COMMISSIONING REPORT

[redacted] Building

CX REPORT DESCRIPTION

This report is a summary of the overall commissioning efforts for your project. Included in this report are copies of all completed commissioning checklists, test sheets, reviews, submittals, etc.

Contents

1.0 Overview

Abbreviations and Definitions

The following are common abbreviations used throughout this commissioning report.

A/E	Architect and/or Design Engineers	PM	Project Manager
CxA	Commissioning Authority	OPR	Owner Project Requirements
GC	General Contractor	BOD	Basis of Design
MC	Mechanical Contractor	CHK	Prefunctional Checklist or PFT
EC	Electrical Contractor	TST	Functional Performance Test or FPT
CC	Controls Contractor	Cx	Commissioning
TAB	Testing and Balancing Contractor	OR	Owner Representative
Subs	Subcontractors to General	BAS	Building Automation System
DA-T	Discharge Air Temperature	FCU	Fan Coil Unit
ERV	Energy Recovery Ventilator		

Project History

The Building underwent an HVAC replacement project [redacted] in 2021-2022 which consisted of the demolition and replacement of the HVAC equipment and systems within the building to improve occupant comfort.

Since this HVAC replacement project has been completed there have been ongoing issues with system performance and occupant comfort. The [redacted] contacted us in early 2024 to inquire about performing a retro-commissioning process on the HVAC equipment and systems within the facility as well as performing a review and study of the original design documents from the 2021 HVAC replacement project. Contained within this report are the results of our on-site testing and design review.

2.0 Our Findings

Throughout the course of performing the design analysis and on-site testing we have identified a number of items which we feel are contributing to the poor performance of the HVAC equipment and systems contained within this facility. A full listing and details of the issues identified during on-site testing can be found under the issues log within section 5.0; below is a high-level summary of the issues that we identified. I will break our findings out into separate categories for ease of reference.

Thermostats

Several design inconsistencies and variations were identified between the design record drawings and as-found conditions which include:

There were several thermostat locations on the drawings which prompted further investigation while on-site. *Note: Field verified mapping is indicated by the dashed lines.*

