Manual for Evaluating the Thermal Performance of the Hamerschlag Hall Green Roof

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1 Abstract

The green roof on Hamerschlag Hall was built with a temperature sensing system. A sensing system was also installed on the control roof on Porter Hall. The temperature data from these systems can be analyzed to evaluate the thermal performance of the green roof. This manual provides information on the materials used in the roofs, the location of the temperature sensing systems, how to collect and interpret the LabView data files, and sample methods for analyzing the data.

2 Introduction

A green roof was built on Hamerschlag Hall at Carnegie Mellon University in Pittsburgh, PA in 2005 to take advantage of and study the benefits of green roofs, which include (Allegheny County, 2010):

- Improved Storm Water Management – The plants and soil can retain storm water. In urban areas this assists in decreasing combined sewer overflows.
- Reduced “urban heat island” effect – A green roof reduces the level of absorbed heat in dense concrete areas.
- Extended life of the roof – Protects the roof from weather, reducing maintenance costs.
- Reduced heating and cooling costs – Provides extra roof insulation. And reduction in the building’s overall heating and cooling costs.
- Aesthetics – Makes the building attractive from aerial view, and provides building users a green space.
- Improved air quality – Plants can absorb carbon dioxide and other pollutants.
- Space for local food production

Little research has been done to quantify these benefits.

Carnegie Mellon University built a green roof on the lower south roof of Hamerschlag Hall in 2005. The roof features sensors which can be used to evaluate the roof’s stormwater management capability and the roof’s thermal performance.

Research on the thermal performance of the Hamerschlag Hall roof aims to determine the amount of heat energy that the roof releases or absorbs and to compare this amount to the heat energy released or absorbed by a conventional control roof with characteristics similar to the roof beneath the green roof. This difference in energy may be combined with building energy models to calculate the energy and cost savings that the roof provides.

This manual is meant to be a comprehensive guide for Hamerschlag Hall green roof temperature data collection and analysis. It provides information regarding the design of the roof and the location and description of temperature sensors, as well as instructions for collecting and analyzing the data which can be followed by future researchers.

3 Detailed Description of Roof

This section provides a description of the Hamerschlag Hall green roof and its temperature sensing system. This includes a description of the control roof, the types of green roof technologies used and the roof layers.

3.1 Plan View

The roof is built on a 150 feet by 30 feet (4500 square foot) flat roof on the south side of Hamerschlag Hall. The control roof is a flat roof on a section of adjacent Porter Hall. Both roofs are shown in Figure 1.

3.2 Control and Green Roof Components

A typical cross section of the existing roof layers and green roof layers is shown in Figure 2.

3.2.1 Control Roof and Existing Roof

The modified bitumen conventional flat roofs on the control roof and beneath the green roof on Hamerschlag Hall are identical. The layers associated with the conventional flat roof underlying the green roof and comprising the control roof are described in this section. They contain the following layers (from top to bottom), as shown in Figure 2:

- Georgia Pacific DensDeck Prime Roof Board(0.6 cm)
- Polylso insulation (5.0 cm)
- Vapor barrier (0.4 cm)
- Concrete deck (20 cm)

3.2.1.1 Georgia Pacific DensDeck Prime Roof Board

Georgia Pacific's "DensDeck is a fiberglass mat faced panel with a specially treated gypsum core that resists moisture and mold growth and also provides sound isolation". It can also reduce maintenance needs "because it adds strength and minimizes damage from hail, foot traffic and high wind events". A 0.25" (0.6 cm) board was used for the Hammerschlag Hall and Porter Hall roofs. This thickness of board provides an R-value of 0.05 h m^2 K/W. (Georgia- Pacific, 2011)

3.2.1.2 Polyisocyanurate Insulation

This layer, which is about 2" (5 cm) thick, provides the majority of the insulation for the roof. The brand used on the roofs was Firestone ISO 300. It is made from a "closed cell polyiso foam core laminated to a coated glass-fiber mat facer." The R-value for this layer is 2.13 m^2 K/W. (Firestone, 2006)

3.2.1.3 Vapor Barrier

This layer is used to prevent any moisture from reaching the concrete deck. This will prevent damage to the deck and leaking. W.P. Hickman Systems, Inc.'s Pika Ply SA-4 was used. The R-value of this layer is negligible.

3.2.1.4 Concrete Deck

The concrete deck provides structural support for the roof layers. The deck on the Hamerschlag Hall and Porter Hall roofs has a thickness of 20 cm (8 in). Concrete is not highly insulating. The deck will contribute an R-value of approximately 0.14 m^2 K/W. (ASHRAE, 1967)

3.2.2 Green Roof

The green roof layers were built on top of the conventional modified bitumen flat roof, and are made up of the following layers (from top to bottom):

- Plants and engineered soil – Depth varies from 10 cm to 20 cm. It remains a constant 10 cm (4”) in the monitoring area.
- Filter fabric (0.4 cm)
- Gravel drainage layer (6.4 cm)
- Geotextile barrier (0.5 cm)
- Capsheet (0.4 cm)
- Three-ply impermeable roofing membrane (0.4 cm)

3.2.2.1 Plants and Engineered Soil

The soil is a mixture of mineral and organic components (<6% by mass). The bulk density of the soil when dry is <0.90 g/cm^3 and <1.30 g/cm^3 at maximum water capacity. The maximum water capacity is 35% by volume, the air content at maximum water capacity is 10% by volume. The depth of the engineered soil varies from 4” to 8” on the roof. The depth remains a constant 4” in monitoring areas. (Carothers & Dzombak, 2005).

