June 22, 2020

Colorado OER Council Grant (2019-2020 academic year)

Dr. Christofer Harper, Department of Construction Management

Course: CON 371 – Mechanical and Plumbing Systems

This file includes the materials developed for the course CON 371 in order to use open education resources for the course. Work began in the Fall 2019 and completed in Spring 2020. The majority of the materials developed were used during the Spring 2020 semester, with the remaining materials developed over the past couple months ready for use in Spring 2021. The information included in this file are:

- OER proposal
- Lesson Slides. Lesson slides were re-created and used adapted OER materials. Homework assignments and exams were also developed, but are not shared here to protect the integrity of the assignments that are t be used in class.
- In-Class Exercises. These are low-stakes activities that are performed in class as we go through the lesson slides. Solutions have not been provided as these are materials used in class that were created from scratch.

Name: Christofer Harper

Department/program: Construction Management

Date: 4/24/2019

Course information:	**Information on the current textbook:**
Course name and number: *CON 371 Mechanical and Plumbing Systems*	Title: *Mechanical and Electrical Systems in Buildings, 6th Edition*
Total enrollment/semester: *90*	Cost: *$204.00 (CSU Bookstore, New) $184.98 (Amazon, New)*
Semester/s offered: *Fall and Spring*	Estimated savings by switching to an open textbook: *$16,648.20 ($184.98 per student)*

Would you be interested in working with an instructional designer and/or librarian? Yes please! There may be an instructional designer or librarian available to assist with implementing projects. Your response to this question will not affect funding decisions.

Narrative OER Plan (2 page max, directly addressing the following questions as relevant to your project):

- How do you plan to go about replacing the textbook in this course? (explicitly: do you plan to adopt an existing open educational resource, adapt existing materials, or create your own materials?)
- What format(s) and/or platform/s will be used (e.g., PDF/A, e-book, video, website, etc.)?
- How will students access the content? Will the OER be accessible via a student's mobile device or smartphone? Will it follow universally accessible design principles?
- What problems do you anticipate?
- How will relevant copyright issues be addressed? Will you be using a Creative Commons license?
- What are your anticipated outcomes and how will you know they were achieved?
- Level of grant requested and plan for using funds (adopt, up to $1000; adapt, up to $2000; create, up to $4000)
- What is your plan for sustaining the use of OER adapted or created beyond initial use?
- When do you plan to implement the content adopted, adapted, or created via this proposal?

Questions, as well as completed proposals (either a Word doc or PDF) should be submitted via email to christine.pawliuk@colostate.edu by April 24, 2019. Decisions will be made by May 1st.

Narrative OER Plan

The course I would like to adapt open education resources (OER) for is CON 371 – Mechanical and Plumbing Systems in the Department of Construction Management. The course description provided in the Colorado State University catalog is: *Heating, ventilation, air conditioning, plumbing, and fire suppression in the built environment.* The course covers the fundamental mechanical and plumbing systems found in buildings so that construction managers can plan, execute, and manage the skilled professionals that install these systems. This is a required upper division undergraduate course for all construction management students. The learning outcomes associated with this course include: 1) Identify and recognize terminology, theory, and components of plumbing, heating, ventilation, air conditioning and fire protection systems; 2) Interpret mechanical and plumbing information from construction drawings and specifications; 3) Apply project document reading skills to perform quantity take-off of mechanical and plumbing systems; and 4) Summarize quality control requirements for mechanical and plumbing systems.

Plan to Replace the Textbook

Currently, I use one textbook for CON 371, which costs $209.00 for a new copy and $134.50 for a used copy at the Colorado State University (CSU) Bookstore, and $184.98 on Amazon for a new copy. The textbook is the best that I have found for the purpose of the class, but I use only half of its content as most of the textbook focuses on the design of mechanical and plumbing systems, which is useful for engineers, but not for construction managers. I have reviewed many other textbooks that cover mechanical and plumbing systems, but they are setup in a similar manner. Therefore, students purchase a textbook that they use for 50% of the class and then I supplement much of the required course materials in the syllabus with my own materials gathered from my industry experience and some OER materials such as YouTube videos and websites for professional mechanical and plumbing organizations. Since I am already using external materials for a portion of the class, I would like to move towards using OER to eliminate the textbook expense for students and to use materials that are more applicable to this course, are readily available, and address the current needs of the construction industry.

I have already been searching for and have used OER materials for portions of the CON 371 class, such as websites, readily available and free-to-distribute articles and reports, and YouTube videos. The plan is to adapt more OER to cover all topics and content in this course to eliminate the need for a textbook. The material will be from open sources provided in Creative Commons, OER Commons, as well as other sites that offer open courseware (OCW) such as the Massachusetts Institute of Technology (MIT) OCW database. I plan to distribute the OER materials to students as: 1) PDF documents covering concepts and practices of mechanical and plumbing systems, 2) videos showing processes and functions of equipment and materials, 3) websites for performing calculations, conducting in-class exercises, and completing homework assignments, and 4) free and open-source software (FOSS) for solving problems using practices similar to industry. Students will access these materials through the Canvas online learning system or email communications so they can access the information from any internet-connected device. Using various types of information and media helps to reach more students based on their learning styles and provides a more interesting delivery of materials that helps keep students engaged. The information will also be adapted based on the universally accessible design principles so that students of all ages and abilities can easily access and use the materials.

Problems/Issues

Below is a list of potential issues, along with a plan to address them if they arise.

- Based on experience, when course materials are changed or revised, it is important that new or revised materials still address the student learning outcome requirements of a course. All materials collected from OER sources will be reviewed against the four learning objectives for CON 371 stated earlier in this proposal. The curriculum committee will also review the OER materials before

using it in the classroom since the curriculum committee is currently solidifying the learning outcomes for accreditation purposes.
- One possible occurrence is losing access to OER materials due to changes in copyright or removal of materials by the originator. However, I believe that this will not affect my plan since I am going to adapt OER materials rather than adopt OER materials for use with the course.
- Since OER materials entail various documents and media formats instead one textbook, there is the potential that students may get confused or lost in the various sources of information provided. I will manage the distribution of the materials wisely throughout the semester so that students know what materials to use and when. I plan to develop and use a detailed syllabus and course schedule, a sequential course layout using modules on Canvas, and weekly announcements made to students.

Copyright
To address possible copyright issues, I plan to use Creative Commons licensing. OER materials are to be adapted for this course, so materials that are openly available will be utilized and refined, while providing credit to the originator. Based on the licensing descriptions from Creative Commons, I plan to use materials that have a license allowing for distributing, remixing, tweaking, and building upon the work. I then plan to license the OER materials that I adapt using Creative Commons so that I provide credit as required to the originator, and for others to openly use, revise, and adapt as they see fit.

Anticipated Outcomes
I anticipate that with proper adaptation of OER materials, student performance will be the same if not better than students that took the class previously using the textbook. In teaching CON 371 for several semesters, I intend to compare the performance of students from previous semesters when I used the textbook to the performance of students when using OER materials. I can use the quantitative measures of grades for homework assignments, quizzes, exams, and projects to investigate students' performance before and after adapting OER materials. Based on students' performance, I will be able to know if the material works as well as the textbook. If the performance is less than anticipated when using OER material to convey the topics of the course, then I plan to refine the course with additional or further adaption of OER materials until the performance matches and eventually exceeds the performance from classes that used the textbook. In addition, I use internal assessments throughout the semester to inquire how students are receiving and learning the material. I plan to revise the assessment to include questions on the use of OER materials in class to get a feel for how students are learning the information.

Sustaining the Use of Adapted OER Materials
To sustain the use of open education resources for this course, I plan to continuously adapt and update the content. I already do this in all the classes that I teach so that the material is current and useful for our CM students. For example, in CON 371, I teach methods to size and install various mechanical and plumbing systems for buildings that, in the traditional process, requires using standardized tables and charts, which is an antiquated process that can be tedious. However, online calculators and software programs can perform the calculations, eliminating the need for the tables and charts. Therefore, for students to gain vital knowledge and to match what the industry is currently doing, I teach these concepts and processes using various software and websites, which are to be OER material. I plan to refine the course content continuously based on what industry is asking for by infusing new and adapted OER materials as needed.

Implementation and Funds Request
My plan for adoption is to work on collecting and adapting material during the summer of 2019. Then, during the fall 2019 semester, I will be able to develop the curriculum for CON 371 based on the OER I collected and adapted in order to use in the spring 2020 semester. I am requesting $2,000 for adapting OER materials for CON 371 – Mechanical and Plumbing Systems as this will provide me with funds to cover my continuing efforts and time needed as well as help me set the framework to adapt OER into the other construction management classes that I teach.

INTRODUCTION TO MECHANICAL SYSTEMS

CON 371 – Mechanical and Plumbing Systems

LEARNING OUTCOMES

- By the end of this lesson, students will be able to:
  1. Understand types of mechanical and plumbing systems
  2. Apply common aspects of mechanical and plumbing systems
  3. Compute payback and cost analyses of energy use in mechanical systems

HVAC – HEATING, VENTILATION, AIR CONDITIONING

- Heating Piping Systems
  - Hot Water System
  - High Temperature Hot Water Systems
  - Steam Systems
  - Radiant Heating Systems
  - Natural Gas Systems – High, Medium & Low Pressure
  - Fuel Oil Systems
  - Solar Heating Systems
  - Ground Water Systems
  - Pneumatic Systems
  - Glycol Systems
  - Heat pumps

- Cooling Piping Systems
  - Chilled Water Systems
  - Low Temperature Chilled Water Systems
  - Refrigeration Piping Systems
  - Ice Storage Systems
  - Brine Systems
  - Ammonia Systems
  - Natural Gas Systems
  - Chilled Water Storage Systems
  - Heat pumps

HVAC AIR SYSTEMS

- Air Distribution Systems
  - High, Medium & Low Pressure Systems
- Heat Recovery Systems
- Car-mon Exhaust Systems
- Radon Exhaust Systems
- Generator Exhaust Systems
- Smoke Control Systems
- Cryogenic Exhaust Systems
- Fume Exhaust Systems

YouTube Video:
Basics of HVAC Systems

PLUMBING SYSTEMS

- Sanitary Waste & Vent Systems
- Storm Water Systems
- Domestic Hot & Cold Water Systems
- Natural Gas Systems
- Life Safety Systems
  - Fire Suppression
  - Medical Gases
  - Steam Sterilization Systems
- Compressed Air Systems
- Solar Domestic Water Systems
- Foundation Drainage Systems
- Laboratory Gases Systems

YouTube Video:
How Home Plumbing Works

PROCESS SYSTEMS

- Hot Oil Systems
- High Purity Gas Systems
- High Purity Air Systems
- High Purity Water Systems
- Deionized Water Systems (DI Systems)
- Reverse Osmosis Systems (RO Water)
- Ozone Systems
- Clean In Place Systems (CIP Systems)
- Food Process Piping Systems
- Acid Waste Systems

FORMS AND UNITS OF ENERGY AND POWER

Energy Type	Energy Unit	Power Unit	Conversion to Btu
Heat	British thermal unit (Btu)	British thermal unit per hour (Btuh)	1.0
Mechanical	Horsepower-hour (hp-hr)	Horsepower (hp)	2,545
Electric	Watt-hour (Wh)	Watt (W)	3.413

ENERGY

- Assume:
- You have a 10,000 SF Building
  - The lighting load is estimated at 1 watt/SF
  - The lights are on an average of 3,000 hours per year

- Question: How many kilowatts (kW) are used each hour? In a year?

$$10{,}000\ SF \times 1 \frac{watt}{SF} = 10{,}000 \frac{Watts}{1{,}000} = 10\ kW$$

$$10\ kW \times 3{,}000\, hrs = 30{,}000\ kWh$$

POWER

For the same 10,000SF building:

- How many Btu’s (heat energy) are generated in the 3,000 hrs?

$$10\ kW \times\ 3{,}413\ \frac{Btuh}{kW} = 34{,}130\ Btuh$$

$$34{,}130\ Btuh\ \times\ 3{,}000\ hrs = 102{,}000{,}000\ Btu's\ per\ year$$

HEAT CAPACITIES (BTU'S)

Common Materials	Density lb/ft^3	Heat Capacity Btu/°F lb
Water	62.4	1.0
Wood	45	0.57
Foam insulation	2.5	0.34
Air	0.075	0.24
Concrete	144	0.21
Steel	489	0.12

- It takes 1 Btu to raise the temperature of 1 lb of water by 1°F
- It takes 0.21 Btu's to raise the temperature of 1 lb of concrete by 1°F

Question: How much heat (Btu's) is stored in a 100 SF Concrete wall, 1 ft. thick, if it is warmed from 65°F to 85°F by exposure to sunlight?

$$(100\text{SF})(1\text{ft}) \times \frac{144 lb}{ft^3} = 14{,}400\ lbs\ (Weight\ of\ wall)$$

$$14{,}400 lbs \times \frac{0.21\ Btu}{°\text{F}\ lb} \times (85°\text{F} - 65°\text{F}) = 60{,}480\ Btu$$

HEATING VALUES OF FUELS

Fuel	Unit of Measure[a]	Nominal Heating Value/Unit, Btu (kJ)	Combustion Efficiency, %
Natural gas	cu ft	1,000 (1,055)	70-85
LP (propane gas)	gal	93,000 (98,000)	70-85
No. 1 oil (diesel)	gal	138,000 (146,000)	75-80
No. 5 oil (heavy)	gal	145,000 (153,000)	72-82
No. 6 oil (bunker C)	gal	153,000 (161,000)	75-80
Soft coal (bituminous)	lb	13,000 (14,000)	75-85
Blank		13,700 (14,800)	
Hard coal (anthracite)	lb	12,500 (13,500)	75-85
Blank		13,200 (14,300)	
Electrical resistance[b]	kWh	3,412 (3,600)	100[b]
Electric heat pump[c]	kWh	10,200 (10,800)	150-300[c]

- Assume – A 75% efficient boiler is required to produce 800,000 Btuh to offset a heating load.
- *Question:* If the boiler uses LP (propane gas), what will the input rate be in gallons per hour?

HEATING VALUES OF FUELS

Question: If the boiler uses LP (propane gas), what will the input rate be in gallons per hour?

Each gallon of LP (propane gas) has a heating value of 93,000 Btu

At 75% efficiency, each gallon will produce a net heating value of:

$$0.75 \times 93{,}000 = 69{,}750\ Btu/gallon$$

To produce 800,000 Btuh:

$$\frac{800{,}000\ Btuh}{69{,}750\ Btu/gallon} = 11.5\ gallons/hr$$

MEASURING PRESSURE OF AIR AND WATER

- Mechanical systems use the flow of air, water and steam to transfer energy

	Measure
Air Flow	Cubic Feet per Minute (CFM)
Air Pressure	Inches of Water Column (in w.c.)
Water Flow	Gallons per Minute (GPM)
Water Pressure	Pounds per Square Inch (psig)
	Feet of head (1 psig = 2.31 ft of head)
Steam Flow	Pounds per hour (lbs/hr)
Steam Pressure	Pounds (lbs)

DECISION MATRIX METHOD - EXAMPLE

How an Owner might think about HVAC options for an office building

		VAV/Reheat		VAC/Convectors		VAV/Dual Duct		Multi-zone		VAV/FTU		Fancoils	
		Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted
Criteria	Weight												
Comfort	8	5	30	8	42	5	30	5	30	8	48	7	42
Flexibility	6	10	60	7	42	8	48	1	4	8	48	7	42
Initial cost	3	10	30	8	24	6	18	4	12	7	21	6	18
Energy Consumption	6	7	42	8	48	7	42	7	42	9	54	9	54
Ease of Maintenance	6	7	42	8	48	9	54	10	60	6	36	5	30
Longevity	6	9	54	7	42	9	54	9	54	6	36	5	30
Acoustics	5	8	40	8	40	8	40	8	40	5	25	5	25
Total score			299		308		296		252		284		255
% score (normalized)			97%		100%		96%		82%		92%		85%
Grade			A		A+		B		F		B		C

How a Developer might think about HVAC options for an office building

		VAV/Reheat		VAC/Convectors		VAV/Dual Duct		Multi-zone		VAV/FTU		Fancoils	
		Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted
Criteria	Weight												
Comfort	3	5	15	8	21	5	15	5	15	8	24	7	21
Flexibility	3	9	30	7	21	8	24	1	4	8	24	7	21
Initial cost	10	9	100	8	80	6	60	4	40	7	70	6	60
Energy Consumption	2	7	14	8	16	7	14	7	14	9	18	9	18
Ease of maintenance	2	7	14	8	16	9	18	10	20	6	12	5	10
Longevity	2	9	18	7	14	9	18	9	18	6	12	5	10
Acoustics	5	8	40	8	40	8	40	8	40	5	25	5	25
Total score			213		211		189		151		185		165
% score (normalized)			100%		97%		87%		69%		85%		76%
Grade			A+		A-		B		D		B		C

STANDARD – SIMPLE PAYBACK ANALYSIS

- An energy-savings device costs $20,000 to install
- It lasts 5 years
- It saves $6,000 in energy each year
- It requires $500 each year for maintenance

Simple payback period is:

$$\$20{,}000/(\$6{,}000 - \$500) \; = 3.6 \; years$$

LIFE-CYCLE COST ANALYSIS

Find the lifecycle cost for an energy-saving device that costs $20,000 to install (Initial capital costs)

- 5 year life span
- Savings of $6,000 in utilities during the first year
- 5% annual escalation in utility costs
- $500 of maintenance during the first year
- 3% increase in maintenance cost each year
- 15% annual rate of return for the investment

LIFE-CYCLE COST ANALYSIS

Year	Installation Cost	Energy Savings	Maintenance Costs	Total Annual Cash Flow	Present Value Total Annual	$Present\ Value = \frac{Cash\ Flow}{(1+i)^t}$
0	($20,000)	$0	$0	($20,000)	($20,000)	
1	$0	$6,000	($500)	$5,500	$4,783	$\frac{\$5{,}500}{(1+0.15)^1} = \$4{,}783$
2	$0	$6,300	($515)	$5,785	$4,374	$\frac{\$5{,}785}{(1+0.15)^2} = \$4{,}374$
3	$0	$6,615	($530)	$6,085	$4,001	$\frac{\$6{,}085}{(1+0.15)^3} = \$4{,}001$
4	$0	$6,946	($546)	$6,399	$3,659	$\frac{\$6{,}399}{(1+0.15)^4} = \$3{,}659$
5	$0	$7,293	($663)	$6,730	$3,346	$\frac{\$6{,}730}{(1+0.15)^5} = \$3{,}346$
Net Present Value of Life-Cycle Cash Flow ($)					$163	

5% annual increase

3% annual increase

$$Net\ Present\ Value = \sum Present\ Value\ Total\ Amount$$

WORKPLACE COST ANALYSIS

Occupancy Density	200 SF/Employee
Employee Salary	$50,000/yr
Fringe Benefits (30%)	$15,000/yr
Employee Cost	$65,000/yr
Employee Cost	$325 per SF/yr

Assume:

- The facility manager reduces the temperature and lighting levels to affect a 20% reduction in utility bills
- Suppose these reductions reduce productivity by 1%
- The energy cost per employee is $400/yr

What is the effect?

COST ANALYSIS PER SF / YEAR

$$- \; Utility\ savings\text{: } \$2.00 \times 20\% \; = \; +\$0.40\ per\ SF/yr$$

$$- \; Productivity\ loss\text{: } \$325 \times 1\% \; = -\$3.25\ per\ SF/yr$$

$$- \; Net\ Loss\text{: } \$0.40 \; - \; \$3.25 \; = -\$2.85\ per\ SF/yr$$

WORKPLACE COST ANALYSIS

Assume:

- The facility manager increases the temperature and lighting levels to affect a 20% increase in utility bills.
- Suppose these increase productivity 1%
- The energy cost per employee is $400/yr

What is the effect?

