YUKON COLLEGE

Recommissioning Investigation

Prepared by:
Johnson Controls Canada L.P.
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EXECUTIVE SUMMARY

This report summarizes the results of a recommissioning investigation report for Yukon College located at 500 College Drive, Whitehorse, YT. In September 2019, the Government of Yukon and Johnson Controls Canada LP entered into an agreement for recommissioning services, to be delivered in five phases. Recommissioning is a process that seeks to re-optimizes the operation of existing equipment and systems. It provides a rigorous investigative approach to identifying problems and system integration issues. This project is funded in part by Natural Resources Canada's Office of Energy Efficiency to promote the value of commissioning for existing buildings.

The objectives of this mandate are the following:

- Resolve operational issues and reduce energy use;
- Assess the building automation system to identify deficiencies;
- Implement identified low-cost/no-cost energy saving opportunities and operational deficiencies through coordination with the current service provider, Johnson Controls;
- Produce a case study report documenting the recommissioning process;
- Client comfort has to be maintained at current level or improved.

The Johnson Controls team, supported by Prism Engineering, conducted site visits in November 2019 and February 2020. We met with representatives of Yukon College to review the operation of the building. We also met with the Johnson Controls service technician to discuss findings. The retrocommissioning process also involved obtaining available technical documentation on the building HVAC equipment and its operation. Documentation such as as-built mechanical drawings, commissioning reports, DDC installation record drawings including points list, sequences of operation, trend logs, operational graphic screenshots were obtained for review of existing HVAC system operation.

This report highlights a number of opportunities to save energy, resolve operational issues, address deferred maintenance and improve occupant comfort at the College. Some air handling units (AHUs) have passing valves, causing the outdoor air dampers to open to cool to supply air temperature setpoint. The Gymnasium heat recovery pump was not operating. Once such issues are resolved, sequences of operation should be revised for optimal performance. Improvements to DDC graphics, especially for the Gymnasium, would increase staff's ability to efficiently operate systems. Many AHUs operate for very long hours or continuously. Due the highly variable hours of a school and the number of zones served by a single AHU, it may not be possible to reduce their weekly scheduled hours. Occupancy sensors, demand-controlled ventilation, and zone-based scheduling measures are recommended to achieve energy savings where schedule changes are impractical. Yukon College was originally built with pneumatic controls. These have been mostly integrated with the DDC system. However, some radiators are still on local pneumatic controls, and cannot coordinate night setbacks with the DDC. Furthermore, some control issues appear to be due to translation issues between pneumatic actuators and DDC commands. Where these issues are present, it is recommended that pneumatic controls be replaced with electronic ones.

The next steps consist of implementating the recommendations for energy savings opportunities and operational deficiencies. Seasonal checks on the operation of the cooling plant should also be performed. A monitoring plan is provided as part of the report to ensure a seamless integration of the recommendations within this report.

1.0 SUMMARY OF RECOMMENDATIONS

A detailed recommissioning investigation at Yukon College located in Whitehorse was completed. Table 1 shows the the recommendations for the energy savings opportunities and operational deficiencies.

Table 1: List of Recommendations

#	ECM Recommendation	Location	Est. Savings ($)	Budgets ($)	Priority	Notes
1	Convert Secondary Loops to Variable Flow	General	$6,858	$165,825.00	3	Excludes replacement of valves
2	Provide Table of FTU Conditions for Each AHU	General	NA	$4,488.00	3	
3	Install Supply Air Temperatures Sensors on FTUs	General	$12,241	$35,904.00	3	Approximately 180 units
4	Retrofit Radiators to DDC and Implement NSBs	General	$6,454	$3,291.20	3	Budget per zone
5	Implement Occupancy Detection and DCV	Gym	$9,756	$21,879.00	2	Budget for both AHU-G1 and G2
6	Investigate AHU-G1 Cycling	Gym	NA	$299.20	1	
7	Repair AHU-G2 Heating Coil Valve	Gym	$7,328	$6,002.70	2	
8	Operate AHU-G1 Heat Recovery Circulation Pump	Gym	$18,858	$2,730.20	1	
9	Improve DDC Graphics	Gym	NA	$1,196.80	1	
10	Retrofit AHU-G2 Inlet Guide to VFT and Replace Pneumatic Controls	Gym	$650	$14,212.00	2	
11	Remove AHU-T5 Overrides	Trades	$10,967	$4,862.00	1	
12	Reconfigure or Repair AHU-T1 Pre-heating Valve	Trades	$23,833	$6,133.60	2	
13	Repair AHU-T6 Controls	Trades	NA	$9,013.40	2	

14	Operate Units on Weekly Schedule	Academics	$52,667	$43,945.00	1	Budget for A1, A2, A3 Plus $500/zone for motion sensor
15	Consolidate Supply Air Temperature Control Loops for AHU-A1,A2,A3	Academics	$48,408	$120,802.00	1	Budget for A1, A2, A3 to convert DX controllers to SNC
16	Remove Flow Sensors and Set Points from AHU-A1,A2, A3 Graphics	Academics	NA	$598.40	1	
17	Revise Supply Fan Control	Academics	$1,428	Add $5,500.00 to ECM 15	1	Accommodate in ECM15 Additional engine required
18	Academics Building FTU Issues	Academics	NA	$9,088.20	1	
19	Operate Return Fan A3B	Academics	NA	$2,730.20	2	
20	Calculate Heat Load and Consumption	Academics Building	NA	$598.40	1	
21	Replace Face-and-bypass Damper Actuators	Commons	$19,048	$90,421.40	2	Add $100k to convert from DX controllers to SNC
22	Upgrade damper actuators on Air Handling Unit C1 (Mech Rm C301)	Commons	NA	$8,000.00	2	Budget to upgrade damper actuators to electric
23	Install HRU Preheat Discharge Temperature Sensors	Commons	NA	Add $1,500.00 to ECM 21	2	
24	Reset AHU-C1/HRU-C1 Supply Air Temperature Setpoint	Commons	$2,242	$3,590.40	1	
25	Prioritize HRU-C1 Operation over AHU-C1 Mixed Air in Cold Weather	Commons	$5,020	11,968.00	1	
26	Schedule AHU-C1, SF-C1, SF-C2	Commons	$31,946	$3,590.40	1	
27	Revise Heating Valves Controls for AHU-R1	Residence	NA	$4,188.80	2	
TOTAL			**$257,703**			

Notes:

- We estimate the accuracy of the budgets provided above to be in the +/- 15% accuracy levels
- The operational benefits are excluded from the estimated savings noted above.
- The engineering fees required to finalize the scope of work for the recommendations above is excluded
- Due to recent COVID-19 events, the timelines for implementation of the recommendations should be discussed further
- “Priority” is defined as the following
    - 1 – Low Cost and/or High Priority
    - 2 – Low Cost and/or Medium Priority
    - 3 – Low Priority
- Combining the implementation of ECMs could generate cost savings
- Proposed sequences of operation will be provided for approved recommendations, as required.

2.0 UTILITY ANALYSIS

2.1 Utility Rates

- Electricity is provided by Atco Electric Yukon through three accounts.
- Oil is provided by North of 60 through one account.
- Propane is provided by Superior Propane through one account. It is used by the kitchen and for campus facilities outside the scope of this investigation.

The average costs of each utility over the past twelve months is shown in Table 2.

Table 2: Rates used for Electricity Savings Estimates (Not including PST)

Vendor	Utility	In effect	Demand	Consumption
Atco Electric Yukon	Electricity	April 2019	$12.30/kW	$0.1318/kWh
North of 60	Oil	March 2019	---	$0.9628
Superior Propane	Propane	June 2019	---	$0.2939

2.2 Energy Use and Cost Summary

Energy usage for three years is presented in Table 3.

Table 3: Energy Account Summaries for Three Years

		2016	2017	2018
Electricity	Use (kWh)	5,436,630	8,026,440	5,243,700
	Cost ($)	$906,417	$1,121,135	$1,001,333
	BEPI (kWh/ft2/yr)	255.1	376.7	246.1
	BECI ($/ft2/yr)	$42.54	$52.61	$46.99
Oil	Use (L)	562,252	451,878	768,109
	Cost ($)	$317,156	$347,228	$738,639
	BEPI (ekWh/ft2/yr)	26.4	21.2	36.0
	BECI ($/ft2/yr)	$14.88	$16.29	$34.66
Propane	Use (L)	11,719	42,041	21,289
	Cost ($)	$3,595	$17,785	$8,541
	BEPI (ekWh/ft2/yr)	0.5	2.0	1.0
	BECI ($/ft2/yr)	$0.17	$0.83	$0.40

3.0 BUILDING AND SYSTEM DESCRIPTIONS

3.1 General Building Description

The Yukon College Whitehorse campus was built in 1986. The Gym was built in 1989. Other buildings have been subsequently added. The buildings identified in Table 4 are included in the recommissioning study.
The energy centre contains the central heating and cooling plants that serve most of the campus. Present day chillers were installed in 2014 and boilers in 2012. Most other mechanical equipment (i.e., air handling units and terminal units) in scope are base-building.

Table 4: Buildings Audited

Building Name	Year of Construction	Area (m^2)
Academic Building (A-Wing)	1986	5,082
Commons Building (C-Wing)	1986	6,920
Trades Building (T-Wing)	1986	5,064
Energy Centre	1986	n/a
Gymnasium	1989	1,668
Residence	n/a	2,575

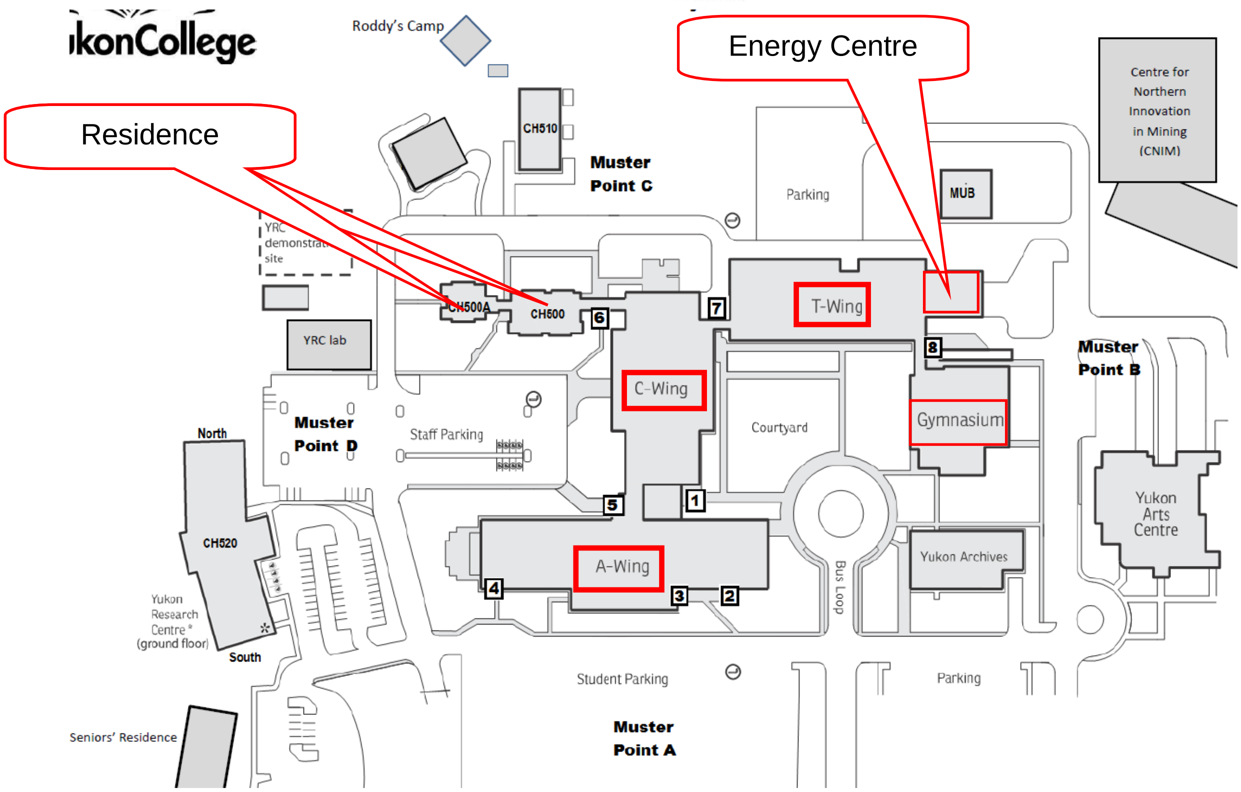


Figure 1: Yukon College Whitehorse Map

3.2 Mechanical Systems Description

General Overview

Yukon College's central heating and cooling plants are in the Energy Centre. Heating is typically provided by hydronic perimeter radiators, fan terminal units (FTUs) with hydronic reheat coils, and air handling unit (AHU) hydronic heating coils. Cooling is typically provided with outdoor air or AHU hydronic cooling coils. Individual buildings have mechanical rooms with the building's AHUs.