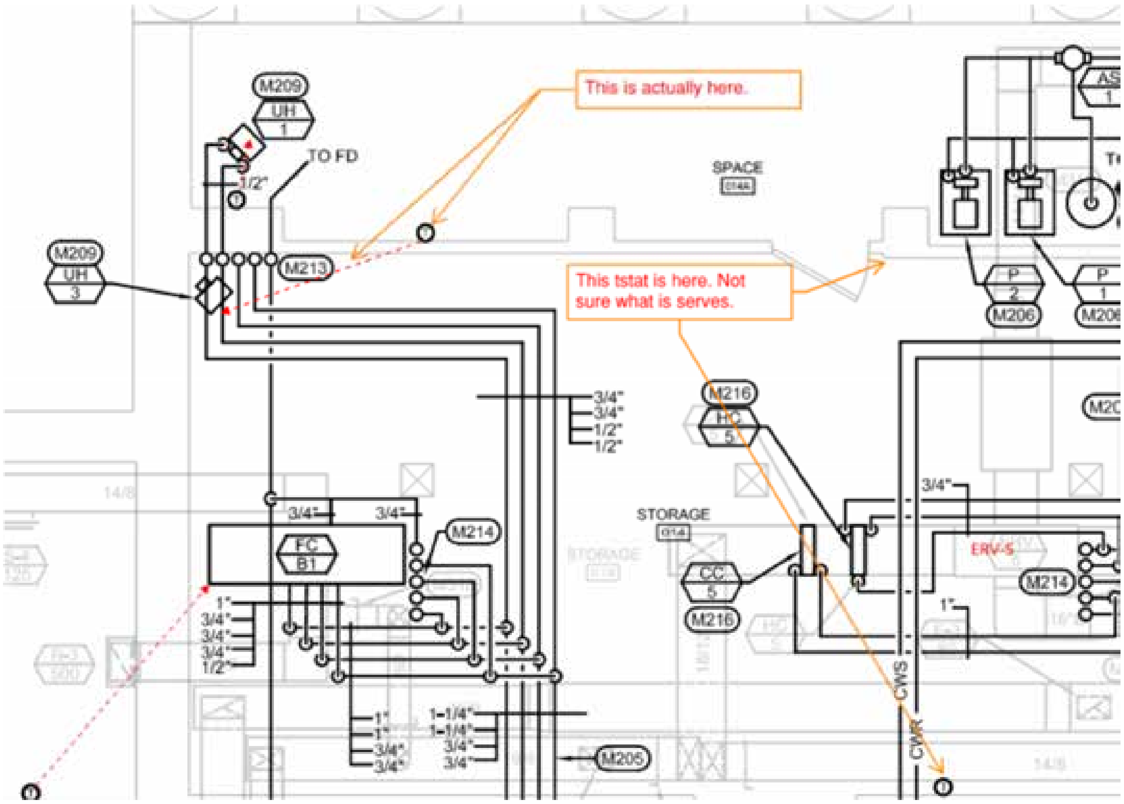


Figure 1: There is an additional unknown thermostat located in room 014. The thermostat for UH-3 was found to be located as shown by the arrow.

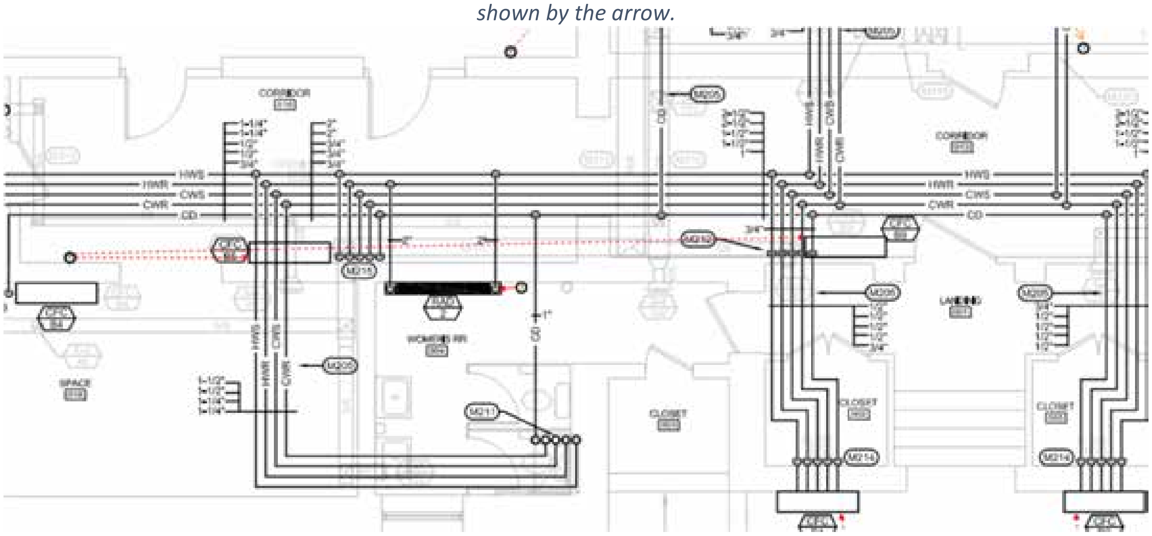


Figure 2: We found that CFC-B5 and B9 are linked and controlled by the same thermostat.

