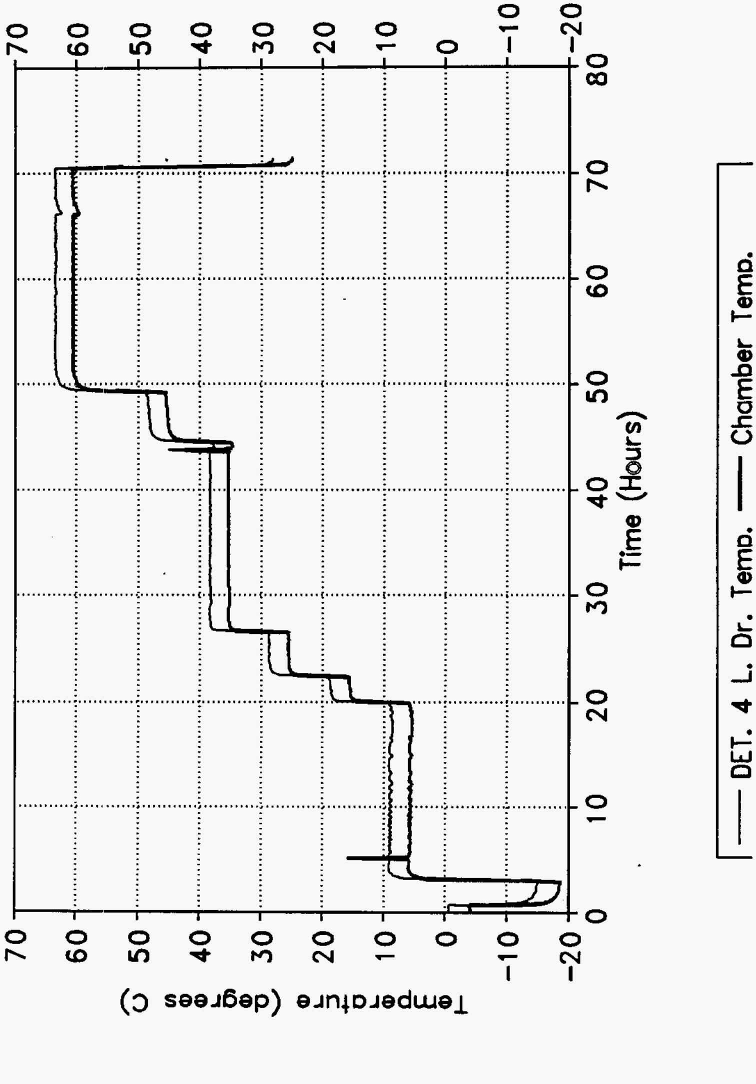


Figure 4-20. DET4 Line Driver Case Temperature.

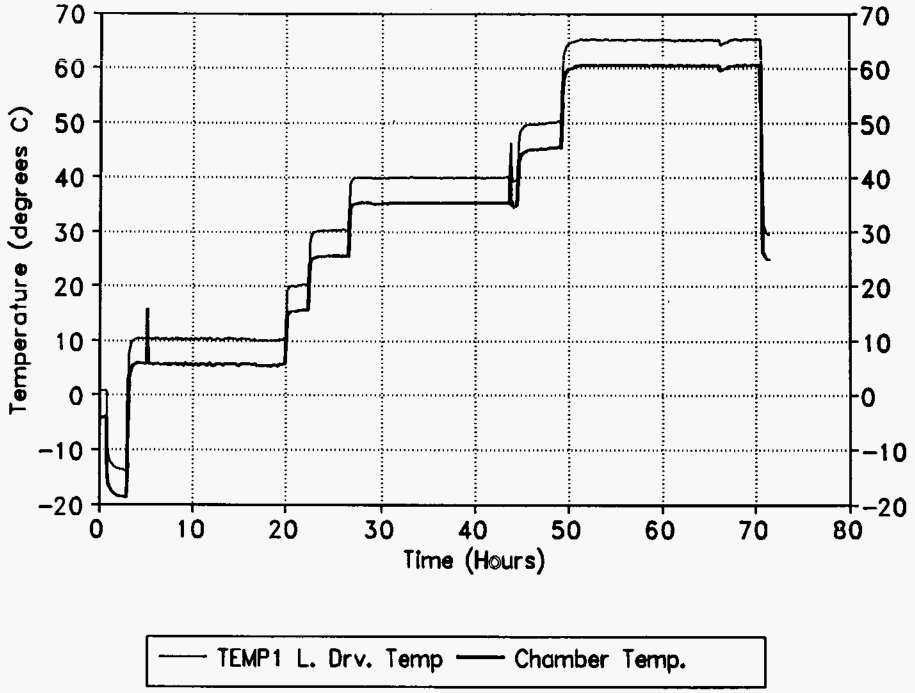


Figure 4-21. **TEMP1 Line Driver Case Temperature.**

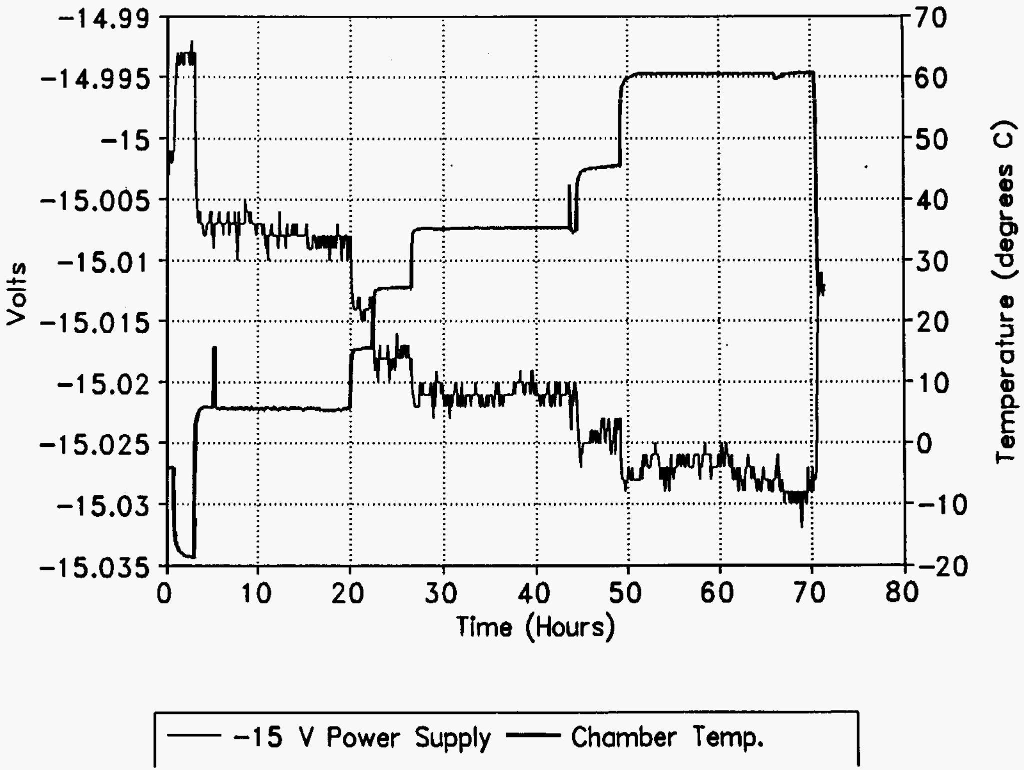


Figure 4-22. **-15 V Regulator Output Voltage.**

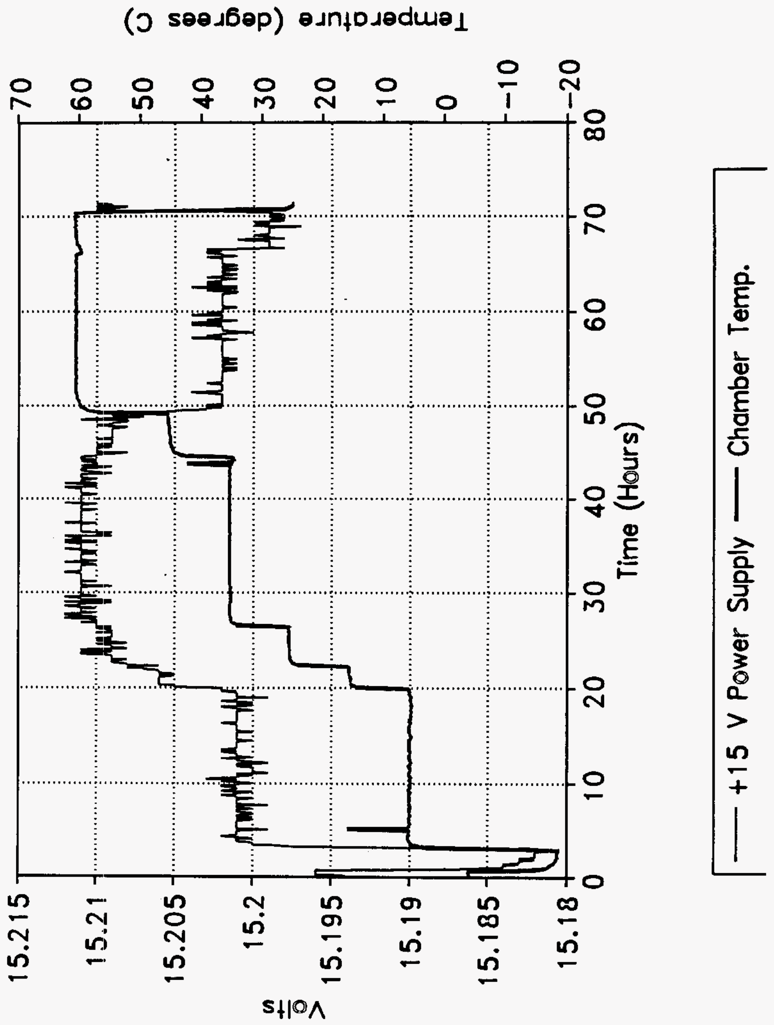


Figure 4-23 +15 V Regulator Output Voltage.

### 4.4.5 Measurement and Test Equipment

Appendix G contains the standards laboratory record sheet for the calibrated test equipment.

**Table 4-8**
**Measurement and Test Equipment List**

| Item | Description | Use | Standards Code Number | Calibration Expiration Date |
|---|---|---|---|---|
| 1 | Tail Pulse Generator<br>Berkeley Nucleonics Corporation BH-1 | Pulse input to detector 1 and 3 input on prototype line driver board. Pulse had 2 to 5 microsecond rise time and 10 microsecond fall time. | Not Applicable | Not Applicable |
| 2 | Tail Pulse Generator<br>Berkeley Nucleonics Corporation DB-2 | Pulse input to detector 2 input on prototype line driver board. Pulse had 2 to 5 microsecond rise time and 10 microsecond fall time. | Not Applicable | Not Applicable |
| 3 | Oscilloscope<br>Tektronix Model 485 | Measure amplitude of input and output waveforms to interface board | 013-51-01-012 | 2/21/97 |
| 4 | Oscilloscope<br>Lecroy Scope System 140<br>Serial No. V1677 | Information Only<br>Collect input and output waveforms to interface board | Not Applicable | Not Applicable |
| 5 | Power Supply<br>Hewlett Packard Model 721 | Provide +12 VDC to prototype line driver board | Not Applicable | Not Applicable |
| 6 | Power Supply<br>Hewlett Packard Model 6114A | Provide precision voltage source for temperature signal (-1 V, 0 V, -1 V) | Not Applicable | Not Applicable |
| 7 | Power Supply<br>Power Designs Inc.. Model TP325 | Provides +24 VDC to interface board | Not Applicable | Not Applicable |
| 8 | System Controller (hard disk etc..)<br>Hewlett Packard 9836C | Collected and stored data from scanner. | Not Applicable | Not Applicable |
| 9 | Scanner<br>Hewlett Packard 3497A | Measured thermocouple output voltage, and output voltage from other data points | 752-67-11-004 | 12/7/97 |
| 10 | Thermocouples Assemblies, 4 each, manufacturer unknown<br>1/8-inch sheathed type K<br>approximately 6-foot long | Measured chamber temperature with one of the thermocouple assemblies | 752-78-02-007 | 12/7/96 |
| 11 | Thermocouple<br>type K, 28 AWG<br>uninsulated, approximately 36 cm long | Information Only | Not Applicable | Not Applicable |
| 12 | Prototype Line Driver Board<br>Temperature inputs for TEMP1 and TEMP2 were connected together and power supply providing temperature signal floating 5 V above ground. | Not Applicable | Non Applicable | Non Applicable |

## 5.0 MOISTURE SENSITIVITY AND CALIBRATION

The SMMS neutron probe was designed to have good sensitivity to changes in moisture concentration, especially for concentrations ranging from 0 to 40 weight percent (wt%) water. The probe was also designed to provide some information about the moisture concentration gradient in the top 15 cm of underlying material. In order to interpret responses from the detector as moisture concentrations the responses must be related to moisture concentrations in the material of interest. Because it is difficult to construct controlled moisture concentration calibration standards using materials similar to the salt-cake-like wastes expected at the tank surface, we chose to make simple moisture-containing calibration standards. Probe responses measured with these standards could then be used to adjust computer modeled predictions so that they agreed. With the computer model results validated, the model could then be used to generate probe responses to many moisture concentration and moisture gradient salt cake waste materials.

### 5.1 MOISTURE STANDARD PREPARATION

The moisture standards were constructed using mixtures of high purity sand, hydrated alumina, and boron carbide. One or more of these constituents was weighed, mixed, sampled, poured into a barrel, and then compacted to produce a completed standard. Appropriate samples were obtained from all standards to provide both confirmation of the moisture content of the standard and to analyze the standard matrix for possible trace quantities of thermal neutron absorbing elements. The completed standards are well characterized; the elemental composition, moisture concentration, and bulk density are all known. The hydrated alumina is very stable and will maintain the uniform distribution of moisture in the standards. The sand and hydrated alumina materials were chosen based upon experience with less stable, more hazardous materials in previous simulants made for the another moisture probe and based upon successful use of these materials in the construction of moisture models for calibration of Hanford Site vadose zone neutron logging tools (Engleman, et al 1995).

The sand used for the standards was obtained from the Unimin Corporation, shipped in sealed 100 pound bags. The product obtained is a Granusil silica filler referred to as Ottawa sand (7020 mesh). This sand is a relatively high purity silica dioxide, has a specific gravity of 2.64 g/cm$^3$, and has an average grain size of about 100 mesh (ASTM E-11). Typical analyses of this product provided by the supplier show that it is expected to consist of greater than 99% pure silicon dioxide. The sand is a light yellow color.

The hydrated alumina used in the standards was obtained from Alcoa Alumina & Chemicals, shipped in sealed 100 pound bags. The product name is C-30 hydrate and it was obtained in 200 to 50 mesh particle size. The specific gravity of the hydrated alumina is 2.42 g/cm$^3$. The chemical formula for hydrated alumina is $Al_2O_3*3(H_2O)$, where, on average, three water molecules are hydrated to each aluminum oxide molecule. The manufacturer claims that the total water content of samples from the lots shipped to us contained a total of 34.8 wt% water. Typical analyses of this product provided by the manufacturer show that it should be about 99% free from impurities. The hydrated aluminum is white in color.

The boron carbide ($B_4C$, 99.5% pure) was obtained from the Alyn Corporation. The specific gravity of the grains is 2.52 g/cm$^3$ and it was purchased in 200 mesh particle size. Boron carbide is a black, non-hazardous, stable substance.

All standards are contained within cylindrical aluminum barrels (30 inch inner diameter, 18 inches tall, 3/16 inch-thick wall) except the standard 1 (4 wt% moisture). Standard 1 is in a larger cylindrical aluminum barrel (36 inch inner diameter, 26 inches tall).

### 5.1.1 Prototype Moisture Standard

Before the matrix materials were used to prepare any standards, samples of each material were taken and analyzed for moisture content (Appendix H). If the samples contained significant free moisture we planned to dry them before using them to fill the standards. Six samples from both the sand and the hydrated alumina were obtained, each from different bags, and three samples of the boron carbide were obtained and sent for moisture analyses. The sand samples all were found to lose less than 0.1 percent of their weight from water loss. The hydrated alumina samples also showed no significant weight loss from water for temperatures up to about 210 °C. Measurements showed that the hydrated alumina samples lost an average of 34.69 percent of their weight from water at a temperature of 1000°C. The samples of boron carbide essentially lost no weight for temperatures up to about 100 °C, but then experienced significant percentage weight gain for higher temperatures because of oxidation. Less than 15 grams of boron carbide is added to any standard, so that significant percent weight gain from this component at high temperatures would contribute little to the weight of the standard matrix or samples. These tests confirmed that the mix constituents contained insignificant free water and, excluding the boron carbide, would be stable at temperatures exceeding 100 °C.

Before all of the moisture standards were constructed, a single test standard was made and was core sampled to confirm that the planned construction technique (mixing, pouring, and then compacting by vibration) would produce standards that contain uniformly distributed moisture. Our primary concern was that the compaction technique, using drum vibrators strapped to the side of the barrel, might cause the moisture containing hydrated alumina to segregate in some way from the other mix constituent(s).

The prototype standard was constructed by mixing 4 batches of sand and hydrated alumina. These constituents were weighed to assure that the ratio of the sand weight to hydrated alumina weight was consistent with a target of 1:1.2145. Table 5-1 shows the weights of materials added each batch. Both materials in each batch were added to a 6.5 cubic foot steel drum mixer and were mixed for 5 to 7 minutes at about 22 revolutions per minute.

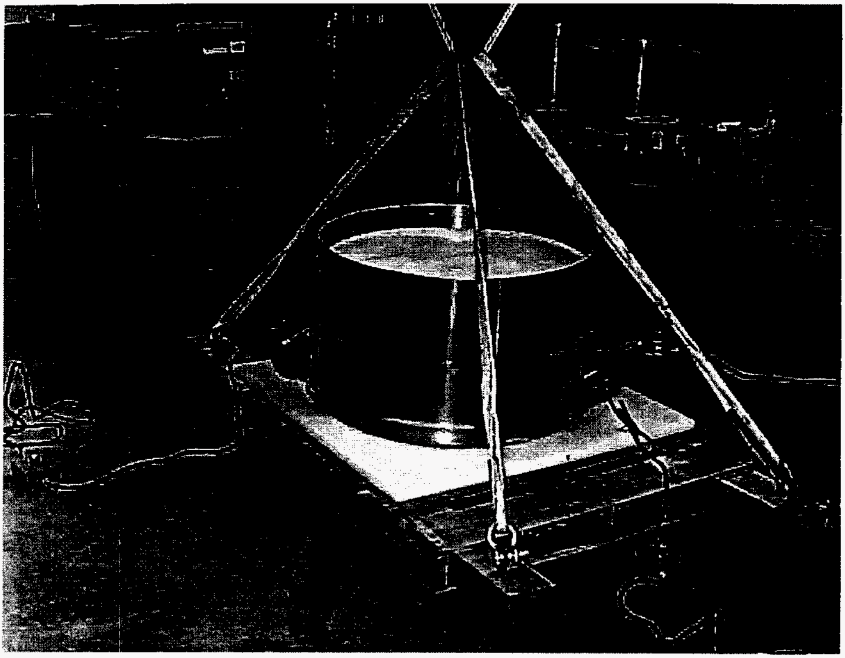
Table 5-1. The constituent weights for each batch of materials mixed and added to the prototype moisture standard.

| Batch | Sand (kg) | Hydrated Alumina (kg) |
|---|---|---|
| 1 | 22.73 | 27.60 |
| 2 | 40.25 | 48.90 |
| 3 | 39.47 | 47.94 |
| 4 | 19.85 | 24.11 |
| Totals | 122.30 | 148.55 |

Each batch was poured into the aluminum standard drum and the mixture surface was smoothed until nearly level. The average height from the mixture surface to the top edge of the barrel, $H_{air}$, was about 6 cm. Three electric vibrators (Vibco model SCR-200) were then attached to barrel mating plates that were steel band strapped to the outside of the barrel. The mating plates were flat on a side with tapped mounting holes, and were curved on the other side to allow the vibrators to couple to the cylindrical barrel wall without damaging it. The vibrators were equally spaced around the drum circumference and were positioned a few inches above the bottom of the drum. Two steel straps (0.5 inch wide) were used to hold the mating plates against the drum. The straps were applied, one at the top and one at the bottom of each mating plate, and were very securely tightened.

The vibrators are adjustable (900 to 4000 RPM) using a simple control dial roughly marked from 0 to 100. All three vibrators were turned on and then stepped through control settings of 10, 20, 50, 60, 66, 76, and finally 72. The vibrators were maintained at each setting for about 15 seconds while a visual inspection of the surface material was performed to look for signs of material segregation. At a setting of 76, some small scale segregation between the white hydrated alumina and the yellow sand could be observed at the material surface. The vibrators were maintained at a setting of 72 for one hour. The vibration was then stopped and the surface checked for level. The surface was found to be about 3/8 inch out of level because the floor was not level. The surface was gently leveled with a trowel. The slight segregation of materials observed, by color, at the surface was not observed in the top 3/8 inch of material during leveling. The quantity $H_{air}$ was measured to be about 8 cm, equivalent to about 2 cm of settling. To create a more level surface during completion of the compaction, the barrel was hoisted into the air and leveled using two slings through a palette under the barrel. Figure 5-1 is a photograph showing one of the final moisture standards as it was compacted in the described configuration using the vibrators. Vibration was continued at an increased setting of 90 for 30 minutes. Some surface segregation was observed at this increased rate and the surface of the mixture was depressed near the barrel wall over each vibrator position. The vibrator speeds were adjusted slightly for all vibrators until they made the least noise (beats were nearly eliminated from the sound) at a given speed. The audible beats are an indication of interference in the vibrational waves due to differences in the vibration frequencies. The surface of the material was leveled and $H_{air}$ was measured to be about 8.9 cm. The vibrators were restarted for 25 minutes on a setting of 90. The surface was smoothed with a trowel and $H_{air}$ was measured to be about 9.3 cm. The vibrators were restarted for 20 minutes on a setting of 96

Figure 5-1. Photograph Showing One of the Final Moisture Standards During Vibrational Compaction.



(maximum). The surface was smoothed with a trowel and $H_{air}$ was measured to be about 9.6 cm. The vibrators were restarted for 20 minutes on a setting of 96 (maximum). The surface was smoothed with a trowel and $H_{air}$ was measured to be about 9.7 cm. Compaction was considered complete at this time because the incremental compaction was insignificant (<0.15 cm). The total compaction was 3.6 cm for a total settling of almost 10 percent of the original matrix height. Table 5-2 summarizes the compaction measurement results for the prototype barrel.

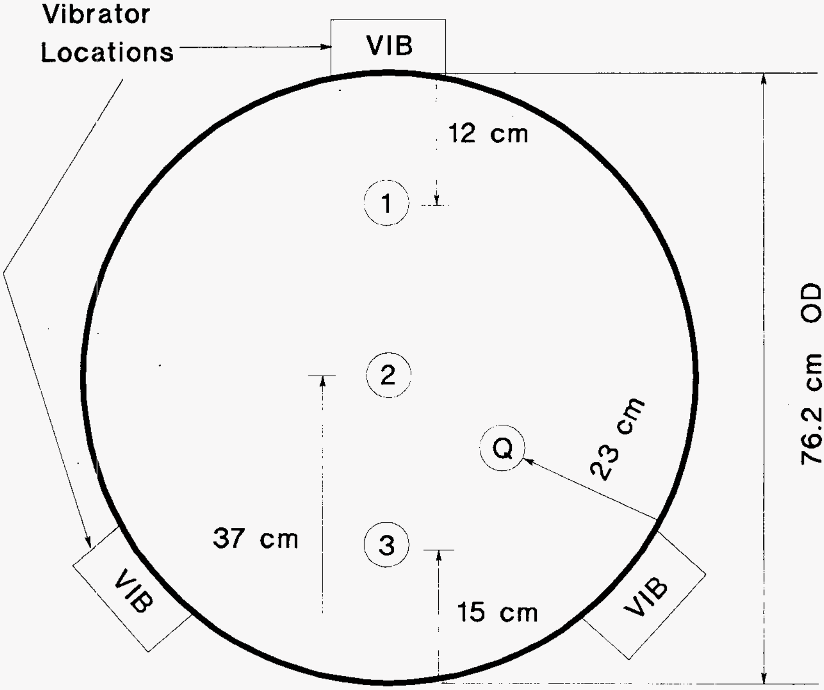
Table 5-2. Compaction measurement results for the prototype barrel.

| Compaction Interval (minutes) | Vibrator Setting (0-96) | $H_{air}$ (cm) | Incremental Compaction $\Delta H_{air}$ (cm) |
|---|---|---|---|
| N/A | N/A | 6.12 | N/A |
| 60 | 72 | 7.98 | 1.86 |
| 30 | 90 | 8.89 | 0.91 |
| 25 | 90 | 9.30 | 0.41 |
| 20 | 96 | 9.60 | 0.30 |
| 30 | 96 | 9.73 | 0.13 |

The surface of the mixture in the prototype barrel was smoothed and the thin aluminum lid was placed on top of the mixture and sealed in place with silicone caulk. The seal was allowed to cure for about 20 hours and then the barrel was transported from the preparation site to the 306E building test area. The aluminum lid remained firmly in contact with the matrix material. The lid was removed and $H_{air}$ was remeasured. $H_{air}$ was found to have not changed during the relocation, to within measurement accuracy. Three stainless steel core sampling tubes (1.076 in ID, 1.151 inch OD) were inserted into the mixture. The tubes could be pushed into the matrix about 5 inches and then were hammered in the remaining distance until they made contact with the bottom of the barrel. A fourth tube, made of clear plastic and about 1 inch OD, was also inserted in the matrix in a similar manner to provide a visual vertical profile of the matrix for qualitative inspection. Figure 5-2 shows the approximate position of each of the sample tubes in the barrel relative to the wall and to the vibrator locations.

The sample tubes were removed, one at a time, by excavating the sand around it until a thin sheet of metal could be slipped over the bottom end of the tube to prevent sample loss. The samples were each poured out in a line on a metal table, preserving the top to bottom orientation. Each sample line was roughly broken into quarter segments, labeled A (top), B, C, D (bottom), which were placed in 60 ml nalgene sample bottles. These samples were analyzed for moisture content using a thermogravimetric technique (see appendix H for complete description and results). Core sample 1 moisture analyses ranged from 16.2 to 21.8 wt% water in the four samples. Core sample 2 moisture analyses ranged from 19.5 to 21.4 wt% water in the four samples. Core sample 3 moisture analyses ranged from 19.4 to 20.6 wt% water in the four samples. The uniformity of the moisture content as a function of depth and as a function of position in the barrel was considered adequate. Only the sample taken in position 1 (near the vibrator) showed what may be a consistent moisture gradient as a function of depth. The results indicate that, near the barrel wall above the vibrator locations, the

Figure 5-2. Sample Locations from Prototype Moisture Standard (View from Above).



simulant may contain slightly increasing moisture content as a function of depth. Since the probe will be placed near the center of the barrel the effects of a small moisture gradient near the wall is likely to be small. The clear plastic sample tube was visually examined for coloration changes that could indicate that segregation of the two mix components had occurred. The entire length of the sample appeared to be uniform in color and well mixed.

### 5.1.2 Final Moisture Standards

The final moisture standards were prepared in a manner consistent with that used to assemble the prototype standard. Weights and measurements of important physical quantities were carefully made with calibrated instruments. Samples were obtained from the different batches to allow for both moisture and elemental analyses to be performed. The most important characteristics of the standards are their moisture concentration, bulk density, and elemental composition.

To obtain a measurement of the bulk density of the matrix in each standard the weight of the added matrix and the filled volume is needed. All weight measurements between 1 and 450 kg were made using a calibrated 1000 pound capacity load cell with a total measurement uncertainty of ±0.168 kg (Omega Engineering Model LCCA-1K). The filled volume as a function of the distance from the top of material to the top of the barrel wall, $H_{air}$, was determined for each barrel. The barrel was weighed while empty and then water was added to the barrel at two different heights, bounding the expected final matrix fill height. At each water fill height ($H_{air1}$ and $H_{air2}$), the weight of the water in the barrel ($W_{fill1}$ and $W_{fill2}$) was measured and $H_{air}$ was measured at four locations, separated by 90 degrees, around the circumference of the barrel wall. The height measurements were made with a metal ruler marked with 1/32 inch degradations (L.S. Starret Co No. 4RGRAD). The four measurements were averaged to give a best estimate of $H_{air}$, while the corresponding volume was obtained by using the density of water to convert the weight of added water to a volume. Assuming a linear relationship between the volume and $H_{air}$, given these two fill height measurements, produces a simple fill volume equation for each barrel (reported in table 5-3) given by (Watson and Shreve1996):

$$V(H_{air}) = \left(\left(\frac{W_{fill2}-W_{fill1}}{H_{air2}-H_{air1}}\right) * H_{air} + \left(W_{fill1} - \left(\frac{W_{fill2}-W_{fill1}}{H_{air2}-H_{air1}}\right) * H_{air1}\right)\right) / \rho_{water}$$

The density of water, $\rho_{water}$, was corrected based upon its measured temperature.

Table 5-3. Measured and calculated physical characteristics of the 16 moisture standard containers.

| Barrel | $H_{air1}$(cm) | $W_{fill1}$(kg) | $H_{air2}$(cm) | $W_{fill2}$(kg) | Volume Function (cm$^3$) |
|---|---|---|---|---|---|
| 1 | 31.57 | 249.56 | 26.52 | 286.38 | $V=(-7305.1*H_{air}+480150)/0.99979$ |
| 2 | 12.36 | 149.84 | 4.13 | 188.67 | $V=(-4715.2*H_{air}+208130)/0.99979$ |
| 3 | 13.37 | 146.97 | 3.63 | 191.02 | $V=(-4521.1*H_{air}+207440)/0.99979$ |
| 4 | 11.93 | 153.83 | 4.96 | 185.65 | $V=(-4568.5*H_{air}+208310)/0.99979$ |
| 5 | 11.83 | 154.07 | 3.31 | 189.07 | $V=(-4111.4*H_{air}+202700)/0.99979$ |
| 6 | 12.86 | 149.88 | 6.35 | 176.27 | $V=(-4054.5*H_{air}+202020)/0.99979$ |
| 7 | 12.74 | 150.33 | 3.33 | 197.06 | $V=(-4968.1*H_{air}+213620)/0.99979$ |
| 8 | 12.88 | 149.48 | 4.31 | 188.65 | $V=(-4569.3*H_{air}+208330)/0.99979$ |
| 9 | 12.32 | 152.22 | 5.91 | 181.29 | $V=(-4535.4*H_{air}+208110)/0.99979$ |
| 10 | 12.74 | 150.44 | 3.75 | 191.37 | $V=(-4553.2*H_{air}+208450)/0.99979$ |
| 11 | 13.00 | 148.87 | 6.27 | 179.42 | $V=(-4541.4*H_{air}+207900)/0.99979$ |
| 12 | 12.64 | 150.70 | 5.12 | 184.74 | $V=(-4526.1*H_{air}+207910)/0.99979$ |
| 13 | 41.93 | 16.98 | 38.71 | 31.92 | $V=(-4647.4*H_{air}+211850)/0.99975$ |
| 14 | 40.91 | 22.24 | 38.24 | 35.78 | $V=(-5054.3*H_{air}+229050)/0.99975$ |
| 15 | 39.61 | 28.42 | 36.67 | 41.97 | $V=(-4613.8*H_{air}+211160)/0.99975$ |
| 16 | 35.54 | 46.12 | 31.71 | 64.05 | $V=(-4681.7*H_{air}+212510)/0.99975$ |

Barrels 2 through 16 are all 76.2±0.4 cm inner diameter and 45.7±0.2 cm deep. Barrel 1 has an inner diameter of about 96.2 cm and is about 66 cm deep. All of the barrels were cleaned with water and dried before use. Barrels 2-6 and 11-16 were all prepared by completely filling them with the appropriate mixture and then compacting them. Barrel 1 was prepared by filling the barrel with 4 of the 13 needed batches before beginning continuous compaction of the material as the remaining batches were mixed and poured. Barrels 7-10 all contain multiple moisture layers. For these barrels the bottom moisture layer was compacted completely by vibration. A circular sheet of aluminum (0.056 cm thick) was placed between each moisture layer and each added thin layer was manually tamped using a 10-inch trowel. Mechanical vibration of each drum was performed over several time intervals (each about 30 minutes). After each interval the surface was gently releveled and measurements taken of the depth from the surface to the top of the barrel wall, $H_{air}$. These measurements were taken with a metal ruler resting on the trowel or the aluminum lid (temporarily placed on the sand surface). Compaction was considered completed when the average measurement of $H_{air}$ increased by less than about 0.18 cm during one compaction time interval (20 minute minimum duration). The average required total compaction time for each barrel mixture was about 2.5 hours. Measurements of $H_{air}$ were made for each final compacted layer for each barrel (on top of the aluminum sheet or lid). The top aluminum lid (0.079 cm thick) was then fitted firmly on top of the matrix and sealed into place using a bead of silicone rubber caulking between it and the barrel wall. The lid is very flexible, so that when the probe is placed upon it good contact will be made with the matrix surface and so that any settling of the underlying matrix could be felt with light hand pressure upon the lid.

Each moisture mix was controlled by mixing constituents, weighed to desired proportions (table 5-4) using a newly purchased calibrated load cell (Omega Engineering Model LCCA-1K) with an accuracy of ±0.168 kg with a read-out meter accurate to 0.005% (Omega Engineering Model DP41-W). The moisture concentrations given by the matrix descriptions (names) are only approximate. The expected moisture concentration was calculated using the manufacturers estimate of the water content of the hydrated alumina (34.81 wt% water), assuming that the other matrix constituents contributed no water. The calculated moisture concentration is given by

$$Moisture_{calculated}(wt\%) = \frac{34.81 * (Weight\ of\ hydrated\ alumina)}{(Weight\ of\ (hydrated\ alumina + sand + boron\ carbide))}\ .$$

Samples of each mix were also obtained, most of which were measured for moisture concentration (see appendix H) to confirm the moisture concentration(s) of each standard. Table 5-5 gives the calculated moisture concentration(s) of each moisture barrel, the average measured moisture concentration, and the calculated bulk density of each moisture layer. The density values, calculated using the volume function and the measured added mass, are reported with uncertainties given by

$$\sigma_{\rho_{mix}} = \frac{W_{fill}}{V_{fill}} \cdot \sqrt{\left(\frac{\sigma_{W_{fill}}}{W_{fill}}\right)^2 + \left(\frac{\sigma_{V_{fill}}}{V_{fill}}\right)^2}$$

The calculated and measured moisture concentration values are, in most cases, in very good agreement. The largest noted discrepancy is for moisture standard 3 where the calculated value is 13.12 wt% and the average measured value is 12.48 wt%. The reported measured value is an average of three samples submitted for moisture analyses from that barrel (appendix G). Measurements of these samples gave moisture values of 11.01, 13.23, and 13.21 wt% water. Two of the three sample values are consistent with the calculated moisture estimate. The discrepancy could be from many causes, but the most likely cause is that the original sample was taken from an area of the mix batch that was not as well mixed as would have been desired. A moisture concentration of 13.1 to 13.2 wt% is most likely correct for this standard. A similar explanation may be applicable for moisture standard 1 where the three samples submitted for moisture analyses contained 3.74, 3.97, and 2.99 wt% water compared with a calculated moisture concentration of 4.11 wt%.

Table 5-4. Relative mass of each constituent for each matrix composition.

| Matrix Description | Sand | Hydrated Alumina | Boron Carbide |
|---|---|---|---|
| 4 wt% water | 1.000 | 0.1305 | 0.0 |
| 8 wt% water | 1.000 | 0.3003 | 0.0 |
| 13 wt% water | 1.000 | 0.6006 | 0.0 |
| 19 wt% water | 1.000 | 1.215 | 0.0 |
| 25 wt% water | 1.000 | 2.592 | 0.0 |
| 35 wt% water | 0.0 | 1.000 | 0.0 |
| 19 wt% water, 1.8E-3 wt% B | 1.000 | 1.215 | 0.00005111 |
| 19 wt% water, 3.6E-3 wt% B | 1.000 | 1.215 | 0.0001022 |

Table 5-5. Calculated and Measured Moisture Concentrations and Densities for Standard Matrix.

| Moisture Standard ID Number | Calculated Moisture (wt%) | Measured Moisture (wt%) | Bulk Density (g/cm$^3$) |
|---|---|---|---|
| 1 | 4.11 | 3.57 | 1.781± 0.005 |
| 2 | 8.12 | 8.04 | 1.696 ±0.005 |
| 3 | 13.12 | 12.48 | 1.636 ±0.006 |
| 4 | 19.14 | 19.33 | 1.636 ±0.006 |
| 5 | 25.15 | 25.29 | 1.587 ±0.005 |
| 6 | 34.8 | 34.47 | 1.512 ±0.005 |
| 7 (bottom layer) | 13.12 | 13.18 | 1.629 ±0.005 |
| 7 (top layer) | 8.11 | 8.52 | 1.54 ±0.09 |
| 8 (bottom layer) | 19.14 | 19.01 | 1.738 ±0.008 |
| 8 (middle layer) | 13.13 | 13.23 | 1.46 ±0.09 |
| 8 (top layer) | 8.12 | 8.23 | 1.69 ±0.12 |
| 9 (bottom layer) | 19.14 | 19.40 | 1.615 ±0.007 |
| 9 (top layer) | 13.12 | 13.02 | 1.59 ±0.12 |
| 10 (bottom layer) | 25.15 | 25.03 | 1.595 ±0.006 |
| 10 (middle layer) | 15.77 | not measured | 1.44 ±0.08 |
| 10 (top layer) | 13.13 | not measured | 1.66 ±0.09 |
| 11 | 19.14 | not measured | 1.601 ±0.005 |
| 12 | 19.14 | not measured | 1.603 ±0.015 |
| 13 | 19.14 | 19.40 | 1.475 ±0.006 |
| 14 | 19.14 | 18.93 | 1.543 ±0.006 |
| 15 | 19.14 | 18.82 | 1.583 ±0.004 |
| 16 | 19.14 | 19.13 | 1.642 ±0.347 |

Standards 7-10 contained multiple moisture layers, while standards 13-16 each contained a single moisture concentration layer of a different thickness. The thicknesses of the layers in these standards was not precisely controlled. Instead, a target layer height was marked on the inside barrel wall and the layer was filled approximately to that height. After the layer had been compacted and/or smoothed and leveled, accurate measurements of the layer height were made. Table 5-6 reports the measured thickness of each layer in each of these standards. For standards 13-16 the thickness of the layer is not entirely uniform, so measured thickness at the barrel wall is given. The barrels used for all standards have a slightly curved bottom caused by the welding of the aluminum during fabrication. For barrels 1 through 12, this curvature (usually about 3-4 mm deeper in the barrel center than at the wall) is considered to be negligible given the large height of material in the barrel.

Table 5-6. The measured thickness and mass of each moisture layer in all moisture standards.

| Standard | Layer/Moisture (wt%) | Thickness (cm) | Total Layer Mass (kg) |
|---|---|---|---|
| 1 | Single / 4 | 62.2 | 804.5 |
| 2 | Single / 8 | 39.0 | 299.6 |
| 3 | Single / 13 | 37.8 | 281.2 |
| 4 | Single / 19 | 38.0 | 277.9 |
| 5 | Single / 25 | 38.4 | 274.6 |
| 6 | Single / 35 | 38.9 | 264.0 |
| 7 | Top / 8 | 2.9 | 19.8 |
| 7 | Bottom / 13 | 35.5 | 265.9 |
| 8 | Top / 8 | 2.5 | 19.8 |
| 8 | Middle / 13 | 3.4 | 22.1 |
| 8 | Bottom / 19 | 30.9 | 244.7 |
| 9 | Top / 13 | 2.8 | 19.9 |
| 9 | Bottom / 19 | 35.2 | 259.9 |
| 10 | Top / 13 | 2.9 | 22.0 |
| 10 | Middle / 19 | 3.2 | 20.6 |
| 10 | Bottom / 25 | 32.5 | 237.0 |
| 11 | Single / 19 | 37.9 | 276.8 |
| 12 | Single / 19 | 37.8 | 276.8 |
| 13 | Single / 19 | 3.9 | 26.1 |
| 14 | Single / 19 | 5.7 | 41.7 |
| 15 | Single / 19 | 7.3 | 54.3 |
| 16 | Single / 19 | 10.4 | 77.8 |

Twenty of the matrix batch samples were submitted to RTL Consulting for elemental analyses (WHC 1996). The primary purpose of these analyses was to identify the presence of any unknown quantities of strong thermal neutron absorbers that might be present in trace quantities in the mixes. Known amounts of boron were added to two of the moisture standards. These tests were also intended to confirm that boron was indeed present in these samples in the expected amounts. Because inexpensive tests were available for silicone and aluminum, two of the primary matrix constituents, we also asked that the samples be analyzed for these elements as additional confirmation of the composition of each mix. Table 5-7 shows a listing of the samples submitted for elemental analyses. The samples were identified by the moisture standard number, the pour (batch) number for that standard, the approximate moisture concentration (wt%), the letter A (designating the sample as the first of two samples taken from each pour), and the word boron if boron was added to the mix.

Table 5-7. A list of the samples submitted for elemental analyses.

| Moisture Standard | Pour Number | Moisture Concentration (wt%) | Boron Added |
|---|---|---|---|
| 1 | 12 | 4 | - |
| 2 | 4 | 8 | - |
| 3 | 3 | 13 | - |
| 4 | 4 | 19 | - |
| 5 | 4 | 25 | - |
| 6 | 3 | 35 | - |
| 7 | 3 | 8 | - |
| 7 | 4 | 13 | - |
| 8 | 3 | 19 | - |
| 9 | 3 | 19 | - |
| 10 | 5 | 19 | - |
| 11 | 1 | 19 | Yes |
| 11 | 3 | 19 | Yes |
| 11 | 4 | 19 | Yes |
| 12 | 2 | 19 | Yes |
| 12 | 3 | 19 | Yes |
| 12 | 4 | 19 | Yes |
| 14 | 2 | 19 | - |
| 15 | 2 | 19 | - |
| 16 | 2 | 19 | - |

Table 5-8 shows the elements for which sample analyses were performed and the analysis method used for each element. Table 5-8 also lists approximate values of the thermal neutron absorption cross section for each element. Elements that have large absorption cross sections, if present in the moisture simulant in unknown quantities, could produce effects upon the response of the probe detectors, especially detector 3. The probability of a thermal neutron being captured by a given element in the matrix is proportional to the product of the absorption cross section and the atomic density of that element. While iron has a relatively low absorption cross section (about 3 bn), it is a common element that is likely found in the matrices. Samarium, while unlikely to be found in the matrix in more than trace amounts could contribute as much to the thermal neutron absorptive properties of the medium as iron because of its very large cross section (5600 bn). Most of the elements were analyzed using a Fison (VG) PQ 11+ inductively coupled plasma / mass spectrometer (ICP/MS). This technique is very accurate at analyzing small quantities of metals, but can not be used for most nonmetals. Three of the nonmetals were analyzed using an ARL 4000 X-Ray Spectrometer to induce and measure the x-ray fluorescence (XRF) of the sample. Three nonmetals, hydrogen, nitrogen, and carbon, were analyzed using a Perkin Elmer Model 2400 Elemental Analyzer (EA). The samples are heated to about 950 °C and the vapors are mixed with a stream of oxygen gas that is fed into this analyzer. Iron was analyzed with an atomic absorption (AA) technique utilizing a Perkin Elmer Zeeman 5000 Atomic Absorption Spectrometer.

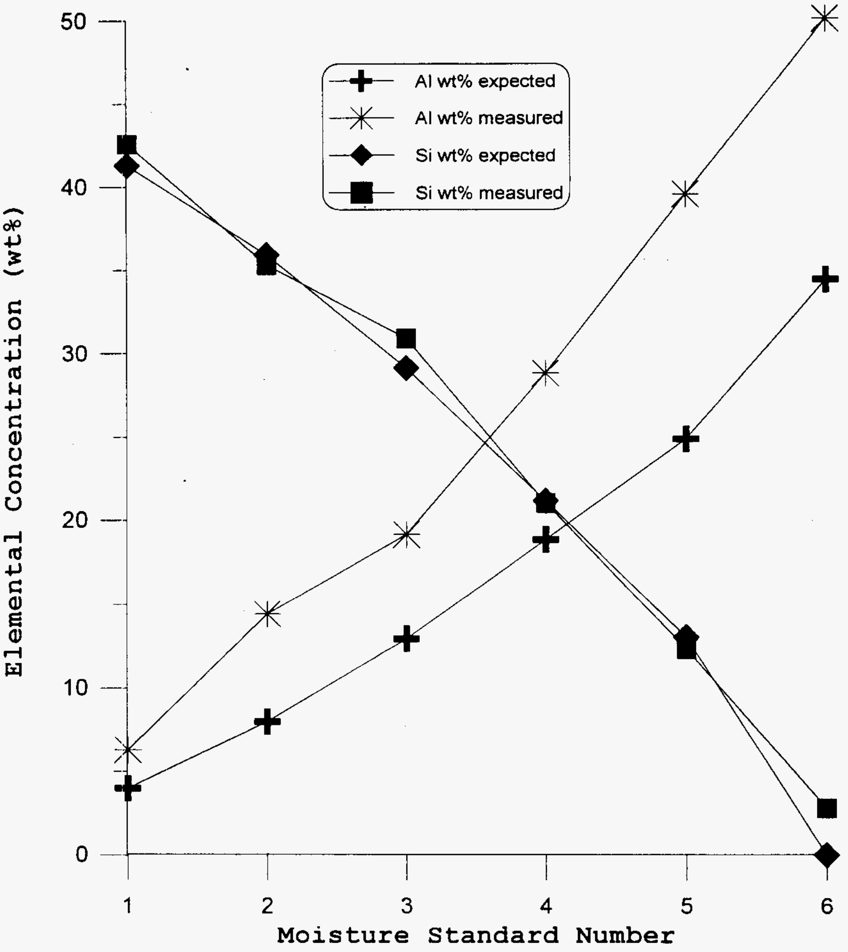
Table 5-8. Elements for which sample analyses were performed and the analysis method used for each element. Approximate thermal neutron absorption cross section is listed for each element.

| | Elemental Analysis Method | | | | Thermal Neutron Absorption |
|---|---|---|---|---|---|
| Element | ICP/MS | XRF | EA | AA | Cross Section (barns) |
| Ag | X | | | | 63 |
| Al | | X | | | <1 |
| B | X | | | | 760 |
| C | | | X | | <1 |
| Cd | X | | | | 2520 |
| Cl | | X | | | 34 |
| Co | X | | | | 37 |
| Cu | X | | | | 4 |
| Fe | | | | X | 3 |
| H | | | X | | <1 |
| Li | X | | | | 71 |
| Mn | X | | | | 13 |
| N | | | X | | 2 |
| Nd | X | | | | 50 |
| Ni | X | | | | 5 |
| Sb | X | | | | 5 |
| Se | X | | | | 12 |
| Si | | X | | | <1 |
| Sm | X | | | | 5600 |

Results showed that all elements analyzed using ICP/MS were present in negligible amounts. Most of these elements were present at levels around 1 ppm, with none of the samples showing more than 8 ppm of any element. Analyses of iron in the samples averaged about 250 ppm. Sand and hydrated alumina suppliers estimated chemical compositions did list iron as an impurity that was likely to be present in amounts around 10-25 ppm.

The XRF analysis results for the aluminum are in error, providing uncertainty in the chlorine analyses. Figure 5-3 shows a comparison between the calculated (using measured weights and molecular formulae) and measured amounts of silicone and aluminum for the samples from standards 1-6. The XRF data were calibrated using National Institute of Standards and Technology (NIST) certified $SiO_2$ for silicon and $Al_2O_3$ for aluminum and using United States Geological Survey (USGS) standard rock material for chlorine. While the silicone concentrations are good agreement with expected values, the measured aluminum concentrations are consistently about

Figure 5-3. Comparisons Between Expected and Measured (XRF) Silicon and Aluminum Concentrations for Moisture Standards 1 Through 6.



50 percent higher than expected. It is not likely that the aluminum concentrations are as high as the measured values. For instance, for the 19 wt% water samples a total of about 65 percent of the total weight is expected from hydrogen, silicone, and oxygen (from $H_2O$ and $SiO_2$ only). The remaining 35 percent of the weight is expected to be from $Al_2O_3$, but the sample analyses report that the ten 19 wt% water samples average 33.2 ±2.5 wt% aluminum. While it is not mathematically impossible to attribute 33 percent of the weight to aluminum, no known compound with this composition exists that would retain the hydrated water molecules. The measured chlorine concentrations averaged 59 ±22 ppm, which are insignificantly low.

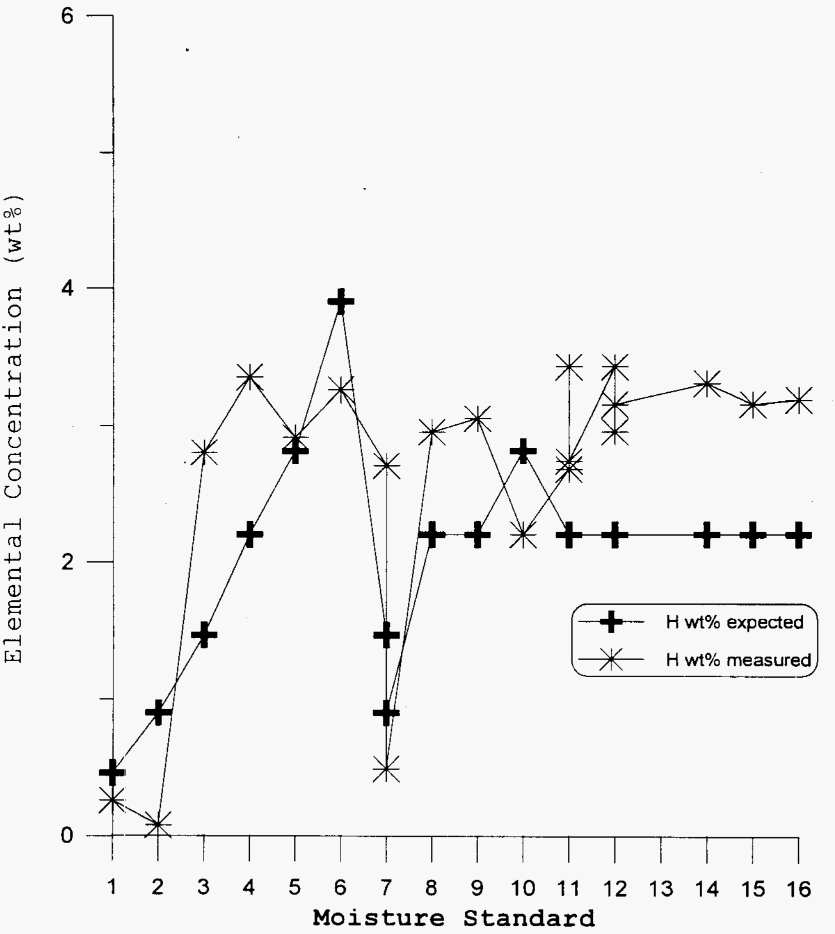
Analysis results for elemental carbon, hydrogen, and nitrogen were not completely consistent with expectations. The hydrogen concentration of the samples may be compared with that expected from both calculations and thermogravimetric measurements if one assumes that most or all hydrogen is from the hydrated water. Figure 5-4 shows a comparison of the calculated and measured hydrogen concentrations for all moisture standard samples. The measured data exhibits a great deal of scatter about the expected trend. This scatter is likely caused by poor sampling techniques used by the analysis laboratory. Similar scatter was observed in the thermogravimetric moisture measurement results until a better sample splitting technique was employed. While the data is not useful for precisely determining the hydrogen concentrations, it does provide general order of magnitude confirmation of expected hydrogen concentrations. If the carbon and nitrogen data are treated as if they are order of magnitude estimates, one may conclude that neither are present in significant amounts.

Analyses for boron in the samples was incomplete. All samples were tested for boron and RTL did not detect significant boron concentrations in any samples, including those taken from standards 11 and 12. RTL resubmitted samples from the samples taken from standards 11 and 12 for reanalysis. For the reanalysis, they subjected the sample to increased concentration of nitric and hydrofluoric acid and high temperature and pressure in an effort to dissociate the boron. RTL concluded that they were unable to properly dissolve boron carbide, even under the conditions of the reanalysis. Measurements of boron in the samples therefore did not include contributions from the added boron carbide. The boron analyses are indicative of the boron present from more common boron containing compounds such as boron oxide.

## 5.2 MOISTURE MEASUREMENT RESULTS

Each of the 16 completed moisture standards were used to perform detector response tests with the neutron probe. For each test the probe was placed on the aluminum lid very near the center of each barrel, resting under its own weight. Each probe was also tested while placed inside two different borated-polyethylene and steel operation check standards. Three complete detector/electronic assemblies have been constructed for use in a probe housing. One assembly is for

Figure 5-4. Comparison of Expected and Measured (EA) Hydrogen Concentrations for All Sample Submitted Moisture Standards.



use with the SMMS system, one was built for deployment using the light duty utility arm (LDUA), and the third assembly was fabricated as a spare. Only one housing was completed and available for use with these tests. These tests, unless stated otherwise, were also completed before a tungsten alloy weight (about 4 kg) was fabricated and added to the top of the probe housing assembly. Computer modeling provided an indication that the tungsten piece will have a negligible effect upon results because it is located far from the source and detectors.

### 5.2.1 Moisture Measurement Technique

Measurements were obtained using the 16 moisture standards by placing the probe, under its own weight, centered on top of the aluminum lid covering the matrix. For the 12 completely filled standards, the probe was placed upon each lid using an aluminum stand connected to the top of the probe housing. Figure 5-5 is a photograph of the probe being held by the aluminum stand as it rests on top of one of the moisture standards, positioned for a measurement. The stand allows the probe to be moved from standard to standard and to be lowered to the center of the surface of the lid while maintaining a safe distance between the probe handling personnel and the exposed neutron source. The probe center was placed within 2-3 cm of the center of the barrel. For the thin layer standards (#13-16), the overhead crane, attached to the probe using the end of the aluminum stand fixture and a lifting strap, was used to lower the probe to the center surface of each standard. For both probe arrangements, the positioning stand and equipment are either positioned far enough from the probe source and detectors or is made of a material, such as aluminum, that has a very low neutron interaction cross section and is a poor neutron moderator and reflector. The moisture standards were arranged in two rows. Each barrel was spaced a minimum of 190 cm (center to center) from any adjacent barrel and a minimum of 220 cm from its center to the room walls.

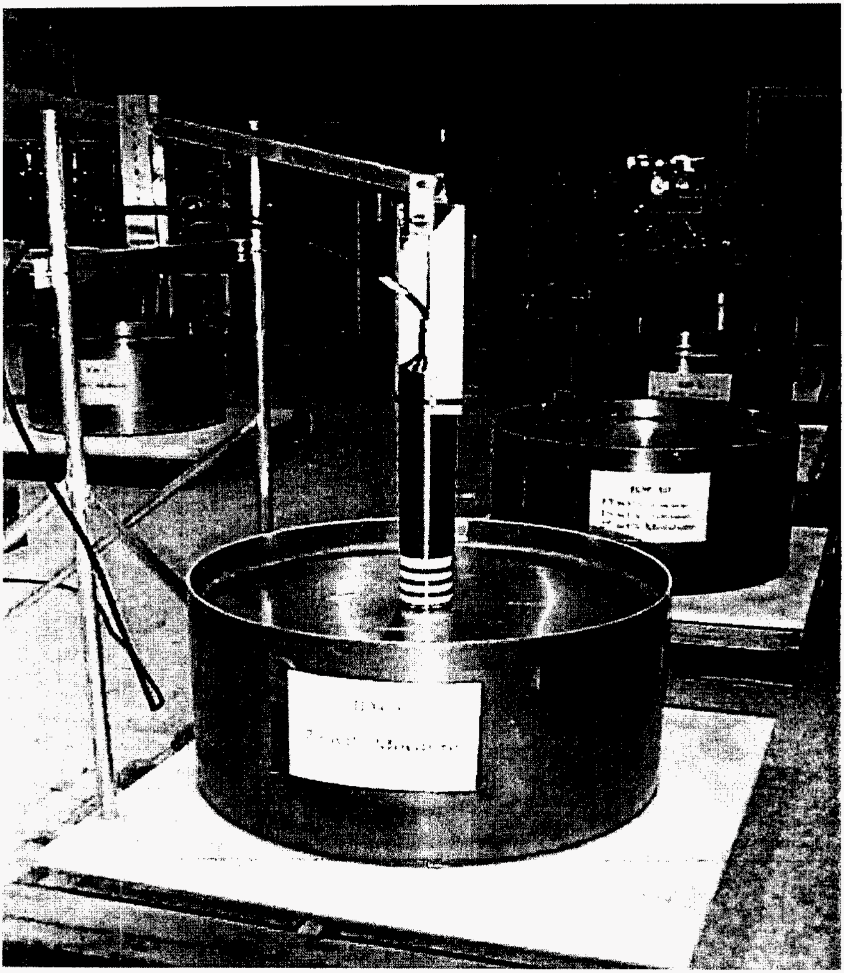
With the probe positioned on a given moisture standard, total neutron counts were simultaneously accumulated from each detector for a preset live time. The signals are counted by an EG&G Ortec Model 919 Spectrum Master Multichannel Buffer (MCB). This MCB will simultaneously process the pulses from up to 4 detectors. The MCB allows the user to set a hardware LLD level and then it collects all signals above this threshold. The signals are stored as a function of pulse height.

Signals from detectors 1 and 2 are transmitted from the probe to the enclosure electronics on the same line, one as a positive pulse and the other as a negative pulse. A small fraction of the pulses from these two detectors will be partially coincident. These pulses may nearly cancel one another and will likely, therefore, not be counted. An estimate of the coincidence rate can be obtained from

$$Coincidence\ Rate = \frac{(w_1 + w_2) * (f_1 + f_2)}{2}$$

where w is the average pulse width and f is the average pulse frequency from detector 1 or 2. Given pulse widths of about 10 microseconds and expected counting rates of about 100 per second, a coincidence rate of about 0.2% is expected. This loss of counts from each detector is small and will

Figure 5-5. Photograph Showing the Probe Placed upon Moisture Standard 6 for a Measurement.



be partially corrected for by the calibration technique in which the computer model is adjusted to match the measured results.

### 5.2.2 Comparison of Experimental Measurements with Computer Modeling Predictions

Computer modeling of detector responses was performed using the Monte Carlo N-Particle (MCNP) code (LANL 1994). This code uses the best available neutron interaction cross sections, exact physics treatment of interactions, and exact user-defined materials and geometries to track the history of a relatively large sample of neutrons produced by the system. The final output of the model provides expected neutron capture rates in the boron-10 lining of each detector. Because of the many mechanical dimensioning tolerances in the probe design and because all neutrons absorbed in each detector lining will not produce a signal pulse that exceeds the LLD settings, the computer modeling predictions are not expected to provide exact matches with observed detector counting rates. Predicted neutron absorption rates should be greater than observed counting rates. However, it was expected that the computer modeled predictions for each detector in each probe could be scaled by an appropriate constant factor so that the modeling predictions for each detector would be in good agreement with measured responses for all experimental arrangements.

The model geometry is very similar to the actual as-built probe. The primary differences between the two include the omission both of most wires (and their surrounding insulation) and of circuit board components. It would be difficult to correctly model either the geometry or materials for each of these items, and it was assumed that they make a negligible contribution to the detector responses. Appendix I provides a copy of the MCNP model input file for the probe on moisture standard 4 and sufficient information to reproduce the input files for the other models. The model assumes that neutrons are isotropically emitted from the $^{252}$Cf source with an energy distribution defined by the Watt Fission Spectrum (LANL 1994):

$$f(E) \ = \ 3.47*10^{7} * \exp(\frac{-E}{1.025}) \ * \ \sinh(2.926 * E)^{1/2}$$

where E is the emitted neutron energy (MeV) and $3.47*10^{7}$ is the neutron emission rate ($s^{-1}$). For determining the detector neutron capture rates, the calculated neutron absorption rates are for the sum of the following reactions in the active region portion of the $^{10}$B lining of each detector:

$$n + {}^{10}B \ \rightarrow \ \alpha + {}^{7}Li$$

$$or$$

$$n + {}^{10}B \ \rightarrow \ 2\alpha + {}^{3}H \ .$$

In the detector an average fraction of all neutron capture events produces enough ionization in the fill gas to cause a large electrical signal to be collected by the anode over a very short time period. The signal height is proportional to the energy deposited in the gas by the reaction products and is unrelated to the energy of the captured neutron.

One parameter in the computer model that significantly affects the predictions is the thickness of the boron coating on the inside of the detector cathode. For our detectors (GE Reuter-Stokes Model RS-P7-402-202 and Model RS-P7-402-203) the boron coating is deposited at a rate of 0.4 mg/cm$^2$ (±15%). This is equivalent to a thickness of 0.00007 ± 0.00001 inches. Modeling was performed to assess the sensitivity of the computer model to changes in the thickness of the coating. For coating thicknesses near those used in our detectors the predicted detector response increased linearly with coating thickness. This result indicates that the coating is not providing significant self-shielding to thermal neutrons and that small differences in the coating thickness should be accounted for by the constant factor applied to the predicted results for each detector. MCNP does not provide a way to model the interactions of the neutron capture reaction products in the boron lining and detector gas to obtain absolute expected counting rates.

All experimental data presented in this report was post processed using the Curvecut code (version 1.0, 07/29/96) to determine a count rate for each detector from the MCB data obtained for each detector. Curvecut uses the falloff rate of the data after the peak in the middle of the neutron capture signal spectrum to locate a reference position in the spectrum. This reference position is used to locate a software controlled lower level discriminator (LLD) level for each detector. This LLD, which located a constant voltage below the reference position, will automatically adjust with small changes in the overall signal gain, maintaining the post processed count rate. A LLD is needed to exclude electrical noise and gamma-ray interference from being counted as part of the neutron capture signal.

Figures 5-6 through 5-14 show comparisons of the model predicted and experimentally measured detector responses to the 16 moisture standards for the detectors in all three probes. For both the modeled and experimental data the plotted count rates have been altered by subtracting the modeled or experimentally measured background count rate. This background count rate was measured by hanging the probe in the center of a large, mostly empty room, (about 12 feet from the floor and ceiling) and was predicted by modeling the probe surrounded with 1 meter of air. As well as subtracting background count rates, a multiplicative correction factor has been applied to the model data, as a whole, for each detector in each probe. Each multiplicative correction factor was determined by performing a least-squares fit between the experimentally measured and factor-corrected model data and adjusting the correction factor until the least-squares sum was minimized. After application of the correction factors, the agreement between the modeling and the experimental arrangements is quite good for all three detectors in each probe.

Since the results from all three detectors will be combined to produce moisture interpretations, small errors in the modeling predictions for one detector will sometimes be partially corrected by the other two detectors. For the calibration measurements, it appears that the most significant and somewhat consistent disagreement occurs for the highest moisture concentration standard (35 wt% moisture standard 6). This standard consists of pure hydrated alumina, making errors in the composition or moisture concentration used for the modeling very unlikely. Detectors 1, 2, and/or 3 (in all three probes) experimentally produced a lower count rate than is predicted by the computer model for this standard. Both detectors 2 and 3 exhibit decreased responses relative to computer

Figure 5-6. Comparison of Experimentally Measured and Computer Model Predicted Responses from Probe 1 Detector 1 to Each of the 16 Moisture Standards.

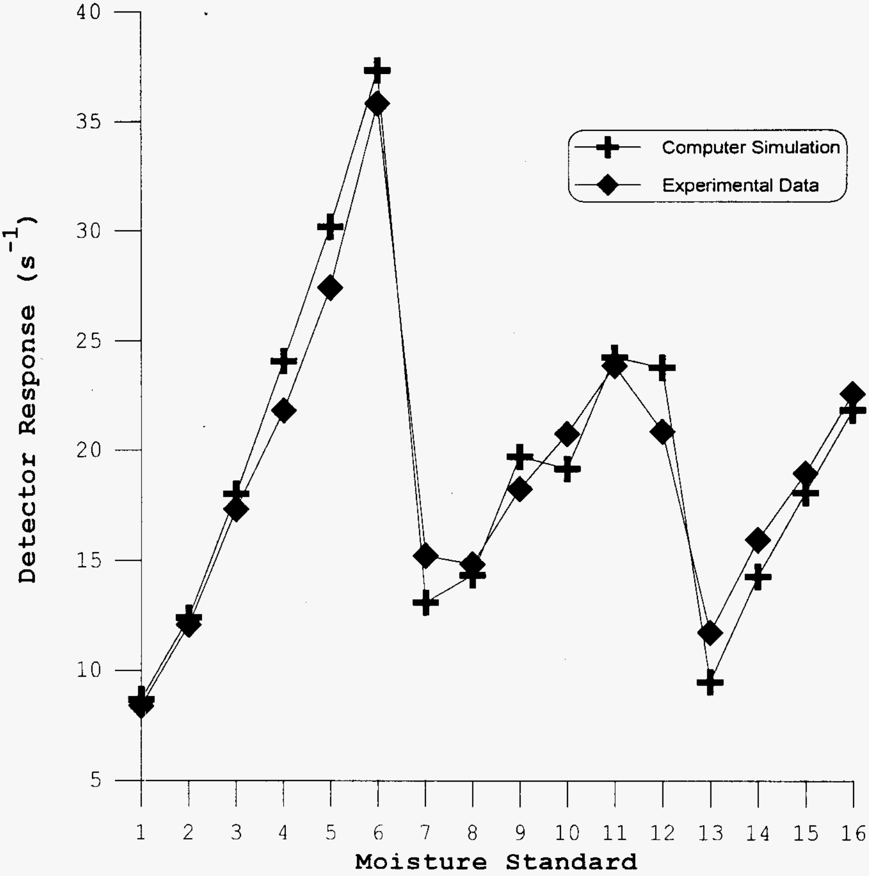


Figure 5-7. Comparison of Experimentally Measured and Computer Model Predicted Responses from Probe 1 Detector 2 to Each of the 16 Moisture Standards.

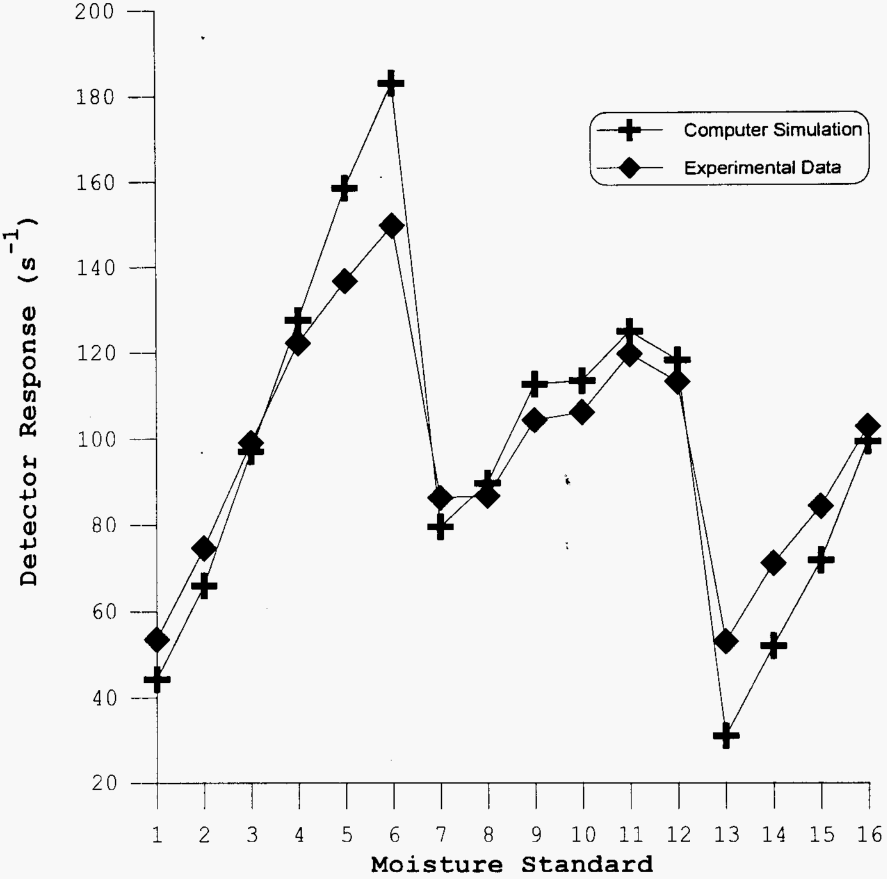


Figure 5-8. Comparison of Experimentally Measured and Computer Model Predicted Responses from Probe 1 Detector 3 to Each of the 16 Moisture Standards.

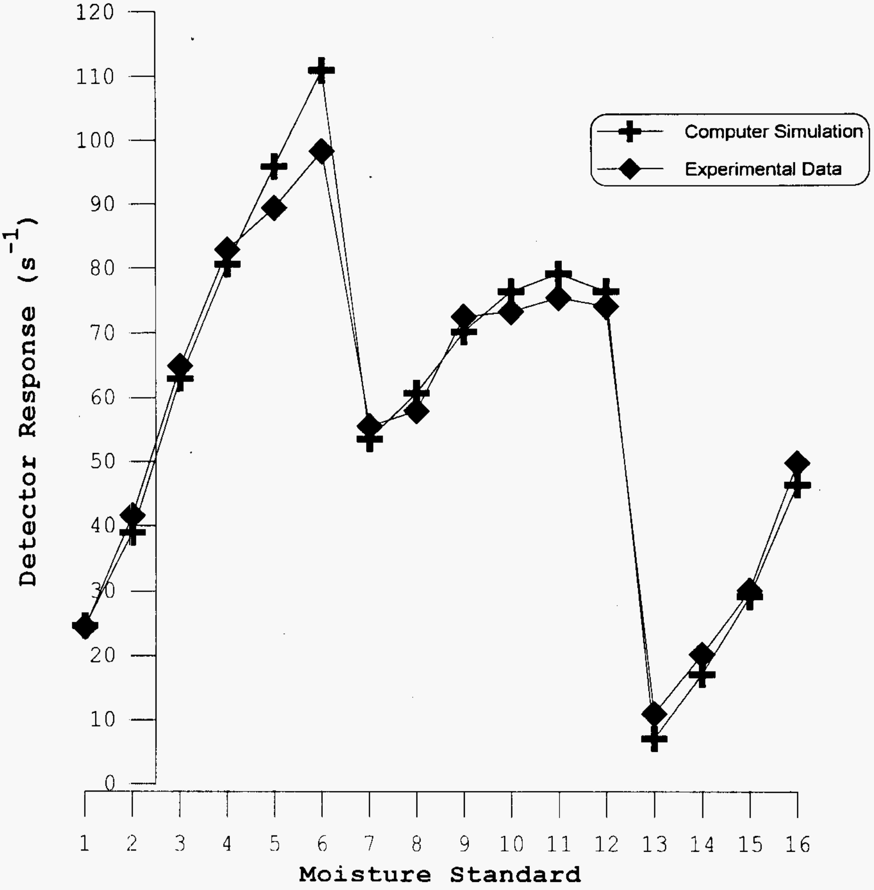


**Figure 5-9. Comparison of Experimentally Measured and Computer Model Predicted Responses from Probe 2 Detector 1 to Each of the 16 Moisture Standards.**

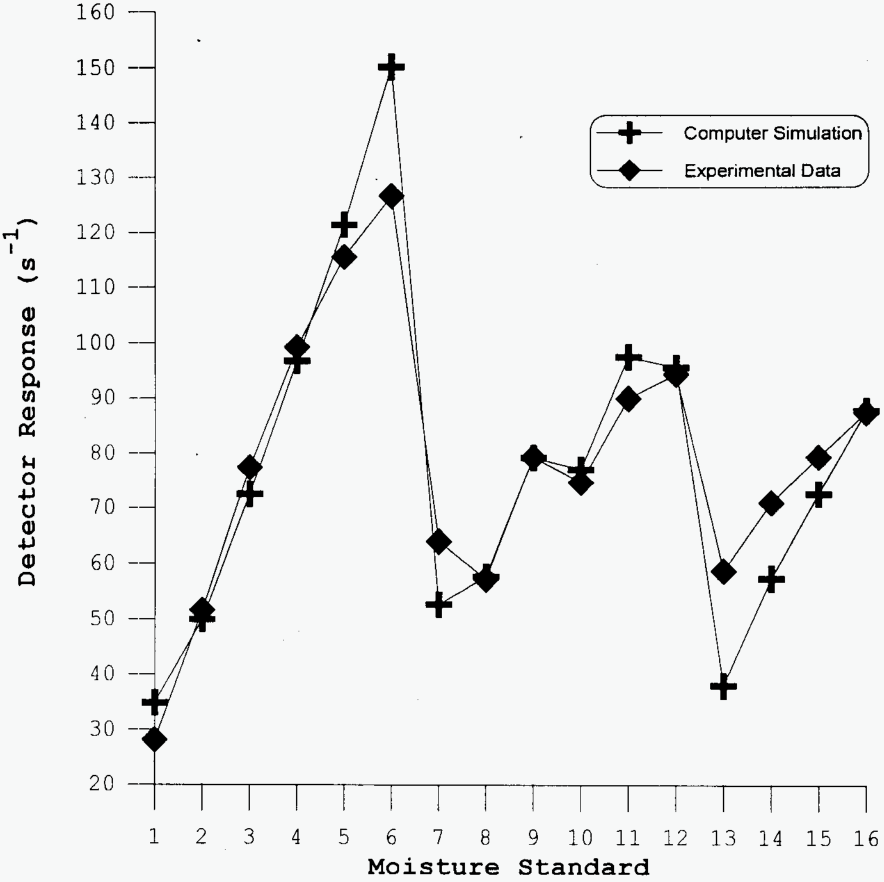


**Figure 5-10. Comparison of Experimentally Measured and Computer Model Predicted Responses from Probe 2 Detector 2 to Each of the 16 Moisture Standards.**

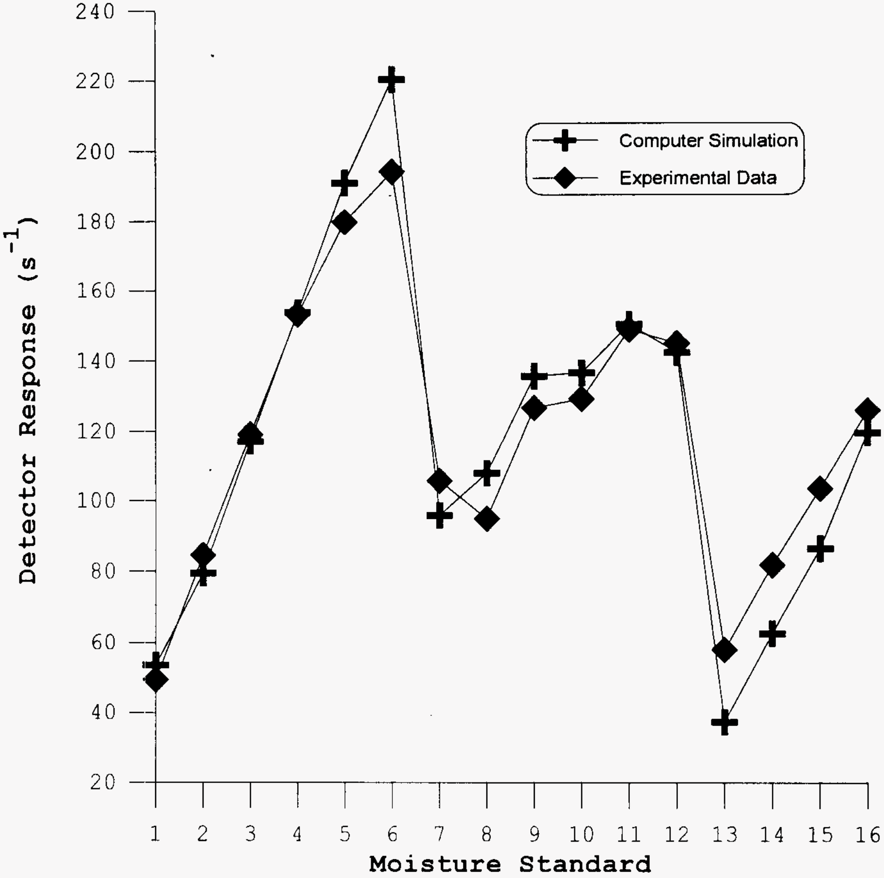


Figure 5-11. Comparison of Experimentally Measured and Computer Model Predicted Responses from Probe 2 Detector 3 to Each of the 16 Moisture Standards.