Heating Systems

The heating plant consists of five CleaverBrooks M5W-4000 3,200 MBH output oil boilers and one Calorite 750 kW electric boiler. The oil boilers each have a dedicated circulation pump (1.5 hp; 330 usgpm; 10 ft head).

Hot Water Distribution

Three pumps circulate heating water through the primary loop. This loop includes three large thermal storage tanks. These tanks are a legacy of the original heating plant and can provide heating for a day without boiler operation. They are now seldom used.

There are two temperature controlled secondary heating water loops. Each loop has circulation pumps and a 3-way valve. One secondary loop serves the trades, commons, residence, academic, and other buildings in the northwest sides of campus; the other serves the southeast sides of campus including the gymnasium, archives, and arts centre. The primary and secondary heating water loops are shown in Figure 2, and main heating pumps are listed in Table 5. All pumps are constant-speed.

Many tertiary heating loops exist to supply radiators, FTUs, and AHU heating coils. The heating water system also serves domestic hot water (DHW) and glycol loops (for AHU preheat coils), typically through heat exchangers located in building-specific mechanical rooms.

Table 5: Summary of Heating Water Pumps

Tag	Description	Power (kW)	Flow (L/s)	Head (kPa)
P-E8	Primary Heating	0.75	5.35	80
P-E6	Primary Heating	3.7	26.3	100
P-E7	Primary Heating	2.2	21.45	60
P-E1, P-E1A, P-E2	Northwest Secondary Heating	11.2	41.23	188
P-E8, P-E9	Southeast Secondary Heating	7.5	20.8	224

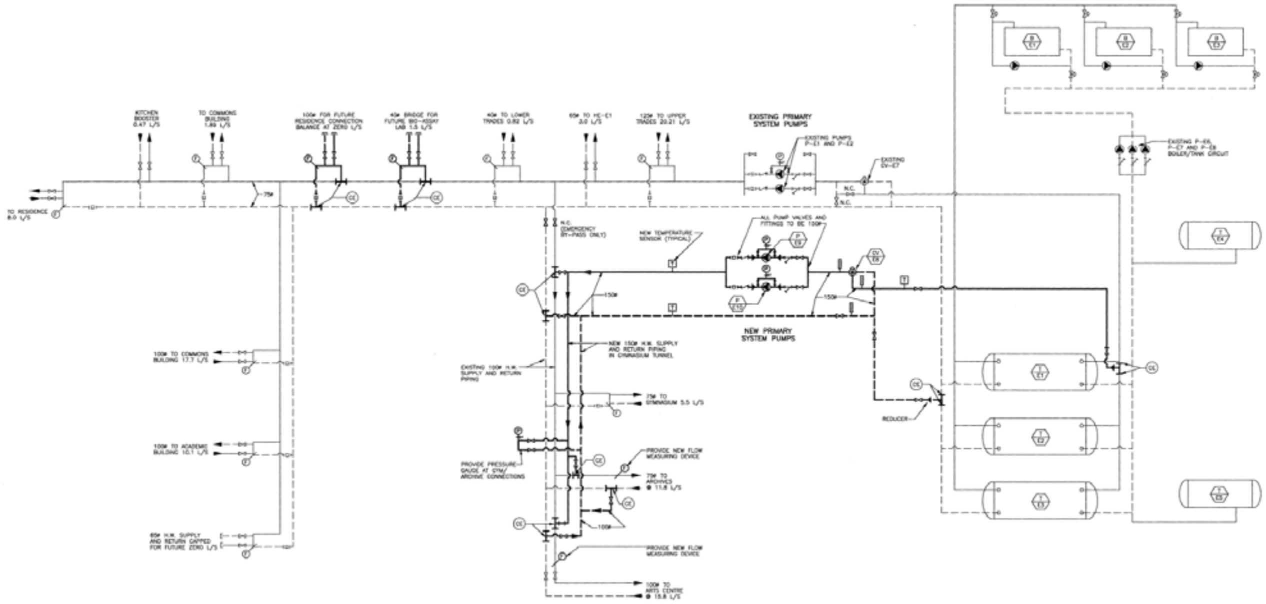


Figure 2: Heating Water System Schematic, 1992. Boilers and boiler piping are outdated.

Cooling Systems

Yukon College is cooled by a chilled water plant located in the Energy Centre. The plant consists a 431 kW Carrier 30RB130 air-cooled chiller (CH-1), a 225 kW Carrier 30RB70 air-cooled chiller, and a 181 kW dry-cooler. Chilled water is distributed throughout the campus by four constant-speed pumps in the Energy Centre.

Table 6: Summary of Chilled Water Pumps

Tag	Description	Power (kW)	Flow (L/s)	Head (kPa)
P-1, P-2	Dry Cooler Glycol Circulation	7.5	10.8	240
P-3, P-4	Chilled Water Circulation	11.2	30.28	209
P-3A, P-4A	Chilled Water Circulation	7.5	10.8	240

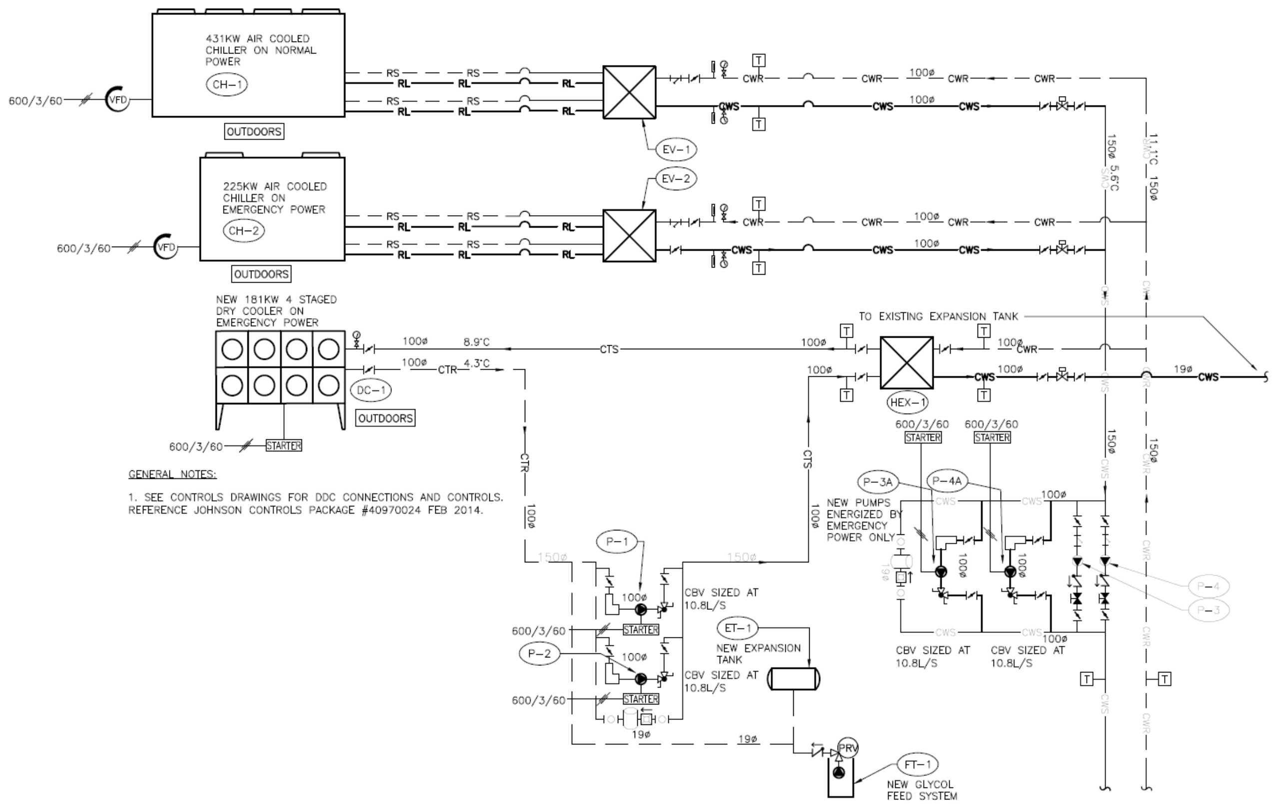


Figure 3: Chilled Water System Schematic

Ventilation Systems - Air Handling Unit(s)

Floor level air handling units provide ventilation to the building. A summary of the units is provided in Table 7

Table 7: Summary of Air Handling Units

Tag	Service	SF & RF/EF Power (kW)	Flow (L/s)	Mixing Section	Flow Control	Preheat Coil	Heating Coil	Cooling Coil
AHU-A1	Academics 1st Floor	11.2 / 2.24	2,723	Yes	VSD	Yes	Yes	Yes
AHU-A2	Academics 2nd Floor West	29.9 / 3.73 (x2)	14,940	Yes	VSD	Yes	Yes	Yes
AHU-A3	Academics 2nd Floor East	29.9 / 3.73 (x2)	15,408	Yes	VSD	Yes	Yes	Yes

AHU-T1	Trades Welding Shop	7.25	n/a	Yes	No	Yes	Yes	No
AHU-T2	Trades Heavy Equipment	7.7	n/a	Yes	No	Yes	Yes	No
AHU-T4	Trades Carpentry	5.14	n/a	Yes	VSD	Yes	Yes	Yes
AHU-T5	Trades Electronics	7.61 / 3.1	n/a	Yes	No	No	Yes	No
AHU-T6	Trades Classrooms	n/a	n/a	Yes	VSD	Yes	Yes	Yes
AHU-T7	Decommissioned	10.9	n/a	No	No	HR	Yes	No
AHU-T8	Energy Centre Boiler Room	7.41	n/a	Yes	No	Yes	Yes	No
AHU-G1	Gymnasium	10 / 5	7,525	Yes	None	HR	Yes	No
AHU-G2	Gym Building Miscellaneous	5 / 1	2,127	Yes	IGV	Yes	Yes	No
SF-C1/ HRU-C2	Lower Floor Commons	29.8	14,393	Yes	VSD	Yes, HR	Yes	Yes
SF-C2/ HRU-C3	Upper Floor Commons	29.8	14,921	Yes	VSD	Yes, HR	Yes	Yes
AHU-C1/ HRU-C1	Commons Cafeteria	11.2	4,955	Yes	VSD	Yes, HR	Yes	Yes
AHU-R1	Residence Building	5	n/a	No	None	Yes	Yes	No

Compressed Air Systems

Pneumatic control systems are supplied with compressed air from two 15 HP DV Systems air compressors installed in the Energy Centre.

Central Building Controls

The mechanical systems in this building are controlled from a BAS controlled with Direct Digital Control (DDC) system. The system is manufactured by Johnson Controls.
Most legacy pneumatic controls have been integrated with the DDC system by installing pressure transducers. However, many standalone radiators not tied to an FTU are still pneumatically controlled.

4.0 PROPOSED MEASURES

4.1 Convert Secondary Loops to Variable Flow (General)

Heating water throughout Yukon College is circulated through a series of constant flow primary, secondary, and tertiary loops. These loops are equipped with constant speed pumps and have their flow rates set with balancing valves. According to operations staff, these pumps have not been balanced since construction, and the balancing valves have been used for isolation due to passing manual isolation valves. This may cause the systems to be circulating more water than necessary. The balancing valves are currently fully open as shown in Figure 4.

Figure 4: Secondary Pumps' Balancing Valves

We recommend installing variable speed drives (VSDs) on the secondary pumps and retrofitting some heating loads with 2-way valves. Per Figure 5, this uses less power than operating at full flow or reducing the flow by throttling valves.

