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Introduction

Building Re-tuning (BRT), as developed, documented and implemented in many buildings by Pacific Northwest National Laboratory (PNNL), is an effective set of low- and no-cost measures capable of reducing building energy consumption.

The effective use of BRT requires a building automation system (BAS) that meets minimum requirements, namely one that has:

1. Been properly configured and commissioned;
2. A prerequisite degree of connectivity to building system sensors; and
3. The ability to capture and store building system parameter values measured at regular intervals for an appreciable period, such as two weeks or longer.

However, the significant majority of today’s medium (25,000-50,000 sf) and large commercial/ institutional buildings (>50,000 sf) do not have a BAS that meets these standards, or may not have a BAS at all. To address this segment of buildings, the CUNY Building Performance Lab (BPL) has developed a set of BRT-like measures that use readily-available data loggers and sensors in lieu of a BAS. These instruments are included in defined kits for each measure, along with a notebook computer and/or tablet and associated data management software. The intent is for these measures to be sufficiently accessible and easily reproducible, so that they may be implemented by a broad audience of facility personnel.

BPL’s solution is referred to as the “noBAS BRT” protocol, and its measures are described in this user guide. Also included are step-by-step instructions to assemble the kits, initialize and install the field equipment, and extract and visualize resulting building system data. Finally, the diagnosis of certain conditions and suggested actions for more efficient building operations are offered for each measure.
Acknowledgements

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Furthermore, these techniques have been developed, piloted and refined with contributions from CUNY BPL interns, staff members, and management. The technique has also been used in many buildings, and the support of every building operator, engineer, custodian, and many others has proved invaluable. We are grateful for their cooperation.

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The Measures

The measures are divided into building system categories: heating systems, chiller plant, air handling units and rooftop units, and distribution and zone comfort.

For heating systems:

1. How is the boiler cycling, and what is the stack temperature?
2. Is hot water reset being used to control hot water supply temperature?
3. How is delta T in hot water loops?
4. Is the condensing boiler operating efficiently?
5. For a steam heating system, what is the condensate return temperature?

For chiller plant:

6. How is delta T between chilled water supply and return on the primary loop?
7. Is condenser water supply temperature well maintained?
8. How is cooling tower fan cycling?

For air handling units, rooftop units and packaged units:

9. Do the fans operate during unoccupied times?
10. How is my outside air controlled?
11. How is my outdoor air damper design minimum position?
12. Is reset being used to control the discharge air temperature (DAT)?
13. Is the discharge air temperature (DAT) hunting?
14. For RTUs, how are compressors cycling?

For distribution and zone comfort:

15. Is the HVAC system managing zone temperatures well?

For each measure, the guide includes the following information:

1. The name and description of the measure
2. The equipment and software required in the associated kit
3. The installation procedure for the kit’s components
4. Data acquisition procedures, i.e., uploading data from loggers
5. Visualization procedures (for creating trend charts)
6. Suggested actions
1. **noBAS Measures for Heating Systems**

1.1 **How is the boiler cycling, and what is the stack temperature?**

1.1.1 **Measure Description**

Look at both burner motor cycling and stack temperature to obtain a deeper understanding of the heating plant’s efficiency.

The burner motor(s)’ on/off status is logged to determine boiler staging performance. It is also used to determine whether short cycling is occurring, when used in combination with stack temperature. Short cycling not only indicates inefficient operation, but also that the motor longevity may be compromised. Stack temperature(s) also helps to determine whether the burner(s) is modulating.

**Note:** If you have a variable frequency drive on the burner motor, the kit described in this module is not capable of accurately assessing on/off status. In such cases, rely solely on stack temperature to help detect and diagnose performance issues.

1.1.2 **Kit Contents (Equipment and Software)**

**For Boiler Cycling:**

1. HOBO® Motor on/off data logger: UX90-004 or UX90-004M, one per boiler

**For Stack Temperature:**

2. Data logger: UX120-014M, up to one per boiler

3. Thermocouple probe, TCP6-K12, one per boiler

Also:

4. PC-based device with USB port (e.g. laptop or Surface Pro 3)

5. HOBOware® software

6. Microsoft Excel

7. CUNY BPL-provided macro-enabled Excel file (Boiler Cycling Visualization.xlsm)
1.1.3 Initialization Procedure: HOBO® Motor On/Off Data Logger (UX90-004)

1. Open the HOBOware® software on your computer.

2. To connect the logger to your computer, plug the small end of the USB cable into the side of logger and plug the large end into the USB port of the computer (with HOBOware® software pre-installed).

3. If the “Select Device” window pops up, make sure that the radio button showing the HOBO® UX90-004M Motor On/Off is selected and click “OK”.

4. Select the launch icon on the HOBOware® toolbar on your laptop to open the configuration options for the logger.
5. Ensure that the logger has enough battery life for the trending period before you start the configuration process.

6. In the description text box, type a boiler name that describes the boiler, as seen in the example below. The general naming template includes the following: create a logger name that includes the building name, space served, system name, and parameter measured. Note that there is a 40-character limit.

![Image](image1.png)

7. In the “Sensors” section, choose the type of logging configuration. The sensors can be configured to log data either by runtime or state. **It is critical that you select “State”**.

![Image](image2.png)

**Note:** When the logger is configured to log state change, the logging interval option is greyed out and cannot be selected for changes. The logging duration is dependent on event duration.

8. Under “Start Logging”, choose the start date and time. Set the logger to start after the installation is complete. Make sure that the start logging time is on the hour. For example, start at 12:00 PM instead of 12:02PM, 12:15 PM, or 12:30 PM.

![Image](image3.png)

9. Under “Stop Logging”, select “never (wrapping)”. 

![Image](image4.png)
10. By default, the LCD will always remain on while logging data. Verify that the “Turn LCD off” box is not checked under “Options”.

11. Click the “Delayed Start” button to launch the logger.

12. Wait until the logger completes launching.
13. A fully configured logger launch should look like this:

![Logger Launch Interface](image)

14. Disconnect the logger from your computer by unplugging the small USB end from the side of the logger.

The next step is to deploy and calibrate the logger on the boiler motor.
1.1.4 Installation Procedure: HOBO® Motor On/Off Data Logger (UX90-004)

1. Deploy the logger on the motor from which you wish to collect your data. Use the mounting magnets on the back of the logger to attach it at a fixed location.

2. When the motor is running, hold down the calibration button until the LCD display reads “Pass”. If the LCD display reads “fail”, the logger needs to be calibrated again. The signal strength should be at least 3 bars, so orient the logger as required to increase the signal strength. Calibration helps the logger identify the magnetic field of that particular motor and ignore any surrounding magnetic fields.

1.1.5 Initialization Procedure: 4 Channel Thermocouple Data Logger (UX120-014M) and Thermocouple Probe (TCP6-K12)

1. Open the HOBOware® Software.

2. To connect the logger to your computer, plug the small end of the USB cable into the side of logger and plug in the large end into the USB port of the computer (with HOBOware® software pre-installed).
3. If the “Select Device” window pops up, make sure that the radio button showing the HOBO UX120-014M 4 Channel Thermocouple logger is selected and click “OK”.

4. Select the launch icon on the HOBOware® toolbar on your laptop to open the configuration options for the loggers.

5. Ensure that the logger has enough battery life for the trending period before you start the configuration process.

6. In the description text box, type a name based on location and function of the equipment, as seen in the example below.
7. In the “Sensors” section, name the thermocouple ports that will be used according to the measure being recorded. For example: Stack 1 Temp.

![Image of Sensors section]

8. In the “Deployment” section, set “Logging Interval” to 1 minute.

![Image of Deployment section]

9. Under “Start Logging”, choose the start date and time for logging data. Set the loggers to start after the installation is complete. Make sure that the start logging time is on the hour. For example, start at 12:00 PM instead of 12:02PM, 12:15 PM, or 12:30 PM.

![Image of Deployment section with start date and time set]
10. Under stop logging, select “Never (wrap when full).”

11. By default, the LCD will always remain on while logging data. Verify that “turn LCD off” box is not checked under “Options”.

12. Click the “Delayed Start” button to launch the logger.

13. A “Launching Logger” window will appear to save all the sections in the initialization procedure. Wait for the progress bar to reach 100% before proceeding.
14. A fully configured logger launch should look like this:

![Logger Launch Screen]

15. Disconnect the logger from your computer by unplugging the small USB end from the side of the logger.

1. Insert the probe end of the thermocouple (TCP6-K12) into the hole on the boiler stack and secure it by using high temperature flue tape. Use tape that is rated up to at least 600°F. Make sure that the thermocouple probe is not installed too close to the heating source and not too close to the end of the stack. If you install the probe in these locations, you may get stack temperature readings that are too high or too low, respectively.
2. Deploy the logger on the dedicated boiler from which you wish to collect your data. Use mounting magnets on the back of the logger to attach it at a fixed location, or use mounting tape and tie break cables.

3. Insert Thermocouple (TCP6-K12) into logger (UX120-014M) as shown in photo above.

**Note:** One data logger is required per boiler, although it may be possible to share one data logger among two or more boilers.
1.1.7 Data Acquisition Procedure: HOBO® Motor On/Off Data Logger (UX90-004)

To retrieve data from the UX90-004 logger:

1. On your Laptop/Surface Pro, open HOBOware®.

2. Connect the logger by plugging the small end of the USB cable into the side of the logger and plugging the large end into a USB port on your computer.

3. If the “Select Device” window pops up, make sure that the radio button showing the HOBO® UX90-004 Motor On/Off is selected and click “OK”.

4. Click “Readout” on the HOBOware® toolbar.

5. If the loggers were previously active, select “Don’t Stop” unless you are removing the loggers from the site.
6. Wait for the data to be read out. Once the readout is complete, choose a location and/or a new filename, or accept the default location and name to save the data.

7. Click “Save”.

8. The plot setup window will appear after you save. Make sure that all boxes are checked for the series that were created in the initialization procedure.

9. The plot setup window should look like this:

   - Under “Select Internal Logger Events to plot”, click “None”
   - Click “Plot” at the bottom of the window. Clicking “Plot” will open up your graph (as shown below).
10. Click on “Export Table Data” on the HOBOware® toolbar as shown below. Save the document to a new folder designated for your data. Make sure this folder is on your desktop, as it will be used during the visualization steps.

11. Save the file as a comma-separated value (CSV) file. This CSV file can be used for further investigation.
1.1.8 Data Acquisition Procedure: HOBO® 4 Channel Thermocouple Data Logger (UX120-014M) and Thermocouple Probe (TCP6-K12)

To retrieve data from the logger:

1. On your laptop/Surface Pro, open HOBOware®.

2. Connect the logger by plugging the small end of the USB cable into the side of the logger and plugging the large end into a USB port on your computer.

3. If the “Select Device” window pops up, make sure that the radio button showing the HOBO® UX120-014M 4 Channel Thermocouple is selected and click “OK”.

4. Click “Readout” button on HOBOware® toolbar.

5. If the loggers were previously active, select “Don’t Stop” unless you are removing the loggers from the site.

6. Wait for the data to be read out. Once the readout is complete, choose a location and/or a new filename, or accept the default location and name to save the data.

7. Click “Save”.

8. The plot setup window will appear after you save. Make sure the series1 box is checked.
8. The plot setup window will appear after you save. Make sure the series1 box is checked.

9. The plot setup window should look like this:

   - Under “Select Internal Logger Events to plot”, click “None”
   - Click “Plot” at the bottom of this window. Clicking “Plot” will open your graph, as shown below.

10. Click on “Export Table Data” on the HOBOware® toolbar as shown below. Save the document to a new folder designated for your data. Make sure this folder is on your desktop, as it will be used during the visualization procedure.

11. Save the file as a comma-separated value (CSV) file. This CSV file can be used for further investigation.
1.1.9 Data Visualization Procedure

Warning:
If the following image appears at any point in the process, click “End”, and check to make sure all of the directions both in the manual and in the file were followed. If so, attempt to continue if possible. If not, please contact BPL with your specific circumstances.

1. Download the CUNY BPL-provided macro-enabled Excel file named “Boiler Cycling Visualization.xlsm” and save it in the same folder as your logged data.

2. Open the folder and check to see that the data files are labeled correctly. Use the file names shown in the table below. (This is to ensure that the Microsoft Excel macro-enabled program can read the files).

<table>
<thead>
<tr>
<th>File Name</th>
<th>Contained Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>boiler_stack.csv</td>
<td>Boiler Stack Temperature</td>
</tr>
<tr>
<td>boiler_motor.csv</td>
<td>Boiler Motor Status</td>
</tr>
</tbody>
</table>
The Microsoft Excel file can manage up to five boilers. The folder should look similar to this:

3. Open the “Boiler Cycling Visualization” macro-enabled Microsoft Excel document.

4. In order for the program to run, you must enable editing, enable content, and trust the document.

5. Click on “Save As” under “File” on the Microsoft Excel top bar to the folder that contains your boiler(s)’ data, and rename this Microsoft Excel file (e.g. “BoilerCyclingVisualization MyBuilding.xlsm”).

6. Follow the steps outlined in the macro-enabled Excel file. **Note:** If data from previous visualizations is in the Microsoft Excel sheet, it can be easily erased by clicking “Clear Data” underneath the BPL Logo on the left side.
a. Choose the number of boilers that you have data for

![Excel workbook screenshot]

b. Click “Import” to import your data. The headers will fill themselves in based on the number of boilers you have. This may take a moment depending on how many boilers you have and the amount of data you collected.

c. Click “Plot Boilers”. This function will plot all your boiler data. The loading time will vary depending on how many boilers you have and the amount of data you collected.

Note: When the graphs appear, they may seem crowded and you will likely see overlap as in the example below if your boiler was cycling while data were collected. This will change when you select the date/time range you would like to visualize; this process is outlined in the next step.
d. The time scale can be changed by using the first dropdown on the left underneath the “Plot” button. The top dropdown defines the start date, and the dropdown directly beneath it defines the length of time. For the boiler, the chart number must also be selected using the dropdown located directly beneath the time length dropdown. Enact changes by clicking “Change Time Range” to choose the beginning date/time and an end date/time that you would like to view.

Note: Your time scale should allow you to see the nuances of your boiler cycling and stack temperature as shown in the image below.

Note: When the graphs appear, they may seem crowded and you will likely see overlap as in the example below if your boiler was cycling while data were collected. This will change when you select the date/time range you would like to visualize; this process is outlined in the next step.
e. If you want to export the graph you have created, simply click “Export Chart” located above “Clear Data”. An image file will be created and put in the folder in which you have the macro-enabled Microsoft Excel file with a time stamp in the name. If you have created multiple plots in one file, you can select which you would like to export.
1.1.10 Suggested Actions

Burn time is determined by looking at stack temperature cycles on the trend chart. The duration commences when stack temperature begins to rise, and it ends when stack temperature drops precipitously.

Look at stack temperature for the individual boilers. If a boiler’s stack temperature is relatively constant during firing, no modulation is occurring. If the burners are capable of modulation, they should be serviced to enable modulation.

If the burn time is very short without a significant variation in stack temperature, consider the following options. For a central plant with only one boiler, check pressuretrol (aquastat) settings for steam (hot water) boilers. Settings should account for a broad enough operating differential to satisfy the two following criteria: first and foremost, such settings creating the variation in pressure (hot water temperature) should ensure the boiler’s ability to provide steam (hot water) appropriately and effectively to the distribution system. Second, the operating differential should be sufficiently large to minimize boiler cycling, but not so large as to cause too broad a range of steam pressure (hot water temperature).

For boilers used in lead-lag mode, ensure that the pressuretrol (aquastat) settings are properly set on the respective boilers to prevent short cycling. Short cycling can occur in either boiler, but is more common for the boiler in lag mode. It is common to rotate the role of a boiler (whether in lead, lag or standby position), and the changes must be made to pressuretrol (aquastat) settings when the boiler roles are changed. Alternatively, installing a programmable lead-lag sequencing controller capable of changing pressuretrol (aquastat) settings will automatically apply the appropriate settings when the boiler roles are changed.

For central plant configurations with burners capable of modulation and multiple boilers set in lead-lag mode, short cycling of the lag boiler may persist. To avoid short cycling, consider using an agastat to delay the call for the lag boiler to fire.

Due to pre-purge and post-purge, motors are on longer than burners. The trend chart may indicate excessive motor cycling based on the rate at which the motor changes from “off” to “on” status and/or by noticing very short off cycles.

Roughly speaking, a good stack temperature at high fire is under 400°F for a gas-fired boiler and under 500°F for an oil-fired boiler.

