LET'S CONNECT

EXPERIENCE: COMMISSIONING

Case Study: MnDOT Asphalt Testing Lab

INTRODUCTION

The Maplewood MnDOT testing facility was originally constructed in 1988. There have been several upgrades and modifications occurring due to changes in facility requirements in the areas within this case study which included the Asphalt (Binders) Lab-94 and Analytical Lab-99.

BUILDING INFORMATION

Building Owner: Minneapolis Department of Transportation (MnDOT)
Building Name: Office of Materials
Building Size: Approximately 5,300 within the scope of this study
Building Location: Maplewood, MN

SCOPE

The scope of this study was to investigate the operations of the heating, ventilating, and air conditioning (HVAC) systems in the Chemical Lab areas and resolve or recommend actions to improve the control of lab pressurization and temperature. The scope of the commissioning study included two primary areas, as well as additional minor support areas.

The owner has noted that occasionally the rooms will fall into a serious negative pressure. This appears to occur during start-up, when the downstream air handlers have not started the fans but the energy recovery unit has.

Due to these issues within the MnDOT Maplewood Materials and Research building it was requested that a Commissioning Provider perform the following re-commissioning activities:

- Verify operation of HVAC equipment for units serving Asphalt Lab 94 and Analytical Lab 99 with emphasis on the pressurization of these spaces.
- Verify the Air and Water Balance of systems (RTU-1, RTU-3, HVAC-3, lab supply and exhaust valves, ERU-1, ERU-3, perforated supply diffusers).
- Verify BAS sequence of operation, response times, PID parameters, and setpoints.

emanuelson-podas
consulting engineers

INSPECTION AND TEST CRITERIA

Inspection of the Air Handling equipment, instrumentation and control sequence of operations against manufactures requirements and facility requirements to ensure proper operation and maintainability.

Spot check and re-balance as needed to achieve proper lab pressures and face velocities of all fume hoods and canopies.

During the site visit, both Labs were put through four test scenarios:

1) Lab in an occupied but not in operation, all hoods closed and canopies off.
2) All hoods off and Canopies on.
3) All Hoods on and Canopies off.
4) All Hoods and Canopies on.

Each test allowed the area to stabilize for 10 minutes to ensure all variables were settled and the system was in control. (Appendix 3 shows results for the testing scenarios)

INITIAL ASSESSMENT

The initial assessment of both labs indicated that the installation of all instruments and equipment meet the design intent. The facility looked to be well maintained with newer equipment installed. Most fume hood controls, and air valves are accessible with a ladder or lift for maintenance. Each lab is discussed further in this study.

Room 94 | The Asphalt Binder Lab

The Asphalt Binder Lab is served by a variable volume Air Handling Unit, an Energy Recovery Unit, two duct mounted humidifiers, and CRC air valves at the room level for supply, fume hood, and general exhaust control. (Appendix 1 shows this equipment in schematic form, plan view and equipment schedules)

The room contains 9 fume hoods and 4 open canopy hoods. The fume hoods are installed with sash sensors and a CRC air valves for exhaust control based on sash position. The canopy hoods do not have sashes, but rather are open-front and have a manual switch which is energized when in use. A general Exhaust CRC valve is used to maintain room pressures when hoods are not in use and to maintain required exhaust offset to maintain space pressure. The supply into the Lab controlled by CRC Control valves and is only controlling the thermal load requirements.

As the airflow schematic indicates, the system is designed to pull air from all fume hoods, through a flat plate energy recovery bundle in the energy recovery air handler and provide tempered air to the primary air handler. As submitted, the air handling unit and energy recovery unit can supply and exhaust 37,4010 cfm with a total fume / canopy hood requirement of 33,810 cfm. The initial walk through indicated that the systems were not maintain correct offset within the space to maintain proper space pressurization and the pressure correlation between the Lab and surrounding areas fluctuated greatly from positive to negative depending on the operation of the hoods and the canopies.

Assessment:

The system was either designed for a lower face velocity or for a diversity of usage (i.e. not all fume hoods should be in use simultaneously). However, at the time of the initial walk-through, all fume hoods (except one) were operating. This may be an issue of personnel discipline, or may be necessitated by actual work requirements. In any event, field testing of airflows did in fact support the assumption that face velocities would be below standards with all hoods in operation. Face velocities measured varied greatly, with many hoods only achieving less than 50 fpm at the time of walk-through.

It should be noted also that the owner conducts experiments in this room which require that space conditions be maintained within certain parameters. Specifically, room conditions should remain within the following constraints: 73.4°F +/- 3.6°F and 50% relative humidity (RH) +/- 10% RH. At the time of the initial walk through, the existing equipment did not achieve this level of control. The space pressure is to be negative to the surrounding corridors and office but positive to the Analytical Lab 99.

