

Silhouette Steel

2411-02

UNOLS COLD LAB

ENVIRONMENTAL TESTS REPORT

Sent to:

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Summary:

The purpose of this experiment was to test the current cold van specification for “real-life” applications and the ability of the current temperature operating system to meet the specification. We also evaluated the abilities of the system to maintain and recover the internal lab temperature settings in different outside environmental conditions. The cold van was taken to an Environmental Test Facility at Dayton T Brown, where it was subjected to a number of tests.

Tests performed:

1. This phase was intended to determine the baseline capabilities of the cold van main chiller system. The van doors were closed, fume hood off. Van cooling systems set to 0°C, chamber ambient temperature of 35°C, increased incrementally to 50°C.
RESULT: The lab held temperature to 40°C, as specified, but loses temperature control at 45°C.
2. This phase was intended to determine the effects of operating the fume hood as well as the effectiveness of the make-up air-cooling system. The van doors were closed, fume hood on at normal setting, with the make-up air cooling system in operation.
RESULT: Mechanical Failure of the system made this test inconclusive.
3. This phase was intended to determine the effects scientific personnel working in the van including the opening and closing of doors and the heat load generated by occupying the van itself. Four lamp heat sources were used to simulate four human bodies in the center of the cold lab main compartment. The door actuators simulated scientific personnel entering and exiting the cold lab every 15 minutes.
RESULT: The van can hold temperature at lower than 35°C ambient and lower than 75% relative humidity, but during this test it was apparent that the opening of the doors significantly affected the system’s ability to maintain temperature.
4. This phase was intended to test the combined effects of both human influence and the fume hood on the ability of the cold lab to maintain operating temperature.
RESULT: Test not completed due to mechanical failure of the system at phase two.
5. This phase was intended to test the “near zero” condition and the system’s ability to maintain temperature in low chamber ambient temperature conditions using the heat elements and defrosts cycles. The van cooling system was set to 10° C and ambient temperature set to 0 °C.
RESULT: The Lab held temperature with no problems, however the hatch temperature was low.

CONCLUSIONS:

The Cold lab meets the specification as it's currently written, however it does not meet actual service conditions in harsher climates. High humidity and high temperatures combined with opening and closing of doors is simply too much for the system to handle. The Cold lab works fine at low chamber ambient temperatures. Current Limitations are:

- Closed Lab to 40°C, 50% relative humidity
- Doors opening, limits operation to 35°C, 50% relative humidity
- Fume Hood Operating: 40°C, 50% relative humidity

RECOMMENDATIONS:

A: insulate the hatch to minimize heat gains through the hatch.

B: install motorized dampers on the exhaust and makeup air to minimize infiltration.

C: re configure the PLC so coils are changed more frequently. Eliminate the air proofing switches and eliminate the electric defrost heaters.

D: Try to mix the air better by adjusting the grill fins to blow in every direction possible, and add small fans to help circulate the air, particularly in the dead spots in the lab.

E: try to reduce the amount of times the door is opened. Change vestibule area to an "air-lock". Provide HVAC into the vestibule area via an air curtain, and install lights that indicate when the air-lock can be opened. Personnel would be expected to stay in the air lock for a period of time before being able to enter or leave the lab. Add a plastic curtain in front of the door to help minimize losses when the door is opened.

F: re-design the air distribution system, use ceiling ducting and wall air curtains for a more balanced distribution and mixing of air in the room.

G: increase wall thickness for higher R-Value: 5"-6" Walls would provide R35-R42, for substantial improvement.

Purpose:

The purpose of this experiment is to test the current cold van specification for “real-life” applications and the ability of the current temperature operating system to meet the specification. We will also evaluate the abilities of the system to maintain and recover the internal lab temperature settings in different outside environmental conditions.

Background:

Cold Van Operating Specification:

"The van is intended to have accurate and stable temperature control for the processing of scientific samples. The cold area of the van shall be thermostatically controlled between 0°C (32°F) and 10°C (50°F). Once the temperature is set, it shall be capable of maintaining an internal temperature accuracy of +/- 1°C with a maximum outside temperature of 38°C (100°F), and a minimum outside temperature of 0°C (32°F)."

Equipment:

The following equipment was used for the experiment:

One UNOLS ISO compliant Cold Lab Van (UNOLS East Coast Van Pool)

Power (3-phase 240VAC) 60A, 480V, 3P, 4 WIRE or 60A, 208V, 3P, 5 WIRE to operate cold lab van (test facility)

Environmental Test Facility at Dayton T Brown

Data display and recording system w/ seven temperature sensors, resolution to the hundredths degree Celsius, one relative humidity sensor, and one airflow sensor.

One heat sources with the equivalent heat output of four human bodies.

Door operating systems (electric w/ 50ft. control cable), two one for outer door, one for inner door

Sensors:

The experiment shall be divided into five (5) phases to determine the effect on internal van temperature during different environmental and operational conditions. Sensor readings shall be recorded every ten seconds for the experiment, at the following locations per the attached sketch:

Sensor #1 - Inside the vestibule with in six (6) inches of the outer door

Sensor #2 - Inside the lab space next to inner door

Sensor #3 - In the middle of lab space (Temperature/Humidity)

Sensor #4 - Inside the roof escape hatch

Sensor #5 - Opposite ends (back wall)

Sensor #6 - On the wall next to cold van temperature recorder

Sensor #7 - Outside the cold van (Temperature/Humidity)

With the exception of the temperature sensors for the escape hatch (placed as close to the hatch as possible), all temperature sensors will be located generally in the center of the assigned location, at a height of ~4 ft. above the van deck. The relative humidity sensor will be placed with temperature sensor # 3 and #7.

Temperature Proposed Test Procedure: Except as described in Phase V, the van cooling systems shall be set to 0°C and allowed to equilibrate to temperature while the environmental chamber is held at a chamber ambient temperature of 35°C. After the cold van has been equilibrated for 6 hours the environmental chamber will be increased in temperature in 5-degree increments. At each increment, the temperature will be held for a period of 2 hours to allow the impact to be accurately assessed. The increase of temperature will be in 5-degree increments continuing up to a temperature of 50°C.

Proposed Test Procedure:

Phase I (~8 hours): This phase is intended to determine the baseline capabilities of the cold van main chiller system. The van doors shall remain CLOSED with the fume hood OFF. Run temperature proposed test procedure as described above.

Phase II (~24 hours): This phase is intended to determine the effects of operating the fume hood as well as the effectiveness of the make-up air-cooling system. The van doors shall remain CLOSED. The fume hood will be turned ON (@ normal setting) with the make-up air cooling system in operation. In addition to the temperature sensors, an airflow sensor will be installed at the exterior opening of the fume hood to record the airflow. The airflow sensor will also record the data at intervals of once a second. At the end of last temperature step the fume hood will be set to purge for 10 minutes, set back to normal, and the lab temperature recovery time recorded. This phase will be repeated at an external relative humidity of 50%, 80%, and 100%. Run temperature proposed test procedure as described above with each humidity setting.

Phase III (~6 hours): This phase is intended to determine the effects scientific personnel working in the van including the opening and closing of doors and the heat load generated by occupying the van itself.

To simulate the effects of scientific personal using cold van under real condition we will use a heat source and a set of door actuators. The heat source will able to simulate the heat produced by four human bodies. This will be located in the center of the cold lab main compartment. The door actuators will be used to simulate scientific personnel entering and exiting the cold lab. The door actuators shall simulate this process every 15 minutes. The phase will be repeated as follows:

Run #1(~2 hours) – Run Duration will be 2 hours. Four Human heat sources, Doors operated through opening and closing every 15 minutes. Temperature set to first temperature determined from Phases I & II, and relative humidity set to first humidity determined from Phase I & II.

Run #2 (~2 hours) – Run Duration will be 2 hours. Four Human heat sources, Doors operated through opening and closing every 15 minutes. Temperature set to second temperature determined from Phases I & II, and relative humidity set to second humidity determined from Phase I & II.

Run #3 (~2 hours) – Run Duration will be 2 hours. Four Human heat sources, Doors operated through opening and closing every 15 minutes. Temperature set to third temperature determined from Phases I & II, and relative humidity set to third humidity determined from Phase I & II.

Phase IV (~6 hours): This phase is intended to test the combined effects of both human influence and the fume hood on the ability of the cold lab to maintain operating temperature. The fume hood shall be ON and the procedures in Phase III repeated.

Phase V (~10 hours):

This phase is intended to test the “near zero” condition and the system’s ability to maintain temperature in low chamber ambient temperature conditions using the heat elements and defrosts cycles. The van cooling systems will be set to 10° C and allowed to equilibrate to temperature while the environmental chamber is held at an chamber ambient temperature of 10°C. After the cold van has been equilibrated for 6 hours the van’s cooling system will be decreased in 2° increments. At each increment the temperature will be held for a period of 2 hours to allow the impact to be accurately assessed. The decrease of temperature down in 2° increments will continue to 0°C.