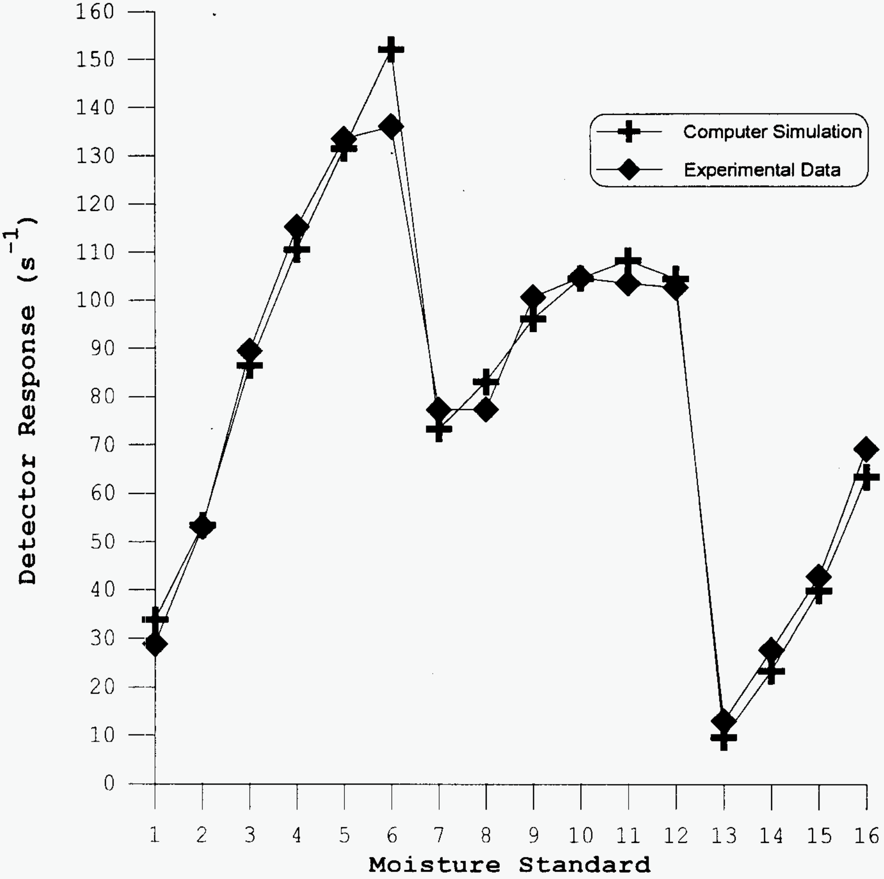


Figure 5-12. Comparison of Experimentally Measured and Computer Model Predicted Responses from Probe 3 Detector 1 to Each of the 16 Moisture Standards.

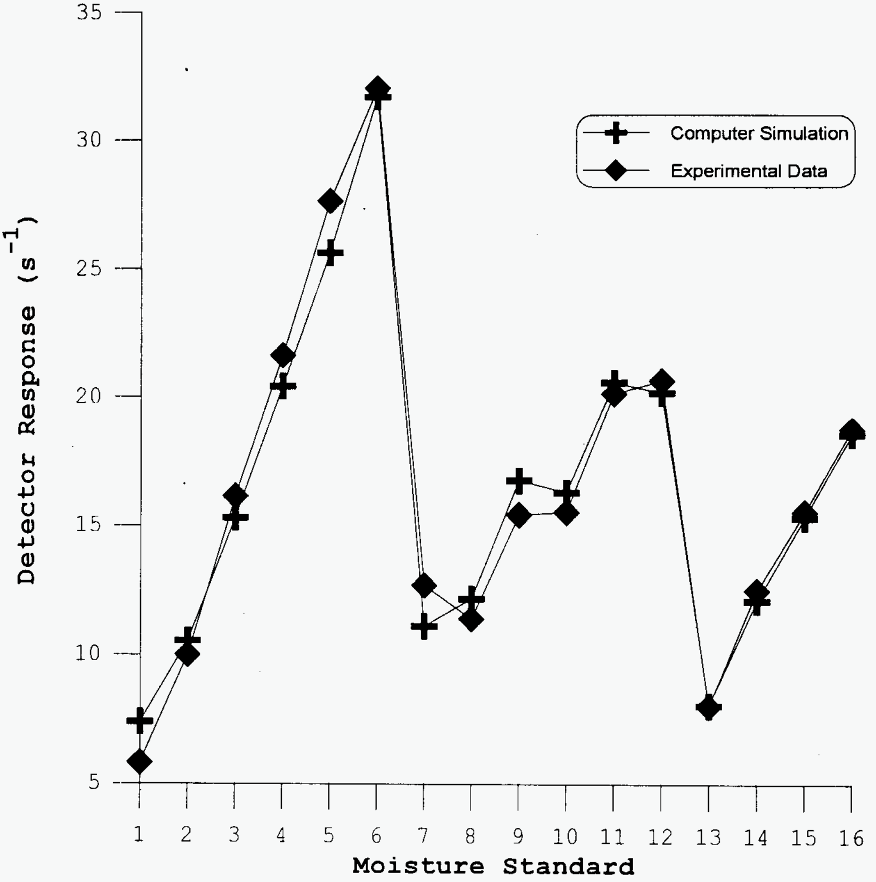


Figure 5-13. Comparison of Experimentally Measured and Computer Model Predicted Responses from Probe 3 Detector 2 to Each of the 16 Moisture Standards.

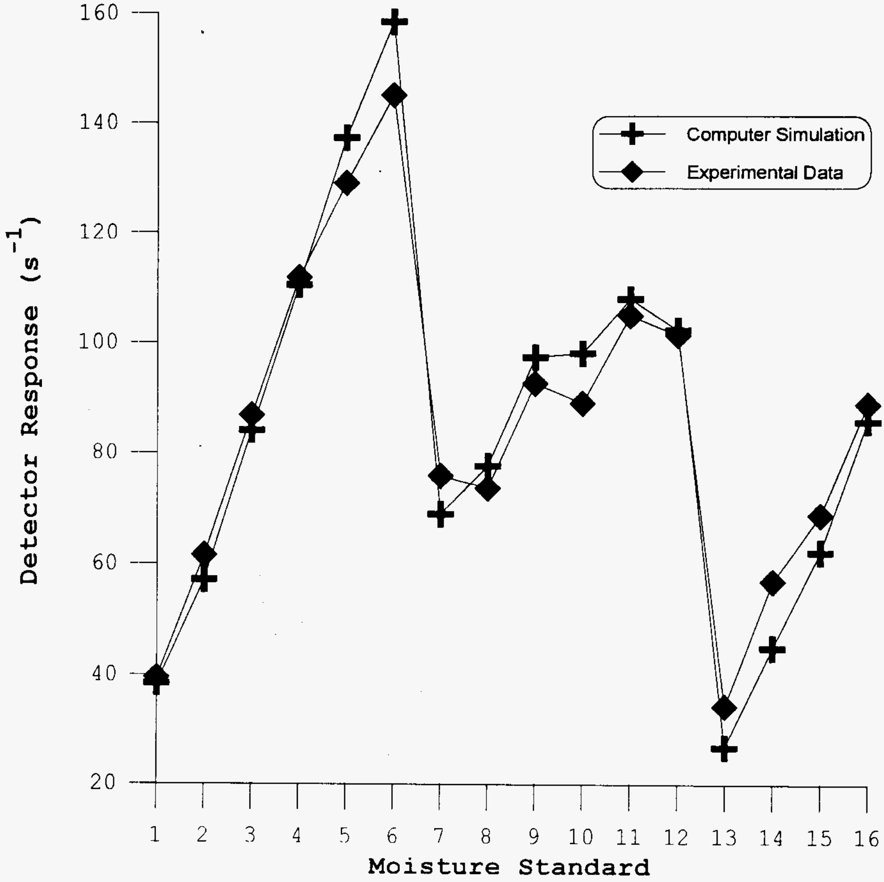
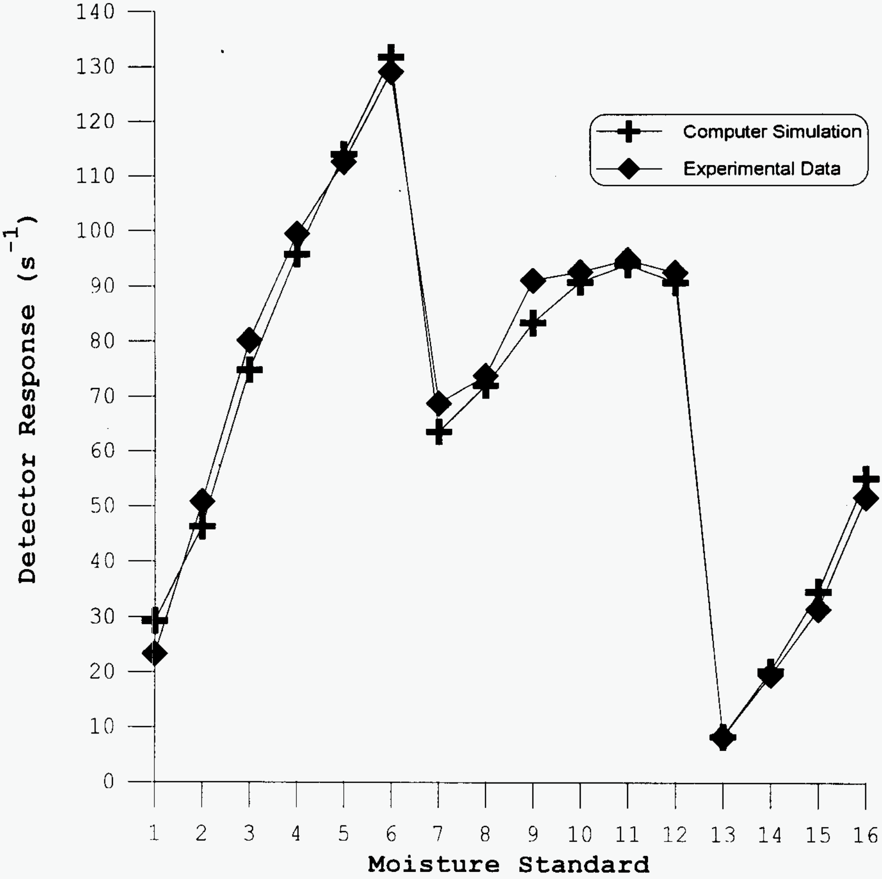


Figure 5-14. Comparison of Experimentally Measured and Computer Model Predicted Responses from Probe 3 Detector 3 to Each of the 16 Moisture Standards.



predictions for probe 1. For probe 2, all three detectors exhibited decreased responses to this standard when compared with predictions. While for probe 3, only detector 2 exhibits a decreased response relative to computer predictions from this standard. The computer model used for each probe is identical. Data obtained with the probes in their final configuration using the actual deployment system electronics compared much more favorably with the computer model predictions (see figures 5-16 through 5-18). It is not clear what changes in the individual model for each probe could be altered to obtain better agreement with the measured results for this standard while maintaining the excellent agreement with most of the other data. Because this measured data was not used to obtain the final calibration of the probes, this unexplained discrepancy is of no consequence.

Moisture standards 7 through 10 are composed of multiple moisture layers in an effort to simulate an increasing moisture concentration gradients near the surface. These standards should give an indication of the investigation depth of each detector while demonstrating the sensitivity of the set of three detectors to a moisture gradient. Simple comparisons of measured results are complicated by the fact that the thicknesses and the bulk densities of the various layers are not the same. Not considering those details, one expects that the standards with the higher moisture concentrations will produce increased responses from all detectors. In general, this trend is evident for the detectors in each probe. It is also expected that detector 3 will exhibit a response closest to that measured for moisture concentration in the bottom layer. This trend can be seen for probe 1 results, for example, from moisture standard 10. The three detector responses on this standard, as a fraction of the responses on standard 5 (25 wt% water), increase from about 75% to about 82% from detector 1 to 3.

Moisture standards 13 through 16 consist of single moisture concentration matrices of increasing thickness. These standards give a clearer indication of the depth of investigation for each detector. Figure 5-15 shows a comparison of the fraction of the total signal (obtained from moisture standard 4) between modeled and measured results for probe 3 on standards 13 through 16. Detector 1 returns a larger fraction of its total signal for the thin layer standards than does detector 2. This indicates that most of the signal returning to detector 1 results from neutrons that have primarily traveled and interacted only in the top several centimeters of material. Adding additional moisture containing material does not increase the detector 1 signal as significantly as it does for detectors 2 and 3. The detectors and their shielding was specifically designed to produce this effect so that information about the moisture gradient near the material surface might be obtained.

For convenience, all tests and calibration measurements described above were performed using a replica of the electronics found in the deployment system mast head. This replica was identical to that found in the actual deployment system except that it lacked the same cable lengths and slip rings and would, of course, contain components that varied, within tolerances, in performance. Final experimental measurements were obtained on moisture standards 1 through 6 using the actual deployment system cabling and electronics for each probe. The data was measured on June 17, 18 and 26, 1996. These measurements were obtained with the probes in final configuration, including modifications such as the addition of the tungsten ballast. Detector response rates, measured by the

Figure 5-15. Comparison of Experimental and Modeled Detector Responses to Increasing Thickness of 19 wt% Moisture Material Beneath Probe.

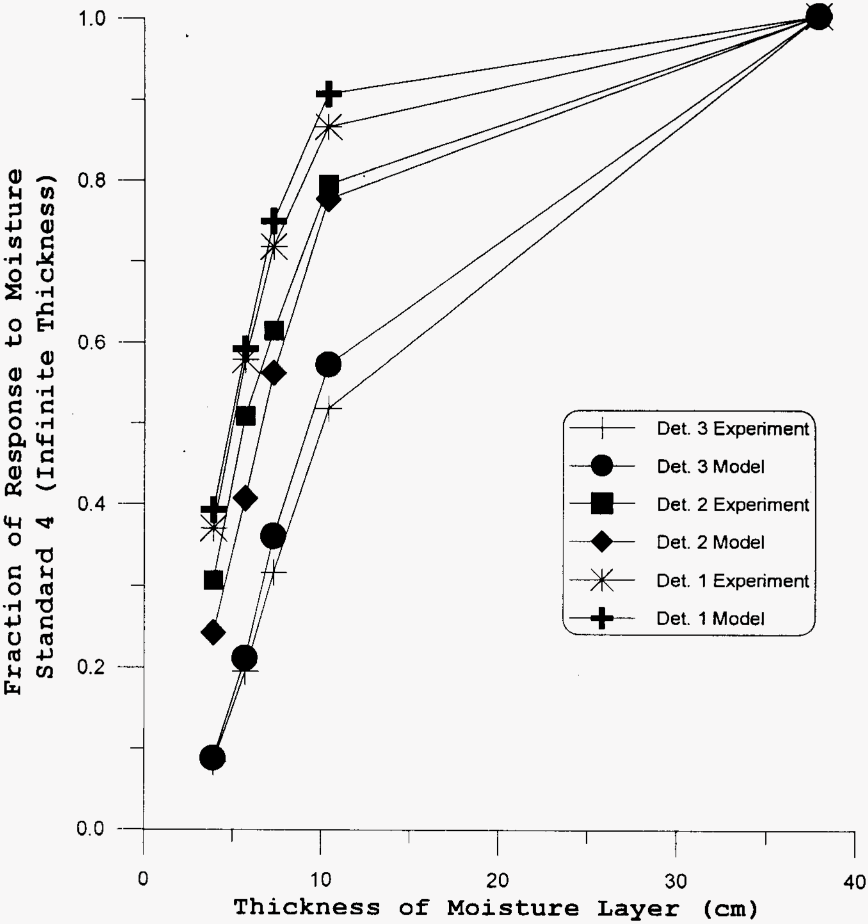


Figure 5-16. Comparison of Final Calibration Data Obtained Through SMMS Deployment System with Computer Modeling for Detector 1 in Each Probe.

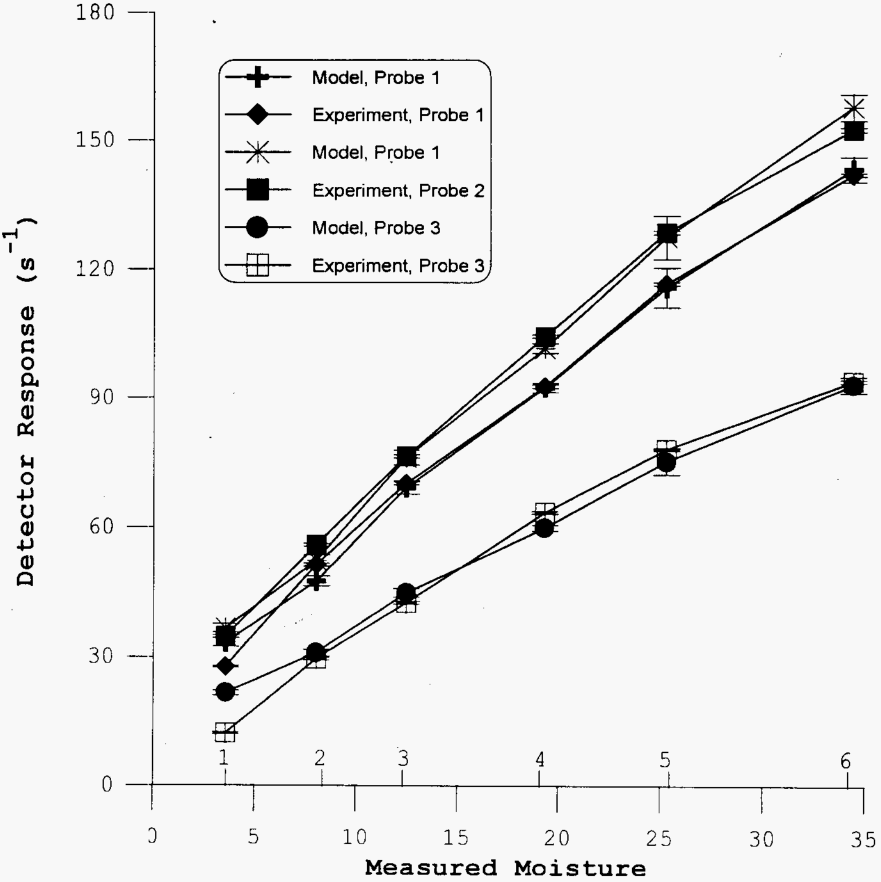


**Figure 5-17. Comparison of Final Calibration Data Obtained Through SMMS Deployment System with Computer Modeling for Detector 2 in Each Probe.**

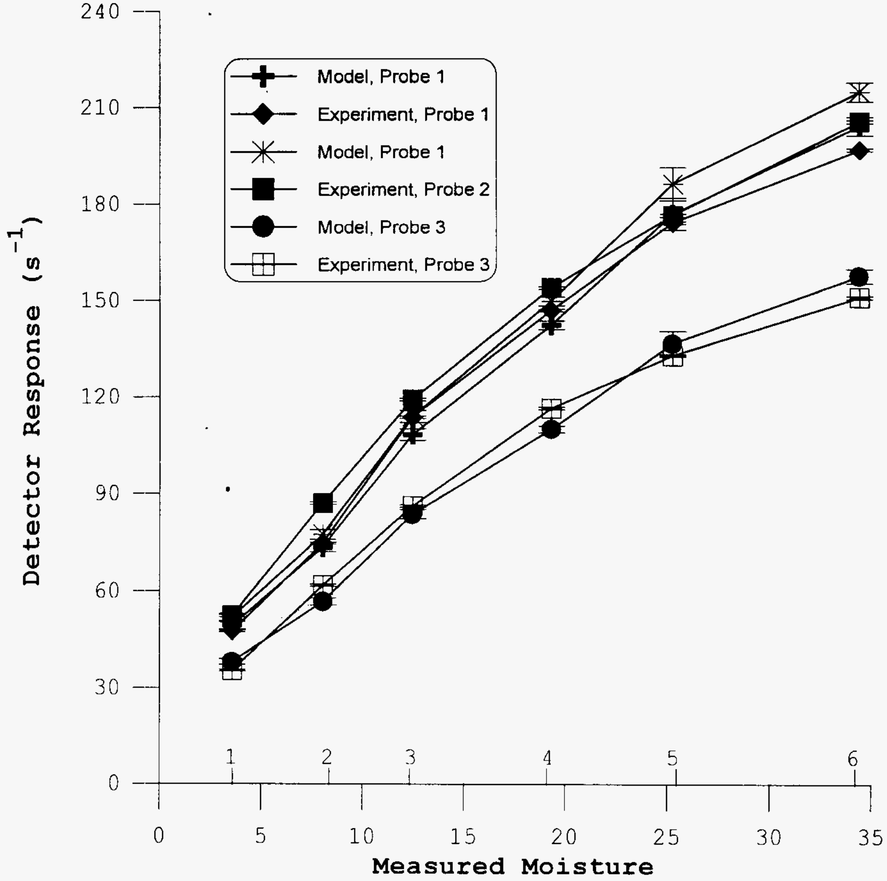
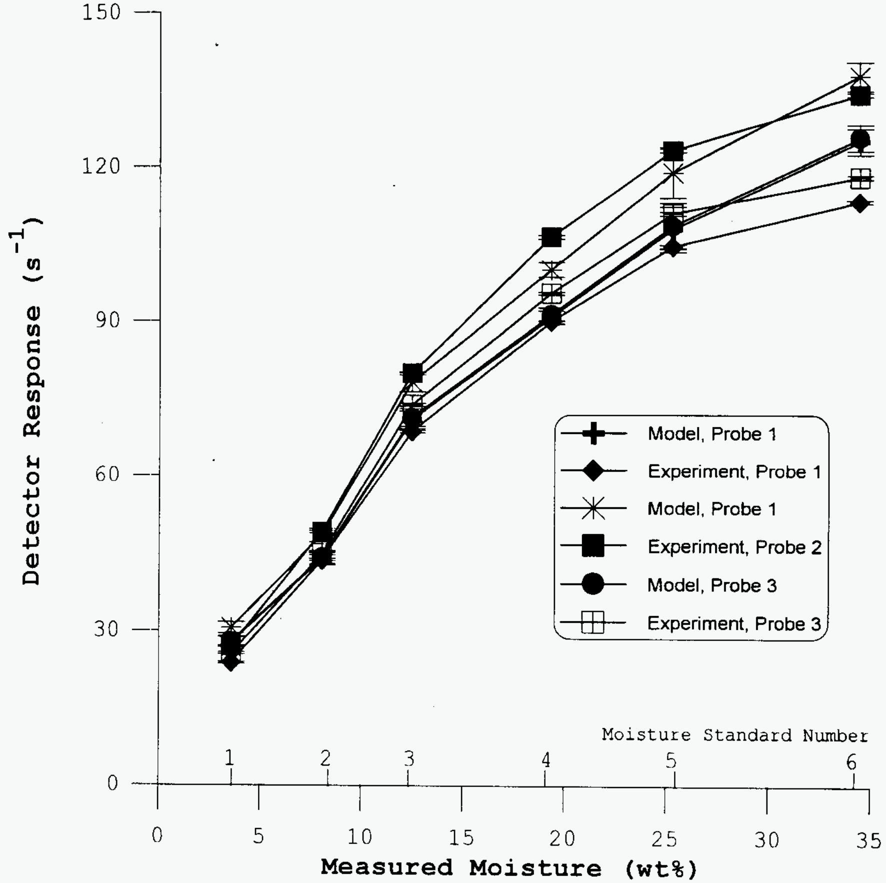


Figure 5-18. Comparison of Final Calibration Data Obtained Through SMMS Deployment System with Computer Modeling for Detector 3 in Each Probe.



data acquisition system after being routed through the deployment system, were similar to those collected through the replica. The computer model predictions were fitted to the data collected through the deployment system as described in a previous paragraph. Figures 5-16 through 5-18 show the comparison between these final measurements and the fitted modeling predictions for each detector in each probe. Table 5-9 lists the correction factor applied to each detector in each probe that provided the best agreement between experimentally measured and computer model predicted results. These final values for the correction factors will be used to correct modeling results for proper interpretation of in-tank measurement data. The correction factors average to about 0.2, indicating that, based upon the computer predictions, roughly 20 percent of the neutrons captured by the detector deposit enough energy in the detector gas to produce a signal above the LLD. Appendix J contains all Curvecut analysis outputs for the final calibration data plotted in figures 5-16 through 5-18.

Table 5-9. The correction factor applied to the computer modeled predictions for each detector in each probe that provided the best agreement between experimentally measured and computer model predicted results.

| Probe | Detector | Correction Factor |
|---|---|---|
| 1 | 1 | 0.182 |
| 1 | 2 | 0.191 |
| 1 | 3 | 0.223 |
| 2 | 1 | 0.200 |
| 2 | 2 | 0.201 |
| 2 | 3 | 0.246 |
| 3 | 1 | 0.118 |
| 3 | 2 | 0.147 |
| 3 | 3 | 0.225 |

### 5.2.3 Standard Estimate of Error

The data from probe 2, presented in table 5-11, was analyzed in order to obtain an estimate of the expected moisture measurement accuracy for the probe. The computer predicted detector responses for probe 2, plotted as a function of the moisture concentration (figures 5-16, 5-17, and 5-18), were each least-square-fitted with a second order polynomial. These polynomials provide relationships between each probe detector response and the moisture concentration. The measured probe detector responses for moisture standards 1 through 6 were then used in these relationships to obtain individual moisture concentration predictions. The sample standard deviation was calculated between the fitted curve and the model predicted detector response rates for each detector. The standard deviation in detector count rate was entered into the curve fit equations to determine a corresponding standard deviation in moisture for each detector. These moisture standard deviations (wt%) are functions of the moisture concentration and were empirically represented by the following equations:

$$\sigma_{M_{det1}} = 0.0055 * M + 0.377$$
$$\sigma_{M_{det2}} = -0.0004 * M^2 + 0.039 * M + 0.432$$
$$\sigma_{M_{det3}} = -0.0012 * M^2 + 0.104 * M + 0.602$$

where M is the moisture concentration (wt%). These uncertainties for each detector may be reduced for the in-tank interpretation by modeling more moisture responses to give more points for the detector moisture response curve fits.

Error was introduced into the calibration by uncertainty in the moisture concentration and density of the moisture calibration standards. An estimate of the uncertainty in the calculated moisture concentration for each standard was obtained from known uncertainties in the measurements of the weights of added constituents and from an estimate in the uncertainty of the moisture concentration of the hydrated alumina. The manufacturer provided two sample measurements (taken from large batches) of the moisture concentration of the hydrated alumina, both measurement results were 34.8 wt% water. The theoretical water concentration of pure, dry aluminum trihydrate is 36.6 wt%. Two measurements of the pure hydrated alumina made by WHC contained 34.47 and 34.69 wt% water. A conservative estimate of the uncertainty in the hydrated alumina moisture concentration was assumed to be 0.25 wt%. For moisture standards 1 through 6 the uncertainties in the densities (table 5-5) are about 0.03 percent and will have a negligible effect upon the hydrogen content. Standard propagation of error was used to determine the uncertainty in the calculated moisture concentration for moisture standards 1 through 6 as a function of the moisture concentration. The moisture uncertainty (wt%) was empirically fit by a linear relationship given below.

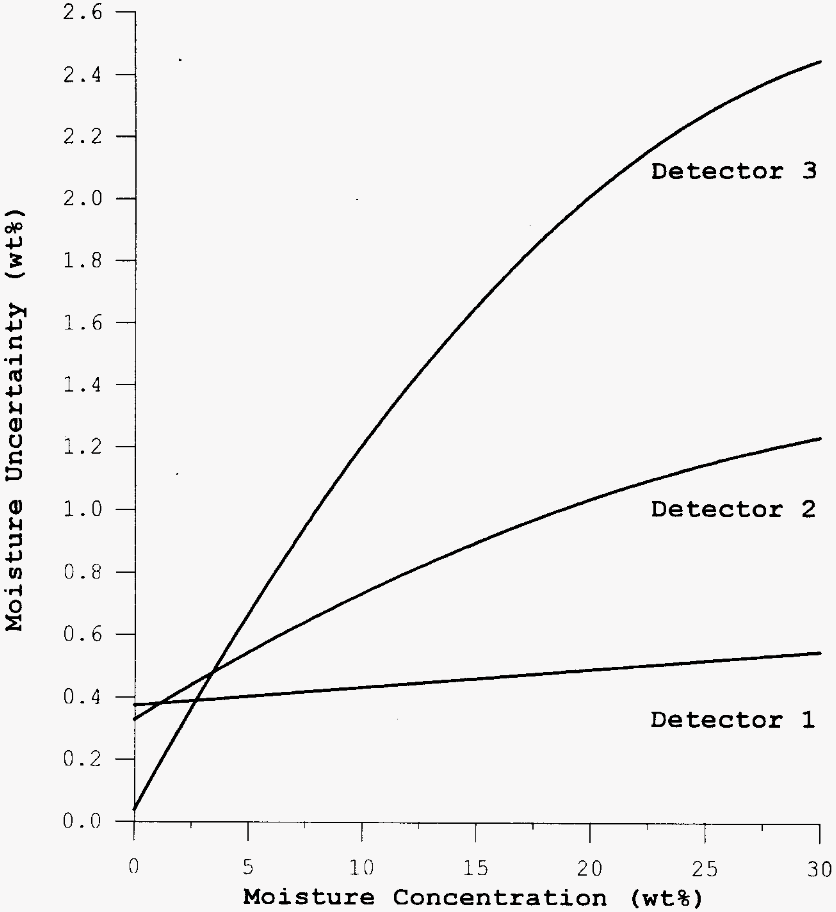
$$\sigma_{M_{standards}} = 0.0072 * M + 0.0018$$

The uncertainty in the moisture concentration from the computer fitting and the uncertainty from the moisture standards are independent and may be combined by adding in quadriture. The results, empirically fitted for each detector and presented below, are representative of the total known uncertainty in the individual detector responses to moisture.

$$detector\ 1: \quad \sigma_M = 0.0072 * M + 0.37$$
$$detector\ 2: \quad \sigma_M = -0.0004 * M^2 + 0.0413 * M + 0.37$$
$$detector\ 3: \quad \sigma_M = -0.00012 * M^2 + 0.1046 * M + 0.60$$

Figure 5-19 shows these combined uncertainties plotted as a function of moisture concentration over a range from 0 to 30 wt% moisture. Each of these individual detector moisture response uncertainties remains below 3 wt% for this range of moistures.

Figure 5-19. The Moisture Measurement Uncertainty of each Detector Derived from the Uncertainties in the Moisture Standards and from Deviations in the Computer Calculated Response Predictions from Measured Responses.



Combining the responses from the three probes to obtain a best estimate of moisture concentration and gradient, as a function of depth, should increase the confidence in a given moisture measurement. How well the measured responses match model predicted response curves for the best moisture solution will indicate a confidence interval on a given moisture interpretation. Other than individual detector response uncertainty to moisture, the confidence interval will be affected by how well the modeling assumptions match the actual conditions.

Material properties that could effect the probe responses include waste bulk density, hydrocarbon concentration, moisture distribution or gradient, and the geometry or arrangement of waste materials near the probe. The uncertainty introduced into the moisture interpretation by these properties will be estimated based upon available in-tank information. Sampling has provided indications of the range of bulk densities to be expected (WASTREN 1993), and computer modeling will be performed to assess the uncertainty introduced by this property. Hydrocarbon or organic concentrations are expected to be relatively low in the tanks, but would systematically bias the moisture interpretations above actual moisture concentrations. Modeling has indicated that, for the organics likely to be present in the waste tanks of interest, the moisture interpretation would be about 2/3 wt% above actual for each 1 wt% organic present. Given information about the organic concentration, the moisture prediction could be corrected. The moisture distribution or gradient near the surface of the waste could affect the moisture interpretation, because we must assume a type of gradient in our modeling. We plan to assume linear gradients are the only ones possible, and if, for example, the moisture increased exponentially near the surface, then our model would only approximate the actual conditions and would introduce uncertainty. This uncertainty would likely decrease the goodness of fit of the measured responses to the best fit moisture. Finally, if measurements are made near waste material geometry anomalies, such as large waste hills or canyons, systematic uncertainties will be introduced into the measured data. For the data to be unaffected by waste geometry, the probe measurements will need to be made at locations where the waste is relatively flat and smooth with no large cracks under the probe and no large waste mounds within about 25 cm of the probe. Visual data obtained from the in-tank video during data acquisition will enable WHC to estimate the uncertainties introduced by waste geometry. Final estimates of the moisture interpretation uncertainties will have both well understood uncertainties on the moisture from the calibration technique and bounds placed upon those uncertainties given different assumed errors in the material properties.

## 6.0 CONTINUING WORK AND IN-TANK DATA INTERPRETATION

The surface of the in-tank waste is known to be irregular in shape. While some portions of the waste surface are expected to be relatively flat over at least small areas, significant surface irregularities will be encountered. In order to help test directors choose the best locations for moisture measurements, computer modeling has been performed to estimate the perturbation upon measured moisture concentrations for many different types of possible surface irregularities. Several simple experimental tests are planned to confirm the modeling results. The modeling predictions and the experimental tests will be formally documented. The results should summarize which type of surface anomalies produce the largest perturbation of measurements and, therefore, should be avoided. Also, the spacing needed between a measurement site and such an anomaly to nearly eliminate its effects upon measurement results will be included.

In-tank probe deployment is currently planned for tank 241-BY-110 in August, 1996. In order to interpret the measurements obtained from this tank, extensive computer modeling of the detector responses to the expected waste material must be performed. We plan to model best estimate salt cake composition material at a bulk density of 1.5 g/cm$^3$ for many different moisture concentrations and linearly increasing moisture gradients (with depth). This density value is very near the average density expected for sludge or salt cake wastes in the Hanford tanks (WASTREN, 1993). Table 6-1 shows the planned salt cake composition to be used in the computer model for 15 wt% water concentration. Other moisture concentrations matrices will be produced by maintaining the relative concentrations of the listed compounds while increasing or decreasing the water concentration. The predicted responses provided by this modeling will be assembled into a library of benchmark data that the Tank Moisture and Anomaly Detection (TMAD) code will utilize to help provide best interpretation of the moisture concentrations from measured data (Finfrock, 1995). The TMAD code will be used to aid scientists in determining the best fit of actual measured responses to predicted responses for possible moisture conditions. Before TMAD can be used, corrections for accumulated probe exposure and source decay may need to be applied. A report will be issued by Nuclear Analysis and Characterization that analyzes all available data obtained from the tank and provides best estimate moisture concentrations and gradients for each measured surface location.

Table 6-1. Example chemical composition planned for generation of computer modeled detector responses to in-tank materials (15 wt% moisture).

| Compound | Concentration (wt%) |
|---|---|
| $H_2O$ | 15 |
| $Na_3AlO_3$ | 6.6 |
| $NaOH$ | 0.8 |
| $Na_2SiO_3$ | 1.3 |
| $Fe(NO_3)_3$ | 1.6 |
| $Na_3PO_4$ | 0.7 |
| $Ca(NO_3)_2$ | 0.5 |
| $NaNO_3$ | 76 |
| $Mg(NO_3)_2$ | 0.2 |
| $Mn(NO_3)_2$ | 0.2 |

## 7.0 CONCLUSIONS

Three surface moisture measurement neutron probes have been fabricated, thoroughly tested in expected in-tank conditions, and calibrated to moisture concentrations. Measurements have been completed that will allow us to make good estimates of in-tank surface moisture concentrations. Tests demonstrate that the probe will function properly in possible extreme tank environmental conditions including simultaneous high temperature (80 C) and high gamma exposure rate fields (210 rad/hr). Changes in both probe temperature from -10 to 80 °C and probe gamma exposure rate from 0 to 210 rad/hr have negligible effects upon detector responses. However, corrections to the measured data will be needed to account for probe voltage supply circuit degradation due to accumulated gamma exposure above $10^4$ rad.

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## APPENDIX A PROBE ASSEMBLY TESTING AND CONFIGURATION

### A.1 Initial Probe Checkout Tests

The following informal procedure contains the tests used to verify the operability of assembled probes. After initial testing of the first assembled probe, the calibration values for charge sensitive preamplifiers were returned to values that had been used with the prototype probe assembly. The procedure was then revised to allow testing of the probe printed circuit boards as an integrated unit rather than individually. This procedures shows that the temperature conversion circuit is very linear and the offset voltage is less than 2 mV or accounts for a 0.2 °C temperature offset. The temperature offset is low enough that it can be ignored.

This test procedure tested all four the boards in the probe. The isolation board was tested to verify its isolation networks are functional and will effectively isolate the probe cable from the energy stored in the probe. Reverse current flow prevention diodes in power circuits for the high voltage power supply (HVPS) and the low voltage power supply (LVPS) were tested for functionality. The zener diode clamps and current limiting resistors for nuclear counting pulse line drivers, COUNT1 and COUNT2 were also operationally checked. The linearity of the temperature sensor signal processing electronics was checked. The operability of the line driver pulse amplifiers was also checked. The linearity and operability of the preamplifier charge sensitive preamplifier was checked. Once the probe was fully assembled the output of all three pulse amplifiers are adjusted to provide a specific pulse amplitude with a known charge input to the charge sensitive amplifiers. The connector nomenclature used on the design drawings are used in the following procedures (WHC, 1996C, 1996D, 1996E, 1996F). Table A.1 list the measurement and test equipment used in performing these tests.

#### A.1.1 HVPS Isolation Network Forward Diode Voltage Drop Test

This test step verifies that isolation diodes are functional and not shorted or opened.

1. Connect a 5100 ohm, 1/4 watt, 5% tolerance, carbon composition resistor at HVPS output, J5 (between output and ground).

2. Apply 15 V at HVPS input, J2 (between input and ground).

3. Measure output voltage at J5, and verify voltage is less than 13.9 volts (3 diode voltage drops, 0.7 to 1.1 V per diode).

   Measured output voltage at J5 13.1 VDC

#### A.1.2 HVPS Isolation Network Reverse Current Isolation Test

This test step verifies that the isolation diodes are not shorted and will prevent a reverse current flow.

1. Connect a 24 V power supply through a 5100 ohm, 1/4 watt, 5% tolerance, carbon composition resistor to the output of the HVPS, J5.

2. Measure the voltage at the HVPS output, J5 (information only):

   Measured output voltage at J5 __19.5 VDC__

3. Measure the voltage at the HVPS input, J2. Verify voltage is less than 22 V.

   Measured input voltage at J2 __<22 V (floating)__
   *Multimeter reading was not steady and bounced around.*

4. Connect an ammeter between input and ground, J2, and measure the current. Verify current measured is less than 1 mA.

   Measured short circuit current at J2 __<0.01 mA__

### A.1.3 LVPS Isolation Network Forward Diode Voltage Drop Test

This test step verifies that isolation diodes are functional and not shorted or opened.

1. Connect a 5100 ohm, 1/4 watt, 5% tolerance, carbon composition resistor at LVPS output, J6 (between output and ground).

2. Apply 15 V at LVPS input, J1 (between input and ground).

3. Measure output voltage at J6, and verify voltage is less than 13.9 volts (3 diode voltage drops, 0.7 to 1.1 V per diode).

   Measured output voltage at J6 __13.08 VDC__

### A.1.4 LVPS Isolation Network Reverse Current Isolation Test

This test step verifies that the isolation diodes are not shorted and will prevent a reverse current flow.

1. Connect a 24 V power supply through 5100 5% carbon composition resistor to the output of the LVPS, J6.

2. Measure the voltage at the LVPS output, J6 (information only):

   Measured output voltage at J6 __19.65 VDC__

3. Measure the voltage at the LVPS input, J1. Verify voltage is less than 16 V.

   Measured input voltage at J1 <16 VDC (floating)
   *Multimeter reading was not steady and bounced around.*

4. Connect an ammeter between input and ground, J1, and measure the current. Verify current measured is less than 1 mA.

   Measured short circuit current at J1 < 1 mA

### A.1.5 COUNT1 Isolation Network Verification Tests

This test step verifies functionality of the 50 ohm current limiting resistor and functionality of the clamping zener diodes.

1. Connect a 20 V power supply through a 5100 ohm resistor to output, J7.

2. Measure and verify voltage at input, J3, is less than 16 V.

   Measured input voltage at J3 14.41 VDC

3. Connect a 20 V power supply through a 5100 ohm resistor to input, J3.

4. Measure and verify voltage at output, J7, is less than 16 V.

   Measured output voltage at J7 14.436 VDC

5. Measure the resistance between input, J3, and output, J7. Verify resistance is 48 to 52 ohms.

   Measured resistance between input, J3, and output, J7 50.95 Ω

### A.1.6 COUNT2 Isolation Network Verification Tests

This test step verifies functionality of the 50 ohm current limiting resistor and functionality of the clamping zener diodes.

1. Connect a 20 V power supply through a 5100 ohm resistor to output, J8.

2. Measure and verify voltage at input, J4, is less than 16 V.

   Measured input voltage at J4 14.436 VDC

3. Connect a 20 V power supply through a 5100 ohm resistor to input, J4.

4. Measure and verify voltage at output, J8, is less than 16 V.

   Measured output voltage at J8 14.45 VDC

5. Measure the resistance between input, J4, and output, J8. Verify resistance is 48 to 52 ohms.

   Measured resistance between input, J4, and output, J8 50.74 Ω

Performed by Jason Gunter/James Bussell Date 4/22/96

### A.1.7 High Voltage/Low Voltage Power Supply Board Functionality Tests

This test steps measured range adjustability of high voltage power supply and current requirements. The low voltage power supply output is measured.

General Test Conditions:

1. 16 VDC applied to power supply input leads
2. high voltage power supply measured with an electrostatic voltmeter

| | Measured Value | Acceptance Range |
|---|---|---|
| High Voltage Minimum Voltage<br>(CW on R2 - oriented as installed) | 565 VDC | 560 to 600 VDC |
| Current Draw at Min. Voltage | 9.959 mA | <12 mA |
| High Voltage Maximum Voltage<br>(CCW on R2 - oriented as installed) | 730 VDC | 720 to 760 VDC |
| Current Draw at Max. Voltage | 13.693 mA | <16 mA |
| High Voltage as Left (650 V) | 650 VDC | 640 to 650 VDC |
| Current Draw at as Left Setting | 12.24 mA | <16 mA |
| Low Voltage Output Voltage<br>(open circuit) | 11.879 VDC | 11.5 to 12.5 VDC |
| Low Voltage Power Supply Current<br>(open circuit) | 0.079 mA | <1 mA |

Performed by Jason Gunter/James Bussell Date 4/22/96

### A.1.8 Line Driver Board Temperature Sensor Signal Converter Test

General Test Conditions:

1. 11 to 13 VDC applied to power supply input leads

Test Conditions:

1. No voltage applied to detector inputs.
2. Apply input voltage between $V_{out}$ and Ground connection (5 V above circuit ground) thru holes as indicated in tables below.

Acceptance Criteria:

Output to be within 10 mV of input value (input value added to 5 V, e.g. -1 V = 4.0000 V on output)

Temperature Sensor #1:

| | | | | | |
|---|---|---|---|---|---|
| Input | -1.000 V | -0.900 V | -0.800 V | -0.700 V | -0.600 V |
| Output | 4.00158 | 4.10152 | 4.20151 | 4.30151 | 4.40150 |
| Input | -0.500 V | -0.400 V | -0.300 V | -0.200 V | -0.100 V |
| Output | 4.50149 | 4.60147 | 4.70157 | 4.80151 | 4.90149 |
| Input | 0.000 V | +0.100 V | +0.200 V | +0.300 V | +0.400 V |
| Output | 5.0146 | 5.10146 | 5.20156 | 5.30148 | 5.40141 |
| Input | +0.500 V | +0.600 V | +0.700 V | +0.800 V | +0.900 V |
| Output | 5.50140 | 5.60138 | 5.70138 | 5.80137 | 5.90137 |
| Input | +1.000 V | | | | |
| Output | 6.00135 | | | | |

**Temperature Sensor #2:**

| | | | | | |
|---|---|---|---|---|---|
| Input | -1.000 V | -0.900 V | -0.800 V | -0.700 V | -0.600 V |
| Output | 4.00139 | 4.10138 | 4.20137 | 4.30136 | 4.40136 |
| Input | -0.500 V | -0.400 V | -0.300 V | -0.200 V | -0.100 V |
| Output | 4.50135 | 4.60133 | 4.70133 | 4.80132 | 4.90132 |
| Input | 0.000 V | +0.100 V | +0.200 V | +0.300 V | +0.400 V |
| Output | 5.00132 | 4.10131 | 5.20130 | 5.30130 | 5.40128 |
| Input | +0.500 V | +0.600 V | +0.700 V | +0.800 V | +0.900 V |
| Output | 5.50128 | 5.60127 | 5.70127 | 5.80126 | 5.90125 |
| Input | +1.000 V | | | | |
| Output | 6.00124 | | | | |

### A.1.8 Line Driver Board Line Driver Amplifier Test

Test Conditions:

1. Apply a positive pulse with amplitude specified below with 1 to 2 microsecond rise time and 5 to 8 microsecond fall time.

2. Set input potentiometer (R1, R8, R11, and R18) to provide maximum signal to amplifiers (fully CCW with components side up).

Acceptance Criteria:

1. Output pulse direction is correct as indicated below.

2. Output pulse amplitude shall change by a factor of two when the input increases from 0.25 $V_{peak}$ to 0.5 $V_{peak}$. The output pulse shape of these pulses shall be same as the input pulse shape.

3 The output amplitude for 1 and 2 $V_{peak}$ pulses shall be greater than 3 $V_{peak}$. The output pulse shape may contain distortion due amplifier saturation.

| | Output at COUNT1 (J6) | | Output at COUNT2 (J7) | |
|---|---|---|---|---|
| Input Value | Input at DET1 (J1) | Input at DET2 (J2) | Input at DET3 (J3) | Input at DET2 (J4) |
| | Output Pulse is negative-going | Output Pulse is positive-going | Output Pulse is negative-going | Output Pulse is positive-going |
| 0.25 $V_{peak}$ | 0.52 | 1.0 | 0.56 | 0.72 |
| 0.50 $V_{peak}$ | 1.25 | 2.2 | 1.3 | 2.7 |
| 1 $V_{peak}$ | 2.5 | 4.4 | 2.5 | 2.7 |
| 2 $V_{peak}$ | 3.6 | 5.6 | 3.8 | 5.2 |

*DC Level Output: J6: 5.252 VDC J7: 5.225 VDC*

TEMP1 (U2) Sensor Serial No. (LASER engraved) A3

Acceptance Criteria Met (YES/NO) YES

Performed by Jason Gunter/James Bussell Date 4/22/96

### A.1.9 Final Probe Assembly Pulse Amplifier Calibration

General Test Conditions:

1. 15 to 17 VDC applied to power connection pins in probe connector

2. High voltage power supply to be turned off except as indicated below.

Test Procedure:

1. Set a pulse generator to produce a negative-going pulse with a 1 microsecond or less rise time and a fall time of greater than 500 microseconds. Set the amplitude of the pulse generator to produce a 200 mV pulse.

2. Connect a 50 ohm coaxial cable to pulse generator and connect a 5 ± 0.5 picofarad silver-mica capacitor to the center conductor of the coaxial cable.

3. Connect the shield of the coaxial cable to the printed circuit board ground plane (power supply common).

4. Connect the capacitor to the high voltage detector connection under test.

5. Measure the output of the probe output connector pin for the detector under test while monitoring the input pulse signal from the pulse generator.

6. For each respective counting channel adjust the attenuator potentiometer on the line driver board until the pulses observed on the output are nominally 1.25 $V_{peak}$ (acceptance range 1.2 to 1.4 $V_{peak}$) (positive-going or negative-going). Record as left values in table below.

7. Remove power from probe. Measure the resistance of R11 between potentiometer wiper and ground on the line driver board. Adjust potentiometer R18 until the same resistance value measured above is measured between the pontentiometer wiper and ground on the line driver board.

Acceptance Criteria:

1. Pulse amplitude with specified value under columns labeled "Pulse

Amplitude Nominal Value."

2. Pulse has 2 to 3 microsecond rise time and 4 to 8 microsecond fall time. Pulse is "smooth" with no glitches or other discontinuities.

3. Pulses are riding on a DC value.

4. DC voltage value of COUNT1 and COUNT2 correspond to the approximate ambient temperature. The DC voltage value of COUNT1 (temperature sensor located on the line driver board) will be 50 to 100 mV larger than the DC voltage value of COUNT2.

### A.1.9 Final Probe Assembly High Voltage and Low Voltage Power Supply Current Draw Measurement

1. Apply power to probe high voltage supply through connector pins L (power) and K (return). Measure and record current draw (information only) on page 2.

2. Apply power to the probe electronics through connector pins M (power) and E (return). Measure and record current draw (information only) on next page.

3. Record serial number of solid state temperature sensor, plastic package - LASER engraved on next page.

| | Detector #1<br>(bottom horizontal detector fully encased in Cadmium)<br>HV2 on Preamplifier Board | | Detector #2<br>(side vertical detector)<br>HV1 on Preamplifier Board | | Detector #3<br>(top center detector)<br>HV3 on Preamplifier Board | |
|---|---|---|---|---|---|---|
| Charge Amplifier | U2 | | U1 | | U3 | |
| Output Pulse Polarity | Negative-going | | Positive-going | | Negative-going | |
| Attenuator Pot on Line Driver Board | R1 | | R8 | | R11 | |
| Signal Name | COUNT1 | | COUNT1 | | COUNT2 | |
| Probe Connector Pin | Coaxial Connector in Pin C | | Coaxial Connector in Pin C | | Coaxial Connector in Pin G | |
| | Nominal Value | Measured Value | Nominal Value | Measured Value | Nominal Value | Measured Value |
| DC Voltage Value | Ambient Temperature in degrees Celsius x 0.01 V + 5.000 V ± 30 mV | 5.2846 | Ambient Temperature in degrees Celsius x 0.01 V + 5.000 V ± 30 mV | Same as DET1 | Ambient Temperature in degrees Celsius x 0.01 V + 5.000 V ± 30 mV | 5.22106 |
| 200 $mV_{peak}$ | 1.25 V<br>1.2 to 1.4 V | 2.5 (negative going) | 1.25 V<br>1.2 to 1.4 V | 2.5 | 1.25 V<br>1.2 to 1.4 V | 2.5 (negative going) |

Probe Amplifier Power Supply
Current Draw (information only) 30.83 mA
Probe High Voltage Power Supply
Current Draw (information only) 12.28 mA

Serial Number of Temperature Sensor in
in Detector #1 Housing, plastic package (LASER engraved) C5
Acceptance Criteria Met (YES/NO) ____
Performed by Jason Gunter/James Bussell Date 4/25/96

## A.2 Final Probe Checkout Tests

### A.2.1 HVPS Isolation Network Forward Diode Voltage Drop Test

This test step verifies that isolation diodes are functional and not shorted or opened

1. Connect a 16 V power supply to probe connector, positive to pin L (red wire from probe) and negative to pin K (black wire from probe).

2. Measure the output voltage at J5, and verify voltage is less than 14.2 volts (3 diode voltage drops, 0.6 to 1.1 V per diode).

   Measured output voltage at J5:

| Probe #1 | Probe #2 | Probe #3 |
|---|---|---|
| 13.72 V | 13.7 V | 13.66 V |

### A.2.2 HVPS Isolation Network Reverse Current Isolation Test

This test step verifies that the isolation diodes are not shorted and will prevent a reverse current flow.

1. Connect a 22 V power supply through a 100 ohm 5% tolerance 1/4 Watt carbon composition resistor to the output of the HVPS, J5.

2. Measure the voltage at the HVPS output, J5 (information only):

   Measured output voltage at J5 :

| Probe #1 | Probe #2 | Probe #3 |
|---|---|---|
| 19.94 V | 19.83 V | 20.01 V |

3. Measure the voltage at the probe connector, between pin L (red wire from probe) and to pin K (black wire from probe). Verify voltage is less than 15.2 V.

   Measured input voltage at Pins L and K:

| Probe #1 | Probe #2 | Probe #3 |
|---|---|---|
| 0.16 mV | < 2 mV | 11.47 V |

4. Connect an ammeter at the probe connector between pin L (red wire from probe) and to pin K (black wire from probe), and measure the current. Verify current measured is less than 1 mA.

Measured short circuit current at pins L and K;

| Probe #1 | Probe #2 | Probe #3 |
|---|---|---|
| 0 mA | 17.5 (?) | 0.001 mA |

*The value recorded for probe #2 appears to be erroneous.*

### A.2.3 LVPS Isolation Network Forward Diode Voltage Drop Test

1. Connect a 16 V power supply to probe connector, positive to pin M (red wire from probe) and negative to pin E (black wire from probe).

2. Measure the output voltage at J6, and verify voltage is less than 14.2 volts (3 diode voltage drops, 0.6 to 1.1 V per diode).

Measured output voltage at J6 :

| Probe #1 | Probe #2 | Probe #3 |
|---|---|---|
| 13.35 mA | 13,46 mA | 13.43. mA |

### A.2.4 LVPS Isolation Network Reverse Current Isolation Test A.1.4 LVPS Isolation Network Reverse Current Isolation Test

1. Connect a 24 V power supply through a 100 ohm 5% tolerance 1/4 Watt carbon composition resistor to the output of the HVPS, J6.

2. Measure the voltage at the LVPS output, J6 (information only):

Measured output voltage at J6 :

| Probe #1 | Probe #2 | Probe #3 |
|---|---|---|
| 19.92 V | 19.87 V | 19.84 V |

3. Measure the voltage at the probe connector, between pin M (red wire from probe) and to pin E (black wire from probe). Verify voltage is less than 15.2 V.

positive lead of ohm meter at cathode of zener diode)

Note: Forward direction resistance will have a high resistance value
Reverse direction resistance will have a lower resistance value

Measured Forward Direction Resistance at J7:

| Probe #1 | Probe #2 | Probe #3 |
|---|---|---|
| 65.9 kΩ | 60.3 kΩ | 40 kΩ |

Measured Reverse Direction Resistance at J7 :

| Probe #1 | Probe #2 | Probe #3 |
|---|---|---|
| 47 kΩ | 34.1 kΩ | 21.4 kΩ |

4. Measure the resistance between input, J3, and output, J7. Verify resistance is 48 to 52 ohms.

Measured resistance between input, J3, and output, J7:

| Probe #1 | Probe #2 | Probe #3 |
|---|---|---|
| 51 Ω | 50.5 Ω | 50.9 Ω |

Measured input voltage at pins M and E :

| Probe #1 | Probe #2 | Probe #3 |
|---|---|---|
| 0.15 mV | 0.14 mV | 11.52 V (?) |

*Value recorded for probe 3 is inconsistent with other measurements.*

4. Connect an ammeter at the probe connector between pin M (red wire from probe) and to pin E (black wire from probe), and measure the current. Verify current measured is less than 1 mA.

Measured short circuit current at pins M and E:

| Probe #1 | Probe #2 | Probe #3 |
|---|---|---|
| -0.00005 mA | < 0.002 mA | 0.004 |

COUNT1 Isolation Network Test:

1. Verify no power is applied to probe.

2. Measure and verify resistance between signal and ground at J3, is greater than 10,000 ohms (both polarity, forward direction -- positive lead of ohm meter at anode of zener diode and reverse direction -- positive lead of ohm meter at cathode of zener diode)

Note: Forward direction resistance will have a high resistance value
Reverse direction resistance will have a lower resistance value

Measured Forward Direction Resistance at J3:

| Probe #1 | Probe #2 | Probe #3 |
|---|---|---|
| 65 kΩ | 60.24 k Ω | 40.4 kΩ |

Measured Reverse Direction Resistance at J3:

| Probe #1 | Probe #2 | Probe #3 |
|---|---|---|
| 46 kΩ | 33.9 kΩ | 21.3 kΩ |

3. Measure and verify resistance between signal and ground at J7, is greater than 10,000 ohms (both polarity, forward -- positive lead of ohm meter at anode of zener diode and reversed --

Isolation Board Checkout Tests
COUNT2 Isolation Network Test:

1. Verify no power is applied to probe.

2. Measure and verify resistance between signal and ground at J4, is greater than 10,000 ohms (both polarity, forward direction -- positive lead of ohm meter at anode of zener diode and reverse direction -- positive lead of ohm meter at cathode of zener diode)

Note: Forward direction resistance will have a high resistance value
Reverse direction resistance will have a lower resistance value

Measured Forward Direction Resistance at J4 :

| Probe #1 | Probe #2 | Probe #3 |
|---|---|---|
| 61.8 kΩ | 37 kΩ | 40 kΩ |

Measured Reverse Direction Resistance at J4:

| Probe #1 | Probe #2 | Probe #3 |
|---|---|---|
| 36 kΩ | 26.3 kΩ | 25.6 kΩ |

3. Measure and verify resistance between signal and ground at J8, is greater than 10,000 ohms (both polarity, forward -- positive lead of ohm meter at anode of zener diode and reversed -- positive lead of ohm meter at cathode of zener diode)

Note: Forward direction resistance will have a high resistance value
Reverse direction resistance will have a lower resistance value

Measured Forward Direction Resistance at J8:

| Probe #1 | Probe #2 | Probe #3 |
|---|---|---|
| 61.8 kΩ | 37 kΩ | 40 kΩ |

Measured Reverse Direction Resistance at J8 :

| Probe #1 | Probe #2 | Probe #3 |
|---|---|---|
| 35.9 kΩ | 26.4 kΩ | 25.6 kΩ |

4. Measure the resistance between input, J4, and output, J8. Verify resistance is 48 to 52 ohms.

Measured resistance between input, J4, and output, J8:

| Probe #1 | Probe #2 | Probe #3 |
|---|---|---|
| 50.7 Ω | 50.5 Ω | 50.4 Ω |

Performed by Jason Gunter/James Bussell
*Tests performed between April 25 and May 13, 1996*

High Voltage/Low Voltage Power Supply Board Checkout Tests
General Test Conditions:

**Caution**

**High Voltage is present during portions of this test.**

High Voltage Power Supply Test

1. Apply 16 VDC to probe connector, positive to pin L (red wire from probe) and negative to pin K (black wire from probe).

2. Measure high voltage power supply output with an electrostatic voltmeter.

3. Measure high voltage power supply current draw with a digital voltmeter.

Low Voltage Power Supply Test

1. 16 VDC applied to probe connector, positive to pin M (red wire from probe) and negative to pin E (black wire from probe).

2. Measure low power supply output voltage and current draw with a digital voltmeter.

High Voltage Minimum Voltage
(R2 fully CW - oriented as installed)

| Measured Value | | | Acceptance Range |
|---|---|---|---|
| Probe #1 | Probe #2 | Probe #3 | |
| 565 VDC | 575 VDC | 575 VDC | 560 to 600 VDC |

Current Draw at Min. Voltage

| Measured Value | | | Acceptance Range |
|---|---|---|---|
| Probe #1 | Probe #2 | Probe #3 | |
| 10.29 mA | 9.5 mA | no t measured | <12 mA |

High Voltage Maximum Voltage
(R2 fully CCW - oriented as installed)

| Measured Value | | | Acceptance Range |
|---|---|---|---|
| Probe #1 | Probe #2 | Probe #3 | |
| 730 VDC | 745 VDC | 740 VDC | 720 to 740 VDC |

Current Draw at Max. Voltage :

| Measured Value | | | Acceptance Range |
|---|---|---|---|
| Probe #1 | Probe #2 | Probe #3 | |
| 14.06 mA | 13.16 mA | not measured | < 16 mA |

High Voltage As Left (Set to 650 V):

| Measured Value | | | Acceptance Range |
|---|---|---|---|
| Probe #1 | Probe #2 | Probe #3 | |
| 650 VDC | 650 VDC | 650 VDC | 640 to 650 VDC |

Current Draw at As Left Setting:

| Measured Value | | | Acceptance Range |
|---|---|---|---|
| Probe #1 | Probe #2 | Probe #3 | |
| 12.26 mA | 11.23 mA | not measured | <16 mA |

Low Voltage Output Voltage
(under load) :

| Measured Value | | | Acceptance Range |
|---|---|---|---|
| Probe #1 | Probe #2 | Probe #3 | |
| 11.87 VDC | 11.80 VDC | 11.88 VDC | 1.5 to 12.5 VDC |

Low Voltage Power Supply Current
(under load):

| Measured Value | | | Acceptance Range |
|---|---|---|---|
| Probe #1 | Probe #2 | Probe #3 | |
| 30.9 mA | 30.05 mA | not measured | 28 to 33 mA |

Performed by Jason Gunter/James Bussell
*Tests performed between May 8 and May 13 1996*

Line Driver Board Checkout Tests
General Test Conditions:

1. 16 VDC applied to probe connector, positive to pin M (red wire from probe) and negative to pin E (black wire from probe).

2. No power applied to high voltage power supply Pins L and K.

Temperature Signal Test:

Test Procedure:
1. No test signals applied to input of charge amplifiers. The quiescent output of charge sensitive amplifiers on the preamplifiers is 0.6 to 0.8 V.

2. Measure the voltage between $V_{out}$ and Ground thru holes for U2 and U5

Acceptance Criteria:

Output to be within 10 mV of measured temperature sensor output voltage added to 5.000 V

Temperature Sensor #1 (U2) output voltage:

| Probe #1 | Probe #2 | Probe #3 |
|---|---|---|
| 0.26759 VDC | 0.2634 VDC | 0.2446 VDC |

COUNT1 Output at probe connector pin C
(coaxial connector):

| Probe #1 | Probe #2 | Probe #3 |
|---|---|---|
| 5.2728 VDC | 5.276067 VDC | 5.2495 VDC |

Temperature Sensor #2 (U5) output voltage::

| Probe #1 | Probe #2 | Probe #3 |
|---|---|---|
| 0.23914 VDC | 0.2337 VDC | 0.2293 VDC |

COUNT2 Output at probe connector pin G

(coaxial connector):

| Probe #1 | Probe #2 | Probe #3 |
|---|---|---|
| 5.23988 VDC | 5.2365 VDC | 5.23084 VDC |

+5 V Reference Voltage:

| Probe #1 | Probe #2 | Probe #3 |
|---|---|---|
| 5.00032 VDC | not measured | 4.9998 VDC |

Pulse Amplifier Test:

Test Procedure:

1. Set a pulse generator to produce a negative-going pulse with a 1 microsecond or less rise time and a fall time of greater than 500 microseconds. Set the amplitude of the pulse generator to produce a 50 mV pulse.

2. Connect a 50 ohm coaxial cable to pulse generator and connect a 5 ± 0.5 picofarad silver-micah capacitor to the center conductor of the coaxial cable.

3. Connect the shield of the coaxial cable to the printed circuit board ground plane (power supply common).

4. Set input potentiometer (R1, R8, R11, and R18) to provide maximum signal to amplifiers.

5. Adjust pulse generator amplitude to produce specified input to the line driver board.

Line Driver Checkout Tests
Acceptance Criteria:

1. Output pulse direction is correct as indicated below.

2. Output pulse amplitude shall change by a factor of two when the input increases from 0.25 $V_{peak}$ to 0.5 $V_{peak}$. The output pulse shape of these pulses shall be same as the input pulse shape.

3 The output amplitude for 1 and 2 $V_{peak}$ pulses shall be greater than 3 $V_{peak}$. The output pulse shape may contain distortion due amplifier saturation.

| Probe #1 | | | |
|---|---|---|---|
| | Output at COUNT1 (J6) Probe Connector Pin C | | Output at COUNT2 (J7) Probe Connector Pin G |
| Input Value to Line Driver Board | DET1<br>(Apply input at HV2 on preamplifier board) | DET2<br>(Apply input at HV1 on preamplifier board) | DET3<br>(Apply input at HV3 on preamplifier board) |
| | Output Pulse is negative-going | Output Pulse is positive-going | Output Pulse is negative-going |
| 0.25 $V_{peak}$ | 0.84 | 0.92 | 0.76 |
| 0.50 $V_{peak}$ | 1.9 | 2.1 | 1.16 |
| 1 $V_{peak}$ | 3.0 | 4.0 | 2.0 |
| 2 $V_{peak}$ | 4.0 (saturated) | 5.8 (saturated) | 4.2 (saturated) |

| Probe #2 | | | |
|---|---|---|---|
| | Output at COUNT1 (J6) Probe Connector Pin C | | Output at COUNT2 (J7) Probe Connector Pin G |
| Input Value to Line Driver Board | DET1<br>(Apply input at HV2 on preamplifier board) | DET2<br>(Apply input at HV1 on preamplifier board) | DET3<br>(Apply input at HV3 on preamplifier board) |
| | Output Pulse is negative-going | Output Pulse is positive-going | Output Pulse is negative-going |
| 0.25 $V_{peak}$ | 0.88 | 1.0 | 0.6 |
| 0.50 $V_{peak}$ | 1.6 | 2.0 | 1.16 |
| 1 $V_{peak}$ | 3.2 | 4.0 | 2.25 |
| 2 $V_{peak}$ | 4.8 (saturated) | 5.8 (saturated) | 4.0 (saturated) |

| **Probe #3** | | | |
|---|---|---|---|
| | **Output at COUNT1 (J6) Probe Connector Pin C** | | **Output at COUNT2 (J7) Probe Connector Pin G** |
| **Input Value to Line Driver Board** | **DET1**<br>**(Apply input at HV2 on preamplifier board)** | **DET2**<br>**(Apply input at HV1 on preamplifier board)** | **DET3**<br>**(Apply input at HV3 on preamplifier board)** |
| | **Output Pulse is negative-going** | **Output Pulse is positive-going** | **Output Pulse is negative-going** |
| **0.25 $V_{peak}$** | **0.88** | **1.0** | **0.6** |
| **0.50 $V_{peak}$** | **1.6** | **2.0** | **1.16** |
| **1 $V_{peak}$** | **3.2** | **4.0** | **2.25** |
| **2 $V_{peak}$** | **4.8 (saturated)** | **5.8 (saturated)** | **4.0 (saturated)** |

TEMP1 (U2) Sensor Serial No. (LASER engraved):

| Probe #1 | Probe #2 | Probe #3 |
|---|---|---|
| A4 | A2 | A3 |

Performed by Jason Gunter/James Bussell

*Tests performed between May 8 and May 13, 1996*

Preamplifier Checkout Tests
General Test Conditions:

1. 16 VDC applied to probe connector, positive to pin M (red wire from probe) and negative to pin E (black wire from probe).

2. No power applied to high voltage power supply Pins L and K.

Test Procedure:

Caution

Do not apply a pulse directly to detector input connection of the charge sensitive amplifiers. Use a 5 picofarad capacitor in series with test signal to charge sensitive amplifiers.

If a pulse is directly applied to charge sensitive amplifier the junction field effect transistor may be damaged on the front end of the amplifier because of the excessive current flow. The input charge from the detector is on order of $10^{-12}$ coulombs over a 5 to 10 microsecond negative-going pulse.

Notes

1. The nominal gain of the charge sensitive amplifiers is $5.2 \times 10^{12}$ V/Coulomb.

2. The charge sensitive amplifier is inverting. A negative-going pulse produces a positive output pulse.

3. The charge supplied to the input of the charge sensitive amplifier for a 50 mV negative-going pulse through a 5 picofarad silver micah capacitor is 0.050 V x (5 x 10-12 Farad) = $2.5 \times 10^{-13}$ Coulombs of charge.

4. The output of the charge sensitive amplifier is then ($5.2 \times 10^{12}$ V/Coulomb) x $2.5 \times 10^{-13}$ Coulombs = 1.3 Volts.

5. The input pulse rise time and fall time must be followed to obtain the proper output pulse due to pulse shaping in the charge sensitive amplifier. If the fall time is too short, the output pulses obtained will have an undershoot which will be saturated at about 0.5 VDC.

1. Set a pulse generator to produce a negative-going pulse with a 1 microsecond or less rise time and a fall time of greater than 500 microseconds. Set the amplitude of the pulse generator to produce a 50 mV pulse.

2. Connect a 50 ohm coaxial cable to pulse generator and connect a 5 ± 0.5 picofarad silver-micah capacitor to the center conductor of the coaxial cable.

Preamplifier Checkout Tests

3. Connect the shield of the coaxial cable to the printed circuit board ground plane (power supply common).

4. Connect the capacitor to the high voltage detector connection under test.

5. Measure the output of the charge sensitive preamplifiers at their respective output connections while monitoring the pulse signal from the pulse generator.