Over 40 species of plants were installed in an arching rainbow arrangement (Figure 3) across the roof. Plant species included a variety of hardy succulent plants such as sedum as well as native grasses. A full list of plants used is provided in Appendix C.

3.2.2.2 Filter Fabric

The filter fabric creates a separation between the soil media and the drainage layer. Fine and organic particles cannot pass the fabric. Roots are able to grow through. The R-value of this layer is negligible.

3.2.2.3 Gravel Drainage Layer

The gravel drainage layer creates sufficient void space to allow excess water to move to roof drains as well as to store water which may be available for plants to utilize. The material is a mixture of exclusively mineral components. The R-value for this layer, when estimated as sand, is about 1.3 h ft^2 F/Btu. (ASHRAE, 1967)

3.2.2.4 Geotextile Barrier

The geotextile barrier retains water for availability to plants and protects the waterproof membrane from mechanical impacts. The material used is a 15 ounce per square yard needle-punched staple fiber non-woven geotextile. The R-value of this layer is negligible.

3.2.2.5 Capsheet

The capsheet is used to protect the underlying conventional roof and to extend the life of the roof. The capsheet used on these roofs was the Pika Ply Supreme FR from W.P. Hickman Systems, Inc. The R-value of this layer is negligible.

3.2.2.6 Three-Ply Impermeable Roofing Membrane

The impermeable membrane is used to prevent moisture from reaching the insulation layers. The membrane used was the same as the vapor barrier used in the existing roof layers, the Pika Ply SA-4 from W.P. Hickman Systems, Inc. The R-value of this layer is also negligible.

4 Temperature Sensors

Thermocouple temperature sensors were placed in multiple layers of the roof to monitor temperatures within the roof ant to assess the insulating value of the materials used. Signals from the sensors are sent to a data logger. The data logger is connected to a computer in an office below the green roof. LabView software (National Instruments) is used to interpret and organize the data.

The location of the temperature sensors within the layers of the Hamerschlag Hall roof can be seen in Figure 2. Temperature sensors were placed on the control roof and green roof below the concrete deck (T1), beneath the insulation (T2), beneath the membrane (T3), and 18” above the surface of the roof (TCE). On the green roof, sensors were also placed below the geotech fabric (T4) and beneath the soil (T5).

There are sets of temperature sensors in three different measurement areas. There are two measurement areas on the green roof (G1 and G2) and one measurement area on the control roof (C1). The locations of the sensors in plan view are shown in Figure 1. Each sensor has a label or ID which appears in the LabView files. Table 1 shows the full list of sensors, the measurement area that the sensors are in, and where within the roof layers the sensor is located. A full equipment list which details the equipment used for the temperature sensing is shown in Table 2.

Currently, LabView only reads data from some of the temperature sensors as some of the sensors are not functional. From green roof G1, data are collected from T4, T5, and TCE, and from one of the T2 and one of the T3 sensors. From green roof G2, data are collected from T1, T4, and T5, and from one of the T2 sensors and one of the T3 sensors. From C1, data is collected from T1 and TCE, and from one of the T2 sensors, and one of the T3 sensors. The sensors from which data are collected from are shown in gray in Table 1.

Occasionally the temperature sensors will need to be recalibrated. Because the sensors have been built into the layers of the roofs, it is only possible to recalibrate the ambient temperature sensors above the roof surface. Calibration procedures are shown in Appendix D.

5 Temperature Data Collection

Temperature data from the roof sensors are sent to a computer below the Hamerschlag roof in Hamerschlag Hall B128. The data are stored in folders on the desktop as LabView files. The files are named using the date on which the data were acquired. The data should be transferred frequently to the CEE server with a USB mass storage device. It should be saved in the GreenRoof folder on the CEE server at \\Cee.andrew.ad.cmu.edu\User_Files\GreenRoof\Private\Temperature Sensors\Temperature sensor data.

To view the data, open Excel and select “Open” from the file menu. In the “Open” window, make sure that “All Files” is selected in the “Files of type” field. Then select the data files you would like to open. A “Text Import Wizard” window will open. The default settings from this wizard will organize the data correctly.

The Excel spreadsheet will show the values for each sensor for every minute of the day. The x-axis time scale needs to be added to the data in Column A below the box which says “X_Value”. The time should start with 00:00, and run until 23:59. The date can also be included if multiple days are plotted on one chart. Row 21 shows the sensor ID label.

The data can be plotted in many ways to see the difference between roof layers, between the control and green roofs, as well as the different behavior of the roof in summer and winter. A sample plot for a week in the summer which shows the difference in ambient and surface temperatures between the green roof and control roof can be seen in Figure 4.