Observations

Actual Test Sequence:

- Phase 1
- Phase 3
- Phase 5
- Phase 2: System Failure
- Phase 4: Test not done. System failure at phase 2.

Phase 1 – run the cold lab with the doors closed and without the exhaust running.

Monday, June 06, 2011

There was 45 minutes where the cold lab temperature dipped below 0°C (Sensor #2 went as low as - 4.6) this was most likely caused by the outside chamber ambient temperature rapidly climbing to its set point of 35°C and the cold lab rapidly lowering to its set point of 0°C. the temperature controller has auto-tuning capability that calculates how much cooling is needed to compensate for load change. In this case the chamber ambient temperature was changed rapidly and then stopped climbing at 35°C (real time weather does not change this rapidly). Therefore this should be considered part of the set up time.

Chamber ambient temperature was set to 35°C for 115 minutes, The test cycle indicates the lab could hold temperature at set point during this test.

Sensor #6 - Near Supco Sensor, 1°C to 1.5°C

Sensor #5 - Back wall, 0°C to - 0.5°C

Sensor #3 - Center of Lab, -1°C to - 1.8°C

Sensor #2 - Front of door, -0. 5°C to -2.6°C

Chamber ambient temperature was set to 40°C for 120 minutes, The test cycle indicates the lab could hold temperature at set point during this test

Sensor #6 - Near Supco Sensor, 1.2°C to 1.7°C

Sensor #5 - Back wall, 0.1°C to -0.4°C

Sensor #3 - Center of Lab, -1.6°C to -1.8°C

Sensor #2 - Front of door, -2.5°C to -2.7°C

Chamber ambient temperature was set to 45°C for 130 minutes, The test cycle indicates the lab could NOT maintain temperature however Sensor #3, center of lab did start to level out at 1.5°C to 2°C as per the trend line

Sensor #6 - Near Supco Sensor, 2°C to 5.3°C

Sensor #5 - Back wall, 0°C to 3.7°C

Sensor #3 - Center of Lab, -1.6°C to 2°C

Sensor #2 - Front of door, -2. °C 8 to 0.8°C

Chamber ambient temperature was set to 50°C for 120 minutes, The test cycle indicates the lab could NOT maintain temperature sensor 3, center of lab did again start to level out at 7.6°C as per the trend line

Sensor #6 - Near Supco Sensor, 5.3°C to 11°C

Sensor #5 - Back wall, 3.7°C to 9.19°C

Sensor #3 - Center of Lab, 2°C to 7.5°C

Sensor #2 - Front of door, 0.8°C to 6.6°C

The Box humidity seemed to have no effect on the box temperature

Ambient Relative humidity ran at 40% The Lab relative humidity ran approximately 25% higher than the ambient, the system spent 9 hours running and only reduced the humidity down to 61% this is a indication of moisture migration from the ambient.

Chamber ambient temperature 35°C, 40°C, 45°C, 50°C total of 8 hours of operation As the Chamber ambient temperature was increased, more moisture had to be introduced into the ambient to maintain the required 40% relative humidity. The effect of this inside the lab was a momentary increase in humidity, indicating moisture migration from the ambient to the Lab.

Chamber ambient temperature 35°C, 40°C, 45°C, 50°C total of 8 hours of operation The hatch temperature ran approximately 15 C above the box Temperature indicating a large heat load

In this phase the heat loads are

- Box load (lights, transformer)
- Ambient heat transfer
- Moisture migration (dehumidification)

It was visually noted that large amounts of moisture were introduced into the Lab space the walls and exhaust hood were dripping with moisture we can also see this on the test results the box ran at 60% to 70 % relative humidity. This is due to moisture migrates from warm to cold, as it migrates the denser cold air cannot retain the same moisture content there for it precipitates when it changes from vapor to a liquid there is a large amount of heat load introduced into the Lab (latent heat load). When the Lab is closed the only non-sealed part is the exhaust intake and makeup up. To better seal this it would be recommended to install motorized dampers on the intake and makeup of the exhaust system this would make the Lab sealed and moisture could not be introduced into the Lab when exhaust is needed the exhaust fan switch could be interlocked with the fan so that the dampers open.

It was also noted the hatch is not insulated therefore creating unnecessary heat load it was recommended putting a Velcro insulation pad over this.

After these two things are done there will be much less load on the system and performance should be increased possibly up to the 45°C range.

Phase 3 – run the cold lab with the doors opening every 15 minutes, without the exhaust running.

Tuesday, June 07, 2011

Chamber ambient temperature was set to 35°C and 75% relative humidity for 120 minutes and the doors opening every 15 minutes the test cycle indicates the lab could hold temperature at set point during this test. every time the doors opened the Lab temperature climbed .5°C and never recovered approximately 90 minutes into the test there was a large change in temperatures this was most likely caused by the switching of the coil and the change in air movements with in the Lab.

Sensor #6 - Near Supco Sensor, 5°C to 7.5°C

Sensor #5 - Back wall, 2°C to 4.8°C

Sensor #3 - Center of Lab, 0°C to 3°C

Sensor #2 - Front of door, -0.5°C to -2.6°C

Chamber ambient temperature was set to 40°C and 75% relative humidity for 120 minutes and the doors opening every 15 minutes the test cycle indicates the lab could not hold temperature at set point during this test. Every time the doors opened the Lab temperature spiked up 3°C and then came back down rapidly but never back down to its set point

Sensor #6 - Near Supco Sensor, 5°C to 7.5°C

Sensor #5 - Back wall, 2°C to 4.8 C

Sensor #3 - Center of Lab, 0°C to 3 C

Sensor #2 - Front of door, -0.5°C to -2.6 C

Chamber ambient temperature was set to 45°C and 75% relative humidity for 120 minutes and the doors opening every 15 minutes the test cycle indicates the lab could not hold temperature at set point during this test. Every time the doors opened the Lab temperature spiked up 3°C and then came back down rapidly but never back down to its set point

Sensor #6 - Near Supco Sensor, 9°C to 15°C

Sensor #5 - Back wall, 5.2°C to 12.3°C

Sensor #3 - Center of Lab, 5°C to 12.3°C

Sensor #2 - Front of door, 4.5°C to 11.5°C

Chamber ambient temperature was set to 35°C and 50% relative humidity for 140 minutes and the doors opening every 15 minutes the test cycle indicates the lab temperature slowly dropped and near the end of the test reached its set points indicating this is the maximum temp/humidity the system can run at with the door opening every 15 minutes.

Sensor #6 - Near Supco Sensor, 15°C to 5.2°C

Sensor #5 - Back wall, 11.8°C to 2.3°C

Sensor #3 - Center of Lab, 11.8°C to 1.6°C

Sensor #2 - Front of door, 11°C to 1°C

Chamber ambient temperature was set to 40°C and 50% relative humidity for 180 minutes and the doors opening every 15 minutes the test cycle indicates the lab temperature could not hold its set point and ran 1.5°C above the allowable set point indicating 35 C / 50 RELATIVE HUMIDITY is the maximum it can run at under these conditions

Sensor #6 - Near Supco Sensor, 5.5°C to 8.6°C

Sensor #5 - Back wall, 2°C to 4.8°C

Sensor #3 - Center of Lab, 1.6°C to 3.5°C

Sensor #2 - Front of door, 1°C to 3.3°C

Chamber ambient temperature was set to 45°C and 50% relative humidity for 140 minutes and the doors opening every 15 minutes the test cycle indicates the lab temperature could not hold its set point and ran 5 C above the allowable set point indicating 35°C / 50 RELATIVE HUMIDITY is the maximum it can run at under these conditions.

Sensor #6 - Near Supco Sensor, 8.8°C to 12°C

Sensor #5 - Back wall, 4.8°C to 8°C

Sensor #3 - Center of Lab, 3.6°C to 6.3°C

Sensor #2 - Front of door, 2.8°C to 6.5°C

Chamber ambient temperature from 35°C to 45°C and relative humidity 50% to 75% and the doors opening every 15 minutes for 13.5 hours. The test cycle indicates the Vestibule between the 2 doors would rapidly climbed when the outside door was open and rapidly drop when the inner door opened indicating heat was added to the Vestibule and then released into the Lab.

Chamber ambient temperature from 35°C to 45°C and relative humidity 50% to 75% and the doors opening every 15 minutes for 13.5 hours. The test cycle indicates that every time the doors opened humidity was introduced Into the Lab.