COST ANALYSIS PER SF / YEAR

$$- \, Utility \; increase\!: \; \$2.00 \times 20\% \; = -\$0.40 \; per \; SF/yr$$

$$- \, Productivity \; gain\!: \; \$325 \times 1\% \; = \; +\$\mathbf{3.25} \; per \; SF/yr$$

$$- \, Net \; Gain\!: \; \$3.25 \; - \; \$.40 \; = \; +\$\mathbf{2.85} \; per \; SF/yr$$

HVAC FUNDAMENTALS

CON 371 – Mechanical and Plumbing Systems

LEARNING OUTCOMES

By the end of this lesson, students will be able to:

1. Understand Simple payback of HVAC related investment decision
2. Define and understand psychrometrics and associated terminology
3. Use psychrometric charts to design mechanical systems
4. Discuss latent and sensible loads and their effect on the conditioning of inside air

SIMPLE PAYBACK ANALYSIS

- An energy-savings option has an initial cost of $30,000
  – It has a 10 year life
  – It saves $6,100 in energy cost each year over a traditional HVAC system
  – It costs $1,000 each year for maintenance
- What is the simple payback period?
- Simple payback period is –
  – Investment / Net savings = number of years to realized savings
  – $30,000/($6,100-$1,000) =5.88 years

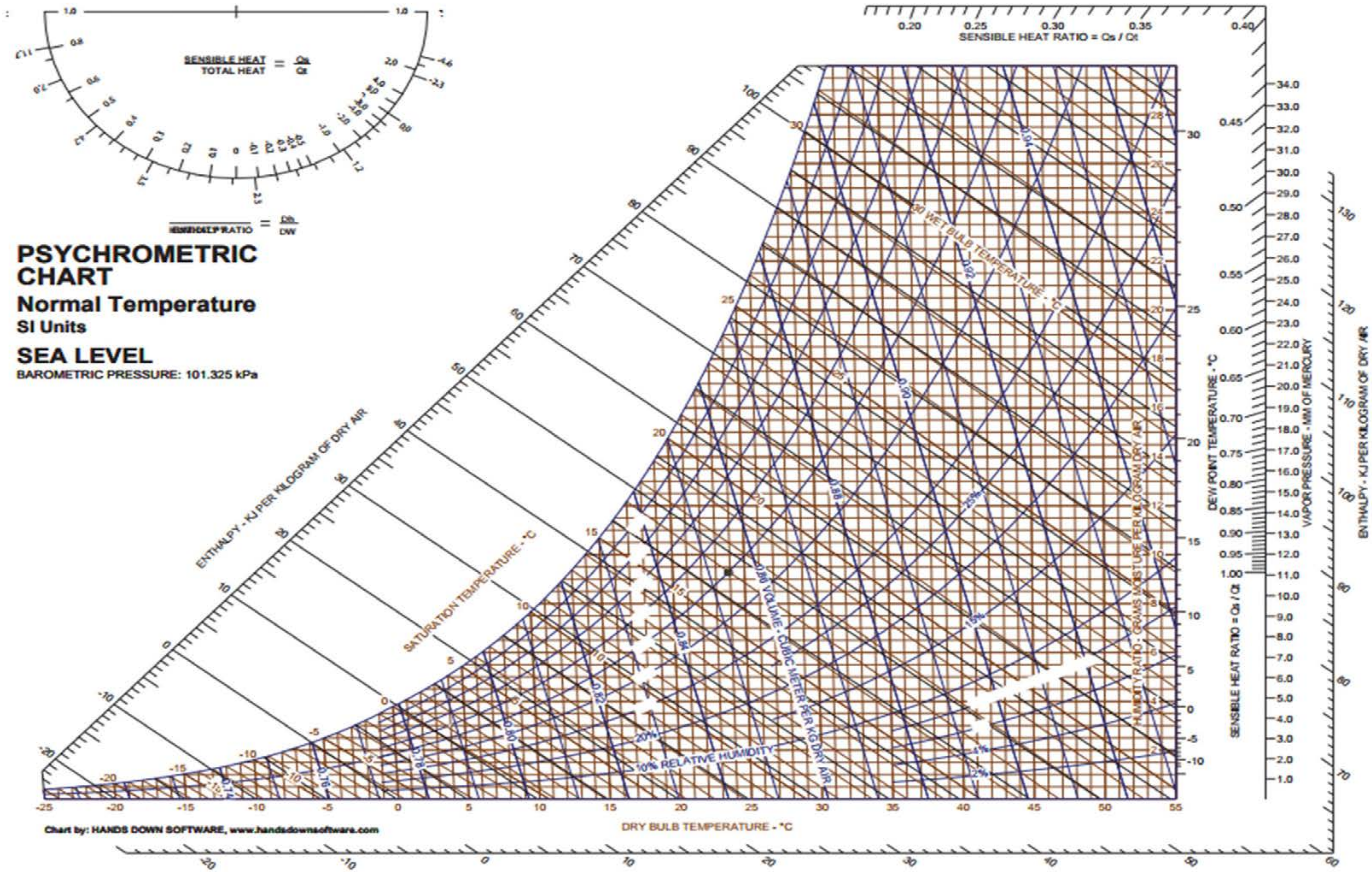
> - How can you use this information to help clients?
> - What is the main limitation to this methodology?

SIMPLE PAYBACK ANALYSIS

Investment ($30,000)	Yearly	Cumulative	Net Cost
Year 1	$5,100	$ 5,100	($24,900)
Year 2	$5,100	$10,200	($19,800)
Year 3	$5,100	$15,300	($14,700)
Year4	$5,100	$20,400	($ 9,600)
Year 5	$5,100	$25,500	($ 4,500)
Year 6	$5,100	$30,600	$ 600
Year 7	$5,100	$35,700	$ 5,700
Year 8	$5,100	$40,800	$10,800
Year 9	$5,100	$45,900	$15,900
Year 10	$5,100	$51,000	$21,000

PSYCHROMETRY

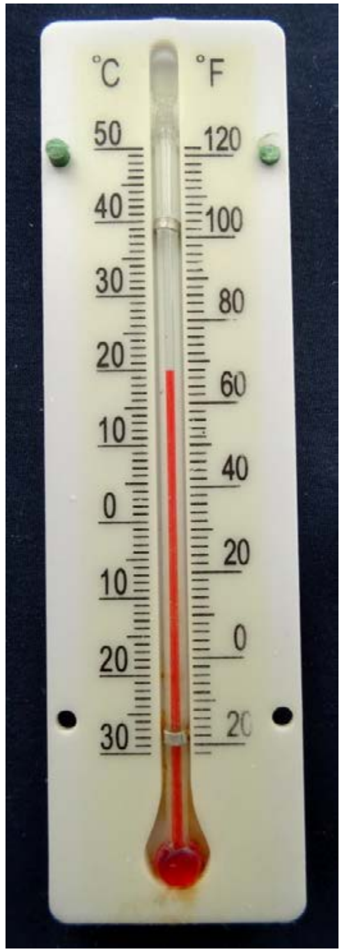
- The science of the physical laws and relationship of air/water vapor mixtures
- For conditioning of air systems, need to know:
  - The temperature and moisture content of air to be conditioned
  - The same properties of the air needed to produce the desired effect



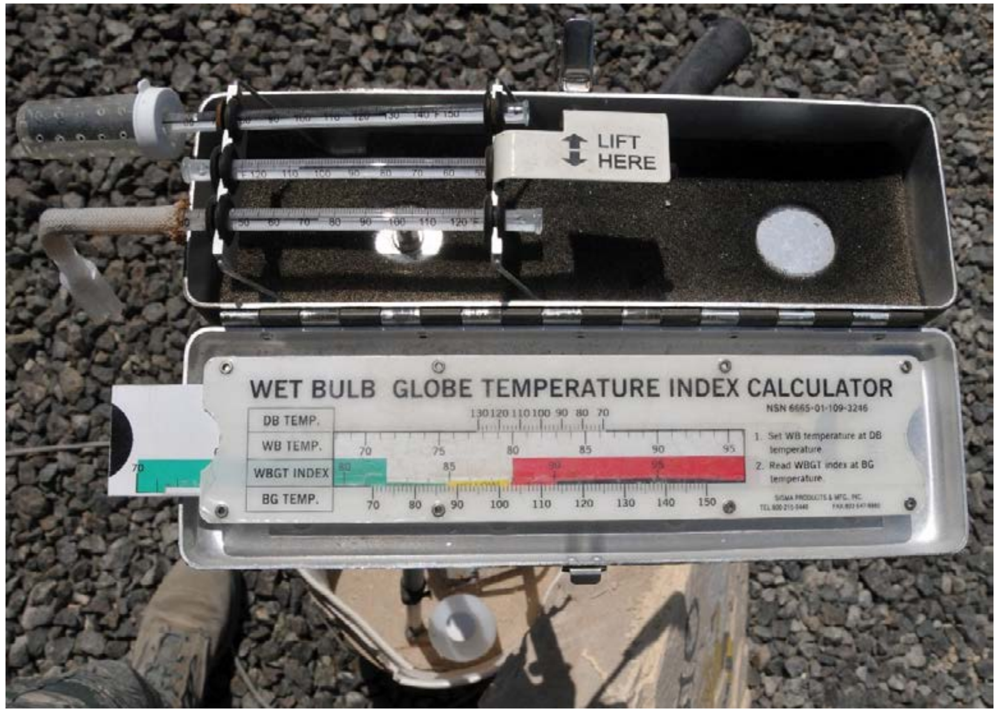
Public domain chart by Bob Hanna, courtesy Wikipedia

PROPERTIES OF AIR

- Dry-bulb temperature (DB)
- Wet-bulb temperature (WB)
- Dew point temperature (DP)
- Relative humidity (RH)
- Humidity ratio (W)
- Enthalpy (H)
- Specific Volume (ʋ)



Dry Bulb (DB)

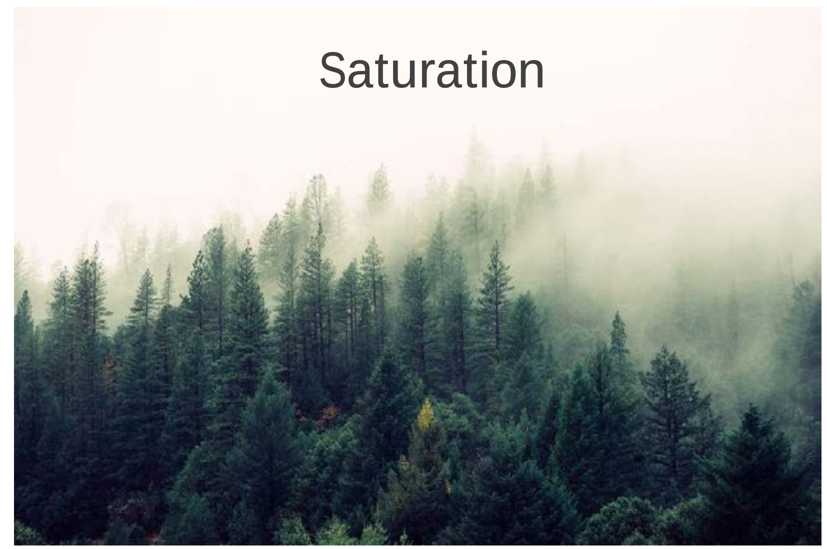


Wet Bulb (WB)

PROPERTIES OF AIR

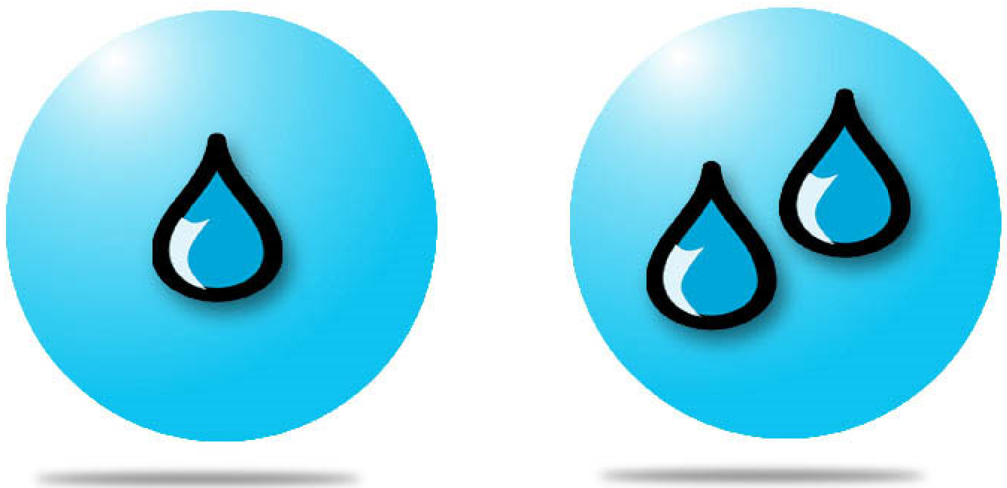
- Dew Point
  - Condensation occurs at the Dew Point Temperature (°F)
- Saturation
  - Fog: Dew Point = Wet Bulb = Dry Bulb

Condensation



RELATIVE HUMIDITY (RH)

$$\text{Relative Humidity (percentage)} = \frac{\text{Amount of moisture that a given amount of air is holding}}{\text{Amount of moisture that a given amount of air can hold}}$$



50% RH

100% RH → Saturated

HUMIDITY RATIO (W)

- Actual weight of water in an air – water vapor mixture
  – Pounds of moisture per pound of dry air
- 7000 grains of water in a pound

NOTE: At sea level one pound of 70°F air occupies approximately 13.5 cubic feet, and one grain of water in that air weighs approximately 0.0022oz or 0.000143lbs

ENTHALPY

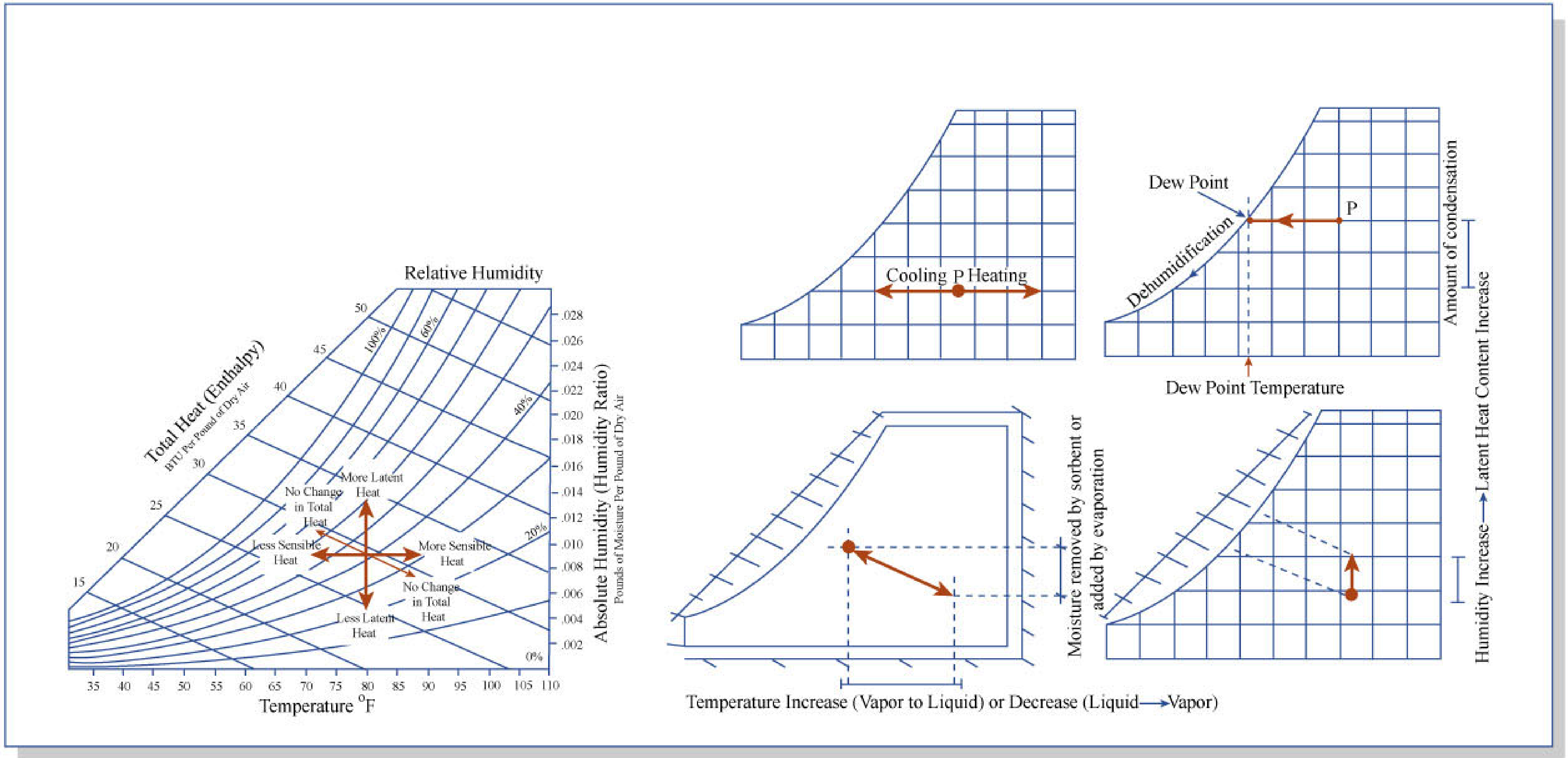
- The total internal heat energy in one pound of air (Btu/lb) at its present condition

$$Enthalpy(H) = Sensible\ Heat + Latent\ Heat$$

SPECIFIC VOLUME (υ)

- The volume of one lb. of dry air at a specific temperature and pressure
- As one lb. of air is heated, it occupies more space → specific volume increases

IMPACTS OF MOVING ALONG PSYCHROMETRIC CHART



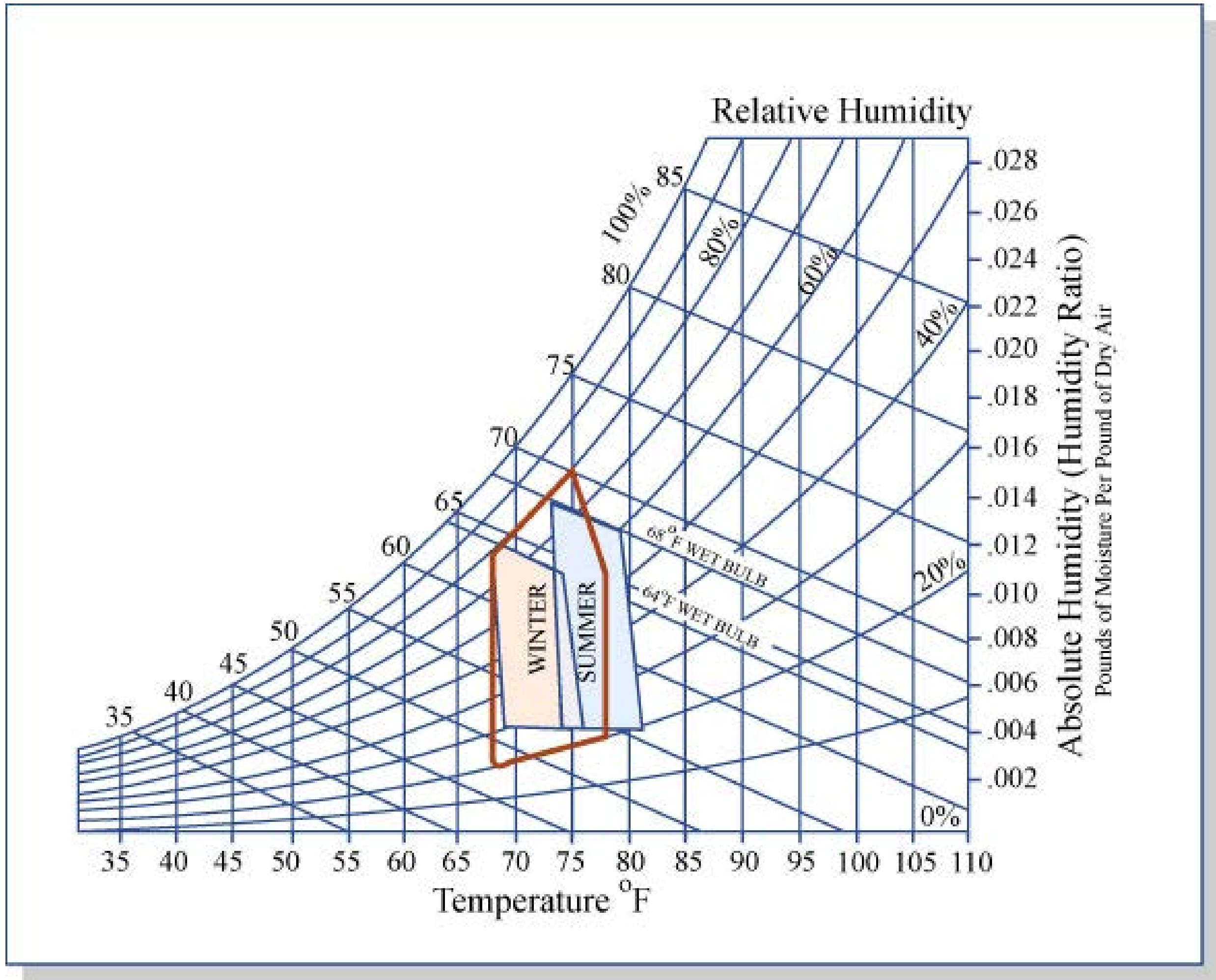
COMFORT FOR BUILDING OCCUPANTS

- Temperature is not the only factor affecting comfort
  - Even if temperature is in an acceptable range, one can still feel uncomfortable
- Variables that affect comfort:
  - Temperature (e.g., DB, WB, DP)
  - Airflow (e.g., FPM)
  - Humidity (e.g., RH, W)

