Assembly and calibration of a compact temperature and relative humidity sensor

Maref, W.; Tardiff, Y.; Booth, D. G.

For the publisher's version, please access the DOI link below./ Pour consulter la version de l'éditeur, utilisez le lien DOI ci-dessous.

Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/20386176
Internal Report (National Research Council of Canada. Institute for Research in Construction), 2002-03-01

National Research Council Canada
Conseil national de recherches Canada

NRC · CNRC

Assembly and Calibration of a Compact Temperature and Relative Humidity Sensor

Maref, W.; Tardiff, Y.; Booth, D.G.

IR-849

www.nrc.ca/irc/ircpubs

Institute for Research in Construction
Institut de recherche en construction
IRC

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

RHT *Relative Humidity and Temperature*
RTD *Resistance Temperature Detector*
RH *Relative Humidity*
R_0 *Resistance at 0° C*
DAU *Data Acquisition Unit*
MC *Moisture Content*
α *(alpha factor) Used in the Callendar-Van Dusen equation (related to the temperature coefficient of resistance (TCR)). The Callendar-Van Dusen equation is used in conjunction with specific RTD constants to calculate temperature.*
OD *Outer Diameter*
V_{sense} *Excitation voltage measured at the sensor*
DMM *Digital Multi-Meter*

NRC·CNRC

LIST OF FIGURES

LIST OF TABLES

1. Introduction

This report describes the manufacturing and calibration of a compact temperature and relative humidity sensor. This study is part of a research project in the building envelope and structure program at the Institute for Research in Construction (IRC). The project included the testing of wall assemblies and components to determine their hygrothermal behaviour. Changes in moisture content (MC) and temperature of the materials undergoing evaluation were measured. Relative humidity (RH) and temperature that prevail in the air in the vicinity and at the surface of these components were also measured. Bulk MC was monitored by weighing the wall assemblies, while the distribution of moisture in individual component was monitored by using moisture pins inserted into the material at different depths and locations. The distribution of moisture depends not only on the properties of the material and the climatic conditions of the ambient air (temperature & relative humidity), but also on the micro-climate at the surface of the material.

To enable monitoring of this microclimate at the surface of wall assemblies, moisture/temperature probes that have directionality and are able to focus on a small area need to be used. An inexpensive relative humidity probe with these characteristics was designed by Cunningham and is described in his paper on the "Development and performance of a small relative humidity sensor for indoor microclimate measurements". With minor modifications to include temperature sensing, an RH probe, based on Cunningham's probe, was designed to monitor the climatic conditions at the surface of materials.

2. Objective

Fabricate and calibrate a relative humidity/temperature (RHT) probe based on the Cunningham design, that is capable of measuring the hygrothermal conditions that prevail in the microclimate at the surface of wall assemblies and wall components.

3. Relative Humidity and Temperature (RHT) probe concept

Basically, the RHT probes is composed of a monolithic integrated circuit for RH measurement, and a thin film platinum resistance temperature detector (RTD) for temperature measurement, both of which are housed in a small cylindrical enclosure. Although RH probes with integrated temperature compensation are available commercially they are larger and four to ten times more expensive [an example is the Honeywell HIH-3602-A and -C with RTD ($122 and $93)]. Cost is an important factor here because 32 RHT sensors were needed for the study.

Following a review of technical literature from several manufacturers of RH and RTD components, a selection was made. The Honeywell HIH-3605-A-P RH sensor was selected, for its low cost (i.e. $36), small size, high accuracy, linearity, and slow drift performance (refer to appendix I). This is the same RH sensor element used by Cunningham. A Honeywell Hycal HEL-775 RTD temperature sensor was selected for the same basic considerations as those of the RH sensor (refer to appendix II).

The following were attributes important to the design of the probes:

1. precision, yet low component cost;
2. ability to sample the microclimate at the surface of wall components;
3. ability to provide fast and accurate response to both moisture and temperature;
4. ease of installation and removal from test materials;
5. ruggedness to withstand repeated use and yet have flexibility to allow movement of the samples to which they are attached; and
6. ease of connection to, and disconnection from, a data acquisition unit (DAU) capable of scanning 32 probes located some 10 m away.

The first two attributes were achieved by the choice of components, and by adopting the proven RH probe concept of Cunningham. The third attribute depends not only on the RH and RTD component characteristics, but also on the wiring used to connect the sensor to the monitoring equipment. To obtain high accuracy and repeatability, a constant current 4-wire resistance measurement method was implemented for the RTD's, while a 4-wire voltage sensing method was chosen for the RH sensors. These methods provide compensation for any loss of signal due to line resistance in the length of cables and multiple connections. The RHT probe electrical wiring is shown in Figure 1. The current-source for resistance measurement is provided internally by the DAU, while the voltage source for the RH sensor is provided by a separate external regulated power supply located at the DAU. To further satisfy the accuracy requirement, all RTD and the RH sensors were calibrated for temperature and humidity. The last three attributes (4, 5 and 6) will be covered later as they are part of the actual probe fabrication.

Fabrication and calibration of the RHT probes was a three-step process. The RTD and RH components were assembled separately as stand-alone devices before being combined into the RHT probe. Therefore, details of the assembly and calibration of the RTD and RH sensor elements will be discussed individually followed by details relevant to RHT probe fabrication and use.

3.1 Resistance Temperature Detector (RTD) sensor assembly

The Hycal HEL-775-A-U-O RTD is an 1000 ohms platinum RTD with an alpha factor (a) of 0.00375 ohms/ohm/°C. The higher resistance provides greater sensitivity and improved signal-to-noise ratio over the conventional 100 ohms RTD. The sensor dimensions are 2.54 mm wide, 5.08 mm long and 2.54 mm thick. A pair of solder leads is incorporated. Connection to the sensor is accomplished in two steps. First, a short flexible shielded cable with a female 5 pin Switchcraft EN3 mini weather-tight connector is attached to the sensor. Second, a 10-m long shielded cable extension is provided to link up with the DAU. The pin out for the connectors of both the RTD and the extension cable is provided in Figure 3. To obtain the desired flexibility and yet provide the shielding and ruggedness desired for the cable connected to the sensor, 22 gauge stranded hook-up wire and thinned copper braiding is used instead of commercial multi-conductor vinyl covered aluminum-polyester shielded cable. Two different lengths were fabricated, one of 0.46 m (for 21 probes) and one of 1.37 m (for 10 probes). The 10-m long extension cable was fabricated using Belden type 8728, 2 pair Beldfoil shielded cable, terminated with a male 5 pin Switchcraft EN3 mini weather-tight connector.

3.2 Resistance Temperature Detector (RTD) sensor calibration

RTD's have a quasi-linear resistance to temperature relationship, which is accurately modelled by the Callendar-Van Dusen equation (refer to Appendix III). To establish the calibration of an RTD only its resistance at 0 °C is required (R_o). For this purpose a digital temperature controlled PolyScience circulating glycol-water bath (PAM #00405) was used along with a precision reference thermometer, a Guild Line 9540 platinum resistance thermometer with 0.001°C resolution (PAM#212439). This instrument had an INMS calibration certificate dated March 10, 2000.

The first attempt at determining R_o of the RTD's, involved measuring the voltage drop at the sensor leads of the RTD while providing a constant current of 0.002 ampere to the positive and negative power leads, and then calculating the resistance of the RTD according to Ohm's law. This measurement of R_o was done early in the fabrication process, prior to the installation of the weather-tight connector. To measure the voltage drop and applied current, two Keithly 196 digital multi-meter (DMM) were used (PAM#131432 and PAM#127796 respectively). Both had calibration certificates by Pylon, dated March 2, 2000. The electrical connections at the RTD sensors needed to be electrically insulated because glycol-water solution, as the heat transfer medium, was electrically conductive. For this purpose small zip-lock plastic bags were used. Two RTD sensors were placed back-to-back such that the platinum resistive element of each was in contact with one of the outer surface of the bag. Each bag was then folded and inserted into the bore of a multi-bore aluminum cylinder (Figure 4) to keep them submerged in the circulating glycol-water solution. The temperature of the solution was monitored and maintained at 0.000 ± 0.001°C. The constant current source was connected to one RTD at a time and monitored until it stabilized; the voltage drop at the sensor lead was then recorded (Figure 5).

This approach proved to be very time consuming and yielded unreliable results. The time period for each RTD to reach equilibrium was long, and despite all the precautions taken, variations in applied current were inevitable. The readout of two DMM could not be logged simultaneously; which also contributed to the variability of the calculated R_o. The long exposure time, up to 6 hours, needed to precondition the RTD's in the refrigerated solution, and the length of time needed to monitor each RTD, 30 minutes to one hour, caused most of the plastic bags to develop leaks thereby affecting the electrical properties of the RTD's. This approach was rapidly abandoned.

During the second attempt at establishing the measurement, time was reduced by connecting all 32 RTD's via their extension cable, to a DAU configured for 4-wire ohm measurement. Measurements were taken for 16 second every 2 minutes. The DAU was a Hewlett Packard system comprising an HP E1401B power frame, an HP E1411B 5½ digit multimeter, an HP E1406 command module, and an HP E1476 64-channel 3-wire multiplexer. Once again, to protect the RTD's, a zip-lock bag was used, this time however, the bag was thinner and measured 300 mm by 300 mm. A separate compartment, fabricated at its base, was used to add weights to keep the bag and its contents submerged in the glycol-water bath. The reason for using a thinner and larger bag was to improve the heat transfer to the sensing elements. The RTD's were again attached to both faces of the bag using electrical tape (Figures 6 and 7). This time however, a small well was formed between pairs of RTD's by attaching a small piece of tubing. This well was provided to insert the precision thermometer at the location of each RTD inside the bag. The bag with the RTD's remained submerged in the refrigerated bath for 16 hours before attempting a measurement.

This approach was no more successful than the previous one. Small air gaps formed between the face of the bag and the RTD elements. This prevented them from reaching and maintaining equilibrium simultaneously at 0.000 ± 0.001°C. With time, the bag deteriorated and allowed some of the glycol-water solution to enter and affect the electrical properties of the sensors. This approach was also abandoned.

The third approach focused on removing any barrier between the RTD and the cooling solution. To achieve this a non-conductive solution was used to submerge the RTD's without affecting their electrical properties. Vegetable oil was chosen as the non-conductive solution. A beaker filled with vegetable oil and weighed down with metal weights was placed in the glycol-water bath. The bath temperature was adjusted so that the reference thermometer indicated 0.000 ± 0.001°C in the vegetable oil. The RTD's were mounted in groups of three on the surface of an electrically insulated aluminium cylinder (Figures 8 and 9). The problem in this approach is that the small volume of oil in the beaker, combined with the heat loss caused by braided shield of the sensors prevented the oil from maintaining equilibrium at the reference temperature.

To overcome this a container was fabricated out of Plexiglas to allow a larger volume of oil to be used (1 litre), and at the same time provide space for agitation of the oil using an electric mixer (Figures 10). The shape and size of the container was selected such that it would fit into the glycol-water bath leaving room for the solution to circulate freely around it. In the lid of the oil container, 32 holes were drilled to separate and retain the RTD's submerged in the oil solution. A 50-mm thick piece of Styrofoam insulation was added to the lid, and the braided shield of RTD's was backed off to minimize heat loss (Figure 11). There was still a problem maintaining the equilibrium of reference temperature.

The fourth and finally successful approach was to use the thin latex membrane of a condom to protect the RTD's against the glycol-water solution of the bath while providing a good interface with the solution. This was accomplished by attaching four RH sensors at a time to the platinum reference thermometer (Figure 12), and inserting them into a condom that was taped to the Styrofoam insulation cover of the bath (Figure 13). The latex membrane was stretched upward near the sensors to remove some of the air, and a small rubber band was inserted just above the sensors to maintain their contact with the membrane. The lid of the bath was put in place taking care to immerse the RH sensors to mid-depth of the circulating solution. By this method it was possible to reach temperature equilibrium of 0.000 ± 0.001°C within one hour.

Results of the RTD calibration are presented in tabulated and graphic forms in Tables 1 to 8 and Figures 14 to 21. All RTD's had a R_o of 1000 ohms within the tolerance limits of ±2 ohms and exhibit excellent stability once at equilibrium (COV better than 0.003 %). RTD sensors 14, 18, and 21 were very close to the lower tolerance for R_o (998 ohms), with a resistance of 998.353, 998.181, and 998.446 ohms respectively.

3.3 Relative Humidity (RH) sensor assembly

The Honeywell HIH-3605-A-P relative humidity sensor has a range of 0-100 % RH. At 25°C, its accuracy is ±2 % RH over this range (note a reversible shift of 3% RH occurs with extended exposure at RH > 90% occurs shift). For the temperature range of -40 to 85 °C the integrated circuit of the sensor produces a linear voltage output versus RH that is proportional to the sensor excitation voltage. Excluding the leads, the 0.6-mm thick sensor measures 7.6 mm by 8.9 mm by 0.6 mm thick. Its three connection leads are spaced at 2.54 mm. The manufacturer recommends that a low-pass filter be used with the sensor to filter out the noise. The low-pass resistance/capacitor (LPRC) filter built for the sensor has a 725-Hertz cut-off frequency. The lower cut-off frequency was used because of the component values that we had on hand at the time. As long as high frequencies (above 1000-Hertz) are filtered out then it did not have an adverse effect if the frequencies above 725-Hertz are also filtered out. The filter is comprised of a 100 ohms resistor and a 2.2-microfarad tantalum capacitor, soldered directly to the leads of the voltage supply at the sensor. As mentioned earlier, for best accuracy given that the output signal is proportional to the applied voltage, a 4-wire connection technique with voltage sensing at the sensor was implemented using the DAU. This is illustrated in Figure 1. Once again, 22 gauge hook-up wire was used for the wiring and thinned copper braiding for shielding (Figure 22). To match with the RTD sensors, two lengths of wires were used for the RH sensors. The 0.46-m length was shielded from the connector up to the base of the sensor, while the 1.37-m length was only shielded for the first 0.15 m beyond the connector. Both were terminated with a male 5 pin Switchcraft EN3 mini weather-tight connector to distinguish them from the RTD sensor connector. A 10 m long extension cable, fabricated using Belden type 8728, 2 pair Beldfoil shielded cable, terminated with a female 5 pin Switchcraft EN3 mini weather-tight connector, was provided for connection to the DAU. The pin-out diagram for both connectors is given in Figure 23.

The excitation voltage for the sensors was provided by a KAAR Corporation precision regulated 5.0-volt power supply Model CM 5 with 0.1% accuracy in regulation. The power supply was installed at the DAU location and connected to each sensor via bus terminals.

3.4 Relative Humidity (RH) sensor calibration

The RH sensors were calibrated in air above salt solutions. Five increments of relative humidity were selected to determine the calibration equation of each sensor, namely 17, 37, 47, 70, and 93 %. The salt solutions were contained in insulated desiccator jars equipped with tightly closing lids. Each jar was installed on a magnetic stirring plate to continuously agitate the salt solution. A perforated porcelain plate was placed above the saturated salt solutions to prevent the possibility of contact with the RH sensors. To provide air movement a small direct current fan was provided near the top of the desiccator lid. Since the age and conditions of the saturated salt solutions were not known, the actual RH inside the jars was measured with a General Eastern Hygro M4 chilled mirror (PAM#212424), equipped with a small air-sampling pump. To monitor the temperature in the jars, the platinum resistance thermometer used for RTD calibrations was inserted through the lid.

The RH sensors were prepared for calibration by backing-off the braided shield on the 0.46-m long sensors to expose the hook-up wires on all sensors. They were then inserted through the lid of the desiccator jar, and bundled up using tie-wraps. Each sensor was then carefully positioned by bending or extending its leads to prevent adjacent sensors from touching each other, while at the same time, taking care to provide sufficient space for air circulation (Figure 24). The aspiration tubing of the air sampling pump was inserted through the lid of the jar and positioned near the centre of the of the RH sensor bundle, while the return air tubing was directed near the ceramic plate covering the saturated salt solution. The lid was weighed down with brass weights to make a good seal. The manufacturer of the RH sensors cautions against exposing them to direct light, since they are light sensitive. To prevent any light from falling onto the face of the sensors a black plastic bag was draped over the lid of the desiccator. The RH sensors were connected to the DAU and power supply by their extension cables. The 32 RH sensors were scanned every minute. Sensor data was not logged until the General Eastern chilled mirror and the reference thermometer indicated a steady state for at least 15 minutes. No less than four, and as many as eight reference relative humidity readings were taken with the General Eastern for the five humidity conditions, and no less than ten, and as many as sixteen readings were taken for each probe for these same humidity conditions.

To determine the calibration equation of each RH sensor, the mean values of the reference RH and the mean of the calculated output-signal voltages to sensor-voltage ratios of the sensors were compared using linear regression analysis. The ratio of the output-signal voltage to sense-voltage is used, instead of the output signal voltage to excitation voltage, to improve accuracy, since the RH sensor output depends on the applied voltage directly at the sensor. Results of the calibration are presented graphically in Figures 25 to 28, where the calibration equation is given as well. To facilitate implementation of the conversion of the output signal of each sensor in the DAU, a generic calibration equation was also developed by grouping the mean data for all the sensors and carrying out a linear regression analysis. The results for the generic calibration are presented in Figure 29. It can be seen that up to approximately 50 % relative humidity this generic calibration can be used without introducing much error. However, above this point the sensors diverge rapidly and this will lead to a significant spread in the measured relative humidity. RH data obtained with the generic calibration equation can always be restored at a later date by using the appropriate sensor calibration equation.