During this test it was apparent that the opening of the doors affected the system's ability to maintain temperature there was heat and humidity introduced into the Lab and the system could not keep up

In this phase the heat loads are

- Box load (lights, transformer)
- Ambient heat transfer
- Moisture migration (dehumidification)
- doors opening and closing Lab is open to the ambient

Improvements

- Insulate the hatch
- Motorized dampers on the exhaust and makeup
- Try to keep door openings to a minimum (airlock?)

Phase 5 – run the cold lab at 10°C with the doors closed the ambient at 0°C for 30 minutes and at 20°C for 30 minutes

Wednesday, June 08, 2011

- The Lab held temperature with no problems, however the hatch temperature was low.
- The system ran satisfactory
- Only improvement would be to insulate the hatch.

Phase 2 – run the cold lab with the doors closed, the exhaust and makeup air running.

Wednesday, June 08, 2011

This test failed soon after it was started. The air proofing switch that changes the cooling coils when there is frost buildup failed.

After looking at the data from the other tests you can see the coils switch over after approximately 20 minutes of operation with high load and humidity. There for a much more dependable way of switching the defrost coils would be by time eliminating sensitive air proofing switches that may go out of calibration during transportation due to vibration. Also as there is much more time between the switch over then first thought; we can eliminate the defrost heater from coming on this should reduce help reduce humidity

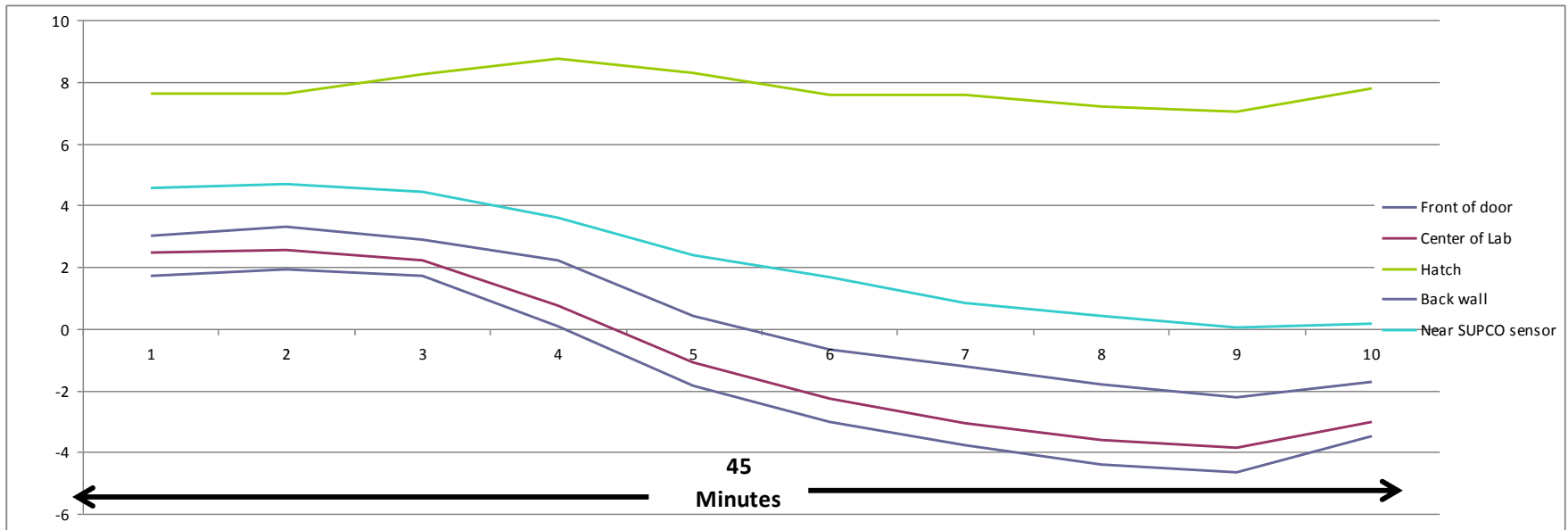
Phase 4 – Test the combined effects of both human influence, and the fumehood on the ability of the cold lab to maintain operating temperature

Wednesday, June 08, 2011

Test not run due to system failure on phase 2.