COMFORT ZONE (ASHRAE STANDARD 55)

- Lower Limit:
  - 68°F @ 30% RH
- Upper Limit:
  - 79°F @ 60% RH

- Airflow < 10 fpm = stuffy
- Airflow > 50 fpm = drafty

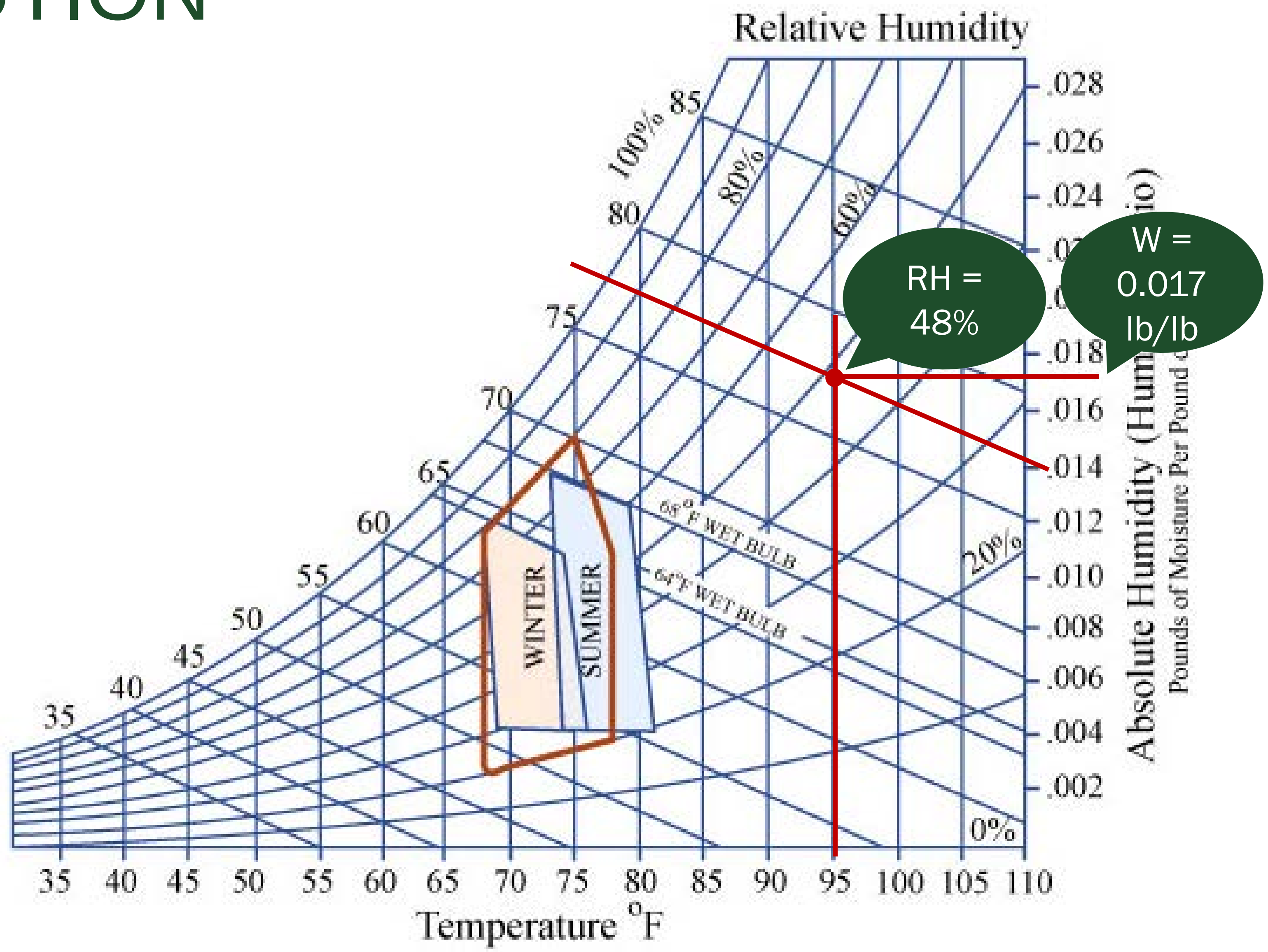


USING PSYCHROMETRIC CHART

- Summer Design Conditions
  - 95°F DB (dry bulb)
  - 78°F WB (wet bulb)

Find: Relative Humidity (RH) and Humidity Ratio (W)

SOLUTION

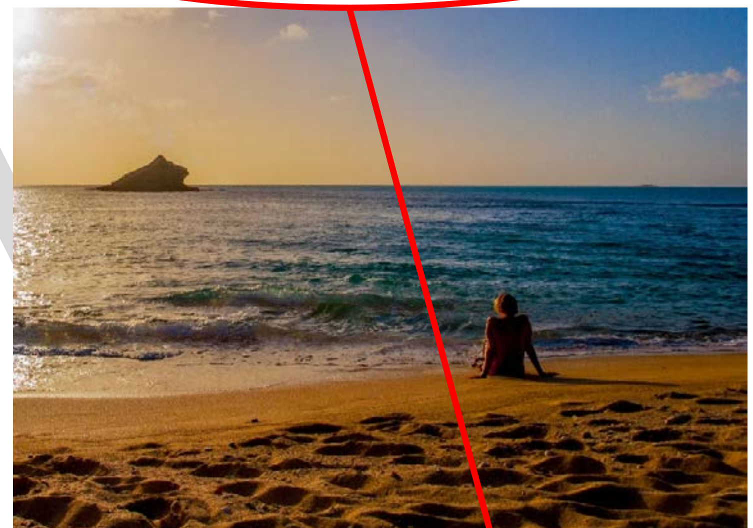


Relative Humidity
100%
80%
60%
20%
0%
85
80
75
70
65
60
55
50
45
40
35
68°F WET BULB
64°F WET BULB
WINTER
SUMMER
.028
.026
.024
.018
.016
.014
.012
.010
.008
.006
.004
.002
35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110
Temperature °F
Absolute Humidity (Hum
Pounds of Moisture Per Pound
RH = 48%
W = 0.017 lb/lb

CONDENSATION

Beverage 45ºF

Beach Conditions 92ºF
60% RH



$$From\ Psychrometric\ Chart: Outdoor\ Dew\ Point = 76°\mathrm{F}$$

$$Bottle\ Surface\ DB\ Temperature = 45°\mathrm{F}$$

$$\boldsymbol{Dew\ Point > Temp\ of\ Beverage\ \rightarrow Bottle\ "Sweats"}$$

CONDENSATION

Winter: Glass surface temperature = 40ºF

$$Outside\ DB\ Temperature = 40°\text{F}$$

Inside Design: 77ºF
30% RH

$$From\ Psychrometric\ Chart:$$
$$Interior\ Dew\ Point = 43°\text{F}$$

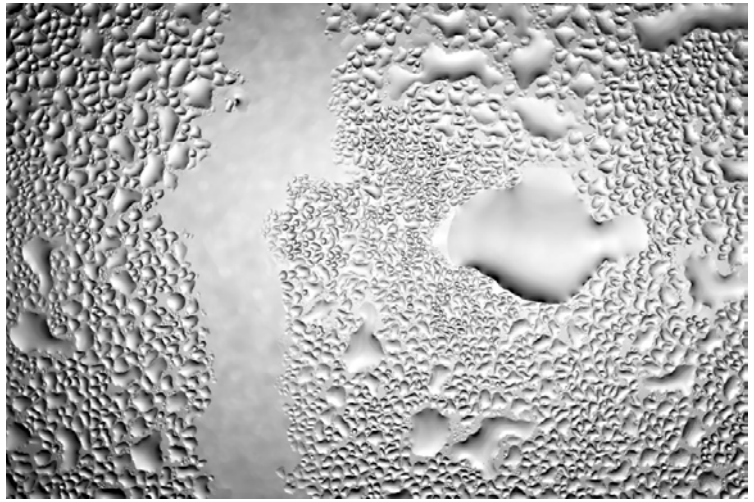
$$\boldsymbol{Interior\ Dew\ Point > Outside\ DB\ Temp \rightarrow Window\ "Foggy"}$$

SENSIBLE LOADS (HEAT)

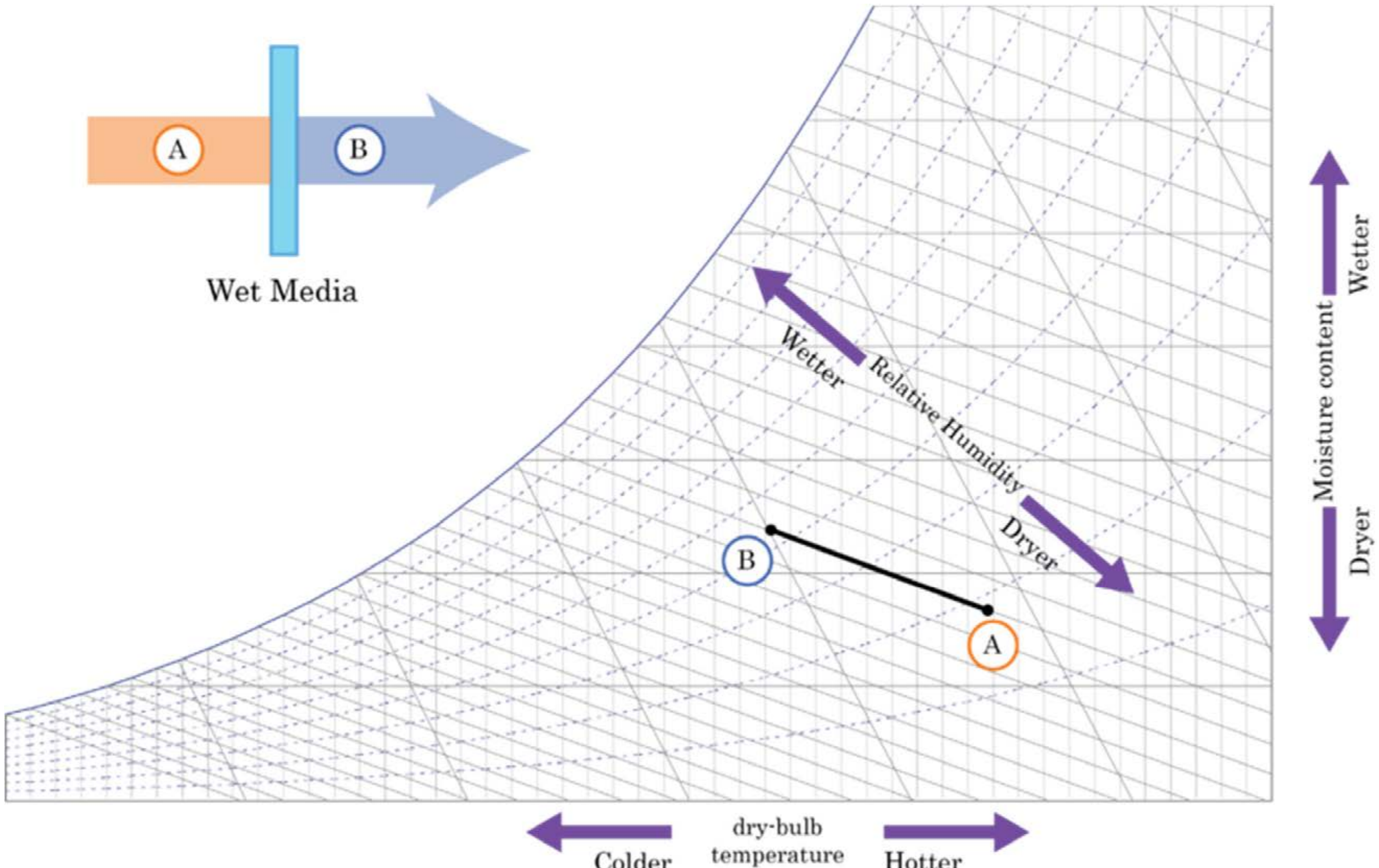
- Part of the load due to a temperature change
- Sources:
  - Energy consumption inside a building (e.g., cooking)
  - Heat transfer into building (conduction)
  - Air exchange with environment (infiltration)

LATENT LOADS (MOISTURE)

- Part of the load due to water vapor (Humidity)
- Sources:
  - Water vapor inside a building (e.g., shower)
  - Air exchange with the environment (infiltration & ventilation)



SENSIBLE AND LATENT LOAD EFFECTS



SENSIBLE AND LATENT HEAT LOADS

Load Components	Sensible Heat Load	Latent Heat Load
Conduction through roof, walls, windows, and skylights	✓	
Solar radiation through windows and skylights	✓	
Conduction through ceilings, partition walls, and floors	✓	
People	✓	✓
Lights/Electrical equipment	✓	
Clothes Washers and Dish Washers	✓	✓
Clothes Dryer	✓	
Shower/bath	✓	✓
Restaurant/kitchen appliances	✓	✓
Infiltration	✓	✓
Ventilation	✓	✓
Mechanical System heat gains (Motors, fans, equipment)	✓	

COOLING SYSTEMS

CON 371 – Mechanical and Plumbing Systems

LEARNING OUTCOMES

- By the end of this lesson, students will be able to:
  1. Calculate cooling loads due to heat gains to a space
  2. Describe the different refrigerant systems for cooling spaces
  3. Define the components and equipment of cooling systems

COOLING LOAD COMPONENTS

Factors that Influence HVAC Load				
FACTORS	HEATING		COOLING	
	Increases Load	Decreases Load	Increases Load	Decreases Load
Outside Temperature	X		X	
Infiltration	X		X	
Ventilation	X		X	
Solar Gain		X	X	
Radiant Heat Gain		X	X	
Heat from Occupants		X	X	
Heat from Lighting		X	X	
Heat from Equipment		X	X	
Heat from Process		X	X	
Humidity from People		X	X	
Humidity from Process		X	X	
Atmospheric Humidity		X	X	

COOLING LOADS CALCULATIONS

- Critical design conditions occur during peak occurrence of heat, humidity, solar effects, internal heat sources
  - Position of the sun
  - Building operations
- Heat Gains include:
  - Conduction
  - Convection
    - Infiltration
    - Ventilation
  - Solar Gains
  - People
  - Equipment

Rules of Thumb
1 Ton of Cooling = 12,000 Btuh
400 CFM = 1 Ton of Cooling (Sea level)
390 SF = 1 Ton of Cooling = 1 SF per CFM (Typical for office building)
Gas Fired/DX VAV System = $4,000 to $4,500 per Ton
20-30 BTU per SF of heating
2.4 GPM per Ton of cooling
3.0 GPM per ton of condenser water

CONDUCTION – WALLS AND ROOFS

$$\boldsymbol{Q = U \times A \times TETD}$$

$Q \ = \ Heat\ transfer(Btuh)$

$U \ = Heat\ Transfer\ Coefficient\ \left(\frac{Btu}{hr \times ft^2 \times \text{°F}}\right)$

$A \ = Area\ of\ Assembly\ (ft^2)$

$TETD = Total\ Equivalent\ Temperature\ Difference\ (\text{°F})$

- Conduction is proportional to
  - the difference in outside and inside temperature
  - The area in which heat is transferred
- R-Value = Resistance to heat transfer

U factor is an index of a construction's tendency to conduct heat.
U is the reciprocal of Thermal Resistance (R-value)

THERMAL RESISTANCE (R)

- Resistance to heat flow
- R-value is the temperature required to cause 1 Btuh to flow through 1 square foot of the material:
- $R = \frac{hr \times ft^2 \times °F}{Btu}$
- Set Btu, ft2, and hours to unity, the equation becomes:
- $R = \frac{1 \times 1 \times °F}{1} = °F$
- Practical applications:
  - Material rated at R19 requires 19°F to cause 1 Btuh of heat to flow through 1 ft^2
  - Material rated at R3 requires 3°F to cause 1 Btuh of heat to flow through 1 ft^2

The higher the R-value, the more resistance that material has to heat flow

TETD FOR FLAT ROOFS

- In calculating cooling loads, using the difference in temperature between the outside and inside does not take into account solar effects
  - TETD accounts for actual temperature difference and solar effects on the surface

			8am		10am		12pm		2pm		4pm		6pm		8pm		10pm		12am	
Roof Construction	Weight (lb/ft^2)	U-value	Dark	Light	Dark	Light	Dark	Light	Dark	Light	Dark	Light	Dark	Light	Dark	Light	Dark	Light	Dark	Light
Light Construction - Exposed to Sun																				
1" insulation + steel siding	7.4	0.213	28	11	65	31	90	48	95	53	78	45	43	27	8	6	1	1	-3	-3
2" insulation + steel siding	7.8	0.125	24	8	61	29	88	46	96	53	81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1" insulation + 1" wood	8.4	0.206	12	2	47	21	77	39	92	50	86	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2" insulation + 1" wood	8.5	0.122	8	0	41	18	72	36	90	48	88	40	65	38	30	19	9	7	1	0
1" insulation + 2.5" wood	12.7	0.193	2	-2	23	8	48	23	70	36	79	42	71	40	50	29	29	17	15	9
2" insulation + 2.5" wood	13.1	0.117	1	-2	19	6	43	20	65	33	76	41	72	40	53	31	33	20	18	11
Medium Construction - Exposed to Sun																				
1" insulation + 4" wood	17.3	0.183	5	0	14	5	31	14	49	24	62	32	65	35	56	31	41	24	29	17
2" insulation + 4" wood	17.8	0.113	6	1	13	4	28	12	45	22	58	30	63	34	56	31	43	25	32	18
1" insulation + 2" heavy weight concrete	28.3	0.206	4	-1	27	11	54	26	74	39	81	44	70	40	45	27	24	15	12	7
2" insulation + 2" heavy weight concrete	28.8	0.122	2	-2	23	9	49	23	70	36	79	43	71	40	49	29	28	17	15	9
4" light weight concrete	17.8	0.213	1	-3	28	11	59	28	82	43	88	48	74	42	44	27	19	12	6	4
6" light weight concrete	24.5	0.157	-2	-4	9	2	31	13	55	27	72	38	76	41	64	36	42	25	25	15
8" light weight concrete	31.2	0.125	6	2	6	1	16	6	32	14	49	24	61	32	34	34	55	31	41	24