Design / Installation Review:

A review of the current installation and programming of CRC valves was completed with a CRC representative. The system operation was tested with all canopies on and fume hoods open and found several valves not making setpoints at 100% open. The room pressure was operating at -.0002 to positive prior to testing. The offset was adjusted from 500 cfm to 3000 cfm and the room pressure maintained -.002 to -.004 during the testing. Per conversation with the client, it has been verified that the canopy valves were sized to meet a 100-fpm face velocity which is unachievable with the current configuration and not necessary. The canopy hoods appeared to have been initially balanced to a required 100-fpm, but this could not be verified as to how it was done due to lack of previous balancing report. All canopies are an open face design accessible from two sides and are not designed to be capable of achieving 100 fpm capture velocity. The canopy hoods are for heat extraction only. The flow requirements for all canopies was reviewed prior to beginning TAB and adjusted at that time.

While initially reviewing the design cfm numbers for each lab the design min cfm for several valves was lower than the minimum capabilities of the valve per the manufacture submittals. In Lab 94 the supply valve design cfm is the same min. and max. as the valve design capabilities. To achieve proper control the required design flow numbers should be set for the heating and cooling loads in the area being served and be within the manufactures range of the air valve.

Testing:

During this testing, it was discovered that while all valves appeared to be operational and track as expected the designed flow numbers did not allow the room to remain measurably negative to the surrounding corridors and positive to the adjacent analytical lab.

During initial testing 4 fume hoods 1, 2, 3, 4, 5 A, 8, & 10 did not reach the design cfm with the valves at 100% open and the exhaust fan at 100%.

During test 2; all valves serving canopy 6 and 1 valve serving canopy 14 did not reach their design number at 100% valve opening with the exhaust fan operating at 96%. It was found that all canopy valves were set up and operating to a maximum cfm value, so when the canopies were in use or left in operation the fume hoods were starved of air with the exhaust fan operating at 100%. All canopies were found to be <50 fpm face velocity.

During both test 2 and 4; supply valves 6, 7, 8, 9, & 10 did not reach their design setpoints at 100% valve open.

The design intent of the General Exhaust should be that it modulates between min and max to maintain room pressure in this condition. During all testing, it did not appear to be in proper control. At a full Exhaust condition, (hoods full open and canopies on) the General Exhaust valve should have to been controlling to minimum CFM.

While testing the airflows several of the exhaust valves exceeded the scheduled design min or max. This was be due to improperly set up valve controls.

Appendix 3 references initial schedules, as -found conditions, testing and the proposed changes.

Resolution:

The requirements of the canopy hoods were evaluated, and heat extraction airflow rates calculated based on the heat loads of the installed ovens. All canopy air valve flow setpoints were then reset to the requirements and air balanced with the TAB contractor.

All fume hood operations were evaluated, and sash sensors reset as needed. The hoods were then rebalanced by the TAB contractor to achieve a face minimum velocity of 80 fpm as recommended by the manufacture. Max sash position labels were installed on each fume.

Functional testing of the fume hoods and canopies was performed to ensure correct space pressure could be maintained through various scenarios of lab operation.

Training of the lab personnel occurred to ensure the correct operation of the systems and capabilities was understood.

The side effect of doing the changes to the hoods was that the room temperatures could now be maintained.

Room 99 | **The Analytical Lab**

The Analytical Lab is served by a variable volume Air Handling Unit, an Energy Recovery Unit, duct mounted humidifier, CRC air valves at the room level for supply, fume hood, general exhaust control and 3 variable volume exhaust fans serving 3 of the fume hoods. (Appendix 2 shows this equipment in schematic form, plan view and equipment schedules)

The room contains six fume hoods, one canopy hood and two bench extractors. The fume hoods are installed with sash sensors and a CRC air valves for exhaust control based on sash position. The canopy hood bench extractors do not have sashes, but rather are open-front and have a manual switch which is energized when in use. A general Exhaust CRC valve is used to maintain room pressures when hoods are not in use and to maintain required exhaust offset to maintain space pressure. The supply into the Lab controlled by CRC Control valves and is only controlling the thermal load requirements.

As the airflow schematic indicates, the system is designed to pull air from all fume hoods, through a flat plate energy recovery bundle in the energy recovery air handler and provide tempered air to the primary air handler. As submitted, the air handling unit and energy recovery unit can supply and exhaust 13,000 cfm with a total fume / canopy hood requirement of 6,665 cfm. The initial walk through indicated that the systems were not maintaining correct offset within the space to maintain proper space pressurization. The pressure correlation between the Analytical Lab and surrounding areas fluctuated greatly from positive to negative depending on the operation of the hoods and the office door positions.