A high stack temperature may indicate that the tubes have soot or scale buildup, inhibiting heat transfer and therefore reducing efficiency. Clean and tune boilers/burners, including a check on the burner modulation and the air fuel ratio.
1.2 Is a hot water reset used to control the hot water supply temperature?

1.2.1 Measure Description

Determine whether a hot water temperature reset schedule based on outdoor air temperature is in use and operating properly. This requires monitoring the hot water supply temperature and the outside air temperature.

It may be the case that a hot water reset is being used; however, this measure will help to verify its performance.

1.2.2 Kit Contents (Equipment and Software)

For Hot Water Temperature:

1. 4-Channel Thermocouple Logger: UX120-014M, one per boiler
2. Surface Temp Self-Adhesive Thermocouple: two per analog logger
3. Pipe insulation
4. Pipe insulation tape

For Outside Air Temperature:

5. Temperature/Relative Humidity Weatherproof Logger: MX2301, one per building

Also Required:

6. PC-based device with USB port (e.g. laptop or Surface Pro)
7. Mobile device with Bluetooth capabilities
8. Hoboware® software installed on a laptop or Surface Pro
9. HoboMobile™ app installed on a tablet or mobile device
10. Microsoft Excel
11. CUNY BPL-provided macro-enabled Excel file (Hot Water Reset Visualization.xlsm)
1.2.3 Initialization Procedure: 4 Channel Thermocouple Logger (UX120-014M)

1. Open the HOBOware® Software on your computer.

2. To connect the logger to a computer, plug the small end of the USB cable into the side of logger and plug the large end into the USB port of the computer (with HOBOware® software pre-installed).

3. If the “Select Device” window pops up, make sure that the radio button showing the HOBO® UX120-014 logger is selected and click “OK”.

4. Select the launch icon on the HOBOware® toolbar on your laptop to open the configuration options for the logger.
5. Ensure that the logger has enough battery life for the trending period before you start the configuration process.

6. In the description text box, type a name based on location and function of the equipment. (e.g. “SiteLocation_HWS_Temp”). Note that there is a 40-character limit.

7. In the “Sensors” section, the thermocouple ports should be named after the parameter that is being recorded (e.g. “Hot Water Supply Temp”).

8. In the “Deployment” section, set the logging interval to 15 minutes.
9. Under “Start Logging”, select “On Date/Time”. Set the loggers to start after the installation is complete. Make sure that the start logging time is on the hour. For example, start at 12:00 PM instead of 12:02 PM, 12:15 PM, or 12:30 PM.

10. Under “Stop Logging”, select “never (wrapping)”.

11. By default, the LCD will always remain on while logging data. Verify that the “Turn LCD off” box is not checked.

12. Click “Delayed Start” to launch the logger.

13. A "Launching Logger” window will appear to save all the sections in the initialization procedure. Wait for the progress bar to reach 100% before proceeding

14. Disconnect logger from computer by unplugging the small USB end from the side of the logger.
1.2.4 Initialization Procedure: Wireless Temperature /Relative Humidity Weatherproof Logger (MX2301)

1. Enable Bluetooth on your device and then open the HOBOmobile™ app.

2. Ensure that the logger has enough battery life for the trending period before you start the configuration process.

3. Tap the logger with the correct serial number. The serial number is shown in both the top left and top right corner of the image below.

4. Name the logger.
   a. Tap “Configure”.
   b. Tap “Name”.

6. Disconnect logger from computer by unplugging the small USB end from the side of the logger.
c. Change the logger name to include the building name, space served, system name, and parameter measured (e.g. “AnytownHS_Boiler_OAT.”) Note that there is a 20-character limit. Tap “Done” after typing in the new name.

5. Tap “Logging Interval”. Set the logging interval to 15 minutes and then tap “Done”.

![Deployment Name](image1.png)

![Logging Interval](image2.png)
   
a. Tap “Start Logging” and then “On Date/Time”.
   
b. Under “Start Logging”, choose the start date and time for logging data. Set the loggers to start after the installation is complete. Make sure that the start logging time is on the hour. For example, start at 12:00 PM instead of 12:02PM, 12:15 PM, or 12:30 PM. Tap “Done”.
7. Select memory and time options.

   a. Tap “Stop Logging”.

   - DEPLOYMENT INFO
     - Name: AnytownHS_Boiler_OAT
     - Group:
     - Location: 40°49’10” N 73°56’58” W
     - Deployment Number: 1

   - LOGGING SETUP
     - Logging Interval: 15m
     - Logging Duration: ~1.2 years
     - Start Logging: 07/24/2017, 18:00:00 EDT
     - Stop Logging: When memory fills
b. Select “Never (Wrap When Full)” as the memory option. Additionally, select “Never” in the time option section.

8. Tap “Start”. The “Configure Success” message indicates that the logger was successfully initialized.
1.2.5 Installation Procedure: 4-Channel Thermocouple Logger (UX120-014M)

1. Stick the first temperature sensor on the hot water supply pipe, ensuring that the sensor is in good physical contact with the pipe and under insulation. This should ensure that there is consistent thermal conductivity between the pipe and the temperature sensor. Be sure that the sensor is secure.

2. Stick the second temperature sensor on the hot water return pipe, ensuring that the sensor is in physical contact with the pipe and under insulation. Make sure that the sensor is secure.

   Note: The material and thickness of pipes vary. To ensure that the temperature sensor is measuring the temperature of the fluid inside the pipe, wrap insulation all the way around the pipe. Also, make sure the insulation traverses twelve to eighteen inches along the pipe, with the sensor centered in the insulation and the insulation secured with pipe insulation tape. This will help to minimize measurement error due to heat transfer to and/or from surroundings.

3. Deploy the UX120-014M logger within reach of the thermocouple(s). Use the mounting magnets on the back of the logger to attach it at a fixed location, or use mounting tape and cable ties if the surface is non-magnetic.
4. Insert the blade connector end of the thermocouple (Omega®SA2C-K Series) into the first two ports on the data logger. Be sure to connect the thermocouples to their corresponding ports as they were set up when initializing the logger.

1.2.6 Installation Procedure: Temperature /Relative Humidity Weatherproof Logger (MX2301)

Using cable ties, mount the weatherproof temp logger to a location outside of the building where it is protected from direct sunlight but is still exposed to airflow. It is important that the logger is placed where it will not be influenced by any sources of heat or other factors that could add error to the measurements; this includes but is not limited to, exhaust vents, dampers, and chilled or hot water pipes.
1.2.7 Data acquisition Procedure – 4 Channel Thermocouple Data Logger (UX120-014M)

1. On your laptop or Surface Pro, open HOBOware®.

2. Connect the logger by plugging the small end of the USB cable into the side of the logger and plugging the large end into a USB port into the computer.

3. Click “Readout” on the HOBOware® toolbar.

4. In the “Select Device“ window that pops up, make sure the radio button showing the HOBO UX120-014M 4 Channel Thermocouple is selected. Click “OK”.

5. If the loggers were previously active, select “Don’t Stop”, unless you are removing the loggers from the site.

6. Wait for the data to be read out. Once the readout is complete, choose a location and/or a new filename, or accept the default location and name to save the data.

7. Click “Save”.

8. The plot setup window will appear after you save. Make sure that all boxes are checked for the series that were created in the initialization procedure.

9. The plot setup window should look like this:

   - Under “Select Internal Logger Events to plot”, click “None”.
   - Click “Plot” at the bottom of the window. Clicking “Plot” will open up your graph (as shown below).

If the loggers were previously active, select “Don’t Stop” unless you are removing the loggers from the site. Once the readout is complete, choose a location and/or a new filename, or accept the default location and name to save the data. Click “Save”. The plot setup window will appear after you save. Make sure that all boxes are checked for the series that were created in the initialization procedure. The plot setup window should look like this:

   - Under “Select Internal Logger Events to plot”, click “None”.
   - Click “Plot” at the bottom of the window. Clicking “Plot” will open up your graph (as shown below).
5. If the loggers were previously active, select “Don’t Stop”, unless you are removing the loggers from the site.

![Stop Logger Window]

6. Wait for the data to be read out. Once the readout is complete, choose a location and/or a new filename, or accept the default location and name to save the data.

7. Click “Save”.

8. The plot setup window will appear after you save. Make sure that all boxes are checked for the series that were created in the initialization procedure.

9. The plot setup window should look like this:

   - Under “Select Internal Logger Events to plot”, click “None”.
   - Click “Plot” at the bottom of the window. Clicking “Plot” will open up your graph (as shown below).

![Plot Setup Window]

![Graph Example]
10. Click on “Export Table Data” on the HOBOware® toolbar as shown below. Save the document to a new folder designated for your data. Make sure this folder is on your desktop, as it will be used during the visualization steps.

11. Save the file as comma-separated values (CSV) file. This CSV file can be used for further investigation.
1.2.8 Data Acquisition Procedure – Wireless Temperature Weatherproof Logger (MX 2301)

1. Enable Bluetooth on your device and then open the HOBOmobile™ app.

2. Tap the logger with the correct serial number. The serial number is shown in both the top right corner of the highlighted row in the image below.

3. Tap “Readout” to download the data. Tap “OK” when the “Readout success” message appears.
4. Tap and then tap the mini graph to view a larger version of the graph or to share the file. Examples of the graphs that will appear are shown below. Tap to export the file.
5. Tap “CSV” and select either “Mail” or “Copy to Dropbox” to export the file.

6. Save the file as comma-separated values (CSV) file. This CSV file can be used for further investigation.
1.2. 9 Data Visualization Procedure:

**Warning:**
If the following image appears at any point in the process, click “End”, and check to make sure all of the directions both in the manual and in the file were followed. If so, attempt to continue if possible. If not, please contact BPL with your specific circumstances.

1. Download the CUNY BPL-provided macro-enabled Microsoft Excel file named “Hot Water Reset visualization.xlsm” and save it in the same folder as your logged data.

2. Open the folder and check to see that the data files are labeled correctly. Use the file names shown in the table below. (This is to ensure that the Microsoft Excel macro-enabled program can read the files).

<table>
<thead>
<tr>
<th>File Name</th>
<th>Contained Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>HWST.csv</td>
<td>Hot Water Supply Temperature</td>
</tr>
<tr>
<td>OAT.csv</td>
<td>Outdoor Air Temperature</td>
</tr>
</tbody>
</table>

3. Open the “Hot Water Reset Visualization” macro-enabled Microsoft Excel File.

4. In order for the program to run, you must enable editing, enable content, and trust the document.

5. Click on “Save As” under “File” on the Microsoft Excel top bar to the folder that contains your boiler(s)’ data, and rename this Microsoft Excel file (e.g. “Boiler-CyclingVisualizationMyBuilding.xlsm”).

Save the file as a comma-separated value (CSV) file. This CSV file can be used for further investigation.
6. Follow the steps outlined in the macro-enabled Microsoft Excel file. **Note:** If data from previous visualizations is in the Microsoft Excel sheet, it can be easily erased by clicking “Clear Data” underneath the BPL Logo on the left side.

a. Choose the number of boilers that you have data for.

b. Click “Import” to import your data. The headers will fill themselves in based on the number of boilers you have. The loading time will vary depending on how many boilers you have, the amount of data you collected, and the performance of your device.
c. Click "Plot Boilers". This function will plot all your boiler data. The loading time will vary depending on how many boilers you have and the amount of data you collected.

Note: When the graphs appear, they may seem crowded and you will likely see overlap if your boiler was cycling while data were collected, as shown in the example below. This will change when you select the date/time range you would like to visualize; this process is outlined in the next step.
c. Click “Plot Boilers”. This function will plot all your boiler data. The loading time will vary depending on how many boilers you have and the amount of data you collected.

Note: When the graphs appear, they may seem crowded and you will likely see overlap if your boiler was cycling while data were collected, as shown in the example below. This will change when you select the date/time range you would like to visualize; this process is outlined in the next step.
d. The time scale can be changed by using the first dropdown on the left underneath the “Plot” button. The top dropdown defines the start date, and the dropdown directly beneath it defines the length of time. For the boiler, the chart number must also be selected using the dropdown located directly beneath the time length dropdown. Enact changes by clicking “Change Time Range” to choose the beginning date/time and an end date/time that you would like to view.
1.2.10 Suggested Actions

Hot water supply temperature (HWST) can be reset based on outdoor air temperature (OAT) to reduce heating energy consumption. High HWST is appropriate when OAT is low, but energy savings can be achieved when a low HWST is used while OAT is high (i.e., when only modest heating is required).

If the data show that hot water reset is not being used or not operating properly, enable (or repair) a reset capability so that the HWST is reduced when the OAT increases. A typical controller might have HWST vary from 140-180°F when OAT varies from 20-50°F. This ability is more reliable and effective with a controller. It may also be implemented manually, i.e., checking the weather and setting the HWST set point daily.

Buildings with zone temperature setbacks and zone controls for the hot water system help to reduce heating energy consumption during unoccupied times. For buildings with hot water systems that do not have zone setback capabilities, program the hot water reset controller to reduce the relationship between HWST and OAT. For example, reduce the HWST by 20°F during unoccupied times relative to HWST during occupied times.
1.3 How is delta T in the hot water loops?

1.3.1 Measure Description

This measure applies to loops in hot water distributions systems with hot water pumps controlled by VFDs that maintain loop differential pressure. Depending on the system design, this measure may apply to the primary loop, secondary loops, or tertiary loops.

In a hot water heating system, the difference between Hot Water Supply Temperature and Hot Water Return Temperature (HWST – HWRT) is often called “delta T”.

A relatively low delta T when loads are high could indicate over pumping in the hot water loop. Use this measure to monitor for the possibility of reducing hot water pumping energy.

1.3.2 Kit Contents (Equipment and Software)

1. HOBO® 4-Channel Thermocouple Logger: UX120-014M
2. OMEGA® SA2C-K Surface Temperature Self-Adhesive Thermocouple, two per analog logger.
3. Pipe insulation
4. Pipe insulation tape

Also:

5. PC-based device with USB port (e.g. laptop or Surface Pro)
6. HOBOware® software
7. Microsoft Excel
8. CUNY BPL-provided macro-enabled Excel file (Hot water loop delta T.xlsm)
1.3.3 Initialization Procedure: HOBO® 4 Channel Thermocouple Data Logger (UX120-014M)

1. Open the HOBOware® software on your computer.

2. To connect the logger to a computer, plug the small end of the USB cable into the side of logger and the large end into the USB port of the computer (with HOBOware® software pre-installed).

3. If the “Select Device” window pops up, make sure that the radio button showing the HOBO® UX120-014 logger is selected and click “OK”.

UX120–014M
4. Select the launch icon on the HOBOware® toolbar on your laptop to open the configuration options for the logger.

5. Ensure that the logger has enough battery life for the trending period before you start the configuration process.

6. In the description text box, type a name based on location and function of the equipment (e.g. “SiteLocation_HotWaterPipe”). Note that there is a 40-character limit.
7. In the “Sensors” section, the thermocouple ports should be named after the parameters that are being recorded (e.g. “HW Supply Temp” and “HW Return Temp”).

8. In the “Deployment” section, set the logging interval to 15 minutes.

9. Under “Start Logging”, choose the start date and time. Set the logger to start after the installation is complete. Make sure that the start logging time is on the hour. For example, start at 12:00 PM instead of 12:02 PM, 12:15 PM, or 12:30 PM.

10. Under “Stop Logging”, select “never (wrapping)”. 
11. By default, the LCD will always remain on while logging data. Verify that the “Turn LCD off” box is not checked.

12. Click the “Delayed Start” button to launch the logger.

13. A “Launching Logger” window will appear to save all the sections in the initialization procedure. Wait for the progress bar to reach 100% before proceeding.

14. Disconnect the logger from the computer by unplugging the small USB end from the side of the logger.
1.3.4 Installation Procedure: HOBO® 4 Channel Thermocouple Data Logger (UX120-014M) and Temperature Sensors (TMC50-HD)

1. Stick the first temperature sensor on the hot water supply pipe, ensuring that the sensor is in good physical contact with the pipe and under insulation. This should ensure that there is consistent thermal conductivity between the pipe and the temperature sensor. Be sure that the sensor is secure.

   **Note:** The material and thickness of pipes vary. To ensure that the temperature sensor is measuring the temperature of the fluid inside the pipe, wrap insulation all the way around the pipe. Also, make sure the insulation traverses twelve to eighteen inches along the pipe, with the sensor centered in the insulation and the insulation secured with pipe insulation tape. This will help to minimize measurement error due to heat transfer to/from surroundings.

2. Stick the second temperature sensor on the hot water return pipe, ensuring that the sensor is in physical contact with the pipe and under insulation. Make sure that the sensor is secure.