This plot shows that surface temperatures are significantly more stable on the green roof than on the control roof. The plot also shows potential problems with the data. It can be seen that there are some differences in the data from the two sensor locations on the green roof. There is also a discrepancy between the ambient temperature data from the control roof and green roof. These discrepancies could be caused by a difference in shade over the sensors, or there could be a calibration problem with the sensors.

In Figure 5, a plot of winter data shows how different the temperature profile is for both roofs in the winter. Again, the temperature data for the green roof is more stable and still shows an inconsistency between the two sensor locations. The discrepancy between the ambient temperature data from the control and green roof can also still be seen.

Comparing the data from these plots with moisture or solar radiation data may help to explain the inconsistencies in the data. Additional plots should be created to compare different metrics depending on which features of the roof are being examined.

6 Data Analysis

The goal of this project was to understand how much heat is entering or leaving the green roof compared to the control roof. Almost all of the heat transfer through the conventional modified bitumen flat roof (conventional roof) layers is conductive. For these layers, a calculated conductive heat flux will be very near the total heat flux. A more complex model which also considers convective and radiant heat transfer would be needed to understand the total flux for the soil layer of the roof. For this reason, the soil layer was not considered in this analysis. The conventional roof layers on each roof, including the concrete deck and insulation, were compared to understand the benefits of the green roof layers. If the soil layer allows for less heat to escape the roof in the winter or less heat to enter the roof in the summer, this will be seen in the conductive transfer in the conventional roof layers below.

To do this analysis, data from sensors T1, T2, and T3 were used at location C1 and at location G2. Data from location G1 were not used because the T1 sensor at this location was not functioning.

Because the temperature data are collected every minute, a time period over which to calculate the flux and total energy lost or gained needed to be selected. Viewing the average daily flux values over a year graphically provided too much detail and made it difficult to see trends in the data. Calculating the flux values every month made it easy to see trends but oversimplified some of the data. For this reason, weekly average flux values were used to understand how the heat transfers through the roof over time.

For the total amount of heat escaping or entering the roof, a period of one month was selected. This was chosen because metered energy is billed monthly. Although this heat energy loss or gain is not equivalent to the changes in metered energy use, viewing energy differences on a monthly basis will be more relevant to a building owner.

A detailed description of the analysis performed to compare the performance of the green roof and control roof can be found in Becker and Wang (2011) which is available in the green roof folder on the CEE server.

7 References

Allegheny County, 2010. *Green Roof* [Online] Available at: http://www.county.allegheny.pa.us/alleghenygreen/COBroof.aspx [Accessed April 24, 2011].

American Society of Heating, Refrigerating and Air-Condition Engineers, Inc. 1967. *Handbook of Fundamentals*. New York, NY: ASHRAE.

Becker, D. and Wang, D., 2011. Green Roof Heat Transfer and Thermal Performance Analysis. Carnegie Mellon University, Pittsburgh, PA.

Carothers, D. and Dzombak, D.A., 2005. *Development of a Green Roof Stormwater Monitoring Protocol and Green Roof Stormwater Modeling Tool*. Carnegie Mellon University, Pittsburgh, PA.

Firestone, 2006. *Firestone ISO 300 Technical Information Sheet* [Online] Available at: http://www.firestonebpco.com/templateFiles/includes/common/displayFile.ashx?fileId=2406 [Accessed April 24, 2011].

Georgia-Pacific, 2011. *DensDeck Roof Boards* [Online] Available at: http://www.gp.com/build/roofboard_densdeck [Accessed April 24, 2011].

Appendix A: Tables

Table 1: Sensor IDs and Location

Measurement Area	Sensor ID	Location
G1	G1-T1	Attach to interior side concrete deck
G1	G1-T2-A	Attach to exterior side vapor barrier (beneath insulation)
G1	G1-T2-B	Attach to exterior side vapor barrier (beneath insulation)
G1	G1-T3-A	Attach to exterior side Mooreboard (beneath membrane)
G1	G1-T3-B	Attach to exterior side Mooreboard (beneath membrane)
G1	G1-T4	Attach to exterior side capsheet (beneath geotech fabric)
G1	G1-T5	Attach to exterior side filter fabric (beneath soil medium)
G1	G1-HF	Attach to exterior side Mooreboard (beneath membrane)
G1	G1-TCE	18”above soil (measures ambient temperature)
G2	G2-T1	Attach to interior side concrete deck
G2	G2-T2-A	Attach to exterior side vapor barrier (beneath insulation)
G2	G2-T2-B	Attach to exterior side vapor barrier (beneath insulation)
G2	G2-T3-A	Attach to exterior side Mooreboard (beneath membrane)
G2	G2-T3-B	Attach to exterior side Mooreboard (beneath membrane)
G2	G2-T4	Attach to exterior side capsheet (beneath geotech fabric)
G2	G2-T5	Attach to exterior side filter fabric (beneath soil medium)
G2	G2-HF	Attach to exterior side Mooreboard (beneath membrane)
G2	G2-TCE	18”above soil (measures ambient temperature)
C1	C1-T1	Attach to interior side metal deck
C1	C1-T2-A	Attach to exterior side concrete deck (beneath insulation)
C1	C1-T2-B	Attach to exterior side concrete deck (beneath insulation)
C1	C1-T3-A	Attach to exterior side insulation (beneath rubber membrane)
C1	C1-T3-B	Attach to exterior side insulation (beneath rubber membrane)
C1	C1-HF	Attach to exterior side insulation (beneath rubber membrane)
C1	C1-TCE	18”above soil (measures ambient temperature)