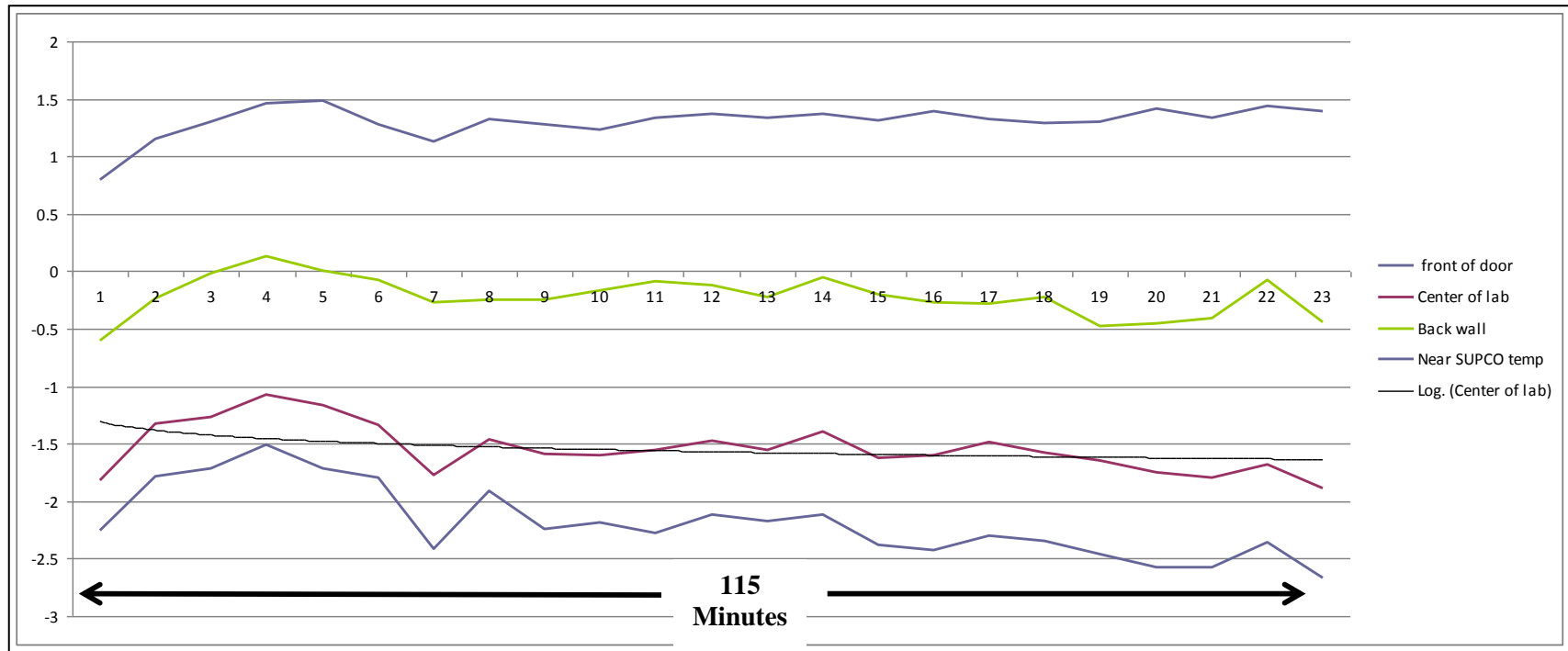
PHASE 1 DATA

PHASE 1 Start Up



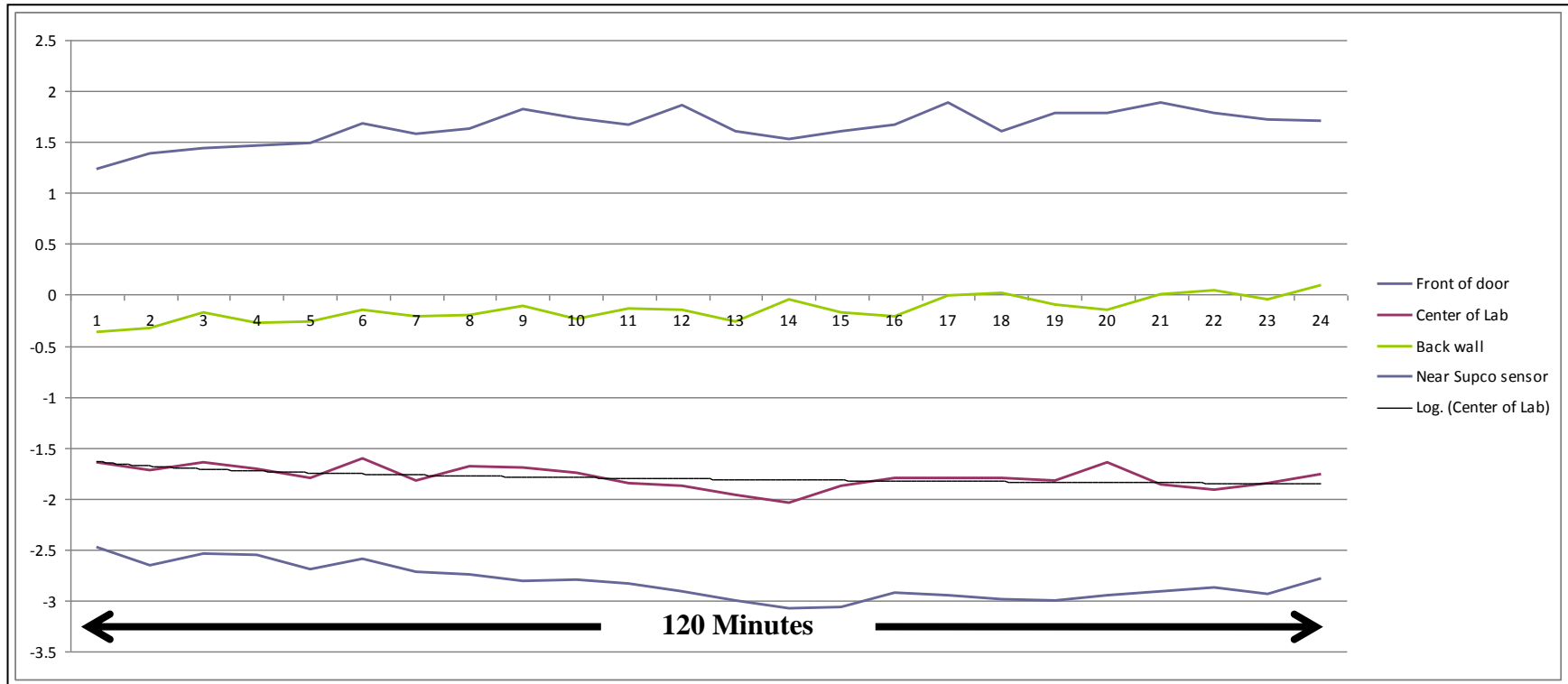
There was 45 minutes where the cold lab temperature dipped below 0°C (Sensor #2 went as low as -4.6) this was most likely caused by the outside ambient temperature rapidly climbing to its set point of 35°C and the cold lab rapidly lowering to its set point of 0°C. the temperature controller has auto-tuning capability that calculates how much cooling is needed to compensate for load change. In this case the ambient temperature was changed rapidly and then stopped climbing at 35°C (real time weather does not change this rapidly). Therefore this should be considered part of the set up time.

PHASE 1 Ambient at 35°C



Ambient temperature was set to 35°C for 115 minutes, The test cycle indicates the lab could hold temperature at set point during this test.
 Sensor #6 - Near Supco Sensor , 1°C to 1.5°C
 Sensor #5 - Back wall, 0°C to - 0.5°C
 Sensor #3 - Center of Lab, -1°C to - 1.8 °C

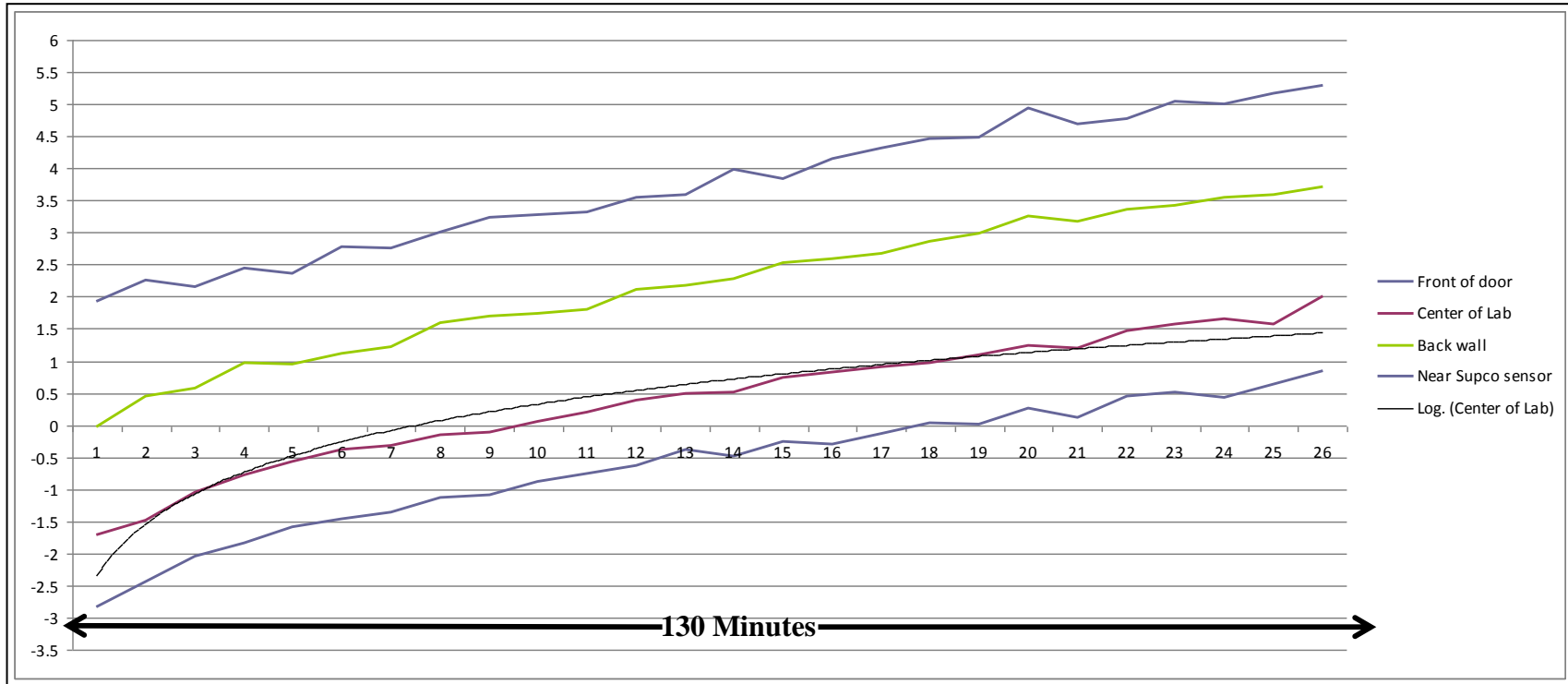
PHASE 1 Ambient at 40°C



Ambient temperature was set to 40°C for 120 minutes, The test cycle indicates the lab could hold temperature at set point during this test

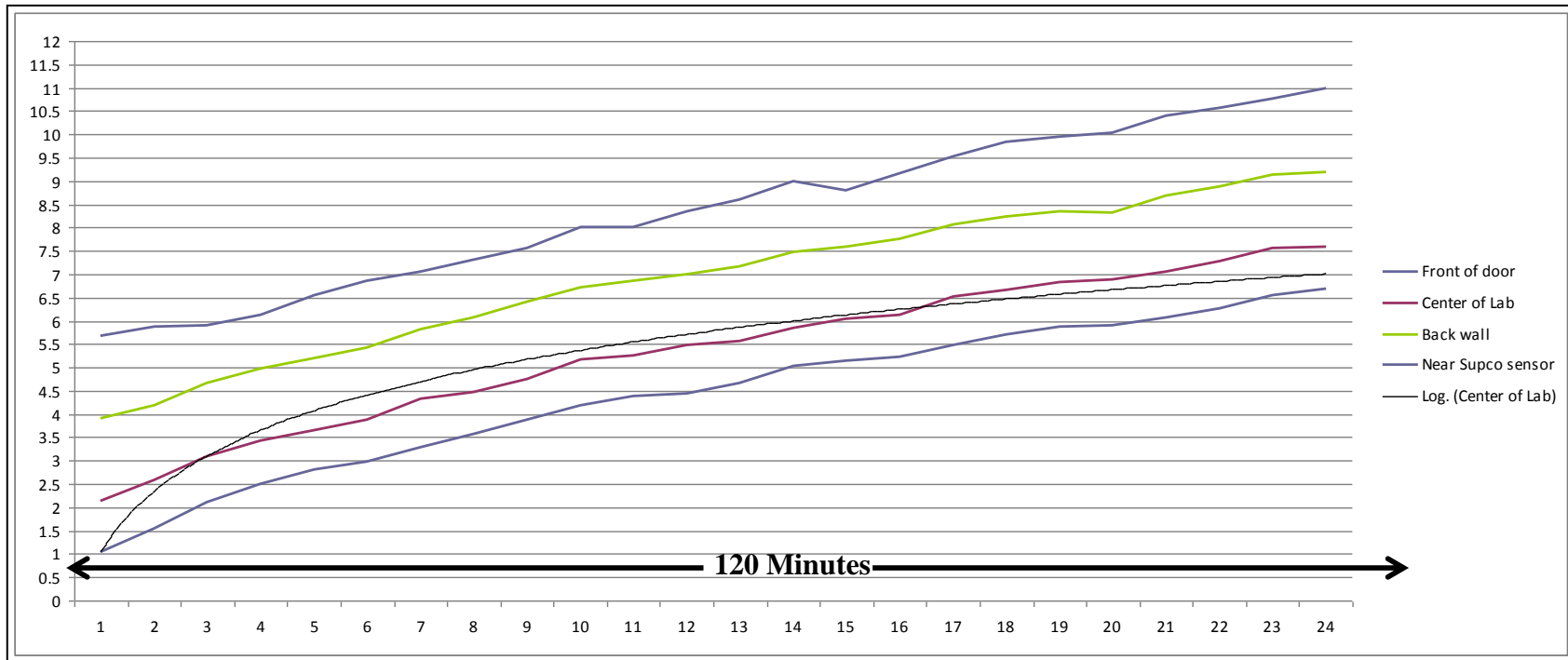
Sensor #6 - Near Supco Sensor, 1.2°C to 1.7°C
 Sensor #5 - Back wall, 0.1°C to -0.4 °C
 Sensor #3 - Center of Lab, -1.6°C to -1.8°C
 Sensor #2 - Front of door, -2.5°C to -2.7°C

