CAE 464/517 HVAC Systems Design

Spring 2023

January 10, 2023

Course Overview and Intro to CAE 464/517

Built
Environment
Research
@ IIT

Advancing energy, environmental, and sustainability research within the built environment

www.built-envi.com

Dr. Mohammad Heidarinejad, Ph.D., P.E.
Civil, Architectural and Environmental Engineering
Illinois Institute of Technology
muh182@iit.edu

INTRODUCTION

About Me

- B.S.E., Mechanical Engineering
  - ❑ Sharif University of Technology Tehran, Iran, 2006
- M.S.E., Architectural Engineering
  - ❑ The Pennsylvania State University, 2011
- Ph.D., Mechanical Engineering
  - ❑ The Pennsylvania State University, 2014

- Experience relevant to this course
  - ❑ ASHRAE, DOE, HUD, EPA, NSF, ComEd, Franklin, ..projects
  - ❑ University of Maryland College Park
  - ❑ Licensed Professional Engineer
  - ❑ ASHRAE New Investigator and IBPSA Emerging Contributor
  - ❑ Developed and taught several courses at Illinois Tech
  - ❑ Recipient of the Michael J. Graff Award for Innovation in Teaching

Introduce Yourself

- Please introduce yourself
- What do you expect from the course?
- How do you think the course will have impact on your career?
- Do you have any relevant internship/work experience?
- Are you looking for summer internship or full-time job?
- Did you take your FE exam?
- Have you worked with Revit and/or AutoCAD?
- Have you seen architectural/MEP drawings?
- Are you graduating this semester?

Course

Classroom and Meeting Time:

- ❑ CAE 464 Section 01: 24202 (undergraduate) – In Person
- ❑ CAE 464 Section 02: 24203 (undergraduate) – Online
- ❑ CAE 517 Section 01: 51444 (graduate) – In Person
- ❑ CAE 517 Section 01: 51446 (graduate) – Online

Classroom and Meeting Time:

- ❑ Location: SB-111
- ❑ Tuesdays and Thursdays, 8:35 AM – 9:50 AM

Course Website:

- ❑ All content will be provided on Blackboard
- ❑ Additional software training videos will be provided

Course

Some Previous Lecture Notes:

The Built Environment Research Group

advancing energy, environmental, and sustainability
research within the built environment
at Illinois Institute of Technology

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CAE 464/517: HVAC Systems Design (Spring 2021)

Course Description

This course introduce students to both theory and applied design procedures for HVAC equipment and systems. By taking this course students will be able to:

1. Understand fundamentals of fluid and energy flows for HVAC equipment and systems
2. Design and size air distribution systems, hydronic systems, and refrigeration systems
3. Design, draw, and read mechanical drawings
4. Design, review, and assess different HVAC designs
5. Propose recommendations to revise HVAC designs and retrofit existing HVAC systems
6. Utilize both hand calculations and computer modeling (graduate students) for sizing air distribution systems, hydronic systems, and refrigeration systems

Course Syllabus (updated as we go; includes current schedule)

- Most recent syllabus, updated January 19, 2021

Lecture

- Lecture 01: Course overview and introduction
- Lecture 02: Review of HVAC system drawings
- Lecture03: Installation
- Lecture 04: Psychrometrics processes and space conditioning
- Lecture 05: Design conditions and heating loads

http://built-envi.com/courses/cae-464-517-hvac-systems-design-spring-2021/

Course Catalog Description

- Study of the fundamental principles and engineering procedures for the design of heating, ventilating, and air conditioning systems
- HVAC system characteristics
- System and equipment selection
- Duct design and layout
- Attention is given to energy conservation techniques and computer applications

Instructor’s Course Objectives & Learning Outcomes

To introduce students to both theory and applied design procedures for HVAC equipment and systems. By taking this course students will be able to:

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3. Design, draw, and read mechanical drawings
4. Design, review, and assess different HVAC designs
5. Propose recommendations to revise HVAC designs and retrofit existing HVAC systems
6. Utilize both hand calculations and computer modeling (graduate students) for sizing air distribution systems, hydronic systems, and refrigeration systems

Office Hours

Instructor:

- Office hours are by appointment only. Please email me to schedule an appointment. Or stop by when you see my office door open to see if I’m free. I have an open door policy.

- ❑ Office: Alumni Memorial Hall Room 204
- ❑ Email: muh182@iit.edu
- ❑ Phone: (312) 567-3426

Office Hours

Teaching Assistant:

- TBD
  - ❑ Name: Mingyu Wang, Ph.D. Candidate, Architectural Engineering
  - ❑ Email: mwang88@hawk.iit.edu

Textbook

- 2021 American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Handbook of Fundamentals (IP unit version)

- The ASHRAE Handbook of Fundamentals isn't exactly a textbook, but rather is a deep and authoritative resource for many aspects of building engineering

- We reference it directly for almost every topic in this class, and you will also continue to use it in future required and elective courses, including CAE 463/524 Building Enclosure Design, CAE 465 Energy Conservation Technologies, CAE 495 Capstone Senior Design, and several others

Textbook

- The ASHRAE Handbook of Fundamentals costs $209 to the general public, but costs only $52 to ASHRAE student members. And ASHRAE student membership is only $25 per year

- You can purchase the handbook and a student membership (if you aren't already a member) online: https://www.ashrae.org/communities/student-zone/membership-and-meetings/student-membership-benefits.

- The 2017 version is also acceptable.

References

In addition to the ASHRAE Handbook of Fundamentals, I will also rely on several other materials in this course. These materials are entirely optional for the student; handouts will be given when necessary, so that no one is required to purchase these items.

References

The list of references includes:

- Amende, K.L., Keen, J.A., Catlin, L.E., Tosh, M., Sneed, A.M., Howell, R.H., *Principles of Heating Ventilating, and Air Conditioning*, 9th Edition, ASHRAE, 2021.
- Behls, H., *Duct Systems Design Guide*, ASHRAE, 2021.
- Engineer's HVAC Handbook, Edition 1.1, Price Industries
- McDowall, R., *Fundamentals of HVAC*, ASHRAE, 2006.
- McQuiston, F.C., Parker, J.D., Spitler, J.D., *Heating, Ventilation, and Air-Conditioning Analysis and Design*, John Wiley & Sons, Inc., 6th Edition, 2005.
- Reddy, T.A., Kreider, J.F., Curtiss, P.S., Rabl, A., *Heating and Cooling of Buildings: Principles and Practices of Energy Efficient Design*, CRC Press, 3rd Edition, 2017.
- Sugarman, S.C., *HVAC Fundamentals*, CRC Press, 3rd Edition, 2016.
- 2018 ASHRAE Handbook: Refrigeration, ASHRAE, 2018.
- 2019 ASHRAE Handbook: HVAC Applications, 2019.
- 2020 ASHRAE Handbook: HVAC Systems and Equipment, 2020.