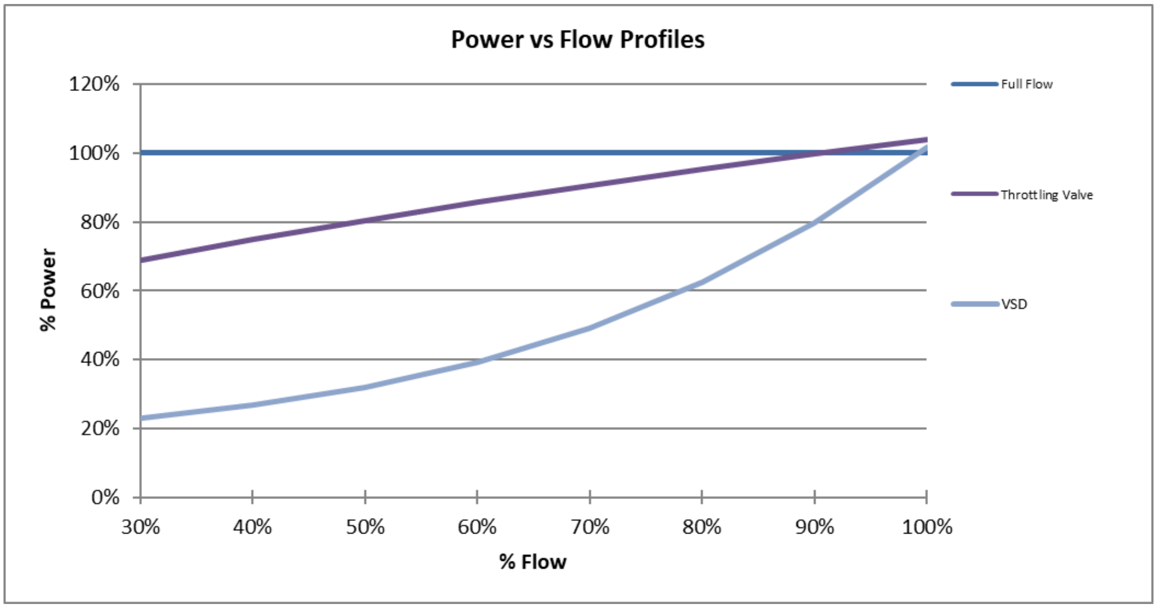


Figure 5: Power vs Flow Profiles for VSDs and Throttling Valves

2-way valves should be implemented on large heating loads that seldom require full flow, such as DHW and AHU heating coils. Enough 3-way valves should be left on the many smaller loads to ensure minimum flow through the systems. This will achieve most of the savings at minimum cost.

Install VSDs on Constant Flow Systems (General)

Even for constant flow systems, there may be savings potential in balancing through variable speed drives instead of balancing valves. Typically, pumps are slightly oversized to ensure they can meet design conditions and are throttled with balancing valves. At high flow percentages, the power used by a VSD drops far faster than for a throttling valve, which means that at 80% of a pump's design flow it will only use 50% power if equipped with a VSD, neglecting VFD and motor part-load inefficiencies, as shown in Figure 5.

We propose re-balancing the constant flow primary loop and other loops for which a variable flow conversion is not desired. The savings potential of retrofitting with VFDs should then be evaluated given the balancing valve settings.

4.2 Provide Table of FTU Conditions for Each AHU (General)

The existing DDC tables of fan terminal units (FTUs) only show zone temperatures. With only this information, it is impossible to quickly assess if the FTUs are meeting zone temperature setpoints. Nor can the cause of any FTU failure be quickly assessed. It is also very difficult to evaluate the performance of supply air temperature or static pressure setpoint reset algorithms.

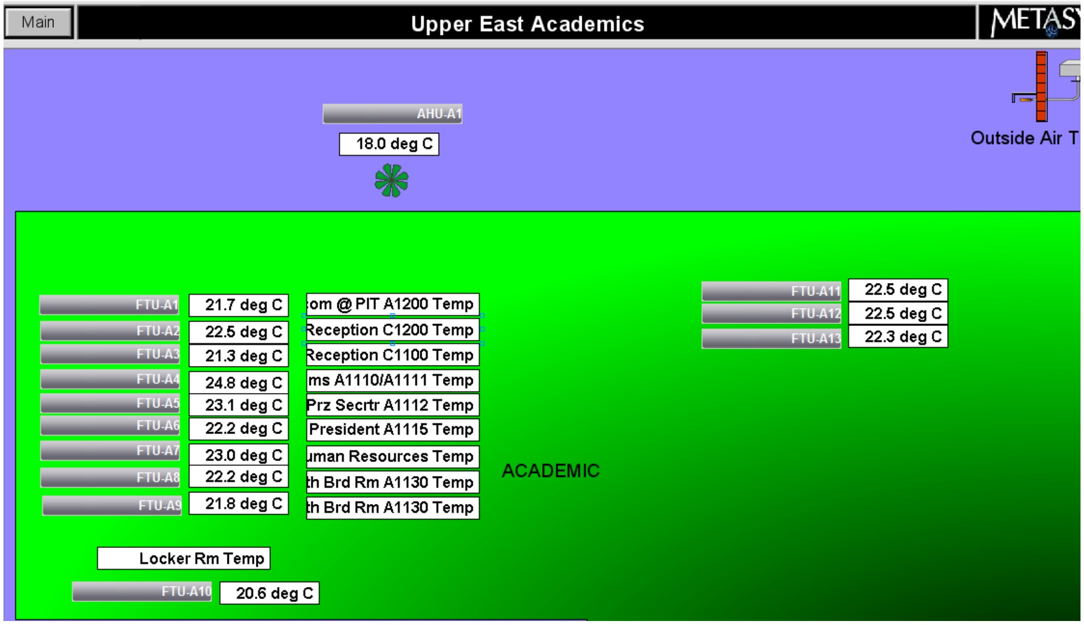


Figure 6: Existing DDC Summary of AHU-A1 FTUs

It is proposed that the FTU tables be revised to show all common FTU parameters, including zone temperature setpoint, supply air flow and setpoint, damper position, fan command, heating output, totalizers, and links to trend data.

4.3 Install Supply Air Temperature Sensors on FTUs (General)

Installing supply air temperature sensors on the FTUs with reheat coils would allow for detection and alarming of passing heating valves. This could be done for all FTUs in a single project, or over time as FTUs are replaced or repaired.

The FTUs typically have a spare input point for a supply air temperature sensor.

4.4 Retrofit Radiators to DDC and Implement NSBs (General)

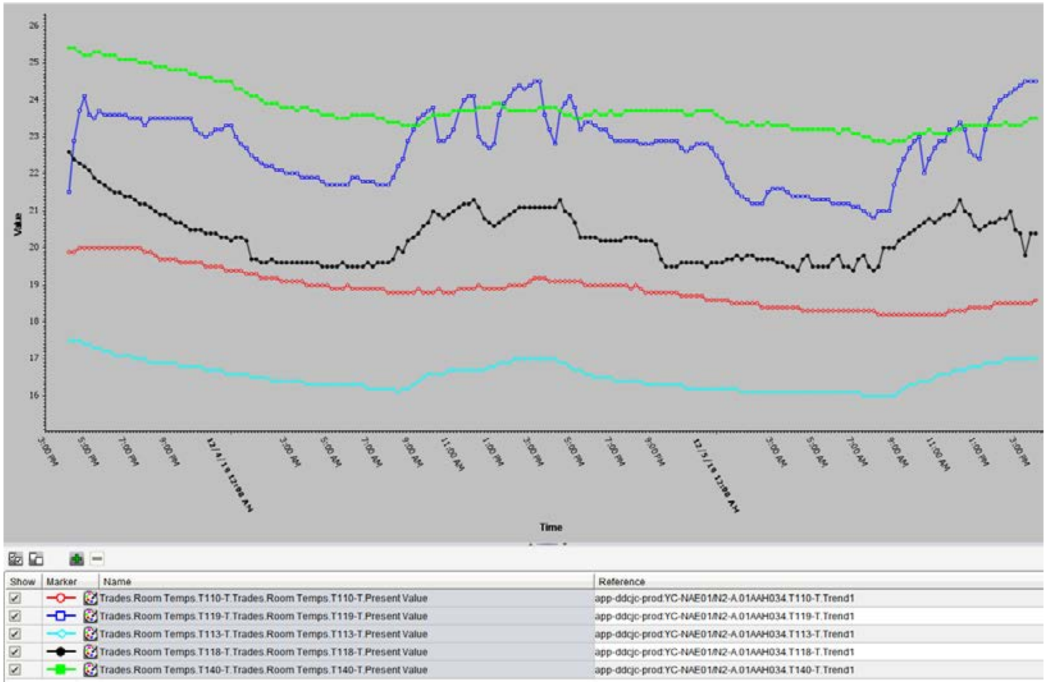


Figure 7: AHU-T5 Zone Temperature Trends

Most pneumatic controls at Yukon College have been integrated with the DDC system by installing transducers. However, radiators that are not tied to any FTU are still typically not tied to the DDC. Other rooms may return temperature readings to the DDC, but the radiators are not controlled, such as the AHU-T5 zones shown in Figure 7. Without full DDC integration, it is difficult to coordinate local controls with global building needs.

Where radiators are on pneumatic controls that are not integrated to the DDC, and their spaces could benefit from night setbacks (NSBs) (i.e., they are exterior zones with consistent unoccupied hours), the radiators should be retrofitted with electronic valves, integrated to DDC, and programmed with NSBs.

Energy savings potential is dependent on the number of applicable zones.

4.5 Implement Occupancy Detection and Demand Controlled Ventilation (Gymnasium)

The existing occupancy schedules for the two air handling units serving the Gymnasium building, AHU-G1 and AHU-G2, are long. The gym was empty during the Tuesday afternoon November 2019 site visit.

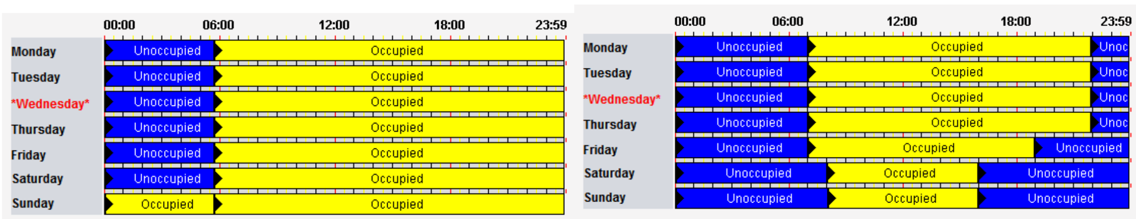


Figure 8: AHU-G1 (left) and AHU-G2 schedules

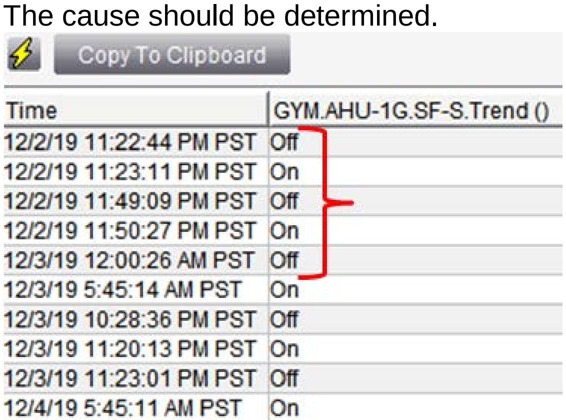
Scheduling a gym manually is difficult due to highly variable occupancy hours. Instead, it is proposed that occupancy and CO_2 sensors be installed to control outdoor ventilation and fan operating hours.

When an occupancy sensor is used in combination with a time-of-day schedule, the sensor can be used to indicate if the Gym is unoccupied when the DDC has scheduled it as occupied. This can be used to switch the zone to standby mode, during which temperature setpoints can be raised or lowered by 0.5°C to 1°C, and the ventilation requirement eliminated.

Installing CO_2 sensors on the AHU return air ducts would allow the quantity of outdoor air to be reduced during periods when occupancy is detected but limited.

4.6 Investigate AHU-G1 Cycling (Gymnasium)

The AHU-G1 supply fan is cycling during weekly scheduled operating hours, especially at night. The cause should be determined.



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Time	GYM.AHU-1G.SF-S.Trend ()
12/2/19 11:22:44 PM PST	Off
12/2/19 11:23:11 PM PST	On
12/2/19 11:49:09 PM PST	Off
12/2/19 11:50:27 PM PST	On
12/3/19 12:00:26 AM PST	Off
12/3/19 5:45:14 AM PST	On
12/3/19 10:28:36 PM PST	Off
12/3/19 11:20:13 PM PST	On
12/3/19 11:23:01 PM PST	Off
12/4/19 5:45:11 AM PST	On

Figure 9: AHU-G1 SF-S Trend

According to the O&M, EF-G1 is supposed to run for only 5 minutes of every half hour. It should be confirmed that the unit is still operating in this manner.

4.7 Repair AHU-G2 Heating Coil Valve (Gymnasium)

The heating coil valve (Figure 10, black, always 0%) appears to be passing on AHU-G2. This is causing the outdoor air damper (light blue) to open to 100% to compensate for the overheating.

