Cone Penetrometer Load Cell Temperature and Radiation Testing Results

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Abstract: This report summarizes testing activities performed at the Pacific Northwest National Laboratory to verify the cone penetrometer load cell can withstand the tank conditions present in 241-AN-101 and 241-AN-106. The tests demonstrated the load cell device will operate under the elevated temperature and radiation levels expected to be encountered during tank farm deployment of the device.

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EXECUTIVE SUMMARY

Testing of the cone penetrometer load cell (Icone) was performed at the Pacific Northwest National Laboratory 318 Building. Testing was designed to determine how the elevated temperatures and dose rates in Tanks 241-AN-101 and 241-AN-106 sludge waste could affect the Icone measurements of tip resistance and inclination.

The Icone was placed in an environmental chamber and the temperature was raised from ambient conditions to an approximately bounding sludge waste temperature of 145 °F. As anticipated, the tip resistance measurement shifted as the Icone equilibrated with the increasing temperature. After 2-2.5 hours of equilibration time, the tip resistance measurement reached a steady value and fluctuation was minimal. Similarly, the tip resistance shifted back to the original measurement values when the temperature was decreased back to ambient conditions. A change in tip resistance measurement was expected with changing temperature and sensor failure was not observed after eight hours at an elevated temperature. Inclination measurements appear to be less affected by temperature changes and fluctuation of the measurements may also be partly attributed to air flow in the environmental chamber as the temperature was adjusted.

The Icone was then placed in the High Exposure Facility and exposed to a Cobalt-60 source at 250 R/hr for twenty-four hours. A dose rate of 250 R/hr was determined to roughly approximate in situ dose rates for Tanks 241-AN-101 and 241-AN-106. Throughout testing, no effect was observed for tip resistance or inclination measurements. Signal drift was not observed for either measurement, indicating failure of the sensors was not observed.

Distance from the Cobalt-60 source was then decreased to reach a dose rate of 34,998 R/hr. Testing at the high exposure rate for one hour did not appear to affect tip resistance, but did appear to produce failure of the inclination sensor. Tip resistance, which is the primary data of interest as the input to determine in situ waste shear strength, maintained steady variability with or without the source present, indicating no significant effect. The inclination data began increasing slowly after twenty-five minutes of exposure and reached a 90 degree value after fifty-two minutes, indicating sensor failure. Further testing appeared to confirm the inclination sensor in the Icone had failed. The high dose rate used in testing is orders of magnitude greater than the anticipated dose rate in the tank sludge, but provided a bounding test case and allowed for observation of how sensor failure is indicated.

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Abbreviations and Acronyms

BDGRE	Buoyant Displacement Gas Release Event
DSA	Documented Safety Analysis
DSGRE	Deep Sludge Gas Release Event
HEF	High Exposure Facility
JCO	Justification for Continued Operation
PCSACS	Personal Computer Surveillance Analysis Computer System
PNNL	Pacific Northwest National Laboratory
TWINS	Tank Waste Inventory Network System
USQ	Unreviewed Safety Question
WRPS	Washington River Protections Solutions, LLC

Units

°F	Degrees Fahrenheit
in	Inch
hr	Hour
kN	Kilo-Newton
m	Meter
N	Newton
R	Rad
°	Degree

1.0 INTRODUCTION

1.1 Background

In response to research by Delft Hydraulics examining the effect of gas production on the storage capacity of artificial sludge depots (van Kessel and van Kesteren, 2002), a new mechanism was proposed for a spontaneous deep sludge gas release event (DSGRE) that is not currently described in RPP-13033, *Tank Farms Documented Safety Analysis* (DSA). This resulted in an Unreviewed Safety Question (USQ). Justification for Continued Operation (JCO) TF-13-01 was approved to allow sludge levels in tanks 241-AN-101 and 241-AN-106 up to 192 inches and 195 inches, respectively, but in order to complete waste retrievals from the 241-C farm tanks, accumulation of additional sludge depth is needed.

In order to address concerns over the potential for a DSGRE and to support the technical justification for continued retrieval of operations into tanks AN-101 and AN-106, in situ sludge waste shear strength data are needed. Implementation of a new buoyant displacement gas release event (BDGRE) safety basis requires showing that Hanford Site sludge waste maintains low gas fractions as settled solids depth is increased, which is also directly related to the shear strength of the waste. Therefore, further safety basis development involves determining the in situ shear strength of the sludge in tanks AN-101 and AN-106. This will be accomplished by taking resistance measurements using a HYSON®[1] 200kN full-flow ball penetrometer, which relates the in situ resistance measurements to shear strength values

1.2 Purpose

The HYSON 200kN full-flow penetrometer system operates by pushing an instrumented ball tip down into the tank sludge at a controlled rate. Resistance on the tip is measured using a load cell and equated to shear strength using empirical relationships. One meter long extending rods are attached one at a time to feed through a hydraulic ram in order to allow the ball to penetrate to the desired depth.

The data collection system consists of a digital ‘cone’, called the ICone®[2], and a digital data acquisition box called IControl®[3]. The ICone contains the load cell device and has a built-in AD-conversion with a micro-controller, which provides a digital pathway to the IControl. The IControl is connected to a computer on which the data is to be recorded using a USB connection. IControl combines the depth information with the obtained cone penetrometer resistance data and provides power to the ICone. A proprietary software called *Gonsite!*®[4] is installed on a computer to record the data and present the results on the screen in real-time. There is also a depth encoder that measures how far the unit has moved in the tank. The depth encoder connects back to the IControl through the control panel.

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[1] HYSON is a trademark of A.P. van den Berg, Heerenveen, Netherlands.

[2] ICone is a trademark of A.P. van den Berg, Heerenveen, Netherlands.

[3] IControl is a trademark of A.P. van den Berg, Heerenveen, Netherlands.

[4] GOonsite! is a trademark of A.P. van den Berg, Heerenveen, Netherlands.

This system has never been used in a highly radioactive, high temperature environment. Concern that the electronic components of the Icone may not survive the high radiation fields encountered in sludge waste or that temperature significantly above ambient conditions could affect resistance measurements, prompted testing at the Pacific Northwest National Laboratory (PNNL) 318 Building. The 318 Building contains environmental chambers where the temperature and humidity conditions can be closely controlled as well as a High Exposure Facility (HEF) where radioactive sources provide the ability to safely test the Icone response to high radiation conditions.

The purpose of testing was twofold: to observe the impact to Icone resistance and inclination measurements from temperatures near that of AN-101 and AN-106 sludge; and to observe the impact to Icone resistance and inclination measurements from radiation exposure near that of AN-101 and AN-106 sludge.

2.0 TEST DESIGN

PNNL provided a test report, shown in Appendix A, documenting the test setup and calibrations for all equipment used in testing. Primary Icone output parameters of concern in this testing were the force measurement and the inclination measurement. The Icone load cell provides a force measurement in kilo-Newtons (kN), which is the primary data input used to determine shear strength. The Icone also measures inclination in degrees (°), which indicates the angle of the load cell to verify verticality. Inclination is not a data input to determine shear strength, but provides a useful tool to ensure the Icone is traveling straight through the material being measured (tank sludge layer) for deployment operations. According to the cone penetrometer vendor, A.P. van den Berg, failure of either sensor should result in a drift from stable readings.

The *GOnsite!* data logging program continuously displays force and inclination measurements on a computer screen, but only records the data over specified depth intervals. A device called a Pulse Encoder Simulator can be used to mimic depth traveled in order to collect data in a laboratory environment. However, due to the time sensitive nature of the project, test results were needed before the device could be procured through A.P van den Berg. As an alternative, data was manually recorded for each test run. The temperature testing data sheets are provided in Appendix B and radiation exposure testing data sheets are provided in Appendix C.

Starting a test run in *GOnsite!* involves zeroing the measurement values, giving users the ability to eliminate any pre-test offset. At the end of the test run, the device is zeroed again to assist in identifying potential damage during deployment. In order to read a non-zero force measurement for these testing activities, each test run began by manually raising the Icone off the surface, zeroing the values to start the test in *GOnsite!*, then lowering the Icone back onto the surface such that the weight of the Icone itself would result in a positive force reading displayed. The actual values recorded in the test runs are of little importance; only the trend in measurements over the course of the test runs versus the initial measured value is significant. As such, the process of zeroing the Icone measurements prior to starting the test was resulted in starting measurements that were not identical for each run. This accounts for variability in measurements between test runs, but is of no significance to the testing strategy.

Each test run was performed using the same Icone device, serial number 090420T. The calibration certificate for the Icone is shown in Appendix D. The cone penetrometer software is documented in RPP-PLAN-55276, *Cone Penetrometer System Software Management Plan*.

2.1 Temperature Test

2.1.1 Hypothesis

Temperature is expected to have an effect on resistance measurements, but not on inclination measurements. According to A.P. van den Berg, the load cell contained in the Icone is affected by temperature changes of more than ± 9 °F. As such, when operating the penetrometer in high temperature environments, it is important to allow the Icone to equilibrate to the in situ temperature before recording data. The expectation is that the force readings change as the Icone changes in temperature, but will remain constant once the Icone reaches a uniform temperature. The time to reach uniform temperature is predicted to be one hour. Inclination measurements are not predicted to show an effect from temperature changes.

2.1.2 Methodology and Setup

Temperature testing took place July 23, 2013 at the PNNL 318 Building, Room 127. The Icone was loaded into an environmental chamber, shown in Figure 1, and supported in the vertical position by a ring stand. A conical tip was used in place of the ball attachment for this test because of vertical space constraints. The conical tip is more sensitive to fluctuations in force measurements, but is expected to have minimal impact on the test.

Figure 1. Icone Loaded in the Environmental Chamber

Chamber temperature was monitored using a Vaisala®[5] temperature/relative humidity probe, a Fluke®[6] 80T-150 temperature probe, and the environmental chamber sensor. See Appendix A for specific information on the devices, including calibration verification.

A maximum testing temperature of 145 °F was selected based on the current conditions of tanks AN-101 and AN-106. Since May 4, 2013, the maximum sludge temperature recorded in AN-101 is 95 °F. Over the same period, the maximum sludge temperature recorded in AN-106 was 138 °F (PCSACS). A temperature of 145 °F was determined to represent a realistic maximum temperature encountered in tank deployment.

Duration for the high temperature exposure test was selected at eight hours, in order to equate to the approximately one work shift. This is expected to be a conservative estimate of the time the Icone could be exposed to elevated temperatures. After setup activities are completed, actual deployment operation of the penetrometer into AN-101 and AN-106 sludge is expected to take less than one shift. Additionally, based on the temperature profile for AN-106, the higher temperature tank, there is limited depth for which the temperature is near 145 °F (PCSACS). The sludge waste temperature near the top surface is around 100 °F and increases gradually over the remaining depth by about 0.5 °F per inch depth. Deployment of the penetrometer through the limited depth at elevated temperatures would be expected to take significantly less than eight hours.

Three separate tests were performed to evaluate the Icone response to temperature changes:

1. Three control runs at ambient conditions
2. Eight hour test beginning at ambient and increasing to about 145 °F
3. Three post-exposure control runs at ambient conditions

2.1.2.1. Pre-Exposure Control Test

The pre-exposure control test consisted of three test runs. These test runs were performed in the environmental chamber at ambient conditions (74 °F). The door to the chamber was left open, as in Figure 1. Each test run was a total of ten minutes in length and measurements of tip resistance and inclination were recorded in one minute intervals. As described previously, the Icone was lifted off the surface prior to starting the test and zeroing the parameters in the *GOnsite!* program. The Icone tip was then lowered back onto the surface and was secured upright with a ring stand. Once in place, the time was started and the first measurement was recorded.

Pre-exposure control testing provided a baseline for natural variation in the measured values. The Icone load cell is very sensitive to fluctuations in force, particularly given the limited force applied by the self-weight of the device.

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[5] Vaisala is a trademark of the Vaisala OY Corporation, Finland.

[6] Fluke is a trademark of the Fluke Corporation, Everett, WA.

2.1.2.2. High Temperature Test

After completing the three control runs described in Section 2.1.2.1, the high temperature test was performed. The test consisted of a single eight hour test run with measurements taken every fifteen minutes. The Icone was lifted off the surface prior to starting the test and zeroing the parameters in the *GOnsite!* program. The Icone tip was then lowered back onto the surface and was secured upright with a ring stand. Once in place, the chamber door was closed and the temperature was set at 145 °F. The first measurement was taken immediately after the set point was changed on the chamber, but before the temperature began to increase. The Icone was then given one hour to equilibrate to the raised temperature conditions. After one hour of equilibration time, the test time was started and measurements were recorded every fifteen minutes.

The initial relative humidity was set at near-zero. To determine the effect of humidity changes, at the six hour mark (6:00) the relative humidity was set to 50%. After one hour of observation, the humidity set point was changed back to 1%.

In order to further observe the effect of temperature changes on the Icone, the temperature was gradually decreased at the end of the test run. The set point was changed to 110 °F at the 7:30 mark, then 72 °F at 7:45, and at 8:00 the system was shut down and the door was opened. Measurements were taken every ten minutes, up until the 8:50 mark.

2.1.2.3. Post-Exposure Control Test

The post-exposure control test consisted of three test runs. These test runs were performed in the environmental chamber at ambient conditions. The door to the chamber was left open, as in Figure 1. Each test run was a total of ten minutes in length and measurements of tip resistance and inclination were recorded in one minute intervals. As described previously, the Icone was lifted off the surface prior to starting the test and zeroing the parameters in the *GOnsite!* program. The Icone tip was then lowered back onto the surface and was secured upright with a ring stand. Once in place, the time was started and the first measurement was recorded.

Similar to pre-exposure testing, post-exposure control testing provided a baseline for natural variation in the measured values. The testing also provided a check to ensure the Icone was not damaged by the high temperature.

2.2 Radiation Exposure Test

2.2.1 Hypothesis

Based on previous experience with electronic equipment operation in radioactive environments, radiation at 250 R/hr is not expected to have an effect on resistance measurements or inclination measurements. However, no data exists to indicate the effect of radiation on the specific components of the Icone.

2.2.2 Methodology and Setup

Radiation testing took place July 25-26, 2013 at the PNNL 318 Building, Room 8, in the High Exposure Facility (HEF). The Icone was set up on the exposure table in the HEF, as shown in Figure 2, and supported in the vertical position by a ring stand. To provide additional height ensuring the source was level with the load cell, the ball end attachment was used in place of the cone tip used in temperature testing. A one meter extending rod was also included for the 24 hour exposure test to raise the data cable above the source as much as possible. Environmental conditions were not controlled, but were monitored with a Fisher Scientific weather station (Appendix A). A Cobalt-60 source was used to provide radiation dose. Calibration of the source is shown in Appendix A.

Figure 2. Icone Setup in the HEF

An exposure rate of 250 R/hr was selected based on the current estimated Cesium-137 inventory for sludge waste in tanks AN-101 and AN-106 (TWINS). An informal MicroShield test run was performed using the estimated Cesium-137 inventory in AN-106 sludge waste to determine an estimated dose rate. The MicroShield®[7] program is not designed to run dose rate calculations for objects submerged within the dose emitter, thus the calculated dose is only a rough estimate and

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[7] MicroShield is a trademark of Grove Software, Inc., Lynchburg, VA.

expected to be bounding. The MicroShield test run output, shown in Appendix E, determined an exposure dose rate of 127 R/hr. That calculated dose rate refers to the dose at the surface of the waste and was doubled to roughly estimate the dose rate for submerging the Icone in the waste (250 R/hr). A secondary check on the dose rate was determined using an approximation for absorbed dose rate at a point within an infinite medium. This informal calculation determined an approximate dose rate of 211 R/hr.

Duration for the radiation exposure test was selected at twenty-four hours, in order to equate to one full day and provide an upper bound of the expected time in the tank. After setup activities are completed, actual deployment operation of the penetrometer into AN-101 and AN-106 sludge is expected to take less than one shift. However, if technical issues were to arise during deployment, it was estimated that the Icone could be left in the sludge for up to a day. Similar to the tank waste temperatures, the dose rates in the sludge will change based on the elevation. A dose rate of 250 R/hr would not be expected to be uniform throughout the sludge layer. Deployment of the penetrometer through the sludge is expected to take significantly less than twenty-four hours.

Four separate tests were performed to evaluate the Icone response to dose rate:

1. Three control runs with no source present
2. Twenty-four hour test at an exposure rate of 250 R/hr using a Cobalt-60 source
3. Three post-exposure control runs with no source present
4. One hour test at an exposure rate of 34,998 R/hr using a Cobalt-60 source

2.2.2.1. Pre-Exposure Control Test

The pre-exposure control test consisted of three test runs. These test runs were performed in the HEF with no source present. The Icone assembly was supported by a ring stand, as shown in Figure 1. Each test run was a total of ten minutes in length and measurements of tip resistance and inclination were recorded in one minute intervals. As described previously, the Icone was lifted off the surface prior to starting the test and zeroing the parameters in the *GOnsite!* program. The Icone was then lowered back onto the surface and was secured upright with the ring stand. Once in place, the time was started and the first measurement was recorded.

Pre-exposure control testing provided a baseline for natural variation in the measured values. The Icone load cell is sensitive to fluctuations in force, particularly given the limited force applied by the self-weight of the device.

2.2.2.2. Twenty-four Hour Radiation Exposure Test

After completing the three control runs described in Section 2.2.2.1, the long term exposure test was performed. The test consisted of a single twenty-four hour test run with measurements taken every thirty minutes. The Icone was lifted off the surface prior to starting the test and zeroing the parameters in the *GOnsite!* program. The Icone was then lowered back onto the surface and was secured upright with a ring stand. Once in place, the Cobalt-60 source was raised and the test was initiated. In order to achieve 250 R/hr dose rate, the Icone was placed about five meters from the source. Calibration information for the Cobalt-60 source is available in Appendix A.

In order to ensure uniform dose for the Icone, the source was removed and the Icone was rotated 180° at the twelve hour (12:00) mark. The test in *GOnsite!* was run continuously, without re-zeroing the measurement values.

2.2.2.3. Post-Exposure Control Test

The post-exposure control test consisted of three test runs. These test runs were performed in the HEF with no source present. The Icone assembly was supported at an angle by a ring stand to prepare for high exposure testing, as shown in Figure 3. Each test run was a total of ten minutes in length and measurements of tip resistance and inclination were recorded in one minute intervals. As described previously, the Icone was lifted off the surface prior to starting the test and zeroing the parameters in the *GOnsite!* program. The Icone was then lowered back onto the surface and was secured upright with the ring stand. Once in place, the time was started and the first measurement was recorded.

