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Ref: Hoffman 5th Floor Lab Study (FSU Project #31856; PEG #214-116)
Sub: Final Report

Dear Biff:

EXECUTIVE SUMMARY:

The Hoffman Chemistry 5th Floor labs consist of three main labs: #505 (1,890 SF w/ 18 Hoods), #506 (1,701 SF w/ 10 Hoods) & #507(1,890 SF w/ 18 Hoods). The other half of the 5th floor consists of three secondary labs with four total fume hoods. The primary focus of this Study is on the three main labs #505, #506 & #507.

The Main Labs are currently served by three Primary Ventilation Systems: PVS-505, PVS-506 and PVS-507. These systems pre-condition 41,220 CFM outside air via heat recovery wheels between the exhaust and outside air sections of the Primary Ventilation Systems (PVS). The Exhaust Air is ducted to six high plume exhaust fans (with 3 of the 6 Exh Fans originally designed for 100% Redundant Standby Operation).

This project calls for an HVAC review of the current systems; identify performance issues; and, make recommendations for corrective measures.

The Engineer performed multiple site visits to review and evaluate existing HVAC equipment performance, review current use and function of the space, and gather information to perform HVAC Equipment Analysis, Duct Analysis and Air Balance Calculations.

The Report Recommends the following Actions:

1. Replace or Modify Existing PVS Units. The existing Primary Ventilation Systems (PVS) have two heat recovery wheels. By design, outside air short-cycles across the wheels to the Exhaust air stream. Currently, both exhaust fans must operate (in part) to over-come the short-cycling in the PVS units. It is recommended that the short-cycle path be eliminated by either replacing the units or modifying the units by removing the wheels and installing Heat Pipes.

2. Each Lab shall have a dedicated Supply & Exhaust System. Operation and Control of dedicated systems are simpler and easier to understand when each system only serves one lab (Note: Currently, Lab #505 has Supply air and Exhaust air provided by PVS-505 & PVS-506.)

3. Balance Air Flow to Each Lab. Exhaust Air flow shall be set to maintain 100 FPM at an 18" Sash Height to comply with FSU Environmental Health & Safety (EH & S) requirements. Supply Air shall be set to maintain a constant differential between the Exhaust Air CFM and the Supply Air CFM. Each Lab shall have slightly negative pressure to comply with current codes.

4. Upgrade Controls. Add Lab quality Supply Air Pressure Independent Constant Volume Boxes to measure and control lab supply air CFM. Add Lab Quality Exhaust Air Pressure Independent Constant Volume Boxes (or improving existing blade-style dampers by adding Siemens actuator and flow measurement via existing differential pressure inputs). Recommended Control Sequences include: Exhaust Air and Supply Air tracking; Normal & Not in Use Modes of Operation (based upon fume hood usage).

5. Lab Design Improvements.

   a. Lab Exhaust Duct shall be designed for 1500 fpm (minimum).
   b. Pressure test existing Exhaust ducts and repair leaks.
   c. Size Supply Duct for design air quantities.
   d. Improve Outside Air intake size and measurement.
   e. Provide sufficient quantity and placement of Supply Diffusers.
   f. Install balancing dampers to assist with Test & Balance.
   g. Add emergency vacuum relief push-button controls by exit doors.

Our Opinion of Probable MEP Construction Cost is located in Appendix A.

In this Study, Pinnacle Engineering Group has provided the following services:

a. Meet with the Owner's Representative to:
   i. Evaluate design issues and subsequent field modifications.
   ii. Review current control sequences.
   iii. Determine acceptable fume hood performance standards.
   iv. Overview applicable HVAC Issues: Airflow, Air Balance, Pressurization, Vacuum Relief, Space Conditions, sound, Maintenance, etc.
b. Drawing Review & Field Work to Document Existing Conditions.
c. Research Current Applicable Codes.
d. Obtain Existing Equipment Data: ERU's AHU, Exhaust Fans, Fume Hoods.
e. Coordinate with and review Siemens Control Sequences.
f. Review Fume Hood Exhaust Requirements.
g. Review Air Balance.
h. Evaluate existing Air Distribution System including Fan Static Pressures, Duct Velocity and Static Pressure Losses.
i. Evaluate existing ERU's, Exhaust Fans and AHU.
j. Review existing available Electrical Capacity.
k. Develop Solutions and associated probable Construction Costs.
   i. Perform Field Work to evaluate Constructability, fit, etc.
l. Submit Report Summarizing existing condition Findings, Conclusions and Recommendations.
m. Present Report to Owner.

BRIEF HISTORY:

Lab #505 was renovated in 2003.

The lab was designed for 18 Lab Crafter Air-Sentry low-flow fume hoods. Each fume hood was designed for 60 FPM face velocity at the standard 18" sash height. At full sash height, the face velocity was less that 45 FPM.

PVS-505 was installed to pre-condition the outside air via use of the fume hood exhaust air. To meet the low-flow fume hood requirements, the PVS Unit was selected for 8,820 CFM (SA & EA). The PVS Unit is connected to two high plume exhaust fans each designed for 8,820 CFM.

During the commissioning phase of the project, the fume hoods would not contain tracer gas at full sash height (as per ASHRAE Std 110).

In 2004, subsequent modifications were made to Lab #505. These modifications included:

1. Redesigning the PVS-505 System to exhaust 10 fume hoods (rather than 18);
2. Designing new PVS-506 to exhaust the other 8 fume hoods;
3. Route the PVS-505 Supply air into one of the two existing 24x24 duct roof penetrations (i.e. the full PVS-505 8,000 CFM was ducted to one, not two, 24x24 ducts);
4. Route the PVS-506 Supply air into the other 24x24 duct roof penetration (8,000 CFM into a duct designed for 4,000 CFM);

The desired result of these modifications included increasing the fume hood standard height face velocity to 100 FPM and full sash height to 72 FPM.

In December 2004, the fume hoods were retested by Exposure Control Technologies (ECT). Again, the fume hoods failed to contain the tracer gas at full sash height in accordance with the ASHRAE Std 110 methodology. The fume hoods did comply with the test at the standard sash height. Similar results were found with the fume hoods in Labs #506 and #507 (which were also modified in 2004).

Between August and October 2006, HVAC Testing Services adjusted fume hood exhaust flows (see Appendix B) as summarized in the Table below:

PVS UNIT#	EXHAUST DESIGN (CFM)	2006 T&B (CFM)	DESIGN PURGE (CFM)	TOTAL (CFM)	EXH FAN ** (%)
505	7,950	11,616	2,531	14,147	85%
506	14,310	19,634	3,361	22,995	100%
507	14,310	17,337	3,361	20,698	90%

****** Note: Both fans are operating

In order to obtain the fume hood T&B exhaust CFM indicated above, both exhaust fans were required to operate. (Note: It is suspected that the actual "purge" CFM exceeds the "design" purge CFM indicated; also, there are duct leaks; this helps provide understanding for the need to operate two Exhaust fans.)