GRADING AND COURSE POLICIES

Course Grading

Grading	Quantity	% of Total for Each	% of Total
Homework	5 (Best of 4)	4	16
Midterm Exam	2	22.5	45
Project Reports (Interim)	3	8	24
Project Report (Final)	1	9	9
Project Presentation (Final)	1	6	6

Grading scale	A	B	C	D	F
UG and G	90% and up	80.0-89.9%	70.0-79.9%	60.0-69.9%	<60.0%

Homework Assignments

- There will be a total of ***5 homework (best of 4)*** assignments
- Homework sets will be assigned based on lecture coverage
- The homework will involve hand calculations, development of spreadsheets, modeling, and/or learning the fundamentals and data analysis
- Each homework will be assigned ***at least a week before*** the homework due date. You must work on the homework assignments ***individually***

Project

- The project focuses on design of air distribution, hydronics, and refrigeration system designs

- The first three parts are designed to assess student's ability to design air distribution, hydronic distribution, and refrigeration systems stand-alone

- The final project submission is an integrated design focusing on integration of air distribution designs with the refrigeration and hydronic systems

- Group of ***two to three students*** can work on the group assignments and submit one submission per group

Final Presentation

- Students are required to present the final project and submit the ***design documents***, including ***mechanical drawings*** on the ***final exam day scheduled by the university***

- Students are required to ***present online***

Exam

- There will be ***two mid-term*** exam focused on the fundamental concepts learned in the course

- Both exams are in-person ***exams*** (open book/open notes)

Late Homework Assignment and Report Policy

- Homework assignments and project reports are due at the ***midnight on the day that it is due***
- Homework assignments and project reports will receive a ***5-point deduction*** for every day that it is late before the solution is posted on Blackboard
- After the ***solution is posted***, the blackboard submission page ***is closed for that particular homework***

Course Topics

Week	Date	Topics	Reading	Assignment Due
1	01/10/23	**Course Overview & Introduction:** Grading, expected skills, and knowledge outcomes **Introduction to HVAC:** Intro to the course and review of HVAC system drawings	F38, F39	
	01/12/23	**Review HVAC Thermodynamics:** Installation in real buildings and intro to moist air properties, Psychrometric chart, sensible and latent heat	F1	
2	01/17/23	**Review HVAC Thermodynamics:** Psychrometric processes and space conditioning	F1	
	01/19/23	**Building Loads:** Indoor and outdoor design conditions	F14	HW 1
3	01/24/23	**Building Loads:** Building heating and cooling load calculations (I)	F17, F18	
	01/26/23	**Building Loads:** OpenStudio training (heating and cooling loads) – Recordings will be provided		
4	01/31/23	**Building Loads:** Building heating and cooling load calculations (II)	F17, F18	
	02/02/23	**Building Loads:** Load calculation examples **Project Assigned**	F17, F18	HW 2

Course Topics

Week	Date	Topics	Reading	Assignment Due
5	02/07/23	**Revit Training**		
	02/09/23	**Review of Fluid Flows:** Intro to fluid flow and ASHRAE 62.1	F3	
6	02/14/23	**Air Distribution Systems:** Principles and air jet patterns	F20, F21	HW 3
	02/16/22	**Air Distribution Systems:** Classification of air diffusion		
7	02/21/23	**Air Distribution Systems:** Diffuser selection	F20	
	02/23/23	**Air Distribution Systems:** Diffuser selection examples and intro to pressure loss in ducts	F20, F21	Project Part 1
8	02/28/23	**Air Distribution Systems:** Pressure loss in ducts and fittings	F20, F21	
	03/02/23	**Air Distribution Systems:** Duct design methods		
9	03/07/23	**Midterm Exam (1)**		
	03/09/23	**Air Distribution Systems:** Fan selection and affinity laws		

Course Topics

Week	Date	Topics	Reading	Assignment Due
10	03/14/23	**Spring Break**		
	03/16/23	**Spring Break**		
11	03/21/23	**Air Distribution Systems:** Fan selection example and air handling unit		
	03/23/23	**Hydronic Systems:** An overview of HVAC hydronic systems (e.g., boilers, chillers, cooling powers)	F22, S13, S32	
12	03/28/23	**Hydronic Systems:** System characteristics and fluid flow, steam system design, system operation and sizing system components	F22, S36	Project Part 2
	03/30/23	**Hydronic Systems:** Centrifugal pumps, operating characteristics, selection parameters influencing performance, affinity laws, combining pump and characteristic curves in system design	F22	
13	04/04/23	**Midterm Exam (2)**		
	04/06/23	**Hydronic Systems:** Pipe system fundamentals fitting coefficients, and equivalent length estimations of ΔP- system	F22	

Course Topics

Week	Date	Topics	Reading	Assignment Due
14	04/11/23	**Hydronic Systems:** control strategies, technology for hydronic systems, 2-way & 3-way valves	F22	HW 4
	04/13/23	**Refrigeration:** Introduction to vapor compression and T-s and P-h diagrams	F2	
15	04/18/23	**Refrigeration:** Vapor compression cycles and applications	F2, F30	Project Part 3
	04/20/23	**Refrigeration:** Potential environmental impacts of refrigerants (global warming, ozone depletion), Cooling towers	F2, R18, S40	
16	04/25/23	**Refrigeration:** Absorption cooling (Principles of operation and cycle analysis)	F2	HW 5
	04/27/23	**HVAC Systems Design:** Integrated Design and Applications (Chilled Beams, Ground Source Heat Pumps, VRF, and Water Source Heat Pumps)	S5	
		air flow strategies (e.g., Constant Air Volume (CAV), Variable Air Volume (VAV), and Dedicated Outdoor Air Systems (DOAS))	S20, S21, S51	
17	TBD	**Final Project Presentation (Integrated Design)**		Final Presentation
	TBD	**Final Project Report (Integrated Design)**		Final Report

Academic Honesty

- It is your responsibility to be familiar with IIT's Code of Academic Honesty. The Code of Academic Honesty can be found online: https://www.iit.edu/student-affairs/student-handbook/fine-print/code-academic-honesty

- You must submit your ***own work for homework***. You are encouraged to discuss and even work with other students on homework (unless explicitly told otherwise), but material that is submitted must be ***your own work***. For group project assignments, each group is to submit their own work

Academic Honesty

- For a ***first violation*** of the IIT Code of Academic Honesty for a homework or project, the homework will receive a grade of ***zero for all involved students*** and the students will be reported to the Designated Dean for Academic Discipline (DDAD)

- For a first violation of the Code of Academic Honesty for a ***major project*** or an examination, the student will ***receive a failing grade*** for the course and the student will be reported to the DDAD. For a second violation, the student will receive also failing grade for the course and be reported to the DDAD

Personal Problems

- If you have illness or personal problems that will affect your performance during the course of the semester, please let me know ***as soon as possible***

- ***"After the fact"*** provides little protection unless there are extreme circumstances. Contact the instructors by phone or e-mail at any time

Personal Problems

- Academic Regulations: https://web.iit.edu/student-affairs/handbook/fine-print/academic-and-department-regulations

*"All students are **expected to attend classes regularly**. Excessive absences may be grounds for a failing grade. Non-attendance does not constitute an official withdrawal. When illness or emergency requires a student to miss an exam and/or more than two days of class, the student must notify the course instructor. It is also recommended that the student **contact the office of the Dean of Students (dos@iit.edu) to request an excused absence.** It will be necessary to provide written documentation of the reason for the absence(s). The Office of Student Affairs manages the process for requesting and documenting excused absences but the decision to excuse an absence is generally made by the Professor. Faculty members determine their own policies for attendance and make-up work."*

Students with Disabilities

- Reasonable accommodations will be made for students with documented disabilities. In order to receive accommodations, students must obtain a letter of accommodation from the Center for Disability Resources

- The Center for Disability Resources (CDR) is located in Life Sciences Room 218, telephone (312) 567-5744 or email: disabilities@iit.edu

Sexual Harassment and Discrimination Information

- Illinois Tech prohibits all sexual harassment, sexual misconduct, and gender discrimination by any member of our community. This includes harassment among students, staff, or faculty. Sexual harassment of a student by a faculty member or sexual harassment of an employee by a supervisor is particularly serious. Such conduct may easily create an intimidating, hostile, or offensive environment.

- Illinois Tech encourages anyone experiencing sexual harassment or sexual misconduct to speak with the Office of Title IX Compliance for information on support options and the resolution process.