These control tests served two purposes. First, the test runs provided a baseline for natural variation in the measured values to ensure the Icone was not damaged by the radiation test. Second, the testing provided a baseline for natural variation in measured values for the Icone placed at an angle without the extending rod attached. The Icone had to be positioned closer to the source in order to achieve 34,998 R/hr, which required placement at an angle.

Figure 3. High Radiation Exposure Test Setup

2.2.2.4. Short Term High Exposure Test

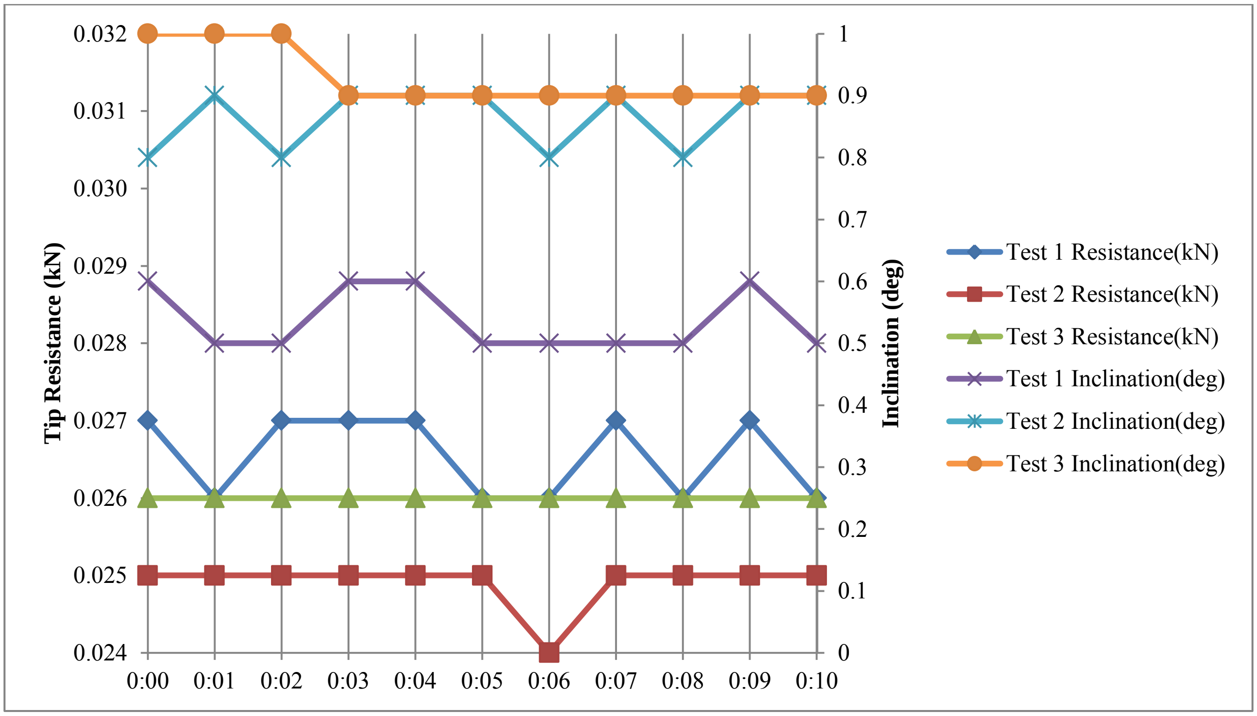
After completing the three control runs described in Section 2.2.2.3, the high exposure test was performed to determine if failure of either sensor could be accomplished using an upper bound dose rate and to observe what indications would be present if sensor failure were to occur. The test consisted of a single one hour test run with measurements taken at varying intervals (typically one minute). The Icone was positioned as shown in Figure 3 in order to ensure the portion of the Icone containing the sensors received a direct dose. The Icone was lifted off the surface prior to starting the test and the parameters were zeroed in the *GOnsite!* program. The Icone was then lowered back onto the surface and was secured at an angle with a ring stand. Once in place, the Cobalt-60 source was raised and the test was initiated. In order to achieve the highest dose rate available, 34,998 R/hr, the Icone was placed about 0.4 meters from the source. Calibration information for the Cobalt-60 source is available in Appendix A.

3.0 TEST RESULTS

3.1 Temperature Test Results

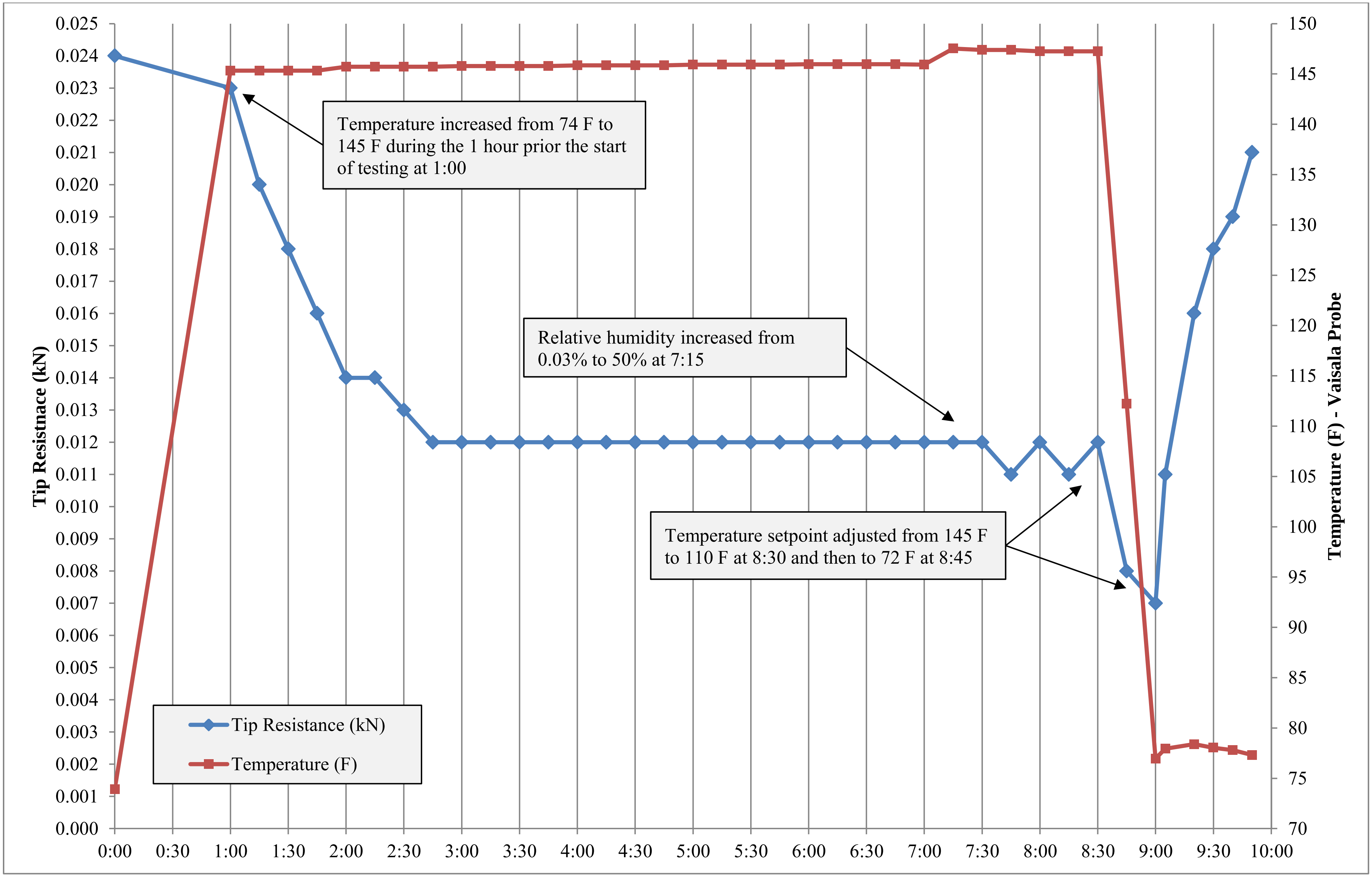
Testing data sheets for all temperature test runs are provided in Appendix B. The pre-exposure control test data prior to the elevated temperature test are shown in Figure 4. The data show some natural variation in tip resistance and inclination measurements at ambient conditions, as anticipated. Tip resistance fluctuations of about 1 N (0.001 kN) and inclination fluctuations of 0.1 degrees were observed during control test runs.

Figure 4. Pre-Temperature Exposure Control Test Results



Test results for the eight hour exposure run are shown in Figure 5 and Figure 6. Figure 5 shows the tip resistance measurements over time versus the chamber temperature changes, while Figure 6 shows the inclination measurements over time versus chamber temperature changes. In order to properly display all the data, including the measurements taken prior to the chamber temperature increase, the actual start time for the eight hour test is shown as 1:00. Therefore, Icone equilibration is shown taking place between the 0:00 and 1:00 marks, and the chamber door was opened to atmospheric conditions at the 9:00 mark.

Figure 5. High Temperature Test Results (Tip Resistance versus Temperature)

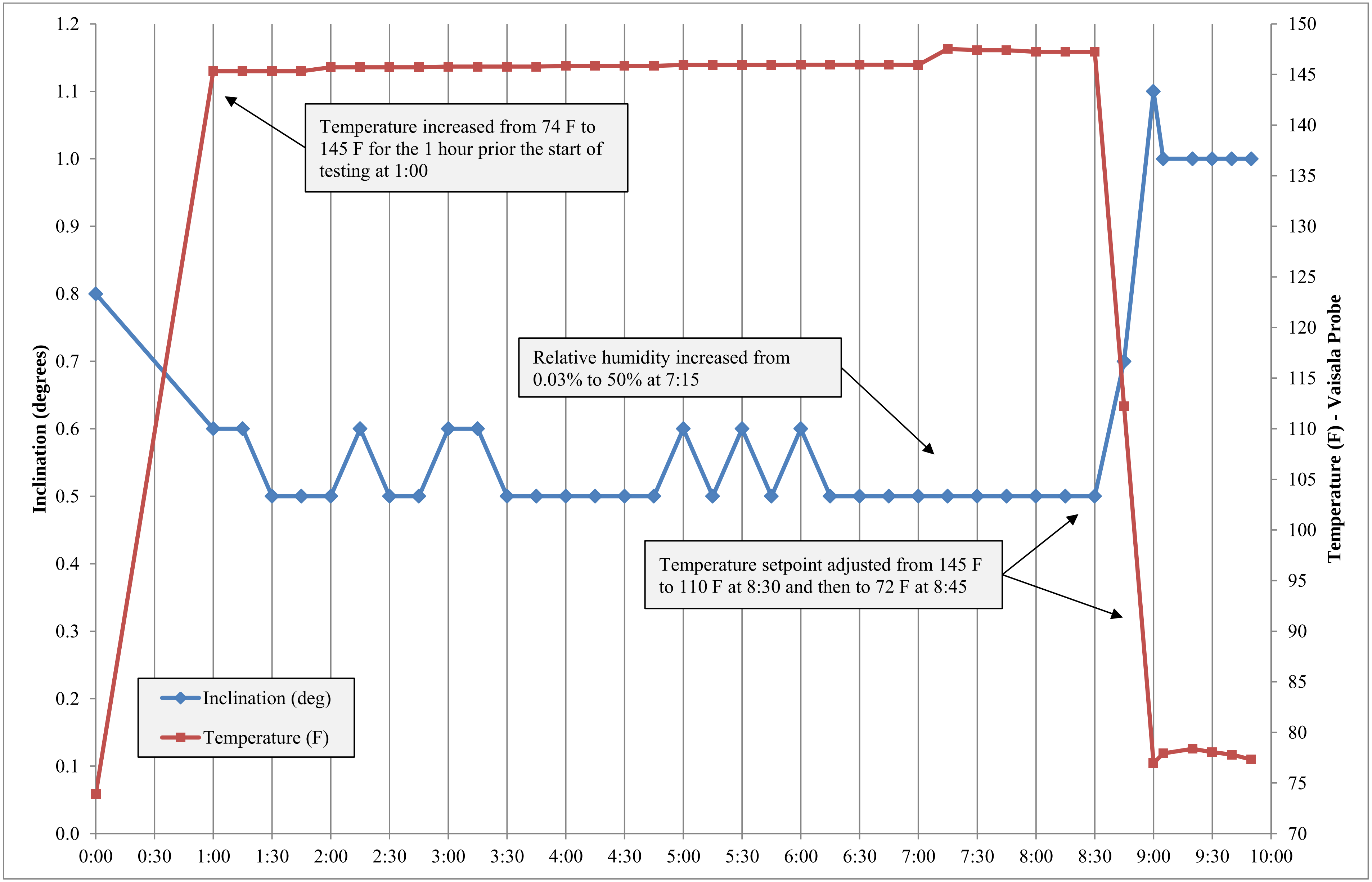


Temperature increased from 74 F to 145 F during the 1 hour prior the start of testing at 1:00

Relative humidity increased from 0.03% to 50% at 7:15

Temperature setpoint adjusted from 145 F to 110 F at 8:30 and then to 72 F at 8:45

Figure 6. High Temperature Test Results (Inclination versus Temperature)



Temperature increased from 74 F to 145 F for the 1 hour prior the start of testing at 1:00

Relative humidity increased from 0.03% to 50% at 7:15

Temperature setpoint adjusted from 145 F to 110 F at 8:30 and then to 72 F at 8:45

As anticipated, temperature changes had an effect on tip resistance measurements, as indicated by the trend shown in Figure 5. After the chamber temperature reached 145 °F, tip resistance measurements shifted downward to a point, then leveled off. Based on the test run results, the Icone took more than an hour to reach an equilibrium temperature when increasing from ambient conditions at 74 °F to 145 °F. The tip resistance stopped decreasing and settled on a constant value, seeming to indicate the Icone reached an equilibrium temperature, after about 2-2.5 hours. The resistance measurements then remained constant until chamber conditions were adjusted.

Relative humidity was increased from 0.03% to 50% at the 7:15 mark. The increased humidity does not appear to have a significant effect on tip resistance, although slight fluctuations of 1 N (0.001 kN) were recorded. Natural fluctuations in resistance measurements are expected based on the pre-exposure control tests.

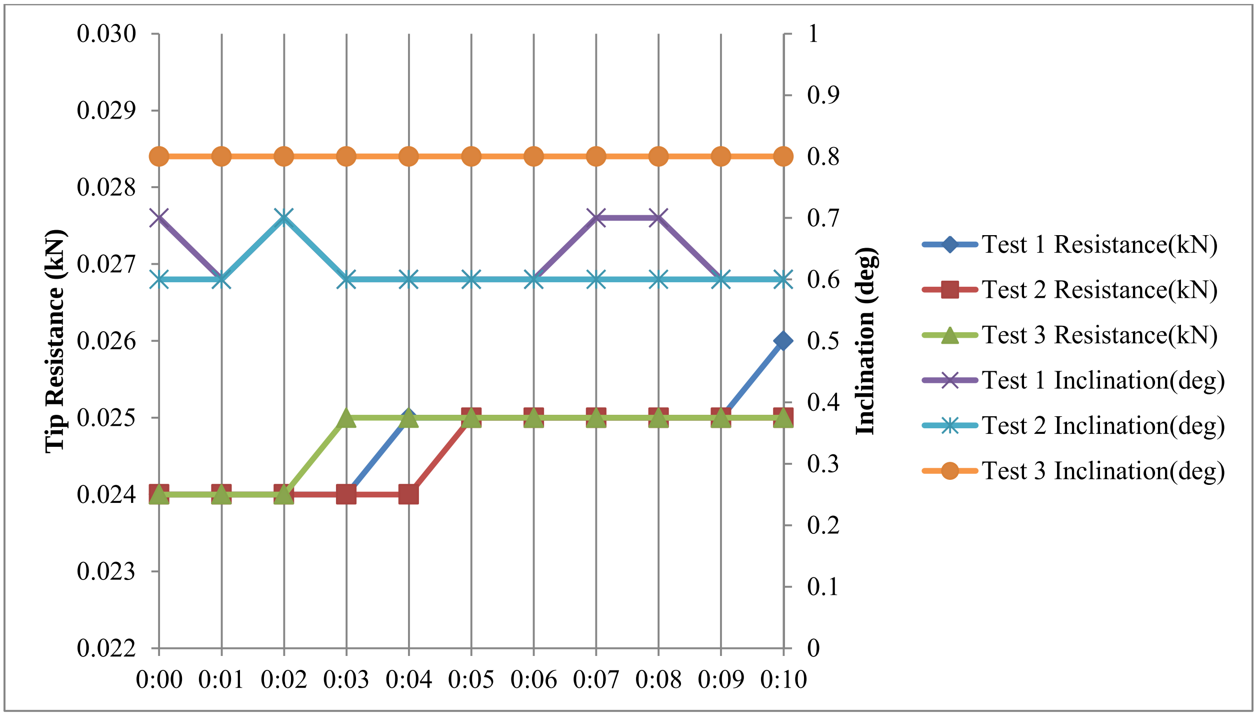
To determine whether the measurement shift was a permanent or temporary effect, the temperature of the chamber was decreased back to ambient conditions over a thirty minute period. As the temperature of the chamber decreased to about 76 °F, the resistance measurements increased, approaching the starting test conditions, as anticipated. This appears to indicate the shift in resistance measurements is a direct result of the temperature change. Damage to the Icone also does not appear likely based on the rise of resistance measurements back toward the original starting values.

Inclination measurements, shown in Figure 6, appear to be less affected by temperature change. The inclination appeared to decrease as the temperature rose, then leveled off for the duration of the test until the temperature was decreased, at which time the inclination rose. It was noted in the data sheets that the temperature probes placed in the chamber were observed swinging slightly at times during the test run. The natural airflow in the chamber from changing temperature conditions may have played a role in the slight change in measurements over the course of the test. The inclination sensor provides resolution of 0.1 degrees, which means slight variations in the environmental conditions could cause a shift in measurements. Both the temperature and the airflow may have played a role in the variability of the measurements.

The post-exposure control test data are shown in Figure 7. Inclination measurements for the three control tests show similar variability of 0.1 degrees to the pre-exposure control tests in Figure 4. The tip resistance measurements show a slightly different trend. Tip resistance for the first two test runs increased steadily at about 1-2 N (0.001-0.002 kN) per ten minute test run. The measurement leveled off during the third test run and remained constant.