3. Deploy the UX120-014M logger within reach of the thermocouples. Use mounting magnets in the back of the logger to attach at a fixed location or use mounting tape and break ties if the surface is non-magnetic.

4. Insert the blade connector end of the thermocouple (Omega®SA2C-K Series) into the first two ports on the data logger. Be sure to connect the thermocouples to their corresponding ports as they were set up when initializing the logger.
1.3.5 Data Acquisition Procedure: HOBO® 4 Channel Thermocouple Data Logger (UX120-014M) and Temperature Sensors (TMC50-HD)

To retrieve data from the UX120-014M data logger:

1. Open HOBOware® on your laptop/Surface Pro,

2. Connect the logger by plugging the small end of the USB cable into the side of the logger and the large end into a USB port on the computer.

3. If the “Select Device” window pops up, make sure that the radio button showing the HOBO® UX120-014M Channel Thermocouple is selected and click “OK”.

4. Click the “Readout” button on the HOBOware® toolbar.

5. If the loggers were previously active, select “Don’t Stop” unless you are removing the loggers from the site.

6. Wait for the data to be read out. Once the readout is complete, choose a location and/or a new filename, or accept the default location and name to save the data.

7. Click “Save”.
6. Wait for the data to be read out. Once the readout is complete, choose a location and/or a new filename, or accept the default location and name to save the data.

![Save dialog box](image)

7. Click “Save”.

8. The plot setup window will appear after you save. Make sure that all boxes are checked for the series that were created in the initialization procedure.

9. The plot setup window should look like this:

![Plot setup window](image)

- Under “Select Internal Logger Events to plot”, click “None”
- Click “Plot” at the bottom of the window. Clicking “Plot” will open up your graph (as shown below).
10. Click on “Export Table Data” on the HOBOware® toolbar as shown below. Save the document to a new folder designated for your data. Make sure this folder is on your desktop, as it will be used during the visualization steps.

11. Save the file as comma-separated values (CSV) file. This CSV file can be used for further investigation.
1. Download the CUNY BPL-provided macro-enabled Microsoft Excel file named “Hot water loop delta T.xlsm” and save the file in the same folder where your logged data is located.

2. Open the folder and check to see that the data files are labeled correctly. Use the file names shown in the table below. (This is to ensure that the Excel macro-enabled program can read the files).

<table>
<thead>
<tr>
<th>File Name</th>
<th>Contained Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>HWST.csv</td>
<td>Hot Water Supply Temperature</td>
</tr>
<tr>
<td>HWRT.csv</td>
<td>Hot Water Return Temperature</td>
</tr>
</tbody>
</table>

3. Open the “Hot water loop delta T.xlsm” macro enabled excel document.

4. In order for the program to run, you must enable editing, enable content, and trust the document.

5. Click on “Save As” under “File” on the Microsoft Excel top bar to the folder that contains your boiler(s)’ data, and rename this Microsoft Excel file (e.g. Hot Water Primary Loop Delta T_my building).
6. Follow the steps outlined in the macro-enabled Excel file. **Note:** If data from previous visualizations is in the Microsoft Excel sheet, it can be easily erased by clicking “Clear Data” underneath the BPL Logo on the left side.

a. Click “Import” to import your data. Then, click “Plot.” This function will plot your data. The loading time will vary depending on the file size.

<table>
<thead>
<tr>
<th>Instructions:</th>
<th>Date/Time</th>
<th>HWST</th>
<th>HWRT</th>
<th>Delta T</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Import Data</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Import</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. To view charts click plot</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Plot</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

HWST and HWRT (°F)

Loop Delta T

Loop Delta T (°F)

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1) Download the CUNY BPL-provided macro-enabled Microsoft Excel file named "Hot water loop delta T.xlsm" and save the file in the same folder where your logged data is located.

2) Open the folder and check to see that the data files are labeled correctly. Use the file names shown in the table below. (This is to ensure that the Excel macro-enabled program can read the files).

3) Open the "Hot water loop delta T.xlsm" macro enabled excel document.

4) In order for the program to run, you must enable editing, enable content, and trust the document.

5) Click on “Save As” under “File” on the Microsoft Excel top bar to the folder that contains your boiler(s)’ data, and rename this Microsoft Excel file (e.g. Hot Water Primary Loop Delta T_my building).

6) Follow the steps outlined in the macro-enabled Excel file.
b. Change the time range if the graph looks too crowded. The time range can be changed by using the first dropdown on the left underneath the “Plot” button. The top dropdown defines the start date, and the dropdown directly beneath it defines the length of time. Enact changes by clicking “Change Time Range” after selecting the start date and the time duration.

c. If you want to export the graph you have created, simply click on the ‘Export Chart’ icon which is located above the ‘Clear Data’ icon. An image file will be created and located in the folder in which you have the Macro-enabled Excel File with a time stamp in the name. If you have created multiple plots in one file, you can select which you would like to export.
1.3.7 Suggested Actions

When heating loads are low, not much heat is imparted to the zones, and a relatively small delta T (HWST – HWRT) is expected.

However, if loads are high, i.e., significant heating is required, a delta T in the loop will be larger. Delta T partially and heavily depends on system design parameters. For example, for all other things being equal, a hot water loop with fewer linear feet of fin and tube radiators will have a lower delta T compared to one with many more linear feet of fin and tube radiators.

A relatively low delta T for your system indicates that there may be over pumping in your hot water loop. Given that the pump has a VFD that is controlled to maintain loop differential pressure, it may be possible to reduce the loop differential pressure set point (LDPSP) and still adequately meet heating needs.

Care must be taken to not reduce the LDPSP so much that inadequate hot water is pumped to the zones. If so, under pumping would compromise the ability of the system to meet the zone temperature set points.

In addition, if the loop being investigated is the primary loop and there are secondary loops, consider the following. When reducing the LDPSP, avoid inadequate pumping such that the secondary loops over pump and reverse the flow in portions of the primary loop. This will occur if the sum of the flow rates in the secondary loops exceeds the primary loop flow rate.

For systems with secondary loops, detecting this issue can be determined with the same equipment (sensors and loggers) provided for this measure. Monitoring the HWST at the beginning of the secondary loop supply lines allows for comparison of the secondary loop HWSTs. If any of the HWSTs in the secondary loop is lower than the HWST in the primary loop where the secondary loop meets the primary loop. Thus, it is an indication that some of the return water from the secondary loop is feeding back and mixing with the water from the primary loop, thus the secondary loop’s HWST is reduced.

Therefore, when applying this measure to the primary hot water loop, it is best to reduce the LDPSP in the primary loop and monitor the HWST in the secondary loops for any decrease below the HWST in the primary loop. If this condition exists, the LDPSP should be increased again to prevent that condition.
1.4 Is the condensing boiler operating efficiently?

1.4.1 Measure Description

Measure the hot water return temperature to determine whether the steam in the flue gas is condensing, thus operating efficiently.

1.4.2 Kit Contents (Equipment and Software)

1. 4-Channel Thermocouple HOBO® Data Logger: UX120-014M, one per boiler
2. OMEGA® SA2C-K Surface Temperature Self-Adhesive Thermocouple, one per return pipe
3. Pipe insulation
4. Pipe insulation tape

Also:

5. PC-based device with USB port (e.g., laptop or Surface Pro)
6. Hoboware® software

4.1.3 Initialization Procedure: HOBO® 4 Channel Thermocouple Data Logger (UX120-014M)

1. Open the HOBOware® software on your computer.
2. To connect the logger to a computer, plug the small end of the USB cable into the side of logger and the large end into the USB port of the computer (with HOBOware® software pre-installed).
3. In the “Select Device” window, make sure that the radio button showing the HOBO® 4 Channel Thermocouple data logger is selected and click “OK”.

4. Select the launch icon on the HOBOware® toolbar on your laptop; this will open the configuration options for the data logger.

5. Ensure that the logger has enough battery life for the trending period before you start the configuration process.

6. In the description text box, type a name based on the building name, system name, and parameter measured.
7. In the “Sensors” section, name the thermocouple ports that will be used according to the measure being recorded. For example: “Hot Water Return Temp.”

8. In the “Deployment” section, set the logging time interval according to the measure being used. Set the interval to 15 minutes.

9. Under “Start Logging”, choose the start date and time. Set the logger to start after the installation is complete. Make sure that the start logging time is on the hour. For example, start at 12:00 PM instead of 12:02PM, 12:15 PM, or 12:30 PM.

10. Under stop logging, select “never (wrapping)”. 

![Image of Sensors configuration](image1)

![Image of Deployment configuration](image2)
11. By default, the LCD will always remain on while logging data. Verify that the “Turn LCD off” is not checked.

```
Deployment

Logging Interval: 1 minute
Logging Duration: Event Dependent
Start Logging: On Date/Time: 07/11/17 01:00:00 PM
Stop Logging: When memory fills
Options: Turn LCD off
```

12. Click the “Delayed Start” button to launch the logger.

```
[Image of Delayed Start button]
```

13. A “Launching Logger” window will appear to save all the sections in the initialization procedure. Wait for the progress bar to reach 100% before proceeding.

```
Launching Logger

Logger is now being configured. DO NOT unplug while logger is being configured.

04% Wrote 444 bytes of 528
```

14. Disconnect logger from computer by unplugging the small USB end from the side of the logger.
1.4.4 Installation Procedure: HOBO® 4 Channel Thermocouple Data Logger (UX120-014M) and Temperature Sensors (TMC50-HD)

1. Wrap the surface temperature self-adhesive thermocouple to the hot water return pipe, ensuring that the sensor is in good physical contact with the pipe, under insulation, and secure. This will ensure that there is consistent thermal conductivity between the pipe and the temperature sensor.

**Note:** The material and thickness of pipes vary. To ensure that the temperature sensor is measuring the temperature of the fluid inside the pipe, wrap insulation all the way around the pipe. Also, make sure the insulation traverses twelve to eighteen inches along the pipe, with the sensor centered in the insulation and the insulation secured with pipe insulation tape. This will help to minimize measurement error due to heat transfer to/from surroundings.

![Diagram](image)

2. Deploy the HOBO® UX120-014M data logger within reach of the temperature sensors. Use mounting magnets on the back of the logger to attach at a fixed location or use mounting tape and break ties if the mounting surface is non-magnetic.
3. Insert the blade connector end of the thermocouple (SA2 Series) into the first two ports on the data logger. Be sure to connect the thermocouples to the ports corresponding to the ports chosen during logger initialization.

1.4.5 Data Acquisition Procedure: HOBO® 4 Channel Thermocouple Data Logger (UX120-014M) and Temperature Sensors (TMC50-HD)

To retrieve data from the HOBO® UX120-014M data logger:

1. Open HOBOware on your laptop/Surface Pro.

2. Connect the logger by plugging the small end of the USB cable into the side of the logger and the large end into a USB port on the computer.

3. If the “Select Device” window pops up, make sure that the radio button showing the HOBO® UX120-014M Channel Thermocouple is selected and click “OK”.

4. Click the “Readout” button located on the HOBOware® toolbar.
5. If the loggers were previously active, select “Don’t Stop” unless you are removing the loggers from the site.

6. Wait for the data to be read out. Once the readout is complete, choose a location and/or a new filename, or accept the default location and name to save the data.

7. Click “Save”.

8. The plot setup window will appear after saving. Make sure that all boxes are checked for the series that were created in the initialization procedure.
9. The plot setup window should look like the following:

10. Check mark the device measure (for this example ‘Hot Water Return Temp’ was check marked) located in the first check box window. In the ‘Select Internal Logger Events to plot’, click ‘None’. Then, click ‘Plot’ located on the bottom right side of this window.

Note: For further investigation and storage outside of HOBOware®, click on “Export Table Data” on the HOBOware® toolbar as shown below. Save the document to a new folder designated for your data.
1.4.6 Visualization Procedure

A graph similar to the following image will be generated shortly after selecting plot.

Note: The default time range can be adjusted if it does not allow you to see the nuances of your graph. Right click on the x-axis and select “Time Axis Properties” to change the time range in HOBOware®. The time scale can be adjusted by using the dropdown box shown in the upper right portion of the image below.

1.4.7 Suggested Actions

Condensing boilers condense and recover the latent heat from the steam in the flue gas when the hot water return temperature is less than about 130˚F. Also, efficiency increases when the return temperature further decreases. If the return temperature is greater than 130˚F, investigate opportunities to reduce it, such as reducing the hot water supply temperature setting and/or reducing the hot water pump speed.
1.5 For steam heating systems, what is the condensate return temperature?

1.5.1 Measure Description
Measure the temperature of the condensate return to determine whether the steam traps are functioning properly.

1.5.2 Kit Contents (Equipment and Software)

1. HOBO® 4-Channel Thermocouple Logger: UX120-014M
2. OMEGA® SA2C-K Surface Temperature Self-Adhesive Thermocouple, two per analog logger.
3. Pipe insulation
4. Pipe insulation tape

Also:
5. PC-based device with USB port (e.g. laptop or Surface Pro)
6. HOBOware® software
7. Microsoft Excel

1.5.3 Initialization Procedure: HOBO® 4 Channel Thermocouple Data Logger (UX120-014M)

1. Open the HOBOware® software on your computer.
2. To connect the logger to a computer, plug the small end of the USB cable into the side of logger and the large end into the USB port of the computer (with HOBOware® software pre-installed).
3. If the “Select Device” window pops up, make sure that the radio button showing the HOBO® UX120-014 logger is selected and click “OK.”

4. Select the launch icon on the HOBOware® toolbar on your laptop to open the configuration options for the logger.

5. Ensure that the logger has enough battery life for the trending period before you start the configuration process.

6. In the description text box, type a name based on location and function of the equipment (e.g. “SiteLocation_CondensateReturnPipe_Temp”). Note that there is a 40-character limit.

7. In the “Sensors” section, the thermocouple ports should be named after the parameter that is being recorded (e.g. “Condensate Return Temp”).
8. In the “Deployment” section, set the logging interval to 15 minutes.

9. Under “Start Logging,” select On Date/Time. Set the loggers to start after the installation is complete. Make sure that the start logging time is on the hour. For example, start at 12:00 PM instead of 12:02PM, 12:15 PM, or 12:30 PM.

10. Under “Stop Logging”, select “never (wrapping)”.

11. By default, the LCD will always remain on while logging data. Verify that the “Turn LCD off” box is not checked.
12. Click the delayed start button to launch the logger.

13. A “Launching Logger” window will appear to save all the sections in the initialization procedure. Wait for the progress bar to reach 100% before proceeding.

14. Disconnect the logger from the computer by unplugging the small USB end from the side of the logger.
1.5.4 Installation Procedure: HOBO® 4 Channel Thermocouple Data Logger (UX120-014M) and Temperature Sensors (TMC50-HD)

1. Wrap the surface temperature self-adhesive thermocouple (see Figure 3) to the condensate return pipe between the steam trap and the boiler, preferably it should be near the condensate tank. Ensure that the sensor is in contact with the pipe, under insulation, and secure.

Note: The material and thickness of pipes vary. To ensure that the temperature sensor is measuring the temperature of the fluid inside the pipe, wrap insulation all the way around the pipe. Also, make sure the insulation traverses twelve to eighteen inches along the pipe, with the sensor centered in the insulation and the insulation secured with pipe insulation tape. This will help to minimize measurement error due to heat transfer to/from surroundings.

2. Deploy the UX120-014M logger within reach of the thermocouple(s). Use the mounting magnets on the back of the logger to attach it at a fixed location or use mounting tape and tiebreak cables if the surface is non-magnetic.

3. Insert the blade connector end of the thermocouple (Omega®SA2C-K Series) into the first two ports on the data logger. Be sure to connect the thermocouples to their corresponding ports as they were set up when initializing the logger.
1.5.5 Data Acquisition Procedure: HOBO® 4 Channel Thermocouple Data Logger (UX120-014M)

To retrieve data from the UX120-014 logger:

1. Open HOBOware® on your laptop/Surface Pro.
2. Connect the logger by plugging the small end of the USB cable into the side of the logger and the large end into a USB port on the computer.
3. Click the “Readout” button on the HOBOware® toolbar.
4. If the “Select Device” window pops up, make sure that the radio button showing the HOBO® UX120-014M is selected and click “OK”.
5. If the loggers were previously active, select “Don’t Stop” unless you are removing the loggers from the site.
6. Wait for the data to be read out. Once the readout is complete, choose a location and/or a new filename, or accept the default location and name to save the data.
7. Click “Save”.

8. The plot setup window will appear after you save. Make sure that all boxes are checked for the series that were created in the initialization procedure.

