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Specification of Equipment used in EEEF-
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by Wahid Maref, Daniel G. Booth, Michael Lacasse and Michael Nicholls

Research Report No. RR-105

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1. Introduction

IRC's Building Envelope and Structure Program has a new and unique test facility that incorporates a computer automated environmental chamber with a weighing system for full-scale wall assemblies (2.43 m x 2.43 m), climate sensors, data acquisition systems and post-processing tools. The climatic chamber, which is unique in North America, is known as Envelope Environmental Exposure Facility (EEEF). It can simulate interior and exterior climatic conditions over an extended period of time, controlling both temperatures (ranging from -47° to +48° C) on the " weather" side of the wall and humidity levels ranging from 10 to 100% RH.

Researchers, in conjunction with key industry partners, are using the facility to benchmark the thermal and moisture performance of walls in various climates, and the interfaces between walls and a) other building elements (such as windows) and b) at the penetrations. The EEEF has been used to gather key information regarding the rate of drying of specific wood-frame wall components when subjected to simulated rainfall. The development of the EEEF has been an on-going effort within the program to help address issues regarding effective moisture control in the building envelope.

Effective moisture control implies both minimizing moisture entries into the system, and maximizing the exit of moisture, which does enter, so that no component in the system stays 'too wet' for 'too long'. But what is "too wet" and "too long"? This facility has proven to be an essential component in determining the limits to which the results from simulation of moisture transport through wall assemblies can be used to help address these issues. It is the primary benchmarking tool of the advanced hygrothermal model hygIRC [1] and the comprehensive series of results derived from full-scale real-time and controlled laboratory experiments have helped substantiate those obtained through simulation.

The facility features several innovations:

- A weighing system that detects water evaporating from the wall by measuring the total wall weight with great precision (in grams) and tracking this weight over time;
- A frame and gasket technique for sealing the wall specimens to the enclosure, without interfering with the weighing process;

- State-of-the-art moisture meters for mapping differential drying on the of the wall;
- A complete data acquisition packages to control and monitor experiments, and a comprehensive data analysis technique for interpreting the results.
- The issues of "too wet" and "too long" and the ability of the wall to "dry out" are tackled in part through the use of the weighing system (see Figure 1 below) and related sensors. The system is capable of continuously monitoring weight changes of 2.43-m x 2.43-m walls having nominal weights of up to 250 kg to the nearest gram over the test period. This permits observing, for example, the "drying out" of a wall component and thereafter focusing on the times at which levels of moisture within the component fall below levels critical to the long-term performance of the component.

Figure 1— Environmental Exposure Envelope Facility (EEEF)

The EEEF is undergoing further development and refinement. Future enhancements include developing and installing apparatus to simulate wind, rain, and infrared radiation.

As first, step, the EEEF was used to conduct a serie of full and mid scale drying experiments.

This document gives you an overview of the serie of experiments that were performed in EEEF.

2. Experimental work performed in the EEEF

A serie of experiments have been conducted to gather data on the hygrothermal behaviour of full-scale wood-frame wall assemblies and wall components when subjected to steady and transient state climatic conditions. Results obtained from those experiments were used to evaluate the expected performance and predictive capabilities of an advanced hygrothermal model called "hygIRC" [1, 2 & 3] and are reported in subsequent documents in details [4, 5, 6, 7, 8, 9, 10 & 11]. The model has been used in the MEWS consortium project (Moisture Management of Exterior Wall Systems) as the primarily analytical tool to conduct a parametric study to assess the hygrothermal performance of various wall assembly types subjected to different climatic conditions. hygIRC presently uses hygrothermal property data derived from the test results undertaken in the laboratory on small-scale specimens, i.e. specimens having dimensions of 0.30 x 0.30-m. A considerable amount of experimental work has already been completed towards assessing the hygrothermal proprieties of various building materials used in wood-frame construction on the basis of this specimen scale. From this work an extensive library of hygrothermal material properties has been developed and used by hygIRC [12-28] and can be accessed by any Advanced Hygrothermal Model (AHM). It has been readily demonstrated that results obtained from these mid-scale tests and those derived from the use of hygIRC [1, 2 & 3] are in close agreement and as such, it is expected that hygIRC can adequately duplicate and help predict hygrothermal behaviour of wall components when subjecting the components to simulated climatic conditions. Its capability in terms of analysing the performance of multiple components systems and complex wall assemblies has been extensively validated [1, 2, 3, 4, 5, 6, &7]. Given that hygIRC was used as a basis for assessing the hygrothermal performance of various types of wall assemblies when subjected to differing climatic conditions as may exist in North America, it was of importance to insure that this apparatus can reproduce key hygrothermal effects within time frames that are no more than half an order of magnitude from those derived from experimental work.

2.1 Objectives

- To determine the hygrothermal behaviour of wood-frame wall components and assemblies when subjected to steady and transient state hygrothermal conditions in a controlled laboratory environment.
- To assess the degree to which the model predicts key hygrothermal effects and the limits to which the model can adequately predict hygrothermal behaviour.

2.2 Scope

The experimental work consisted of determining the hygrothermal behaviours of wood-frame wall components and assemblies under controlled laboratory conditions such that measurable hygrothermal effects could be recorded and compared to that derived from using hygIRC. Full-scale experiments were conducted on wall assemblies nominally having dimensions of 2.43 x 2.43-m. The wall components to be evaluated as those typically used in the fabrication of the respective wall assemblies being proposed for evaluation; the list of components and their respective hygrothermal properties are those taken from the material database as developed by IRC laboratory. Measurable hygrothermal effects include changes in total moisture content (MC) of material changes in weight of wall components or assemblies over time.

Comparison, analysis and review of key hygrothermal effects evident from experimental results were compared to those obtained from simulations using hygIRC and were made on the basis of: gravimetric analysis as a function of time; point values of moisture content, temperature and relative humidity in specific areas of interest; and, visual examination of surfaces for condensate or other effects due to moisture transport.

2.3 Approach

To achieve the above objectives, the experimental work consisted of both mid-scale and full-scale experiments. As well, in order to verify experimental results and develop a basis for validation of hygIRC, extensive use of this model was made. It was used to help develop the experimental details by simulating conditions to which materials components and assemblies will be subjected prior to testing, and thereafter, provide information as to the expected response of the various proposed test assemblies. It has also been used to analyse results derived from the experiments.

There were a number of advantages gained from carrying out mid-scale experiments to augment information obtained from full-scale tests. In terms of relating simulation results on the basis of material properties derived from small-scale tests, they permitted:

- Linking results obtained on small scale specimens (0.30 x 0.30-m) to those derived from full-scale experiments (2.43 x 2.43-m);
- Assessing the significance of scale effects between small and mid-scale test results (e.g., gravity effects are not consider important in small-scale tests but potentially should be taken into consideration in larger scale tests).

From a practical standpoint, and to adequately prepare for the more complex full-scale experiments, mid-scale work also allowed for:

- Determining the extent to which data can be averaged over a given component area on the basis of the location and spacing of moisture sensors;
- Developing test protocols for calibrating various types of moisture sensors;
- Setting-up of data acquisition protocols;
- Determining wetting protocols for wood components.
- Assessing the significance and limitations of gravimetric analysis.
- Determining the relationship between small and full-scale tests and linkage through results derived from mid-scale experiments (Figure 2).

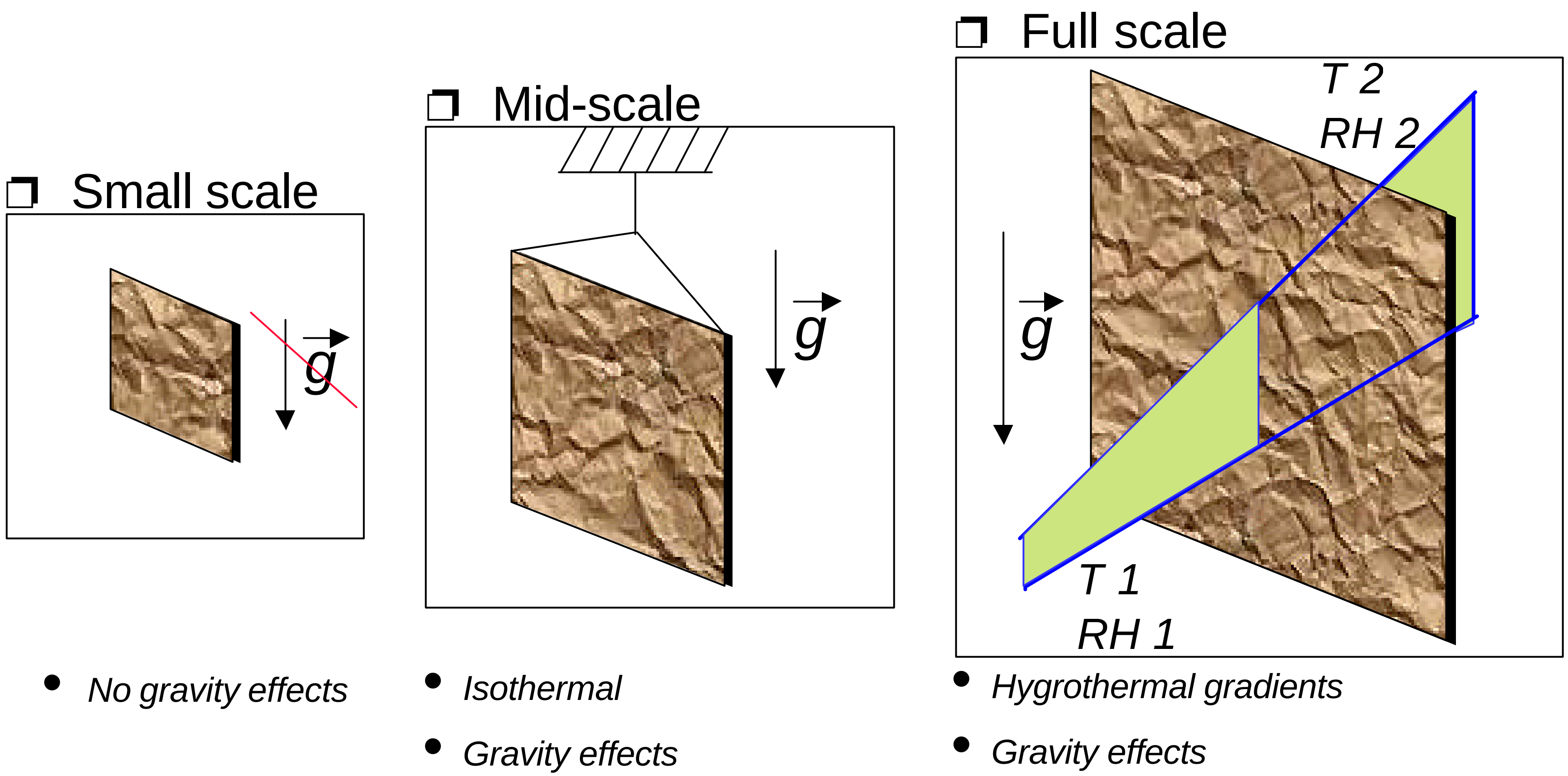

Figure 2— Depiction of linkage between results derived from tests on *small-scale* specimens to those obtained from *full-scale* wall assemblies through tests conducted on *mid-scale* specimens. The letter *g*, refers to gravity and alludes to gravitational effects, the downward arrow indicating the direction of the effect. In the figure showing full-scale tests, T and RH refer to temperature and relative humidity respectively and the different values on either side of the specimen indicate that to is being subjected to a hygrothermal gradient.

The mid-scale experiments have been carried out in controlled laboratory conditions on panels and assemblies having nominal dimensions of 0.8m (W) x 1.0m (L). This size was deemed a reasonable compromise between small and full-scale experiments and one for which scaling effects would likely be evident.

An initial series of mid-scale tests were conducted prior to proceeding with full-scale tests, and the technical advantages gained from completing this series were readily applied to full-scale experiments. This initial series consisted of collecting data on the "drying" characteristics of saturated oriented strand board (OSB) sheathing and other combinations of OSB in contact with different water resistive barrier (WRB) materials or other materials for which understanding a hygrothermal response was required or useful. A subsequent series of mid-scale experiments were then completed in parallel with full-scale experiments in order to provide additional information on the wetting and drying phenomena of the various panels, assemblies and related wall components.

Full-scale tests (i.e. panel assemblies having dimensions 2.43 x 2.43-m) were carried out in controlled laboratory conditions over a period of time sufficiently long as to permit quantifying gravimetrically, the change, and rate of change, in moisture content of critical wall assembly components. As well, real-time point measurements of total moisture content of materials were made to define the hygrothermal behaviour of wall components and assemblies. Measurable hygrothermal effects were recorded and compared to that derived from using hygIRC.