PHASE 1 Ambient at 45°C



Ambient temperature was set to 45°C for 130 minutes, The test cycle indicates the lab could NOT maintain temperature however Sensor #3, center of lab did start to level out at 1.5°C to 2°C as per the trend line
 Sensor #6 - Near Supco Sensor, 2°C to 5.3°C
 Sensor #5 - Back wall, 0°C to 3.7°C
 Sensor #3 - Center of Lab, -1.6°C to 2°C
 Sensor #2 - Front of door, -2.8°C to 0.8°C

PHASE 1 Ambient at 50°C



Ambient temperature was set to 50°C for 120 minutes, The test cycle indicates the lab could NOT maintain temperature Sensor #3, center of lab did again start to level out at 7.6°C as per the trend line

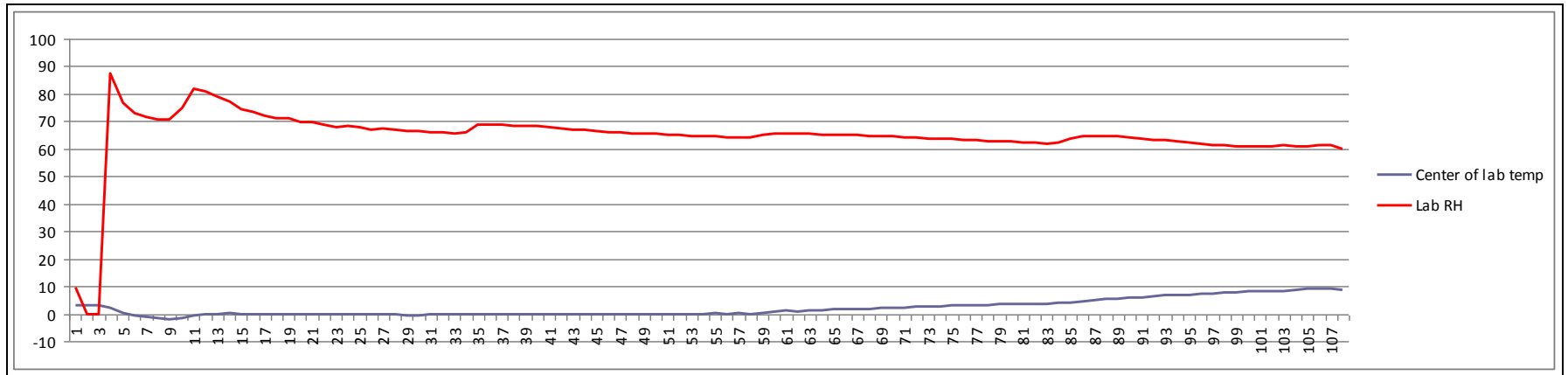
Sensor #6 - Near Supco Sensor, 5.3°C to 11°C

Sensor #5 - Back wall, 3.7°C to 9.19°C

Sensor #3 - Center of Lab, 2°C to 7.5 °C

Sensor #2 - Front of door, 0.8°C to 6.6°C

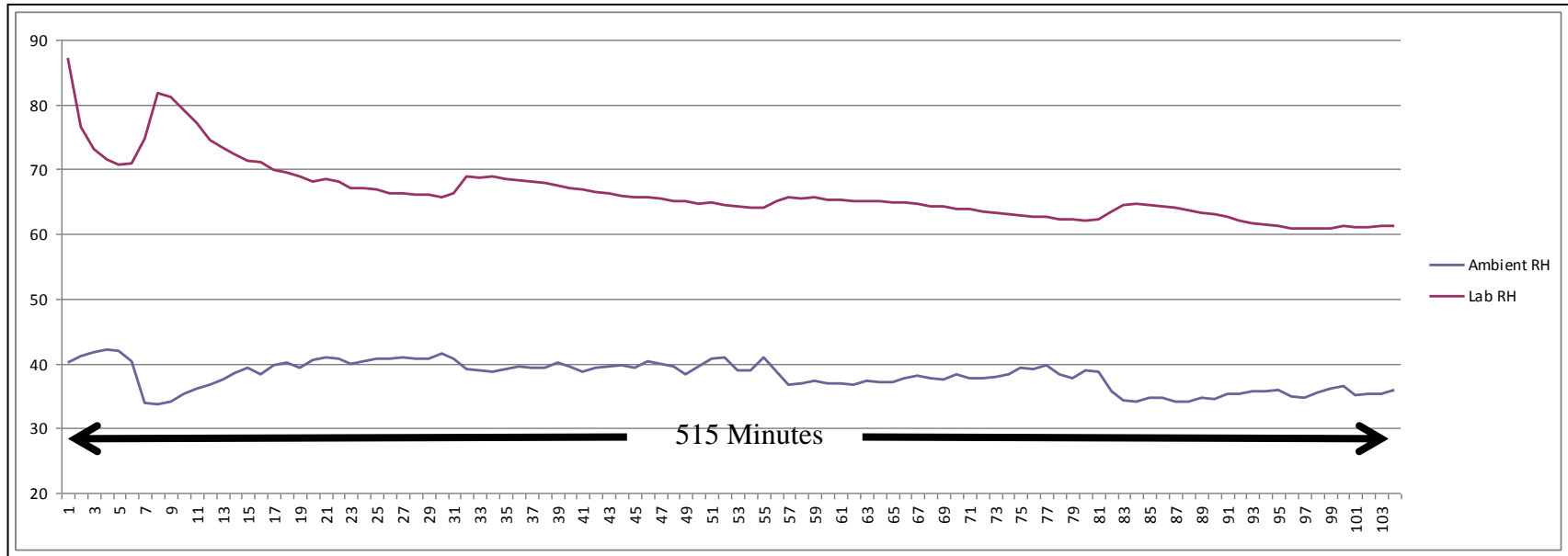
PHASE 1 Lab Relative Humidity Versus Temperature