Table 2: Temperature measurement equipment list

Supplier	Contact	Part Description	Part #
National Instruments	www.ni.com	FP-1000 RS-232/RS-485 Network Module	777517-00
	(888) 280-7645	RS-232 Cable, 9-pin D-sub, 3m	777566-03
		FP-TC-120 Thermocouple Input Module	777518-120
		FP-AI-110 Analog Input Module	777518-110
		PS-4 Power Supply, 24 VDC, Universal Power Input Din Rail Mount	778586-90
		FP-TB-1 Universal Terminal Base, Screw Terminals	777519-01
		FP-TB-3 Isotherman Terminal Base, Screw Terminals	777519-03
Omega Engineering	www.omega.com	Type T thermocouple wire, 50'	PP-T-24-50
	1-888-TC-OMEGA	Type T thermocouple extension wire, 1000'	EXPP-T-20-1000
		Type T thermocouple extension wire, 500'	EXOO-T-20-500
Radio Shack	www.radioshack.com	Outdoor 4-Conductor Phone Cable-100'	278-385

Appendix B: Figures

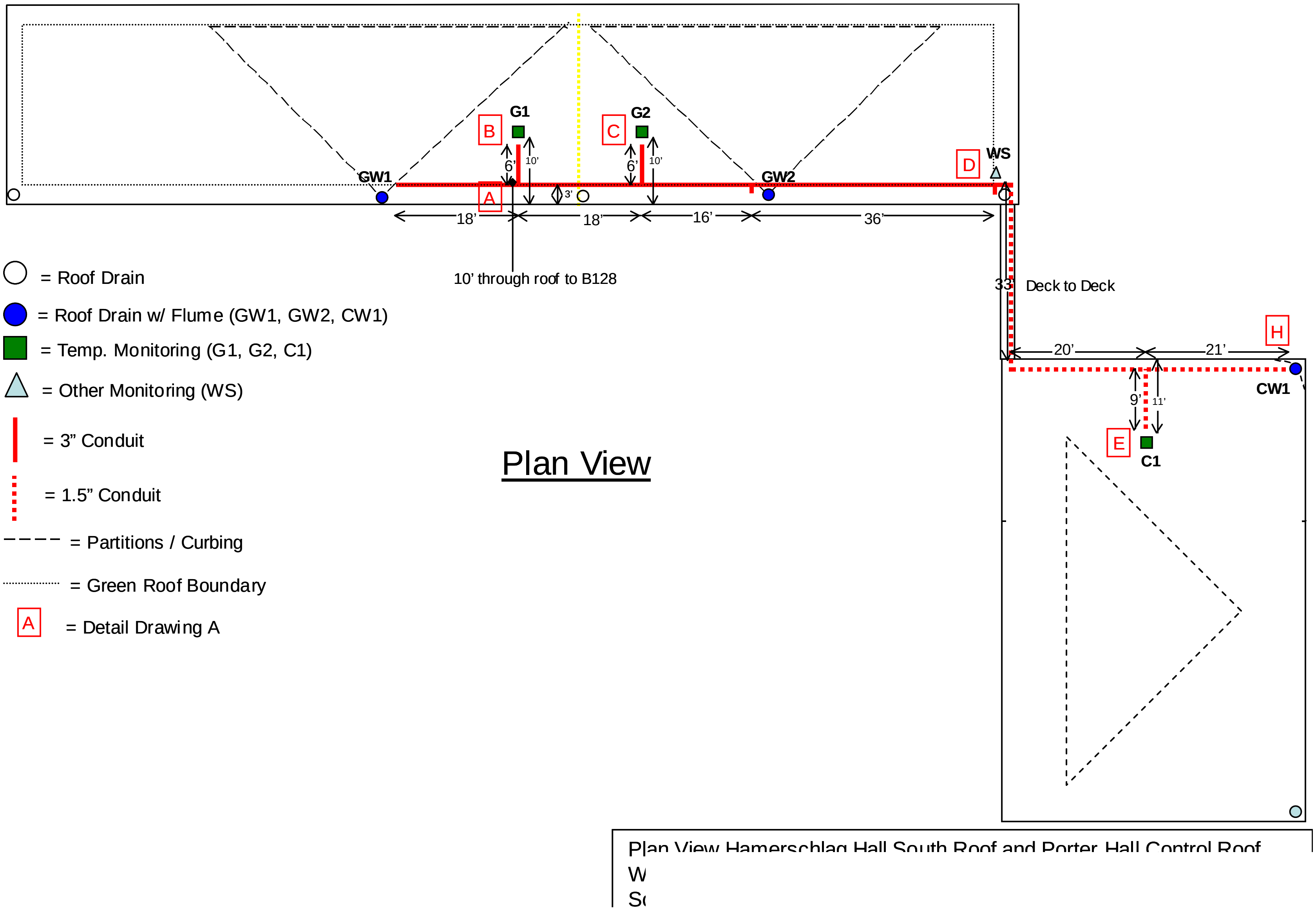
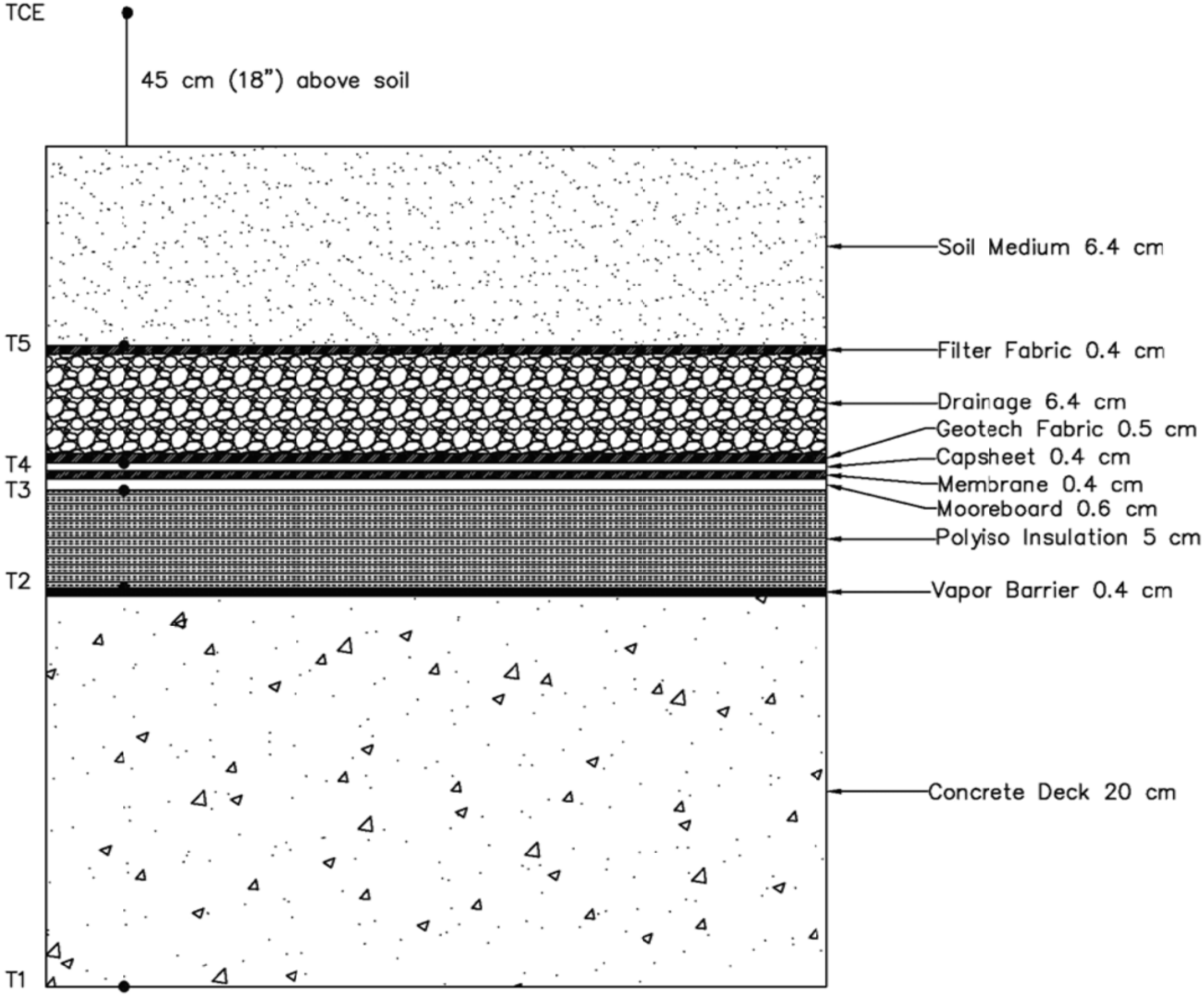


Figure 1: Plan view of Hamerschlag Hall green roof and control roof on Porter Hall at Carnegie Mellon University. Source: modified from Carothers and Dzombak (2005)


TCE
45 cm (18") above soil
T5
T4
T3
T2
T1
Soil Medium 6.4 cm
Filter Fabric 0.4 cm
Drainage 6.4 cm
Geotech Fabric 0.5 cm
Capsheet 0.4 cm
Membrane 0.4 cm
Mooreboard 0.6 cm
Polyiso Insulation 5 cm
Vapor Barrier 0.4 cm
Concrete Deck 20 cm

le)