TETD = 79°F for 1” ins. + 2.5” wood, dark color roof at 4pm

TETD FOR SUNLIT WALLS

	8am		10am		12pm		2pm		4pm		6pm		8pm		10pm		12pm	
Wall Orientation	Dark	Light	Dark	Light	Dark	Light	Dark	Light	Dark	Light	Dark	Light	Dark	Light	Dark	Light	Dark	Light
Wall Construction: 1" stucco + air space + 2" insulation (Weight = 29lb/ft^2; U = 0.11)																		
NE	27	16	31	18	26	17	24	17	24	18	23	17	20	15	17	13	15	11
E	32	18	41	24	37	22	29	30	28	20	26	19	23	16	20	14	18	13
SE	25	15	36	21	38	23	33	21	28	20	26	18	22	16	19	14	18	12
S	14	9	20	13	28	18	33	22	31	21	25	18	20	15	17	13	15	11
SW	17	11	20	13	24	16	34	22	42	27	41	26	28	19	20	14	18	12
W	17	11	20	13	24	16	30	20	42	27	48	30	33	22	22	15	19	13
NW	14	9	17	11	21	14	23	17	31	21	38	25	28	19	18	13	16	11
N	14	9	15	10	17	12	20	15	21	16	21	16	18	14	14	11	12	9
Wall Construction: 4" Face brick + air space + 4" heavyweight concrete (Weight = 70lb/ft^2; U = 0.28)																		
NE	16	11	18	12	20	13	22	14	23	15	24	16	24	16	23	16	22	16
E	19	13	21	14	25	16	29	17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SE	19	13	19	13	22	14	26	16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
S	16	12	15	11	16	11	18	12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SW	20	14	19	13	18	12	19	13	22	14	27	17	31	20	32	20	30	20
W	22	14	20	13	19	13	30	13	22	14	26	17	31	20	33	21	32	21
NW	18	12	16	11	16	11	17	11	18	12	21	14	25	17	27	18	26	18
N	13	10	12	9	13	9	13	10	15	11	16	12	18	13	18	14	18	14

TETD = 13°F for face brick-air space-concrete wall, west-facing, light exterior color, at 2pm

HEAT CONDUCTION EXAMPLE

- Sunlit Wall Section:
  - Summer Exterior Temp: $DB = 93°F$
  - Indoor Design: $DB = 75°F$
  - 100ft long; 10ft high
  - West-facing wall
  - 4” Face brick (light color) + air space + 4” concrete
  - Time is 2pm
- Determine Heat Gain

U = 0.28

TETD = 13°F

Wall Type: 4” face brick + air space + 4” concrete

$$Q = (0.28)(100ft \times 10ft)(13°\mathrm{F}) = 3{,}640\ Btuh$$

SOLAR GAIN

- Factors:
  - Direction window faces (N, NW, W, SW, S, SE, E, NE)
  - Window arrangement (Fenestration)
  - Time of day (Morning vs. Afternoon)
  - Month of the year (January vs. August)
  - Latitude (Sun light direction)
  - Interior partition wall construction (Thermal mass)
  - Exterior surface absorptivity (Color)
  - Type of floor covering
  - Shading devices

- Solar effects due to gain through windows/skylights

$$Q = (U \times A \times TD) + (SC \times A \times SHGF)$$

$SHGF = Solar\ Heat\ Gain\ Factor\ \left(\frac{Btuh}{ft^2}\right)$

$SC = Shading\ Coefficient\ (dimensionless)$

SOLAR HEAT GAIN FACTOR (SHGF)

- Amount of solar heat entering a window at a given latitude, time of year, and orientation

	Solar Heat Gain Factor (SHGF) Btuh/ft^2									
	Solar Time	N	NE	E	SE	S	SW	W	NW	Horizontal
January 21 (Winter)	8am	5	17	111	133	75	5	5	5	13
	10am	16	16	123	241	213	51	16	16	96
	12pm	19	19	20	179	254	179	20	19	133
	2pm	16	16	16	51	21	241	123	16	96
	4pm	5	5	5	5	75	133	111	17	13
	Solar Time	N	NE	E	SE	S	SW	W	NW	Horizontal
April 21 (Spring)	6am	11	72	88	52	5	4	4	4	11
	8am	22	128	225	189	41	21	21	21	124
	10am	30	37	153	194	121	32	30	30	218
	12pm	33	33	36	108	155	108	36	33	253
	2pm	30	30	30	32	121	194	153	37	218
	4pm	22	21	21	21	41	189	225	128	124
	6pm	11	4	4	4	5	52	88	72	11
	Solar Time	N	NE	E	SE	S	SW	W	NW	Horizontal
July 21 (Summer)	6am	37	125	137	68	10	10	10	10	31
	8am	28	148	216	160	29	26	26	26	145
	10am	35	56	146	159	80	36	35	35	231
	12pm	38	38	41	80	109	80	41	38	282
	2pm	35	35	35	36	80	159	146	56	231
	4pm	28	26	26	26	29	160	216	148	145
	6pm	37	10	10	10	10	68	137	125	31
	8pm	0	0	0	0	0	0	2	1	0
	Solar Time	N	NE	E	SE	S	SW	W	NW	Horizontal
October 21 (Fall)	6am	1	20	45	41	12	1	1	1	3
	8am	10	49	173	187	88	10	10	10	43
	10am	21	22	139	238	196	38	21	21	140
	12pm	24	24	26	165	234	165	26	24	177
	2pm	21	21	21	39	196	238	139	22	140
	4pm	10	10	10	10	88	187	173	49	43
	6pm	1	1	1	1	12	41	45	20	3

SHADING COEFFICIENT (SC)

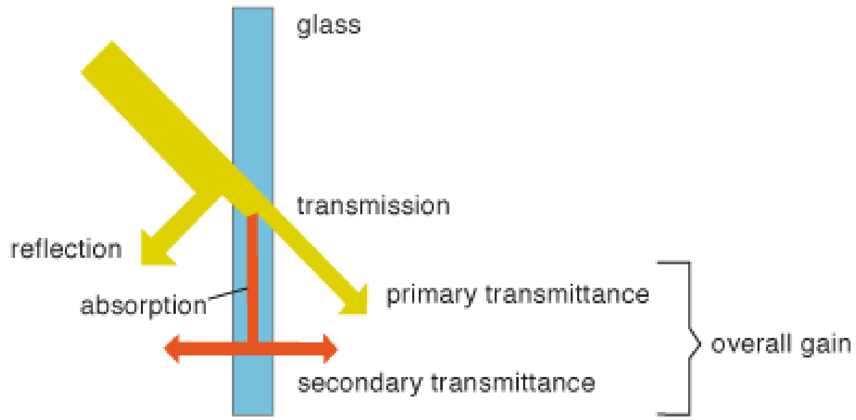
- The ratio between solar heat admitted through a given type of glass to that would be admitted through single-strength clear glass under identical conditions

Type of Glass	U-Factor	SC	SHGC	VT	VT/SHGC Ratio
Single strength clear glass	1.05	1.00	0.86	0.90	1.05
1″ insulating glass, 1/4″, clear	0.47	0.80	0.70	0.79	1.13
ANSI/ASHRAE/IES Std. 90.1-2013 Zone 1 (southern US) minimum performance	0.50	0.29	0.25	0.28	1.10
ANSI/ASHRAE/IES Std. 90.1-2013 Zone 4 (middle US) minimum performance	0.35	0.46	0.40	0.44	1.10
ANSI/ASHRAE/IES Std. 90.1-2013 Zone 6 (northern US) minimum performance	0.32	0.46	0.40	0.44	1.10
Solar control double glazed clear with low-E coating	0.29	0.44	0.44	0.0.7	1.84
Low solar gain double glazed reflective with low-E coating and argon fill	0.24	0.20	0.17	0.14	0.82

SOLAR GAIN EXAMPLE

- Window Section:
  - Outside Temperature: $DB = 93°F$
  - Indoor Design Temperature: $DB = 75°F$
  - Window: Solar control double glazed clear with low-e coating
  - Window is 3ft x 5ft
  - East facing in April at 2pm
  - Determine Solar Gain

$U = 0.29$ (From SC table)
$A = 3 \times 5 = 15ft^2$
$T = 93 - 75 = 18°F$
$SC = 0.44$
$SHGF = 30\ btuh/ft^2$



$$Q = (0.29)(15ft^2)(18°F) + (0.44)(15ft^2)(30) = 276\ Btuh$$

CALCULATING INFILTRATION

- Air infiltration is typically lower in hot weather
  - Winds are warmer, lower temperature difference
- Humidity needs to be considered
  - Warm air holds more moisture than cool air

Measured in lbs of moisture per one lb of dry air

Equations with Air Constants

$$Q_{Sensible} = 1.1 \times CFM \times TD$$

$$Q_{Latent} = 4{,}840 \times CFM \times (W_{final} - W_{initial})$$

<u>Crack Method</u>

$$CFM = \frac{LF \times CFH}{60}$$

<u>Air Change Method</u>

$$CFM = \frac{Vol \times RCH}{60}$$

CALCULATING INFILTRATION – AIR CHANGES METHOD

- 20ft x 60ft x 10ft room
- Summer: 0.50 RCH
- IA conditions: DB=72°F at 50% RH → $W = 0.0084$
- OA conditions: DB=95°F at WB = 73°F → $W = 0.0124$
- What is the heat gain due to infiltration?

$$Q_{Sensible} = (1.1)\frac{(20 \times 60 \times 10)(0.50)}{60}(23°\text{F}) = 2{,}530 \text{ Btuh}$$

$$Q_{Latent} = (4{,}840)\frac{(20 \times 60 \times 10)(0.50)}{60}(0.0124 - 0.0084) = 1{,}936 \text{ Btuh}$$

$$Q_{Total} = 2{,}530 + 1{,}936 = 4{,}466 \text{ Btuh}$$

CALCULATING VENTILATION

- Using outside air for A/C results in sensible and latent loads

Equations with Air Constants

$$Q_{Sensible} = 1.1 \times CFM \times TD$$

$$Q_{Latent} = 4{,}840 \times CFM \times (W_{final} - W_{initial})$$

<u>Air Change Method</u>

$$CFM = \frac{Vol \times RCH}{60}$$

<u>Occupancy Method</u>

$$CFM = \frac{CFM}{Person} \times No.\,of\ Persons$$

DETERMINING VENTILATION REQUIREMENTS

Minimum Ventilation Rates in Breathing Zone				
			Default Values	
Occupancy Category	People Outdoor Air Rate (CFM/person)	Area Outdoor Air Rate (CFM/ft^2)	Occupant Density (# people/1000ft^2)	CFM/person
Classrooms (ages 5–8)	10	0.12	25	15
Classrooms (age 9 plus)	10	0.12	35	13
Lecture hall (fixed seats)	7.5	0.06	150	8
Office space	5	0.06	5	17
Reception areas	5	0.06	30	7
Main entry lobbies	5	0.06	10	11
Libraries	5	0.12	10	17
Retail sales	7.5	0.12	15	16
Gym, stadium (play area)	—	0.30	30	—
Spectator areas	7.5	0.06	150	8

VENTILATION – OCCUPANCY METHOD

- 1,500 SF Retail store
  - From Previous Slide: Occupancy = 15people/1,000SF → 22 people total
  - From previous slide: CFM/person = 16
- IA conditions: DB=75°F at 40%RH → $W = 0.0074$
- OA conditions: DB= 95°F at WB=80°F → $W = 0.0185$

How many Btuh's gained due to ventilation?

$$Q_{Sensible} = (1.1)\left(\frac{16CFM}{person}\right)(22\ persons)(20°\mathrm{F}) = 7{,}744\ Btuh$$

$$Q_{Latent} = (4{,}840)\left(\frac{16CFM}{person}\right)(22\ persons)(0.0185 - 0.0074) = 18{,}910\ Btuh$$

$$Q_{Total} = 7{,}744 + 18{,}910 = 26{,}654\ Btuh$$

OTHER HEAT GAINS

- People
  - Sensible and Latent loads
- Lighting
  - Sensible loads
- Restaurant Equipment
  - Sensible and Latent loads
- Office Equipment
  - Sensible loads

SYSTEM HEAT GAINS

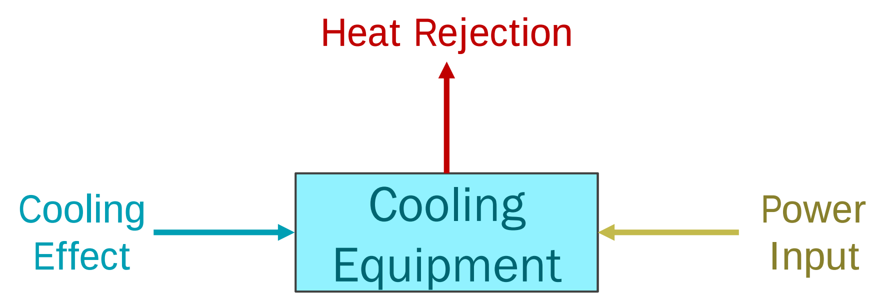
- Fan Motors
- Fan blades
- Duct friction
- Ductwork
  - If insulated – Add 1-3% depending of the extent of the duct work
  - Not insulated – Add 10 – 15% depending on extent of duct work or climate (best to calculate gain by conduction)
  - Duct leakage – If outside of conditioned space add 5%

AIR CONDITIONING

- Definition
  - Process of treating air in an indoor environment to establish and maintain required standard of temperature, humidity, cleanliness, and motion
- Capacity measured in Tons
  - 1 Ton of A/C = 12,000 Btuh
- Proper sizing of cooling system is critical
  - Oversize = Short cycling
  - Undersize = Cannot handle max loads

COEFFICIENT OF PERFORMANCE (COP)

- The energy efficiency of refrigeration processes
  - The Higher the value, the lower the energy consumption
- Vapor compression refrigeration cycle
  - COP Ranges from 2.5 to 7
- Absorption refrigeration cycle
  - COP ranges from 0.5 to 2.0



$$COP = \frac{Cooling\ Effect}{Power\ Input}$$

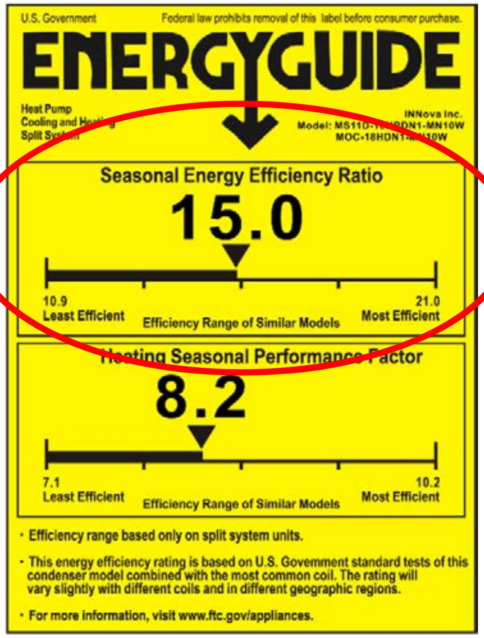
EXAMPLE

An A/C system can remove 100,000 Btuh while using 10 kW of electricity. What is the COP?

$$1\ kW = 3{,}412\ Btuh$$

$$COP = \frac{100{,}000\ Btuh}{10kW \times \left(3{,}412\ {}^{Btuh}/_{kW}\right)} = 2.93$$

SEASONAL ENERGY EFFICIENCY RATIO (SEER)



- Number of Btu's removed by 1 watt of electricity (Btu/Wh)
  - Index of MPG for A/C
  - Rating typically range from 10 – 18 SEER
  - Water cooled condensers can achieve higher SEER

EXAMPLE

An A/C unit removes 180 million Btu's and uses 12,000 kWh of electricity during the summer season. What is the SEER?

$$SEER = \frac{180{,}000{,}000\ Btu}{12{,}000kWh\ \times\ 1{,}000\ {}^{W}/_{kW}} = 15.0\ {}^{Btu}/_{Wh}$$

REFRIGERATION SYSTEMS

- Refrigeration systems
  - Vapor Compression
  - Absorption
  - Evaporative Cooling

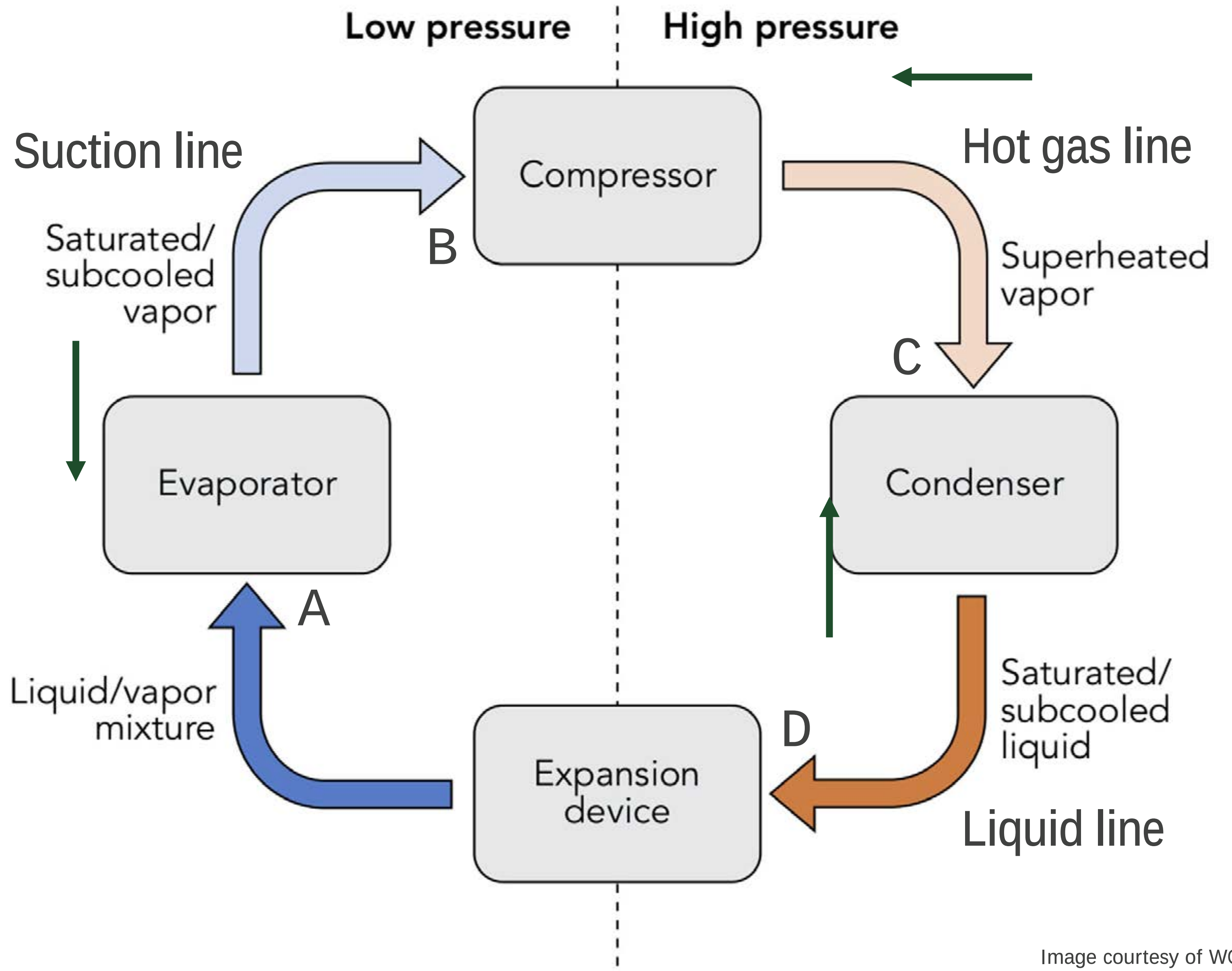
Used for different applications and climates

REFRIGERATION SYSTEMS: EFFECTS OF PRESSURE

- Increase in pressure on a refrigerant
  - Increased boiling, condensing, and saturation points
  - Converts liquid to gas/vapor
- Decrease in pressure on a refrigerant
  - Decreased boiling, condensing, and saturation points
  - Converts gas/vapor back to liquid