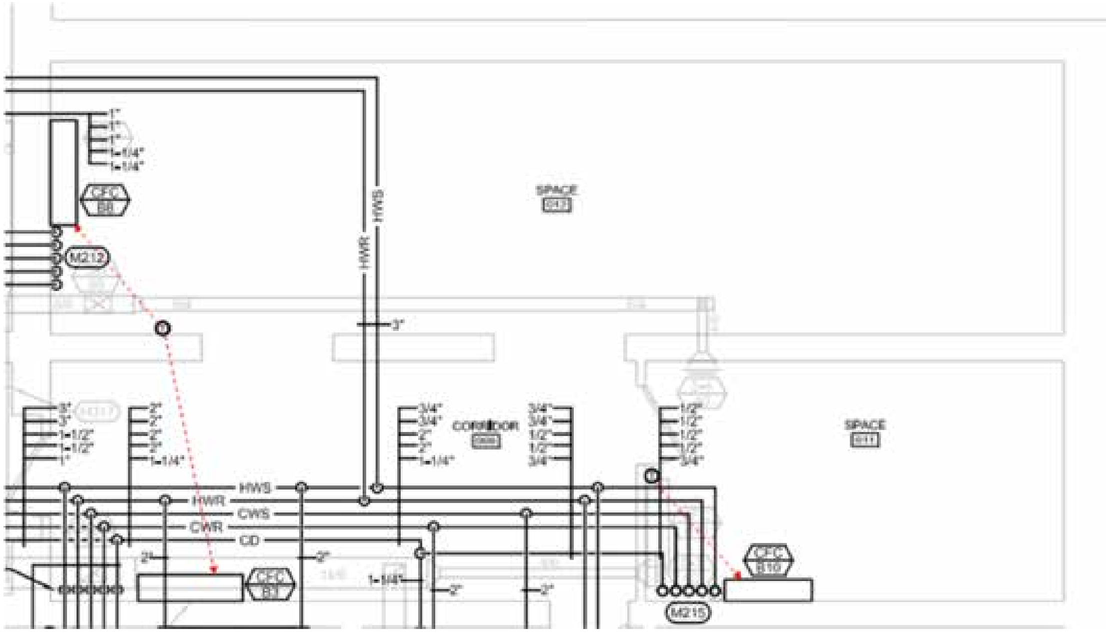


Figure 3: We found that CFC-B8 and CFC-B3 are linked and controlled by the same thermostat.

To summarize the thermostat issues:

- Thermostat in Room 104 does not control anything as far as we can tell.
- Thermostat for Unit Heater 3 is on the other side of the wall from where it was indicated in the drawings.
- CFC-B5 and CFC- B9 are linked and controlled by the same thermostat.
- CFC-B8 and CFC-B3 are linked and controlled by the same thermostat.

These thermostat issues <u>are not likely</u> contributing significantly to the building issues.

Chilled Water System

We identified several inconsistencies involving this system between the design record drawings and the O&M data.

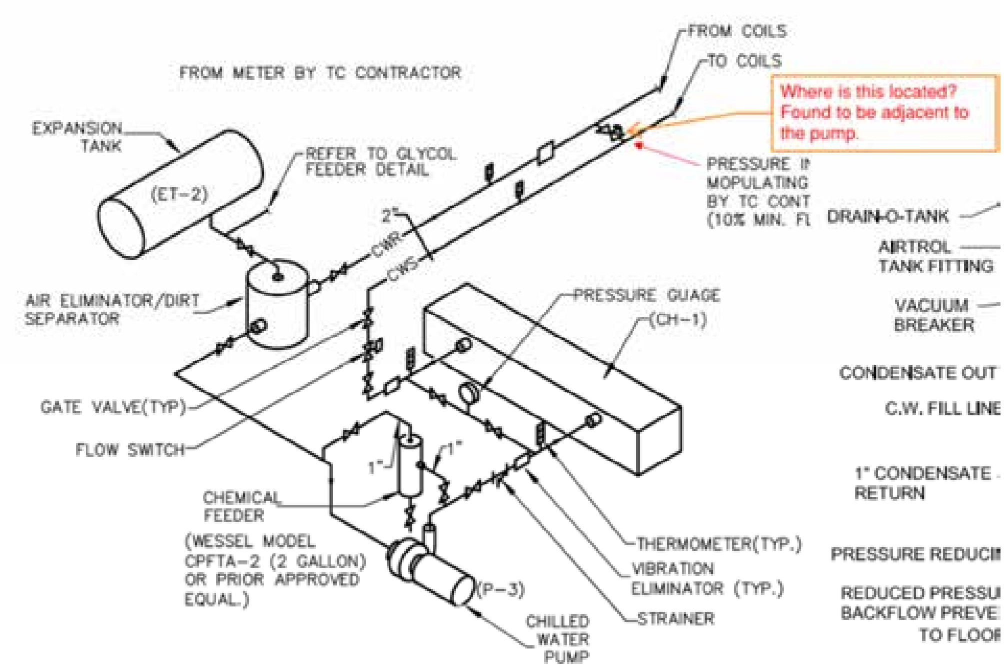
Design chilled water flow and pump sizing do not match. According to the record drawings, the air-cooled chiller was sized with a 55 gpm maximum flow and a 15 gpm minimum flow requirement. The single, primary chilled water pump is sized at 40 gpm with a 65 ft/hd. In reviewing the chiller design submittals, a 55 gpm flow rate was indicated. What we found however, is that all the design chilled water flows add up to 29.8 gpm which is 54% of the design chiller flow and also short of the chilled water pump design sizing criteria. The balanced flow for the chilled water pump was indicated as 29 gpm at 73.9 ft/hd. The chiller will not be able to achieve full design performance without the design water flows. ***This <u>is possibly a large</u> contributor to the building issues, specifically the building overheating. Additionally, the chiller will have a shorter life-span due to excessive cycling.***

- Design chilled water pump = 40 gpm @ 65 ft/hd.
- Balanced chilled water pump = 29 gpm @ 73.9 ft/hd.