The full-scale tests were to proceed in a series of steps, each step comprised of evaluating the hygrothermal response of a full-scale specimen to specified laboratory controlled conditions. The initial step consisted of determining the response of a single sheet of OSB to specified conditions whereas each subsequent step has been an increased level of complexity in regard to the number of assembly components being modelled and for which data were reconciled with the experiment. It was envisaged that this step-wise approach would permit more explicit understanding of the relative contribution of each component to key hygrothermal effects. In this way, complex assemblies of components, such as the proposed MEWS generic wall assemblies, were analyzed and their hygrothermal response to steady or transient state climatic conditions characterised in relation to that simulated using hygIRC.

As mentioned previously, hygIRC was used extensively to model both mid- and full-scale experiments and results obtained from experiment were readily compared to simulation results. In essence, the work was iterative in nature in that hygIRC was first used to simulate the proposed experiment and thereafter was used to verify the extent to which the experimental results match those of the simulation.

In the instance where it was used prior to conducting experiments, simulations provided some insight into the expected hygrothermal effects from which the placement of sensors were optimized to capture the expected effects. It was necessarily used following the experiment to verify the expected results and as well, as a tool to help analyse the results.

3. Equipment used in the EEEF

The series of experiments performed in this chamber gathered data on hygrothermal behavior of mid and full-scale wall assemblies and wall components and the results were used to compare the results obtained from simulation using hygIRC.

The equipment used for the mid and full-scale experiment is:

- Weighing system in order to have the total moisture content (MC) by weight;
  The weighing system is described in details in sections 3.1 and 3.2 below. It comprised pneumatic cylinders and Loadcells.
- Moisture pin sensors in order to quantitatively measure the MC distribution within the sheathing board OSB (see details in section 3.6).

To control temperature and relative humidity in the EEEF a Honeywell and Nortec systems respectively were installed. General Eastern RHT probes were installed in the chamber to check the uniformity of the temperature in the EEEF.

Figure 3 shows all the equipment used in the EEEF to perform the full and mid-scale drying tests and their electrical wiring connections. All outer grayed boxes represent transducers and output devices. They are entitled:

- Mid-scale Loadcells
- Mid-scale Moisture Pins

- Full-scale Moisture Pins
- Moisture Pin Calibration
- General Eastern RH&T
- Relative Humidity Probes (Relative Humidity Sensors / Resistive Thermal Devices)
- Full-scale Loadcells
- Full-scale Cylinders
- Mid-scale Cylinders
- EEEF Relative Humidity
- EEEF Temperature

The three inner shaded boxes are Data Acquisition Unit (DAU) and control units. They are entitled:

- DOCO DAU & Control
- HP DAU #2
- HP DAU #1

There are also five other systems in the EEEF Wiring. They are entitled:

- Honeywell Control System
- Compressed Air and Water Supply
- Power Supplies
- Mid-scale LC & Fuses
- GE RH & T Sensor Connections

3.1 Full-scale experiment

3.1.1 Weighing system description

The weighing system is capable of determining the rate of evaporation of water from a wall assembly specimen in which key wall components have been conditioned prior to test trials to adsorb significant quantities of water (i.e. 20-60% wt. for which 60% is over saturation of the component) [29].

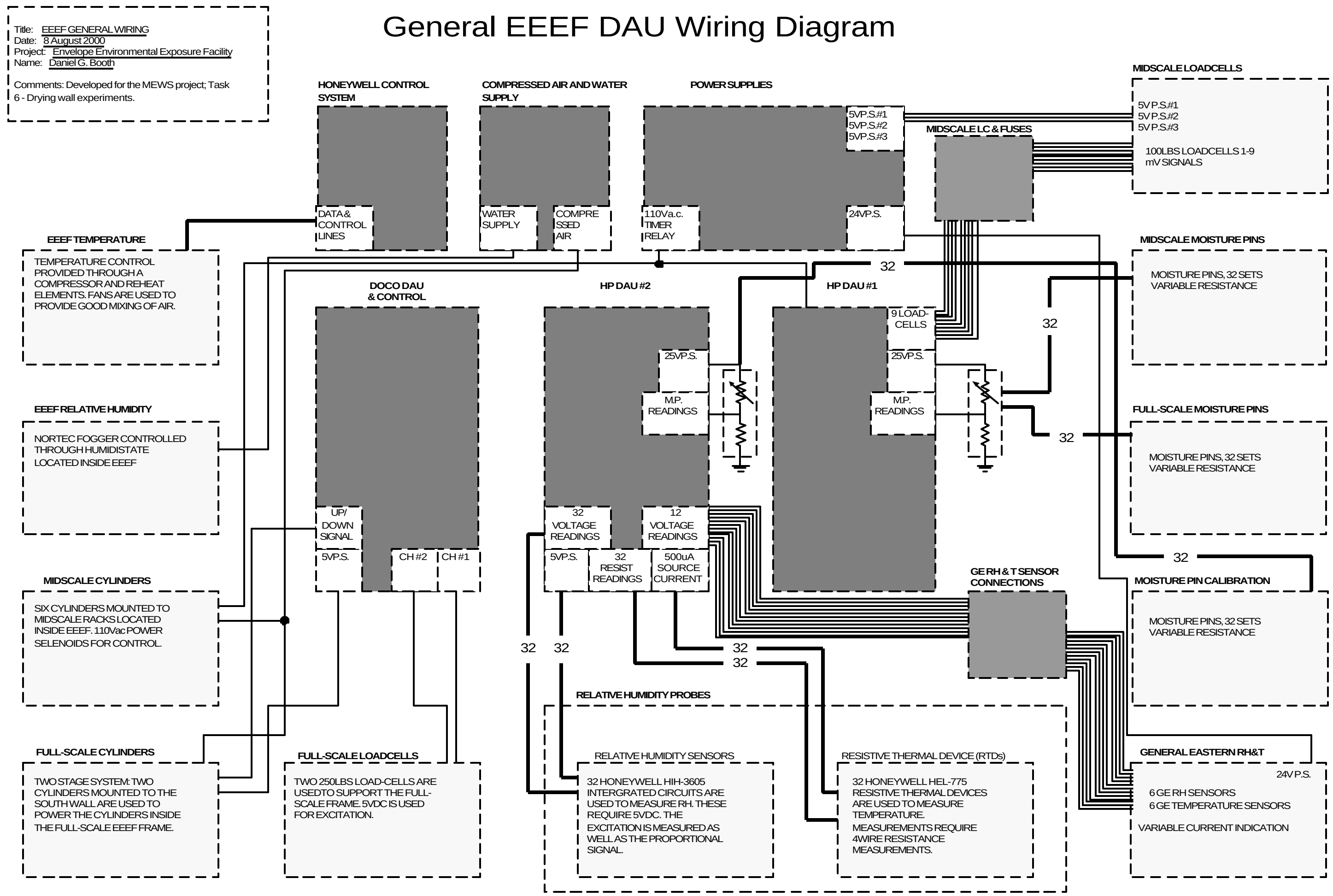

Figure 3 — General EEEF data acquisition units wiring diagram

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Specimen weights may vary up to approximately 225 kg (500 lbs.) whereas the initial weight of water in specific components of the test panel might be in the order of approximately 20 kg. The current set-up provides a resolution of ca. 1/90000 or 2.5 grams of moisture in 225-kg total specimen weight. A rough calculation suggests that for a 2.43-m by 2.43-m (8 ft. by 8 ft.) specimen comprised of two oriented strand board (OSB) sheathing at, for example, 5% moisture content (MC - i.e. 2-kg moisture in 40-kg dry wt.) a resolution of 1/90000 will discern a change of 0.125 % MC (i.e. 2.5-g in 2-kg). Hence, the ability of the system to detect changes in MC is greater than an order of magnitude at 5% MC.

Over the course of the test, the specimen must be weighed repeatedly over the test period that may extend up to 4-weeks. From a technological point of view there are two main difficulties: compensating for the zero drift which undoubtedly occurs in load cells when subjected to long-term loading conditions, and; providing for the precision needed to resolve minute changes in moisture content of assembly components.

The "Precision Wall Weighing System" (Figure 4) is itself comprised of three sub-systems. The:

- Mechanical weighing system;
- Data acquisition system; and
- Software system.

A brief description of each item is provided below and the principal of operation is likewise described.

Both mid and full-scale tests were carried out simultaneously in the EEEF and consequently efforts were made to prepare the EEEF for both these tests. Work focused on applying a seal to the frame (Figure 5) and fabricating a calibration wall (Figure 6).

The inflatable frame seal should have a regulated pressure of 5 psi.

The calibration wall was fabricated to seal the EEEF chamber. This permitted conditioning the chamber when conducting performance trials without having any specimens mounted to or within the EEEF.

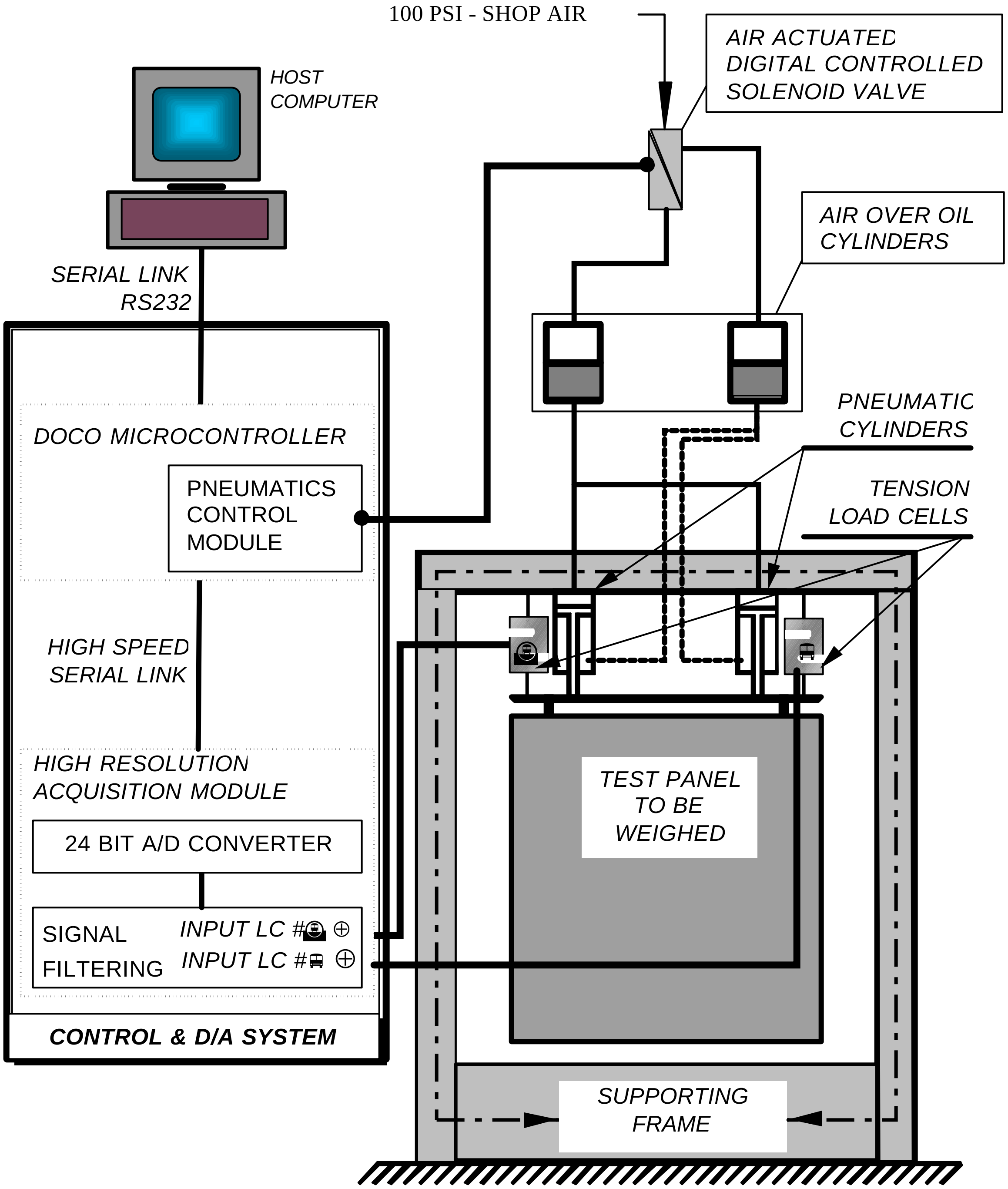


Figure 4— Schematic of precision wall weighing system showing principal system components