VAPOR COMPRESSION REFRIGERATION SYSTEM

[YouTube Video: Vapor Compression Refrigeration Cycle]

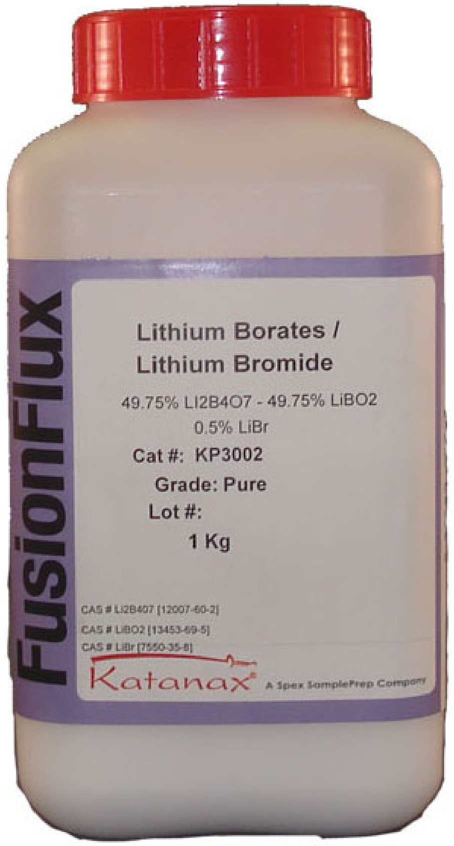


ABSORPTION REFRIGERATION CYCLE

Refrigerant = Distilled water

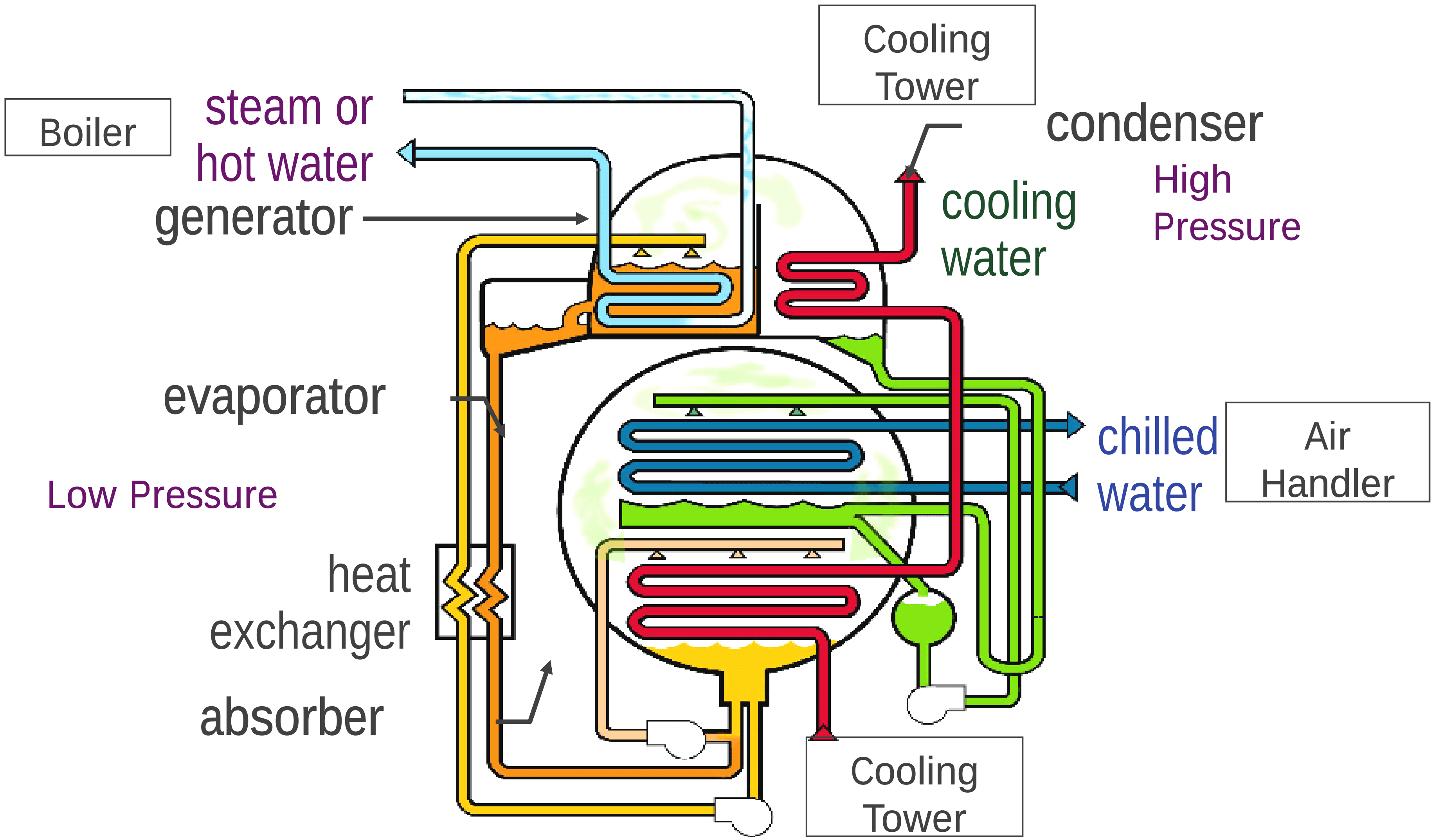
- Stable
- Nontoxic
- Low cost
- Readily available
- Environmentally friendly
- High latent heat of vaporization

- Absorbent = Lithium Bromide (LiBr)
  - High affinity for water
  - Higher boiling point than water
  - Non-toxic



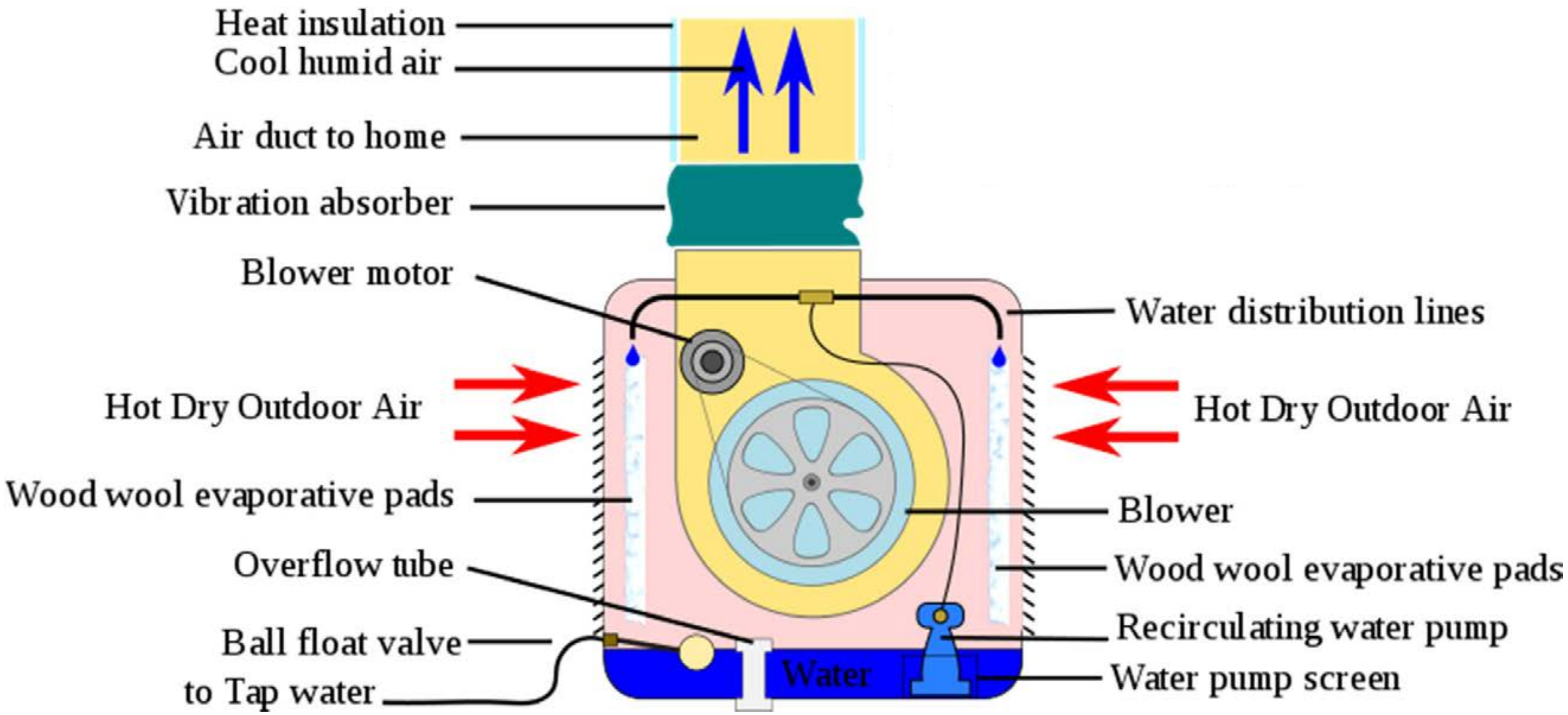
ABSORPTION REFRIGERATION CYCLE

YouTube Video: [How Absorption Chillers Work]



EVAPORATIVE COOLING

- Economical alternative for arid climates (Swamp Coolers)



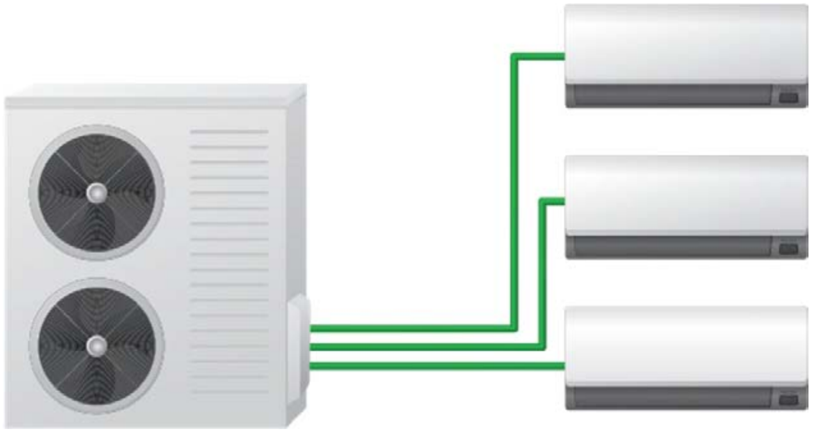
COOLING SYSTEMS – SPLIT SYSTEM

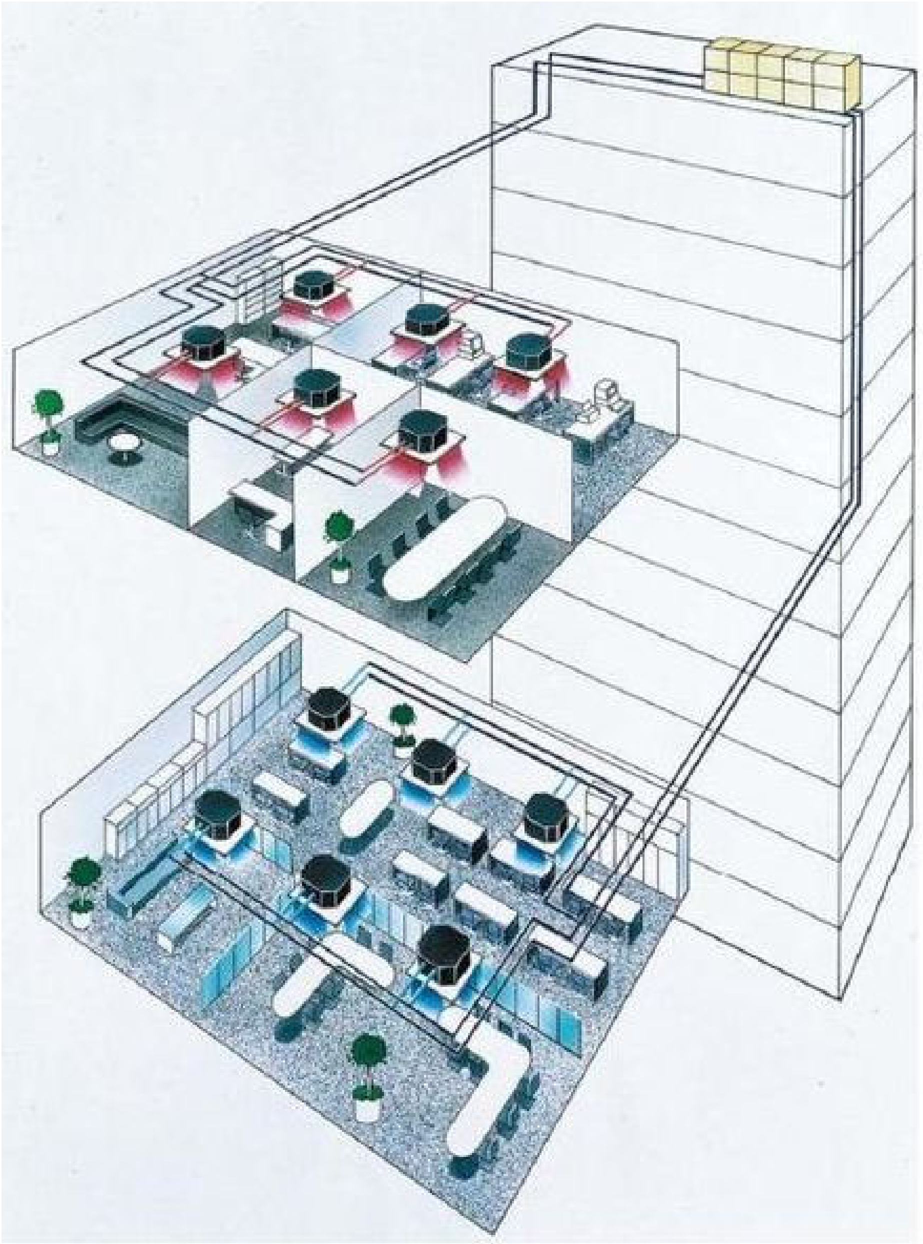
- Direct Expansion (DX)
- Uses refrigerant
- Evaporator coil inside, condenser outside

Condensing units outside a building

VRF SYSTEMS

- Variable Refrigerant Flow (VRF) Heat Pump and Heat-Recovery Systems
  - Serves multiple DX fan coils
  - Allows for better individual room controls





DX VS. CHILLERS

Direct Expansion

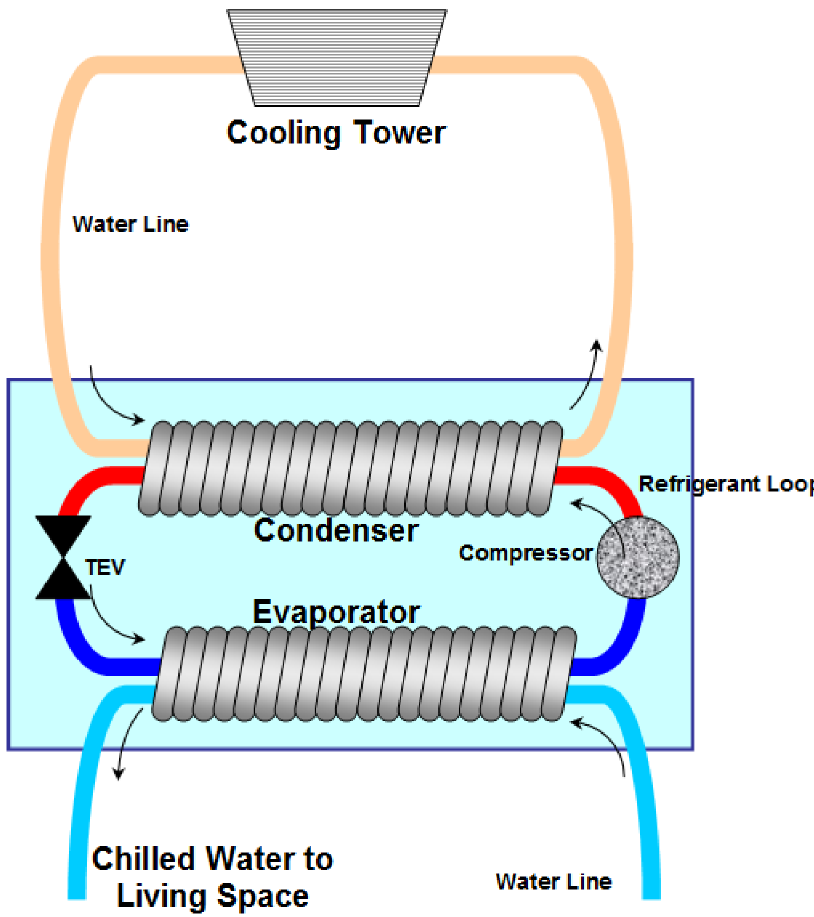
- Less Expensive Installation
- Serves one A/C unit
- Sized for accumulated peak design load
- Louder and more visible
- Extensive external refrigerant piping and valves
- Refrigerant is expensive and harmful to environment

Chilled Water

- More Expensive Installation
- Serves multiple A/C units
- Sized for net demand load
- Quieter and less visible
- Confines refrigerant to less equipment
- More flexibility for rearrangement/expansion of facility

COMPRESSION CYCLE CHILLERS

Type	Compressor	Operations
Reciprocating	Positive displacement using two or more cylinders	- Operates above atmospheric pressure - Noisy - Energy inefficient - Not used in new applications
Scroll	A rotating fixture compresses refrigerant against a stationary elliptical assembly	- Longer component life - Low noise - Efficient performance w/ digital unloading - Compact, small footprint
Rotary Helical	Screw-type, consisting of either one or two intermeshing helical grooved rotors	- Operates above atmospheric pressure - Low vibration - Noisy
Centrifugal	Turbo-compressors with impellers to draw in refrigerant	- Most energy efficient - Most reliable - Most expensive - Relatively quiet



COMPRESSION CYCLE CHILLERS

Air-Cooled Chiller with R-410A refrigerant scroll compressor
SIZE: 15-175 tons

Water-Cooled Chiller with R-134A centrifugal compressor
SIZE: up to 8,000 tons

Water-Cooled Chiller with R-410A refrigerant scroll compressor
SIZE: Up to 2,000 tons

ABSORPTION CYCLE CHILLERS

Uses gas combustion or hot-process waste gas as energy source

Direct-Fired
SIZE: up to 1,500 tons

Two-Stage Indirect-Fired
(Higher COP than single-stage)
SIZE: up to 3,000 tons

Uses steam or very hot water as energy source

HEAT REJECTION

Type	Capacity Range, Tons	Airflow, CFM per Ton	kW Input per Million (MM) Btuh	Applications
Air-cooled				
Air-cooled condensers (propeller fans)	3 – 150	500 – 700	9.0 – 12.0	Commercial cooling systems where towers are not practical and for year-round systems where freezing of cooling towers is difficult to control, as in extreme climates.
Dry coolers (propeller fans)	3 – 65	1000 – 1400	10.0 – 13.0	Can be used to cool condenser water or to directly cool chilled water in northern climates; not economical in southern climates.
Water-Cooled Cooling Towers				
Packaged induced draft (propeller fan)	5 – 1600	200 – 250	2.0 – 3.0	Ideal for small to large cooling plants. Somewhat less expensive than built-up towers, but usually have a shorter life span.
Packaged forced draft (Centrifugal fan)	10 – 400	200 – 250	4.0 – 6.0	Ideal for small to large cooling plants. Somewhat less expensive than built-up towers, but usually have a shorter life span.
Field-erected induced draft (propeller fans)	200 – 1800	200 – 250	1.5 – 2. 0	For use with medium to large water-cooled systems. Towers can be built up to 20,000 tons per cell; however, the most commonly used pre-engineered sizes range from 200 to 1800 tons.
Water-spray type of fluid coolers (centrifugal fans)	5 – 150	500 – 700	14.0 – 18.0	Minimizes water treatment requirements. Eliminates condenser freeze protection when used with water glycol solution. Can be used for direct chilled-water cooling during cold weather.