EXISTING CONDITIONS:

GENERAL OBSERVATIONS:

A preliminary site visit was conducted on August 1, 2014; follow-up sites visit were conducted on September 26th, September 29th, October 17th, and October 24th 2014. The following observations were noted:

1. Lab #505 is extremely negative pressure.
2. Lab #505 Outdoor intakes are covered with bird screen and are partially blocked.
3. Lab #505 four (4) additional laminar flow diffusers have been added to the lab.
4. Lab #505 is partially served by EVS-505 & EVS-506 (Supply & Exhaust)
5. Lab #506 is negative pressure but less so that Lab #505.
6. Air is moving from 506 to 505 (Including plenum space).
7. Air is moving from 506 to 507 (less movement than from 506 to 505).
8. Lab #507 four (4) laminar flow diffusers have been removed (tap's are capped).
9. Lab #507 diffuser air noise is obvious.
10. Lab #507 Roof Drain passes through both supply ducts (on the East side of Lab).
11. Lab #507 Roof penetrations are not completely sealed: daylight seen and stained tiles.
12. Relief Dampers – Have been installed for Lab's #505, #506 & #507.
13. Elevator – air is being drawn through elevator shaft at a high volume.
14. Utility Chase Doors – Air is being drawn out of closed chase access doors.
15. Generally observed Space Temperature was 68ºF-72ºF.
16. Generally observed Relative Humidity was 59% - 70% RH.
17. Room #517 ceiling tiles felt damp with corners turned up. Despite initial review, source of moisture was not readily apparent.
18. VVT-518 (Locker Room) – Upstream flexible duct connector has separated from the Medium Pressure Duct.
19. 505, 506, 507 Fume Hoods are all Lab Crafters, Air Sentry, M# HBASC6.
20. Lab #505 and #507 have 18 Fume Hoods; Lab #506 has 10 Fume Hoods.
21. All Fume Hoods have an operable baffle control; baffles are not all operational.
22. Each Fume Hood has a Blade-Style Control Damper (with blades fixed in place).
23. Each Lab has two exhaust fans; both operate to maintain 100 fpm sash velocity.
24. Exh Fans are controlled to a fixed "Normal" set point from 7:00AM – 7:00 PM
25. Exh Fans are controlled in "sleep mode" from 7:00PM – 7:00AM (50% Reduced Flow).
26. Siemen's installed differential pressure sensors at 3 strategic doors in 2011; Lab #505, NE Door had a differential pressure of 0.212" wc (at 9:30am on Sept 29, 2014)
27. Lab's are pretty heavily used M-R; minimal use on Fridays.
28. PVS-505 & PVS-506 have recently replaced the CHW Coils (Froze during the Winter).
29. PVS-506 Enthalpy Wheel is fixed in place with a pipe; sections are missing from wheel.
30. PVS-505 Exhaust Fans (EF-035-3A & -3B) do not have isolation dampers.
31. Steam Reheat Coils were valved off to PVS-505 & PVS-506.
32. PVS-505, -506, -507 do not have a pre-heat coil (CHW Coil protected by Enthalpy Wheel).

BUILDING DESCRIPTION:

The 5th Floor Labs have a gross area of 10,440 FT^2. The facility has been in use approximately 50 years. The facility is a five story building.

Building construction is: brick and block; there is a pan floor construction (w/ approximately 24”x24” max duct can pass through pan); roof is believed to be single-ply roof with insulation (R-20 est); ceilings are 24”x24” lay-in acoustical tile; window area is very limited and is in the exterior doors.

The 5th Floor Plan HVAC Drawings dated April 12, 2004 (and Revision #2 October 20, 2004) appear to fairly accurately represent existing conditions (with the exception of Diffuser lay-out).

Photographs of the existing Facility are located in Appendix E.

MECHANICAL:

GENERAL:

The Hoffman 5th Floor Labs are basically divided into two sides: East Labs #505, #506 and #507 and West Labs #509, #517 and #520. A description of the HVAC Systems follows below.

EAST LABS #505, #506 and #507:

The Hoffman 5th Floor East Labs #505, #506 and #507 are served by Primary Ventilation Systems (PVS) with a Total Energy Wheel and a Passive Dehumidification Wheel. PVS-505 was installed in 2003. PVS-506 & PVS-507 were installed in 2004. These PVS Units are located on the roof and were designed for 90 mph wind loads (per Sheet M0.1, General Note #35).

The PVS Units are a split AHU with an Outside Air Section and an Exhaust Section. The Outside Air Section has a Supply Fan in a blow through arrangement (pressurizing the Outside Air Section relative to the Exhaust Section). The Exhaust Section does not have an integral Exhaust fan; however, there are two exhaust fans (one standby) remote to the PVS Unit. Purge air is washed across the Wheels from the Outside Air Section to the Exhaust Air Section. Seals must be maintained to prevent excessive purge air (particularly with the high static pressures in the PVS Units). In addition, the Original Selection of PVS-505 indicates “Minimum purge pressure will need to be set up during startup and will probably only permit about a 40% turndown of the supply fan.”

The Units have Siemens controls.

A summary of the existing HVAC Systems is indicated below and in Appendix C

WEST LABS #509, #516, #517 & #520:

AHU-5-1 is a 100% Outside Air Handler which serves the West Labs. This AHU was installed in 2004 and is in good condition. The AHU has a VSD and constant volume boxes for each room (except Room #516). The AHU is located in a conditioned West MER.

The Air handler unit is a constant volume, draw-through AHU. The AHU controls are provided by Siemens.

A summary of the existing AHU performance data is indicated below and in Appendix C.

<u>EXHAUST FANS:</u>

The existing Lab exhaust is from the Lab Fume Hoods. The East Labs exhaust through the PVS Units for energy recovery. All of the fume hood exhaust is ducted to High Plume Exhaust Fans.

PVS-505 Unit Exhaust fans were designed for “low-flow” fume hoods. For proper operation, both fans must run all the time to maintain 100 FPM fume hood sash velocity.

The PVS-506 & PVS-507 Unit Exhaust Fans are designed for 100% Standby operation; however, FSU is currently running both fans near 100% capacity to maintain 100 FPM fume hood exhaust.

The West Labs exhaust is manifolded together and exits the roof where it is headered with fume hood exhaust from other building floors. The main header connects to Exhaust Fans EF-035-2A, EF-035-2B, EF-035-2C.

A summary of the existing Exhaust Fan performance data is indicated below.

EXISTING HVAC CONDITIONS:

EXISTING PRIMARY VENTILATION SYSTEMS (PVS) HEAT RECOVERY UNITS

TAG	PVS-505	PVS-506 & PVS-507
OA CFM	11,351	19,561
SA CFM	8,820	16,200
RA CFM EA CFM	8,820 11,351	19,561 16,200
ESP	4.8	4.1
HP	15	30
ELECTRICAL	208/3	460/3

COOLING COIL	PVS-505	PVS-506 & PVS-507
EAT (DB/WB)	80.4/67.3	94/77
LAT (DB/WB)	52.14/52.10	77.6/65.7
SENSIBLE(KBTUH)	298.8	514.1
TOTAL (KBTUH)	445.9	773.7
EWT/LWT (F)	45/55	45/55
GPM	47	88

HEATING COIL (STEAM)	PVS-505	PVS-506 & PVS-507
EAT (DB)	61.1	62.0
LAT (DB)	93.8	92.1
TOTAL (KBTUH)	313.8	530.6
STEAM (#/HR)	326.3	551.7
APD (IN WG)	0.19	0.05
PSIG	5.0	5.0

EXISTING 100% OUTSIDE AIR UNIT DATA

TAG	AHU-5-1 DESIGN	AHU-5-1 ACTUAL
SA CFM	7,600	4,900
OA CFM	7,600	4,900
RPM		
ESP	1.5	0.62
HP	7.5	7.5
ELECTRICAL	460/3	460/3

COOLING COIL	AHU-5-1 DESIGN	AHU-5-1 ACTUAL
EAT (DB/WB)	96/80	96/80
LAT (DB/WB)	55.0/54.9	55.0/54.9
SENSIBLE(KBTUH)	345.0	222.4
TOTAL (KBTUH)	703.0	453.0
EWT/LWT (F)	45/61	45/61
GPM	87.9	56.7