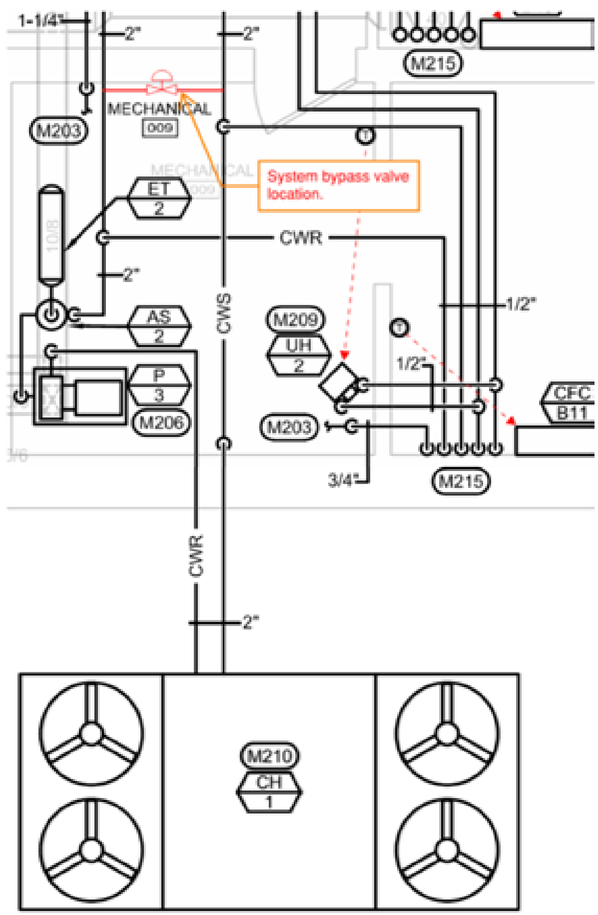
- Design chiller full load flow = 55 gpm
- Balanced chiller flow = 29 gpm with pump triple duty balancing valve 100% open
- Design total chilled water flow = 29.8 gpm
- Balanced total chilled water flow = 32.0 gpm

After reviewing the balancing report that was included in the O&M materials that was dated 1/13/2023, we found that the measured differential pressures at multiple coils located in the 2nd floor ceiling space were at the upper range for the IMI automatic flow control valves. The design pressure range for these automatic flow control valves is listed at 2-32 psi. Reviewing the TAB report, it looks like CC-03, FC-201, and FC-202 were all measured with a differential pressure close to the minimum range limit for the automatic flow control valves (3-6 psi). Our assumption is that the Balancing Contractor had to increase the chilled water system pressure so that the pressures measured at those worst-case coils would fall within the control range for the valves. The consequence of this, however, is that the remainder of the flow control valves in the 2nd floor ceiling, which are furthest away from the pump, are around 24-26 psi. This increase in system pressure contributes to the system head pressure that the pump must overcome. Ideally, the pressure drop at the most remote devices should fall within the 5-10 psi range. ***This is possibly a contributing factor to the building issues, specifically the building overheating.***

The chilled water system volume was also an item of question while performing the design analysis. The design vs. installed conditions for the chiller, pump, and devices aren't coordinated. Part of this relates to the installation details for the chilled water system (detail 3/M501) which shows a 2-way bypass valve for providing minimum flow control for the chiller as all devices are 2-way control valves. Neither the detail, nor the drawings indicate where this 2-way bypass valve should be located. We found on-site that this bypass valve was installed in the same room as the chilled water pump. ***This location of this bypass valve is <u>likely a large</u> contributor to the building issues, specifically the building overheating. (See below.)***



3 CHILLED WATER PIPING SCHEMATIC
NO SCALE



Ideally a system bypass valve for minimum flow is installed closer to the **end of the run** on the chilled water loop.