← 535 Minutes →

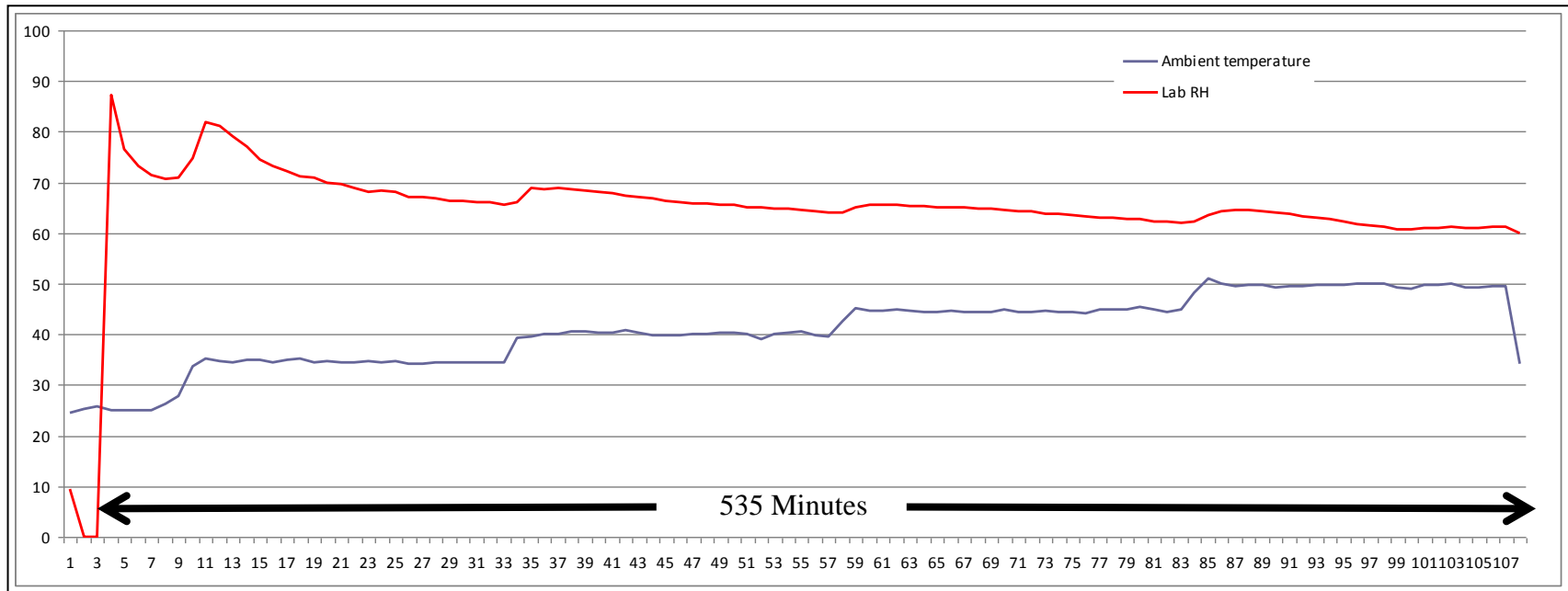
The Lab humidity seemed to have no effect on the box temperature

PHASE 1 Lab Relative Humidity Versus Ambient Relative Humidity



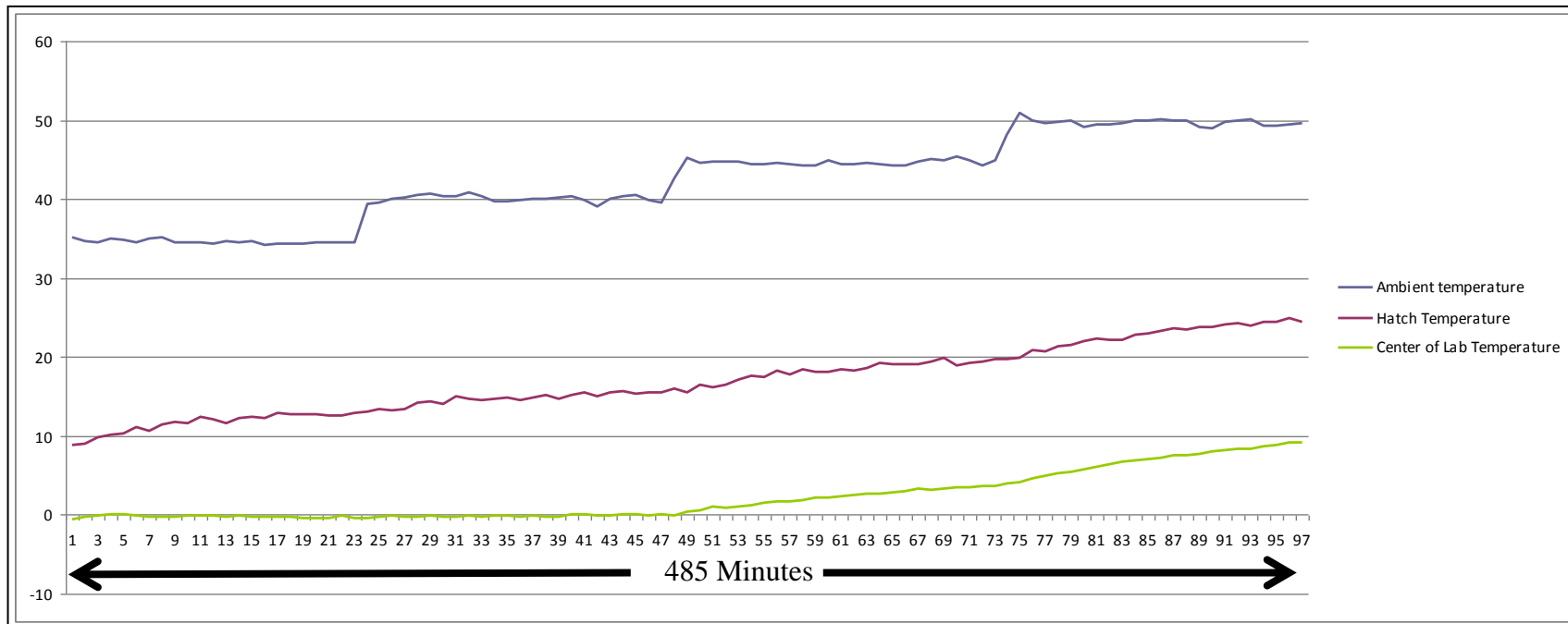
Ambient Relative humidity ran at 40% The Lab relative humidity ran approximately 25% higher than the ambient, the system spent 9 hours running and only reduced the humidity down to 61%. This is a indication of moisture migration from the ambient.

PHASE 1 Chamber Ambient Temperature Versus Lab Relative Humidity



Ambient temperature 35 °C, 40°C, 45°C, 50°C total of 8 hours of operation As the Ambient temperature was increased, more moisture had to be introduced into the ambient to maintain the required 40% Relative Humidity. The effect of this inside the lab was a momentary increase in humidity indicating moisture migration from the ambient to the Lab.

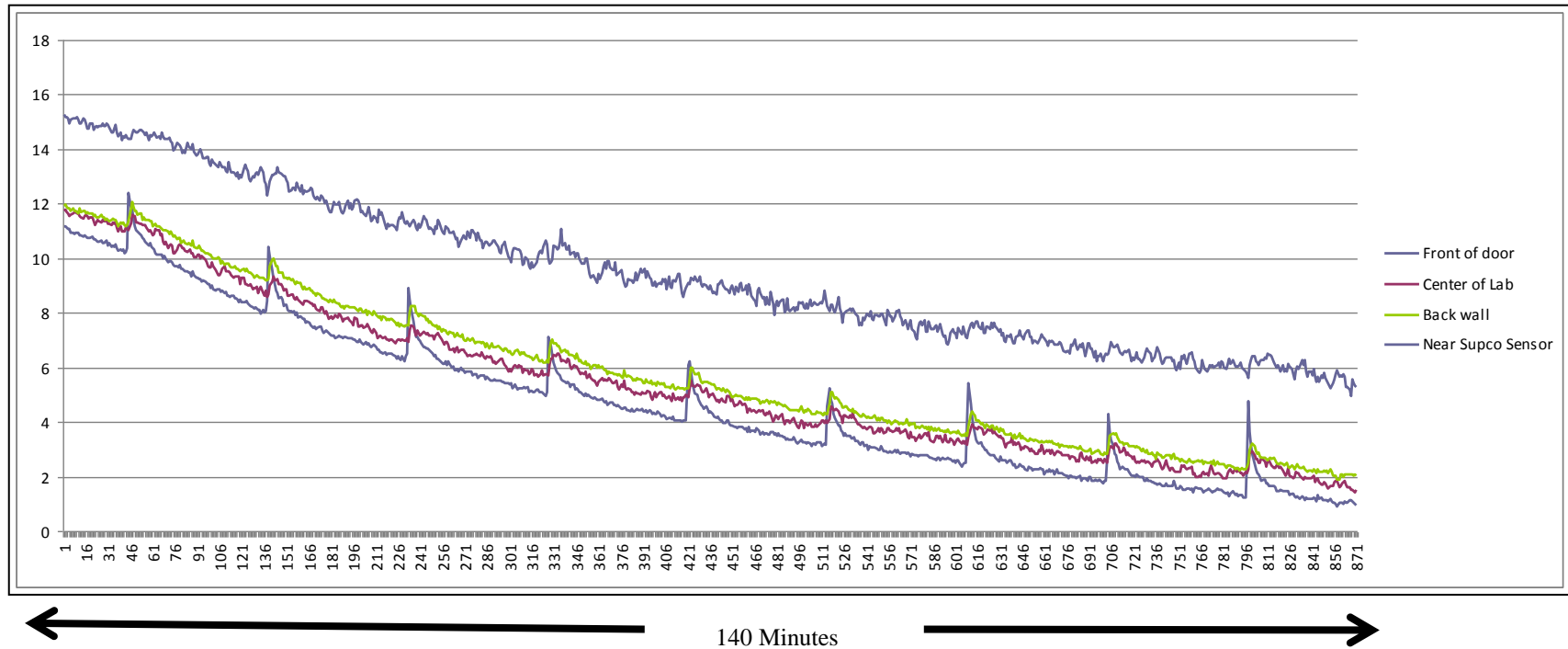
PHASE 1 Chamber Ambient Temperature Versus Hatch Temperature



Ambient temperature 35°C, 40°C, 45°C, 50°C total of 8 hours of operation The hatch temperature ran approximately 15°C above the box Temperature, indicating a large heat load.