Figure 3: Arching rainbow planting arrangement on the Hamerschlag Hall roof

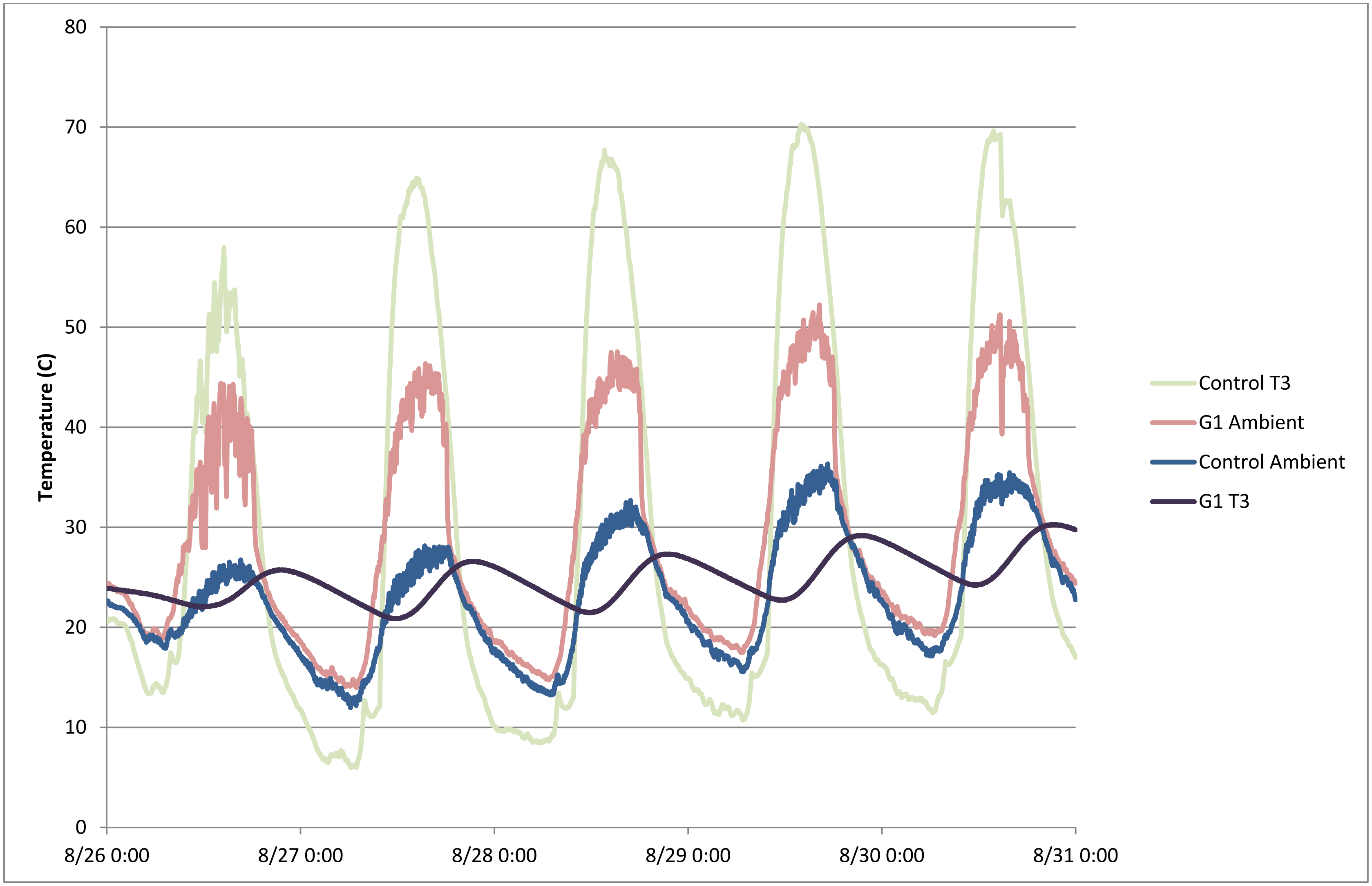


Figure 4: Sample plot for summer data for Hamerschlag Green Roof and Porter Control Roof, August 26-30, 2010