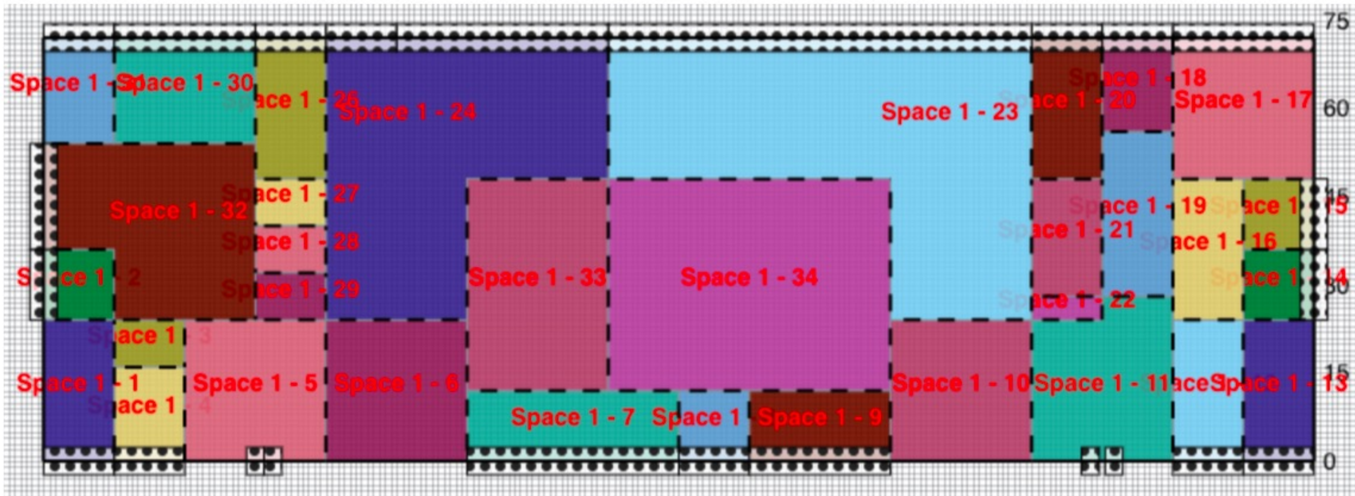
Sexual Harassment and Discrimination Information

- You can report sexual harassment electronically at iit.edu/incidentreport, which may be completed anonymously. You may additionally report by contacting the Title IX Coordinator, Virginia Foster at foster@iit.edu or the Deputy Title IX Coordinator at eespeland@iit.edu.
- For confidential support, you may reach Illinois Tech's Confidential Advisor at (773) 907-1062. You can also contact a licensed practitioner in Illinois Tech's Student Health and Wellness Center at student.health@iit.edu or (312)567-7550
- For a comprehensive list of resources regarding counseling services, medical assistance, legal assistance and visa and immigration services, you can visit the Office of Title IX Compliance website at https://www.iit.edu/title-ix/resources.

SAMPLE SUBMISSIONS

Sample Submissions

- Load Calculation



Comparison of OpenStudio to Hand Calculations: Airflow

Thermal zone	Airflow				
	Calculated (cfm)	OpenStudio space loads (cfm)	OpenStudio outdoor air (cfm)	OpenStudio total (cfm)	Difference (%)
1	2495	670	141	811	68%
2	11216	4551	226	4777	57%
3	5252	2492		2492	
4	2205	892	71	963	56%
5	2685	888	42	930	65%
6	5473	2057	197	2254	59%
7	2742	801	60	861	69%
8	2356	1278	59	1337	43%

Sample Submissions

- Air distribution calculation:

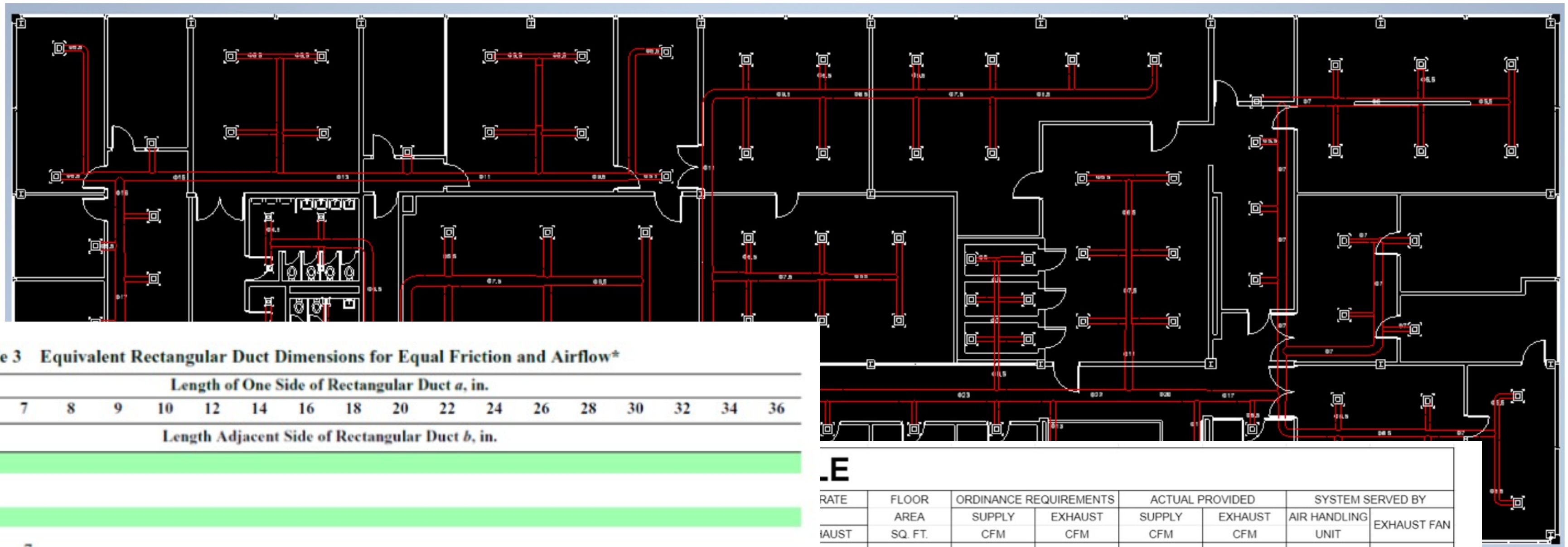


Table 3 Equivalent Rectangular Duct Dimensions for Equal Friction and Airflow*

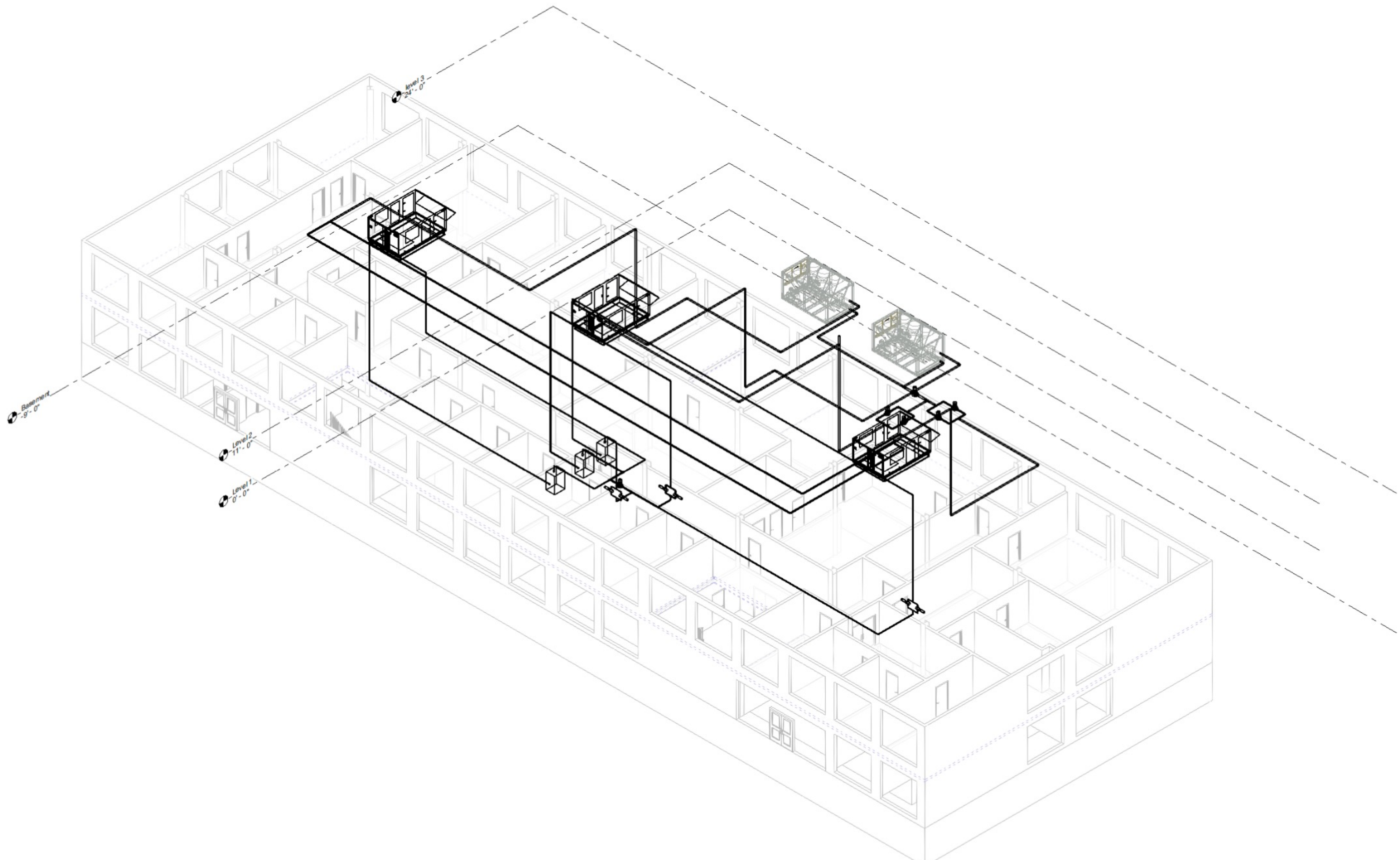
Circular Duct Diameter, in.	Length of One Side of Rectangular Duct *a*, in. (Length Adjacent Side of Rectangular Duct *b*, in.)																	
	4	5	6	7	8	9	10	12	14	16	18	20	22	24	26	28	30	32	34	36
5	5																			
5.5	6	5																		
6	8	6																		
6.5	9	7	6																	
7	11	8	7																	
7.5	13	10	8	7																
8	15	11	9	8																
8.5	17	13	10	9																
9	20	15	12	10	8															
9.5	22	17	13	11	9															
10	25	19	15	12	10	9														
10.5	29	21	16	14	12	10														
11	32	23	18	15	13	11	10													
11.5		26	20	17	14	12	11													
12		29	22	18	15	13	12													
12.5		32	24	20	17	15	13													
13		35	27	22	18	16	14	12												
13.5		38	29	24	20	17	15	13												
14			32	26	22	19	17	14												
14.5			35	28	24	20	18	15												
15			38	30	25	22	19	16	14											
16			45	36	30	25	22	18	15											
17				41	34	29	25	20	17	16										
18				47	39	33	29	23	19	17										
19				54	44	38	33	26	22	19	18									
20					50	43	37	29	24	21	19									
21					57	48	41	33	27	23	20									
22					64	54	46	36	30	26	23	20								

.E

			RATE AUST	FLOOR AREA SQ. FT.	ORDINANCE REQUIREMENTS SUPPLY CFM	ORDINANCE REQUIREMENTS EXHAUST CFM	ACTUAL PROVIDED SUPPLY CFM	ACTUAL PROVIDED EXHAUST CFM	SYSTEM SERVED BY AIR HANDLING UNIT	SYSTEM SERVED BY EXHAUST FAN
			22	336	98	74	158	119	AHU-1	EX-1
			22	576	971	728	1092	819	AHU-1	EX-1
			12	192	311	233	314	236	AHU-1	EX-1
			18	288	437	328	436	327	AHU-1	EX-1
			15	240	75	56	158	119	AHU-1	EX-1
			30	40	88	66	130	98	AHU-1	EX-1
			18	288	81	61	196	147	AHU-1	EX-1
			9	144	247	185	249	187	AHU-1	EX-1
			9	144	247	185	249	187	AHU-1	EX-1
			18	288	495	371	546	410	AHU-1	EX-1
			9	144	247	185	249	187	AHU-1	EX-1
114	CLASSROOM	432	324	232	1196	897	1179	884	AHU-1	EX-1
116	UNIVERSITY LAB	881	661	2348	4142	3107	4376	3282	AHU-1	EX-1
117	UNIVERSITY LAB	685	514	1826	910	683	942	707	AHU-1	EX-1