PHASE 3 DATA

PHASE 3: 35°C, 50% RELATIVE HUMIDITY



Ambient temperature was set to 35°C and 50% relative humidity for 140 minutes and the doors opening every 15 minutes. The test cycle indicates the lab temperature slowly dropped, and near the end of the test reached its set points, indicating this is the maximum temp/humidity the system can run at with the door opening every 15 minutes.

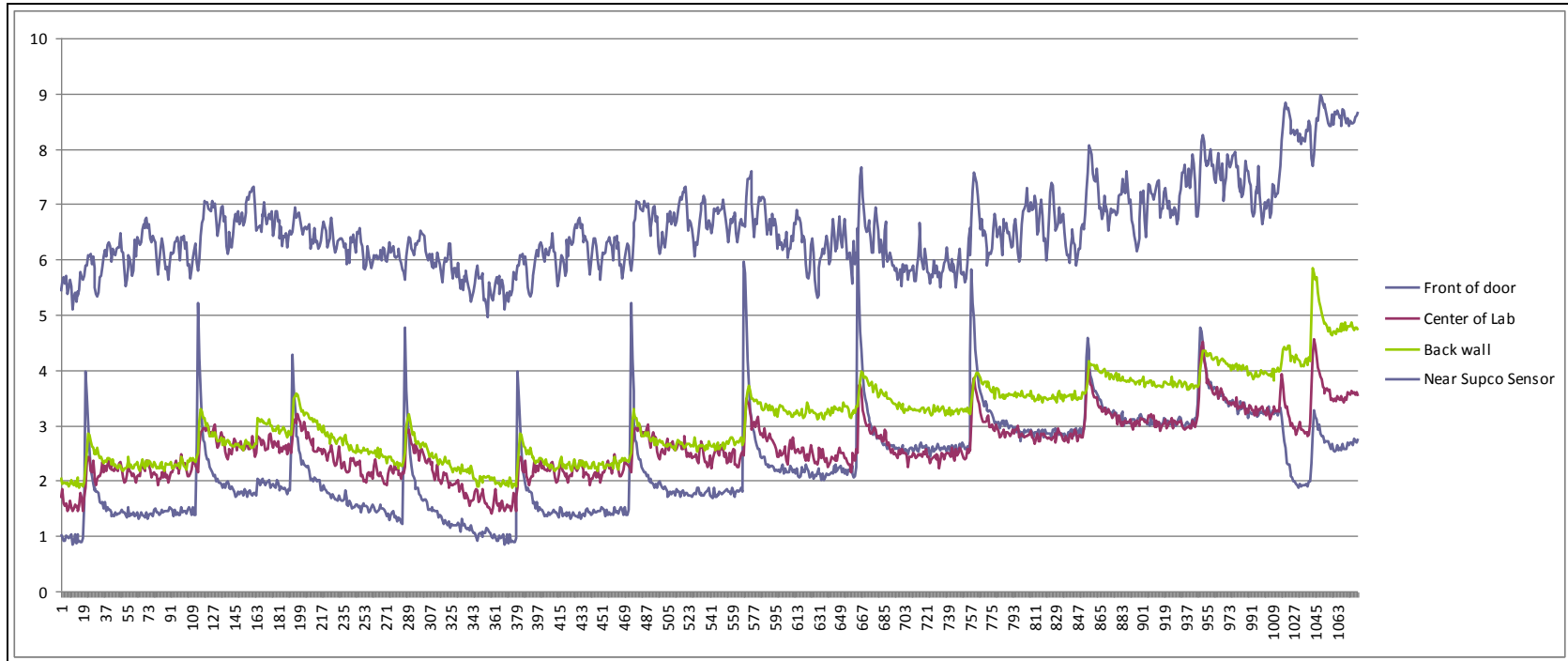
Sensor #6 - Near Supco Sensor , 15°C to 5.2°C

Sensor #5 - Back wall, 11.8°C to 2.3 °C

Sensor #3 - Center of Lab, 11.8°C to 1.6°C

Sensor #2 - Front of door, 11°C to 1°C

PHASE 3: 40°C, 50% RELATIVE HUMIDITY

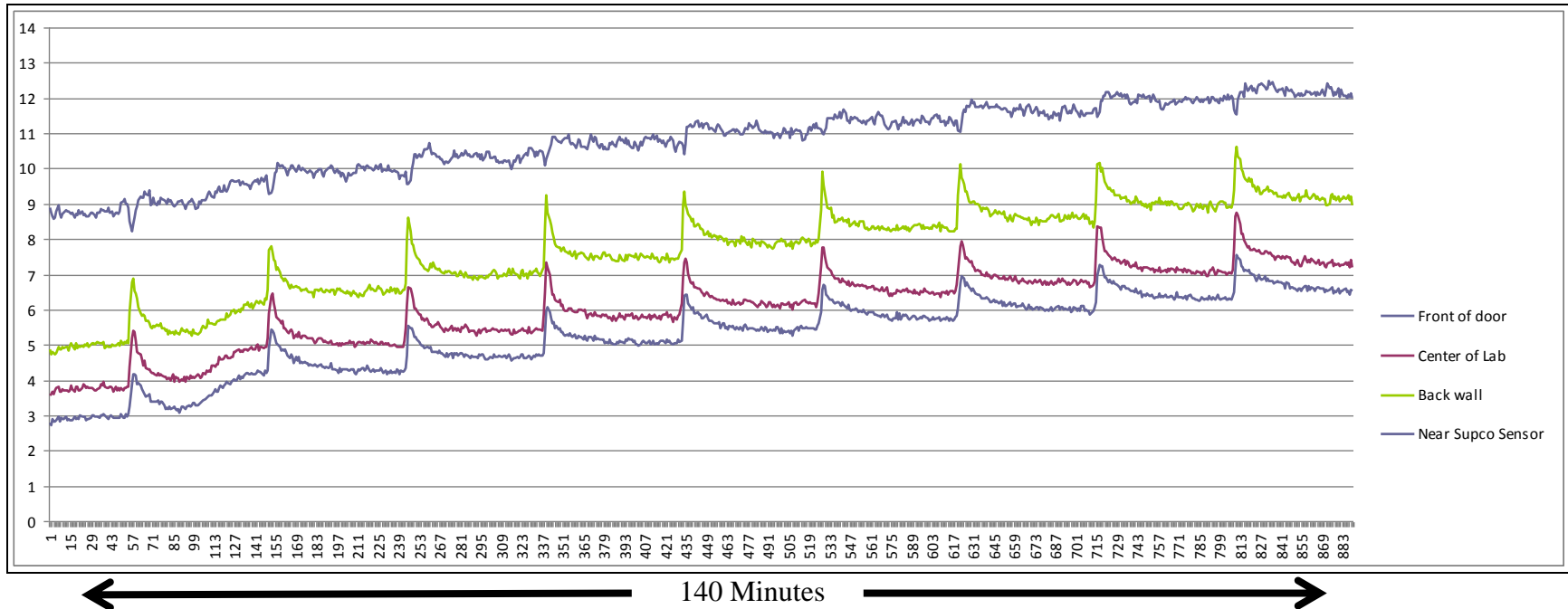


← 180 Minutes →

Ambient temperature was set to 40°C and 50% relative humidity for 180 minutes and the doors opening every 15 minutes. The test cycle indicates the lab temperature could not hold its set point and ran 1.5°C above the allowable set point indicating 35°C / 50% relative humidity is the maximum it can run at under these conditions.