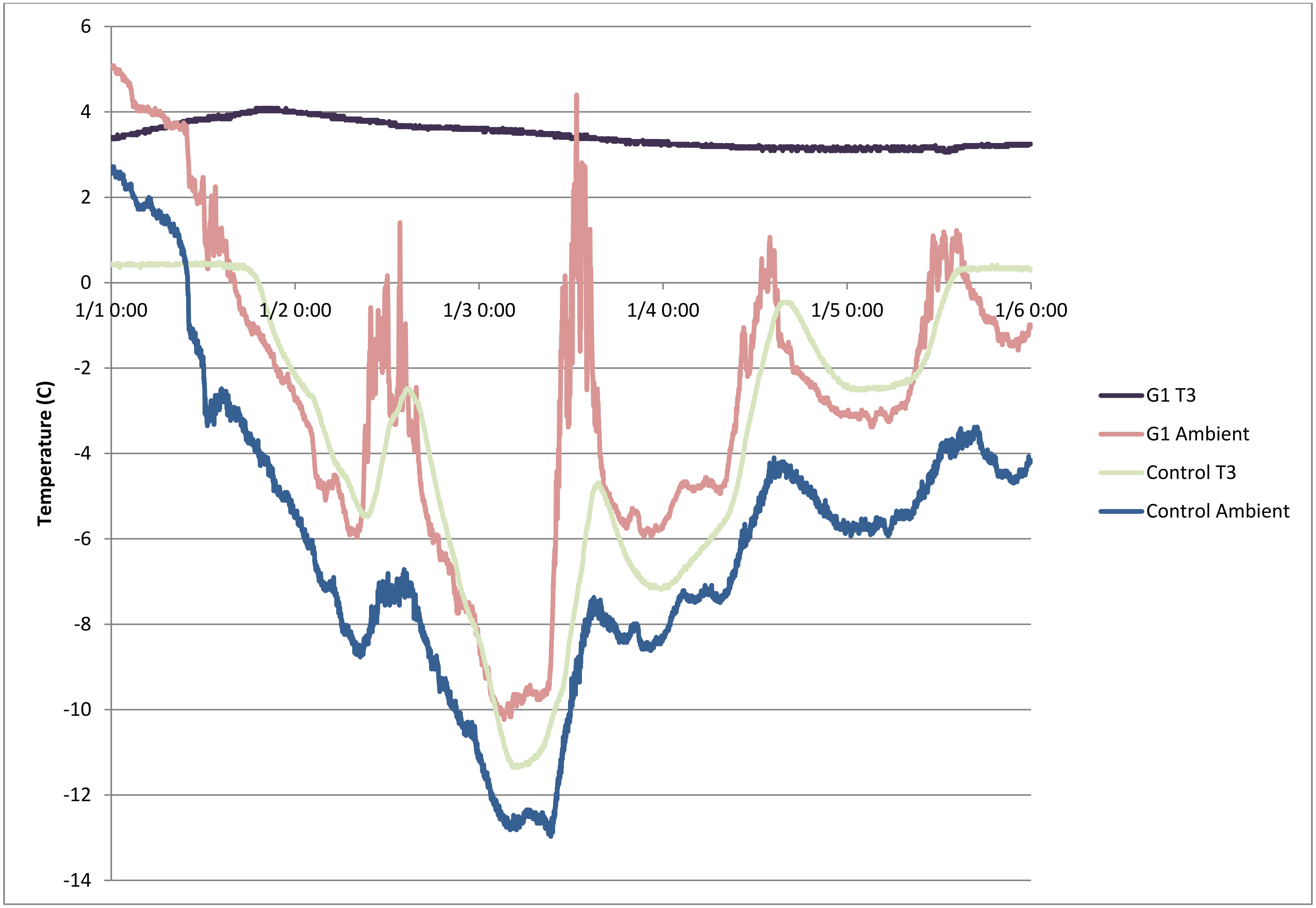


Figure 5: Sample plot for winter data for Hamerschlag green roof and Porter control roof, January 1-5 2010

Appendix C: Plant List

Species	Qty	
Achillea umbellate	35	72 cell plug
Alliumschoenoprassum	70	72 cell plug
Armeria maritima Alba	70	72 cell plug
Aster alpinus	35	72 cell plug
Campanula carpatica Blaue clips	35	72 cell plug
Campanula rotundifolia	70	72 cell plug
Dianthus carthusianorum	70	72 cell plug
Dianthus deltoids	70	72 cell plug
Delosperma nubigenum 'Basutoland'	70	72 cell plug
Euphorbia polychroma	20	72 cell plug
Orostachys boehmeri	70	72 cell plug
Hieracium pilosella	70	72 cell plug
Talanium parvifolium	70	72 cell plug
Talanium calycinum	70	72 cell plug
Lavandula angustifolia Dwarf Blue	20	Quart
Linum perenne	35	72 cell plug
Oenothera missouriensis	35	72 cell plug
Oreganum vulgare Compactum	50	72 cell plug
Petrorhagia saxifraga	50	72 cell plug
Salvia nemerosa Marcus	20	72 cell plug
Saxifraga cotyledon Southside Seedling	35	72 cell plug
Sedum acre 'Aureum'	280	72 cell plug
Sedum album	280	72 cell plug
Sedum album Coral Carpet	280	72 cell plug
Sedum cauticola 'Lidakense'	70	72 cell plug
Sedum cauticola 'Bertram Andreson'	70	72 cell plug
Sedum floriferum Weihenstephaner Gold	350	72 cell plug
Sedum hybridum Immergrunchen	350	72 cell plug
Sedum refexum	350	72 cell plug
Sedum cristatum	70	72 cell plug
Sedum forsteranum	70	72 cell plug
Sedum sexangulare	350	72 cell plug
Sedum spurium Album Suberbum	280	72 cell plug
Sedum spurium Fuldaglut	350	72 cell plug
Sedum 'Matrona'	35	72 cell plug
Silene maritime	70	72 cell plug
Thymus serpyllum	70	72 cell plug
Thymus citriodorus Silver Queen	35	72 cell plug
Verbascum phoeniceum	35	72 cell plug