6. Set the pulse generator amplitude to values below and measure the charge sensitive amplifier output as indicated.

Acceptance Criteria:

1. Output pulse amplitude with specified value under columns labeled "Pulse Amplitude Nominal Value."

2. Output pulse has 2 to 3 microsecond rise time and 4 to 8 microsecond fall time. Pulse is "smooth" with no glitches or other discontinuities.

| **Probe #1** | | | | | | |
|---|---|---|---|---|---|---|
| | **Detector #1 (J2)**<br>(bottom horizontal detector fully encased in Cadmium)<br>**HV2 on Preamplifier Board** | | **Detector #2 (J1)**<br>(side vertical detector)<br>**HV1 on Preamplifier Board** | | **Detector #3 (J3)**<br>(top center detector)<br>**HV3 on Preamplifier Board** | |
| **Charge Amplifier** | U2 | | U1 | | U3 | |
| **Output Pulse Polarity** | Positive-going | | Positive-going | | Positive-going | |
| | Pulse Amplitude Nominal Value | Pulse Amplitude Measured Value | Pulse Amplitude Nominal Value | Pulse Amplitude Measured Value | Pulse Amplitude Nominal Value | Pulse Amplitude Measured Value |
| 50 $mV_{peak}$ | 1.3 V<br>1.1 to 1.5 V | 1.4 | 1.3 V<br>1.1 to 1.5 V | 1.5 | 1.3 V<br>1.1 to 1.5 V | 1.4 |
| 100 $mV_{peak}$ | 2.6 V<br>2.2 to 3.0 V | 2.9 | 2.6 V<br>2.2 to 3.0 V | 2.8 | 2.6 V<br>2.2 to 3.0 V | 2.9 |
| 200 $mV_{peak}$ | 5.2 V<br>4.4 to 6.0 V | 5.8 | 5.2 V<br>4.4 to 6.0 V | 5.6 | 5.2 V<br>4.4 to 6.0 V | 5.6 |

| Probe #2 | | | | | | |
|---|---|---|---|---|---|---|
| | Detector #1<br>(J2)<br>(bottom horizontal detector fully encased in Cadmium)<br>HV2 on Preamplifier Board | | Detector #2<br>(J1)<br>(side vertical detector)<br>HV1 on Preamplifier Board | | Detector #3<br>(J3)<br>(top center detector)<br>HV3 on Preamplifier Board | |
| Charge Amplifier | U2 | | U1 | | U3 | |
| Output Pulse Polarity | Positive-going | | Positive-going | | Positive-going | |
| | Pulse Amplitude Nominal Value | Pulse Amplitude Measured Value | Pulse Amplitude Nominal Value | Pulse Amplitude Measured Value | Pulse Amplitude Nominal Value | Pulse Amplitude Measured Value |
| 50 $mV_{peak}$ | 1.3 V<br>1.1 to 1.5 V | 1.4 | 1.3 V<br>1.1 to 1.5 V | 1.5 | 1.3 V<br>1.1 to 1.5 V | 1.4 |
| 100 $mV_{peak}$ | 2.6 V<br>2.2 to 3.0 V | 2.9 | 2.6 V<br>2.2 to 3.0 V | 2.8 | 2.6 V<br>2.2 to 3.0 V | 2.9 |
| 200 $mV_{peak}$ | 5.2 V<br>4.4 to 6.0 V | 5.8 | 5.2 V<br>4.4 to 6.0 V | 5.6 | 5.2 V<br>4.4 to 6.0 V | 5.6 |

**Probe #3**

| | Detector #1 (J2) (bottom horizontal detector fully encased in Cadmium) HV2 on Preamplifier Board | | Detector #2 (J1) (side vertical detector) HV1 on Preamplifier Board | | Detector #3 (J3) (top center detector) HV3 on Preamplifier Board | |
|---|---|---|---|---|---|---|
| Charge Amplifier | U2 | | U1 | | U3 | |
| Output Pulse Polarity | Positive-going | | Positive-going | | Positive-going | |
| | Pulse Amplitude Nominal Value | Pulse Amplitude Measured Value | Pulse Amplitude Nominal Value | Pulse Amplitude Measured Value | Pulse Amplitude Nominal Value | Pulse Amplitude Measured Value |
| 50 $mV_{peak}$ | 1.3 V<br>1.1 to 1.5 V | 1.6 | 1.3 V<br>1.1 to 1.5 V | 1.62 | 1.3 V<br>1.1 to 1.5 V | 1.5 |
| 100 $mV_{peak}$ | 2.6 V<br>2.2 to 3.0 V | 3.3 | 2.6 V<br>2.2 to 3.0 V | 2.36 | 2.6 V<br>2.2 to 3.0 V | 3.2 |
| 200 $mV_{peak}$ | 5.2 V<br>4.4 to 6.0 V | 6.8 | 5.2 V<br>4.4 to 6.0 V | 6.1 | 5.2 V<br>4.4 to 6.0 V | 6.4 |

**U1 will not drive line driver pot when set to provide not attenuation. Results at that setting: 50 mV in - 1.5 V out; 100 mV in - 2.5 V out; and 200 mV in - 2.7 V out.**

Performed by Jason Gunter/James Bussell
*Tests performed between May 8* and May 13, 1996

Final Probe Assembly Checkout Tests
General Test Conditions:

1. 15 to 17 VDC applied to power connection pins in probe connector

2. High voltage power supply to be turned off except as indicated below.

Test Procedure:

1. Set a pulse generator to produce a negative-going pulse with a 1 microsecond or less rise time and a fall time of greater than 500 microseconds. Set the amplitude of the pulse generator to produce a 100 mV pulse.

2. Connect a 50 ohm coaxial cable to pulse generator and connect a 5 ± 0.5 picofarad silver-micah capacitor to the center conductor of the coaxial cable.

3. Connect the shield of the coaxial cable to the printed circuit board ground plane (power supply common).

4. Connect the capacitor to the high voltage detector connection under test.

5. Measure the output of the probe output connector pin for the detector under test while monitoring the input pulse signal from the pulse generator.

6. For each respective counting channel adjust the attenuator potentiometer on the line driver board until the pulses observed on the output are nominally 1.25 $V_{peak}$ (acceptance range 1.2 to 1.4 $V_{peak}$) (positive-going or negative-going). Record as left values in table below.

5. Set potentiometer R18 on line driver board fully CCW.

6. Measure and record current draw to probe electronics through Pins M (power) and E (return) (information only) on next page.

7. Measure and record current draw to probe high voltage power supply through Pins L (power) and K (return) (information only) on next page.

Final Probe Assembly Checkout Test

8. Record serial number of solid state temperature sensor, plastic package - LASER engraved on next page.

Acceptance Criteria:

1. Pulse amplitude with specified value under columns labeled "Pulse Amplitude Nominal Value."
2. Pulse has 2 to 3 microsecond rise time and 4 to 8 microsecond fall time. Pulse is "smooth" with no glitches or other discontinuities.
3. Pulses are riding on a DC value.
4. DC voltage value of COUNT1 and COUNT2 correspond to the approximate ambient temperature. The DC voltage value of COUNT1 (temperature sensor located on the line driver board) will be 50 to 100 mV larger than the DC voltage value of COUNT2.

| Probe #1 | | | | | | |
|---|---|---|---|---|---|---|
| | Detector #1<br>(bottom horizontal detector fully encased in Cadmium)<br>HV2 on Preamplifier Board | | Detector #2<br>(side vertical detector)<br>HV1 on Preamplifier Board | | Detector #3<br>(top center detector)<br>HV3 on Preamplifier Board | |
| Charge Amplifier | U2 | | U1 | | U3 | |
| Output Pulse Polarity | Negative-going | | Positive-going | | Negative-going | |
| Attenuator Pot on Line Driver Board | R1 | | R8 | | R11 | |
| Signal Name | COUNT1 | | COUNT1 | | COUNT2 | |
| Probe Connector Pin | Coaxial Connector in Pin C | | Coaxial Connector in Pin C | | Coaxial Connector in Pin G | |
| | Nominal Value | Measured Value | Nominal Value | Measured Value | Nominal Value | Measured Value |
| DC Voltage Value | Ambient Temperature in degrees Celsius x 0.01 V + 5.000 V ± 30 mV | 5.27585 | Ambient Temperature in degrees Celsius x 0.01 V + 5.000 V ± 30 mV | Same as DET1 | Ambient Temperature in degrees Celsius x 0.01 V + 5.000 V ± 30 mV | 5.24287 |
| 100 $\text{mV}_{peak}$ | 1.25 V<br>1.2 to 1.4 V | 1.25 | 1.25 V<br>1.2 to 1.4 V | 1.25 | 1.25 V<br>1.2 to 1.4 V | 1.25 |

| Probe #2 | | | | | | |
|---|---|---|---|---|---|---|
| | **Detector #1**<br>(bottom horizontal detector fully encased in Cadmium)<br>HV2 on Preamplifier Board | | **Detector #2**<br>(side vertical detector)<br>HV1 on Preamplifier Board | | **Detector #3**<br>(top center detector)<br>HV3 on Preamplifier Board | |
| Charge Amplifier | U2 | | U1 | | U3 | |
| Output Pulse Polarity | Negative-going | | Positive-going | | Negative-going | |
| Attenuator Pot on Line Driver Board | R1 | | R8 | | R11 | |
| Signal Name | COUNT1 | | COUNT1 | | COUNT2 | |
| Probe Connector Pin | Coaxial Connector in Pin C | | Coaxial Connector in Pin C | | Coaxial Connector in Pin G | |
| | Nominal Value | Measured Value | Nominal Value | Measured Value | Nominal Value | Measured Value |
| DC Voltage Value | Ambient Temperature in degrees Celsius x 0.01 V + 5.000 V ± 30 mV | 5.2659 | Ambient Temperature in degrees Celsius x 0.01 V + 5.000 V ± 30 mV | 5.2659 | Ambient Temperature in degrees Celsius x 0.01 V + 5.000 V ± 30 mV | 5.2372 |
| 100 $mV_{peak}$ | 1.25 V<br>1.2 to 1.4 V | 1.25 | 1.25 V<br>1.2 to 1.4 V | 1.25 | 1.25 V<br>1.2 to 1.4 V | 1.25 |

| Probe #3 | | | | | | |
|---|---|---|---|---|---|---|
| | **Detector #1**<br>(bottom horizontal detector fully encased in Cadmium)<br>HV2 on Preamplifier Board | | **Detector #2**<br>(side vertical detector)<br>HV1 on Preamplifier Board | | **Detector #3**<br>(top center detector)<br>HV3 on Preamplifier Board | |
| Charge Amplifier | U2 | | U1 | | U3 | |
| Output Pulse Polarity | Negative-going | | Positive-going | | Negative-going | |
| Attenuator Pot on Line Driver Board | R1 | | R8 | | R11 | |
| Signal Name | COUNT1 | | COUNT1 | | COUNT2 | |
| Probe Connector Pin | Coaxial Connector in Pin C | | Coaxial Connector in Pin C | | Coaxial Connector in Pin G | |
| | Nominal Value | Measured Value | Nominal Value | Measured Value | Nominal Value | Measured Value |
| DC Voltage Value | Ambient Temperature in degrees Celsius x 0.01 V + 5.000 V ± 30 mV | Same as DET2 | Ambient Temperature in degrees Celsius x 0.01 V + 5.000 V ± 30 mV | 5.2647 | Ambient Temperature in degrees Celsius x 0.01 V + 5.000 V ± 30 mV | 5.235 |
| 100 $mV_{peak}$ | 1.25 V<br>1.2 to 1.4 V | 1.25 | 1.25 V<br>1.2 to 1.4 V | 1.25 | 1.25 V<br>1.2 to 1.4 V | 1.25 |

Probe Final Assembly Checkout Tests
Probe Amplifier Power Supply
Current Draw (information only):

| Probe #1 | Probe #2 | Probe #3 |
|---|---|---|
| 31.09 mA | 30.52 mA | 31.12 mA |

Probe High Voltage Power Supply
Current Draw (information only):

| Probe #1 | Probe #2 | Probe #3 |
|---|---|---|
| 0.26759 VDC | 0.2634 VDC | 0.2446 VDC |

Serial Number of Temperature
Sensor on Detector #1 Housing,
plastic package (LASER engraved) C5

| Probe #1 | Probe #2 | Probe #3 |
|---|---|---|
| C5 | C2 | C4 |

Performed by Jason Gunter/James Bussell
*Tests performed between April 25 to May 13, 1996*

## Table A.1
## Measurement and Test Equipment List Used for Checkout Test of Probe Assemblies

| Item | Description | Use | Standards Code Number | Calibration Expiration Date |
|---|---|---|---|---|
| 1 | Tail Pulse Generator<br>Berkeley Nucleonics Corporation BH-1 | Pulse input to detector 1 and 3 input on prototype line driver board. Pulse had 2 to 5 microsecond rise time and 10 microsecond fall time. | Not Applicable | Not Applicable |
| 2 | Tail Pulse Generator<br>Berkeley Nucleonics Corporation DB-2 | Pulse input to detector 2 input on prototype line driver board. Pulse had 2 to 5 microsecond rise time and 10 microsecond fall time. | Not Applicable | Not Applicable |
| 2 | Oscilloscope<br>Tektronix Model 485 | Measure amplitude of input and output waveforms to interface board | 013-51-01-012 | 2/21/97 |
| 4 | Keithley Model 2000<br>Digital Multimeter | Voltage, current, and resistance measurements | 804-45-08-010 | 3/13/97 |
| 5 | Sensitive Research Corporation Model ESD Electrostatic Voltmeter, 300 to 1500 VDC<br>Instrument has almost infinite input impedance. | Measure high voltage power supply voltage | 804-45-17-001 | 12/01/96 |
| 6 | Power Supply | Provide power to probe assembly and provide test voltages as required | Not Applicable | Not Applicable |
| 7 | Fluke Model 702 Documenting Process Calibrator<br>Serial No. 6240608 | Provide precision voltage input to test probe temperature sensor electronics linearity<br>Output verified with item multimeter, item 4 | Not Applicable | Not Applicable |

### A.3.1 Probe Configuration

Tables A.3.1 shows the serial numbers of the temperature sensors and the DC-DC converters incorporated into the three assembled probes. Table A.3.2 shows serial numbers of the boron-10 lined detector tubes and the charge sensitive preamplifiers in each of the probe assemblies. The data sheets for calibration checks of the temperature sensors follows Table A.3.1. Data sheets for the detector tubes follows Table A.3.2.

**Table A.3.1**
**Probe Configuration Data for DC-DC Converter and Temperature Sensors**

| Probe | Serial Number[†] of Lower Temperature Sensor TEMP2 (located in detector #1 housing) | Serial Number[†] of Lower Temperature Sensor TEMP1 (located on line driver board) | Serial Number of How Voltage Power Supply DC-DC Converter |
|---|---|---|---|
| Production Probe #1 | A4 | C5 | 23133 |
| Production Probe #2 | A2 | C2 | 23113 |
| Production Probe #3 | A3 | C4 | |

Notes:
[†] Serial numbers are laser engraved on top of metal can of upper temperature sensor and in plastic of lower temperature sensor.

## Temperature Sensor Standards Laboratory Calibration Data Sheet Page 1 of 5

### WESTINGHOUSE STANDARDS LABORATORY PHYSICAL AND ELECTRICAL REPORT

CUSTODIAN/ADDRESS: BUSSELL JH ~~L6-38~~ H6-11

STANDARDS CODE NUMBER: 804-80-02-009

NEW: ✓

MODIFY:

REFERENCE NUMBER: 398477

ORGANIZATION CODE: W74770

WORK ORDER: E46600

INSTRUMENT: TEMPERATURE XDUCER SHOP MADE 18 EACH

SERIAL NUMBER: N/A

PROPERTY NUMBER: N/A

RECALL STATUS: 1 ACTIVE 2 NONRECALL 3 SUSPENDED 4 DELETED 5 PM 6 NONDATA M&TE 2

RECALL CYCLE: 360

TOLERANCE HISTORY:

ROOM: STVS

BUILDING: 2440

SERVICE DEPARTMENT: 4

DATE RECEIVED: 960322

TOLERANCE AS RECEIVED: 1 IN 2 OUT [✓ 3 NA] 4 FAILED

SENDER: W)J BUSSELL 6-9621

COMMENTS: Verification Only

SHIPPING DAY: WE

INSTRUMENT SPECIFICATIONS: AS FOUND ONLY

TRAINING HOURS:

CALIBRATION HOURS: 3.0

REPAIR HOURS:

OTHER HOURS: 3.2

MATERIALS:

TOTAL CHARGE = ($125 x SUM OF HOURS) + MATERIALS

STANDARD(S) USED IN CALIBRATION TRACEABLE TO NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY OR NATIONALLY RECOGNIZED STANDARDS 4:1 RATIO N/A Y ☐ N ☐

| | EXPIRATION DATE | | EXPIRATION DATE |
|---|---|---|---|
| 002-79-03-002 | 5-4-96 | 002-45-08-022 | 1-8-96 |
| 002-45-08-051 | 6-29-96 | 002-79-06-036 | 3-12-97 |
| 002-45-08-052 | 1-29-97 | | |

REMARKS: * COULDNT GET A STABLE RDG ON A2 - FLOATING VOLTAGE

DATE CALIBRATED: 3-22-96

DATE DUE: N/A

AMBIENT TEMPERATURE = 15.7

PROCEDURE NUMBER: As found only

see inst. pg. A1-2-3

RUSH

APPROVED BY: 3-22-96 DJ Nelson

CALIBRATED BY: 030

Hanford Operations and Engineering Contractor for the United States Department of Energy

Westinghouse Hanford Company
Subsidiary of Westinghouse Electric Corporation
Box 1970, Richland, WA 99352

PAGE 1 OF 5

## Temperature Sensor Standards Laboratory Calibration Data Sheet Page 2 of 5

| PROCEDURE NAME - 17 | STANDARDS CODE NUMBER | REFERENCE NUMBER |
|---|---|---|
| | 804-80-02-009 | 398447 |

DATA SHEET

P.S. VDC

| T.P. - 24.2 | | T.S. # | PS 5VDC Nom ~~INDICATION~~ | UUT | | ~~MANUFACTURER~~ 12 VDC nom ~~5~~ ~~SPECIFICATION~~ |
|---|---|---|---|---|---|---|
| | | | | AS FOUND | FINAL | |
| C6 | .246 | 1 | 5.005 | 4.7693 | SAME | 12.006 |
| C2 | .244 | 2 | 5.006 | 4.7661 | | '' |
| C1 | .241 | 3 | 5.006 | 4.7709 | | 12.005 |
| C3 | .242 | 4 | '' | 4.7666 | | 12.006 |
| C8 | .242 | 5 | '' | 4.7681 | | '' |
| C7 | .239 | 6 | '' | 4.7699 | | 12.005 |
| C5 | .235 | 7 | '' | 4.7667 | | 12.006 |
| C4 | .231 | 8 | '' | 4.7636 | | '' |
| A1 | .229 | 9 | '' | 4.7656 | | '' |
| A2 ? ~~A7~~ | | 10 | | * | | |
| A3 | .226 | 11 | '' | 4.7648 | | '' |
| A4 | .240 | 12 | 5.005 | 4.7648 | | 12.006 |
| A5 | .239 | 13 | '' | 4.7656 | | '' |
| A9 | .237 | 14 | '' | 4.7645 | | '' |
| A8 | .233 | 15 | '' | 4.7663 | | '' |
| A7 | .225 | 16 | '' | 4.7647 | | '' |
| A6 | .219 | 17 | '' | 4.7639 | | '' |
| A10 | .214 | 18 | '' | 4.7658 | ↓ | '' |
| | +12 | 19 | | | | |
| | +5 | 20 | | | | |
| | GND | 21 | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

| APPROVED BY | CALIBRATED BY | Page |
|---|---|---|
| O. J. Nelson 3-22-96 | 30 | 2 of 5 |

Temperature Sensor Standards Laboratory Calibration Data Sheet Page 3 of 5

|  |  |  |
|---|---|---|
| PROCEDURE NAME - 17 | STANDARDS CODE NUMBER<br>914-80-07-009 | REFERENCE NUMBER<br>358 477 |

DATA SHEET

P.S. VDC

| T.P. 20. °C |  | T.S. # | PS 5VDC nom ~~INDICATION~~ | AS FOUND | FINAL | ~~MANUFACTURER~~ 12 VDC nom ~~SPECIFICATION~~ |
|---|---|---|---|---|---|---|
| C6 | .173 | 1 | 5.000 | 5.2063 VDC | Same | 12.008 |
| C2 | .169 | 2 | 4.999 | 5.2025 |  | 12.011 |
| C1 | .165 | 3 | 4.998 | 5.2075 |  | 12.012 |
| C3 | .160 | 4 | 4.997 | 5.2007 |  | 12.012 |
| C8 | .152 | 5 | ~~5.2007~~ 4.997 | 5.2017 |  | 12.013 |
| C7 | .197 | 6 | 5.003 | 5.2104 |  | 12.007 |
| C5 | .194 | 7 | 5.003 | 5.2084 |  | 12.007 |
| C4 | .196 | 8 | 5.004 | 5.2060 |  | 12.007 |
| A1 | .212 | 9 | 5.003 | 5.2108 |  | 12.007 |
| A2 ? ~~A3~~ |  | 10 |  | * |  |  |
| A3 | .225 | 11 | 5.003 | 5.2094 |  | 12.007 |
| A4 | .230 | 12 | 5.002 | 5.2105 |  | 12.006 |
| A5 | .225 | 13 | 5.002 | 5.2103 |  | 12.006 |
| A9 | .209<br>~~.221~~ | 14 | 5.002 | 5.2093<br>~~5.2098~~ |  | 12.006 |
| A8 | .210 | 15 | 5.003 | 5.2108 |  | 12.006 |
| A7 | .221 | 16 | 5.002 | 5.2086 |  | 12.006 |
| A6 | .224 | 17 | 5.003 | 5.2090 |  | 12.006 |
| A10 | .223 | 18 | 5.003 | 5.2128 |  | 12.006 |
|  | +12 | 19 |  |  |  |  |
|  | +5 | 20 |  |  |  |  |
|  | GND | 21 |  |  |  |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |

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|---|---|---|
| APPROVED BY 3-22-96<br>D. J. Nelson | CALIBRATED BY<br>38 | Page<br>3 of 5 |

# Temperature Sensor Standards Laboratory Calibration Data Sheet Page 4 of 5

| PROCEDURE NAME - 17 | STANDARDS CODE NUMBER | REFERENCE NUMBER |
|---|---|---|
|  | 804-80-02-009 | 358477 |

## DATA SHEET

P.S. VDC

| T.P. 50- °C |  | T.S. # | PS 5VDC Nom ~~INDICATION~~ | AS FOUND | FINAL | ~~MANUFACTURER~~ 12 VDC nom ~~SPECIFICATION~~ |
|---|---|---|---|---|---|---|
| C6 | .091 | 1 | 5.006 | 5.5701 | same | 12.007 |
| C2 | .094 | 2 | 5.005 | 5.5066 |  | 12.007 |
| C1 | .094 | 3 | 5.005 | 5.5132 |  | 12.007 |
| C3 | .093 | 4 | 5.004 | 5.5044 |  | 12.007 |
| C8 | .076 | 5 | 5.003 | 5.5071 |  | 12.007 |
| C7 | .099 | 6 | 5.004 | 5.5076 |  | 12.007 |
| C5 | .099 | 7 | ~~5.5054~~ 5.004 | 5.5059 |  | 12.007 |
| C4 | .084 | 8 | 5.004 | 5.5026 |  | 12.007 |
| A1 | .087 | 9 | 5.003 | 5.5094 |  | 12.007 |
| A2 ? ~~A3~~ | ~~.090~~ | 10 |  | * |  |  |
| A3 | .090 | 11 | 5.003 | 5.5062 |  | 12.007 |
| A4 | .092 | 12 | 5.003 | 5.5031 |  | 12.007 |
| A5 | .094 | 13 | 5.003 | 5.5075 |  | 12.007 |
| A9 | .095 | 14 | 5.003 | 5.5064 |  | 12.007 |
| A8 | .093 | 15 | 5.003 | 5.5089 |  | " |
| A7 | .091 | 16 | 5.002 | 5.5066 |  | " |
| A6 | .090 | 17 | 5.002 | 5.5059 |  | " |
| A10 | .094 | 18 | 5.001 | 5.5090 |  | " |
|  | +12 | 19 |  |  |  |  |
|  | +5 | 20 |  |  |  |  |
|  | GND | 21 |  |  |  |  |
|  |  |  |  |  |  |  |
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## Temperature Sensor Standards Laboratory Calibration Data Sheet Page 5 of 5

| PROCEDURE NAME - 17 | STANDARDS CODE NUMBER | REFERENCE NUMBER |
|---|---|---|
| | 804-80-02-009 | 398477 |

### DATA SHEET

P.S. VDC

| T.P. #. | T.S. # | PS 5VDC Nom ~~INDICATION~~ | AS FOUND | FINAL | ~~MANUFACTURER~~ 12 VDC nom ~~5~~ ~~SPECIFICATION~~ |
|---|---|---|---|---|---|
| C6 .877 | 1 | 5.002 | 5.9029 | Same | 12.007 |
| C2 .885 | 2 | 5.002 | 5.8984 | | '' |
| C1 .886 | 3 | '' | 5.9091 | | '' |
| C3 .886 | 4 | '' | 5.8987 | | '' |
| C8 .887 | 5 | 5.003 | 5.9033 | | '' |
| C7 .886 | 6 | 5.003 | 5.9020 | | '' |
| C5 .884 | 7 | 5.001 | 5.8993 | | '' |
| C4 .883 | 8 | 5.002 | 5.8955 | | '' |
| A1 .879 | 9 | '' | 5.9057 | | '' |
| A2 ? ~~A3~~ .876 | 10 | '' | * ~~5.9057~~ | | '' |
| A3 .876 | 11 | 5.001 | 5.9044 | | '' |
| A4 .87~~8~~ | 12 | 5.001 | 5.9041<br>~~5.9025~~ | | '' |
| A5 .873 | 13 | '' | 5.9023 | | '' |
| A9 .862 | 14 | '' | 5.9021 | | '' |
| A8 .858 | 15 | '' | 5.9053 | | '' |
| A7 .854 | 16 | '' | 5.9021<br>~~5.9027~~ | | '' |
| A6 .853 | 17 | 5.000 | 5.9016 | | 12.007 |
| A10 .857 | 18 | 5.001 | 59.059 | | '' |
| +12 | 19 | | | | |
| +5 | 20 | | | | |
| GND | 21 | | | | |
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| APPROVED BY | CALIBRATED BY | Page |
|---|---|---|
| 3-22-96<br>D. J. Nelson | 30 | 5 of 5 |

Standards Laboratory Calibration Data Sheet Appendix Page 1

840-80-02-009

398477
3-22-96

PC Board

| | | | | |
|---|---|---|---|---|
| A | 1 | 1 | BROWN | |
| B | 2 | 2 | Red | |
| C | 3 | 3 | ORANGE | |
| D | 4 | 4 | YEllow | |
| E | 5 | 5 | GREEN | |
| F | 6 | 6 | BLUE | |
| H | 7 | 7 | VIOLET | |
| J | 8 | 8 | GRAY | |
| K | 9 | N/C | | |
| L | 10 | 9 | white | |
| M | 11 | 10 | BLACK | WHT<br>BLK<br>BRN |
| N | 12 | +12 | | |
| P | 13 | 11 | BROWN | |
| R | 14 | 12 | RED | |
| S | 15 | 13 | ORANGE | |
| T | 16 | 14 | YELLOW | |
| U | 17 | 15 | GREEN | |
| V | 18 | 16 | BLUE | |
| W | 19 | 17 | VIOLET | |
| X | 20 | 18 | GRAY | RED<br>ORN<br>YEL |
| Y | 21 | +5V | | |
| Z | 22 | GROUND | | GRN<br>BLU |

Terminal Strip

| | |
|---|---|
| 1 | 1 |
| 2 | 2 |
| 3 | 3 |
| 4 | 4 |
| 5 | 5 |
| 6 | 6 |
| 7 | 7 |
| 8 | 8 |
| 9 | 9 |
| 10 | 10 |
| 11 | 11 |
| 12 | 12 |
| 13 | 13 |
| 14 | 14 |
| 15 | 15 |
| 16 | 16 |
| 17 | 17 |
| 18 | 18 |
| +5 | 19 |
| +12 | 20 |
| Gnd | 21 |
| N/C | 22 |

Temperatures
- 20°C or lowest possible
40°C
100°C

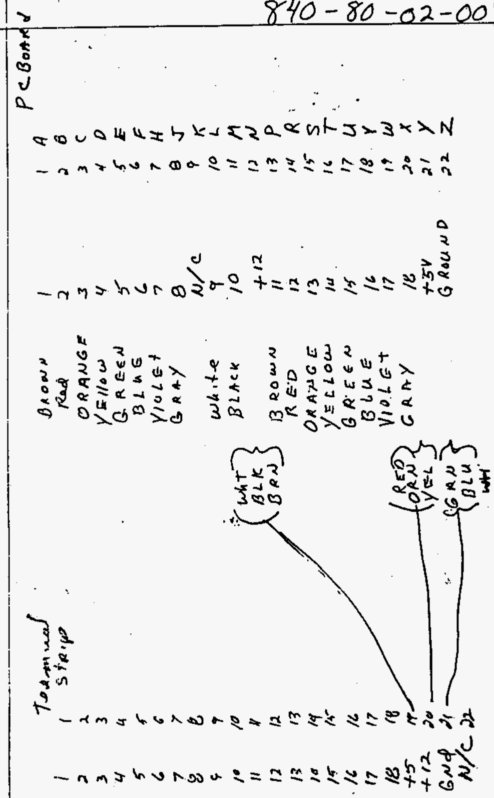
3-22-96
D.J.N

(30)

A-1

Standards Laboratory Calibration Data Sheet Appendix Page 2

840-80-02-009 398477



3-22-96
D. J. Nelson

(30)

A-2

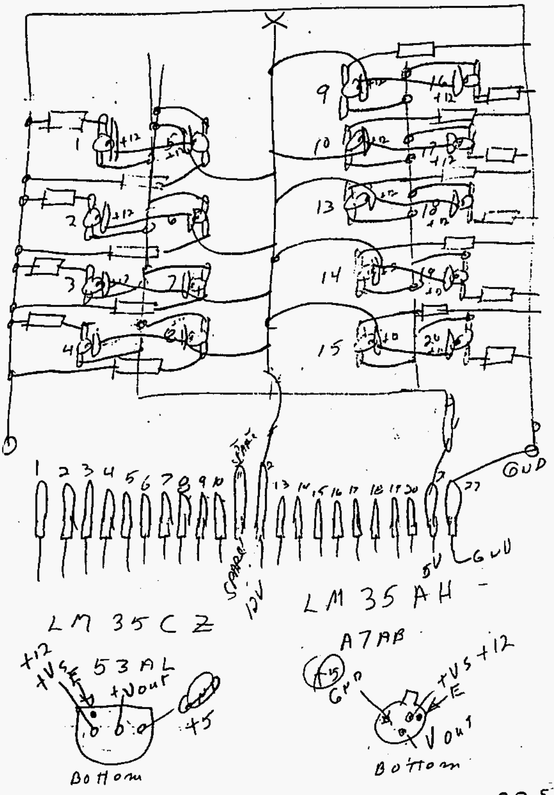
Standards Laboratory Calibration Data Sheet Appendix Page 3

PAD TRANS

840-80-02-009

398477

D:\ACSUP\NPN.
NPN.
PNP.



3-22-96
D. J. Nelson

30

A-3

## Table A.3.2
## Probe Configuration Data for Neutron Detectors and Charge Sensitive Amplifiers

| Probe | Detector | Detector Manufacturer and Model | Detector Serial Number | Preamplifier[†] Charge Amplifier Reference Designator | Charge Amplifier Serial Number | Charge[‡] Amplifier Gain (V/pC) | Comments |
|---|---|---|---|---|---|---|---|
| Prototype | #1 (bottom) | GE Reuter Stokes RS-P7-0402-202 | 95D04304 | U2 | 1557 | 5.89 | Prototype probe assembly used for initial calibration tests and for gamma radiation tolerance testing. Detectors remove from probe and placed in production probe #3. |
| | #2 (side) | GE Reuter Stokes RS-P7-0402-203 | 95D04307 | U1 | 1558 | 6.07 | Prototype probe assembly used for initial calibration tests and for gamma radiation tolerance testing. Detectors remove from probe and placed in production probe #3. |
| | #3 (top) | GE Reuter Stokes RS-P7-0402-203 | 95D04309 | U3 | 1560 | 5.63 | Prototype probe assembly used for initial calibration tests and for gamma radiation tolerance testing. Detectors remove from probe and placed in production probe #3. |
| Production Probe #1 | #1 (bottom) | GE Reuter Stokes RS-P7-0402-202 | 95D04306 | U2 | 1568 | 5.68 | |
| | #2 (side) | GE Reuter Stokes RS-P7-0402-203 | 95D07361 | U1 | 1569 | 5.74 | |
| | #3 (top) | GE Reuter Stokes RS-P7-0402-203 | 95D07360 | U3 | 1570 | 5.74 | |
| Production Probe #2 | #1 (bottom) | GE Reuter Stokes RS-P7-0402-202 | 95D04302 | U2 | 1562 | 5.74 | |
| | #2 (side) | GE Reuter Stokes RS-P7-0402-203 | 95DO7166 | U1 | 1563 | 6.00 | |

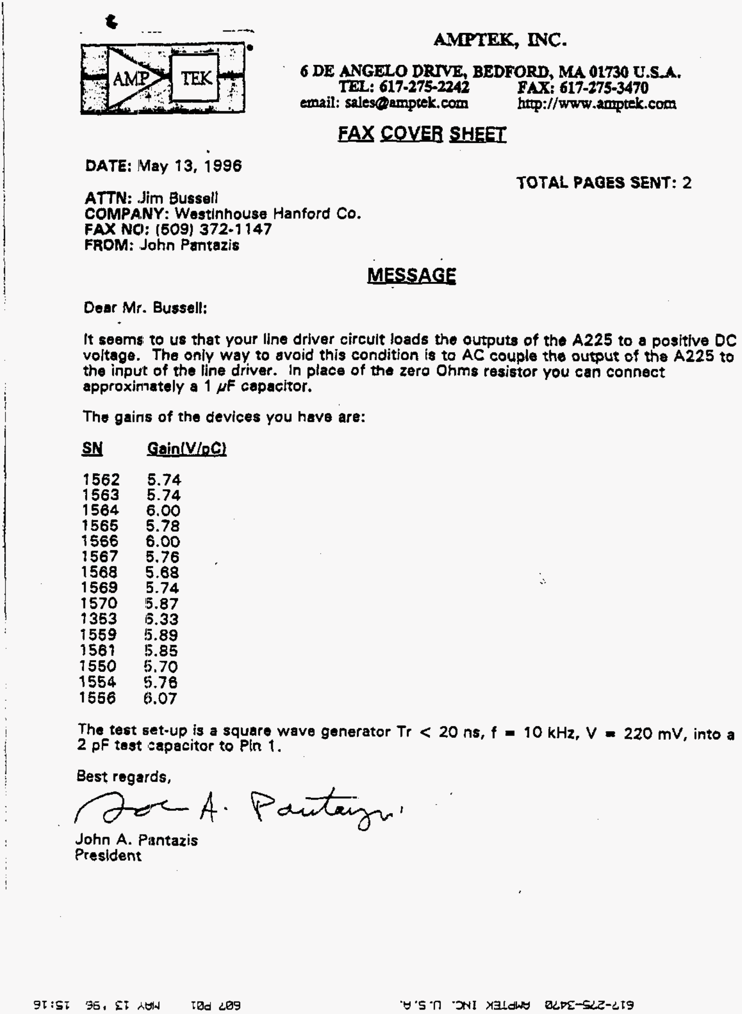
|  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|
|  | #3 (top) | GE Reuter Stokes RS-P7-0402-203 | 95D07362 | U3 | 1564 | 5.74 |  |
| Production Probe #3 | #1 (bottom) | GE Reuter Stokes RS-P7-0402-202 | 95DO4304 | U2 | 1567 | 5.76 | Detectors have been irradiated to 3 x$10^5$ Rad in prototype probe. Ceramic-metal seals are brown rather than white. |
|  | #2 (side) | GE Reuter Stokes RS-P7-0402-203 | 95D04307 | U1 | 1566 | 6.00 | Detectors have been irradiated to 3 x$10^5$ Rad in prototype probe. Ceramic-metal seals are brown rather than white. |
|  | #3 (top) | GE Reuter Stokes RS-P7-0402-203 | 95D04309 | U3 | 1565 | 5.78 | Detectors have been irradiated to 3 x$10^5$ Rad in prototype probe. Ceramic-metal seals are brown rather than white. |

Notes

[†] Reference designator used is from H-14-100481 REV 0, released 5/96.

[‡] Charge sensitive amplifier gain measured by applying a 10 kHz, $T_r$ < 20 ns, V = 200 mV, into a 2 pF test capacitor into Pin 1 of charge amplifier and measuring the output of the charge amplifier at Pin 8.

May 13 fax from AMPTEK with amplifier gains.



**AMPTEK, INC.**

**6 DE ANGELO DRIVE, BEDFORD, MA 01730 U.S.A.**
**TEL: 617-275-2242** **FAX: 617-275-3470**
email: sales@amptek.com http://www.amptek.com

## FAX COVER SHEET

**DATE:** May 13, 1996

**TOTAL PAGES SENT:** 2

**ATTN:** Jim Bussell
**COMPANY:** Westinhouse Hanford Co.
**FAX NO:** (509) 372-1147
**FROM:** John Pantazis

## MESSAGE

Dear Mr. Bussell:

It seems to us that your line driver circuit loads the outputs of the A225 to a positive DC voltage. The only way to avoid this condition is to AC couple the output of the A225 to the input of the line driver. In place of the zero Ohms resistor you can connect approximately a 1 $\mu$F capacitor.

The gains of the devices you have are:

| SN | Gain(V/pC) |
|---|---|
| 1562 | 5.74 |
| 1563 | 5.74 |
| 1564 | 6.00 |
| 1565 | 5.78 |
| 1566 | 6.00 |
| 1567 | 5.76 |
| 1568 | 5.68 |
| 1569 | 5.74 |
| 1570 | 5.87 |
| 1353 | 6.33 |
| 1559 | 5.89 |
| 1561 | 5.85 |
| 1550 | 5.70 |
| 1554 | 5.76 |
| 1556 | 6.07 |

The test set-up is a square wave generator Tr < 20 ns, f = 10 kHz, V = 220 mV, into a 2 pF test capacitor to Pin 1.

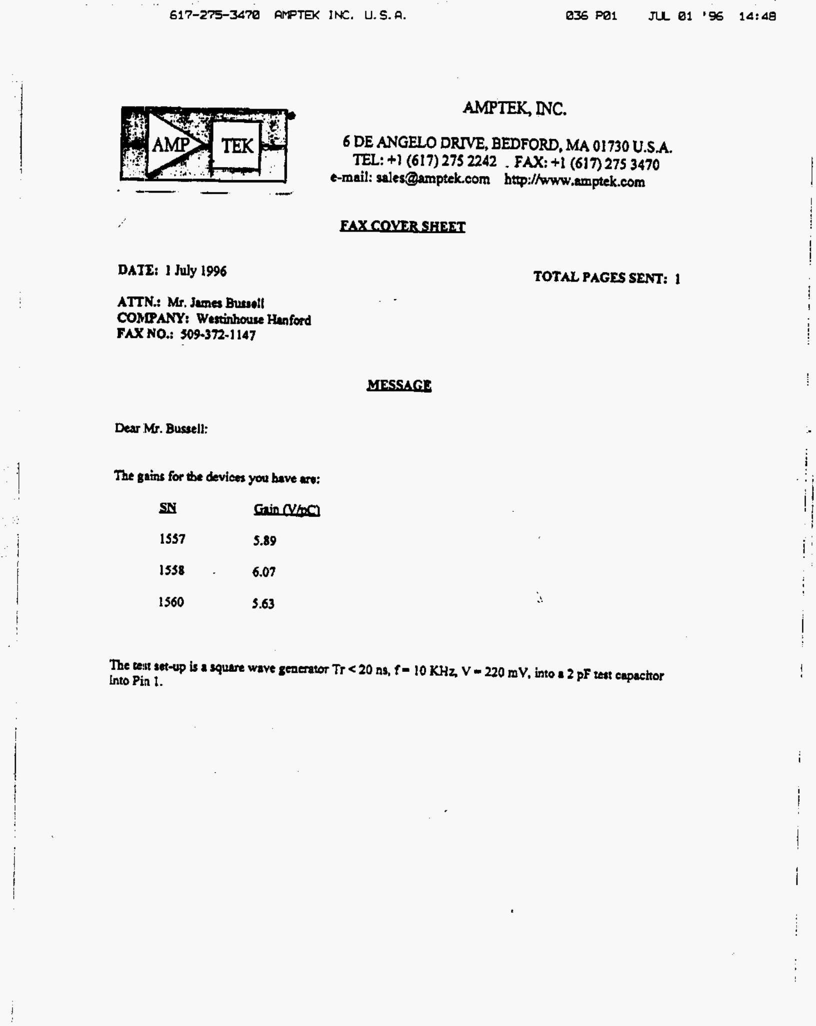
Best regards,

A. Pantazis

John A. Pantazis
President

617-275-3470 AMPTEK INC. U.S.A. 607 P01 MAY 13 '96 15:16

July 1 fax from AMPTEK with amplifier gains



617-275-3470 AMPTEK INC. U.S.A. 036 P01 JUL 01 '96 14:48

AMPTEK, INC.

6 DE ANGELO DRIVE, BEDFORD, MA 01730 U.S.A.
TEL: +1 (617) 275 2242 . FAX: +1 (617) 275 3470
e-mail: sales@amptek.com http://www.amptek.com

**FAX COVER SHEET**

**DATE:** 1 July 1996

**TOTAL PAGES SENT:** 1

**ATTN.:** Mr. James Bussell
**COMPANY:** Westinhouse Hanford
**FAX NO.:** 509-372-1147

**MESSAGE**

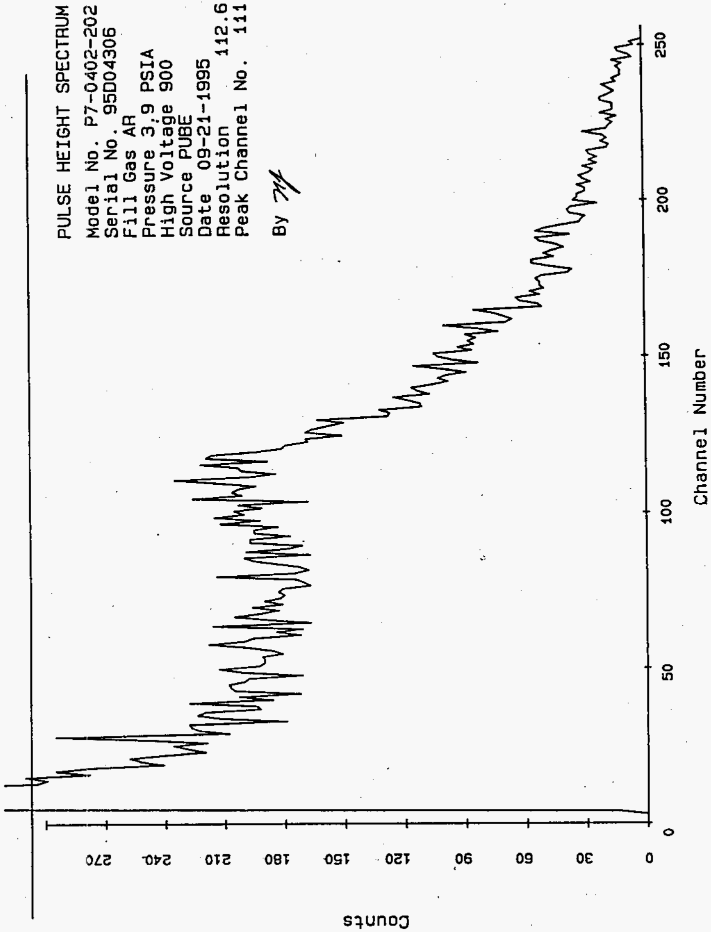
Dear Mr. Bussell:

The gains for the devices you have are:

| SN | Gain (V/pC) |
|---|---|
| 1557 | 5.89 |
| 1558 | 6.07 |
| 1560 | 5.63 |

The test set-up is a square wave generator Tr < 20 ns, f = 10 KHz, V = 220 mV, into a 2 pF test capacitor into Pin 1.

Data sheet (energy spectrum) for counter RS-P7-0402-202 Serial No. 95D04306 - Probe #1 Bottom Detector

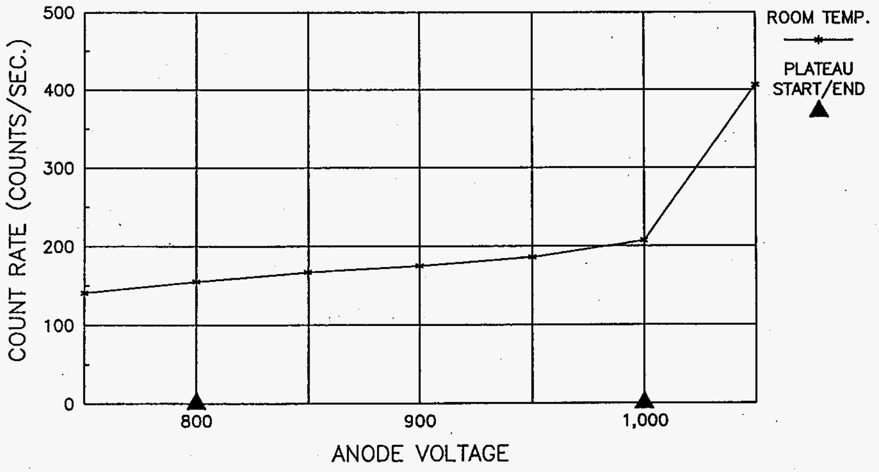


Plateau Characteristics for 95D04306 - Probe #1 Bottom Detector

# PLATEAU CHARACTERISTICS

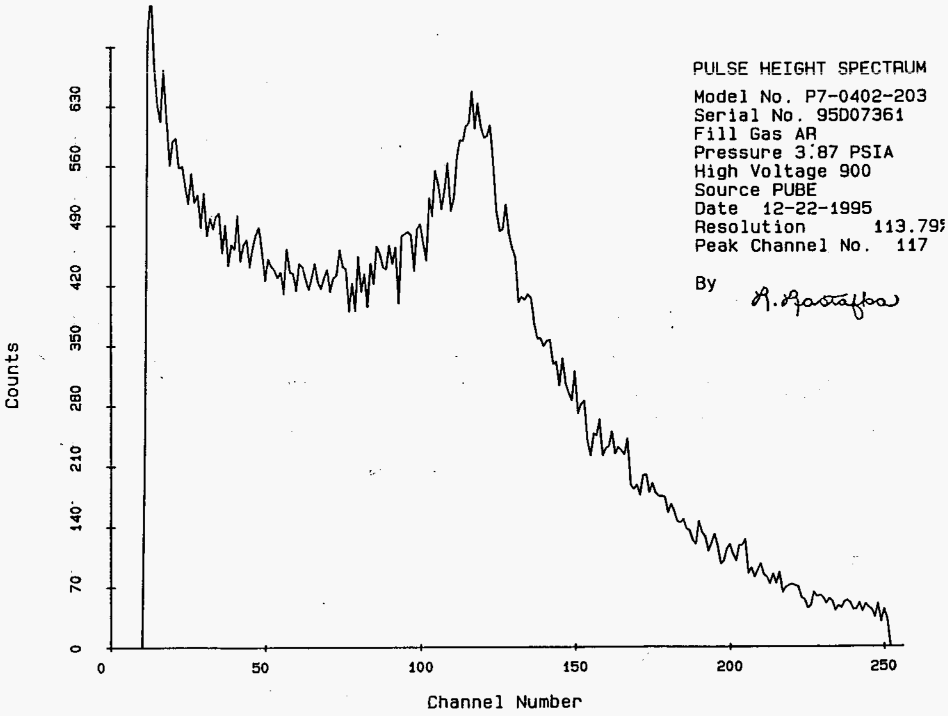
## MODEL No. P7-0402-202

## SERIAL No. 95D04306



SENSITIVITY: .29 CPS/NV
FILL GAS: Ar
PRESSURE: 3.9 PSIA

LENGTH > 200 VOLTS
SLOPE < 14.40%/100 VOLTS
TESTED BY: N. JOHNSON DATE: 9/22/95



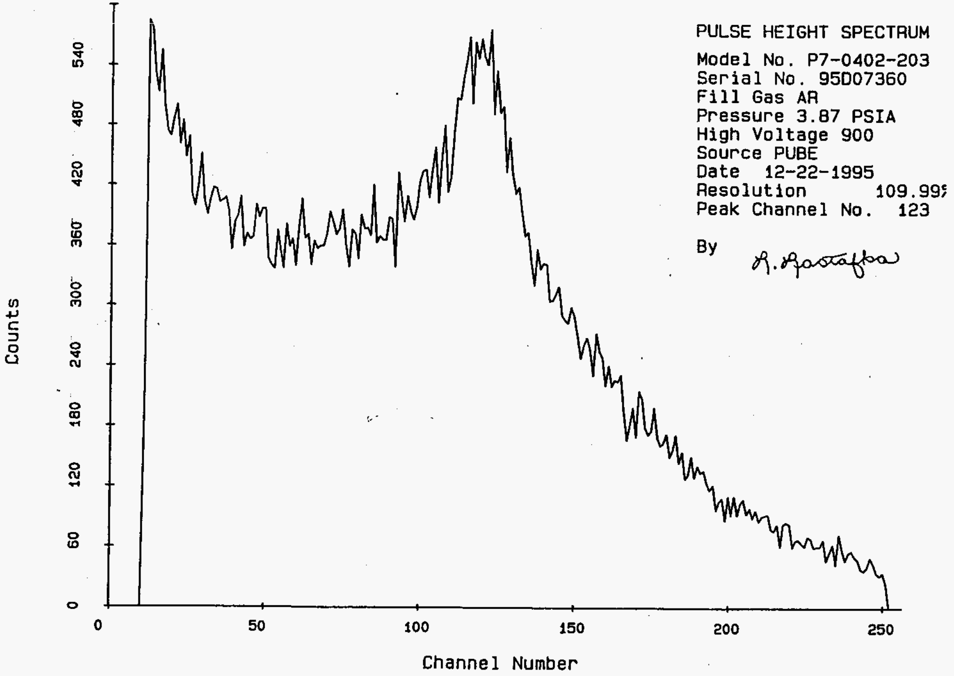
PULSE HEIGHT SPECTRUM

Model No. P7-0402-203
Serial No. 95D07361
Fill Gas AR
Pressure 3.87 PSIA
High Voltage 900
Source PUBE
Date 12-22-1995
Resolution 113.79
Peak Channel No. 117

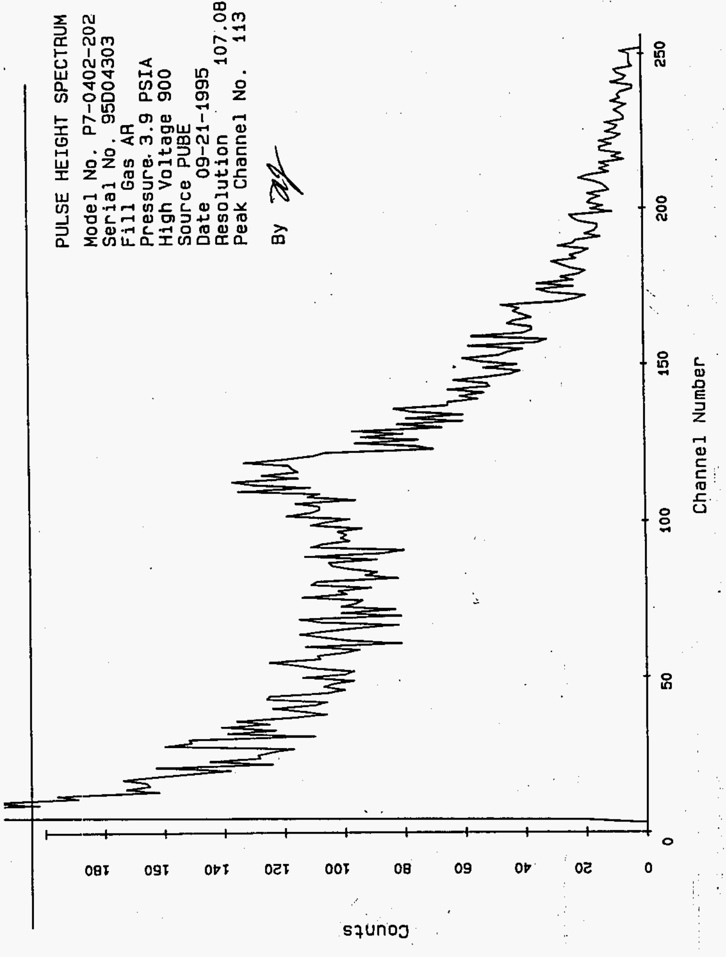
By

Data sheet (energy spectrum) for counter RS-P7-0402-203 Serial 95D07361 - Probe #1 Side Detector

Data sheet (energy spectrum) for counter RS-P7-0402-203 Serial 95D07360 - Probe #1 Top Detector



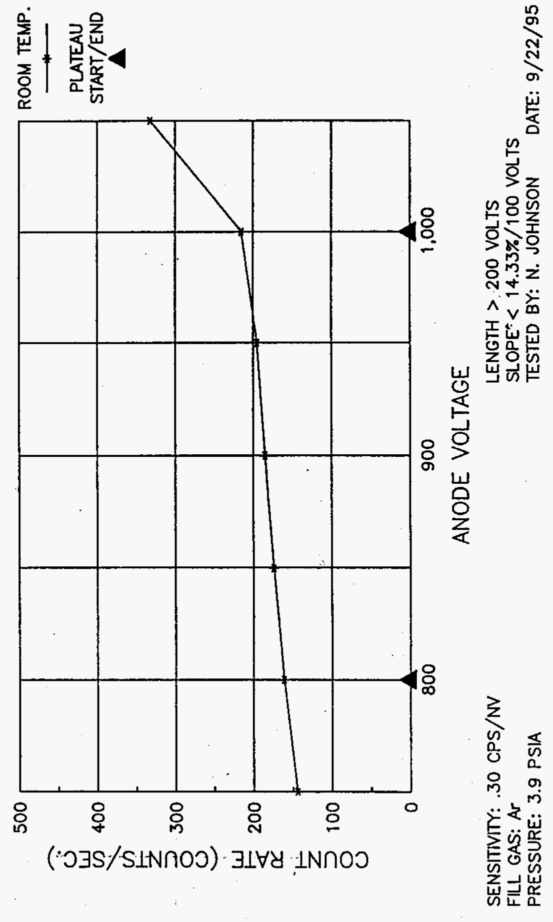
Data sheet (energy spectrum) for counter RS-P7-0402-202 Serial No. 95D04303 - Probe #2 Bottom Detector



Plateau Characteristics for 95D04303 - Probe #2 Bottom Detector

## PLATEAU CHARACTERISTICS

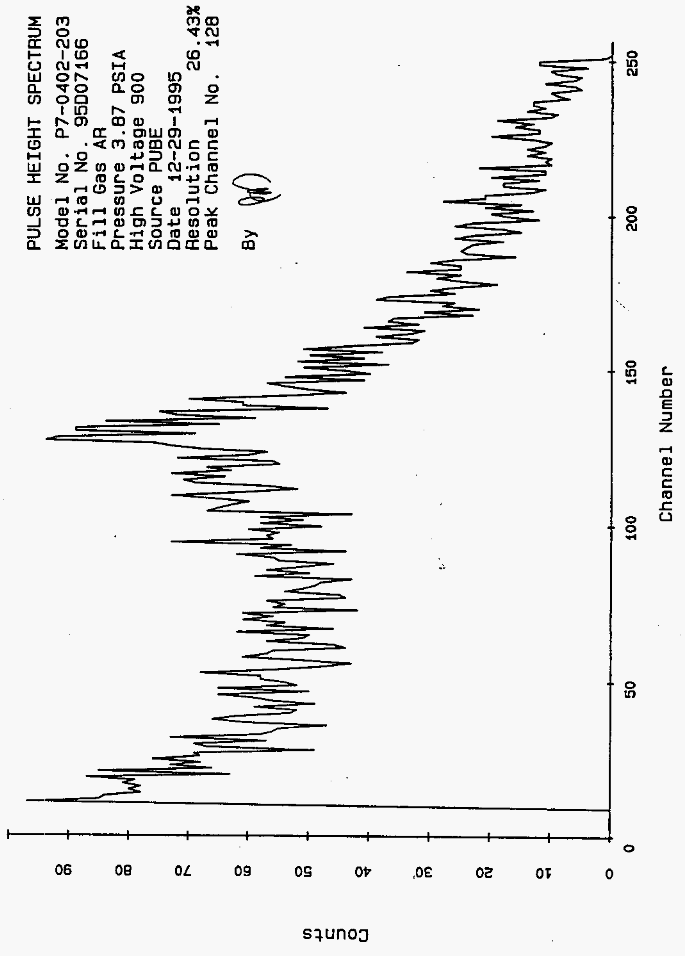
MODEL No. P7-0402-202
SERIAL No. 95D04303



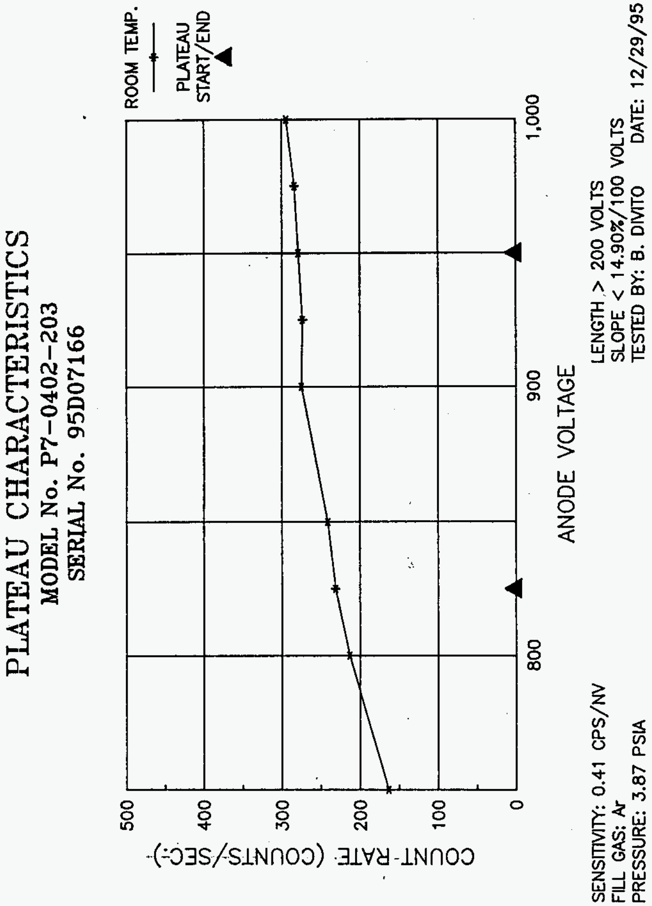
SENSITIVITY: .30 CPS/NV
FILL GAS: Ar
PRESSURE: 3.9 PSIA

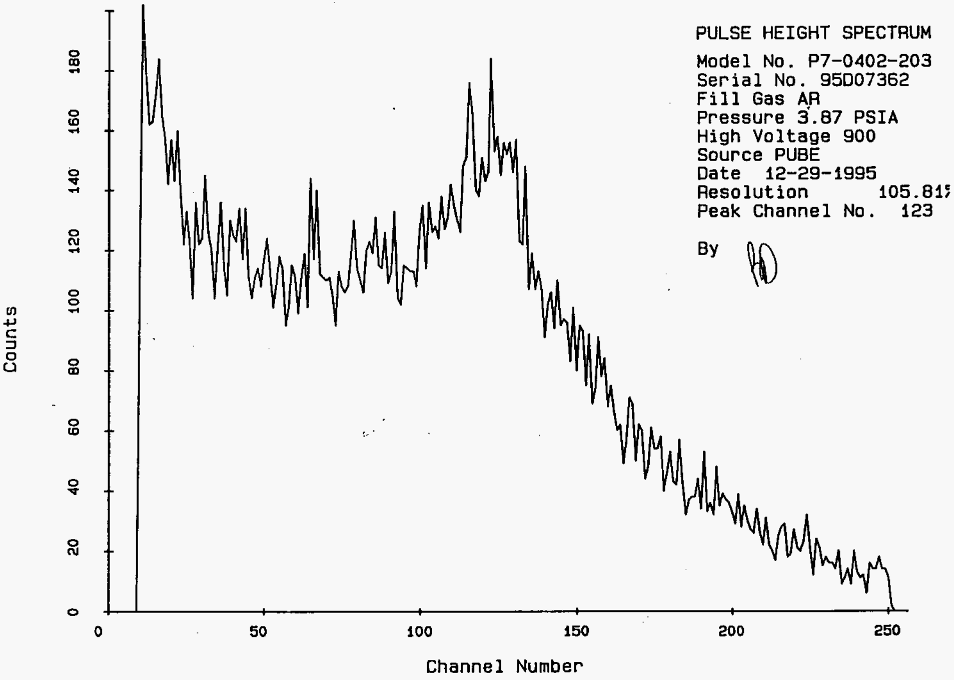
LENGTH > 200 VOLTS
SLOPE* < 14.33%/100 VOLTS
TESTED BY: N. JOHNSON DATE: 9/22/95

Data sheet (energy spectrum) for counter RS-P7-0402-203 Serial 95D07166 - Probe #2 Side Detector



Plateau Characteristics for 95D07166 - Probe #2 Top Detector



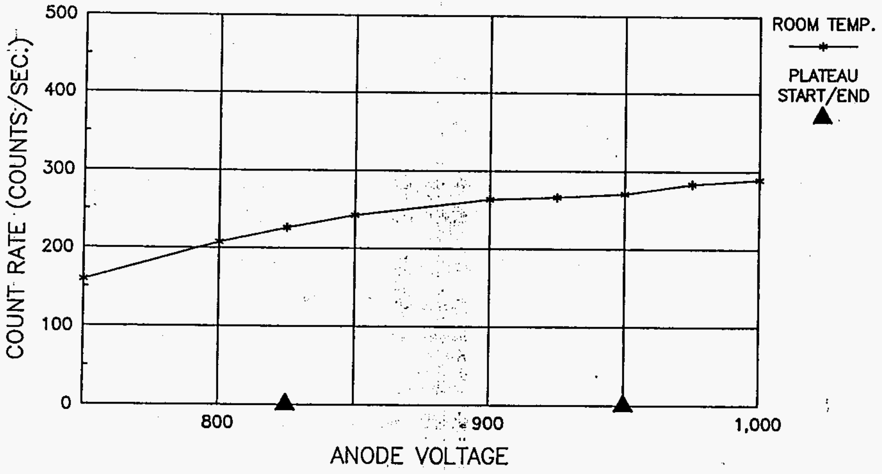


PULSE HEIGHT SPECTRUM
Model No. P7-0402-203
Serial No. 95D07362
Fill Gas AR
Pressure 3.87 PSIA
High Voltage 900
Source PUBE
Date 12-29-1995
Resolution 105.81
Peak Channel No. 123

By

Data sheet (energy spectrum) for counter RS-P7-0402-203 Serial 95D07362 - Probe #2 Top Detector

# PLATEAU CHARACTERISTICS
MODEL No. P7-0402-203
SERIAL No. 95D07362

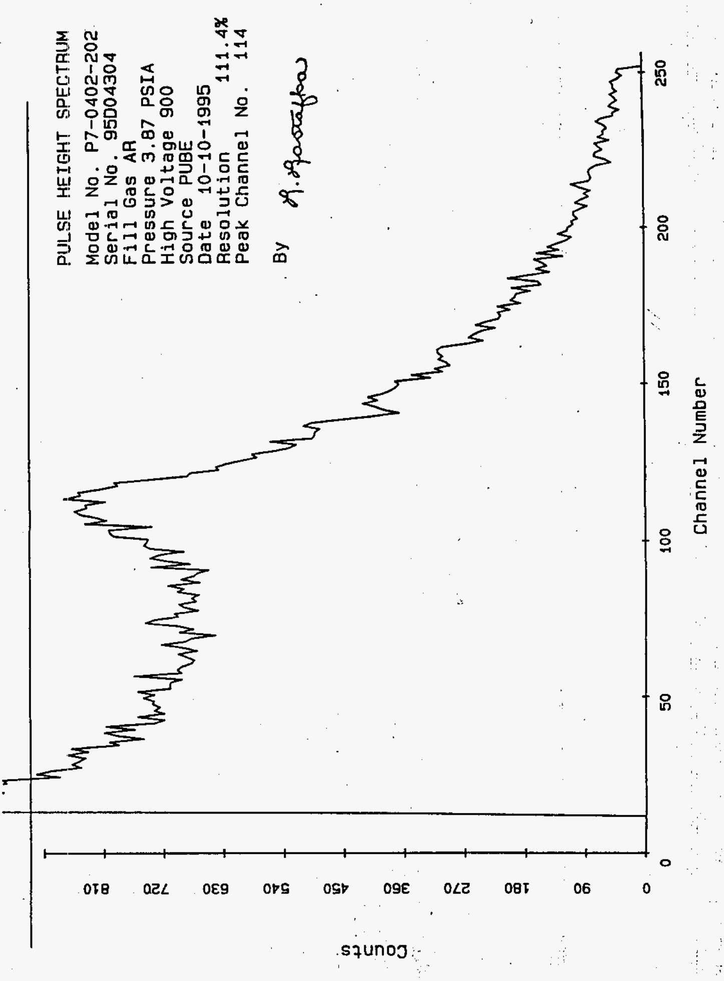


SENSITIVITY: 0.40 CPS/NV
FILL GAS: Ar
PRESSURE: 3.87 PSIA

LENGTH > 200 VOLTS
SLOPE < 14.52%/100 VOLTS
TESTED BY: B. DIVITO DATE: 12/29/95

Plateau Characteristics for 95D07362 - Probe #2

Data sheet (energy spectrum) for counter RS-P7-0402-202 Serial No. 95D04304 - Probe #3

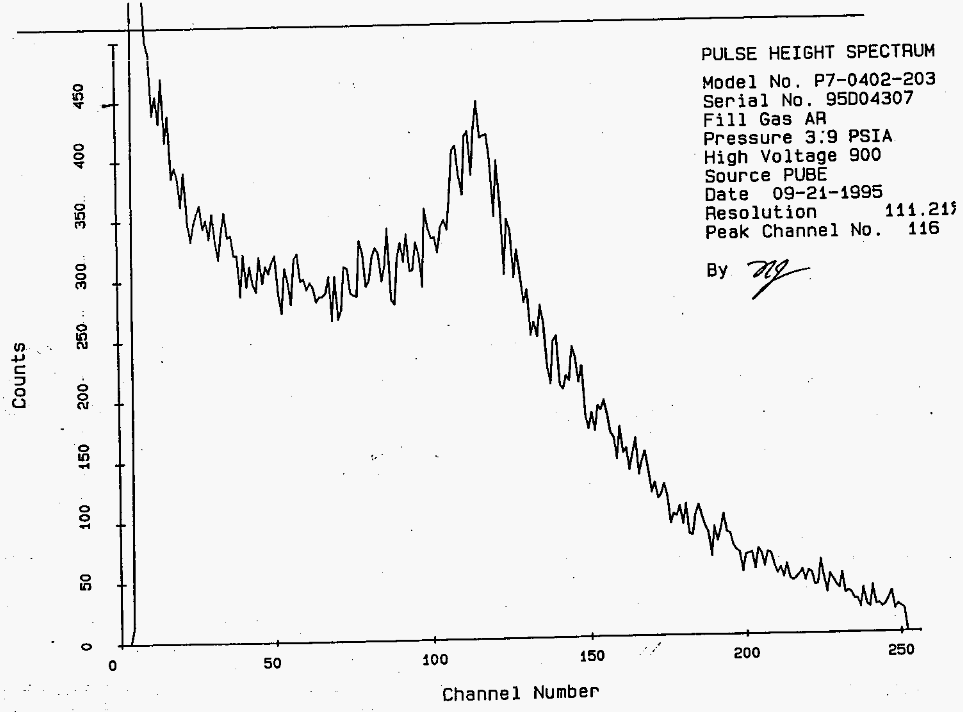


PULSE HEIGHT SPECTRUM

Model No. P7-0402-202
Serial No. 95D04304
Fill Gas AR
Pressure 3.87 PSIA
High Voltage 900
Source PUBE
Date 10-10-1995
Resolution 111.4%
Peak Channel No. 114

By

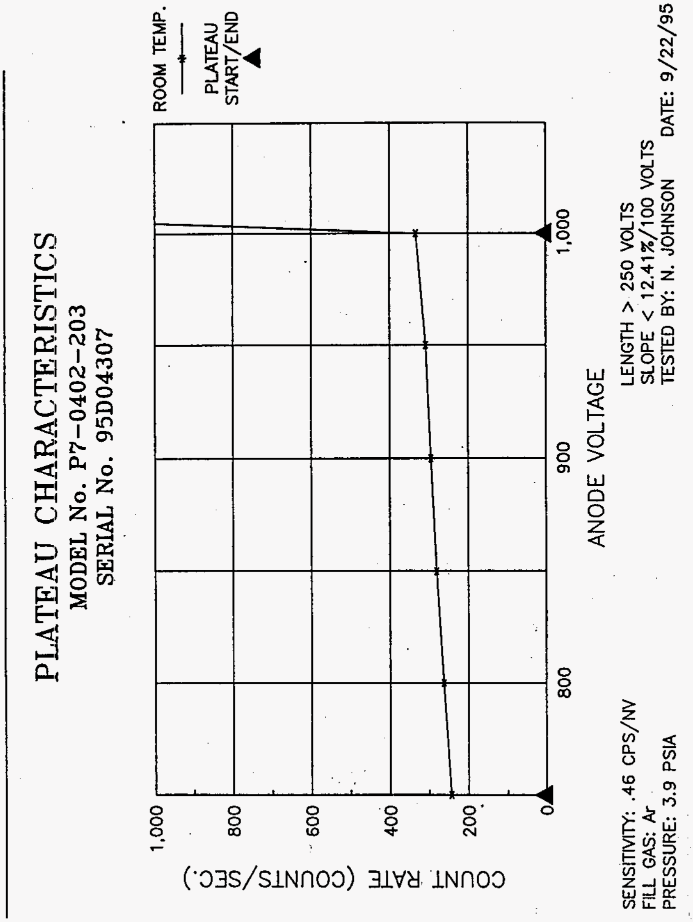
Data sheet (energy spectrum) for counter RS-P7-0402-203 Serial 95D04307 - Probe #3

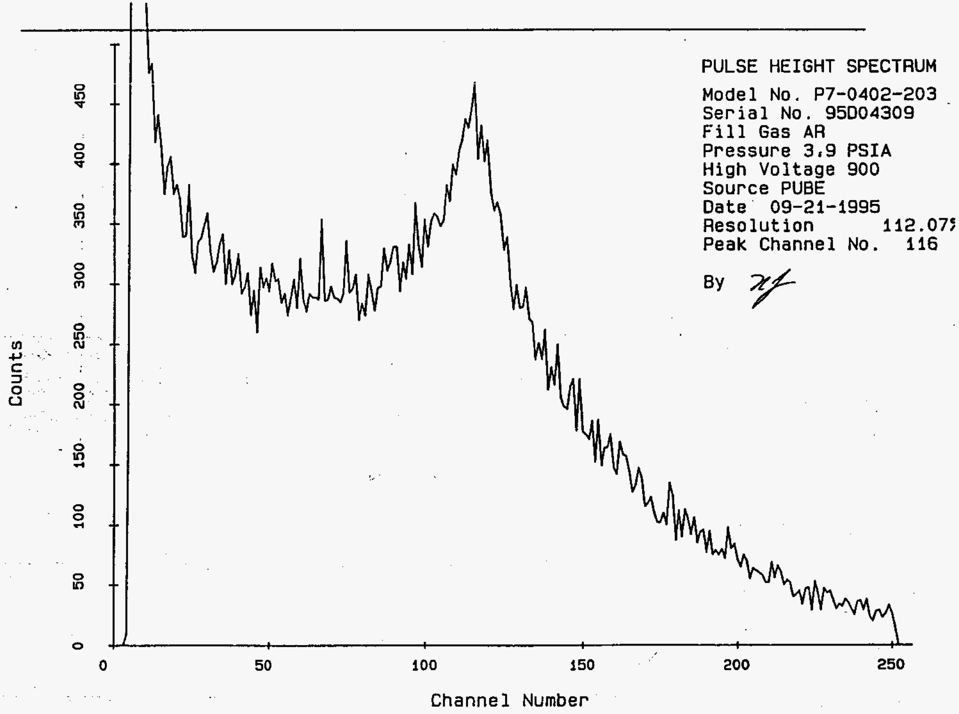


PULSE HEIGHT SPECTRUM
Model No. P7-0402-203
Serial No. 95D04307
Fill Gas AR
Pressure 3.9 PSIA
High Voltage 900
Source PUBE
Date 09-21-1995
Resolution 111.21
Peak Channel No. 116

By

Plateau Characteristics for 95D04307 - Probe #3



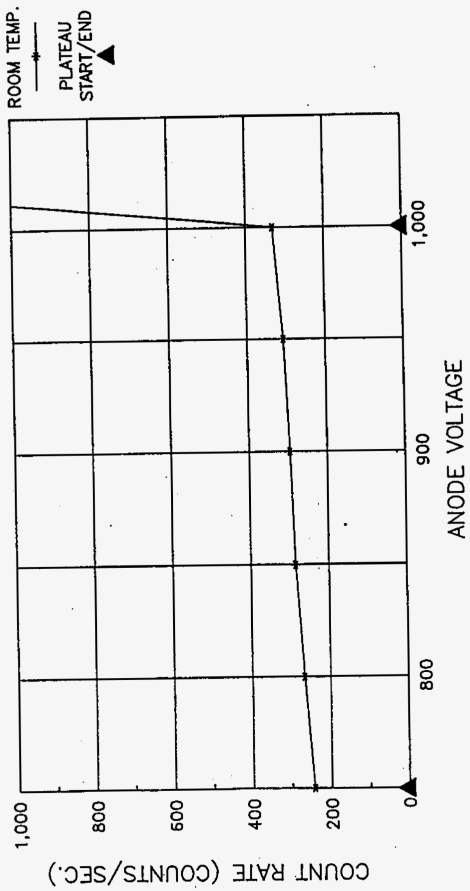


Data sheet (energy spectrum) for counter RS-P7-0402-203 Serial 95D04309 - Probe #3

Plateau Characteristics for 95D04309 - Probe #3

# PLATEAU CHARACTERISTICS

MODEL No. P7-0402-203
SERIAL No. 95D04309



LENGTH > 250 VOLTS
SLOPE < 12.25%/100 VOLTS
TESTED BY: N. JOHNSON
DATE: 9/22/95

SENSITIVITY: .46 CPS/NV
FILL GAS: Ar
PRESSURE: 3.9 PSIA

# APPENDIX B HIGH EXPOSURE FACILITY CALIBRATION REPORT

**Battelle**
Pacific Northwest Laboratories

Project No. __________

Internal Distribution

IC&E M&TE Records Custodian
GL Carter
File/LB

**Date** March 25, 1996

**To** *Calibration File - High Level Room Sources*

**From** LE Steffens

**Subject** Annual Calibration of High Level Room Gamma Sources

During the period November 2 through 6, 1995, the High Exposures Facility (HEF) sources were calibrated. Sources included in this calibration are $^{137}$Cs 318-040, 318-044 and $^{60}$Co 318-037, 318-353. Twenty-six positions, as listed on the attached table, were assessed. Appropriate corrections were made for electromter readings, ionization chamber response (Roentgen/Coulomb) and ambient temperature and pressure conditions to correct the response to 22°C and 760 mmHg. Calibration measuremtns were performed in accordance with *Calibration Procedure for 318 Building Gamma Sources*, revision September 1990. This calibration is valid through November, 1996.