HEATING COIL	AHU-5-1 DESIGN	AHU-5-1 ACTUAL
EAT (DB)	20.0	20.0
LAT (DB)	55.0	55.0
SENSIBLE(KBTUH)	289.0	186.3
TOTAL (KBTUH)	289.0	186.3
EWT/LWT (F)	180/150	180/150
GPM	19.2	12.4

EXISTING EXHAUST FAN DATA

EXISTING EXHAUST AIR FAN DESIGN DATA					
Tag	CFM	Type	Ext. Static	Fan Motor HP	COMMENTS
EF-035-3A & 3B	8820	HIGH PLUME	3.10”	10	LAB #505 (NOTE #1, #2)
EF-035-506A & 506B	20000	HIGH PLUME	4.0”	25	LAB #505 & #506 (NOTE #1)
EF-035-507A & 507B	20000	HIGH PLUME	4.0”	25	LAB #507 (NOTE #1)
EF-035-2A		HIGH PLUME			MULTI FLOOR LAB EXH
EF-035-2B & 2C	7000	HIGH PLUME	3.0”	10	MULTI-FLOOR LAB EXH

Note #1: Original Design one fan was designated as back-up; however, currently both fans must operate to meet fume hood exhaust requirements.
Note #2: 208/3/60

EXISTING FUME HOOD DATA

EXISTING FUME HOOD DATA					
LAB	CFM	Type	QUANTITY	LENGTH	MANUFACTURER
505	795	BYPASS	18	6	Lab Crafters Air Sentry
506	795	BYPASS	10	6	Lab Crafters Air Sentry
507	795	BYPASS	18	6	Lab Crafters Air Sentry
509	1080	BYPASS	1	8	
516	540	BYPASS	1	4	
517	1080	BYPASS	1	8	
520	1080	BYPASS	1	8	

Note: CFM indicated is required for 100 FPM at 18” Sash Height

CALCULATIONS:

FUME HOOD FLOW (CFM) CALCULATIONS

Design Sash Height (18") – Area = 7.875 SF

- Recommend 80 – 120 FPM, the Required Exhaust Flow is 630 CFM to 945 CFM

Full Sash Height (25") – Area = 10.94 SF

- Recommend 60 – 100 FPM, the Required Exhaust Flow is 656 CFM to 1094 CFM

The Design Fume Flow Rate is 795 CFM (or 100 FPM). Therefore, this flow rate meets the Design Sash Height Velocity and Full Sash Height Velocity Requirements.

VENTILATION CALCULATIONS:

For most facilities, Ventilation Air requirements are driven by the number of people in the room; however, as is the case for most labs, the outside air requirements are often driven by the make-up air requirements of the fume hoods. Such is the case with this project.

On a "people" basis, the ventilation required for the lab is 640 CFM (assuming 30 people @ 10 CFM/Person and 1,890 SF at 0.18 CFM/SF).

For a Lab with hazardous chemicals, FBC 2010 Mechanical, Exhaust Systems, Chapter 502.8.1 requires 1 CFM/SF Ventilation Air. Utilizing 1,890 SF of Lab Area, the required Ventilation Air is 1,890 CFM.

For this Lab #505 & #507, there are 18 fume hoods. Each fume hood has been designed for 795 CFM Exhaust; therefore, 14,310 CFM of Make-up (i.e. Ventilation) Air is required.

For Lab #506, there are 10 fume hoods. Each fume hood has been designed for 795 CFM Exhaust; therefore, 7,950 CFM of Make-up (i.e. Ventilation) Air is required.

Lab Ventilation is often analyzed on an air change per hour basis. The Table Below lists required Air Changes per Hour for each Lab ranging from 4 ACH to 10 ACH.

LAB #	Area (FT2)	Volume (FT3)	4 ACH (CFM)	6 ACH (CFM)	8 ACH (CFM)	10ACH (CFM)
505	1,890	17,010	1,134	1,701	2,268	2,835
506	1,701	15,309	1,020	1531	2,040	2,552
507	1,890	17,010	1,134	1701	2,268	2,835

Therefore, for Lab #505 & #507, the Design Ventilation is 14,310 CFM. The minimum CFM for 10 ACH is 2,835 CFM; however, for practical purposes, the Exhaust fan will not generally cycle less than 25% or 3,600 CFM (minimum).

Likewise, for Lab #506, the Design Ventilation is 7,950 CFM. The minimum CFM for 10 ACH is 2,552 CFM (minimum).

(Note: The Ventilation Air Quantities indicated above will be met by the Exhaust System; the Make-up Air will be slightly less due to negative pressure requirement of the Lab.)

STATIC PRESSURE CALCULATIONS:

Static Pressure Calculations are included in Appendix B and summarized below for each PVS System. Supply Fan represents the External Static Pressure (excluding PVS pressure drop). Exhaust Fan represents the Static Pressure utilized for Fan Selection.

PVS Unit	Sch'd S. Fan (In wg)	Calc'd S. Fan (In wg)	Sch'd E. Fan (In wg)	Calc'd E. Fan (In wg)
505	0.50"	1.20"	3.1"	4.0"
506	1.25"	1.25"	4.0"	4.25"
507	1.25"	0.84"	4.0"	4.0"

Analysis:

1. PVS-505 Supply Fan is undersized.
2. PVS-505 Exhaust Fans are undersized (and should be designed for 100% redundancy.)
3. PVS-506 Calculated Supply Air ESP is higher than PVS-507 due to the 8,000 CFM in the 24x24 duct serving Lab #505.
4. PVS-506 Calculated Exhaust Air SP is higher than PVS-507 due to serving fume hoods in Lab #505.
5. Scheduled Exh Fan were selected at:
   a. PVS-505 at 3.1" @8,820 CFM vs 4.0" @ 7,950 CFM
   b. PVS-506 at 4.0" @20,000 CFM vs 4.25" @ 14,310 CFM
   c. PVS-507 at 4.0" @20,000 CFM vs 4.0" @ 14,310 CFM

AIR BALANCE CALCULATIONS:

The existing "Design" Air Balance Calculations are summarized below:

AREA	OA (CFM)	EA (CFM)	RELATIVE PRESSURE
Lab #505	16,000	14,310	Positive
Lab #506	8,000	7,950	Slightly Positive
Lab #507	14,840	14,310	Slightly Positive

Although the original design was for Slightly Positive Lab's, the current conditions are extremely negative. The new Air Balance will be slightly negative pressure in compliance with NFPA 45, Ch 8.3.4.

CODE RESEARCH:

2010 FBC (Building), 443.3.6.4 Chemistry Laboratories and Science Classrooms

HVAC Systems in Chemistry labs and science classrooms shall be designed and installed to ensure that chemicals originating from the space are not recirculated.

Exception: A high capacity emergency exhaust system providing 20 air changes per hour…

Evaluation: This requirement is not applicable to the project as there is NO recirculation of air.

2010 FBC (Mechanical), Exhaust Systems, Ch 501.2.1 Location of Exhaust Outlets

Discharge 30 feet from property lines and combustible walls and openings into building.

Discharge 10 feet above roof.

2010 FBC (Mechanical), Exhaust Systems, Ch 502.8.1 Hazardous Material Storage

Ventilation rate of 1 CFM/SF.

Ventilation Shall Operate Continuously.

Manual Shut-Off Control Required outside the room in a position adjacent to the access door to the room. Switch shall be a break-glass or other approved type and shall be labeled "Ventilation System Emergency Shutoff".

Ventilation System shall be designed to consider the density of the potential fumes or vapors (lighter than air within 12" of highest point in the room).

Ventilation shall provide air movement across entire portions of the room.

Exhaust air shall not be recirculated.