3.5 Relative Humidity and Temperature (RHT) probe fabrication

The final step in the fabrication of the RHT probe consisted in joining the RTD sensors with their companion RH sensors, and providing a light proof shroud to cover the sensing elements while allowing air to be admitted into the probe in a controlled manner. The group of RTD and RH sensors with the shortest lead wires (0.46 m) have copper braided shielding from the weather-tight connector up to the base of each sensing element. To assemble these into probes the copper braids were joined together by placing the RTD sensor facing the RH sensor and then aligning it just below the RH sensing element to provide free access to it. At that point the braids were soldered together. A length of shrinkable tubing was placed over this junction, and a small tie-wrap was added near the two Switchcraft connectors to complete the assembly. For the sensors with a 1.37-m lead wire, only the RTD's had shielding extending from the connector to the sensor itself. To fabricate the probe, an opening long enough to allow the RH sensor to be inserted, was punctured into the braided shield at approximately 15-cm from the connector. By compressing the braided shield of the RTD towards the opening, this enlarged the shield sufficiently to feed the RH sensor through. The braided shield was then pulled back over the cabling of both sensors. The junction of the braided shields near the connectors was soldered and covered with a short length of shrinkable tubing. The RTD and RH elements were aligned in the same manner as with the shorter probes, and shrinkable tubing was used to bind them together.

The light proof shroud was made from 12.5 mm OD shrinkable tubing, having a nominal length of 50 mm. The top of the tubing was first heated over a 10-mm distance and then immediately clamped to close off the top. The 10 mm by 10 mm protrusion caused by clamping the hot tubing not only blocks out ambient light but also serves as a tab to anchor the probe to a test surface. Next a 2.5 mm^2 hole was cut through the face of the tubing approximately 2 mm from the base of the tab. The shroud was then placed over the probe with the drilled hole facing the RH sensor element, and secured in place by heat shrinking it on to the probe. Figure 30 is a close-up view of the shroud in place over the tip of the probe, while Figure 31 gives a general view of the two probe lengths.

The 32 probes were connected via their extension wires to the DAU (Figures 32 and 33). Two HP E1476 64-channel 3-wire multiplexers were used to connect the probes. The configurations and connection details for the two multiplexer cards used for monitoring the RTD and RH sensors are provided in Figures 34 and 35 respectively. Details of the excitation voltage connections to the RTD's are not shown. The voltage excitation consists of a positive and negative bus that provides a regulated 5.0 volts to all the sensors continuously.

Typical scans of temperature and relative humidity outputs of the RHT probes randomly placed in climatic chamber in an area of approximately 1m by 1m, and exposed to a controlled environment at approximately 24 °C and 30 % relative humidity are presented in Figure 36 and 37. The temperature data for probes #14, #18, #19, and #21 is not shown because the RTD's had become defective. All RTDs had their own calibration curves worked out and their specific Ro was used. A generic calibration equation was used for all RH sensors. Based on the average temperature over 250 minutes (23.45 °C), the range of temperature variation measured is ±0.40 °C. Based on the average RH (27.2 %) over the same time period, the range of relative humidity variation measured is ±2.0 % RH. The RHT probes therefore measure temperature to an accuracy of ±0.40 °C, and relative humidity to an accuracy of ±2.0 %°RH.

Acknowledgements

Many thanks to Rock Glazer who helped us in the development of the probes.

References

Cunningham, M.J., "Development and performance of a small relative humidity sensor for indoor microclimate measurements", Building and Environment 34 (1999), pp. 349-352