On November 1, 1995, prior to the radiological calibration, Greg Carter performed measurements to assess the remote positioning system. This system was found to be within ±0.5% over its entire range. This verification is documented on page 2 of the HEF Maintenance Log (LRB BNW 56057) maintained currently in Room 2.

Traceability to the National Institute of Standards and Technology (NIST) for this calibrations is established through use of the below listed Capintec ionization chamber. The Capintec Model PM-30 air ionization chamber (CII30.4277) was directly calibrated by the NIST (i.e., a secondary standard).

The following equipment was used:

| | |
|---|---|
| Ionization Chamber: | Capintec PM-30 Air Ionization Chamber,<br>S/N CII30.4277 |
| Electrometer: | Keithley Model 6517, S/N 0612426 |
| Bias Supply | 300Volt External Battery |
| Temperature Standard: | Cole/Parmer Type J, S/N 577785 |
| Pressure Standard: | A.I.R., 101-07-01-002 |

Calibration File - High Level Room Sources
March 25, 1996
Page 2

The following values/conditions were used:

| | |
|---|---|
| Bias Supply: | ± 300 Volts |
| PM-30 Chamber CF: | 1.140E8 R/C $^{137}$Cs, 1.134E8 $^{60}$Co |
| Offset: | -0.076 and -0.075 (see attached for specific points) |
| Electrometer Correction Factor: | 1.001 (Auto, readings above 2nC)<br>1.001 (2nC, readings below 2nC) |

Data regarding this calibration is summarized in Attachment 1. Raw data is recorded in Laboratory Record Book (LRB) BNW-54355, pages 134 through 135.

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Calibration performed by: Lyn E. Steffens 3/25/96

Lyn E. Steffens
Calibration Research and Accreditation

Report approved by: 3/25/96

R. Kim Piper
Calibration Research and Accreditation

| Measurement Dates: November 2-6, 1995 | | | | | |
|---|---|---|---|---|---|
| Computer Distance (m) | Chamber Offset (m) | Exposure Rate (R/h) | | | |
| | | 318-040 | 318-044 | 318-037 | 318-353 |
| 0.300 | -0.075 | 2.565E+01 | 2.551E+02 | 1.496E+03 | 5.709E+04 |
| 0.400 | -0.075 | 1.428E+01 | 1.419E+02 | 8.423E+02 | 3.422E+04 |
| 0.500 | -0.075 | 9.062E+00 | 9.009E+01 | 5.354E+02 | 2.260E+04 |
| 0.600 | -0.075 | 6.242E+00 | 6.219E+01 | 3.704E+02 | 1.592E+04 |
| 0.700 | -0.075 | 4.574E+00 | 4.549E+01 | 2.709E+02 | 1.177E+04 |
| 0.800 | -0.075 | 3.483E+00 | 3.467E+01 | 2.068E+02 | 9.059E+03 |
| 0.900 | -0.075 | 2.736E+00 | 2.739E+01 | 1.629E+02 | 7.164E+03 |
| 1.000 | -0.076 | 2.221E+00 | 2.218E+01 | 1.325E+02 | 5.827E+03 |
| 1.250 | -0.076 | 1.414E+00 | 1.411E+01 | 8.439E+01 | 3.729E+03 |
| 1.500 | -0.075 | 9.811E-01 | 9.747E+00 | 5.838E+01 | 2.593E+03 |
| 1.750 | -0.075 | 7.197E-01 | 7.143E+00 | 4.268E+01 | 1.899E+03 |
| 2.000 | -0.075 | 5.486E-01 | 5.446E+00 | 3.268E+01 | 1.453E+03 |
| 2.250 | -0.075 | 4.355E-01 | 4.303E+00 | 2.584E+01 | 1.148E+03 |
| 2.500 | -0.075 | 3.516E-01 | 3.478E+00 | 2.084E+01 | 9.296E+02 |
| 2.750 | -0.075 | 2.892E-01 | 2.873E+00 | 1.718E+01 | 7.683E+02 |
| 3.000 | -0.075 | 2.420E-01 | 2.407E+00 | 1.432E+01 | 6.449E+02 |
| 3.250 | -0.075 | 2.077E-01 | 2.055E+00 | 1.226E+01 | 5.495E+02 |
| 3.500 | -0.075 | 1.802E-01 | 1.783E+00 | 1.065E+01 | 4.775E+02 |
| 3.750 | -0.075 | 1.565E-01 | 1.554E+00 | 9.299E+00 | 4.155E+02 |
| 4.000 | -0.075 | 1.364E-01 | 1.365E+00 | 8.155E+00 | 3.656E+02 |
| 4.250 | -0.075 | 1.214E-01 | 1.208E+00 | 7.220E+00 | 3.241E+02 |
| 4.500 | -0.075 | 1.078E-01 | 1.078E+00 | 6.415E+00 | 2.886E+02 |
| 4.750 | -0.075 | 9.740E-02 | 9.694E-01 | 5.774E+00 | 2.590E+02 |
| 5.000 | -0.075 | 8.890E-02 | 8.756E-01 | 5.216E+00 | 2.346E+02 |
| 5.250 | -0.075 | 8.020E-02 | 7.965E-01 | 4.754E+00 | 2.128E+02 |
| Jig (1) | | | | 2.736E+00 | |

# APPENDIX C 3730 $^{60}$Co FACILITY CALIBRATION

Battelle
Pacific Northwest Laboratories

3730 $^{60}$Co FACILITY CALIBRATION

**Date** December 5, 1984

**To** G. L. Jones

**From** J. L. Pappin

**Subject** 3730 $^{60}$Co FACILITY CALIBRATION

Results for the recent calibration of all exposure tubes at the 3730 $^{60}$Co Facility are attached. Calibration data were collected from 8/24/84 thru 10/5/84. The calibrations were formed using an ion chamber and thermoluminescent dosimeters (TLD's).

The ion chamber measurements were made using a Capintec PR-06C chamber with build up cap, S/N C11G 64053, and a Keithley electrometer, S/N 115092. The ion chamber is a transfer standard which carries a calibration certificate for $^{60}$Co from the National Bureau of Standards dated 5/28/82. The calibration of this chamber was confirmed by direct comparison with a Capintec PM-30 chamber which carries a calibration certificate for $^{60}$Co from the National Bureau of Standards dated 1/25/84. The ion chamber calibration measurements were performed in Tube #21 with the chamber centered 6, 8, and 10 inches from the bottom of the tube on 8/24/84, which is the official date of calibration for all tubes. Ion chamber calibration results are given in Table 1.

Table 1: Ion Chamber Calibration Tube 21, 8/24/84

| Position inches from bottom | Calibrated $10^5$ R/h |
|---|---|
| 6 | 4.76 |
| 8 | 5.06 |
| 10 | 5.16 |

TLD exposures were made by placing packets containing three TLD 800's inside the center of a 33" long x 1 1/2" diameter plastic (lucite) tube having 32 positions at 1" intervals. This tube provides electronic equilibrium and reproducible geometry and is shown in photo #1. The lucite tube has three holes drilled thru it such that plastic rods may be inserted for alignment at the center at the $^{60}$Co exposure tubes. During TLD exposures the lucite tube containing TLD 800 packets is lowered down until it rests on the bottom and in the center of a $^{60}$Co exposure tube. The exposure times for the TLD's were controlled and recorded.

The TLD 800's ($Li_2Br_4O_7$:Mn) were calibrated by placing TLD packets in the lucite rod at positions that correspond to the positions of the NBS traceable ion chamber calibrations. A series of TLD exposures for varying times provided data to determine the TLD response versus exposure data. These data were then fit using the power function $X=(y/a)^{1/b}$ where x = exposure, $10^4$R, and y = TLD response. The resulting formula was used to calculate the calibrated R/h from TLD response data in all the $^{60}$Co exposure tubes at the 3730 facility. The calibrated exposure rates for the $^{60}$Co exposure tubes at the 3730 facility are presented in Table 2

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**PNL TABLE 1. Ion Chamber Calibration, 8/24/84, TUBE 21**

| POSITION (INCHES FROM BOTTOM) | | CALIBRATED |
|---|---|---|
| | FLUX: | $10^5$ R/h |
| 6 | | 4.76 |
| 8 | | 5.06 |
| 10 | | 5.16 |

## PNL TABLE 2. Calibrated Exposure Rates
## 3730 $^{60}$Co FACILITY, 8/24/84.

| POSITION (INCHES FROM BOTTOM) | TUBE #1 | TUBE #2 | TUBE #3 | TUBE #4 | TUBE #5 | TUBE #6 |
|---|---|---|---|---|---|---|
| FLUX: | $10^6$ R/h | $10^5$ R/h | $10^5$ R/h | $10^5$ R/h | $10^4$ R/h | $10^4$ R/h |
| 1 | 0.862 | 2.50 | 2.22 | 1.50 | 8.83 | 2.07 |
| 3 | 1.28 | 3.51 | 2.79 | 1.59 | 8.86 | 5.78 |
| 5 | 2.32 | 4.83 | 3.42 | 1.56 | 8.99 | 6.44 |
| 7 | 3.97 | 7.44 | 4.21 | 1.67 | 9.35 | 6.48 |
| 9 | 5.78 | 9.37 | 4.58 | 1.64 | 9.73 | 6.77 |
| 11 | 6.33 | 10.7 | 5.01 | 1.61 | 9.65 | 6.67 |
| 13 | 6.47 | 11.0 | 5.06 | 1.51 | 9.29 | 6.63 |
| 15 | 6.01 | 10.7 | 4.72 | 1.38 | 9.37 | 6.91 |
| 17 | 5.18 | 9.00 | 4.49 | 1.28 | 9.17 | 6.71 |
| 19 | 3.37 | 6.79 | 3.52 | 1.17 | 8.69 | 6.51 |
| 21 | 1.79 | 4.94 | 3.02 | 1.04 | 7.94 | 6.26 |
| 23 | 0.93 | 3.16 | 2.43 | 0.70 | 7.66 | 6.12 |
| 25 | 0.53 | 2.33 | 1.83 | 0.48 | 7.05 | 6.17 |
| 27 | 0.33 | 1.57 | 1.42 | 0.32 | 3.00 | 4.55 |
| 29 | 0.18 | 1.04 | 1.04 | 0.24 | 1.83 | 2.13 |
| 31 | 0.12 | 0.69 | 0.67 | 0.17 | 1.35 | 1.15 |

| POSITION (INCHES FROM BOTTOM) | TUBE #7 | TUBE #8 | TUBE #9 | TUBE #10 | TUBE #11 | TUBE #12 |
|---|---|---|---|---|---|---|
| FLUX: | $10^4$ R/h | $10^4$ R/h | $10^4$ R/h | $10^4$ R/h | $10^5$ R/h | $10^5$ R/h |
| 1 | 5.16 | 1.26 | 1.01 | 0.22 | 3.01 | 2.82 |
| 3 | 5.77 | 3.21 | 3.16 | 0.50 | 3.70 | 4.09 |
| 5 | 5.72 | 4.05 | 3.57 | 1.46 | 4.39 | 5.34 |
| 7 | 5.82 | 4.23 | 3.62 | 2.36 | 4.79 | 6.63 |
| 9 | 5.74 | 4.22 | 3.58 | 2.92 | 5.45 | 7.94 |
| 11 | 5.56 | 4.18 | 3.82 | 3.12 | 5.53 | 8.30 |
| 13 | 5.65 | 4.49 | 3.66 | 3.06 | 4.94 | 8.41 |
| 15 | 5.40 | 4.58 | 3.62 | 3.16 | 4.07 | 7.12 |
| 17 | 5.23 | 4.47 | 3.66 | 3.08 | 3.55 | 6.42 |
| 19 | 5.09 | 4.41 | 3.62 | 3.07 | 2.84 | 4.89 |
| 21 | 4.68 | 4.05 | 3.50 | 2.99 | 2.16 | 3.38 |
| 23 | 2.36 | 4.24 | 3.59 | 3.02 | 1.61 | 2.42 |
| 25 | 1.36 | 3.92 | 3.46 | 3.09 | 1.08 | 1.66 |
| 27 | 0.86 | 2.89 | 2.19 | 2.98 | 0.76 | 1.02 |
| 29 | 0.59 | 1.34 | 0.97 | 2.90 | 0.50 | 0.73 |
| 31 | 0.50 | 0.91 | 0.58 | 1.59 | 0.35 | 0.54 |

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## PNL TABLE 2. Calibrated Exposure Rates (Continued)
## 3730 $^{60}Co$ FACILITY, 8/24/84.

| POSITION (INCHES FROM BOTTOM) | | TUBE #13 | TUBE #14 | TUBE #15 | TUBE #15A | TUBE #15B | TUBE #16 |
|---|---|---|---|---|---|---|---|
| | FLUX: | $10^5$ R/h | $10^5$ R/h | $10^5$ R/h | $10^5$ R/h | $10^4$ R/h | $10^5$ R/h |
| 1 | | 3.30 | 3.16 | 1.73 | 1.03 | 1.96 | 5.12 |
| 3 | | 4.59 | 3.97 | 2.18 | 1.26 | 2.26 | 7.93 |
| 5 | | 6.26 | 4.73 | 2.67 | 1.39 | 2.70 | 11.4 |
| 7 | | 7.15 | 5.66 | 3.03 | 1.52 | 2.90 | 13.1 |
| 9 | | 8.02 | 6.02 | 3.10 | 1.55 | 2.96 | 14.6 |
| 11 | | 8.28 | 5.79 | 3.11 | 1.67 | 2.95 | 14.6 |
| 13 | | 8.02 | 5.53 | 3.06 | 1.59 | 2.84 | 14.6 |
| 15 | | 6.99 | 4.79 | 2.82 | 1.45 | 2.70 | 13.2 |
| 17 | | 5.74 | 3.93 | 2.63 | 1.36 | 2.51 | 11.4 |
| 19 | | 4.35 | 3.29 | 2.18 | 1.16 | 2.18 | 8.38 |
| 21 | | 3.07 | 2.59 | 1.79 | 1.03 | 1.93 | 4.95 |
| 23 | | 2.54 | 1.87 | 1.46 | 0.85 | 1.61 | 2.93 |
| 25 | | 1.61 | 1.38 | 1.13 | 0.68 | 1.33 | 1.69 |
| 27 | | 1.07 | 0.90 | 0.77 | 0.52 | 1.07 | 1.10 |
| 29 | | 0.76 | 0.61 | 0.57 | 0.41 | 0.84 | 0.65 |
| 31 | | 0.53 | 0.50 | 0.40 | 0.32 | 0.70 | 0.47 |

| POSITION (INCHES FROM BOTTOM) | | TUBE #17 | TUBE #18 | TUBE #19 | TUBE #20 | TUBE #21[1] | TUBE #21[2] |
|---|---|---|---|---|---|---|---|
| | FLUX: | $10^5$ R/h | $10^5$ R/h | $10^5$ R/h | $10^5$ R/h | $10^5$ R/h | $10^5$ R/h |
| 1 | | 1.83 | 1.45 | 1.43 | 1.55 | 1.81 | 2.14 |
| 3 | | 2.40 | 2.09 | 2.07 | 2.29 | 3.16 | 3.34 |
| 5 | | 2.86 | 2.50 | 2.77 | 3.05 | 4.36 | 4.28 |
| 7 | | 3.40 | 3.19 | 3.39 | 3.54 | 5.05 | 5.03 |
| 9 | | 3.37 | 3.44 | 3.62 | 3.78 | 5.38 | 5.52 |
| 11 | | 3.29 | 3.39 | 3.73 | 3.87 | 5.28 | 5.67 |
| 13 | | 3.19 | 3.48 | 3.50 | 3.69 | 5.17 | 5.52 |
| 15 | | 2.76 | 3.28 | 3.15 | 3.43 | 4.40 | 4.72 |
| 17 | | 2.30 | 2.69 | 2.77 | 2.72 | 3.95 | 4.14 |
| 19 | | 1.62 | 1.99 | 2.11 | 2.07 | 2.70 | 2.84 |
| 21 | | 1.11 | 1.31 | 1.41 | 1.32 | 1.62 | 1.74 |
| 23 | | 0.67 | 0.84 | 0.82 | 0.78 | 0.94 | 1.05 |
| 25 | | 0.44 | 0.55 | 0.49 | 0.49 | 0.57 | 0.64 |
| 27 | | 0.30 | 0.36 | 0.33 | 0.34 | 0.37 | 0.43 |
| 29 | | 0.21 | 0.26 | 0.23 | 0.23 | 0.26 | 0.31 |
| 31 | | 0.16 | 0.18 | 0.18 | 0.17 | 0.18 | 0.22 |

---

[1] – WITH AUTOCLAVE IN TUBE #16

[2] – WITHOUT AUTOCLAVE IN TUBE #16

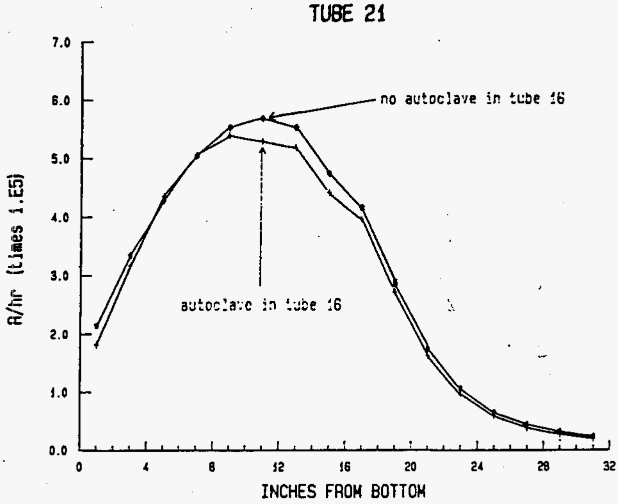
## PNL TABLE 2. Calibrated Exposure Rates (Continued) 3730 $^{60}$Co FACILITY, 8/24/84.

| POSITION (INCHES FROM BOTTOM) | | TUBE #22 | TUBE #23A | TUBE #24A | TUBE #25A | TUBE #26A | TUBE #27A |
|---|---|---|---|---|---|---|---|
| | FLUX: | $10^5$ R/h | $10^4$ R/h | $10^4$ R/h | $10^4$ R/h | $10^4$ R/h | $10^3$ R/h |
| 1 | | 1.86 | 1.92 | 2.24 | 1.72 | 0.96 | 5.15 |
| 3 | | 2.74 | 2.39 | 2.70 | 1.96 | 1.14 | 6.66 |
| 5 | | 3.71 | 3.05 | 3.46 | 2.53 | 1.46 | 7.43 |
| 7 | | 4.11 | 3.28 | 3.97 | 2.96 | 1.61 | 9.23 |
| 9 | | 4.78 | 3.59 | 4.05 | 3.08 | 1.67 | 9.36 |
| 11 | | 4.85 | 3.90 | 4.27 | 3.34 | 1.74 | 9.67 |
| 13 | | 4.82 | 3.71 | 4.24 | 3.07 | 1.76 | 9.25 |
| 15 | | 4.42 | 3.69 | 4.01 | 2.97 | 1.77 | 9.53 |
| 17 | | 3.68 | 3.45 | 3.68 | 2.76 | 1.53 | 8.44 |
| 19 | | 2.68 | 2.90 | 3.13 | 2.43 | 1.46 | 7.82 |
| 21 | | 1.70 | 2.46 | 2.54 | 2.09 | 1.24 | 6.94 |
| 23 | | 0.99 | 1.94 | 1.94 | 1.61 | 1.03 | 5.84 |
| 25 | | 0.58 | 1.36 | 1.40 | 1.19 | 0.81 | 4.64 |
| 27 | | 0.38 | 1.04 | 1.06 | 0.83 | 0.61 | 3.65 |
| 29 | | 0.24 | 0.78 | 0.80 | 0.65 | 0.45 | 2.81 |
| 31 | | 0.19 | 0.66 | 0.61 | 0.49 | 0.33 | 2.29 |

| POSITION (INCHES FROM BOTTOM) | | TUBE #28A | TUBE #29A | TUBE #30A | TUBE #31A | TUBE #32A | TUBE #33A |
|---|---|---|---|---|---|---|---|
| | FLUX: | $10^3$ R/h | $10^3$ R/h | $10^3$ R/h | $10^2$ R/h | $10^2$ R/h | $10^3$ R/h |
| 1 | | 2.55 | 1.54 | 0.74 | 4.36 | 3.40 | 2.39 |
| 3 | | 3.17 | 1.77 | 0.85 | 4.64 | 4.23 | 3.22 |
| 5 | | 3.79 | 2.13 | 1.05 | 6.46 | 5.94 | 3.44 |
| 7 | | 3.95 | 2.41 | 1.11 | 6.77 | 7.50 | 3.84 |
| 9 | | 4.24 | 2.34 | 1.17 | 7.97 | 8.91 | 3.89 |
| 11 | | 4.74 | 2.51 | 1.29 | 8.50 | 9.19 | 4.03 |
| 13 | | 4.65 | 2.43 | 1.24 | 8.89 | 9.98 | 4.11 |
| 15 | | 4.46 | 2.39 | 1.21 | 8.71 | 10.50 | 4.09 |
| 17 | | 4.28 | 2.36 | 1.20 | 8.53 | 9.80 | 4.20 |
| 19 | | 3.79 | 2.24 | 1.17 | 8.82 | 10.60 | 4.18 |
| 21 | | 3.38 | 1.91 | 1.08 | 8.45 | 10.60 | 4.06 |
| 23 | | 3.04 | 1.76 | 0.98 | 7.74 | 10.10 | 3.61 |
| 25 | | 2.64 | 1.51 | 0.90 | 6.81 | 9.38 | 2.73 |
| 27 | | 2.20 | 1.31 | 0.81 | 6.48 | 9.03 | 2.06 |
| 29 | | 1.76 | 1.14 | 0.74 | 5.49 | 7.73 | 1.64 |
| 31 | | 1.46 | 0.93 | 0.60 | 5.36 | 6.26 | 1.22 |

Sources of error that exist in the 3730 $^{60}$Co facility include source decay and exposure geometry. No source decay was applied to TLD data during the month of TLD exposures following the traceable ion chamber calibration of Tube 21. The ion chamber calibration made on 8/24/84 is the official data of calibration for all tubes. The exposure rate at the facility also changes with geometry caused radiation scatter and attenuation. The calibration of Tube 21 was effected by the presence of a dense object in Tube 16. Dense objects were also present in Tubes 5, 7, and 28A during the calibration (see exposure tube map). A graph of the Tube 21 exposure rates with and without the dense object in Tube 16 is presented.

Sources of error for this calibration include: exposure geometry, ion chamber measurement error, TLD response error, calibration curve fit error, and source decay error. The estimated uncertainty associated with the TLD readings at each position is 10%. The overall average tube calibration uncertainty is estimated to be 6% (near the maximum). This calibration is recorded in long BNW 50560.


TUBE 21
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
R/hr (times 1.E5)
0
4
8
12
16
20
24
28
32
INCHES FROM BOTTOM
no autoclave in tube 16
autoclave in tube 16

## APPENDIX D RADIATION TEST DATA FOR NATIONAL SEMICONDUCTOR LP291 VOLTAGE REGULATOR

The information presented in this appendix was downloaded over the internet from NASA's Jet Propulsion Laboratory RADA server. The internet address is http://radnet.jpl.nasa.gov. The test results were found in the Kaman Sciences DASIAC/ERRIC database.

DEVICE: LP2951H/883B TEST AGENCY: GODDARD SPACE FLIGHT CENTER

DESCRIPTION: Adjustable Micropower Voltage Regulator MFG: NSC

TEST NO.: 6012.SMY TEST DATE: 12/12/90 DATE CODE: 8811

THIS DATA IS ASSUMED CORRECT AND RELIABLE. HOWEVER, JPL ASSUMES NO RESPONSIBILITY FOR THE CONTENT.

*******************************************************************************

A radiation evaluation was performed on LP2951H/883 to determine the total dose tolerance of these parts. A brief summary of the test results is provided below. For detailed information, refer to Tables I through IV.

The total dose testing was performed using a cobalt-60 gamma ray source. During the radiation testing, two parts were irradiated under bias and one part was used as a control sample. The total dose radiation steps were 2, 5, 10, 20, 45, 70 and 100 krad. After 100 krad, parts were annealed at 25C for 24 and 168 hours, and then the irradiation was continued to 200 krad (cumulative). The dose rate was between 0.1 - 5.0 krad/hour, depending on the total dose level (see Table II for radiation schedule). After each radiation exposure and annealing treatment, parts were electrically tested according to the test conditions and the specification limits listed in Table III.

All (2) parts passed all tests on irradiation up to 45 krad. At 70 krad, both parts significantly exceeded the specification limits on Ground Current IQ+, (readings were 18.08 and 32.17 mA against the specification limit of 12 mA). Also, both parts failed (marginally) to meet the minimum specification limit for Output Voltage (VO/m). At 100 krad, parts showed increased degradation in both of the above parameters. Additionally, the parts also exceeded the specification limits on Load Regulation and Error Output Low Voltage (VREF/M). On annealing for 24 and 168 hours, the parts showed partial recovery. Table IV provides the mean and standard deviation values for each parameter after different radiation exposures and annealing treatments.

*******************************************************************************

TABLE I. Part Information

| | |
|---|---|
| Generic Part Number: | LP2951H/883B |
| ISTP Common Buy Part Number: | LP2951H/883B |
| ISTP Common Buy Control Number: | 3845 |
| Manufacturer: | National Semiconductor Corp. |
| Lot Date Code: | 8811 |
| Quantity Tested: | 3 |
| Serial Numbers of *Radiation Samples*: | *85, 86* |
| Serial Numbers of Control Sample: | 84 |
| | Voltage Regulator |
| Part Technology: | Bipolar |
| Package Style: | 8-Lead Can |

**************************************************************************************

TABLE II. Radiation Schedule

| EVENTS | DATE |
|---|---|
| 1) Initial Electrical Measurements | 12/12/90 |
| 2) 2 krad irradiation @ 100 rad/hr | 12/26/90 |
| Post 2 krad Electrical Measurements | 12/27/90 |
| 3) 5 krad irradiation @ 150 rad/hr | 12/27/90 |
| Post 5 krad Electrical Measurements | 12/28/90 |
| 4) 10 krad irradiation @ 74 rad/hr | 12/28/90 |
| Post 10 krad Electrical Measurements | 12/31/90 |
| 5) 20 krad irradiation @ 227 rad/hr | 12/31/90 |
| Post 20 krad Electrical Measurements | 01/02/91 |
| 6) 45 krad irradiation @ 1250 rad/hr | 01/02/91 |
| Post 45 krad Electrical Measurements | 01/03/91 |
| 7) 70 krad irradiation @ 1250 rad/hr | 01/03/91 |
| Post 70 krad Electrical Measurements | 01/04/91 |
| 8) 100 krad irradiation @ 441 rad/hr | 01/04/91 |
| Post 100 krad Electrical Measurements | 01/07/91 |
| 9) 24 hrs annealing | |
| Post 24 hr Electrical Measurements | 01/08/91 |
| 10) 168 hrs annealing | |
| Post 168 hr Electrical Measurements | 01/14/91 |
| 11) 200 krad irradiation @ 5000 rad/hr | 01/14/91 |
| Post 200 krad Electrical Measurements | 01/15/91 |

Notes:

1) All parts were radiated under bias at the cobalt-60 gamma ray facility at GSFC.

2) All electrical measurements were performed off-site at 25C.

3) Annealing performed at 25C under bias. ****************************************************************************

Table III. Electrical Characteristics of LP2951H/883

(TA = 25C, VIN = 6V, CI = 1uF unless otherwise specified.)

| Test | Conditions | Limits Min | Limits Max | Units |
|---|---|---|---|---|
| Iq+ | II = 100uA | | 120 | µA |
| IQ+ | II = 100mA | | 12 | mA |
| VO/m | | 4.97 | | V |
| VO/M | | | 5.03 | V |
| VREF/m | | 3.0 | | V |
| VREF/M | VIN = 4.5V | | 250 | mV |

| | | |
|---|---|---|
| REG/Id 100uA < Il < 100mA | 5.0 | mV |
| REG/In 6V < VIN < 30V | 5.0 | mV |
| VDIF/m VIN - VOUT = 100mV | 80 | mV |

TABLE IV: Summary of Electrical Measurements after
Total Dose Exposures and Annealing for LP2951H/883 1/, 2/

Total Dose Exposure (krad)

| | | Initials | 10 | 20 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Spec. Limits | | | | | | | | | | |
| Parameters | | min | max | mean | sd | mean | sd | mean | sd | | |
| Iq+ | uA | | 120 | 70.4 | 0.2 | 88.0 | 1.0 | 88.2 | 0.2 | | |
| IQ+ | mA | | 12 | 6.5 | 0.5 | 7.7 | 0.3 | 8.3 | 0.4 | | |
| VO/m | V | 4.97 | | 5.01 | 0 | 5.0 | 0 | 5.0 | 0 | | |
| VO/M | V | | 5.03 | 5.01 | 0 | 5.0 | 0 | 4.99 | 0 | | |
| VREF/m | V | 3.0 | | 4.26 | 0 | 4.25 | 0 | 4.27 | .01 | | |
| VREF/M | mV | | 250 | | 141 | | 1 | 145 | 3 | 150 | 1 |
| REG/Id | mV | | 5 | -0.8 | 0.2 | -0.9 | 0.2 | 0.35 | 0.35 | | |
| REG/In | mV | | 5 | 1.4 | 0.4 | 1.1 | 0.3 | 2.0 | 0.4 | | |
| VDIF/m | mV | | 80 | PASS | | PASS | | PASS | | | |

Total Dose Exposure (krad)

| | | 45 | 70 | 100 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Spec. Limits | | | | | | | | | | |
| Parameters | | min | max | mean | sd | mean | sd | mean | sd | | |
| Iq+ | uA | | 120 | 91.0 | | 9.0 | 57.1 | 0 | 48.0 | 1.0 | |
| IQ+ | mA | | 12 | 9.0 | 0.1 | 25 | 7 | >128 | - | | |
| VO/m | V | 4.97 | | 4.98 | .01 | 4.95 | .01 | 4.82 | .02 | | |
| VO/M | V | | 5.03 | 4.98 | .01 | 4.94 | .01 | 4.83 | .02 | | |
| VREF/m | V | 3.0 | | 4.26 | 0 | 4.26 | 0 | 4.26 | 0 | | |
| VREF/M | mV | | 250 | | 183 | | 1 | 183 | 4 | 700 | 400 |
| REG/Id | mV | | 5 | 2.1 | 0.3 | 4.6 | 1.5 | 13.0 | 1.2 | | |
| REG/In | mV | | 5 | 1.8 | 0.1 | 1.2 | 1.2 | 2.1 | 1.2 | | |
| VDIF/m | mV | | 80 | PASS | | PASS | | PASS | | | |

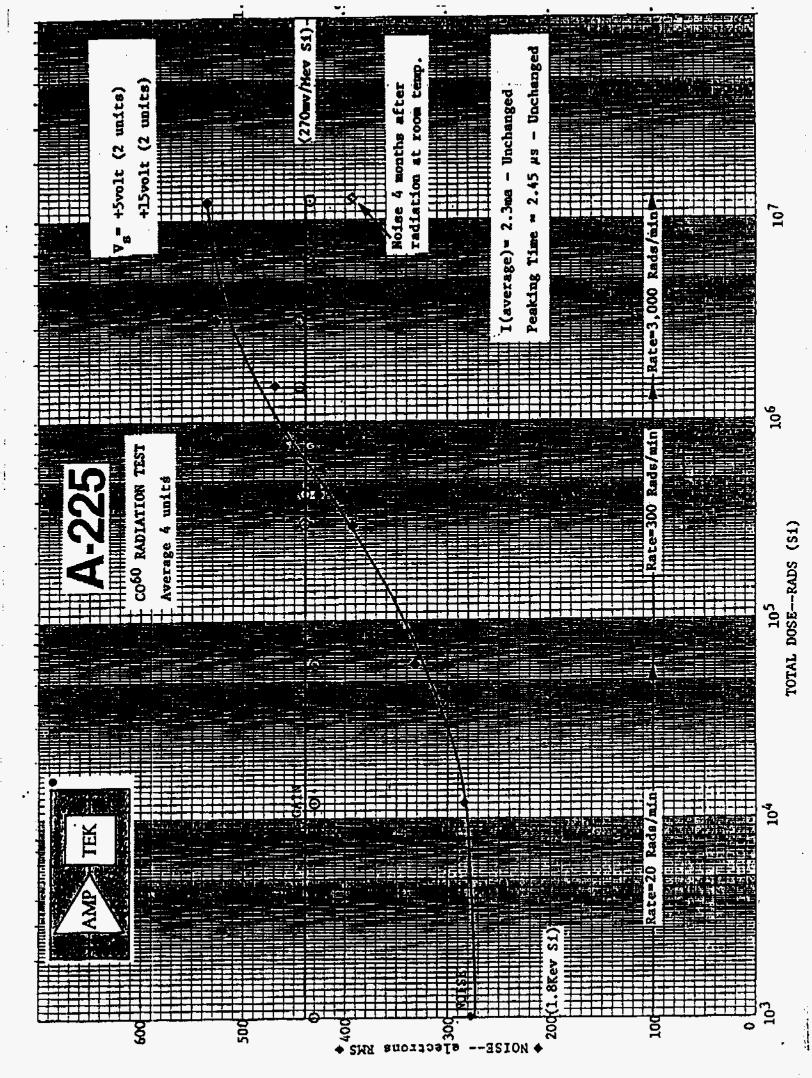
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| = | | | Anneal | Total Dose | | | | |
| | | 168 hrs | 200k | | | | | |
| | Spec. Limits | | | | | | | |
| Parameters | | min | max | mean | sd | mean | sd | |
| Iq+ | uA | | 120 | 51.0 | | 2.0 | 43.9 | 0.3 |
| IQ+ | mA | | 12 | >128 | - | >128 | - | |
| VO/m | V | 4.97 | | 4.84 | .02 | 4.73 | .03 | |
| VO/M | V | | 5.03 | 4.85 | .03 | 4.72 | .02 | |
| VREF/m | V | 3.0 | | 4.28 | | .01 | 4.26 | 0 |
| VREF/M | mV | | 250 | | 355 | 130 | over | |
| REG/Id | mV | | 5 | 6.93 | | .03 | over | |
| REG/In | mV | | 5 | 1.9 | 0.2 | 6.0 | 0.4 | |
| VDIF/m | mV | | 80 | PASS | | PASS | | |

Notes:

1/ The mean and standard deviation values were calculated over the two parts irradiated in this testing. The control sample remained constant throughout the testing and is not included in this table.

2/ Table IV provides radiation characteristics of parts at selected total dose exposures and annealing treatments. The data at other radiation exposures and annealing treatments is available and can be obtained upon request.

APPENDIX E RadIATION TEST DATA FOR AMPTEK A225 CHARGE SENSITIVE AMPLIFIER



# APPENDIX F RAW DATA FROM SMMS INTERFACE BOARD TEMPERATURE TESTS

## Table F-1
## Data Recorded During Interface Board Temperature Test

| Time (HOURS) | Neg. V. Reg. Case Temp. U13 (°C) | Pos. V. Reg. Case Temp. U12 (°C) | Switching Reg. Case Temp. U11 (°C) | DET 4 Line Driver Case Temp U8 (°C) | TEMP 1 Line Driver Case Temp U4 (°C) | Chamber Temp. (°C) | Positive Voltage Regulator Output (V) | Negative Voltage Regulator Output (V) | TEMP1 Vouttage Output -100°C = -10 +100°C =+10 (V) | TEMP2 Voltage Output -100°C = -10 +100°C= +10 (V) | Nominal 24 V Input Voltage to Board (V) | Raw TEMP 2 Voltage Input -100°C = 4 0°C = 5 +100°C = 6 (V) | RAW TEMP 1 Voltage Input -100°C = 4 0°C = 5 +100°C = 6 (V) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.000 | 1.400 | 6.800 | 3.200 | -0.500 | 0.900 | -4.000 | 15.196 | -15.002 | -10.054 | -10.047 | 27.428 | 4.0005 | 3.9996 |
| 0.058 | 1.500 | 6.800 | 3.200 | -0.600 | 0.900 | -4.000 | 15.196 | -15.001 | -10.054 | -10.046 | 27.426 | 4.0004 | 3.9996 |
| 0.158 | 1.500 | 6.900 | 3.300 | -0.500 | 1.000 | -4.100 | 15.195 | -15.002 | -10.054 | -10.047 | 27.428 | 4.0005 | 3.9996 |
| 0.211 | 1.400 | 6.900 | 3.200 | -0.500 | 0.800 | -3.900 | 15.194 | -15.003 | 9.937 | 9.954 | 27.431 | 6.0010 | 6.0002 |
| 0.234 | 1.500 | 6.800 | 3.200 | -0.600 | 0.600 | -4.100 | 15.195 | -15.002 | -0.058 | -0.046 | 27.429 | 5.0007 | 4.9999 |
| 0.263 | 1.400 | 6.700 | 3.300 | -0.500 | 0.800 | -4.200 | 15.196 | -15.001 | 9.934 | 9.950 | 27.431 | 6.0010 | 6.0003 |
| 0.363 | 1.500 | 6.800 | 3.400 | -0.600 | 0.900 | -4.000 | 15.196 | -15.001 | 9.941 | 9.955 | 27.431 | 6.0011 | 6.0005 |
| 0.463 | 1.600 | 6.900 | 3.300 | -0.500 | 0.800 | -4.000 | 15.196 | -15.002 | 9.937 | 9.957 | 27.432 | 6.0013 | 6.0002 |
| 0.563 | 1.500 | 6.900 | 3.300 | -0.400 | 1.000 | -3.900 | 15.196 | -15.002 | 9.937 | 9.957 | 27.434 | 6.0013 | 6.0003 |
| 0.663 | 1.400 | 6.900 | 3.400 | -0.500 | 0.900 | -3.900 | 15.196 | -15.001 | 9.940 | 9.954 | 27.433 | 6.0011 | 6.0007 |
| 0.763 | 1.500 | 6.800 | 3.300 | -0.600 | 0.700 | -4.000 | 15.196 | -15.001 | 9.940 | 9.954 | 27.432 | 6.0011 | 6.0005 |
| 0.810 | 0.000 | 4.500 | 1.200 | -4.000 | -2.200 | -7.600 | 15.195 | -15.001 | -10.050 | -10.045 | 27.428 | 4.0004 | 4.0000 |
| 0.910 | -7.600 | -3.000 | -6.600 | -10.900 | -9.400 | -14.500 | 15.187 | -14.996 | 9.942 | 9.957 | 27.433 | 6.0010 | 6.0005 |
| 1.010 | -9.700 | -4.900 | -8.300 | -12.400 | -10.900 | -16.100 | 15.186 | -14.994 | 9.942 | 9.957 | 27.441 | 6.0011 | 6.0005 |
| 1.110 | -10.800 | -5.700 | -9.300 | -13.200 | -12.000 | -16.800 | 15.184 | -14.993 | 9.943 | 9.958 | 27.442 | 6.0010 | 6.0005 |
| 1.210 | -11.200 | -6.000 | -9.600 | -13.500 | -12.200 | -17.100 | 15.184 | -14.994 | 9.942 | 9.958 | 27.443 | 6.0011 | 6.0005 |
| 1.310 | -11.500 | -6.200 | -9.800 | -13.500 | -12.400 | -17.300 | 15.184 | -14.994 | 9.942 | 9.958 | 27.442 | 6.0009 | 6.0005 |
| 1.410 | -11.700 | -6.500 | -10.000 | -13.900 | -12.600 | -17.600 | 15.183 | -14.994 | 9.943 | 9.958 | 27.442 | 6.0008 | 6.0006 |
| 1.510 | -11.900 | -6.600 | -10.300 | -14.100 | -12.900 | -17.800 | 15.184 | -14.993 | 9.943 | 9.958 | 27.442 | 6.0011 | 6.0006 |
| 1.610 | -12.100 | -6.900 | -10.400 | -14.300 | -13.000 | -18.000 | 15.183 | -14.993 | 9.943 | 9.958 | 27.444 | 6.0008 | 6.0006 |
| 1.710 | -12.300 | -7.000 | -10.600 | -14.400 | -13.100 | -18.100 | 15.183 | -14.994 | 9.943 | 9.958 | 27.446 | 6.0011 | 6.0006 |
| 1.810 | -12.300 | -7.100 | -10.700 | -14.400 | -13.200 | -18.100 | 15.183 | -14.994 | 9.943 | 9.958 | 27.444 | 6.0011 | 6.0005 |
| 1.910 | -12.500 | -7.200 | -10.800 | -14.700 | -13.400 | -18.300 | 15.182 | -14.993 | 9.942 | 9.958 | 27.447 | 6.0012 | 6.0005 |
| 2.010 | -12.700 | -7.300 | -10.900 | -14.700 | -13.500 | -18.400 | 15.183 | -14.993 | 9.943 | 9.958 | 27.445 | 6.0009 | 6.0004 |
| 2.110 | -12.700 | -7.500 | -11.000 | -14.800 | -13.500 | -18.500 | 15.182 | -14.993 | 9.943 | 9.958 | 27.447 | 6.0012 | 6.0008 |
| 2.210 | -12.600 | -7.300 | -11.000 | -14.700 | -13.400 | -18.400 | 15.182 | -14.993 | 9.943 | 9.958 | 27.446 | 6.0012 | 6.0005 |
| 2.310 | -12.700 | -7.300 | -11.000 | -14.900 | -13.600 | -18.500 | 15.182 | -14.993 | 9.943 | 9.958 | 27.447 | 6.0013 | 6.0005 |
| 2.410 | -12.700 | -7.400 | -10.900 | -14.700 | -13.400 | -18.500 | 15.182 | -14.994 | 9.943 | 9.958 | 27.447 | 6.0011 | 6.0005 |
| 2.510 | -12.800 | -7.400 | -11.100 | -14.900 | -13.600 | -18.500 | 15.182 | -14.994 | 9.943 | 9.958 | 27.445 | 6.0011 | 6.0007 |
| 2.610 | -12.800 | -7.400 | -11.000 | -14.800 | -13.500 | -18.500 | 15.182 | -14.993 | 9.943 | 9.958 | 27.444 | 6.0011 | 6.0006 |
| 2.682 | -12.900 | -7.700 | -11.200 | -14.900 | -13.900 | -18.600 | 15.182 | -14.992 | -10.046 | -10.041 | 27.443 | 4.0004 | 3.9998 |
| 2.719 | -12.800 | -7.500 | -11.200 | -14.900 | -13.800 | -18.600 | 15.182 | -14.993 | 9.939 | 9.954 | 27.445 | 6.0011 | 6.0005 |
| 2.737 | -12.900 | -7.600 | -11.200 | -15.000 | -13.800 | -18.700 | 15.182 | -14.994 | -0.052 | -0.042 | 27.443 | 5.0007 | 5.0002 |
| 2.837 | -13.000 | -7.500 | -11.300 | -15.100 | -13.800 | -18.700 | 15.181 | -14.994 | -0.054 | -0.039 | 27.442 | 5.0006 | 4.9999 |
| 2.892 | -13.000 | -7.700 | -11.300 | -15.100 | -13.900 | -18.800 | 15.182 | -14.993 | 9.939 | 9.961 | 27.444 | 6.0013 | 6.0003 |
| 2.992 | -12.700 | -7.300 | -10.900 | -14.800 | -13.600 | -18.600 | 15.182 | -14.993 | 9.942 | 9.958 | 27.444 | 6.0010 | 6.0006 |
| 3.092 | -9.500 | -4.600 | -6.900 | -8.700 | -7.800 | -12.300 | 15.184 | -14.995 | 9.941 | 9.956 | 25.380 | 6.0011 | 6.0005 |
| 3.192 | 4.900 | 10.400 | 8.300 | 6.300 | 7.300 | 2.900 | 15.197 | -15.004 | 9.939 | 9.953 | 25.409 | 6.0011 | 6.0005 |
| 3.292 | 8.300 | 12.600 | 10.400 | 7.300 | 8.600 | 3.800 | 15.198 | -15.006 | 9.939 | 9.953 | 25.418 | 6.0011 | 6.0005 |
| 3.392 | 9.300 | 13.500 | 11.100 | 7.900 | 9.300 | 4.500 | 15.199 | -15.007 | 9.939 | 9.953 | 25.421 | 6.0014 | 6.0005 |
| 3.492 | 9.900 | 13.700 | 11.900 | 8.600 | 9.900 | 5.000 | 15.200 | -15.006 | 9.939 | 9.953 | 25.423 | 6.0012 | 6.0005 |
| 3.592 | 10.200 | 14.000 | 12.000 | 8.500 | 9.900 | 5.400 | 15.200 | -15.006 | 9.940 | 9.953 | 25.424 | 6.0011 | 6.0005 |
| 3.692 | 10.400 | 14.200 | 12.300 | 8.800 | 10.100 | 5.600 | 15.200 | -15.007 | 9.940 | 9.953 | 25.424 | 6.0011 | 6.0006 |
| 3.792 | 10.700 | 14.400 | 12.500 | 9.000 | 10.300 | 5.700 | 15.201 | -15.007 | 9.940 | 9.953 | 25.423 | 6.0016 | 6.0005 |

## Table F-1
## Data Recorded During Interface Board Temperature Test

| Time (HOURS) | Neg. V. Reg. Case Temp. U13 (°C) | Pos. V. Reg. Case Temp. U12 (°C) | Switching Reg, Case Temp. U11 (°C) | DET 4 Line Driver Case Temp U8 (°C) | TEMP 1 Line Driver Case Temp U4 (°C) | Chamber Temp. (°C) | Positive Voltage Regulator Output (V) | Negative Voltage Regulator Output (V) | TEMP1 Vouttage Output -100°C = -10 +100°C =+10 (V) | TEMP2 Voltage Output -100°C = -10 +100°C= +10 (V) | Nominal 24 V Input Voltage to Board (V) | Raw TEMP 2 Voltage Input -100°C = 4 0°C = 5 +100°C = 6 (V) | RAW TEMP 1 Voltage Input -100°C = 4 0°C = 5 +100°C = 6 (V) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.892 | 10.700 | 14.400 | 12.500 | 9.100 | 10.400 | 5.800 | 15.201 | -15.007 | 9.940 | 9.953 | 25.421 | 6.0011 | 6.0006 |
| 3.992 | 10.900 | 14.700 | 12.700 | 9.200 | 10.400 | 6.000 | 15.201 | -15.008 | 9.940 | 9.953 | 25.412 | 6.0005 | 6.0005 |
| 4.092 | 11.000 | 14.700 | 12.700 | 9.200 | 10.600 | 6.000 | 15.201 | -15.008 | 9.940 | 9.953 | 25.410 | 6.0012 | 6.0005 |
| 4.192 | 11.000 | 14.800 | 12.700 | 9.200 | 10.600 | 6.100 | 15.200 | -15.008 | 9.940 | 9.953 | 25.410 | 6.0015 | 6.0007 |
| 4.292 | 11.000 | 14.800 | 12.600 | 9.100 | 10.500 | 6.000 | 15.201 | -15.008 | 9.940 | 9.953 | 25.409 | 6.0010 | 6.0005 |
| 4.392 | 11.100 | 14.800 | 12.600 | 9.200 | 10.400 | 6.000 | 15.202 | -15.007 | 9.940 | 9.953 | 25.409 | 6.0011 | 6.0006 |
| 4.492 | 11.100 | 14.800 | 12.600 | 9.200 | 10.600 | 6.000 | 15.201 | -15.007 | 9.940 | 9.953 | 25.410 | 6.0010 | 6.0006 |
| 4.592 | 11.100 | 14.600 | 12.700 | 9.200 | 10.600 | 5.900 | 15.201 | -15.007 | 9.940 | 9.953 | 25.410 | 6.0012 | 6.0005 |
| 4.692 | 11.200 | 14.800 | 12.600 | 9.100 | 10.500 | 6.100 | 15.201 | -15.006 | 9.940 | 9.954 | 25.410 | 6.0011 | 6.0005 |
| 4.792 | 11.100 | 14.600 | 12.600 | 9.100 | 10.400 | 5.900 | 15.201 | -15.006 | 9.940 | 9.953 | 25.411 | 6.0011 | 6.0005 |
| 4.892 | 11.100 | 14.600 | 12.600 | 9.100 | 10.600 | 5.800 | 15.201 | -15.008 | 9.940 | 9.953 | 25.411 | 6.0011 | 6.0005 |
| 4.992 | 11.100 | 14.600 | 12.500 | 9.100 | 10.400 | 5.900 | 15.201 | -15.007 | 9.940 | 9.953 | 25.412 | 6.0011 | 6.0006 |
| 5.092 | 11.100 | 14.800 | 12.600 | 9.100 | 10.500 | 6.000 | 15.199 | -15.009 | 9.940 | 9.953 | 25.412 | 6.0006 | 6.0006 |
| 5.192 | 11.000 | 14.600 | 12.600 | 9.100 | 10.400 | 15.900 | 15.201 | -15.007 | 9.940 | 9.953 | 25.414 | 6.0012 | 6.0006 |
| 5.292 | 11.100 | 14.500 | 12.500 | 9.100 | 10.400 | 5.900 | 15.201 | -15.007 | 9.940 | 9.953 | 25.411 | 6.0006 | 6.0006 |
| 5.392 | 11.100 | 14.600 | 12.600 | 9.100 | 10.400 | 5.900 | 15.201 | -15.007 | 9.940 | 9.953 | 25.413 | 6.0011 | 6.0006 |
| 5.492 | 11.100 | 14.800 | 12.600 | 9.200 | 10.500 | 6.000 | 15.201 | -15.007 | 9.940 | 9.953 | 25.411 | 6.0011 | 6.0005 |
| 5.592 | 10.900 | 14.600 | 12.400 | 9.100 | 10.500 | 5.900 | 15.201 | -15.007 | 9.940 | 9.954 | 25.413 | 6.0006 | 6.0004 |
| 5.692 | 10.800 | 14.400 | 12.400 | 8.800 | 10.200 | 5.600 | 15.201 | -15.006 | 9.940 | 9.953 | 25.413 | 6.0016 | 6.0005 |
| 5.792 | 11.000 | 14.500 | 12.500 | 8.900 | 10.300 | 5.700 | 15.201 | -15.007 | 9.940 | 9.953 | 25.413 | 6.0012 | 6.0006 |
| 5.892 | 11.000 | 14.600 | 12.600 | 9.200 | 10.600 | 5.900 | 15.201 | -15.007 | 9.940 | 9.953 | 25.413 | 6.0011 | 6.0005 |
| 5.992 | 11.000 | 14.400 | 12.500 | 9.100 | 10.500 | 5.900 | 15.201 | -15.007 | 9.940 | 9.953 | 25.414 | 6.0011 | 6.0006 |
| 6.092 | 10.800 | 14.400 | 12.400 | 8.900 | 10.300 | 5.600 | 15.200 | -15.008 | 9.940 | 9.954 | 25.413 | 6.0011 | 6.0006 |
| 6.192 | 11.000 | 14.500 | 12.600 | 9.200 | 10.700 | 5.900 | 15.201 | -15.007 | 9.940 | 9.953 | 25.413 | 6.0011 | 6.0006 |
| 6.292 | 11.000 | 14.700 | 12.600 | 9.300 | 10.600 | 6.000 | 15.201 | -15.007 | 9.940 | 9.953 | 25.415 | 6.0011 | 6.0005 |
| 6.392 | 10.900 | 14.600 | 12.500 | 9.100 | 10.400 | 5.900 | 15.200 | -15.007 | 9.940 | 9.953 | 25.414 | 6.0010 | 6.0005 |
| 6.492 | 10.800 | 14.300 | 12.400 | 8.900 | 10.200 | 5.600 | 15.201 | -15.007 | 9.940 | 9.953 | 25.414 | 6.0005 | 6.0006 |
| 6.592 | 11.000 | 14.500 | 12.500 | 8.900 | 10.400 | 5.600 | 15.201 | -15.006 | 9.940 | 9.954 | 25.413 | 6.0011 | 6.0005 |
| 6.692 | 11.000 | 14.500 | 12.600 | 9.000 | 10.400 | 5.700 | 15.200 | -15.007 | 9.940 | 9.953 | 25.415 | 6.0011 | 6.0005 |
| 6.792 | 11.000 | 14.500 | 12.600 | 9.200 | 10.600 | 5.900 | 15.200 | -15.008 | 9.940 | 9.953 | 25.415 | 6.0012 | 6.0005 |
| 6.892 | 10.900 | 14.500 | 12.400 | 8.900 | 10.400 | 5.700 | 15.201 | -15.007 | 9.940 | 9.953 | 25.414 | 6.0011 | 6.0005 |
| 6.992 | 10.900 | 14.400 | 12.400 | 8.800 | 10.200 | 5.600 | 15.201 | -15.007 | 9.940 | 9.953 | 25.415 | 6.0011 | 6.0005 |
| 7.092 | 11.000 | 14.600 | 12.600 | 9.200 | 10.500 | 5.900 | 15.201 | -15.007 | 9.940 | 9.953 | 25.415 | 6.0011 | 6.0005 |
| 7.192 | 10.900 | 14.600 | 12.500 | 9.200 | 10.500 | 6.000 | 15.201 | -15.007 | 9.940 | 9.953 | 25.415 | 6.0011 | 6.0005 |
| 7.292 | 10.800 | 14.400 | 12.300 | 8.800 | 10.100 | 5.500 | 15.200 | -15.007 | 9.940 | 9.953 | 25.415 | 6.0014 | 6.0004 |
| 7.392 | 11.000 | 14.600 | 12.500 | 9.000 | 10.400 | 5.800 | 15.201 | -15.006 | 9.940 | 9.953 | 25.415 | 6.0010 | 6.0006 |
| 7.492 | 10.900 | 14.600 | 12.500 | 9.000 | 10.400 | 5.900 | 15.201 | -15.007 | 9.940 | 9.953 | 25.415 | 6.0010 | 6.0005 |
| 7.592 | 10.900 | 14.500 | 12.400 | 8.700 | 10.200 | 5.500 | 15.201 | -15.008 | 9.940 | 9.953 | 25.416 | 6.0011 | 6.0004 |
| 7.692 | 11.000 | 14.500 | 12.600 | 9.100 | 10.500 | 5.800 | 15.199 | -15.010 | 9.940 | 9.953 | 25.415 | 6.0011 | 6.0005 |
| 7.792 | 11.000 | 14.500 | 12.600 | 9.100 | 10.500 | 5.800 | 15.201 | -15.006 | 9.940 | 9.953 | 25.414 | 6.0016 | 6.0005 |
| 7.892 | 10.900 | 14.600 | 12.400 | 9.000 | 10.400 | 5.800 | 15.201 | -15.008 | 9.940 | 9.953 | 25.415 | 6.0011 | 6.0005 |
| 7.992 | 10.800 | 14.400 | 12.400 | 8.800 | 10.200 | 5.600 | 15.201 | -15.007 | 9.940 | 9.954 | 25.415 | 6.0011 | 6.0005 |
| 8.092 | 11.000 | 14.700 | 12.600 | 9.000 | 10.400 | 5.800 | 15.201 | -15.007 | 9.940 | 9.953 | 25.415 | 6.0011 | 6.0006 |
| 8.192 | 11.000 | 14.800 | 12.600 | 9.200 | 10.700 | 6.000 | 15.201 | -15.007 | 9.940 | 9.953 | 25.415 | 6.0011 | 6.0006 |

## Table F-1
## Data Recorded During Interface Board Temperature Test

| Time (HOURS) | Neg. V. Reg. Case Temp. U13 (°C) | Pos. V. Reg. Case Temp. U12 (°C) | Switching Reg, Case Temp. U11 (°C) | DET 4 Line Driver Case Temp U8 (°C) | TEMP 1 Line Driver Case Temp U4 (°C) | Chamber Temp. (°C) | Positive Voltage Regulator Output (V) | Negative Voltage Regulator Output (V) | TEMP1 Vouttage Output -100°C = -10 +100°C =+10 (V) | TEMP2 Voltage Output -100°C = -10 +100°C= +10 (V) | Nominal 24 V Input Voltage to Board (V) | Raw TEMP 2 Voltage Input -100°C = 4 0°C = 5 +100°C = 6 (V) | RAW TEMP 1 Voltage Input -100°C = 4 0°C = 5 +100°C = 6 (V) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8.292 | 10.900 | 14.500 | 12.500 | 9.200 | 10.500 | 5.900 | 15.200 | -15.007 | 9.940 | 9.953 | 25.415 | 6.0011 | 6.0006 |
| 8.392 | 10.800 | 14.300 | 12.400 | 8.700 | 10.100 | 5.500 | 15.201 | -15.007 | 9.940 | 9.953 | 25.415 | 6.0010 | 6.0006 |
| 8.492 | 11.000 | 14.700 | 12.600 | 9.200 | 10.500 | 6.000 | 15.201 | -15.007 | 9.940 | 9.953 | 25.416 | 6.0012 | 6.0005 |
| 8.592 | 10.900 | 14.500 | 12.500 | 9.100 | 10.500 | 5.800 | 15.201 | -15.005 | 9.940 | 9.953 | 25.416 | 6.0011 | 6.0006 |
| 8.692 | 10.800 | 14.400 | 12.400 | 8.800 | 10.200 | 5.600 | 15.202 | -15.006 | 9.940 | 9.953 | 25.414 | 6.0010 | 6.0005 |
| 8.792 | 11.000 | 14.800 | 12.700 | 9.200 | 10.600 | 6.000 | 15.201 | -15.006 | 9.940 | 9.953 | 25.416 | 6.0010 | 6.0005 |
| 8.892 | 10.800 | 14.600 | 12.500 | 9.100 | 10.400 | 5.900 | 15.201 | -15.006 | 9.940 | 9.953 | 25.415 | 6.0011 | 6.0005 |
| 8.992 | 10.900 | 14.300 | 12.400 | 8.800 | 10.200 | 5.500 | 15.200 | -15.007 | 9.940 | 9.954 | 25.415 | 6.0011 | 6.0006 |
| 9.092 | 10.800 | 14.300 | 12.400 | 8.700 | 10.200 | 5.400 | 15.201 | -15.007 | 9.940 | 9.953 | 25.415 | 6.0011 | 6.0006 |
| 9.192 | 10.900 | 14.700 | 12.600 | 9.200 | 10.600 | 6.000 | 15.202 | -15.006 | 9.940 | 9.953 | 25.415 | 6.0010 | 6.0005 |
| 9.292 | 10.900 | 14.700 | 12.500 | 9.200 | 10.500 | 6.000 | 15.201 | -15.007 | 9.940 | 9.953 | 25.415 | 6.0011 | 6.0006 |
| 9.392 | 10.900 | 14.700 | 12.500 | 9.100 | 10.400 | 5.900 | 15.201 | -15.007 | 9.940 | 9.953 | 25.415 | 6.0009 | 6.0004 |
| 9.492 | 10.800 | 14.500 | 12.400 | 8.900 | 10.300 | 5.700 | 15.201 | -15.007 | 9.940 | 9.953 | 25.416 | 6.0011 | 6.0006 |
| 9.592 | 10.800 | 14.400 | 12.400 | 8.700 | 10.000 | 5.400 | 15.202 | -15.007 | 9.940 | 9.953 | 25.416 | 6.0010 | 6.0006 |
| 9.692 | 11.000 | 14.600 | 12.700 | 9.100 | 10.500 | 5.800 | 15.202 | -15.008 | 9.940 | 9.953 | 25.415 | 6.0011 | 6.0005 |
| 9.792 | 10.900 | 14.600 | 12.600 | 9.200 | 10.500 | 5.900 | 15.201 | -15.007 | 9.940 | 9.953 | 25.416 | 6.0010 | 6.0004 |
| 9.892 | 10.900 | 14.500 | 12.500 | 9.000 | 10.400 | 5.800 | 15.201 | -15.007 | 9.940 | 9.953 | 25.416 | 6.0010 | 6.0005 |
| 9.992 | 10.700 | 14.400 | 12.300 | 8.800 | 10.100 | 5.500 | 15.200 | -15.007 | 9.940 | 9.953 | 25.414 | 6.0007 | 6.0005 |
| 10.092 | 10.900 | 14.400 | 12.400 | 8.700 | 10.100 | 5.500 | 15.201 | -15.007 | 9.940 | 9.954 | 25.416 | 6.0010 | 6.0005 |
| 10.192 | 11.000 | 14.700 | 12.600 | 9.100 | 10.500 | 5.900 | 15.202 | -15.007 | 9.940 | 9.953 | 25.416 | 6.0010 | 6.0004 |
| 10.292 | 10.900 | 14.400 | 12.500 | 9.100 | 10.500 | 5.800 | 15.201 | -15.007 | 9.940 | 9.953 | 25.416 | 6.0010 | 6.0005 |
| 10.392 | 10.800 | 14.500 | 12.300 | 9.000 | 10.300 | 5.800 | 15.201 | -15.008 | 9.940 | 9.953 | 25.416 | 6.0010 | 6.0005 |
| 10.492 | 10.800 | 14.600 | 12.300 | 8.800 | 10.200 | 5.700 | 15.203 | -15.008 | 9.940 | 9.953 | 25.415 | 6.0010 | 6.0005 |
| 10.592 | 10.800 | 14.400 | 12.400 | 8.800 | 10.100 | 5.500 | 15.201 | -15.007 | 9.940 | 9.953 | 25.415 | 6.0010 | 6.0005 |
| 10.692 | 10.900 | 14.300 | 12.400 | 8.700 | 10.200 | 5.400 | 15.201 | -15.008 | 9.940 | 9.953 | 25.416 | 6.0010 | 6.0005 |
| 10.792 | 11.000 | 14.500 | 12.600 | 8.900 | 10.400 | 5.700 | 15.200 | -15.009 | 9.940 | 9.953 | 25.416 | 6.0010 | 6.0005 |
| 10.892 | 11.000 | 14.700 | 12.600 | 9.200 | 10.700 | 6.000 | 15.201 | -15.008 | 9.940 | 9.953 | 25.417 | 6.0010 | 6.0005 |
| 10.992 | 10.900 | 14.500 | 12.500 | 9.100 | 10.400 | 5.900 | 15.199 | -15.010 | 9.940 | 9.954 | 25.416 | 6.0012 | 6.0007 |
| 11.092 | 10.800 | 14.700 | 12.400 | 9.100 | 10.500 | 5.900 | 15.200 | -15.008 | 9.940 | 9.953 | 25.418 | 6.0014 | 6.0005 |
| 11.192 | 10.900 | 14.600 | 12.400 | 9.000 | 10.300 | 5.900 | 15.200 | -15.008 | 9.940 | 9.953 | 25.417 | 6.0010 | 6.0005 |
| 11.292 | 10.900 | 14.500 | 12.500 | 9.100 | 10.500 | 5.700 | 15.200 | -15.008 | 9.940 | 9.954 | 25.418 | 6.0011 | 6.0005 |
| 11.392 | 10.800 | 14.600 | 12.400 | 8.900 | 10.200 | 5.700 | 15.200 | -15.007 | 9.940 | 9.953 | 25.417 | 6.0010 | 6.0006 |
| 11.492 | 10.800 | 14.300 | 12.300 | 8.700 | 10.100 | 5.500 | 15.200 | -15.008 | 9.940 | 9.953 | 25.416 | 6.0010 | 6.0005 |
| 11.592 | 10.900 | 14.500 | 12.500 | 8.800 | 10.300 | 5.600 | 15.200 | -15.008 | 9.940 | 9.953 | 25.416 | 6.0011 | 6.0006 |
| 11.692 | 11.000 | 14.700 | 12.700 | 9.200 | 10.600 | 6.000 | 15.201 | -15.008 | 9.940 | 9.953 | 25.417 | 6.0005 | 6.0006 |
| 11.792 | 10.900 | 14.600 | 12.500 | 9.100 | 10.500 | 6.000 | 15.200 | -15.008 | 9.940 | 9.953 | 25.417 | 6.0015 | 6.0005 |
| 11.892 | 10.900 | 14.500 | 12.500 | 9.100 | 10.500 | 5.900 | 15.201 | -15.008 | 9.940 | 9.953 | 25.416 | 6.0011 | 6.0005 |
| 11.992 | 10.900 | 14.500 | 12.400 | 9.000 | 10.300 | 5.700 | 15.201 | -15.008 | 9.940 | 9.953 | 25.416 | 6.0010 | 6.0006 |
| 12.092 | 10.900 | 14.300 | 12.400 | 8.600 | 10.100 | 5.500 | 15.199 | -15.009 | 9.940 | 9.953 | 25.416 | 6.0010 | 6.0005 |
| 12.192 | 10.900 | 14.400 | 12.400 | 8.700 | 10.100 | 5.500 | 15.200 | -15.008 | 9.940 | 9.953 | 25.416 | 6.0010 | 6.0005 |
| 12.292 | 11.000 | 14.500 | 12.500 | 8.800 | 10.300 | 5.600 | 15.201 | -15.006 | 9.940 | 9.953 | 25.415 | 6.0010 | 6.0006 |
| 12.392 | 10.800 | 14.200 | 12.300 | 8.700 | 10.100 | 5.400 | 15.201 | -15.008 | 9.940 | 9.954 | 25.416 | 6.0007 | 6.0005 |
| 12.492 | 10.900 | 14.800 | 12.600 | 9.200 | 10.600 | 6.100 | 15.201 | -15.008 | 9.940 | 9.953 | 25.415 | 6.0010 | 6.0008 |
| 12.592 | 10.900 | 14.500 | 12.500 | 9.100 | 10.500 | 5.900 | 15.202 | -15.008 | 9.940 | 9.953 | 25.416 | 6.0010 | 6.0005 |

## Table F-1
## Data Recorded During Interface Board Temperature Test

| Time (HOURS) | Neg. V. Reg. Case Temp. U13 (°C) | Pos. V. Reg. Case Temp. U12 (°C) | Switching Reg, Case Temp. U11 (°C) | DET 4 Line Driver Case Temp U8 (°C) | TEMP 1 Line Driver Case Temp U4 (°C) | Chamber Temp. (°C) | Positive Voltage Regulator Output (V) | Negative Voltage Regulator Output (V) | TEMP1 Vouttage Output -100°C = -10 +100°C =+10 (V) | TEMP2 Voltage Output -100°C = -10 +100°C= +10 (V) | Nominal 24 V Input Voltage to Board (V) | Raw TEMP 2 Voltage Input -100°C = 4 0°C = 5 +100°C = 6 (V) | RAW TEMP 1 Voltage Input -100°C = 4 0°C = 5 +100°C = 6 (V) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12.692 | 10.900 | 14.600 | 12.400 | 9.000 | 10.400 | 5.800 | 15.200 | -15.008 | 9.940 | 9.953 | 25.416 | 6.0009 | 6.0005 |
| 12.792 | 10.900 | 14.600 | 12.400 | 9.000 | 10.500 | 5.800 | 15.201 | -15.008 | 9.940 | 9.953 | 25.416 | 6.0010 | 6.0006 |
| 12.892 | 10.900 | 14.500 | 12.500 | 9.100 | 10.400 | 5.800 | 15.201 | -15.008 | 9.940 | 9.953 | 25.416 | 6.0009 | 6.0005 |
| 12.992 | 10.800 | 14.600 | 12.400 | 9.000 | 10.400 | 5.800 | 15.201 | -15.009 | 9.940 | 9.953 | 25.416 | 6.0011 | 6.0006 |
| 13.092 | 10.800 | 14.500 | 12.300 | 8.900 | 10.200 | 5.600 | 15.201 | -15.007 | 9.940 | 9.953 | 25.416 | 6.0010 | 6.0005 |
| 13.192 | 10.800 | 14.300 | 12.400 | 8.900 | 10.300 | 5.600 | 15.202 | -15.008 | 9.940 | 9.953 | 25.416 | 6.0011 | 6.0005 |
| 13.292 | 10.900 | 14.400 | 12.400 | 8.800 | 10.200 | 5.500 | 15.201 | -15.008 | 9.940 | 9.954 | 25.416 | 6.0011 | 6.0005 |
| 13.392 | 11.000 | 14.700 | 12.600 | 9.000 | 10.500 | 5.900 | 15.201 | -15.008 | 9.940 | 9.953 | 25.416 | 6.0010 | 6.0006 |
| 13.492 | 11.000 | 14.600 | 12.700 | 9.200 | 10.600 | 5.900 | 15.202 | -15.008 | 9.940 | 9.953 | 25.416 | 6.0011 | 6.0003 |
| 13.592 | 10.900 | 14.500 | 12.500 | 9.100 | 10.400 | 5.800 | 15.201 | -15.008 | 9.940 | 9.953 | 25.416 | 6.0011 | 6.0004 |
| 13.692 | 11.000 | 14.600 | 12.500 | 9.100 | 10.600 | 5.900 | 15.201 | -15.007 | 9.940 | 9.953 | 25.416 | 6.0009 | 6.0004 |
| 13.792 | 10.900 | 14.600 | 12.600 | 9.200 | 10.500 | 5.900 | 15.201 | -15.008 | 9.940 | 9.953 | 25.415 | 6.0012 | 6.0005 |
| 13.892 | 10.900 | 14.600 | 12.600 | 9.200 | 10.600 | 5.900 | 15.201 | -15.007 | 9.940 | 9.953 | 25.414 | 6.0010 | 6.0005 |
| 13.992 | 11.000 | 14.600 | 12.600 | 9.200 | 10.600 | 5.900 | 15.201 | -15.008 | 9.940 | 9.953 | 25.416 | 6.0010 | 6.0005 |
| 14.092 | 10.900 | 14.500 | 12.600 | 9.100 | 10.500 | 5.900 | 15.201 | -15.007 | 9.940 | 9.953 | 25.416 | 6.0011 | 6.0005 |
| 14.192 | 11.000 | 14.700 | 12.600 | 9.200 | 10.600 | 5.900 | 15.201 | -15.008 | 9.940 | 9.953 | 25.416 | 6.0010 | 6.0005 |
| 14.292 | 10.900 | 14.700 | 12.500 | 9.100 | 10.400 | 5.900 | 15.201 | -15.008 | 9.940 | 9.953 | 25.416 | 6.0012 | 6.0005 |
| 14.392 | 10.900 | 14.600 | 12.500 | 9.200 | 10.500 | 5.900 | 15.200 | -15.008 | 9.940 | 9.953 | 25.415 | 6.0010 | 6.0005 |
| 14.492 | 10.900 | 14.500 | 12.500 | 9.000 | 10.400 | 5.800 | 15.201 | -15.008 | 9.940 | 9.953 | 25.415 | 6.0010 | 6.0005 |
| 14.592 | 10.900 | 14.600 | 12.400 | 9.000 | 10.300 | 5.800 | 15.201 | -15.008 | 9.940 | 9.953 | 25.415 | 6.0010 | 6.0004 |
| 14.692 | 10.800 | 14.400 | 12.300 | 8.800 | 10.200 | 5.600 | 15.201 | -15.008 | 9.940 | 9.953 | 25.415 | 6.0006 | 6.0005 |
| 14.792 | 10.800 | 14.400 | 12.400 | 8.700 | 10.100 | 5.500 | 15.201 | -15.008 | 9.940 | 9.953 | 25.415 | 6.0010 | 6.0006 |
| 14.892 | 10.800 | 14.300 | 12.300 | 8.600 | 10.100 | 5.400 | 15.201 | -15.008 | 9.940 | 9.953 | 25.415 | 6.0011 | 6.0005 |
| 14.992 | 10.800 | 14.400 | 12.400 | 8.700 | 10.300 | 5.400 | 15.201 | -15.008 | 9.940 | 9.953 | 25.413 | 6.0007 | 6.0005 |
| 15.092 | 10.900 | 14.300 | 12.400 | 9.000 | 10.300 | 5.700 | 15.201 | -15.008 | 9.940 | 9.953 | 25.414 | 6.0010 | 6.0005 |
| 15.192 | 10.900 | 14.400 | 12.500 | 9.100 | 10.400 | 5.800 | 15.201 | -15.007 | 9.940 | 9.953 | 25.415 | 6.0009 | 6.0004 |
| 15.292 | 11.000 | 14.600 | 12.500 | 9.100 | 10.500 | 5.900 | 15.201 | -15.009 | 9.940 | 9.953 | 25.415 | 6.0012 | 6.0005 |
| 15.392 | 10.900 | 14.400 | 12.400 | 9.000 | 10.400 | 5.800 | 15.200 | -15.008 | 9.940 | 9.953 | 25.415 | 6.0011 | 6.0006 |
| 15.492 | 10.900 | 14.600 | 12.600 | 9.100 | 10.500 | 5.900 | 15.201 | -15.009 | 9.940 | 9.953 | 25.415 | 6.0010 | 6.0005 |
| 15.592 | 10.900 | 14.500 | 12.500 | 9.100 | 10.400 | 5.900 | 15.201 | -15.009 | 9.940 | 9.953 | 25.414 | 6.0010 | 6.0005 |
| 15.692 | 10.900 | 14.500 | 12.600 | 9.100 | 10.400 | 5.900 | 15.201 | -15.009 | 9.940 | 9.953 | 25.415 | 6.0011 | 6.0005 |
| 15.792 | 10.900 | 14.500 | 12.400 | 9.000 | 10.300 | 5.800 | 15.201 | -15.009 | 9.940 | 9.953 | 25.414 | 6.0010 | 6.0005 |
| 15.892 | 10.700 | 14.500 | 12.400 | 9.000 | 10.400 | 5.800 | 15.201 | -15.008 | 9.940 | 9.953 | 25.414 | 6.0010 | 6.0005 |
| 15.992 | 10.900 | 14.600 | 12.400 | 8.900 | 10.400 | 5.900 | 15.201 | -15.008 | 9.940 | 9.953 | 25.414 | 6.0009 | 6.0005 |
| 16.092 | 10.800 | 14.400 | 12.500 | 9.100 | 10.400 | 5.800 | 15.201 | -15.008 | 9.940 | 9.953 | 25.416 | 6.0010 | 6.0005 |
| 16.192 | 10.800 | 14.300 | 12.400 | 8.800 | 10.100 | 5.600 | 15.201 | -15.008 | 9.940 | 9.953 | 25.413 | 6.0005 | 6.0005 |
| 16.292 | 10.900 | 14.400 | 12.300 | 8.700 | 10.200 | 5.600 | 15.202 | -15.009 | 9.940 | 9.953 | 25.414 | 6.0010 | 6.0005 |
| 16.392 | 10.900 | 14.500 | 12.400 | 8.700 | 10.200 | 5.600 | 15.201 | -15.009 | 9.940 | 9.953 | 25.414 | 6.0005 | 6.0005 |
| 16.492 | 11.000 | 14.500 | 12.500 | 8.800 | 10.300 | 5.600 | 15.201 | -15.008 | 9.940 | 9.953 | 25.414 | 6.0009 | 6.0004 |
| 16.592 | 10.900 | 14.800 | 12.600 | 9.100 | 10.400 | 6.000 | 15.201 | -15.009 | 9.940 | 9.953 | 25.414 | 6.0011 | 6.0005 |
| 16.692 | 10.800 | 14.300 | 12.300 | 8.700 | 10.100 | 5.500 | 15.201 | -15.008 | 9.940 | 9.953 | 25.414 | 6.0010 | 6.0005 |
| 16.792 | 10.800 | 14.500 | 12.300 | 8.700 | 10.100 | 5.500 | 15.201 | -15.009 | 9.940 | 9.953 | 25.414 | 6.0010 | 6.0005 |
| 16.892 | 10.800 | 14.400 | 12.200 | 8.700 | 10.000 | 5.600 | 15.201 | -15.008 | 9.940 | 9.953 | 25.412 | 6.0011 | 6.0005 |
| 16.992 | 10.900 | 14.300 | 12.400 | 8.700 | 10.100 | 5.400 | 15.201 | -15.008 | 9.940 | 9.953 | 25.414 | 6.0010 | 6.0005 |