HEAT REJECTION – COOLING TOWERS

- Produce water at appropriate temps for condensing by evaporation
  - Circulated water is evaporated to cool the remaining water
- Capable of producing water temps 10°F cooler than DB temps

The cooling tower for the West Ford Flat power plant, which is part of The Geysers, the world's largest geothermal power development.

HEAT REJECTION: AIR-COOLED VS. WATER-COOLED

Air-Cooled Systems

- Uses air to cool and condense
- Lower installation costs
- Higher energy costs
- No water freezing issues
- Water treatment not required
- No water drift concerns
- No condensing water pump
- Lower capacity range

Water-Cooled Systems

- Uses water to cool and condense
- Higher installation costs
- Lower energy costs (more efficient)
- Concerns for freezing in extreme climates
- Elaborate treatment and filtration of water
- Pumps needed
- Higher capacity range

HEATING SYSTEMS AND EQUIPMENT

CON 371 – Mechanical and Plumbing Systems

LEARNING OUTCOMES

By the end of this lesson, students will be able to:

1. Calculate heating loads due to heat losses to a space
2. Evaluate the different heat sources and fuel selections available for heating
3. Explain the equipment for different heating systems

HEATING LOAD COMPONENTS

Factors that Influence HVAC Load				
FACTORS	HEATING		COOLING	
	Increases Load	Decreases Load	Increases Load	Decreases Load
Outside Temperature	X		X	
Infiltration	X		X	
Ventilation	X		X	
Solar Gain		X	X	
Radiant Heat Gain		X	X	
Heat from Occupants		X	X	
Heat from Lighting		X	X	
Heat from Equipment		X	X	
Heat from Process		X	X	
Humidity from People		X	X	
Humidity from Process		X	X	
Atmospheric Humidity		X	X	

HEATING LOADS CALCULATIONS

- Heat transfers by:
  - Conduction – Heat transfer in solids
    - Walls, windows, ceilings, roofs
  - Convection – Heat transfer in liquids (and air)
    - Infiltration, ventilation
  - Radiation – Heat transfer through a space with or without air

Public domain photo by Moussa, Courtesy Wikimedia Commons

HEAT LOSS - CONDUCTION

$$Q = U \times A \times TD$$

- $Q \;=\; Heat\, transfer(Btuh)$
- $U \;= Heat\, Transfer\; Coefficient\, \left(\frac{btu}{hr \times ft^2 \times °\mathrm{F}}\right)$
- $A \;= Area\; of\; Assembly(ft^2)$
- $TD = Temperature\; Difference\; (°\mathrm{F})$

U factor is an index of a construction's tendency to conduct heat. U is the reciprocal of Thermal

THERMAL RESISTANCE (R)

- Resistance to heat flow
- R-value is the temperature required to cause 1 Btuh to flow through 1 square foot of the material:
- $R = \frac{hr \times ft^2 \times °\mathrm{F}}{Btu}$
- Set Btu, ft^2, and hours to unity, the equation becomes:
- $R = \frac{1 \times 1 \times °\mathrm{F}}{1} = °\mathrm{F}$
- Practical applications:
  - Material rated at R - 19 requires 19°F to cause 1 Btuh to flow through 1 ft^2
  - Material rated at R - 3 requires 3°F to cause 1 Btuh to flow through 1 ft^2

The higher the R-value, the more resistance that material has to heat flow

EXAMPLE R-VALUES: BUILDING MATERIALS

	Thermal Resistance (R)	
Material	(ft^2 – °F) per Inch-Btuh	(ft^2 – °F) per Btuh
Gypsum board, 1/2″	—	0.45
Plywood, 1/2″	—	0.62
Plywood, 3/4″	—	0.93
OSB	0.9	—
3-1/2″ fiberglass batt	—	13.00
Fiberglass	4.00	—
Expanded polyisocyanurate	7.20	—
Expanded polyurethane	6.25	—
Expanded polystyrene	4.00	—
Face brick	0.17	—
6″ concrete block	—	1.20
8″ concrete block	—	1.35
12″ concrete block	—	1.45
Stucco/plaster	0.1	—
Concrete (140 lb./ft^3)	—	0.10
Concrete, light weight	—	0.30
Asphalt shingle roofing	—	0.44
Wood shingle roofing	—	0.80
Builtup roofing (3/8″)	—	0.33
Aluminum siding	—	0.61
Framing lumber	1.00	—
Outside air film	—	0.17
Inside air film, horizontal heat flow	—	0.68
Inside air film, heat flow up	—	0.61
Inside air film, heat flow down	—	0.92

R-VALUES: AIR FILM

- Film of air clings to any surface
- Air film has a resistance to heat flow
  - Depends on thickness of air film
    - Still Air = thick air film (Inside room)
    - Air with wind = less thickness (Outside air)
- Orientation of heat flow
  - Up, down, horizontal

	Resistance
Item	($ft^2 - °F$) per Btuh
Outside air film	0.17
Inside air film, horizontal heat flow	0.68
Inside air film, heat flow up	0.61
Inside air film, heat flow down	0.92

THERMAL RESISTANCE AND CONDUCTANCE

- Outdoor temperature = 10°F
- Indoor temperature = 75°F
- Room Dimension = 50ft x 20 ft
- Find the u-value
- Find the heat loss due to conductance

Thermal Resistance (R)

Outside air film	0.17
AL siding (hollow back)	0.61
8" concrete block	1.35
R13 insulation board	13.00
½"gypsum board	0.45
indoor-air film	0.68
R_{total}	16.26

$$U = \frac{1}{R_{total}} = \frac{1}{16.26} = 0.062$$

$$Q = (0.062)(50ft \times 20ft)(75°F - 10°F) = 4{,}030\ btuh$$

WINTER INFILTRATION

- Two Methods: Crack method and Room change per hour (RCH) method

Equations with Air Constants

$$Q_{Sensible} = 1.1 \times CFM \times TD$$

$$\cancel{Q_{Latent} = \ldots M \times \Delta W}$$

Winter infiltration typically only concerned with sensible loads

<u>Crack Method</u>

$$CFM = \frac{LF \times CFH/LF}{60min/hr}$$

<u>Air Change Method</u>

$$CFM = \frac{Vol \times RCH}{60min/hr}$$

CRACK METHOD

Lower the pressure difference, the tighter the construction

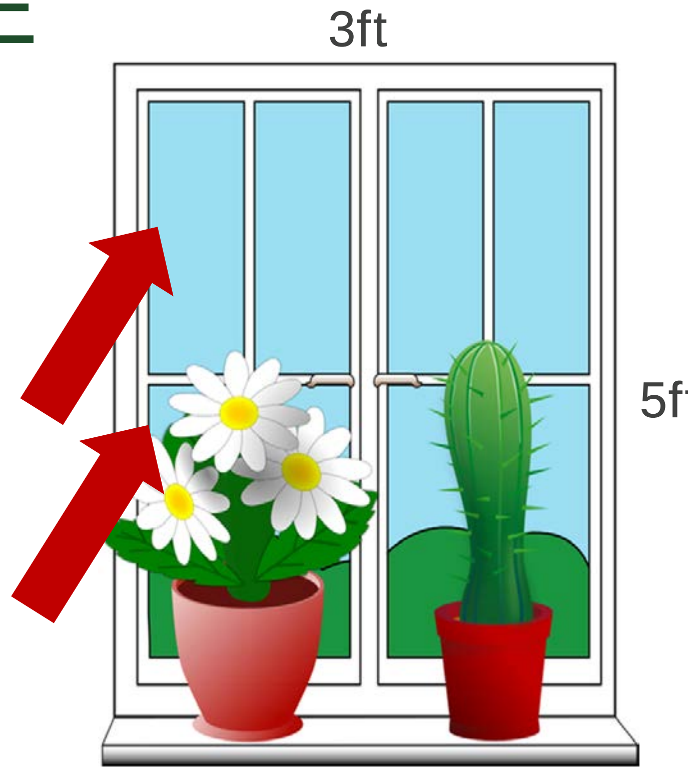
		Pressure Difference		
Type	Description	0.10	0.20	0.30
Wood, double hung window	Weather-stripped or non-weather-stripped, loose fit	77 CFH/LF	122 CFH/LF	150 CFH/LF
	Non-weather-stripped, average fit	27 CFH/LF	43 CFH/LF	57 CFH/LF
	Weather-stripped, average fit	14 CFH/LF	23 CFH/LF	50 CFH/LF
Frame-wall leakage	Around frame in masonry wall, not caulked	17 CFH/LF	26 CFH/LF	34 CFH/LF
	Around frame in masonry wall, caulked	3 CFH/LF	5 CFH/LF	6 CFH/LF
	Around frame in wood framed wall	13 CFH/LF	21 CFH/LF	29 CFH/LF

$$Q_{Sensible} = 1.1 \times CFM \times TD$$

$$CFM = \frac{LF \times \frac{CFH}{LF}}{60min/hr}$$

CRACK METHOD EXAMPLE

- Given:
  - 3’ x 5’ Double Hung Window
  - Wood window, wood framing
  - No added humidification
  - Inside conditions: $DB = 75°F$
  - Outside conditions: $DB = -5°F$
  - Tight construction (Pressure difference = 0.10)



$LF = 3 + 3 + 5 + 5 = 16LF$

How many Btuh’s are lost due to frame wall infiltration?

$$Q_{Sensible} = (1.1)\left(16LF \times \frac{13CFH/LF}{60min/hr}\right)(80°F) = 305\ Btuh$$

WINTER VENTILATION

- Occupancy method
- Air change per hour (RCH) method

Equations with Air Constants

$$Q_{Sensible} = 1.1 \times CFM \times TD$$

$$Q_{Latent} = \cancel{4{,}84 \ldots \times \Delta W}$$

<u>Air Change Method</u>

$$CFM = \frac{Vol \times RCH}{60}$$

<u>Occupancy Method</u>

$$CFM = \frac{CFM}{Person} \times No.of\ Persons$$

DETERMINING VENTILATION REQUIREMENTS

- Occupancy Type
- Number of Occupants

$$CFM = \frac{CFM}{Person} \times No. of\ Persons$$

Minimum Ventilation Rates in Breathing Zone				
			Default Values	
Occupancy Category	People Outdoor Air Rate (CFM/person)	Area Outdoor Air Rate (CFM/ft^2)	Occupant Density (# people/1000ft^2)	CFM/person
Classrooms (ages 5–8)	10	0.12	25	15
Classrooms (age 9 plus)	10	0.12	35	13
Lecture hall (fixed seats)	7.5	0.06	150	8
Office space	5	0.06	5	17
Reception areas	5	0.06	30	7
Main entry lobbies	5	0.06	10	11
Libraries	5	0.12	10	17
Retail sales	7.5	0.12	15	16
Gym, stadium (play area)	—	0.30	30	—
Spectator areas	7.5	0.06	150	8

VENTILATION - CFM PER PERSON

Given:

- 2,000 SF Library → 10 people per 1,000SF = 20 person occupancy
- No added humidification
- IA conditions: $DB = 75°\text{F}$
- OA conditions: $DB = -5°\text{F}$

How many Btuh's lost due to ventilation?

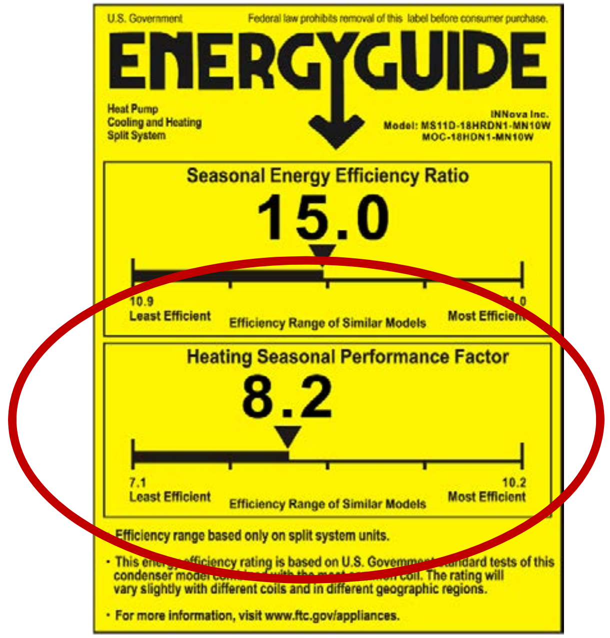
$$Q_{Sensible} = (1.1)\left(\frac{17CFM}{person}\right)(20\ persons)(80°\text{F}) = 29{,}920\ Btuh$$

BASIC COMPONENTS OF HEATING SYSTEMS

- *Steam System* – Steam boilers, heat transfer equip (exchangers, coils), combustion air supply and preheating, make-up air supply and preheating, flue gas venting, condensate return, water, fuel, control and safety devices
- *Water System* – Hot water boilers and circulating pumps, similar components to steam systems with no condensate pump/return
- *Air System* – Furnaces, in-space air heaters, ductwork, fuel, combustion air, flue gas components like steam or hot water systems. Electric furnaces do not require flue gas removal
- *Infrared System* – Heaters (electric, gas) and flue gas venting
- *Heat Pump System* – Air-to-air, air-to-water, water-to-water, and air-to-refrigerant systems, pumps, and compressors, reversing valves (for heating and cooling)
- *Cogeneration System* – Use waste heat from power generation, engine generators with heat recovery, micro-turbines and fuel cells

HEATING SEASONAL PERFORMANCE FACTOR (HSPF)

- Number of Btu's added by 1 watt of electricity (Btu/Wh)
  - Measure of efficiency of air source heat
  - pumps
- HSPF > 8 = High efficiency



- Example:
  - Heat pump provides 10 million Btu's and uses 1,500 kWh of electricity during the winter season

$$\text{HSPF} = \frac{10{,}000{,}000\ Btu}{1500\ kWh\ \times 1{,}000\text{Wh/kWh}} = 6.67\ {}^{Btu}/_{Wh}$$

CIRCULATING AIR SYSTEMS (FURNACE)

- Heat distributed by an air stream through a heating unit to supply ducts
- Duct Length < 200LF
  - Transporting hot air over longer distances is not practical due to duct work, fan, and temperature losses (Would require very large ductwork: not economical)
- Must make realistic cost projections to assure an economical/sustainable selection

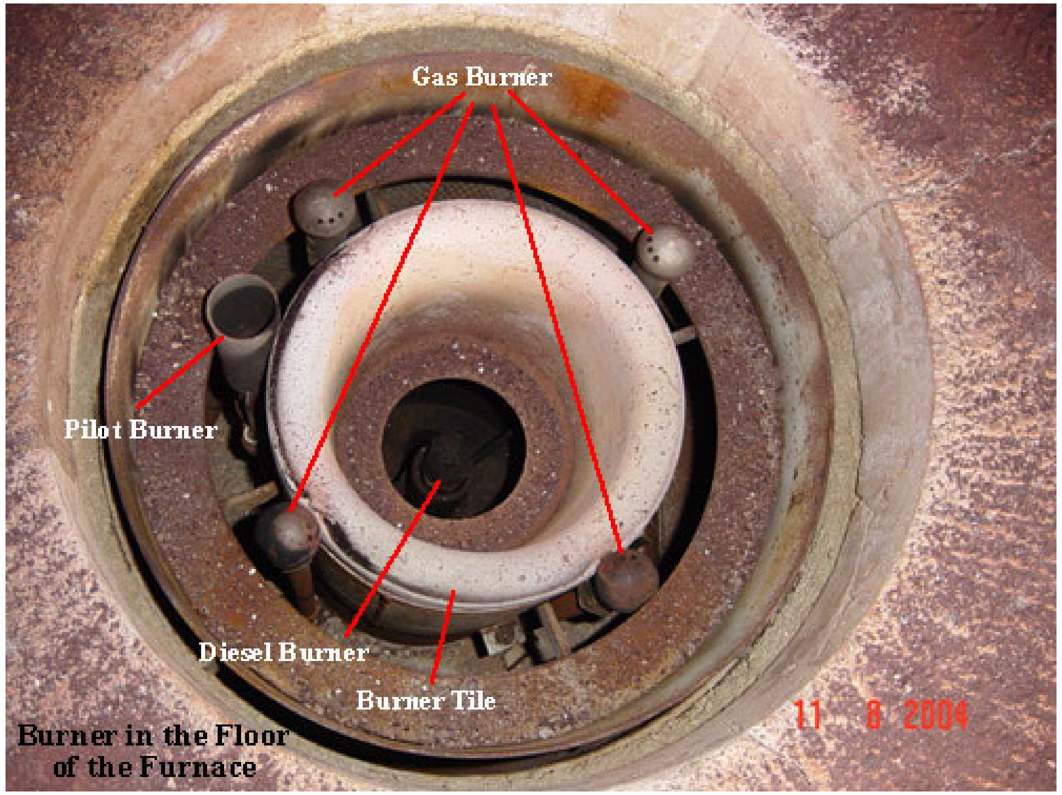
HEATING UNITS – AIR

- Types of Furnaces
  - Fuel type
    - Gas, Oil, Electric
  - Combustion process
    - Open chamber vs. sealed chamber (Impulse)
  - Design and construction
    - Cabinet (Vert. vs. horiz.)
    - Airflow (Up vs. down)
    - Air delivery (duct vs. no duct)
    - Construction (indoor vs. outdoor, pad mounted vs. roof-mounted)
  - Services
    - Heating only vs. heating/cooling combination

YouTube Video: How a Furnace Works

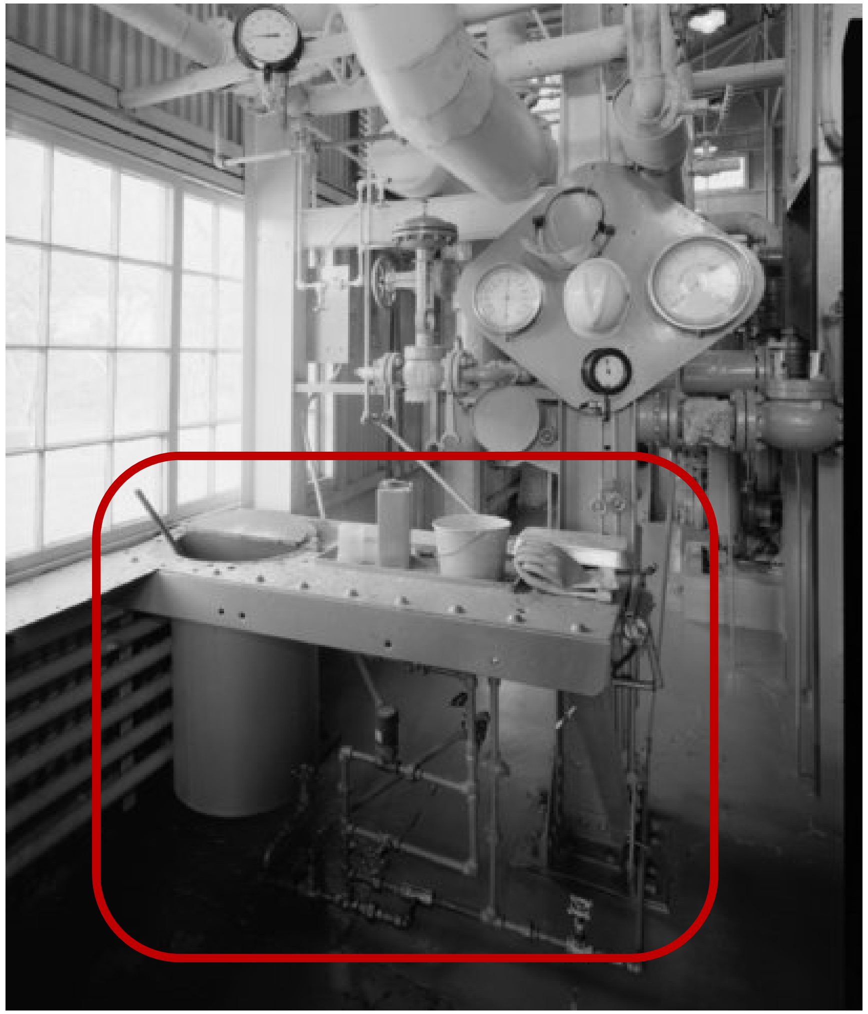
BURNERS

- Mix fuel with air and ignite mixture for combustion
- Atmospheric burners
  - Used with small to medium sized gas boilers
  - Uses natural draft from stack for combustion air
- Power burners
  - Used with large size gas boilers
  - Incorporates a blower/fan to supply combustion air (forced draft)
- Firing Oil
  - Steam atomizers used in large facilities firing heavy oil
  - Air atomizers used for firing light oil