Since this system bypass is located in close proximity to the chiller and pump, we believe that this is contributing to a situation where the chiller is not experiencing enough system volume to allow for stable chiller operation. According to the chiller IOM information, the chiller should have a 2-minute minimum on-time to maintain the proper oil level, the compressors must cycle on for a minimum of 2 minutes. This 2-minute minimum runtime is not possible with the volume of the chilled water system as-designed, installed, and controlled currently. This is especially evident during periods of lower system demand - when most of the building cooling control valves are closed.

Closely related to the previous issue, we also found that the operation of the heating and cooling coils associated with the ERV units to be poorly controlled. We observed hunting behavior in the control of the heating and cooling which does not allow for consistent flow through the chilled water loop. ***This is exacerbating the lack of system volume from the location of the bypass valve.***

Another issue with the chilled water bypass leg is that it is not meeting its purpose of providing minimum flow protection for the chiller. The chiller is rated to have a minimum flow rate of 15.3 gpm at minimum load and 55 gpm at full load. Currently [redacted] is controlling the minimum flow bypass valve to maintain a 30 gpm flow at all times. This is incorrect and results in the valve being 70-80% open most of the time. Since this valve is open and bypassing 30 gpm at all times, this contributes to the chiller not being able to maintain minimum run times. ***This is likely a large contributor to building issues, specifically the building overheating.***

Energy Recovery Ventilators (ERV's)

Several items were identified regarding the energy recovery ventilators.

While performing the review of the design documents, I found that control and coordination of the heating and cooling coils installed downstream of the ERV's was not clearly identified or specified in the design sequence of operations. However, there were sequences addressing the control of these coils provided in the temperature control shop drawings, and those were approved without addressing the coordination of this equipment. These sequences indicated that the downstream coils would control to a discharge air temperature sensor with a setpoint that is reset based on the outdoor air temperature. This reset schedule was indicated and ultimately programmed as when the OAT ranges from -20 F to 95 F that the discharge air temperature setpoint would follow a straight-line relationship of 95 deg F to 55 deg F. During our testing, we observed that the valves were indeed modulating to maintain the setpoint. The problem with this sequence is that the fan coil units are trying to control space temperature setpoints and the cooling capacity for these fan coil units are sized for a 75 deg F entering air temperature. Between the warm air being returned from the space, approximately 75-80 degrees, and the fresh air being supplied to the fan coil units from the ERV's and coils, which we observed between 90-95 degrees at times, the fan coil unit's ability to provide sufficient cooling capacity is overwhelmed.

This is exasperated by the lack of stable delivery of chilled water. The operation of the coils and valves is independent of the ERV operational mode as the BAS was indicating that the units were in economizing mode, however valves were still modulating between heating and cooling. ***This <u>is likely a moderate</u> contributor to the building issues, specifically the building overheating.***

The design also has multiple ERV's sharing intake/exhaust hood ductwork. While this could be successfully implemented, we are not confident that the twinned ERV's operation is sufficiently synchronized to support this. We did observe that the twinned ERV's cycle their dampers at the same time, what we could not verify was the airflow directions of the twinned units. There is no access to allow for an internal view of the damper direction on the interior of the [redacted] units without removing body panels. Without this verification we could not determine if the units that share the intake/exhaust connections were both operating in the same manner. We also observed that the [redacted] system was commanding the ERV's to be in economizer mode, however, we found that the internal energy recovery dampers were still cycling. These internal dampers are also supposed to cycle at even intervals of 60 seconds, but we timed them and found they cycle at seemingly random intervals. Sometimes the dampers would switch after 60 seconds, and other times they would switch after 5 minutes or anywhere in between those times. The operation and control of the [redacted] units is not performing as designed. ***This <u>is likely a less significant</u> contributor to the building issues, specifically the building overheating.***

During our testing, we observed significant variations in discharge temperatures from the ERV units to the inlets to the FCU's. The random damper switching intervals and the operation of the heating and cooling coils appears to be chasing the temperature setpoint and resulted in a large temperature swing in the air leaving the ERV's. ***This <u>is likely significant contributor</u> to lack of stable temperature control, as well as energy efficiency issues.***