Due to a slow cool down time for the chamber, the temperatures for the three runs were slightly different, as shown on the data sheets (Appendix B). The control runs took place immediately following the high temperature test and based on the trend in Figure 5, the Icone was likely still equilibrating to the decreased chamber temperature. The slight increase in tip resistance is consistent with the Icone returning to ambient temperature. It was also noted on the data sheets that the Icone was warm when the first post-test control run started, compared to the condition prior to testing. Given that the measurement is zeroed before each control run, the total shift in tip resistance over the three runs was 0.004 kN. Based on the end point resistance for the high temperature test of 0.021 kN, adding 0.004 kN would result in a tip resistance of 0.025 kN, which matches the starting point prior to increasing the temperature. Tip resistance appeared to level off and stabilize during the third control run, indicating the Icone reached ambient conditions about two hours after the chamber temperature was decreased from 145 °F, which is also consistent with the time it took to reach equilibrium when the temperature was increased during testing.

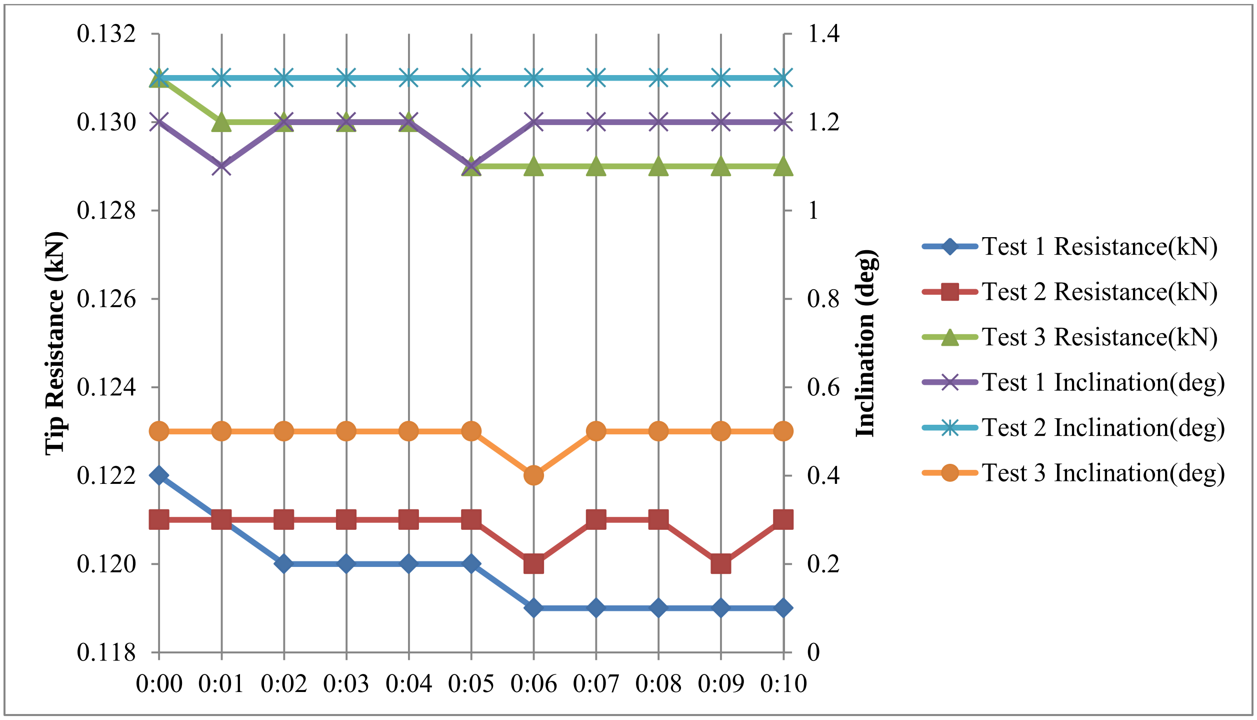
Figure 7. Post-Temperature Exposure Control Test Results



3.2 Radiation Exposure Test Results

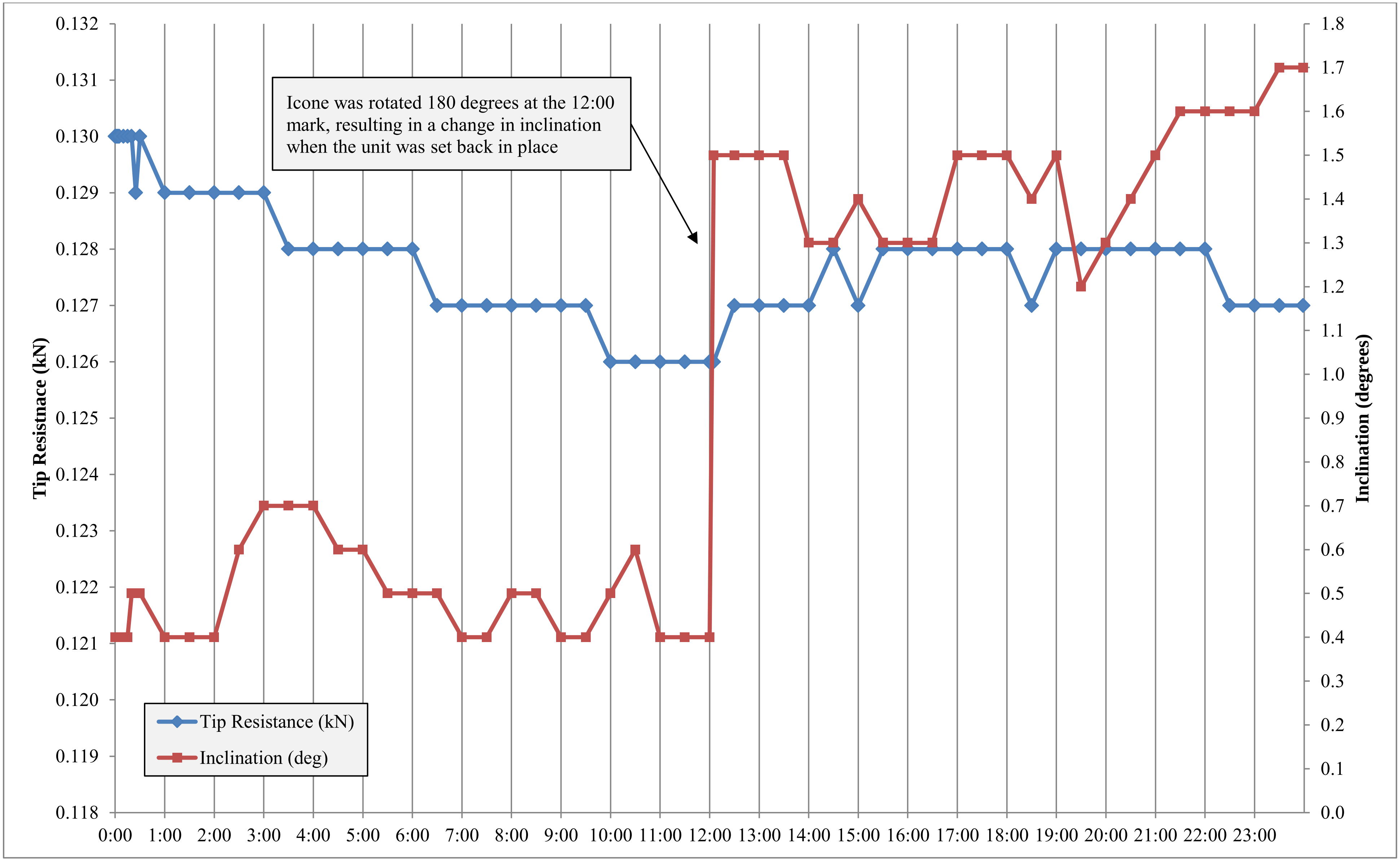
Testing data sheets for all radiation test runs are provided in Appendix C. The pre-exposure control test data prior to the elevated temperature test are shown in Figure 8. The data show some natural variation in tip resistance and inclination measurements at ambient conditions, as anticipated. Tip resistance fluctuations of about 3 N (0.003 kN) and inclination fluctuations of 0.2 degrees were observed during control test runs. These values are slightly larger than those observed in the temperature control tests, but larger fluctuations are anticipated with the setup in the HEF facility because the Icone had an additional extending rod attached above the load cell, which provides greater self-weight and is more prone to slight fluctuations given the stabilizing point on the ring stand, shown in Figure 2.

Figure 8. Pre-Radiation Exposure Control Test Results



Test data for the twenty-four hour exposure run are shown in Figure 9. Tip resistance and inclination measurements are shown over time. In total, the Icone received a dose of 6,000 R. The test data remained stable for the duration of the test, except for the mid-test rotation. The Icone was rotated 180 degrees at the 12:00 mark and was not secured in the exact same position on the ring stand, resulting in a shift in inclination values. Tip resistance measurements showed total fluctuations of about 4 N (0.004 kN), which is consistent with the natural variation determined in pre-exposure control tests. Inclination measurements varied by about 0.3 degrees prior to rotation and about 0.5 degrees after rotation. This test appears to show the dose rate did not have a significant effect on the tip resistance or inclination measurements.

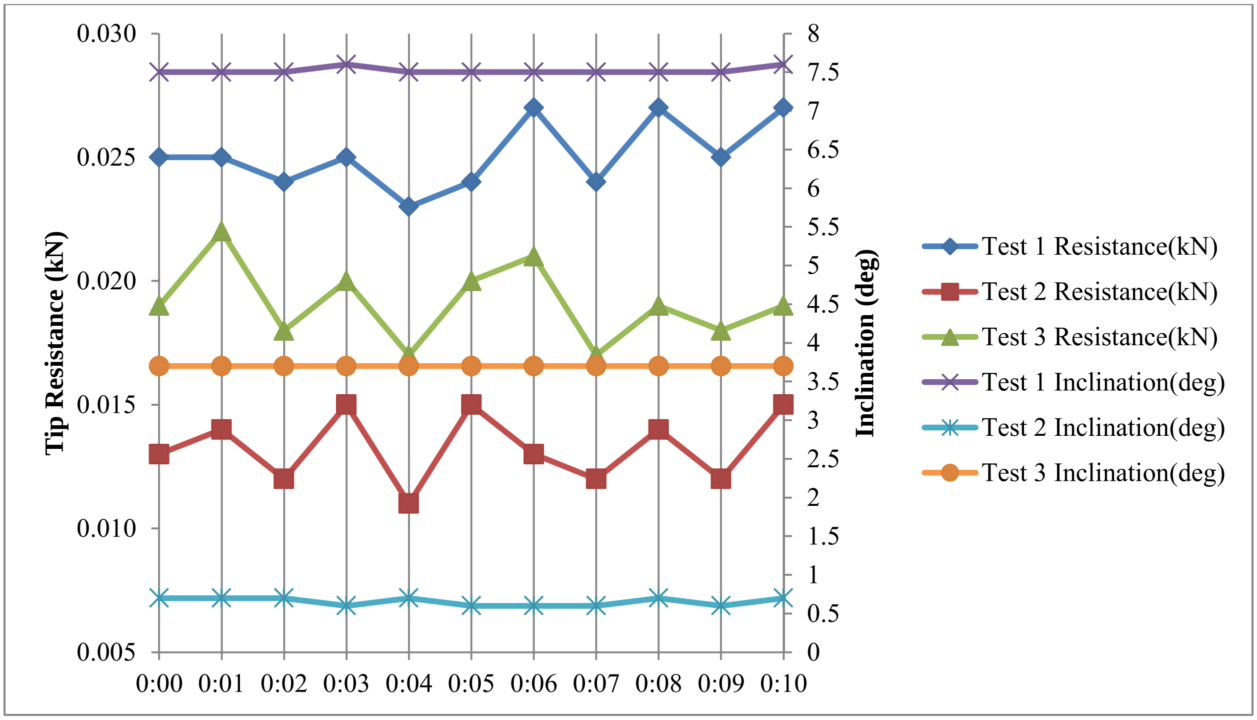
Figure 9. Radiation Exposure Test Results (250 R/hr)



Control tests were then performed after the twenty-four hour exposure test, shown in Figure 10. These test runs were performed in the HEF with no source present. The Icone assembly was supported at an angle by a ring stand to prepare for high exposure testing, as shown in Figure 3. These tests were designed to provide a baseline for natural variation in the measured values to ensure the Icone was not damaged by the radiation test and to provide a baseline for natural variation in measured values for the Icone placed at an angle without the extending rod attached.

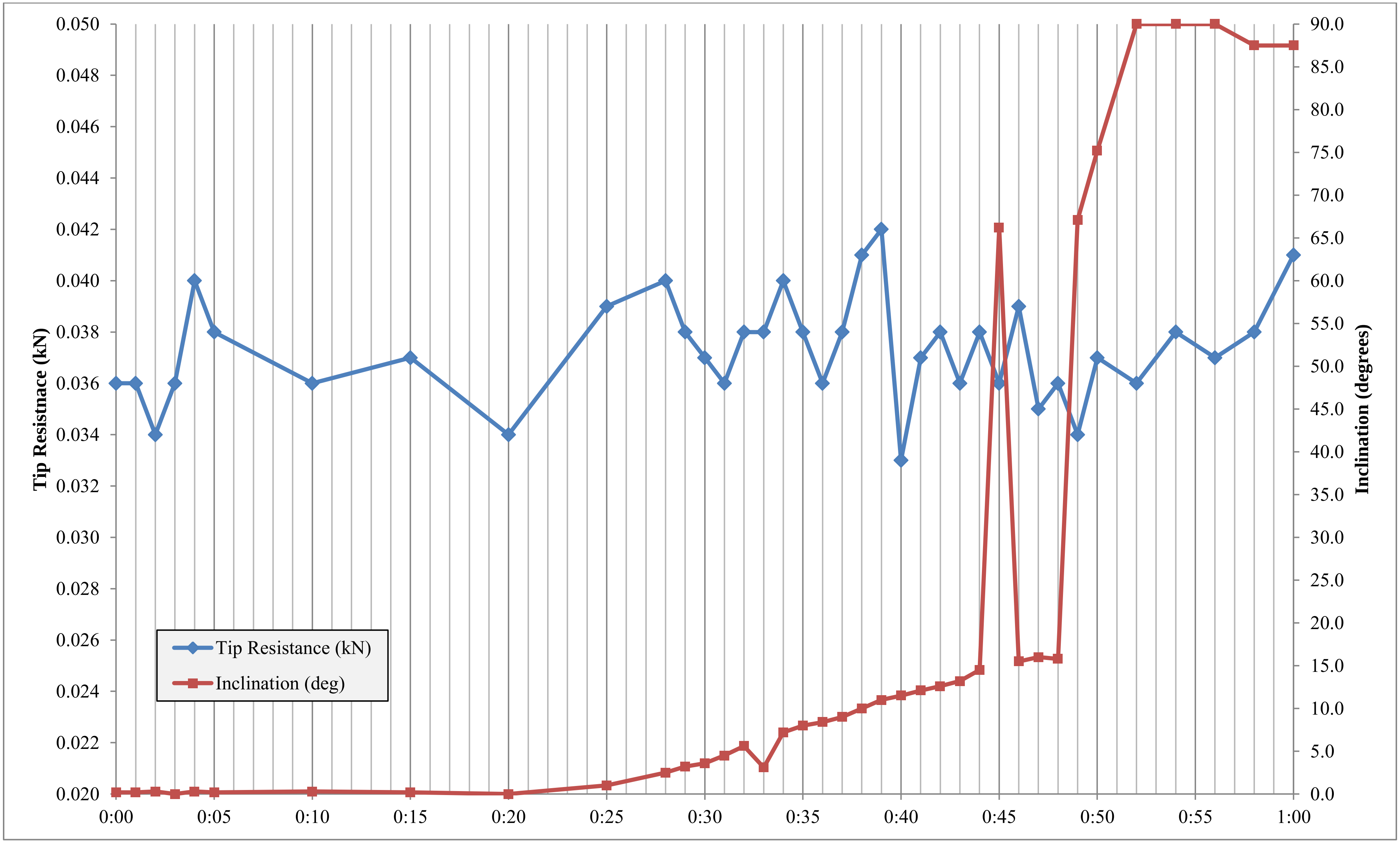
The data show some natural variation in tip resistance and inclination measurements at ambient conditions, as anticipated. Tip resistance fluctuations of about 4-5 N (0.004-0.005 kN) and inclination fluctuations of 0.1 degrees were observed during control test runs. The inclination measurements varied greatly from run to run due to difficulty zeroing the Icone at the same angle as it was held by the ring stand. However, absolute values are not important between runs; only fluctuations are observed for determining measurement drift.

Figure 10. Post-Radiation Exposure Control Test Results



The Icone was then exposed to the Cobalt-60 source at a distance of 0.4 meters, resulting in a dose rate of 34,998 R/hr. Test results are shown in Figure 11. Tip resistance measurements were observed fluctuating up to 8 N (0.008 kN) prior to raising the source to initiate the test, as noted in the data sheets in Appendix C, indicating placement of the Icone may not have been exactly the same as the control tests run previously. Tip resistance throughout the test primarily fluctuated about 5 N (0.005 kN), with a few isolated measurements separated by 9 N. Given the fluctuations prior to commencing the test, the variation during testing is not deemed to be a result of the radiation. Despite fluctuations, the tip resistance data show a consistent measurement throughout the test. However, the inclination sensor appears to have failed about twenty-five minutes into the test, as shown by the steady increase in inclination.

Figure 11. Radiation Exposure Test Results (34,998 R/hr)



During high exposure of 34,998 R/hr, the inclination measurement began steadily increasing by about one degree per minute at the 25:00 mark of the test. At the 45:00 mark, the inclination began providing erratic measurements and ultimately spiked to 90 degrees at the 52:00 mark. Live camera footage of the Icone setup in the HEF confirmed the assembly was not in motion, indicating a failed sensor.

To confirm the results, a second high exposure test run was performed without resetting the Icone. A test run was initiated in *GOnsite!*, which zeroed the tip resistance and inclination in place (i.e., both parameters started at zero for the test, rather than lifting the assembly prior to zeroing). The test was again run at 34,998 R/hr for five minutes and the results are shown in Appendix C. The tip resistance maintained fluctuation of about 6 N (0.006 kN) during the test, but the inclination began to rise immediately, ending at 8.2 degrees after only five minutes, confirming the inclination sensor had failed.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

4.1.1 Temperature Effects

As anticipated, temperature changes appear to affect tip resistance measurements. Increasing the testing chamber from 74 °F to 145 °F resulted in a shift in resistance measurements that took approximately 2-2.5 hours to stabilize. Based on the test run results, the Icone took more than the anticipated hour to reach an equilibrium temperature when increasing from ambient conditions to a sludge waste temperature of 145 °F. The tip resistance leveled out at a constant value during the high temperature test indicating the Icone reached equilibrium temperature. Failure of the tip resistance sensor was not observed, based on the resistance measurements returning to pre-test conditions as the temperature was decreased.