FEEDWATER SYSTEM

- Steam condenses to water when releasing latent heat
  - Called condensate
- Feedwater system returns the condensate to the boiler for reuse
- Makes up shortages due to leaks and blowdowns
- Preheats water to boiler operating temperature
- Removes undissolved air and uncondensed gas (deaerator)



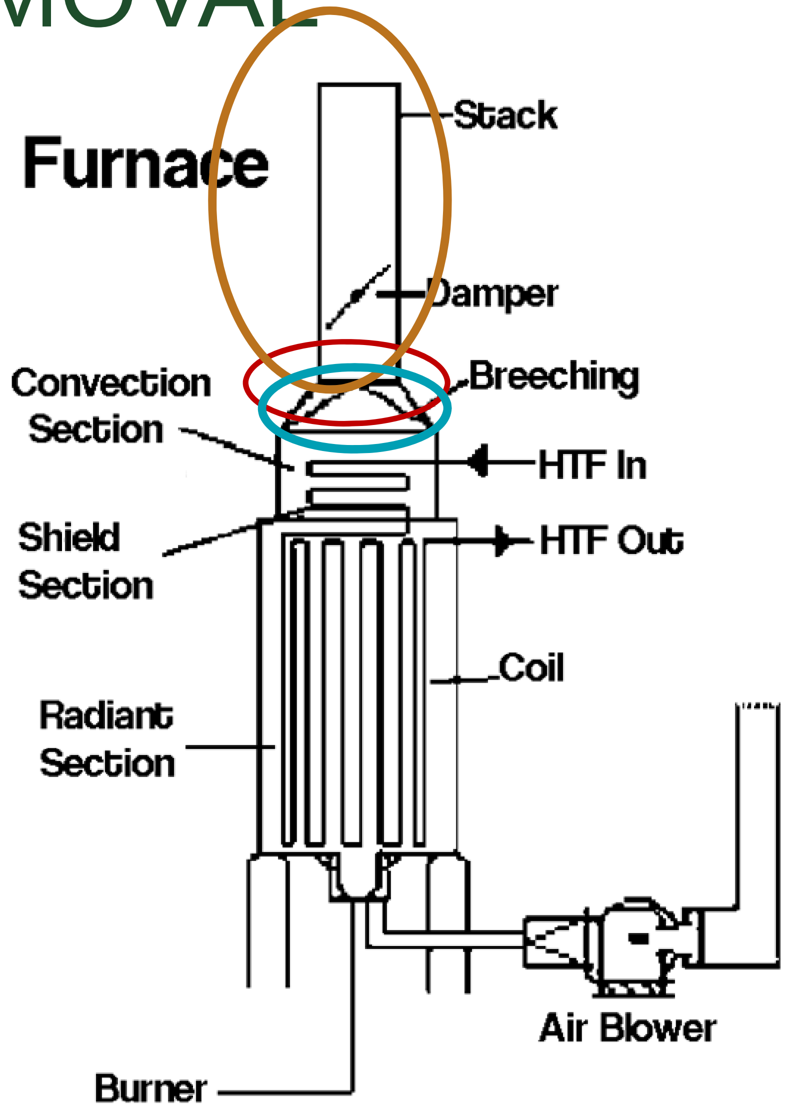
FUEL SUPPLY – HOLDING TANKS

- Gaseous fuels are pressurized and flow without pumps
- Liquid fuels are stored in tanks and must be pumped
  - Simple suction pump system
  - Pressurized loop pump system
- Tank location
  - Direct-burial tanks
  - Aboveground tanks
  - Inside tanks
- Oil heating system (for low-cost heavy oils)
  - In the tank
  - At the pipes
  - Burner preheater

Photo courtesy of Pxfuel, Free for Commercial Use

FLUE – TOXIC GAS REMOVAL

- Flue Construction
  - Stack – Steel, masonry, or manufactured
  - Breeching – Typ. 10 gauge steel covered with high temp insulation
    - PVC pipe also used for furnace applications
  - Expansion joints – Allows movement due to expansion from heat



HEATING UNITS – SPLIT SYSTEM

- Gas Furnace and Cooling Coil

Up-Flow
(Basement)

Down-Flow
(Main floor closet)

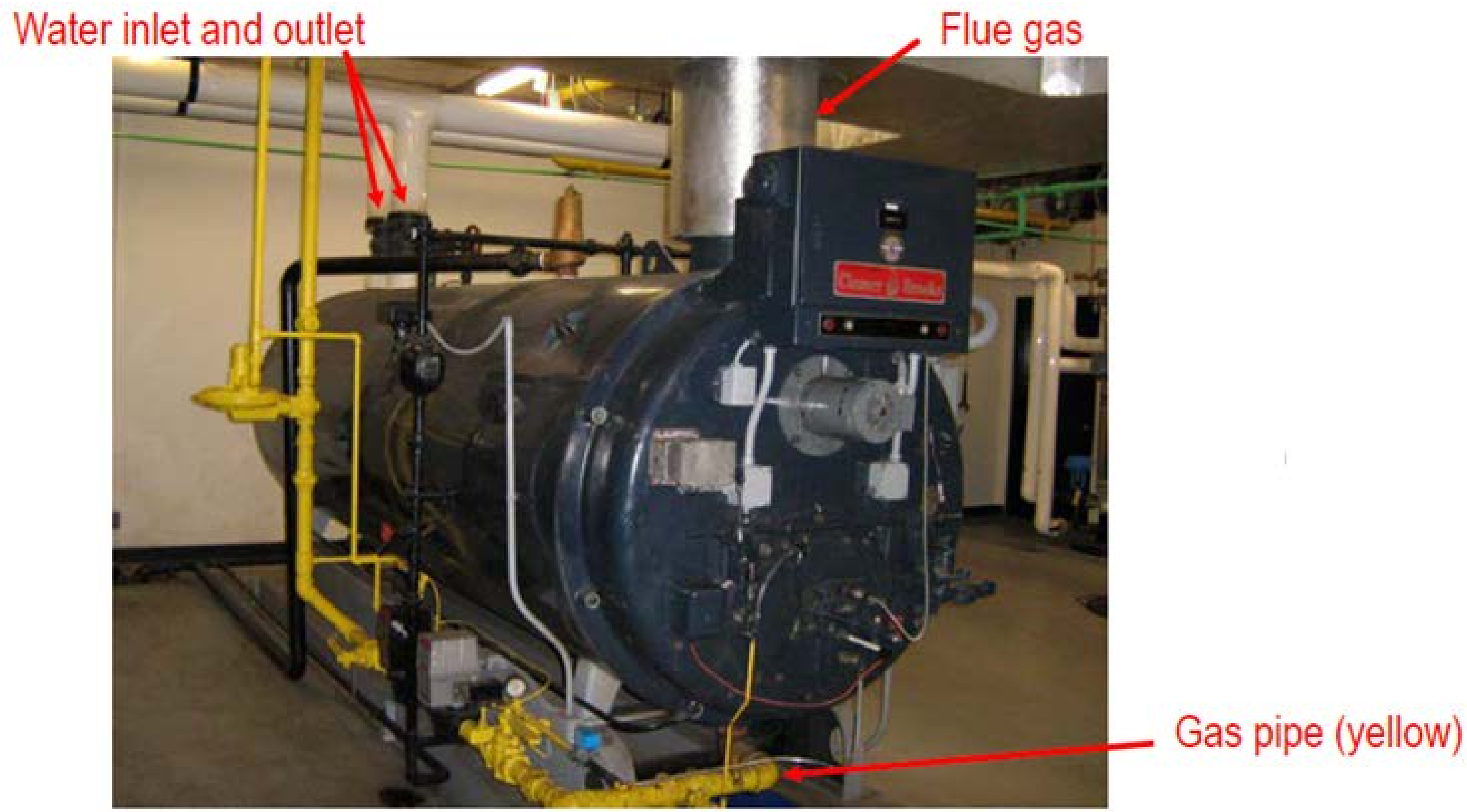
Horizontal
(Upper floor or attic)

HYDRONIC HEATING – BOILERS

- Heat is distributed by a pumped water system through a heating unit to supply piping
- Selection based on load demand and load profile
- Boilers classified by:
  - Source of energy
    - Gas, oil, electric, coal, biomass
  - Heat transfer surface
    - Water tube or fire tube
    - Electrical resistance or electrode
  - Combustion chamber
    - Low firebox or high firebox
  - Working pressure and temperature
  - Size and capacity

BOILERS

- Hot water boilers (as shown below) more common in smaller buildings/applications
- Use natural gas, oil,or electricity

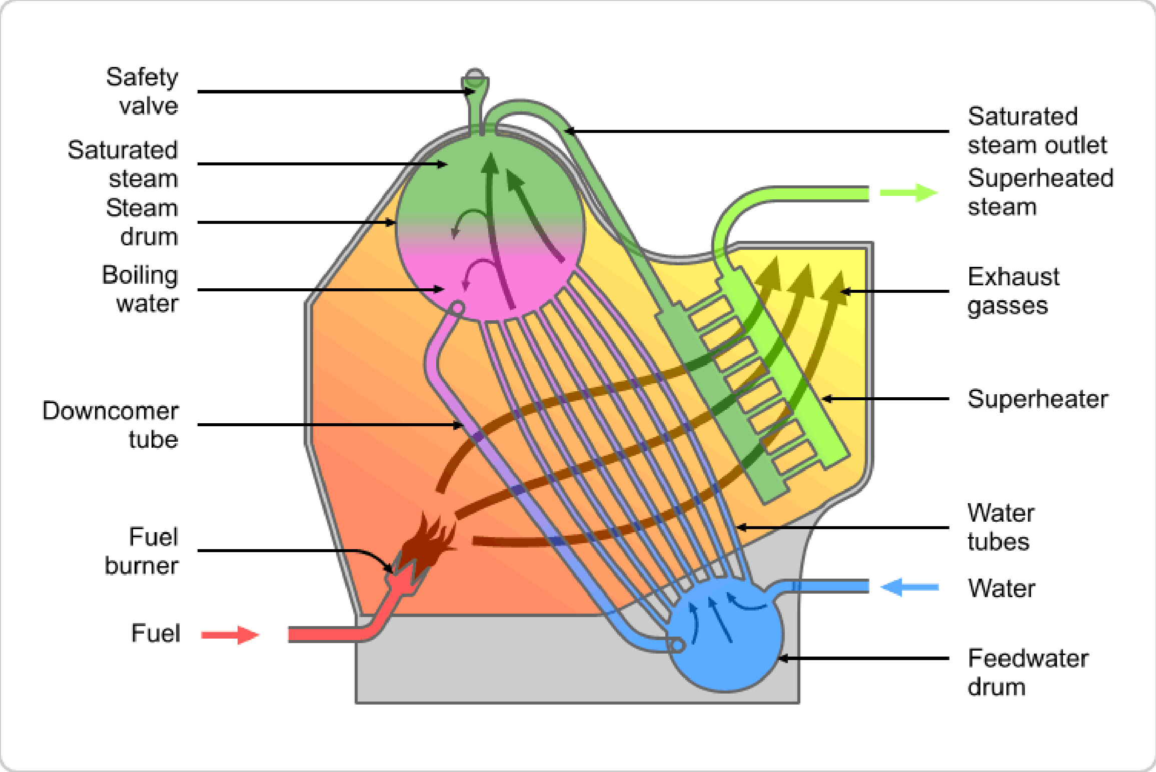


FIRE TUBE BOILERS

- Fire Tube – Low Firebox Scotch Marine
  - Combustion gasses flow through tubes surrounded by water and then exhausted to the stack
  - Responds quickly to load fluctuations
  - Low pressure steam or hot water

WATER TUBE BOILERS

- Water Tube – High Firebox
  - Water flows through tubes surrounded by combustion gasses
  - High pressure steam
  - Contains less water than fire tube boilers so can respond quickly to load fluctuations



CAST-IRON BOILERS

- Series of vertical section units filled with water
- Expandable by adding additional sections
- Not used for high pressure steam due to weakness of cast-iron
- Operation pressure: 15 psi steam,100 psi for water
- Each boiler has a pump to circulate water between the supply and return headers
- With the primary and secondary pumping system, operation of the boiler can be sequenced to conserve energy

ELECTRIC BOILERS

- Hot water or steam
- Nearly 100% efficiency
- Heat losses due to radiation and convection
- No flue stack (no gasses to exhaust)
- Electricity typically more expensive than gas or oil
- Selection based on capital/operating costs and fuel availability

HOT WATER OR STEAM?

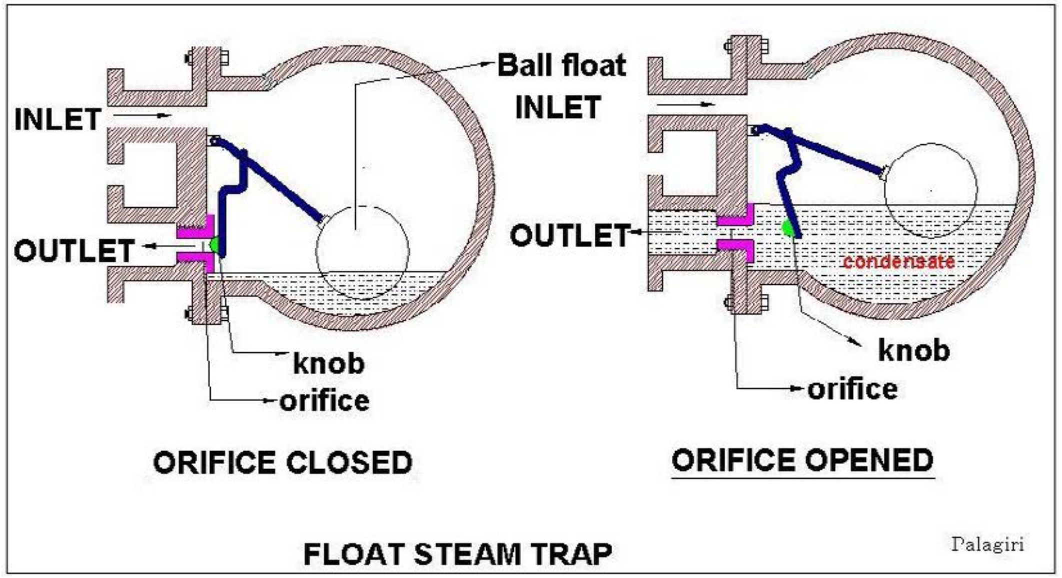
- Hot Water Generation
  - Simpler design and less maintenance
  - Systems provide heat only
- Steam Generation
  - Larger pipe sizes
  - Not suitable for facilities with ceiling height limitations
- Hybrid Generation
  - *Two systems:* Hot water generators for facility heating and a separate steam boiler for other steam requirements
  - Use Steam-to-Water heat exchangers for heating hot water for steam requirements (e.g., kitchen, laundry)

HOT WATER GENERATION

- Hot-water systems operate at different temperatures
- Low Temperature Hot Water System (LTW)
  - Temp < 250°F
  - Boilers operate between 180°F and 240°F
  - Ideal for single-building applications
- Medium Temperature Hot-Water System (MTW)
  - 250°F < Temp < 350°F
  - Increases the heating capacity
  - Reduced pipe sizes / Increased capital costs
- High Temperature Hot-Water System (HTW)
  - Temp > 350°F
  - Materials and equipment rated for higher temps
  - Ideal for campus-type facilities

STEAM GENERATION

- Steam systems operate at different pressures
- Expands 1000x its original state
  - Creates its own transport system
  - No pumps
- Low Pressure Steam Systems (< 15psi)
  - Piping configurations same for water
  - Operating temps 220°F to 250°F
- Medium and High Pressure Steam Systems (60 – 350 psi)
  - Requires using steam traps



Ball Float Steam Trap

HVAC WATER TREATMENT

- Required for steam systems and desirable for closed-circuit water systems
- Temperature changes affect the solubility of minerals and oxygen in water
  - Can reduce heat transfer rate
  - Can reduce water or steam flow rate
  - Can cause corrosion or destruction of HVAC equipment
- Principles of HVAC Treatment (More on this when we get to domestic water systems)
  - Removal of solids in water (Scale)
  - Removal of oxygen (Corrosion)
  - Reduction of acidity in water (Corrosion)
  - Inhibitor (Corrosion)

SELECTION OF EQUIPMENT

- Once system choice is made then equipment is selected using the following:
  - Boilers – Load demand & profile
  - Burners – safety, insurance, and code considerations
  - Feedwater systems – ensure water quality
  - Fuel Supply Systems – for liquid fuels, adequate capacity
  - Combustion air supply – large volumes, heated air increases efficiency
  - Flue Gas Discharge – length of stack, high-rise very expensive.
  - Water Treatment Systems – water softeners and chemical feeders to control corrosive and scale-forming characteristics of water.

OPERATING & SAFETY CONTROLS

- Operating T&P controls-start/stop or modulate the burner as required
- Operating limit controls-shut down burner if temp increases when in low-fire mode
- High-limit T&P-manual reset, shut down if abnormal conditions exist.
- Low-water control for steam boilers
- High/low, gas, oil pressure controls
- Flame failure controls –pilot or main flame failure
- P or P&T relief valves
- Power burners-control combustion air damper
- Flue gas control –monitor the emissions
- Sequencing of boilers based on demand
- Additional sensors as required by system design

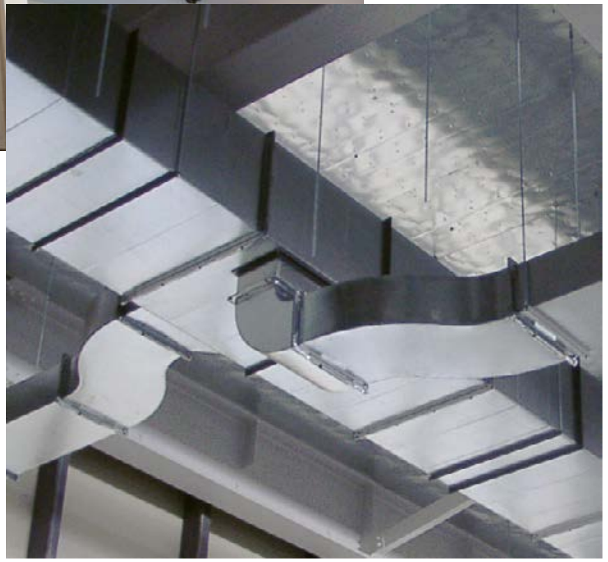
SHEET METAL & DUCTWORK

CON 371 – Mechanical and Plumbing Systems

LEARNING OUTCOMES

- By the end of this lesson, students will be able to:
  - Discuss the components of ductwork
  - Understand the importance of ductwork design, layout, and coordination
  - Determine the size of ductwork for construction projects

The performance of a Central HVAC System is impacted by the design and installation of the ductwork



AIR STREAMS

- Ductwork carries various air streams
  - Supply air (SA)
  - Return air (RA)
  - Exhaust air (EA)
  - Make up air (MUA)/Outside air (OA)
  - Mixed air (MA)

CLASSIFICATION OF DUCTWORK

- Seven classes from Sheet Metal and Air Conditioning National Association (SMACNA) regulations
  - Common to group as Low pressure/velocity, medium pressure/velocity, or high pressure/velocity
- Based on pressure → in of w.c. (1 w.c. = 0.036 psi)
- Based on velocity (flow of air) → Feet per min (ft/m or FPM)
- Lower velocities = reduce friction, power use, and noise
  - But need to ensure that velocity is high enough to provide comfort

Class Type	Class Pressure	Operating Pressure, in. W.C.	Maximum Velocity, ft per min (fpm)	Design Velocity, ft per min (fpm)	
				Main	Branch
1	1/2″ w.c.	−1/2″ to +1/2″	2000	Up to 2000	Up to 800
2	1″ w.c.	−1″ to +1″	2500	Up to 2500	Up to 1200
3	2″ w.c.	−2″ to +2″	2500	Up to 2500	Up to 1500
4	3″ w.c.	−3″ to +3″	4000	Up to 4000	Up to 2000
5	4″ w.c.	−3″ to +4″	4000	Up to 4000	Up to 3000
6	5″ w.c.	5″ to +6″	5000	Up to 5000	Up to 4000
7	6″ w.c.	0″ to +10″	5000	Up to 5000	Up to 4000

RECTANGULAR METAL DUCT

- Typically low-velocity duct
- Used for low head clearance or limited ceiling plenum space
- Typically needs to be fabricated

ROUND METAL DUCT

- Medium to high velocity ducts
- Offers less resistance to air flow than rectangular ducts
- Typically used as branches from primary rectangular duct
- Typically comes pre-fabricated

FLEX DUCT

- Used to connect ducts to supply, return and exhaust devices

Public Domain Photo courtesy of US Department of Energy

DUCTWORK MATERIAL

- *Galvanized Steel* – Most widely used material for ductwork
- *Aluminum* – Lightweight and corrosion-resistant; Flex ducts
- *Stainless Steel* – Laboratory fume hoods; Exposed ductwork
- *Heavy Steel* – Ducts exhausting kitchen hoods over ranges and fryers (fire-resistant)
- *Plastic* – Ducts carry moist air or for ventilation (Greenhouses, Asbestos Abatement)
- *Fabric* – Ducts for high-humidity facilities (Swimming pools, Rec Centers)

DUCTWORK MATERIAL WEIGHT

EXAMPLE

Find the weight of a 40”x14” duct that is 50ft in length. The duct is fabricated of 20 ga. aluminum.

$$Perimeter = \frac{40 + 40 + 14 + 14}{12} = 9ft$$

$$Surface\ Area = (9ft)(50ft) = 450SF$$

$$Weight = (450SF)(0.452lb/SF) = 203\ lbs$$

Why is the weight important?