9. The plot setup window should look like this:

   - Under “Select Internal Logger Events to plot”, click “None”
   - Click “Plot” at the bottom of the window. Clicking “Plot” will open up your graph (as shown below).

Note: For further investigation and storage outside of HOBOware®, click on “Export Table Data” on the HOBOware® toolbar as shown below. Save the document to a new folder designated for your data.
1.5.6 Visualization Procedure

The following is an example of the graphs that you will see on HOBOware®.

Note: The default time range can be adjusted if it does not allow you to see the nuances of your graph. Right click on the x-axis and select “Time Axis Properties” to change the time range in HOBOware®. The time scale can be adjusted by using the dropdown box shown in the upper right portion of the image below.
1.5.7 Suggested Actions

If the condensate return temperature consistently peaks well above 160 °F, you may have a failed steam trap and further investigation is warranted.

Check the F&T steam traps first. If there is a Y-strainer downstream of the trap, open the strainer to check for an appreciable amount of steam leakage. If so, repair the trap.

If there is no Y-strainer downstream of the F&T trap, check the temperature difference across the trap. If the difference is 30 °F or more, the trap should be working properly. For a difference of less than 30 °F, the trap may have failed.
2. noBAS Measures for Chiller Plant

2.1 What is the Delta T between the chilled water supply and return on the primary loop?

2.1.1 Measure Description

This measure applies to chilled water distribution systems with chilled water pumps controlled by a VFD.

The rise in chilled water supply temperature to chilled water return temperature (CHWRT – CHWST) is often called “delta T”. A relatively low delta T when loads are high could indicate over pumping in the primary chilled water loop. Use this measure to monitor for the possibility of reduced chilled water pumping.

2.1.2 Kit Contents (Equipment and Software)

1. 4-Channel Thermocouple HOBO® Data Logger: Onset UX120-014M, one per chiller
2. OMEGA® SA2C-K Surface Temperature Self-Adhesive Thermocouple, one per pipe
3. Pipe insulation
4. Pipe insulation tape

Also:

5. PC-based device with USB port (e.g. laptop or Surface Pro 3)
6. Hoboware® software
7. Microsoft Excel
8. CUNY BPL-provided macro-enabled Excel file (Chilled Water Delta T Visualization.xlsm)
2.1.3 Initialization Procedure: HOBO® 4 Channel Thermocouple Data Logger (UX120-014M)

1. Open the HOBOware® Software on your computer.

2. To connect the logger to a computer, plug the small end of the USB cable into the side of logger and the large end into the USB port of the computer (with HOBOware® software pre-installed).

3. If the “Select Device” window pops up, make sure that the radio button showing the HOBO® UX120-014M 4 Channel Thermocouple data logger is selected and click “OK”.

4. Select the launch icon on the HOBOware® toolbar on your laptop; this will open the configuration options for the logger.
5. Ensure that the logger has enough battery life for the trending period before you start the configuration process.

6. In the description text box, type a name based on the building name, system name, and parameter measured. The general naming template includes the following: create a logger name that includes the building name, space served, system name, and parameter measured. Note that there is a 40-character limit.

7. In the “Sensors” section, name the thermocouple ports that will be used according to the measure being recorded. For example: Chilled Water Supply Temp, Chilled Water Return Temp.

8. In the “Deployment” section, set the logging time interval according to the measure being used. Set the interval to 15 minutes.
9. Under “Start Logging”, choose the start date and time for logging data. Set the loggers to start after the installation is complete. Make sure that the start logging time is on the hour. For example, start at 12:00 PM instead of 12:02PM, 12:15 PM, or 12:30 PM.

![Deployment settings](image)

10. Under stop logging, select “never (wrapping)”.

11. By default, LCD will always remain on while logging data. Verify that the “Turn LCD off” is not checked.

![Deployment settings](image)

12. Click the “Delayed Start” button to launch the logger.

![Delayed Start button](image)

13. A “Launching Logger” window will appear to save all the sections in the initialization procedure. Wait for the progress bar to reach 100% before proceeding.

![Launching Logger](image)

14. Disconnect logger from computer by unplugging the small USB end from the side of the logger.
2.1.4 Installation Procedure: HOBO® 4 Channel Thermocouple Data Logger (UX120-014M) and Temperature Sensors (TMC50-HD)

1. Wrap the surface temperature self-adhesive thermocouple to the chilled water supply pipe, ensuring that the sensor is in good physical contact with the pipe, under insulation, and secure. This will ensure that there is consistent thermal conductivity between the pipe and the temperature sensor.

   **Note:** The material and thickness of pipes vary. To ensure that the temperature sensor is measuring the temperature of the fluid inside the pipe, wrap insulation all the way around the pipe. Also, make sure the insulation traverses twelve to eighteen inches along the pipe, with the sensor centered in the insulation and the insulation secured with pipe insulation tape. This will help to minimize measurement error due to heat transfer to/from surroundings.

2. Wrap the second temperature sensor to the chilled water return pipe, ensuring that the sensor is in physical contact with the pipe and under insulation. Make sure that the sensor is secure.

3. Deploy the HOBO® UX120-014M data logger within reach of the temperature sensors. Use mounting magnets in the back of the logger to attach at a fixed location or use mounting tape and break ties if the surface is non-magnetic.

4. Insert the blade connector end of the thermocouple (SA2 Series) into the first two ports on the data logger. Be sure to connect the thermocouples to the ports corresponding to the ports chosen during logger initialization.
2.1.5 Data acquisition Procedure: HOBO® 4 Channel Thermocouple Data Logger (UX120-014M) and Temperature Sensors (TMC50-HD)

1. On your laptop/Surface Pro, open HOBOware®.

2. Connect the logger by plugging the small end of the USB cable into the side of the logger and plugging the large end into a USB port on your computer.

3. Click “Readout” on the HOBOware® toolbar.

4. If the “Select Device” window pops up, make sure that the radio button showing the HOBO® UX120-014M 4 Channel Thermocouple is selected and click “OK”.

5. If the loggers were previously active, select “Don’t Stop” unless you are removing the loggers from the site.

6. A progress bar displays while the data is being read out. Once the readout is complete, choose a location and/or a new filename or accept the default location and name to save the data.
7. Click “Save”.

8. The plot setup window will appear after saving. Make sure that all boxes are checked for the series that were created in the initialization procedure.

9. The plot setup window should look like the following:

   - Under “Select Internal Logger Events to plot”, click “None”
   - Click “Plot” at the bottom of the window. Clicking “Plot” will open up your graph (as shown below).
10. Click on “Export Table Data” on the HOBOware® toolbar as shown below. Save the document to a new folder designated for your data. Make sure this folder is on your desktop, as it will be used during the visualization steps.

11. Save the file as a comma-separated values (CSV) file. This CSV file can be used for further investigation.
2.1.6 Visualization Procedure

1. Download the CUNY BPL-provided macro-enabled Excel file named “Chilled Water Delta T.xlsm” and save the “Chilled Water Delta T” file in the same folder where your logged data is located.

2. Open the folder and check to see that the data files are labeled correctly. Use the file names shown in the table below. (This is to ensure that the Excel macro program can read the files).

<table>
<thead>
<tr>
<th>File Name</th>
<th>Contained Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHWST.csv</td>
<td>Chilled Water Supply Temperature</td>
</tr>
<tr>
<td>CHWST.csv</td>
<td>Chilled Water Supply Temperature</td>
</tr>
</tbody>
</table>

3. Open the “Chilled Water Delta T” macro-enabled excel document.

4. In order for the program to run you must enable editing, enable content, and trust the document.

5. Save As to the folder that contains the data (the folder from step 1., and rename this Excel file (e.g. Chilled Water Delta T my building).

6. Follow the steps outlined in the macro. **Note: If data from previous visualizations is in the excel sheet, it can be easily erased using the ‘Clear Data’ button on the left side underneath the BPL Logo.**

7. Click the ‘Import’ button’ to upload the data into the macro-enabled excel file.
8. Verify that chilled water supply and return temperature data are in the correctly labeled columns and that values are seen in the Delta T column.

<table>
<thead>
<tr>
<th>Instructions</th>
<th>Date/Time</th>
<th>CH+WST</th>
<th>CH+RST</th>
<th>Delta T</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Import</td>
<td>2/10/2016 14:54</td>
<td>43.637</td>
<td>43.098</td>
<td>5.243</td>
</tr>
<tr>
<td></td>
<td>2/10/2016 14:55</td>
<td>43.676</td>
<td>43.236</td>
<td>5.439</td>
</tr>
<tr>
<td></td>
<td>2/10/2016 14:56</td>
<td>43.682</td>
<td>43.316</td>
<td>5.464</td>
</tr>
<tr>
<td></td>
<td>2/10/2016 14:57</td>
<td>43.642</td>
<td>43.101</td>
<td>5.443</td>
</tr>
<tr>
<td></td>
<td>2/10/2016 14:59</td>
<td>43.715</td>
<td>43.209</td>
<td>5.507</td>
</tr>
<tr>
<td>2. To view charts click plot</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. If you would like to adjust the range of dates to view, select desired range below, then click “Change Date/Time Range” for the graph you would like to adjust</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. To save graph, click export, your chart will be saved as a picture in the same folder as this file</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

9. Click “Plot”. This function will plot all of your data. The loading time will vary depending on how many you have and the amount of data you collected.

10. The time scale can be changed by using the first dropdown on the left underneath the “Plot” button. The top dropdown defines the start date, and the dropdown directly beneath it defines the length of time. For the chiller water loop, the chart number must also be selected using the dropdown located directly beneath the time length dropdown. Enact changes by clicking “Change Time Range” to choose the beginning date/time and an end date/time that you would like to view.
11. If you want to export the graph you have created, simply click “Export Chart” located above “Clear Data”. An image file will be created and put in the folder in which you have the macro-enabled Microsoft Excel file with a time stamp in the name. If you have created multiple plots in one file, you can select which you would like to export.

A plot will be generated shortly after selecting plot as seen in the example below:
2.1.7 Suggested Actions

When cooling loads are low, not much heat is imparted to the chilled water, and a relatively small delta T (CHWRT – CHWST) is expected.

However, if loads are high, i.e., significant cooling is required, the delta T will be relatively large. Delta T partially and heavily depends on system design parameters. For example, for all other things being equal, a chilled water distribution system with smaller coils will have a low delta T, and one with smaller chilled water pumping capacity (pipe sizes, pump and/or pump motor sizes) will have a higher delta T. Looking at the delta T across a variety of system designs, a typical range is 8 – 25 °F.

A relatively low delta T for your system indicates that there may be over pumping in the primary chilled water loop. If the pump has a VFD that is controlled to maintain loop differential pressure, it may be possible to reduce the loop differential pressure set point (LDPSP) and still adequately meet cooling needs.

Care must be taken to not reduce the LDPSP so much that inadequate chilled water is pumped to the cooling coils. If so, insufficient cooling may occur. For example, in an associated AHU that has a discharge air temperature set point (DATSP) that controls the cooling coil valve, under pumping may compromise the ability of the AHU to meet the DATSP and thus potentially not meet zone temperature set points.

In addition, special consideration must be given for systems with secondary or even tertiary loops. When reducing the LDPSP, care must be taken to avoid inadequate pumping such that the pumps in the secondary loops over pump and reverse the flow in portions of the primary loop. This will occur if the sum of the flow rates in the secondary loops exceeds the primary loop flow rate.

Detecting this issue can be determined with the same equipment (sensors and loggers) provided for this measure. Monitoring the CHWST at the beginning of the supply lines to the secondary loops allows for comparison of the secondary loop CHWSTs. In the figure below, CHWST-A, CHWST-B and CHWST-C should all equal CHWST-Primary. If any of the secondary loop supply temperatures exceed CHWST-Primary, then some of the return water from the secondary loop is feeding back and mixing with the water from the primary loop. The secondary loop’s CHWST is then higher than the CHWST in the primary loop.

Therefore, it is better to reduce the LDPSP in the primary loop and monitor the CHWST in the secondary loops for any increase above the CHWST in the primary loop.
Detecting this issue can be determined with the same equipment (sensors and loggers) provided for this measure. Monitoring the CHWST at the beginning of the supply lines to the secondary loops allows for comparison of the secondary loop CHWSTs. In the figure below, CHWST-A, CHWST-B and CHWST-C should all equal CHWST-Primary. If any of the secondary loop supply temperatures exceed CHWST-Primary, then some of the return water from the secondary loop is feeding back and mixing with the water from the primary loop. Therefore, it is better to reduce the LDPSP in the primary loop and monitor the CHWST in the secondary loops for any increase above the CHWST in the primary loop.
2.2 Is condenser water supply temperature well-maintained?

2.2.1 Measure Description

This measure applies to condenser water loops where condenser water supply temperature (from cooling tower to chiller) is maintained by cooling tower fan speed and/or cooling tower fan staging.

Measure the condenser water supply temperature when the condenser water loop pumps are running to determine if the systems are maintaining a proper condenser water supply temperature. Use this to identify an opportunity to investigate the control loop controlling condenser supply water temperature.

Note: If your system has a variable frequency drive on your condenser water pumps, the kit described in this module is not capable of accurately assessing on/off status of pumps. The measure may still be used, however special consideration, to be described herein, must be given when reading the trend charts.

2.2.2 Kit Contents (Equipment and Software)

1. HOBO® 4-Channel Thermocouple Data Logger: HOBO UX120-014M, one per chiller
2. Omega® SA2C-K Surface Temp Self-Adhesive Thermocouple, one per pipe
3. HOBO® Motor On/Off Logger: Onset UX90-004M
4. Pipe Insulation
5. Pipe Insulation Tape

Also:

7. CUNY BPL-provided macro-enabled Excel file (Condenser Water Supply Temperature Visualization)
8. PC-based device with USB port (e.g. laptop or Surface Pro)
9. Hoboware® software.
2.2.3 Initialization Procedure: HOBO® Motor On/Off Data Logger (UX90-004)

1. Open the HOBOware® software on your computer.

2. To connect the logger to a computer, plug the small end of the USB cable to the side of logger and the large end into the USB port of the computer (with HOBOware® software pre-installed).

3. If the “Select Device” window pops up, make sure the radio button showing the HOBO® UX90-004M Motor On/Off is selected and click “OK”.

4. Select the launch icon on the HOBOware® toolbar on your laptop to open the configuration options for the logger.

5. Ensure that the logger has enough battery life for the trending period before you start the configuration process.
6. In the description text box, type a name that describes the condenser water loop, as seen in the example below. The general naming template includes the following: create a logger name that includes the building name, space served, system name, and parameter measured. Note that there is a 40-character limit.

![Building Condenser Water Pumps](image)

7. In the “Sensors” section, choose the type of logging configuration. The sensors can be configured to log data either by runtime or state. **It is critical that you select “State”**.

![Configure Sensors to Log](image)

**Note**: when the logger is configured to log state change, the logging interval option is greyed out and cannot be selected for changes. The logging duration is dependent on event duration.

8. Under “Start Logging”, choose the start date and time. Set the logger to start after the installation is complete. Make sure that the start logging time is on the hour. For example, start at 12:00 PM instead of 12:02PM, 12:15 PM, or 12:30 PM.

![Deployment](image)

9. Under “Stop Logging”, select **“never (wrapping)”**.
10. By default, the LCD will always remain on while logging data. Verify that the “Turn LCD off” box is not checked under “Options”.

11. Click the “Delayed Start” button to launch the logger.

12. A “Launching Logger” window will appear to save all the sections in the initialization procedure. Wait for the progress bar to reach 100% before proceeding.
13. A fully configured launch logger should look like this:

![Image of a launch logger configuration screen]

14. Disconnect the logger from your computer by unplugging the small USB end from the side of the logger.

The next step is to deploy and calibrate the logger on the pump motor.
2.2.4 Installation Procedure: HOBO® Motor On/Off Data Logger (UX90-004)

1. Deploy the logger on the motor from which you wish to collect your data. Use the mounting magnets on the back of the logger to attach it at a fixed location.

   **NOTE:** Do NOT deploy this logger on motors with VFDs. The sensor only detects the motor being on from 50 – 60 Hz. This would lead to erroneous and possibly misleading data.

2. When the motor is running, hold down the calibration button until the LCD display reads “Pass”. If the LCD display reads “fail”, the logger needs to be calibrated again. The signal strength should be at least 3 bars, so orient the logger as required to increase the signal strength. Calibration helps the logger identify the magnetic field of that particular motor and ignore any surrounding magnetic fields.
2.2.5 Initialization Procedure: HOBO® 4-Channel Thermocouple Data Logger (UX120-014M)

1. Open the HOBOware® software on your computer.

2. To connect the logger to a computer, plug the small end of the USB cable into the side of logger and the large end into the USB port of the computer (with HOBOware® software pre-installed).