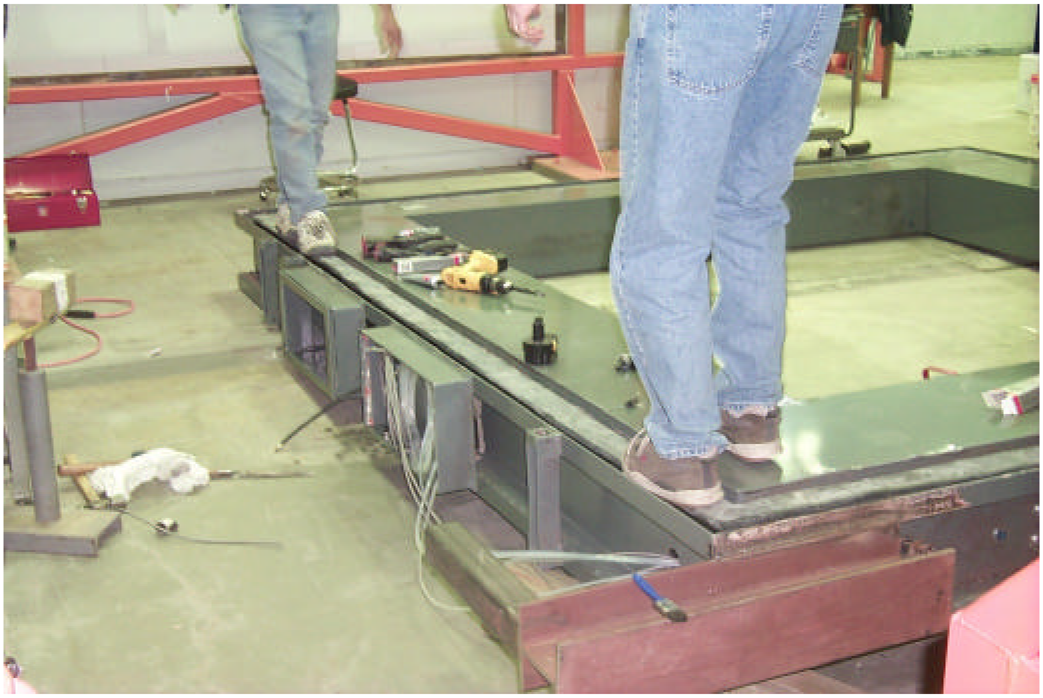


Figure 5— Application of the frame seal

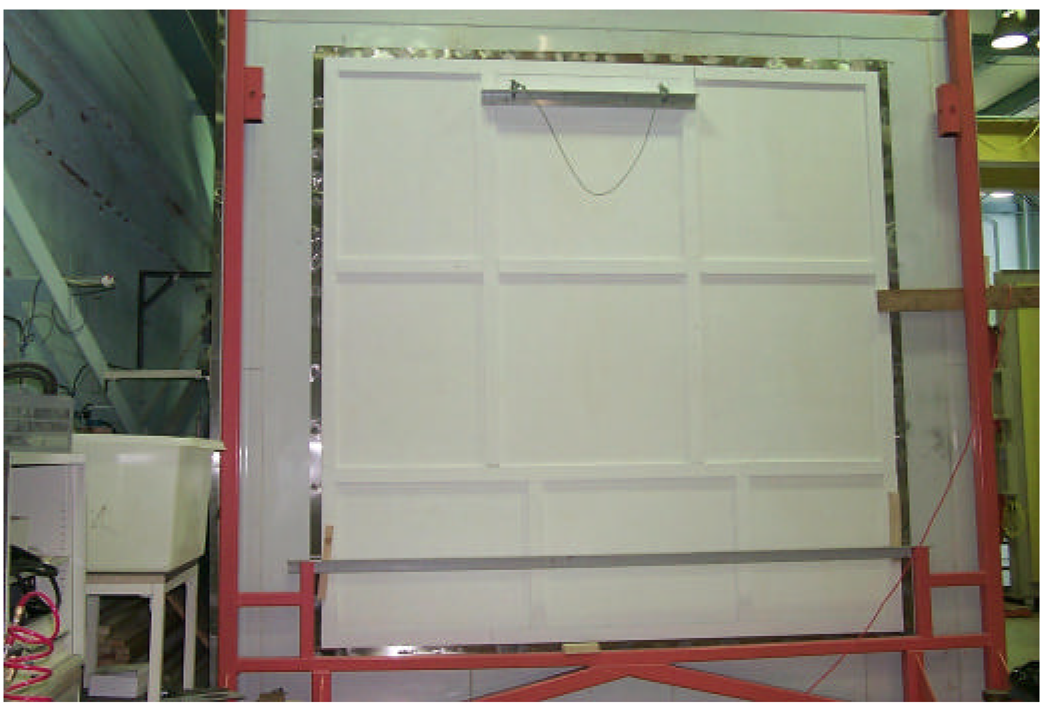


Figure 6— Calibration wall

3.1.2 Mechanical weighing system

The mechanical weighing system consists of two load cells attached to a structural steel frame and a pneumatic lift system comprised of two pistons to which the wall is attached by means of a transverse connection bar. The load cells used in this system are OMEGA type “S” (model # LC105-250) each capable of sustaining loads of up to 114 kg (250 lbs.) such that two load cells can sustain a total load 227 kg (500 lbs.). The capacity of the weighing system can be increased without loss of resolution, by replacing the load cells with models capable of sustaining heavier loads. The lift system is comprised of two pneumatic pistons, both having a 200-mm stroke, and these are affixed to the transverse connection bar that transmits the weight of the wall specimen to these pistons. This arrangement permits moving the specimen over a distance of about 25-mm and in turn permits the load cells to take up the specimen load and hence provide data on the weight of the specimen each time a measurement is taken. The full-scale frame cylinders should have a regulated pressure of 15 psi. For electrical wiring see Figure 3 ("full-scale cylinders" & full-scale Loadcells" boxes). This operation is very important since load cells inherently drift from their “zero” position if operated for periods of time exceeding 2-3 days. Given that a test sequence might be taken over several weeks, and in some cases months, the possibility of eliminating the effects of load cell zero drift become paramount. The manner in which the load cells are configured also permits determining the centre of gravity of the specimen along its transverse axis and hence determining as well, possible moisture transport from one side of the assembly to the other. The full-scale Loadcells require 5 VDC as an excitation. One power supply provides excitation to the two Loadcells.

3.1.3 DOCO DAU & Control

The data acquisition system is comprised of DOCO 2000 acquisition card (DOCO Microsystems Inc.) to which is connected a high-resolution acquisition system specifically devised for capturing data from the load cells (see Figure 7). This high-resolution system permits filtering and then converting of an analog input signal. The input signal to the A/D converter is obtained from the output of each load cell. The output signals once digitised are sent to the host computer via a serial port.

The analog to digital converter (signal to data bit) used in the data acquisition system is an "ADC Bridge Transducer" (Analog Devices AD7730) typical of the type used in precision weighing application (e.g. METTLER™ precision balance). This converter is a SIGMA-DELTA type device that permits conversions having a 24-bit resolution (i.e., 2^{24} = 1/16777216). Integrated to the converter is a programmable gain amplifier that permits analysing a vast number of input signals from ±10 mV to 80 mV. It also contains a programmable numerical filter that allows elimination of high frequency noise typically evident on the input signal. Whereas the resolution is high (i.e. ca. 1/100 000), the response time is poor, thus only 2 acquisitions per second can be made using this technique.

The data acquisition and control card is utilized as the interface to the host computer and the acquisition system, and is connected to the host through the serial port. The control card likewise permits activation of an air-actuated solenoid valve. The valve controls the action of the pneumatic pistons that cause the wall specimens to be raised or lowered upon instructions from the host computer.

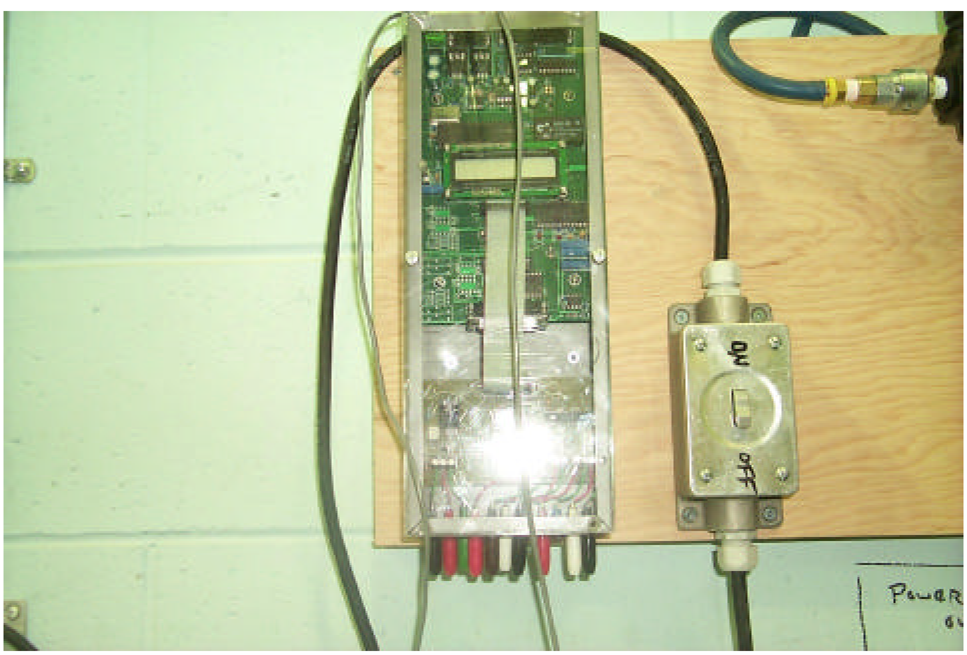


Figure 7— DOCO Data acquisition

3.1.4 Software system

The software functions in a Windows® environment and permits configuration of different operation parameters such as the frequency of acquisition cycles, the delay before acquisitions are started, the number of conversions to be taken at each reading as well as the type of filtering required for the input signal. This software application also permits visualising the acquired data on a continuous basis as well as information related to the load cell calibration. This software is called "WALL"

3.1.5 Principal of operation

Once in operation, the software system automatically causes the wall to be weighed at specific pre-determined intervals and captures the necessary data for each cell over a pre-assigned number of readings from which average values are calculated. As well, upon each intervening cycle, the load cells are re-set. The acquisition sequence is completed over four stages:

1. The pneumatic pistons, fully retracted, thus place the wall specimen in an “up” position and thereby relieve the load cells of the weight of the wall. A reading of each load cell is then taken representing the “zero” or set point for each cell.
2. The pistons are then slowly extended thereby lowering the wall specimen and thus engaging the load cells. After a programmable delay, a second reading is taken from each load cell. The delay permits the wall to stabilise itself in the lowered position and insures that the load cells are properly engaged prior to a reading being taken.
3. From this reading is subtracted the initial reading obtained for the set point and the weight of the wall can now be determined.
4. The wall is brought to the “up” position once again thus liberating the load cells from their load and the subsequent cycle starts from stage 1.

It should be noted that each reading is comprised of 100 consecutive conversions and an average is calculated on these 100 data items. This permits increasing the system resolution by a factor of roughly 10. Each conversion takes about a second. This is principally due to the process of numerical filtration as well as the converter. Thus each reading having 100 conversions requires about two minutes to complete.

3.2 Mid-scale experiment

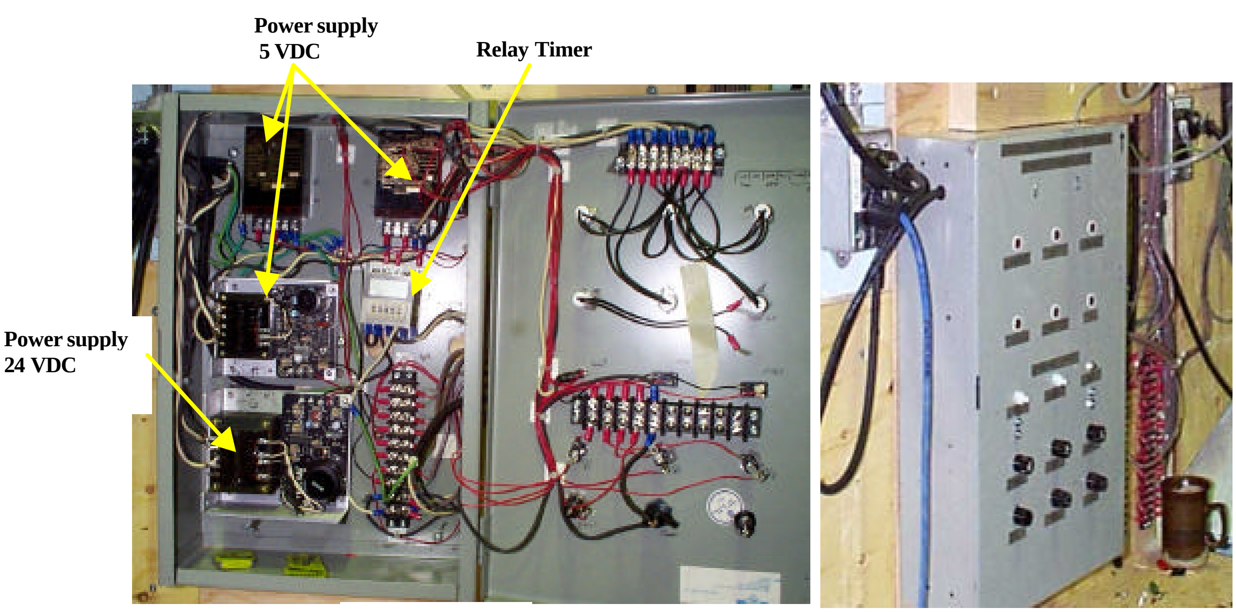
3.2.1 Weighing system description

Three weighing systems (Figure 8), each capable of accommodating three specimens were fabricated such that weight changes could be monitored over extended periods of time. Hence the weight of a total of nine different specimens were simultaneously be monitored from which a gravimetric analysis on individual specimens was completed.