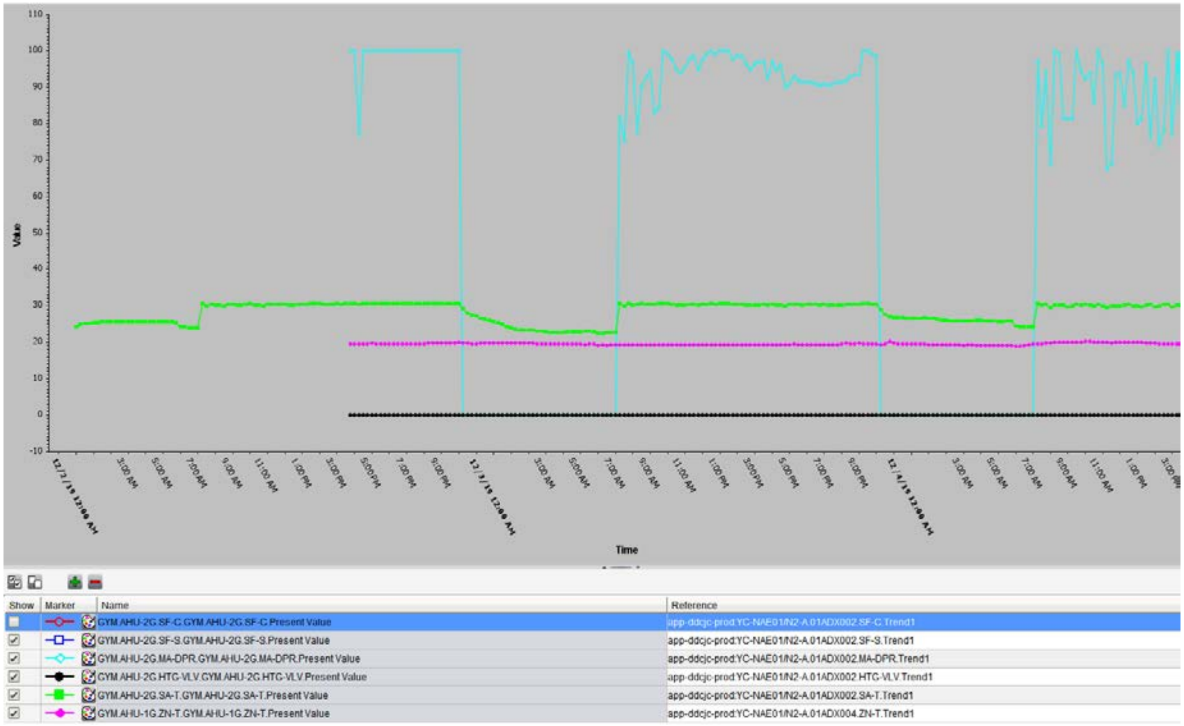


Figure 10: AHU-G2 Trends

The valve should be repaired. Alternately, the existing pneumatic valve could be replaced with an electronic valve.

4.8 Operate AHU-G1 Heat Recovery Circulation Pump (Gymnasium*)*

The AHU-G1 glycol heat recovery coil circulation pump (Pump G2) was not running at the time of the site visits but was locked out by maintenance. At the time, the outdoor air temperature was around -10°C, suggesting heat recovery was desirable. Pump command and status are not shown in the DDC graphics. Trend data shows Pump G2 has not operated for over a year.

Figure 11: AHU-G1 Heat Recovery Circulation Pump G2 Lockout

Service on Pump G2 should be completed and the pump should operate when heat recovery is beneficial. It should also be shown on the DDC graphics.

4.9 Improve DDC Graphics (Gymnasium)

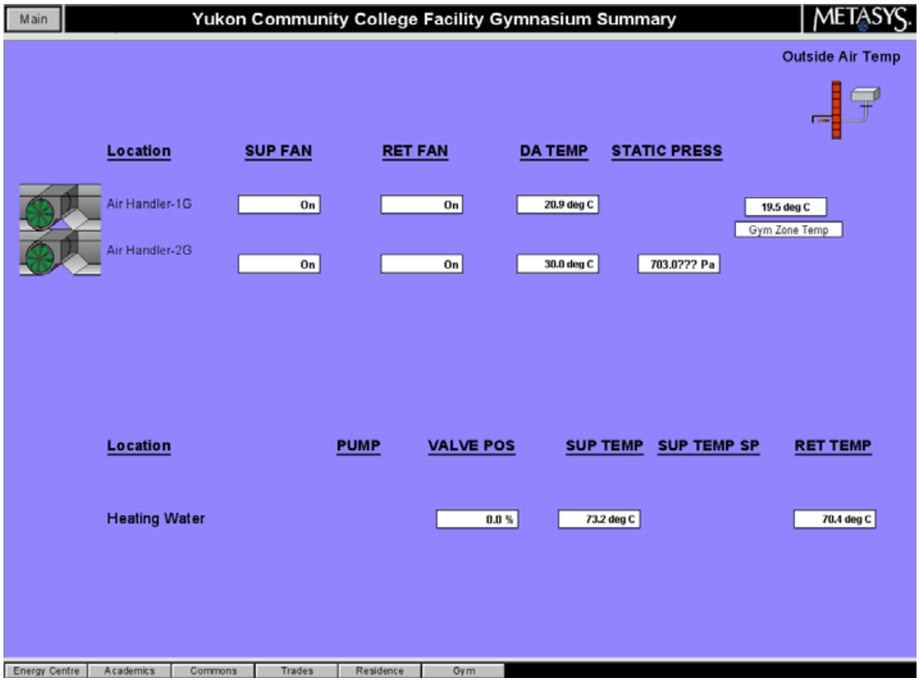


Figure 12: Existing Gym DDC Graphics

The sole DDC graphic for the Gymnasium is shown in Figure 12. The graphic fails to show heat recovery coil operation, outdoor air fraction, and valve positions. This can cause equipment

failures to be missed, such as that in Measure 5.2.4. The graphic also does not provide a viewer any information on the design of the AHU systems.
It is recommended that the graphics be improved to align with those in other Yukon College buildings. This would include showing schematics of each AHU, and all control parameters.

4.10 Retrofit AHU-G2 Inlet Guide Vanes to VFT and Replace Pneumatic Controls (Gymnasium)

AHU-G2 is reading high static pressure. It is equipped with inlet guide vanes, controlled by the DDC via pneumatic actuator. Some FTUs served by AHU-G2 still have pneumatic controls. The high static pressure reading suggests some actuators are stuck closed.
It is recommended to:

- upgrade existing pneumatic controllers to electric controllers and integrate with DDC;
- lock AHU-G2 inlet guide vanes fully open and remove the actuator;
- replace AHU-G2 fan motors; and
- install VFD on AHU-G2 supply fan.

4.11 Remove AHU-T5 Overrides (Trades Building)

At the time of our review the Trades Building glycol system was disabled. This required some AHUs to be disabled (e.g., AHU-T3) or overridden (e.g., AHU-T4, with its supply fan overridden off).

AHU-T5's supply and return fans were overridden On. This causes continuous operation, increasing fan energy use and ventilation heating. The reason for the overrides should be determined and corrected, allowing operation to weekly schedule.

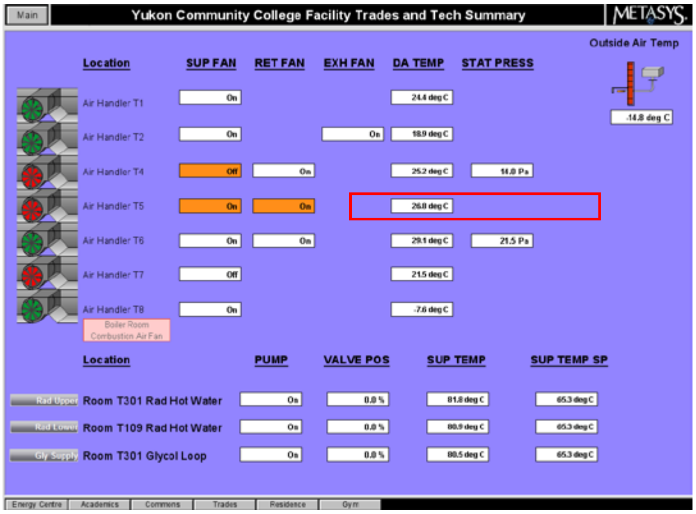


Figure 13: Trades Building Summary DDC Graphic

EF-5 had also been operating continuously since 20-Nov-2019. It should be determined if it is interlocked to AHU-T5. If not, the reason for continuous operation should be determined.

Time	Trades.EXH-FANS.EF5-S.Trend ()
8/27/19 8:34:37 PM PDT	??? Off
8/27/19 8:34:56 PM PDT	Off
8/27/19 8:36:18 PM PDT	??? Off
8/27/19 8:36:31 PM PDT	Off
8/27/19 9:45:52 PM PDT	??? Off
11/10/19 1:34:14 AM PST	Off
11/18/19 1:57:23 AM PST	Off
11/20/19 12:08:09 PM PST	On

Figure 14: Trades EF-5 Status Log

4.12 Reconfigure or Repair AHU-T1 Pre-Heating Valve (Trades Building)

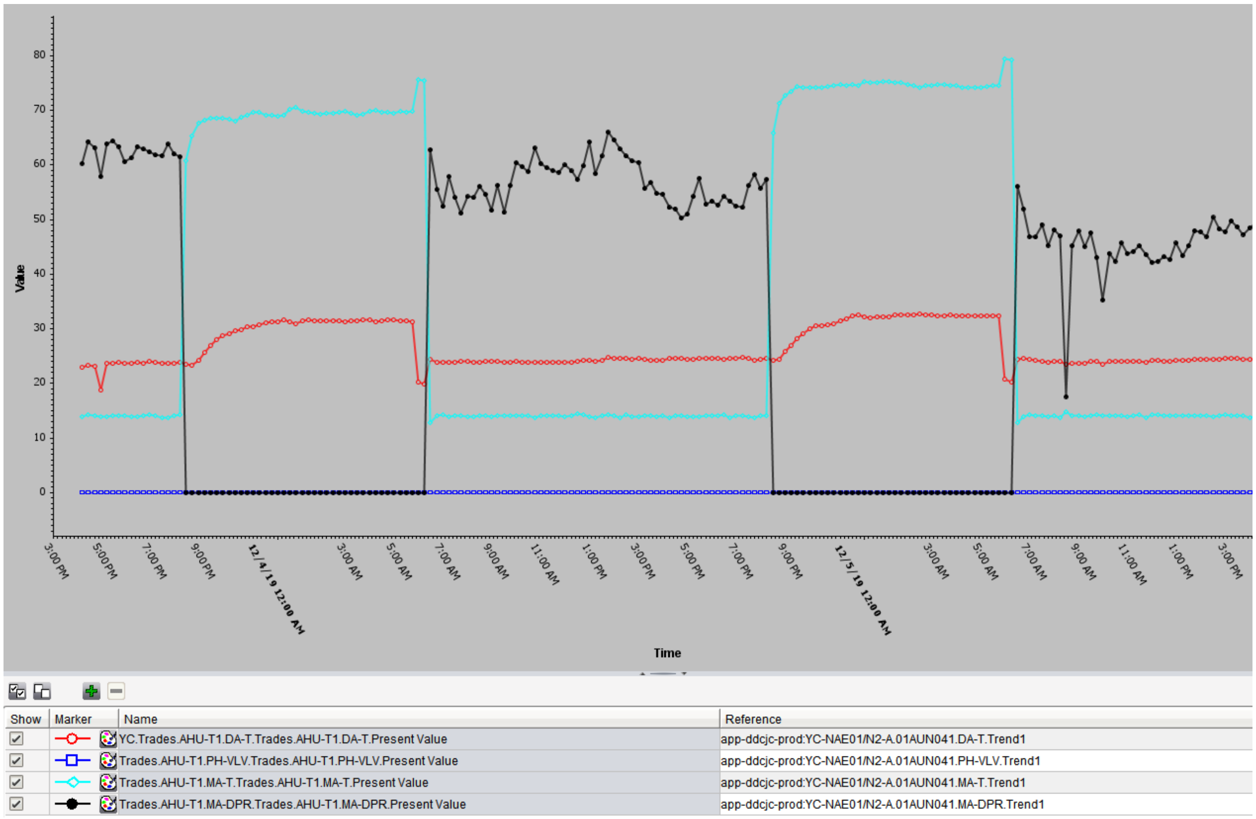


Figure 15: AHU-T1 Trends

AHU-T1's preheat valve is at 0% in Figure 15 (dark blue), but providing a lot of heat as evidenced by the high supply air temperature (red). The mixing damper (black) is modulating to maintain the supply air temperature setpoint, reaching 65% at times in cold winter weather. It is not clear if 0% represents the valve being fully open, or if the valve is passing. However, there is unnecessary simultaneous heating and cooling in both cases.
The mixed air temperature is also reaching 69°C when the unit is disabled, and the outdoor air damper is closed. This may be partially due to freeze protection logic.