Temperature did not appear to significantly affect the inclination measurements. The inclination appeared to decrease as the temperature rose, then leveled off for the duration of the test until the temperature was decreased, at which time the inclination rose. It was noted in the data sheets that the temperature probes placed in the chamber were observed swinging slightly at times during the test run. The natural airflow in the chamber from changing temperature conditions may have played a role in the slight change in measurements over the course of the test, in addition to the air temperature change. Failure of the inclination sensor was not observed.

At the elevated test temperature of 145 °F, relative humidity did not appear to have a significant effect on tip resistance or inclination measurements.

4.1.2 Radiation Effects

Radiation exposure at a dose rate of 250 R/hr for twenty-four hours did not appear to affect tip resistance or inclination measurements. Test data remained stable for the duration of the test, compared to pre-test control runs. Signal drift was not observed for either measurement indicating failure of the sensors was not observed.

Radiation exposure at a dose rate of 34,998 R/hr for one hour did not appear to affect tip resistance, but did appear to produce failure of the inclination sensor. Tip resistance, which is the primary data of interest as the input to determine in situ waste shear strength, maintained steady variability with or without the source present, indicating no significant effect. The inclination data began increasing slowly after twenty-five minutes of exposure and reached a 90 degree value after fifty-two minutes, indicating sensor failure. Further testing appeared to confirm the inclination sensor in the Icone had failed. The high dose rate used in testing is orders of magnitude greater than the anticipated dose rate in AN-101 or AN-106 sludge, but provided a bounding test case and allowed for observation of how sensor failure is indicated.

4.2 Recommendations

- Allow adequate time for the Icone to equilibrate to the in situ sludge temperature in AN-101 and AN-106 during tank deployment. Given the apparent shift in tip resistance measurements, ensuring time for the Icone to reach in situ temperature is important to minimize measurement drift.

- Minimize total deployment time for the Icone in the sludge waste. While testing performed at the estimated sludge waste dose rate did not produce failure of Icone sensors, minimizing the time in the tank will decrease the likelihood of sensor failure.

- Ensure Icone 090420T is not used in deployment activities.

5.0 REFERENCES

Operating Instructions HYSON 200 kN on Skid with Power Pack, Issue Number: 1, Date of Issue: 01/30/2012, Order Number 54984, A.P. van den Berg Machinefabriek, Heerenveen, Netherlands.

Personal Computer Surveillance Analysis Computer System (PCSACS), Queried 06/15/2013, [Temperature Profile].

RPP-13033, 2013, *Tank Farms Documented Safety Analysis*, Rev. 4-T, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-PLAN-55276, 2013, *Cone Penetrometer System Software Management Plan*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

Tank Waste Information Network System (TWINS), Queried 06/15/2013, [Best Basis Calculation Detail].

TF-13-01, 2013, *Justification for Continued Operation for Potential Large Spontaneous Gas Release Event in Deep Sludge*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

Van Kessel, T., and W.G.M van Kesteren, 2002, “Gas Production and Transport in Artificial Sludge Depots,” *Waste Management*, vol. 22, p. 19-28, Elsevier Science Ltd.

APPENDIX A

PNNL REPORT FOR CONE PENETROMETER LOAD CELL TEST

Pacific Northwest
NATIONAL LABORATORY

Proudly Operated by **Battelle** *Since 1965*

Report for Cone Penetrometer Load Cell Test

ITL-13-002 rev 2

Smith, PJ
Hilliard, JR
Brandal, HE

August 2013

Name (printed)	Signature	Representing	Date
Jim Hilliard		PNNL	8/23/13
Hans Brandal		PNNL	AUG 23, 2013
Phil Smith	Philip J Smith	PNNL	8/23/13

Summary

Temperature and radiation hardness testing for the Cone Penetrometer Load Cell (Load Cell) was conducted for Washington River Protection Solutions (WRPS) per Statement of Work 36437-146, and planning document ITL-13-001, *Planning Document for Cone Penetrometer Load Cell*. The testing was performed at the Pacific Northwest National Laboratory (PNNL) 318 Building with assistance from WRPS staff members. Temperature testing (8 hours at 145 °F) revealed no effect to the load cell resistance measurements. Radiation hardness testing performed twice; one test at 250 R/h, no effect to the load cell resistance measurements was noted, however, the second test at 34,998 R/h showed a change of the inclination sensor reading, there was no effect to the load cell resistance measurements on the Load cell. It should be noted, PNNL staff members were responsible for setting up, controlling, and operating the 318 Building equipment per PNNL approved standard operating procedures as well as escorting the WRPS representatives. The WRPS staff members were responsible for operating the cone penetrometer load cell, and collecting testing data/results.

Detailed Discussion

Temperature Test

Temperature testing for the Cone Penetrometer Load Cell began July 23, 2013 at 0700 at the 318 building room 127. Over the next hour, measurement and test equipment (M&TE) consisting of a Vaisala temperature/relative humidity probe (attachment 1), a Fluke 80T-150 (attachment 2 and 3) temperature probe were placed in the environmental chamber at the approximate position of Cone Penetrometer Load Cell (see figure 1).

Figure 1. Cone Penetrometer Load Cell in Environmental Chamber.

The Vaisala temp/humidity probe is the more accurate of the two temperature probes used in this test; the Fluke 80T-150U has a faster response time and was used to indicate the rate of change. After all equipment was in place, a WRPS staff member conducted 3 separate 10 minute control tests at ambient temperature. After completion of the control tests, the chamber temperature was set to 145 °F; warming and stabilization of the environmental chamber required approximately an hour.

Testing began at approximately 9:30 am, and continued for 8 hours, during this time, measurements were taken by the WRPS staff member. After the conclusion of the 8 hour run, the temperature setpoint was adjusted to 72 °F in order to allow measurements to return to the pretest condition; final temperature recorded was 77 °F. Three separate ten minute control tests were conducted at ambient temperature (~75 °F) by the WRPS staff member. Additionally, the setpoint for relative humidity changed from near zero to 50% at the 6 hour mark; no effect was observed and the relative humidity was set to 1% approximately an hour later. For a detailed accounting of effects observed, please refer to documentation prepared by WRPS staff.

Radiation Hardness Test

Radiation hardness testing for the Cone Penetrometer Load Cell began July 25, 2013 at 0700 at the 318 building room 8, the High Exposure Facility (HEF).The HEF is capable of exposure rates exceeding 60 kR/h. For the first radiation hardness test; a long duration test (24 h) which included a 180 ° rotation at the 12 hour mark, a lower exposure rate of 250 R/h was used. Environmental conditions were monitored by a Fisher Scientific weather station (attachment 4); the room temperature was 73 °F with a relative humidity of ~ 30%. The Load Cell was placed approximately 5 m from the radioactive source (5,655 Ci ^{60}Co – ID# 318-528, RMT 12155), equipment cabling was suspended above and out of the radiation field (see Figure 2), and 3 separate control tests, each 10 minutes in duration, were performed by WRPS staff. Calibration of the HEF Source #8 (318-528) is found in attachment 5.

Figure 2. Preparation for Long Duration Radiation Hardness testing

At the conclusion of the three control tests, the 24 hr long duration test began (at approximately 9:30 am). Measurements were taken at intervals by WRPS staff throughout the duration of the test. Upon completion of the 24 hr test run, 3 ten minute control tests were performed. No significant effects on the resistance or inclination measurements from the 24 h test run were noted.

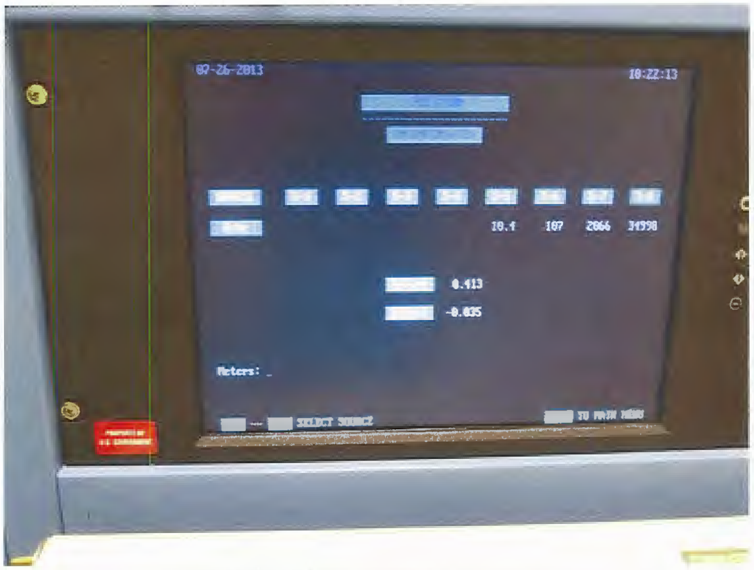


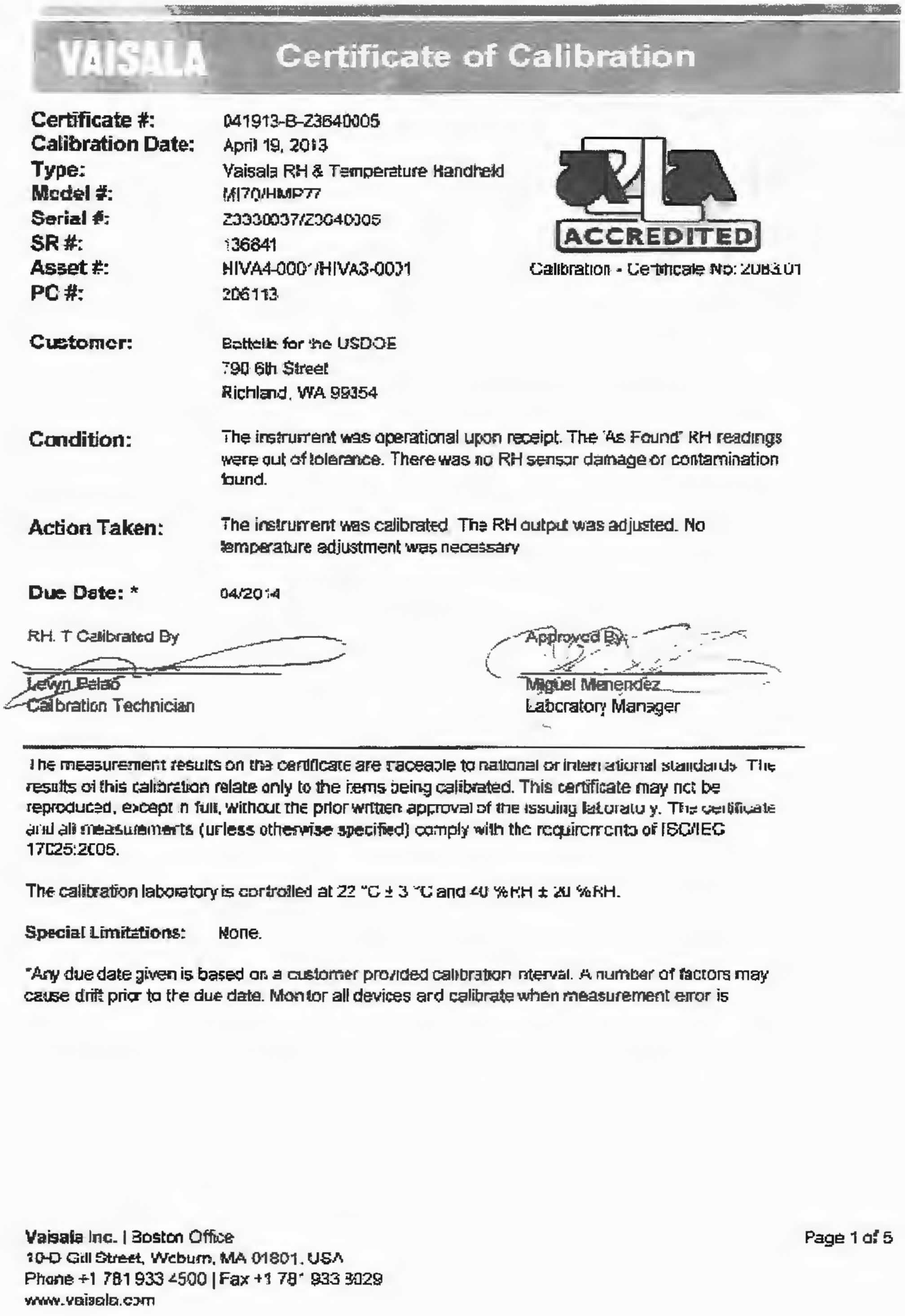
Figure 3. HEF Control Computer

Figure 4. Load Cell position for short duration test.

A one hour test run was then performed at 35 kR/h (34,998 R/h) with the same ^{60}Co source at a much shorter distance, approximately 0.4 m, on July 26, 2013.

It should be noted that the source is positioned in the center of the irradiator column, thus the distance (0.4 m) is measured from the source position, not the irradiator column. At approximately 10:30 am, the short duration test began, after approximately 25 minutes; the WRPS staff member reported that the inclination measurement began increasing. By visual observation of the Load Cell, WRPS and PNNL staff determined that the Load Cell was not moving and that the radiation was suspected to be causing the incorrect inclination measurement. The inclination measurement kept increasing until the 45 minute mark, at which time the readings became increasingly erratic and reached 90 degrees; please refer to WRPS documentation for a detailed discussion of the effects noted during this testing. A five minute control test was then performed. Effects noted by the WRPS representatives during this test indicated that the inclination readings did not return to pretest levels; the levels began to increase until the test ended, indicating a failed sensor; this 5 minute test occurred within the approximately 35 kR/h (34,998 R/h) ^{60}Co source field. All equipment was then removed from the HEF and WRPS staff departed the 318 building.

ATTACHMENT 1. Vaisala Temperature/Humidity Probe



VAISALA

Certificate of Calibration

Certificate #: 041913-B-Z3640005
Calibration Date: April 19, 2013
Type: Vaisala RH & Temperature Handheld
Model #: MI70/HMP77
Serial #: Z3330037/Z3040005
SR #: 136841
Asset #: HIVA4-0001/HIVA3-0001
PC #: 206113

ACCREDITED
Calibration - Certificate No: 2083.01

Customer:
Battelle for the USDOE
790 6th Street
Richland, WA 99354

Condition: The instrument was operational upon receipt. The 'As Found' RH readings were out of tolerance. There was no RH sensor damage or contamination found.

Action Taken: The instrument was calibrated. The RH output was adjusted. No temperature adjustment was necessary

Due Date: * 04/2014

RH. T Calibrated By

Lewyn Belao
Calibration Technician

Approved By:

Miguel Menendez
Laboratory Manager

The measurement results on the certificate are traceable to national or international standards. The results of this calibration relate only to the items being calibrated. This certificate may not be reproduced, except in full, without the prior written approval of the issuing laboratory. The certificate and all measurements (unless otherwise specified) comply with the requirements of ISO/IEC 17025:2005.

The calibration laboratory is controlled at 22 °C ± 3 °C and 40 %RH ± 20 %RH.

Special Limitations: None.

*Any due date given is based on a customer provided calibration interval. A number of factors may cause drift prior to the due date. Monitor all devices and calibrate when measurement error is

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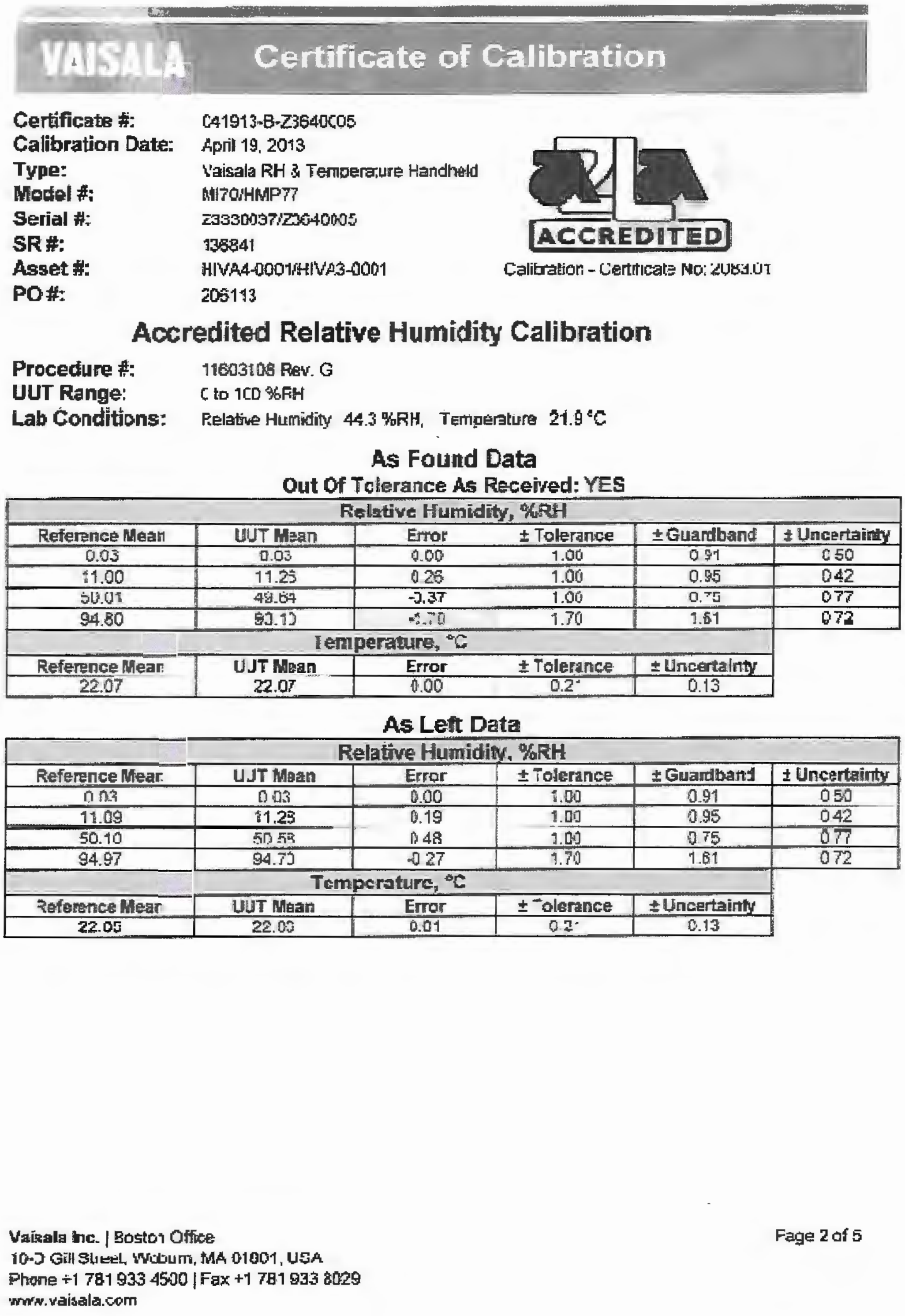
ATTACHMENT 1 (continued)