## Table F-1
## Data Recorded During Interface Board Temperature Test

| Time (HOURS) | Neg. V. Reg. Case Temp. U13 (°C) | Pos. V. Reg. Case Temp. U12 (°C) | Switching Reg. Case Temp. U11 (°C) | DET 4 Line Driver Case Temp U8 (°C) | TEMP 1 Line Driver Case Temp U4 (°C) | Chamber Temp. (°C) | Positive Voltage Regulator Output (V) | Negative Voltage Regulator Output (V) | TEMP1 Vouttage Output -100°C = -10 +100°C =+10 (V) | TEMP2 Voltage Output -100°C = -10 +100°C= +10 (V) | Nominal 24 V Input Voltage to Board (V) | Raw TEMP 2 Voltage Input -100°C = 4 0°C = 5 +100°C = 6 (V) | RAW TEMP 1 Voltage Input -100°C = 4 0°C = 5 +100°C = 6 (V) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 17.092 | 10.800 | 14.400 | 12.400 | 8.700 | 10.100 | 5.500 | 15.201 | -15.009 | 9.940 | 9.953 | 25.414 | 6.0009 | 6.0004 |
| 17.192 | 10.800 | 14.500 | 12.300 | 8.700 | 10.100 | 5.600 | 15.201 | -15.008 | 9.940 | 9.953 | 25.414 | 6.0011 | 6.0005 |
| 17.292 | 10.800 | 14.500 | 12.400 | 8.600 | 10.100 | 5.400 | 15.201 | -15.008 | 9.940 | 9.953 | 25.414 | 6.0010 | 6.0005 |
| 17.392 | 10.900 | 14.500 | 12.400 | 8.700 | 10.200 | 5.500 | 15.201 | -15.009 | 9.940 | 9.953 | 25.413 | 6.0010 | 6.0004 |
| 17.492 | 10.800 | 14.400 | 12.300 | 8.600 | 10.100 | 5.500 | 15.201 | -15.008 | 9.940 | 9.953 | 25.414 | 6.0009 | 6.0004 |
| 17.592 | 10.900 | 14.400 | 12.400 | 8.800 | 10.200 | 5.400 | 15.201 | -15.008 | 9.940 | 9.953 | 25.414 | 6.0010 | 6.0005 |
| 17.692 | 10.900 | 14.400 | 12.400 | 8.800 | 10.200 | 5.500 | 15.200 | -15.010 | 9.940 | 9.953 | 25.414 | 6.0010 | 6.0005 |
| 17.792 | 10.800 | 14.400 | 12.300 | 8.800 | 10.200 | 5.600 | 15.201 | -15.008 | 9.940 | 9.953 | 25.414 | 6.0008 | 6.0005 |
| 17.892 | 10.800 | 14.300 | 12.400 | 8.700 | 10.100 | 5.400 | 15.201 | -15.008 | 9.940 | 9.953 | 25.414 | 6.0011 | 6.0004 |
| 17.992 | 10.800 | 14.200 | 12.400 | 8.700 | 10.100 | 5.400 | 15.202 | -15.008 | 9.940 | 9.953 | 25.414 | 6.0011 | 6.0005 |
| 18.092 | 10.900 | 14.200 | 12.400 | 8.600 | 10.000 | 5.400 | 15.200 | -15.009 | 9.940 | 9.953 | 25.414 | 6.0014 | 6.0005 |
| 18.192 | 10.900 | 14.300 | 12.400 | 8.600 | 10.100 | 5.400 | 15.201 | -15.008 | 9.940 | 9.953 | 25.413 | 6.0010 | 6.0004 |
| 18.292 | 10.900 | 14.300 | 12.400 | 8.800 | 10.200 | 5.400 | 15.200 | -15.009 | 9.940 | 9.953 | 25.414 | 6.0012 | 6.0005 |
| 18.392 | 11.000 | 14.500 | 12.500 | 8.900 | 10.200 | 5.500 | 15.201 | -15.008 | 9.940 | 9.953 | 25.413 | 6.0010 | 6.0005 |
| 18.492 | 10.800 | 14.300 | 12.300 | 8.700 | 10.000 | 5.400 | 15.200 | -15.009 | 9.940 | 9.953 | 25.414 | 6.0012 | 6.0002 |
| 18.592 | 10.800 | 14.500 | 12.400 | 8.900 | 10.200 | 5.700 | 15.202 | -15.007 | 9.940 | 9.954 | 25.414 | 6.0010 | 6.0004 |
| 18.692 | 10.800 | 14.400 | 12.400 | 9.000 | 10.400 | 5.600 | 15.201 | -15.008 | 9.940 | 9.953 | 25.415 | 6.0010 | 6.0005 |
| 18.792 | 10.800 | 14.500 | 12.300 | 8.800 | 10.100 | 5.600 | 15.201 | -15.008 | 9.940 | 9.953 | 25.414 | 6.0013 | 6.0005 |
| 18.892 | 10.800 | 14.400 | 12.300 | 8.700 | 10.100 | 5.500 | 15.201 | -15.008 | 9.940 | 9.953 | 25.413 | 6.0010 | 6.0005 |
| 18.992 | 10.900 | 14.300 | 12.300 | 8.600 | 10.100 | 5.500 | 15.199 | -15.010 | 9.940 | 9.953 | 25.414 | 6.0011 | 6.0005 |
| 19.092 | 10.800 | 14.400 | 12.400 | 8.700 | 10.100 | 5.500 | 15.201 | -15.009 | 9.940 | 9.953 | 25.414 | 6.0011 | 6.0005 |
| 19.192 | 10.900 | 14.300 | 12.400 | 8.700 | 10.100 | 5.500 | 15.201 | -15.008 | 9.940 | 9.953 | 25.414 | 6.0010 | 6.0005 |
| 19.292 | 10.900 | 14.600 | 12.500 | 9.000 | 10.400 | 5.900 | 15.201 | -15.009 | 9.940 | 9.953 | 25.414 | 6.0011 | 6.0005 |
| 19.392 | 10.900 | 14.500 | 12.400 | 8.900 | 10.300 | 5.900 | 15.201 | -15.008 | 9.940 | 9.953 | 25.414 | 6.0006 | 6.0005 |
| 19.492 | 10.800 | 14.300 | 12.300 | 8.800 | 10.200 | 5.600 | 15.201 | -15.008 | 9.940 | 9.953 | 25.413 | 6.0010 | 6.0005 |
| 19.592 | 10.800 | 16.200 | 12.500 | 8.900 | 10.200 | 5.700 | 15.202 | -15.008 | 9.940 | 9.953 | 27.434 | 6.0010 | 6.0006 |
| 19.660 | 10.900 | 16.300 | 12.800 | 9.100 | 10.500 | 5.900 | 15.201 | -15.010 | -0.060 | -0.045 | 27.434 | 5.0010 | 4.9999 |
| 19.712 | 11.000 | 16.300 | 12.800 | 9.200 | 10.500 | 6.000 | 15.202 | -15.009 | -10.057 | -10.047 | 27.433 | 4.0007 | 3.9996 |
| 19.802 | 11.000 | 16.100 | 12.700 | 9.000 | 10.400 | 5.800 | 15.202 | -15.008 | 9.937 | 9.956 | 27.439 | 6.0012 | 6.0002 |
| 19.902 | 10.900 | 16.300 | 12.600 | 9.100 | 10.400 | 5.900 | 15.202 | -15.009 | 9.937 | 9.956 | 27.439 | 6.0013 | 6.0002 |
| 20.002 | 11.000 | 16.100 | 12.700 | 9.100 | 10.500 | 5.900 | 15.202 | -15.008 | 9.940 | 9.953 | 27.439 | 6.0010 | 6.0003 |
| 20.102 | 17.700 | 22.300 | 20.500 | 17.800 | 19.100 | 14.600 | 15.205 | -15.012 | 9.941 | 9.953 | 25.396 | 6.0011 | 6.0005 |
| 20.202 | 19.200 | 23.200 | 21.300 | 17.900 | 19.300 | 14.700 | 15.205 | -15.013 | 9.941 | 9.953 | 25.405 | 6.0010 | 6.0005 |
| 20.302 | 19.900 | 23.700 | 21.800 | 18.300 | 19.800 | 15.100 | 15.205 | -15.014 | 9.941 | 9.953 | 25.409 | 6.0010 | 6.0005 |
| 20.402 | 20.100 | 23.900 | 21.900 | 18.500 | 20.000 | 15.300 | 15.206 | -15.014 | 9.941 | 9.953 | 25.410 | 6.0010 | 6.0006 |
| 20.502 | 20.300 | 23.900 | 22.100 | 18.500 | 20.100 | 15.300 | 15.206 | -15.014 | 9.941 | 9.953 | 25.412 | 6.0010 | 6.0005 |
| 20.602 | 20.400 | 24.100 | 22.100 | 18.500 | 20.000 | 15.500 | 15.206 | -15.014 | 9.941 | 9.953 | 25.413 | 6.0010 | 6.0005 |
| 20.702 | 20.300 | 24.000 | 22.100 | 18.700 | 20.200 | 15.400 | 15.206 | -15.014 | 9.941 | 9.953 | 25.413 | 6.0011 | 6.0005 |
| 20.802 | 20.300 | 24.200 | 22.100 | 18.600 | 20.100 | 15.500 | 15.206 | -15.013 | 9.941 | 9.953 | 25.412 | 6.0009 | 6.0003 |
| 20.902 | 20.400 | 24.100 | 22.100 | 18.600 | 20.100 | 15.400 | 15.206 | -15.013 | 9.941 | 9.953 | 25.414 | 6.0010 | 6.0004 |
| 21.002 | 20.400 | 24.000 | 22.100 | 18.500 | 19.900 | 15.400 | 15.206 | -15.014 | 9.942 | 9.953 | 25.414 | 6.0010 | 6.0005 |
| 21.102 | 20.500 | 24.000 | 22.100 | 18.600 | 20.000 | 15.500 | 15.206 | -15.014 | 9.942 | 9.953 | 25.415 | 6.0010 | 6.0004 |
| 21.202 | 20.500 | 24.300 | 22.300 | 18.800 | 20.300 | 15.600 | 15.206 | -15.015 | 9.942 | 9.953 | 25.415 | 6.0010 | 6.0005 |
| 21.302 | 20.600 | 24.200 | 22.300 | 18.800 | 20.200 | 15.600 | 15.205 | -15.015 | 9.942 | 9.953 | 25.415 | 6.0006 | 6.0005 |

## Table F-1
## Data Recorded During Interface Board Temperature Test

| Time (HOURS) | Neg. V. Reg. Case Temp. U13 (°C) | Pos. V. Reg. Case Temp. U12 (°C) | Switching Reg. Case Temp. U11 (°C) | DET 4 Line Driver Case Temp U8 (°C) | TEMP 1 Line Driver Case Temp U4 (°C) | Chamber Temp. (°C) | Positive Voltage Regulator Output (V) | Negative Voltage Regulator Output (V) | TEMP1 Vouttage Output -100°C = -10 +100°C =+10 (V) | TEMP2 Voltage Output -100°C = -10 +100°C= +10 (V) | Nominal 24 V Input Voltage to Board (V) | Raw TEMP 2 Voltage Input -100°C = 4 0°C = 5 +100°C = 6 (V) | RAW TEMP 1 Voltage Input -100°C = 4 0°C = 5 +100°C = 6 (V) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21.402 | 20.600 | 24.400 | 22.400 | 18.800 | 20.300 | 15.700 | 15.206 | -15.014 | 9.942 | 9.953 | 25.415 | 6.0010 | 6.0005 |
| 21.502 | 20.600 | 24.200 | 22.400 | 18.800 | 20.300 | 15.600 | 15.205 | -15.015 | 9.942 | 9.953 | 25.415 | 6.0011 | 6.0004 |
| 21.602 | 20.700 | 24.300 | 22.400 | 18.800 | 20.300 | 15.700 | 15.206 | -15.014 | 9.942 | 9.953 | 25.414 | 6.0006 | 6.0004 |
| 21.702 | 20.700 | 24.400 | 22.500 | 18.800 | 20.400 | 15.700 | 15.206 | -15.014 | 9.942 | 9.953 | 25.415 | 6.0010 | 6.0005 |
| 21.802 | 20.700 | 24.400 | 22.400 | 18.800 | 20.400 | 15.700 | 15.206 | -15.014 | 9.942 | 9.953 | 25.414 | 6.0010 | 6.0005 |
| 21.902 | 20.600 | 24.400 | 22.300 | 18.800 | 20.400 | 15.700 | 15.206 | -15.014 | 9.942 | 9.953 | 25.417 | 6.0012 | 6.0005 |
| 22.002 | 20.600 | 26.000 | 22.600 | 18.800 | 20.400 | 15.800 | 15.207 | -15.014 | 9.942 | 9.953 | 27.433 | 6.0010 | 6.0005 |
| 22.024 | 20.700 | 25.900 | 22.600 | 18.800 | 20.400 | 15.700 | 15.207 | -15.013 | -0.057 | -0.048 | 27.432 | 5.0007 | 5.0001 |
| 22.046 | 20.700 | 26.200 | 22.600 | 18.800 | 20.400 | 15.700 | 15.207 | -15.013 | -10.057 | -10.051 | 27.432 | 4.0003 | 3.9998 |
| 22.072 | 20.800 | 26.000 | 22.700 | 19.000 | 20.500 | 15.700 | 15.207 | -15.013 | -0.061 | -0.052 | 27.434 | 5.0008 | 5.0001 |
| 22.081 | 20.700 | 26.200 | 22.600 | 18.900 | 20.400 | 15.800 | 15.208 | -15.013 | -10.057 | -10.051 | 27.433 | 4.0003 | 3.9998 |
| 22.181 | 20.700 | 26.000 | 22.600 | 18.900 | 20.300 | 15.700 | 15.207 | -15.013 | 9.937 | 9.953 | 27.439 | 6.0013 | 6.0003 |
| 22.281 | 20.700 | 26.000 | 22.700 | 18.900 | 20.300 | 15.700 | 15.207 | -15.013 | 9.941 | 9.953 | 27.440 | 6.0010 | 6.0005 |
| 22.381 | 20.700 | 26.000 | 22.700 | 18.900 | 20.500 | 15.700 | 15.206 | -15.013 | 9.942 | 9.953 | 27.439 | 6.0009 | 6.0004 |
| 22.481 | 25.900 | 32.600 | 29.300 | 27.000 | 28.000 | 23.800 | 15.208 | -15.016 | 9.943 | 9.952 | 27.442 | 6.0010 | 6.0005 |
| 22.581 | 28.600 | 34.300 | 31.100 | 27.400 | 29.000 | 24.400 | 15.208 | -15.019 | 9.944 | 9.952 | 27.444 | 6.0011 | 6.0005 |
| 22.681 | 29.300 | 34.900 | 31.700 | 27.900 | 29.500 | 24.900 | 15.209 | -15.018 | 9.944 | 9.953 | 27.441 | 6.0010 | 6.0005 |
| 22.781 | 29.700 | 35.100 | 32.000 | 28.200 | 29.800 | 25.100 | 15.209 | -15.018 | 9.944 | 9.952 | 27.442 | 6.0010 | 6.0005 |
| 22.881 | 29.900 | 35.300 | 32.200 | 28.400 | 30.100 | 25.200 | 15.209 | -15.018 | 9.944 | 9.953 | 27.442 | 6.0009 | 6.0003 |
| 22.981 | 30.000 | 35.400 | 32.300 | 28.400 | 30.000 | 25.300 | 15.208 | -15.020 | 9.944 | 9.952 | 27.443 | 6.0010 | 6.0005 |
| 23.081 | 30.100 | 35.500 | 32.400 | 28.500 | 30.100 | 25.400 | 15.209 | -15.018 | 9.944 | 9.953 | 27.442 | 6.0010 | 6.0005 |
| 23.181 | 30.200 | 35.500 | 32.400 | 28.600 | 30.200 | 25.400 | 15.209 | -15.017 | 9.944 | 9.953 | 27.442 | 6.0011 | 6.0005 |
| 23.281 | 30.200 | 35.600 | 32.500 | 28.600 | 30.100 | 25.400 | 15.209 | -15.018 | 9.944 | 9.953 | 27.442 | 6.0005 | 6.0004 |
| 23.381 | 30.200 | 35.600 | 32.500 | 28.600 | 30.200 | 25.400 | 15.209 | -15.018 | 9.945 | 9.953 | 27.442 | 6.0010 | 6.0005 |
| 23.481 | 30.300 | 35.800 | 32.500 | 28.600 | 30.300 | 25.500 | 15.209 | -15.018 | 9.944 | 9.953 | 27.443 | 6.0011 | 6.0005 |
| 23.581 | 30.300 | 35.800 | 32.500 | 28.600 | 30.200 | 25.600 | 15.211 | -15.018 | 9.945 | 9.953 | 27.443 | 6.0010 | 6.0005 |
| 23.681 | 30.300 | 35.800 | 32.500 | 28.700 | 30.300 | 25.500 | 15.211 | -15.018 | 9.945 | 9.953 | 27.442 | 6.0010 | 6.0005 |
| 23.781 | 30.300 | 35.700 | 32.600 | 28.700 | 30.300 | 25.500 | 15.210 | -15.018 | 9.945 | 9.953 | 27.442 | 6.0010 | 6.0005 |
| 23.881 | 30.300 | 35.800 | 32.600 | 28.700 | 30.400 | 25.600 | 15.209 | -15.018 | 9.945 | 9.953 | 27.442 | 6.0009 | 6.0003 |
| 23.981 | 30.300 | 35.700 | 32.600 | 28.700 | 30.300 | 25.500 | 15.209 | -15.018 | 9.945 | 9.953 | 27.442 | 6.0010 | 6.0005 |
| 24.081 | 30.400 | 35.800 | 32.600 | 28.800 | 30.400 | 25.500 | 15.211 | -15.017 | 9.945 | 9.953 | 27.442 | 6.0010 | 6.0005 |
| 24.181 | 30.400 | 35.800 | 32.600 | 28.700 | 30.400 | 25.600 | 15.208 | -15.020 | 9.945 | 9.953 | 27.443 | 6.0010 | 6.0005 |
| 24.281 | 30.400 | 35.800 | 32.700 | 28.700 | 30.400 | 25.500 | 15.209 | -15.018 | 9.945 | 9.953 | 27.441 | 6.0005 | 6.0005 |
| 24.381 | 30.400 | 35.800 | 32.600 | 28.700 | 30.400 | 25.600 | 15.209 | -15.019 | 9.945 | 9.953 | 27.443 | 6.0010 | 6.0004 |
| 24.481 | 30.500 | 35.900 | 32.600 | 28.600 | 30.400 | 25.600 | 15.209 | -15.018 | 9.945 | 9.953 | 27.442 | 6.0011 | 6.0005 |
| 24.581 | 30.400 | 35.900 | 32.600 | 28.700 | 30.400 | 25.600 | 15.209 | -15.018 | 9.945 | 9.953 | 27.443 | 6.0011 | 6.0005 |
| 24.681 | 30.400 | 35.800 | 32.700 | 28.900 | 30.400 | 25.500 | 15.210 | -15.018 | 9.945 | 9.953 | 27.442 | 6.0010 | 6.0005 |
| 24.781 | 30.400 | 35.900 | 32.600 | 28.700 | 30.400 | 25.600 | 15.208 | -15.019 | 9.945 | 9.953 | 27.444 | 6.0011 | 6.0005 |
| 24.881 | 30.400 | 35.800 | 32.700 | 28.800 | 30.500 | 25.700 | 15.209 | -15.018 | 9.945 | 9.953 | 27.443 | 6.0008 | 6.0005 |
| 24.981 | 30.500 | 35.800 | 32.600 | 28.700 | 30.300 | 25.600 | 15.210 | -15.016 | 9.945 | 9.953 | 27.442 | 6.0008 | 6.0005 |
| 25.081 | 30.400 | 35.800 | 32.600 | 28.700 | 30.300 | 25.600 | 15.209 | -15.018 | 9.945 | 9.953 | 27.442 | 6.0012 | 6.0005 |
| 25.181 | 30.400 | 35.800 | 32.600 | 28.700 | 30.400 | 25.600 | 15.209 | -15.018 | 9.945 | 9.953 | 27.443 | 6.0010 | 6.0005 |
| 25.281 | 30.500 | 35.900 | 32.600 | 28.700 | 30.400 | 25.600 | 15.210 | -15.018 | 9.945 | 9.953 | 27.443 | 6.0010 | 6.0005 |
| 25.381 | 30.500 | 35.900 | 32.600 | 28.600 | 30.300 | 25.700 | 15.209 | -15.018 | 9.945 | 9.953 | 27.442 | 6.0010 | 6.0006 |

## Table F-1
## Data Recorded During Interface Board Temperature Test

| Time (HOURS) | Neg. V. Reg. Case Temp. U13 (°C) | Pos. V. Reg. Case Temp. U12 (°C) | Switching Reg, Case Temp. U11 (°C) | DET 4 Line Driver Case Temp U8 (°C) | TEMP 1 Line Driver Case Temp U4 (°C) | Chamber Temp. (°C) | Positive Voltage Regulator Output (V) | Negative Voltage Regulator Output (V) | TEMP1 Vouttage Output -100°C = -10 +100°C =+10 (V) | TEMP2 Voltage Output -100°C = -10 +100°C= +10 (V) | Nominal 24 V Input Voltage to Board (V) | Raw TEMP 2 Voltage Input -100°C = 4 0°C = 5 +100°C = 6 (V) | RAW TEMP 1 Voltage Input -100°C = 4 0°C = 5 +100°C = 6 (V) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25.481 | 30.500 | 35.900 | 32.600 | 28.700 | 30.400 | 25.600 | 15.209 | -15.017 | 9.945 | 9.953 | 27.443 | 6.0010 | 6.0005 |
| 25.581 | 30.400 | 35.900 | 32.600 | 28.800 | 30.300 | 25.600 | 15.209 | -15.018 | 9.945 | 9.953 | 27.443 | 6.0009 | 6.0007 |
| 25.681 | 30.400 | 35.900 | 32.600 | 28.700 | 30.500 | 25.600 | 15.209 | -15.017 | 9.945 | 9.953 | 27.443 | 6.0010 | 6.0004 |
| 25.781 | 30.400 | 35.800 | 32.600 | 28.700 | 30.300 | 25.500 | 15.209 | -15.017 | 9.942 | 9.956 | 27.443 | 6.0017 | 6.0001 |
| 25.797 | 30.400 | 35.800 | 32.600 | 28.600 | 30.300 | 25.500 | 15.209 | -15.017 | -0.059 | -0.046 | 27.440 | 5.0012 | 4.9999 |
| 25.839 | 30.400 | 35.800 | 32.700 | 28.800 | 30.500 | 25.600 | 15.210 | -15.017 | -10.062 | -10.051 | 27.438 | 4.0007 | 3.9995 |
| 25.939 | 30.500 | 35.900 | 32.700 | 28.700 | 30.500 | 25.600 | 15.209 | -15.018 | 9.939 | 9.953 | 27.443 | 6.0013 | 6.0003 |
| 26.039 | 30.400 | 35.800 | 32.700 | 28.800 | 30.500 | 25.600 | 15.209 | -15.017 | 9.944 | 9.953 | 27.441 | 6.0010 | 6.0005 |
| 26.139 | 30.400 | 34.100 | 32.400 | 28.700 | 30.300 | 25.500 | 15.209 | -15.018 | 9.944 | 9.953 | 25.394 | 6.0009 | 6.0004 |
| 26.239 | 30.400 | 34.200 | 32.400 | 28.700 | 30.300 | 25.600 | 15.209 | -15.017 | 9.945 | 9.953 | 25.403 | 6.0010 | 6.0004 |
| 26.339 | 30.300 | 34.100 | 32.300 | 28.700 | 30.300 | 25.600 | 15.210 | -15.018 | 9.945 | 9.953 | 25.407 | 6.0009 | 6.0003 |
| 26.439 | 30.200 | 34.100 | 32.300 | 28.900 | 30.400 | 25.800 | 15.209 | -15.018 | 9.945 | 9.953 | 25.411 | 6.0010 | 6.0004 |
| 26.439 | 29.900 | 34.500 | 32.200 | 28.500 | 30.100 | 25.500 | 15.210 | -15.019 | 9.945 | 9.953 | 25.352 | 5.8351 | 6.0005 |
| 26.539 | 30.400 | 34.100 | 32.300 | 28.600 | 30.200 | 25.500 | 15.210 | -15.018 | 9.945 | 9.953 | 25.407 | 5.9687 | 6.0005 |
| 26.639 | 37.200 | 41.900 | 40.300 | 37.200 | 38.700 | 34.200 | 15.210 | -15.021 | 9.947 | 9.952 | 25.411 | 6.0454 | 6.0004 |
| 26.739 | 38.500 | 42.500 | 40.900 | 37.300 | 38.900 | 34.300 | 15.210 | -15.021 | 9.947 | 9.951 | 25.415 | 5.9155 | 6.0005 |
| 26.839 | 39.200 | 43.100 | 41.500 | 37.800 | 39.400 | 34.700 | 15.210 | -15.021 | 9.947 | 9.952 | 25.417 | 6.0290 | 6.0005 |
| 26.939 | 39.400 | 43.300 | 41.700 | 38.000 | 39.600 | 34.800 | 15.211 | -15.022 | 9.947 | 9.951 | 25.417 | 6.0264 | 6.0003 |
| 27.039 | 39.700 | 43.500 | 41.800 | 38.100 | 39.700 | 35.000 | 15.210 | -15.022 | 9.947 | 9.951 | 25.418 | 6.0014 | 6.0006 |
| 27.139 | 39.700 | 43.600 | 41.900 | 38.200 | 39.800 | 35.200 | 15.210 | -15.022 | 9.947 | 9.952 | 25.419 | 5.9274 | 6.0005 |
| 27.239 | 39.800 | 43.600 | 41.900 | 38.200 | 39.900 | 35.100 | 15.210 | -15.022 | 9.947 | 9.952 | 25.420 | 5.9830 | 6.0005 |
| 27.339 | 39.900 | 43.700 | 42.100 | 38.300 | 40.000 | 35.200 | 15.212 | -15.022 | 9.948 | 9.952 | 25.420 | 5.9195 | 6.0005 |
| 27.439 | 39.900 | 43.700 | 42.000 | 38.200 | 39.900 | 35.100 | 15.210 | -15.022 | 9.947 | 9.952 | 25.420 | 5.8925 | 6.0005 |
| 27.539 | 39.900 | 43.800 | 42.000 | 38.300 | 40.000 | 35.200 | 15.211 | -15.020 | 9.948 | 9.952 | 25.421 | 5.9485 | 6.0007 |
| 27.639 | 40.000 | 43.800 | 42.000 | 38.300 | 40.000 | 35.300 | 15.212 | -15.021 | 9.948 | 9.952 | 25.422 | 5.8858 | 6.0003 |
| 27.739 | 39.900 | 43.700 | 42.000 | 38.400 | 40.000 | 35.300 | 15.211 | -15.021 | 9.948 | 9.952 | 25.423 | 5.8645 | 6.0006 |
| 27.839 | 40.000 | 43.700 | 42.100 | 38.400 | 39.900 | 35.300 | 15.212 | -15.020 | 9.948 | 9.952 | 25.424 | 5.9741 | 6.0005 |
| 27.939 | 39.900 | 43.700 | 42.000 | 38.300 | 40.000 | 35.300 | 15.210 | -15.021 | 9.948 | 9.952 | 25.425 | 5.9452 | 6.0005 |
| 28.039 | 40.000 | 43.800 | 42.100 | 38.400 | 40.000 | 35.300 | 15.211 | -15.021 | 9.948 | 9.952 | 25.426 | 5.9133 | 6.0006 |
| 28.139 | 40.000 | 43.800 | 42.100 | 38.400 | 40.000 | 35.300 | 15.211 | -15.021 | 9.948 | 9.952 | 25.427 | 5.9053 | 6.0005 |
| 28.239 | 40.000 | 43.700 | 42.200 | 38.400 | 40.000 | 35.300 | 15.211 | -15.021 | 9.948 | 9.952 | 25.426 | 5.8271 | 6.0005 |
| 28.339 | 40.000 | 43.700 | 42.100 | 38.400 | 39.900 | 35.300 | 15.211 | -15.021 | 9.948 | 9.952 | 25.426 | 5.8209 | 6.0005 |
| 28.439 | 40.000 | 43.800 | 42.200 | 38.400 | 40.100 | 35.300 | 15.210 | -15.021 | 9.948 | 9.952 | 25.426 | 5.8263 | 6.0003 |
| 28.539 | 40.000 | 43.800 | 42.100 | 38.400 | 40.000 | 35.300 | 15.211 | -15.021 | 9.948 | 9.952 | 25.427 | 5.9601 | 6.0006 |
| 28.639 | 40.000 | 43.800 | 42.200 | 38.500 | 40.000 | 35.300 | 15.212 | -15.021 | 9.948 | 9.952 | 25.426 | 5.8291 | 6.0005 |
| 28.739 | 40.000 | 43.800 | 42.200 | 38.400 | 40.000 | 35.300 | 15.211 | -15.020 | 9.948 | 9.952 | 25.426 | 5.8956 | 6.0005 |
| 28.839 | 40.000 | 43.800 | 42.100 | 38.400 | 40.000 | 35.300 | 15.211 | -15.021 | 9.948 | 9.952 | 25.426 | 5.8624 | 6.0005 |
| 28.939 | 39.900 | 43.700 | 42.000 | 38.400 | 39.900 | 35.200 | 15.209 | -15.023 | 9.948 | 9.952 | 25.426 | 5.9497 | 6.0006 |
| 29.039 | 39.900 | 43.700 | 42.000 | 38.200 | 39.800 | 35.200 | 15.212 | -15.020 | 9.948 | 9.952 | 25.426 | 5.8279 | 6.0005 |
| 29.139 | 39.900 | 43.600 | 42.000 | 38.300 | 39.900 | 35.200 | 15.210 | -15.021 | 9.948 | 9.952 | 25.426 | 5.8717 | 6.0005 |
| 29.239 | 39.900 | 43.600 | 42.000 | 38.200 | 39.900 | 35.100 | 15.209 | -15.022 | 9.948 | 9.952 | 25.425 | 5.8945 | 6.0005 |
| 29.339 | 39.900 | 43.600 | 41.900 | 38.100 | 39.800 | 35.100 | 15.211 | -15.019 | 9.948 | 9.952 | 25.424 | 5.8777 | 6.0003 |
| 29.439 | 39.800 | 43.600 | 41.900 | 38.200 | 39.800 | 35.100 | 15.211 | -15.020 | 9.948 | 9.952 | 25.425 | 5.9266 | 6.0005 |
| 29.539 | 39.800 | 43.600 | 41.900 | 38.100 | 39.800 | 35.100 | 15.212 | -15.020 | 9.948 | 9.952 | 25.425 | 5.8290 | 6.0004 |

## Table F-1
## Data Recorded During Interface Board Temperature Test

| Time (HOURS) | Neg. V. Reg. Case Temp. U13 (°C) | Pos. V. Reg. Case Temp. U12 (°C) | Switching Reg, Case Temp. U11 (°C) | DET 4 Line Driver Case Temp U8 (°C) | TEMP 1 Line Driver Case Temp U4 (°C) | Chamber Temp. (°C) | Positive Voltage Regulator Output (V) | Negative Voltage Regulator Output (V) | TEMP1 Vouttage Output -100°C = -10 +100°C =+10 (V) | TEMP2 Voltage Output -100°C = -10 +100°C= +10 (V) | Nominal 24 V Input Voltage to Board (V) | Raw TEMP 2 Voltage Input -100°C = 4 0°C = 5 +100°C = 6 (V) | RAW TEMP 1 Voltage Input -100°C = 4 0°C = 5 +100°C = 6 (V) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 29.639 | 39.900 | 43.600 | 42.000 | 38.200 | 39.900 | 35.100 | 15.210 | -15.020 | 9.948 | 9.952 | 25.425 | 5.8604 | 6.0005 |
| 29.739 | 39.800 | 43.500 | 41.800 | 38.200 | 39.800 | 35.100 | 15.211 | -15.020 | 9.948 | 9.952 | 25.425 | 5.9263 | 6.0004 |
| 29.839 | 39.900 | 43.600 | 42.000 | 38.300 | 39.900 | 35.200 | 15.211 | -15.021 | 9.948 | 9.953 | 25.425 | 5.8195 | 6.0003 |
| 29.939 | 39.900 | 43.600 | 41.900 | 38.200 | 39.800 | 35.200 | 15.211 | -15.020 | 9.948 | 9.953 | 25.425 | 5.8697 | 6.0006 |
| 30.039 | 39.900 | 43.600 | 42.000 | 38.300 | 39.800 | 35.200 | 15.211 | -15.021 | 9.948 | 9.953 | 25.424 | 5.8710 | 6.0005 |
| 30.139 | 39.900 | 43.600 | 42.000 | 38.200 | 39.800 | 35.100 | 15.211 | -15.022 | 9.948 | 9.953 | 25.425 | 5.8307 | 6.0004 |
| 30.239 | 39.900 | 43.600 | 42.100 | 38.300 | 40.000 | 35.200 | 15.211 | -15.021 | 9.948 | 9.953 | 25.425 | 5.8289 | 6.0006 |
| 30.339 | 39.900 | 43.600 | 42.000 | 38.300 | 39.900 | 35.300 | 15.211 | -15.022 | 9.948 | 9.952 | 25.425 | 5.8412 | 6.0004 |
| 30.439 | 39.900 | 43.600 | 42.100 | 38.300 | 39.900 | 35.200 | 15.211 | -15.021 | 9.948 | 9.953 | 25.425 | 5.8121 | 6.0005 |
| 30.539 | 39.900 | 43.700 | 42.000 | 38.200 | 39.900 | 35.200 | 15.211 | -15.021 | 9.948 | 9.953 | 25.425 | 5.9459 | 6.0005 |
| 30.639 | 39.900 | 43.700 | 42.000 | 38.200 | 39.900 | 35.200 | 15.211 | -15.021 | 9.948 | 9.953 | 25.425 | 5.8521 | 6.0005 |
| 30.739 | 39.900 | 43.700 | 42.000 | 38.200 | 39.800 | 35.200 | 15.209 | -15.023 | 9.948 | 9.953 | 25.425 | 5.8931 | 6.0006 |
| 30.839 | 40.000 | 43.800 | 42.000 | 38.300 | 40.000 | 35.300 | 15.211 | -15.021 | 9.948 | 9.953 | 25.425 | 5.8439 | 6.0004 |
| 30.939 | 40.000 | 43.700 | 42.000 | 38.400 | 40.000 | 35.300 | 15.211 | -15.021 | 9.948 | 9.953 | 25.425 | 5.8010 | 6.0005 |
| 31.039 | 40.000 | 43.800 | 42.100 | 38.300 | 40.000 | 35.300 | 15.211 | -15.022 | 9.948 | 9.953 | 25.425 | 5.8030 | 6.0005 |
| 31.139 | 40.000 | 43.800 | 42.100 | 38.300 | 39.900 | 35.300 | 15.211 | -15.021 | 9.948 | 9.953 | 25.425 | 5.9410 | 6.0003 |
| 31.239 | 40.000 | 43.800 | 42.200 | 38.400 | 40.100 | 35.300 | 15.210 | -15.021 | 9.949 | 9.953 | 25.426 | 5.9515 | 6.0007 |
| 31.339 | 40.100 | 43.800 | 42.200 | 38.400 | 40.100 | 35.300 | 15.211 | -15.020 | 9.948 | 9.953 | 25.425 | 5.8814 | 6.0005 |
| 31.439 | 40.100 | 43.800 | 42.200 | 38.400 | 40.000 | 35.300 | 15.211 | -15.020 | 9.949 | 9.953 | 25.425 | 5.8147 | 6.0004 |
| 31.539 | 40.000 | 43.900 | 42.100 | 38.400 | 40.100 | 35.300 | 15.211 | -15.021 | 9.948 | 9.953 | 25.425 | 5.8617 | 6.0004 |
| 31.639 | 40.100 | 43.800 | 42.200 | 38.300 | 40.000 | 35.300 | 15.211 | -15.022 | 9.949 | 9.953 | 25.425 | 5.8892 | 6.0005 |
| 31.739 | 40.100 | 43.800 | 42.100 | 38.300 | 40.000 | 35.300 | 15.211 | -15.021 | 9.948 | 9.953 | 25.425 | 5.8565 | 6.0005 |
| 31.839 | 40.000 | 43.800 | 42.100 | 38.400 | 40.100 | 35.400 | 15.211 | -15.022 | 9.949 | 9.953 | 25.425 | 5.9396 | 6.0005 |
| 31.939 | 40.100 | 43.800 | 42.200 | 38.500 | 40.000 | 35.300 | 15.211 | -15.022 | 9.949 | 9.953 | 25.425 | 5.8183 | 6.0005 |
| 32.039 | 40.000 | 43.700 | 42.100 | 38.400 | 39.900 | 35.300 | 15.211 | -15.020 | 9.949 | 9.953 | 25.424 | 5.8821 | 6.0005 |
| 32.139 | 40.000 | 43.800 | 42.100 | 38.400 | 40.000 | 35.300 | 15.211 | -15.022 | 9.949 | 9.953 | 25.425 | 5.7994 | 6.0004 |
| 32.239 | 40.100 | 43.800 | 42.100 | 38.400 | 40.000 | 35.300 | 15.212 | -15.021 | 9.949 | 9.953 | 25.425 | 5.8172 | 6.0005 |
| 32.339 | 40.100 | 43.900 | 42.100 | 38.400 | 40.000 | 35.300 | 15.211 | -15.022 | 9.949 | 9.953 | 25.426 | 5.9393 | 6.0004 |
| 32.439 | 40.100 | 43.700 | 42.200 | 38.300 | 40.000 | 35.300 | 15.211 | -15.022 | 9.949 | 9.953 | 25.425 | 5.9497 | 6.0005 |
| 32.539 | 40.000 | 43.800 | 42.100 | 38.300 | 39.900 | 35.200 | 15.211 | -15.021 | 9.949 | 9.953 | 25.425 | 5.9360 | 6.0004 |
| 32.639 | 40.100 | 43.900 | 42.100 | 38.300 | 40.000 | 35.300 | 15.211 | -15.021 | 9.949 | 9.953 | 25.424 | 5.8149 | 6.0005 |
| 32.739 | 40.000 | 43.700 | 42.100 | 38.400 | 39.900 | 35.300 | 15.211 | -15.021 | 9.949 | 9.953 | 25.426 | 5.9332 | 6.0005 |
| 32.839 | 40.000 | 43.700 | 42.100 | 38.500 | 39.900 | 35.300 | 15.211 | -15.021 | 9.949 | 9.953 | 25.425 | 5.8361 | 6.0003 |
| 32.939 | 40.100 | 43.800 | 42.200 | 38.500 | 40.000 | 35.300 | 15.211 | -15.021 | 9.949 | 9.953 | 25.424 | 5.8445 | 6.0003 |
| 33.039 | 40.100 | 43.900 | 42.200 | 38.400 | 40.100 | 35.400 | 15.210 | -15.022 | 9.949 | 9.953 | 25.424 | 5.8834 | 6.0005 |
| 33.139 | 40.000 | 43.800 | 42.100 | 38.500 | 40.200 | 35.400 | 15.211 | -15.021 | 9.949 | 9.953 | 25.425 | 5.9285 | 6.0005 |
| 33.239 | 40.100 | 43.800 | 42.200 | 38.500 | 40.100 | 35.300 | 15.211 | -15.021 | 9.949 | 9.953 | 25.424 | 5.8139 | 6.0004 |
| 33.339 | 40.200 | 43.900 | 42.200 | 38.400 | 40.000 | 35.300 | 15.212 | -15.021 | 9.949 | 9.953 | 25.424 | 5.7999 | 6.0005 |
| 33.439 | 40.100 | 43.800 | 42.200 | 38.400 | 40.000 | 35.400 | 15.210 | -15.021 | 9.949 | 9.953 | 25.424 | 5.7976 | 6.0005 |
| 33.539 | 40.100 | 43.800 | 42.100 | 38.500 | 40.000 | 35.400 | 15.211 | -15.020 | 9.949 | 9.953 | 25.425 | 5.7903 | 6.0005 |
| 33.639 | 40.000 | 43.800 | 42.100 | 38.400 | 40.000 | 35.400 | 15.211 | -15.021 | 9.949 | 9.953 | 25.425 | 5.9184 | 6.0004 |
| 33.739 | 40.000 | 43.800 | 42.200 | 38.400 | 40.000 | 35.300 | 15.211 | -15.021 | 9.949 | 9.953 | 25.424 | 5.8368 | 6.0006 |
| 33.839 | 40.000 | 43.700 | 42.100 | 38.400 | 39.900 | 35.300 | 15.211 | -15.021 | 9.949 | 9.953 | 25.424 | 5.8348 | 6.0004 |
| 33.939 | 40.100 | 43.800 | 42.100 | 38.300 | 40.000 | 35.400 | 15.211 | -15.022 | 9.949 | 9.953 | 25.424 | 5.8424 | 6.0005 |

## Table F-1
## Data Recorded During Interface Board Temperature Test

| Time (HOURS) | Neg. V. Reg. Case Temp. U13 (°C) | Pos. V. Reg. Case Temp. U12 (°C) | Switching Reg, Case Temp. U11 (°C) | DET 4 Line Driver Case Temp U8 (°C) | TEMP 1 Line Driver Case Temp U4 (°C) | Chamber Temp. (°C) | Positive Voltage Regulator Output (V) | Negative Voltage Regulator Output (V) | TEMP1 Vouttage Output -100°C = -10 +100°C =+10 (V) | TEMP2 Voltage Output -100°C = -10 +100°C= +10 (V) | Nominal 24 V Input Voltage to Board (V) | Raw TEMP 2 Voltage Input -100°C = 4 0°C = 5 +100°C = 6 (V) | RAW TEMP 1 Voltage Input -100°C = 4 0°C = 5 +100°C = 6 (V) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 34.039 | 40.000 | 43.800 | 42.100 | 38.300 | 40.000 | 35.300 | 15.211 | -15.022 | 9.949 | 9.953 | 25.424 | 5.9170 | 6.0004 |
| 34.139 | 40.100 | 43.800 | 42.100 | 38.400 | 40.000 | 35.300 | 15.211 | -15.021 | 9.949 | 9.953 | 25.424 | 5.9404 | 6.0004 |
| 34.239 | 40.100 | 43.700 | 42.200 | 38.400 | 40.000 | 35.300 | 15.210 | -15.021 | 9.949 | 9.953 | 25.424 | 5.8177 | 6.0004 |
| 34.339 | 40.000 | 43.800 | 42.100 | 38.300 | 40.000 | 35.400 | 15.211 | -15.022 | 9.949 | 9.953 | 25.424 | 5.8390 | 6.0004 |
| 34.439 | 40.000 | 43.900 | 42.100 | 38.400 | 40.100 | 35.400 | 15.210 | -15.022 | 9.949 | 9.953 | 25.424 | 5.8785 | 6.0005 |
| 34.539 | 40.100 | 43.800 | 42.100 | 38.300 | 39.900 | 35.300 | 15.211 | -15.022 | 9.949 | 9.953 | 25.424 | 5.8512 | 6.0004 |
| 34.639 | 40.000 | 43.800 | 42.100 | 38.300 | 40.000 | 35.300 | 15.212 | -15.021 | 9.949 | 9.953 | 25.424 | 5.8087 | 6.0004 |
| 34.739 | 40.000 | 43.800 | 42.100 | 38.300 | 40.000 | 35.300 | 15.211 | -15.022 | 9.949 | 9.953 | 25.424 | 5.8985 | 6.0003 |
| 34.839 | 40.000 | 43.900 | 42.100 | 38.400 | 40.000 | 35.300 | 15.211 | -15.021 | 9.949 | 9.953 | 25.424 | 5.9419 | 6.0004 |
| 34.939 | 40.100 | 43.700 | 42.200 | 38.400 | 40.000 | 35.300 | 15.211 | -15.022 | 9.949 | 9.953 | 25.424 | 5.9467 | 6.0004 |
| 35.039 | 40.000 | 43.700 | 42.100 | 38.400 | 40.000 | 35.300 | 15.211 | -15.021 | 9.949 | 9.954 | 25.424 | 5.8784 | 6.0004 |
| 35.139 | 40.000 | 43.800 | 42.100 | 38.300 | 40.000 | 35.300 | 15.211 | -15.021 | 9.949 | 9.954 | 25.424 | 5.8671 | 6.0005 |
| 35.239 | 40.000 | 43.700 | 42.100 | 38.300 | 39.900 | 35.300 | 15.211 | -15.021 | 9.949 | 9.954 | 25.423 | 5.8820 | 6.0005 |
| 35.339 | 40.000 | 43.700 | 42.200 | 38.400 | 40.000 | 35.300 | 15.212 | -15.021 | 9.949 | 9.954 | 25.424 | 5.9447 | 6.0005 |
| 35.439 | 40.100 | 43.800 | 42.100 | 38.400 | 40.000 | 35.300 | 15.210 | -15.022 | 9.949 | 9.954 | 25.423 | 5.9323 | 6.0006 |
| 35.539 | 40.100 | 43.800 | 42.100 | 38.400 | 40.000 | 35.400 | 15.210 | -15.022 | 9.949 | 9.954 | 25.424 | 5.8810 | 6.0004 |
| 35.639 | 40.000 | 43.700 | 42.100 | 38.500 | 40.000 | 35.400 | 15.212 | -15.021 | 9.949 | 9.954 | 25.424 | 5.8812 | 6.0006 |
| 35.739 | 40.000 | 43.700 | 42.100 | 38.300 | 40.000 | 35.300 | 15.211 | -15.020 | 9.949 | 9.953 | 25.423 | 5.9446 | 6.0004 |
| 35.839 | 40.000 | 43.800 | 42.000 | 38.300 | 39.900 | 35.300 | 15.211 | -15.021 | 9.949 | 9.954 | 25.423 | 5.8558 | 6.0004 |
| 35.939 | 40.100 | 43.900 | 42.000 | 38.300 | 40.000 | 35.300 | 15.211 | -15.021 | 9.949 | 9.954 | 25.423 | 5.8755 | 6.0005 |
| 36.039 | 40.100 | 43.800 | 42.100 | 38.300 | 39.900 | 35.300 | 15.212 | -15.020 | 9.949 | 9.954 | 25.423 | 5.9436 | 6.0004 |
| 36.139 | 40.000 | 43.700 | 42.100 | 38.400 | 40.000 | 35.300 | 15.209 | -15.022 | 9.949 | 9.954 | 25.423 | 5.8248 | 6.0005 |
| 36.239 | 40.100 | 43.800 | 42.100 | 38.300 | 39.900 | 35.300 | 15.210 | -15.021 | 9.949 | 9.954 | 25.423 | 5.8086 | 6.0005 |
| 36.339 | 39.900 | 43.600 | 42.100 | 38.300 | 39.900 | 35.200 | 15.210 | -15.021 | 9.949 | 9.954 | 25.423 | 5.9130 | 6.0005 |
| 36.439 | 40.100 | 43.800 | 42.100 | 38.300 | 39.900 | 35.300 | 15.209 | -15.022 | 9.949 | 9.954 | 25.423 | 5.9373 | 6.0007 |
| 36.539 | 40.100 | 43.800 | 42.200 | 38.400 | 40.000 | 35.400 | 15.211 | -15.021 | 9.949 | 9.954 | 25.422 | 5.9344 | 6.0003 |
| 36.639 | 40.100 | 43.700 | 42.200 | 38.300 | 40.000 | 35.400 | 15.211 | -15.021 | 9.949 | 9.954 | 25.422 | 5.8628 | 6.0006 |
| 36.739 | 40.100 | 43.800 | 42.200 | 38.300 | 40.000 | 35.300 | 15.211 | -15.021 | 9.949 | 9.954 | 25.423 | 5.9473 | 6.0004 |
| 36.839 | 40.000 | 43.900 | 42.100 | 38.400 | 40.000 | 35.400 | 15.211 | -15.021 | 9.949 | 9.954 | 25.422 | 5.9234 | 6.0006 |
| 36.939 | 40.100 | 43.900 | 42.100 | 38.400 | 40.000 | 35.400 | 15.211 | -15.021 | 9.949 | 9.954 | 25.422 | 5.8562 | 6.0003 |
| 37.039 | 40.100 | 43.800 | 42.200 | 38.400 | 40.000 | 35.300 | 15.211 | -15.021 | 9.949 | 9.954 | 25.422 | 5.8691 | 6.0004 |
| 37.139 | 40.000 | 43.800 | 42.000 | 38.400 | 40.000 | 35.400 | 15.211 | -15.021 | 9.949 | 9.954 | 25.422 | 5.8875 | 6.0004 |
| 37.239 | 40.100 | 43.800 | 42.100 | 38.200 | 40.000 | 35.300 | 15.211 | -15.021 | 9.949 | 9.954 | 25.424 | 5.9351 | 6.0006 |
| 37.339 | 40.000 | 43.700 | 42.100 | 38.500 | 40.000 | 35.400 | 15.211 | -15.021 | 9.949 | 9.954 | 25.422 | 5.8780 | 6.0004 |
| 37.439 | 40.100 | 43.800 | 42.000 | 38.300 | 40.000 | 35.300 | 15.210 | -15.021 | 9.949 | 9.954 | 25.422 | 5.8140 | 6.0005 |
| 37.539 | 40.100 | 43.700 | 42.100 | 38.200 | 39.900 | 35.300 | 15.212 | -15.021 | 9.949 | 9.954 | 25.422 | 5.9098 | 6.0004 |
| 37.639 | 40.000 | 43.700 | 42.100 | 38.300 | 39.900 | 35.300 | 15.211 | -15.020 | 9.949 | 9.954 | 25.423 | 5.8746 | 6.0006 |
| 37.739 | 40.100 | 43.800 | 42.100 | 38.300 | 39.900 | 35.300 | 15.211 | -15.020 | 9.950 | 9.954 | 25.422 | 5.8431 | 6.0003 |
| 37.839 | 40.000 | 43.700 | 42.000 | 38.300 | 39.900 | 35.300 | 15.211 | -15.021 | 9.949 | 9.954 | 25.422 | 5.8372 | 6.0004 |
| 37.939 | 40.100 | 43.700 | 42.100 | 38.400 | 40.000 | 35.300 | 15.211 | -15.020 | 9.949 | 9.954 | 25.422 | 5.8264 | 6.0004 |
| 38.039 | 40.100 | 43.800 | 42.000 | 38.300 | 40.000 | 35.300 | 15.211 | -15.020 | 9.949 | 9.954 | 25.423 | 5.7969 | 6.0005 |
| 38.139 | 40.000 | 43.700 | 42.100 | 38.300 | 39.900 | 35.300 | 15.211 | -15.020 | 9.949 | 9.954 | 25.423 | 5.8030 | 6.0004 |
| 38.239 | 40.000 | 43.700 | 42.100 | 38.400 | 40.000 | 35.400 | 15.211 | -15.020 | 9.950 | 9.954 | 25.422 | 5.8471 | 6.0003 |
| 38.339 | 40.000 | 43.800 | 42.100 | 38.400 | 40.000 | 35.300 | 15.211 | -15.019 | 9.950 | 9.954 | 25.422 | 5.9285 | 6.0003 |

## Table F-1
## Data Recorded During Interface Board Temperature Test

| Time (HOURS) | Neg. V. Reg. Case Temp. U13 (°C) | Pos. V. Reg. Case Temp. U12 (°C) | Switching Reg, Case Temp. U11 (°C) | DET 4 Line Driver Case Temp U8 (°C) | TEMP 1 Line Driver Case Temp U4 (°C) | Chamber Temp. (°C) | Positive Voltage Regulator Output (V) | Negative Voltage Regulator Output (V) | TEMP1 Vouttage Output -100°C = -10 +100°C =+10 (V) | TEMP2 Voltage Output -100°C = -10 +100°C= +10 (V) | Nominal 24 V Input Voltage to Board (V) | Raw TEMP 2 Voltage Input -100°C = 4 0°C = 5 +100°C = 6 (V) | RAW TEMP 1 Voltage Input -100°C = 4 0°C = 5 +100°C = 6 (V) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 38.439 | 40.100 | 43.800 | 42.100 | 38.300 | 39.900 | 35.300 | 15.211 | -15.020 | 9.949 | 9.954 | 25.422 | 5.9460 | 6.0006 |
| 38.539 | 40.100 | 43.800 | 42.100 | 38.300 | 40.000 | 35.300 | 15.211 | -15.020 | 9.949 | 9.954 | 25.420 | 5.9180 | 6.0004 |
| 38.639 | 40.000 | 43.700 | 42.100 | 38.300 | 39.900 | 35.300 | 15.211 | -15.020 | 9.949 | 9.954 | 25.423 | 5.8171 | 6.0004 |
| 38.739 | 40.100 | 43.800 | 42.100 | 38.400 | 40.000 | 35.300 | 15.211 | -15.021 | 9.949 | 9.954 | 25.422 | 5.8260 | 6.0004 |
| 38.839 | 40.000 | 43.700 | 42.100 | 38.400 | 40.000 | 35.300 | 15.210 | -15.021 | 9.950 | 9.954 | 25.423 | 5.8767 | 6.0006 |
| 38.939 | 40.000 | 43.700 | 42.100 | 38.400 | 40.000 | 35.400 | 15.211 | -15.020 | 9.949 | 9.954 | 25.422 | 5.8110 | 6.0005 |
| 39.039 | 40.000 | 43.700 | 42.100 | 38.300 | 39.900 | 35.400 | 15.211 | -15.020 | 9.949 | 9.954 | 25.422 | 5.8079 | 6.0004 |
| 39.139 | 40.100 | 43.800 | 42.200 | 38.400 | 40.000 | 35.300 | 15.211 | -15.020 | 9.950 | 9.954 | 25.422 | 5.8849 | 6.0003 |
| 39.239 | 40.000 | 43.700 | 42.000 | 38.300 | 39.900 | 35.300 | 15.211 | -15.020 | 9.950 | 9.954 | 25.422 | 5.8068 | 6.0006 |
| 39.339 | 40.100 | 43.900 | 42.200 | 38.400 | 40.100 | 35.400 | 15.211 | -15.020 | 9.950 | 9.954 | 25.422 | 5.8593 | 6.0005 |
| 39.439 | 40.100 | 43.900 | 42.100 | 38.300 | 40.000 | 35.300 | 15.210 | -15.021 | 9.950 | 9.954 | 25.421 | 5.8071 | 6.0005 |
| 39.539 | 40.000 | 43.800 | 42.100 | 38.400 | 40.000 | 35.300 | 15.212 | -15.020 | 9.950 | 9.954 | 25.422 | 5.8420 | 6.0005 |
| 39.639 | 40.100 | 43.800 | 42.100 | 38.300 | 40.000 | 35.300 | 15.211 | -15.019 | 9.950 | 9.954 | 25.422 | 5.8793 | 6.0005 |
| 39.739 | 40.100 | 43.900 | 42.200 | 38.400 | 40.000 | 35.300 | 15.211 | -15.019 | 9.950 | 9.954 | 25.422 | 5.9212 | 6.0005 |
| 39.839 | 40.000 | 43.900 | 42.100 | 38.300 | 40.000 | 35.300 | 15.211 | -15.021 | 9.950 | 9.954 | 25.423 | 5.9348 | 6.0005 |
| 39.939 | 40.100 | 43.800 | 42.100 | 38.400 | 40.000 | 35.300 | 15.211 | -15.021 | 9.950 | 9.954 | 25.422 | 5.8175 | 6.0005 |
| 40.039 | 40.000 | 43.800 | 42.100 | 38.400 | 40.000 | 35.400 | 15.211 | -15.020 | 9.950 | 9.954 | 25.423 | 5.9217 | 6.0005 |
| 40.139 | 40.100 | 43.800 | 42.200 | 38.300 | 40.000 | 35.300 | 15.211 | -15.021 | 9.950 | 9.954 | 25.422 | 5.9410 | 6.0005 |
| 40.239 | 40.100 | 43.900 | 42.100 | 38.300 | 40.000 | 35.300 | 15.211 | -15.021 | 9.950 | 9.954 | 25.421 | 5.9036 | 6.0004 |
| 40.339 | 40.100 | 43.800 | 42.200 | 38.400 | 40.000 | 35.300 | 15.211 | -15.021 | 9.950 | 9.954 | 25.422 | 5.8506 | 6.0003 |
| 40.439 | 40.100 | 43.800 | 42.100 | 38.500 | 40.000 | 35.300 | 15.211 | -15.021 | 9.950 | 9.954 | 25.422 | 5.9397 | 6.0005 |
| 40.539 | 40.000 | 43.800 | 42.100 | 38.400 | 40.000 | 35.400 | 15.210 | -15.022 | 9.950 | 9.954 | 25.422 | 5.8968 | 6.0004 |
| 40.639 | 40.000 | 43.700 | 42.000 | 38.300 | 39.800 | 35.300 | 15.211 | -15.021 | 9.950 | 9.954 | 25.422 | 5.8815 | 6.0004 |
| 40.739 | 40.100 | 43.800 | 42.100 | 38.300 | 39.900 | 35.300 | 15.211 | -15.021 | 9.950 | 9.955 | 25.422 | 5.8189 | 6.0003 |
| 40.839 | 40.100 | 43.800 | 42.100 | 38.400 | 39.900 | 35.300 | 15.211 | -15.021 | 9.950 | 9.954 | 25.421 | 5.9068 | 6.0002 |
| 40.939 | 40.000 | 43.800 | 42.100 | 38.400 | 39.900 | 35.400 | 15.211 | -15.022 | 9.950 | 9.954 | 25.422 | 5.8083 | 6.0005 |
| 41.039 | 40.000 | 43.800 | 42.100 | 38.300 | 39.900 | 35.400 | 15.211 | -15.021 | 9.950 | 9.954 | 25.421 | 5.9278 | 6.0004 |
| 41.139 | 40.100 | 43.800 | 42.100 | 38.300 | 39.900 | 35.300 | 15.211 | -15.021 | 9.950 | 9.955 | 25.421 | 5.8178 | 6.0005 |
| 41.239 | 40.100 | 43.800 | 42.200 | 38.300 | 40.000 | 35.300 | 15.212 | -15.021 | 9.950 | 9.955 | 25.422 | 5.8085 | 6.0004 |
| 41.339 | 40.100 | 43.800 | 42.000 | 38.200 | 39.900 | 35.300 | 15.210 | -15.020 | 9.950 | 9.954 | 25.422 | 5.9041 | 6.0004 |
| 41.439 | 40.100 | 43.800 | 42.100 | 38.300 | 40.000 | 35.300 | 15.210 | -15.021 | 9.950 | 9.955 | 25.422 | 5.8106 | 6.0004 |
| 41.539 | 40.100 | 43.700 | 42.100 | 38.300 | 39.900 | 35.300 | 15.211 | -15.021 | 9.950 | 9.955 | 25.421 | 5.8279 | 6.0005 |
| 41.639 | 40.100 | 43.900 | 42.100 | 38.400 | 40.000 | 35.400 | 15.212 | -15.022 | 9.950 | 9.955 | 25.422 | 5.9127 | 6.0006 |
| 41.739 | 40.100 | 43.800 | 42.200 | 38.400 | 40.000 | 35.400 | 15.210 | -15.022 | 9.950 | 9.955 | 25.422 | 5.8390 | 6.0004 |
| 41.839 | 40.100 | 43.800 | 42.100 | 38.300 | 40.000 | 35.400 | 15.211 | -15.021 | 9.950 | 9.955 | 25.421 | 5.8042 | 6.0004 |
| 41.939 | 40.100 | 43.900 | 42.200 | 38.400 | 40.100 | 35.300 | 15.211 | -15.021 | 9.950 | 9.955 | 25.423 | 5.9067 | 6.0004 |
| 42.039 | 40.100 | 43.700 | 42.200 | 38.400 | 40.000 | 35.400 | 15.211 | -15.021 | 9.950 | 9.955 | 25.421 | 5.8596 | 6.0004 |
| 42.139 | 40.200 | 43.800 | 42.200 | 38.300 | 40.000 | 35.300 | 15.210 | -15.022 | 9.950 | 9.954 | 25.421 | 5.8169 | 6.0005 |
| 42.239 | 40.100 | 43.900 | 42.200 | 38.400 | 40.100 | 35.400 | 15.211 | -15.020 | 9.950 | 9.955 | 25.421 | 5.8131 | 6.0005 |
| 42.339 | 40.000 | 43.700 | 42.200 | 38.400 | 39.900 | 35.400 | 15.211 | -15.020 | 9.950 | 9.955 | 25.421 | 5.8712 | 6.0004 |
| 42.439 | 40.100 | 43.700 | 42.100 | 38.400 | 40.000 | 35.400 | 15.211 | -15.021 | 9.950 | 9.955 | 25.420 | 5.8904 | 6.0004 |
| 42.539 | 40.100 | 43.800 | 42.100 | 38.400 | 40.000 | 35.400 | 15.211 | -15.020 | 9.950 | 9.955 | 25.422 | 5.8077 | 6.0004 |
| 42.639 | 40.100 | 43.900 | 42.100 | 38.300 | 40.000 | 35.400 | 15.211 | -15.020 | 9.950 | 9.955 | 25.422 | 5.9030 | 6.0003 |
| 42.739 | 40.100 | 43.800 | 42.100 | 38.400 | 40.000 | 35.400 | 15.209 | -15.022 | 9.950 | 9.955 | 25.423 | 5.8205 | 6.0005 |

## Table F-1
## Data Recorded During Interface Board Temperature Test

| Time (HOURS) | Neg. V. Reg. Case Temp. U13 (°C) | Pos. V. Reg. Case Temp. U12 (°C) | Switching Reg. Case Temp. U11 (°C) | DET 4 Line Driver Case Temp U8 (°C) | TEMP 1 Line Driver Case Temp U4 (°C) | Chamber Temp. (°C) | Positive Voltage Regulator Output (V) | Negative Voltage Regulator Output (V) | TEMP1 Vouttage Output -100°C = -10 +100°C =+10 (V) | TEMP2 Voltage Output -100°C = -10 +100°C= +10 (V) | Nominal 24 V Input Voltage to Board (V) | Raw TEMP 2 Voltage Input -100°C = 4 0°C = 5 +100°C = 6 (V) | RAW TEMP 1 Voltage Input -100°C = 4 0°C = 5 +100°C = 6 (V) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 42.839 | 40.100 | 43.700 | 42.100 | 38.400 | 39.900 | 35.300 | 15.210 | -15.021 | 9.950 | 9.955 | 25.422 | 5.8900 | 6.0004 |
| 42.939 | 40.100 | 43.800 | 42.100 | 38.400 | 40.000 | 35.400 | 15.211 | -15.021 | 9.950 | 9.955 | 25.422 | 5.8199 | 6.0005 |
| 43.039 | 40.100 | 43.800 | 42.100 | 38.400 | 40.000 | 35.400 | 15.211 | -15.021 | 9.950 | 9.955 | 25.422 | 5.9393 | 6.0003 |
| 43.139 | 40.100 | 43.800 | 42.200 | 38.400 | 40.100 | 35.300 | 15.211 | -15.021 | 9.950 | 9.955 | 25.422 | 5.9503 | 6.0005 |
| 43.171 | 40.100 | 43.800 | 42.100 | 38.400 | 40.000 | 35.300 | 15.211 | -15.021 | 9.950 | 9.954 | 25.423 | 5.8352 | 6.0005 |
| 43.271 | 40.100 | 45.500 | 42.400 | 38.500 | 40.200 | 35.400 | 15.210 | -15.021 | 9.950 | 9.955 | 27.444 | 5.8590 | 6.0005 |
| 43.346 | 40.200 | 45.600 | 42.400 | 38.400 | 40.100 | 35.400 | 15.210 | -15.021 | -0.056 | -0.045 | 27.442 | 5.6249 | 4.9998 |
| 43.381 | 40.200 | 45.500 | 42.400 | 38.400 | 40.100 | 35.400 | 15.210 | -15.020 | -10.062 | -10.052 | 27.441 | 5.4466 | 3.9994 |
| 43.404 | 40.200 | 45.600 | 42.400 | 38.400 | 40.300 | 35.400 | 15.209 | -15.020 | 9.941 | 9.951 | 27.446 | 5.8697 | 6 |
| 43.504 | 40.100 | 43.900 | 42.200 | 38.400 | 40.000 | 35.300 | 15.211 | -15.021 | 9.947 | 9.958 | 25.392 | 5.8648 | 6.0001 |
| 43.604 | 39.800 | 43.500 | 41.900 | 38.200 | 39.700 | 35.100 | 15.211 | -15.020 | 9.947 | 9.957 | 25.409 | 5.9172 | 6.0001 |
| 43.704 | 39.900 | 43.600 | 41.900 | 38.300 | 39.700 | 35.200 | 15.210 | -15.021 | 9.950 | 9.955 | 25.416 | 5.8809 | 6.0004 |
| 43.804 | 44.300 | 49.200 | 47.500 | 45.100 | 46.400 | 42.300 | 15.210 | -15.022 | 9.951 | 9.953 | 25.415 | 5.8755 | 6.0004 |
| 43.904 | 43.900 | 46.100 | 45.000 | 38.900 | 41.200 | 35.800 | 15.210 | -15.024 | 9.951 | 9.954 | 25.415 | 5.8831 | 6.0004 |
| 44.004 | 39.900 | 43.300 | 41.600 | 37.700 | 39.400 | 34.600 | 15.211 | -15.021 | 9.950 | 9.955 | 25.418 | 5.9518 | 6.0004 |
| 44.104 | 39.400 | 43.100 | 41.500 | 37.700 | 39.300 | 34.600 | 15.210 | -15.022 | 9.950 | 9.955 | 25.419 | 5.8930 | 6.0003 |
| 44.204 | 39.400 | 43.100 | 41.400 | 37.700 | 39.300 | 34.700 | 15.211 | -15.020 | 9.950 | 9.955 | 25.419 | 5.8962 | 6.0003 |
| 44.304 | 39.500 | 43.300 | 41.600 | 37.900 | 39.500 | 34.900 | 15.211 | -15.021 | 9.947 | 9.958 | 25.419 | 5.8220 | 6.0001 |
| 44.404 | 39.600 | 43.300 | 41.600 | 38.000 | 39.500 | 34.900 | 15.211 | -15.020 | 9.950 | 9.955 | 25.418 | 5.9440 | 6.0005 |
| 44.504 | 39.700 | 43.500 | 41.700 | 37.900 | 39.600 | 34.900 | 15.211 | -15.021 | 9.950 | 9.955 | 25.419 | 5.8268 | 6.0005 |
| 44.604 | 44.200 | 49.200 | 47.500 | 45.200 | 46.400 | 42.200 | 15.210 | -15.023 | 9.952 | 9.953 | 25.419 | 5.9246 | 6.0003 |
| 44.704 | 47.400 | 51.400 | 50.000 | 46.400 | 47.900 | 43.400 | 15.210 | -15.025 | 9.953 | 9.952 | 25.420 | 5.8182 | 6.0004 |
| 44.804 | 48.200 | 52.000 | 50.600 | 46.900 | 48.500 | 43.900 | 15.209 | -15.026 | 9.953 | 9.952 | 25.421 | 5.9248 | 6.0004 |
| 44.904 | 48.500 | 52.400 | 51.000 | 47.200 | 48.800 | 44.100 | 15.208 | -15.027 | 9.953 | 9.952 | 25.419 | 5.9338 | 6.0006 |
| 45.004 | 48.800 | 52.600 | 51.300 | 47.400 | 49.100 | 44.400 | 15.209 | -15.026 | 9.954 | 9.952 | 25.424 | 5.8201 | 6.0005 |
| 45.104 | 49.100 | 52.900 | 51.400 | 47.600 | 49.300 | 44.600 | 15.210 | -15.026 | 9.954 | 9.952 | 25.421 | 5.9369 | 6.0005 |
| 45.204 | 49.200 | 53.000 | 51.700 | 47.800 | 49.500 | 44.700 | 15.210 | -15.025 | 9.954 | 9.952 | 25.420 | 5.9340 | 6.0004 |
| 45.304 | 49.300 | 53.000 | 51.700 | 47.800 | 49.400 | 44.800 | 15.210 | -15.025 | 9.954 | 9.952 | 25.420 | 5.9342 | 6.0003 |
| 45.404 | 49.400 | 53.100 | 51.700 | 47.700 | 49.400 | 44.800 | 15.210 | -15.025 | 9.954 | 9.952 | 25.420 | 5.9447 | 6.0006 |
| 45.504 | 49.500 | 53.200 | 51.900 | 47.900 | 49.500 | 44.800 | 15.209 | -15.025 | 9.954 | 9.952 | 25.419 | 5.8488 | 6.0005 |
| 45.604 | 49.500 | 53.300 | 51.900 | 47.900 | 49.700 | 45.000 | 15.210 | -15.025 | 9.954 | 9.952 | 25.421 | 5.8981 | 6.0005 |
| 45.704 | 49.600 | 53.300 | 51.900 | 47.900 | 49.600 | 44.900 | 15.209 | -15.025 | 9.954 | 9.952 | 25.421 | 5.8382 | 6.0004 |
| 45.804 | 49.600 | 53.400 | 52.000 | 48.100 | 49.800 | 45.100 | 15.210 | -15.025 | 9.954 | 9.952 | 25.422 | 5.8109 | 6.0005 |
| 45.904 | 49.600 | 53.400 | 51.900 | 48.100 | 49.800 | 45.100 | 15.209 | -15.025 | 9.954 | 9.952 | 25.421 | 5.8056 | 6.0004 |
| 46.004 | 49.700 | 53.300 | 52.000 | 48.000 | 49.700 | 45.000 | 15.209 | -15.024 | 9.954 | 9.952 | 25.421 | 5.9539 | 6.0004 |
| 46.104 | 49.700 | 53.400 | 52.000 | 48.100 | 49.800 | 45.100 | 15.209 | -15.024 | 9.954 | 9.952 | 25.421 | 5.8412 | 6.0009 |
| 46.204 | 49.700 | 53.400 | 52.000 | 48.000 | 49.800 | 45.100 | 15.209 | -15.025 | 9.954 | 9.952 | 25.421 | 5.9412 | 6.0004 |
| 46.304 | 49.700 | 53.500 | 52.000 | 48.100 | 49.800 | 45.100 | 15.209 | -15.025 | 9.954 | 9.952 | 25.420 | 5.8117 | 6.0004 |
| 46.404 | 49.700 | 53.400 | 52.000 | 48.100 | 49.800 | 45.200 | 15.210 | -15.024 | 9.954 | 9.952 | 25.421 | 5.9247 | 6.0004 |
| 46.504 | 49.800 | 53.500 | 52.100 | 48.100 | 49.800 | 45.100 | 15.209 | -15.024 | 9.954 | 9.952 | 25.421 | 5.9214 | 6.0004 |
| 46.604 | 49.700 | 53.400 | 51.900 | 48.100 | 49.800 | 45.100 | 15.209 | -15.025 | 9.954 | 9.952 | 25.421 | 5.8990 | 6.0004 |
| 46.704 | 49.800 | 53.500 | 52.100 | 48.100 | 49.800 | 45.100 | 15.209 | -15.024 | 9.955 | 9.952 | 25.420 | 5.8782 | 6.0004 |
| 46.804 | 49.800 | 53.500 | 52.200 | 48.300 | 49.900 | 45.200 | 15.209 | -15.025 | 9.955 | 9.952 | 25.419 | 5.8500 | 6.0005 |
| 46.904 | 49.800 | 53.500 | 52.100 | 48.200 | 50.000 | 45.300 | 15.209 | -15.025 | 9.955 | 9.952 | 25.420 | 5.8223 | 6.0003 |