As in the Asphalt Binder Lab, the owner conducts experiments in this room which require that space conditions be maintained within the same parameters: 73.4°F +/- 3.6°F and 50% relative humidity (RH) +/- 10% RH the existing equipment did not achieve this level of control. The space pressure is to be negative to the surrounding labs and office spaces.

This space differs from the Asphalt Binder Lab in how the air is exhausted and supplied. While in the Asphalt Binder Lab all fume hoods are exhausted through the energy recovery unit, in the Analytical Lab only a portion of the fume hoods are exhausted through this lab's energy recovery unit, with the remainder of the fume hoods exhausted through dedicated roof-mounted variable speed exhaust fans. These fans vary the speed based on the position of the sash on the fume hood. A bypass valve is installed within the ductwork to maintain a minimum flow through the hood and fan when the sash is closed.

Assessment:

Three of the hoods and the canopy are controlled using CRC air valves, the remaining hoods in the space (hoods #21, 22, and 23) are connected directly to dedicated roof-mounted exhaust fans. Nominally, these exhaust fans are sized to achieve 100 fpm face velocity, respectively. However actual airflows are significantly lower, indicating that the fans are either not operating per design and/or that the hoods themselves are not able to maintain consistent airflow. All airflow measurements were taken across the face of the fume hoods in this lab.

Design / Installation Review:

As with the Asphalt lab During a review of the initial design, it was noted that the valve design numbers scheduled did not meet the capabilities of the valves as per the manufactures data sheets. It was also found that the design cfm requirements for fume hoods 23A and 23B both exceeded and were less than the requirements for hood per the manufacturer's recommendations.

With space pressurization being a major concern, the control needed to incorporate a means of tracking fume hood sash positions and the control of the exhaust in the space to maintain an offset. During a review of the Building Automation System (BAS) there was no general exhaust control within the program for this area.

Another issue discovered during the review were improper feedback signals from the CRC valves to the BAS. This caused the system to not track actual sash position.

Testing:

The room pressure was maintaining neutral to slightly positive. It was noted that the Analytical office is open to the mezzanine above with no way to isolate the room other than closing the door. During testing, it was discovered that the valves tracked as expected and the room was able to remain measurably negative to the surrounding labs and offices during all 4-test scenarios.

It was found during test 3 & 4 that fume hood 23A & 23B did not make the required 100-fpm face velocity or design flows, these hoods share a common exhaust fan, EF-23. This looks to be due to the valves not tracking to correct fume hood flow requirements.

The max airflows for several of the exhaust valves exceeded the design min or max. This was due to improperly set up valve controls or compensating for duct design issues.

EF-21, EF-22, & EF-23 all indicated a bypass damper position in a percentage open position but when reviewing the installation did not see a modulating damper on the bypass damper. There is, however, a manual quadrant handle mounted to the bypass damper at the exhaust fan. While reviewing the Lab 99 IO and RTU-3 IO there was no mention of any EF bypass dampers.

The provided submittals called out for a Fully Modulating bypass damper.

Appendix 3 references initial schedules, as -found conditions, testing and the proposed changes.

Resolution:

To prevent air from bypassing the AHU, the analytical office (Room 97) door must remain closed to prevent loss of pressure in the main lab.

The BAS program was changed to include the general exhaust valve and a programmed offset to ensure proper tracking of the exhaust out of the space.

Exhaust fans were properly set up with modulating bypass dampers which tracked the fume hood sash position and were set up to show on the BAS operators' interface. Each exhaust fan was balanced to ??

All fume hood operations were evaluated, and sash sensors reset as needed. The hoods were then rebalanced by the TAB contractor to achieve a face minimum velocity of 80 fpm as recommended by the manufacturer. Max sash position labels were installed on each fume.

After the programming changes and final air balancing functional testing of the fume hoods and canopies was performed to ensure correct space pressure could be maintained through various scenarios of lab operation.

Training of the lab personnel occurred to ensure the correct operation of the systems and capabilities was understood.

Support Area(s) Assessment:

There are several additional support areas; offices, XRF room, and storage room which should be noted that have a direct influence on the pressurization of both labs, these are shown in plan views for each area in Appendix's A and B. A separate air handling unit, AHU-2 with variable air volume terminal units supplies air to these areas.