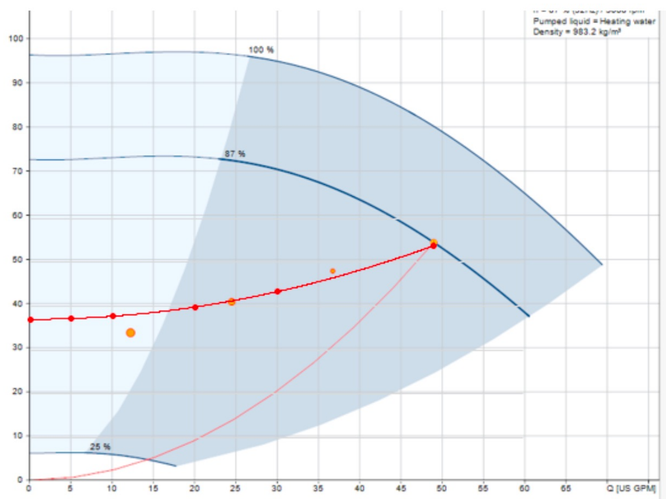
Sample Submissions

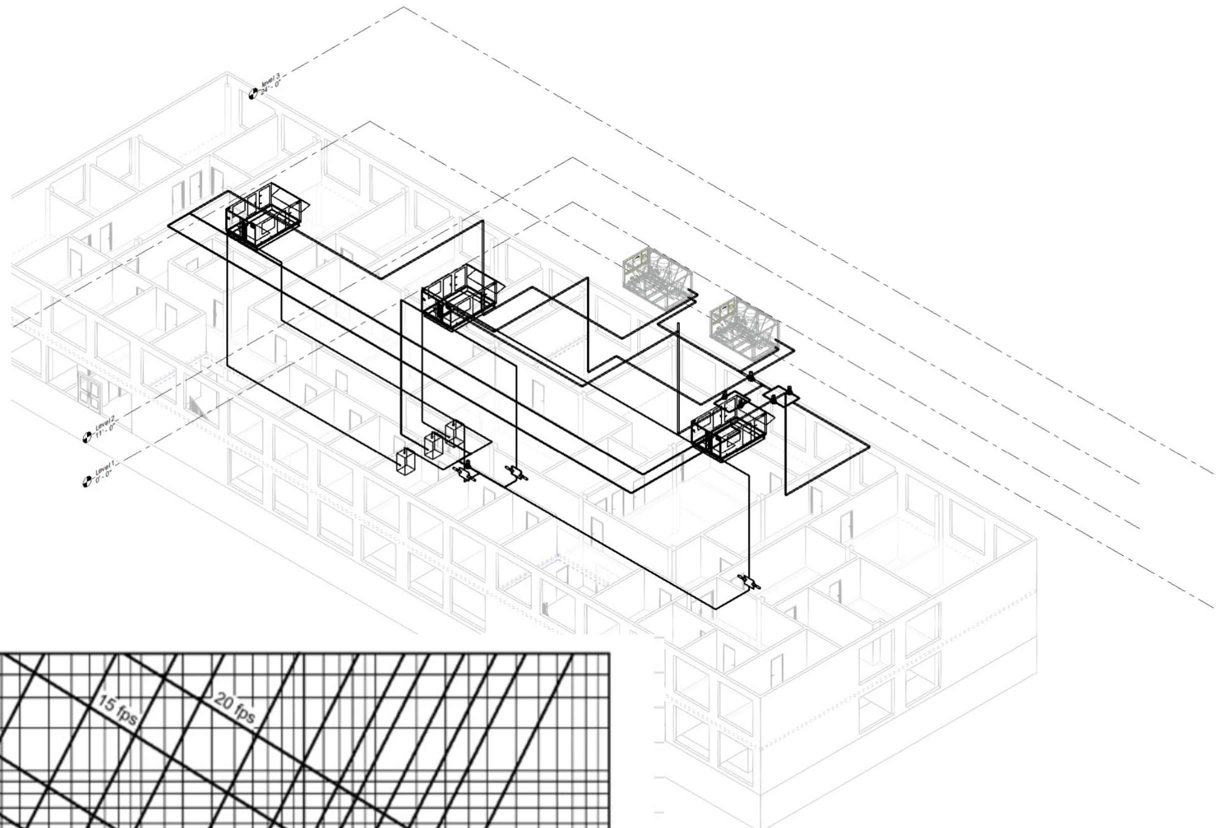
- Hydronic calculation

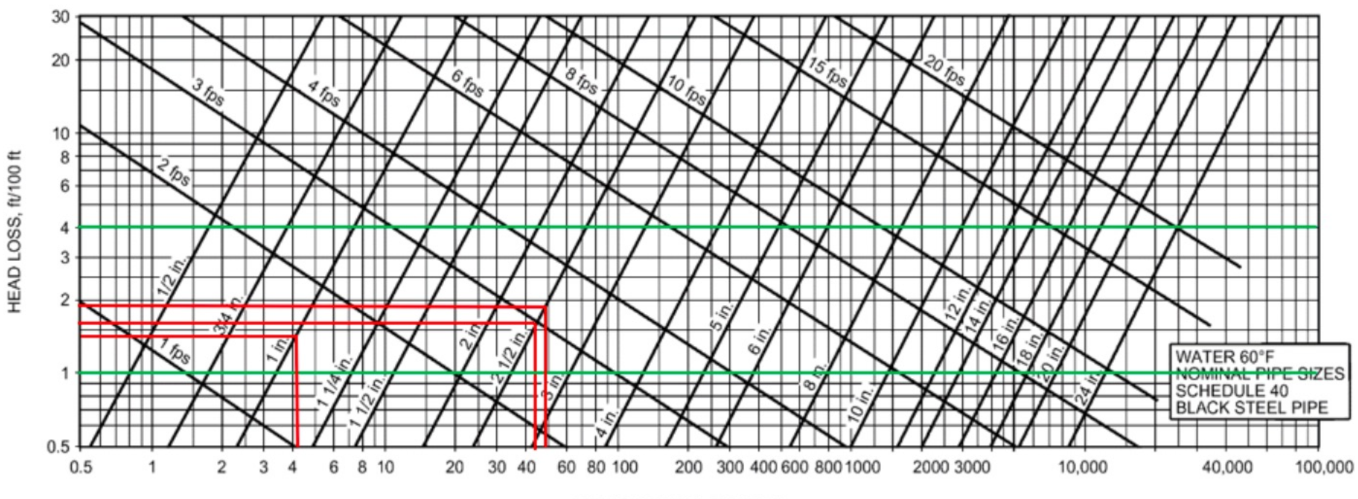


Sample Submissions

- Load Calculation







WHY DO WE LEARN ABOUT HVAC?

Why Do We Learn About HVAC

https://www.kemptoncarr.co.uk/news-and-knowledge/is-damp-or-poor-ventilation-ruining-your-home/
https://www.goldeagle.com/tips-tools/mold-vs-mildew-whats-difference/

Why Do We Learn About HVAC

THE CORONAVIRUS CRISIS

Hospital Scrambles To Find Patients Before Freezer Failure Ruins 830 Vaccines

January 5, 2021 · 9:12 PM ET

VANESSA ROMO

Somewhere around 2 a.m. the compressor of the freezer holding vials of the medicine at the Adventist Health Ukiah Valley Medical Center in Mendocino County, Calif., failed, President Judson Howe told NPR.

That started a ticking clock on the shelf life of the vaccines, which can only be used for 12 hours once they're removed from refrigeration of 36 to 46 degrees Fahrenheit.

Normally, this would have triggered an alarm, Howe explained. But for some unknown reason, that also failed.

It wasn't until "a staff member physically checked it — stuck his hand in the freezer" at about 11:45 a.m. that anyone realized something was grievously wrong.

That gave the staff just over two hours before the vaccines would be declared unusable.

https://www.npr.org/sections/coronavirus-live-updates/2021/01/05/953779007/hospital-scrambles-to-find-patients-before-freezer-failure-ruins-830-vaccines#:~:text=A%20team%20of%20fast%2Dacting,the%20Moderna%20COVID%2D19%20vaccine.

Why Do We Learn About HVAC

Department of Education

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School Building Ventilation Survey

We look forward to kicking off the 2020-2021 school year together with you. As always, the health and safety of our staff, students and families is our number one priority.

Properly ventilated classrooms are key to our reopening our schools safely. We have been working around the clock to ensure that every school has been carefully surveyed for ventilation by consulting engineers under the direction of the New York City School Construction Authority. The results of your child's school building ventilation survey will be posted on the individual school page on our website, on the Overview tab, under Building Ventilation Information.

- **Use Find a School to get your school page and see the report.**

We found that the ventilation in more than 95 percent of our classrooms is in good working order. Out of the 64,000 classrooms we surveyed, fewer than 3,000 had issues. These results for individual schools are preliminary and are intended to help focus our repair and maintenance efforts. They do not indicate any space's ability to open, as we are continuing to repair and correct any outstanding ventilation issues.

https://www.schools.nyc.gov/about-us/reports/school-building-ventilation-survey

Why Do We Learn About HVAC

Chicago Public Schools

PARENTS STUDENTS COMMUNITY STAFF SELECT LANGUAGE ▼

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SERVICES AND SUPPORTS

- School Facilities
- Facility Standards
- **Air Quality Testing**
- Water Quality Testing
- Capital Improvement Program Support
- Emergency Temporary Relocations