4.13 Repair AHU-T6 Controls (Trades Building)

AHU-T6 serves the classrooms in the Trades building. It has numerous control issues. During a site visit in February 2020, all the spaces served by AHU-T6 were too warm (23°C vs average setpoint of 17°C). The supply fan was not operating per physical observation, despite being commanded on by the DDC.

DDC damper commands are not reflected in the field. According to the DDC, during the February 2020 site visit MAD was 100% (full return), relief was 10% open, and min OAD was 100% open. However, MAD was actually 0% (full relief), relief was 100% open, and min OAD was closed.
During the November 2019 site visit, the damper actuator was observed to be broken, as shown in Figure 16. The large labels throughout Yukon College, and particularly in the Trades Building mechanical rooms, are misleading.

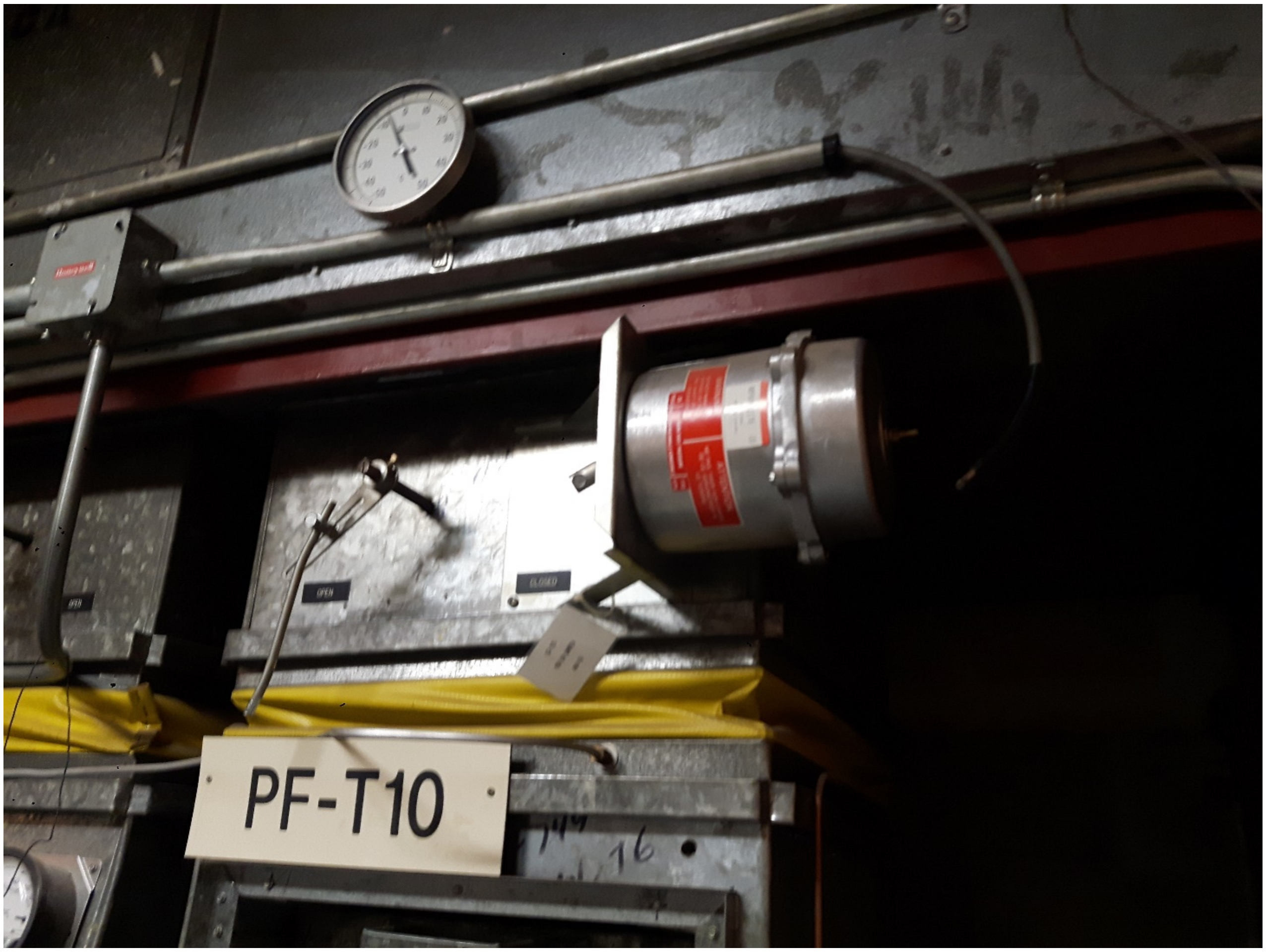


Figure 16: AHU-T6 Damper Actuator

AHU-T6's supply fan and dampers should be repaired and resume operating. Failed damper actuators should be replaced with electric actuators. All damper Electric Pneumatic Transducers (EPTs) should be replaced, or the actuators upgraded to electric. The controls should be recommissioned by a service technician.

4.14 Operate Units on Weekly Schedules (Academics Building)

AHUs A1, A2, and A3 are scheduled to operate continuously. If this is not necessary, it results in excessive fan energy and ventilation heating.
The occupancy schedules of all zones served by these units should be determined. The weekly schedules should be refined to reflect actual occupancy hours. Night Setbacks (NSBs) should be implemented to limit zone temperature drop during unoccupied hours. Perimeter radiators should provide first-stage NSB heating. If additional heat from the AHUs is required, mixing dampers should be positioned for full recirculation. Optimal starts should be implemented to ensure comfortable temperatures at the start of occupied hours.

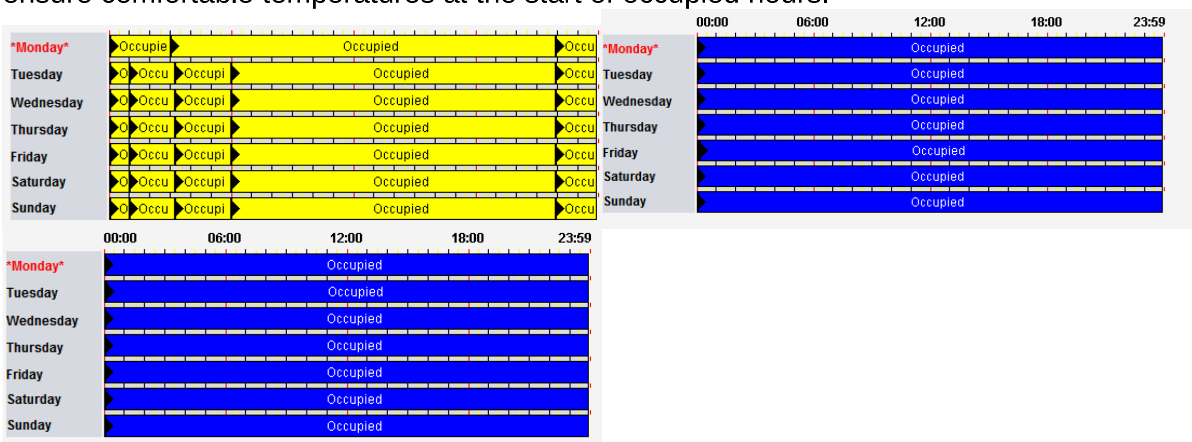


Figure 17: AHU-A1, A2, and A3 Weekly Operating Schedules

Demand Controlled Ventilation (Academics Building)

The minimum outside air setting for the outside air dampers on the air handling units are typically set high enough to ensure that outdoor ventilation requirements are met under design occupancy conditions. Design conditions reflect the academic building being fully occupied, which seldom occurs. It is proposed to install CO2 sensors on system supplies to control the ventilation rate. Reducing the quantity of outside air to be heated and cooled will result in energy savings.

Zone-Based Scheduling, Occupancy Sensors, and Standby Modes (Academics Building)

Occupancy schedules in academic buildings are expected to be highly variable, with different rooms occupied at different times of day. Corridors, common areas, and security desks may be partially occupied for very long hours, but classrooms will often be vacant.
Zones which are known to have consistently reduced hours should be provided their own schedules. During their scheduled unoccupied hours, the zones' FTUs are not required to

circulate air, and NSB temperatures can be implemented. AHU supply air temperature resets should not consider the requirements of unoccupied zones.
Zones that are often but unpredictably unoccupied should be equipped with occupancy sensors. When used in combination with a time-of-day schedule (either for the AHU or the zone), the sensor can be used to indicate if the zone is unoccupied although the DDC has scheduled it as occupied. This can be used to switch the zone to standby mode. In this mode, the temperature setpoints can be raised or lowered by 0.5°C to 1°C, and the FTUs can be disabled for satisfied zones.

4.15 Consolidate Supply Air Temperature Control Loops for AHUs A1, A2, and A3 (Academics Building)

AHU-A1 and AHU-A2 have separate preheat and supply air temperature setpoints. Separate control loops exist to control the different valves and dampers. As shown for AHU-A1, mixing dampers (blue) and the heating valve (red) are cycling to control supply air temperature (green).

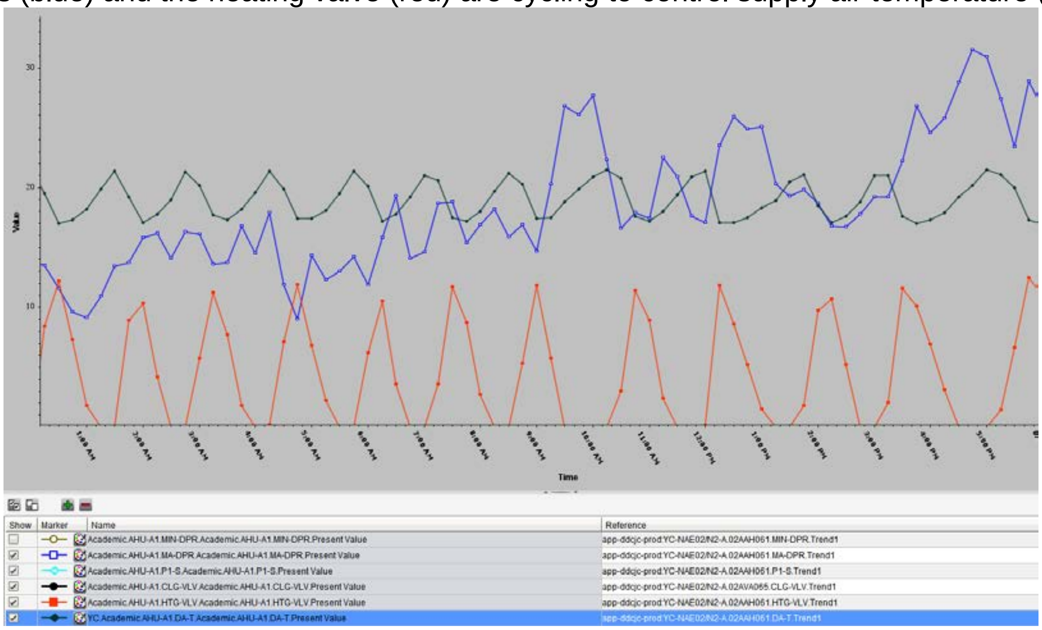


Figure 18: AHU-A1 Temperature Control Trends

The controls should be revised to use one split range PID loop to control supply air temperature with all dampers and valves (preheat, heating, and cooling), and one loop to maintain a mixed air temperature low limit.
For AHU-A2, this issue is causing the preheat and heating valves to open at the same time the mixing damper command exceeds the 25% minimum setting (red square Figure 19). Based on a 22°C return air temperature, the unit is operating with about 65% outdoor air. The result is an avoidable ventilation heating load.