2010 FBC (Energy) 503.2.5.2.2.2 Fume Hoods

Building with fume hood systems having a total exhaust rate greater than 15,000 CFM shall include at least one of the following features:

1. Variable Air Volume Hood Exhaust and room supply systems capable of reducing exhaust and makeup air volume to 50 percent or less of design values.
2. Direct makeup (auxiliary) air supply equal to at least 75 percent of the exhaust rate, heated no more than 2 F below room set point, cooled to no more than 3 F above room set point, no humidification added, and no simultaneous heating and cooling used for dehumidification control.
3. Heat recovery systems to precondition makeup air from fume hood exhaust in accordance with section 503.2.6 (Exhaust Air Energy Recovery) without using any exception.

(Note: 503.2.6 Exhaust Air Energy Recovery for Cooling Systems "Individual cooling fan systems that have both a design supply air capacity of 5,000 CFM or greater and a minimum outside air supply of 70 percent or greater of the design supply air quantity shall have an energy recovery system that provides a change in the enthalpy of outdoor air supply of 50% or more of the difference between the outside air and return air at design conditions.")

NFPA 45 (2004), Fire Protection for Laboratories Using Chemicals, Ch 8 Laboratory Ventilating Systems and Hood Requirements

8.3.4 The air pressure in the laboratory work areas shall be negative with respect to corridors and non-laboratory areas of the laboratory unit.

8.3.5 The location of supply diffusion devices shall be chosen so as to avoid air currents that would adversely affect the performance of chemical fume hoods, exhaust systems, and fire detection or extinguishing systems.

8.4.6 Chemical fume hood face velocities and exhaust volumes shall be sufficient to contain contaminates generated within the hood and exhaust them outside of the building.

8.4.12 Air exhausted from chemical fume hoods and special exhaust systems shall be discharged above the roof at a location, height, and velocity sufficient to prevent re-entry of chemicals and to prevent exposures to personnel. (Note: NFPA 45 Appendix A8.4.12 information indicates "Exhaust stacks should extend at 10 feet above the highest point on the roof.)

8.5.6 Materials used for vibration isolation connectors shall comply with 8.5.2. (Note: Subsection 8.5.2 indicates "Combustible ducts or duct linings shall have a flame spread index of 25 or less when tested in accordance with NFPA 255, Standard Method of Test of Surface Burning Characteristics of Building Materials. Test specimens shall be of the minimum thickness used in the construction of the duct or duct lining.)

8.5.8 Controls and dampers, where required for balancing or control of the exhaust system, shall be of a type that, in event of failure, will fail open to ensure continuous draft.

8.5.9 Hand holes, where installed for damper, sprinkler, or fusible link inspection or resetting and for residue clean-out purposes, shall be equipped with tight-fitting covers provided with substantial fasteners.

8.5.10.3 Exhaust ducts from chemical fume hoods and other exhaust systems within the same laboratory unit shall be permitted to be combined within that laboratory unit.

8.8.7.1 A flow monitor shall be installed on each chemical fume hood.

8.9.2 Chemical fume hoods shall not be located adjacent to a single means of access or high traffic areas.

8.10.3.1 Automatic Fire Dampers shall not be used in laboratory hood exhaust systems.

8.10.4 Fire detection and alarm systems shall not be interlocked to automatically shut down laboratory hood exhaust fans….

A.8.2.2: A minimum ventilation rate for unoccupied laboratories (e.g., nights and weekends) is four room air changes per hour. Occupied laboratories typically operate at rates of greater than eight room air changes per hour, consistent with the conditions of use for the laboratory. It is not the intent of the standard to require emergency or standby power for laboratory ventilation systems. (Note: This is Appendix information.)

NFPA 55 (2005), Storage, Use, and Handling of Compressed and Liquefied Gases in Portable Cylinders, Ch 6 Building Related Controls

Same requirements noted as shown above for 2010 FBC (Mechanical), Exhaust Systems, Ch 502.8.

6.16.6 "Ventilation Discharge shall terminate at a point not less than 50 feet from intakes of air-handling systems, air-conditioning equipment, and air compressors."

NFPA 91 (2004), Standard for the Installation of Blower and Exhaust Systems

4.1.11 Exhaust ducts shall not pass through fire walls, as defined by NFPA 221, Standard for Fire Walls and Fire Barrier Walls.

ANSI Z9.5 – 2012 Laboratory Ventilation

The 2012 American National Standards Institute (ANSI)/American Industrial Hygiene Association (AIHA) Z9.5 "Laboratory Ventilation" standard, recommends new minimum fume hood flow guidelines that are based on the internal volume of the fume hood and internal air changes per hour (ACH). Instead of specifying that a minimum flow of 25 cubic feet per minute per square foot (cfm/ft^2) be maintained, ANSI/AIHA Z9.5 now states that "laboratory fume hoods shall maintain a minimum exhaust volume to ensure that contaminants are properly diluted and exhausted from a hood," where a range of 375 ACH to 150 ACH is recommended. (Note: An internal air change rate of 375 ACH is roughly equivalent to 25 cfm/ft^2 and 150 ACH corresponds to roughly 10 cfm/ft^2.) The ANSI Z9.5 standard requires users to consider the following when selecting an appropriate minimum air change rate and minimum fume hood flow:

- Control of ignition sources within hood
- Design of hood (materials, etc.)
- Maximum chemical generation rates in hood
- Potential for increased hood corrosion due to decreased flow
- Effect of reduction on exhaust stack discharge velocity
- Fume hood density
- Need to affect directional air flow
- Operating range of fume hood

ASHRAE 2011 HVAC Applications, Chapter 16 Laboratories

FSU Design Guidelines and Specifications (Mechanical) March 25, 2011

FUME HOODS:

General: Due to safety and energy consumption implications of fume hoods and the constantly changing technology, the University has not established standards for fume hoods. Each installation shall be coordinated with the Project Manager and approved by Environmental Health and Safety and the Utilities Director. In general, the intent is to use low flow hoods and to provide remote monitoring of the sash position through the campus energy management system.

Performance: Fume hoods shall meet the following performance requirements: Supplier to provide factory ANSI/ASHRAE 110-1995 test of hood. Hood to have a rating of 8.0 AM 0.05 using the above test. Hood to be tested using ANSI/ASHRAE 110-1995 after installation in lab (testing to be provided and paid for by the hood supplier) and shall achieve a rating of 8.0 AI 0.05. If the hood does not achieve the rating and the CFM and static pressure meet the supplier performance data the fume hood supplier shall be responsible for any system changes and upgrades needed to achieve the "as-installed" rating.

The Definitions for the Performance Criteria above is:

AM = As Manufactured
AI = As Installed
AU = As Used (Not Shown Above)

8.0 = Concentration of Source Gas (usually Sulfur Hexafluoride – SF6)
0.05 = Maximum parts per million (ppm) acceptable for 5 minutes average, usually at 3 different mannequin positions: Left, Center & Right. (Note: typically the AI acceptable concentration level is 0.10 ppm – which is what the Labs were originally tested at in 2003/2004)

Lab Design Considerations

Avoid locating Fume Hoods in Exit Paths.

Locate Diffusers such that they have no influence on the directional air flow at the fume hood.

Supply Air Diffusers shall be designed for 50 FPM max at 6 feet above floor; and, not greater than 30 FPM at Fume Hood.

Locate Outside Air Intakes minimum 50 feet from discharge point of any fume hood exhaust.

Setback of fume hood exhaust during unoccupied hours must be coordinated with FSU Environmental Health & Safety (for acceptable closed sash fume hood exhaust rate or minimum room Air Changes per Hour)

Hoods should pass capture efficiency test such as ASHRAE 110, SAMA LF10 Performance Criteria.