The A/E's design intent documents and the temperature control shop drawings list that the ERV's run at low speed continuously unless there is a call from a dehumidistat, then the fan shifts to high speed for a duration of time. **During on-site testing and verification we identified that there are no humidity sensors installed in the building.** Due to this, we found that the ERV's run at a constant speed and do not vary speed as designed. The A/E's design documents and shop drawings also indicated the ability to switch between heat recovery and economizer modes. While this was included, we found that the units were not responding to the BAS command to operate in economizer mode. ***These <u>are likely moderate contributors</u> to building issues, specifically the building overheating.***

Fan Coil Units (FCU's)

We only found minor issues related to the fan coil units and for the most part these were operating as per the design intent. The items found consisted of the following:

- FC-206: We measured the space temperature 2 deg F higher than the BAS.
- CFC-F2: This unit was not getting water flow during our testing. [redacted] stroked the valve a couple of times and it appeared to start flowing water. This will be something to keep an eye on.
- FCU's: While not specifically an issue, the high space temperature alarms were not enabled. Programming is in place, just disabled.
- The entering air temperature due to the ERV's is greater than the cooling performance criteria.
- ***These are minor issues and <u>not likely</u> large contributing factors to the building issues.***

Finned Tube Radiation and Unit Heaters

Items identified involving this equipment included:

- Lack of BAS graphics as shown in approved shop drawings. There are no graphics for finned tube radiation units and UH's.
- UH-1&3 were found to be twinned together even though there are separate thermostats between the two rooms they serve.
- Differences between the BAS space temperature readings vs what we measured.
- UH-4 heating valve was found to be stuck open and not responding to BAS commands to close the valve.
- ***These are minor issues and <u>not likely</u> large contributing factors to the building issues.***

Heating System

We did not find any significant issues with the heating water system. We did find that the heating loop pumps were mis-labeled in relation to the disconnects and the BAS points, but functionally the heating water system was found to be working.

One item that we identified during the testing was the operation of the heating loop bypass valve. This valve operation was not included in the design documents or in the temperature control shop drawings. We were able to determine that this bypass valve is functioning in the minimum flow control for the heating loop. If the heating pump is at minimum speed and the heating differential pressure exceeds setpoint, the bypass valve will modulate open to maintain the heating loop differential pressure at setpoint. In normal operation, this valve remains closed.

BAS and Miscellaneous Items

A number of points were found to be in manual override and not operating under automatic BAS control. A full list of these points are found under ISSUE-045.

We also found that the current chilled water differential pressure setpoint is higher than the balanced differential pressure setpoint. The current setpoint is set to 27.0 psi while the balancing report indicates 25.0 psi. As stated earlier, we believe that the balancing of the chilled water system could be improved upon to lower pump speeds and reduce energy consumption.

These are minor issues and <u>not likely</u> large contributing factors to the building issues.

3.0 Recommendations

We feel that there are multiple opportunities to improve the performance and operation of the systems within the building. The recommendations contained within this report can be addressed in any order, unless otherwise noted.

Thermostats

We recommend checking accuracy of the thermostats and either replacing or implementing off-sets within the BAS. In general, when we did measure a temperature that was more than 1.5 deg F from what the BAS indicated, we measured higher than what the space sensor indicated. This can contribute to the documented occupant complaints of warm space temperatures.

We recommend that the unit heater and finned tube radiation units be fully incorporated into the BAS graphics as they were called out in the approved shop drawings. The UH thermostat twinning that was noted above should also be corrected.

These changes will bring the building into compliance with the design intent in this area, but are unlikely to provide much relief from overheating.

Chilled Water System

We feel that there are multiple items that need to be address in regard to the chilled water system, which is the source of the nature of the observed occupant complaints.

The most critical item to address is the stable operation of the air-cooled chiller. This chiller is currently exhibiting multiple faults and struggling to operate in a stable manner during periods of lower load. Our recommendations are as follows:

1. Chiller faults need to be corrected. The chiller should also be serviced and exterior coil fins cleaned.
2. Chilled water system volume needs to be increased. The current chilled water system does not support the stable and minimum runtime operation of the chiller. This results in excessive cycling of the chiller and increased wear and tear on the chiller. Possible methods for addressing the system volume may include:
    a. Replacing several of the 2-way control valves in the chilled water loop with 3-way control valves. We recommend that if this is done, that the valves for the FCU's and ERV's located in the 2^{nd} floor ceiling space be replaced to 3-way control valves. This will

act as expanding the volume of the chilled water loop during periods of reduced load by forcing water within the chilled water loop to circulate in a larger section of piping vs the current configuration.