The XRF Room contains the lab x-ray fluorescing machine which produces a great deal of heat which is returned to AHU-2

The Hazardous Materials Storage Room includes a dedicated exhaust fan nominally sized at 500 cfm which draws transfer air from Lab 99. This nominal rate does meet (and exceed) code requirements for hazardous material storage, but lab personnel and field investigation indicate the airflow through the space is inadequate for ventilation of hazardous materials. It is likely that the fan no longer operates at design.

Interpretation/Results:

It appears that the design and TAB work performed prior to this assessment did not review the requirements for the equipment installed or fully document the equipment serving these areas.

All design cfm requirement for these labs needed to be reviewed to ensure correct matching of valve capabilities to the fume hood or canopy requirements to meet the required face velocities and heat extraction. The valves must have the correct cfm requirements set. In both labs, the bias was set too low to allow for the differential of the supply and exhaust to maintain a negative room pressure through various lab operations.

Canopy hoods in Lab-94 appeared to be initially setup and balanced to provide a face velocity that was not achievable due to the open canopy design and heat loads were not considered for these hoods in the initial design. All air valves serving the canopy hoods were reset to achieve proper heat extraction flow vs a standard capture velocity. This reduced the overall system flow requirement by for each canopy by almost 50%.

The rooms were air balanced to the new flow numbers with the final room pressures for Lab-94 -0.005"wc to the corridor and Lab-99 -0.006"wc to Lab-94 (lab 99 is also negative to the adjacent Metro lab). All testing was completed with doors closed and hoods in both min and max positions.

The final room offsets for both labs were set at 2,000 cfm from the as found volume of 550 cfm.

Appendix 3 references initial schedules, as-found conditions, testing and the proposed changes

In Lab-99 the offset may be artificially high due to the infiltration from the outside door. There were several hundred cfm coming in around the door seals and light is visible through the seals on an exterior door.

#	Description of Deficiency Discovered During Commissioning Process	Description of Resolution (or plan for resolution of outstanding deficiency)
1	All canopy air volumes seemed to exceed the requirement for heat removal from canopies.	Calculated current heat generation within canopies and volumes required to remove heat. Reduced air volumes proportionately to meet heat load requirements.
2	All fume hoods were found with the same 250 cfm minimum flow value regardless of size.	Adjusted minimum flows to be 30% of maximum value.
3	A default differential volume offset was setup within each lab. Infiltration / Exfiltration of the labs was not considered during initial setup.	Adjusted offsets to proper levels to provide required lab pressurizations.
4	During TAB there was an issue getting proper CW flow to RTU-3.	This issue was not resolved during Cx time on site. The site was looking into the issue.
5	General exhaust tracking not properly set up within both Lab-94 and Lab-99.	Both labs have the general exhaust tracking no in place and offsets programmed to maintain room pressures.

ADDITIONAL FINAL OBSERVATIONS REGARDING SYSTEM PERFORMANCES:

The installation of the systems is installed as designed. The system appeared to be designed to only provide capture velocities of the open canopies vs. heat capture. This approach required that higher than required air volumes be set for the air valves serving the open canopies. After recalculating the requirements for the heat load of the current installation the canopy volumes were reduced which led to a reduction of fan speeds, proper offsets and required room pressurizations.

During water balancing there was an issue getting proper CW flow to RTU-3. The issue may be that when designed the building CW system was not increased to provide the additional cooling flow required for the new cooling coils. The as found condition had both cooling valves 100% open which is also the condition as of the date of this report and as noted in the TAB report.

During the water balancing it was discovered that RTU1 was running low on flow per the design submittals and ERU-3 had no measurable flow across the balancing valve for the unit. After walking the ERU-3 system, found no closed valves, and cycled the actuated valves to check for improper setup with the same results, no measurable flow. We did find the CW system bypass valve indicating 100% open on the BAS but when overriding it closed, it had no effect on the unit's flow.

The OA temperature installation needs to be looked at. Throughout testing it was observed that the OA conditions reported on the BAS did not match the actual conditions. During gathering information for this final report, it was observed that the OAT indicated >90F with actual temperatures in the low 80s as reported by the national weather service. This effect on all systems using OAT to reset temperatures causes improper control of the economizer modes and the temperature resets based on OA conditions. It was recommended that only 2 sensors be installed at this facility, one as primary with a redundant back up in case of failure.

RECOMMENDATIONS FOR FOLLOW-UP WORK AT THIS SITE:

1) Review the current cooling load requirements and make necessary adjustments to the system. This was completed by the site team.
2) Annual controls review to ensure proper operation of valves and hoods. This is being completed by the MnDOT controls team.

RICK DALE, CCP, CxTS
Director of Commissioning
rdale@epinc.com

- 30+ years' experience in facilities operation and maintenance
- Certified Commissioning Professional (CCP)
- Member of Building Commissioning Association (BCxA)