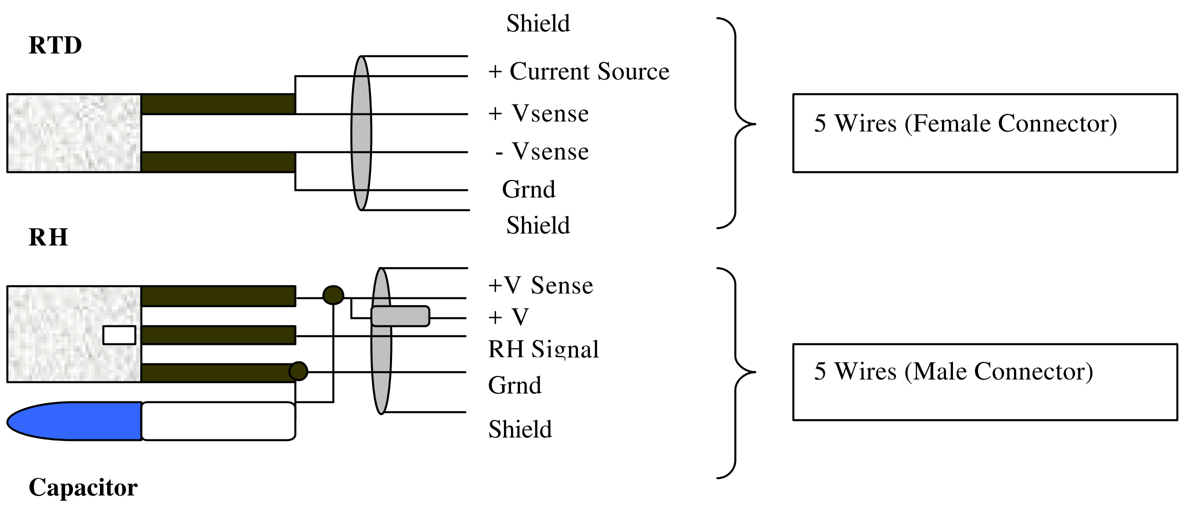


Figure 1 RHT probe electrical wiring

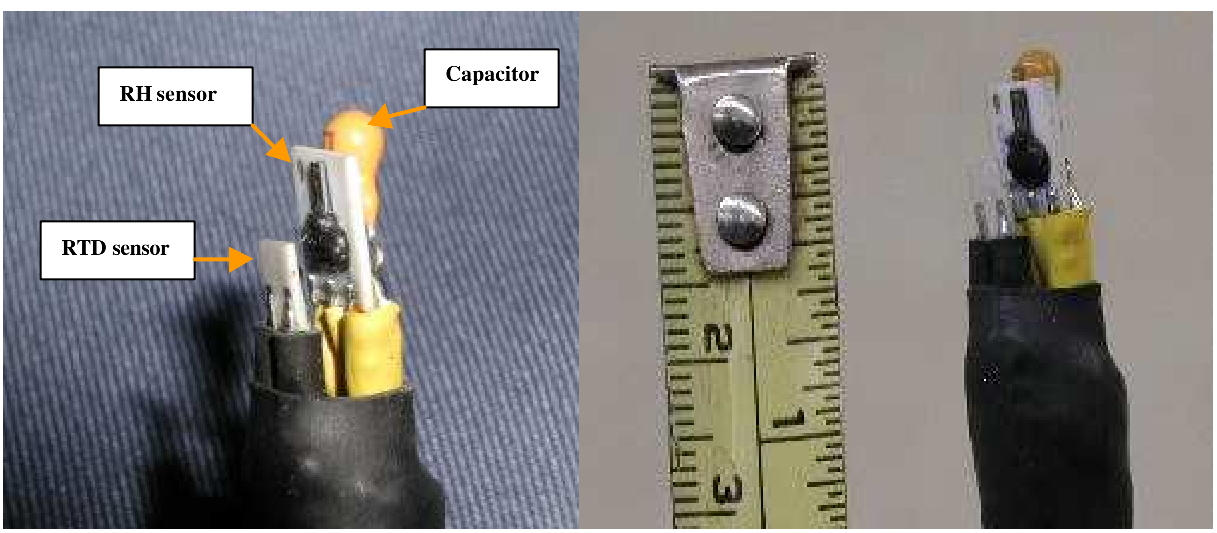


Figure 2 RHT sensor close-up

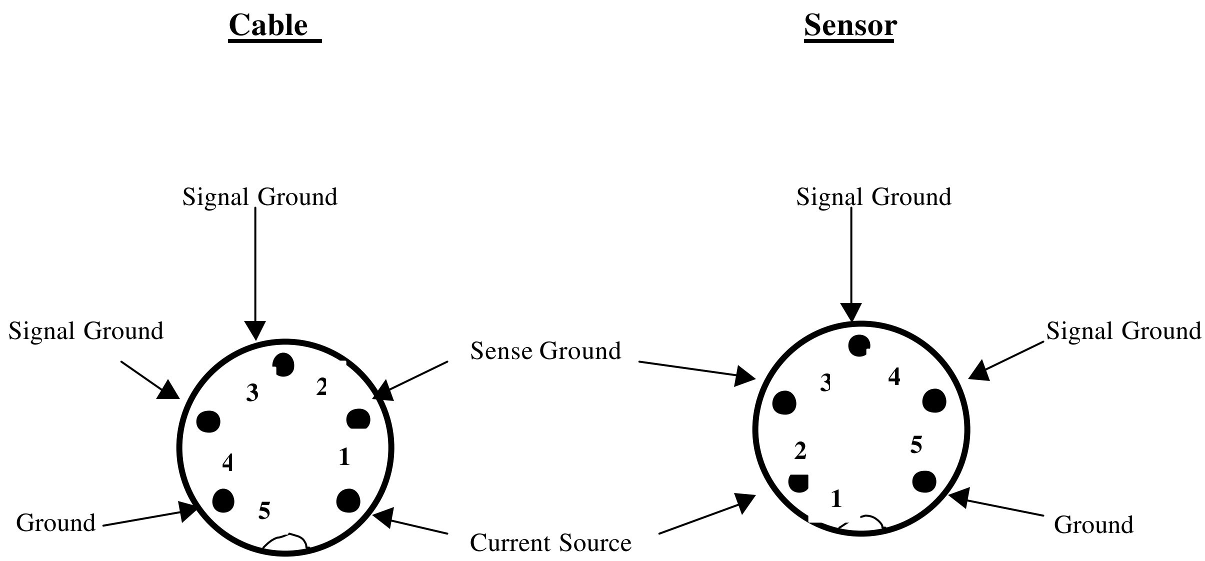


Figure 3 Pin for the connectors for both RTD sensors and cable

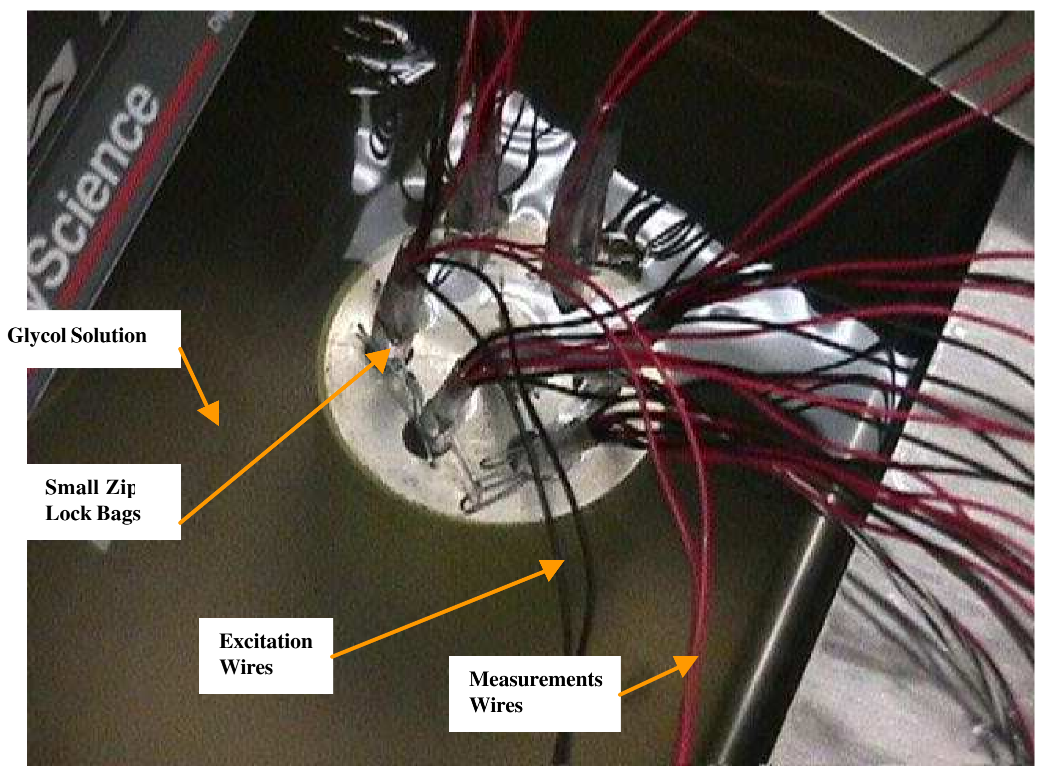


Figure 4 Submersion of the RTD in circulating glycol-water solution

NRC·CNRC

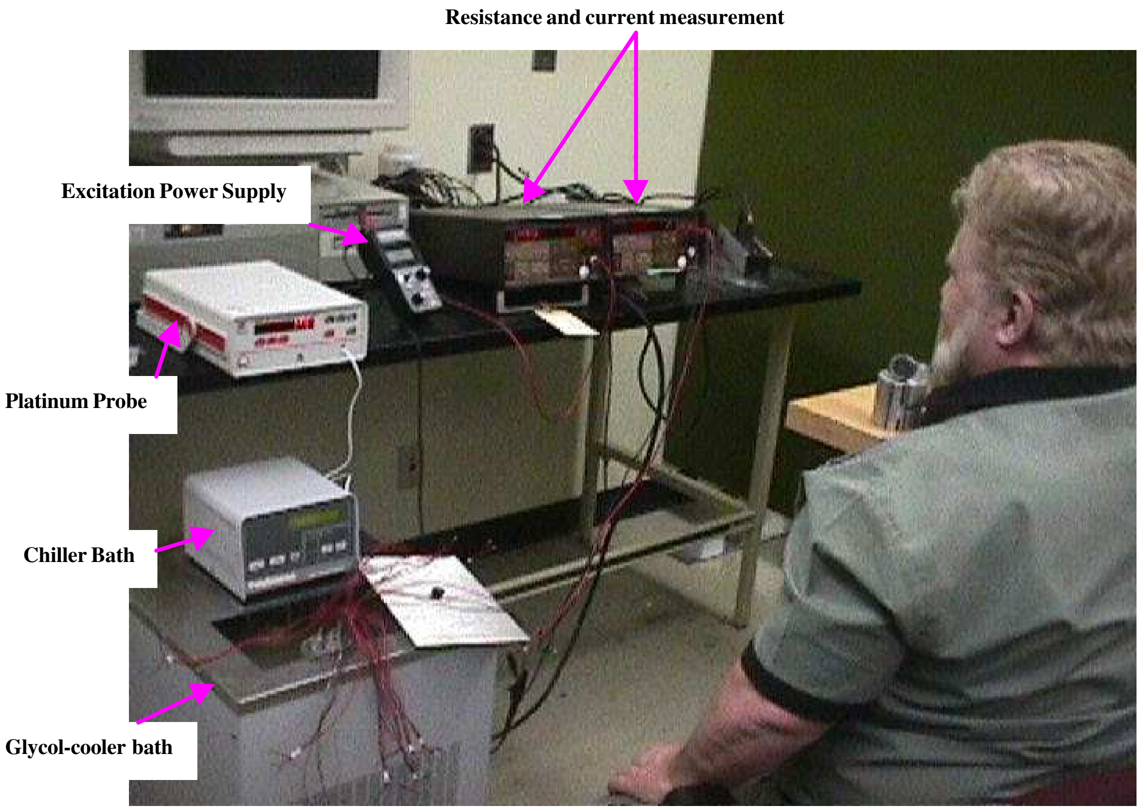


Figure 5 Monitoring the temperature of the solution

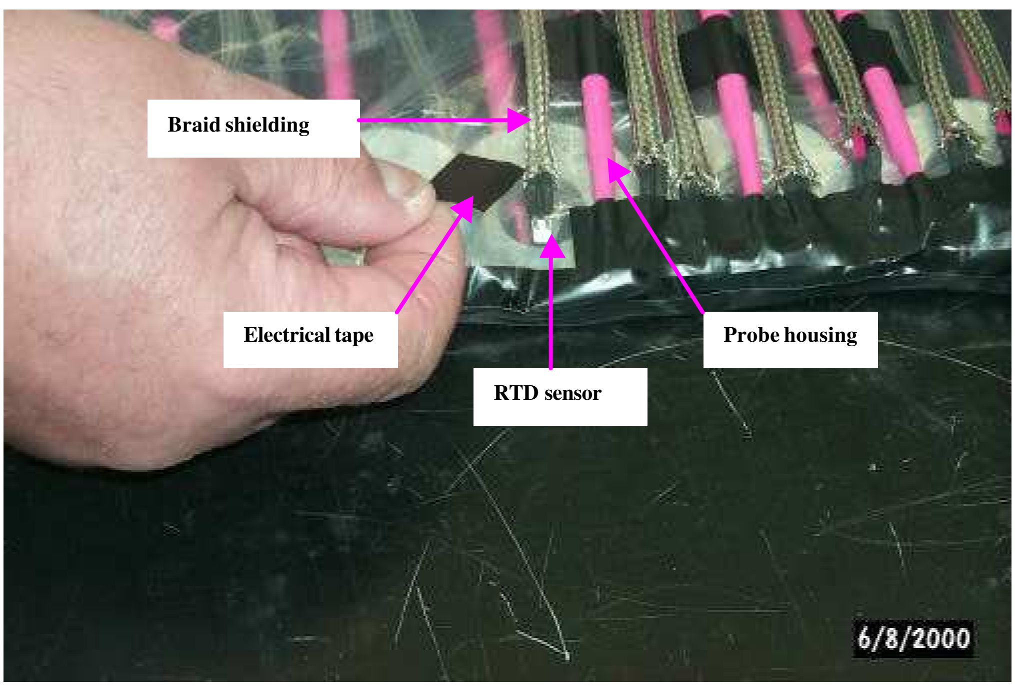


Figure 6 Attaching the RTD using electrical tape to both faces of the bag

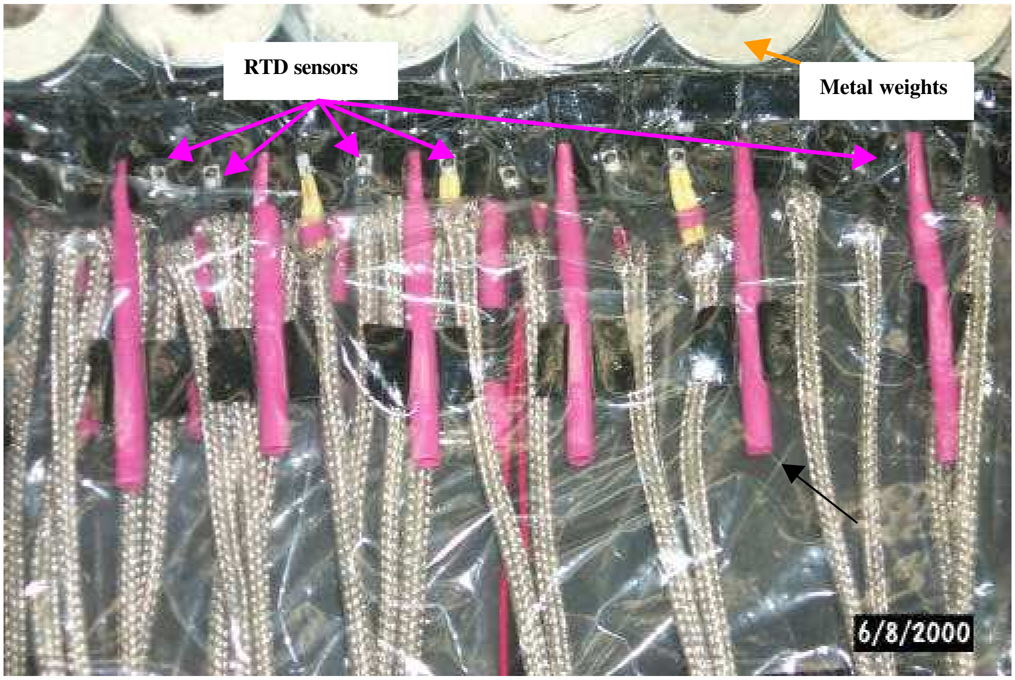


Figure 7 Bag maintaining the RTD sensors

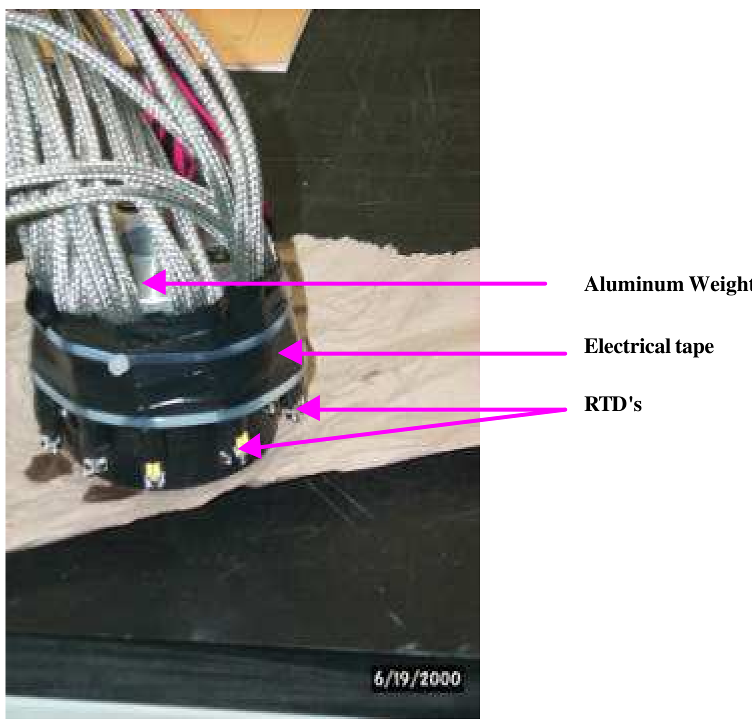


Figure 8 Grouping the RTDs on an insulated aluminum cylinder

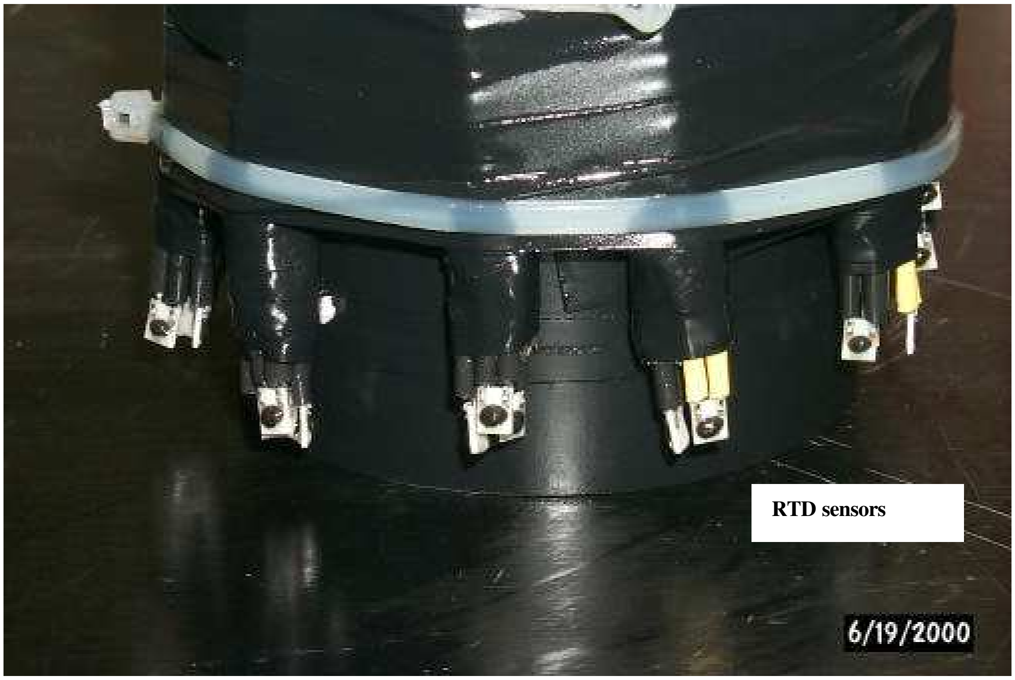


Figure 9 Close-up of RTDs grouped on an insulated aluminum cylinder

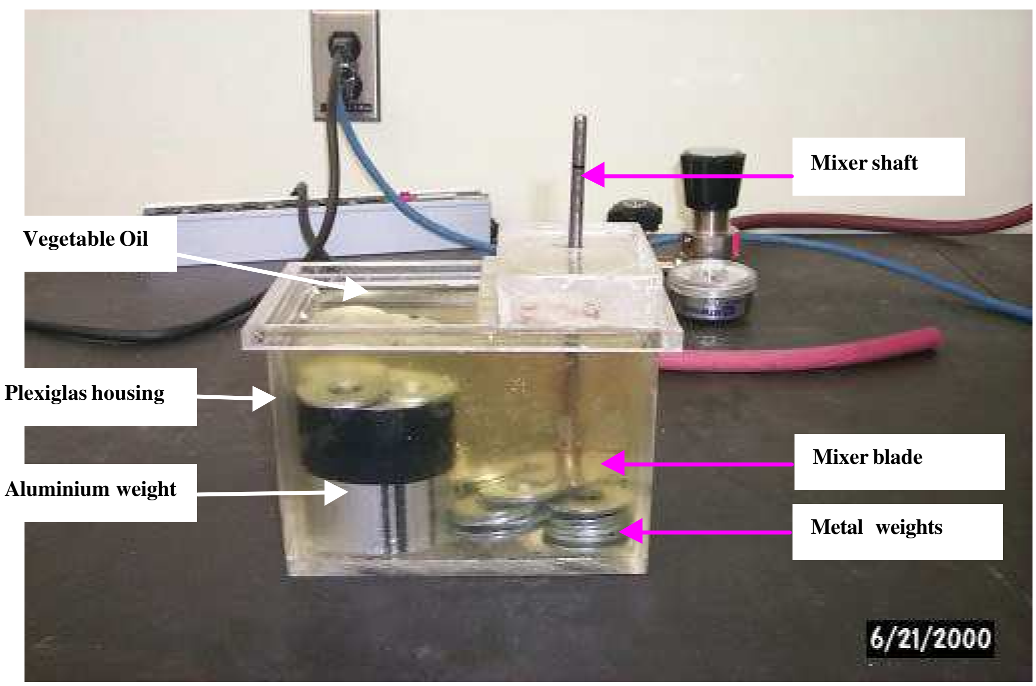


Figure 10 Plexiglas bath

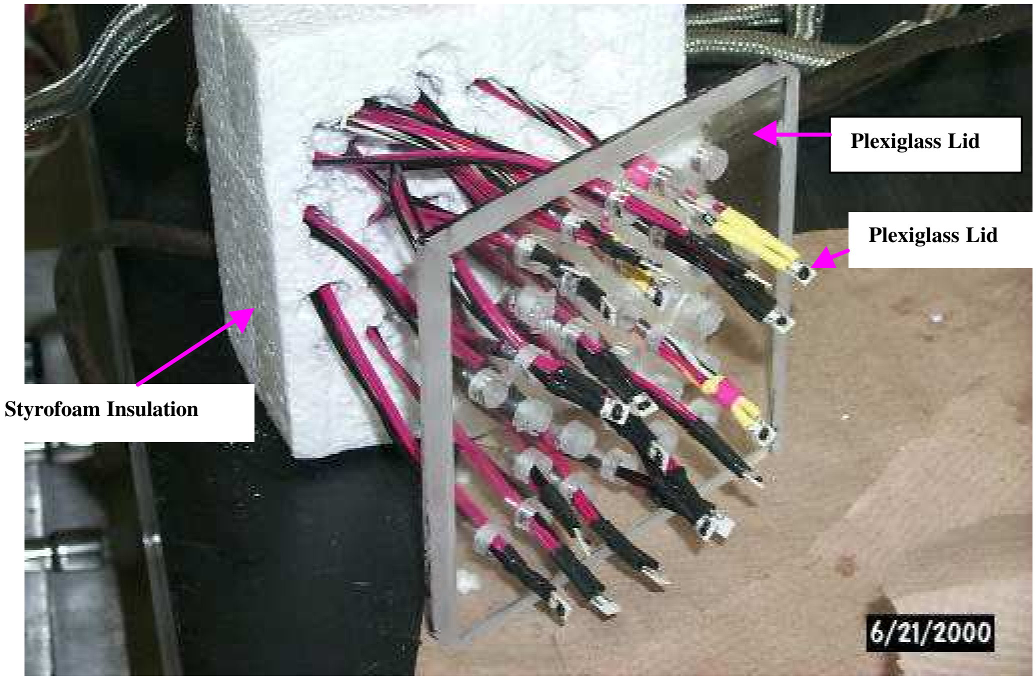


Figure 11 System to minimize the heat loss

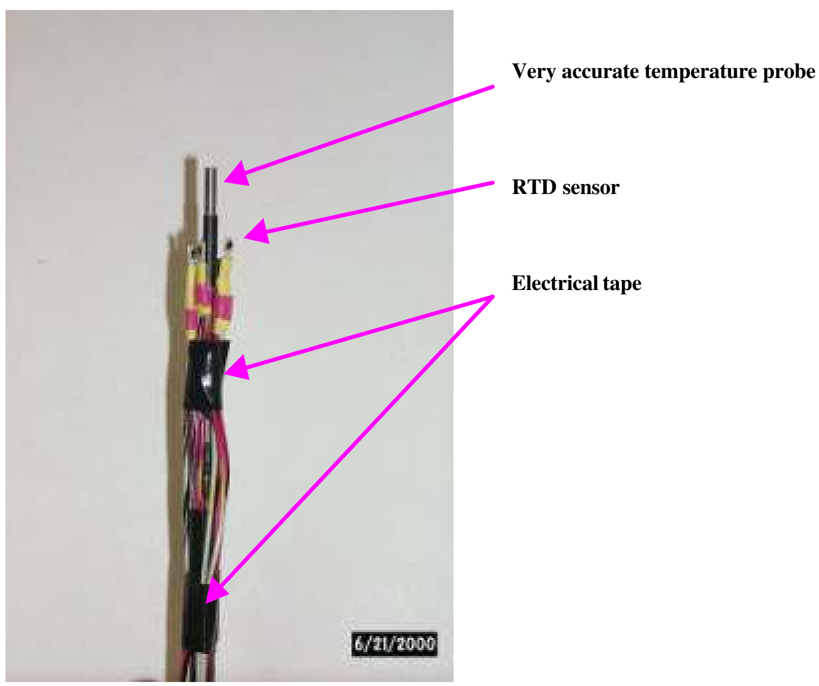


Figure 12 Platinum reference thermometer attached to groups of 4 RTDs

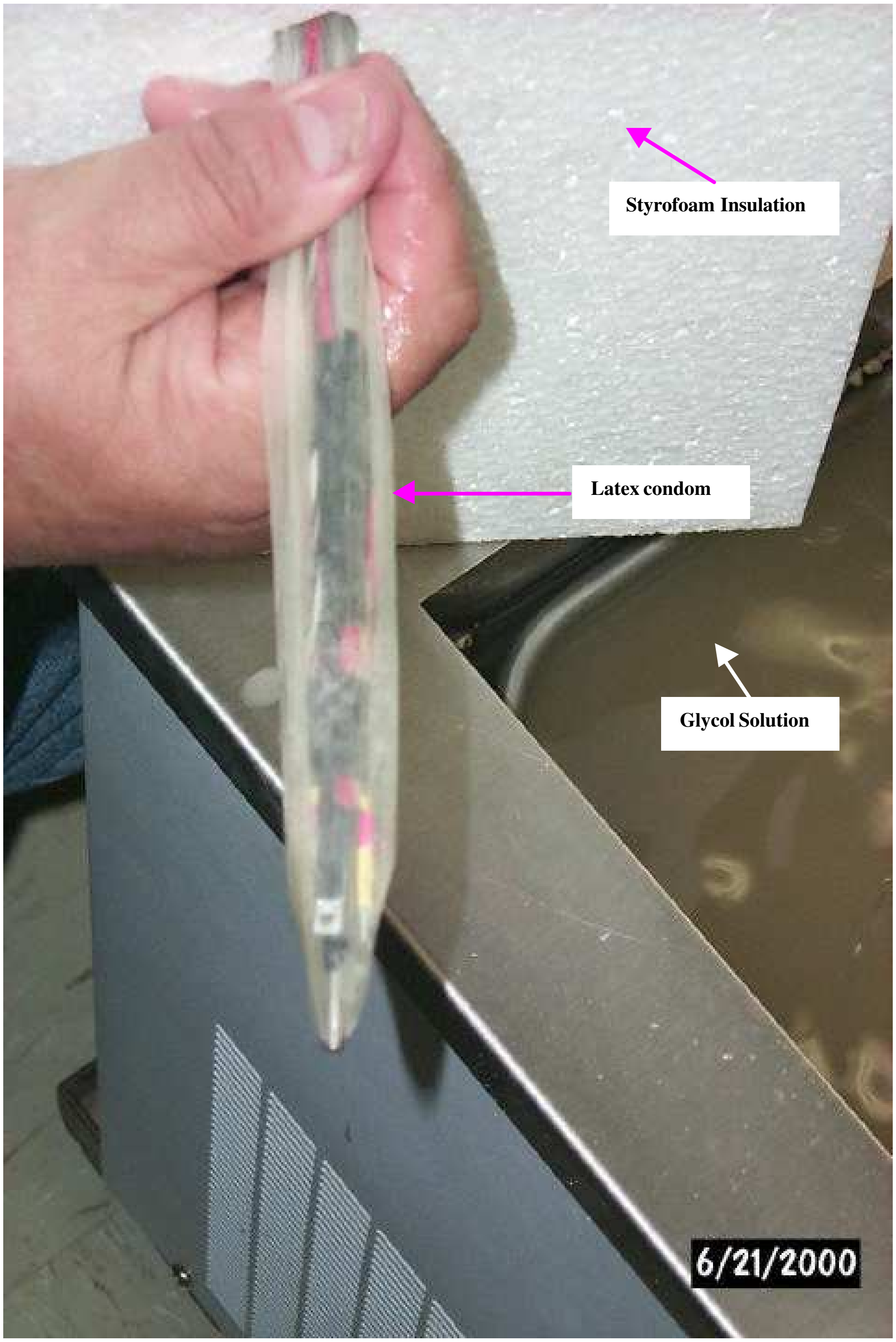


Figure 13 Insertion of the platinum reference and RTD into a condom

NRC·CNRC

Elapsed Time (min)	Reference Temperature	RTD #0	RTD #1	RTD #30	RTD #31
1		999.313	1000.549	1000.350	999.721
2		999.320	1000.548	1000.349	999.729
3		999.328	1000.545	1000.352	999.720
4	0.000 ± 0.001°C	999.330	1000.542	1000.346	999.723
5		999.327	1000.548	1000.346	999.725
6		999.324	1000.542	1000.341	999.729
7		999.325	1000.542	1000.347	999.725
Average		999.324	1000.545	1000.347	999.725
Stdev		0.00576	0.00318	0.00355	0.00355
COV (%)		0.00058	0.00032	0.00035	0.00036