VAISALA **Certificate of Calibration**

Certificate #: 041913-B-Z3640005
Calibration Date: April 19, 2013
Type: Vaisala RH & Temperature Handheld
Model #: MI70/HMP77
Serial #: Z3330037/Z3640005
SR #: 136841
Asset #: HIVA4-0001/HIVA3-0001
PO #: 206113

ACCREDITED
Calibration - Certificate No: 2083.01

Accredited Relative Humidity Calibration

Procedure #: 11603108 Rev. G
UUT Range: 0 to 100 %RH
Lab Conditions: Relative Humidity 44.3 %RH, Temperature 21.9 °C

As Found Data

Out Of Tolerance As Received: YES

Relative Humidity, %RH					
Reference Mean	UUT Mean	Error	± Tolerance	± Guardband	± Uncertainty
0.03	0.03	0.00	1.00	0.91	0.50
11.00	11.25	0.26	1.00	0.95	0.42
50.01	49.64	-0.37	1.00	0.75	0.77
94.80	93.10	-1.70	1.70	1.61	0.72

Temperature, °C				
Reference Mean	UUT Mean	Error	± Tolerance	± Uncertainty
22.07	22.07	0.00	0.21	0.13

As Left Data

Relative Humidity, %RH					
Reference Mean	UUT Mean	Error	± Tolerance	± Guardband	± Uncertainty
0.03	0.03	0.00	1.00	0.91	0.50
11.09	11.28	0.19	1.00	0.95	0.42
50.10	50.58	0.48	1.00	0.75	0.77
94.97	94.70	-0.27	1.70	1.61	0.72

Temperature, °C				
Reference Mean	UUT Mean	Error	± Tolerance	± Uncertainty
22.05	22.03	0.01	0.21	0.13

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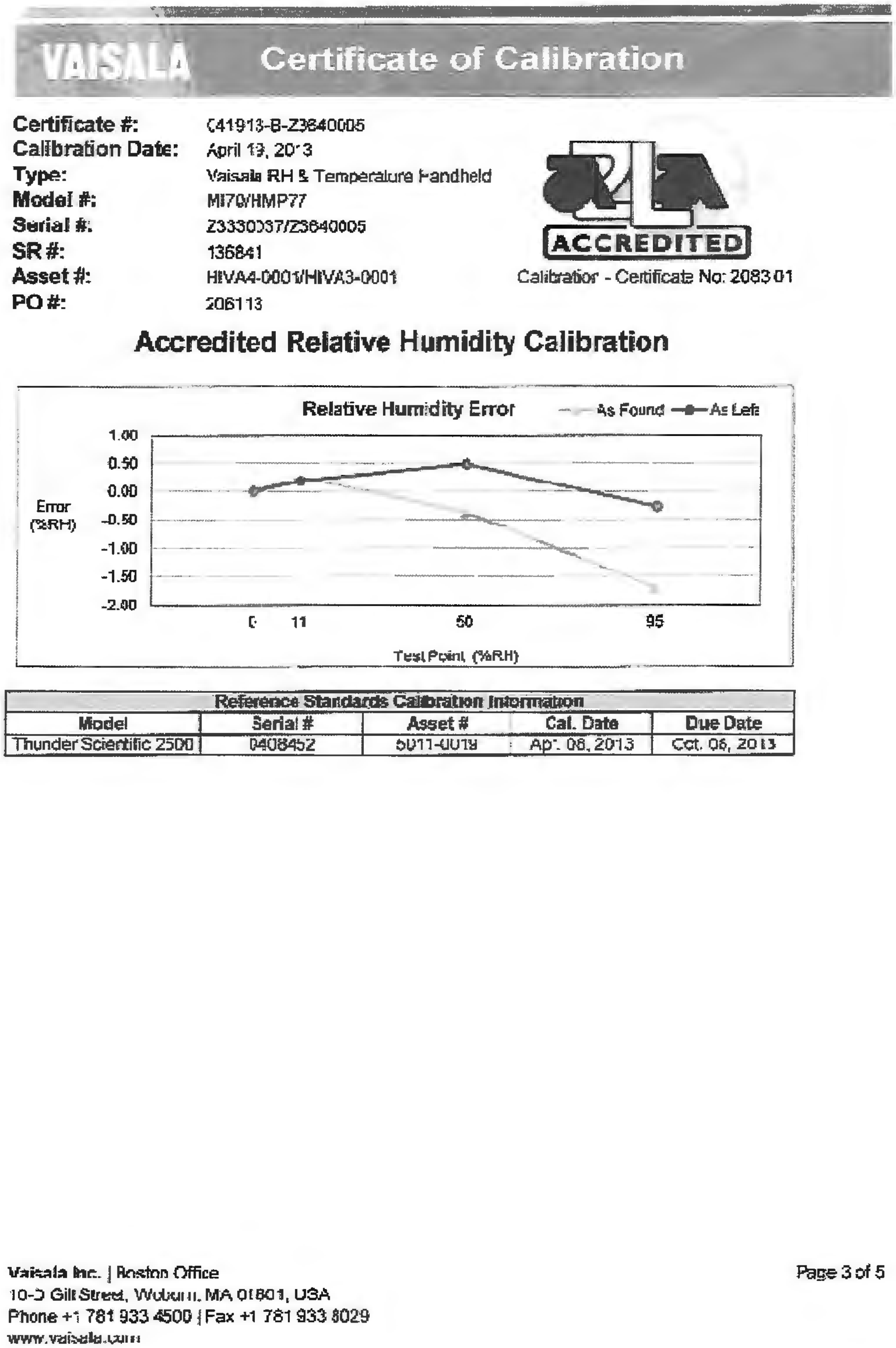
ATTACHMENT 1 (continued)



VAISALA **Certificate of Calibration**

Certificate #: C41913-B-Z3840005
Calibration Date: April 19, 2013
Type: Vaisala RH & Temperature Handheld
Model #: MI70/HMP77
Serial #: Z3330037/Z3840005
SR #: 136841
Asset #: HIVA4-0001/HIVA3-0001
PO #: 206113

ACCREDITED
Calibration - Certificate No: 2083.01

Accredited Relative Humidity Calibration

Reference Standards Calibration Information				
Model	Serial #	Asset #	Cal. Date	Due Date
Thunder Scientific 2500	0408452	5011-0019	Apr. 08, 2013	Oct. 06, 2013

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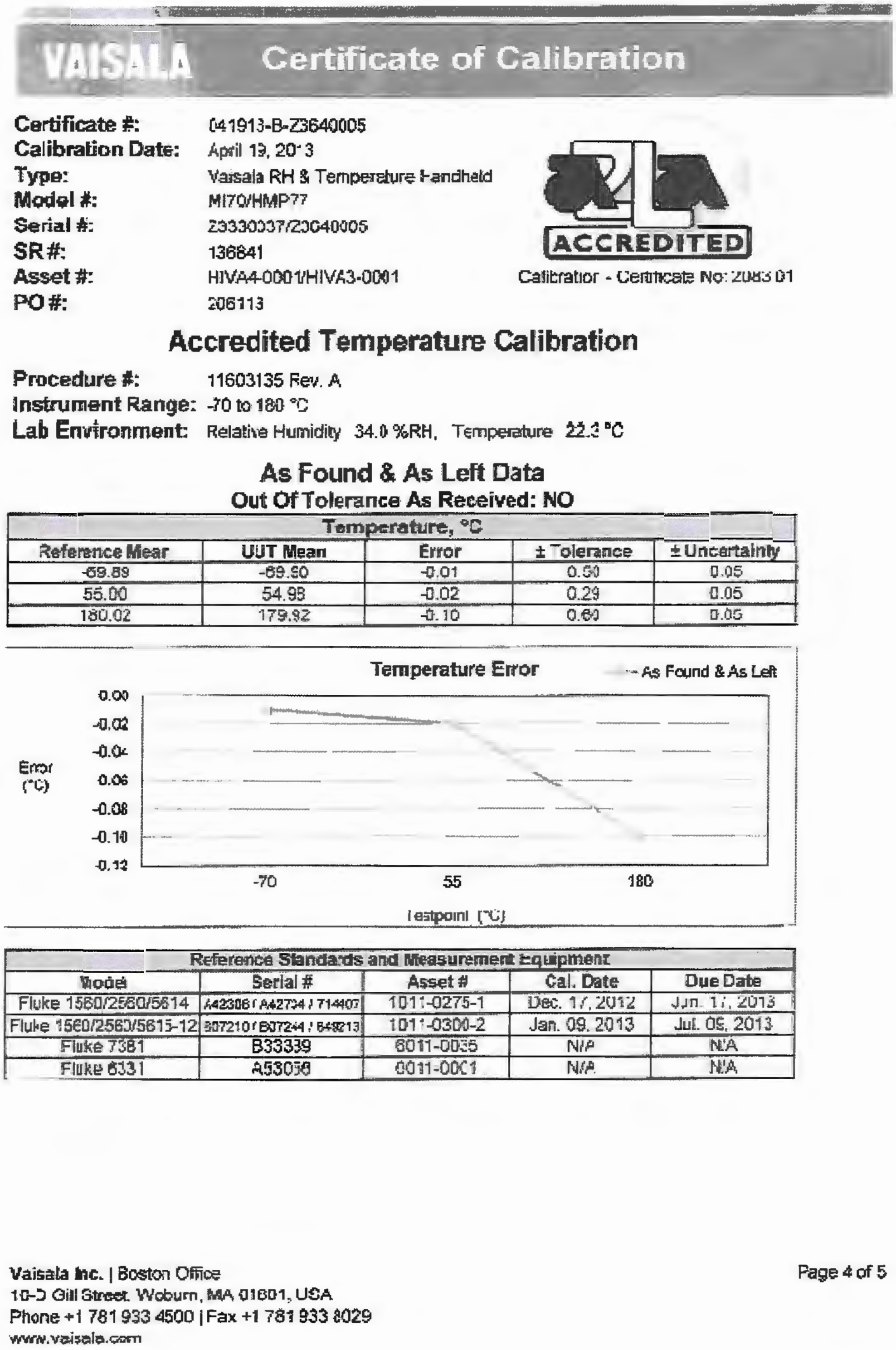
ATTACHMENT 1 (continued)



VAISALA **Certificate of Calibration**

Certificate #: 041913-B-Z3640005
Calibration Date: April 19, 2013
Type: Vaisala RH & Temperature Handheld
Model #: MI70/HMP77
Serial #: Z3330037/Z3640005
SR #: 136841
Asset #: HIVA4-0001/HIVA3-0001
PO #: 206113

ACCREDITED
Calibration - Certificate No: 2083.01

Accredited Temperature Calibration

Procedure #: 11603135 Rev. A
Instrument Range: -70 to 180 °C
Lab Environment: Relative Humidity 34.0 %RH, Temperature 22.3 °C

As Found & As Left Data

Out Of Tolerance As Received: NO

Temperature, °C				
Reference Mean	UUT Mean	Error	± Tolerance	± Uncertainty
-69.89	-69.90	-0.01	0.50	0.05
55.00	54.98	-0.02	0.29	0.05
180.02	179.92	-0.10	0.60	0.05

Temperature Error

Reference Standards and Measurement Equipment				
Model	Serial #	Asset #	Cal. Date	Due Date
Fluke 1560/2560/5614	A42306 / A42734 / 714407	1011-0275-1	Dec. 17, 2012	Jun. 17, 2013
Fluke 1560/2560/5615-12	B07210 / B07244 / 649213	1011-0300-2	Jan. 09, 2013	Jul. 09, 2013
Fluke 7381	B33339	6011-0035	N/A	N/A
Fluke 6331	A53036	6011-0001	N/A	N/A

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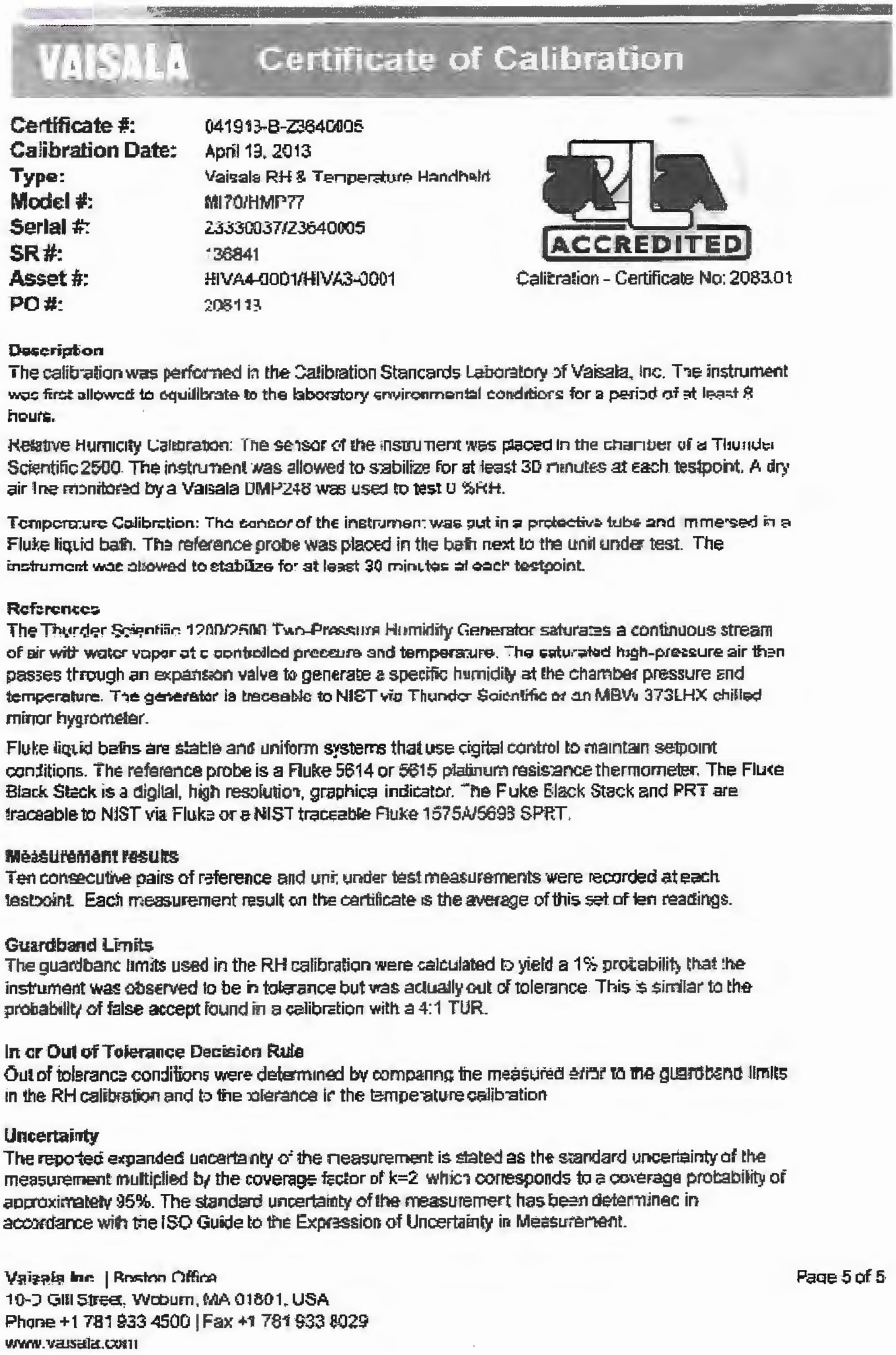
ATTACHMENT 1 (continued)



VAISALA Certificate of Calibration

Certificate #: 041913-B-Z3640005
Calibration Date: April 19, 2013
Type: Vaisala RH & Temperature Handheld
Model #: MI70/HMP77
Serial #: 23330037/Z3640005
SR #: 136841
Asset #: HIVA4-0001/HIVA3-0001
PO #: 208113

ACCREDITED
Calibration - Certificate No: 2083.01

Description

The calibration was performed in the Calibration Standards Laboratory of Vaisala, Inc. The instrument was first allowed to equilibrate to the laboratory environmental conditions for a period of at least 8 hours.

Relative Humidity Calibration: The sensor of the instrument was placed in the chamber of a Thunder Scientific 2500. The instrument was allowed to stabilize for at least 30 minutes at each testpoint. A dry air line monitored by a Vaisala DMP248 was used to test 0 %RH.

Temperature Calibration: The sensor of the instrument was put in a protective tube and immersed in a Fluke liquid bath. The reference probe was placed in the bath next to the unit under test. The instrument was allowed to stabilize for at least 30 minutes at each testpoint.

References

The Thunder Scientific 1200/2500 Two-Pressure Humidity Generator saturates a continuous stream of air with water vapor at a controlled pressure and temperature. The saturated high-pressure air then passes through an expansion valve to generate a specific humidity at the chamber pressure and temperature. The generator is traceable to NIST via Thunder Scientific or an MBW 373LHX chilled mirror hygrometer.

Fluke liquid baths are stable and uniform systems that use digital control to maintain setpoint conditions. The reference probe is a Fluke 5614 or 5615 platinum resistance thermometer. The Fluke Black Stack is a digital, high resolution, graphical indicator. The Fluke Black Stack and PRT are traceable to NIST via Fluke or a NIST traceable Fluke 1575A/5699 SPRT.

Measurement results

Ten consecutive pairs of reference and unit under test measurements were recorded at each testpoint. Each measurement result on the certificate is the average of this set of ten readings.

Guardband Limits

The guardband limits used in the RH calibration were calculated to yield a 1% probability that the instrument was observed to be in tolerance but was actually out of tolerance. This is similar to the probability of false accept found in a calibration with a 4:1 TUR.