Figure 8 — Automated-weighing system for mid-scale specimens showing load cell support beams, load cells, pneumatic pistons and specimen holders.

3.2.2 Mechanical weighing system

The need for intermittent weighing of specimens was brought about by the expected "zero drift" of load cells if subjected to continuous measurements over periods exceeding a few days. Given that the anticipated drying periods for these tests could extend to several days, if not weeks in certain instances, it was decided that to mitigate the possible load cell effects a system would be devised that permitted weighing specimens on an intermittent basis. This was achieved by having the specimens engage and disengage from the load cells at predetermined time intervals through the action of servo-controlled, time-actuated, pneumatic cylinders. The cylinders, placed at either end of a support beam, regulate the movement of the beam to which the load cells are attached. Each support beam is equipped with three variable resistance load cells having a nominal capacity of 50 ± 0.2-kg. Changes in weigh are recorded from load cell measurements on the DAU #1 system. All cylinders are connected to the same regulator, so for proper operation the pressure must be to at least 60 psi. For each rack there is a solenoid-operated valve. When this valve is actuated the cylinders are forced up. The solenoid valve receives its signal from a relay timer that is located in the "Power Supplies housing Box" (see Figure 9). The mid-scale load cells require 5VDC as an excitation. Three power supplies are provided for the 9 Loadcells. Consequently one power supply powers three Loadcells. For isolation it would be ideal if each loadcell was powered by its own power supply. This would be an improvement because any change in loadcell resistance would not effect the other two Loadcells that are connected in parallel. The power supplies for the mid-scale Loadcells are located inside electrical box (See Figure 9).



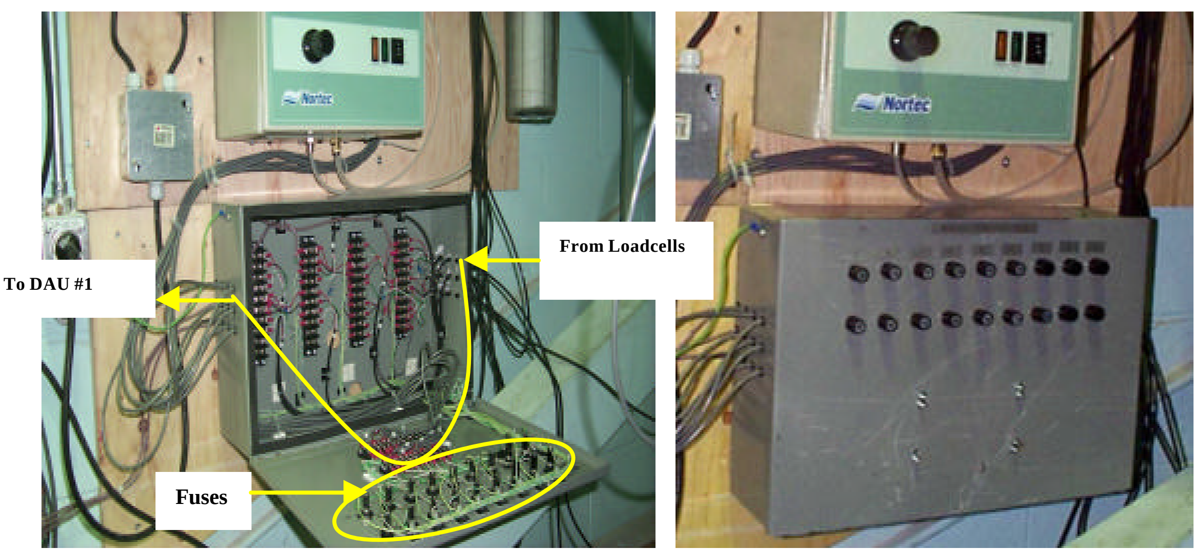
Interior Exterior

Figure 9 — Inside and outside view of power supply housing box

The 5V power supplies were used to excite three load cells located on each of the mid-scale test racks. The 24V-power supply was used to provide excitation for the RH sensors (General Eastern). All power supply outputs included fuses and power on indicator lights. A relay timer indicator light was also installed and it was very useful in discerning weather or not the mid-scale load-cells were loaded.

The outputs of all the power supplies in the power supply box are fused at 10mA. The fuse box contains the terminal strips used to connect the load-cells to the DAU. The fuses (18) are connected from the load-cell output signal to the DAU to prevent any current surge from overloading the load-cell's strain gage electrical circuit.

The return signals from the mid-scale Loadcells are differential voltages and therefore care must be taken in insuring that the ground terminal wire is not inadvertently shorted to chassis ground. The fuses are located in the electrical panel "Mid-scale LC & Fuses" (See Figure 10). A generalized full-scale output from the Loadcells is around 15mV.



Interior **Exterior**

Figure 10 — Inside and outside the fuse box

For wiring diagrams of the power supply connections please refer to Figure 11. For wiring of the loadcell fuses please refer to Figure 12. For loadcell and timer relay connection to the DAU refers to wiring diagrams for “DAU#1” (Figure 13).