3. If the “Select Device” window pops up, make sure that the radio button showing the HOBO® UX120-014M logger is selected and click “OK”.

4. Select the launch icon on the HOBOware® toolbar on your laptop; this will open the configuration options for the loggers.
5. Ensure that the logger has enough battery life for the trending period before you start the configuration process.

6. In the description text box, type a name based on the building name, system name, and parameter measured. The general naming template includes the following: create a logger name that includes the building name, space served, system name, and parameter measured. Note that there is a 40-character limit.

7. In the “Sensors” section, name the thermocouple ports that will be used according to the measure being recorded. For example: Condenser Water Supply Temp.

8. In the “Deployment” section, set the logging time interval according to the measure being used. For condenser water supply temperature, **set the interval to 15 minutes**.
9. Under “Start Logging”, choose the start date and time for logging data. Set the loggers to start after the installation is complete. Make sure that the start logging time is on the hour. For example, start at 12:00 PM instead of 12:02PM, 12:15 PM, or 12:30 PM.

10. Under stop logging, select “never (wrapping)”.

11. By default, LCD will always remain on while logging data. Verify that the “Turn LCD off” is not checked.

12. Click the “Delayed Start” button to launch the logger. Wait until the logger completes launching.

13. A “Launching Logger” window will appear to save all the sections in the initialization procedure. Wait for the progress bar to reach 100% before proceeding.

14. Disconnect logger from your computer by unplugging the small USB end from the side of the logger.
2.2.6 Installation Procedure: HOBO® 4-Channel Thermocouple Logger (UX120-014M) and Omega® Surface Temp Self-Adhesive Thermocouple (SA2C-K).

1. Wrap the first temperature sensor to the condenser water supply pipe, ensuring that the sensor is in good physical contact with the pipe and under insulation. This will ensure that there is consistent thermal conductivity between the pipe and the temperature sensor. Be sure that the sensor is secure.

   Note: The material and thickness of pipes vary. To ensure that the temperature sensor is measuring the temperature of the fluid inside the pipe, wrap insulation all the way around the pipe. Also, make sure the insulation traverses twelve to eighteen inches along the pipe, with the sensor centered in the insulation and the insulation secured with pipe insulation tape. This will help to minimize measurement error due to heat transfer to/from surroundings.

2. Deploy the UX120-014M logger within reach of the thermocouple(s). Use the mounting magnets on the back of the logger to attach it at a fixed location or use mounting tape and tiebreak cables if the surface is non-magnetic.

3. Insert the blade connector end of the thermocouple (SA2 Series) into the first two ports on the data logger. Be sure to connect the thermocouples to their corresponding ports as they were set up when initializing the logger.
2.2.7 Data Acquisition Procedure: HOBO® Motor On/Off Data Logger (UX90-004)

To retrieve data from the UX90-004 logger:

1. On your laptop/surface pro, open HOBOware®.
2. Connect the logger by plugging the small end of the USB cable into the side of the logger and plugging the large end into a USB port on your computer.
3. If the “Select Device” window pops up, make sure that the radio button showing the HOBO® UX90-004 Motor On/Off is selected and click “OK”.
4. Click “Readout” on the HOBOware® toolbar
5. If the loggers were previously active, select “Don’t Stop” unless you are removing the loggers from the site.
6. Wait for the data to be read out. Once the readout is complete, choose a location and/or a new filename, or accept the default location and name to save the data.

7. Click “Save”.

8. The plot setup window will appear after saving. Make sure that all boxes are checked for the series that were created in the initialization procedure.
9. The plot setup window should look like this:

- Under “Select Internal Logger Events to plot”, click “None”
- Click “Plot” at the bottom of the window. Clicking “Plot” will open up your graph (as shown below).

10. Click on “Export Table Data” on the HOBOware® toolbar as shown below. Save the document to a new folder designated for your data. Make sure this folder is on your desktop, as it will be used during the visualization steps.
11. Save the file as comma-separated values (CSV) file. This CSV file can be used for further investigation.

2.2.8 Data Acquisition Procedure: HOBO® Data logger (UX120-014M) and Thermocouple Probe (TCP6-K12)

To retrieve data from the UX120-014M data logger:

1. On your laptop/surface pro, open HOBOware®.

2. Connect the logger by plugging the small end of the USB cable into the side of the logger and plugging the large end into a USB port on your computer.

3. If the “Select Device” window pops up, make sure that the radio button showing the HOBO® UX90-004 Motor On/Off is selected and click “OK”.

4. Click “Readout” button on HOBOware® toolbar.
5. If the loggers were previously active, select “Don’t Stop” unless you are removing the loggers from the site.

6. Wait for the data to be read out. Once the readout is complete, choose a location and/or a new filename, or accept the default location and name to save the data.

7. Click “Save”.

8. The plot setup window will appear after you save. Make sure the series1 box is checked.
9. The plot setup window should look like this

- Under the “Select Internal Logger Events to plot” click “None”
- Then, click “Plot” at the bottom of this window (circled in red). Clicking “Plot” will open up your graph (see below example).

10. Click on “Export Table Data” on the HOBOware® toolbar as shown below.
Save the document to a new folder designated for your data. Make sure this folder is on your desktop, as it will be used during the visualization procedure.
11. Save the file as a comma-separated value (CSV) file. This CSV file can be used for further investigation.

2.2.9 Visualization Procedure

1. Download the CUNY BPL-provided macro-enabled Excel file named “Condenser water supply temperature.xlsm” and Save the “Condenser water supply temperature file in the same folder where your logged data is located.

2. The Excel file can manage up to three pumps, therefore the folder may look similar to the following Open the folder and check to see that the data files are labeled correctly. Use the file names shown in the table below. (This is to ensure that the excel program can read the files)
3. Open the “Condenser Water Supply Temperature” macro enabled excel document.

4. In order for the program to run you must enable editing, enable content, and trust the document.

5. Click on “Save As” under “File” on the Microsoft Excel top bar, save the file to the folder from step 1, and rename this document. (e.g. condenser water supply temperature my building.xlsm).

6. Follow the steps outlined in the macro-enabled Excel file. **Note: If data from previous visualizations is in the Microsoft Excel sheet, it can be easily erased by clicking “Clear Data” underneath the BPL Logo on the left side.**

   a. Choose the numbers of pumps in the condenser water loop that you have data for.
a. Choose the numbers of pumps in the condenser water loop that you have data for.

b. Click “Import” to import your data. The headers will fill themselves in based on the number of pumps you have. This may take a moment depending on how many pumps you have and the amount of data you collected.

c. Click “Plot”. This function will plot all your condenser data. The loading time will vary depending on how many pumps you have and the amount of data you collected.

d. The time scale can be changed by using the first dropdown on the left underneath the “Plot” button. The top dropdown defines the start date, and the dropdown directly beneath it defines the length of time. For the boiler, the chart number must also be selected using the dropdown located directly beneath the time length dropdown. Enact changes by clicking “Change Time Range” to choose the beginning date/time and an end date/time that you would like to view.
e. If you want to export the graph you have created, simply click “Export Chart” located above “Clear Data”. An image file will be created and put in the folder in which you have the macro-enabled Microsoft Excel file with a time stamp in the name. If you have created multiple plots in one file, you can select which you would like to export.

2.2.10 Suggested Actions

When reading the trend chart, if you were unable to deploy motor on/off loggers on the condenser water pumps because they have VFD, then you have no data regarding motor status. Knowledge of when CW pumps are turned off is critical. CW temperature will float when the pumps are off. Take care not to draw conclusions from changes in CWST at times when the pumps are off.

Check to see whether the condenser water supply temperature (CWST) follows the known CWST set point when the condenser water pump(s) is on. If not, check condenser water loop equipment (pumps, fans, VFDs, temperature sensors) and/or tune the control loop.
2.3 How is cooling tower fan cycling?

2.3.1 Measure Description

Measure cycling on cooling tower fans to determine whether fans are short cycling or running when cooling is not required. Short cycling reduces the life of motors, thus increasing the frequency of motor replacements.

This measure is for cooling towers with fans not controlled by variable frequency drives (VFDs). This limitation is due to the motor on/off logger’s inability to detect motors when VFDs drop below 50 Hz.

2.3.2 Kit Contents (Equipment and Software)

For Fan Cycling:

1. HOBO® Motor on/off data logger: UX90-004 or UX90-004M, one per fan

Also:

2. PC-based device with USB port (e.g. laptop or Surface Pro)
3. HOBOware® software
4. Microsoft Excel
2.3.3 Initialization Procedure: HOBO® Motor On/Off Data Logger (UX90-004)

1. Open the HOBOware® software on your computer.

2. To connect the logger to a computer, plug the small end of the USB cable into the side of logger and plug the large end into the USB port of the computer (with HOBOware® software pre-installed).

3. If the “Select Device” window pops up, make sure that the radio button showing the HOBO® UX90-004 Motor On/Off is selected and click “OK”.

![Select Device Window](image-url)
4. Select the launch icon on the HOBOware® toolbar on your laptop to open the configuration options for the logger(s).

![Image of HOBOware Pro interface]

5. Ensure that the logger has enough battery life for the trending period before you start the configuration process.

6. In the description tab, label the equipment. The general naming template includes the following: create a logger name that includes the building name, space served, system name, and parameter measured. (e.g. “SiteLocation_CoolingTowerFan_#1”). **Note: There is a 40-character limit.**

![Image of HOBOware UX90-004M Motor On/Off]

7. In the “Sensors” section, the sensors can be configured to log data either by runtime or state. It is critical that you select “State”.

![Image of Sensors configuration] logs data as how long the states last and stores date/time when there is a change in state.

8. Under “Start Logging”, choose the start date and time. Set the logger to start after the installation is complete. Make sure that the start logging time is on the hour. For example, start at 12:00 PM instead of 12:02PM, 12:15 PM, or 12:30 PM.
Deployment

Logging Mode: Fixed Interval
Logging Duration: 46.8 years
Start Logging: On Date/Time 07/19/17 12:00:00 PM

Note: When the logger(s) is configured to log state change, the logging interval option is greyed out and cannot be selected for changes. The logging duration is dependent on event duration.

9. Under “Stop Logging”, select “never (wrapping)”.

10. By default, the LCD will always remain on while logging data. Verify that the “Turn LCD off” box is not checked under “Options”.

11. Click the “Delayed Start” button to launch the logger.

12. A “Launching Logger” window will appear to save all the sections in the initialization procedure. Wait for the progress bar to reach 100% before proceeding.
13. A fully configured logger launch should look like this:

![Logger Launch Window](image)

14. Disconnect the logger from your computer by unplugging the small USB end from the side of the logger.

The next step is to deploy and calibrate the logger on the fan motor.
2.3.4 Installation Procedure: HOBO® Motor On/Off Data Logger (UX90-004)

1. For cooling tower fan motors exposed to outdoor environments and/or high moisture, place the logger in a sealable plastic bag to keep it dry. Deploy the logger on the motor from which you wish to collect your data. Use the mounting magnets on the back of the logger to attach it at a fixed location.

2. When the motor is running, hold down the calibration button until the LCD display reads “Pass”. If the LCD display reads “fail”, the logger needs to be calibrated again. The signal strength should be at least 3 bars, so orient the logger as required to increase the signal strength. Calibration helps the logger identify the magnetic field of that particular motor and ignore any surrounding magnetic fields.
3. Once the logger is installed on a fan you should have a setup like this:

Note: You should be careful not to wear any loose clothing that could potentially get caught in any fan or motor equipment while calibrating and installing the logger. Since the motor must be on please make sure that the fan blades are not too close to the motor when setting up these loggers. If they are, choose a different system to explore or try to calibrate the logger on an identical motor where the fan blades are not too close to the motor. Finally, if you know how strong the motor's magnetic field is, you can use the internal calibration method that is described in HOBO® products user manual.
2.3.5 Data Acquisition Procedure: HOBO® Motor On/Off Data Logger (UX90-004)

To retrieve data from the UX90-004 data logger:

1. On your laptop/Surface Pro, open HOBOware®.
2. Connect the logger by plugging the small end of the USB cable into the side of the logger and the large end into a USB port on the computer.
3. If the “Select Device” window pops up, make sure that the radio button showing the HOBO® UX90-004 Motor On/Off is selected and click “OK”.
4. Click “Readout” on the HOBOware® toolbar.
5. If the loggers were previously active, select “Don’t Stop” unless you are removing the loggers from the site.
6. Wait for the data to be read out. Once the readout is complete, choose a location and/or a new filename, or accept the default location and name to save the data.

7. Click “Save.”

8. The plot setup window will appear after you save. Make sure that all of the boxes are checked for the series that were created in the initialization procedure.
9. The plot setup window should look like this:

- Under “Select Internal Logger Events to plot”, click “None”
- Click “Plot” at the bottom of the window. Clicking “Plot” will open up your graph (as shown below).

Note: For further investigation and storage outside of HOBOware, click on “Export Table Data” on the HOBOware® toolbar as shown below. Save the document to a new folder designated for your data.
2.3.6 Visualization Procedure

The following is an example of a graph that you will see in HOBOware®.

Note: The default time range can be adjusted if it does not allow you to see the nuances of your graph. Right click on the x-axis and select “Time Axis Properties” to change the time range in HOBOware®. The time scale can be adjusted by using the dropdown box shown in the upper right portion of the image below.
2.3.7 Suggested Actions

If cooling tower fans are running when cooling is not required, change the operating schedule to match the start-up and occupancy schedule. This can be implemented manually, though installing / using a programmable controller will usually produce more reliable results.

If short cycling is found, investigate the equipment and/or tune the control loop to prevent it. Short cycling might be mitigated by increasing the operating differential of the Condenser Water Supply Temperature (condenser water leaving the cooling tower / entering the chiller) associated with the CWST set point.
3. noBAS Measures for Air Handling & Rooftop Units

3.1 Do the fans operate during unoccupied times?

3.1.1 Measure Description

The supply fan status in an air handling unit (AHU) or roof top unit (RTU) is measured to confirm that the fan(s) is OFF when it should not be operating. In most equipment, supply and return fans run simultaneously, thus diagnosing issues for the supply fan is an indication of the same situation for the associated return fan.

Note: This measure applies to fans that are not controlled by a variable frequency drive (VFD). This limitation is due to the motor on/off logger’s inability to detect motors controlled by VFDs running at less than 50 Hz.

3.1.2 Kit Contents (Equipment and Software)

1. HOBO® Motor on/off data logger: UX90-004 or UX90-004M, one per fan
2. PC-based device with USB port (e.g. laptop or Surface Pro)
3. HOBOware® software
4. Microsoft Excel

3.1.3 Initialization Procedure: HOBO® Motor On/Off Data Logger (UX90-004)

1. Open the HOBOware® software on your computer.
2. To connect the logger to your computer, plug the small end of the USB cable into the side of logger and plug the large end into the USB port of the computer (with HOBOware® software pre-installed).
3. If the “Select Device” window pops up, make sure that the radio button showing the HOBO® UX90-004 Motor On/Off is selected and click “OK”.

4. Select the launch icon on the HOBOware® toolbar on your laptop to open the configuration options for the logger(s).

5. Ensure that the logger(s) has enough battery life for the trending period before you start the configuration process.

6. In the description tab, label the equipment. The general naming template includes the following: create a logger name that includes the building name, space served, system name, and parameter measured. (e.g. “SiteLocation-Unit Location-Unit #”). Note: There is a 40-character limit.
7. In the “Sensors” section, the sensors can be configured to log data either by runtime or state. **It is critical that you select “State”**.

![Sensors configuration](image)

Logs data as how long the states last and stores date/time when there is a change in state.

8. Under “Start Logging”, choose the start date/ and time for logging data. Set the logger(s) to start after the installation is complete. Make sure that the start logging time is on the hour. For example, start at noon 12:00 PM instead of 12:02PM, 12:15 PM, or 12:30 PM.

![Deployment settings](image)

Note: When the logger(s) is configured to log state change, the logging interval option is greyed out and cannot be selected for changes. The logging duration is dependent on event duration.

9. Under “Stop Logging”, select “**never (wrapping)**”.

10. By default, the LCD will always remain on while logging data. Verify that the “Turn LCD off” box is not checked under “Options”.

![Deployment options](image)
11. Click “Delayed Start” button to launch the logger.

![Delayed Start button](image)

12. A “Launching Logger” window will appear to save all the sections in the initialization procedure. Wait for the progress bar to reach 100% before proceeding.