In or Out of Tolerance Decision Rule

Out of tolerance conditions were determined by comparing the measured error to the guardband limits in the RH calibration and to the tolerance in the temperature calibration

Uncertainty

The reported expanded uncertainty of the measurement is stated as the standard uncertainty of the measurement multiplied by the coverage factor of k=2 which corresponds to a coverage probability of approximately 95%. The standard uncertainty of the measurement has been determined in accordance with the ISO Guide to the Expression of Uncertainty in Measurement.

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ATTACHMENT 2 – Fluke 80T-150U

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NATIONAL LABORATORY

Instrumentation Services and Technology
M&TE Calibration Services
P7-01, P.O. Box 999
Richland, WA 99352

IS&T Record of Calibration

Barcode: TPFL1-0006

UNIT UNDER TEST (U.U.T.)

Model / Manufacturer: 80T-150U/Fluke

Serial #: 92590020

Function: Temperature Probe

TRC #: N/A

GENERAL CONDITION AND COMMENTS ON U.U.T.

Unit is in serviceable condition. Both outputs (°C and °F) were calibrated. Unit is scaled to provide 1 millivolt output per °C or per °F.

CALIBRATION RELATED INFORMATION

Date of Calibration: 5/31/2013

Next Calibration Due: 5/31/2014

Ambient Temperature: 70.1°F

Ambient Pressure: 29.8 in. Hg

Ambient Humidity: 38%

Procedure Used: Cal-21 rev. 8

Tolerance: ±5.0°C/±9.0°F

Limitations: -49°C to 150°C/-56°F to 306°F

Original sent to: TRIM
Date: 6/5/13 **Initials:** JTCE
Other cc:
Dan Sisk

In-Field Calibration:
☐ YES
☑ NO

As-Found Condition:
☑ IN-TOLERANCE
☐ OUT-OF-TOLERANCE
☐ UNKNOWN
☐ NA

If As-Found condition is UNKNOWN or NA, enter reason:

STANDARDS USED

(Standards are traceable to the National Institute of Standards and Technology)

Barcode #	Name of Standard	Expiration Date	Meets 4:1 TAR
37363	Omega PRHTEMP2000 Weather Station	2/26/2014	N/A
13250	HP 3458A DMM	2/19/2014	Yes
22361	Hart 5626 PRT	4/15/2014	Yes

APPROVALS

PNL
11

Metrology Technician Name

Metrology Technician Stamp

Phil Smith
Metrology Engineer Name

Metrology Engineer Signature

JUN 05 2013
Approval Date

You may comment on our services via http/calibration.pnl.gov/feedback.htm

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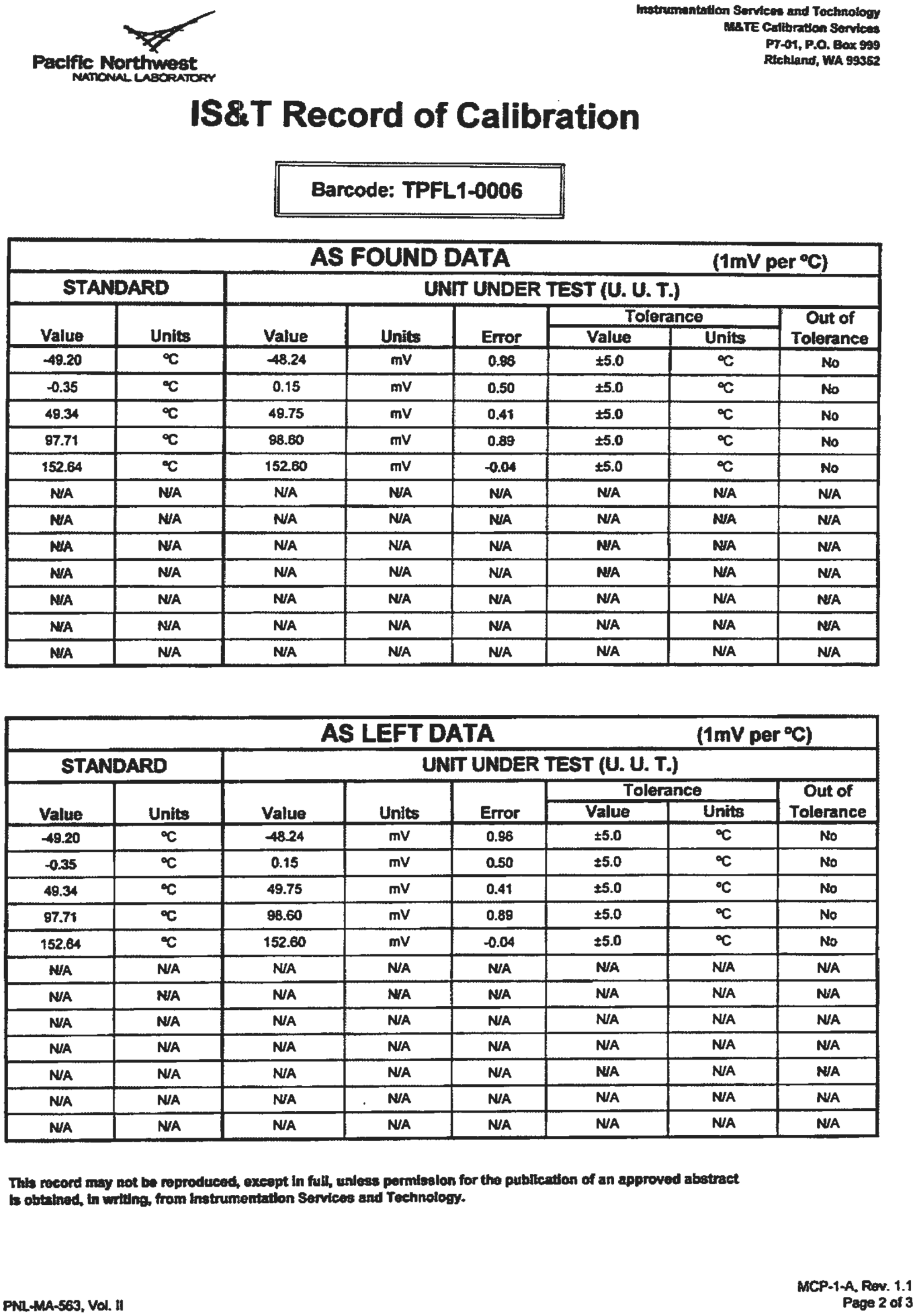
ATTACHMENT 2 (continued)



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Richland, WA 99352

IS&T Record of Calibration

Barcode: TPFL1-0006

AS FOUND DATA (1mV per °C)

STANDARD		UNIT UNDER TEST (U. U. T.)					
					Tolerance		Out of
Value	Units	Value	Units	Error	Value	Units	Tolerance
-49.20	°C	-48.24	mV	0.96	±5.0	°C	No
-0.35	°C	0.15	mV	0.50	±5.0	°C	No
49.34	°C	49.75	mV	0.41	±5.0	°C	No
97.71	°C	98.60	mV	0.89	±5.0	°C	No
152.64	°C	152.60	mV	-0.04	±5.0	°C	No
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

AS LEFT DATA (1mV per °C)

STANDARD		UNIT UNDER TEST (U. U. T.)					
					Tolerance		Out of
Value	Units	Value	Units	Error	Value	Units	Tolerance
-49.20	°C	-48.24	mV	0.96	±5.0	°C	No
-0.35	°C	0.15	mV	0.50	±5.0	°C	No
49.34	°C	49.75	mV	0.41	±5.0	°C	No
97.71	°C	98.60	mV	0.89	±5.0	°C	No
152.64	°C	152.60	mV	-0.04	±5.0	°C	No
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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ATTACHMENT 2 (continued)

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Richland, WA 99352

IS&T Record of Calibration

Barcode: TPFL1-0006

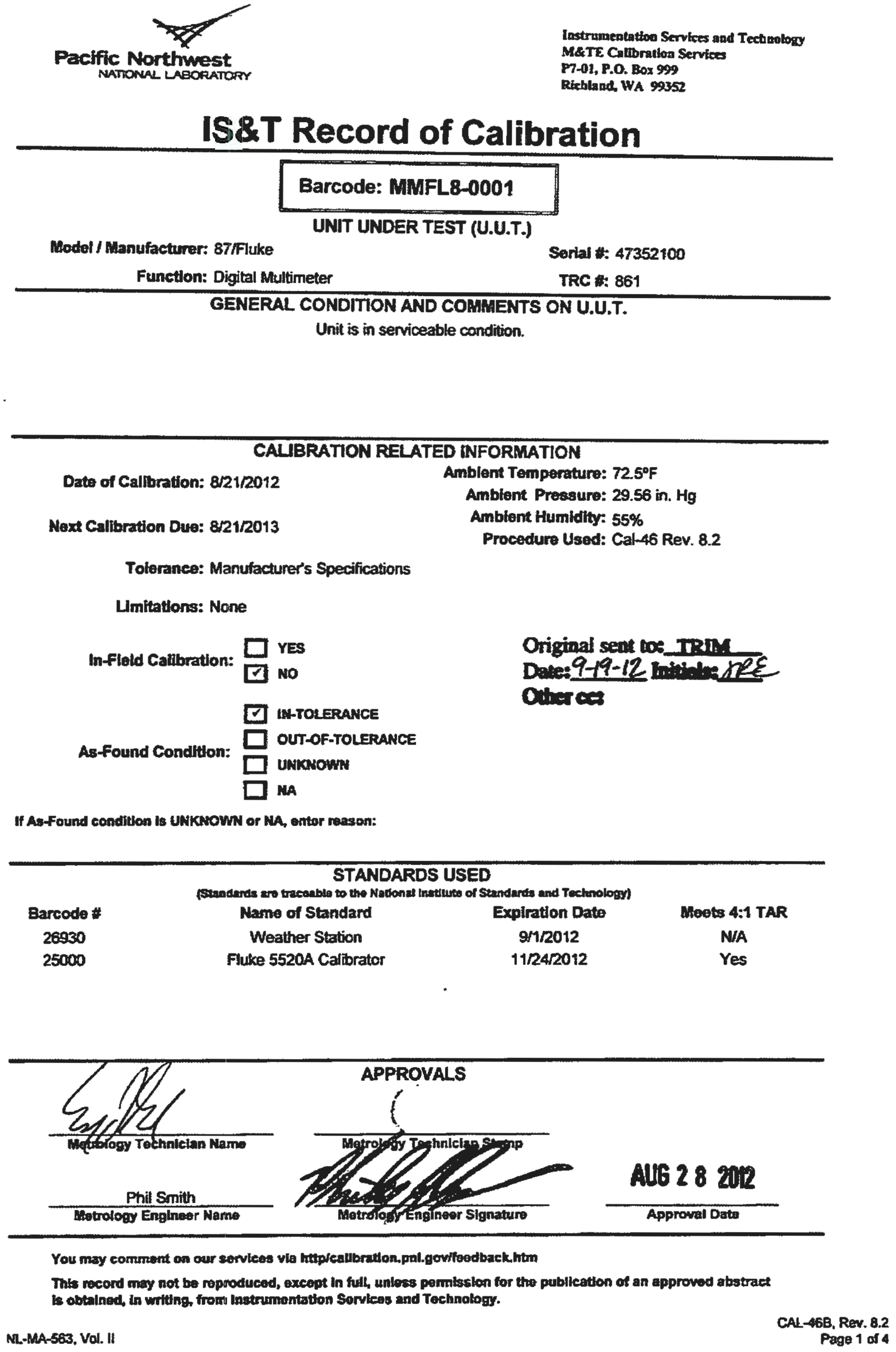
AS FOUND DATA (1mV per °F)

STANDARD		UNIT UNDER TEST (U. U. T.)					
					Tolerance		Out of Tolerance
Value	Units	Value	Units	Error	Value	Units	
-56.56	°F	-55.49	mV	1.07	±9.0	°F	No
31.40	°F	31.46	mV	0.06	±9.0	°F	No
120.90	°F	121.21	mV	0.31	±9.0	°F	No
207.89	°F	209.09	mV	1.20	±9.0	°F	No
306.84	°F	306.63	mV	-0.21	±9.0	°F	No
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

AS LEFT DATA (1mV per °F)

STANDARD		UNIT UNDER TEST (U. U. T.)					
					Tolerance		Out of Tolerance
Value	Units	Value	Units	Error	Value	Units	
-56.58	°F	-55.49	mV	1.07	±9.0	°F	No
31.40	°F	31.46	mV	0.06	±9.0	°F	No
120.90	°F	121.21	mV	0.31	±9.0	°F	No
207.89	°F	209.09	mV	1.20	±9.0	°F	No
306.84	°F	306.63	mV	-0.21	±9.0	°F	No
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

ATTACHMENT 3 – Fluke 87 Digital Multimeter



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Richland, WA 99352

IS&T Record of Calibration

Barcode: MMFL8-0001

UNIT UNDER TEST (U.U.T.)

Model / Manufacturer: 87/Fluke

Serial #: 47352100

Function: Digital Multimeter

TRC #: 861

GENERAL CONDITION AND COMMENTS ON U.U.T.

Unit is in serviceable condition.

CALIBRATION RELATED INFORMATION

Date of Calibration: 8/21/2012

Next Calibration Due: 8/21/2013

Ambient Temperature: 72.5°F

Ambient Pressure: 29.56 in. Hg

Ambient Humidity: 55%

Procedure Used: Cal-46 Rev. 8.2

Tolerance: Manufacturer's Specifications

Limitations: None

In-Field Calibration: ☐ YES ☑ NO

As-Found Condition:
☑ IN-TOLERANCE
☐ OUT-OF-TOLERANCE
☐ UNKNOWN
☐ NA

If As-Found condition is UNKNOWN or NA, enter reason:

Original sent to: TRIM
Date: 9-19-12 Initials: RPE
Other cc:

STANDARDS USED

(Standards are traceable to the National Institute of Standards and Technology)

Barcode #	Name of Standard	Expiration Date	Meets 4:1 TAR
26930	Weather Station	9/1/2012	N/A
25000	Fluke 5520A Calibrator	11/24/2012	Yes

APPROVALS

Metrology Technician Name

Metrology Technician Stamp

Phil Smith
Metrology Engineer Name

Metrology Engineer Signature

AUG 28 2012
Approval Date

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ATTACHMENT 3 (continued)

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IS&T Record of Calibration

Fluke 87 True RMS Multimeter

Barcode: MMFL8-0001

Testing the Display

Step	Input from standard	UUT			
		Function / Range	Allowable Output	As-found pass?	As-left pass?
1	None	Display test mode	Per Figure 3-3	Pass	Pass

Table 3-2. Rotary Switch Test

Step	Input from standard	UUT			
		Function / Range	Allowable Output	As-found output	As-left output
1	None	OFF	▨	Off	Off
2	None	V AC	-12 to 12	0000	0000
3	None	V DC	-44 to -20	-0030	-0030
4	None	mV DC	-76 to -52	-0063	-0063
5	None	Ohms	-108 to -84	-0098	-0098
6	None	Diode	-140 to -116	-0129	-0129
7	None	mA/A	-172 to -148	-0162	-0162
8	None	µA	-204 to -180	-0192	-0192

Table 3-3. AC Voltage Test

Step	Input from standard		UUT			
	Voltage	Frequency	Function / Range	Allowable Output	As-found output	As-left output
1	350.0 mV	60 Hz	V AC	347.1 to 352.9	350.5	350.5
2	350.0 mV	1 kHz	V AC	346.1 to 353.9	350.9	350.9
3	350.0 mV	5 kHz	V AC	342.6 to 357.4	350.0	350.0
4	350.0 mV	20 kHz	V AC	341.0 to 359.0	355.0	355.0
5	3.500 V	60 Hz	V AC	3.473 to 3.527	3.503	3.503
6	3.500 V	1 kHz	V AC	3.461 to 3.539	3.504	3.504
7	3.500 V	5 kHz	V AC	3.426 to 3.574	3.494	3.494
8	3.500 V	20 kHz	V AC	3.410 to 3.590	3.506	3.506
9	35.00 V	60 Hz	V AC	34.73 to 35.27	35.02	35.02
10	35.00 V	1 kHz	V AC	34.61 to 35.39	35.07	35.07
11	35.00 V	5 kHz	V AC	34.26 to 35.74	34.95	34.95
12	35.00 V	20 kHz	V AC	34.10 to 35.90	34.88	34.88
13	350.0 V	60 Hz	V AC	347.3 to 352.7	350.1	350.1
14	350.0 V	1 kHz	V AC	346.1 to 353.9	350.9	350.9
15	350.0 V	5 kHz	V AC	342.6 to 357.4	350.9	350.9
16	100.0 V	20 kHz	V AC	96.0 to 104.0	100.6	100.6
17	200.0 V	20 kHz	V AC	194.0 to 206.0	201.3	201.3
18	300.0 V	20 kHz	V AC	292.0 to 308.0	301.6	301.6
19	900 V	60 Hz	V AC	892 to 908	906	906
20	900 V	1 kHz	V AC	887 to 913	909	909
21	900 V	5 kHz	V AC	878 to 922	909	909

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IS&T Record of Calibration

Fluke 87 True RMS Multimeter

Barcode: MMFL8-0001

Table 3-4. Frequency Test

Step	Input from standard		UUT			
	Voltage (sine wave)	Frequency	Function / Range	Allowable Output	As-found output	As-left output
1	150 mV rms	19.000 kHz	400 mV AC + Hz	18.998 to 19.002	18.999	18.999
2	150 mV rms	190.00 kHz	400 mV AC + Hz	189.98 to 190.02	189.99	189.99

Table 3-5. Frequency Counter Sensitvity and Trigger Level Tests

Step	Input from standard		UUT			
	Amplitude (RMS)	Frequency	Function / Range	Allowable Output	As-found output	As-left output
1	300 mV AC	1 kHz	4 V AC	999.8 to 1000.2	999.9	999.9
2	1.7 V AC	1 kHz	4 V DC	999.8 to 1000.2	999.9	999.9
3	1.0 V AC	1 kHz	4 V DC	000.0	000.0	000.0
4	6.0 V AC	1 kHz	40 V DC	999.8 to 1000.2	999.9	999.9
5	2.0 V AC	1 kHz	40 V DC	000.0	000.0	000.0

Table 3-6. DC Voltage Test

Step	Input from standard		UUT			
	Voltage	Frequency	Function / Range	Allowable Output	As-found output	As-left output
1	3.500 V	DC	V DC	3.495 to 3.505	3.500	3.500
2	35.00 V	DC	V DC	34.95 to 35.05	35.00	35.00
3	-35.00 V	DC	V DC	-34.95 to -35.05	-34.99	-34.99
4	350.0 V	DC	V DC	349.5 to 350.5	349.9	349.9
5	1000 V	DC	V DC	998 to 1002	1000	1000