## Table F-1
## Data Recorded During Interface Board Temperature Test

| Time (HOURS) | Neg. V. Reg. Case Temp. U13 (°C) | Pos. V. Reg. Case Temp. U12 (°C) | Switching Reg, Case Temp. U11 (°C) | DET 4 Line Driver Case Temp U8 (°C) | TEMP 1 Line Driver Case Temp U4 (°C) | Chamber Temp. (°C) | Positive Voltage Regulator Output (V) | Negative Voltage Regulator Output (V) | TEMP1 Vouttage Output -100°C = -10 +100°C =+10 (V) | TEMP2 Voltage Output -100°C = -10 +100°C= +10 (V) | Nominal 24 V Input Voltage to Board (V) | Raw TEMP 2 Voltage Input -100°C = 4 0°C = 5 +100°C = 6 (V) | RAW TEMP 1 Voltage Input -100°C = 4 0°C = 5 +100°C = 6 (V) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 47.004 | 49.800 | 53.500 | 52.100 | 48.100 | 49.800 | 45.200 | 15.209 | -15.025 | 9.955 | 9.952 | 25.421 | 5.8340 | 6.0004 |
| 47.104 | 49.700 | 53.500 | 52.100 | 48.300 | 49.900 | 45.300 | 15.209 | -15.024 | 9.955 | 9.952 | 25.421 | 5.8138 | 6.0003 |
| 47.204 | 49.900 | 53.600 | 52.300 | 48.300 | 50.000 | 45.300 | 15.209 | -15.023 | 9.955 | 9.952 | 25.421 | 5.7816 | 6.0004 |
| 47.304 | 49.800 | 53.500 | 52.200 | 48.200 | 49.800 | 45.200 | 15.209 | -15.023 | 9.955 | 9.952 | 25.422 | 5.7988 | 6.0005 |
| 47.404 | 49.800 | 53.500 | 52.200 | 48.300 | 50.000 | 45.300 | 15.209 | -15.023 | 9.955 | 9.952 | 25.422 | 5.8187 | 6.0005 |
| 47.504 | 49.800 | 53.500 | 52.000 | 48.200 | 49.900 | 45.200 | 15.209 | -15.024 | 9.955 | 9.953 | 25.424 | 5.7757 | 6.0004 |
| 47.604 | 49.800 | 53.500 | 52.100 | 48.200 | 49.900 | 45.200 | 15.208 | -15.025 | 9.955 | 9.953 | 25.429 | 5.8614 | 6.0005 |
| 47.704 | 49.900 | 53.600 | 52.200 | 48.300 | 50.000 | 45.300 | 15.209 | -15.024 | 9.955 | 9.953 | 25.433 | 5.7957 | 6.0003 |
| 47.804 | 49.900 | 53.700 | 52.200 | 48.300 | 50.000 | 45.300 | 15.209 | -15.024 | 9.955 | 9.952 | 25.436 | 5.8907 | 6.0005 |
| 47.904 | 50.000 | 53.700 | 52.400 | 48.400 | 50.100 | 45.400 | 15.210 | -15.023 | 9.955 | 9.952 | 25.436 | 5.8963 | 6.0004 |
| 48.004 | 50.000 | 53.800 | 52.300 | 48.400 | 50.100 | 45.400 | 15.209 | -15.024 | 9.955 | 9.953 | 25.435 | 5.8071 | 6.0004 |
| 48.104 | 50.000 | 53.800 | 52.400 | 48.500 | 50.200 | 45.400 | 15.209 | -15.024 | 9.955 | 9.952 | 25.437 | 5.8825 | 6.0005 |
| 48.204 | 50.000 | 53.800 | 52.400 | 48.400 | 50.100 | 45.400 | 15.208 | -15.026 | 9.955 | 9.953 | 25.437 | 5.9090 | 6.0004 |
| 48.304 | 50.100 | 53.800 | 52.400 | 48.300 | 50.100 | 45.400 | 15.208 | -15.025 | 9.955 | 9.952 | 25.438 | 5.7828 | 6.0004 |
| 48.404 | 50.000 | 53.800 | 52.400 | 48.400 | 50.100 | 45.400 | 15.208 | -15.025 | 9.955 | 9.952 | 25.436 | 5.7760 | 6.0005 |
| 48.504 | 50.000 | 53.700 | 52.400 | 48.300 | 50.100 | 45.400 | 15.211 | -15.024 | 9.955 | 9.953 | 25.436 | 5.7917 | 6.0003 |
| 48.604 | 50.200 | 53.800 | 52.500 | 48.500 | 50.200 | 45.500 | 15.210 | -15.023 | 9.955 | 9.953 | 25.435 | 5.8823 | 6.0003 |
| 48.704 | 50.100 | 53.800 | 52.300 | 48.300 | 50.100 | 45.400 | 15.208 | -15.026 | 9.955 | 9.953 | 25.436 | 5.7905 | 6.0004 |
| 48.804 | 50.100 | 55.500 | 52.500 | 48.400 | 50.200 | 45.600 | 15.207 | -15.024 | 9.952 | 9.955 | 27.459 | 5.8514 | 6.0001 |
| 48.811 | 50.100 | 55.500 | 52.500 | 48.400 | 50.200 | 45.500 | 15.207 | -15.023 | -0.055 | -0.048 | 27.455 | 5.6872 | 4.9998 |
| 48.842 | 50.100 | 55.600 | 52.600 | 48.500 | 50.400 | 45.500 | 15.208 | -15.024 | -10.061 | -10.053 | 27.454 | 5.2979 | 3.9995 |
| 48.878 | 50.100 | 55.700 | 52.600 | 48.600 | 50.300 | 45.600 | 15.208 | -15.023 | 9.945 | 9.948 | 27.460 | 5.9113 | 6.0001 |
| 48.978 | 50.100 | 54.000 | 52.500 | 48.600 | 50.300 | 45.600 | 15.209 | -15.024 | 9.952 | 9.955 | 25.412 | 5.8142 | 6.0001 |
| 49.078 | 50.100 | 53.900 | 52.400 | 48.500 | 50.100 | 45.500 | 15.209 | -15.023 | 9.956 | 9.956 | 25.428 | 5.7764 | 6.0004 |
| 49.165 | 50.100 | 53.900 | 52.400 | 48.500 | 50.200 | 45.500 | 15.209 | -15.023 | 9.955 | 9.953 | 25.432 | 5.9422 | 6.0005 |
| 49.176 | 50.100 | 53.800 | 52.400 | 48.400 | 50.100 | 45.400 | 15.209 | -15.024 | 9.955 | 9.953 | 25.432 | 5.9051 | 6.0004 |
| 49.181 | 50.100 | 53.800 | 52.400 | 48.500 | 50.200 | 45.500 | 15.209 | -15.023 | 9.955 | 9.953 | 25.432 | 5.8383 | 6.0003 |
| 49.197 | 50.200 | 53.900 | 52.500 | 48.500 | 50.200 | 45.500 | 15.210 | -15.023 | 9.955 | 9.953 | 25.433 | 5.9025 | 6.0004 |
| 49.204 | 50.100 | 53.800 | 52.500 | 48.500 | 50.200 | 45.500 | 15.209 | -15.024 | 9.955 | 9.953 | 25.433 | 5.8117 | 6.0004 |
| 49.304 | 55.400 | 60.400 | 59.000 | 56.500 | 57.800 | 53.700 | 15.207 | -15.026 | 9.958 | 9.950 | 25.436 | 5.8757 | 6.0005 |
| 49.404 | 61.000 | 65.300 | 64.400 | 60.600 | 62.200 | 57.500 | 15.205 | -15.028 | 9.962 | 9.946 | 25.437 | 5.9403 | 6.0004 |
| 49.504 | 62.200 | 66.300 | 65.200 | 61.400 | 63.000 | 58.500 | 15.205 | -15.028 | 9.963 | 9.945 | 25.439 | 5.8206 | 6.0004 |
| 49.604 | 62.800 | 66.800 | 65.600 | 61.700 | 63.500 | 58.800 | 15.203 | -15.028 | 9.963 | 9.945 | 25.439 | 5.8002 | 6.0004 |
| 49.704 | 63.200 | 67.300 | 66.100 | 62.200 | 63.900 | 59.300 | 15.203 | -15.029 | 9.964 | 9.945 | 25.440 | 5.9034 | 6.0004 |
| 49.804 | 63.600 | 67.600 | 66.400 | 62.400 | 64.200 | 59.500 | 15.202 | -15.028 | 9.964 | 9.945 | 25.440 | 5.7991 | 6.0004 |
| 49.904 | 63.800 | 67.700 | 66.500 | 62.500 | 64.300 | 59.600 | 15.203 | -15.028 | 9.964 | 9.945 | 25.441 | 5.7867 | 6.0003 |
| 50.004 | 63.900 | 67.900 | 66.600 | 62.600 | 64.400 | 59.800 | 15.203 | -15.028 | 9.965 | 9.945 | 25.441 | 5.8099 | 6.0006 |
| 50.104 | 64.000 | 67.900 | 66.800 | 62.800 | 64.500 | 59.800 | 15.203 | -15.027 | 9.965 | 9.945 | 25.441 | 5.8402 | 6.0004 |
| 50.204 | 64.100 | 68.000 | 66.900 | 62.800 | 64.600 | 59.900 | 15.202 | -15.028 | 9.965 | 9.945 | 25.442 | 5.9376 | 6.0004 |
| 50.304 | 64.200 | 68.100 | 66.900 | 62.900 | 64.700 | 60.100 | 15.202 | -15.028 | 9.965 | 9.945 | 25.442 | 5.8077 | 6 |
| 50.404 | 64.300 | 68.200 | 66.900 | 62.900 | 64.800 | 60.000 | 15.202 | -15.028 | 9.965 | 9.945 | 25.441 | 5.8823 | 6.0005 |
| 50.504 | 64.300 | 68.100 | 67.000 | 62.900 | 64.700 | 60.000 | 15.202 | -15.027 | 9.965 | 9.945 | 25.443 | 5.9486 | 6.0005 |
| 50.604 | 64.300 | 68.200 | 67.000 | 63.000 | 64.800 | 60.100 | 15.202 | -15.028 | 9.965 | 9.945 | 25.443 | 5.9563 | 6.0003 |
| 50.704 | 64.500 | 68.400 | 67.200 | 63.100 | 64.900 | 60.300 | 15.202 | -15.028 | 9.966 | 9.945 | 25.443 | 5.8846 | 6.0005 |

## Table F-1
## Data Recorded During Interface Board Temperature Test

| Time (HOURS) | Neg. V. Reg. Case Temp. U13 (°C) | Pos. V. Reg. Case Temp. U12 (°C) | Switching Reg, Case Temp. U11 (°C) | DET 4 Line Driver Case Temp U8 (°C) | TEMP 1 Line Driver Case Temp U4 (°C) | Chamber Temp. (°C) | Positive Voltage Regulator Output (V) | Negative Voltage Regulator Output (V) | TEMP1 Vouttage Output -100°C = -10 +100°C =+10 (V) | TEMP2 Voltage Output -100°C = -10 +100°C= +10 (V) | Nominal 24 V Input Voltage to Board (V) | Raw TEMP 2 Voltage Input -100°C = 4 0°C = 5 +100°C = 6 (V) | RAW TEMP 1 Voltage Input -100°C = 4 0°C = 5 +100°C = 6 (V) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 50.804 | 64.500 | 68.600 | 67.300 | 63.300 | 65.100 | 60.300 | 15.202 | -15.028 | 9.965 | 9.945 | 25.444 | 5.8056 | 6.0006 |
| 50.904 | 64.600 | 68.500 | 67.300 | 63.200 | 65.000 | 60.400 | 15.202 | -15.028 | 9.966 | 9.945 | 25.444 | 5.8682 | 6.0004 |
| 51.004 | 64.700 | 68.500 | 67.400 | 63.300 | 65.000 | 60.400 | 15.202 | -15.028 | 9.966 | 9.945 | 25.444 | 5.8145 | 6.0003 |
| 51.104 | 64.600 | 68.600 | 67.300 | 63.300 | 65.200 | 60.400 | 15.202 | -15.028 | 9.966 | 9.946 | 25.444 | 5.7827 | 6.0005 |
| 51.204 | 64.700 | 68.600 | 67.400 | 63.300 | 65.200 | 60.500 | 15.202 | -15.028 | 9.966 | 9.946 | 25.443 | 5.9304 | 6.0004 |
| 51.304 | 64.700 | 68.700 | 67.400 | 63.400 | 65.200 | 60.500 | 15.202 | -15.028 | 9.966 | 9.946 | 25.443 | 5.9463 | 6.0004 |
| 51.404 | 64.700 | 68.600 | 67.500 | 63.500 | 65.200 | 60.500 | 15.203 | -15.027 | 9.966 | 9.946 | 25.445 | 5.9475 | 6.0005 |
| 51.504 | 64.700 | 68.700 | 67.400 | 63.300 | 65.200 | 60.500 | 15.204 | -15.028 | 9.966 | 9.946 | 25.445 | 5.9518 | 6.0003 |
| 51.604 | 64.700 | 68.600 | 67.400 | 63.400 | 65.100 | 60.500 | 15.202 | -15.026 | 9.966 | 9.946 | 25.444 | 5.8025 | 6.0004 |
| 51.704 | 64.800 | 68.700 | 67.500 | 63.300 | 65.200 | 60.500 | 15.202 | -15.027 | 9.966 | 9.946 | 25.446 | 5.8109 | 6.0005 |
| 51.804 | 64.800 | 68.700 | 67.600 | 63.500 | 65.300 | 60.500 | 15.202 | -15.027 | 9.966 | 9.946 | 25.445 | 5.8279 | 6.0004 |
| 51.904 | 64.800 | 68.700 | 67.500 | 63.400 | 65.200 | 60.500 | 15.202 | -15.026 | 9.966 | 9.946 | 25.445 | 5.8347 | 6.0005 |
| 52.004 | 64.700 | 68.700 | 67.400 | 63.400 | 65.200 | 60.500 | 15.202 | -15.026 | 9.966 | 9.946 | 25.445 | 5.8286 | 6.0003 |
| 52.104 | 64.700 | 68.700 | 67.500 | 63.400 | 65.100 | 60.500 | 15.202 | -15.027 | 9.966 | 9.946 | 25.445 | 5.8983 | 6.0003 |
| 52.204 | 64.800 | 68.800 | 67.400 | 63.300 | 65.200 | 60.500 | 15.202 | -15.027 | 9.966 | 9.946 | 25.444 | 5.8311 | 6.0004 |
| 52.304 | 64.800 | 68.700 | 67.500 | 63.400 | 65.200 | 60.500 | 15.202 | -15.027 | 9.966 | 9.946 | 25.445 | 5.8010 | 6.0004 |
| 52.404 | 64.800 | 68.700 | 67.400 | 63.400 | 65.200 | 60.500 | 15.203 | -15.027 | 9.967 | 9.946 | 25.445 | 5.9233 | 6.0003 |
| 52.504 | 64.800 | 68.700 | 67.500 | 63.400 | 65.200 | 60.600 | 15.202 | -15.027 | 9.967 | 9.946 | 25.445 | 5.8712 | 6.0003 |
| 52.604 | 64.800 | 68.700 | 67.500 | 63.500 | 65.200 | 60.500 | 15.202 | -15.026 | 9.967 | 9.947 | 25.445 | 5.8629 | 6.0003 |
| 52.704 | 64.800 | 68.700 | 67.500 | 63.400 | 65.200 | 60.500 | 15.202 | -15.026 | 9.967 | 9.947 | 25.445 | 5.8853 | 6.0005 |
| 52.804 | 64.800 | 68.800 | 67.500 | 63.400 | 65.200 | 60.500 | 15.202 | -15.026 | 9.967 | 9.947 | 25.445 | 5.8982 | 6.0004 |
| 52.904 | 64.800 | 68.700 | 67.500 | 63.400 | 65.300 | 60.600 | 15.202 | -15.026 | 9.967 | 9.947 | 25.445 | 5.7921 | 6.0004 |
| 53.004 | 64.800 | 68.700 | 67.500 | 63.400 | 65.300 | 60.500 | 15.202 | -15.025 | 9.967 | 9.947 | 25.444 | 5.9034 | 6.0005 |
| 53.104 | 64.800 | 68.700 | 67.400 | 63.400 | 65.100 | 60.400 | 15.202 | -15.026 | 9.967 | 9.947 | 25.445 | 5.9374 | 6.0004 |
| 53.204 | 64.800 | 68.700 | 67.500 | 63.400 | 65.200 | 60.500 | 15.202 | -15.026 | 9.967 | 9.947 | 25.445 | 5.8444 | 6.0004 |
| 53.304 | 64.800 | 68.700 | 67.400 | 63.400 | 65.200 | 60.600 | 15.202 | -15.026 | 9.967 | 9.947 | 25.446 | 5.8893 | 6.0003 |
| 53.404 | 64.800 | 68.700 | 67.500 | 63.400 | 65.200 | 60.600 | 15.202 | -15.027 | 9.967 | 9.947 | 25.445 | 5.8949 | 6.0005 |
| 53.504 | 64.800 | 68.700 | 67.400 | 63.400 | 65.100 | 60.500 | 15.202 | -15.027 | 9.967 | 9.947 | 25.445 | 5.9298 | 6.0003 |
| 53.604 | 64.800 | 68.600 | 67.500 | 63.400 | 65.200 | 60.500 | 15.202 | -15.028 | 9.967 | 9.947 | 25.445 | 5.8015 | 6.0006 |
| 53.704 | 64.800 | 68.800 | 67.600 | 63.400 | 65.300 | 60.500 | 15.202 | -15.027 | 9.967 | 9.947 | 25.445 | 5.9405 | 6.0005 |
| 53.804 | 64.800 | 68.700 | 67.500 | 63.500 | 65.300 | 60.600 | 15.201 | -15.028 | 9.967 | 9.947 | 25.445 | 5.8239 | 6.0005 |
| 53.904 | 64.800 | 68.700 | 67.500 | 63.400 | 65.200 | 60.500 | 15.202 | -15.027 | 9.967 | 9.947 | 25.445 | 5.8035 | 6.0004 |
| 54.004 | 64.800 | 68.700 | 67.500 | 63.500 | 65.300 | 60.500 | 15.201 | -15.029 | 9.967 | 9.947 | 25.445 | 5.9452 | 6.0007 |
| 54.104 | 64.800 | 68.700 | 67.500 | 63.400 | 65.200 | 60.500 | 15.202 | -15.028 | 9.967 | 9.947 | 25.445 | 5.9224 | 6.0004 |
| 54.204 | 64.800 | 68.700 | 67.500 | 63.500 | 65.300 | 60.500 | 15.202 | -15.027 | 9.967 | 9.948 | 25.445 | 5.8740 | 6.0004 |
| 54.304 | 64.900 | 68.700 | 67.600 | 63.400 | 65.300 | 60.500 | 15.202 | -15.027 | 9.967 | 9.947 | 25.445 | 5.7883 | 6.0004 |
| 54.404 | 64.900 | 68.700 | 67.500 | 63.400 | 65.100 | 60.500 | 15.202 | -15.027 | 9.967 | 9.948 | 25.444 | 5.7818 | 6.0005 |
| 54.504 | 64.900 | 68.700 | 67.500 | 63.400 | 65.200 | 60.600 | 15.201 | -15.029 | 9.967 | 9.948 | 25.445 | 5.8923 | 6.0005 |
| 54.604 | 64.800 | 68.600 | 67.500 | 63.400 | 65.100 | 60.500 | 15.202 | -15.027 | 9.967 | 9.948 | 25.444 | 5.7909 | 6.0006 |
| 54.704 | 64.800 | 68.700 | 67.500 | 63.400 | 65.200 | 60.600 | 15.202 | -15.026 | 9.967 | 9.948 | 25.444 | 5.9409 | 6.0006 |
| 54.804 | 64.800 | 68.700 | 67.500 | 63.500 | 65.200 | 60.600 | 15.202 | -15.027 | 9.967 | 9.948 | 25.446 | 5.8093 | 6.0005 |
| 54.904 | 64.800 | 68.600 | 67.400 | 63.300 | 65.100 | 60.500 | 15.202 | -15.027 | 9.967 | 9.948 | 25.446 | 5.7857 | 6.0001 |
| 55.004 | 64.800 | 68.700 | 67.500 | 63.500 | 65.200 | 60.600 | 15.201 | -15.028 | 9.967 | 9.948 | 25.445 | 5.7849 | 6.0004 |
| 55.104 | 64.700 | 68.700 | 67.500 | 63.400 | 65.200 | 60.600 | 15.202 | -15.027 | 9.967 | 9.948 | 25.445 | 5.7788 | 6.0006 |

## Table F-1
## Data Recorded During Interface Board Temperature Test

| Time (HOURS) | Neg. V. Reg. Case Temp. U13 (°C) | Pos. V. Reg. Case Temp. U12 (°C) | Switching Reg. Case Temp. U11 (°C) | DET 4 Line Driver Case Temp U8 (°C) | TEMP 1 Line Driver Case Temp U4 (°C) | Chamber Temp. (°C) | Positive Voltage Regulator Output (V) | Negative Voltage Regulator Output (V) | TEMP1 Vouttage Output -100°C = -10 +100°C =+10 (V) | TEMP2 Voltage Output -100°C = -10 +100°C= +10 (V) | Nominal 24 V Input Voltage to Board (V) | Raw TEMP 2 Voltage Input -100°C = 4 0°C = 5 +100°C = 6 (V) | RAW TEMP 1 Voltage Input -100°C = 4 0°C = 5 +100°C = 6 (V) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 55.204 | 64.800 | 68.600 | 67.500 | 63.400 | 65.200 | 60.500 | 15.202 | -15.027 | 9.967 | 9.948 | 25.445 | 5.7843 | 6.0006 |
| 55.304 | 64.800 | 68.700 | 67.500 | 63.300 | 65.200 | 60.500 | 15.202 | -15.027 | 9.967 | 9.948 | 25.445 | 5.9035 | 6.0004 |
| 55.404 | 64.800 | 68.700 | 67.500 | 63.500 | 65.200 | 60.600 | 15.202 | -15.026 | 9.967 | 9.948 | 25.445 | 5.9282 | 6.0004 |
| 55.504 | 64.800 | 68.700 | 67.500 | 63.400 | 65.100 | 60.500 | 15.202 | -15.027 | 9.967 | 9.948 | 25.444 | 5.9541 | 6.0004 |
| 55.604 | 64.800 | 68.700 | 67.500 | 63.300 | 65.200 | 60.500 | 15.202 | -15.026 | 9.967 | 9.948 | 25.445 | 5.8172 | 6.0004 |
| 55.704 | 64.800 | 68.700 | 67.500 | 63.400 | 65.200 | 60.600 | 15.202 | -15.026 | 9.967 | 9.948 | 25.444 | 5.9456 | 6.0006 |
| 55.804 | 64.800 | 68.700 | 67.500 | 63.300 | 65.200 | 60.500 | 15.202 | -15.027 | 9.967 | 9.948 | 25.444 | 5.8053 | 6.0004 |
| 55.904 | 64.800 | 68.700 | 67.500 | 63.400 | 65.100 | 60.500 | 15.202 | -15.026 | 9.967 | 9.948 | 25.444 | 5.8105 | 6.0004 |
| 56.004 | 64.800 | 68.600 | 67.400 | 63.400 | 65.100 | 60.500 | 15.202 | -15.026 | 9.967 | 9.948 | 25.444 | 5.9251 | 6.0006 |
| 56.104 | 64.800 | 68.700 | 67.600 | 63.400 | 65.200 | 60.500 | 15.202 | -15.026 | 9.968 | 9.948 | 25.443 | 5.9337 | 6.0004 |
| 56.204 | 64.800 | 68.700 | 67.400 | 63.400 | 65.200 | 60.500 | 15.202 | -15.027 | 9.967 | 9.948 | 25.443 | 5.8051 | 6.0004 |
| 56.304 | 64.900 | 68.700 | 67.600 | 63.500 | 65.200 | 60.600 | 15.202 | -15.027 | 9.968 | 9.948 | 25.443 | 5.8727 | 6.0004 |
| 56.404 | 64.800 | 68.700 | 67.400 | 63.300 | 65.200 | 60.500 | 15.202 | -15.026 | 9.968 | 9.949 | 25.444 | 5.8096 | 6.0004 |
| 56.504 | 64.800 | 68.700 | 67.500 | 63.400 | 65.200 | 60.500 | 15.202 | -15.026 | 9.968 | 9.948 | 25.444 | 5.8887 | 6.0005 |
| 56.604 | 64.700 | 68.700 | 67.400 | 63.400 | 65.200 | 60.500 | 15.202 | -15.026 | 9.968 | 9.949 | 25.444 | 5.7866 | 6.0004 |
| 56.704 | 64.800 | 68.700 | 67.400 | 63.400 | 65.200 | 60.600 | 15.202 | -15.027 | 9.968 | 9.949 | 25.444 | 5.7890 | 6.0005 |
| 56.804 | 64.800 | 68.700 | 67.500 | 63.400 | 65.300 | 60.600 | 15.202 | -15.027 | 9.968 | 9.949 | 25.446 | 5.8551 | 6.0004 |
| 56.904 | 64.800 | 68.700 | 67.500 | 63.400 | 65.200 | 60.500 | 15.202 | -15.027 | 9.968 | 9.949 | 25.444 | 5.8583 | 6.0004 |
| 57.004 | 64.800 | 68.700 | 67.400 | 63.400 | 65.200 | 60.500 | 15.202 | -15.027 | 9.968 | 9.949 | 25.444 | 5.9398 | 6.0004 |
| 57.104 | 64.700 | 68.600 | 67.400 | 63.300 | 65.100 | 60.500 | 15.201 | -15.027 | 9.968 | 9.949 | 25.444 | 5.8644 | 6.0003 |
| 57.204 | 64.700 | 68.700 | 67.500 | 63.400 | 65.300 | 60.500 | 15.204 | -15.026 | 9.968 | 9.949 | 25.443 | 5.9318 | 6.0004 |
| 57.304 | 64.800 | 68.700 | 67.400 | 63.300 | 65.200 | 60.500 | 15.202 | -15.026 | 9.968 | 9.949 | 25.444 | 5.8173 | 6.0004 |
| 57.404 | 64.700 | 68.700 | 67.500 | 63.400 | 65.200 | 60.500 | 15.203 | -15.026 | 9.968 | 9.949 | 25.444 | 5.7913 | 6.0004 |
| 57.504 | 64.700 | 68.700 | 67.400 | 63.400 | 65.200 | 60.600 | 15.202 | -15.026 | 9.968 | 9.949 | 25.444 | 5.7842 | 6.0005 |
| 57.604 | 64.800 | 68.700 | 67.500 | 63.500 | 65.200 | 60.600 | 15.202 | -15.026 | 9.968 | 9.949 | 25.444 | 5.7998 | 6.0006 |
| 57.704 | 64.800 | 68.700 | 67.500 | 63.400 | 65.200 | 60.500 | 15.202 | -15.026 | 9.968 | 9.949 | 25.444 | 5.9376 | 6.0005 |
| 57.804 | 64.800 | 68.700 | 67.500 | 63.400 | 65.200 | 60.500 | 15.200 | -15.028 | 9.968 | 9.949 | 25.444 | 5.9032 | 6.0004 |
| 57.904 | 64.800 | 68.700 | 67.500 | 63.500 | 65.200 | 60.600 | 15.201 | -15.027 | 9.968 | 9.949 | 25.444 | 5.8734 | 6.0004 |
| 58.004 | 64.800 | 68.700 | 67.400 | 63.400 | 65.100 | 60.500 | 15.202 | -15.027 | 9.968 | 9.949 | 25.444 | 5.9494 | 6.0006 |
| 58.104 | 64.800 | 68.600 | 67.500 | 63.400 | 65.200 | 60.500 | 15.202 | -15.027 | 9.968 | 9.949 | 25.444 | 5.9547 | 6.0005 |
| 58.204 | 64.800 | 68.700 | 67.500 | 63.400 | 65.200 | 60.500 | 15.202 | -15.026 | 9.968 | 9.949 | 25.446 | 5.9528 | 6.0006 |
| 58.304 | 64.900 | 68.700 | 67.500 | 63.400 | 65.200 | 60.600 | 15.202 | -15.026 | 9.968 | 9.949 | 25.443 | 5.7997 | 6.0004 |
| 58.404 | 64.800 | 68.700 | 67.500 | 63.500 | 65.300 | 60.600 | 15.202 | -15.025 | 9.968 | 9.949 | 25.443 | 5.8262 | 6.0004 |
| 58.504 | 64.700 | 68.700 | 67.400 | 63.400 | 65.100 | 60.500 | 15.202 | -15.026 | 9.968 | 9.949 | 25.443 | 5.8551 | 6.0004 |
| 58.604 | 64.800 | 68.700 | 67.500 | 63.400 | 65.200 | 60.500 | 15.204 | -15.026 | 9.968 | 9.949 | 25.442 | 5.8446 | 6.0004 |
| 58.704 | 64.800 | 68.600 | 67.500 | 63.300 | 65.200 | 60.400 | 15.202 | -15.026 | 9.968 | 9.949 | 25.444 | 5.7814 | 6.0004 |
| 58.804 | 64.800 | 68.600 | 67.500 | 63.300 | 65.100 | 60.500 | 15.204 | -15.026 | 9.968 | 9.950 | 25.442 | 5.8250 | 6.0004 |
| 58.904 | 64.800 | 68.600 | 67.500 | 63.400 | 65.200 | 60.500 | 15.202 | -15.026 | 9.968 | 9.949 | 25.442 | 5.8130 | 6.0004 |
| 59.004 | 64.800 | 68.700 | 67.400 | 63.300 | 65.200 | 60.500 | 15.203 | -15.026 | 9.968 | 9.949 | 25.444 | 5.9457 | 6.0004 |
| 59.104 | 64.700 | 68.600 | 67.500 | 63.400 | 65.200 | 60.500 | 15.201 | -15.028 | 9.968 | 9.949 | 25.444 | 5.8306 | 6.0004 |
| 59.204 | 64.800 | 68.700 | 67.400 | 63.400 | 65.100 | 60.600 | 15.203 | -15.027 | 9.968 | 9.949 | 25.444 | 5.8514 | 6.0004 |
| 59.304 | 64.800 | 68.700 | 67.400 | 63.400 | 65.200 | 60.500 | 15.202 | -15.027 | 9.968 | 9.949 | 25.444 | 5.8752 | 6.0004 |
| 59.404 | 64.800 | 68.700 | 67.500 | 63.400 | 65.300 | 60.500 | 15.202 | -15.027 | 9.968 | 9.949 | 25.445 | 5.7838 | 6.0004 |
| 59.504 | 64.800 | 68.700 | 67.500 | 63.400 | 65.200 | 60.500 | 15.202 | -15.027 | 9.968 | 9.949 | 25.444 | 5.8272 | 6.0004 |

## Table F-1
## Data Recorded During Interface Board Temperature Test

| Time (HOURS) | Neg. V. Reg. Case Temp. U13 (°C) | Pos. V. Reg. Case Temp. U12 (°C) | Switching Reg. Case Temp. U11 (°C) | DET 4 Line Driver Case Temp U8 (°C) | TEMP 1 Line Driver Case Temp U4 (°C) | Chamber Temp. (°C) | Positive Voltage Regulator Output (V) | Negative Voltage Regulator Output (V) | TEMP1 Vouttage Output -100°C = -10 +100°C =+10 (V) | TEMP2 Voltage Output -100°C = -10 +100°C= +10 (V) | Nominal 24 V Input Voltage to Board (V) | Raw TEMP 2 Voltage Input -100°C = 4 0°C = 5 +100°C = 6 (V) | RAW TEMP 1 Voltage Input -100°C = 4 0°C = 5 +100°C = 6 (V) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 59.604 | 64.800 | 68.700 | 67.500 | 63.400 | 65.200 | 60.500 | 15.202 | -15.027 | 9.968 | 9.949 | 25.443 | 5.8593 | 6.0005 |
| 59.704 | 64.900 | 68.700 | 67.600 | 63.500 | 65.300 | 60.500 | 15.204 | -15.027 | 9.968 | 9.950 | 25.443 | 5.7998 | 6.0004 |
| 59.804 | 64.700 | 68.700 | 67.500 | 63.500 | 65.200 | 60.600 | 15.202 | -15.027 | 9.968 | 9.949 | 25.443 | 5.8772 | 6.0005 |
| 59.904 | 64.800 | 68.700 | 67.500 | 63.400 | 65.300 | 60.600 | 15.203 | -15.026 | 9.968 | 9.950 | 25.444 | 5.7991 | 6.0003 |
| 60.004 | 64.800 | 68.700 | 67.600 | 63.400 | 65.300 | 60.500 | 15.202 | -15.026 | 9.968 | 9.950 | 25.444 | 5.8904 | 6.0004 |
| 60.104 | 64.800 | 68.700 | 67.500 | 63.400 | 65.200 | 60.500 | 15.202 | -15.027 | 9.968 | 9.950 | 25.443 | 5.8476 | 6.0006 |
| 60.204 | 64.800 | 68.700 | 67.500 | 63.400 | 65.200 | 60.500 | 15.202 | -15.025 | 9.968 | 9.950 | 25.443 | 5.7844 | 6.0003 |
| 60.304 | 64.800 | 68.600 | 67.500 | 63.400 | 65.200 | 60.500 | 15.202 | -15.026 | 9.968 | 9.950 | 25.444 | 5.8043 | 6.0004 |
| 60.404 | 64.800 | 68.700 | 67.500 | 63.400 | 65.200 | 60.400 | 15.202 | -15.026 | 9.968 | 9.950 | 25.444 | 5.9292 | 6.0005 |
| 60.504 | 64.800 | 68.700 | 67.600 | 63.500 | 65.300 | 60.600 | 15.201 | -15.027 | 9.968 | 9.950 | 25.444 | 5.8514 | 6.0004 |
| 60.604 | 64.800 | 68.700 | 67.500 | 63.400 | 65.200 | 60.500 | 15.202 | -15.026 | 9.968 | 9.950 | 25.444 | 5.7990 | 6.0005 |
| 60.704 | 64.800 | 68.700 | 67.400 | 63.400 | 65.300 | 60.600 | 15.202 | -15.025 | 9.968 | 9.950 | 25.443 | 5.7890 | 6.0004 |
| 60.804 | 64.800 | 68.700 | 67.500 | 63.400 | 65.300 | 60.500 | 15.202 | -15.026 | 9.968 | 9.950 | 25.445 | 5.9278 | 6.0004 |
| 60.904 | 64.800 | 68.700 | 67.500 | 63.300 | 65.200 | 60.500 | 15.202 | -15.026 | 9.968 | 9.950 | 25.444 | 5.8767 | 6.0005 |
| 61.004 | 64.800 | 68.600 | 67.400 | 63.400 | 65.200 | 60.500 | 15.202 | -15.026 | 9.968 | 9.950 | 25.443 | 5.7831 | 6.0004 |
| 61.104 | 64.800 | 68.600 | 67.400 | 63.400 | 65.100 | 60.500 | 15.202 | -15.027 | 9.968 | 9.950 | 25.443 | 5.9180 | 6.0004 |
| 61.204 | 64.700 | 68.600 | 67.400 | 63.300 | 65.200 | 60.500 | 15.202 | -15.027 | 9.968 | 9.950 | 25.443 | 5.8900 | 6.0004 |
| 61.304 | 64.800 | 68.700 | 67.400 | 63.300 | 65.100 | 60.500 | 15.202 | -15.026 | 9.968 | 9.950 | 25.444 | 5.8045 | 6.0005 |
| 61.404 | 64.800 | 68.700 | 67.400 | 63.400 | 65.100 | 60.500 | 15.202 | -15.028 | 9.968 | 9.950 | 25.443 | 5.7842 | 6.0005 |
| 61.504 | 64.800 | 68.600 | 67.500 | 63.400 | 65.100 | 60.400 | 15.202 | -15.028 | 9.968 | 9.950 | 25.444 | 5.8897 | 6.0004 |
| 61.604 | 64.800 | 68.700 | 67.400 | 63.400 | 65.200 | 60.600 | 15.202 | -15.027 | 9.968 | 9.950 | 25.443 | 5.7942 | 6.0004 |
| 61.704 | 64.800 | 68.700 | 67.500 | 63.300 | 65.100 | 60.500 | 15.202 | -15.028 | 9.968 | 9.950 | 25.443 | 5.9250 | 6.0006 |
| 61.804 | 64.800 | 68.700 | 67.500 | 63.400 | 65.200 | 60.500 | 15.202 | -15.028 | 9.968 | 9.950 | 25.443 | 5.8038 | 6.0004 |
| 61.904 | 64.800 | 68.600 | 67.400 | 63.300 | 65.200 | 60.500 | 15.202 | -15.027 | 9.968 | 9.950 | 25.443 | 5.7817 | 6.0004 |
| 62.004 | 64.800 | 68.700 | 67.500 | 63.300 | 65.200 | 60.500 | 15.201 | -15.029 | 9.968 | 9.950 | 25.443 | 5.8240 | 6.0005 |
| 62.104 | 64.800 | 68.600 | 67.400 | 63.300 | 65.100 | 60.500 | 15.201 | -15.028 | 9.968 | 9.950 | 25.442 | 5.8231 | 6.0004 |
| 62.204 | 64.800 | 68.700 | 67.500 | 63.400 | 65.200 | 60.500 | 15.203 | -15.027 | 9.968 | 9.950 | 25.443 | 5.8640 | 6.0003 |
| 62.304 | 64.800 | 68.600 | 67.400 | 63.300 | 65.200 | 60.500 | 15.202 | -15.028 | 9.968 | 9.950 | 25.442 | 5.7794 | 6.0004 |
| 62.404 | 64.800 | 68.600 | 67.400 | 63.300 | 65.100 | 60.400 | 15.202 | -15.028 | 9.968 | 9.950 | 25.443 | 5.8734 | 6.0004 |
| 62.504 | 64.700 | 68.600 | 67.400 | 63.400 | 65.200 | 60.500 | 15.201 | -15.029 | 9.968 | 9.950 | 25.443 | 5.9364 | 6.0005 |
| 62.604 | 64.800 | 68.700 | 67.500 | 63.400 | 65.300 | 60.500 | 15.204 | -15.028 | 9.968 | 9.950 | 25.442 | 5.8156 | 6.0004 |
| 62.704 | 64.700 | 68.600 | 67.400 | 63.300 | 65.100 | 60.600 | 15.201 | -15.029 | 9.968 | 9.950 | 25.443 | 5.7957 | 6.0004 |
| 62.804 | 64.700 | 68.700 | 67.400 | 63.400 | 65.200 | 60.600 | 15.203 | -15.028 | 9.968 | 9.950 | 25.442 | 5.8472 | 6.0004 |
| 62.904 | 64.700 | 68.700 | 67.400 | 63.300 | 65.200 | 60.500 | 15.202 | -15.027 | 9.968 | 9.950 | 25.443 | 5.9081 | 6.0004 |
| 63.004 | 64.800 | 68.700 | 67.500 | 63.400 | 65.300 | 60.500 | 15.203 | -15.027 | 9.968 | 9.950 | 25.443 | 5.9331 | 6.0005 |
| 63.104 | 64.800 | 68.600 | 67.500 | 63.400 | 65.100 | 60.500 | 15.202 | -15.026 | 9.968 | 9.950 | 25.442 | 5.9332 | 6.0004 |
| 63.204 | 64.800 | 68.800 | 67.600 | 63.500 | 65.300 | 60.600 | 15.203 | -15.027 | 9.968 | 9.950 | 25.443 | 5.9433 | 6.0005 |
| 63.304 | 64.800 | 68.700 | 67.400 | 63.400 | 65.200 | 60.500 | 15.202 | -15.027 | 9.968 | 9.950 | 25.442 | 5.8322 | 6.0004 |
| 63.404 | 64.800 | 68.700 | 67.500 | 63.400 | 65.100 | 60.500 | 15.202 | -15.027 | 9.968 | 9.950 | 25.442 | 5.9054 | 6.0004 |
| 63.504 | 64.800 | 68.700 | 67.500 | 63.400 | 65.100 | 60.600 | 15.201 | -15.028 | 9.968 | 9.950 | 25.442 | 5.8532 | 6.0004 |
| 63.604 | 64.800 | 68.700 | 67.500 | 63.400 | 65.200 | 60.600 | 15.203 | -15.027 | 9.968 | 9.951 | 25.442 | 5.8623 | 6.0005 |
| 63.704 | 64.800 | 68.600 | 67.500 | 63.300 | 65.200 | 60.400 | 15.202 | -15.027 | 9.968 | 9.951 | 25.442 | 5.8041 | 6.0004 |
| 63.804 | 64.700 | 68.600 | 67.400 | 63.400 | 65.200 | 60.500 | 15.202 | -15.028 | 9.968 | 9.950 | 25.442 | 5.8942 | 6.0005 |
| 63.904 | 64.700 | 68.700 | 67.500 | 63.400 | 65.200 | 60.500 | 15.202 | -15.028 | 9.968 | 9.951 | 25.442 | 5.8022 | 6.0004 |

## Table F-1
## Data Recorded During Interface Board Temperature Test

| Time (HOURS) | Neg. V. Reg. Case Temp. U13 (°C) | Pos. V. Reg. Case Temp. U12 (°C) | Switching Reg, Case Temp. U11 (°C) | DET 4 Line Driver Case Temp U8 (°C) | TEMP 1 Line Driver Case Temp U4 (°C) | Chamber Temp. (°C) | Positive Voltage Regulator Output (V) | Negative Voltage Regulator Output (V) | TEMP1 Vouttage Output -100°C = -10 +100°C =+10 (V) | TEMP2 Voltage Output -100°C = -10 +100°C= +10 (V) | Nominal 24 V Input Voltage to Board (V) | Raw TEMP 2 Voltage Input -100°C = 4 0°C = 5 +100°C = 6 (V) | RAW TEMP 1 Voltage Input -100°C = 4 0°C = 5 +100°C = 6 (V) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 64.004 | 64.800 | 68.600 | 67.500 | 63.300 | 65.200 | 60.400 | 15.201 | -15.029 | 9.968 | 9.950 | 25.442 | 5.9036 | 6.0004 |
| 64.104 | 64.800 | 68.700 | 67.500 | 63.500 | 65.300 | 60.500 | 15.202 | -15.028 | 9.968 | 9.951 | 25.442 | 5.9462 | 6.0003 |
| 64.204 | 64.700 | 68.600 | 67.400 | 63.300 | 65.100 | 60.500 | 15.202 | -15.028 | 9.968 | 9.951 | 25.442 | 5.8008 | 6.0005 |
| 64.304 | 64.800 | 68.700 | 67.500 | 63.400 | 65.100 | 60.500 | 15.202 | -15.028 | 9.968 | 9.951 | 25.442 | 5.7831 | 6.0004 |
| 64.404 | 64.800 | 68.700 | 67.400 | 63.300 | 65.200 | 60.500 | 15.201 | -15.029 | 9.968 | 9.951 | 25.442 | 5.9224 | 6.0005 |
| 64.504 | 64.700 | 68.700 | 67.400 | 63.400 | 65.200 | 60.600 | 15.201 | -15.029 | 9.968 | 9.950 | 25.442 | 5.8009 | 6.0004 |
| 64.604 | 64.700 | 68.700 | 67.500 | 63.400 | 65.200 | 60.500 | 15.202 | -15.028 | 9.968 | 9.951 | 25.442 | 5.8959 | 6.0003 |
| 64.704 | 64.800 | 68.700 | 67.500 | 63.400 | 65.200 | 60.500 | 15.202 | -15.028 | 9.968 | 9.951 | 25.443 | 5.8011 | 6.0005 |
| 64.804 | 64.800 | 68.700 | 67.500 | 63.400 | 65.200 | 60.400 | 15.202 | -15.027 | 9.968 | 9.951 | 25.442 | 5.9307 | 6.0003 |
| 64.904 | 64.800 | 68.700 | 67.500 | 63.400 | 65.200 | 60.500 | 15.201 | -15.028 | 9.968 | 9.951 | 25.443 | 5.9305 | 6.0004 |
| 65.004 | 64.900 | 68.700 | 67.600 | 63.500 | 65.200 | 60.600 | 15.202 | -15.028 | 9.968 | 9.951 | 25.443 | 5.9352 | 6.0005 |
| 65.104 | 64.700 | 68.700 | 67.500 | 63.500 | 65.300 | 60.600 | 15.202 | -15.028 | 9.968 | 9.951 | 25.443 | 5.8473 | 6.0004 |
| 65.204 | 64.800 | 68.700 | 67.500 | 63.500 | 65.200 | 60.600 | 15.202 | -15.028 | 9.968 | 9.951 | 25.441 | 5.8498 | 6.0004 |
| 65.304 | 64.800 | 68.700 | 67.500 | 63.400 | 65.200 | 60.600 | 15.202 | -15.028 | 9.968 | 9.951 | 25.443 | 5.9469 | 6.0004 |
| 65.404 | 64.800 | 68.700 | 67.500 | 63.400 | 65.300 | 60.500 | 15.202 | -15.029 | 9.968 | 9.951 | 25.443 | 5.8811 | 6.0003 |
| 65.504 | 64.800 | 68.700 | 67.500 | 63.400 | 65.200 | 60.500 | 15.202 | -15.028 | 9.968 | 9.951 | 25.443 | 5.8977 | 6.0005 |
| 65.604 | 64.800 | 68.700 | 67.400 | 63.300 | 65.100 | 60.500 | 15.202 | -15.029 | 9.968 | 9.951 | 25.442 | 5.8472 | 6.0005 |
| 65.704 | 64.700 | 68.600 | 67.500 | 63.400 | 65.200 | 60.500 | 15.203 | -15.029 | 9.968 | 9.951 | 25.443 | 5.9399 | 6 |
| 65.804 | 64.800 | 68.700 | 67.500 | 63.400 | 65.200 | 60.500 | 15.201 | -15.029 | 9.968 | 9.951 | 25.444 | 5.9158 | 6.0005 |
| 65.904 | 64.800 | 68.700 | 67.500 | 63.400 | 65.100 | 60.600 | 15.202 | -15.028 | 9.968 | 9.951 | 25.443 | 5.8326 | 6.0004 |
| 66.004 | 64.700 | 68.700 | 67.500 | 63.400 | 65.200 | 60.500 | 15.202 | -15.028 | 9.968 | 9.951 | 25.444 | 5.9126 | 6.0004 |
| 66.104 | 64.800 | 68.700 | 67.500 | 63.500 | 65.200 | 60.500 | 15.202 | -15.028 | 9.968 | 9.951 | 25.443 | 5.8642 | 6.0002 |
| 66.204 | 64.000 | 67.800 | 66.500 | 62.400 | 64.200 | 59.500 | 15.203 | -15.027 | 9.968 | 9.951 | 25.443 | 5.9447 | 6.0004 |
| 66.304 | 64.000 | 67.800 | 66.600 | 62.600 | 64.300 | 59.700 | 15.203 | -15.026 | 9.968 | 9.952 | 25.442 | 5.7959 | 6.0004 |
| 66.404 | 64.100 | 67.900 | 66.800 | 62.600 | 64.500 | 59.700 | 15.202 | -15.028 | 9.968 | 9.951 | 25.444 | 5.7995 | 6.0004 |
| 66.504 | 64.200 | 68.000 | 66.900 | 62.800 | 64.600 | 59.800 | 15.203 | -15.027 | 9.968 | 9.952 | 25.442 | 5.8072 | 6.0005 |
| 66.604 | 64.200 | 69.500 | 66.900 | 62.900 | 64.600 | 59.900 | 15.199 | -15.029 | 9.968 | 9.951 | 27.460 | 5.9813 | 6.0005 |
| 66.704 | 64.300 | 69.800 | 67.000 | 62.900 | 64.700 | 60.000 | 15.198 | -15.029 | 9.968 | 9.951 | 27.464 | 6.0420 | 6.0004 |
| 66.804 | 64.400 | 69.900 | 67.200 | 63.000 | 64.900 | 60.100 | 15.199 | -15.028 | 9.968 | 9.951 | 27.465 | 6.0260 | 6.0004 |
| 66.904 | 64.300 | 69.900 | 67.100 | 62.900 | 64.700 | 60.100 | 15.199 | -15.029 | 9.968 | 9.951 | 27.466 | 5.8724 | 6.0005 |
| 67.004 | 64.400 | 69.900 | 67.200 | 63.100 | 64.800 | 60.100 | 15.199 | -15.029 | 9.968 | 9.951 | 27.466 | 5.9524 | 6.0005 |
| 67.104 | 64.500 | 70.000 | 67.300 | 63.200 | 65.000 | 60.300 | 15.199 | -15.030 | 9.968 | 9.951 | 27.467 | 5.8368 | 6.0005 |
| 67.204 | 64.600 | 70.200 | 67.400 | 63.300 | 65.200 | 60.500 | 15.199 | -15.029 | 9.968 | 9.951 | 27.467 | 5.9400 | 6.0004 |
| 67.304 | 64.600 | 70.200 | 67.300 | 63.100 | 65.000 | 60.400 | 15.199 | -15.029 | 9.969 | 9.951 | 27.467 | 5.8496 | 6.0005 |
| 67.404 | 64.700 | 70.200 | 67.500 | 63.300 | 65.200 | 60.400 | 15.199 | -15.029 | 9.969 | 9.951 | 27.467 | 5.9218 | 6.0004 |
| 67.504 | 64.700 | 70.300 | 67.400 | 63.300 | 65.200 | 60.600 | 15.199 | -15.029 | 9.969 | 9.951 | 27.467 | 5.8601 | 6.0005 |
| 67.604 | 64.800 | 70.300 | 67.600 | 63.400 | 65.300 | 60.400 | 15.201 | -15.030 | 9.969 | 9.951 | 27.467 | 5.8760 | 6.0003 |
| 67.702 | 64.800 | 70.400 | 67.500 | 63.400 | 65.300 | 60.600 | 15.199 | -15.029 | -0.045 | -0.051 | 27.464 | 5.6760 | 4.9998 |
| 67.723 | 64.800 | 70.500 | 67.600 | 63.400 | 65.400 | 60.600 | 15.198 | -15.029 | -10.054 | -10.056 | 27.462 | 5.4189 | 3.9995 |
| 67.823 | 64.800 | 70.400 | 67.700 | 63.400 | 65.300 | 60.600 | 15.199 | -15.029 | 9.965 | 9.953 | 27.467 | 6.1874 | 6 |
| 67.923 | 64.800 | 70.400 | 67.700 | 63.500 | 65.400 | 60.500 | 15.199 | -15.030 | 9.968 | 9.950 | 27.467 | 5.8649 | 6.0004 |
| 68.023 | 64.700 | 70.200 | 67.500 | 63.400 | 65.200 | 60.500 | 15.200 | -15.029 | 9.969 | 9.950 | 27.466 | 5.8411 | 6.0005 |
| 68.123 | 64.700 | 70.300 | 67.500 | 63.400 | 65.200 | 60.600 | 15.199 | -15.030 | 9.969 | 9.950 | 27.466 | 5.9536 | 6.0004 |
| 68.223 | 64.800 | 70.400 | 67.600 | 63.400 | 65.200 | 60.500 | 15.199 | -15.029 | 9.969 | 9.950 | 27.466 | 5.8457 | 6.0004 |

## Table F-1
## Data Recorded During Interface Board Temperature Test

| Time (HOURS) | Neg. V. Reg. Case Temp. U13 (°C) | Pos. V. Reg. Case Temp. U12 (°C) | Switching Reg, Case Temp. U11 (°C) | DET 4 Line Driver Case Temp U8 (°C) | TEMP 1 Line Driver Case Temp U4 (°C) | Chamber Temp. (°C) | Positive Voltage Regulator Output (V) | Negative Voltage Regulator Output (V) | TEMP1 Vouttage Output -100°C = -10 +100°C =+10 (V) | TEMP2 Voltage Output -100°C = -10 +100°C= +10 (V) | Nominal 24 V Input Voltage to Board (V) | Raw TEMP 2 Voltage Input -100°C = 4 0°C = 5 +100°C = 6 (V) | RAW TEMP 1 Voltage Input -100°C = 4 0°C = 5 +100°C = 6 (V) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 68.323 | 64.800 | 70.400 | 67.600 | 63.400 | 65.300 | 60.500 | 15.199 | -15.030 | 9.969 | 9.951 | 27.467 | 5.8272 | 6.0004 |
| 68.423 | 64.800 | 70.300 | 67.500 | 63.300 | 65.200 | 60.500 | 15.199 | -15.030 | 9.969 | 9.950 | 27.467 | 5.8855 | 6.0004 |
| 68.523 | 64.800 | 70.300 | 67.500 | 63.400 | 65.100 | 60.600 | 15.199 | -15.029 | 9.969 | 9.950 | 27.467 | 5.8918 | 6.0005 |
| 68.623 | 64.700 | 70.400 | 67.600 | 63.500 | 65.400 | 60.600 | 15.199 | -15.029 | 9.969 | 9.951 | 27.467 | 5.8281 | 6.0006 |
| 68.723 | 64.800 | 70.400 | 67.600 | 63.500 | 65.400 | 60.600 | 15.199 | -15.030 | 9.969 | 9.951 | 27.467 | 5.9712 | 6.0004 |
| 68.823 | 64.800 | 70.400 | 67.600 | 63.500 | 65.300 | 60.700 | 15.199 | -15.029 | 9.969 | 9.951 | 27.467 | 5.9772 | 6.0005 |
| 68.923 | 64.900 | 70.500 | 67.700 | 63.500 | 65.400 | 60.700 | 15.197 | -15.032 | 9.969 | 9.950 | 27.467 | 5.8554 | 6.0004 |
| 69.023 | 64.900 | 70.400 | 67.600 | 63.400 | 65.300 | 60.500 | 15.199 | -15.029 | 9.969 | 9.951 | 27.467 | 5.9769 | 6.0004 |
| 69.123 | 64.800 | 70.400 | 67.600 | 63.300 | 65.200 | 60.600 | 15.200 | -15.029 | 9.969 | 9.951 | 27.467 | 5.9045 | 6.0004 |
| 69.223 | 64.800 | 70.400 | 67.600 | 63.400 | 65.300 | 60.600 | 15.199 | -15.029 | 9.969 | 9.951 | 27.467 | 5.8197 | 6.0004 |
| 69.323 | 64.900 | 70.500 | 67.600 | 63.500 | 65.400 | 60.700 | 15.199 | -15.029 | 9.969 | 9.951 | 27.467 | 5.8307 | 6.0004 |
| 69.423 | 64.700 | 70.400 | 67.500 | 63.400 | 65.300 | 60.600 | 15.200 | -15.030 | 9.969 | 9.951 | 27.467 | 5.9639 | 6.0004 |
| 69.523 | 64.800 | 70.500 | 67.600 | 63.500 | 65.400 | 60.600 | 15.198 | -15.030 | 9.969 | 9.951 | 27.469 | 5.9077 | 6.0004 |
| 69.623 | 64.800 | 70.400 | 67.600 | 63.400 | 65.200 | 60.500 | 15.199 | -15.027 | 9.969 | 9.951 | 27.467 | 5.9773 | 6.0006 |
| 69.723 | 64.800 | 70.400 | 67.600 | 63.600 | 65.300 | 60.700 | 15.199 | -15.028 | 9.969 | 9.951 | 27.467 | 5.8410 | 6.0004 |
| 69.823 | 64.800 | 70.500 | 67.600 | 63.500 | 65.300 | 60.700 | 15.198 | -15.029 | 9.969 | 9.951 | 27.467 | 5.8183 | 6.0004 |
| 69.923 | 64.800 | 70.400 | 67.600 | 63.500 | 65.300 | 60.600 | 15.198 | -15.028 | 9.969 | 9.951 | 27.467 | 5.9107 | 6.0004 |
| 70.023 | 64.800 | 70.400 | 67.600 | 63.400 | 65.300 | 60.500 | 15.199 | -15.029 | 9.969 | 9.951 | 27.468 | 5.9653 | 6.0004 |
| 70.123 | 64.800 | 70.400 | 67.600 | 63.400 | 65.300 | 60.600 | 15.199 | -15.027 | 9.969 | 9.951 | 27.468 | 5.9560 | 6.0004 |
| 70.223 | 64.900 | 70.300 | 67.600 | 63.500 | 65.200 | 60.600 | 15.198 | -15.029 | 9.969 | 9.951 | 27.467 | 5.8311 | 6.0005 |
| 70.323 | 64.800 | 70.400 | 67.700 | 63.600 | 65.400 | 60.700 | 15.199 | -15.028 | 9.969 | 9.951 | 27.468 | 5.8626 | 6.0005 |
| 70.423 | 64.900 | 70.400 | 67.700 | 63.500 | 65.400 | 60.700 | 15.199 | -15.028 | 9.969 | 9.951 | 27.467 | 5.9581 | 6.0004 |
| 70.523 | 64.900 | 70.400 | 67.600 | 63.400 | 65.300 | 60.500 | 15.199 | -15.028 | 9.969 | 9.951 | 27.468 | 5.8942 | 6.0004 |
| 70.623 | 61.700 | 65.200 | 63.000 | 55.700 | 58.500 | 52.400 | 15.202 | -15.027 | 9.966 | 9.954 | 27.467 | 5.8756 | 6.0005 |
| 70.723 | 44.400 | 47.100 | 44.100 | 37.600 | 40.000 | 34.500 | 15.210 | -15.019 | 9.958 | 9.961 | 27.467 | 5.9119 | 6.0005 |
| 70.823 | 33.700 | 37.700 | 34.300 | 29.600 | 31.200 | 26.400 | 15.210 | -15.013 | 9.955 | 9.962 | 27.466 | 5.9570 | 6.0004 |
| 70.923 | 31.500 | 36.400 | 33.100 | 29.000 | 30.600 | 25.800 | 15.209 | -15.012 | 9.954 | 9.962 | 27.467 | 5.9796 | 6.0006 |
| 71.023 | 30.800 | 35.800 | 32.400 | 28.500 | 30.100 | 25.400 | 15.208 | -15.013 | 9.954 | 9.962 | 27.467 | 5.9308 | 6.0005 |
| 71.123 | 30.300 | 35.500 | 32.200 | 28.300 | 29.900 | 25.200 | 15.210 | -15.012 | 9.954 | 9.962 | 27.468 | 5.8832 | 6.0004 |
| 71.223 | 30.100 | 35.300 | 32.000 | 28.100 | 29.600 | 25.100 | 15.209 | -15.011 | 9.953 | 9.962 | 27.468 | 5.9730 | 6.0004 |
| 71.323 | 30.100 | 35.300 | 32.000 | 28.100 | 29.600 | 25.000 | 15.209 | -15.013 | 9.953 | 9.962 | 27.467 | 5.9204 | 6.0004 |
| 71.423 | 30.000 | 35.400 | 32.000 | 28.100 | 29.700 | 25.100 | 15.210 | -15.012 | 9.953 | 9.962 | 27.467 | 5.9920 | 6.0005 |

# APPENDIX G STANDARDS LABORATORY CALIBRATION RECORDS

| Measurement and Test Equipment Index | | | |
|---|---|---|---|
| Item | M&TE | Standards Code | Use |
| 1 | Tektronix 485 Oscilloscope | 013-51-01-012 | Pulse and waveform measurement |
| 2 | Data Acquisition System | 752-67-11-004 | Probe and interface board temperature Test |
| 3 | Thermocouples, Type K | 752-78-02-007 | Probe and interface board temperature test |
| 4 | Kilovoltmeter | 804-45-17-001 | Electrostatic voltmeter, measurement a of probe high voltage (almost infinite input impedance) |
| 5 | Digital Multimeter | 804-45-08-010 | Voltage and resistance measurements |
| 6 | Electronic Balance | 679-06-01-002 | Weighing moisture standard samples |

## WESTINGHOUSE STANDARDS LABORATORY PHYSICAL AND ELECTRICAL REPORT

CUSTODIAN/ADDRESS: OLIVER JW<br>L6-13

STANDARDS CODE NUMBER: 013-51-01-012

NEW

MODIFY

REFERENCE NUMBER: 397353

ORGANIZATION CODE: W8A100

WORK ORDER: E46600

INSTRUMENT: OSCILLOSCOPE<br>TEKTRONIX 485

SERIAL NUMBER: B143078

PROPERTY NUMBER: WA03466

RECALL STATUS: 1 ACTIVE 2 NONRECALL 3 SUSPENDED 4 DELETED 5 PM 6 NONDATA MATE — 1

RECALL CYCLE: 360

TOLERANCE HISTORY: IIII

ROOM: N/A

BUILDING: 306E

SERVICE DEPARTMENT: 2

DATE RECEIVED: 960212

TOLERANCE AS RECEIVED: 1 IN 2 OUT 3 NA 4 FAILED — 1

SENDER: W) CANTRELL 6-6439

COMMENTS:

SHIPPING DAY: WE

INSTRUMENT SPECIFICATIONS:

TRAINING HOURS:

CALIBRATION HOURS: 8.0

REPAIR HOURS:

OTHER HOURS: 4.0

MATERIALS:

TOTAL CHARGE = ($120 x SUM OF HOURS) + MATERIALS

STANDARD(S) USED IN CALIBRATION TRACEABLE TO NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY OR NATIONALLY RECOGNIZED STANDARDS 4:1 RATIO Y ☒ N ☐

| | EXPIRATION DATE | | EXPIRATION DATE |
|---|---|---|---|
| 002-52-01-013 | 3/9/96 | 002-52-02-016 | 11/3/96 |
| 002-52-05-007 | 9/22/96 | 002-51-01-027 | 10/3/96 |
| 002-52-02-014 | 12/7/96 | | |

REMARKS:

DATE CALIBRATED: 2/12/96

DATE DUE: 2/12/97

PROCEDURE NUMBER: WHC-TEK4-85(9-74)

AMBIENT TEMPERATURE =

REPAIRED A.C.
CORD. CLEANED SCOPE.
CHECKS w/ MFGR's
ALL SPECS.
TOUCHED ADJUSTMENTS
up FOR OPTIMUM PERFORMANCE
SCOPE FROM POOR

APPROVED BY: MJ Charney 2-14-96

CALIBRATED BY: WHC SDL 52

Hanford Operations and Engineering Contractor for the United States Department of Energy

Westinghouse Hanford Company Subsidiary of Westinghouse Electric Corporation Box 1970, Richland, WA 99352

PAGE 1 OF 4

Hanford Engineering Development Laboratory

## REPORT OF CALIBRATION

PHYSICAL & ELECTRICAL STANDARDS LABORATORY

CODE NO 013-51-01-012

DATE 2/12/96

JOB AUTHORIZATION NO

ITEM IDENTIFICATION (MANUFACTURER-MODEL-SERIAL NO.) Oscilloscope TEKTRONIX Model 485

PROPERTY NO

DUE DATE

STDS.SER.NO.

CUSTOMER LOCATION RM.NO.

SPECIFICATIONS: See Calibration Procedure and below.

APPROVED
DATE 14-16-88

Calibration Traceable to the National Bureau of Standards or Nationally Recognized Standards

EQUIPMENT USED

METHOD OF MEASUREMENT (PROCEDURE NO.) WHC-TEK-485/R485 (9-74 Rev. B)

REMARKS:

| FUNCTION | TEST | | INDICATION CH#1 | | INDICATION CH#2 | | TOLERANCES |
|---|---|---|---|---|---|---|---|
| | | | AS FOUND | FINAL | AS FOUND | FINAL | |
| 1. Bandwidth Vert. | A | B | Pass | Pass | Pass | Pass | ① @ -3 db |
| 2. Risetime Main | A | B | " | " | " | " | < ① sec |
| 3. Preamp | A | B | N/A | | N/A | | < sec |
| 4. Deflection | A&B | .001 v/div | N/A | | N/A | | ± % |
| 5. " | | .002 " | " | | " | | ± % |
| 6. " | | .005 | w/i 2% | Same | w/i 2% | Same | ± 2 % |
| 7. " | | .01 | | | | | ± " % |
| 8. " | | .02 | | | | | ± " % |
| 9. " | | .05 | | | | | ± " % |
| 10. " | | .1 | | | | | ± " % |
| 11. " | | .2 | | | | | ± " % |
| 12. " | | .5 | | | | | ± " % |
| 13. " | | 1.0 | | | | | ± " % |
| 14. " | | 2.0 | | | | | ± " % |
| 15. " | | 5.0 | | | | | ± " % |
| 16. " | | 10.0 | N/A | | N/A | | ± % |
| 17. " | | 20.0 | " | | " | | ± % |
| 18. " | | 50.0 | " | | " | | ± % |
| 19. Triggering | | | MAIN | | DLYD | | |
| Internal | .3 div | 50 MHZ | Pass | Pass | Pass | Pass | Stabile Display |
| Internal | 1.5 div | 350 MHZ | | | | | " " |
| External | 20 mv | 50 MHZ | | | | | " " |
| External | 100 mv | 350 MHZ | | | | | " " |

Both 1MOHM & 50 OHM MODE w/ MFGRS SPECS

APPROVED BY mg Channy 2-14-96

CALIBRATED BY WHC STD LAB WB

ACCEPT TAG NO. NA

CONDITIONALLY ACCEPT TAG NO. NA

NCR NO. NA

PAGE 2 OF 4

Hanford Engineering Development Laboratory

## REPORT OF CALIBRATION

PHYSICAL & ELECTRICAL STANDARDS LABORATORY
(CONTINUED)

CODE NO. 013-51-01-012
DATE 2/12/96

| FUNCTION | TEST | X1 INDICATION |  | MAG |  | TOLERANCES |
|---|---|---|---|---|---|---|
| SWEEPTIME |  | AS FOUND | FINAL | AS FOUND | FINAL |  |
| Delayed (cont.) | .05 µ sec | w/i 2% | Same | N/A |  | ± 2% Mag ± N/A |
|  | .1 " |  |  |  |  | " " |
|  | .2 " |  |  |  |  | " " |
|  | .5 " |  |  |  |  | " " |
|  | 1.0 " |  |  |  |  | " " |
|  | 2.0 " |  |  |  |  | " " |
|  | 5.0 " |  |  |  |  | " " |
|  | 10.0 " |  |  |  |  | " " |
|  | 20.0 " |  |  |  |  | " " |
|  | 50.0 " |  |  |  |  | " " |
|  | .1 msec |  |  |  |  | " " |
|  | .2 " | w/i 3% | Same | N/A |  | ± 3% " |
|  | .5 " | " | " | " |  | " " |
| Differential Dial | Diff.1.00 to 9.00 | AS FOUND | FINAL | N/A | N/A | Diff.1.00 to 9.00 |
| Accuracy | Indication | Pass | Pass |  |  | =8.00 ± .05 |
|  |  |  |  |  |  |  |
| Display | Functional | Pass | Pass |  |  |  |
| Checks |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
| Calibrator | 1 Meg/50 ohms | 50mV @ | MEG 1MHZ [illegible] |  |  |  |
| Amplitude | 5 / .5 v | 5 Volts | Same |  |  | ± .5% / ±1% |
| Frequency | 1MHZ or 1000Hz | 997 KHZ |  |  |  | ± .25% |
|  |  | 993 HZ |  |  |  |  |
| ① BANDWIDTH |  |  |  |  |  |  |
| 50 Ω: 350 MHZ | ;Rt = 1 nsec |  |  |  |  |  |
| 1 Ω: 250 MHZ | ;Rt + 1.4 nsec |  |  |  |  |  |

| APPROVED BY | CALIBRATED BY | ACCEPT TAG NO. | CONDITIONALLY ACCEPT TAG NO. | NCR NO. | PAGE |
|---|---|---|---|---|---|
| Charney 2-14-96 | STD LAB 52 | N/A | N/A | N/A | 4 of 4 |

## WESTINGHOUSE STANDARDS LABORATORY PHYSICAL AND ELECTRICAL REPORT

CUSTODIAN/ADDRESS: JORDAN SR
L6-13

STANDARDS CODE NUMBER: 752-67-11-004

NEW: ☐
MODIFY: ☐

REFERENCE NUMBER: 395852

ORGANIZATION CODE: W8A100

WORK ORDER: N4H4F

INSTRUMENT: DATA ACQUSN SYSTEM
H-P 3497A
CONTROL UNIT

SERIAL NUMBER: 2511A02694

PROPERTY NUMBER: WB96051

RECALL STATUS: 1
1 ACTIVE
2 NONRECALL
3 SUSPENDED
4 DELETED
5 PM
6 NONDATA MATE

RECALL CYCLE: 360

TOLERANCE HISTORY: IIII

ROOM: N/A

BUILDING: 305

SERVICE DEPARTMENT: 4

DATE RECEIVED: 951206

TOLERANCE AS RECEIVED: 2
1 IN
2 OUT /
3 NA
4 FAILED

SENDER: W) SQUIER 6-4346

COMMENTS:

SHIPPING DAY: WE

INSTRUMENT SPECIFICATIONS: SEE TOLERANCE COLUMN

TRAINING HOURS:

CALIBRATION HOURS: 1.5

REPAIR HOURS:

OTHER HOURS:

MATERIALS:

TOTAL CHARGE = ($120 x SUM OF HOURS) + MATERIALS

STANDARD(S) USED IN CALIBRATION TRACEABLE TO NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY OR NATIONALLY RECOGNIZED STANDARDS

4:1 RATIO Y ☑ N ☐

| | EXPIRATION DATE | | EXPIRATION DATE |
|---|---|---|---|
| 002-79-06-040 | 3-13-96 | 002-45-08-051 | 2-2-96 |
| 002-45-08-036 | 2-9-96 | - - - | |
| 002-14-01-036 | 5-2-96 | - - - | |

REMARKS: (WP-16)

DATE CALIBRATED: 12-7-95

DATE DUE: 12-7-96

PROCEDURE NUMBER: WHC-67-11-3497A(12-82)

AMBIENT TEMPERATURE = 20 C

APPROVED BY: 12-8-95 D. J. Nelson

CALIBRATED BY: WHC STD LAB 99

Hanford Operations and Engineering Contractor for the United States Department of Energy

Westinghouse Hanford Company
Subsidiary of Westinghouse Electric Corporation
Box 1970, Richland, WA 99352

PAGE 1 OF 3

| | | |
|---|---|---|
| PROCEDURE NAME - 16<br>WHC-67-11-3497A(12-82) | STANDARDS CODE NUMBER<br>752-67-11-004 | REFERENCE NUMBER<br>395852 |

DATA SHEET

| DMM RANGE AND DISPLAY | STANDARD READING | DMM READING | | ONE YEAR TOLERANCE |
|---|---|---|---|---|
| | | AS FOUND | FINAL | |
| .1V 5½ DIGIT | .100000 | ,100000 | Same | ± 18 μV |
| 1.0V | 1.00000 | 1,00005 | | ± 160 μV |
| 10.0V | 1.1111 | 1,11117 | | ± .3 mV |
| | 2.2222 | 2,2223 | | ± .4 mV |
| | 3.3333 | 3,3334 | | ± .6 mV |
| | 4.4444 | 4,4445 | | ± .8 mV |
| | 5.5555 | 5,5557 | | ± .9 mV |
| | 6.6666 | 6,6668 | | ± 1.1 mV |
| | 7.7777 | 7,7780 | | ± 1.3 mV |
| | 8.8888 | 8,8891 | | ± 1.4 mV |
| | 9.9999 | 10,0002 | | ± 1.6 mV |
| | 10.0000 | 10,0003 | | ± 1.6 mV |
| 100.0V | 50.000 | 50,003 | | ± 8.0 mV |
| | 100.000 | 100,006 | | ± 16.0 mV |
| | -100.000 | -100,006 | | ± 16.0 mV |
| | - 50.000 | -50,003 | | ± 8.0 mV |
| AUTO RANGE | 50.000 | +50,003 | | ± 8.0 mV |
| | 5.0000 | 5,0002 | | ± .8 mV |
| | .50000 | ,50003 | | ± 80 μV |
| | .050000 | ,050000 | | ± 10 μV |
| 10V 4½ DIGIT | 9.000 | 9,000 | | ± 3.0 mV |
| 10V 3½ DIGIT | 9.00 | 9,00 | | ± 20 mV |
| | | | | |
| | | | | |
| | | | | |

| | | |
|---|---|---|
| APPROVED BY 12-8-95<br>O.J. Nelson | CALIBRATED BY WHC STD LAB 39 | Page<br>2 of 3 |

| PROCEDURE NAME - 16 | STANDARDS CODE NUMBER | REFERENCE NUMBER |
|---|---|---|
| WHC-67-11-3497A(12-82) | 752-67-11-004 | 395852 |

DATA SHEET

| DMM RANGE AND DISPLAY | STANDARD READING | STANDARD INDICATION | | ONE YEAR TOLERANCE |
|---|---|---|---|---|
| | | AS FOUND | FINAL | |
| CURRENT OUT | | | | |
| 1 ma | | 1.00004 | same | ± 320 ua |
| 100 ua | | 99.997 | | ± .032 ua |
| 10ua | | 10.000 | | ± .0032 ua |
| | | | | |
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| APPROVED BY | CALIBRATED BY | Page |
|---|---|---|
| 12-8-95<br>D. J. Nelson | WHC STD LAB 10 | 3 of 3 |

# WESTINGHOUSE STANDARDS LABORATORY PHYSICAL AND ELECTRICAL REPORT

| | | | | | |
|---|---|---|---|---|---|
| CUSTODIAN/ADDRESS<br>JORDAN SR<br>L6-13 | STANDARDS CODE NUMBER<br>752-78-02-007 | | | NEW ✓<br>MODIFY | REFERENCE NUMBER<br>395855 |
| | | | | ORGANIZATION CODE<br>W8A100 | WORK ORDER<br>N4H4F |
| INSTRUMENT<br>THERMOCOUPLES<br>TYPE K<br>4 EACH | SERIAL NUMBER<br>N/A | PROPERTY NUMBER<br>N/A | RECALL STATUS<br>1 ACTIVE<br>2 NONRECALL<br>3 SUSPENDED<br>4 DELETED<br>5 PM<br>6 NONDATA M&TE<br>1 | RECALL CYCLE<br>360 | TOLERANCE HISTORY |
| | ROOM N/A / BUILDING 305 | SERVICE DEPARTMENT<br>4 | | DATE RECEIVED<br>951206 | TOLERANCE AS RECEIVED<br>1 IN<br>2 OUT<br>3 NA<br>4 FAILED<br>1 |
| SENDER<br>W) SQUIER 6-4346 | COMMENTS | | | SHIPPING DAY<br>WE | |

INSTRUMENT SPECIFICATIONS ± 2.2°C -24°C TO 66°C

STANDARD(S) USED IN CALIBRATION TRACEABLE TO NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY OR NATIONALLY RECOGNIZED STANDARDS 4:1 RATIO Y ☑ N ☐

| | EXPIRATION DATE | | EXPIRATION DATE |
|---|---|---|---|
| 002-79-06-001 | 7-28-96 | | |
| 002-14-01-038 | 1-12-96 | | |

TRAINING HOURS

CALIBRATION HOURS 2.5

REPAIR HOURS

OTHER HOURS

MATERIALS

TOTAL CHARGE = ($120 x SUM OF HOURS) + MATERIAL:

REMARKS

DATE CALIBRATED 12-7-95

DATE DUE 12-7-96

PROCEDURE NUMBER WHC-4-TC-CAL REV.3

AMBIENT TEMPERATURE =

| SERIAL NUMBER | STANDARD °C | AS FOUND °C | SERIAL NUMBER | STANDARD | AS FOUND |
|---|---|---|---|---|---|
| 790 | -23.3 | -22.3 | | | |
| 791 | " | -22.8 | | | |
| 792 | " | -23.2 | | | |
| 793 | " | -23.3 | | | |
| 790 | 21.8 | 21.7 | | | |
| 791 | " | " | | | |
| 792 | " | 21.6 | | | |
| 793 | " | 21.8 | | | |
| 790 | 66.4 | 66.6 | | | |
| 791 | " | " | | | |
| 792 | " | 66.4 | | | |
| 793 | " | 66.5 | | | |

APPROVED BY R J Nelson 12-8-95

CALIBRATED BY

Hanford Operations and Engineering Contractor for the United States Department of Energy

Westinghouse Hanford Company Subsidiary of Westinghouse Electric Corporation Box 1970, Richland, WA 99352

PAGE 1 OF 1

WESTINGHOUSE STANDARDS LABORATORY PHYSICAL AND ELECTRICAL REPORT E466OD

CUSTODIAN/ADDRESS
BUSSELL JH
L6-38

STANDARDS CODE NUMBER 804-45-17-001

NEW ☐
MODIFY ☐

REFERENCE NUMBER 395797

ORGANIZATION CODE W74770

WORK ORDER E03034

INSTRUMENT
KILOVOLTMETER
SENS. RSCH. ESD
ELECTROSTATIC

SERIAL NUMBER 922813

PROPERTY NUMBER N/A

RECALL STATUS
1 ACTIVE
2 NONRECALL
3 SUSPENDED
4 DELETED
5 PM
6 NONDATA M&TE
1

RECALL CYCLE 360

TOLERANCE HISTORY III

ROOM N/A

BUILDING 306E

SERVICE DEPARTMENT 1

DATE RECEIVED 951130

SHIPPING DAY WE

TOLERANCE AS RECEIVED
1 IN
2 OUT
3 NA
4 FAILED
1

SENDER W)J BUSSELL 6-9621

COMMENTS M.S. +/-1% F.S.