Table 1: Resistance, R_o, at 0°C, for RTD's 1, 2, 30, and 31

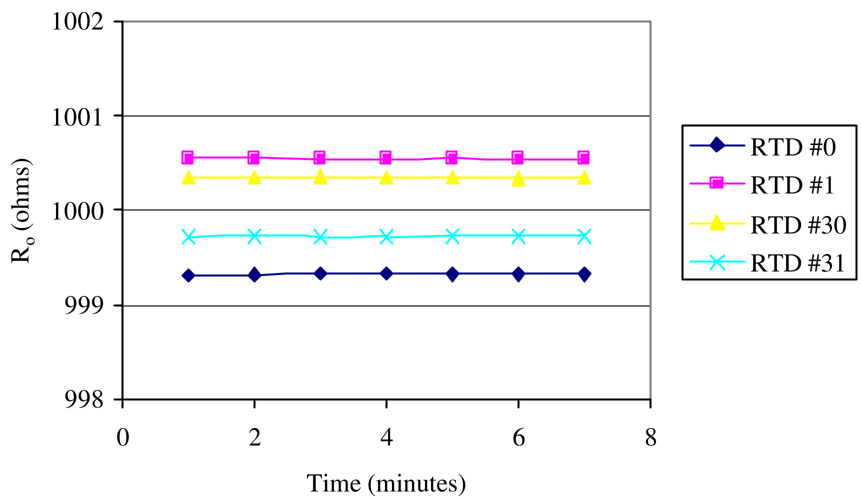


Figure 14 Stability of RTD resistance during calibration

NRC·CNRC

Elapsed Time (min)	Reference Temperature	RTD #2	RTD #3	RTD #4	RTD #5
1	0.000 ± 0.001°C	999.313	1000.549	1000.35	999.721
2		999.320	1000.548	1000.349	999.729
3		999.328	1000.545	1000.352	999.72
4		999.330	1000.542	1000.346	999.723
5		999.327	1000.548	1000.346	999.725
6		999.324	1000.542	1000.341	999.729
7		999.325	1000.542	1000.347	999.725
Average		999.324	1000.545	1000.347	999.725
Stdev		0.00576	0.00318	0.00355	0.00355
COV (%)		0.00058	0.00032	0.00035	0.00036

Table 2: Resistance, R_o, at 0°C, for RTD's 2 to 5

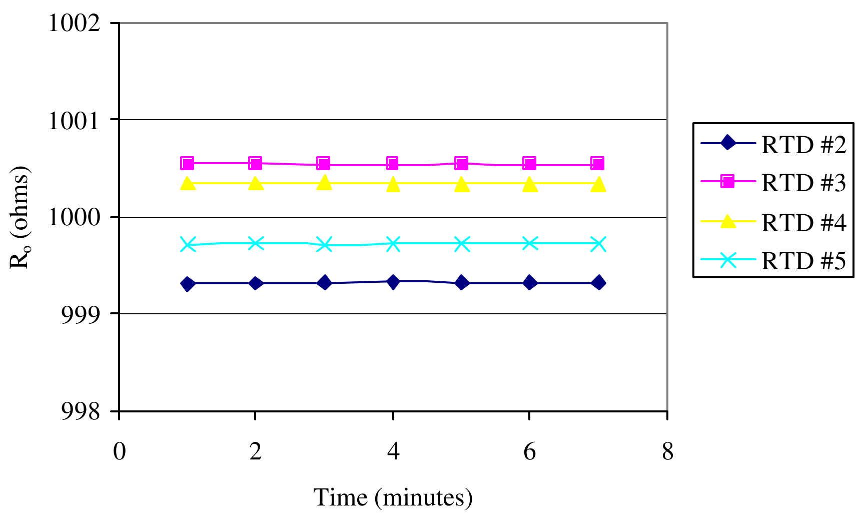


Figure 15 Stability of RTD resistance during calibration

Elapsed Time (min)	Reference Temperature	RTD #6	RTD #7	RTD #8	RTD #9
1	0.000 ± 0.001°C	999.896	1000.732	999.550	999.731
2		999.887	1000.718	999.539	999.717
3		999.875	1000.709	999.534	999.708
4		999.884	1000.702	999.529	999.699
5		999.869	1000.698	999.527	999.700
6		999.868	1000.689	999.517	999.693
7		999.867	1000.697	999.521	999.703
Average		999.878	1000.706	999.531	999.707
Stdev		0.01120	0.01459	0.01118	0.01292
COV (%)		0.00112	0.00146	0.00112	0.00129

Table 3 Resistance, R_o, at 0°C, for RTD's 6 to 9

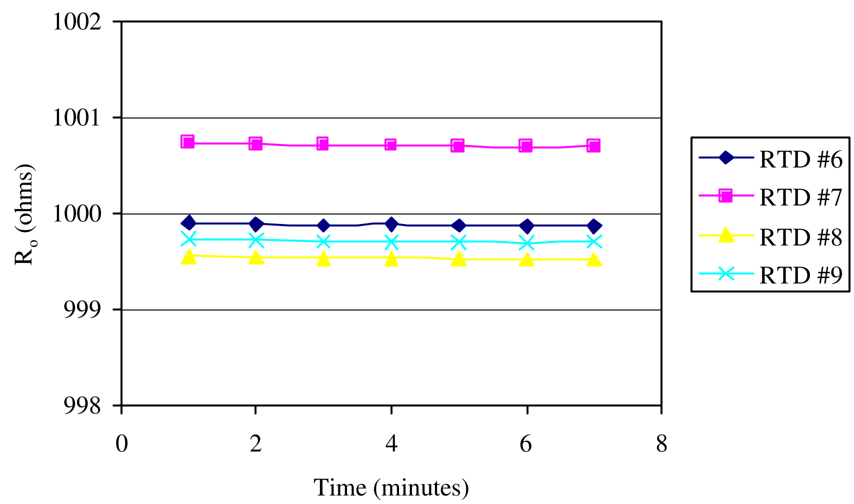


Figure 16 Stability of RTD resistance during calibration

Elapsed Time (min)	Reference Temperature	RTD #10	RTD #11	RTD #12	RTD #13
1	0.000 ± 0.001°C	999.818	1000.675	1000.079	1000.013
2		999.831	1000.678	1000.088	1000.012
3		999.829	1000.68	1000.078	1000.004
4		999.823	1000.675	1000.077	1000.002
5		999.822	1000.681	1000.08	1000.004
6		999.831	1000.686	1000.083	1000.008
7		999.827	1000.682	1000.082	1000.005
Average		999.826	1000.680	1000.081	1000.007
Stdev		0.00498	0.00395	0.00374	0.00426
COV (%)		0.00050	0.00039	0.00037	0.00043

Table 4 Resistance, R_o, at 0°C, for RTD's 10 to 13

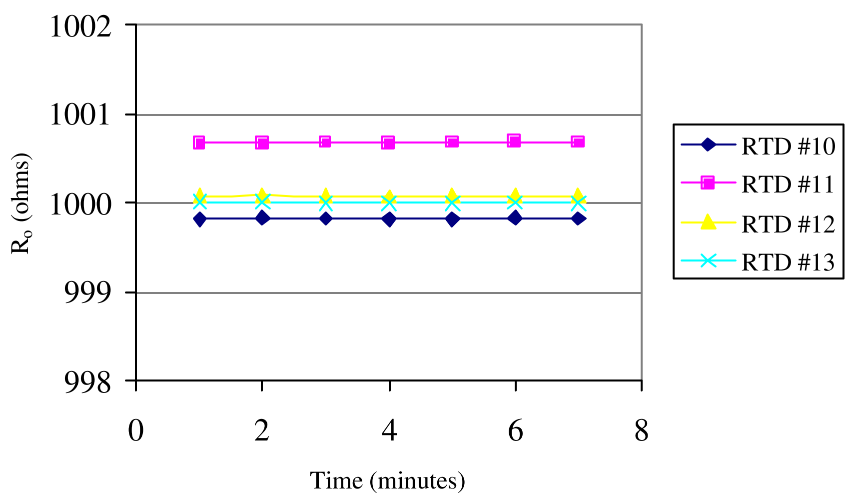


Figure 17 Stability of RTD resistance during calibration

Elapsed Time (min)	Reference Temperature	RTD #14	RTD #15	RTD #16	RTD #17
1	0.000 ± 0.001°C		1000.052	999.707	1000.111
2			1000.05	999.702	1000.111
3		998.311	1000.043	999.697	1000.105
4		998.335	1000.041	999.695	1000.103
5		998.358	1000.035	999.684	1000.097
6		998.37	1000.029	999.689	1000.095
7		998.391	1000.029	999.688	1000.095
Average		998.353	1000.040	999.695	1000.102
Stdev		0.03101	0.00932	0.00818	0.00700
COV (%)		0.00311	0.00093	0.00082	0.00070

Table 5 Resistance, R_o, at 0°C, for RTD's 14 to 17

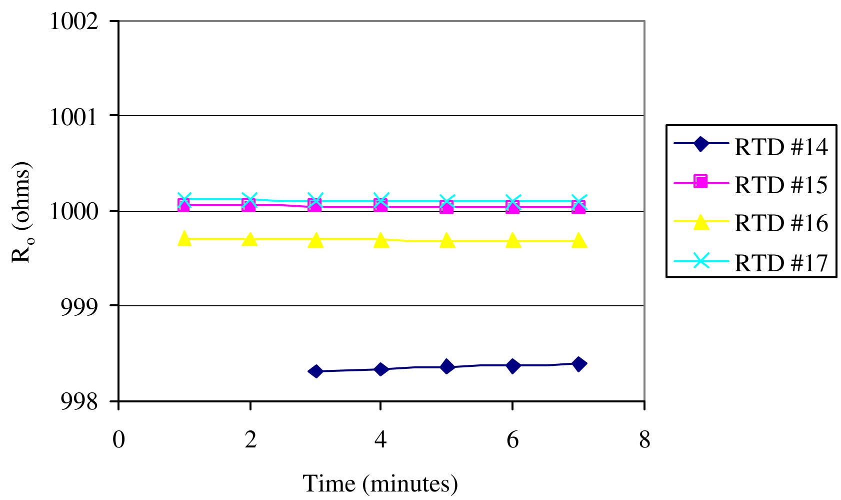


Figure 18 Stability of RTD resistance during calibration

Elapsed Time (min)	Reference Temperature	RTD #18	RTD #19	RTD #20	RTD #21
1		998.11	1000.255	999.5	998.424
2		998.156	1000.251	999.534	998.437
3		998.191	1000.247	999.565	998.448
4	0.000 ± 0.001°C	998.211	1000.251	999.589	998.458
5		998.236	1000.251	999.609	998.462
6			1000.25		
7			1000.256		
Average		998.181	1000.252	999.559	998.446
Stdev		0.04922	0.00305	0.04342	0.01556
COV (%)		0.00493	0.00030	0.00434	0.00156

Table 6 Resistance, R_o, at 0°C, for RTD's 18 to21

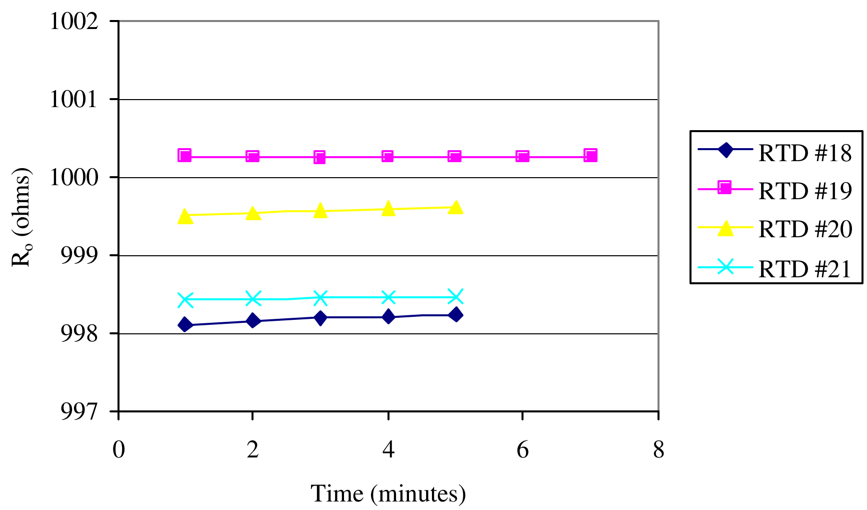


Figure 19 Stability of RTD resistance during calibration

Elapsed Time (min)	Reference Temperature	RTD #22	RTD #23	RTD #24	RTD #25
1					
2		999.566	999.721	1000.121	1000.052
3		999.568	999.722	1000.121	1000.061
4		999.573	999.719	1000.125	1000.060
5	0.000 ± 0.001°C	999.569	999.717	1000.119	1000.065
6		999.573	999.716	1000.125	1000.064
7		999.567	999.721	1000.118	1000.063
Average		999.569	999.719	1000.122	1000.061
Stdev		0.00294	0.00242	0.00252	0.00471
COV (%)		0.00029	0.00024	0.00025	0.00047

Table 7 Resistance, R_o, at 0°C, for RTD's 22 to 25

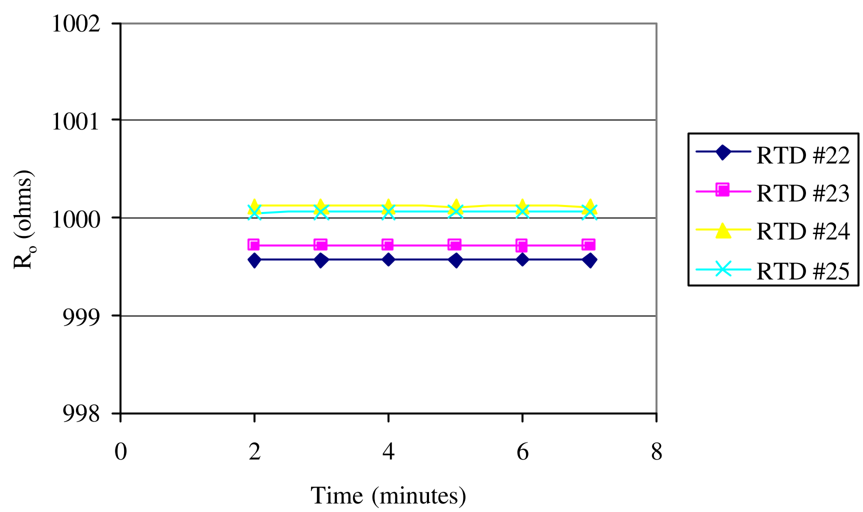


Figure 20 Stability of RTD resistance during calibration

Elapsed Time (min)	Reference Temperature	RTD #26	RTD #27	RTD #28	RTD #29
1	0.000 ± 0.001°C	999.566	999.721	1000.121	1000.052
2		999.568	999.722	1000.121	1000.061
3		999.573	999.719	1000.125	1000.060
4		999.569	999.717	1000.119	1000.065
5		999.573	999.716	1000.125	1000.064
6		999.567	999.721	1000.118	1000.063
7					
Average		999.569	999.719	1000.122	1000.061
Stdev		0.00294	0.00242	0.00252	0.00471
COV (%)		0.00029	0.00024	0.00025	0.00047