Table 3-7. 1-MS MIN MAX Test

Step	Input from standard		UUT			
	Voltage	Frequency	Function / Range	Allowable Output	As-found output	As-left output
1	2.0 V	60 Hz	V DC + min/max + beep	2.765 to 2.890	2.820	2.820
2	2.0 V	60 Hz	V DC + min/max + beep	-2.765 to -2.890	-2.816	-2.816

Testing the mV DC Function

Step	Input from standard		UUT			
	Voltage	Frequency	Function / Range	Allowable Output	As-found output	As-left output
1	350 mV	DC	mV DC	349.5 to 350.5	350.0	350.0

Table 3-8. Ohms Tests

Step	Input from standard	UUT			
		Function / Range	Allowable Output	As-found output	As-left output
1	190.0 Ω	Ω	189.5 to 190.5	190.1	190.1
2	19.00 kΩ	Ω	18.95 to 19.05	19.00	19.00
3	1.900 MΩ	Ω	1.895 to 1.905	1.900	1.900
4	19.00 MΩ	Ω	18.78 to 19.22	18.98	18.98
5	100.0 MΩ	40 nanosiemen	9.80 to 10.20 nS	9.99	9.99

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IS&T Record of Calibration

Fluke 87 True RMS Multimeter

Barcode: MMFL8-0001

Table 3-9. Capacitance Tests

Step	Input from standard	UUT			
		Function / Range	Allowable Output * from guardbanding	As-found output	As-left output
1	1.0 µF	Capacitance	0.96 to 1.04	0.99	0.99
2	0.470 µF	Capacitance	0.463 to 0.477 *	0.469	0.469
3	0.0470 µF	Capacitance	0.0463 to 0.0477 *	0.0473	0.0473
4	4.70 µF	Capacitance + Rel.	4.63 to 4.77 *	4.69	4.69

Checking the Diode Test Function

Step	Input from standard		UUT			
	Voltage	Frequency	Function / Range	Allowable Output	As-found output	As-left output
1	3.000 V	DC	Diode Test	2.939 to 3.061	2.989	2.989

Table 3-10. mA Tests

Step	Input from standard		UUT			
	Current	Frequency	Function / Range	Allowable Output	As-found output	As-left output
1	35.00 mA	DC	mA DC	34.91 to 35.09	35.02	35.02
2	350.0 mA	DC	mA DC	349.1 to 350.9	350.0	350.0
3	35.00 mA	60 Hz	mA AC	34.63 to 35.37	35.15	35.15
4	35.00 mA	1.0 kHz	mA AC	34.63 to 35.37	35.16	35.16
5	350.0 mA	60 Hz	mA AC	346.3 to 353.7	350.8	350.8
6	350.0 mA	1.0 kHz	mA AC	346.3 to 353.7	351.3	351.3

Table 3-11. µA Tests

Step	Input from standard		UUT			
	Current	Frequency	Function / Range	Allowable Output	As-found output	As-left output
1	350.0 µA	DC	µA DC	349.0 to 351.0	350.2	350.2
2	3500 µA	DC	µA DC	3491 to 3509	3499	3499
3	350.0 µA	60 Hz	µA AC	346.3 to 353.7	351.3	351.3
4	350.0 µA	1.0 kHz	µA AC	346.3 to 353.7	351.3	351.3
5	3500 µA	60 Hz	µA AC	3463 to 3537	3506	3506
6	3500 µA	1.0 kHz	µA AC	3463 to 3537	3511	3511

Table 3-12. Current Tests

Step	Input from standard		UUT			
	Current	Frequency	Function / Range	Allowable Output	As-found output	As-left output
1	3500 mA	DC	mA / A DC	3491 to 3509	3503	3503
2	10.00A	DC	mA / A DC	9.96 to 10.04	10.00	10.00
3	3500 mA	60 Hz	mA / A AC	3463 to 3537	3508	3508
4	3500 mA	1.0 kHz	mA / A AC	3463 to 3537	3515	3515
5	10.00 A	60 Hz	mA / A AC	9.88 to 10.12	10.06	10.06
6	10.00 A	1.0 kHz	mA / A AC	9.88 to 10.12	10.07	10.07

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ATTACHMENT 4 – Fisher 02-400 Digital Weather Station

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P7-01, P.O. Box 999
Richland, WA 99352

IS&T Record of Calibration

Barcode: WSFI1-0004

UNIT UNDER TEST (U.U.T.)

Model / Manufacturer: 02-400/Fisher

Serial #: N/A

Function: Digital Weather Station

TRC #: 680

GENERAL CONDITION AND COMMENTS ON U.U.T.

Unit is missing battery compartment cover (does not affect operation of unit). Altitude set to 0 feet during barometric pressure calibration. Altitude set to 120 feet after calibration was complete.

**This tolerance is for IS&T Internal Use Only (Guardbanding). Item is calibrated to the specifications listed on the first page*

CALIBRATION RELATED INFORMATION

Date of Calibration: 6/13/2013

Next Calibration Due: 6/13/2014

Ambient Temperature: 69.5°F

Ambient Pressure: 29.59 in. Hg

Ambient Humidity: 35%

Procedure Used: Cal-P2 rev. 1.2: Cal-45 rev. 4

Tolerance: ±1.8°F, ±0.1477 in. Hg

Limitations: 60°F to 80°F, 25.0 to 31.0 in. Hg

In-Field Calibration: ☐ YES ☑ NO

As-Found Condition:
☑ IN-TOLERANCE
☐ OUT-OF-TOLERANCE
☐ UNKNOWN
☐ NA

If As-Found condition is UNKNOWN or NA, enter reason:

Original sent to: TRIM
Date: 6-18-13 **Initials:**
Other cc:

STANDARDS USED

(Standards are traceable to the National Institute of Standards and Technology)

Barcode #	Name of Standard	Expiration Date	Meets 4:1 TAR
37363	Omega PRHTEMP2000	2/26/2014	N/A
22361	Hart 5626 PRT	4/15/2014	Yes
17403	Heise System 54: 0 to 15 PSIA	9/4/2013	Yes
23481	Heise System 54: 0 to 150 PSIA	9/4/2013	No-Guardbanded

APPROVALS

Metrology Technician Name

11

Metrology Technician Stamp

HANS BRANDAL
~~Phil Smith~~
Metrology Engineer Name

13-618
Metrology Engineer Signature

JUN 18, 2013
Approval Date

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Richland, WA 99352

IS&T Record of Calibration

Barcode: WSFI1-0004

AS FOUND DATA

STANDARD		UNIT UNDER TEST (U. U. T.)					
					Tolerance		Out of Tolerance
Value	Units	Value	Units	Error	Value	Units	
58.97	°F	59.0	°F	0.03	±1.8	°F	No
64.31	°F	63.5	°F	-0.81	±1.8	°F	No
69.38	°F	68.9	°F	-0.48	±1.8	°F	No
74.71	°F	74.3	°F	-0.41	±1.8	°F	No
81.43	°F	80.6	°F	-0.83	±1.8	°F	No
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

AS LEFT DATA

STANDARD		UNIT UNDER TEST (U. U. T.)					
					Tolerance		Out of Tolerance
Value	Units	Value	Units	Error	Value	Units	
58.97	°F	59.0	°F	0.03	±1.8	°F	No
64.31	°F	63.5	°F	-0.81	±1.8	°F	No
69.38	°F	68.9	°F	-0.48	±1.8	°F	No
74.71	°F	74.3	°F	-0.41	±1.8	°F	No
81.43	°F	80.6	°F	-0.83	±1.8	°F	No
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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IS&T Record of Calibration

Barcode: WSFI1-0004

AS FOUND DATA

STANDARD		UNIT UNDER TEST (U. U. T.)					
					Tolerance		Out of Tolerance
Value	Units	Value	Units	Error	Value	Units	
24.958	in. Hg	24.89	in. Hg	-0.07	±0.1477	in. Hg	No
26.484	in. Hg	26.43	in. Hg	-0.05	±0.1477	in. Hg	No
28.013	in. Hg	27.96	in. Hg	-0.05	±0.1477	in. Hg	No
29.621	in. Hg	29.59	in. Hg	-0.03	±0.1477	in. Hg	No
31.080	in. Hg	31.01	in. Hg	-0.07	±0.1083*	in. Hg	No
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

AS LEFT DATA

STANDARD		UNIT UNDER TEST (U. U. T.)					
					Tolerance		Out of Tolerance
Value	Units	Value	Units	Error	Value	Units	
24.958	in. Hg	24.89	in. Hg	-0.07	±0.1477	in. Hg	No
26.484	in. Hg	26.43	in. Hg	-0.05	±0.1477	in. Hg	No
28.013	in. Hg	27.96	in. Hg	-0.05	±0.1477	in. Hg	No
29.621	in. Hg	29.59	in. Hg	-0.03	±0.1477	in. Hg	No
31.080	in. Hg	31.01	in. Hg	-0.07	±0.1083*	in. Hg	No
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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ATTACHMENT 5

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Internal Distribution

Date January 30, 2013

To IS&T and CR&A QA Files

From Roger A. Gregg

Subject Source 318-528, SRII1-0003 (High Exposure Facility #8) Annual Calibration Verification (Tracking No. 13027)

Calibration verification of High Exposure Facility (HEF) Co-60 source 318-528, coupled with the operational software *hef.exe, version 10/18/11 11:35 AM*, was performed on January 25, 2013. The protocol for this routine verification follows CR&A procedure TP-1P04 and involves measuring the exposure rate in air in both the *Position Mode* and *Exposure Rate Mode* at the computer-selected points that correspond to 20% and 80% of each decade, as attainable. All measurement results were compared to the exposure rates displayed by the computer in the "Uncompensated" mode, which reflect exposure rates determined in, and decayed from calibration measurements of January 2012. All measurements were performed without the lead attenuator in place.

Appropriate corrections were made for electrometer offset (as appropriate), ionization chamber response (Roentgen/Coulomb) and ambient temperature and pressure conditions to correct the response to 22° C and 760 mmHg. Ion chamber measurements were performed in accordance with TP-1P02, *Photon Measurements Using Air Ionization Chambers*, revision 0.

The components used to evaluate the individual uncertainties and their magnitudes are detailed on the data summary (spreadsheet printout) available within Attachment 1. In a review of the data summary, it was noted that uncertainties at closer distances (e.g., 0.5 and 0.3 m) may be low due to conservative assumptions of the calculations within the spreadsheet. At the 0.3 m position, the true uncertainty appears to be roughly 1% higher. This shortcoming is not judged to be of critical importance to this measurement as all measured errors are within the conservatively estimated uncertainties.

Traceability to the National Institute of Standards and Technology (NIST) for this calibration is established through use of the Exradin Model A12 ionization chamber, s/n XA102351, one of the in-house working standards, which is traceable through direct comparison to the secondary standard PM-30 ion chamber, S/N CII30.7502.

APPENDIX B

TEMPERATURE TESTING DATA SHEETS

Data Collector	Date	Test	Cone ID
Jordan Follett	7/23/13	Temp Test 1	090420T I-CFXY-10

Time	Tip Resistance (kN)	Friction Ratio (%)	Inclination (°)
0:00	0.027	0.00	0.6
0:01	0.026	0.00	0.5
0:02	0.027	0.00	0.5
0:03	0.027	0.00	0.6
0:04	0.027	0.00	0.6
0:05	0.026	0.00	0.5
0:06	0.026	0.00	0.5
0:07	0.027	0.00	0.5
0:08	0.026	0.00	0.5
0:09	0.027	0.00	0.6
0:10	0.026	0.00	0.5

Begin End

Comments	-0.077 -0.026 0.4 -0.6	23.3°C

Data Collector	Date	Test	Cone ID
Jordan Follett	7/23/13	Temp Test 2	~~[illegible]~~ 090420T I-CFXY-10

Time	Tip Resistance (kN)	Friction Ratio (%)	Inclination (°)
0:00	0.025	0.00	0.8
0:01	0.025	0.00	0.9
0:02	0.025	0.00	0.8
0:03	0.025	0.00	0.9
0:04	0.025	0.00	0.9
0:05	0.025	0.00	0.9
0:06	0.024	0.00	0.8
0:07	0.025	0.00	0.9
0:08	0.025	0.00	0.8
0:09	0.025	0.00	0.9
0:10	0.025	0.00	0.9

Comments	Begin	End	
	-0.076	-0.052	23.3°C
	-0.025	-0.025	
	1.5	0.7	
	-0.4	-0.4	

Data Collector	Date	Test	Cone ID
Jordan Follett	7/23/13	Temp Test 3	090420T I-CFXY-10

Time	Tip Resistance (kN)	Friction Ratio (%)	Inclination (°)
0:00	0.026	0.00	1.0
0:01	0.026	0.00	1.0
0:02	0.026	0.00	1.0
0:03	0.026	0.00	0.9
0:04	0.026	0.00	0.9
0:05	0.026	0.00	0.9
0:06	0.026	0.00	0.9
0:07	0.026	0.00	0.9
0:08	0.026	0.00	0.9
0:09	0.026	0.00	0.9
0:10	0.026	0.00	0.9

Comments	Begin	End	
	-0.076	-0.051	23.3°C
	-0.025	-0.025	
	0.3	-0.2	
	-2.2	-1.3	

Data Collector	Date	Test	Cone ID
Jordan Follett	7/23/13	High Temp Test Sh.1	090420T I-CFXY-10

	Time	Tip Resistance (kN)	Friction Ratio (%)	Inclination (°)	
8:00	0:00	~~0.023~~ *0.024 J.F. 7/23/13	0.00	~~1.1~~ 0.8 * J.F. 7/23/13	oven 73.9°F
9:00	0:00	0.023	0.00	0.6	74.0°F multimeter
oven: 148 °F luke: 145.9°F	0:15	0.020	0.00	0.6	
aisala: 145.33°F	0:30	0.018	0.00	J.F. 7/23/13 0.5	
o: 148 °F	0:45	0.016	0.00	0.5	
F: 146.3°F V: 145.72°F	1:00	0.014	0.00	0.5	
RH 0.03%	1:15	0.014	0.00	0.6	
	1:30	0.013	0.00	0.5	
o: 148.0 °F	1:45	0.012	0.00	0.5	
: 146.3 °F : 145.78 °F	2:00	0.012	0.00	0.6	
RH 0.03 %	2:15	0.012	0.00	0.6	
	2:30	0.012	0.00	0.5	
: 148.0 °F	2:45	0.012	0.00	0.5	
: 146.4 °F V: 145.86 °F	3:00	0.012	0.00	0.5	
RH 0.03 %	3:15	0.012	0.00	0.5	
	3:30	0.012	0.00	0.5	
o: 148.0 °F	3:45	0.012	0.00	0.5	
: 146.6 °F : 145.93 °F	4:00	0.012	0.00	0.6	
RH 0.03%	4:15	0.012	0.00	0.5	
	4:30	0.012	0.00	0.6	
o: 148.0 °F	4:45	0.012	0.00	0.5	
F: 146.5 °F V: 145.97 °F	5:00	0.012	0.00	0.6	

RH 0.03 %

Comments	* cone moved when inserting temp probe; inclination corrected resistance Begin End -0.077 -0.056 -0.025 -0.029 0.5 0.5 -1.6 -0.6 → temp probe observed swinging in chamber indicating air flow that may impact values utilized Fluke 80T temp probe MMFL8-0001

TPFL1-0006

also used Vaisala MI70 HIVA4-0001

Data Collector	Date	Test	Cone ID
Jordan Follett	7/23/13	High Temp Test St. 2	

	Time	Tip Resistance (kN)	Friction Ratio (%)	Inclination (°)
	5:15	0.012	0.00	0.5
	5:30	0.012	0.00	0.5
: 148 °F : 146.6 °F	5:45	0.012	0.00	0.5
: 145.93 °F RH 0.03 %	6:00	0.012	0.00	0.5
	* 6:15	0.012	0.00	0.5
	6:30	0.012	0.00	0.5
: 148.1 °F : 147.8 °F	6:45	0.011	0.00	0.5
: 147.24 °F RH 50.14%	7:00	0.012	0.00	0.5
	7:15	0.011	0.00	0.5
	2.51% RH 7:30	0.012	0.00	0.5
: 71.8 °F : 74.7 °F : 76.95 °F	7:45	0.008	0.00	0.7
RH 5.58%	8:00	0.07	0.00	1.1
: 77.93	8:05	0.011	0.00	1.0
: 78.39	8:20	0.016	0.00	1.0
: 78.03	8:30	J.F. 7/23/13 0.018	0.00	1.0
: 77.81	8:40	0.019	0.00	1.0
: 77.31	8:50	0.021	0.00	1.0
V:				
V:				
V:				
V:				

Comments	→ increased RH at 6:00 from 0% setpoint to 50% * → at 6:15 reading, RH = 48.73% T= 147.53 °F → at 6:30 reading, RH= 49.79% T= 147.39 °F → changed RH to 1% at 7:17 2.51% at 7:30 → changed T setpoint from 145 to 110 °F at 7:30

→ 7:45 T = 112.22 RH 2.58%

→ changed T setpoint to 72°F at 7:45

→ shut off chamber and opened door at 8:00

Cone warm to touch at conclusion of test

Data Collector	Date	Test	Cone ID
Jordan Follett	7/23/13	Temp Test 4 (control)	090420T I-CFXY-10

Time	Tip Resistance (kN)	Friction Ratio (%)	Inclination (°)
0:00	0.024	0.00	0.7
0:01	0.024	0.00	0.6
0:02	0.024	0.00	0.7
0:03	0.024	0.00	0.6
0:04	0.025	0.00	0.6
0:05	0.025	0.00	0.6
0:06	0.025	0.00	0.6
0:07	0.025	0.00	0.7
0:08	0.025	0.00	0.7
0:09	0.025	0.00	0.6
0:10	0.026	0.00	0.6

start end

Comments	77.32°F at 0:00 -0.081 -0.056 37.02 % RH -0.029 -0.029 76.63 °F at 0:10 0.3 0.7 38.18 % -0.6 -1.2 started test immediately following 8 hr temp test; Icone still above ambient temp at start

Data Collector	Date	Test	Cone ID
Jordan Follett	7/23/13	Temp Test 5 (control)	0904207 I-CFXY-10

Time	Tip Resistance (kN)	Friction Ratio (%)	Inclination (°)
0:00	0.024	0.00	6.6
0:01	0.024	0.00	0.6
0:02	0.024	0.00	0.7
0:03	0.024	0.00	0.6
0:04	0.024	0.00	0.6
0:05	0.025	0.00	0.6
0:06	0.025	0.00	0.6
0:07	0.025	0.00	0.6
0:08	0.025	0.00	0.6
0:09	0.025	0.00	0.6
0:10	0.025	0.00	0.6