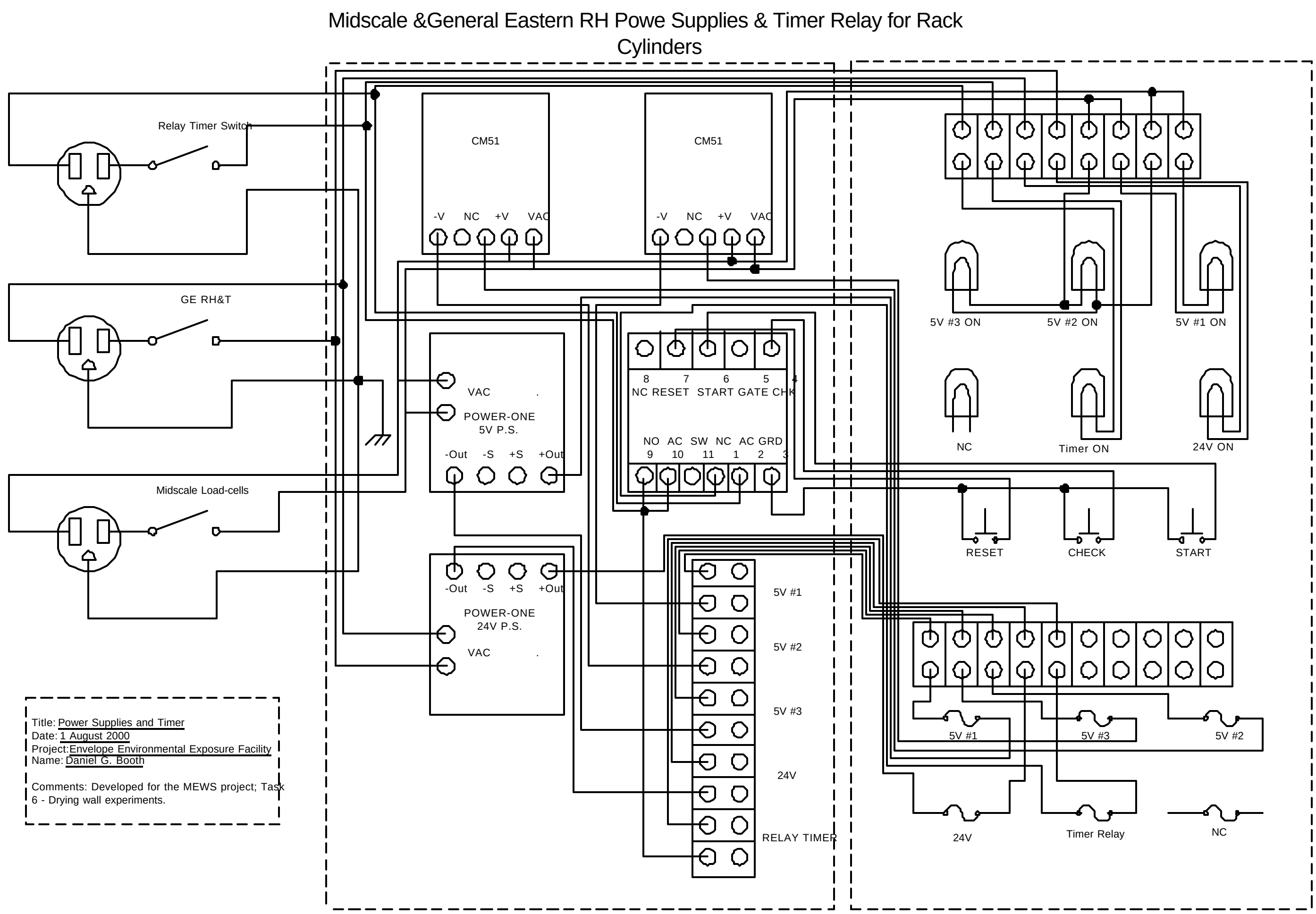


Figure 11 — Wiring diagram of power supply connections

Midscale LC Connections & Fuses

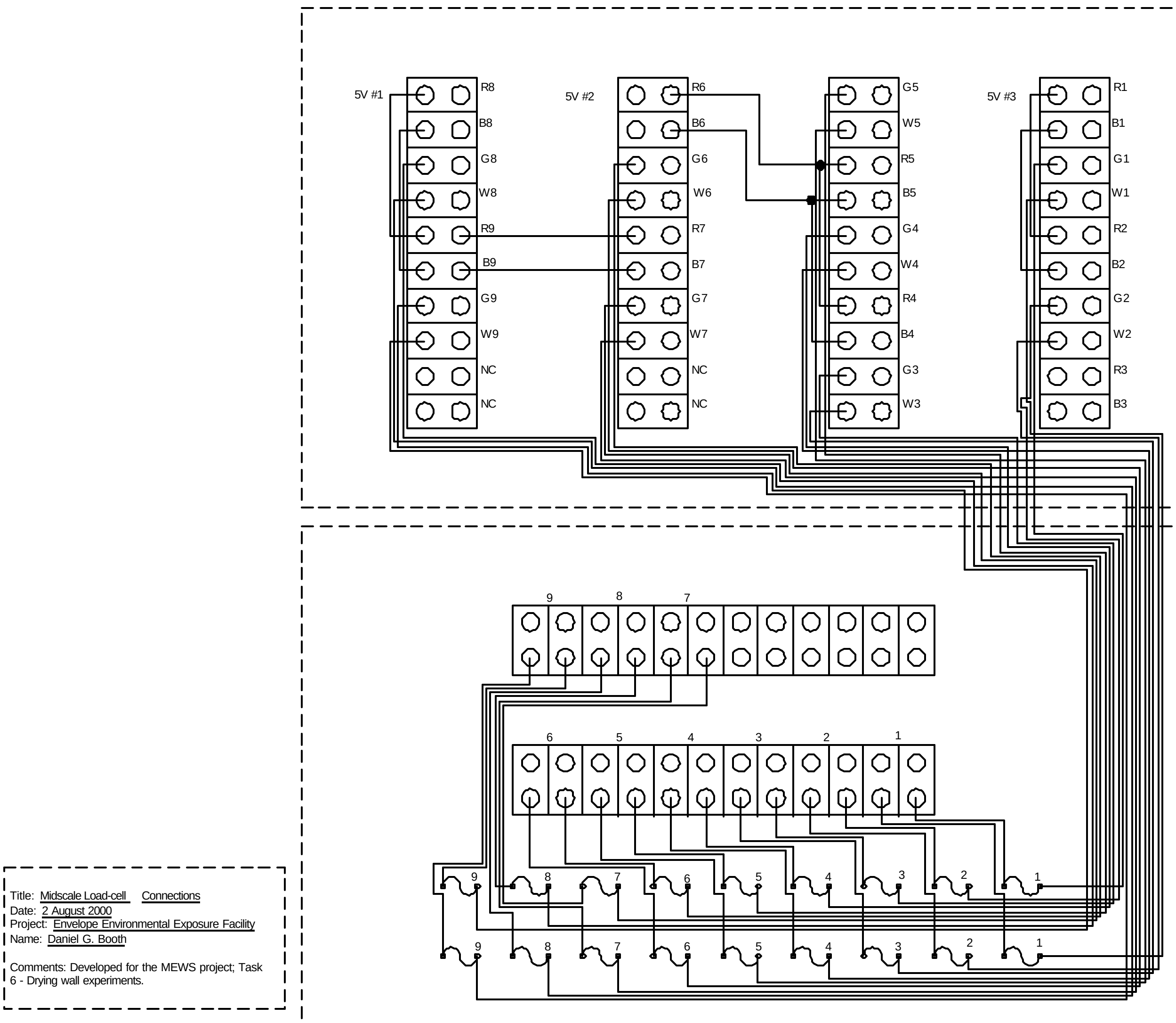


Figure 12 — Wiring diagram for Loadcells fuses

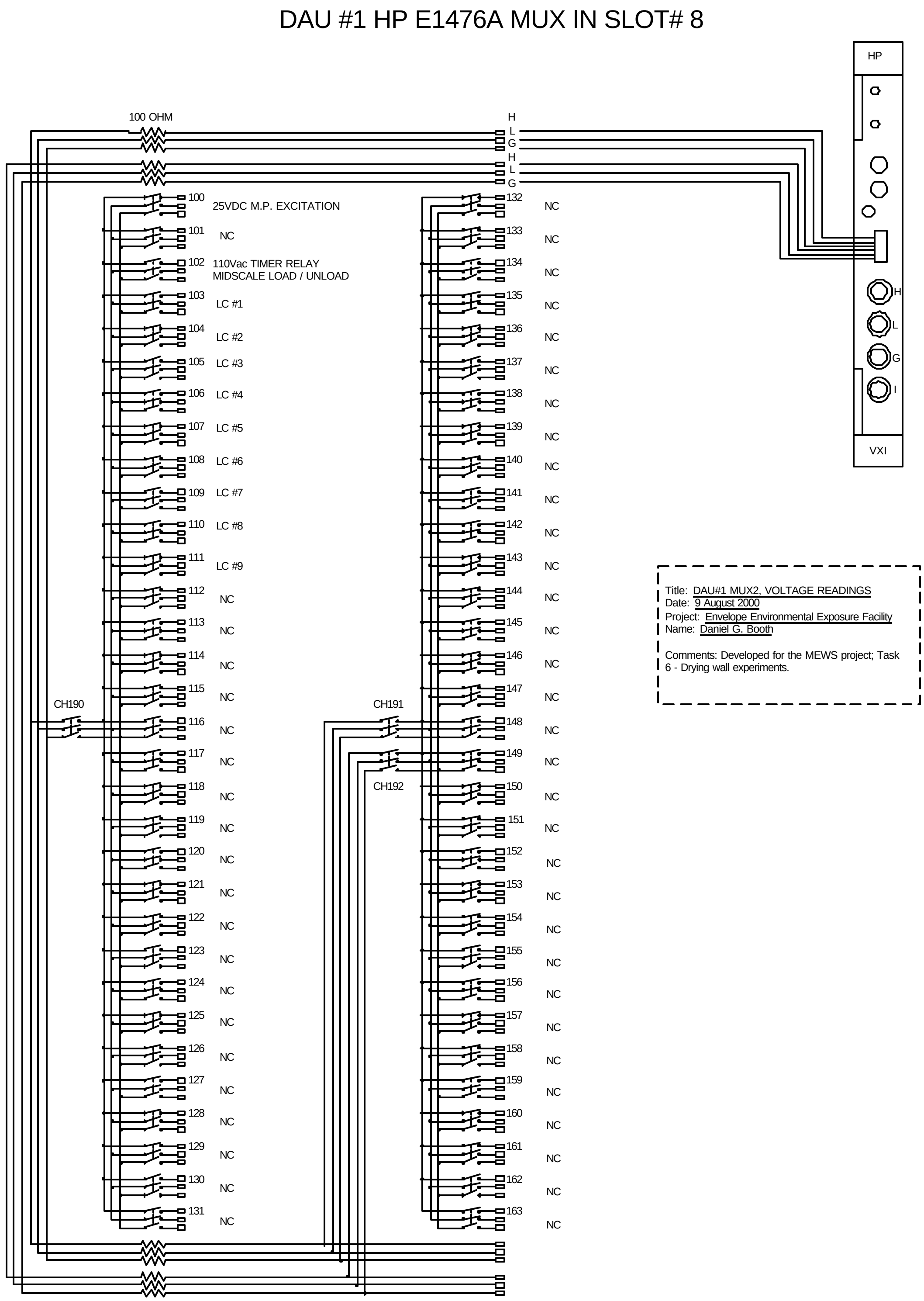


Figure 13 — Wiring diagram of Loadcells to data acquisition (DAU #1)

3.2.3 Data acquisition system (DAU #1)

The load-cells are connected to a HP-E1476A 3-wire Multiplexer unit in which the third channel is connected to timer relay that controls the upward and downward motion of the pneumatically driven central beam to which are affixed the set of three load-cells (Figure 13). The relay signal is connected to the DAU such that the position of the load-cells is known and this is communicated to the software so that readings are only taken when the timer relay is energized and the load-cells are under tension (Figure 14).

Each individual load-cell was calibrated against an Instron type UTM by taking simultaneous readings of tensile load and voltage measurements from the load-cell using a Digital Multimeter (Keithly). Acquisitions were taken every 10 seconds and directly downloaded to the hard drive where access to the data can be made on a continual basis.

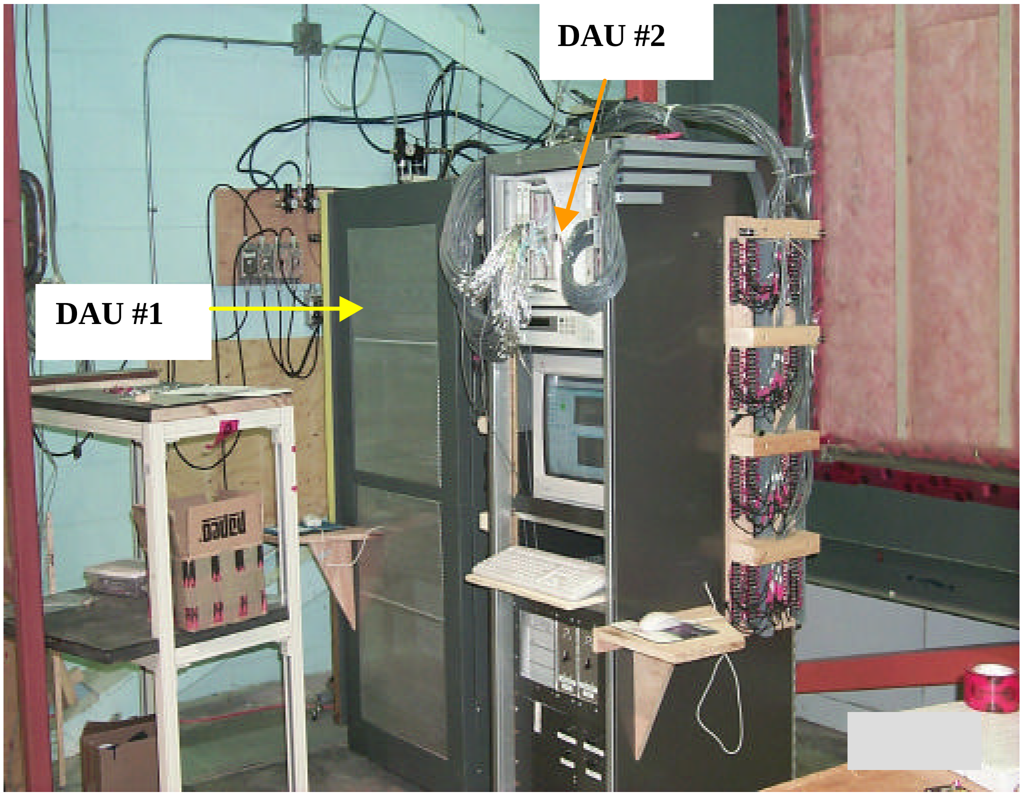


Figure 14 — Data acquisition units (DAU #1 and 2)

3.2.4 Software system

The Hewlett Packard Visual Engineering Environment (HPVEE version 5.0) software program is used to collect data from load-cells. It functions in Windows NT environment and permits configuration operation parameters such as the frequency of acquisition cycles, the duration of the test and file name where the data will be recorded. The reading were taken only when the load cells have a load.

3.2.5 Principal of operation

The relay timer for the mid-scale weighting system should be set such that the load cells are loaded for 20 minutes and unloaded for 20 minutes. Load cell readings occur only when loaded. When loaded the load cells outputs are scanned and recorded by the DAU every two minutes.

3.3 EEEF Temperature

The temperature control of the EEEF chamber is accomplished through a Honeywell control system. In summary a compressor is used to pump coolant around the inside of the EEEF. The pipes containing the coolant cool the surrounding air. Air is circulated around the pipes and throughout the EEEF by means of fans and baffling. Reheat heating elements are controlled by a Solid State Relay (SSR) which is energized by signals from the Honeywell control board.

The computer, programmable logic controller (PLC), and electrical cabinet for the Honeywell system are mounted to the West Side of the EEEF. For details see Honeywell temperature control manual [31]. Temperature can be maintained at steady state set point, or executing a temperature ramping controlled by Honeywell control system.

3.3.1 Precautions to take before test start-up

- One major consideration before starting the EEEF is the compressor used to cool the EEEF. The compressor is located directly below the EEEF in the roofing lab. There is an electrical box located above the EEEF that supplies power to the compressor. This is usually always on, however, if ever the power is off then the compressor will have to be powered on and cannot be started for 48 hours. This is because of the need to raise temperature of oil located in the compressor. There are heating elements that keep the oil quite viscous, however, if the oil is only at room temperature, too much back pressure will be created within the compressor which may cause damage to the compressor.

- Also, if the control boards are powered off and then powered back on, then an alarm will sound. This alarm is for an over-temperature condition. There are two reset buttons (Figure 15) located above the EEEF control computer. The horn will shut off when the "**Defrost Heater Reset**" is depressed to reset the system.

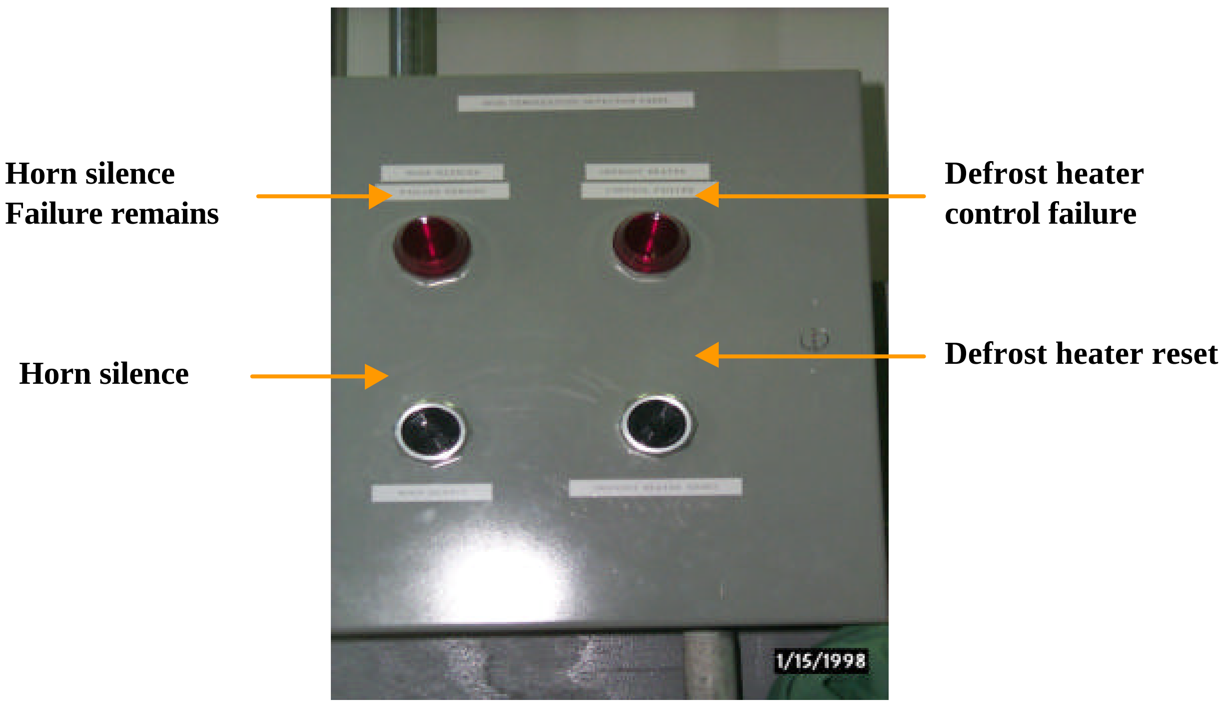


Figure 15 — High Temperature Detection Panel

3.3.2 Principal of operation

The EEEF control computer uses Honeywell software to send signals to a Honeywell control board. The system may require you to log onto the system. To do this, use the enter-ID and then type the password. The characters will not appear as you type. Once logged on you should go to the area marked "**Chamber**" and use the mouse to click over the square marker. Once in the chamber application you will be able to "**zoom**" in on a graphical display of the EEEF temperature system. The graphical interface states what systems are on and off. This involves systems such as the compressor, the fans, and the reheat elements. Different temperatures are also indicated throughout the system. By clicking on the compressor and system icons, **ON/OFF**, **Manual**, and **Automatic** pop-up display will appear. Simply click on the parameter that you wish to change. To set the temperature you should click on the temperature reading in the center of the chamber. You will then be able to change the indicated set point and click on "**Update**". With this done the system will respond to the new set point in order to reach the desired condition.