HOME / SERVICES AND SUPPORTS / SCHOOL FACILITIES

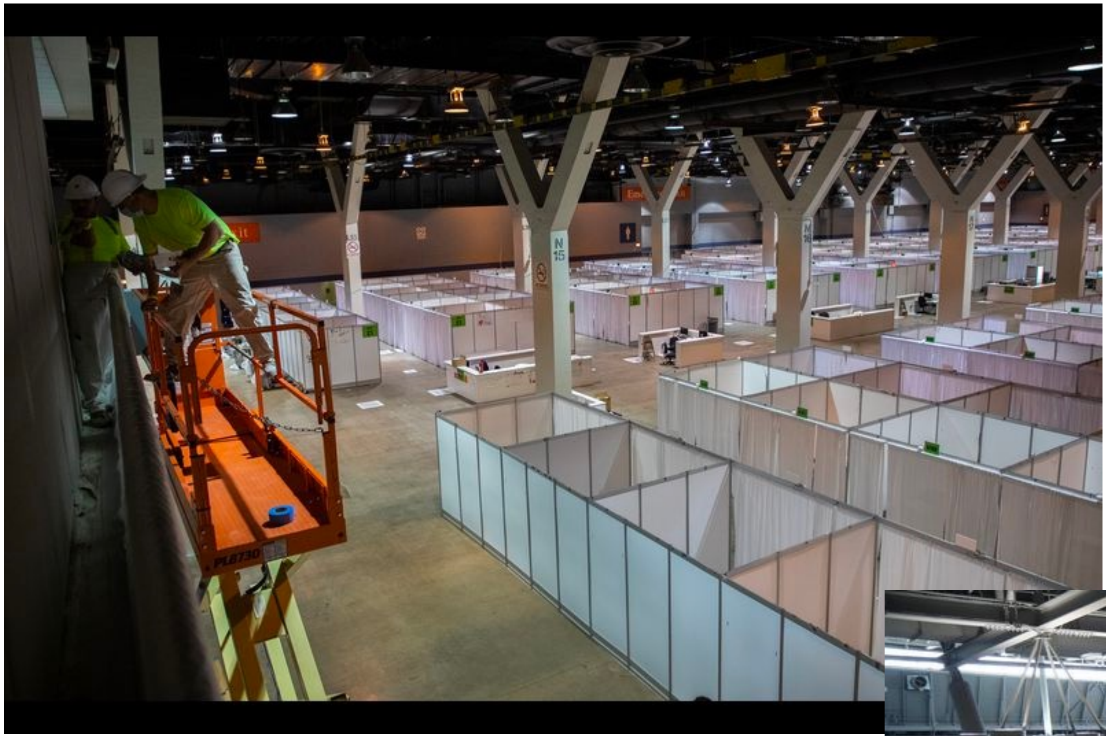
Ventilation and Indoor Air Quality Assessment

As we have committed to you and your family throughout our response to COVID-19, the health and wellness of our school communities is paramount.

To ensure school buildings are prepared for a return to in-person instruction, we worked to ensure every classroom has a working window or a mechanical ventilation system to dilute air particles that may have viruses or bacteria and allow old air to move out of the classroom.

https://www.cps.edu/services-and-supports/school-facilities/air-quality-testing/

Why Do We Learn About HVAC



https://www.bizjournals.com/boston/news/2020/04/06/a-look-inside-the-new-field-hospital-at-the-boston.html
https://www.chicagotribune.com/coronavirus/ct-coronavirus-mccormick-place-convert-field-hospital-20200403-duafjtk25vcjpi2ywdfqpd24le-story.html

INTRODUCTION TO BUILDING HVAC SYSTEMS

Building HVAC Systems

- HVAC stands for Heating, Ventilation, and Air-Conditioning:
  - Heating: Boiler, furnace, heat pump, waste heat, heating coils
  - Ventilation: Outdoor air required for the spaces (e.g., ASHRAE 62.1)
  - Air-Conditioning: Chilled-water systems, cooling coils, Direct Expansion (DX) refrigerant systems

https://www.indiamart.com/proddetail/direct-expansion-cooling-coil-11707532291.html & http://acscomfort.com/hvac-central-systems

Building HVAC Systems

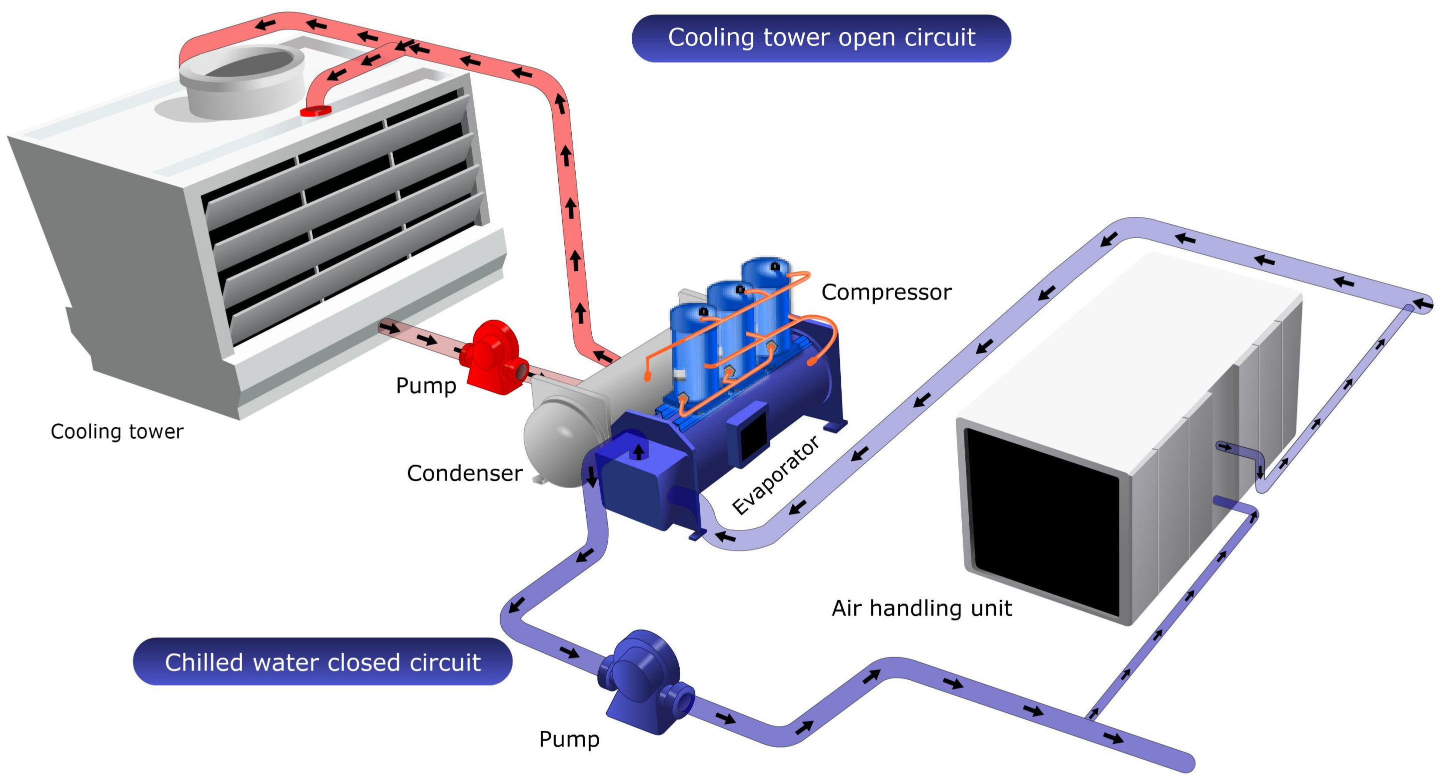
- Purpose of building HVAC systems is to control indoor air parameters within required:
  - ❑ Thermal comfort
  - ❑ Indoor air quality

Building HVAC Systems

- To achieve required indoor air parameters, the system needs to conduct one or more than one of the following heat transfer processes:
  - Heat
  - Cool
  - Humidify
  - Dehumidify
  - Filtration