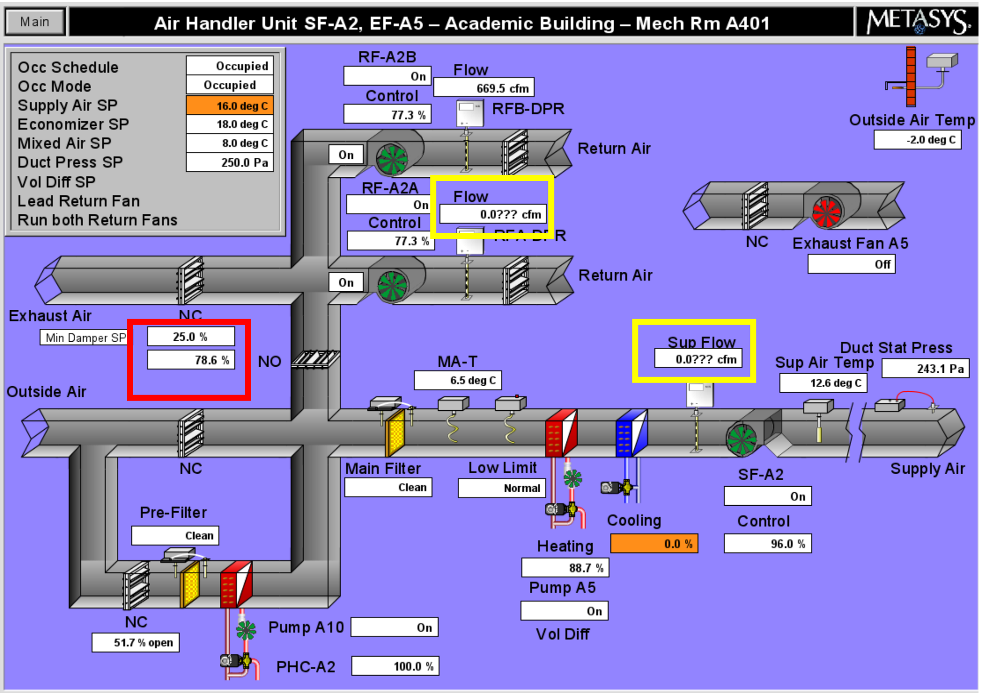


Figure 19: AHU-A2 DDC Graphic

4.16 Remove Flow Sensors and Setpoints from AHUs A1, A2, and A3 Graphics (Academics Building)

AHU-A1's return air flow sensor is reading negative despite the return fan operating.

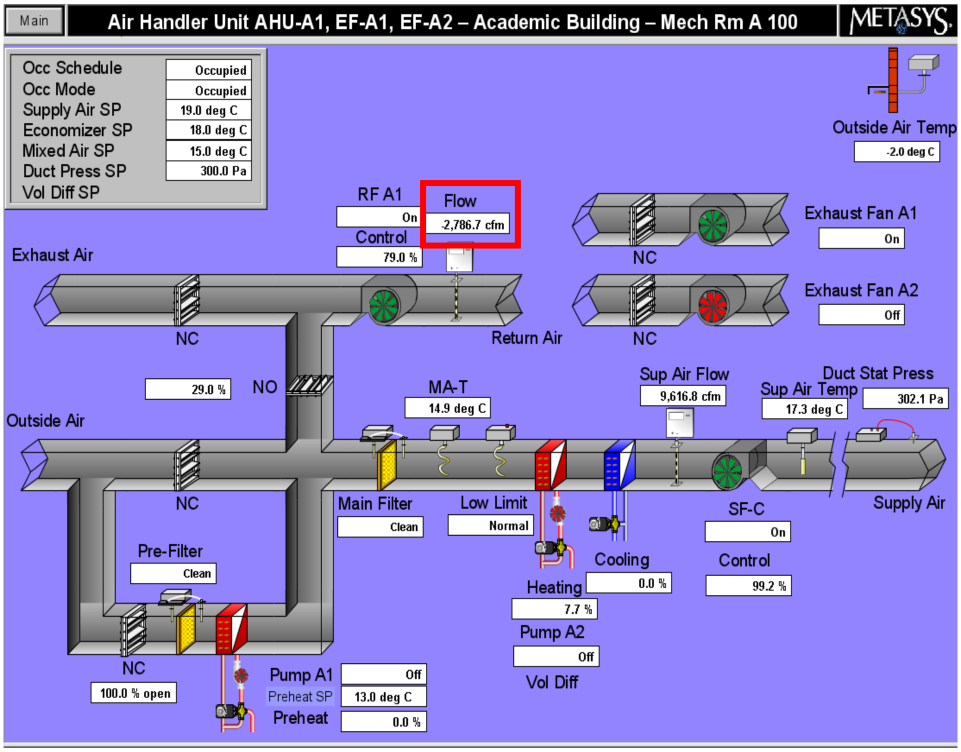


Figure 20: AHU-A1 DDC Graphic, Showing Defective RA-F Sensor

AHU-A2's supply and return air flow sensors are not returning readings (yellow squares Figure 19). AHU-A3 has the same issue.

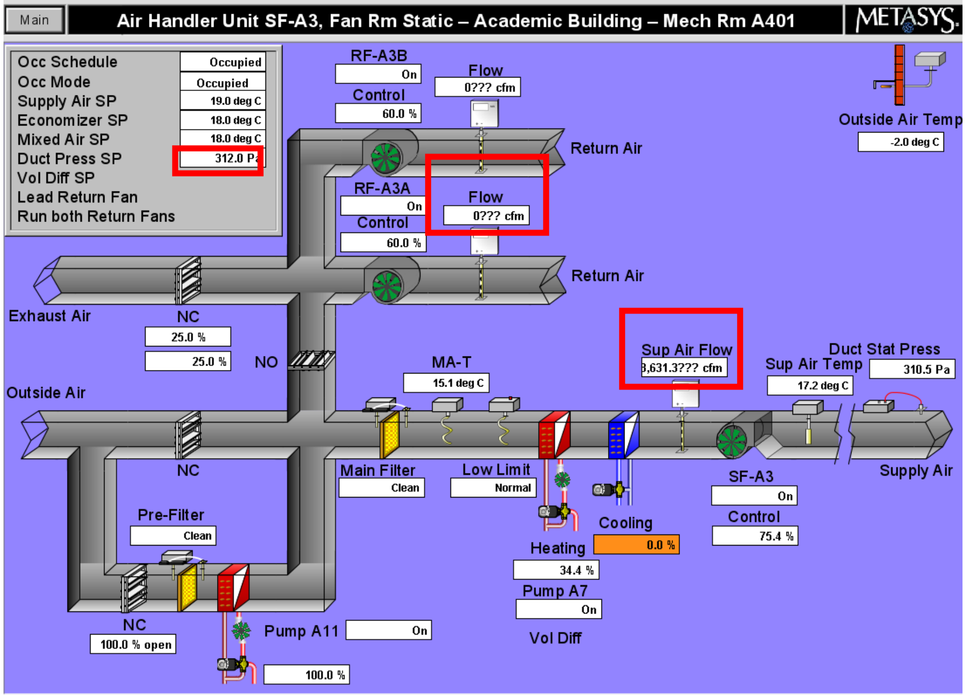


Figure 21: AHU-A3 DDC Graphic, Showing Defective Flow Sensors

The air flow sensors are not used in the current control sequences. They should be removed from the graphics along with legacy control setpoints.

4.17 Revise Supply Fan Control (Academics Building)

AHU-A2 was failing to meet its supply air static pressure setpoint of 250 Pa. Most of the time the system achieved a supply air pressure around 170 Pa. AHUs A1 and A3 are achieving higher static pressures.

It is recommended that supply static pressure reset control be implemented. The supply static pressure setpoints would be reset based on the number of FTUs that are failing to meet flow setpoint despite having fully open dampers. The upper limit of the supply air static pressure setpoint would be the current setpoint.

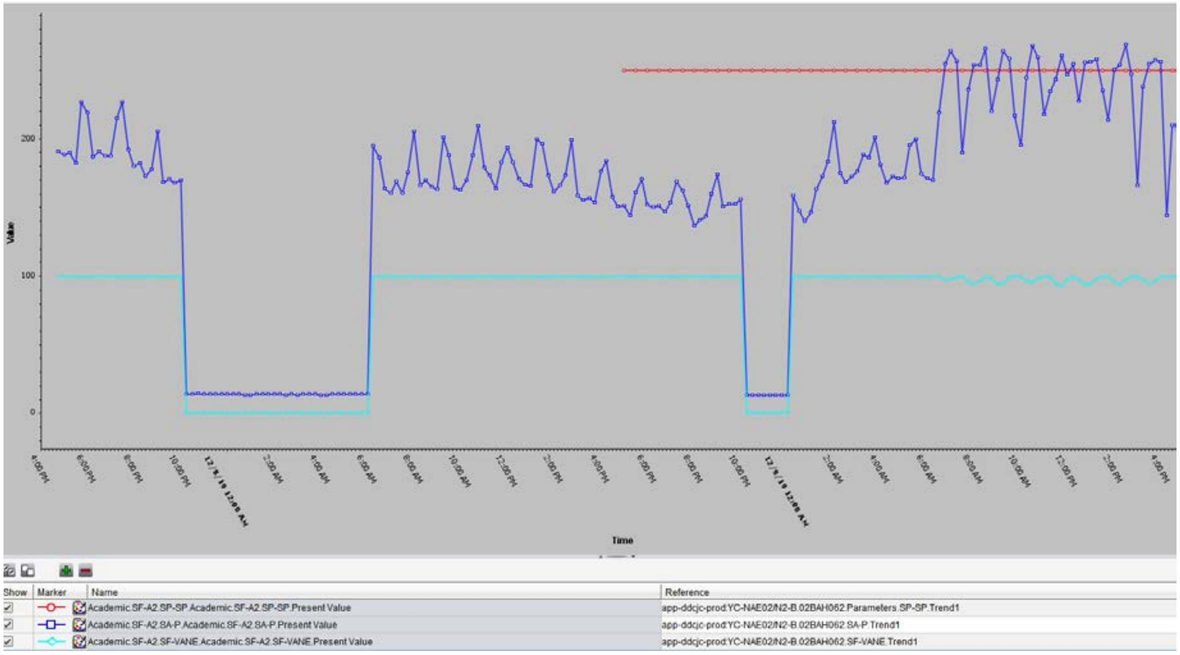
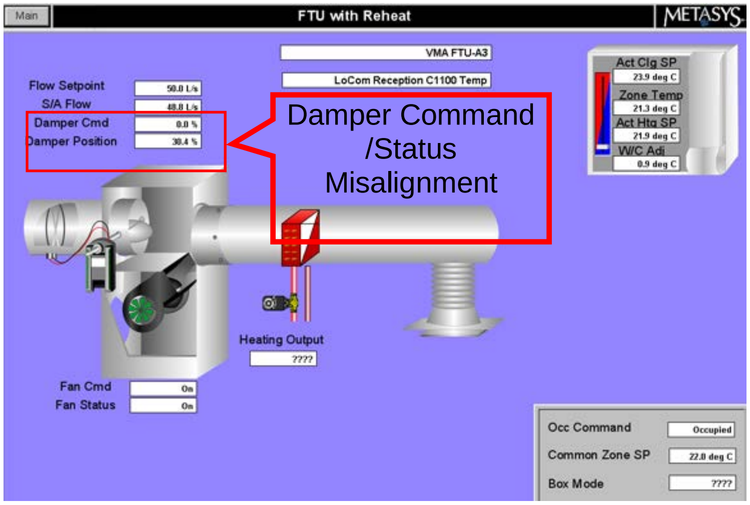


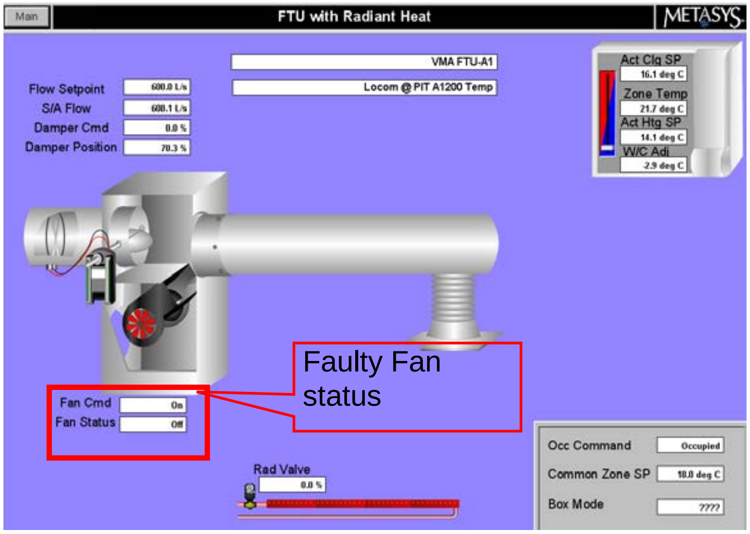
Figure 22: AHU-A2 Supply Air Flow Control Trends