Consider connecting Fume Hood Exhaust to Emergency Power.

Noise from Fans, ductwork and air velocities shall not exceed 65 dBA inside the Lab area.

Slope ductwork down towards the fume hood (Guideline 1/8” per Foot).

Fume Hood Exhaust ductwork:

- Minimum 18 gauge, Type 304 or 316 SS
- Slip Joints with clear silicone (or Heliarc inert gas with Type 316 welded seams)
- Follow SMACNA Round Industrial Duct Construction Standards for Duct supports and reinforcement using SS material
- Follow SMACNA 1995 (2nd Ed) HVAC Duct Construction Standards using Type 316 SS for exhaust stack on roof.
- The duct system shall be tested for leakage in accordance with SMACNA HVAC Duct Leakage Test Manual – Latest Edition. Medium pressure duct shall meet Class 6 requirements (rectangular) or Class 3 (round). Test should show zero leakage.
- Dampers for adjusting the hood air velocity may be incorporated into the ductwork.
- Duct Velocities should fall within the range of 1500 – 2000 FPM.
- Flex connectors must meet 25/50 flame/smoke rating and be rated for pressure/velocities in use.

CONCLUSIONS:

1. **The PVS System Design is Difficult to Understand**

As indicated above (and in Appendix C), the existing PVS Systems are designed differently than a standard 100% Outside Air System (including those with heat recovery such as heat pipes and air-to-air heat exchangers). In addition to the unfamiliar components, the PVS systems are designed for different air flow rates: entering, leaving and between each component (see Appendix C – PVS Graphic). As a minimum, the System Design requires accurate flow measurement for the Outside Air (Entering & Leaving the PVS) and the Exhaust Air (Entering & Leaving the PVS); this does not currently exist.

Likewise, the existing selections for the PVS Units and Exhaust Fans do not match the Supply Air & Exhaust Air indicated for the SA Diffusers and the Fume Hoods on the Floor Plans. A Summary is indicated below:

UNIT #	ENTERING OA CFM	LEAVING OA CFM	DIFFUSER CFM
PVS-505	11,351	8,820	8,000
PVS-506	19,561	16,200	16,000
PVS-507	19,561	16,200	14,840

UNIT #	ENTERING EA CFM	LEAVING EA CFM	HOOD CFM	EXH FAN
PVS-505	8,820	11,351	7,950	8,820 (Note 1)
PVS-506	16,200	19,561	14,310	20,000 (Note 2)
PVS-507	16,200	19,561	14,310	20,000 (Note 2)

Note #1: Two Fans Required; Fans selected for 60 FPM vs 100 FPM at Std Sash Height
Note #2: Two Fans Currently Operate to maintain Fume Hood Exhaust

The above just adds to the complexity of understanding the system design intent.

An understanding of the Design intent is imperative for all those who will be responsible for operating and maintaining the equipment.

2. **The PVS System Design is Difficult to Control**

Due in part to the complexities of the PVS System design indicated above, the existing system is inherently difficult to control. Compounding the difficulty of control is the fact that insufficient Control points are available for the operator to make an informed adjustment to the control system set points.

Currently, the PVS System Control Graphic Screens show Outside Air Flow Entering the PVS and Exhaust Air Entering the PVS. As indicated above, these values are insufficient to evaluate and adjust the controls (Particularly the Graphic Screen for PVS-505 as it does not show the additional OA CFM provided from PVS-506.) The current PVS Systems require four (4) reliable Flow Sensors for monitoring and control of the PVS Systems.

Due to the complexities of the PVS Systems, a simplified version of the original Sequence of Operation has been put into place for the 5th floor labs. The Current controls are based upon providing sufficient exhaust air to maintain the fume hood sash at 100 FPM (at normal sash height of 18"). This is accomplished by setting the exhaust fans (including the "lag" exhaust fan) at a fixed percentage of 60 hz (See Exhaust Fan Table above). These values were obtained by the last (or one of the last) Test & Balance adjustments. Likewise, the Supply Fans are similarly adjusted. (Note: There are "tweaks" to this procedure based on experience and additional points (e.g. door differential pressure, duct velocity measurements and the like.)

Currently, any Control adjustments must be performed by an operator having intimate knowledge of the Hoffman Building PVS Systems.

Another complexity in the control system is introduced in the Conclusion Item #3.

3. Lab #505 & #506 Require Dedicated Supply and Exhaust Systems

Currently Supply Air for Lab #505 is provided by PVS-505 & PVS-506. In addition, Exhaust Air for Lab #505 & Lab #506 is a combination of exhaust fans associated with PVS-505 and PVS-506. Therefore, adjustment to PVS-506 affects both Labs #505 & #506. Likewise, adjustment to EF-035-506A & EF-035-506B affects both labs #505 & #506.

On a Lab level and PVS System level "design" air flows are summarized below:

LAB #505	PVS-505	PVS-506	TOTAL
Supply Air CFM	8,000	8,000	16,000
Exhaust Air CFM	7,950	6,360	14,310
LAB #506			
Supply Air CFM	0	8,000	8,000
Exhaust Air CFM	0	7,950	7,950
TOTAL PVS			
Supply Air CFM	8,000	16,000	
Exhaust Air CFM	7,950	14,310	

Not having dedicated systems adds to the complexity of operation and control: Lab Level and PVS System Level. Dedicated Systems simplify operation and control.

(Note: It should be noted that PVS-505 was originally selected and designed for 18 low-flow fume hoods. When this design was inadequate, PVS-506 was installed to provide the additional Supply Air and Exhaust Air required as indicated in the table above.)

4. The System Design is Difficult to Maintain

Due to the high static pressures associated with PVS & EF System, the system can not be safely serviced without total shut-down of the System. Shut-down's require a Control operator to be involved; and, shut-downs for any length of time must be accomplished during off-lab hours.

Further, without a basic understanding of the design intent, field adjustments can be made which will impact the performance of the system.

5. <u>Short-Circuit of Outside Air to Exhaust Air in the PVS Units</u>

The Original Design for the SEMCO PVS Units includes "purge" air for the Total Energy Wheel and the Passive Dehumidification Wheel. The Design "purge" air ranges from 2,500 CFM to 3,400 CFM. However, during the original start-up of the PVS Units, T&B indicated 5,000 CFM was actually being purged. The SEMCO manufacturer's representative was sent to the site and able to correct the purge to nearly the selection conditions. However, years have gone by since that time and unless the seals are actively maintained, the excessive pressures (4.0" – 4.8" SP) can cause short-circuiting and/or door leaks to occur. As indicated above, PVS-506 & PVS-507 have two exhaust fans of 20,000 CFM each and 4.0" SP. One Fan is designed as a 100% back-up; however, both exhaust fans are now required to operate at nearly full speed to maintain fume hood exhaust requirements. (Note: PVS unit casing leaks, door leaks and exhaust duct leaks are also suspected – including a large opening at the inlet flexible connection at PVS-506. The PVS units and Exhaust Ductwork should be pressure tested and leaks repaired.)

As far as PVS-505 is concerned, the Exhaust fans were originally designed for low-flow hoods; the intent was to have one fan as a standby; however, both Exhaust Fans must operate to meet the minimum fume hood exhaust rate of 100 FPM (at 18" Sash Height). In addition, both EF's must operate as they do not currently have isolation dampers.

Other PVS Deficiencies noted include:

a. Insufficient CHW Coil Protection. During this last winter, both CHW Coils burst. The current design requires the Total Energy Wheel to operate to protect the coils. If it is not turning, the CHW Coil will be subject to freezing conditions. A more reliable Pre-Heat Coil is recommended.
b. Flow Sensor type is unreliable. Some flow sensors have flow straighteners. A high pressure, removable, gasketed access panel is required to clean the debris from the flow straighteners and velocity sensor probes.