Building HVAC Systems

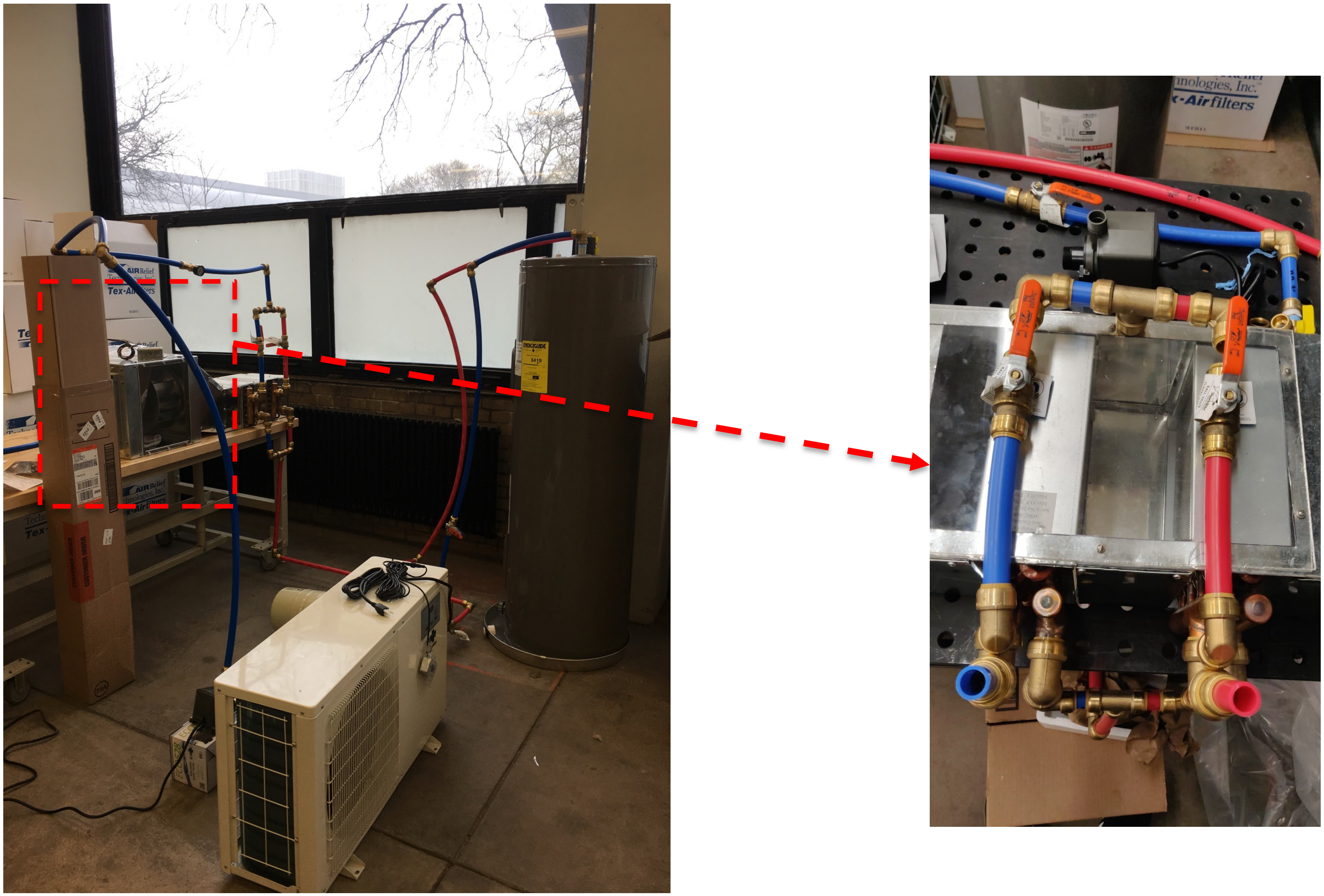
- Commercial HVAC system may include four main parts:
  - ❑ Primary systems or central plant
  - ❑ Distribution system
  - ❑ Terminal devices
  - ❑ Controls



http://refrigerationandairconditioning.danfoss.us/applications/chillers/#/

Building HVAC Systems

- ASHRAE UG Equipment Lab (On-going)



Building HVAC Systems

- Primary systems are major energy consumers
  - In small buildings, we usually call them heating and cooling devices
  - In large buildings, we usually call them equipment and systems
- For large buildings sometimes they are called “plants” or “loops”
- Examples of a heating device is a boiler or furnace
- An example of a cooling system is a vapor compression

Building HVAC Systems

- Secondary systems distribute the cooling (or heating) produced by the primary systems (e.g., chillers or boilers) to the building spaces (e.g., specific rooms or thermal zones). Four types are:

  - All-water
  - All-air
  - Air-water systems
  - Refrigerant
  - Air-water-refrigerant
  - Air-refrigerant

What are the advantages and disadvantages of each type?

Building HVAC Systems

- Secondary system(s) may have different working fluids:

  - Hydronic systems (Water or steam)
    - Heat transfer to space by natural or forces convection
    - Only sensible load is met this way

  - Air systems (Air)
    - Both sensible and latent loads are met by a single supply air stream to each space
    - Deliver the required air ventilation
    - Require large volume of air

Building HVAC Systems

- Secondary systems entail:
  - Distribution system:
    - Ducts or pipes to carry working fluids
  - Equipment to compensate for pressure drop and move the working fluids:
    - Fans or pumps
  - Heat exchanger devices to transfer cool or heat from the working fluid to air:
    - Cooling or heating coils
  - Terminal devices to control, distribute, and deliver cooled or heated air to different zones:
    - Radiators, fan coils, room diffusers
  - Control devices to modulate the flow:
    - Temperature sensors, valves, dampers, thermostats

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- Sources for primary energy for heating/cooling are:
  - ❑ Produced steam or hot water
  - ❑ Produced renewable electricity
  - ❑ Coal
  - ❑ Natural gas
  - ❑ Fuel oil
  - ❑ Biomass

https://www.alamy.com/water-panels-for-using-renewable-sun-energy-are-placed-on-house-roof-solar-hot-water-system-modern-energy-saving-technology-image221774114.html
http://www.riteboiler.com/index.php/products/hot-water-boilers/outdoor-atmospheric

Building HVAC Systems

- Heating equipment, energy, distribution, and cycle options:
  - **Equipment:** Boiler, furnace, heat pump, electric resistance
  - **Energy:** Natural gas, oil, steam, electrical, renewable, waste heat
  - **Distribution:** Air, steam, water
  - **Cycle:** Vapor compression, combustion, renewable

Building HVAC Systems

- Cooling equipment, energy, distribution, and cycle options:
  - **Equipment:** Air conditioner, chiller, heat pump
  - **Energy:** Electrical, natural gas, steam, waste heat, renewable
  - **Distribution:** Chilled water, air
  - **Cycle:** Vapor compression, absorption