![Launching Logger window](image)

13. A fully configured logger launch should look like this:

![Fully configured logger](image)

14. Disconnect the logger from your computer by unplugging the small USB end from the side of the logger.

The next step is to deploy and calibrate the logger on the fan motor.
3.1.4 Installation Procedure: HOBO® Motor On/Off Data Logger (UX90-004)

1. Deploy the logger on the motor from which you wish to collect your data. Use the mounting magnets on the back of the logger to attach it at a fixed location.

2. When the motor is running, hold down the “calibration button” until the LCD display reads “Pass.” If the LCD display reads “fail,” the logger needs to be calibrated again. The signal strength should be at least 3 bars, so orient the logger as required to increase the signal strength. Calibration will help the logger to only identify the magnetic field of the motor and ignore not any surrounding magnetic fields.
3. Once the logger is installed on a fan you should have a setup like this:

![Image of a fan with a logger installed](image)

Note: That you should be careful not to wear any lose clothing that could potentially get caught in any fan or motor equipment while calibrating and installing the logger. Since the motor must be on, make sure that the fan blades are not too close to the motor when setting up these loggers. If they are, choose a different system to explore or try to calibrate the logger on an identical motor where the fan blades are not too close to the motor. Finally, if you know how strong the motor's magnetic field is, you can use the internal calibration method that is described in HOBO® products user manual.

### 3.1.5 Data Acquisition & Visualization Procedure: HOBO® Motor On/Off Data Logger (UX90-004)

1. On your laptop/Surface Pro, open HOBOware®.
2. Connect the logger by plugging the small end of the USB cable into the side of the logger and plugging the large end into a USB port on your computer.
3. If the “Select Device” window pops up, make sure that the radio button showing the HOBO® UX90-004 Motor On/Off is selected and click “OK”.

![Select Device Window]

4. Click “Readout” on the HOBOware® toolbar.

![HOBOware Toolbar]

5. If the loggers were previously active, select “Don’t Stop” unless you are removing the loggers from the site.

![Stop Logger Window]

6. Wait for the data to be read out. Once the readout is complete, choose a location and/or a new filename, or accept the default location and name to save the data.

7. Click “Save”.
8. The plot setup window will appear after you save. Make sure that all of the boxes are checked for the series that were created in the initialization procedure.
9. The plot setup window should look like this:

Under “Select Internal Logger Events to plot”, click “None”
Click “Plot” at the bottom of the window. Clicking “Plot” will open up your graph (as shown below)

Note: For further investigation and storage outside of HOBOware, click on “Export Table Data” on the HOBOware® toolbar as shown below. Save the document to a new folder designated for your data.
3.1.6 Visualization Procedure

The following graph is from a sample of fan operation data:

Note: The default time range can be adjusted if it does not allow you to see the nuances of your graph. Right click on the x-axis to change the time range in HOBOware® and select “Time Axis Properties”. The time scale can be adjusted by using the dropdown box shown in the upper right portion of the image below.
3.1.7 Suggested Actions:

Fans should only operate during three conditions:

1. Served zones are occupied.
2. The building is in start-up mode.
3. AHUs / RTUs are used during unoccupied times to meet zone setback temperatures, and there is an associated call for heating or cooling during these times.

If fans are running during any other times, change the operating schedule to match the above conditions. The installation / use of a programmable controller will generally provide more reliable results, though manual operation may also be used.
3.2 How Is My Outside Air control?

3.2.1 Measure Description

In this critical measure, we seek to assure that outside air is properly controlled. Over-ventilation can cause significant energy waste. Note that under-ventilation can also cause significant occupant discomfort.

Given data for the four temperatures in an air handler/rooftop unit/packaged unit (outdoor, mixed, discharge, and return), and given knowledge of the supply fan status, occupancy, and start up schedules, this measure can determine whether outdoor air is properly managed.

Note: This measure assumes that neither Demand Control Ventilation nor Energy or Heat Recover Ventilation are in use.

3.2.2 Kit Contents (Equipment and Software)

1. (4) HOBO® MX1101 Wireless Temperature Sensors (DAT, MAT, RAT, and OAT)
2. Apple/Android enabled device
3. HOBOmobile™ software/app
4. Microsoft Excel
5. CUNY BPL-provided macro-enabled Microsoft Excel file (OA Control, DAT Hunting, and DAT Reset.xlsm)

It is recommended that this measure is done in conjunction with the measure “Do the fans operate during unoccupied times?”
3.2.3 Initialization Procedure: HOBO® MX1101 Wireless Temperature Logger

1. Enable Bluetooth on your device, and then open the HoboMobile™ app.

2. Ensure that the logger has enough battery life for the trending time period.

3. Tap the logger with the correct serial number. The serial number is shown in both the top left and top right corners of the image below.

4. Name the logger.
   
a. Tap “Configure”.
   
b. Tap “Name”.
   
c. Change the logger name to include the building name, space served, system name, and parameter measured (e.g. “AnytownHS_GymAHU_DAT.”) Note that there is a 20-character limit. Tap “Done” after typing in the new name.
5. Tap “Logging Interval”. Set the logging interval to 15 minutes and then tap “Done”.

   a. Tap “Start Logging” and then “On Date/Time”.
   b. Select a date and time. Make sure that the start logging time is on the hour. For example, start at 12:00 instead of 12:02, 12:15, or 12:30. Tap “Done”.

7. 07/11/2017, 12:00:00 EDT
7. Select memory and time options.

a. Tap “Stop Logging”.

b. Select “Never (Wrap When Full)” as the memory option. Additionally, select “Never” in the time option section.

8. Tap “Start”. The “Configure Success” message indicates that the logger was successfully initialized.
3.2.4 Installation Procedure: HOBO® MX1101 Wireless Temperature Logger

1. Deploy the logger at a location from which you wish to collect data. **Note:** That sensor locations should be selected where accurate temperature measurements are anticipated.

2. Depending on the measure you are implementing, one or more of the following will apply:
   
   a. Special consideration should be given to the DAT sensor placement such that the air streams are truly mixed. For example, the sensor should be downstream of heating coils because it may also record heat from the coils. The same applies to cooling coils.
   
   b. Special consideration should be given to the MAT sensor placement such that the sensor is located after a good mixing of OA and RA has already occurred. Also, ensure that the sensor is not so close to heating or cooling coils that it will affect the air temperature readings.
   
   c. Special consideration should be given to the OAT sensor placement such that the sensor is close to the OA damper, but not exposed to rain or sunlight.
   
   d. Special consideration should be given to the RAT sensor placement such that the sensor is located after mixing from multiple zones has already occurred. Also, ensure that the sensor is upstream of the return air damper.

3. Use mounting magnets on the back of the logger to attach it at a fixed location, or use mounting tape and break ties if the surface is non-magnetic.

3.2.5 Data Acquisition: HOBO® MX1101 Wireless Temperature Logger

1. Enable Bluetooth on your device and then open the HoboMobile™ app.

2. Tap the logger with the correct serial number. The serial number is shown in the top right corner of the image below.
3. Tap “Readout” to download the data. Tap “OK” when the “Readout success” message appears.
4. Tap and then tap the mini graph to view a larger version of the graph or to share the file. Examples of the graphs that will appear are shown below.
5. Tap the option tab [ ] on the top right corner of the graph.

6. Uncheck RH.
The graph will populate with only the temperature readings.
8. Tap “CSV” and select either “Mail” or “Copy to Dropbox” to export and save the file.
3.2.6 Visualization Procedure

**Warning:**
If the following image appears at any point in the process, click “End”, and check to make sure all the directions in both the manual and the macro-enabled Microsoft Excel file were followed. If so, attempt to continue, if possible. If not, please contact BPL with your specific circumstances.

1. Download the CUNY BPL-provided macro-enabled Excel file named “OA Control, DAT Hunting, and DAT Reset.xlsm” and save it in the same folder as your logged data.

2. Follow the directions regarding file name conventions outlined in the macro. Generally, the .csv should follow the name of the parameter in the macro-enabled Microsoft Excel file. For example, in the OA control macro, the RAT CSV file should be named “RAT.csv”. Make sure to delete or move old files and rename the new file to the correct name.

<table>
<thead>
<tr>
<th>File Name</th>
<th>Contained Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>DAT.csv</td>
<td>Discharge Air Temperature</td>
</tr>
<tr>
<td>MAT.csv</td>
<td>Mixed Air Temperature</td>
</tr>
<tr>
<td>OAT.csv</td>
<td>Outdoor Air Temperature</td>
</tr>
<tr>
<td>RAT.csv</td>
<td>Return Air Temperature</td>
</tr>
</tbody>
</table>

3. Open the “OA Control, DAT Hunting, and DAT Reset” macro-enabled Microsoft Excel document.

4. In order for the program to run, you must enable editing, enable content, and trust the document.
5. Click on “Save As” under “File” on the Microsoft Excel top bar to the folder that contains your temperature data, and rename this Microsoft Excel file (e.g. “OAControlMyBuilding.xlsx”).

6. Follow the steps outlined in the macro-enabled Excel file. **Note: If data from previous visualizations is in the Microsoft Excel sheet, it can be easily erased by clicking “Clear Data” underneath the BPL Logo on the left side.**

7. Import the data by clicking “Import”. The DAT Hunting/OA Control macro-enabled Microsoft Excel file can process DAT, MAT, OAT, and RAT, but only requires DAT. For the best results, use all of the measures available.

8. Plot data by clicking “Plot”. It can be found on the left side of all macro-enabled Microsoft Excel files. For DAT Hunting/OA Control, select the appropriate worksheet by clicking on the tabs located in the bottom left corner of the program. The “Plot” button will be located on the left of each worksheet.
9. The time scale can be changed by using the first dropdown on the left underneath the “Plot” button. The top dropdown defines the start date, and the dropdown directly beneath it defines the length of time. For the boiler, the chart number must also be selected using the dropdown located directly beneath the time length dropdown. Enact changes by clicking “Change Time Range” to choose the beginning date/time and an end date/time that you would like to view.

10. If you want to export the graph you have created, simply press “Export Chart” above the “Clear Data” button. An image file will be created and located in the folder “noBAS BRT Charts” with a time stamp. If you have created multiple plots in one file, you can select which you would like to export.
3.2.7 Suggested Actions

When analyzing the data for this measure, knowledge of the fan status is critical. If the fan is off, all temperature sensors are measuring stagnant air temperatures and no conclusions requiring air temperatures can be drawn during these times. It is recommended that this measure is done in conjunction with measure “Do the fans operate during unoccupied times?” Doing so correlates the times when the fans are off so that the temperatures during those times can be explicitly ignored.

Knowledge of the operating schedule is also critical. The analysis must incorporate the times when the building is occupied, unoccupied, and in start-up mode. During unoccupied and start-up times, the OA damper should be closed. Closed OA dampers are indicated when the data show RAT = MAT when the fan is on.

In heating mode, during occupied hours, the outdoor air damper should be in the designed minimum position. Generally, MAT should be much closer to RAT than it is to OAT. If not, verify that the outdoor air damper is at its designed minimum position.

In cooling mode, during occupied hours, if OAT is less than RAT, conditions are usually favorable for air-side economizing\(^1\). When air-side economizing, MAT should be close or equal to OAT. If not, make sure the outdoor air damper is at its designed maximum position; usually this means “fully open”. Regarding the sequence of operations, if OAT is less than the DAT Set Point, the OA should be tempered with return air to have the DAT meet the DAT Set Point. This assumes the dampers can modulate to mix OA and RA such that DAT meets the DAT Set Point.

In cooling mode, during occupied hours, when conditions are not favorable for economizing [i.e., (OAT+2) > RAT], the outdoor air damper should be in the designed minimum position. If MAT is not much closer to RAT than it is to OAT, verify that the outdoor air damper is at its designed minimum position.

A more careful analysis regarding the amount of outdoor air introduced is determined by calculating the “outdoor air fraction” (OAF). OAF varies from zero to one, where “zero” means there is zero percent outdoor air in the mixed air (all return air), and “one” means the mixed air is one hundred percent outdoor air (i.e., return air is fully exhausted). OAF can be determined either via “spot checking”, calculated for a given time or set of times, or via a simple analytic method for all times using a spreadsheet tool. The method requires using the value OAF = [(MAT - RAT) / (OAT - RAT)]. Note that this equation can only produce a reliable result if OAT is significantly different from RAT. Otherwise, the denominator will be close to zero and confidence plummets in the accuracy of the calculated OAF.

\(^1\) A more precise expression for favorable economizing conditions is based on enthalpy, which accounts for the energy in the air’s moisture. Favorable economizing conditions exist when the OA enthalpy is less than the RA enthalpy. However, enthalpy measures are often less reliable than dry-bulb temperature measurements. A NYC weather data analysis shows that a 2°F margin correlates with a 96 percent probability that OA enthalpy is below RA enthalpy. This suggests economizing when (OAT+2) is less than RAT. Thus, “dry bulb economizing” with a 2°F margin is reasonably reliable.
3.3 Is my outdoor air damper at the minimum required position?

3.3.1 Measure Description

A good operating level of ventilation strikes a good balance between indoor air quality and energy efficiency. Under-ventilation compromises air quality, and over-ventilation wastes energy since it requires additional heating or cooling energy of outdoor air than is needed.

For buildings that do not have demand control ventilation, there exists a minimum outdoor air damper position that should be set such that the maximum CO2 concentration for any served zone reaches the maximum level considered sufficient for good indoor air quality. This measure determines whether the minimum outdoor air damper position is selected to capture the right balance between healthy indoor air quality during maximum load occupancy and energy efficiency. It's worth noting that the minimum OA damper position, by design, over ventilates when zones are not at maximum load occupancy.

This measure must be done when air-side economizing is not in use. This typically occurs during the height of heating and cooling seasons, i.e., during extreme temperatures. Otherwise, the additional air that is introduces for free cooling reduces the CO2 concentration.

3.3.2 Kit Contents (Equipment and Software)

Data from the CO2 sensor / logger (MX1102) may be acquired either via Bluetooth using an iPad and HOBOmobile™ software or through a wired connection using a Surface Pro / laptop and HOBOware®. Only the wireless method of data acquisition is described in the data acquisition section.

1. HOBO® CO2 sensor / logger (MX1102)
2. iPad
3. HOBOmobile™ software
3.3.3 Initialization Procedure: HOBO® Wireless CO2 Data Logger (MX1102)

1. Enable Bluetooth on your device and then open the HOBOmobile™ app.
2. Ensure that the logger has enough battery life for the trending time period.
3. Tap the logger with the correct serial number. The serial number is shown in both the top left and top right corner of the image below.

4. Name the logger.
   a. Tap “Configure.”
   b. Tap “Name.”
   c. Change the logger name to include the building name, space served, system name, and parameter measured (e.g. “AnytownHS_GymA-HU_C02.”) Note that there is a 20-character limit. Tap “Done” after typing in the new name.
5. Tap “Logging Interval.” Set the logging interval to 15 minutes and then tap “Done.”

   a. Tap “Start Logging” and then “On Date/Time.”
   b. Select a date and time. Make sure that the start logging time is on the hour. For example, start at 12:00 instead of 12:02, 12:15, or 12:30. Tap “Done.”
7. Select memory and time options.
   
a. Tap “Stop Logging.”

b. Select “Never (Wrap When Full)” as the memory options. Additionally, select “Never” in the time option section.
8. Make sure the CO2 toggle is enabled.

![CO2 Toggle](image)

9. Select Altitude Compensation and tap on the “Enable Altitude Compensation” toggle to enable it.

10. Enter the altitude above or below sea level (if you don’t know your location’s exact elevation, the average elevation in New York City is 33’. Tap “Done”.

![Altitude Compensation](image)

11. Tap “Start.” The “Configure Success” message indicates that the logger was successfully initialized.

![Configure Success](image)
3.3.4 Installation Procedure: HOBO® Wireless CO2 Data Logger (MX1102)

1. The CO2 sensor in the logger requires calibration to ensure accurate readings.

   Steps for CO2 calibration:

   a. Bring the logger outside on a dry day and place it on a surface that has no connection to a ventilation system because that air might skew CO2 readings. Hold down the calibration button shown below to start the five-minute manual calibration process of the CO2 sensor. Release the calibration button once you hear the logger alarm confirming the start of the calibration process. The calibration reading and icon text on the LCD screen will flash throughout the calibration process.