The PVS Units should be modified or replaced to eliminate short-circuiting by either:

Option A. Removing the wheels and installing new heat pipes, or

Option B. Installing new 100% OA Pre-Conditioning Units with air-to-air heat exchanger and/or heat pipes in a more traditional arrangement.

The New or Modified PVS Units should serve only one Lab. The Following actions should be taken depending on which option is selected:

Option A: PVS-506 should serve Lab #505; and, PVS-505 should serve Lab #506. PVS-507 will continue to serve Lab #507. Two additional Supply drops (i.e. roof penetrations) will be required for Lab #505.

Option B: Size the new units to serve only one lab each

In addition, the Exhaust Fans should be modified or replaced to match the Fume Hood Requirements for each Lab (e.g. For lab #506, the 20,000 CFM EFs will be replaced or modified for 14,310 CFM EFs) at the Design Static Pressure.

6. The Systems are Difficult to Balance

Reams of T&B Reports and Data attest to the fact that there is great difficulty in balancing the current lab systems. The reasons are varied and include:

a. Difficulty understanding the System;
b. Undersized Systems (PVS-505 & EFs-505);
c. Oversized Systems (EFs-506 & EFs-507);
d. Short-Circuit Air (and/or leaks) at the PVS Systems;
e. Over-lapping of Systems (PVS-505 & PVS-506) serving multiple labs (#505 & #506);
f. Improperly sized ductwork;
g. Improperly sized outdoor air intake;
h. Improperly sized diffusers;
i. Lack of balancing dampers and/or Control Boxes;
j. Sacrificing low-flow design intent for real-world requirements (i.e. FSU EH&S)

As indicated in Conclusion Item #1 above, the original design for the labs was for positive room pressure. However, the existing rooms are currently extremely negative pressure (particularly Lab #505). The general reasons for this are indicated above.

A symptom of this extreme negative condition is the hanging up of the elevator door. As can be readily observed, a massive amount of air is being drawn from the elevator into the lab. At times, this causes the elevator door to get hung up which stops the elevator. This condition is attributed to the extreme negative conditions of the lab. (Note: While conducting field work, a door in the lab was opened, thus creating a "path of least resistance". As soon as this door was opened, air ceased to be drawn from the elevator into the lab.)

7. Lab Controls are Inadequate

The Lab Fume Hood Exhaust is manifolded together with ducts that have varying pressure drops with no means of balancing.

All of the existing fume hood outlets have a 10" (304 SS) Flow Safe Linear trim-rotary motion electric valve (blade-type). However, the valves are not actuated to maintain fume hood flow; the valves have been manually set for sash velocity.

The Lab Supply ducts do not have any means of measuring nor controlling supply flow. The PVS Units are currently controlled by setting Supply and Exhaust Fans at a fixed operational point and summarized as follows:

PVS UNIT #	PVS-505	PVS-506	PVS-507
SUPPLY FAN	100%	90%	100%
EXHAUST FANS	85%	100%	90%

*Note: The Design calls for one Exh Fan; however, both Exh Fans operate

The "Normal" Setpoint indicated above are maintained from 7AM – 7PM. The controls currently have a "Sleep" mode from 7PM – 7AM. "Sleep" mode reduces setpoints to about 50% of the Normal mode.

8. <u>Lab Duct Design Improvements are Needed</u>

All of the Supply Ducts, Exhaust Ducts and Outside Air Ducts have been analyzed for proper size, velocity and pressure drop. The following summarizes the findings:

a. Lab #505:
   1. All Supply Air Ductwork is too small.
   2. All Fume Hood Exhaust Duct (except 10" connecting fume hood duct) is oversized (1500 FPM is not maintained).
   3. Existing Fume Hood Exhaust has a choke point (i.e. 22" to 18")
   4. Supply air from PVS-506 (8000 CFM) is undersized (i.e. 24"x24" at 0.25"/100' pressure loss; in comparison, PVS-506 Supply Air to Lab #506 is 8000 CFM in two 24"x24" ducts). Therefore, Lab #505 will always be "starved" for air.

b. PVS-506 Currently serves Lab #505 & Lab #506. The Supply duct has three drops: one to Lab #505 and two to Lab #506.
c. Exhaust duct sizes entering PVS-506 & PVS-507 are over-sized (1260 FPM)
d. PVS-505 Outside Air Intake is too small (4000 CFM, NC-51, 0.294" SP, 22"x22" intake)
e. PVS-506 & PVS-507 Outside Air Intake is too small (4750 CFM, NC-39, 0.125" SP loss, 28"x28" intake)
f. Balancing Dampers are needed in Ducts to assist in balancing air flow.

9. <u>Diffusers are not adequately Sized</u>

The existing Supply Air Diffusers are Titus M#TLFAA, 24"x48"x12" Neck. These are vertically laminar flow Diffusers. The Diffuser Quantities and Supply Air CFM are indicated below.

LAB	SA CFM	QUANTITY	SA PER DIFFUSER
505	16,000	24	667 CFM
506	8,000	15	533 CFM
507	14,840	24	618 CFM

Referring to the Titus Performance Data in Appendix C, the existing diffusers will have a 7' vertical projection (at 50 fpm) with 400 CFM. Diffusers over lab tables should have a maximum 295 CFM. According to the table above, the CFM/Diffusers are exceeding the maximum recommended CFM. [Note: This is particularly evident in Lab #507 where the air noise is excessive. (As a side note, 4 diffusers have been removed from this room and relocated to Lab #505.) Also, air noise would be evident in Lab #505; however, undersized ducts are preventing full Supply air flow in this lab.]

10. <u>Fume Hood Issues</u>

The Fume Hoods were not designed for 100 FPM at Full Sash Height (and thus failed Tracer Gas Tests).

The Existing Lab Crafters Air Sentry Fume Hoods M#HBASC6 (date 10/02) were originally designed for low flow operation (40-60 FPM). However, for various reasons, the Fume Hoods never operated as anticipated. The Hoods are now set at 100 FPM at Standard Sash Height (except during "sleep" mode). The following items are also noted:

a. Baffle operation is unreliable to inoperative. Baffles are controlled by fume hood pressure/velocity sensor.
b. Hoods located in main walk-ways will be subject to cross-currents (e.g. Hoods #505 D, #505E, #507D, #507E) and also greater safety issues.
c. Hoods are arranged in a Side by Side configuration which can cause performance challenges.
d. A blade-type control damper is located on the discharge of each fume hood; however, the damper is in a fixed position and does not operate.
e. A plenum exists above each lab (created by transfer ducts, relief damper eggcrate grilles and major negative pressure); fume hood operation can be negatively affected by plenums.
f. Fume Hood Quantities in each Lab should be reviewed. Fewer Fume hoods decreases construction and operational costs significantly.

The existing fume hoods are Bypass type meaning that a constant amount of Exhaust Air no matter the sash height.

11. <u>Building Issues</u>

The Hoffman Building was constructed in the 1960's. The 5th Floor labs open directly outside (rather than into a conditioned corridor). Current codes require Chemistry labs to operate under slight negative pressure. Therefore, unconditioned outside air will be drawn into the lab through doors, cracks, relief dampers, etc. Currently, the Labs are under a very negative pressure such that large quantities of outside air are being drawn through doors and even through the elevator shaft and utility chases.

In addition, the "tighter" the construction of the Building the more easily the HVAC System can maintain differential pressure in the Lab.

New Roof Top Equipment will need to be secured to 130 mph wind loads (vs. 90 mph original design).