INSTRUMENT SPECIFICATIONS

TRAINING HOURS

CALIBRATION HOURS 1.0

REPAIR HOURS

OTHER HOURS

MATERIALS

TOTAL CHARGE =
($120 x SUM OF HOURS) + MATERIALS

STANDARD(S) USED IN CALIBRATION TRACEABLE TO NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY OR NATIONALLY RECOGNIZED STANDARDS 4:1 RATIO Y ☒ N ☐

| | EXPIRATION DATE | | EXPIRATION DATE |
|---|---|---|---|
| 002-79-06-039 | 031396 | | |
| 002-14-01-033 | 020696 | | |
| | | | |

REMARKS

DATE CALIBRATED 120195

DATE DUE 120196

PROCEDURE NUMBER WHC-1-AC-DC-ELECT-VM REV.1

AMBIENT TEMPERATURE = 21.6°

| ESD | STANDARD READING | | |
|---|---|---|---|
| READING | AS FOUND | FINAL | TOLERANCE |
| .3 KV | 300 V | | ± 15 V |
| .6 | 598 | | |
| .9 | 900 | | |
| 1.2 | 1198 | | |
| 1.5 | 1496 | | |

APPROVED BY D. J. Nelson 12-4-95

CALIBRATED BY Albert C. Mi

Hanford Operations and
Engineering Contractor
for the United States
Department of Energy

Westinghouse Hanford Company
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Electric Corporation
Box 1970, Richland, WA 99352

PAGE 1 OF 1

## WESTINGHOUSE STANDARDS LABORATORY PHYSICAL AND ELECTRICAL REPORT

**CUSTODIAN/ADDRESS** BUSSELL JH
L6-38

**STANDARDS CODE NUMBER** 804-45-08-010

**NEW** ✓

**MODIFY**

**REFERENCE NUMBER** 398123

**ORGANIZATION CODE** W74770

**WORK ORDER** E46600

**INSTRUMENT** DIGITAL MULTIMETER
KEITHLEY 2000
ELECTROSTATIC

**SERIAL NUMBER** 0597895

**PROPERTY NUMBER** N/A

**RECALL STATUS** 1 ACTIVE 2 NONRECALL 3 SUSPENDED 4 DELETED 5 PM 6 NONDATA M&TE: 1

**RECALL CYCLE** 360

**TOLERANCE HISTORY**

**ROOM** STVS

**BUILDING** 2440

**SERVICE DEPARTMENT** 1

**DATE RECEIVED** 960307

**TOLERANCE AS RECEIVED** 1 IN 2 OUT 3 NA 4 FAILED: /

**SENDER** W)J BUSSELL 6-9621

**COMMENTS**

**SHIPPING DAY** WE

**INSTRUMENT SPECIFICATIONS** 1 Year See Tolerance Column

**STANDARD(S) USED IN CALIBRATION TRACEABLE TO NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY OR NATIONALLY RECOGNIZED STANDARDS** 4:1 RATIO Y ☑ N ☐

| | EXPIRATION DATE | | EXPIRATION DATE |
|---|---|---|---|
| 002-14-01-033 | 9-1-96 | | |
| 002-79-06-039 | 3-12-97 | | |
| | | | |

**TRAINING HOURS**

**CALIBRATION HOURS** 3.0

**REPAIR HOURS**

**OTHER HOURS** 2

**MATERIALS**

**TOTAL CHARGE = ($125 x SUM OF HOURS) + MATERIALS**

**REMARKS**

**DATE CALIBRATED** 3-13-96

**DATE DUE** 3-13-97

**PROCEDURE NUMBER** Vm-1-Keithley (11-94) 2000

**AMBIENT TEMPERATURE** = 22.5°C

**APPROVED BY** D. J. Nelson 3-13-96

**CALIBRATED BY**

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Department of Energy

Westinghouse Hanford Company
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Electric Corporation
Box 1970, Richland, WA 99352

**PAGE** 1 OF 2

Hanford Engineering Development Laboratory

## REPORT OF CALIBRATION

PHYSICAL & ELECTRICAL STANDARDS LABORATORY

(CONTINUED)

CODE NO.

DATE

| Standard Frequency | Function & Range | Standard Output | 2000 Indication | | MFG's Tolerance |
|---|---|---|---|---|---|
| | DCV 100MV | 100 mV | 99.9986 | 99.9996 | ±8.5 uV |
| | 1V | 1V | .999992 | .999998 | ±37 uV |
| | 10V | 10V | 9.99997 | 10.00001 | ±350 uV |
| | 100V | 100V | 99.9985 | 100.0002 | ±5.1 mV |
| | 1000V | 1000V | 999.990 | 1000.006 | ±61 mV |
| 1KHz | ACV 100mV | 100mV | 100.004 | 100.001 | ±90uV |
| 50KHz | " | " | 100.011 | 100.008 | ±170uV |
| 1KHz | 1V | 1V | 1.00003 | 1.00001 | ±900uV |
| 50KHz | " | " | .99996 | 1.00017 | ±1.7mV |
| 1KHz | 10V | 10V | 10.0002 | 10.0000 | ±9mV |
| 50KHz | " | " | 10.0012 | 10.0007 | ±17mV |
| 1KHz | 100V | 100V | 100.001 | 100.000 | ±90mV |
| 50KHz | " | " | 100.001 | 100.021 | ±170mV |
| 1KHz | 750V | 700V | 700.00 | 700.00 | ±645mV |
| 50KHz | " | " | 699.86 | 699.97 | ±1.215V |
| | DCI 10mA | 10mA | 10.0006 | 9.99957 | ±5.4uA |
| | 100mA | 100mA | 99.9991 | 99.9958 | ±90 uA |
| | 1A | 1A | .999990 | .999994 | ±840uA |
| | 3A | 2.2A | 2.20006 | 2.20006 | ±2.68mA |
| 1KHz | ACI 1A | 1A | .99995 | 1.00000 | ±1.4mA |
| " | 2.2A | 2.2A | 2.1999 | 2.2004 | ±5.1mA |
| NOTE: 4w To | OHM 4 Wire | | | | ± |
| 5700A OUT + | 100Ω | 99.99933 | 99.9948 | 100.0002 | ±14m OHM |
| Sens. Term: | 1KΩ | .9999046 | .999882 | .999930 | ±110m " |
| EXT. Sens. "ON" | 10KΩ | 9.999302 | 9.99890 | 9.99931 | ±1.1 " |
| | 100KΩ | 99.99365 | 99.9900 | 99.9938 | ±11 " |
| | 1MΩ | .9999020 | .999862 | .999905 | ±110 " |
| | 10MΩ | 9.998317 | 9.99720 | 9.99826 | ±4.1K " |
| NOTE: 4w To | 100MΩ | 99.98941 | 99.9340 | 99.9880 | ±153K " |
| 5700A OUT | | | | | |
| Term. only. | | | | | |

APPROVED BY 3-13-96 D. J. Nelson

CALIBRATED BY STD LAB 39

PAGE 2 of 2

WESTINGHOUSE STANDARDS LABORATORY PHYSICAL AND ELECTRICAL REPORT

CUSTODIAN/ADDRESS CASTO ML L6-38

STANDARDS CODE NUMBER 679-06-01-002

NEW ☐ MODIFY ☐

REFERENCE NUMBER 392717

ORGANIZATION CODE W0M530

WORK ORDER J0M30

INSTRUMENT ELECTRONIC BALANCE SARTORIUS 1207

SERIAL NUMBER 2906032

PROPERTY NUMBER WA44148

RECALL STATUS 1 ACTIVE 2 NONRECALL 3 SUSPENDED 4 DELETED 5 PM 6 NONDATA M&TE 1

RECALL CYCLE 90

TOLERANCE HISTORY IIII

ROOM 174A

BUILDING 306E

SERVICE DEPARTMENT 7

DATE RECEIVED 950801

TOLERANCE AS RECEIVED 1 IN 2 OUT 3 NA 4 FAILED 1

SENDER

COMMENTS

SHIPPING DAY NA

INSTRUMENT SPECIFICATIONS +/-1.6MG 0-80 GRAMS

TRAINING HOURS

CALIBRATION HOURS 1.0

STANDARD(S) USED IN CALIBRATION TRACEABLE TO NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY OR NATIONALLY RECOGNIZED STANDARDS 4:1 RATIO Y ☐ N ☒ Best acceptable

EXPIRATION DATE

EXPIRATION DATE

002-82-02-033 1-26-96

REPAIR HOURS

OTHER HOURS

MATERIALS

TOTAL CHARGE = ($120 x SUM OF HOURS) + MATERIALS

REMARKS CORNER LOADING - (X) PASSED, ( ) FAILED

DATE CALIBRATED 11-30-95

DATE DUE 2-25-96

PROCEDURE NUMBER WHC-7-LAB-BALANCE REV.2 1207

AMBIENT TEMPERATURE =

| TEST POINT | AS FOUND | FINAL |
|---|---|---|
| 20 GRAMS | 20.0061 grams | Same |
| 50 GRAMS | 50.0006 " | " |
| 80 GRAMS | 80.0008 " | " |

APPROVED BY 12-4-95 D J Nelson

CALIBRATED BY

WHC SID LAB 53

Hanford Operations and
Engineering Contractor
for the United States
Department of Energy

Westinghouse Hanford Company
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Electric Corporation
Box 1970, Richland, WA 99352

PAGE 1 OF 1

# APPENDIX H THERMOGRAVIMETRIC MOISTURE ANALYSES OF MOISTURE STANDARD SAMPLES

Westinghouse
Hanford Company

**Internal Memo**

From: Plutonium Process Support Laboratories 15F00-96-046
Phone: 373-2419 T5-12
Date: May 17, 1996
Subject: RESULTS OF WATER CONTENT ANALYSES OF NEUTRON STANDARDS (REVISED)

To: W. T. Watson HO-3~~0~~2

cc: C. S. Sutter T5-12
GSB File/LB

This letter reports the results of water content analyses of neutron standards completed in the Plutonium Process Support Laboratories. A total of 58 samples were submitted for analysis, including samples of the starting materials used in preparing the standard mixtures (silica sand, aluminum hydroxide, and boron carbide).

Initially, the samples were analyzed using a Netzsch thermal analyzer-mass spectrometer. This instrument measures weight loss, heat loss/gain, and simultaneously identifies gases evolved as a sample is heated at a constant rate in the furnace. Analysis of the aluminum hydroxide with this instrument showed that the material is stable up to about 210 °C, where it begins to lose water. Water loss is rapid at 300 °C, but is slow from 320 °C to 800 °C. These data show that the samples must be heated to about 1000 °C for several hours to drive off all the water. The mass spectral data show that water is the only significant volatile compound evolved during the heating.

In the first attempts to measure water content, samples were taken from the sample containers with no attempt to homogenize the mixtures. Five to thirty grams of sample were placed in alumina crucibles and heated in a muffle furnace for two hours at 1000 °C. The crucible weight, sample + crucible weight , and the sample + crucible weight after heating were measured. the results of these analyses are given in Attachment 1. This procedure did not give satisfactory results because of poor reproducibility of the weight loss for a given sample. This was due to the inhomogeneity of the samples. Noticeable layering of the samples was observed in the sample bottles. Even large samples (20 to 30 grams) gave poor reproducibility of the results.

The next water content measurements were performed using a LECO Corporation TGA-601 thermogravimetric analyzer. This instrument allows analysis of 19 samples simultaneously and measures the weight loss of each sample every few minutes as the samples are heated. A typical weight loss versus time curve is shown for sample MS3-P3-13%-B in Figure 1. The sample was heated at 15 °C/minute to 1000 °C and then held constant. The weight loss versus time curve shows that no additional weight was lost after about 60 minutes after reaching 1000°C.

Analyses of the starting materials were also performed with the LECO thermal analyzer to determine their water content. Weight loss versus time curves for the silica sand, aluminum hydroxide, and boron carbide are shown in Figures 2, 3, and 4, respectively. The silica sand contains very little water. Weight loss measurements were less than 0.1 % for this material. Weight losses for the aluminum hydroxide averaged 34.69 %, which is very close to the theoretical weight loss of 34.64 % for $Al(OH)_3$ going to $Al_2O_3$ +

$H_2O$. The boron carbide, $B_4C$, gained weight (about 8 to 15 %) because of oxidation to $B_2O_3$.

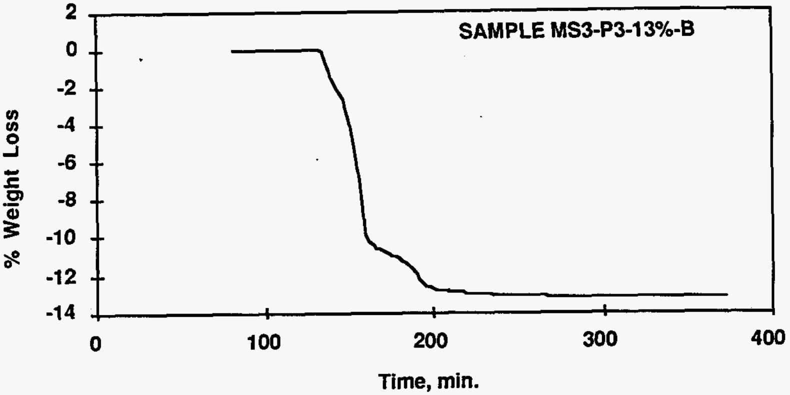

Figure 1. Weight Loss Versus Time for Sample MS3-P3-13%-B (4.9409 g sample heated at 15 °C/minute to 1000 °C).

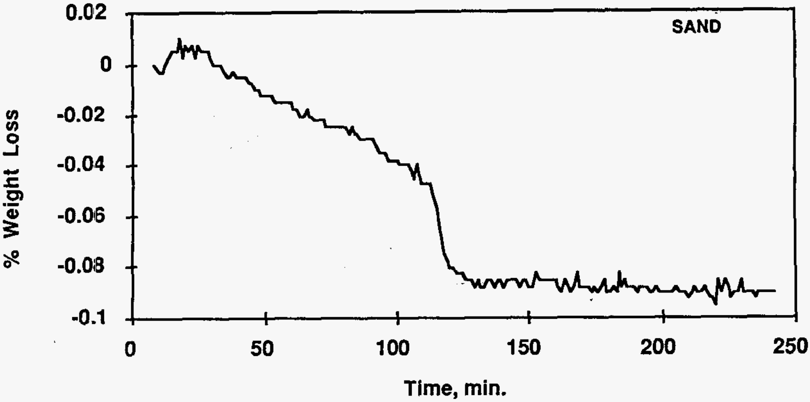

Figure 2. Weight Loss Versus Time for Silica Sand (3.9854 g sample heated at 15 °C/minute to 1000 °C).

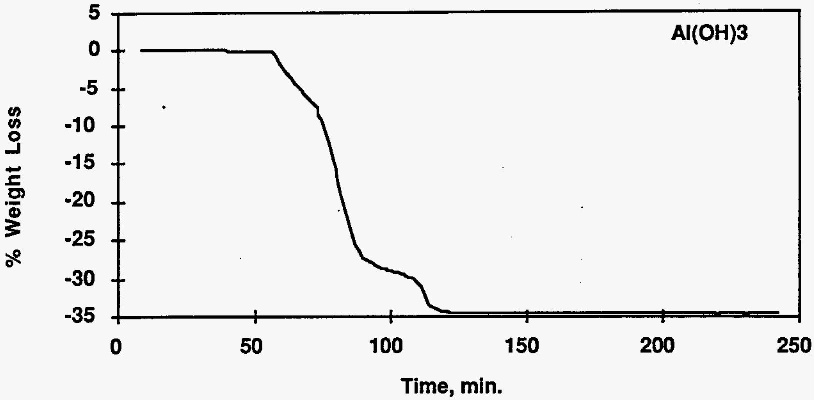

Figure 3. Weight Loss Versus Time for Aluminum Hydroxide (2.9515 g sample heated at 15 °C/minute to 1000 °C).

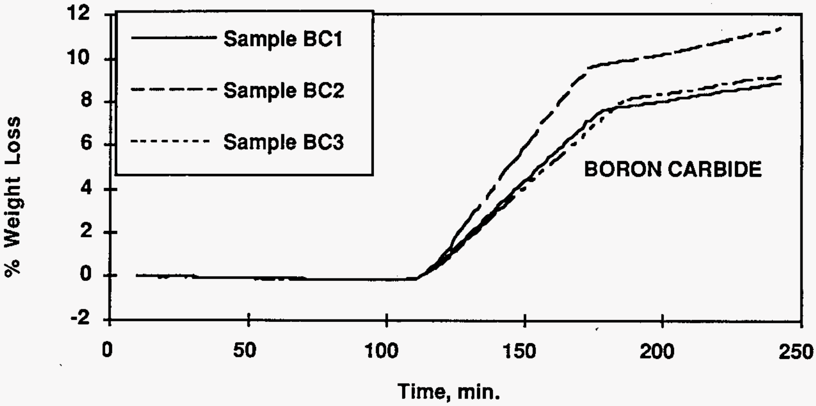

Figure 4. Weight Loss Versus Time for Three Boron Carbide Samples (2.8889 g, 2.1031 g, and 2.8240 g samples, respectively, heated at 15 °C/minute to 1000 °C).

The results of initial measurements of the standard mixtures with the LECO instrument again gave poor reproducibility as shown in Attachment 2. This was due to non-uniformity of the five-gram samples used in the analyses.

An attempt to prepare homogeneous samples was made using the cone and quarter technique. This again failed to yield reproducible results for duplicate analysis of the samples as shown in Attachment 3.

Finally, a vibrating sample splitter was tested to determine if representative samples could be prepared. This was very successful since, according to duplicate samples, the differences were less than 0.04%. Weight loss results using the vibrating sample splitter to prepare reproducible samples and using the LECO thermal analyzer are given in Attachment 4. A summary of the results of these analyses is given in the following table. The errors given in this table are differences in duplicate analyses.

| Sample Number | Weight Loss, Percent<br>Weighted Average | Average From Splitting | Error |
|---|---|---|---|
| 1A | | 16.20 | |
| 1B | | 18.94 | 0.02 |
| 1C | | 21.82 | 0.04 |
| 1D | | 19.74 | 0.01 |
| 2A | | 20.31 | 0.02 |
| 2B | | 20.35 | 0.02 |
| 2C | | 21.40 | 0.01 |
| 2D | | 19.45 | 0.04 |
| 3A | | 19.97 | 0.08 |
| 3B | | 20.58 | 0.05 |
| 3C | | 19.39 | 0.01 |
| 3D | | 19.55 | 0.01 |
| Al(OH)3 | | 34.69 | 0.01 |
| Sand | | 0.10 | 0.02 |
| Boron Carbide-1 | | -9.62 | 1.61 |
| Boron Carbide-2 | | -10.24 | 2.22 |
| Boron Carbide-3 | | -11.96 | 5.56 |
| MS2-P1-8%-B | 8.30 | | |
| MS2-P3-8%-B | | 8.02 | 0.01 |
| MS2-P4-8%-B | | 7.94 | 0.01 |
| MS3-P1-13%-B | | 11.01 | 0.02 |
| MS3-P2-13%-B | | 13.23 | 0.09 |
| MS3-P3-13%-B | | 13.21 | 0.01 |
| MS4-P1-19%-B | | 19.40 | 0.01 |
| MS4-P2-19%-B | | 19.16 | 0.11 |
| MS4-P3-19%-B | | 19.20 | 0.04 |
| MS4-P4-19%-B | | 19.56 | 0.03 |
| MS5-P1-25%-B | | 25.52 | 0.01 |
| MS5-P2-25%-B | | 25.26 | 0.03 |
| MS5-P3-25%-B | | 25.24 | 0.03 |

| | Weight Loss, Percent | | |
|---|---|---|---|
| Sample Number | Weighted Average | Average From Splitting | Error |
| MS5-P4-25%-B | | 25.13 | 0.02 |
| MS6-P2-35%-B | | 34.47 | 0.01 |
| MS6-P3-35%-B | | 34.47 | 0.01 |
| MS7-P1-13%-B | | 13.33 | 0.01 |
| MS7-P2-13%-B | | 13.05 | 0.02 |
| MS7-P3-13%-B | | 13.16 | 0.04 |
| MS7-P4-8%-B | | 8.52 | 0.03 |
| MS8-P1-19%-B | | 19.21 | 0.14 |
| MS8-P2-19%-B | | 18.67 | 0.01 |
| MS8-P3-19%-B | | 19.16 | 0.04 |
| MS8-P4-13%-B | | 13.23 | 0.04 |
| MS8-P5-8%-B | | 8.23 | 0.02 |
| MS9-P1-19%-B | | 19.86 | 0.02 |
| MS9-P2-19%-B | | 19.51 | 0.03 |
| MS9-P3-19%-B | | 18.82 | 0.01 |
| MS9-P4-13%-B | | 13.02 | 0.05 |
| MS10-P1-25%-B | | 25.41 | 0.01 |
| MS10-P2-25%-B | | 25.50 | 0.10 |
| MS10-P3-25%-B | | 24.07 | 0.01 |
| MS10-P4-25%-B | | 25.12 | 0.04 |
| MS12-P2-8%-B | | 7.89 | 0.03 |
| MS13-P1-19%-B | 19.40 | | |
| MS14-P2-19%-B | | 18.93 | 0.07 |
| MS15-P2-19%-B | | 18.82 | 0.08 |
| MS16-P2-19%-B | | 19.13 | 0.04 |
| MS1-P7-4%-B | | 3.74 | 0.01 |
| MS1-P12-4%-B-1 | | 3.97 | 0.01 |
| MS1-P9-4%-B-1 | | 2.99 | 0.01 |

If you have questions concerning these analyses please contact me.

GS Barney

G. S. Barney, Sr. Advisory Scientist
Plutonium Process Support Laboratories

Attachments (4)

Attachment 1

15F00-96-046

## Replicate Weight Loss Measurements Without Homogenizing the Samples (Heating in a Muffle Furnace)

| Sample | Crucible Wt., g | Sample + Crucible Wt., g<br>Before Heating | Sample + Crucible Wt., g<br>After Heating | Sample Wt., g | Wt. Loss, g | % Wt. Loss |
|---|---|---|---|---|---|---|
| 1A | 13.7638 | 18.7740 | 17.9622 | 5.0102 | 0.8118 | 16.2029 |
| 2A | 5.2289 | 10.2236 | 9.3485 | 4.9947 | 0.8751 | 17.5206 |
| 3A | 5.4160 | 10.4680 | 9.5309 | 5.0520 | 0.9371 | 18.5491 |
| 1B | 5.8687 | 10.8519 | 9.9944 | 4.9832 | 0.8575 | 17.2078 |
| 2B | 5.3458 | 10.3907 | 9.4925 | 5.0449 | 0.8982 | 17.8041 |
| 3B | 5.8251 | 10.7146 | 9.8877 | 4.8895 | 0.8269 | 16.9117 |
| 1C | 5.2558 | 10.3035 | 9.3476 | 5.0477 | 0.9559 | 18.9373 |
| 2C | 5.9005 | 10.8592 | 9.9906 | 4.9587 | 0.8686 | 17.5167 |
| 3C | 5.4847 | 10.6145 | 9.6755 | 5.1298 | 0.9390 | 18.3048 |
| 1D | 5.6428 | 10.7590 | 9.8544 | 5.1162 | 0.9046 | 17.6811 |
| 2D | 5.2304 | 10.5379 | 9.6146 | 5.3075 | 0.9233 | 17.3961 |
| 3D | 6.0280 | 11.0258 | 10.1883 | 4.9978 | 0.8375 | 16.7574 |
| Sand | 6.0279 | 11.0729 | 11.0674 | 5.0450 | 0.0055 | 0.1090 |
| Al(OH)3 | 5.8688 | 10.8696 | 9.1453 | 5.0008 | 1.7243 | 34.4805 |
| 2B-1 | 5.4847 | 10.5018 | 9.6009 | 5.0171 | 0.9009 | 17.9566 |
| 2B-2 | 5.8254 | 10.8857 | 9.9649 | 5.0603 | 0.9208 | 18.1965 |
| 2B-3 | 5.2289 | 10.2439 | 9.2936 | 5.0150 | 0.9503 | 18.9492 |
| 2B-4 | 5.2304 | 10.3947 | 9.439 | 5.1643 | 0.9557 | 18.5059 |
| 3C-1 | 18.8370 | 34.2000 | 31.2135 | 15.3630 | 2.9865 | 19.4396 |
| 3C-2 | 18.9613 | 34.4701 | 31.4450 | 15.5088 | 3.0251 | 19.5057 |
| 3C-3 | 19.3257 | 34.6997 | 31.6875 | 15.3740 | 3.0122 | 19.5928 |
| 1C-1 | 18.8353 | 34.4982 | 31.5062 | 15.6629 | 2.9920 | 19.1025 |
| 1C-2 | 18.9606 | 34.2189 | 31.1212 | 15.2583 | 3.0977 | 20.3017 |
| 2C-1 | 19.3263 | 37.0484 | 33.8766 | 17.7221 | 3.1718 | 17.8974 |
| 2C-2 | 13.7666 | 29.7243 | 26.7474 | 15.9577 | 2.9769 | 18.6549 |
| MS2-P1-8%-B-1 | 26.0227 | 47.4832 | 45.5236 | 21.4605 | 1.9596 | 9.1312 |
| MS2-P1-8%-B-2 | 26.0818 | 55.9448 | 53.5521 | 29.8630 | 2.3927 | 8.0123 |
| MS13-P1-19%-B-1 | 25.5623 | 47.4002 | 42.9871 | 21.8379 | 4.4131 | 20.2084 |
| MS13-P1-19%-B-2 | 26.6638 | 47.5108 | 43.3451 | 20.8470 | 4.1657 | 19.9823 |
| MS3-P1-13%-B-1 | 26.7266 | 44.209 | 41.8045 | 17.4824 | 2.4045 | 13.7538 |
| MS3-P1-13%-B-2 | 25.6197 | 43.748 | 41.1857 | 18.1283 | 2.5623 | 14.1343 |

## Duplicate Weight Loss Measurements Without Homogenizing the Samples

| Sample | Wt Before Heating, g | Wt. After Heating, g | % Wt. Loss |
|---|---|---|---|
| MS2-P1-8%-B-1 | 2.2683 | 2.1705 | 4.3116 |
| MS3-P1-13%-B-1 | 4.6163 | 4.0553 | 12.1526 |
| MS3-P1-13%-B-2 | 4.6501 | 4.2042 | 9.5890 |
| MS4-P1-19%-B-1 | 4.5343 | 3.7119 | 18.1373 |
| MS4-P1-19%-B-2 | 4.8611 | 3.9422 | 18.9031 |
| MS5-P1-25%-B-1 | 4.7377 | 3.6776 | 22.3758 |
| MS5-P1-25%-B-2 | 4.8656 | 3.6835 | 24.2951 |
| MS7-P1-13%-B-1 | 4.9016 | 4.2894 | 12.4898 |
| MS7-P1-13%-B-2 | 4.7463 | 4.2125 | 11.2467 |
| MS8-P1-19%-B-1 | 4.9241 | 4.0611 | 17.5260 |
| MS8-P1-19%-B-2 | 4.7187 | 3.9614 | 16.0489 |
| MS9-P1-19%-B-1 | 4.5454 | 3.7737 | 16.9776 |
| MS9-P1-19%-B-2 | 4.8259 | 3.9534 | 18.0795 |
| MS10-P1-25%-B-1 | 4.7222 | 3.6317 | 23.0930 |
| MS10-P1-25%-B-2 | 4.8268 | 3.6493 | 24.3950 |
| MS13-P1-19%-B-1 | 4.3901 | 3.5976 | 18.0520 |
| MS13-P1-19%-B-2 | 4.62 | 3.8795 | 16.0281 |
| MS4-P2-19%-B-1 | 4.7502 | 3.9553 | 16.7340 |
| MS4-P2-19%-B-2 | 4.8568 | 3.9041 | 19.6158 |
| 1B-1 | 4.7325 | 3.8762 | 18.0940 |
| 1B-2 | 4.7126 | 3.8182 | 18.9789 |
| 1D-1 | 4.7874 | 3.8899 | 18.7471 |
| 1D-2 | 4.6187 | 3.7676 | 18.4273 |
| 2D-1 | 4.8673 | 4.0158 | 17.4943 |
| 2D-2 | 4.5637 | 3.7055 | 18.8049 |
| 2A-1 | 4.7078 | 3.8089 | 19.0938 |
| 2A-2 | 3.6784 | 3.0822 | 16.2081 |
| 3A-1 | 4.8756 | 4.0576 | 16.7774 |
| 3A-2 | 4.5623 | 3.6765 | 19.4156 |
| 2B -1 | 4.7469 | 3.9415 | 16.9669 |
| 2B -2 | 4.7506 | 3.8524 | 18.9071 |
| 3B-1 | 4.6895 | 3.8919 | 17.0082 |
| 3B-2 | 4.7727 | 3.8922 | 18.4487 |
| 3D-1 | 4.84 | 4.0487 | 16.3492 |
| 3D-2 | 4.8549 | 4.0286 | 17.0199 |
| 1C-1 | 5.6038 | 4.5971 | 17.9646 |
| 1C-2 | 4.1132 | 3.1576 | 23.2325 |
| 1C-3 | 4.8652 | 3.8009 | 21.8758 |

Attachment 3

15F00-96-046

### Duplicate Weight Loss Measurements After Cone and Quartering the Samples

| Sample | Wt Before Heating, g | Wt. After Heating, g | % Wt. Loss |
|---|---|---|---|
| 2C-1 | 4.472 | 3.6594 | 18.17 |
| 2C-2 | 4.8021 | 3.8513 | 19.8 |
| 3C-1 | 6.2134 | 5.0552 | 18.64 |
| 3C-2 | 5.4682 | 4.3893 | 19.73 |
| MS9-P2-19%-B-1 | 3.6082 | 2.7751 | 23.09 |
| MS9-P2-19%-B-2 | 4.149 | 3.3146 | 20.11 |
| MS12-P2-8%-B-1 | 2.9399 | 2.6844 | 8.69 |
| MS12-P2-8%-B-2 | 3.2471 | 2.8529 | 12.14 |
| MS15-P2-19%-B-1 | 4.936 | 3.8757 | 21.48 |
| MS15-P2-19%-B-2 | 4.6792 | 3.8753 | 17.18 |
| MS16-P2-19%-B-1 | 3.8712 | 3.2383 | 16.35 |
| MS16-P2-19%-B-2 | 4.9846 | 3.9269 | 21.22 |
| MS5-P2-25%-B-1 | 4.1777 | 3.2469 | 22.28 |
| MS5-P2-25%-B-2 | 4.5618 | 3.4068 | 25.32 |
| MS3-P2-13%-B-1 | 4.7144 | 4.1826 | 11.28 |
| MS3-P2-13%-B-2 | 4.6665 | 4.0174 | 13.91 |
| MS7-P2-13%-B-1 | 3.579 | 3.1220 | 12.77 |
| MS7-P2-13%-B-2 | 4.3321 | 3.6974 | 14.65 |
| MS7-P2-13%-B-3 | 4.5673 | 3.9137 | 14.31 |

## Duplicate Weight Loss Measurements After Splitting with the Vibrating Sample Splitter

| Sample | Wt Before Heating, g | Wt. After Heating, g | % Wt. Loss |
|---|---|---|---|
| MS10-P2-25%-B-1 | 4.8387 | 3.6071 | 25.4531 |
| MS10-P2-25%-B-2 | 4.6777 | 3.4821 | 25.5596 |
| MS8-P2-19%-B-1 | 4.3901 | 3.5702 | 18.6761 |
| MS8-P2-19%-B-2 | 4.2852 | 3.4853 | 18.6666 |
| MS6-P2-35%-B-1 | 4.1711 | 2.733 | 34.4777 |
| MS6-P2-35%-B-2 | 4.2327 | 2.7737 | 34.4697 |
| MS14-P2-19%-B-1 | 4.3094 | 3.4923 | 18.9609 |
| MS14-P2-19%-B-2 | 4.1175 | 3.3396 | 18.8925 |
| MS2-P3-8%-B-1 | 3.8597 | 3.5497 | 8.0317 |
| MS2-P3-8%-B-2 | 3.9976 | 3.6772 | 8.0148 |
| MS6-P3-35%-B-1 | 4.1187 | 2.6991 | 34.4672 |
| MS6-P3-35%-B-2 | 4.2181 | 2.7638 | 34.4776 |
| MS8-P3-19%-B-1 | 4.808 | 3.8857 | 19.1826 |
| MS8-P3-19%-B-2 | 4.5994 | 3.719 | 19.1416 |
| MS10-P3-25%-B-1 | 4.9429 | 3.7533 | 24.0668 |
| MS10-P3-25%-B-2 | 4.824 | 3.6629 | 24.0692 |
| MS7-P3-13%-B-1 | 4.7423 | 4.1187 | 13.1497 |
| MS7-P3-13%-B-2 | 4.499 | 3.908 | 13.1363 |
| MS7-P3-13%-B-3 | 4.6533 | 4.0402 | 13.1756 |
| MS3-P3-13%-B-1 | 4.9409 | 4.288 | 13.2142 |
| MS3-P3-13%-B-2 | 4.6909 | 4.071 | 13.2149 |
| MS4-P3-19%-B-1 | 4.1731 | 3.3708 | 19.2255 |
| MS4-P3-19%-B-2 | 4.0497 | 3.2726 | 19.1891 |
| MS5-P3-25%-B-1 | 4.5667 | 3.4147 | 25.2261 |
| MS5-P3-25%-B-2 | 4.4472 | 3.3239 | 25.2586 |
| MS9-P3-19%-B-1 | 4.0804 | 3.3123 | 18.8241 |
| MS9-P3-19%-B-2 | 4.2048 | 3.4136 | 18.8166 |
| MS2-P4-8%-B-1 | 4.191 | 3.858 | 7.9456 |
| MS2-P4-8%-B-2 | 4.2856 | 3.9452 | 7.9429 |
| MS5-P4-25%-B-1 | 4.4681 | 3.3448 | 25.1404 |
| MS5-P4-25%-B-2 | 4.6043 | 3.4475 | 25.1243 |
| MS4-P4-19%-B-1 | 4.1549 | 3.3415 | 19.5769 |
| MS4-P4-19%-B-2 | 4.0476 | 3.2566 | 19.5424 |
| MS10-P4-25%-B-1 | 4.382 | 3.2801 | 25.1461 |
| MS10-P4-25%-B-2 | 4.492 | 3.3641 | 25.1091 |
| MS8-P4-13%-B-1 | 3.783 | 3.2818 | 13.2487 |
| MS8-P4-13%-B-2 | 3.9688 | 3.4435 | 13.2357 |
| MS8-P4-13%-B-3 | 3.8626 | 3.3522 | 13.2139 |
| MS9-P4-13%-B-1 | 4.6672 | 4.0605 | 12.9992 |
| MS9-P4-13%-B-2 | 4.5704 | 3.9739 | 13.0514 |
| MS7-P4-8%-B-1 | 4.4672 | 4.0873 | 8.5042 |
| MS7-P4-8%-B-2 | 4.5346 | 4.1478 | 8.5300 |
| MS8-P5-8%-B-1 | 5.0182 | 4.6047 | 8.2400 |
| MS8-P5-8%-B-2 | 5.0204 | 4.6075 | 8.2244 |
| Sand | | | 0.11 |
| Al(OH)3 | | | 34.69 |
| MS3-P1-13%-B-1 | 3.8473 | 3.4233 | 11.0207 |
| MS3-P1-13%-B-2 | 3.8693 | 3.4435 | 11.0046 |
| MS4-P1-19%-B-1 | 4.3109 | 3.4751 | 19.3881 |
| MS4-P1-19%-B-2 | 4.4241 | 3.5657 | 19.4028 |

Attachment 4 (Cont.)

| Sample | Wt Before Heating, g | Wt. After Heating, g | % Wt. Loss |
|---|---|---|---|
| MS5-P1-25%-B-1 | 5.875 | 4.3757 | 25.5200 |
| MS5-P1-25%-B-2 | 6.0048 | 4.4722 | 25.5229 |
| MS7-P1-13%-B-1 | 5.5542 | 4.8137 | 13.3323 |
| MS7-P1-13%-B-2 | 5.785 | 5.0136 | 13.3345 |
| MS8-P1-19%-B-1 | 5.5119 | 4.4489 | 19.2855 |
| MS8-P1-19%-B-2 | 5.3949 | 4.3623 | 19.1403 |
| MS9-P1-19%-B-1 | 4.6054 | 3.6899 | 19.8788 |
| MS9-P1-19%-B-2 | 4.7102 | 3.7749 | 19.8569 |
| MS10-P1-25%-B-1 | 5.986 | 4.4648 | 25.4126 |
| MS10-P1-25%-B-2 | 6.0761 | 4.5327 | 25.4012 |
| MS13-P1-19%-B-1 | 2.7913 | 2.3304 | 16.5120 |
| MS4-P2-19%-B-1 | 4.4894 | 3.629 | 19.1651 |
| MS4-P2-19%-B-2 | 4.353 | 3.521 | 19.1133 |
| MS4-P2-19%-B-3 | 4.4327 | 3.5847 | 19.1306 |
| 1B-1 | 4.546 | 3.6841 | 18.9595 |
| 1B-2 | 4.6464 | 3.7674 | 18.9179 |
| 1D-1 | 4.4117 | 3.5404 | 19.7498 |
| 1D-2 | 4.271 | 3.4281 | 19.7354 |
| 2D-1 | 4.8765 | 3.9272 | 19.4668 |
| 2D-2 | 4.9892 | 4.0199 | 19.4280 |
| 2A-1 | 4.1145 | 3.2793 | 20.2989 |
| 2A-2 | 4.2905 | 3.4185 | 20.3240 |
| 3A-1 | 3.8119 | 3.0488 | 20.0189 |
| 3A-2 | 3.8272 | 3.0643 | 19.9336 |
| 2B -1 | 5.0535 | 4.0244 | 20.3641 |
| 2B -2 | 5.0755 | 4.0432 | 20.3389 |
| 3B-1 | 4.5274 | 3.5962 | 20.5681 |
| 3B-2 | 4.522 | 3.5899 | 20.6126 |
| 3D-1 | 6.2911 | 5.0613 | 19.5483 |
| 3D-2 | 5.9974 | 4.8246 | 19.5551 |
| 1C-1 | 2.7864 | 2.1784 | 21.8203 |
| 1C-2 | 2.7342 | 2.1371 | 21.8382 |
| 1C-3 | 1.7993 | 1.407 | 21.8029 |
| 2C-1 | 3.8036 | 2.9895 | 21.4034 |
| 2C-2 | 3.7902 | 2.9794 | 21.3920 |
| 3C-1 | 5.5491 | 4.4728 | 19.3959 |
| 3C-2 | 5.5879 | 4.5044 | 19.3901 |
| MS9-P2-19%-B-1 | 6.4175 | 5.1667 | 19.4905 |
| MS9-P2-19%-B-2 | 6.2311 | 5.0144 | 19.5262 |
| MS12-P2-8%-B-1 | 5.4447 | 5.0163 | 7.8682 |
| MS12-P2-8%-B-2 | 5.4385 | 5.0088 | 7.9011 |
| MS15-P2-19%-B-1 | 3.774 | 3.0619 | 18.8686 |
| MS15-P2-19%-B-2 | 3.9251 | 3.1876 | 18.7893 |
| MS16-P2-19%-B-1 | 3.6508 | 2.953 | 19.1136 |
| MS16-P2-19%-B-2 | 3.8026 | 3.0745 | 19.1474 |
| MS5-P2-25%-B-1 | 3.3103 | 2.4736 | 25.2757 |
| MS5-P2-25%-B-2 | 3.385 | 2.5304 | 25.2467 |
| MS3-P2-13%-B-1 | 3.616 | 3.1353 | 13.2937 |
| MS3-P2-13%-B-2 | 3.5076 | 3.0382 | 13.3824 |
| MS7-P2-13%-B-1 | 3.2101 | 2.7914 | 13.0432 |
| MS7-P2-13%-B-2 | 3.2624 | 2.8363 | 13.0609 |
| MS7-P2-13%-B-3 | 3.257 | 2.8324 | 13.0365 |

Attachment 4 (Cont.)

| Sample | Wt Before Heating, g | Wt. After Heating, g | % Wt. Loss |
|---|---|---|---|
| Sand-1 | 3.9854 | 3.9818 | 0.0903 |
| Sand-2 | 3.4234 | 3.4202 | 0.0935 |
| Al(OH)3-1 | 2.9515 | 1.9274 | 34.6976 |
| Al(OH)3-2 | 4.3203 | 2.8215 | 34.6920 |
| Boron Carbide 1-1 | 2.8889 | 3.1435 | -8.8130 |
| Boron Carbide 1-2 | 2.3931 | 2.6426 | -10.4258 |
| Boron Carbide 2-1 | 2.1031 | 2.3418 | -11.3499 |
| Boron Carbide 2-2 | 2.8627 | 3.1242 | -9.1347 |
| Boron Carbide 3-1 | 1.4317 | 1.6427 | -14.7377 |
| Boron Carbide 3-2 | 2.824 | 3.0831 | -9.1749 |
| MS1-P7-4%-B-1 | 4.3073 | 4.1462 | 3.74 |
| MS1-P7-4%-B-2 | 4.3533 | 4.1909 | 3.73 |
| MS1-P12-4%-B-1 | 4.2403 | 4.0720 | 3.97 |
| MS1-P12-4%-B-2 | 4.3551 | 4.1826 | 3.96 |
| MS1-P9-4%-B-1 | 4.2145 | 4.0885 | 2.99 |
| MS1-P9-4%-B-2 | 4.3965 | 4.2650 | 2.99 |

## APPENDIX I MCNP INPUT FILES

Input files modeling the 16 moisture standards can be created by changing the moisture standard 4 file. Below is the moisture standard 4 input file (the only one listed in its entirety), and the differences between the moisture standard 4 input file and each other moisture standard input files, 1 through 16.

At the front of each line there is either a "<" or a ">". The lines beginning with the symbol < are from the moisture standard 4 file and are the lines that need to be changed (altered, deleted, or supplemented) in order to create the other moisture standard file. The lines beginning with > are from the other moisture standard file and provide the required alteration to create the new input deck.

Each set of differences is under its appropriate moisture standard title. The "---" are simply separaters that help to group small sections of differences between the input files and may be overlooked.

### Moisture Standard 4

```
As-Built Surface Neutron, Cd d#1 .055", Cd d#2 .006", Stand#4 19wt%
c  Det#1 B-10 TALLY REGION 80-100%
   1    6  -2.34  31 -160 27 -28  imp:n=300
c  DET#2 B-10 TALLY REGION 80-100%
   2    6  -2.34  67 -167 70 -71  imp:n=310
c  DET#3 B-10 TALLY REGION 80-100%
   3    6  -2.34  78 -174 80 -82 imp:n=300
c  narrow part of source housing
   4    4  -8.02  (9 7 -2 -5 4) (6:14) imp:n=100
c  entrance slot to source cavity
   5   13 -.000114 ((16 (-86:87)):(-18 -87 86))
        (3 -17 -1 -15 ) #(107 -106) imp:n=100
c  probe housing bottom
   6    4  -8.02  -4 3 -1 6 #5 #55  imp:n=100
c  Ar/CO2 Det#1
   7   9 -.001  (-29 26 -31):(153 -30 31 -29):(-30 31 -152 26)  imp:n=300
c  SS Cathode Det# 1
   8    4  -8.02  26 -29 -23 30  imp:n=225
c  Polyethylene Det#1
   9    3  -0.96  (-21 22 -34 26 )(59 :24 :-25 ) imp:n=200
c  main cadmium Det#1
  10    8  -8.65  (-34 35 21 -20 ) imp:n=100
```

```
c  top cadmium washer det#1
  11    8  -8.65  (-36 35 -21 38 39 ) imp:n=100
c  bottom cadmium hat det#1
 12  8  -8.65  ((34 -33 -20 22 40):(34 -32 22 -37 ):(-32 29 -22 )) imp:n=100
c  ss clip around det#1
  13    4  -8.02  (20 -19 -33 60) imp:n=100
c  ss plate screwed to cad shield
  14    4  -8.02  (-51 49 -52 95 41 93) imp:n=90
c  cad shield under det#3
  15    8  -8.65  (50 -49 -52 53 41 88 89 90 91 92 93) #53 imp:n=90
c  Aluminum in poly insert of det#1
  16    5  -2.699  -24 25 22 -21 26 -34 -59 imp:n=150
c  sides of probe housing (bottom third)
  17    4  -8.02  ((-1 2 4 -11):(-4 -6 -1 14)) #5 #54 #55 imp:n=100
c  Ar/CO2 Det#2
  18  9 -.001 (69 -72 -67):(155 67 -66 -72):(-154 67 -66 69) imp:n=310
c  Cathode Det#2
  19    4  -8.02  66 -58 69 -72  imp:n=300
c  ss top Det#2
  20    4  -8.02  -58 72 -73  imp:n=100
c  bottom ss Det#2
  21    4  -8.02  -58 68 -69  imp:n=100
c  Polyethylene Det#2
  22    3  -0.96  58 -56 65 -74  imp:n=200
c  SS mounting sleeve det#2
  23    4  -8.02  (56 -61 65 -74 ):(64 -65 -61 ) imp:n=200
c  polyimide bottom det#2
  24    7  1.4  -58 65 -68  imp:n=100
c  polyimide on cadmium plating
  26    7  1.4  62 -63 44 -74  imp:n=100
c  cadmium det#2
  25    8  -8.65  (61 -62 -74 64 ):(44 -64 -62 ) imp:n=140
c  SS mounting sleeve
  27  4 -8.02 ((45 63 -41 -75 44):(-44 43 -41 45):
             (4 -43 -41 63 45)) #13 imp:n=110
c  wide part of probe source housing
  28    4  -8.02  (-9 8 -2 4 -5 6) #5 #55 imp:n=100
 c  Ar+CO2 gas det#3
 29  9  -.001  (81 -83 -78):(157 -83 78 -77):(-156 81 78 -77) imp:n=300
c  Cathode wall det#3
  30    4  -8.02  77 -76 81 -83 imp:n=200
c  bottom ss det#3
  31    4  -8.02  -76 79 -81  imp:n=100
c  top ss wall det#3
  32    4  -8.02  83 -84 -76  imp:n=100
c  polyimide det#3
  33    7  1.4  (76 -47 -84 79 ):(51 -79 -47 ) imp:n=200
```

```
c   ss mounting sleeve det#3
  34    4  -8.02  (47 -46 -85 51 ) imp:n=150
c   polyimide around det#1
  35    7  1.4     (23 -22 26 -29) imp:n=200
c  air space below cad in probe
  36  13 -.000114 (-50 4 -2 41 19 60)(5:-8:(-7 9)) 95 #53 imp:n=100
  37  13 -.000114 (-50 4 -2 41 20 -60)(5:-8:(-7 9)) #53 imp:n=100
  38  13 -.000114 (37 -2 33 -19):(-37 -2 32) imp:n=100
  39  13 -.000114 (-20 -2 -35) imp:n=100
  40  13 -.000114 (63 -41 4 -75 -45 -2):(-63 4 -43):(-63 -45 43 -44) imp:n=100
  41  13 -.000114 (36 -21 -26):(-38 35 -36):(-21 -39 35 -36) imp:n=100
c  ss screws in cad shield
  42  4  -8.02 -88 50 -49 imp:n=100
  43  4  -8.02 -89 50 -49 imp:n=100
  44  4  -8.02 -90 50 -49 imp:n=100
  45  4  -8.02 -91 50 -49 imp:n=100
  46  4  -8.02 95 -53 50 -49 imp:n=100
  47  4  -8.02 -92 50 -49 imp:n=100
c   #10 threaded rod
  48  4  -8.02 (-129 51 -97):(-51 -95 5) imp:n=100
c   main thick wall portion of housing
  49  4  -8.02 -12 2 11 -130 imp:n=100
c   air above cad plate below top of det#3
  50  13 -.000114 (-2 51 -85) ((46 41 97):(63 75 -41)
     :(58 -63 74):(73 -58)) 90 88 imp:n=100
c  around around cad/ss plate
  51  13 -.000114 (-2 52 50 -51 41) imp:n=100
c  slot in cad/ss plate for wire pass through
  52  13 -.000114 (-93 -51 50) #51 imp:n=100
c  det#1 stiffener
  53  4  -8.02 98 -99 100 -49 101 -102 imp:n=100
c  source holder grab hole
  54  13 -.000114 107 -15 -104 imp:n=100
c  source holder nut
  55  4  -8.02 -106 104 107 -15 imp:n=100
c  source holder threads/body
  56  4  -8.02 -6 15 -108 imp:n=100
c  source capsule
  57  4  -8.02 (-109 108 -112 105):(110 -109 -105):
        (108 -111 -105) imp:n=100
c  air around source capsule
  58 13  -.000114 (112 -6 108 -14):(-14 109 -112) imp:n=100
c  Pd-Cf2O3 NEUTRON SOURCE
  59 1   -10.0  -113 115 -114       imp:n=100
c  air around source
  60 13  -.000114 -105 111 -110 #59  imp:n=100
c  electrical board #1
```

```
  61 10  -1.21  116 -117 -2 97 90 88 imp:n=90
c  threaded rod
  62   4  -8.02  51 -129 -90 imp:n=100
c  threaded rod
  63   4  -8.02  51 -129 -88 imp:n=100
c  electrical board #2
  64 10  -1.21 120 -121 -2 97 90 88 imp:n=100
c  electrical board #3
  65 10  -1.21  122 -123 -2 97 90 88 imp:n=100
c  electrical board #4
  66 10  -1.21  126 -127 -2 97 90 88 imp:n=100
c   air above top of det#3 below first electrical board
  67  13 -.000114 (-2 85 -116 90 88 97 47):(-47 84 -116) imp:n=90
c   air between board 1 and ss plate 40
  68  13 -.000114 (-2 117 -118 90 88 97) imp:n=90
c   air between ss plate 40 and board #2
  69  13 -.000114 (-2 119 -120 90 88 97) imp:n=90
c   air between board #2 and board #3
  70  13 -.000114 (-2 121 -122 90 88 97) imp:n=90
c  SS ground Plane #40
  71 4  -8.02  118 -119 -2 97 90 88 imp:n=90
c  SS ground Plane #41
  72 4  -8.02  124 -125 -2 97 90 88 imp:n=90
c  SS ground Plane #39
  73 4  -8.02  128 -129 -2 97 90 88 imp:n=90
c   air between board #3 and SS plate #41
  74  13 -.000114 (-2 123 -124 90 88 97) imp:n=90
c   air between SS plate #41 and board #4
  75  13 -.000114 (-2 125 -126 90 88 97) imp:n=90
c   air between board #4 & SS plate #39
  76  13 -.000114 (-2 127 -128 90 88 97) imp:n=90
c  bottom of cablehead
  77 4  -8.02 103 -130 -12 131 #49 imp:n=70
c   air between board #4 & SS plate #39
  78  13 -.000114 -2 129 -103 imp:n=70
c  cablehead nut
  79 4  -8.02 130 -132 131 -12 imp:n=50
c  cablehead neck
  80 4  -8.02 132 -133 131 -134 imp:n=50
c  air around cablehead neck
  81 13 -.000114 132 -133 134 -12 imp:n=40
c  cable
  82 13 -.000114    103 -133 -131 imp:n=50
c  air around probe above barrel lip
  83 13 -.000114 142 -143 144 -145 139 -133 1 #49 #79 #81 imp:n=100
c  top 0-3cm layer of hydrated alumina + sand (inner cylinder)
  84 2 -1.605 -140 146 -135 -151 imp:n=100
```

```
c  3-6cm layer of hydrated alumina + sand (inner cylinder)
  85 2 -1.605 -146 147 -135 -151 imp:n=100
c  6-9cm layer of hydrated alumina + sand (inner cylinder)
  86 2 -1.605 -147 148 -135 -151 imp:n=90
c  9-20cm layer of hydrated alumina + sand (inner cylinder)
  87 2 -1.605 -148 149 -135 -151 imp:n=75
c  20-30cm layer of hydrated alumina + sand (inner cylinder)
  88 2 -1.605 -149 150 -135 -151 imp:n=60
c  30cm-bottom layer of hydrated alumina + sand (inner cylinder)
  89 2 -1.605 -150 137 -135 -151 imp:n=50
c  Aluminum barrel (upper sides)
  90 5 -2.699 (-139 135 -136 149) imp:n=90
c  Aluminum lid (top)
  91 5 -2.699 -3 140 -135 imp:n=100
c  Air inside barrel
  92  13 -.000114 3 -139 -135 1 #49 imp:n=100
c  poly under barrel (inner cylinder)
  93  3 -0.96 141 -138 -151 imp:n=30
c  air around barrel
  94 13 -.000114 136 138 -139 142 -143 144 -145 imp:n=40
c  Aluminum barrel (bottom)
  95 5 -2.699 -135 138 -137 imp:n=40
c  top 0-3cm layer of hydrated alumina + sand (outer ring)
  96 2 -1.605 -140 146 -135 151 imp:n=100
c  3-6cm layer of hydrated alumina + sand (outer ring)
  97 2 -1.605 -146 147 -135 151 imp:n=90
c  6-9cm layer of hydrated alumina + sand (outer ring)
  98 2 -1.605 -147 148 -135 151 imp:n=80
c  9-20cm layer of hydrated alumina + sand (outer ring)
  99 2 -1.605 -148 149 -135 151 imp:n=65
c  20-30cm layer of hydrated alumina + sand (outer ring)
 100 2 -1.605 -149 150 -135 151 imp:n=50
c  30cm-bottom layer of hydrated alumina + sand (outer ring)
 101 2 -1.605 -150 137 -135 151 imp:n=40
c  poly under barrel (outer)
 102  3 -0.96  141 -138  142 -143 144 -145  151  imp:n=20
c  Aluminum barrel (bottom sides)
 103  5 -2.699  (138 135 -136 -149)  imp:n=50
c  extended B10 coating bottom of det#1
 104  6  -2.34  31 -30 152 -27 imp:n=300
c  extended B10 coating top of det#1
 105  6  -2.34  31 -30 28 -153 imp:n=300
c  extended B10 coating bottom of det#2
 106  6  -2.34  67 -66 154 -70 imp:n=300
c  extended B10 coating top of det#2
 107  6  -2.34  67 -66 71 -155 imp:n=300
c  extended B10 coating bottom of det#2
```

```
 108  6  -2.34  78 -77 156 -80 imp:n=300
c  extended B10 coating top of det#2
 109  6  -2.34  78 -77 82 -157 imp:n=300
c   hole in cad det#1 for temp sensor
 110  13 -.000114 -40 -20 22 34 -33 37 imp:n=90
c   DET#1 B-10 TALLY REGION 70%
 200  6  -2.34  160 -161 27 -28  imp:n=300
c   DET#1 B-10 TALLY REGION 60%
 201  6  -2.34  161 -162 27 -28  imp:n=300
c   DET#1 B-10 TALLY REGION 50%
 202  6  -2.34  162 -163 27 -28  imp:n=300
c   DET#1 B-10 TALLY REGION 40%
 203  6  -2.34  163 -164 27 -28  imp:n=300
c   DET#1 B-10 TALLY REGION 30%
 204  6  -2.34  164 -165 27 -28  imp:n=300
c   DET#1 B-10 TALLY REGION 20%
 205  6  -2.34  165 -166 27 -28  imp:n=300
c   DET#1 B-10 TALLY REGION 10%
 206  6  -2.34  166 -30 27 -28  imp:n=300
c   DET#2 B-10 TALLY REGION 70%
 207  6  -2.34  167 -168 70 -71  imp:n=310
c   DET#2 B-10 TALLY REGION 60%
 208  6  -2.34  168 -169 70 -71  imp:n=310
c   DET#2 B-10 TALLY REGION 50%
 209  6  -2.34  169 -170 70 -71  imp:n=310
c   DET#2 B-10 TALLY REGION 40%
 210  6  -2.34  170 -171 70 -71  imp:n=310
c   DET#2 B-10 TALLY REGION 30%
 211  6  -2.34  171 -172 70 -71  imp:n=310
c   DET#2 B-10 TALLY REGION 20%
 212  6  -2.34  172 -173 70 -71  imp:n=310
c   DET#2 B-10 TALLY REGION 10%
 213  6  -2.34  173 -66 70 -71   imp:n=310
c   DET#3 B-10 TALLY REGION 70%
 214  6  -2.34  174 -175 80 -82  imp:n=300
c   DET#3 B-10 TALLY REGION 60%
 215  6  -2.34  175 -176 80 -82  imp:n=300
c   DET#3 B-10 TALLY REGION 50%
 216  6  -2.34  176 -177 80 -82  imp:n=300
c   DET#3 B-10 TALLY REGION 40%
 217  6  -2.34  177 -178 80 -82  imp:n=300
c   DET#3 B-10 TALLY REGION 30%
 218  6  -2.34  178 -179 80 -82  imp:n=300
c   DET#3 B-10 TALLY REGION 20%
 219  6  -2.34  179 -180 80 -82  imp:n=300
c   DET#3 B-10 TALLY REGION 10%
 220  6  -2.34  180 -77 80 -82   imp:n=300
```

```
c   outside (void)
 150   0   -141:-142:143:-144:145:133  imp:n=0

   1      cz     4.2138599
   2      cz     3.8963599
   3      pz     0.0000000
   4      pz     0.3175000
   5      pz     1.5367000
c  outer source hole
   6     c/y     3.0480000     0.6604000     0.3568700
   7      px     2.5400000
   8      px     2.1844000
   9      py    -0.7112000
c  top of thin wall section of probe housing
  11       pz     10.426700
c  outer diameter of thick part (upper 2/3) of probe housing
  12      cz     4.3815
  13      pz     44.754799
  14      py     1.5240000
  15      py    -1.7780000
  16      px     2.3368000
  17      pz     1.2954000
  18     c/y     2.9718000     0.6604000     0.6350000
  19     c/y     0.0000000     1.7578   1.41478
  20     c/y     0.0000000     1.76000     1.28778
  21     c/y     0.0000000     1.76000     1.1480800
  22     c/y     0.0000000     1.76000     0.6400800
  23     c/y     0.0000000     1.76000     0.6350000
  24      p      0.3400000     0.0000000     1.0000000     2.3825200
  25      p      0.3400000     0.0000000     1.0000000     1.0833100
  26      py    -2.1285200
  27      py    -0.6299200
  28      py     2.3164800
  29      py     3.5864799
  30     c/y     0.0000000     1.76000     0.5588000
c  Inner B-10 lining 0.4 mg/cm2
  31     c/y     0.0000000     1.76000     0.5586265
  32      py     3.72618
  33      py     2.77622
  34      py     2.6365200
  35      py    -3.05562
  36      py    -2.9159200
  37     c/y     0.0000000     1.76000     0.77978
  38     c/y     0.0000000     1.76000     0.3175000
  39     c/y     0.0000000     2.73260     0.3175000
  40   c/y  0.822 1.41  0.3175
c  Hole in Cad under Det#3 for support rod
```

```
  41     c/z   -2.6974800    0.0000000    1.26492
  43      pz    0.47498
  44      pz    0.62738
  45      px   -3.3400999
  46      cz    0.7937500
  47      cz    0.6489700
  48      pz    11.772900
  49      pz    4.5084999
  50      pz    4.3433999
c  top of ss plate below det#3
  51      pz    4.6659799
c  radius of cad/SS shield
  52      cz    3.8353999
  53     c/z    3.0162500    0.0000000    0.5041900
c   inner polyethylene inner Det#2
c   poly outer Det#2
  56     c/z   -2.6974800    0.0000000    1.0096500
c   poly inner Det#2
  57     c/z   -2.6974800    0.0000000    0.6489700
  58     c/z   -2.6974800    0.0000000    0.6350000
  59      p   -16.436870    0.0000000    1.0000000    2.3825200
  60      py   -0.8970000
c   inner ss cad-plated peice for det#2
c   SS plated piece outer det#2
  61     c/z   -2.6974800    0.0000000    1.1112500
c   0.003" Cad outer Det#2
  62     c/z   -2.6974800    0.0000000    1.11379
c   polyimide outer
  63     c/z   -2.6974800    0.0000000    1.11887
c   Inner bottom cadmium Det#2
  64      pz    0.62992
c   Inside bottom ss plated peice det#2
  65      pz    0.71882
c   inner cathode det#2
  66     c/z   -2.6974800    0.0000000    0.5588000
c   inner B-10 coating det#2
  67     c/z   -2.6974800    0.0000000    0.5586265
c   inner top polyimide det#2
  68      pz    0.7239
c   inner bottom ss cathode det#2
c   Bottom Active Region DET#2
  69      pz    0.8001
  70      pz    2.1590000
c   top active region det#2
  71      pz    6.4769999
c   Inside top Det#2
  72      pz    7.8993999
```

```
c  Top of Det#2
 73      pz     7.9755999
c  top of polyethylene det#2
 74      pz     7.7165199
c  top of ss mounting sleeve det#2
 75      pz     7.2008999
c  Inner polyimid det#3
 76      cz     0.6438900
c  inner cathode Det#3
 77      cz     0.5676900
c  Inner B-10 lining Det#3
 78      cz     0.5675165
c  bottom Det#3
 79      pz     4.6710599
c  bottom active region det#3
 80      pz     6.1696599
c  inside bottom det#3
 81      pz     4.7472599
c  top active region det#3
 82      pz     10.487660
c  inside top det#3
 83      pz     11.910060
c  top det#3
 84      pz     11.986260
c  top mounting sleeve det#3
 85      pz     11.650980
c  through source slot
 86      pz     0.6604
c  through source slot
 87      px     2.9718
c  screw in cad shield X Y R
 88  c/z  -1.51 -2.6 0.18669
c  screw in cad shield X Y R
 89  c/z  -2.41 -1.82 0.18669
c  screw in cad shield X Y R
 90  c/z  -1.51 2.6 0.18669
c  screw in cad shield X Y R
 91  c/z  -0.37 2.99 0.18669
c  screw in cad shield X Y R
 92  c/z  2.78 -1.18 0.18669
c  slot in cad shield X Y R
 93  c/z  -.45 -3.40 0.4572
c  #10 threaded rod OD
 95  c/z 3.01625 0 0.2413
c  top of thick walled outer housing (17.875 in.)
 96  pz  45.4025
c  standoff around #10 threaded rod
```

```
  97  c/z 3.01625 0 0.3937
c  left side of det#1 stiffener
  98  px 1.44028
c  right side of det#1 stiffener
  99  px 1.51648
c  bottom of det#1 stiffener
 100  pz  1.5367
c front edge of det#1 stiffener
 101  py  -1.27
c back edge of det#1 stiffener
 102  py   1.27
c bottom of cable head
 103  pz   41.529
c   source holder threaded grab hole radius
 104      c/y     3.0480000      0.6604000      0.207
c  source capsule ID
 105   c/y    3.0480000      0.6604000  0.196
c   source holder nut radius
 106      c/y     3.0480000      0.6604000      0.40
c   source holder nut end
 107   py   -2.16
c   source holder thread/capsule interface
 108   py   -0.686
c   source holder capsule end
 109   py    0.686
c  source capsule inner bottom end
 110   py    0.450
c  source capsule inner top end
 111   py   -0.165
c  source capsule/holder OD
 112   c/y      3.0480000      0.6604000      0.3175
c  source OD
 113   c/y      3.0480000      0.6604000      0.00935
c  source top
 114   py   0.15185
c  source bottom
 115   py   0.13315
c  bottom (#1) electrical board (bottom)
 116   pz   16.756
c  bottom (#1) electrical board (top)
 117   pz   16.914
c  (#40) electrical SS ground plane (bottom)
 118   pz   18.971
c  (#40) electrical SS ground plane (top)
 119   pz   19.129
c  (#2) electrical board (bottom)
 120   pz   20.551
```

```
c  (#2) electrical board (top)
 121   pz   20.708
c  (#3) electrical board (bottom)
 122   pz   24.188
c  (#3) electrical board (top)
 123   pz   24.345
c  (#41) electrical SS ground plane (bottom)
 124   pz   28.307
c  (#41) electrical SS ground plane (top)
 125   pz   28.460
c  (#4) electrical board (bottom)
 126   pz   29.882
c  (#4) electrical board (top)
 127   pz   30.04
c  (#39) electrical SS ground plane (bottom)
 128   pz   31.462
c  (#39) electrical SS ground plane (top)
 129   pz   31.615
c  top shoulder of cable head
 130   pz  43.74
c  cable OD
 131   cz  1.06
c  approx top cable head nut
 132   pz  46.92
c   top of cable head
 133    pz   52.73
c   OD of cable head neck
 134    cz    1.4
c   ID Aluminum Barrel
 135    cz  38.1
c   OD Aluminum Barrel
 136    cz  38.58
c   inside bottom Al barrel ******
137    pz   -37.577
c   outside bottom Al barrel(18" - Hair)  Barrel#4 Hair = 2.831 in. ****
138    pz   -38.053
c    top of Al barrel *****
139    pz   7.191
c    top of top mixture
140   pz  -0.0794
c   polyethylene under barrel (bottom) ******
141   pz  -43.133
c   polyethylene under barrel (left side x)
142   px  -48.26
c   polyethylene under barrel (right side x)
143   px   48.26
c   polyethylene under barrel (front side y)
```

```
144   py  -48.26
c  polyethylene under barrel (back side y)
145   py   48.26
c  3 cm below top of mixture
146   pz  -3.0794
c  6 cm below top of mixture
147   pz  -6.0794
c  9 cm below top of mixture
148   pz  -9.0794
c  20 cm below top of mixture
149   pz  -20.0794
c  30 cm below top of mixture
150   pz  -30.0794
c  cylindrical importance map in barrel
151    cz   20.0
c  extension of B10 coating at bottom of det#1
152    py  -1.430
c  extension of B10 coating at top of det#1
153    py   3.116
c  extension of B10 coating at bottom of det#2
154    pz   1.245
c  extension of B10 coating at top of det#2
155    pz   7.391
c  extension of B10 coating at bottom of det#3
156    pz   5.256
c  extension of B10 coating at top of det#3
157    pz   11.402
c  inner B-10 coating 70% det#1
160   c/y  0.0 1.76  0.558679
c  inner B-10 coating 60% det#1
161  c/y  0.0 1.76  0.558696
c  inner B-10 coating 50% det#1
162   c/y  0.0 1.76  0.558713
c  inner B-10 coating 40% det#1
163   c/y  0.0 1.76  0.558731
c  inner B-10 coating 30% det#1
164   c/y  0.0 1.76  0.558748
c  inner B-10 coating 20% det#1
165   c/y  0.0 1.76  0.558766
c  inner B-10 coating 10% det#1
166   c/y  0.0 1.76  0.558783
c  inner B-10 coating 70% det#2
167   c/z  -2.69748  0.0  0.558679
c  inner B-10 coating 60% det#2
168  c/z  -2.69748  0.0 0.558696
c  inner B-10 coating 50% det#2
169   c/z  -2.69748  0.0  0.558713
```

```
c  inner B-10 coating 40% det#2
170  c/z  -2.69748  0.0  0.558731
c  inner B-10 coating 30% det#2
171  c/z  -2.69748  0.0  0.558748
c  inner B-10 coating 20% det#2
172  c/z  -2.69748  0.0  0.558766
c  inner B-10 coating 10% det#2
173  c/z  -2.69748  0.0  0.558783
c  inner B-10 coating 70% det#3
174  cz  0.567569
c  inner B-10 coating 60% det#3
175  cz   0.567586
c  inner B-10 coating 50% det#3
176  cz  0.567603
c  inner B-10 coating 40% det#3
177  cz  0.567621
c  inner B-10 coating 30% det#3
178  cz  0.567638
c  inner B-10 coating 20% det#3
179  cz  0.567656
c  inner B-10 coating 10% det#3
180  cz  0.567673
c outside sphere
 200   cz  70

mode  n
phys:n  20  20
c  15.0 micrograms Cf-252
sdef  cel d1  pos fcel d2  axs 0 1 0  ext fcel d3
     rad fcel d4  wgt=3.47e7  erg d5
sc1  source cell is Cf-252 source in cell 59
si1  l 59
sp1  d  1.0
sc2  source location is centered in cell 59
ds2  l  3.048 0.1425 0.6604
sc3  source extent
ds3  s  6
sc4  source radius
ds4  s  7
sc5  energy distribution: Cf-252 Watt Spontaneous Fission Spectrum
sp5  -3  1.025  2.926
sc6  source extent is 0.0187 centimeter total length
si6  0.00935
sp6  -21  0
sc7  source radius is .00935 centimeters
si7  0.0  0.00935
sp7  -21  1
```

```
e0    4e-7 7e-7 1.5e-6 3e-6 1e-5 1e-4 .1 2.2 20
f4:n    1 200 201 202 203 204 205 206 t  $ detector regions
c      0.1409  (B-10 atoms)/(barn-cm)
fm4     0.1409   6   207          $ (n,alpha) interactions
f14:n   2 207 208 209 210 211 212 213 t  $ detector regions
fm14    0.1409   6   207          $ (n,alpha) interactions
f24:n   3 214 215 216 217 218 219 220 t  $ detector regions
fm24    0.1409   6   207          $ (n,alpha) interactions
c                    Cf-252  -  Pd-Cf2O3
m1    98252.35c  -0.119
      98250.35c  -0.069
      8016.50c   -0.018
      46105.50c  -0.363
      46108.50c  -0.431
c                hydrated alimina + sand  (19.1 wt% water)
m2     1001.50c  -0.0216
       8016.50c  -0.5786
      11023.50c  -0.0009
      13027.50c  -0.1907
      14000.50c  -0.2080
      26000.55c  -0.0001
m2t   lwtr.01t
c                    UHMW Polyethylene (0.96 g/cm3)
m3    1001.50c 2.000000
     6000.50c 1.000000
m3t   poly.01t
c                    304 stainless steel (8.02 g/cm3)
m4    6000.50c   -0.08
      25055.50c  -2.0
      15031.50c  -0.045
      16032.50c  -0.03
      14000.50c  -0.75
      24000.50c  -19.0
      26000.55c  -68.245
      7014.50c   -0.1
      28000.50c  -9.75
c                    6061 Aluminum  (2.699 g/cm3)
m5    13027.50c  -97.92
      14000.50c  -0.6
      29000.50c  -0.28
      12000.50c  -1.0
      24000.50c  -0.2
c                    B-10 92% enriched  (2.34g/cm3)
m6     5010.50c  -.92
       5011.50c  -0.08
c                    polyimide (1.4 g/cm3)
m7     6000.50c   22
```

```
          1001.50c   14
          8016.50c   7
          7014.50c   2
m7t   poly.01t
c                   cadmium   (8.65 g/cm3)
m8    48000.50c    -1.00
c                   90%Ar + 10%CO2
m9     6000.50c   -0.027
          8016.50c  -0.073
         18000.35c  -0.900
c                   fiberglass/copper electrical boards
m10    1001.50c  -0.0453
          5010.50c  -0.00228        $ 8.1 wt% B2O3, 50 wt% fiber, 50 wt% epoxy
          5011.50c  -0.010206
          6000.50c  -0.282
          8016.50c  -0.4107
         11023.50c  -0.0103
         12000.50c  -0.0225
         13027.50c  -0.0337
         14000.50c  -0.1178
         16032.50c  -0.000399
         20000.50c  -0.0737
         22000.50c  -0.00686
         26000.55c  -0.00412
m10t    poly.01t                 $ hydrogen in poylethylene 300 K
c                   air (1.138e-3 g/cm3)
m13     7014.50c   0.8000
          8016.50c   0.2000
totnu
nps   100000000
print   60 120 126 140
```