4.18 Academics Building FTU Issues (Academics Building)

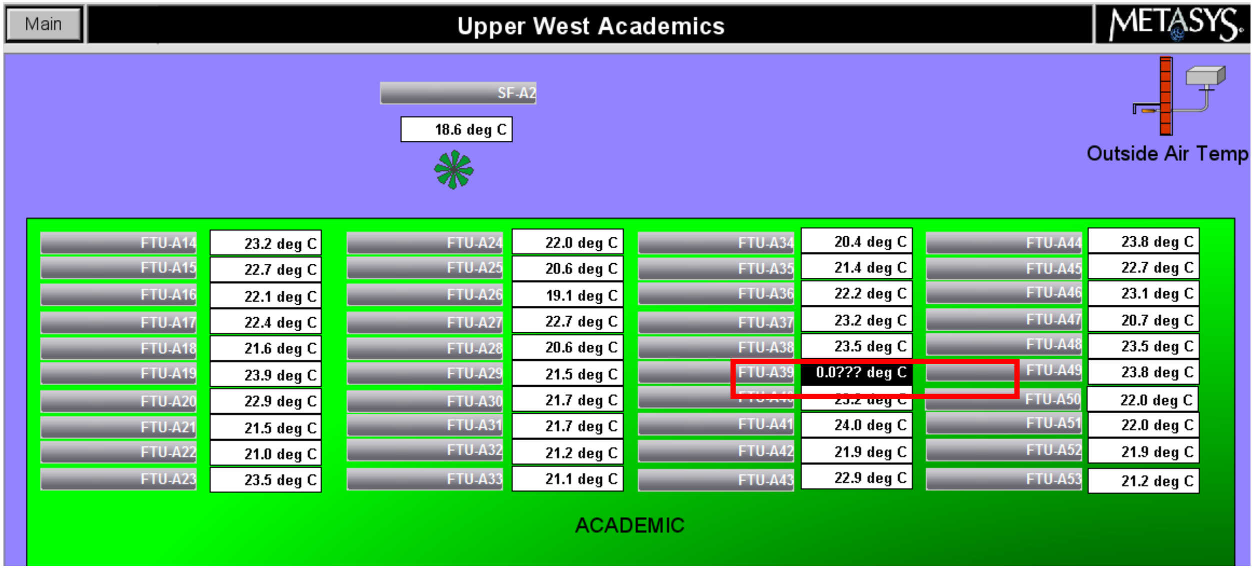
This section describes issues observed with the operation of FTUs in the Academics Building. These issues typically are not energy savings opportunities, but adversely impact building operation or occupant comfort.

Inconsistent or incorrect information on fan and damper

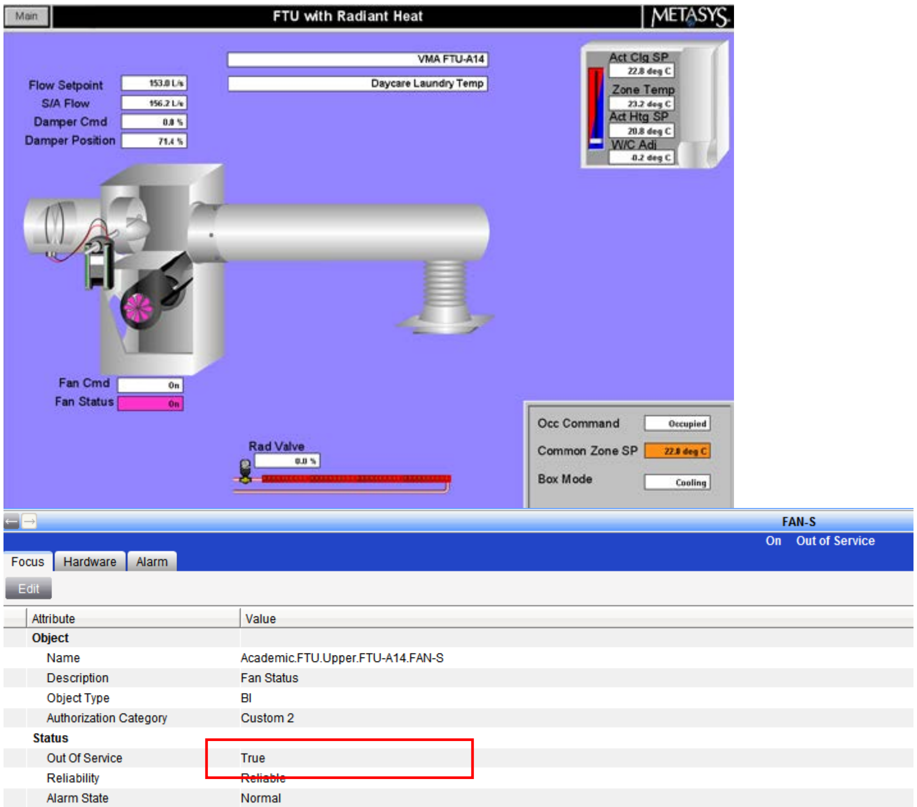




Defective FTU-A39 Room Temperature Indication



Defective Fan Status



A similar issue was observed for FTU-A16.

4.19 Operate Return Fan A3B (Academics Building)

Return fan A3B status was shown as ON at the DDC, but the fan was not operating, and the starter was set to manual off. Minor draft could be felt in the connection between Commons and Academics, which is undesirable, especially in cold weather. The reason why A3B was manually switched off could not be determined during the recommissioning investigation. It is recommended return fan A3B be operated.

4.20 Calculate Heat Load and Consumption for Academics Buidling

Heating water supply and return temperatures and flow rate are shown in the DDC for the Academics Building. It is recommended to calculate and trend load (BTU/hr) and consumption (BTU or GJ) for the building.

4.21 Replace Face-and-Bypass Damper Actuators (Commons Building)

Heat recovery units HRU C1-C3 serve AHU C1-C3, as shown in Figure 23. Each HRU has an air-to-air heat exchanger (Figure 23 incorrectly shows them as heat wheels) equipped with face-and-bypass dampers. The face-and-bypass dampers are not tied to the DDC.

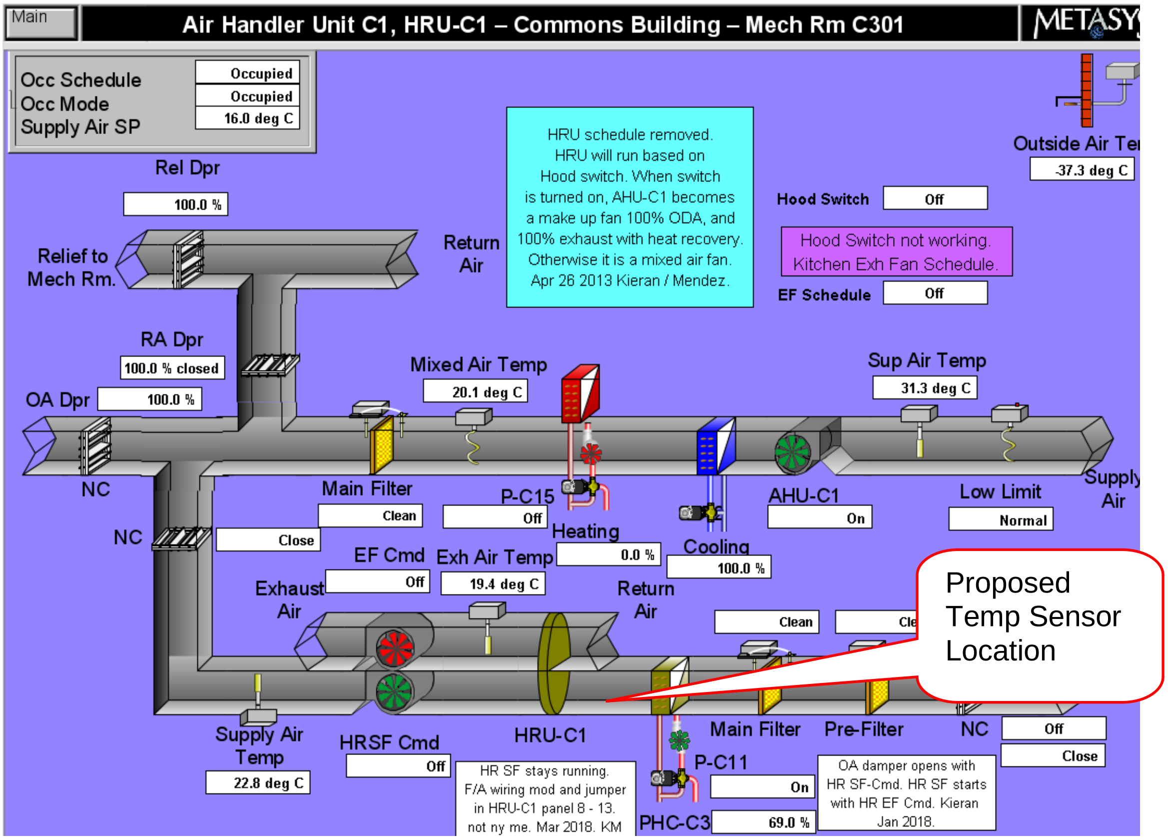


Figure 23: AHU-C1/HRU-C1 DDC Graphic

The face-and-bypass damper actuators have failed on HRU C1-C3. HRU-C1 and HRU-C2 are stuck open on bypass, causing no heat recovery and very high energy use. HRU-C3's face-and-bypass dampers are closed, and its fans are blowing/sucking through closed dampers.

Figure 24: HRU-C1 Face-and-Bypass Dampers (from both sides)

It is recommended that the face-and-bypass damper actuators on HRU C1-C3 be replaced and integrated with the DDC.

4.22 Upgrade damper actuators on Air Handling Unit C1 (Commons Building)

Figure 23 shows AHU-C1, located in mechanical room C301, operating at 100% outdoor air in -37°C outdoor air temperature. In reality, AHU-C1/HRU-C1 operates as a mixed air unit after 5pm (Figure 23 was captured after 5pm). When operating as a mixed air unit, the relief, return, and outdoor dampers modulate per local pneumatic controls and their positions do not reflect the DDC commands. The pneumatic actuators were tested on-site and are operational.

The service provider has been notified and can address the replacement of the failed pneumatic transducers during a scheduled routine maintenance site visit. Optionally, electric damper actuators could be installed to replace the existing actuators.

4.23 Install HRU Preheat Discharge Temperature Sensors (Commons Building)

There is no temperature sensor between the preheat coil and air-to-air heat exchanger in each HRU. This makes it impossible to determine if the heat exchanger is effective or if the preheat valve is passing. We recommend installing a temperature sensor at the location shown in Figure 23 on HRU C1-C3.

4.24 Reset AHU-C1/HRU-C1 Supply Air Temperature Setpoint (Commons Building)

The AHU-C1 supply air temperature setpoint is currently fixed at 16°C. This is likely too low in cold weather. If the zones were satisfied when Figure 23 was captured, then a supply air temperature of ~31°C may be suitable (though it should be too high for an interior kitchen). This low supply air temperature setpoint would cause simultaneous heating and cooling if achieved. It is recommended that a supply air temperature reset be implemented. Ideally, zone temperatures would be used. If these cannot be integrated with the DDC, an exhaust air temperature reset would be the next best possibility. Zones that are subsequently frequently too warm should be integrated with the DDC and used in the reset.

4.25 Prioritize HRU-C1 Operation over AHU-C1 Mixed Air in Cold Weather (Commons Building)

In Figure 23, AHU-C1/HRU-C1 is operating as a mixed air unit because it is after 5pm and the kitchen is unoccupied. The outdoor air damper is not at 100% open as shown in Figure 23, but it is being maintained to a minimum outdoor air position. Although the operation of HRU-C1 may not be necessary when the kitchen is unoccupied, providing minimum outdoor air through the HRU is less expensive with outdoor air temperature at -37°C.

It is recommended that AHU/HRU C1-C3 operate as heat recovery units when the cost of heating minimum outdoor air to thermal balance temperature is greater than the cost of heating the HRU supply air after heat recovery to thermal balance temperature plus operating the HRU supply and exhaust fans. Ideally this calculation would be performed in the DDC, accounting for current utility rates and varying minimum outdoor air flow requirements.

4.26 Schedule AHU-C1, SF-C1, SF-C2 (Commons Building)

AHU-C1, SF-C1, and SF-C2 serve the commons building. All three units operate 24/7. The college closes at midnight daily. It is recommended that these units shut down during the unoccupied hours, and the zones revert to night set back (NSB) temperature setpoints. If the units are required to operate to maintain NSBs or for morning warm-up, they should operate as mixed air units with minimum outdoor air of 0%.