Table 8 Resistance, R_o, at 0°C, for RTD's 26 to 29

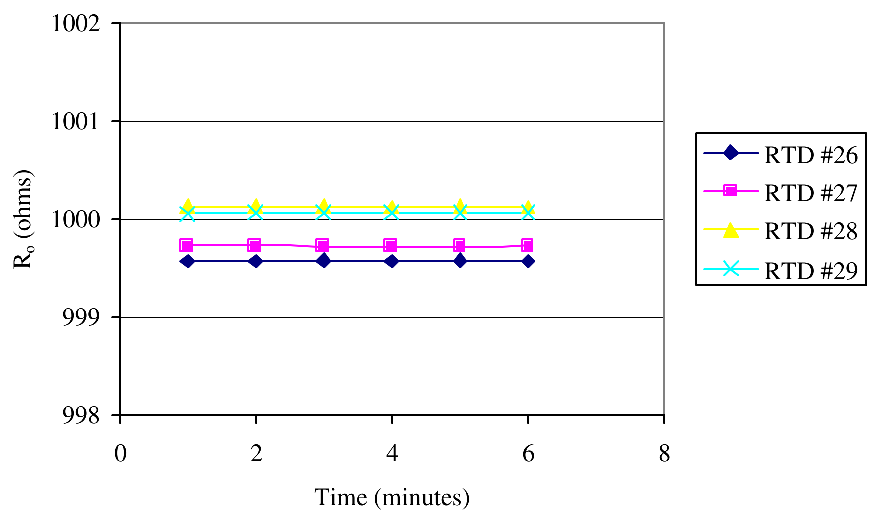


Figure 21 Stability of RTD resistance during calibration

Figure 22 Relative Humidity sensors

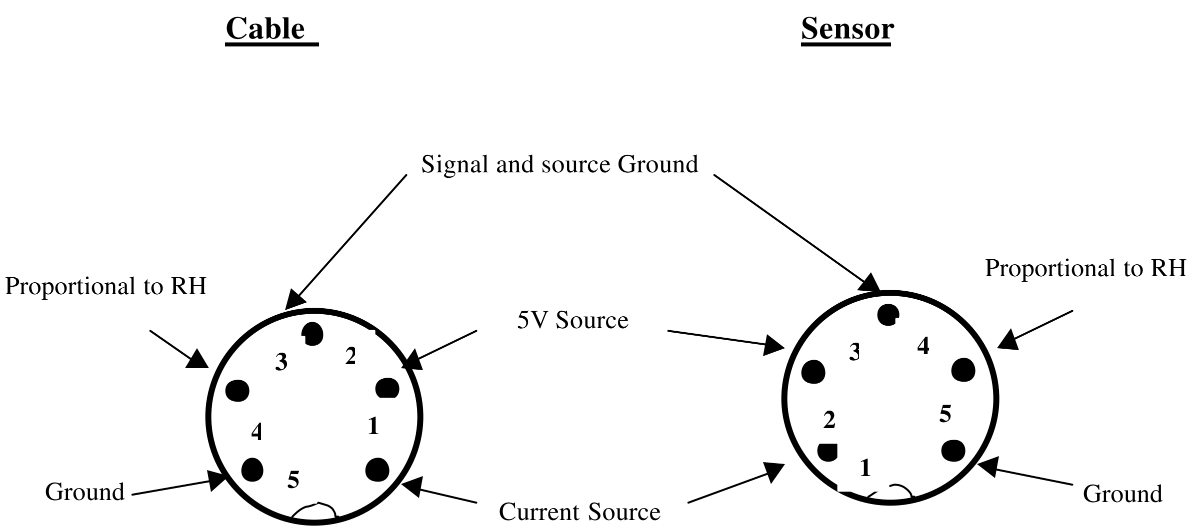


Figure 23 Pin out for the connectors for both RH sensors and cable

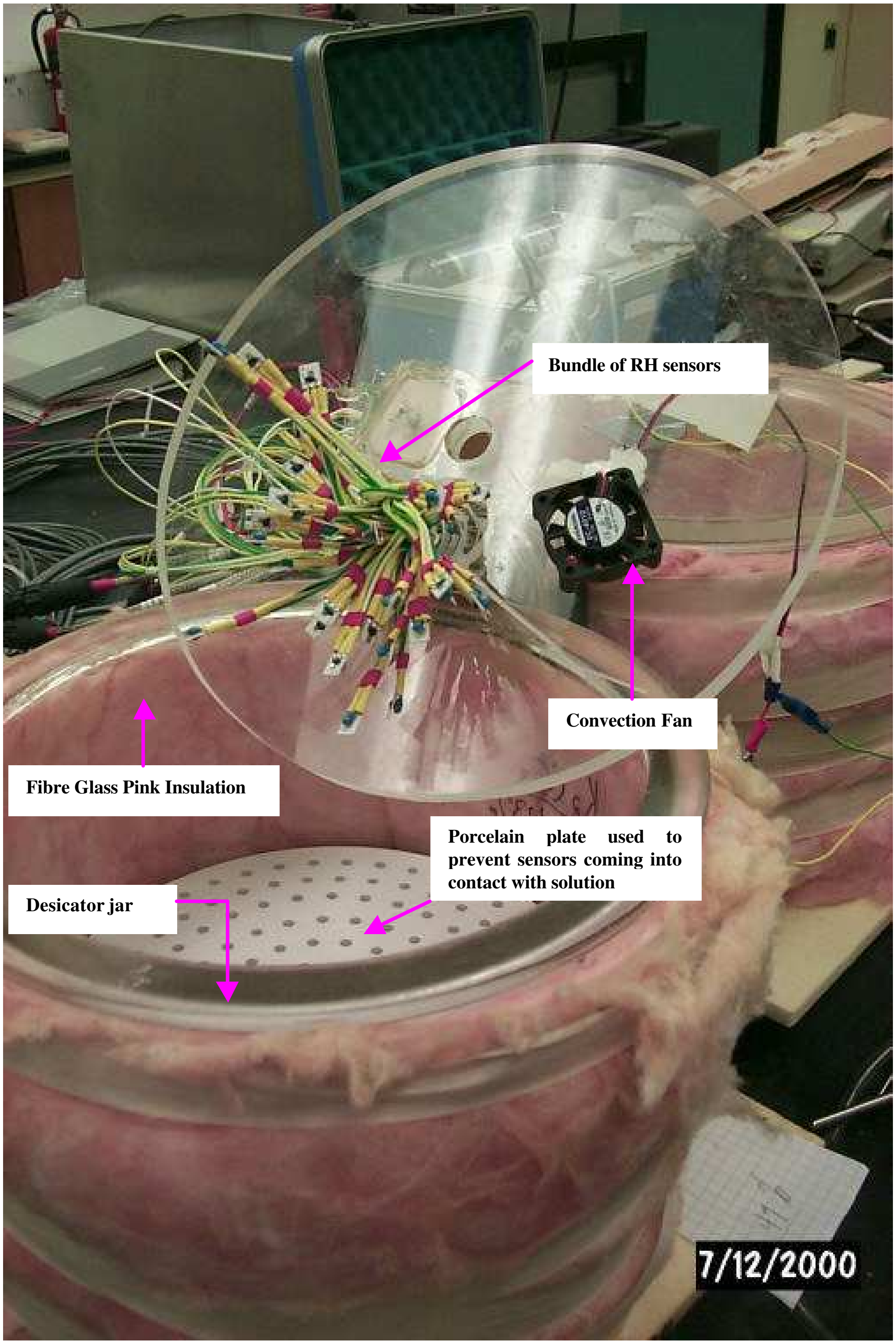


Figure 24 Lid and container (desiccator jar)