12. <u>5th Floor West Lab Issues</u>

The 5th Floor West Labs are served by a 100% OA Air Handler Unit AHU-5-1. This AHU was originally selected for 7600 CFM SA, but currently operates at 4900 CFM SA. The four fume hood's exhaust (indicated above), have a total of 3,780 CFM EA. Therefore, each Lab is slightly positive. The excess Air [4900 – 400 (to MER) – 3780(Fume Hood) = 720 CFM] is available for make-up for Labs #505, #506 & #507.

The West Labs have various ceiling grilles and transfer grilles for pressure relief. It is recommended that the transfer grille between Lab #509 and the MER be capped off. In addition, the transfer grille between Lab #509 and Lab #507 should also be capped off. There is also a transfer grille between Locker Room #518 and Lab #517 that has been capped off; however, an

abandoned CHW pipe is now functioning as a transfer “duct” between the locker room and Room #516 (which is drawing a significant amount of air).
Room #516 (with small fume hood) should have a dedicated Constant Volume Box (CV Box).

Fume Hoods should have a lab grade CV Box on Discharge.

VVT-518 high pressure flex duct has disconnected from the high pressure duct main. This should be reconnected.

Due to the high negative pressure in the Labs it is expected that humidity issues would be prevalent; however, high humidity was only evident in Lab #517; ceiling tiles felt damp and had curled corners. Paint was also pealing off the pan ceiling (above the lay-in ceiling).

RECOMMENDATIONS:

1. **Modify or Replace Existing PVS Units**.

Option A: Modify Existing PVS Units – For the sake of this Study, the Recommendation considers removing the existing Wheels and installing new Heat Pipes. The components will remain in roughly the same place. This will allow the access doors to remain as-is and will provide a means of accessing filters, cleaning coils, etc.

The study does recommend a fail-safe pre-heat steam coil be considered.

Supply Fan will need to be replaced (probably Fan Wall):

TAG #	SA CFM	ESP	TSP
PVS-505:	7,780	2.0”	4.8”
PVS-506:	14,010	2.0”	4.8”
PVS-507:	14,010	2.0”	4.8”

Exhaust Fans will need to be replaced (and Isolation Dampers installed EF-505A&B):

TAG #	SA CFM	ESP	TSP
EF-505A&B:	7,950	2.75”	4.75”
EF-506A&B:	14,310	2.75”	4.75”
EF-507A&B:	14,310	2.75”	4.75”

CHW Coil will be selected to operate (not greater than):

ECC	83.6 F/76.9 F		
LCC	52.8 F/52.1 F		
MBH Total	658.2 (7,780 CFM)	or	1,185.2 (14,010 CFM)
MBH Sensible	263.6		474.7
GPM Req’d**	73.1 GPM		131.7 GPM

(**Note: Delta T per original Coil Selection at 45 – 63. Total CHW Req’d= 336.5 GPM)

CHW Available:

TAG #	GPM	NOTES
PVS-505	47.0	Per Original Selection (Appendix C)
PVS-506	98.4	Per Drawing Schedule
PVS-507	98.4	Per Drawing Schedule
PVS-520 (Not Built)	54.0	Per Drawing Schedule
AHU-5-1	31.2	Differential between 7600 CFMvs4900 CFM
TOTAL	329 GPM Available	(Note: 336.5 GPM; therefore, ok.) (Note: Existing CHW Pipe Size – ok.)

Steam Coils will be selected to operate:

ECC	25.0 F		
LCC	95.0 F (Delta T is 70 F, but Heat Pipe Recovery ~ 35 F)		
MBH Total	299.5 (7,780 CFM)	or	539.4 (14,010 CFM)
#/HR Steam**	312.0		562.0

(**Note: Total Steam Required = 1,436 #/HR)

Steam Available:

TAG #	#/HR	NOTES
PVS-505	326.3	Per Original Selection (Appendix C)
PVS-506	455.0	Per Drawing Schedule
PVS-507	455.0	Per Drawing Schedule
PVS-520 (Not Built)	174.0	Per Drawing Schedule
TOTAL	1,410.0 #/HR	(Note: 1,436 #/Hr Req'd; therefore, ok) (Note: Steam/Cond Main Size ok; upsize take-off piping to AHU one size.)

In addition, the PVS Unit Door seals and section gaskets shall be inspected and replaced.

Next, the Exhaust Fan Isolation Damper Operation must be verified for EF-506A&B and EF-507A&B. New Isolation Dampers are required for EF-505A&B.

Also, Exhaust Fans shall be selected for 100% Redundant operation.

Lastly, the PVS Units will have to be secured for 130 mph wind loads. Structural Engineering will be required.

Option B: Replace Existing PVS Units -

This Option considers replacing the existing PVS Units with new over/under (or side by side) AHU's with Air-to-Air Heat Exchangers to pre-condition the Outside Air. The Pre-Conditioned Outside Air will then pass through a chilled water coil section, a reheat coil section (steam) and a fan section.

The existing AHU structures will be modified to fit the new AHUs. It is recommended that the each Lab AHU be installed above that lab it serves. This will require increasing the height of the structure for the Lab #505 Unit.

Refer to Appendix D for selection information.

2. **Each Lab shall have a dedicated Supply & Exhaust System**. Currently Supply Air for Lab #505 is provided by PVS-505 & PVS-506. In addition, Exhaust Air for Lab #505 & Lab #506 is a combination of exhaust fans associated with PVS-505 and PVS-506. Therefore, it becomes very difficult to control air flow in each lab. Operation and Control of dedicated systems are simpler and easier to understand when each system only serves one lab. This can be accomplished as follows:

   Option A: Modify Existing PVS Units –

   PVS-505 Supply and Exhaust will be ducted to Lab #506. (Note: PVS-505 is sized for a Lab with 10 fume hoods.) This will be accomplished by ducting PVS-505 Supply Duct to the existing two 24x24 SA drops to Lab #506. All of Lab #506 Fume Hood Exhaust will be ducted to the existing two 22" round lab exhaust ducts and then routed on the roof to PVS-505.

   PVS-506 Supply and Exhaust will be ducted to Lab #505. (Note: PVS-506 is sized for a Lab with 18 fume hoods.) The Supply duct from PVS-506 will be routed to the existing two 24"x24" SA Duct roof connections plus two new 24"x24" SA Duct roof penetrations will be added. All of the Lab #505 SA Duct will be replaced. All of Lab #505 Exhaust duct will be replaced and routed to the two existing 24" round roof penetrations. This exhaust duct will connect to a main duct on the roof and be routed to PVS-506. In addition, all of Lab #505 Fume Hood Exhaust will be ducted to the existing two 18" round lab exhaust ducts (actually located in lab #506) and then routed on the roof to PVS-506.

   PVS-507 will continue to serve Lab #507.

   Option B: Replace Existing PVS Units –

   If Option B is selected, then the new AHUs will be placed over the associated Labs and will be ducted to each lab accordingly.

   (Note: CHW/Steam Pipe Sizes will need to be increased for the new AHU-505 (3" CHWS & R, 2.5" Steam & 1.25" Condensate)

   NOTE: The Opinion of Cost for Option A & Option B includes replacement of the existing high-plume Exhaust Fans. The Greenheck Vendor is checking with the factory on the option of modifying the existing fans. Deduct Costs will be indicated below the Opinion of Costs.

   NOTE: The Design Phase should include a verification of Pump Head for the new CHW piping and coil pressure loss.

3. **Balance Air Flow to Each Lab**. Exhaust Air flow shall be set to maintain 100 FPM at an 18" Sash Height to comply with FSU Environmental Health & Safety (EH & S) requirements. Supply Air shall be set to maintain a constant differential between the Exhaust Air CFM and the Supply Air CFM. Each Lab shall have slightly negative pressure to comply with current codes.