- Sensor #6 - Near Supco Sensor, 5.5°C to 8.6°C
- Sensor #5 - Back wall, 2 °C to 4.8°C
- Sensor #3 - Center of Lab, 1.6 °C to 3.5°C
- Sensor #2 - Front of door, 1°C to 3.3°C

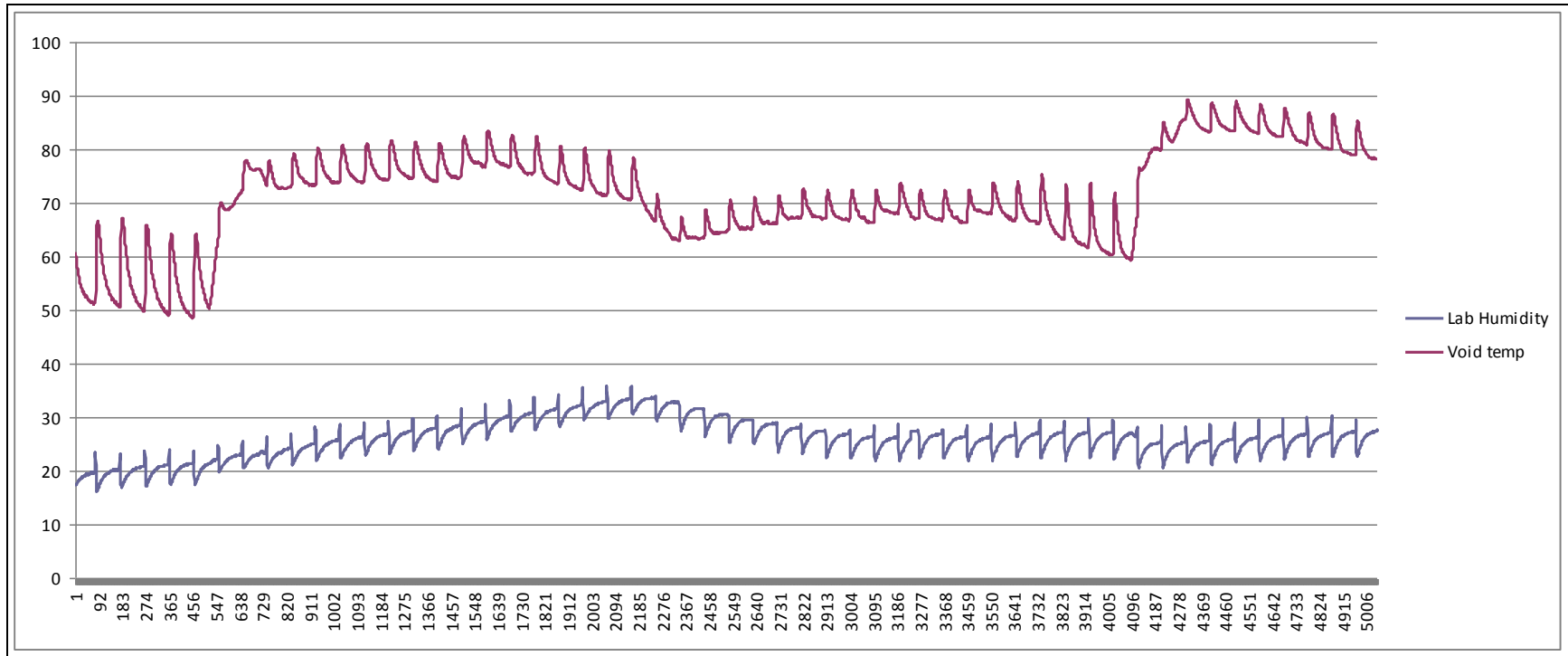
PHASE 3: 45°C, 50% RELATIVE HUMIDITY



Ambient temperature was set to 45°C and 50 relative humidity for 140 minutes and the doors opening every 15 minutes. The test cycle indicates the lab temperature could not hold its set point and ran 5°C above the allowable set point indicating 35°C / 50 relative humidity is the maximum it can run at under these conditions.

Sensor #6 - Near Supco Sensor , 8.8°C to 12°C
 Sensor #5- Back wall, 4.8°C to 8 °C
 Sensor #3 - Center of Lab, 3.6°C to 6.3 °C
 Sensor #2 - Front of door, 2.8°C to 6.5°C

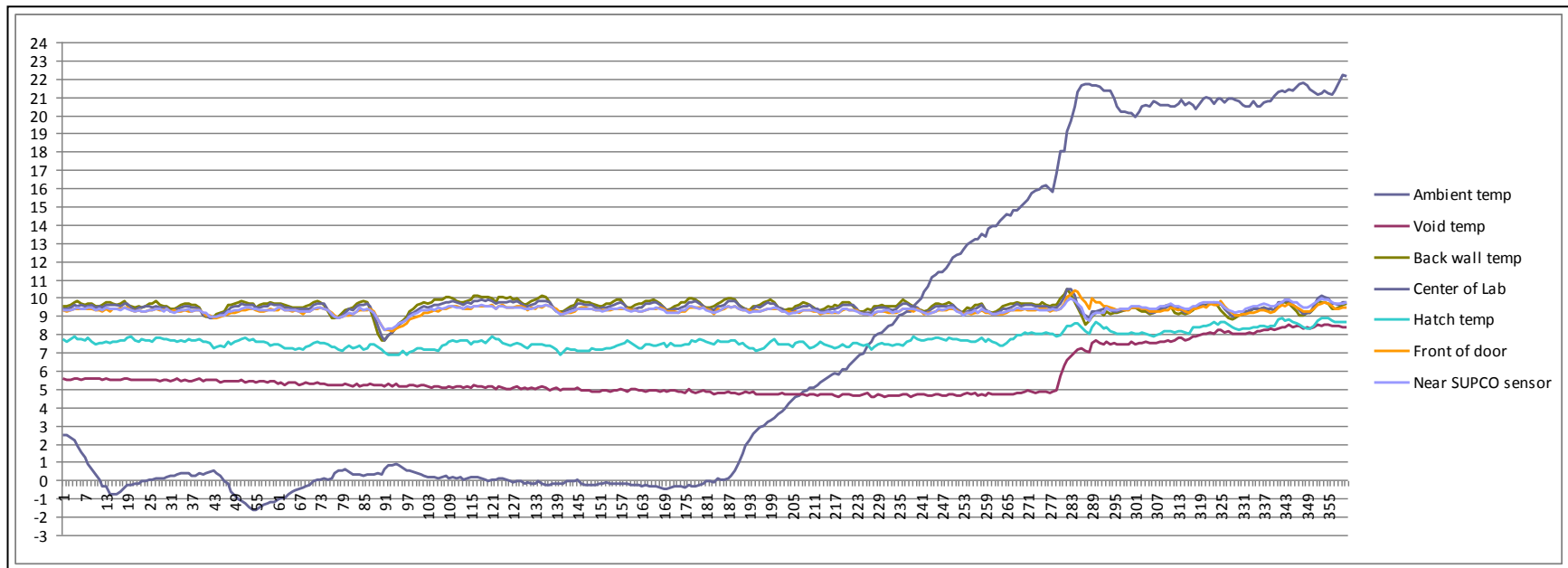
PHASE 3: Lab Humidity and Vestibule Temperature



← 810 Minutes →

Ambient temperature from 35°C to 45°C and relative humidity 50% to 75% and the doors opening every 15 minutes for 13.5 hours. The test cycle indicates that every time the doors opened humidity was introduced into the Lab.

PHASE 5 DATA



Run the cold lab at 10°C with the doors closed the ambient at 0°C for 30 minutes and at 20°C for 30 minutes. The Lab held temperature with no problems the hatch temperature was low.

CONCLUSIONS:

The Cold lab meets the specification as it's currently written, however it does not meet actual service conditions in harsher climates. High humidity and high temperatures combined with opening and closing of doors is simply too much for the system to handle.

The Cold lab works fine at low chamber ambient temperatures. Current Limitations are:

- Closed Lab to 40°C, 50% relative humidity
- Doors opening, limits operation to 35°C, 50% relative humidity
- Fume Hood Operating: 40°C, 50% relative humidity

RECOMMENDATIONS:

The following recommendations are listed according to cost, from lowest to highest. Recommendations A thru D are attainable on existing labs. E is more costly, and requires a definition of procedure; F&G are for future labs only.

- A: insulate the hatch to minimize heat gains through the hatch. A padded hatch cover that either snaps or Velcro into place with a handle to tear it away in emergencies, 1" to 2" thick.
- B: install motorized dampers on the exhaust and makeup air to minimize infiltration.
- C: re configure the PLC so coils are changed more frequently. Eliminate the air proofing switches and eliminate the electric defrost heaters. This will improve reliability for transport, as well as reduce the amount of humidity inside the lab, which makes it difficult for the system to recover.
- D: Air temperatures in the Lab are surprisingly uneven. Try to mix the air better by adjusting the grill fins to blow in every direction possible, and add small fans to help circulate the air, particularly in the dead spots in the lab.
- E: try to reduce the amount of times the door is opened. Change vestibule area to an "air-lock". Provide HVAC into the vestibule area via an air curtain, and install lights that indicate when the air-lock can be opened. Personnel would be expected to stay in the air lock for a period of time before being able to enter or leave the lab. Add a plastic curtain in front of the door to help minimize losses when the door is opened.
- F: re-design the air distribution system, use ceiling ducting and wall air curtains (ie Trace Metal Van) for a more balanced distribution and mixing of air in the room.
- G: increase wall thickness for higher R-Value: 5"-6" Walls would provide R35-R42, for substantial improvement.

APPENDIX: Pictures from Test Lab