3.4 EEEF Relative humidity

Relative humidity was achieved through a dehumidifier and pneumatic actuated fogger (Nortec) (Figure 16) coupled to a set point controller. There is no dynamic control of RH at the moment. A Nortec humidification system was installed adjacent to the EEEF such that humidity levels within the environmental chamber could be maintained to predetermined levels. The system includes a spray nozzle (Figure 17) defrost to prevent freezing at the nozzle outlet in the event that spray is required when the temperature within the EEEF drops below freezing. This defrost system uses a temperature sensor and thermostat relay in which the relay allows current to flow to an incandescent light bulb located next to the spray nozzle. The relay is activated when the temperature is lower than the thermostat set point.

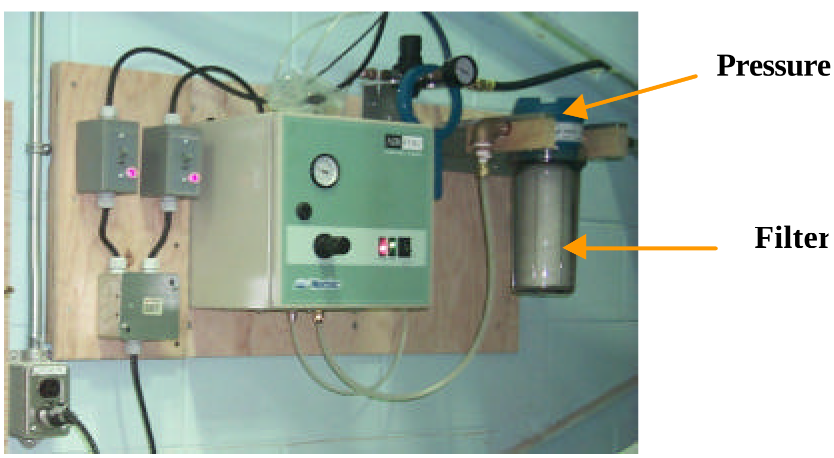


Figure 16 — NORTEC humidification system

The Nortec RH system requires both water and compressed air for operation. This is provided on the South wall of the mezzanine. The Nortec humidity system works as the Bernouilli principal to operate. The Nortec should have a regulated pressure of 40 psi. The water supply is fed through a filter (Figure 16). This is necessary because of the fine spray nozzle located in the EEEF. Impurities can cause the humidity system to become clogged.

The RH system is currently controlled by a rheostat but six General Eastern RH&T sensors are located inside the EEEF and will be used for control in the future. They are currently used for gathering data inside on chamber temperature and humidity.

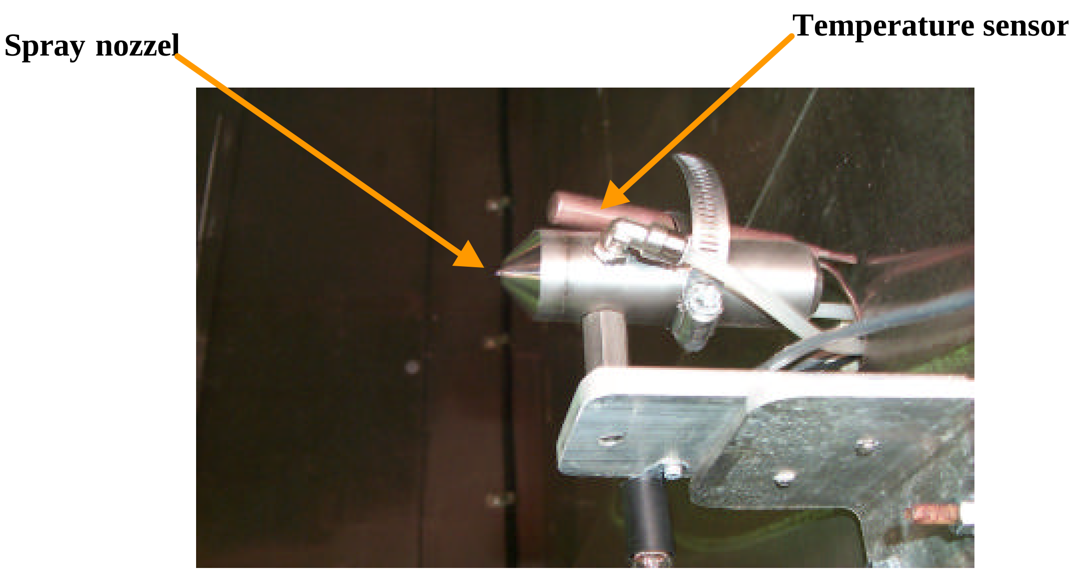


Figure 17 — NORTEC humidification nozzle

3.5 General Eastern Relative Humidity and Temperature probes

The EEEF is instrumented with six General Eastern RH and temperature probes (GE). Calibration of the RH sensors was made by measuring voltage as a function of relative humidity and subjecting them to 15.2%, 25.2%, 44.1%, 50.2%, 70.0%, 70.2%, and 75.2% RH. These sensors were then mounted within the EEEF as shown in Figure 18 (? - indicates location of probe in EEEF).

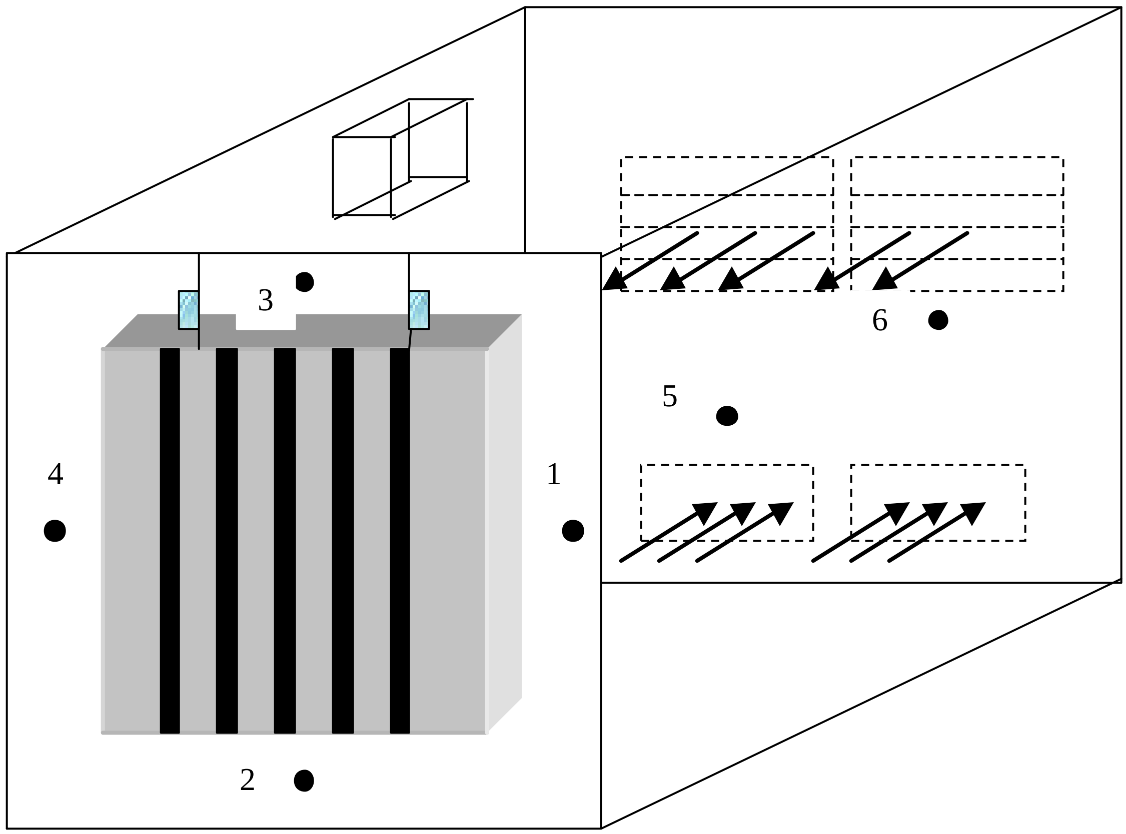
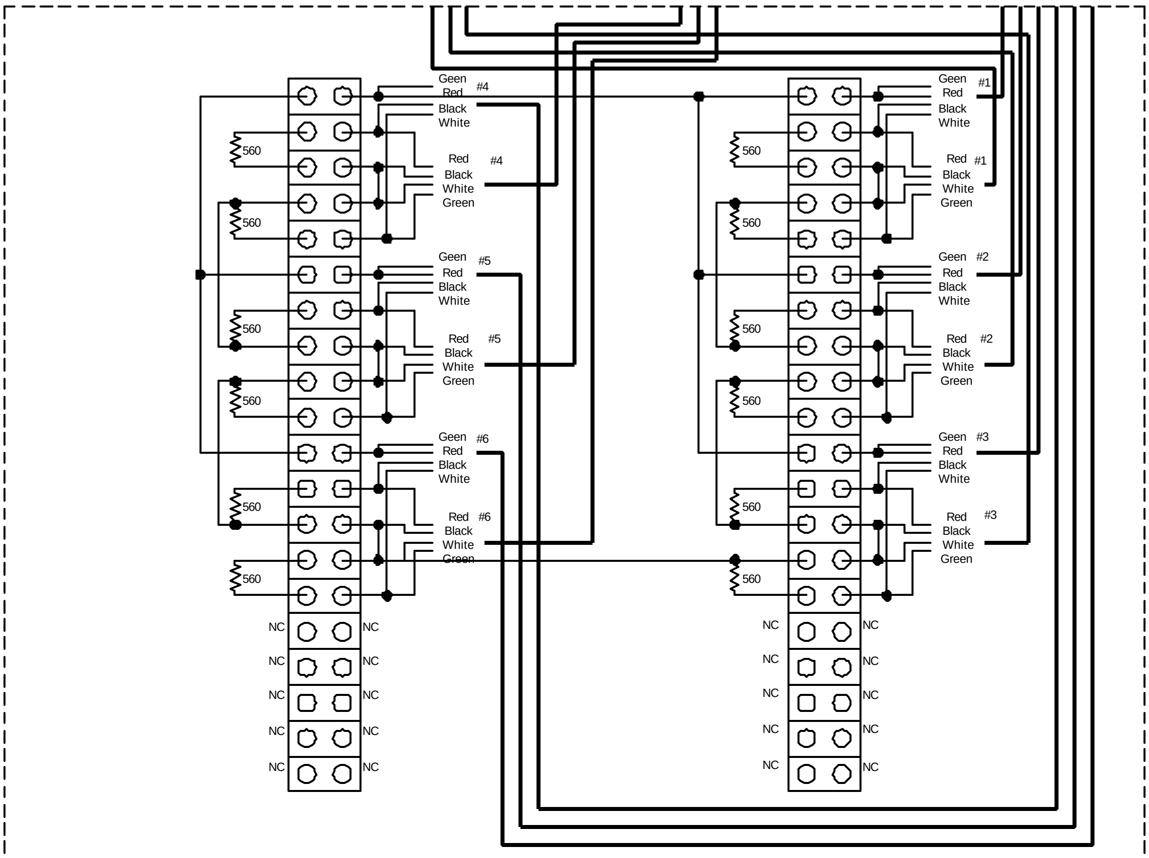


Figure 18 — Location of RH and temperature probes in EEEF

Inside the power supply housing box (Figure 9) there is a 24 VDC power supply. It was used to provide excitation for GE RH sensors. The General Eastern RH&T probes output a 4-20mA signal that is proportional to the humidity and temperature measured. There are 6 of these devices located inside the EEEF. Data is gathered from them through DAU #2. The current signals are converted into voltage signals through 560ohm resistors located in the “GE RH&T Sensor Connections” electrical panel. Temperature calibration has not been performed but the general equation is used; this to can be found in the notebook.
For a wiring diagram of the current to voltage conversion please refer to “EEEF General Eastern Humidity & Temperature Connections” box in Figure 3. For connection to DAU#2 please refer to the wiring diagrams provided in Figure 19.

EEEF General Eastern Humidity &Temperature Sensor Connections



Title: General Eastern Connections
Date: 4 August 2000
Project: Envelope Environmental Exposure Facility
Name: Daniel G. Booth

Comments: Developed for the MEWS project; Task 6 - Drying wall experiments.