4. **Upgrade Controls**. Add Lab quality Supply Air Pressure Independent Constant Volume Boxes to measure and control lab supply air CFM. Add Lab Quality Exhaust Air Pressure Independent Constant Volume Boxes by adding Siemens actuator and flow measurement via existing differential pressure inputs. Recommended Control Sequences include: Exhaust Air and Supply Air tracking; Normal & Not in Use Modes of Operation (based upon fume hood usage).

   According to Siemens, the existing Flow-Safe Linear Trim Rotary Motion Electric Valves have good flow characteristics. The valves have pick-up points for flow measurement. New Siemens Actuators can be installed on each fume hood control valve.

   Lab Quality Pressure Independent Supply Air Constant Volume Control Boxes should be added on each SA Drop (i.e. minimum of 4 for Lab #505; 2 for Lab #506; and, 4 for Lab #507. Note: the physical size of the CV Box may limit the size of boxes that will fit in the ceiling and thus increase the # of boxes required.)

   Control graphics should be updated to show design and actual CFM's.

   Controls should also include "emergency" Relief Air mushroom switch at each door.

   During off-hours, exhaust (and associated supply) air quantities can be set back to flow quantities as indicated above in "Ventilation Calculations".

   Exhaust Fans will be controlled to operate one at any given time.

5. **Lab Duct Design Improvements**.

   a. Lab Exhaust Duct shall be designed for 1500 fpm (minimum).

      Exhaust Duct in Lab #505 is not properly sized and should be replaced.

      Exhaust Duct on the roof is sized for 1250 fpm. Providing dedicated PVS service to Lab #505 & Lab #506 will include replacing roof mounted ductwork. Further discussion will be needed with FSU on the replacement of the remaining roof exhaust ductwork.

      Exhaust Duct is sized properly for Lab #506 & Lab #507.

   b. Pressure Test Existing Exhaust Duct and Repair Leaks.

      All fume hood exhaust duct should be pressurized and all leaks repaired. (Note: A large leak was found at the flex connection at PVS-506. Pressure testing existing exhaust ducts will probably require installing temporary caps on duct ends.)

      It should be noted that the existing ceiling mounted exhaust duct is all insulated. Insulation will have to be repaired after tests.

      It is also recommended that the PVS Units also be pressured tested and leaks repaired.

It is also recommended that all field cut-in access panels (to clean flow sensors) be removed and high quality, high pressure, gasketed, stainless steel access doors be installed.

Lastly, it is recommended that all flexible connections be checked and replaced. Further, the flexible connection material should be able to with stand the very high static pressures in the ductwork.

c. Size Supply Duct for design air quantities.

Supply Duct in Lab #505 is not properly sized and should be replaced. Two new roof penetrations will be required.

Supply Duct is sized properly for Lab #506 & Lab #507

d. Improve Outside Air intake size and measurement.

The existing Outside Air intake size is inadequate. Additional intake grilles are needed to increase the free area available. For PVS-505, at minimum an additional 2 intake grilles are needed (and the existing grilles should be replaced with egg crate type to increase free area). For PVS-506 & PVS-5-707, at minimum an additional 1 intake grille is needed. (Note: As an alternative, if plume heights are sufficient from lab exhaust fans, it may be possible to have the OA intake at roof level. Fifty foot difference between Exhaust and Outside Intake is recommended.)

e. Provide sufficient quantity and placement of Supply Diffusers.

The existing Supply Air Diffusers have a maximum CFM limit of 295 CFM over lab tables and 400 CFM elsewhere. Assuming an average 350 CFM, then the following quantities are required:

LAB	SA CFM	QUANTITY Available	QUANTITY Required
505	14,010	24	40
506	7,780	15	22
507	14,010	24	40
TOTAL		63	102

A Radial Style Diffuser can distribute approximately 600 CFM each; however, the diffuser does protrude from the ceiling about 6". Due to this, and the relatively lower ceiling height (8'-6"), this was not considered an option. However, during the design phase of the project, an air distribution analysis is recommended. For the sake of the project budget, adding the appropriate quantity of the existing air distribution devices will be included.

f. Add Balancing Dampers to assist with Test & Balance.

Supply ducts require balancing dampers at duct splits to assist with Test & Balance of air quantities.

Exhaust ducts should be sized and arranged to minimize the need for balancing dampers. If required, dampers shall be very high quality, ultra-low leakage, stainless steel type.

g. Add Emergency Vacuum Relief Push-Button Controls by Exit Doors.

During the original project, a condition occurred where the exhaust fans operated without the supply fans. The static pressure is such that the exit doors were held shut. As a result, vacuum relief openings were provided. Currently these relief dampers open when the exhaust fans operate but the supply fans do not. As this sequence could possibly be changed, it is recommended that a fail-safe arrangement be provided: a mushroom switch at each exit door that will open the relief dampers when pushed.

6. **Fume Hood Modifications**.

This analysis is based on acceptable fume hood operation of 100 FPM at standard 18" Sash Height.

The most significant impact on HVAC systems in labs is directly associated with the number and type of fume hoods. FSU should consider the need to have 18 fume hoods for each lab.

Based on information obtained from Lab Crafters representative, it does not appear necessary to make modifications to the existing Air Sentry Fume Hoods.

The following summarizes information obtained from a conference call with William Mabanta Jr of Lab Crafters, Ronkonkoma, NY:

1. The Hoods were originally selected for low-flow (40-60FPM). Now, the hoods are being operated at 100 FPM at Std Sash Height. What potential issues are associated with this change? **There are no potential issues associated with operating the hoods at 100 FPM.**

2. Will higher face velocities potentially cause loss of containment? For example, if the hood actually operated at 150 FPM at Std sash height? Full Height? ***No; containment will be maintained at the higher velocities.***

3. Each Lab has about 18 Hoods (most of which are side by side). Are there potential performance issues associated with this many hoods in a lab? ***There is for low-flow operation; but, not when operating at 100 FPM.***

4. For side by side hoods, can all of the controls be accessed from the top and front (and not from the side)?

5. What controls the baffles? Some are working and some are not. (I understand from the Owner that in the future they will control the exhaust for constant air flow during occupied conditions and constant air flow (about 50%) during unoccupied conditions.) Should the baffle controls be repaired (and how can that be done) or can they just be set at a fixed position? Are there any hood issues with this control strategy? ***The baffles are controlled off of sash velocity (via open port on the right side of the fume hood). The baffle motors may have gone bad; they can be ordered via sales@labcrafters.com. When***

operating the hoods at 100 FPM, it does not matter where the baffles are positioned. Baffle position is used to create a vortex for containment purposes at low-flow.

6. Will a plenum above the fume hoods cause operational problems? ***No. There is not an opening in the ceiling space.***

7. Verify the fume hoods are bypass type (meaning constant exhaust no matter sash height)? ***Yes.***

OPINION OF PROBABLE MEP CONSTRUCTION COST:

Our Pre-Design Opinion of Probable Construction Cost is located in Appendix A. (This cost is based on a contractor performing the work. The Cost does not include A/E fees or Construction Management fees and costs. This cost is based on today's dollars and does not include escalation.)

Sincerely,

PINNACLE ENGINEERING GROUP, P.A.

Craig H. Allen, P.E., LEED AP
President

Attachments:
a. Appendix "A" Opinion of Probable Construction Cost
b. Appendix "B" Calculations & Data
c. Appendix "C" Vendor Data – Existing
d. Appendix "D" Vendor Data – Proposed
e. Appendix "E" Photographic Images