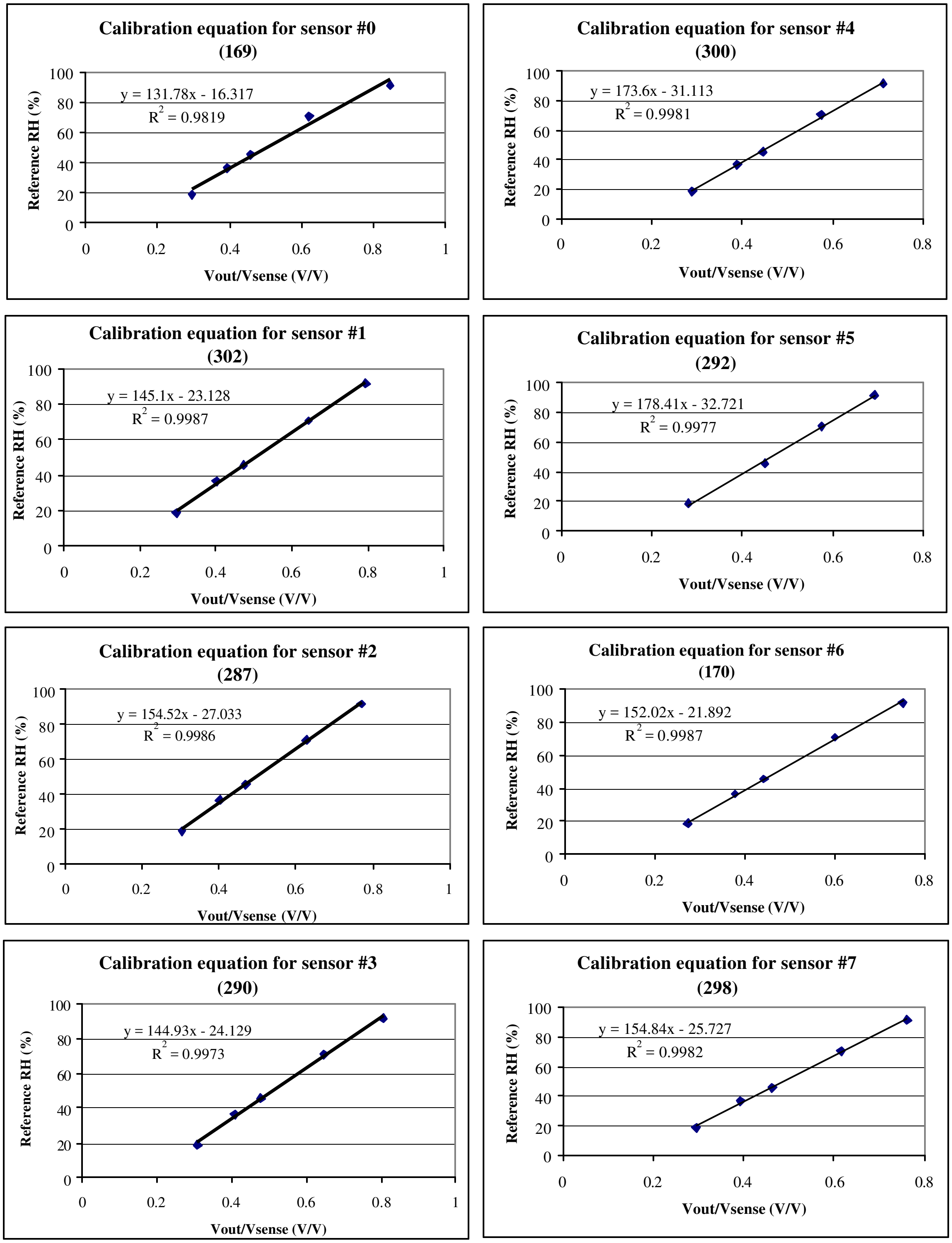


Figure 25 Calibration equations for RH sensors #0 to #7

Note: Number in brackets is the serial number of the RH sensor

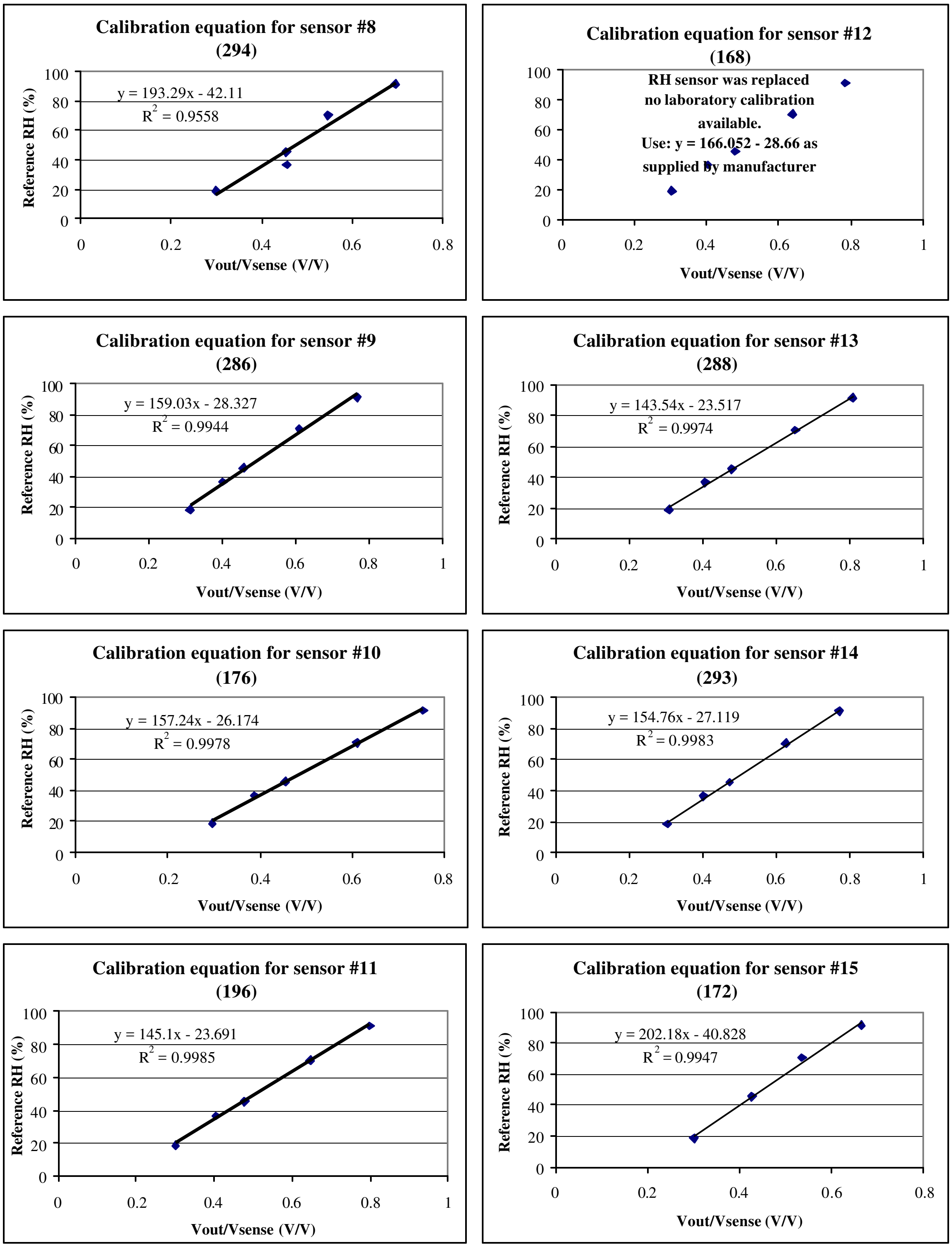


Figure 26 Calibration equations for RH sensors #8 to #15

Note: Number in brackets is the serial number of the RH sensor

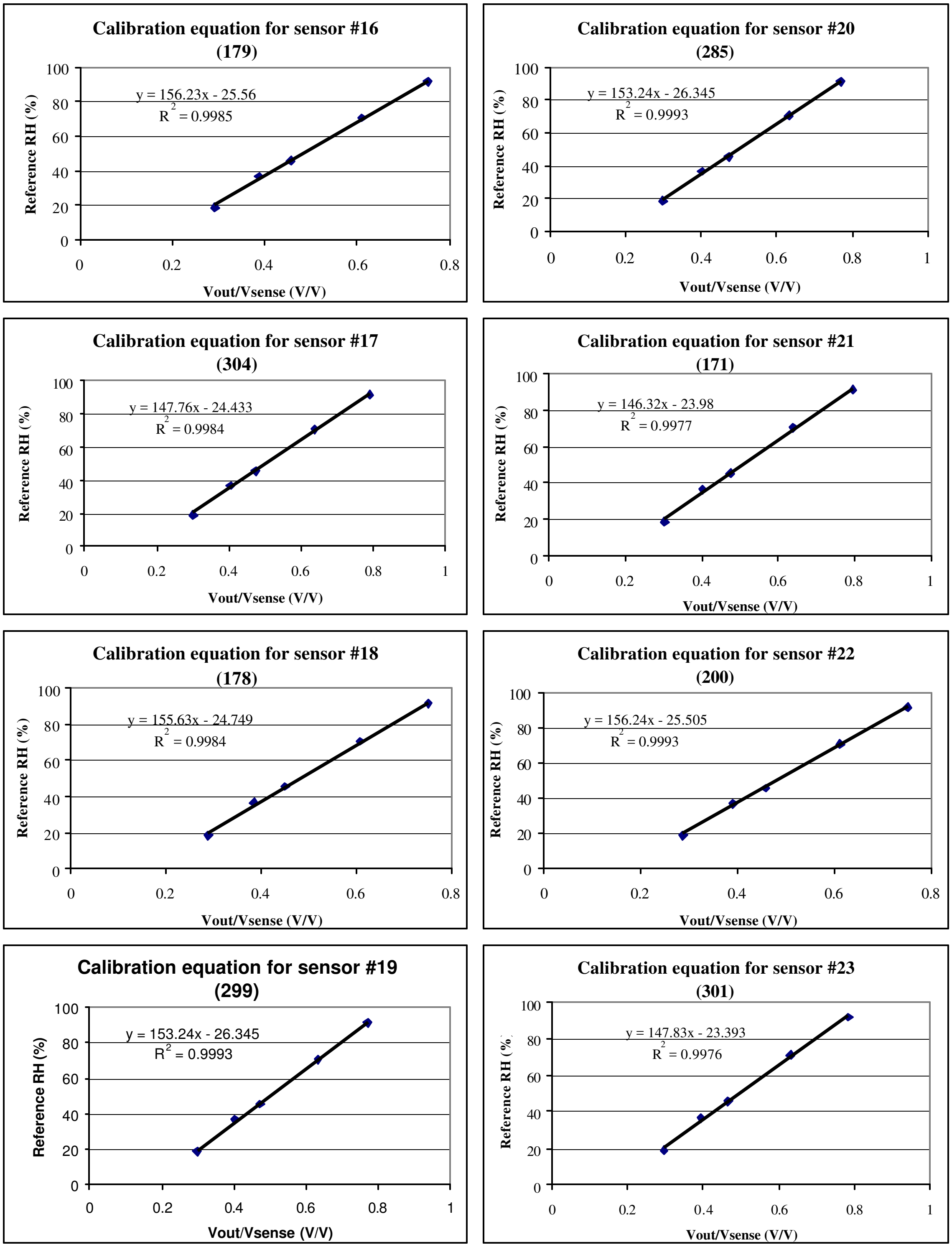


Figure 27 Calibration equations for RH sensors #16 to #23

Note: Number in brackets is the serial number of the RH sensor

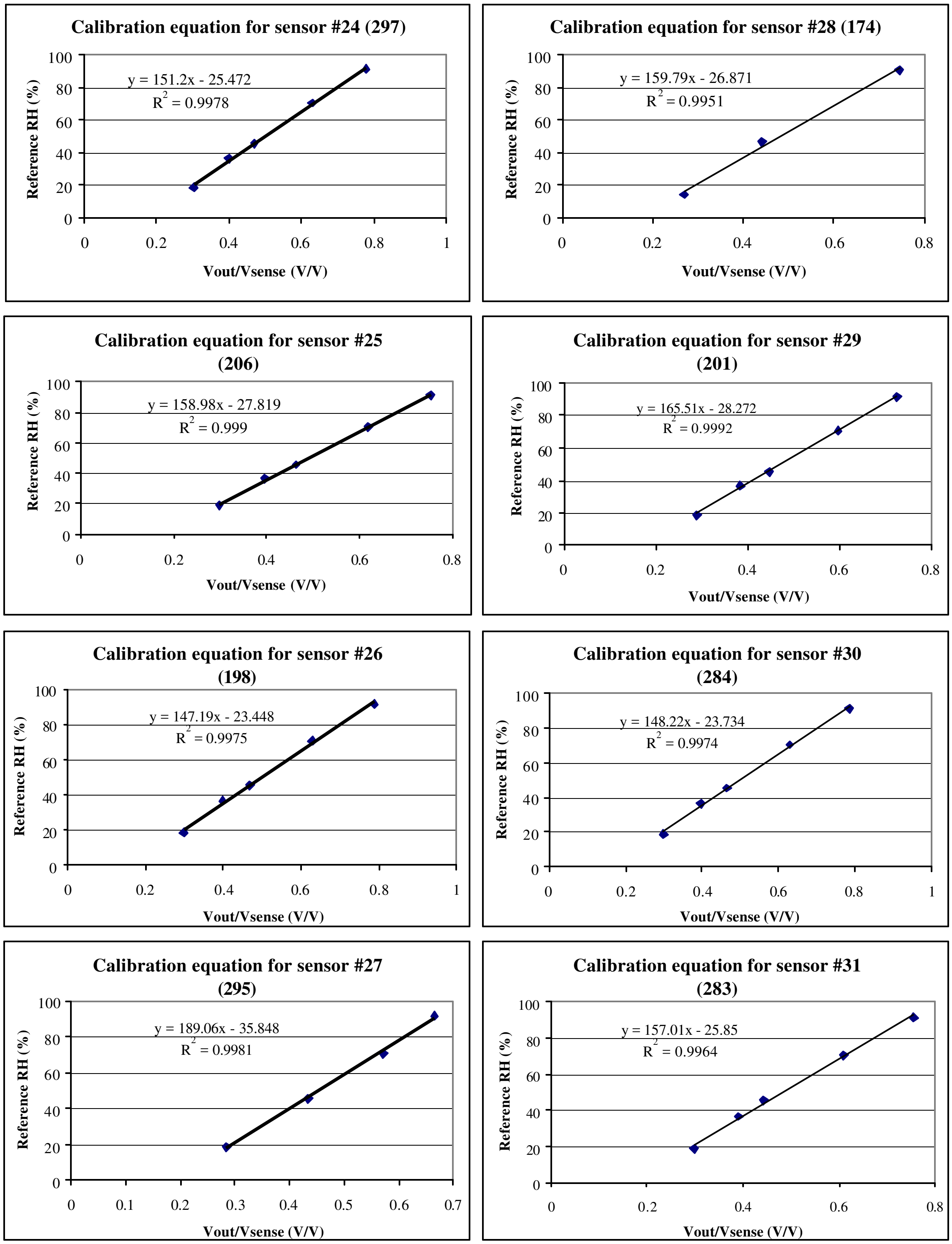


Figure 28 Calibration equations for RH sensors #23 to #31

Note: Number in brackets is the serial number of the RH sensor

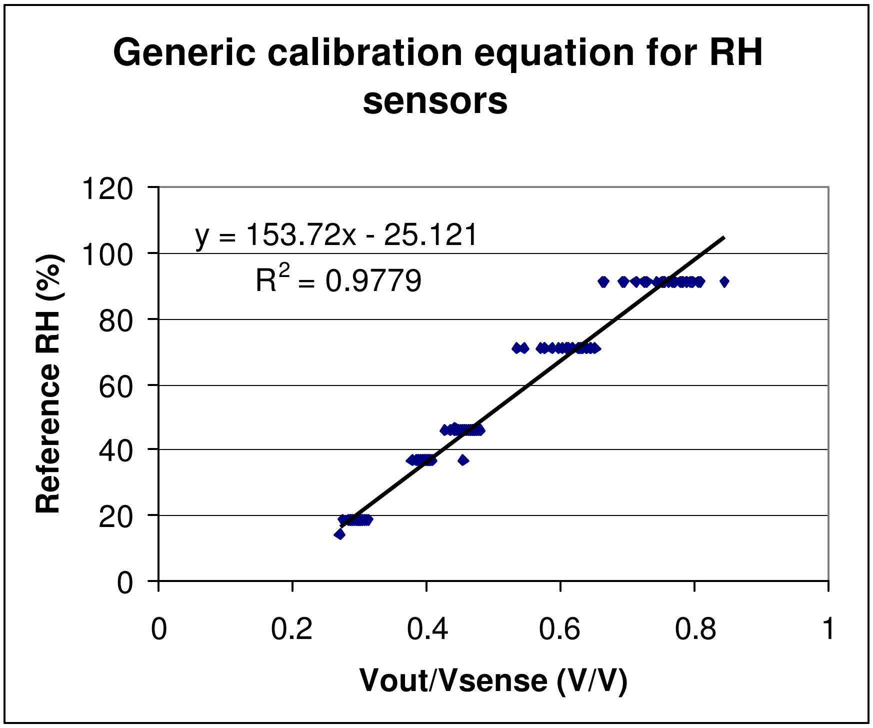


Figure 29 Generic calibration equation for RH sensors

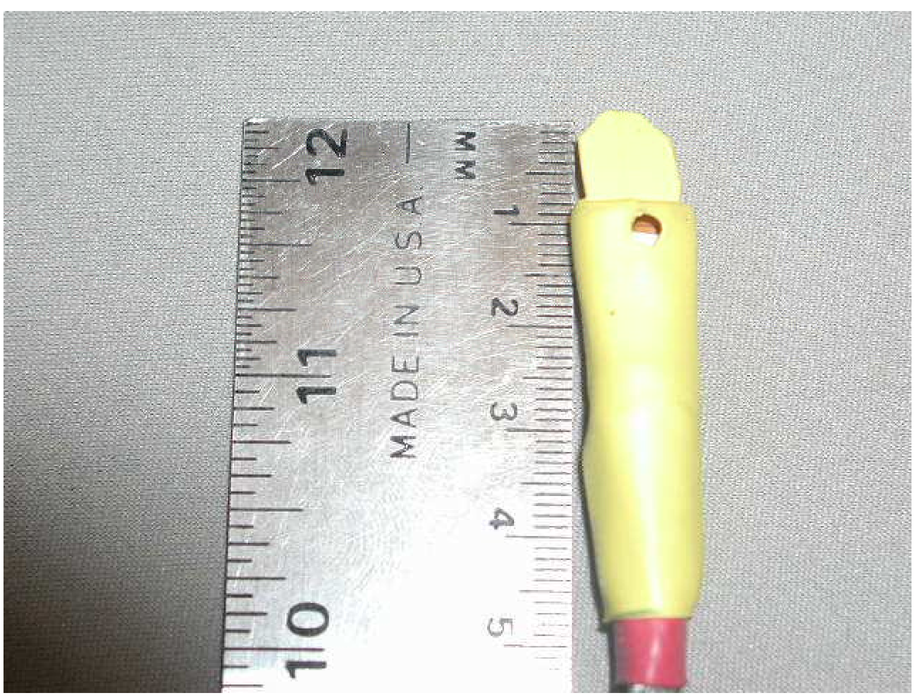


Figure 30 Close-up view of the shroud in place over the tip of the probe

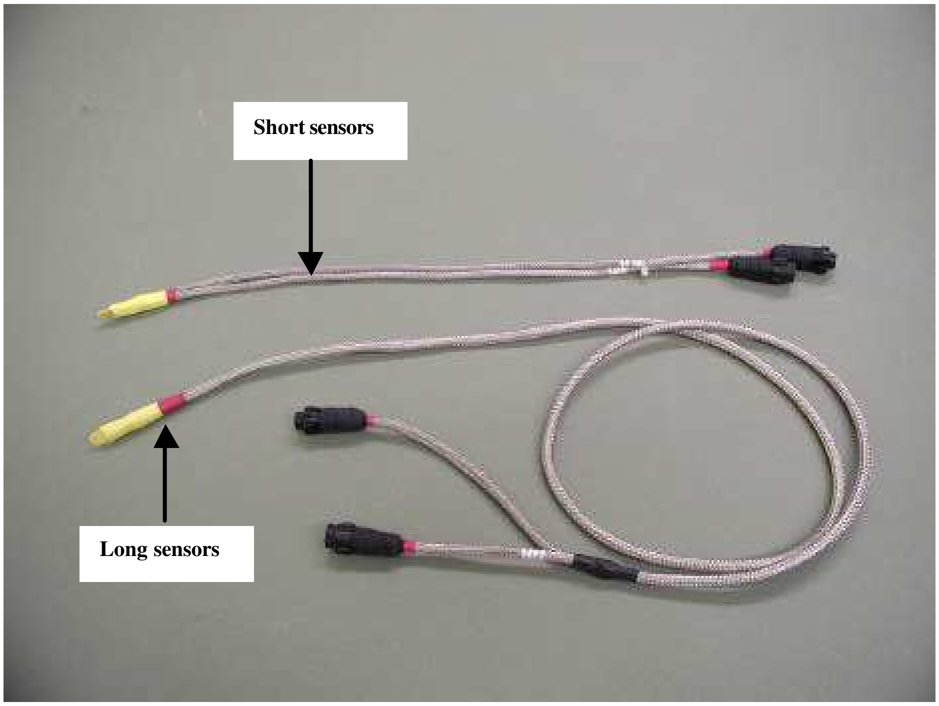


Figure 31 General view of two lengths of probes

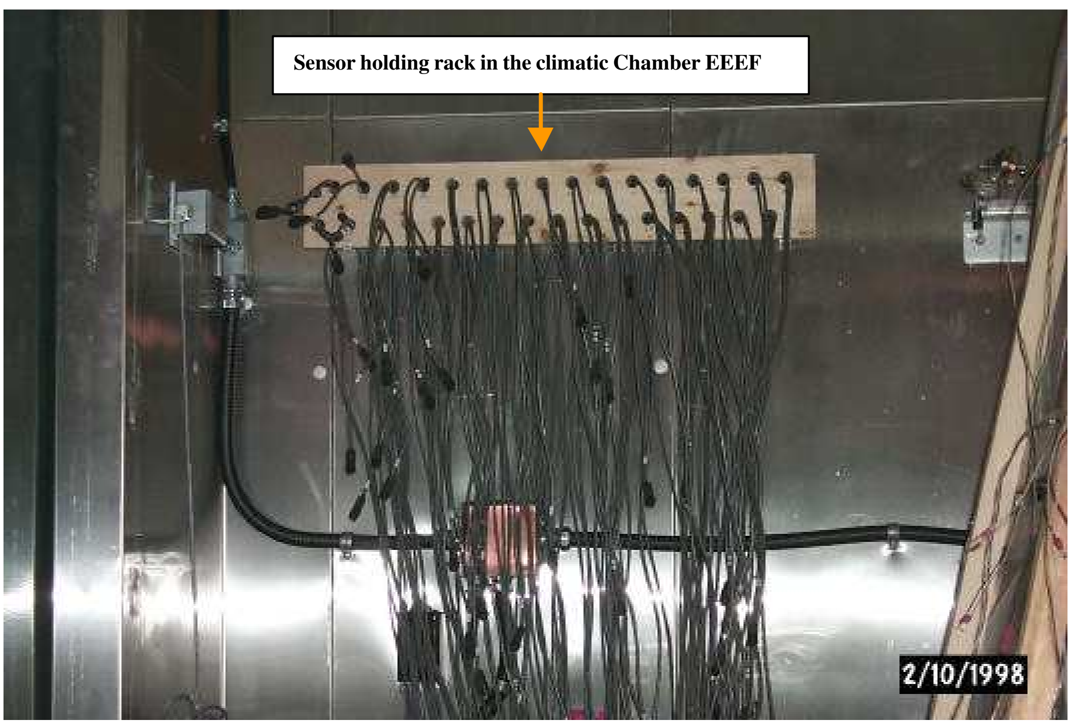


Figure 32 Position of the probe in the climatic chamber

Figure 33 Connection of the probe to Data Acquisition Unit # 2(DAU)