Figure 19 — Wiring diagram for the General Eastern RH&T probes

3.6 Moisture Sensors

Two types of moisture sensors are used in these experiments:

Moisture pins, used to assess the bulk moisture content of wood based materials;

Surface moisture sensors, to determine the surface moisture content of sheathing materials.

Moisture pins (DELMHORST Manufacturing Co.) ? of type 496 (Insulated, 28-mm; 1? " penetration), shown in Figure 20, and type 1849 (Insulated, 12.7-mm; ½" penetration) were used to assess the moisture content of wood-based materials. Calibration techniques used to determine the moisture content as a function of material resistance are described in report [10].

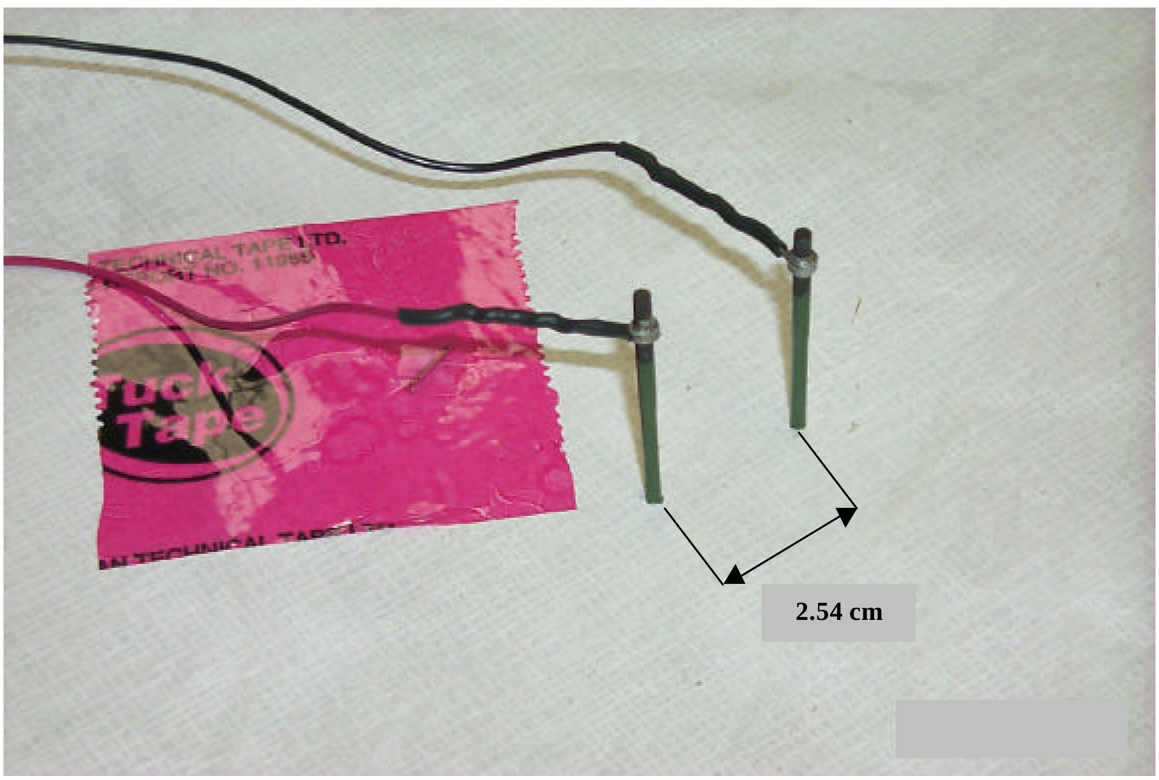


Figure 20 — Pair of moisture sensor

Surface moisture sensors ? to determine the surface moisture content of sheathing materials. These types of sensors were fabricated in-house (Figure 21). Calibration of these sensors was described in report [30]

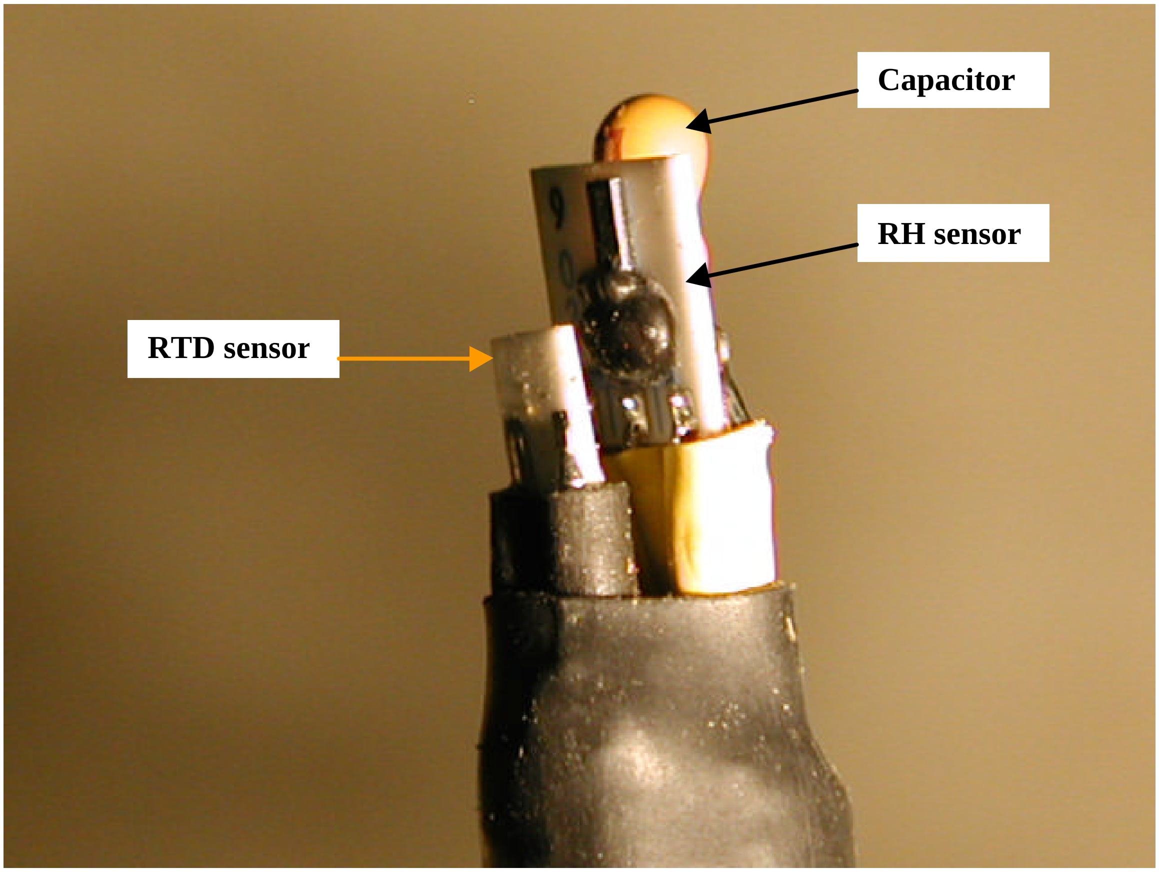


Figure 21 — Relative humidity and RTD probe (RH&T) close-up

3.6.1 Moisture pins for Mid-scale and Full-scale

The moisture pins are inserted into the wood specimen one-inch apart. The resistance measured between these pins will vary with the amount of moisture in the sample. The relationship of resistance to moisture content in wood is not linear but is rather exponential. From previous research we can see that moisture contents for Douglas Fir of around 25% leads to resistance readings of 0.5M ohm. When moisture content drops to about 7% the resistance increases drastically to 22400M ohms. This large range of resistance is hard to measure using standard resistive meters.

In order to take these resistive measurements a voltage divider circuit was created. 25VDC excitation is used to send current through the pins and specimen. Then the current passed through a fixed 10M-ohm resistor. A voltage measurement was taken across this resistor. Knowing what the voltage was at this point and knowing the fixed resistance of 10M ohm allows us to calculate the current using Ohms Law (Please note that with such high resistance the E1411B meter itself does not have sufficient input resistance to be ignored. This means that the meter must be considered as part of the circuit). Knowing this current through the lower half of the voltage divider and the voltage at this point allows us to calculate the resistance at the moisture pin probes. Again this is done using Ohms Law.

Moisture pin measurements for mid-scale measurements and full-scale are taken from data acquisition unit (DAU #1- see Figure 22). Moisture pin calibration measurements are taken from DAU#2 (see Figure 23). Please note that this requires two voltage divider circuits for the two DAU systems.

For wiring diagrams please refer to the wiring diagrams provided for DAU#1 and DAU#2 (Figure 3).

3.6.2 Surface moisture sensors (Relative Humidity and Temperature probe (RH&T))

Relative Humidity Sensors:

32 Honeywell HIH-3605 Integrated Circuit (IC) capacitor type relative humidity sensors are used to sense the humidity near the surface of the test samples. Each sensor requires 5 volts excitation. Ideally each sensor should have its own regulator but in experimentation it was found that measurement of the excitation as well as the return RH signal allowed some tolerance in excitation variation. However, this requires that two channels be used per sensor. The ratio of the output signal to the excitation indicates the relative humidity.

Resistive Thermal Devices (RTDs):

32 Honeywell HEL-775 RTDs (Figure 24) are used to measure temperature. These RTDs require a four-wire resistance measurement technique (Figure 25). One channel is used to source 500uA current and the other is used to measure the resistance. In order to use these devices accurately the resistance of each individual RTD at 0’C (value “Ro”) needs to be obtained. 32 RH&T probes have been developed. The RH and RTD chips are piggybacked upon each other and incased in shrink-wrap plastic. There is a small hole cut

into the shrink-wrap that allows the surrounding environment to enter the cavity. For more details such experimental results and calibration refer to report [30]

3.7 Compressed Air and Water Supply

As mentioned often in the above text, both water and air pressure is used in the EEEF systems. The water and compressed air is provided from the South wall of the Mezzanine. These specific supplies were added lately by ASPM for the demands that the systems require.

4. Acknowledgment

The authors would like to thank all the people listed below for their contribution in the development of drying experiments performed in EEEF by their many useful suggestions or participating in some experiments: Daniel Perrier, Michael Swinton, Nady Said, Raymond Demers, Ken Trischuk, William Lei, Peter Beaulieu, David Van Reenen, Yvon Tardiff, Denis Richard from DOCO Microsystems and Nicholas Krouglikof from Union College, Schenectady, NY.

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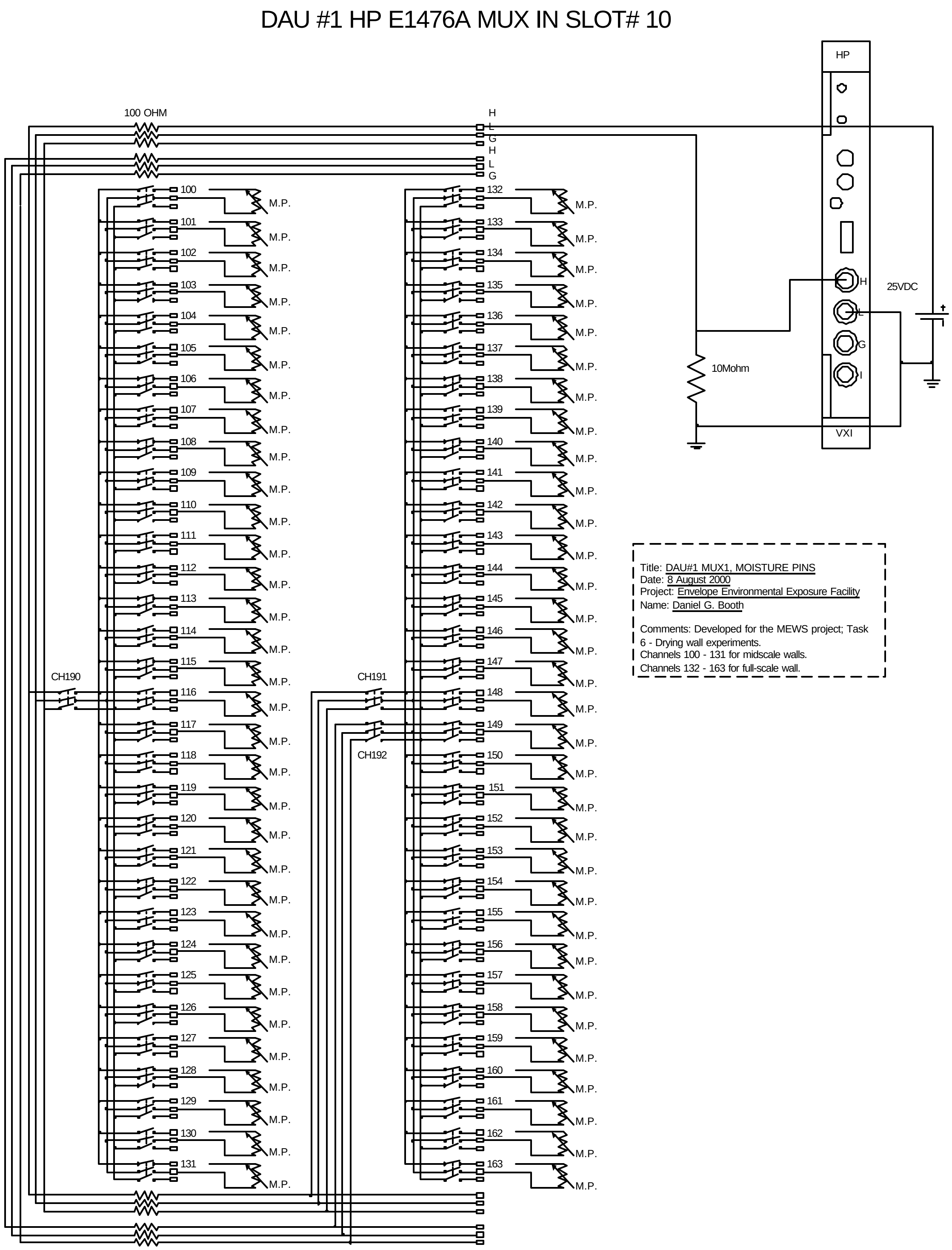