Comments	76.61 °F at 0:00 38.35 % 75.83 °F at 0:10 35.51 % Start end -0.080 -0.055 -0.029 -0.028 0.6 1.0 -1.4 -0.9

Data Collector	Date	Test	Cone ID
Jordan Follett	7/23/13	Temp Test 6 (control)	090420T I-CFXY-10

Time	Tip Resistance (kN)	Friction Ratio (%)	Inclination (°)
0:00	0.024	0.00	0.8
0:01	0.024	0.00	0.8
0:02	0.024	0.00	0.8
0:03	0.025	0.00	0.8
0:04	0.025	0.00	0.8
0:05	0.025	0.00	0.8
0:06	0.025	0.00	0.8
0:07	0.025	0.00	0.8
0:08	0.025	0.00	0.8
0:09	0.025	0.00	0.8
0:10	0.025	0.00	0.8

Comments	75.79 °F 36.34 % at 0:00 75.84 °F at 0:10 36.01 % Start end -0.079 -0.054 -0.028 -0.028 0.3 1.2 -1.7 -1.5

APPENDIX C

RADIATION EXPOSURE TESTING DATA SHEETS

Data Collector	Date	Test	Cone ID
Jordan Follett	7/25/13	Rad Control Pre-Test 1	090420T I-CFXY-10

Time	Tip Resistance (kN)	Friction Ratio (%)	Inclination (°)
0:00	0.122	0.00	1.2
0:01	0.121	0.00	1.1
0:02	0.120	0.00	1.2
0:03	0.120	0.00	1.2
0:04	0.120	0.00	1.2
0:05	0.120	0.00	1.1
0:06	0.119	0.00	1.2
0:07	0.119	0.00	1.2
0:08	0.119	0.00	1.2
0:09	0.119	0.00	1.2
0:10	0.119	0.00	1.2

	Start Values	End Values	Temperature (°F)	RH (%)
Comments	-0.098	0.021	73.4	33
	-0.022	-0.026		
	0.3	1.5		
	1.1	0.9		

Data Collector	Date	Test	Cone ID
Jordan Follett	7/25/13	Rad Control Pre-Test 2	090420T I-CFXY-10

Time	Tip Resistance (kN)	Friction Ratio (%)	Inclination (°)
0:00	0.121	0.00	1.3
0:01	0.121	0.00	1.3
0:02	0.121	0.00	1.3
0:03	0.121	0.00	1.3
0:04	0.121	0.00	1.3
0:05	0.121	0.00	1.3
0:06	0.120	0.00	1.3
0:07	0.121	0.00	1.3
0:08	0.121	0.00	1.3
0:09	0.120	0.00	1.3
0:10	0.121	0.00	1.3

Comments	Start Values	End Values	Temperature (°F)	RH (%)
	-0.096	0.025	73.4	33
	-0.025	-0.026		
	2.3	1.9		
	0.7	-0.5		

Data Collector	**Date**	**Test**	**Cone ID**
Jordan Follett	7/25/13	Rad Control Pre-Test 3	090420T I-CFXY-10

Time	**Tip Resistance (kN)**	**Friction Ratio (%)**	**Inclination (°)**
0:00	0.131	0.00	0.5
0:01	0.130	0.00	0.5
0:02	0.130	0.00	0.5
0:03	0.130	0.00	0.5
0:04	0.130	0.00	0.5
0:05	0.129	0.00	0.5
0:06	0.129	0.00	0.4
0:07	0.129	0.00	0.5
0:08	0.129	0.00	0.5
0:09	0.129	0.00	0.5
0:10	0.129	0.00	0.5

Comments	Start Values	End Values	Temperature (°F)	RH (%)
	-0.092	0.037	74.3	33
	-0.026	-0.026		
	1.4	1.0		
	-0.2	0.1		

Data Collector	Date	Test	Cone ID
Dustin May	7-25-13	24 hr Exposure	090420T I-CFXY-10

Start time: 9:25am

Time	Tip Resistance (kN)	Friction Ratio (%)	Inclination (°)	Temperature (°F)	Relative Humidity (%)
0:00	0.130	0.00	0.4	74.3	33
0:01	0.130	0.00	0.4	74.3	33
0:02	0.130	0.00	0.4	74.3	33
0:03	0.130	0.00	0.4	74.3	33
0:04	0.130	0.00	0.4	74.3	33
0:05	0.130	0.00	0.4	74.3	33
0:10	0.130	0.00	0.4	74.3	33
0:15	0.130	0.00	0.4	74.3	33
0:20	0.130	0.00	0.5	74.3	33
0:25	0.129	0.00	0.5	74.3	33
0:30	0.130	0.00	0.5	73.4	33
1:00	0.129	0.00	0.4	74.3	32
1:30	0.129	0.00	0.4	74.3	32
2:00	0.129	0.00	0.4	74.3	31
2:30	0.129	0.00	0.6	74.3	31
3:00	0.129	0.00	0.7	73.4	31
3:30	0.128	0.00	0.7	74.3	31
4:00	0.128	0.00	0.7	74.3	31
4:30	0.128	0.00	0.6	74.3	31
5:00	0.128	0.00	0.6	73.4	31
5:30	0.128	0.00	0.5	73.4	31

Comments	Start Values End Values

Data Collector	Date	Test	Cone ID
Dustin May	7-25-13	24 hr Exposure	090420T I-CFXY-10

Time	Tip Resistance (kN)	Friction Ratio (%)	Inclination (°)	Temperature (°F)	Relative Humidity (%)
6:00 ~~0:00~~	0.128	0.00	0.5	73.4	30
6:30	0.127	0.00	0.5	73.4	30
7:00	0.127	0.00	0.4	73.4	30
7:30	0.127	0.00	0.4	73.4	31
8:00	0.127	0.00	0.5	73.4	31
8:30	0.127	0.00	0.5	73.4	31
9:00	0.127	0.00	0.4	73.4	31
9:30	0.127	0.00	0.4	73.4	31
10:00	0.126	0.00	0.5	73.4	31
10:30	0.126	0.00	0.6	73.4	32
11:00	0.126	0.00	0.4	73.4	33
11:30	0.126	0.00	0.4	73.4	33
* 12:00	0.126	0.00	0.4	73.4	33
12:05	0.126	0.00	1.5	73.4	33
12:30	0.127	0.00	1.5	73.4	33
13:00	0.127	0.00	1.5	73.4	32
13:30	0.127	0.00	1.5	73.4	32
14:00	0.127	0.00	1.3	73.4	31
14:30	0.128	0.00	1.3	73.4	28
15:00	0.127	0.00	1.4	73.4	27
15:30	0.128	0.00	1.3	73.4	26

Comments	Start Values End Values * 12:00 → rotated load cell 180° (tip resistance remained the same, inclination slightly changed due to manual rotation)

Data Collector	Date	Test	Cone ID
Jordan Follett	7/26/13	24 Hr Exposure Test	090420T I-CFXY-10

Time	Tip Resistance (kN)	Friction Ratio (%)	Inclination (°)	Temperature (°F)	Relative Humidity (%)
300a ~~0:00~~ 16:00	0.128	0.00	1.3	73.4	25
16:30	0.128	0.00	1.3	74.3	25
17:00	0.128	0.00	1.5	73.4	25
17:30	0.128	0.00	1.5	73.4	25
18:00	0.128	0.00	1.5	73.4	25
18:30	0.127	0.00	1.4	73.4	30
19:00	0.128	0.00	1.5	73.4	30
19:30	0.128	0.00	1.2	73.4	31
20:00	0.128	0.00	1.3	73.4	32
20:30	0.128	0.00	1.4	73.4	32
21:00	0.128	0.00	1.5	73.4	31
21:30	0.128	0.00	1.6	73.4	31
22:00	0.128	0.00	1.6	74.3	31
22:30	0.127	0.00	1.6	74.3	31
23:00	0.127	0.00	1.6	74.3	31
23:30	0.127	0.00	1.7	74.3	31
300a 24:00	0.127	0.00	1.7	74.3	31

Comments

Start Values	End Values
-0.096	0.032
-0.026	-0.024
0.8	0.7
-0.4	1.4

✓ 6000R total

Data Collector	Date	Test	Cone ID
Jordan Follett	7/25/13	Rad Control Post-Test 1	090420T I-CFXY-10

Time	Tip Resistance (kN)	Friction Ratio (%)	Inclination (°)
0:00	0.025	0.00	7.5
0:01	0.025	0.00	7.5
0:02	0.024	0.00	7.5
0:03	0.025	0.00	7.6
0:04	0.023	0.00	7.5
0:05	0.024	0.00	7.5
0:06	0.027	0.00	7.5
0:07	0.024	0.00	7.5
0:08	0.027	0.00	7.5
0:09	0.025	0.00	7.5
0:10	0.027	0.00	7.6

	Start Values	End Values	Temperature (°F)	RH (%)
Comments	-0.083 -0.024 90.0 -0.1	-0.058 -0.024 90.0 7.5	75.2	30

- Tests run with cone positioned for high exposure test
- rod was removed and Icone was placed at an angle

Data Collector	Date	Test	Cone ID
Jordan Follett	7/25/13	Rad Control Post-Test 2	090420T I-CFXY-10

Time	Tip Resistance (kN)	Friction Ratio (%)	Inclination (°)
0:00	0.013	0.00	0.7
0:01	0.014	0.00	0.7
0:02	0.012	0.00	0.7
0:03	0.015	0.00	0.6
0:04	0.011	0.00	0.7
0:05	0.015	0.00	0.6
0:06	0.013	0.00	0.6
0:07	0.012	0.00	0.6
0:08	0.014	0.00	0.7
0:09	0.012	0.00	0.6
0:10	0.015	0.00	0.7

	Start Values	End Values	Temperature (°F)	RH (%)
Comments	-0.075	-0.061	75.2	30
	-0.024	-0.024		
	90.0	90.0		
	-3.9	-3.3		

Data Collector	Date	Test	Cone ID
Jordan Follett	7/25/13	Rad Control Post-Test 3	090420T I-CFXY-10

Time	Tip Resistance (kN)	Friction Ratio (%)	Inclination (°)
0:00	0.019	0.00	3.7
0:01	0.022	0.00	3.7
0:02	0.018	0.00	3.7
0:03	0.020	0.00	3.7
0:04	0.017	0.00	3.7
0:05	0.020	0.00	3.7
0:06	0.021	0.00	3.7
0:07	0.017	0.00	3.7
0:08	0.019	0.00	3.7
0:09	0.018	0.00	3.7
0:10	0.019	0.00	3.7

Comments	Start Values	End Values	Temperature (°F)	RH (%)
			75.2	30
	-0.081	-0.062		
	-0.024	-0.024		
	90.0	90.0		
	3.2	6.9		

Data Collector	Date	Test	Cone ID
Jordan Follett	7/26/13	High Rad Test sh. 1	090420T I-CPXY-10

Time	Tip Resistance (kN)	Friction Ratio (%)	Inclination (°)	Temperature (°F)	Relative Humidity (%)
0:00	0.036	0.00	0.1	75.2	30
0:00	0.033	0.00	0.1	75.2	30
0:00	~~0.04~~ 0.039 J.F. 7/26/13	0.00	0.2	75.2	30
0:00	0.031	0.00	0.2	75.2	30
0:01	0.036	0.00	0.2	74.3	29
0:02	0.034	0.00	0.3	74.3	29
0:03	0.036	0.00	0.0	74.3	29
0:04	0.040	0.00	0.3	74.3	29
0:05	0.038	0.00	0.2	74.3	29
0:10	0.036	0.00	0.3	74.3	29
0:15	0.037	0.00	0.2	75.2	27
0:20	0.034	0.00	0.0	74.3	28
0:25	0.039	0.00	1.0.	74.3	28
~~0:30~~ 0:28	0.040	0.00	2.5	74.3	28
~~0:35~~ 0:29	0.038	0.00	3.2	74.3	28
~~0:40~~ 0:30	0.037	0.00	3.6	74.3	28
~~0:45~~ 0:31	0.036	0.00	4.5	74.3	28
~~0:50~~ 0:32	0.038	0.00	5.1	74.3	28
~~0:55~~ 0:33	0.038	0.00	6.1	74.3	28
~~1:00~~ 0:34	0.040	0.00	7.2	74.3	28
0:35	0.038	0.00	8.0	74.3	28

Comments

Start Values	End Values
-0.097	-0.060
-0.024	-0.024
90	3.8
8.3	-1.0

resis. values jumping before test began

~35,000 R/h (34,998 R/h)

Test 8

→ inclination began to change at 25 min mark verified w/ camera that rod/Icone did not appear to be slipping

Data Collector	Date	Test	Cone ID
Jordan Follett	7/26/13	High Rod Test sl. 2	090420T I-CFXY-10

Time	Tip Resistance (kN)	Friction Ratio (%)	Inclination (°)	Temperature (°F)	Relative Humidity (%)
~~0:00~~ 0:36	0.036	0.00	8.4	74.3	28
0:37	0.038	0.00	9.0	74.3	28
0:38	0.041	0.00	10.0	74.3	28
0:39	0.042	0.00	11.0	74.3	28
0:40	0.033	0.00	11.5	74.3	28
0:41	0.037	0.00	12.1	74.3	28
0:42	0.038	0.00	12.6	74.3	28
0:43	0.036	0.00	13.2	74.3	28
0:44	0.038	0.00	14.5	74.3	28
0:45	0.036	0.00	66.2	74.3	28
0:46	0.039	0.00	15.5	74.3	28
0:47	0.035	0.00	16.0	74.3	28
0:48	0.036	0.00	15.8	74.3	28
0:49	0.034	0.00	67.1	74.3	28
0:50	0.037	0.00	75.2	74.3	28
0:52	0.036	0.00	90.0	74.3	28
0:54	0.038	0.00	90.0	74.3	28
0:56	0.037	0.00	90.0	74.3	28
0:58	0.038	0.00	J.F. 7/26/13 ~~90.0~~ 87.5	74.3	28
1:00	0.041	0.00	J.F. 7/26/13 ~~70.0~~ 86.2	74.3	28

Comments

Start Values End Values

→ jumped to 66°, then 14° at 0:44
-again at 0:45 66.2°
* inclination failure suspected

→ video appears to show stable
Icone; no slipping

Data Collector	Date	Test	Cone ID
		High Rad Test Sl. 5	

Time	Tip Resistance (kN)	Friction Ratio (%)	Inclination (°)	Temperature (°F)	Relative Humidity (%)
0:00	-0.002	0.00	0.1	74.3	28
0:01	0.000	0.00	1.4	74.3	28
0:02	-0.002	0.00	3.1	74.3	28
0:03	-0.006	0.00	4.7	74.3	28
0:04	-0.005	0.00	7.0	74.5	28
0:05	-0.001	0.00	8.2	74.3	28

Comments

Start Values	End Values
-0.058	-0.061
-0.024	-0.024
3.8	10.2
-1.0	5.4

→ started new test in GOnsite!

→ maintained high rad

→ re-zero of Icone (all parameters)

APPENDIX D

ICONE CALIBRATION CERTIFICATE

BEPROEVINGSPROTOCOL
Icone

Leverancier:	A.P. v.d. Berg Machinefabriek B.V. Heerenveen
Ordernummer:	44462.4
Klant:	AP van den Berg Inc. (Hanford)
Werkopdrachtnummer:	44462.4
Conustype:	ELCI-10CFI → Tip 5kN!
Conusnummer:	090420

Te beproeven/controleren item	**Gewenste waarde**	**Check of waarde**
Isolatieweerstand	Goed	>2 Gohm
Rechtheid	S=<0,2 mm	O.K. mm
Nulpunt Punt	Goed	-0.174 MPa
Nulpunt Kleef	Goed	-0.030 MPa
Nulpunt Waterspanning	Goed	n.v.t. kPa
Nulpunt Helling X Nulpunt Helling Y	Goed Goed	0.2 ° 0.0 °
Wordt de conusweerstand juist weergegeven?	Ja	0-5 MPa
Wordt de Kleefmeting juist weergegeven?	Ja	0-0.667 MPa
Wordt de Waterspanning juist weergegeven?	Ja	n.v.t.
Wordt de Helling juist weergegeven?	Ja	0-10-20°
Conus herkenning werkt bij in- en uitschakelen?	Ja	O.K

Eventuele opmerkingen:

Sensitive Icone: Tip 0-5 kN!
Suitable for T-Bar.

Gekalibreerd door: Bram Bekkema	Datum: 29-4-'09	Paraaf:
Eindcontrole : Erik Landskroon	Datum: 29-4-'09	Paraaf:

M:\Casper Ouwejan\Beproevingsprotocol Icone.doc

APPENDIX E

MICROSHIELD TEST RUN FOR AN-106 SLUDGE DOSE RATE

MicroShield 7.02
DOE (7.02-0000)

Date	By	Checked

Filename	Run Date	Run Time	Duration
Case1	June 12, 2013	10:37:44 AM	00:00:00

Project Info

Case Title	AN-106 Sludge
Description	Dose rate at surface of tank waste
Geometry	8 - Cylinder Volume - End Shields

Source Dimensions

Height	241.3 cm (7 ft 11.0 in)
Radius	762.0 cm (25 ft)

Dose Points

A	X	Y	Z
#1	0.0 cm (0.0 in)	242.57 cm (7 ft 11.5 in)	0.0 cm (0.0 in)

Shields

Shield N	Dimension	Material	Density
Source	2.69e+07 in³	Water	1.66
Air Gap		Air	0.00122

Source Input: Grouping Method - Actual Photon Energies

Nuclide	Ci	Bq	μCi/cm³	Bq/cm³
Ba-137m	1.4190e+005	5.2503e+015	3.2238e+002	1.1928e+007
Cs-137	1.5000e+005	5.5500e+015	3.4078e+002	1.2609e+007

Buildup: The material reference is Source Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0318	1.087e+14	7.088e+03	1.931e+04	5.904e+01	1.608e+02
0.0322	2.005e+14	1.347e+04	3.726e+04	1.084e+02	2.998e+02
0.0364	7.298e+13	6.489e+03	2.120e+04	3.687e+01	1.205e+02
0.6616	4.724e+15	2.491e+07	6.554e+07	4.830e+04	1.271e+05
Totals	**5.106e+15**	**2.494e+07**	**6.562e+07**	**4.850e+04**	**1.276e+05**