Moisture Standard 1

```
< As-Built Surface Neutron, Cd d#1 .055", Cd d#2 .006", Stand#4 19wt%
---
> As-Built Surface Neutron Probe 1/22/96, Rev 0, Standard#3 13wt%
<  12   8  -8.65  ((34 -33 -20 22 40):(34 -32 22 -37 ):(-32 29 -22 )) imp:n=100
---
>    12    8  -8.65  (34 -33 -20 22 40):(34 -32 22 -37 ):(-32 29 -22 ) imp:n=100
<  29  9  -.001  (81 -83 -78):(157 -83 78 -77):(-156 81 78 -77) imp:n=300
---
```

```
> 29  9  -.001  (81 -83 -78):(157 -83 78 -77):(-156 81 78 -77) imp:n=300
<   84 2 -1.605 -140 146 -135 -151 imp:n=100
---
>   84 2 -1.781 -140 146 -135 -151 imp:n=100
<   85 2 -1.605 -146 147 -135 -151 imp:n=100
---
>   85 2 -1.781 -146 147 -135 -151 imp:n=100
<   86 2 -1.605 -147 148 -135 -151 imp:n=90
---
>   86 2 -1.781 -147 148 -135 -151 imp:n=90
<   87 2 -1.605 -148 149 -135 -151 imp:n=75
---
>   87 2 -1.781 -148 149 -135 -151 imp:n=75
<   88 2 -1.605 -149 150 -135 -151 imp:n=60
---
>   88 2 -1.781 -149 150 -135 -151 imp:n=60
<   89 2 -1.605 -150 137 -135 -151 imp:n=50
< c  Aluminum barrel (upper sides)
<   90 5 -2.699 (-139 135 -136 149) imp:n=90
---
>   89 2 -1.781 -150 137 -135 -151 imp:n=50
<   91 5 -2.699 -3 140 -135 imp:n=100
---
>   90 5 -2.699 -3 140 -135 imp:n=100
<   92  13 -.000114 3 -139 -135 1 #49 imp:n=100
---
>   91  13 -.000114 3 -139 -135 1 #49 imp:n=100
<   93  3 -0.96 141 -138 -151 imp:n=30
< c  air around barrel
<   94 13 -.000114 136 138 -139 142 -143 144 -145 imp:n=40
---
>   92  3 -0.96 141 -138 -151 imp:n=30
> c  poly under barrel (outer)
>   93  3 -0.96  141 -138  142 -143 144 -145  151  imp:n=15
> c  Aluminum barrel (bottom sides)
>   94 5 -2.699  (138 135 -136 -149)  imp:n=50
<   96 2 -1.605 -140 146 -135 151 imp:n=100
---
>   96 2 -1.781 -140 146 -135 151 imp:n=100
<   97 2 -1.605 -146 147 -135 151 imp:n=90
---
>   97 2 -1.781 -146 147 -135 151 imp:n=90
<   98 2 -1.605 -147 148 -135 151 imp:n=80
---
>   98 2 -1.781 -147 148 -135 151 imp:n=80
<   99 2 -1.605 -148 149 -135 151 imp:n=65
---
```

```
>   99 2 -1.781 -148 149 -135 151 imp:n=65
<  100 2 -1.605 -149 150 -135 151 imp:n=50
---
>  100 2 -1.781 -149 150 -135 151 imp:n=50
<  101 2 -1.605 -150 137 -135 151 imp:n=40
< c  poly under barrel (outer)
<  102  3 -0.96  141 -138  142 -143 144 -145  151  imp:n=20
< c  Aluminum barrel (bottom sides)
<  103  5 -2.699  (138 135 -136 -149)  imp:n=50
< c  extended B10 coating bottom of det#1
---
>  101 2 -1.781 -150 137 -135 151 imp:n=40
> c  air around barrel
>  102 13 -.000114 136 138 -139 142 -143 144 -145 imp:n=40
> c  Aluminum barrel (upper sides)
>  103 5 -2.699 (-139 135 -136 149) imp:n=90
< c   hole in cad det#1 for temp sensor
<  110  13 -.000114 -40 -20 22 34 -33 37 imp:n=90
---
> 110  13 -.000114 -40 -20 22 34 -33 37 imp:n=90
< c   0.003" Cad outer Det#2
---
> c   0.001" Cad outer Det#2
< 135    cz  38.1
---
> 135    cz  48.1
< 136    cz  38.58
---
> 136    cz  48.58
< 137    pz   -37.577
< c   outside bottom Al barrel(18" - Hair)  Barrel#4 Hair = 2.831 in. ****
< 138    pz   -38.053
---
> 137    pz   -62.7
> c   outside bottom Al barrel   Hair = 1.531 in. ****
> 138    pz   -63.18
< 139    pz   7.191
---
> 139    pz   3.81
< 141   pz  -43.133
---
> 141   pz  -73.34
< 142   px  -48.26
---
> 142   px  -48.59
< 143   px   48.26
---
```

```
> 143   px   48.59
< 144   py  -48.26
---
> 144   py  -48.59
< 145   py   48.26
---
> 145   py   48.59
< 151    cz   20.0
---
> 151    cz   26.0
< phys:n   20  20
< c              hydrated alumina + sand  (19.33 wt% water)
< m2      1001.50c  -0.0216
<        8016.50c  -0.5786
<       11023.50c  -0.0009
<       13027.50c  -0.1907
<       14000.50c  -0.2080
---
> c              hydrated alumina + sand  (3.57 wt% water)
> m2      1001.50c  -0.0043
>        8016.50c  -0.5417
>       11023.50c  -0.0004
>       13027.50c  -0.0375
>       14000.50c  -0.4160
< nps   100000000
---
> nps    26000000
```

Moisture Standard 2

```
< As-Built Surface Neutron, Cd d#1 .055", Cd d#2 .006", Stand#4 19wt%
---
> As-Built Surface Neutron Probe 1/22/96, Rev 0, Standard#2 8wt%
<  12   8  -8.65  ((34 -33 -20 22 40):(34 -32 22 -37 ):(-32 29 -22 )) imp:n=100
---
> 12   8  -8.65  ((34 -33 -20 22 40):(34 -32 22 -37 ):(-32 29 -22 )) imp:n=100
<  29  9  -.001  (81 -83 -78):(157 -83 78 -77):(-156 81 78 -77) imp:n=300
---
> 29  9  -.001  (81 -83 -78):(157 -83 78 -77):(-156 81 78 -77) imp:n=300
<    84 2 -1.605 -140 146 -135 -151 imp:n=100
---
>    84 2 -1.696 -140 146 -135 -151 imp:n=100
<    85 2 -1.605 -146 147 -135 -151 imp:n=100
---
```

```
>  85 2 -1.696 -146 147 -135 -151 imp:n=100
<  86 2 -1.605 -147 148 -135 -151 imp:n=90
---
>  86 2 -1.696 -147 148 -135 -151 imp:n=90
<  87 2 -1.605 -148 149 -135 -151 imp:n=75
---
>  87 2 -1.696 -148 149 -135 -151 imp:n=75
<  88 2 -1.605 -149 150 -135 -151 imp:n=60
---
>  88 2 -1.696 -149 150 -135 -151 imp:n=60
<  89 2 -1.605 -150 137 -135 -151 imp:n=50
---
>  89 2 -1.696 -150 137 -135 -151 imp:n=50
<  96 2 -1.605 -140 146 -135 151 imp:n=100
---
>  96 2 -1.696 -140 146 -135 151 imp:n=100
<  97 2 -1.605 -146 147 -135 151 imp:n=90
---
>  97 2 -1.696 -146 147 -135 151 imp:n=90
<  98 2 -1.605 -147 148 -135 151 imp:n=80
---
>  98 2 -1.696 -147 148 -135 151 imp:n=80
<  99 2 -1.605 -148 149 -135 151 imp:n=65
---
>  99 2 -1.696 -148 149 -135 151 imp:n=65
<  100 2 -1.605 -149 150 -135 151 imp:n=50
---
>  100 2 -1.696 -149 150 -135 151 imp:n=50
<  101 2 -1.605 -150 137 -135 151 imp:n=40
---
>  101 2 -1.696 -150 137 -135 151 imp:n=40
<  110  13 -.000114 -40 -20 22 34 -33 37 imp:n=90
---
>  110  13 -.000114 -40 -20 22 34 -33  37 imp:n=90
< 137    pz   -37.577
< c   outside bottom Al barrel(18" - Hair)  Barrel#4 Hair = 2.831 in. ****
< 138    pz   -38.053
---
> 137    pz   -39.042
> c   outside bottom Al barrel(18" - Hair)  Barrel#2 Hair = 2.629 in. ****
> 138    pz   -39.518
< 139    pz   7.191
< c    top of top mixture
---
> 139    pz   6.678
> c    top of top mixture
< 141   pz  -43.133
```

```
---
> 141   pz  -49.678
< c   polyethylene under barrel (right side x)
---
> c   polyethylene under barrel (right side x)
< c   polyethylene under barrel (back side y)
---
> c   polyethylene under barrel (back side y)
< phys:n   20  20
< c              hydrated alumina + sand  (19.33 wt% water)
< m2     1001.50c  -0.0216
<       8016.50c  -0.5786
<      11023.50c  -0.0009
<      13027.50c  -0.1907
<      14000.50c  -0.2080
---
> c              hydrated alumina + sand  (8.04 wt% water)
> m2     1001.50c  -0.0089
>       8016.50c  -0.5516
>      11023.50c  -0.0006
>      13027.50c  -0.0785
>      14000.50c  -0.3603
< nps   100000000
---
> nps   28000000
```

Moisture Standard 3

```
< As-Built Surface Neutron, Cd d#1 .055", Cd d#2 .006", Stand#4 19wt%
---
> As-Built Surface Neutron Probe 1/22/96, Rev 0, Standard#3 13wt%
<  12   8  -8.65  ((34 -33 -20 22 40):(34 -32 22 -37 ):(-32 29 -22 )) imp:n=100
---
>   12     8  -8.65  (34 -33 -20 22 40):(34 -32 22 -37 ):(-32 29 -22 ) imp:n=100
<  29  9  -.001  (81 -83 -78):(157 -83 78 -77):(-156 81 78 -77) imp:n=300
---
> 29  9  -.001  (81 -83 -78):(157 -83 78 -77):(-156 81 78 -77) imp:n=300
<   84 2 -1.605 -140 146 -135 -151 imp:n=100
---
>   84 2 -1.636 -140 146 -135 -151 imp:n=100
<   85 2 -1.605 -146 147 -135 -151 imp:n=100
---
>   85 2 -1.636 -146 147 -135 -151 imp:n=100
<   86 2 -1.605 -147 148 -135 -151 imp:n=90
```

```
---
>  86 2 -1.636 -147 148 -135 -151 imp:n=90
<  87 2 -1.605 -148 149 -135 -151 imp:n=75
---
>  87 2 -1.636 -148 149 -135 -151 imp:n=75
<  88 2 -1.605 -149 150 -135 -151 imp:n=60
---
>  88 2 -1.636 -149 150 -135 -151 imp:n=60
<  89 2 -1.605 -150 137 -135 -151 imp:n=50
---
>  89 2 -1.636 -150 137 -135 -151 imp:n=50
<  96 2 -1.605 -140 146 -135 151 imp:n=100
---
>  96 2 -1.636 -140 146 -135 151 imp:n=100
<  97 2 -1.605 -146 147 -135 151 imp:n=90
---
>  97 2 -1.636 -146 147 -135 151 imp:n=90
<  98 2 -1.605 -147 148 -135 151 imp:n=80
---
>  98 2 -1.636 -147 148 -135 151 imp:n=80
<  99 2 -1.605 -148 149 -135 151 imp:n=65
---
>  99 2 -1.636 -148 149 -135 151 imp:n=65
<  100 2 -1.605 -149 150 -135 151 imp:n=50
---
>  100 2 -1.636 -149 150 -135 151 imp:n=50
<  101 2 -1.605 -150 137 -135 151 imp:n=40
---
>  101 2 -1.636 -150 137 -135 151 imp:n=40
< 137    pz  -37.577
< c   outside bottom Al barrel(18" - Hair)  Barrel#4 Hair = 2.831 in. ****
< 138    pz  -38.053
---
> 137    pz  -37.849
> c   outside bottom Al barrel(18" - Hair)  Barrel#3 Hair = 3.099 in. ****
> 138    pz  -38.325
< 139    pz  7.191
< c    top of top mixture
---
> 139    pz  7.871
> c    top of top mixture *******
< 141   pz  -43.133
---
> 141   pz  -43.405
< phys:n   20  20
< c              hydrated alumina + sand  (19.33 wt% water)
< m2      1001.50c  -0.0216
```

```
<       8016.50c  -0.5786
<      11023.50c  -0.0009
<      13027.50c  -0.1907
<      14000.50c  -0.2080
---
> c              hydrated alumina + sand  (12.48 wt% water)
> m2      1001.50c  -0.0140
>       8016.50c  -0.5623
>      11023.50c  -0.0007
>      13027.50c  -0.1229
>      14000.50c  -0.3000
< nps   100000000
< print   60 120 126 140
---
> nps   30000000
> print   60 110 120 126 140
```

## Moisture Standard 5

```
< As-Built Surface Neutron, Cd d#1 .055", Cd d#2 .006", Stand#4 19wt%
---
> As-Built Surface Neutron Probe 1/22/96, Rev 0, Standard#4 19wt%
<  12   8  -8.65  ((34 -33 -20 22 40):(34 -32 22 -37 ):(-32 29 -22 )) imp:n=100
---
>   12    8  -8.65  (34 -33 -20 22 40):(34 -32 22 -37 ):(-32 29 -22 ) imp:n=100
<  29  9  -.001  (81 -83 -78):(157 -83 78 -77):(-156 81 78 -77) imp:n=300
---
> 29  9  -.001  (81 -83 -78):(157 -83 78 -77):(-156 81 78 -77) imp:n=300
<   84 2 -1.605 -140 146 -135 -151 imp:n=100
---
>   84 2 -1.587 -140 146 -135 -151 imp:n=100
<   85 2 -1.605 -146 147 -135 -151 imp:n=100
---
>   85 2 -1.587 -146 147 -135 -151 imp:n=100
<   86 2 -1.605 -147 148 -135 -151 imp:n=90
---
>   86 2 -1.587 -147 148 -135 -151 imp:n=90
<   87 2 -1.605 -148 149 -135 -151 imp:n=75
---
>   87 2 -1.587 -148 149 -135 -151 imp:n=75
<   88 2 -1.605 -149 150 -135 -151 imp:n=60
---
>   88 2 -1.587 -149 150 -135 -151 imp:n=60
<   89 2 -1.605 -150 137 -135 -151 imp:n=50
```

```
---
>  89 2 -1.587 -150 137 -135 -151 imp:n=50
<  96 2 -1.605 -140 146 -135 151 imp:n=100
---
>  96 2 -1.587 -140 146 -135 151 imp:n=100
<  97 2 -1.605 -146 147 -135 151 imp:n=90
---
>  97 2 -1.587 -146 147 -135 151 imp:n=90
<  98 2 -1.605 -147 148 -135 151 imp:n=80
---
>  98 2 -1.587 -147 148 -135 151 imp:n=80
<  99 2 -1.605 -148 149 -135 151 imp:n=65
---
>  99 2 -1.587 -148 149 -135 151 imp:n=65
< 100 2 -1.605 -149 150 -135 151 imp:n=50
---
> 100 2 -1.587 -149 150 -135 151 imp:n=50
< 101 2 -1.605 -150 137 -135 151 imp:n=40
---
> 101 2 -1.587 -150 137 -135 151 imp:n=40
< 137    pz   -37.577
< c   outside bottom Al barrel(18" - Hair)  Barrel#4 Hair = 2.831 in. ****
< 138    pz   -38.053
---
> 137    pz   -38.483
> c   outside bottom Al barrel(18" - Hair)  Barrel#5 Hair = 2.849 in. ****
> 138    pz   -38.959
< 139    pz   7.191
---
> 139    pz   7.237
< 141   pz  -43.133
---
> 141   pz  -41.499
< phys:n   20  20
< c              hydrated alumina + sand  (19.33 wt% water)
< m2      1001.50c  -0.0216
<          8016.50c  -0.5786
<         11023.50c  -0.0009
<         13027.50c  -0.1907
<         14000.50c  -0.2080
---
> c              hydrated alumina + sand  (25.29 wt% water)
> m2      1001.50c  -0.0283
>          8016.50c  -0.5929
>         11023.50c  -0.0012
>         13027.50c  -0.2496
>         14000.50c  -0.1280
```

```
---
> ctme    935
```

Moisture Standard 6

```
< As-Built Surface Neutron, Cd d#1 .055", Cd d#2 .006", Stand#4 19wt%
---
> As-Built Surface Neutron Probe 1/22/96, Rev 0, Standard#3 13wt%
<  12   8  -8.65  ((34 -33 -20 22 40):(34 -32 22 -37 ):(-32 29 -22 )) imp:n=100
---
> 12   8  -8.65  ((34 -33 -20 22 40):(34 -32 22 -37 ):(-32 29 -22 )) imp:n=100
<  29  9  -.001  (81 -83 -78):(157 -83 78 -77):(-156 81 78 -77) imp:n=300
---
> 29  9  -.001  (81 -83 -78):(157 -83 78 -77):(-156 81 78 -77) imp:n=300
<    84 2 -1.605 -140 146 -135 -151 imp:n=100
---
>    84 2 -1.512 -140 146 -135 -151 imp:n=100
<    85 2 -1.605 -146 147 -135 -151 imp:n=100
---
>    85 2 -1.512 -146 147 -135 -151 imp:n=100
<    86 2 -1.605 -147 148 -135 -151 imp:n=90
---
>    86 2 -1.512 -147 148 -135 -151 imp:n=90
<    87 2 -1.605 -148 149 -135 -151 imp:n=75
---
>    87 2 -1.512 -148 149 -135 -151 imp:n=75
<    88 2 -1.605 -149 150 -135 -151 imp:n=60
---
>    88 2 -1.512 -149 150 -135 -151 imp:n=60
<    89 2 -1.605 -150 137 -135 -151 imp:n=50
---
>    89 2 -1.512 -150 137 -135 -151 imp:n=50
<    96 2 -1.605 -140 146 -135 151 imp:n=100
---
>    96 2 -1.512 -140 146 -135 151 imp:n=100
<    97 2 -1.605 -146 147 -135 151 imp:n=90
---
>    97 2 -1.512 -146 147 -135 151 imp:n=90
<    98 2 -1.605 -147 148 -135 151 imp:n=80
---
>    98 2 -1.512 -147 148 -135 151 imp:n=80
<    99 2 -1.605 -148 149 -135 151 imp:n=65
---
>    99 2 -1.512 -148 149 -135 151 imp:n=65
```

```
<  100 2 -1.605 -149 150 -135 151 imp:n=50
---
>  100 2 -1.512 -149 150 -135 151 imp:n=50
<  101 2 -1.605 -150 137 -135 151 imp:n=40
---
>  101 2 -1.512 -150 137 -135 151 imp:n=40
<  110  13 -.000114 -40 -20 22 34 -33 37 imp:n=90
---
> 110  13 -.000114 -40 -20 22 34 -33 37 imp:n=90
<   63      c/z    -2.6974800     0.0000000     1.11887
---
>   63      c/z    -2.6974800     0.0000000     1.11887
< 137    pz   -37.577
< c   outside bottom Al barrel(18" - Hair)  Barrel#4 Hair = 2.831 in. ****
< 138    pz   -38.053
---
> 137    pz   -38.933
> c   outside bottom Al barrel(18" - Hair)  Barrel#6 Hair = 2.672 in. ****
> 138    pz   -39.409
< 139    pz   7.191
---
> 139    pz   6.787
< 141   pz  -43.133
---
> 141   pz  -41.949
< phys:n   20  20
< c              hydrated alumina + sand  (19.33 wt% water)
< m2      1001.50c  -0.0216
<        8016.50c  -0.5786
<       11023.50c  -0.0009
<       13027.50c  -0.1907
<       14000.50c  -0.2080
<       26000.55c  -0.0001
---
> c              hydrated alumina + sand  (34.47 wt% water)
> m2      1001.50c  -0.0386
>        8016.50c  -0.6148
>       11023.50c  -0.0015
>       13027.50c  -0.3405
>       14000.50c  -0.0046
< nps   100000000
---
> nps    24000000
```

Moisture Standard 7

```
< As-Built Surface Neutron, Cd d#1 .055", Cd d#2 .006", Stand#4 19wt%
---
> As-Built Surface Neutron Probe 1/22/96, Rev 0, Standard#7 13wt%
< 12  8 -8.65  ((34 -33 -20 22 40):(34 -32 22 -37 ):(-32 29 -22 )) imp:n=100
---
>   12  8 -8.65  ((34 -33 -20 22 40):(34 -32 22 -37 ):(-32 29 -22 )) imp:n=100
<   18  9 -.001 (69 -72 -67):(155 67 -66 -72):(-154 67 -66 69) imp:n=310
---
>  18  9 -.001 (69 -72 -67):(155 67 -66 -72):(-154 67 -66 69) imp:n=310
<   84 2 -1.605 -140 146 -135 -151 imp:n=100
---
>   84 11 -1.47 -140 146 -135 -151 imp:n=100
<   85 2 -1.605 -146 147 -135 -151 imp:n=100
---
>   85 2 -1.62 -146 147 -135 -151 imp:n=100
<   86 2 -1.605 -147 148 -135 -151 imp:n=90
---
>   86 2 -1.62 -147 148 -135 -151 imp:n=90
<   87 2 -1.605 -148 149 -135 -151 imp:n=75
---
>   87 2 -1.62 -148 149 -135 -151 imp:n=75
<   88 2 -1.605 -149 150 -135 -151 imp:n=60
---
>   88 2 -1.62 -149 150 -135 -151 imp:n=60
<   89 2 -1.605 -150 137 -135 -151 imp:n=50
---
>   89 2 -1.62 -150 137 -135 -151 imp:n=50
<   96 2 -1.605 -140 146 -135 151 imp:n=100
---
>   96 11 -1.54 -140 146 -135 151 imp:n=100
<   97 2 -1.605 -146 147 -135 151 imp:n=90
---
>   97 2 -1.629 -146 147 -135 151 imp:n=90
<   98 2 -1.605 -147 148 -135 151 imp:n=80
---
>   98 2 -1.629 -147 148 -135 151 imp:n=80
<   99 2 -1.605 -148 149 -135 151 imp:n=65
---
>   99 2 -1.629 -148 149 -135 151 imp:n=65
<  100 2 -1.605 -149 150 -135 151 imp:n=50
---
>  100 2 -1.629 -149 150 -135 151 imp:n=50
<  101 2 -1.605 -150 137 -135 151 imp:n=40
---
>  101 2 -1.629 -150 137 -135 151 imp:n=40
```

```
< 137   pz  -37.577
< c   outside bottom Al barrel(18" - Hair)  Barrel#4 Hair = 2.831 in. ****
< 138   pz  -38.053
---
> 137   pz  -38.212
> c   outside bottom Al barrel(18" - Hair)  Barrel#7 Hair = 2.956 in. ****
> 138   pz  -38.688
< 139   pz  7.191
< c    top of top mixture
< 140   pz  -0.0794
---
> 139   pz  7.509
> c    top of top mixture *******
> 140   pz  -0.4414
< 141   pz  -43.133
---
> 141   pz  -43.767
< c   3 cm below top of mixture
< 146   pz  -3.0794
---
> c   boundary 8/13 wt%
> 146   pz  -2.871
< phys:n   20  20
< c              hydrated alumina + sand  (19.33 wt% water)
< m2      1001.50c  -0.0216
<          8016.50c  -0.5786
<         11023.50c  -0.0009
<         13027.50c  -0.1907
<         14000.50c  -0.2080
---
> c              hydrated alumina + sand  (13.18 wt% water)
> m2      1001.50c  -0.0147
>          8016.50c  -0.5640
>         11023.50c  -0.0007
>         13027.50c  -0.1298
>         14000.50c  -0.2907
> c              hydrated alumina + sand  (8.52 wt% water)
> m11     1001.50c  -0.0095
>          8016.50c  -0.5528
>         11023.50c  -0.0006
>         13027.50c  -0.0837
>         14000.50c  -0.3533
>         26000.55c  -0.0001
> m11t    lwtr.01t
< nps   100000000
< print   60 120 126 140
---
```

```
> nps    45000000
> print   60 110 120 126 140
```

Moisture Standard 8

```
< As-Built Surface Neutron, Cd d#1 .055", Cd d#2 .006", Stand#4 19wt%
---
> As-Built Surface Neutron Probe 1/22/96, Rev 0, Standard#8 13wt%
< 12   8  -8.65  ((34 -33 -20 22 40):(34 -32 22 -37 ):(-32 29 -22 )) imp:n=100
---
>    12   8  -8.65  ((34 -33 -20 22 40):(34 -32 22 -37 ):(-32 29 -22 )) imp:n=100
<    18  9 -.001 (69 -72 -67):(155 67 -66 -72):(-154 67 -66 69) imp:n=310
---
>   18  9 -.001 (69 -72 -67):(155 67 -66 -72):(-154 67 -66 69) imp:n=310
<    84 2 -1.605 -140 146 -135 -151 imp:n=100
---
>    84 11 -1.690 -140 146 -135 -151 imp:n=100
<    85 2 -1.605 -146 147 -135 -151 imp:n=100
---
>    85 12 -1.460 -146 147 -135 -151 imp:n=100
<    86 2 -1.605 -147 148 -135 -151 imp:n=90
---
>    86 2 -1.738 -147 148 -135 -151 imp:n=90
<    87 2 -1.605 -148 149 -135 -151 imp:n=75
---
>    87 2 -1.738 -148 149 -135 -151 imp:n=75
<    88 2 -1.605 -149 150 -135 -151 imp:n=60
---
>    88 2 -1.738 -149 150 -135 -151 imp:n=60
<    89 2 -1.605 -150 137 -135 -151 imp:n=50
---
>    89 2 -1.738 -150 137 -135 -151 imp:n=50
<    96 2 -1.605 -140 146 -135 151 imp:n=100
---
>    96 11 -1.690 -140 146 -135 151 imp:n=100
<    97 2 -1.605 -146 147 -135 151 imp:n=90
---
>    97 12 -1.460 -146 147 -135 151 imp:n=90
<    98 2 -1.605 -147 148 -135 151 imp:n=80
---
>    98 2 -1.740 -147 148 -135 151 imp:n=80
<    99 2 -1.605 -148 149 -135 151 imp:n=65
---
>    99 2 -1.740 -148 149 -135 151 imp:n=65
```

```
<  100 2 -1.605 -149 150 -135 151 imp:n=50
---
>  100 2 -1.740 -149 150 -135 151 imp:n=50
<  101 2 -1.605 -150 137 -135 151 imp:n=40
---
>  101 2 -1.740 -150 137 -135 151 imp:n=40
< 137    pz   -37.577
< c   outside bottom Al barrel(18" - Hair)  Barrel#4 Hair = 2.831 in. ****
< 138    pz   -38.053
---
> 137    pz   -38.529
> c   outside bottom Al barrel(18" - Hair)  Barrel#8 Hair = 2.831 in. ****
> 138    pz   -39.006
< 141   pz  -43.133
---
> 141   pz  -44.085
< phys:n   20  20
< c              hydrated alumina + sand  (19.33 wt% water)
< m2      1001.50c  -0.0216
<        8016.50c  -0.5786
---
> c              hydrated alumina + sand  (19.01 wt% water)
> m2      1001.50c  -0.0213
>        8016.50c  -0.5779
<       13027.50c  -0.1907
<       14000.50c  -0.2080
---
>       13027.50c  -0.1875
>       14000.50c  -0.2123
> c              hydrated alumina + sand  (8.23 wt% water)
> m11     1001.50c  -0.0092
>        8016.50c  -0.5521
>       11023.50c  -0.0006
>       13027.50c  -0.0808
>       14000.50c  -0.3572
>       26000.55c  -0.0001
> m11t    lwtr.01t
> c              hydrated alumina + sand  (13.23 wt% water)
> m12     1001.50c  -0.0148
>        8016.50c  -0.5641
>       11023.50c  -0.0007
>       13027.50c  -0.1303
>       14000.50c  -0.2900
>       26000.55c  -0.0001
> m12t    lwtr.01t
< nps   100000000
---
```

```
> nps   45000000
```

Moisture Standard 9

```
< As-Built Surface Neutron, Cd d#1 .055", Cd d#2 .006", Stand#4 19wt%
---
> As-Built Surface Neutron Probe 1/22/96, Rev 0, Standard#9 13wt%
<  12   8  -8.65  ((34 -33 -20 22 40):(34 -32 22 -37 ):(-32 29 -22 )) imp:n=100
---
>   12     8  -8.65  (34 -33 -20 22 40):(34 -32 22 -37 ):(-32 29 -22 ) imp:n=100
<   18  9 -.001 (69 -72 -67):(155 67 -66 -72):(-154 67 -66 69) imp:n=310
---
>  18  9 -.001 (69 -72 -67):(155 67 -66 -72):(-154 67 -66 69) imp:n=310
<   84 2 -1.605 -140 146 -135 -151 imp:n=100
---
>   84 11 -1.59 -140 146 -135 -151 imp:n=100
<   85 2 -1.605 -146 147 -135 -151 imp:n=100
---
>   85 2 -1.615 -146 147 -135 -151 imp:n=100
<   86 2 -1.605 -147 148 -135 -151 imp:n=90
---
>   86 2 -1.615 -147 148 -135 -151 imp:n=90
<   87 2 -1.605 -148 149 -135 -151 imp:n=75
---
>   87 2 -1.615 -148 149 -135 -151 imp:n=75
<   88 2 -1.605 -149 150 -135 -151 imp:n=60
---
>   88 2 -1.615 -149 150 -135 -151 imp:n=60
<   89 2 -1.605 -150 137 -135 -151 imp:n=50
---
>   89 2 -1.615 -150 137 -135 -151 imp:n=50
<   96 2 -1.605 -140 146 -135 151 imp:n=100
---
>   96 11 -1.53 -140 146 -135 151 imp:n=100
<   97 2 -1.605 -146 147 -135 151 imp:n=90
---
>   97 2 -1.620 -146 147 -135 151 imp:n=90
<   98 2 -1.605 -147 148 -135 151 imp:n=80
---
>   98 2 -1.620 -147 148 -135 151 imp:n=80
<   99 2 -1.605 -148 149 -135 151 imp:n=65
---
>   99 2 -1.620 -148 149 -135 151 imp:n=65
<  100 2 -1.605 -149 150 -135 151 imp:n=50
```

```
---
> 100 2 -1.620 -149 150 -135 151 imp:n=50
< 101 2 -1.605 -150 137 -135 151 imp:n=40
---
> 101 2 -1.620 -150 137 -135 151 imp:n=40
< 137   pz  -37.577
< c  outside bottom Al barrel(18" - Hair)  Barrel#4 Hair = 2.831 in. ****
< 138   pz  -38.053
---
> 137   pz  -38.12
> c  outside bottom Al barrel(18" - Hair)  Barrel#9 Hair = 2.992 in. ****
> 138   pz  -38.597
< 139   pz  7.191
---
> 139   pz  7.5997
< 141  pz  -43.133
---
> 141  pz  -43.676
< 146  pz  -3.0794
---
> 146  pz  -2.7127
< phys:n  20  20
< c              hydrated alumina + sand  (19.33 wt% water)
< m2     1001.50c  -0.0216
<        8016.50c  -0.5786
<       11023.50c  -0.0009
<       13027.50c  -0.1907
<       14000.50c  -0.2080
---
> c              hydrated alumina + sand  (19.4 wt% water)
> m2     1001.50c  -0.0217
>        8016.50c  -0.5788
>       11023.50c  -0.0010
>       13027.50c  -0.1913
>       14000.50c  -0.2071
> c              hydrated alumina + sand  (13.02 wt% water)
> m11     1001.50c  -0.0146
>        8016.50c  -0.5636
>       11023.50c  -0.0007
>       13027.50c  -0.1282
>       14000.50c  -0.2928
>       26000.55c  -0.0001
> m11t   lwtr.01t
> c                    BY-104 Saltcake Simulant, 15% H2O
> m15    1001.50c  -0.017168
>        7014.50c  -0.1234
>        8016.50c  -0.5923
```

```
>       11023.50c  -0.2466
>       12000.50c  -0.0003
>       13027.50c  -0.0126
>       14000.50c  -0.0031
>       15031.50c  -0.0012
>       20000.50c  -0.0009
>       25055.50c  -0.0005
>       26000.55c  -0.0021
> m15t    lwtr.01t
< nps   100000000
---
> nps   35000000
```

Moisture Standard 10

```
< As-Built Surface Neutron, Cd d#1 .055", Cd d#2 .006", Stand#4 19wt%
---
> As-Built Surface Neutron Probe 1/22/96, Rev 0, Standard#10 19wt%
<  12   8  -8.65  ((34 -33 -20 22 40):(34 -32 22 -37 ):(-32 29 -22 )) imp:n=100
---
>    12   8  -8.65  ((34 -33 -20 22 40):(34 -32 22 -37 ):(-32 29 -22 )) imp:n=100
<  29  9  -.001  (81 -83 -78):(157 -83 78 -77):(-156 81 78 -77) imp:n=300
---
>    29  9  -.001  (81 -83 -78):(157 -83 78 -77):(-156 81 78 -77) imp:n=300
<    84 2 -1.605 -140 146 -135 -151 imp:n=100
---
>    84 11 -1.66 -140 146 -135 -151 imp:n=100
<    85 2 -1.605 -146 147 -135 -151 imp:n=100
---
>    85 12 -1.44 -146 147 -135 -151 imp:n=100
<    86 2 -1.605 -147 148 -135 -151 imp:n=90
---
>    86 2 -1.595 -147 148 -135 -151 imp:n=90
<    87 2 -1.605 -148 149 -135 -151 imp:n=75
---
>    87 2 -1.595 -148 149 -135 -151 imp:n=75
<    88 2 -1.605 -149 150 -135 -151 imp:n=60
---
>    88 2 -1.595 -149 150 -135 -151 imp:n=60
<    89 2 -1.605 -150 137 -135 -151 imp:n=50
---
>    89 2 -1.595 -150 137 -135 -151 imp:n=50
<    96 2 -1.605 -140 146 -135 151 imp:n=100
---
```

```
>   96 11 -1.63 -140 146 -135 151 imp:n=100
<   97 2 -1.605 -146 147 -135 151 imp:n=90
---
>   97 12 -1.42 -146 147 -135 151 imp:n=90
<   98 2 -1.605 -147 148 -135 151 imp:n=80
---
>   98 2 -1.600 -147 148 -135 151 imp:n=80
<   99 2 -1.605 -148 149 -135 151 imp:n=65
---
>   99 2 -1.600 -148 149 -135 151 imp:n=65
<  100 2 -1.605 -149 150 -135 151 imp:n=50
---
>  100 2 -1.600 -149 150 -135 151 imp:n=50
<  101 2 -1.605 -150 137 -135 151 imp:n=40
---
>  101 2 -1.600 -150 137 -135 151 imp:n=40
< 137   pz  -37.577
< c   outside bottom Al barrel(18" - Hair)  Barrel#4 Hair = 2.831 in. ****
< 138   pz  -38.053
---
> 137   pz  -38.72
> c   outside bottom Al barrel(18" - Hair)  Barrel#10 Hair = 2.756 in. ****
> 138   pz  -39.20
< 139   pz  7.191
< c    top of top mixture
---
> 139   pz  7.08
> c    top of 13% layer mixture
< 141   pz  -43.133
---
> 141   pz  -41.50
< c   3 cm below top of mixture
< 146   pz  -3.0794
< c   6 cm below top of mixture
< 147   pz  -6.0794
---
> c   top of 19% layer
> 146   pz  -2.882
> c   top of 25% layer
> 147   pz  -5.961
< phys:n   20  20
< c             hydrated alumina + sand  (19.33 wt% water)
< m2      1001.50c  -0.0216
<         8016.50c  -0.5786
<        11023.50c  -0.0009
<        13027.50c  -0.1907
<        14000.50c  -0.2080
```

```
---
> c              hydrated alumina + sand  (25.03 wt% water)
> m2      1001.50c  -0.0280
>        8016.50c  -0.5922
>       11023.50c  -0.0011
>       13027.50c  -0.2470
>       14000.50c  -0.1315
> c              hydrated alumina + sand  (13.13 wt% water)
> m11     1001.50c  -0.0147
>        8016.50c  -0.5638
>       11023.50c  -0.0007
>       13027.50c  -0.1292
>       14000.50c  -0.2914
>       26000.55c  -0.0001
> m11t   lwtr.01t
> c              hydrated alumina + sand  (19.14 wt% water)
> m12     1001.50c  -0.0214
>        8016.50c  -0.5782
>       11023.50c  -0.0009
>       13027.50c  -0.1887
>       14000.50c  -0.2106
>       26000.55c  -0.0001
> m12t   lwtr.01t
< nps   100000000
---
> nps    35000000
```

Moisture Standard 11

```
< As-Built Surface Neutron, Cd d#1 .055", Cd d#2 .006", Stand#4 19wt%
---
> As-Built Surface Neutron Probe 1/22/96, Rev 0, Standard#11 19wt%, low B
< c   Polyethylene Det#1
---
> c   Polyethylene Det#1
< c   main cadmium Det#1
---
> c   main cadmium Det#1
<  12   8  -8.65  ((34 -33 -20 22 40):(34 -32 22 -37 ):(-32 29 -22 )) imp:n=100
---
>   12   8  -8.65  ((34 -33 -20 22 40):(34 -32 22 -37 ):(-32 29 -22 )) imp:n=100
<   18  9 -.001 (69 -72 -67):(155 67 -66 -72):(-154 67 -66 69) imp:n=310
---
>  18  9 -.001 (69 -72 -67):(155 67 -66 -72):(-154 67 -66 69) imp:n=310
```

```
<   84 2 -1.605 -140 146 -135 -151 imp:n=100
---
>   84 2 -1.601 -140 146 -135 -151 imp:n=100
<   85 2 -1.605 -146 147 -135 -151 imp:n=100
---
>   85 2 -1.601 -146 147 -135 -151 imp:n=100
<   86 2 -1.605 -147 148 -135 -151 imp:n=90
---
>   86 2 -1.601 -147 148 -135 -151 imp:n=90
<   87 2 -1.605 -148 149 -135 -151 imp:n=75
---
>   87 2 -1.601 -148 149 -135 -151 imp:n=75
<   88 2 -1.605 -149 150 -135 -151 imp:n=60
---
>   88 2 -1.601 -149 150 -135 -151 imp:n=60
<   89 2 -1.605 -150 137 -135 -151 imp:n=50
---
>   89 2 -1.601 -150 137 -135 -151 imp:n=50
<   96 2 -1.605 -140 146 -135 151 imp:n=100
---
>   96 2 -1.601 -140 146 -135 151 imp:n=100
<   97 2 -1.605 -146 147 -135 151 imp:n=90
---
>   97 2 -1.601 -146 147 -135 151 imp:n=90
<   98 2 -1.605 -147 148 -135 151 imp:n=80
---
>   98 2 -1.601 -147 148 -135 151 imp:n=80
<   99 2 -1.605 -148 149 -135 151 imp:n=65
---
>   99 2 -1.601 -148 149 -135 151 imp:n=65
<  100 2 -1.605 -149 150 -135 151 imp:n=50
---
>  100 2 -1.601 -149 150 -135 151 imp:n=50
<  101 2 -1.605 -150 137 -135 151 imp:n=40
---
>  101 2 -1.601 -150 137 -135 151 imp:n=40
< c   hole in cad det#1 for temp sensor
---
> c    outside (void)
>  c   hole in cad det#1 for temp sensor
< c    outside (void)
<  150   0   -141:-142:143:-144:145:133  imp:n=0
---
> 150   0   -141:-142:143:-144:145:133  imp:n=0
< c   Bottom Active Region DET#2
> c   Bottom Active Region DET#2
< 137    pz   -37.577
```

```
< c   outside bottom Al barrel(18" - Hair)  Barrel#4 Hair = 2.831 in. ****
< 138    pz   -38.053
---
> 137    pz   -38.064
> c   outside bottom Al barrel(18" - Hair)  Barrel#11 Hair = 3.014 in. ****
> 138    pz   -38.54
< 141   pz  -43.133
---
> 141   pz  -43.62
< phys:n   20  20
< c              hydrated alumina + sand  (19.33 wt% water)
< m2      1001.50c  -0.0216
<         8016.50c  -0.5786
---
> c              hydrated alumina + sand  (19.14 wt% water, 0.0018 wt% B)
> m2      1001.50c  -0.0214
>         5010.50c  -0.00000319
>         5011.50c  -0.0000149
>         6000.50c  -0.000005
>         8016.50c  -0.5782
<        13027.50c  -0.1907
<        14000.50c  -0.2080
---
>        13027.50c  -0.1888
>        14000.50c  -0.2106
< nps   100000000
---
> nps   25000000
```

Moisture Standard 12

```
< As-Built Surface Neutron, Cd d#1 .055", Cd d#2 .006", Stand#4 19wt%
---
> As-Built Surface Neutron Probe 1/22/96, Rev 0, Standard#12 19wt%, high B
<  12   8  -8.65  ((34 -33 -20 22 40):(34 -32 22 -37 ):(-32 29 -22 )) imp:n=100
---
>    12   8  -8.65  ((34 -33 -20 22 40):(34 -32 22 -37 ):(-32 29 -22 )) imp:n=100
<    18  9 -.001 (69 -72 -67):(155 67 -66 -72):(-154 67 -66 69) imp:n=310
---
>   18  9 -.001 (69 -72 -67):(155 67 -66 -72):(-154 67 -66 69) imp:n=310
<    84 2 -1.605 -140 146 -135 -151 imp:n=100
---
>    84 2 -1.603 -140 146 -135 -151 imp:n=100
<    85 2 -1.605 -146 147 -135 -151 imp:n=100
```

```
---
>  85 2 -1.603 -146 147 -135 -151 imp:n=100
<  86 2 -1.605 -147 148 -135 -151 imp:n=90
---
>  86 2 -1.603 -147 148 -135 -151 imp:n=90
<  87 2 -1.605 -148 149 -135 -151 imp:n=75
---
>  87 2 -1.603 -148 149 -135 -151 imp:n=75
<  88 2 -1.605 -149 150 -135 -151 imp:n=60
---
>  88 2 -1.603 -149 150 -135 -151 imp:n=60
<  89 2 -1.605 -150 137 -135 -151 imp:n=50
---
>  89 2 -1.603 -150 137 -135 -151 imp:n=50
<  96 2 -1.605 -140 146 -135 151 imp:n=100
---
>  96 2 -1.603 -140 146 -135 151 imp:n=100
<  97 2 -1.605 -146 147 -135 151 imp:n=90
---
>  97 2 -1.603 -146 147 -135 151 imp:n=90
<  98 2 -1.605 -147 148 -135 151 imp:n=80
---
>  98 2 -1.603 -147 148 -135 151 imp:n=80
<  99 2 -1.605 -148 149 -135 151 imp:n=65
---
>  99 2 -1.603 -148 149 -135 151 imp:n=65
<  100 2 -1.605 -149 150 -135 151 imp:n=50
---
>  100 2 -1.603 -149 150 -135 151 imp:n=50
<  101 2 -1.605 -150 137 -135 151 imp:n=40
---
>  101 2 -1.603 -150 137 -135 151 imp:n=40
< c   Bottom Active Region DET#2
> c   Bottom Active Region DET#2
< 137    pz   -37.577
---
> 137    pz   -37.922
< 138    pz   -38.053
---
> 138    pz   -38.398
< 141   pz  -43.133
---
> 141   pz  -43.478
< phys:n   20  20
< c              hydrated alumina + sand  (19.33 wt% water)
< m2      1001.50c  -0.0216
<         8016.50c  -0.5786
```

```
<       11023.50c  -0.0009
<       13027.50c  -0.1907
<       14000.50c  -0.2080
---
> c               hydrated alumina + sand  (7.9 wt% water, 0.0036 wt% B)
> m2      1001.50c  -0.0088
>        8016.50c  -0.5513
>       11023.50c  -0.0006
>       13027.50c  -0.0774
>       14000.50c  -0.3618
< nps   100000000
---
> nps   25000000
```

Moisture Standard 13

```
< As-Built Surface Neutron, Cd d#1 .055", Cd d#2 .006", Stand#4 19wt%
---
> As-Built Surface Neutron Probe 1/22/96, Rev 0, Standard#3 13wt%
<  12   8  -8.65  ((34 -33 -20 22 40):(34 -32 22 -37 ):(-32 29 -22 )) imp:n=100
---
> 12   8  -8.65  ((34 -33 -20 22 40):(34 -32 22 -37 ):(-32 29 -22 )) imp:n=100
<    84 2 -1.605 -140 146 -135 -151 imp:n=100
---
>    84 2 -1.475 -140 -137 -135 -151 imp:n=100
<    85 2 -1.605 -146 147 -135 -151 imp:n=100
---
> c   85 2 -1.475 -146 147 -135 -151 imp:n=100
<    86 2 -1.605 -147 148 -135 -151 imp:n=90
---
> c   86 2 -1.475 -147 148 -135 -151 imp:n=90
<    87 2 -1.605 -148 149 -135 -151 imp:n=75
---
> c   87 2 -1.475 -148 149 -135 -151 imp:n=75
<    88 2 -1.605 -149 150 -135 -151 imp:n=60
---
> c   88 2 -1.475 -149 150 -135 -151 imp:n=60
<    89 2 -1.605 -150 137 -135 -151 imp:n=50
---
> c   89 2 -1.475 -150 137 -135 -151 imp:n=50
<    90 5 -2.699 (-139 135 -136 149) imp:n=90
---
>    90 5 -2.699 (-139 135 -136 -137) imp:n=90
< c  poly under barrel (inner cylinder)
```

```
<   93  3 -0.96 141 -138 -151 imp:n=30
---
> c  aluminum stand under barrel (inner cylinder)
>   93  5 -2.699 141 -158 -151 imp:n=80
<   94 13 -.000114 136 138 -139 142 -143 144 -145 imp:n=40
---
>   94 13 -.000114 136 158 -139 142 -143 144 -145 imp:n=40
<   95 5 -2.699 -135 138 -137 imp:n=40
---
>   95 5 -2.699 -135 -138 137 #93 imp:n=90
<   96 2 -1.605 -140 146 -135 151 imp:n=100
---
>   96 2 -1.475 -140 -137 -135 151 imp:n=100
<   97 2 -1.605 -146 147 -135 151 imp:n=90
---
> c   97 2 -1.475 -146 147 -135 151 imp:n=90
<   98 2 -1.605 -147 148 -135 151 imp:n=80
---
> c   98 2 -1.475 -147 148 -135 151 imp:n=80
<   99 2 -1.605 -148 149 -135 151 imp:n=65
---
> c   99 2 -1.475 -148 149 -135 151 imp:n=65
<  100 2 -1.605 -149 150 -135 151 imp:n=50
---
> c  100 2 -1.475 -149 150 -135 151 imp:n=50
<  101 2 -1.605 -150 137 -135 151 imp:n=40
< c  poly under barrel (outer)
<  102  3 -0.96  141 -138  142 -143 144 -145  151  imp:n=20
---
> c  101 2 -1.475 -150 137 -135 151 imp:n=40
> c  aluminum stand under barrel (outer)
>  102  5 -2.699 141 -158  142 -143 144 -145  151  imp:n=80
<  103  5 -2.699  (138 135 -136 -149)  imp:n=50
---
>  103  5 -2.699  (-138 135 -136 137)  imp:n=80
<  110  13 -.000114 -40 -20 22 34 -33 37 imp:n=90
---
> 110  13 -.000114 -40 -20 22 34 -33 37 imp:n=90
> c  air gap under barrel
> 225  13  -.000114   -136 138 158 imp:n=80
< c   inside bottom Al barrel ******
< 137    pz   -37.577
< c   outside bottom Al barrel(18" - Hair)  Barrel#4 Hair = 2.831 in. ****
< 138    pz   -38.053
< c    top of Al barrel *****
< 139    pz   7.191
---
```

```
> c   inside bottom Al barrel (outside bottom +0.9525cm)******
> 137    sz   721.2008 725.675
> c   outside bottom Al barrel(18-3/8" - Hair)  Barrel#13 Hair = 16.445 in.****
> 138    sz   720.7246 725.675
> c    top of Al barrel (outside bottom +45.72cm)*****
> 139    pz   41.77
< c   polyethylene under barrel (bottom) ******
< 141   pz  -43.133
---
> c   aluminum under barrel (bottom) (outside bottom - 0.635cm)******
> 141   pz  -5.40114
> c aluminum undder barrel (top)
> 158    pz   -4.98045
< phys:n   20  20
< c               hydrated alumina + sand  (19.33 wt% water)
< m2      1001.50c  -0.0216
<        8016.50c  -0.5786
<       11023.50c  -0.0009
<       13027.50c  -0.1907
<       14000.50c  -0.2080
---
> c               hydrated alumina + sand  (19.4 wt% water)
> m2      1001.50c  -0.0217
>        8016.50c  -0.5788
>       11023.50c  -0.0010
>       13027.50c  -0.1914
>       14000.50c  -0.2071
< nps   100000000
---
> nps   120000000
```

Moisture Standard 14

```
< As-Built Surface Neutron, Cd d#1 .055", Cd d#2 .006", Stand#4 19wt%
---
> As-Built Surface Neutron Probe 1/22/96, Rev 0, Standard#14 19wt%
<  12   8  -8.65  ((34 -33 -20 22 40):(34 -32 22 -37 ):(-32 29 -22 )) imp:n=100
---
> 12   8  -8.65  ((34 -33 -20 22 40):(34 -32 22 -37 ):(-32 29 -22 )) imp:n=100
<  29  9  -.001  (81 -83 -78):(157 -83 78 -77):(-156 81 78 -77) imp:n=300
---
> 29  9  -.001  (81 -83 -78):(157 -83 78 -77):(-156 81 78 -77) imp:n=300
<    84 2 -1.605 -140 146 -135 -151 imp:n=100
---
```

```
>   84 2 -1.543 -140 -137 -135 -151 imp:n=100
<   85 2 -1.605 -146 147 -135 -151 imp:n=100
---
> c  85 2 -1.543 -146 147 -135 -151 imp:n=100
<   86 2 -1.605 -147 148 -135 -151 imp:n=90
---
> c  86 2 -1.543 -147 148 -135 -151 imp:n=90
<   87 2 -1.605 -148 149 -135 -151 imp:n=75
---
> c  87 2 -1.543 -148 149 -135 -151 imp:n=75
<   88 2 -1.605 -149 150 -135 -151 imp:n=60
---
> c  88 2 -1.543 -149 150 -135 -151 imp:n=60
<   89 2 -1.605 -150 137 -135 -151 imp:n=50
---
> c  89 2 -1.543 -150 137 -135 -151 imp:n=50
<   90 5 -2.699 (-139 135 -136 149) imp:n=90
---
>   90 5 -2.699 (-139 135 -136 -137) imp:n=90
< c  poly under barrel (inner cylinder)
<   93  3 -0.96 141 -138 -151 imp:n=30
---
> c  aluminum stand under barrel (inner cylinder)
>   93  5 -2.699 141 -158 -151 imp:n=80
<   94 13 -.000114 136 138 -139 142 -143 144 -145 imp:n=40
---
>   94 13 -.000114 136 158 -139 142 -143 144 -145 imp:n=40
<   95 5 -2.699 -135 138 -137 imp:n=40
---
>   95 5 -2.699 -135 -138 137 #93 imp:n=90
<   96 2 -1.605 -140 146 -135 151 imp:n=100
---
>   96 2 -1.543 -140 -137 -135 151 imp:n=100
<   97 2 -1.605 -146 147 -135 151 imp:n=90
---
> c  97 2 -1.543 -146 147 -135 151 imp:n=90
<   98 2 -1.605 -147 148 -135 151 imp:n=80
---
> c  98 2 -1.543 -147 148 -135 151 imp:n=80
<   99 2 -1.605 -148 149 -135 151 imp:n=65
---
> c  99 2 -1.543 -148 149 -135 151 imp:n=65
<  100 2 -1.605 -149 150 -135 151 imp:n=50
---
> c  100 2 -1.543 -149 150 -135 151 imp:n=50
<  101 2 -1.605 -150 137 -135 151 imp:n=40
< c  poly under barrel (outer)
```

```
<  102  3 -0.96  141 -138  142 -143 144 -145  151  imp:n=20
---
> c  101 2 -1.543 -150 137 -135 151 imp:n=40
> c  aluminum stand under barrel (outer)
>  102  5 -2.699 141 -158  142 -143 144 -145  151  imp:n=80
<  103  5 -2.699  (138 135 -136 -149)  imp:n=50
---
>  103  5 -2.699  (-138 135 -136 137)  imp:n=80
<  110  13 -.000114 -40 -20 22 34 -33 37 imp:n=90
---
>  110  13 -.000114 -40 -20 22 34 -33 37 imp:n=90
> c   air gap under barrel
>  225 13 -.000114   -136 138 158  imp:n=80
<   19      c/y      0.0000000      1.7578     1.41478
---
>   19      c/y      0.0000000      1.7578      1.41478
<   63      c/z    -2.6974800      0.0000000      1.11887
---
>   63      c/z    -2.6974800      0.0000000      1.11887
<  135    cz  38.1
---
>  135    cz  38.3
<  136    cz  38.58
< c   inside bottom Al barrel ******
< 137    pz   -37.577
< c   outside bottom Al barrel(18" - Hair)  Barrel#4 Hair = 2.831 in. ****
< 138    pz   -38.053
< c    top of Al barrel *****
< 139    pz    7.191
---
>  136    cz  38.78
> c   inside bottom Al barrel (outside bottom +0.9525cm)******
> 137    sz   727.4235  733.945
> c   outside bottom Al barrel(18" - Hair)  Barrel#14 Hair = 15.738 in. ****
> 138    sz   726.9472  733.945
> c    top of Al barrel (outside bottom +45.72cm)*****
> 139    pz   39.975
< c   polyethylene under barrel (bottom) ******
< 141   pz  -43.133
---
> c   aluminum under barrel (bottom) (outside bottom - 0.635cm)******
> 141   pz  -7.4184
> c  aluminum under barrel (top)
> 158    pz -6.9977
< phys:n   20  20
< c                hydrated alumina + sand  (19.33 wt% water)
< m2       1001.50c  -0.0216
```

```
<       8016.50c  -0.5786
---
> c               hydrated alumina + sand  (18.93 wt% water)
> m2      1001.50c  -0.0212
>       8016.50c  -0.5777
<      13027.50c  -0.1907
<      14000.50c  -0.2080
---
>      13027.50c  -0.1867
>      14000.50c  -0.2134
< nps   100000000
---
> nps   60000000
```

Moisture Standard 15

```
< As-Built Surface Neutron, Cd d#1 .055", Cd d#2 .006", Stand#4 19wt%
---
> As-Built Surface Neutron Probe 1/22/96, Rev 0, Standard#15 19wt%
<  12   8  -8.65  ((34 -33 -20 22 40):(34 -32 22 -37 ):(-32 29 -22 )) imp:n=100
---
> 12   8  -8.65  ((34 -33 -20 22 40):(34 -32 22 -37):(-32 29 -22)) imp:n=100
<  29  9  -.001  (81 -83 -78):(157 -83 78 -77):(-156 81 78 -77) imp:n=300
---
> 29  9  -.001  (81 -83 -78):(157 -83 78 -77):(-156 81 78 -77) imp:n=300
<    84 2 -1.605 -140 146 -135 -151 imp:n=100
---
>    84 2 -1.583 -140 -137 -135 -151 imp:n=100
<    85 2 -1.605 -146 147 -135 -151 imp:n=100
---
> c   85 2 -1.429 -146 147 -135 -151 imp:n=100
<    86 2 -1.605 -147 148 -135 -151 imp:n=90
---
> c   86 2 -1.429 -147 148 -135 -151 imp:n=90
<    87 2 -1.605 -148 149 -135 -151 imp:n=75
---
> c   87 2 -1.429 -148 149 -135 -151 imp:n=75
<    88 2 -1.605 -149 150 -135 -151 imp:n=60
---
> c   88 2 -1.429 -149 150 -135 -151 imp:n=60
<    89 2 -1.605 -150 137 -135 -151 imp:n=50
---
> c   89 2 -1.429 -150 137 -135 -151 imp:n=50
<    90 5 -2.699 (-139 135 -136 149) imp:n=90
```

```
---
>   90 5 -2.699 (-139 135 -136 -137) imp:n=90
< c  poly under barrel (inner cylinder)
<   93  3 -0.96 141 -138 -151 imp:n=30
---
> c  aluminum stand under barrel (inner cylinder)
>   93  5 -2.699 141 -158 -151 imp:n=80
<   94 13 -.000114 136 138 -139 142 -143 144 -145 imp:n=40
---
>   94 13 -.000114 136 158 -139 142 -143 144 -145 imp:n=40
<   95 5 -2.699 -135 138 -137 imp:n=40
---
>   95 5 -2.699 -135 -138 137 #93 imp:n=90
<   96 2 -1.605 -140 146 -135 151 imp:n=100
---
>   96 2 -1.583 -140 -137 -135 151 imp:n=100
<   97 2 -1.605 -146 147 -135 151 imp:n=90
---
> c   97 2 -1.429 -146 147 -135 151 imp:n=90
<   98 2 -1.605 -147 148 -135 151 imp:n=80
---
> c   98 2 -1.429 -147 148 -135 151 imp:n=80
<   99 2 -1.605 -148 149 -135 151 imp:n=65
---
> c   99 2 -1.429 -148 149 -135 151 imp:n=65
<  100 2 -1.605 -149 150 -135 151 imp:n=50
---
> c  100 2 -1.429 -149 150 -135 151 imp:n=50
<  101 2 -1.605 -150 137 -135 151 imp:n=40
< c  poly under barrel (outer)
<  102  3 -0.96  141 -138  142 -143 144 -145  151  imp:n=20
---
> c  101 2 -1.429 -150 137 -135 151 imp:n=40
> c  aluminum stand under barrel (outer)
>  102  5 -2.699 141 -158  142 -143 144 -145 151  imp:n=80
<  103  5 -2.699  (138 135 -136 -149)  imp:n=50
---
>  103  5 -2.699  (-138 135 -136 137)  imp:n=80
< c   hole in cad det#1 for temp sensor
<  110  13 -.000114 -40 -20 22 34 -33 37 imp:n=90
---
> 110  13 -.000114 -40 -20 22 34 -33 37 imp:n=90
> c   air gap under barrel
>  225 13 -.000114   -136 138 158  imp:n=80
< c   inside bottom Al barrel ******
< 137    pz   -37.577
< c   outside bottom Al barrel(18" - Hair)  Barrel#4 Hair = 2.831 in. ****
```

```
< 138   pz  -38.053
< c   top of Al barrel *****
< 139   pz   7.191
---
> c  inside bottom Al barrel (outside bottom +0.9525cm)******
> 137    sz  725.6755  733.945
> c  outside bottom Al barrel(18" - Hair)  Barrel#15 Hair = 15.094 in. ****
> 138    sz  725.2032  733.945
> c   top of Al barrel (outside bottom +45.72cm)*****
> 139   pz   38.339
< c  polyethylene under barrel (bottom) ******
< 141   pz  -43.133
---
> c  aluminum under barrel (bottom) (outside bottom - 0.635cm)******
> 141   pz  -9.1664
> c  aluminum under barrel (top)
> 158   pz -8.7457
< phys:n   20  20
< e0    4e-7 7e-7 1.5e-6 3e-6 1e-5 1e-4 .1 2.2 20
< c              hydrated alumina + sand  (19.33 wt% water)
< m2      1001.50c  -0.0216
<        8016.50c  -0.5786
---
> c              hydrated alumina + sand  (18.82 wt% water)
> m2      1001.50c  -0.0211
>        8016.50c  -0.5774
<       13027.50c  -0.1907
<       14000.50c  -0.2080
---
>       13027.50c  -0.1856
>       14000.50c  -0.2149
< nps   100000000
---
> nps   60000000
```

Moisture Standard 16

```
< As-Built Surface Neutron, Cd d#1 .055", Cd d#2 .006", Stand#4 19wt%
---
> As-Built Surface Neutron Probe 1/22/96, Rev 0, Standard#3 13wt%
<  12   8  -8.65  ((34 -33 -20 22 40):(34 -32 22 -37 ):(-32 29 -22 )) imp:n=100
---
> 12   8  -8.65  ((34 -33 -20 22 40):(34 -32 22 -37 ):(-32 29 -22 )) imp:n=100
<  29  9  -.001  (81 -83 -78):(157 -83 78 -77):(-156 81 78 -77) imp:n=300
```

```
---
> 29  9  -.001  (81 -83 -78):(157 -83 78 -77):(-156 81 78 -77) imp:n=300
<   84 2 -1.605 -140 146 -135 -151 imp:n=100
---
>   84 2 -1.642 -140 -137 -135 -151 imp:n=100
<   85 2 -1.605 -146 147 -135 -151 imp:n=100
---
> c  85 2 -1.429 -146 147 -135 -151 imp:n=100
<   86 2 -1.605 -147 148 -135 -151 imp:n=90
---
> c  86 2 -1.429 -147 148 -135 -151 imp:n=90
<   87 2 -1.605 -148 149 -135 -151 imp:n=75
---
> c  87 2 -1.429 -148 149 -135 -151 imp:n=75
<   88 2 -1.605 -149 150 -135 -151 imp:n=60
---
> c  88 2 -1.429 -149 150 -135 -151 imp:n=60
<   89 2 -1.605 -150 137 -135 -151 imp:n=50
---
> c  89 2 -1.429 -150 137 -135 -151 imp:n=50
<   90 5 -2.699 (-139 135 -136 149) imp:n=90
---
>   90 5 -2.699 (-139 135 -136 -137) imp:n=90
< c  poly under barrel (inner cylinder)
<   93  3 -0.96 141 -138 -151 imp:n=30
---
> c  aluminum stand under barrel (inner cylinder)
>   93  5 -2.699 141 -158 -151 imp:n=80
<   94 13 -.000114 136 138 -139 142 -143 144 -145 imp:n=40
---
>   94 13 -.000114 136 158 -139 142 -143 144 -145 imp:n=40
<   95 5 -2.699 -135 138 -137 imp:n=40
---
>   95 5 -2.699 -135 -138 137 #93 imp:n=90
<   96 2 -1.605 -140 146 -135 151 imp:n=100
---
>   96 2 -1.642 -140 -137 -135 151 imp:n=100
<   97 2 -1.605 -146 147 -135 151 imp:n=90
---
> c  97 2 -1.429 -146 147 -135 151 imp:n=90
<   98 2 -1.605 -147 148 -135 151 imp:n=80
---
> c  98 2 -1.429 -147 148 -135 151 imp:n=80
<   99 2 -1.605 -148 149 -135 151 imp:n=65
---
> c  99 2 -1.429 -148 149 -135 151 imp:n=65
<  100 2 -1.605 -149 150 -135 151 imp:n=50
```

```
---
> c  100 2 -1.429 -149 150 -135 151 imp:n=50
<  101 2 -1.605 -150 137 -135 151 imp:n=40
< c  poly under barrel (outer)
<  102  3 -0.96  141 -138  142 -143 144 -145  151  imp:n=20
---
> c  101 2 -1.429 -150 137 -135 151 imp:n=40
> c  aluminum stand under barrel (outer)
>  102  5 -2.699 141 -158  142 -143 144 -145  151  imp:n=80
<  103  5 -2.699  (138 135 -136 -149)  imp:n=50
---
>  103  5 -2.699  (-138 135 -136 137)  imp:n=80
< c   hole in cad det#1 for temp sensor
<  110  13 -.000114 -40 -20 22 34 -33 37 imp:n=90
---
> 110  13 -.000114 -40 -20 22 34 -33 37 imp:n=90
> c   air gap under barrel
>  225 13 -.000114   -136 138 158  imp:n=80
< c   inside bottom Al barrel ******
< 137    pz   -37.577
< c   outside bottom Al barrel(18" - Hair)  Barrel#4 Hair = 2.831 in. ****
< 138    pz   -38.053
< c    top of Al barrel *****
< 139    pz   7.191
---
> c   inside bottom Al barrel (outside bottom +0.9525cm)******
> 137    sz   722.8055  733.945
> c   outside bottom Al barrel(18" - Hair)  Barrel#16 Hair = 13.8875 in. ****
> 138    sz   722.3332  733.945
> c    top of Al barrel (outside bottom +45.72cm)*****
> 139    pz   35.274
< c   polyethylene under barrel (bottom) ******
< 141   pz  -43.133
---
> c   aluminum under barrel (bottom) (outside bottom - 0.635cm)******
> 141   pz  -12.0364
< c   inner B-10 coating 70% det#1
---
> c  aluminum under barrel (top)
> 158    pz -11.6157
> c   inner B-10 coating 70% det#1
< phys:n   20  20
602,603c604,605
< c               hydrated alumina + sand  (19.33 wt% water)
< m2      1001.50c  -0.0216
<        8016.50c  -0.5786
---
```

```
> c              hydrated alumina + sand  (19.13 wt% water)
> m2     1001.50c  -0.0214
>       8016.50c  -0.5782
<      13027.50c  -0.1907
<      14000.50c  -0.2080
---
>      13027.50c  -0.1887
>      14000.50c  -0.2107
< nps   100000000
---
> nps   60000000
```

# Appendix J. CURVECUT Output from Processing of Final Calibration Measurement Data.

Table J-1. Output from CURVECUT Data Processing Code for the Final Experimental Calibration Data Measured with Probe 1 (Displayed in Figures 5-16, 5-17 and 5-18).

| | Probe 1 | | | | | | |
|---|---|---|---|---|---|---|---|
| | Detector | Peak | Cut off | Ref | Raw Rate | Rate | Error |
| Background | 1 | 46 | 191 | 491 | 54.61 | 30.083 | 0.127 |
| | 2 | 52 | 171 | 471 | 40.199 | 26.673 | 0.12 |
| | 3 | 51 | 239 | 539 | 8.096 | 3.842 | 0.045 |
| | | | | | | | |
| Moisture Standard 1 | 1 | 46 | 219 | 519 | 106.71 | 57.913 | 0.214 |
| | 2 | 48 | 182 | 482 | 112.19 | 74.401 | 0.243 |
| | 3 | 54 | 224 | 524 | 44.837 | 27.649 | 0.148 |
| | | | | | | | |
| Moisture Standard 2 | 1 | 43 | 191 | 491 | 135.443 | 81.553 | 0.275 |
| | 2 | 51 | 182 | 482 | 151.578 | 101.444 | 0.306 |
| | 3 | 49 | 215 | 515 | 73.144 | 47.401 | 0.209 |
| | | | | | | | |
| Moisture Standard 3 | 1 | 44 | 206 | 506 | 171.523 | 100.243 | 0.313 |
| | 2 | 48 | 167 | 467 | 200.534 | 140.341 | 0.371 |
| | 3 | 50 | 223 | 523 | 112.796 | 72.377 | 0.266 |
| | | | | | | | |
| Moisture Standard 4 | 1 | 44 | 208 | 508 | 209.069 | 122.745 | 0.347 |
| | 2 | 48 | 168 | 468 | 248.542 | 173.374 | 0.412 |
| | 3 | 49 | 229 | 529 | 147.568 | 93.646 | 0.303 |
| | | | | | | | |
| Moisture Standard 5 | 1 | 43 | 202 | 502 | 243.59 | 146.679 | 0.379 |
| | 2 | 49 | 166 | 466 | 286.372 | 200.611 | 0.443 |
| | 3 | 49 | 226 | 526 | 168.537 | 108.181 | 0.326 |
| | | | | | | | |
| Moisture Standard 6 | 1 | 44 | 201 | 501 | 282.248 | 171.978 | 0.423 |
| | 2 | 50 | 172 | 472 | 323.086 | 222.997 | 0.482 |
| | 3 | 48 | 232 | 532 | 185.476 | 116.866 | 0.349 |

Table J-2. Output from CURVECUT Data Processing Code for the Final Experimental Calibration Data Measured with Probe 2 (Displayed in Figures 5-16, 5-17 and 5-18).

| | Probe 2 | | | | | | |
|---|---|---|---|---|---|---|---|
| | Detector | Peak | Cut off | Ref | Raw Rate | Rate | Error |
| Background | 1 | 47 | 185 | 485 | 59.974 | 32.768 | 0.145 |
| | 2 | 50 | 170 | 470 | 40.994 | 27.403 | 0.133 |
| | 3 | 49 | 210 | 510 | 8.969 | 4.531 | 0.054 |
| | | | | | | | |
| Moisture Standard 1 | 1 | 44 | 187 | 487 | 115.994 | 67.638 | 0.25 |
| | 2 | 51 | 164 | 464 | 115.005 | 79.934 | 0.272 |
| | 3 | 48 | 206 | 506 | 50.057 | 31.476 | 0.171 |
| | | | | | | | |
| Moisture Standard 2 | 1 | 44 | 187 | 487 | 149.1 | 88.834 | 0.304 |
| | 2 | 55 | 155 | 455 | 158.631 | 114.268 | 0.345 |
| | 3 | 49 | 205 | 505 | 83.528 | 53.547 | 0.236 |
| | | | | | | | |
| Moisture Standard 3 | 1 | 43 | 197 | 497 | 186.273 | 109.24 | 0.337 |
| | 2 | 50 | 164 | 464 | 208.424 | 146.543 | 0.391 |
| | 3 | 53 | 201 | 501 | 128.161 | 84.297 | 0.296 |
| | | | | | | | |
| Moisture Standard 4 | 1 | 48 | 187 | 487 | 224.766 | 137.115 | 0.378 |
| | 2 | 50 | 163 | 463 | 256.441 | 181.096 | 0.434 |
| | 3 | 49 | 196 | 496 | 165.641 | 110.785 | 0.34 |
| | | | | | | | |
| Moisture Standard 5 | 1 | 43 | 183 | 483 | 260.226 | 161.311 | 0.41 |
| | 2 | 49 | 166 | 466 | 291.107 | 203.546 | 0.46 |
| | 3 | 48 | 198 | 498 | 191.071 | 127.542 | 0.364 |
| | | | | | | | |
| Moisture Standard 6 | 1 | 43 | 188 | 488 | 301.185 | 185.096 | 0.439 |
| | 2 | 48 | 166 | 466 | 332.741 | 232.489 | 0.492 |
| | 3 | 49 | 198 | 498 | 207.355 | 138.265 | 0.38 |

Table J-3. Output from CURVECUT Data Processing Code for the Final Experimental Calibration Data Measured with Probe 3 (Displayed in Figures 5-16, 5-17 and 5-18).

| | Probe 3 | | | | | | |
|---|---|---|---|---|---|---|---|
| | Detector | Peak | Cut off | Ref | Raw Rate | Rate | Error |
| Moisture Standard 1 | 1 | 43 | 240 | 540 | 82.95 | 43.158 | 0.2 |
| | 2 | 50 | 151 | 451 | 87.26 | 62.87 | 0.241 |
| | 3 | 49 | 174 | 474 | 44.019 | 30.091 | 0.167 |
| | | | | | | | |
| Moisture Standard 2 | 1 | 43 | 227 | 527 | 110.019 | 60.646 | 0.244 |
| | 2 | 50 | 143 | 443 | 120.417 | 89.216 | 0.296 |
| | 3 | 50 | 199 | 499 | 74.4 | 49.186 | 0.22 |
| | | | | | | | |
| Moisture Standard 3 | 1 | 43 | 242 | 542 | 138.613 | 73.581 | 0.277 |
| | 2 | 49 | 154 | 454 | 157.257 | 113.355 | 0.344 |
| | 3 | 49 | 184 | 484 | 112.978 | 78.247 | 0.285 |
| | | | | | | | |
| Moisture Standard 4 | 1 | 44 | 233 | 533 | 169.838 | 94.394 | 0.304 |
| | 2 | 48 | 141 | 441 | 192.366 | 143.685 | 0.375 |
| | 3 | 48 | 188 | 488 | 145.524 | 99.837 | 0.313 |
| | | | | | | | |
| Moisture Standard 5 | 1 | 44 | 233 | 533 | 169.838 | 94.394 | 0.304 |
| | 2 | 48 | 141 | 441 | 192.366 | 143.685 | 0.375 |
| | 3 | 48 | 188 | 488 | 145.524 | 99.837 | 0.313 |
| | | | | | | | |
| Moisture Standard 6 | 1 | 44 | 234 | 534 | 223.27 | 124.825 | 0.34 |
| | 2 | 48 | 150 | 450 | 245.156 | 177.999 | 0.406 |
| | 3 | 51 | 183 | 483 | 175.49 | 122.281 | 0.336 |

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