Species	**Qty**	
Yucca filamentosa	5	Quart
Bouteloua curtipendula	20	
Calamagrostis ac Karl Forster	10	
		Height at planting (in)
Pinus mugo var. Pumilio	6	18
Buddleja alternifolia	3	36
Genista sagittalis	10	12
Jasminum nudiflorum	5	36

Appendix D: Calibration Procedures

Temperature Sensor Calibration

Purpose

To determine if the ambient temperature reading is accurate and if not, calculate a calibration factor to adjust the data to more reasonable levels.

Materials

- Bottle of Water
- Ice
- Thermometer

Procedure

1. Bring the bottle of water and the thermometer to the roof and let the water acclimate to the outdoor temperature.
2. Remove the ambient temperature sensor from the radiation shield.
3. Attach the thermometer and sensor together in a stable position protected from wind and direct sun.
4. Wait until temperature is stable.
5. Record the thermometer reading and the time.
6. Check live data from the measurement and automation mode screen. (see "navigating measurement and automation mode")
7. Record the temperature reading of the ambient sensor.
8. Add ice to the bottle of water.
9. Put the sensor and thermometer into the ice water bath and allow to acclimate.
10. Wait until the temperature is stable (should be at 0°C)
11. Record the temperature and time.
12. Read the sensor output in the measurement and automation mode.
13. Record temperature and time.
14. Return to the roof and make sure the thermometer temperature is stable at 0.

Data and Observations

If the ambient sensor is recording accurate date the output should be around 0 degrees C.

FP-TC-120 Module Calibration

Purpose

The purpose of this module calibration test is to determine if all channels in both the FP-TC-120 @3 and FP-TC-120 @4 are reading the same temperature output. From this, the accuracy of temperature readings can be determined since the thermocouple sensors are fed through the modules and read as temperature data.

Materials

- Bottle of Water
- "Control" Thermocouple Sensor
    - An unused thermocouple attached to a sensor wire with a blue connector.
- Thermometer

Procedure

1. Place the thermocouple and thermometer into the bottle of water.
2. Place the bottle of water in a secure location near the temperature sensor modules to be calibrated.

3. Make sure the bottle is located far from any heat or cooling source due to the sensitivity of the sensor.
4. Allowed the water in the bottle to acclimate to the temperature of the room where the modules are located for about one hour.
5. Close all active programs in Labview to allow for access to measurement and automation mode. (See "Navigating Measurement and Automation Mode")
6. Remove the sensor connected to channel 0 and attach the control thermocouple sensor.
7. Record the temperature observed from the live measurement and automation screen in Labview after waiting about 10 seconds.
8. Note any changes or erratic readings.
9. Remove the control thermocouple sensor from channel 0 and replace the appropriate sensor.
10. Repeat this process with all 16 channels in both modules.
11. After evaluating all 16 channels, asses that all connections are tight and all sensors are connected to the appropriate channels.

Data and Observations

Readings for each channel after the 10 second count were recorded. If any changes were observed soon after the original reading this was also recorded and an average was calculated. From these data an average of all possible readings was determined as well as a conversion factor for all temperature readings.

The data observed on April 1, 2008 show that all control readings were fairly consistent between each channel. This lack of variation translates to minimal conversion factors and the graphs of both original and adjusted data were virtually identical. Because these factors were so close to 1.0, these conversion factors were not used in Labview.

Conversion Factor Data

Module 1: FP-TC-120 @3

Channel	Sensor	Reading 1	Reading 2	Average	Conversion Factor
0	G1-TCE-1	24.910505	24.910505	24.910505	1.002995
1	G1-TCE-2	24.910505	24.910505	24.910505	1.002995
2	G1-T2-A	24.910505	24.910505	24.910505	1.002995
3	G1-T3-A	24.910505	24.910505	24.910505	1.002995
4	G1-T5	24.910505	24.910505	24.910505	1.002995
5	G2-T1	24.910505	24.910505	24.910505	1.002995
6	G2-T2-A	24.754864	24.848249	24.801557	1.007378
7	G2-T3-A	24.817122	24.848249	24.832686	1.006123

Module 2: FP-TC-120 @4

Channel	Sensor	Reading 1	Reading 2	Average	Conversion Factor
0	C1-TCE-2	25.003891	25.003891	25.003891	0.999253
1	C1-TCE-1	24.848249	24.848249	24.848249	1.005497
2	C1-T1	25.003891	25.035019	25.019455	0.998630
3	C1-T2-A	25.003891	25.035019	25.019455	0.998630
4	C1-T3-A	25.221790	25.221790	25.221790	0.990576
5	G2-T4	25.066147	25.159533	25.112840	0.994905
6	G1-T4	25.003891	25.066147	25.035019	0.998009
7	G2-T5	25.066147	25.066147	25.066147	0.996766