   b. Another option for increasing the volume of the chilled water system will be to add a chilled water buffer tank into the system. This buffer tank could be located in the chilled water pump room and teed into the chilled water loop. If this is implemented long with the addition of 3-way control valves then the capacity of a buffer tank does not need to be very large. Exact sizing is recommended to be provided in coordination with [redacted] but a volume between 50-100 gallons should be sufficient. By providing additional volume to the chilled water system, this would allow the chiller to run for longer periods when it is cycled on to ensure proper oil levels and reduce excessive starts. A buffer tank will also allow for longer periods between chiller starts.
   c. We do not believe that the chiller needs to be enabled and running down to the OA temps that it is currently operating to. If the economizer function of the ERV's can be corrected and chiller operation improved, the chiller enable setpoint can be adjusted upwards closer towards 55 deg F.
3. Chilled water loop bypass valve operation needs to be corrected. This bypass valve should be programmed to ensure that flow through the chilled is never less than 15.3 gpm. This valve should be closed unless flow through the chiller drops below 15.3 gpm. As it is currently being controlled, chilled water is continually being short-circuited through the system and back to the chiller.
4. Chilled water system balancing should be reviewed. There were (3) units located on the 2nd floor that had low differential pressure readings. We recommend that these flow control valves be inspected and possibly have the internal cartridge replaced. If this is done, then the chilled water loop could be balanced to a lower speed and system pressure which would help to reduce excessive head pressures for the pump.
5. We recommend that the chilled water loop expansion tank be inspected, and air charge checked. It was unclear if the tank indicator was showing a faulty internal bladder or not. The air charge should also be checked and adjusted to match the installed height of the chilled water column. Refer to recommendations below for the preventative maintenance for procedures to achieve this.

These changes will bring the building into compliance with the design intent in this area, and are very likely to provide relief from overheating.

Energy Recovery Ventilators (ERV's)

We recommend the operation of the ERV's gets corrected as follows:

1. Economizer/heat recovery modes need to be achieved. The ERV's are currently not responding to the BAS economizer enable command.
   a. When in economizer mode, ERV internal damper switching should not occur.
   b. When in heat recovery mode, ERV internal damper switching should be done every 60 seconds as indicated in the IOM material.

c. We recommend that the ERV's on the 2nd floor be un-twinned. As they are currently designed and installed two units share an intake and exhaust connection. We feel the chances of twinned ERV's coming out of sync with each other is too great. If the operation of twinned ERV's is not fully synchronized and controlled then the adjacent unit can negatively affect the performance of the associated ERV.

2. Control of the ERV heating and cooling valves needs to be corrected.
    a. When the ERV is in economizer mode, the valves should be disabled.
    b. Programming of the DAT-SP control should be changed. We do not recommend that the current programming remain. The current control is allowing ERV DAT's to exceed the design criteria for the FCU cooling performance.

These changes will improve building performance and temperature control; they are changes not specifically included in the design intent.

Fan Coil Units (FCU's)

We do not have any concerns with the fan coil units other than correcting any issues found. The greatest impact on performance of the FCU's will be in controlling the entering air temperature from the ERV's and in maintaining a stable chilled water temperature. ***Correcting issues found (see Issue Log) will contribute to improved building performance.***

Finned Tube Radiation and Unit Heaters

We do not have any concerns with the finned tube radiation or unit heaters other than correcting any issues found. ***Correcting issues found (see Issue Log) will contribute to improved building performance.***

Heating System

We recommend that the chilled water loop expansion tank be inspected, and air charge checked. It was unclear if the tank indicator was showing a faulty internal bladder or not. The air charge should also be checked and adjusted to match the installed height of the chilled water column. Refer to recommendations below for the preventative maintenance for procedures to achieve this. ***Correcting issues found (see Issue Log) will contribute to improved building performance.***

BAS and Miscellaneous Items

We recommend that the points identified as being overridden be reviewed and released to automatic control if appropriate.

Balancing of the chilled water system should be revisited if system volume is increased and the excessive system head can be addressed. Any new setpoints should be programmed into the BAS.

Correcting issues found (see Issue Log) will contribute to improved building performance.