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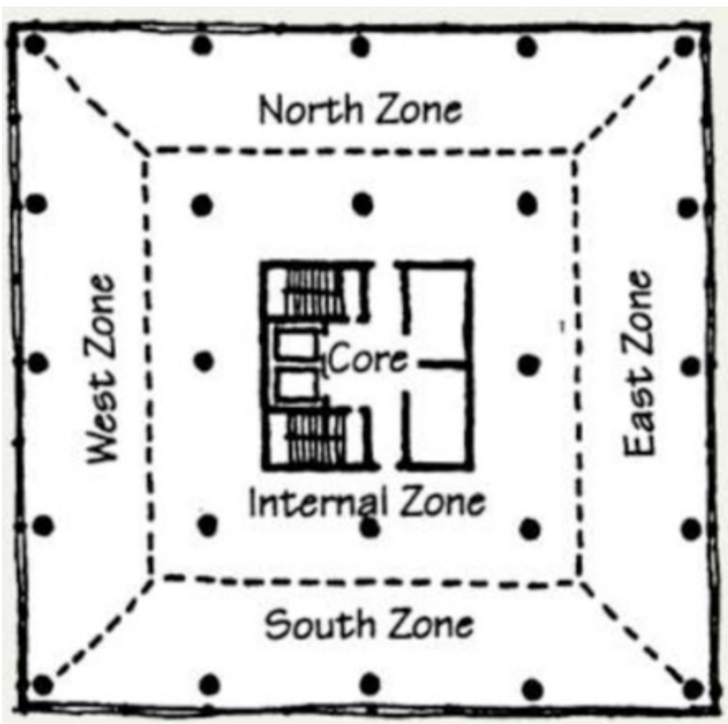
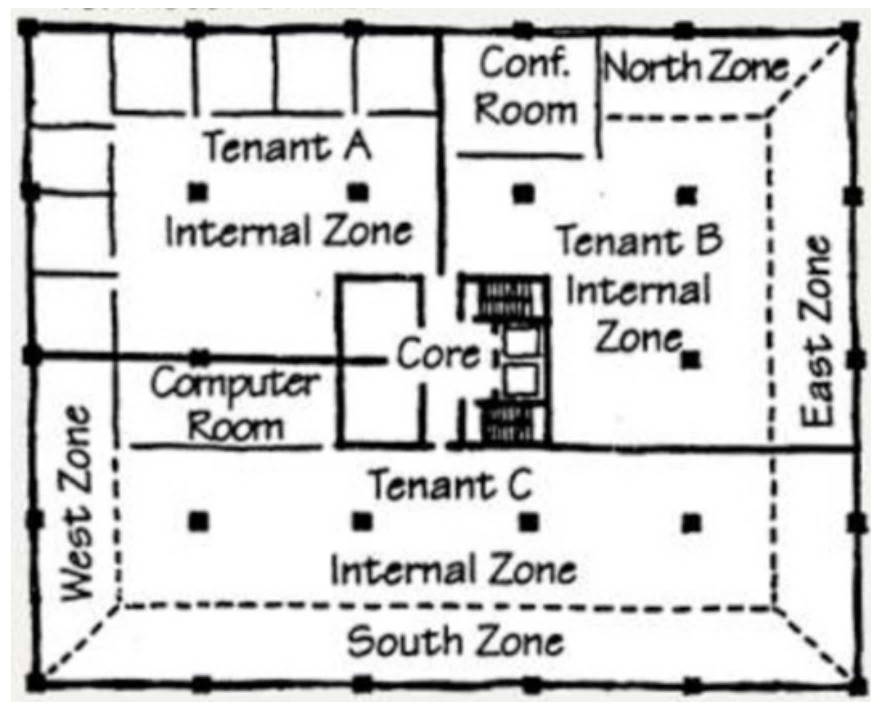
- Thermal zone or zone:
  - ❑ Is a space or collection of spaces having similar space-conditioning requirements
  - ❑ Has the same heating and cooling setpoint



Based on orientation and floor



Based on spaces

Reddy et al. 2017

Building HVAC Systems

- Common ventilation types:

  - ❑ Constant Air Volume (CAV):
    - Hold the system airflow rate constant
    - Let the space thermostat modulate the supply air temperature

  - ❑ Variable Air Volume (VAV):
    - Modulate supply airflow rate
    - Hold the supply air inlet temperature constant

  - ❑ Dedicated Outdoor Air System (DOAS):
    - Consist of two parallel systems
    - Deliver outdoor to handle both latent and sensible loads
    - Include a parallel system to handle mostly sensible loads

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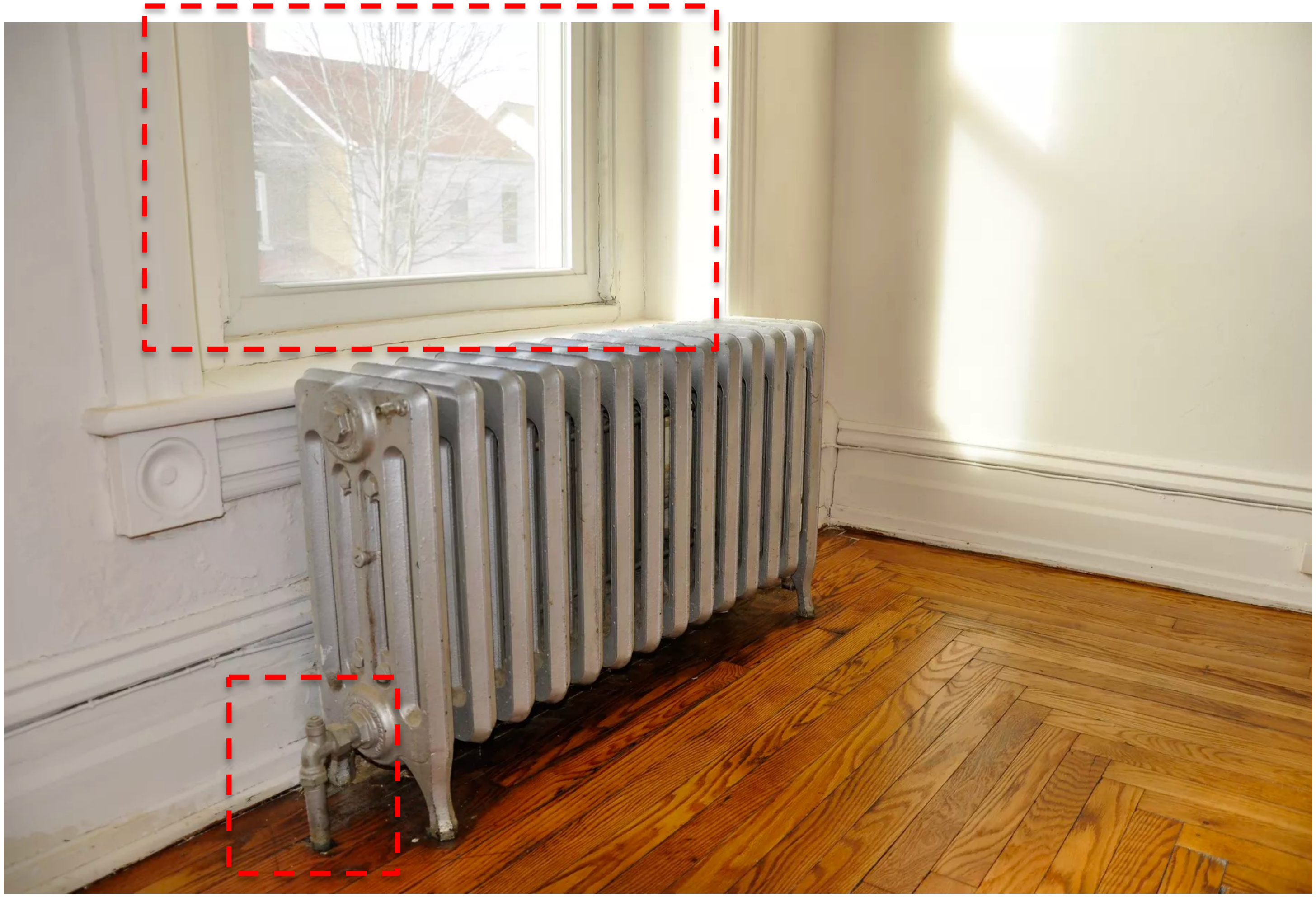
- Can we have a system with no ventilation type?



Why do you think most of the radiators are located under the windows?

https://ny.curbed.com/2018/1/3/16845686/weather-nyc-311-heat-hot-water-complaint

Building HVAC Systems

- Strategies to understand the topics in this class is to identify:
  - ❑ System types:
    - Air distribution systems
    - Hydronic systems
    - Refrigeration systems
  - ❑ Energy sources
  - ❑ Primary and secondary
  - ❑ Ventilation types

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- HVAC systems categories in terms of their distribution and integration of components are categorized as:

  - Unitary
    - Local systems
    - Each room has an HVAC system
  - Centralized
    - Central systems (all HVAC equipment in one room)
    - Semi-central systems
  - District
    - Central systems (all HVAC equipment in one room)
    - Semi-central systems

Building HVAC Systems

- How do we select HVAC systems?
  - Performance requirements (loads, process)
  - Capacity requirements (building types, loads)
  - Spatial requirements (building types)
  - First costs (location, size of HVAC, investment)
  - Operating costs
  - Reliability
  - Flexibility
  - Maintainability

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