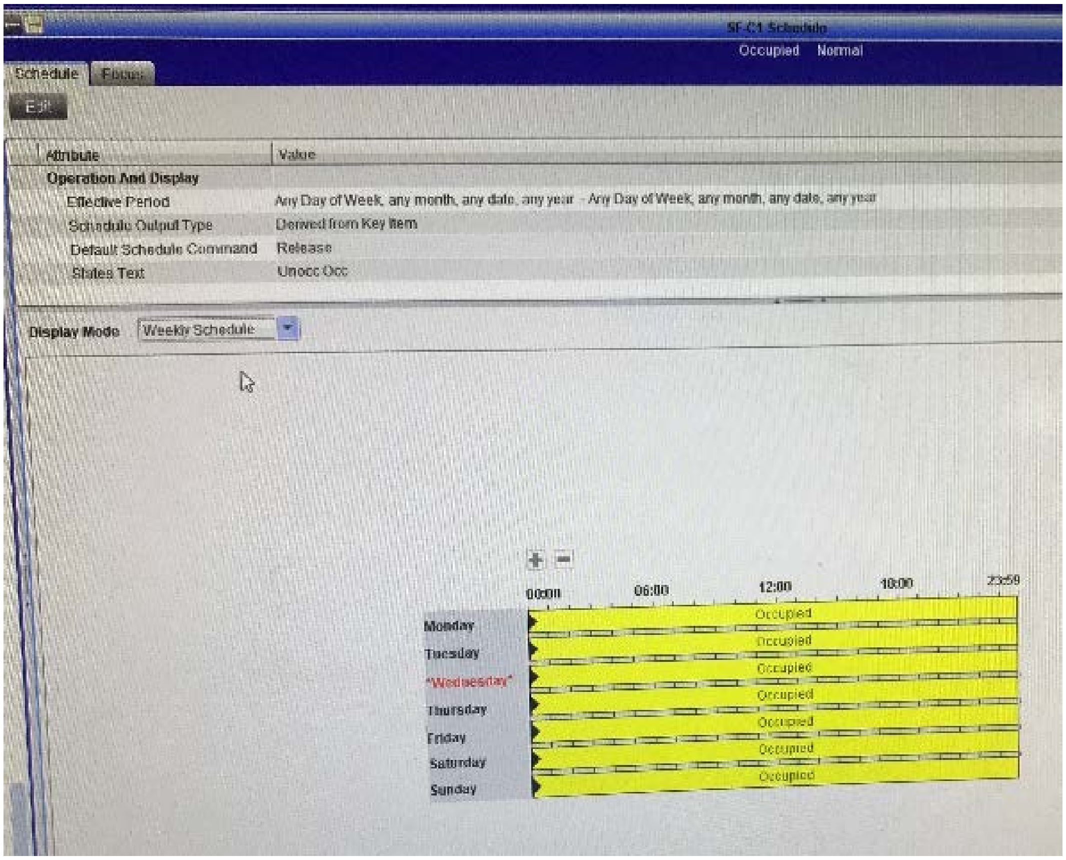


Figure 25: SF-C1 Schedule

4.27 Revise Heating Valves Controls for AHU-R1 (Residence)

The AHU-R1 supply air fan was tripped on low temperature when observed on the DDC system. This is likely due to poor heating valve control. A proportional low limit control loop should be implemented to ensure the preheat coil outlet temperature does not fall below setpoint.

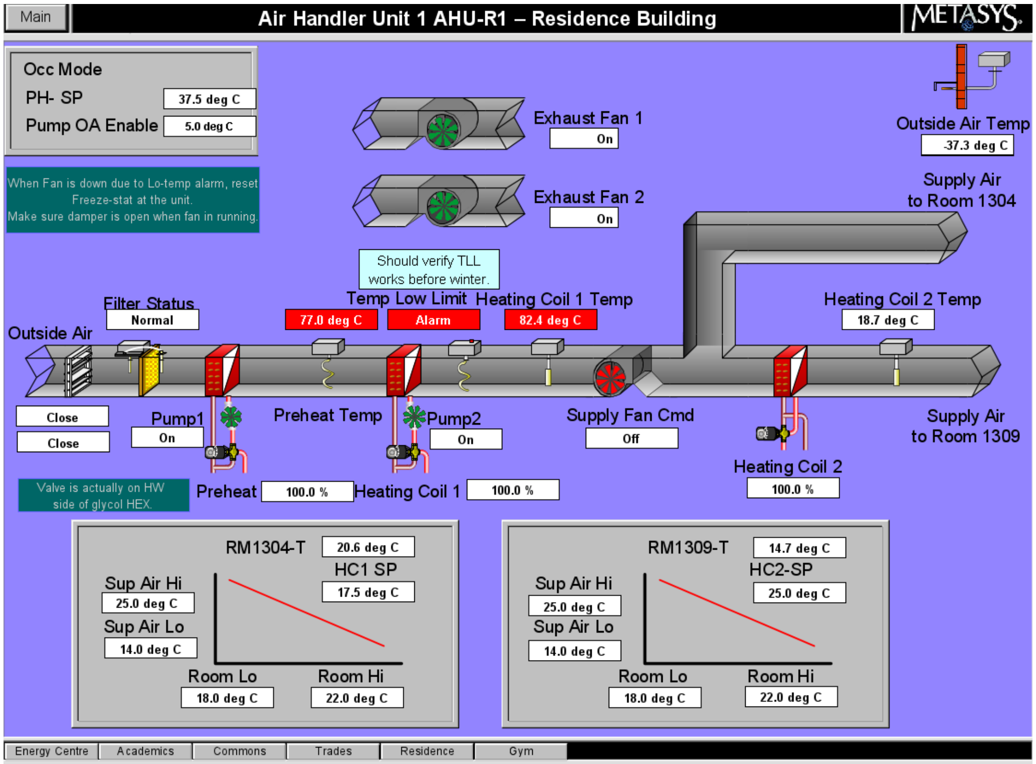


Figure 26: AHU-R1 DDC Graphic

If the above control fails to rectify the problem, it may be that the preheat valve is oversized. In this case it is recommended that it be replaced. If the existing valve is pneumatic, it should be replaced with an electronic valve.

4.28 Investigated, No Recommendation

Trades AHU-T4, T5, and T7 Repairs

AHU-T7 was not operating during the investigation. It has been decommissioned.
AHU-T4 and T5 were operating at 100% return air during the investigation. Both units' supply fans were disabled for maintenance.

Heat Recovery for AHU-R1

AHU-R1 is a 100% outdoor air unit. According to trend data (Figure 27), it operates continuously (other than when malfunctioning). This makes it a good candidate for exhaust air heat recovery.

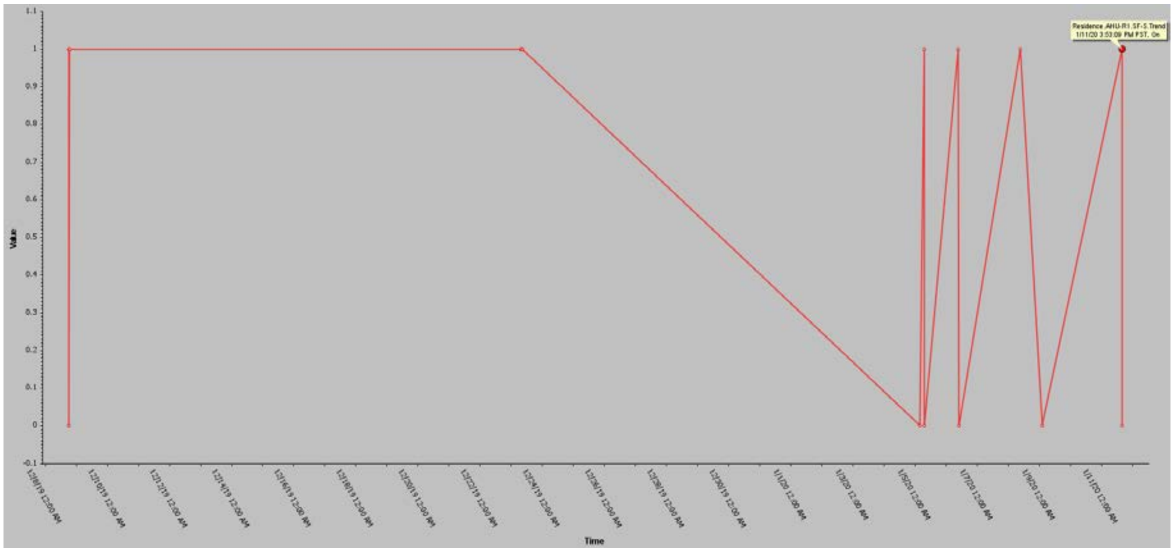


Figure 27: AHU-R1 Supply Fan Status Trend

However, the exhaust fans are above the 2nd floor ceiling, and at opposite ends of the wing. The outdoor air intake is underground. This makes in uneconomical to install a heat recovery system. The location of the outdoor air intake is also unsuitable for installing a solar wall.

Figure 28: AHU-R1 Outdoor Air Intake

4.0 SENSORS REQUIRING RE-CALIBRATION

During the investigation, it was found that some sensors, points were either giving no readings or faulty readings. Below table shows a list of all sensors requiring calibration.

Table 8: Summary of Sensors, Points Either Giving No Readings or Faulty Readings

#	System	Location	Sensor
1	AHU-G1	Gym	▪ SF-S ▪ Circ. Pump G2 status and command
2	AHU-G2	Gym	▪ SA-P
3	AHU-T1	Trades	▪ Pre-Heating Valve
4	AHU-T6	Trades	▪ SAP ▪ SAT/DAT ▪ SF-S ▪ MA-DPR ▪ OA-DPR ▪ EA-DPR
8	FTU-A39	Academics	▪ Zone Temperature
9	FTU-A16	Academics	▪ Fan Status
10	FTU-A14	Academics	▪ Fan Status
11	A3B	Academics	▪ RF-S ▪ RF-Cmd
12	AHU C1	Commons	▪ MA-DPR ▪ EA-DPR ▪ RA-DPR ▪ OA-DPR ▪ SA-T

5.0 MONITORING PLAN

The table below shows the monitoring plan to document project results from the approved ECM recommendations. The list of recommended parameters to be trended at BAS will be provided for each approved ECM.

Table 9: Monitoring Plan To Document Project Results

#	ECM Recommendations	Resolution Status	Resolution Description	Recommended BAS Trends	Seasonal checks
1	Convert Secondary Loops to Variable Flow (General)			☐ TBD	☐ Heating
2	Provide Table of FTU Conditions for Each AHU (General)			☐ TBD	
3	Install Supply Air Temperatures Sensors on FTUs (General)			☐ TBD	
4	Retrofit Radiators to DDC and Implement NSBs (General)			☐ TBD	☐ Heating ☐ Cooling
5	Implement Occupancy Detection and DCV (Gym)			☐ TBD	☐ Heating ☐ Cooling
6	Investigate AHU-G1 Cycling (Gym)			☐ TBD	
7	Repair AHU-G2 Heating Coil Valve (Gym)			☐ TBD	☐ Heating
8	Operate AHU-G1 Heat Recovery Circulation Pump (Gym)			☐ TBD	☐ Heating
9	Improve DDC Graphics (Gym)			☐ TBD	
10	Retrofit AHU-G2 Inlet Guide to VFT and Replace Pneumatic Controls (Gym)			☐ TBD	
11	Remove AHU-T5 Overrides (Trades)			☐ TBD	
12	Reconfigure or Repair AHU-T1 Pre-heating Valve (Trades)			☐ TBD	☐ Heating
13	Repair AHU-T6 Controls (Trades)			☐ TBD	

14	Operate Units on Weekly Schedule (Academics)			☐ TBD	☐ Heating ☐ Cooling
15	Consolidate Supply Air Temperature Control Loops for AHU-A1,A2,A3 (Academics)			☐ TBD	☐ Heating ☐ Cooling
16	Remove Flow Sensors on AHU-A1,A2, A3 (Academics)				
17	Revise Supply Fan Control (Academics)			☐ TBD	
18	Academics Building FTU Issues (Academics)				
19	Operate Return Fan A3B (Academics)			☐ TBD	
20	Calculate Heat Load and Consumption (Academics)			☐ TBD	☐ Heating
21	Replace Face-and-bypass Damper Actuators (Commons)			☐ TBD	☐ Heating
22	Integate Dampers with BAS (Commons)			☐ TBD	☐ Heating ☐ Cooling
23	Install HRU Preheat Discharge Temperature Sensors (Commons)			☐ TBD	
24	Reset AHU-C1/HRU-C1 Supply Air Temperature Setpoint (Commons)			☐ TBD	☐ Heating ☐ Cooling
25	Prioritize HRU-C1 Operation over AHU-C1 Mixed Air in Cold Weather (Commons)			☐ TBD	☐ Heating
26	Schedule AHU-C1, SF-C1, SF-C2 (Commons)			☐ TBD	☐ Heating ☐ Cooling
27	Revise Heating Valves Controls for AHU-R1 (Residence)			☐ TBD	☐ Heating

END OF DOCUMENT