Preventative Maintenance

We would like to provide the following recommendations for preventative maintenance work that should be performed to maintain the full operational efficiency of HVAC components:

- Fan coil units, finned tube radiation, and UH's
    - Perform quarterly reviews of the BAS system to ensure that there are no points overridden in an operator override. Release any overrides as necessary.
    - We recommend commanding the FCU reheat coil valves open then fully closed annually to ensure that the valve actuator is operational. While doing this, verify via the BAS that the FCU discharge air temperature rises when the valve is commanded open and drops when commanded closed. For FTR, you will need to manually feel the element to see if it heats up when the valve is commanded open.
    - If you experience reduced FCU reheat performance and valve operation has been verified, visually inspect the FCU coil inlet side and inspect for fouling of the coil. If the coil is found to be fouled, clean per the manufacturer's recommendations. If no fouling is found, then check the ERV discharge air temperature and the heating system operation.
    - Perform periodic site inspection walks to ensure that no equipment or anything is exerting a false load on thermostats. i.e., copy machines under the thermostat, individual space heaters, etc.
    - For finned tube operation and efficiency, ensure no furniture is positioned directly in front of the FTR unit. These units rely on convective airflow to function optimally.
- ERV's
    - We recommend that the heating and cooling coils within the ERV's be checked annually for damaged fins, leaks, or excessive fouling. If fouling is found, follow the manufacturer's instructions for cleaning to ensure optimal performance.
    - Condensate drain pans and the drain lines should be checked at least annually to ensure no condensate flow restrictions.
    - Perform periodic inspection and maintenance such as greasing bearings and damper movement verification at least annually.
    - Perform quarterly reviews of the BAS system to ensure that there are no points overridden in an operator override. Release any overrides as necessary.
- HEX and pumps
    - Perform periodic inspections on the heating (and cooling) system pumps and perform maintenance as required. Check for bearing noise, seal leaks, motor coupling wear, excessive vibration, etc.
    - Perform monthly inspections during the heating system of the steam to water heat exchangers and associated valves.

- Perform quarterly checks on the glycol levels. Correct as required.
    - Perform an annual inspection and check on the expansion tank pressure. To verify air pressure in the expansion tank, isolate the tank from system flow via the isolation valve. Then fully drain the tank. Once the expansion tank is empty and isolated from the system, use a tire air pressure gauge to check pressure. Tank air pressure should be approx. **21-25 psi** in accordance with the height of the building (pressure=height (ft) of the water column above the tank divided by 2.31 + 5 psi). Adjust as required and then open the tank back up to the system. Drained glycol can be added back into the glycol fill pump.
    - Perform periodic inspections to ensure pump VFD's are in AUTO mode and not in HAND mode. Also verify there are no faults present.
    - Perform quarterly reviews of the BAS system to ensure that there are no points overridden in an operator override. Release any overrides as necessary.
- Chiller
    - Perform an annual inspection of the condition of the coils on the unit. Depending on local conditions, there may be fouling of the coils from cottonwood seeds, dust from farming, pollen, etc. which can foul the coils. This fouling will reduce the efficiency of the unit. By monitoring and cleaning the units as required, you can help to maintain performance and efficiency.
    - Annually check and measure refrigerant levels on the units to ensure optimal performance and compressor service life.
    - Perform quarterly checks on the glycol levels. Correct as required.
    - Perform an annual inspection and check on the expansion tank pressure. To verify air pressure in the expansion tank, isolate the tank from system flow via the isolation valve. Then fully drain the tank. Once the expansion tank is empty and isolated from the system, use a tire air pressure gauge to check pressure. Tank air pressure should be approx. **21-25 psi** in accordance with the height of the chilled water system (pressure=height (ft) of the water column above the tank divided by 2.31 + 5 psi). Adjust as required and then open the tank back up to the system. Drained glycol can be added back into the glycol fill pump.
    - Perform quarterly reviews of the BAS system to ensure that there are no points overridden in an operator override. Release any overrides as necessary.

4.0 Test Methods

The functional verification testing methods included the following:

- Manual point overrides
- Placing a false load on sensors (i.e., ice pack or hair dryer)
- Taking points out of service and entering in a false value
- Trend log analysis and review/observation of equipment operation
- Visual inspection
- Verification of accuracy of sensors against our annually calibrated equipment

5.0 Reference Materials

Attached is a copy of the bluerithm issues log and copies of the executed functional testing sheets.