Figure 22 — Wiring diagram for moisture pins connection to DAU #1

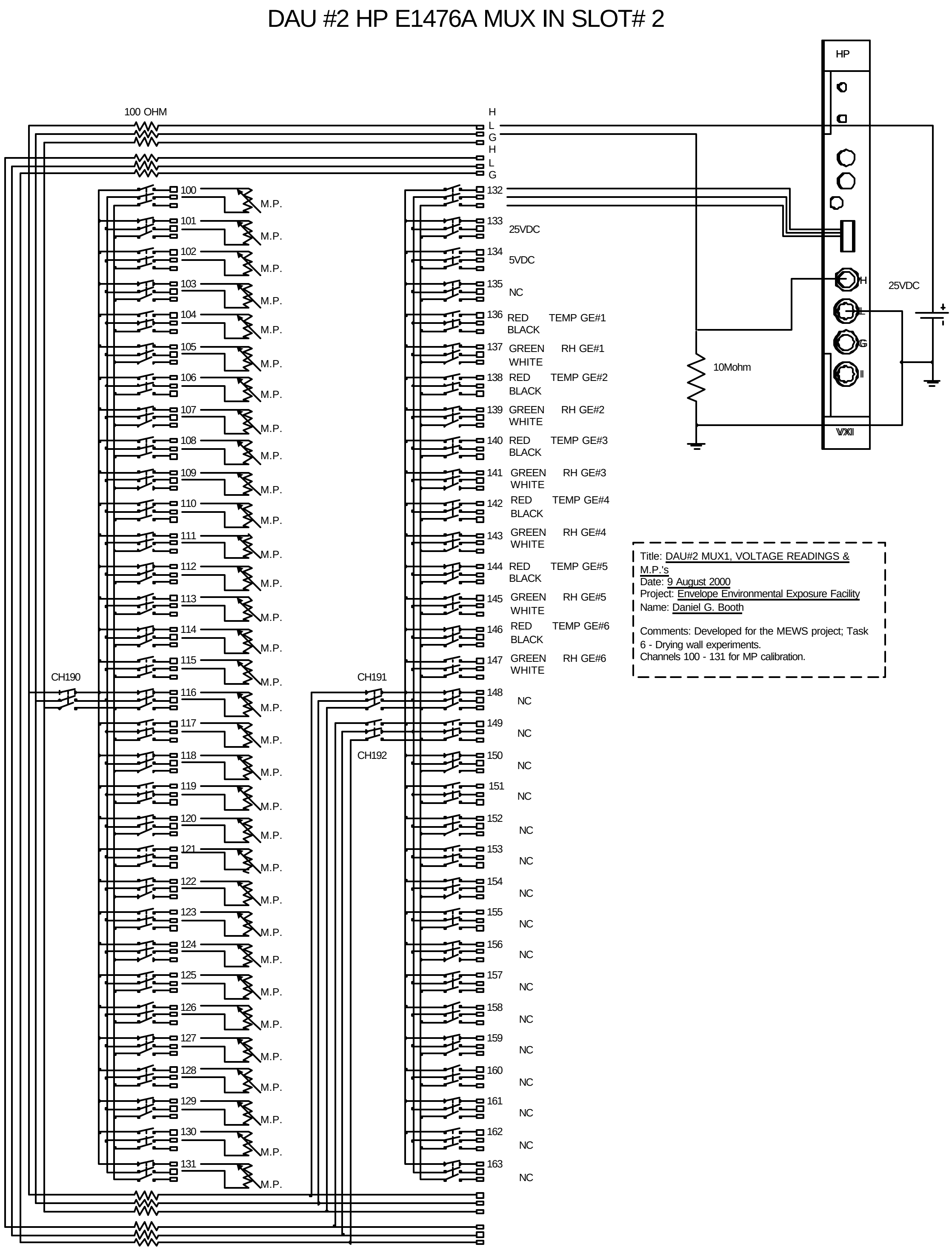

Figure 23 — Wiring diagram for moisture pins and GE probes connection to DAU#2

DAU #2 HP E1476A MUX IN SLOT# 3

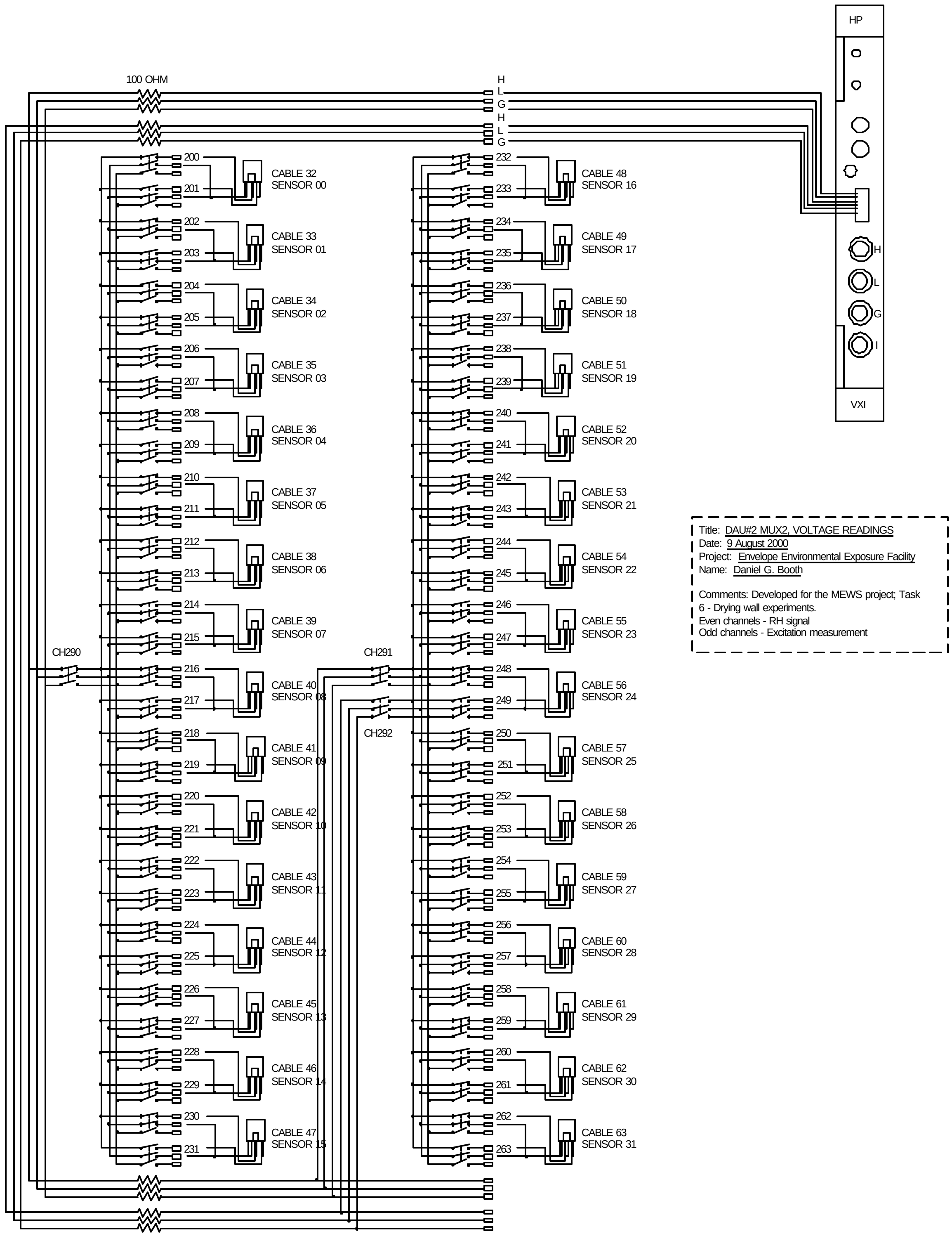

Figure 24 — Wiring diagram for RH sensors connection to DAU #2

DAU #2 HP E1476A MUX IN SLOT# 12

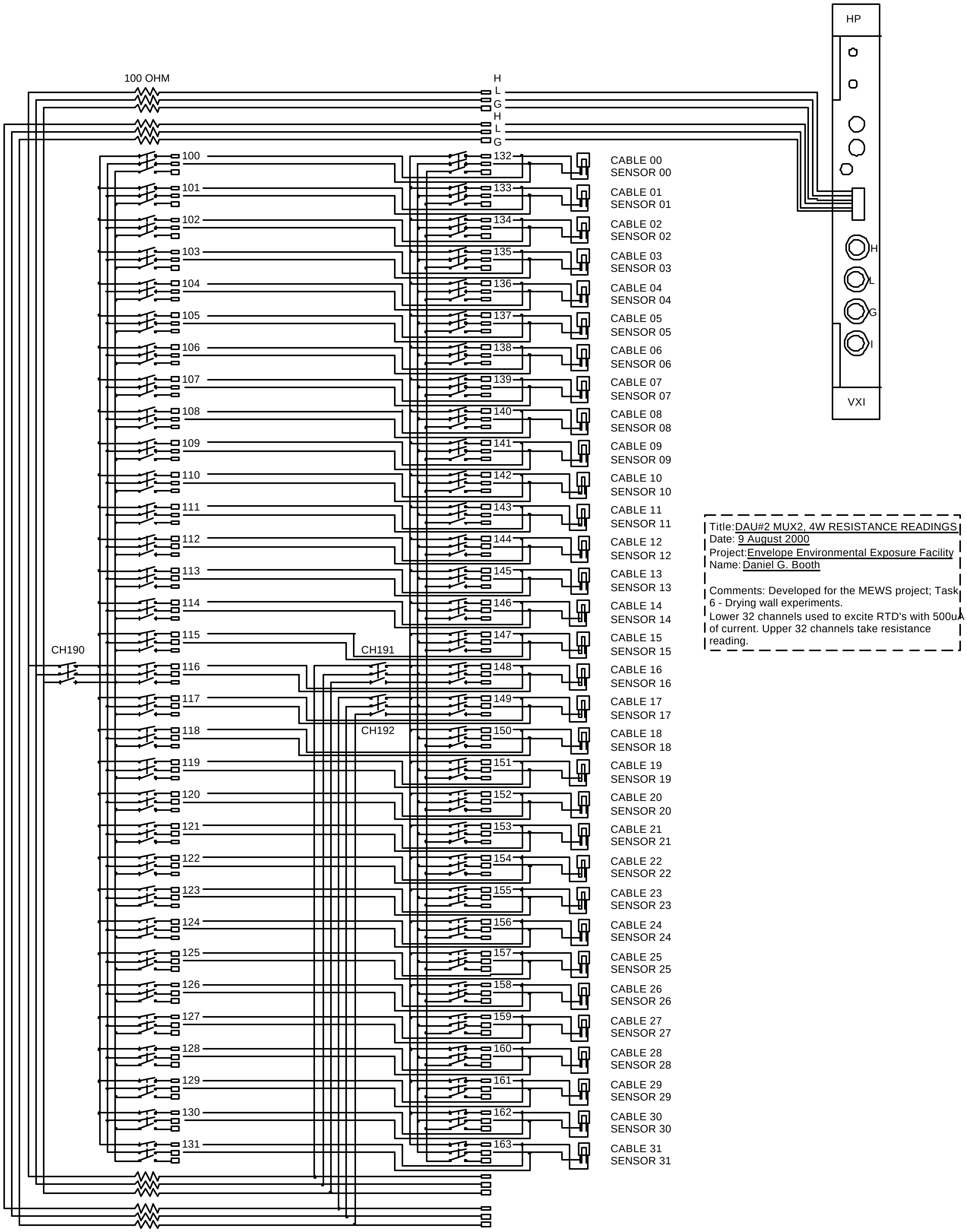

Figure 25 — Wiring diagram for RTD sensors connection to DAU #2