   DO NOT BREATHE ON THE LOGGER DURING THE CALIBRATION PROCESS.

   b. At the time the calibration process ends, the calibration reading and icon will stop flashing and remain solid as seen on the LCD screen.

   c. Verify that the outside CO2 concentrations are around 400 ppm.

   d. If the CO2 readings are not between 370 ppm and 450 ppm, repeat the calibration steps. If the problem persists, then try at a different location. For example, avoid calibrating near vehicular traffic.
2. Deploy the CO2 Sensor / logger at zone locations where you wish to record CO2 concentrations.

If the AHU/RTU is dedicated to a specific zone (e.g. a gymnasium or auditorium), locating the device in the return air duct will produce an accurate result.

Otherwise, deploy loggers in the zones that have the highest occupant load for the zones served by a selected AHU/RTU. To identify these zones, consider conference rooms, classrooms, waiting rooms and congested corridors. Ideally the logger will be located about 3 feet above the floor level and in a space where the air is well mixed. Therefore, avoid installing in the throw of a diffuser or in a corner where air may not mix well.

Use the mounting magnets located on the back of the logger to attach at a fixed location. If the mounting magnets are ineffective, secure the logger using mounting tape, tiebreak cables, or wall mounting holes.

e. An example of a properly calibrated CO2 sensor is shown below.
3.3.5 Data Acquisition/Visualization Procedure: Wireless CO2 Data Logger (MX1102)

1. Enable Bluetooth on your device and then open the HOBOmobile™ app.
2. Tap the logger with the correct serial number. The serial number is shown in the top right corner of the image below.

<table>
<thead>
<tr>
<th>AHU 7- OAT</th>
<th>SN 10373709 MX1101</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stopped 69.30°F 83.67%</td>
<td>✓</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gym CO2 Return</th>
<th>SN 10376318 MX1702</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stopped 72.65°F 63.65% 587ppm</td>
<td>✓</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DAT</th>
<th>SN 10605092 MX1101</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stopped 69.34°F 100.00%</td>
<td>✓</td>
</tr>
</tbody>
</table>

3. Tap “Readout” to download the data. Tap “Ok” when the “Readout success” message appears.

4. Tap Data Files and then tap the mini-graph to view a larger version of the graph or to share the file. A graph will appear like the examples below.
5. Tap the graph with the right logger name. A larger version of this graph will appear.

6. Tap the option tab on the top right corner of the graph.
7. Uncheck the Temp, RH, and DewPt sensors.

8. The graph will populate with only the CO2 readings.

9. Tap  to export the file.

10. Save logged data by selecting file type
    
    **Note:** make sure you save the data as both a HOBO® file and CSV file.
11. Tap “HOBO” or CSV and select either “Mail” or “Copy to Dropbox” to export the file for file saving or further analysis.

3.3.6 Suggested Actions

During high occupant load, if the level of CO2 concentration is over 1,100 ppm, ventilation is insufficient for a healthy environment. Increase the minimum outside air damper position. (Note that this will increase energy consumption, but occupant health and comfort must take precedence.) If the CO2 concentration is under 800 ppm, decrease the minimum outside air damper position. This is a trial and error procedure; after adjusting the minimum OA damper position, follow up with another sampling of CO2 measurements to see if the desired effect is reached (800 – 1,100 ppm peak CO2 concentration).

As mentioned in the measure description, this measure should be done during extreme temperature conditions to avoid air-side economizing while gathering data. Otherwise there is a risk of concluding that over ventilation is occurring when, in fact, air side economizing may have been in use. This risk is eliminated if this measure is done together with OA Control, which offers guidance on determine the times when air-side economizing is in use. CO2 concentration must be ignored at the times when economizing is in use.
3.4 Is a reset being used to control the discharge air temperature (DAT)?

3.4.1 Measure Description
Monitor the DAT to determine whether a reset or change in DAT set point can be used to operate more efficiently.

3.4.2 Kit Contents (Equipment and Software)
For RAT and DAT:

1. Wireless temperature logger: HOBO® MX1101, one per each temperature location

Also:

2. iPad, iPhone or Android
3. HOBOmobile™ software
4. PC-based device (e.g. laptop or Surface Pro)
5. Microsoft Excel
6. CUNY BPL-provided macro-enabled Excel file (OA Control, DAT Hunting, and DAT Reset.xlsx)
3.4.3 Initialization Procedure: HOBO® Wireless Temperature Logger (MX1101)

1. Enable Bluetooth on your device, and then open the HoboMobile™ app.

2. Ensure that the logger has enough battery life remaining.

3. Tap the logger with the correct serial number. The serial number is shown in both the top left and the top right corner of the image below.

4. Name the logger.
   a. Tap “Configure.”
   b. Tap “Name.”
   c. Change the logger name to include the building name, space served, system name, and parameter measured (e.g. “AnytownHS_GymAHU_DAT”). Note that there is a 20-character limit. Tap “Done” after typing in the new name.
5. Tap “Logging Interval.” Set the logging interval to 15 minutes and then tap “Done”.

   a. Tap “Start Logging” and then “On Date/Time”.
   b. Select a date and time. Make sure that the start logging time is on the hour. For example, start at 12:00 instead of 12:02, 12:15, or 12:30. Tap “Done”.

   07/11/2017, 12:00:00 EDT
7. Select memory and time options.

   a. Tap “Stop Logging.”

   b. Select “Never (Wrap When Full)” as the memory option. Additionally, select “Never” in the time option section.

8. Tap “Start”. The “Configure Success” message indicates that the logger was successfully initialized.
3.4.4 Installation Procedure: HOBO® Wireless Temperature Logger (MX1101)

1. Deploy the logger at a location from which you wish to collect data. Note that sensor locations should be selected where accurate temperature measurements are anticipated.

2. Depending on the measure you are implementing one or more of the following will apply:

   a. Special consideration should be given to the DAT sensor placement such that the air streams are truly mixed. For example, the sensor should be downstream of heating coils because it may also record heat from the coils. The same applies to cooling coils.

   b. Special consideration should be given to the RAT sensor placement such that the sensor is located after mixing from multiple zones has already occurred. Also, ensure that the sensor is upstream of the return air damper.

3. Use mounting magnets on the back of the logger to attach at a fixed location or use mounting tape and break ties if the surface is non-magnetic.
3.4.5 Data Acquisition Procedure: HOBO® Wireless Temperature Logger (MX1101)

1. Enable Bluetooth on your device and then open the HOBOmobile™ app.

2. Tap the logger with the correct serial number. The serial number is shown in the top right corner of the image below.

3. Tap “Readout” to download the data. Tap “OK” when the “Readout success” message appears.

4. Tap and then tap the mini graph to view a larger version of the graph or to share the file. Examples of the graphs that will appear are shown below. Tap to export the file.
5. Tap the option tab on the top right corner of the graph.
6. Uncheck RH.

7. The graph will populate with only the temperature readings.
8. Tap “CSV” and select either “Mail” or “Copy to Dropbox” to export the file.
Troubleshooting note:

If the following image appears at any point in the process, click “End”, and check to make sure all the directions in both the manual and the macro-enabled Microsoft Excel file were followed. If so, attempt to continue, if possible. If not, please contact BPL with your specific circumstances.

1. Download the CUNY BPL-provided macro-enabled Excel file named “OA Control, DAT Hunting, and DAT Reset.xlsm” and save the file in the same folder where your logged data are located.

2. Open the folder and check to see that the data files are labeled correctly. Use the file names shown in the table below. (This is to ensure that the Excel Macro program can read the files).

<table>
<thead>
<tr>
<th>File Name</th>
<th>Contained Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>DAT.csv</td>
<td>Discharge Air Temperature</td>
</tr>
<tr>
<td>RAT.csv</td>
<td>Return Air Temperature</td>
</tr>
</tbody>
</table>

3. Open the “OA Control, DAT Hunting, and DAT Reset.xlsm” macro enabled excel document.

4. In order for the program to run you must enable editing, enable content, and trust the document.

5. Click on “Save As” under “File” on the Microsoft Excel top bar to the folder that contains your temperature data, and rename this Microsoft Excel file (e.g. Hot Water Primary Loop Delta T_my building).
6. Follow the steps outlined in the macro-enabled Excel file. **Note:** If data from previous visualizations is in the Microsoft Excel sheet, it can be easily erased by clicking “Clear Data” underneath the BPL Logo on the left side.

a. Click “Import” to import your data in the “Data” tap.

b. Then, click “Plot Data” in the “Reset DAT” tap. This function will plot your data. The loading time will vary depending on the file size.

c. Change the time range if the graph looks too crowded. The time range can be changed by using the first dropdown on the left underneath the “Plot Data” button. The top dropdown defines the start date, and the dropdown directly beneath it defines the length of time. Enact changes by clicking “Change Time Range” after selecting the start date and the time duration.

d. If you want to export the graph you have created, simply click the ‘Export’ button. An image file will be created and located in the folder in which you have the Macro-enabled Excel File with a time stamp in the name. If you have created multiple plots in one file,
d. If you want to export the graph you have created, simply click the ‘Export’ button. An image file will be created and located in the folder in which you have the Macro-enabled Excel File with a time stamp in the name. If you have created multiple plots in one file, you can select which you would like to export.
3.4.7 Suggested Actions

IN COOLING MODE
A DAT set point that’s too low can cause over cooling. This may be evident in the trend chart showing a RAT indicative of zone temperatures being too low. In air distribution systems with reheat, a DAT set point too low can also cause excessive use of reheat. Increasing the DAT set point will mitigate both issues. Incrementally increase the DAT set point, ensuring that all zones served are satisfied.

IN HEATING MODE
It is often the case that an air system serves the same zone(s) as another heating system such as perimeter hot water or steam. Furthermore, it is also often the case that the controls for these two systems are not interlocked / coordinated.

During occupied times, discharge air should include a fraction of outdoor air for ventilation, and the OA damper should be set to minimum position (see related measures for improved OA Control and OA Minimum Damper Position). If all zones served by an AHU / RTU have two heating systems, and if the non-air system can satisfy the zones, DAT does not have to be greater than the ZTSP to heat the zone. However, if the zone thermostat controls a VAV damper and the thermostat calls for heat in such an air system, the call for heat should not result in the VAV damper allowing more air if the DAT is less than the ZTSP. If so, simultaneous heating and cooling is occurring, albeit with OA and not mechanical cooling.

A common strategy for such dual-system scenarios is to set the perimeter heating system to provide the bulk of the heating and set up the air system to fine tune the zone temperature. In these cases, DAT set point must be higher than the ZTSP.
3.5 Is the discharge air temperature (DAT) hunting?

3.5.1 Measure Description

This measure applies to AHU / RTUs with a DAT set point.

DAT hunting is characterized by wide swings in DAT rather than settling on or near the DAT set point. This may be an indication of multiple issues that can lead to inefficient operation.

This measure is for these AHU / RTUs that have a DAT set point that does not change dynamically. It aims to track Discharge Air Temperature (DAT) to confirm that it is relatively stable.

3.5.2 Kit Contents (Equipment and Software)

1. HOBO® MX1101 Wireless Temperature Sensors (DAT, MAT, RAT, and OAT).
2. Apple/Android device.
3. HOBOmobile™ software/app.

It is recommended that this measure be done in conjunction with the measure “How is my outside air control?”

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1 Some sequences of operations use dynamic DAT set points based on other operating parameters intended to enhance efficiency and comfort.
3.5.3 Initialization Procedure: HOBO® Wireless Temperature Logger (MX1101)

1. Enable Bluetooth on your device, and then open the HoboMobile™ app.
2. Ensure that the logger has enough battery life for the trending time period.
3. Tap the logger with the correct serial number. The serial number is shown in the top right corner of the image below.

4. Name the logger.
   a. Tap “Configure.”
   b. Tap “Name.”
   c. Change the logger name to include the building name, space served, system name, and parameter measured (e.g. “AnytownHS_GymAHU_DAT.”) Note that there is a 20-character limit. Tap “Done” after typing in the new name.
5. Tap “Logging Interval.” Set the logging interval to 15 minutes and then tap “Done.”

   a. Tap “Start Logging” and then “On Date/Time.”
   b. Select a date and time. Make sure that the start logging time is on the hour. For example, start at noon instead of 12:02 PM. Tap “Done.”

7. Select memory and time options.
   a. Tap “Stop Logging.”
   b. Select never (wrap when full) for memory options. Additionally, select never in the time option section.
7. Select memory and time options.
   a. Tap “Stop Logging.”
   b. Select never (wrap when full) for memory options. Additionally, select never in the time option section.

8. Tap “Start.” The “Configure Success” message indicates that the logger was successfully initialized.
3.5.4 Installation Procedure: HOBO® Wireless Temperature Logger (MX1101)

1. Ensure that the logger has enough battery life remaining.

2. Deploy the logger at a location from which you wish to collect data. Note that sensor locations should be selected where accurate temperature measurements are anticipated.

3. Depending on the measure you are implementing one or more of the following will apply:

   a. Special consideration should be given to the DAT sensor placement such that the air streams are truly mixed. For example, the sensor should be downstream of heating coils because it may also record heat from the coils. The same applies to cooling coils.

4. Use mounting magnets in the back of the logger to attach at a fixed location or use mounting tape and break ties if the surface is non-magnetic.

3.5.5 Data Acquisition: HOBO® Wireless Temperature Logger (MX1101)

1. Enable Bluetooth on your device and then open the HOBOmobile™ app.

2. Tap the logger with the correct serial number. The serial number is shown in the top right corner of the image below.

3. Tap “Start.” The “Configure Success” message indicates that the logger was successfully initialized.

4. Tap “Readout” to download the data. Tap “OK” when the “Readout success” message appears.

Examples of the graphs that will appear are shown below. Tap to export the file.
3. Tap “Readout” to download the data. Tap “OK” when the “Readout success” message appears.

4. Tap and then tap the mini-graph to view a larger version of the graph or to share the file. Examples of the graphs that will appear are shown below. Tap to export the file.
5. Tap the option tab on the top right corner of the graph.

6. Uncheck RH. The graph will populate with only the temperature readings.
7. The graph will populate with only the temperature readings.
8. Tap “HOBO” or CSV and select either “Mail” or “Copy to Dropbox” to export the data for file saving or further analysis.

Note: If you would like to use the macro for DAT Hunting, which is bundled with OA Control and DAT Reset, select “HOBO®” and select either “Mail” or “Copy to Dropbox” to export the file and continue with the following directions. The file name for the Macro is called, “OA Control, DAT Hunting, and DAT Reset.xlsm”.
3.5.6 Visualization Procedure

1. A graph similar to the image below was generated in the HOBOmobile™ software and exported in the previous section. This graph should be sufficient for analysis, however if you decided to use the macro-enabled excel file bundled with OA control, simply reference the directions outlined in the “How is my outdoor air control?” measure’s data visualization procedure.
3.5.7 Suggested Actions

DAT should settle on the DAT set point and not vary widely during operation. DAT hunting is characterized by wide DAT swings throughout the day. This may indicate multiple issues that can lead to inefficient operation. If the DAT is hunting, consider the following:

1. AHU / RTU designs vary widely and may or may not be able to finely modulate air heating or cooling. Determine whether dramatic changes in DAT correlate with discrete steps in heating or cooling modulation, such as compressor staging or gas burner staging. For example, an RTU with two compressors may simply stage up from zero to one to two compressors, running at full speed, as called for by the DAT and DATSP. This behavior is not DAT hunting and is a common characteristic of operation for such technology. However, DAT hunting is not expected for heating and cooling coils with valves controlled to settle on the DAT set point.

2. DAT hunting can be caused by simultaneous / alternating heating and cooling. This can occur if the AHU/RTU is capable of calling for heating or cooling to drive the DAT to the DATSP as needed. As DAT drops while compressors are on, if the heating set point is reached, then the heating function may engage. DAT will then rise, potentially to the cooling set point, when cooling (compressors or chilled water) may start again. And so on.

To prevent this oscillation that causes significant energy loss, ensure there is a wide enough dead band between the cooling and heating cut in temperatures. The recommended dead band is no less than 5 °F.

3. It is possible that DAT hunting is triggered by simultaneous heating and cooling due to leaky valves on the heating / cooling coils. Check for valve leaks. Note that this can occur if the pressure in the hot water / chilled water pipes is high enough to unseat the valves, i.e. loop differential pressure set point exceeds the rated pressure for the valve.

4. It is possible that temperature sensors are out of calibration or are located improperly. If so, the sequence of operations may be driven by inaccurate measurements, leading to improper operation. Check temperature sensors for accuracy and placement.
3.6 For Roof Top Units (RTU), how are compressor(s) cycling?