DAU #2 HP E1476A MUX IN SLOT# 12

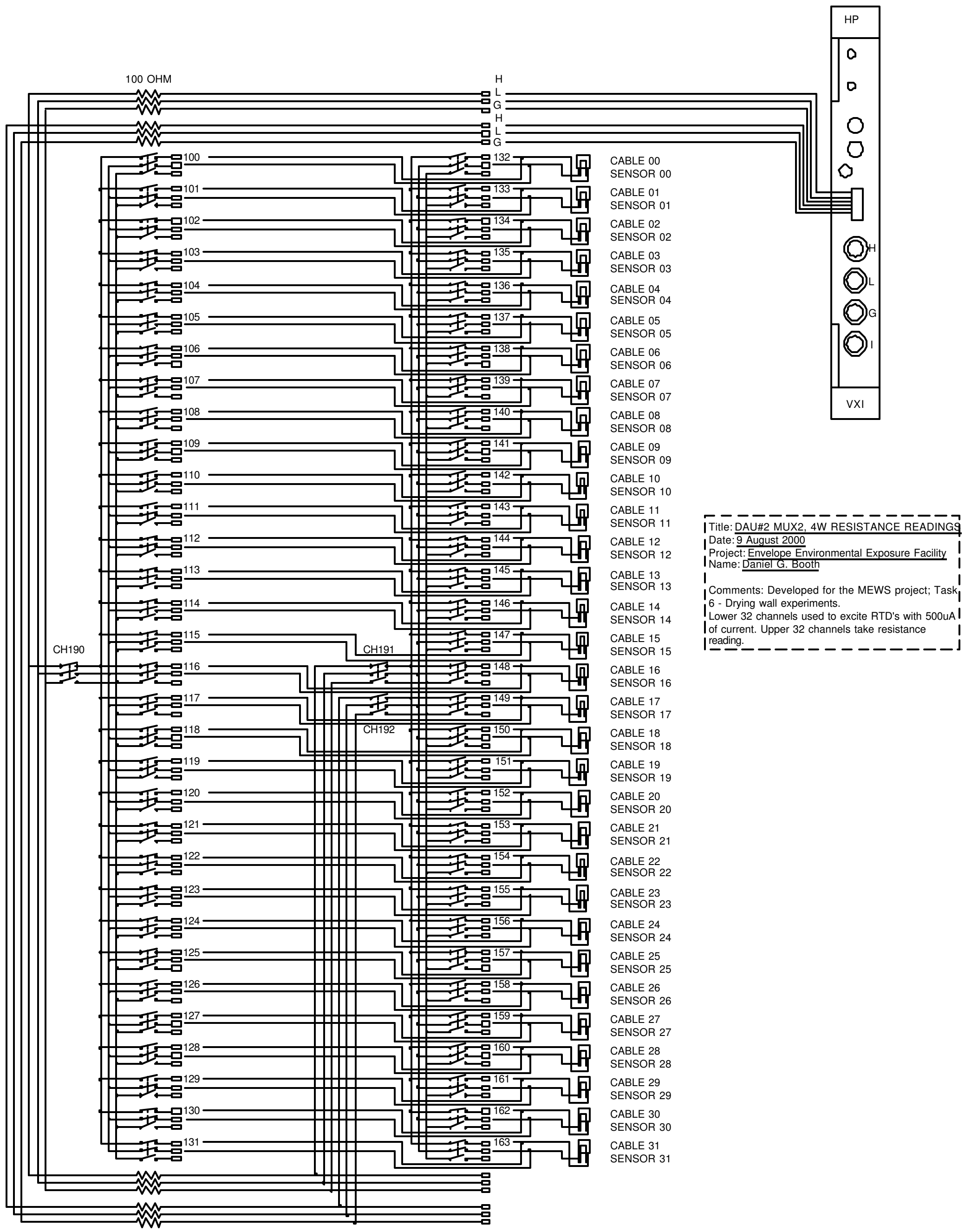


Figure 34 Multiplexer card used for monitoring RTD sensors

DAU #2 HP E1476A MUX IN SLOT# 3

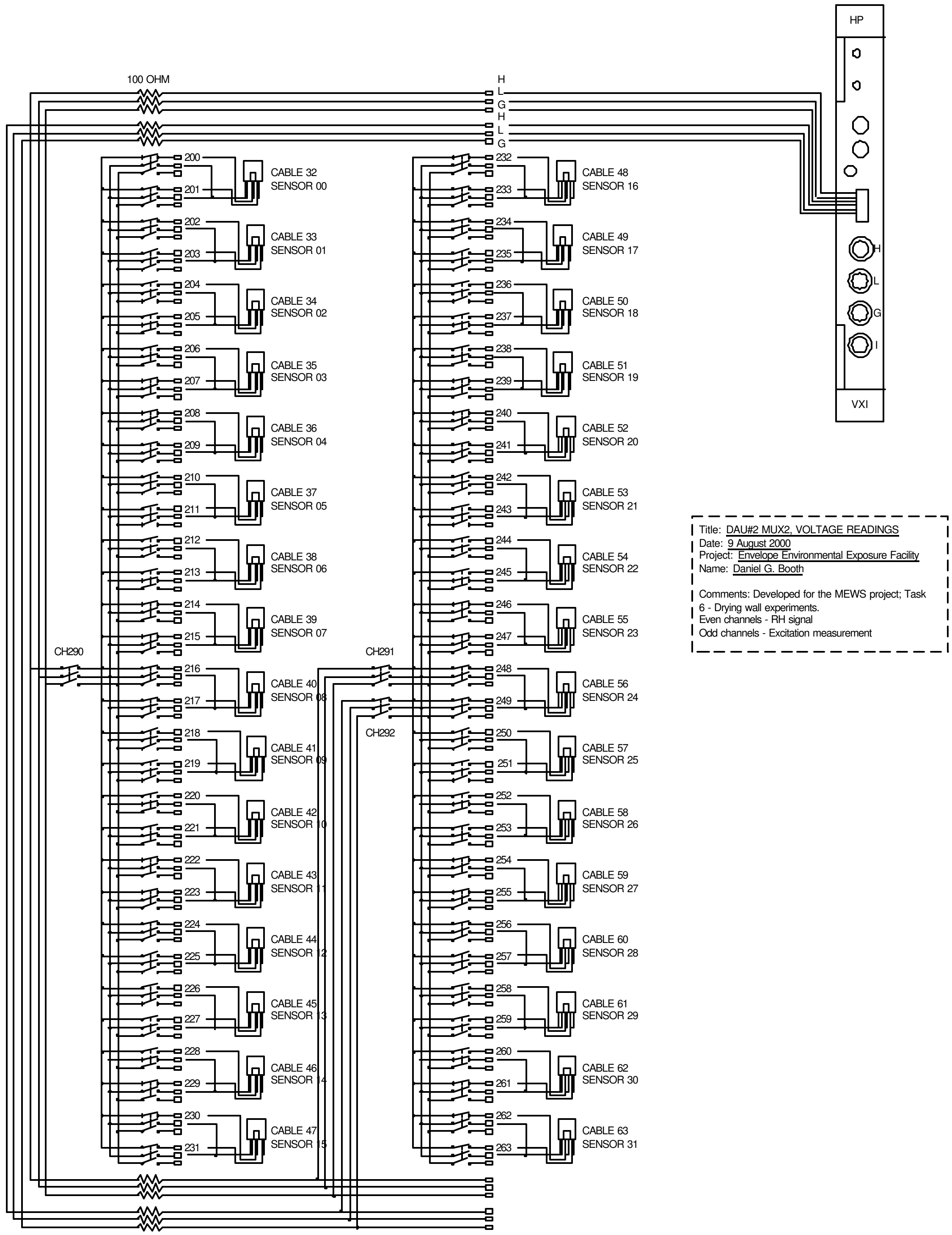


Figure 35 Multiplexer card used for monitoring the RH sensors

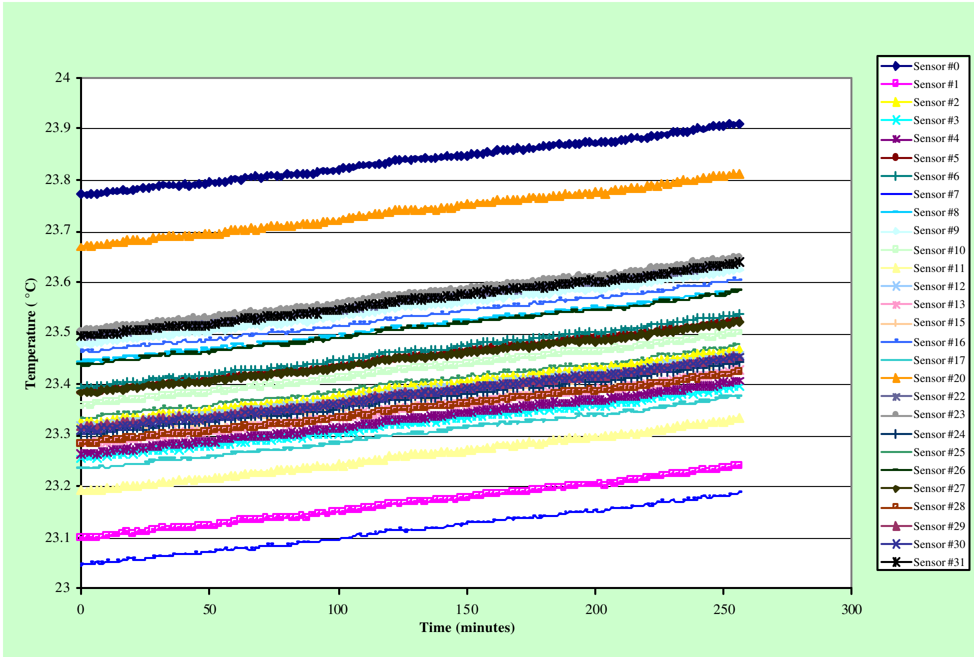


Figure 36 Typical scan of RTD's for controlled environmental conditions

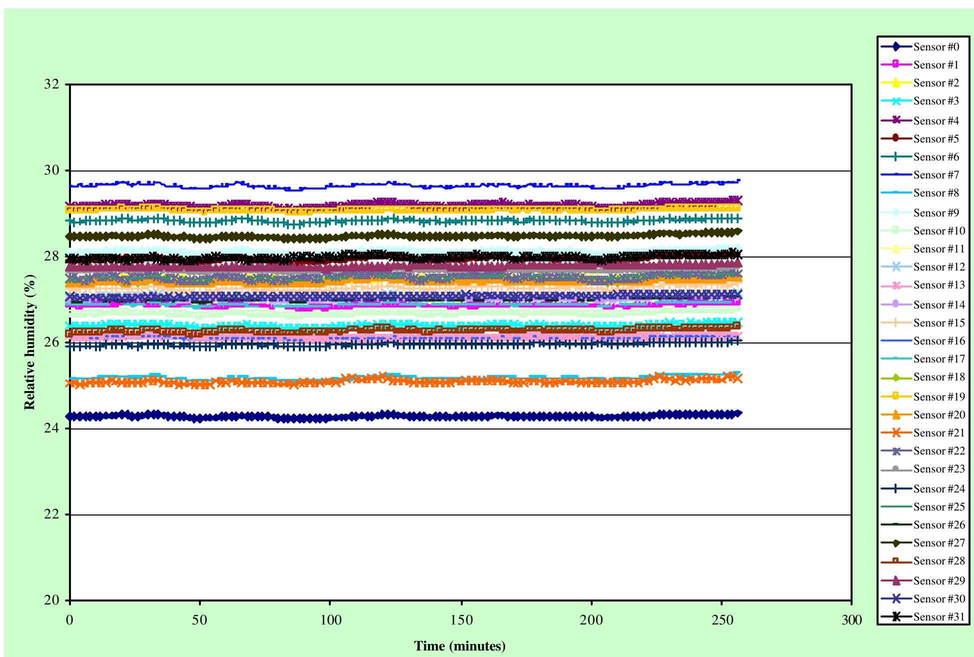


Figure 37 Sample of RH data from RHT probes exposed to controlled environmental conditions

Appendix I: Manufacturer's specifications for RH sensors

Humidity Sensors
Relative Humidity

HIH Series

FEATURES
- Linear voltage output vs %RH
- Laser trimmed interchangeability
- Low power design
- High accuracy
- Fast response time
- Stable, low drift performance
- Chemically resistant

TYPICAL APPLICATIONS
- Refrigeration
- Drying
- Meteorology
- Battery-powered systems
- OEM assemblies

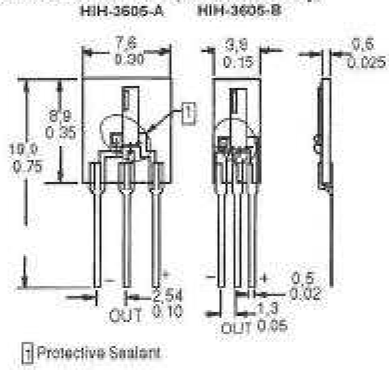
GENERAL INFORMATION
The HIH-3605 monolithic IC (Integrated Circuit) humidity sensor is designed specifically for high volume OEM (Original Equipment Manufacturer) users. Direct input to a controller or other device is made possible by this sensor's linear voltage output. With a typical current draw of only 200 μA, the HIH-3605 is ideally suited for low drain, battery powered systems.

The HIH-3605 delivers instrumentation quality RH sensing performance in a low cost, solderable SIP (Single In-line Package). Available in two lead spacing configurations, the RH sensor is a laser trimmed thermoset polymer capacitive sensing element with on-chip integrated signal conditioning.

ORDER GUIDE

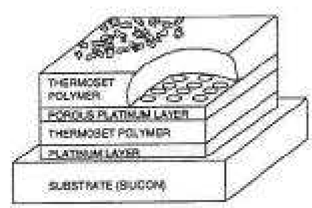
Catalog Listing	Description
HIH-3605-A	Integrated circuit humidity sensor, 0.100 in. lead pitch SIP
HIH-3605-A-CP	Integrated circuit humidity sensor, 0.100 in. lead pitch SIP with calibration and data printout
HIH-3605-B	Integrated circuit humidity sensor, 0.050 in. lead pitch SIP
HIH-3605-B-CP	Integrated circuit humidity sensor, 0.050 in. lead pitch SIP with calibration and data printout.

MOUNTING DIMENSIONS (for reference only)



NIST CALIBRATION
HIH-3605 sensors may be ordered with a NIST calibration and sensor specific data printout. Append "−CP" to the model number to order.

RH SENSOR CONSTRUCTION
Sensor construction consists of a planar capacitor with a second polymer layer to protect against dirt, dust, oils and other hazards.



CAUTION
PRODUCT DAMAGE
The inherent design of this component causes it to be sensitive to electrostatic discharge (ESD). To prevent ESD-induced damage and/or degradation, take normal ESD precautions when handling this product.

Humidity

Humidity Sensors

Relative Humidity

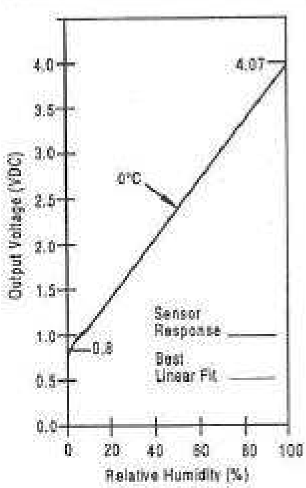
PERFORMANCE SPECIFICATIONS

Parameter	Conditions
RH Accuracy[1]	±2% RH, 0-100% RH non-condensing, 25°C, V_{supply} = 5 VDC
RH Interchangeability	±5% RH, 0-60% RH; ±8% @ 90% RH typical
RH Linearity	±0.5% RH typical
RH Hysteresis	±1.2% of RH span maximum
RH Repeatability	±0.5% RH
RH Response Time, 1/e	15 sec in slowly moving air at 25°C
RH Stability	±1% RH typical at 50% RH in 5 years
Power Requirements Voltage Supply Current Supply	 4 to 5.8 VDC, sensor calibrated at 5 VDC 200 µA at 5 VDC, 2 mA typical at 9 VDC
Voltage Output V_{supply} = 5 VDC Drive Limits	V_{out} = V_{supply} (0.0062 (Sensor RH) +0.16), typical @ 25°C (Data printout provides a similar, but sensor specific, equation at 25°C.) 0.8 to 3.9 VDC output @ 25°C typical Push/pull symmetric: 50 µA typical, 20 µA minimum, 100 µA maximum Turn-on ≤0.1 second
Temp. Compensation Effect @ 0% RH Effect @ 100% RH	True RH = (Sensor RH)/(1.093-.0012T), T in °F True RH = (Sensor RH)/(1.0546-0.00216T), T in °C ±0.007% RH/°C (negligible) −0.22% RH/°C (<1% RH effect typical in occupied space systems above 15°C (59°F))
Humidity Range Operating Storage	 0 to 100% RH, non-condensing[1] 0 to 90% RH, non-condensing
Temperature Range Operating Storage	 −40° to 85°C (−40° to 185°F) −51° to 125°C (−60° to 257°F)
Package[2]	Three pin solderable ceramic SIP
Handling	Static sensitive diode protected to 15 kV maximum

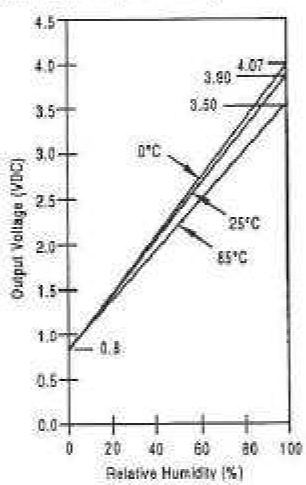
Notes:

1. Extended exposure to ≥90% RH causes a reversible shift of 3% RH.
2. This sensor is light sensitive. For best results, shield the sensor from bright light.

OUTPUT VOLTAGE VS RELATIVE HUMIDITY (at 0°C)



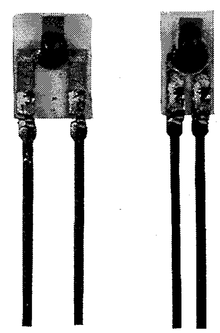
OUTPUT VOLTAGE VS RELATIVE HUMIDITY (at 0°C, 25°C, and 85°C)



Appendix II: Manufacturer's specifications for RTD sensors

Temperature Sensors
Platinum RTDs

HEL-775 Series



FEATURES
- Linear resistance vs temperature
- Accurate and Interchangeable
- Excellent stability
- Small size
- Printed circuit mountable
- Ceramic SIP package

TYPICAL APPLICATIONS
- HVAC – room, duct and refrigerant equipment
- Instrument and probe assemblies
- Electronic assemblies – temperature compensation
- Process control – temperature regulation

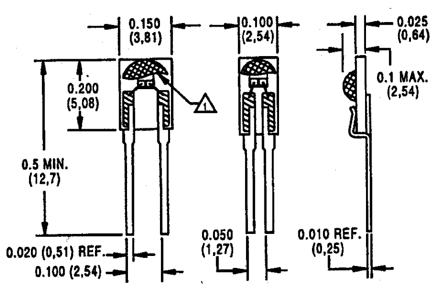
HEL-775 platinum RTDs are designed to measure temperatures from −55° to +150°C (−67° to 302°F) in printed circuit boards, temperature probes, or other lower temperature applications. Solderable leads in 0.050″ or 0.100″ spacing provide strong connections for wires or printed circuits.

The 1000Ω, 375 alpha version, provides 10x greater sensitivity and signal-to-noise. The 0.050″ lead space models are ideal for probes.

ORDER GUIDE

HEL-775-A	Ceramic SIP pkg. 0.100″ lead spacing		
HEL-775-B	Ceramic SIP pkg. 0.050″ lead spacing		
	-U	1000Ω, 0.00375 Ω/Ω/°C	
	-T	100Ω, 0.00385 Ω/Ω/°C, DIN specification	
		-0	±0.2% Resistance Trim (Standard)
		-1	±0.1% Resistance Trim (Optional)

MOUNTING DIMENSIONS (for reference only) mm/in.
HEL-775-A HEL-775-B



CAUTION
PRODUCT DAMAGE
The inherent design of this component causes it to be sensitive to electrostatic discharge (ESD). To prevent ESD-induced damage and/or degradation, take normal ESD precautions when handling this product.

Fig. 1: Wheatstone Bridge 2-Wire Interface

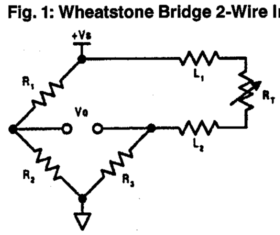


Fig. 2: Linear Output Voltage

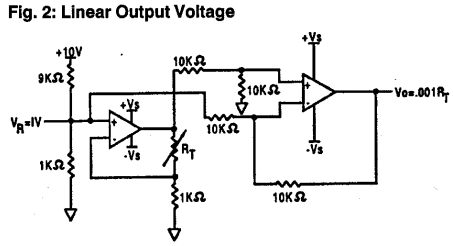
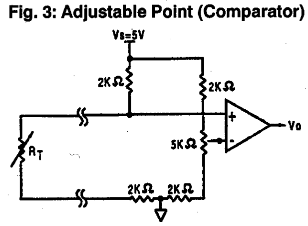


Fig. 3: Adjustable Point (Comparator) Interface



Temperature

FUNCTIONAL BEHAVIOR

$R_T = R_0(1+AT+BT^2-100CT^3+CT^4)$
RT = Resistance (Ω) at temperature T (°C)
R_0 = Resistance (Ω) at 0°C
T = Temperature in °C

$A = \alpha + \frac{\alpha\delta}{100}$ $B = \frac{-\alpha\delta}{100^2}$ $C_{T<0} = \frac{-\alpha\beta}{100^4}$

Alpha, α (°C^{-1})	0.00375 ±0.000029	0.003850 ±0.000010
Delta, δ (°C)	1.605 ± 0.009	1.4999 ± 0.007
Beta, β (°C)	0.16	0.10863
A (°C^{-1})	3.81×10^{-3}	3.908×10^{-3}
B (°C^{-2})	-6.02×10^{-7}	-5.775×10^{-7}
C (°C^{-4})	-6.0×10^{-12}	-4.183×10^{-12}

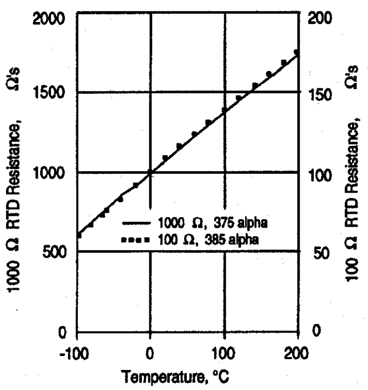
Both β = 0 and C = 0 for T>0°C

ACCURACY VS TEMPERATURE

Tolerance	Standard ±0.2%		Optional ±0.1%	
Temperature (°C)	±ΔR* (Ω)	±ΔT (°C)	±ΔR* (Ω)	±ΔT (°C)
−200	6.8	1.6	5.1	1.2
−100	2.9	0.8	2.4	0.6
0	2.0	0.5	1.0	0.3
100	2.9	0.8	2.2	0.6
200	5.6	1.6	4.3	1.2
300	8.2	2.4	6.2	1.8
400	11.0	3.2	8.3	2.5
500	12.5	4.0	9.6	3.0
600	15.1	4.8	10.4	3.3

* 1000Ω RTD. Divide ΔR by 10 for 100Ω RTD.

RESISTANCE VS TEMPERATURE CURVE



SPECIFICATIONS

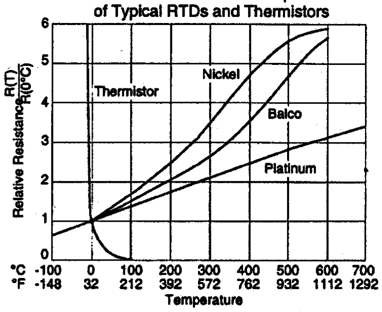
Sensor Type	Thin film platinum RTD: R_0 = 1000 Ω @ 0°C; alpha = 0.00375 Ω/Ω/°C R_0 = 100 Ω @ 0°C; alpha = 0.00385 Ω/Ω/°C
Temperature Range	−55° to +150°C (−67° to +302°F)
Temperature Accuracy	±0.5°C or 0.8% of temperature, °C (R_0 ±0.2% trim), whichever is greater ±0.3°C or 0.6% of temperature, °C (R_0 ±0.1% trim), whichever is greater (optional)
Base Resistance and Interchangeability, $R_0 \pm \Delta R_0$	1000 ± 2 Ω (±0.2%) @ 0°C or 100 ± 0.2 Ω (±0.2%) @ 0°C 1000 ± 1 Ω (±0.1%) @ 0°C or 100 + 0.2 Ω (+0.2%) @ 0°C (optional)
Linearity	±0.15% of full scale for temperatures spanning −55° to 150°C
Time Constant	<10 sec. in air at 10 ft./sec.
Operating Current	1 mA maximum in still air for <0.3°C (0.5°F) self heating
Stability	<0.05°C per 5 years in occupied environments
Self Heating HEL-775-A HEL-775-B	 9.7mW/°C nominal in air at 10ft/sec, 4.3mW/°C nominal in enclosed still air 6.8mW/°C nominal in air at 10ft/sec, 3.0mW/°C nominal in enclosed still air
Insulation Resistance	>50 MΩ @ 50 VDC @ 25°C
Construction	Alumina substrate with epoxy protection
Lead Material	Phosphor bronze with bright tin lead 60/40 plating
Lead Configuration	2-wire

Appendix III: Platinum resistance Vs. Temperature relationship

PLATINUM RTD RESISTANCE VS. TEMPERATURE FUNCTION

PLATINUM is a precious metal with a very stable and near linear resistance versus temperature function. While intrinsically less sensitive than thermistors or other metals, thin film RTDs provide very high base resistance and high device sensitivity.

Relative Resistance Vs Temperature of Typical RTDs and Thermistors



Platinum's resistance versus temperature function is accurately modeled by the Callendar-Van Dusen equation. This equation uses constants A, B and C, derived from resistance measurements at 0°C, 100°C and 260°C.

Callendar-Van Dusen Equation:

$$R_T = R_0(1+AT+BT^2-100CT^3+CT^4)$$

R_T = Resistance (Ω) at temperature T (°C)
R_0 = Resistance (Ω) at 0°C
T = Temperature in °C

For T>0°C, the quadratic formula can be used to solve for Temperature as a function of measured resistance with the result:

$$0 = R_0BT^2+R_0AT+(R_0-R_T) \text{ implies...}$$

$$T_R = \frac{-R_0A+\sqrt{R_0^2A^2-4R_0B(R_0-R_T)}}{2R_0B}$$

Platinum RTDs are specified by resistance at 0°C, $\mathbf{R_0}$, and alpha, α, a term related to the temperature coefficient of resistance, or TCR. The Callendar-Van Dusen constants A, B and C are derived from alpha α and other constants, delta δ and beta β, which are obtained from actual resistance measurements. Common Callendar-Van Dusen constant values are shown in the table below:

CALLENDAR-VAN DUSEN CONSTANTS†

Alpha, α (°C⁻¹)	.003750 ± .00003	.003850 ± .0001
Delta, δ (°C)	1.605 ± 0.009	1.4999 ± 0.007
Beta, β* (°C)	0.16	0.10863
A (°C⁻¹)	3.81×10^{-3}	3.908×10^{-3}
B (°C⁻²)	-6.02×10^{-7}	-5.775×10^{-7}
C (°C⁻⁴)*	-6.0×10^{-12}	-4.183×10^{-12}

*Both β = 0 and C = 0 for T>0°C

The definitions of the Callendar Van Dusen constants: A, B, C, and alpha, delta and beta (α, δ and β), and their inter-relationships are given by the equations below. In all cases, the values of the constants and the fundamental accuracy and repeatability performance of an RTD is determined by the repeatability of the empirically measured resistance values:

$R_0 \pm \Delta R_0 R_{100} \pm \Delta R_{100}$ and $R_{260} \pm \Delta R_{260}$

$$A = \alpha + \frac{\alpha \cdot \delta}{100} \qquad B = \frac{-\alpha \cdot \delta}{100^2} \qquad C_{T<0} = \frac{-\alpha \cdot \beta}{100^4}$$

$$\alpha = \frac{R_{100} - R_0}{100 \cdot R_0} \qquad \delta = \frac{R_0 \cdot (1 + \alpha \cdot 260) - R_{260}}{4.16 \cdot R_0 \cdot \alpha}$$

$$\beta = \text{Constant for } T<0°C$$

TOLERANCE STANDARDS AND ACCURACY

IEC 751, the most commonly used standard for Platinum RTDs defines two performance classes for 100Ω, 0.00385 alpha Pt TRDs, **Class A** and **Class B**. These performance classes (also known as **DIN A** and **DIN B** due to DIN 43760) define tolerances on ice point and temperature accuracy. These tolerances are also often applied to Pt RTDs with ice point resistance outside of IEC 751's 100Ω assumption.

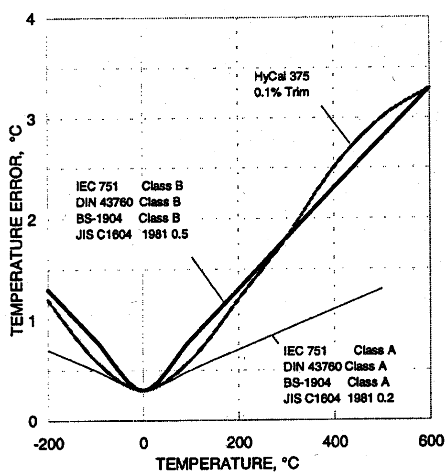
Class C and **Class D** (*each doubling the prior tolerance level*) are also used.

INTERNATIONAL STANDARDS

Standard	Comment	
IEC 751	Defines Class A and B performance for 100Ω 0.00385 alpha Pt RTDs.	
DIN 43760	Matches IEC 751.	
BS-1904	Matches IEC 751.	
JIS C1604	Matches IEC 751. Adds 0.003916 alpha.	
ITS-90	Defines temperature scale and transfer standard.	
Parameter	**IEC 751 Class A**	**IEC 751 Class B**
R_0	100Ω ± 0.06%	100Ω ± 0.12%
Alpha, α	.00385 ± .000063	.00385 ± .000063
Range	−200°C to 650°C	−200°C to 850°C
Res., R_T*	$\pm(.06+.0008\lvert T\rvert-2E\text{-}7T^2)$	$\pm(.12+.0019\lvert T\rvert-6E\text{-}7T^2)$
Temp, T**	$\pm(0.3+0.002\lvert T\rvert)$°C	$\pm(0.3+0.005\lvert T\rvert)$°C

*Units are Ωs. Values apply to 100Ω Pt RTDs only. Scale by ratio of the R_0s to apply to other ice point resistances.
*Applies to all 0.00385 alpha Pt RTDs independent of ice point, R_0.

PRTD TEMPERATURE ACCURACY



While IEC 751 only addresses 100Ω 385 alpha RTDs, its temperature accuracy requirements are often applied to such other platinum RTDs. However, manufacturers generally present both resistance-vs-temperature accuracies and temperature accuracies in tabular form for direct review.

The Callendar Van Dusen equation analytically addresses the tolerance and accuracy of a Pt RTD at any point within its operating temperature range independent of alpha and ice point resistance. The Resistance Limit-of-Error function (i.e. sensor resistance interchangeability as a function of temperature) can be calculated by taking the differential of the Callendar Van Dusen equation w.r.t. R_0, α and δ and applying the associated uncertainties. While an Expected (RMS) Error function can also be calculated, design engineers are typically interested only in the Limit-of-Error (LOE) function since it characterizes worst case behavior. The LOE function for resistance for T>0°C is:

$$\Delta R_{LOE} = \Delta R_0(1+AT+BT^2) + \Delta AR_0T + \Delta BR_0T$$

$$= \Delta R_0 + \Delta\alpha T + (\Delta\alpha\delta + \alpha\Delta\delta)\left(\frac{T}{100} + \frac{T^2}{100^2}\right)$$

Similarly, obtain the Temperature Limit-of-Error (i.e. temperature interchangeability) function using two approaches:

1. Multiply the derivative of R_T by the uncertainty ΔR_T

$$\Delta T_{T_1} = \Delta R_{T_1} \times \left.\frac{\partial R_T}{\partial T}\right|_{T_1}$$

2. Solve the Callendar Van Dusen equation for T, take the differential w.r.t. R_0, α and δ, then apply the appropriate uncertainties. In practice, it is "easier" to take the differential w.r.t. A and B and then apply ΔA and ΔB as calculated from α, Δα, δ and Δδ.

$$\Delta T_{LOE} = \frac{\Delta A}{2B} + \frac{A\Delta B}{2B^2} + \frac{\Delta B\sqrt{R_0^2A^2-4R_0B(R_0-R_T)}}{2R_0^2B^2} +$$

$$\frac{[R_0^2A^2-4R_0B(R_0-R_T)]^{-\frac{1}{2}}\,[A\Delta AR_0^2+2R_0\Delta B(R_0-R_T)]}{2R_0B}$$

The second relationship could also be calculated in terms of the basic empirical data: $R_0\pm\Delta R_0$, $R_{100}\pm\Delta R_{100}$ and $R_{260}\pm\Delta R_{260}$.

Reference/Index

RESISTANCE AND ACCURACY TABLES

PLATINUM RTD RESISTANCE-VS-TEMPERATURE				
Ice Point, Alpha Value & RTD Type	1000Ω 0.00375 Pt Thin Film	100Ω 0.00385 Pt Thin Film	100Ω 0.00385 Pt WW	100Ω 0.003902 Pt WW
Temperature °C	**Resistance (Ω)**			
-200	199.49	18.10	18.10	19.76
-180	284.87	26.81	26.81	28.01
-160	368.57	35.35	35.35	36.17
-140	450.83	43.75	43.75	44.27
-120	531.83	52.04	52.04	52.31
-100	611.76	60.21	60.21	60.31
-80	690.78	68.30	68.30	68.27
-60	769.01	76.32	76.32	76.22
-40	846.58	84.27	84.27	84.15
-20	923.55	92.16	92.16	92.08
0	1000.00	100.00	100.00	100.00
20	1075.96	107.79	107.79	107.92
40	1151.44	115.54	115.54	115.84
60	1226.44	123.24	123.24	123.76
80	1300.96	130.89	130.89	131.69
100	1375.00	138.50	138.50	139.61
120	1448.56	146.06	146.06	147.53
140	1521.63	153.57	153.57	155.45
160	1594.22	161.04	161.04	163.37
180	1666.33	168.46	168.46	171.29
200	1737.96	175.83	175.83	179.21
220	1809.11	183.16	183.16	187.14
240	1879.78	190.43	190.43	195.06
260	1949.96	197.67	197.67	202.98
280	2019.67	204.85	204.85	210.90
300	2088.89	211.99	211.99	218.82
320	2157.63	219.08	219.08	226.74
340	2225.89	226.12	226.12	234.66
360	2293.66	233.12	233.12	242.59
380	2360.96	240.07	240.07	250.51
400	2427.78	246.98	246.98	258.43
420	2494.11	253.83	253.83	266.35
440	2559.96	260.65	260.65	274.27
460	2625.33	267.41	267.41	282.19
480	2690.22	274.13	274.13	290.11
500	2754.63	280.80	280.80	298.04
520	2818.55	287.42	287.42	305.96
540	2881.99	294.00	294.00	313.88
560	2944.96	300.53	300.53	321.80
580	3007.44	307.01		
600	3069.44	313.44		
620	3130.96	319.83		
640	3191.99	326.18		
660	3252.55	332.47		
680	3312.62	338.72		
700	3372.21	344.92		
720	3431.32	351.08		
740	3489.95	357.18		
750	3519.09	360.22		

Sensor accuracy is a function of production tolerance and any additional calibration which the sensor may get. Calibration can improve the accuracy of an RTD by 10X over production tolerance.

The accuracy values in the table below apply to production tolerance tight trim RTDs with ice point tolerances of R_0 ±0.1%. The thin film values are for tight trim platinum RTDs. Both thin film and wire wound tight trim RTDs with 0.00385 alpha values meet IEC 751 Class B.

In qualifying volumes, RTDs can be laser trimmed for tight resistance interchangeability at any temperature between 0°C and 150°C or to an ice point resistance other than 100Ω or 1000Ω. Laser trimming also allows matching the resistance of RTD's with different alpha values at a target temperature.

ACCURACY* VS TEMPERATURE			
Ice Point, Alpha Value	1000Ω 0.00375	100Ω 0.00385	100Ω 0.003902
Temperature °C	**±ΔResistance (Ω)**		
-200	5.1	0.5	0.5
-100	2.4	0.3	0.3
0	1.0	0.1	0.1
100	2.2	0.2	0.2
200	4.3	0.4	0.4
300	6.2	0.6	0.6
400	8.3	0.8	0.8
500	9.6	1.0	1.0
600	10.4	1.2	1.2
Temperature °C	**±ΔTemperature (°C)**		
-200	1.2	1.2	1.2
-100	0.6	0.6	0.6
0	0.3	0.3	0.3
100	0.6	0.6	0.6
200	1.2	1.2	1.2
300	1.8	1.8	1.8
400	2.5	2.5	2.5
500	3.0	3.0	3.0
600	3.3	3.6	3.6

*Figures are for production tolerance tight trim RTDs.