3.6.1 Measure Description

Record the compressor(s)' on/off status to ensure that the compressor(s) are cycling properly. Measure DAT and MAT to ensure DAT is lower than MAT when the compressor(s) is running. Measure OAT to ensure compressor(s)' run time correlates with OAT (i.e. tons / cooling degree days).

Note: Compressor longevity (mean time to failure) is strongly correlated to compressor cycles. Thus rapid cycling will lead to more frequent replacement. This measure addresses not only operational efficiency, but also an important and potentially costly maintenance issue.

3.6.2 Kit Contents (Equipment and Software)

For Compressor Cycling:

1. HOBO® Motor On/Off Logger: UX90-004 or UX90-004M, one per compressor

For Temperature:

2. HOBO® Wireless Temperature Data Logger: MX1101, 4 per RTU

Also:

3. PC-based device with USB port (e.g. laptop or Surface Pro 3)
4. HOBOware® software
5. Ipad or Mobile Device
6. Hobomobile™ application for mobile device.
7. Microsoft Excel
8. CUNY BPL-provided macro-enabled Excel File (RTU Compressor Cycling Visualization.xlsm)
3.6.3 Initialization Procedure: HOBO® Motor On/Off Data Logger (UX90-004)

1. Open the HOBOware® software on your computer.

2. To connect the logger to a computer, plug the small end of the USB cable into the side of logger and the large end into the USB port of the computer (with HOBOware® software pre-installed).

3. If the “Select Device” window pops up, make sure that the radio button showing the HOBO® UX90-004M Motor On/Off data logger is selected and click “OK”.

![UX90-004 Diagram](image-url)
4. Select the launch icon on the HOBOware® toolbar on your laptop to open the configuration options for the logger.

5. Ensure that the logger has enough battery life for the trending period before you start the configuration process.

6. In the description text box, type a compressor name that describes the compressor as seen in the example below. The general naming template includes the following: create a logger name that includes the building name, space served, system name, and parameter measured. Note that there is a 40-character limit.

7. In the “Sensors” section, choose the type of logging configuration. The sensors can be configured to log data either by runtime or state. It is critical that you select “State”. Note: When the logger is configured to log state change, the logging interval option is greyed out and cannot be selected for changes. The logging duration is dependent on event duration.
8. Under “Start Logging”, choose the start date and time. Set the logger to start after the installation is complete. Make sure that the start logging time is on the hour. For example, start at 12:00 PM instead of 12:02 PM, 12:15 PM, or 12:30 PM.

9. Under “Stop Logging”, select “never (wrapping)”. 

10. By default, the LCD will always remain on while logging data. Verify that the “Turn LCD off” box is not checked under “Options”. 

11. Click “Delayed Start” to launch the logger. 

12. A “Launching Logger” window will appear to save all the sections in the initialization procedure. Wait for the progress bar to reach 100% before proceeding.
13. A fully configured logger launch should look like this:

![Logger Launch UI](image)

14. Click “Save”.

15. Disconnect the logger from your computer by unplugging the small USB end from the side of the logger.

The next step is to deploy and calibrate the logger on the compressor motor.
3.6.4 Initialization Procedure: HOBO® Wireless Temperature Data Logger (MX1101)

1. Enable Bluetooth on your device and then open the HOBOmobile™ app.

2. Ensure that the logger has enough battery life for the trending period before you start the configuration process.

3. Tap the logger with the correct serial number. The serial number is shown in the top right corner of the image below.

4. Name the logger.
   a. Tap “Configure.”
   b. Tap “Name.”
   c. Change the logger name to include the building name, space served, system name, and parameter measured (e.g. “AnytownHS_GymAHU_DAT.”) Note that there is a 20-character limit. Tap “Done” after typing in the new name.
5. Tap “Logging Interval.” Set the logging interval to 15 minutes and then tap “Done.”

   a. Tap “Start Logging” and then “On Date/Time.”
   b. Select a date and time. Make sure that the start logging time is on the hour. For example, start at noon instead of 12:02, 12:15, or 12:30. Tap “Done.”

7. Select memory and time options.
7. Select memory and time options.
   
   a. Tap “Stop Logging.”

   b. Select “Never (Wrap When Full)” for memory options. Additionally, select “Never” in the time option section.

8. Tap “Start.” The “Configure Success” message indicates that the logger was successfully initialized.
3.6.5 Installation Procedure: HOBO® Motor On/Off Data Logger (UX90-004)

1. Deploy the logger on the motor from which you wish to collect your data. Use the mounting magnets on the back of the logger to attach it at a fixed location.

2. When the motor is running, hold down the calibration button until the LCD display reads “Pass”. If the LCD display reads “fail”, the logger needs to be calibrated again. The signal strength should be at least 3 bars, so orient the logger as required to increase the signal strength. Calibration helps the logger identify the magnetic field of that particular motor and ignore any surrounding magnetic fields.
3.6.6 Installation Procedure: HOBO® Wireless Temperature Data Logger (MX1101)

1. Deploy the logger at a location where you wish to collect data from.

   **Note:** Sensor locations should be selected where accurate temperature measurements are anticipated. For example, sensors should not be near heating coils because they may also record heat from the coils. This also applies to cooling coils.

2. Depending on the measure you are implementing, one or more of the following will apply:

   a. Special consideration should be given to the DAT sensor placement such that the air streams are truly mixed. For example, the sensor should be downstream of heating coils because it may also record heat from the coils. The same applies to cooling coils.

   b. Special consideration should be given to the MAT sensor placement such that the sensor is located after a good mixing of OA and RA has already occurred. Also, ensure that the sensor is not near heating or cooling coils.

   c. Special consideration should be given to the OAT sensor placement such that the sensor is close to the OA damper, but not exposed to rain or sunlight.

   d. Special consideration should be given to the RAT sensor placement such that the sensor is located after mixing from multiple zones has already occurred. Also, ensure that the sensor is upstream of the return air damper.

3. Use mounting magnets on the back of the logger to attach it at a fixed location, or use mounting tape and break ties if the surface is non-magnetic.
3.6.7 Data Acquisition: HOBO® Motor On/Off Data Logger (UX90-004)

To offload data from the UX90-004 data logger:

1. On your laptop/Surface Pro, open HOBOware®
2. Connect the logger: plug the small end of the USB cable into the side of the logger and the large end into a USB port on the computer.
3. If the “Select Device” window pops up, make sure that the radio button showing the HOBO® UX90-004 Motor On/Off is selected and click “OK”.
4. Click “Readout” button on the HOBOware® toolbar.
5. If the loggers were previously active, select “Don’t Stop” unless you are removing the loggers from the site.
6. Wait for the data to be read out. Once the readout is complete, choose a location and/or a new filename, or accept the default location and name to save the data.

7. Click “Save”.

8. The plot setup window will appear after saving. Make sure that all boxes are checked for the series that were created in the initialization procedure.
9. The plot setup window should look like this:

- Under “Select Internal Logger Events to plot”, click “None”
- Click “Plot” at the bottom of the window. Clicking “Plot” will open up your graph (as shown below).

10. Click on “Export Table Data” on the HOBOware® toolbar as shown below. Save the document to a new folder designated for your data. Make sure this folder is on your desktop, as it will be used during the visualization procedure.

3.6.8 Data Acquisition: HOBO® Wireless Temperature Data Logger (MX1101)

1. Enable Bluetooth on your device and then open the HOBOmobile™ app.
2. Tap the logger with the correct serial number. The serial number is shown in the top right corner of the image below.
3. Tap “Readout” to download the data. Tap “OK” when the “Readout success” message appears.

4. Tap and then tap the mini graph to view a larger version of the graph or to share the file. Examples of the graphs that will appear are shown below. Tap to export the file.
5. Tap the option tab on the top right corner of the graph.

6. Uncheck RH.

7. The graph will populate with only the temperature readings.
8. Tap “CSV” and select either “Mail” or “Copy to Dropbox” to export the file.
3.6.9 Visualization Procedure

Warning:
If the following image appears at any point in the process, click ‘End’, and check to make sure all of the directions both in the manual and in the file were followed. If so, attempt to continue if possible. If not please contact BPL with your specific circumstances.

Microsoft Visual Basic

Run-time error '1004':
Excel cannot find the text file to refresh this external data range.
Check to make sure the text file has not been moved or renamed, then try the refresh again.

1. Download the CUNY BPL-provided macro-enabled Excel file named “RTU Cycling Visualization.xlsm” and save it in the same folder as your logged data.

2. Open the folder and check to see that the data files are labeled correctly. Use the file names shown in the table below. (This is to ensure that the Microsoft Excel macro-enabled program can read the files).

<table>
<thead>
<tr>
<th>File Name</th>
<th>Contained Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>DAT.csv</td>
<td>Discharge Air Temperature</td>
</tr>
<tr>
<td>MAT.csv</td>
<td>Mixed Air Temperature</td>
</tr>
<tr>
<td>OAT.csv</td>
<td>Outdoor Air Temperature</td>
</tr>
<tr>
<td>RAT.csv</td>
<td>Return Air Temperature</td>
</tr>
<tr>
<td>Compressor_#.csv</td>
<td>Compressor Status</td>
</tr>
</tbody>
</table>
3. Open the “RTU Compressor Visualization” macro-enabled Microsoft Excel document.

4. In order for the program to run, you must enable editing, enable content, and trust the document.

5. Click on “Save As” under “File” on the Microsoft Excel top bar to the folder that contains your compressor(s)’ data, and rename this Microsoft Excel file (e.g. “RTUCyclingVisualizationMyBuilding.xlsm”).

6. Follow the steps outlined in the macro-enabled Excel file. **Note:** If data from previous visualizations is in the Microsoft Excel sheet, it can be easily erased by clicking “Clear Data” underneath the BPL Logo on the left side.
a. Choose the number of compressors that you have data for.

b. Import the data by clicking the 'Import' button. The RTU Compressor Macro can import up to 5 compressor data sets.
c. Click “Plot”. This function will plot all your compressor data. The loading time will vary depending on how many compressors you have and the amount of data you collected.

Note: When the graphs appear, they may seem crowded and you will likely see overlap as in the example below if your compressor was cycling while data were collected. This will change when you select the date/time range you would like to visualize; this process is outlined in the next step.
d. The time scale can be changed by using the first dropdown on the left underneath the “Plot” button. The top dropdown defines the start date, and the dropdown directly beneath it defines the length of time. For the compressor, the chart number must also be selected using the dropdown located directly beneath the time length dropdown. Enact changes by clicking “Change Time Range” to choose the beginning date/time and an end date/time that you would like to view.

2/13/2016 0:00
1 day

Note: Your time scale should allow you to see the nuances of your compressor cycling as shown in the image below.
d. If you want to export the graph you have created, simply press “Export Chart” above the “Clear Data” button. An image file will be created and located in the folder “noBAS BRT Charts” with a time stamp. If you have created multiple plots in one file, you can select which you would like to export.

3.6.10 Suggested Actions

Short cycling occurs when a compressor is ON/OFF for a shorter time than the minimum ON/OFF time specified by the manufacturer before turning ON/OFF again. Short cycling can dramatically reduce a compressor’s lifetime and increase energy consumption.

If short cycling is found, you may be able to mitigate it by adjusting the operating differential of the control loop. This will permit a wider fluctuation in DAT around the DATSP.

If the DAT is not significantly lower than the MAT when the compressor(s) is running, or if the drop in temperature is small for any given compressor is staged on, check the compressor(s)’ refrigerant charge.

Compressor(s) run time should decrease when the OAT is lower, as not as much cooling is required. Compare the compressor(s)’ runtime with daily OAT, and confirm there is a correlation.
4  noBas for Distribution & Zone Comfort

4.1  Is the HVAC system managing zone temperatures well?

4.1.1  Measure Description

Measure the zone temperatures to determine whether under / over heating or under / over cooling is occurring. Also, in buildings with occupancy schedules, determine whether night / weekend zone temperature setbacks are being used.

4.1.2  Kit Contents (Equipment and Software)

1. Wireless Temperature HOBO® Data Logger: MX1101, one per zone
2. HoboMobile™ app installed on a tablet or mobile device with Bluetooth capabilities
3. HOBOware® software
4. Microsoft Excel

4.1.3  Initialization Procedure: HOBO® Wireless Temperature Data Logger (MX1101)

1. Enable Bluetooth on your device and then open the HoboMobile™ app.
2. Ensure that the logger has enough battery life for the trending time period.
3. Tap the logger with the correct serial number. The serial number is always shown in the top right corner, as seen in the image below.

4. Name the logger.

   a. Tap “Configure”.

The serial number is always shown in the top right corner, as seen in the image below.
b. Tap “Name”.

![Image of Name field]

```
Name
```

- Change the logger name to include the building name, space served, system name, and parameter measured (e.g. “Site_GymAHU_ZoneTemp.”). Note that there is a 20-character limit. Tap “Done” after typing in the new name.

5. Tap “Logging Interval”. Set the logging interval to 15 minutes and then tap “Done”.

   a. Tap “Start Logging” and then “On Date/Time”.
   b. Select a date and time. Make sure that the start logging time is on the hour. For example, start at 12:00 PM instead of 12:02 PM, 12:15 PM, or 12:30 PM. Tap “Done”.

![Image of Logging Interval]

![Image of Start Logging]
b. Select a date and time. Make sure that the start logging time is on the hour. For example, start at 12:00 PM instead of 12:02 PM, 12:15 PM, or 12:30 PM. Tap “Done”.

<table>
<thead>
<tr>
<th>DATE</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>June</td>
<td>10</td>
<td>2016</td>
</tr>
<tr>
<td>July</td>
<td>11</td>
<td>2017</td>
</tr>
<tr>
<td>August</td>
<td>12</td>
<td>2018</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TIME</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>08</td>
<td>11</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>12</td>
<td>01</td>
<td>01</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

07/11/2017, 12:00:00 EDT

7. Select memory and time options.

a. Tap “Stop Logging”.

b. Select “Never (Wrap When Full)” for memory options. Additionally, select “Never” in the time option section.
8. Tap “Start”. The “Configure Success” message indicates that the logger was successfully initialized.

4.1.4 Installation Procedure: HOBO® Wireless Temperature Data Logger (MX1101)

1. Deploy the logger at a location from which you wish to collect data. Note that sensor locations should be selected where accurate temperature measurements are anticipated.

   Note: Installing temperature sensors in zones requires a clear understanding of the zone boundaries. Sensors should be installed on an interior wall, far from the zone edges (i.e. far from an adjacent zone), 3-6 feet from the floor, far from any source of heat, and directly in the throw of diffusers. For smaller zones and zones thought to have uniform climate control, one sensor per zone is recommended. In large zones or zones thought to have uneven temperature control, using two sensors placed far apart within the zone may provide useful/actionable information.

2. Use mounting magnets on the back of the logger to attach it at a fixed location, or use mounting tape and break ties if the surface is non-magnetic.
4.1.5 Data Acquisition: HOBO® Wireless Temperature Data Logger (MX1101)

1. Enable Bluetooth on your device and then open the HoboMobile™ app.

2. Tap the logger with the correct serial number. The serial number is shown in the top right corner of the row shown below.

3. Tap “Readout” to download the data. Tap “OK” when the “Readout success” message appears.
4. Tap and then tap the mini graph to view a larger version of the graph or to share the file. A graph will appear like the examples below. Tap to export the file.

5. Tap the option tab on the top right corner of the graph.
6. Uncheck RH.

7. The graph will populate with only the temperature readings.
8. Tap “CSV” and select either “Mail” or “Copy to Dropbox” to export and save the file.
4.1.6 Visualization Procedure

Click on located in the lower toolbar. In the “Data Files” section, all saved plots can be viewed, as shown below.
4.1.7 Suggested Actions

Check trend charts to see whether zone temperatures are in a comfortable range and stable. Operators may choose to follow ASHRAE Standard 55, “Thermal Environmental Conditions for Human Occupancy”. This standard indicates, for example, that during the winter at 50 percent indoor relative humidity, zone temperatures of about 70-76°F will make most occupants comfortable. The same is true during the summer for 50 percent relative humidity in the temperature range 75-81°F. Adjust zone temperature set points accordingly.

For buildings with unoccupied times, night / weekend zone temperature setbacks allow zone temperatures to float and reduce energy consumption. This is assuming that OA dampers are closed during these times. Data indicating so are most notable in perimeter zones. If there is no indication of night / weekend setbacks, implement a zone temperature setback schedule. Night / weekend setbacks must be coupled with start-up procedures timed to ensure zones are satisfied when occupancy begins.

Note: During occupied times, zone temperatures for public agency buildings should follow agency guidelines. For example, zone temperatures set points during the heating and cooling seasons may be 68°F and 78°F, respectively.