	Steel Sheet		Galvanized Steel		Stainless Steel		Aluminum	
Gauge	Thickness (in)	Lb/ft^2	Thickness (in)	Lb/ft^2	Thickness (in)	Lb/ft^2	Thickness (in)	Lb/ft^2
8	0.164	6.875	0.168	7.031	0.172	6.930	0.129	1.813
9	0.150	6.250	0.153	6.406	0.156		0.114	1.614
10	0.135	5.625	0.138	5.781	0.141	5.670	0.102	1.438
11	0.120	5.000	0.123	5.156	0.125	5.040	0.091	1.280
12	0.105	4.375	0.108	4.531	0.109	4.410	0.081	1.140
13	0.090	3.750	0.093	3.906	0.094		0.072	1.016
14	0.075	3.125	0.079	3.281	0.078	3.150	0.064	0.905
15	0.067	2.813	0.071	2.969	0.070		0.057	0.806
16	0.060	2.500	0.064	2.656	0.063	2.520	0.051	0.717
17	0.054	2.250	0.058	2.406	0.056		0.045	0.639
18	0.048	2.000	0.052	2.156	0.050	2.016	0.040	0.569
19	0.042	1.750	0.046	1.906	0.044		0.036	0.507
20	0.036	1.500	0.040	1.656	0.038	1.512	0.032	0.452
21	0.033	1.375	0.037	1.531	0.034		0.029	0.402
22	0.030	1.250	0.034	1.406	0.031	1.260	0.025	0.357
23	0.027	1.125	0.031	1.281	0.028		0.023	0.319
24	0.024	1.000	0.028	1.125	0.025	1.008	0.020	0.284
25	0.021	0.875	0.025	1.031	0.022		0.018	0.253
26	0.018	0.750	0.022	0.906	0.019	0.756	0.016	0.224
27	0.016	0.688	0.020	0.844	0.017		0.014	0.200
28	0.015	0.625	0.019	0.781	0.016		0.013	0.178
29	0.014	0.563	0.017	0.719	0.014		0.011	0.160
30	0.012	0.500	0.016	0.656	0.013		0.010	0.141

DUCT SEALING

- Sealing of duct can improve the efficiency of air delivery systems by up to 30%
- Performed before applying external insulation
- Materials used
  - Mastic or metal foil adhesive tape
  - Seals seams and connections
- Sealing Applications
  - Ducts running through enclosed and unconditioned spaces
  - Ducts exposed to the outdoors

Foil Tape

Mastic Sealant

DUCTWORK INSULATION

- Insulation inside ductwork called duct liner
  - Reduces heating/cooling loss
  - Prevents condensation on exterior of ductwork
  - Provides noise reduction as sound absorbed by liner
  - Can be installed during fabrication
  - Difficult to fit liner into round duct joints and elbows
- Exterior insulation typically used for round duct
  - Fiberglass fabric wrapped with a plastic vapor barrier
    - More expensive since typically installed in the field
- In large applications, fire-resistant coating with insulation may be applied to ductwork

US Dept of Energy Reading: Minimizing Energy Losses in Ducts

Exterior Insulated Ductwork

SOUND CONTROL FOR DUCTWORK

- Sound attenuators
  - Special duct fittings called sound traps
  - Contain sound-absorbing materials (e.g. fiberglass insulation) with a perforated metal face
  - Installed at the discharge of AHUs to prevent distribution of fan noise, at return air openings, and near noisy equipment rooms
- Silencers
  - Works like an automobile muffler
  - Specially designed to reflect sound waves to reduce noise

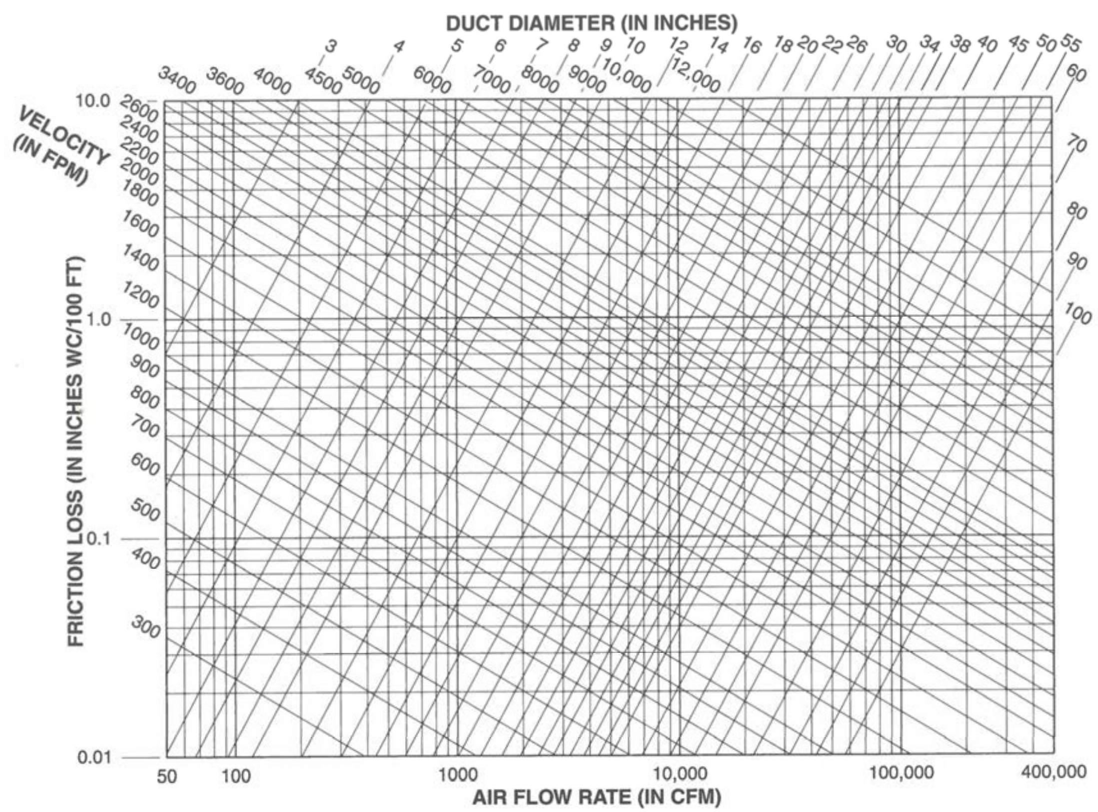
DUCTWORK SIZING METHODS

- *Equal Friction* – Establishes a constant pressure loss per unit of duct length (e.g., 0.1 in w.c. per 100ft of duct)
- *Static Regain* – Based on Bernoulli's Equation (holds static pressure constant throughout system)
- *Constant (Equal) Velocity* – Considers that each duct section has the same air velocity

NOTE: Duct sizing does require some engineering judgment, and therefore two engineers could design different, but equivalent systems for the same facility

EQUAL FRICTION METHOD

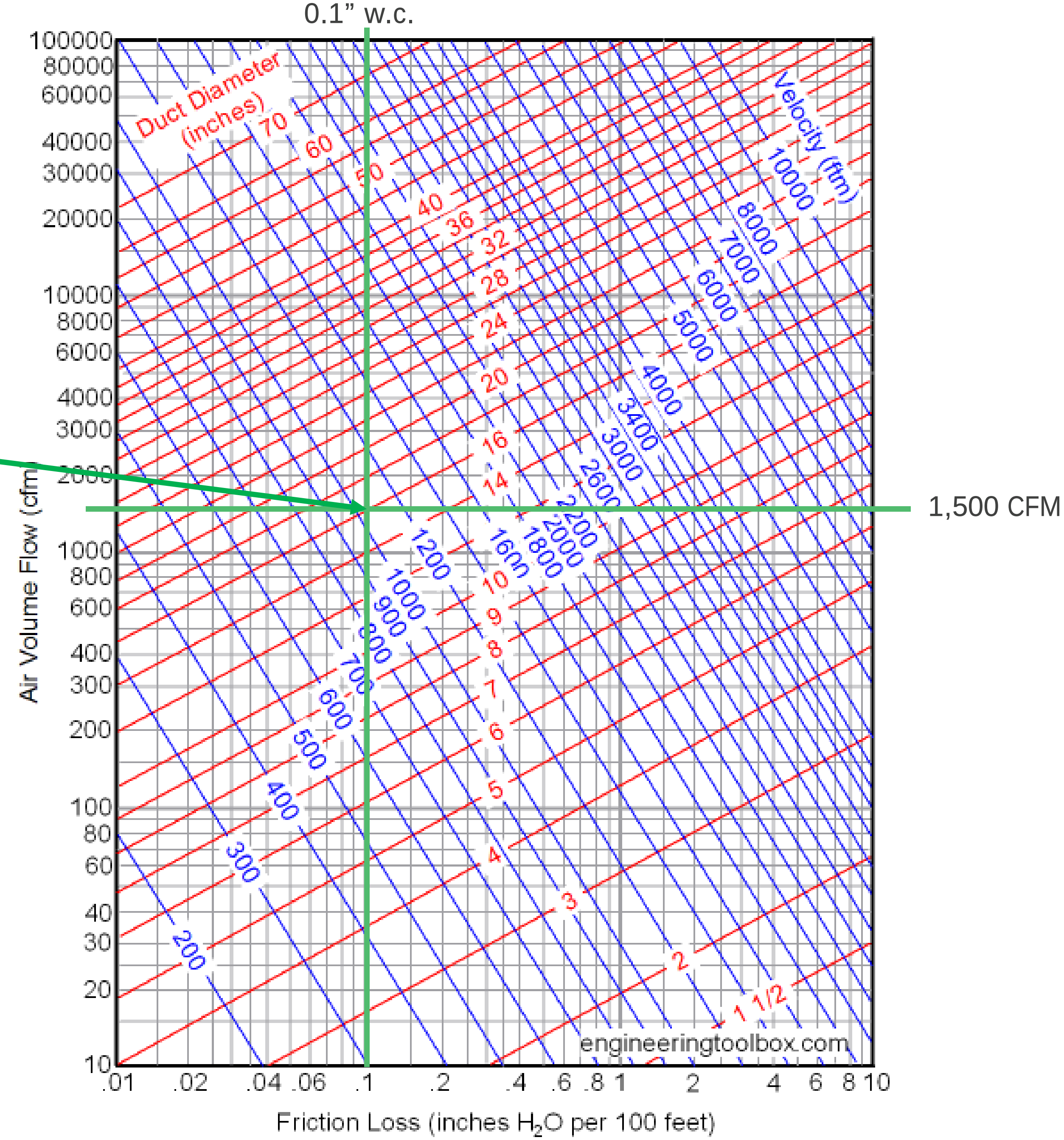
- Based on sizing duct for a system with a constant pressure drop per unit length
- Lacks equalization of pressure drops in duct branches unless layout is exactly symmetrical
  - Use of dampers throughout system to balance pressure and flow rate
- Used in small to medium type facilities
  - Ranges from 0.05” to 0.2” of w.c. for pressure drop per 100ft



EQUAL FRICTION METHOD EXAMPLE

Air flow rate in a section of duct is 1,500 CFM. The static pressure drop is 0.1”w.c. Find the size of the duct using the equal friction chart.

Round Duct Size = 16”



ROUND TO RECTANGULAR

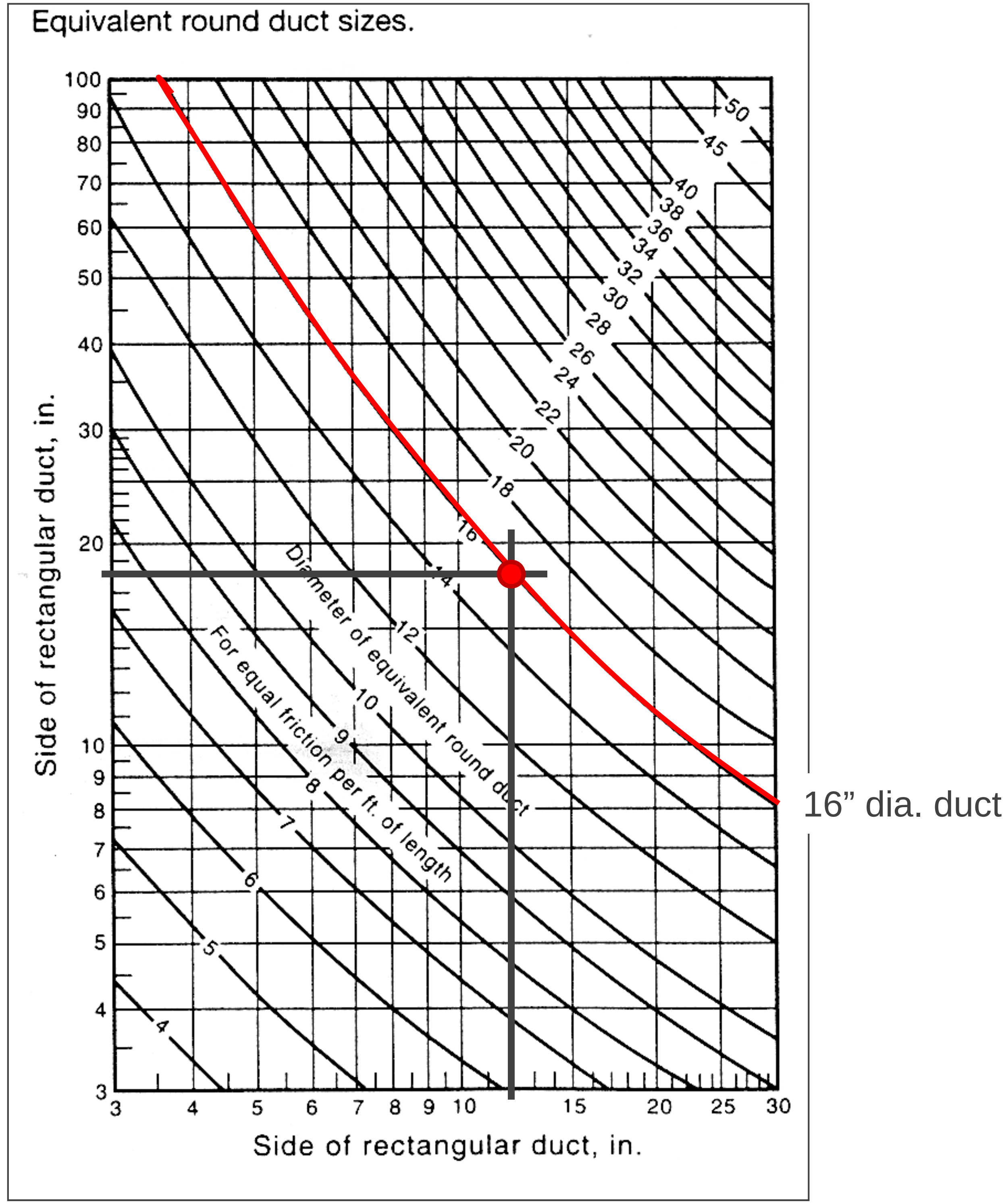
$$16'' \text{ dia. duct } = 18'' \times 12''$$

Rectangular duct (using even numbers and aspect ratio of 2 or less)

Aspect ratio of the duct:

$$\frac{18''}{12''} = 1.5$$

NOTE: Cross-sectional area of rectangular duct needs to be equivalent or larger than the cross-sectional area of a round duct



ROUND TO RECTANGULAR

Equivalent Rectangular Ductwork Conversion Table												
Duct Diameter (in)	Rectangular Size (in)	Aspect Ratio										
		1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.50	4.00
6"	WxH		6"x5"									
7"	WxH	6"x6"	8"x6"									
8"	WxH	7"x7"	9"x7"	9"x6"	11"x6"							
9"	WxH	8"x8"	9"x7"	11"x7"	11"x6"	12"x6"	14"x6"					
10"	WxH	9"x9"	10"x8"	12"x8"	12"x7"	14"x7"	14"x6"	15"x6"	17"x6"			
11"	WxH	10"x10"	11"x9"	12"x8"	14"x8"	14"x7"	16"x7"	18"x7"	17"x6"	18"x6"	21"x6"	
12"	WxH	11"x11"	13"x10"	14"x9"	14"x8"	16"x8"	16"x7"	18"x7"	19"x7"	21"x7"	21"x6"	24"x6"
13"	WxH	12"x12"	14"x11"	15"x10"	16"x9"	18"x9"	18"x8"	20"x8"	19"x7"	21"x7"	25"x7"	24"x6"
14"	WxH	13"x13"	14"x11"	17"x11"	18"x10"	18"x9"	20"x9"	20"x8"	22"x8"	24"x8"	25"x7"	28"x7"
15"	WxH	14"x14"	15"x12"	17"x11"	18"x10"	20"x10"	20"x9"	23"x9"	25"x9"	24"x8"	28"x8"	28"x7"
16"	WxH	15"x15"	16"x13"	18"x12"	19"x11"	20"x10"	23"x10"	23"x9"	25"x9"	27"x9"	28"x8"	32"x8"
17"	WxH	16"x16"	18"x14"	20"x13"	21"x12"	22"x11"	25"x11"	25"x10"	28"x10"	27"x9"	32"x9"	32"x8"
18"	WxH	16"x16"	19"x15"	21"x14"	23"x13"	24"x12"	25"x11"	28"x11"	28"x10"	30"x10"	32"x9"	36"x9"
19"	WxH	17"x17"	20"x16"	21"x14"	23"x13"	24"x12"	27"x12"	28"x11"	30"x11"	30"x10"	35"x10"	36"x9"
20"	WxH	18"x18"	20"x16"	23"x15"	25"x14"	26"x13"	27"x12"	30"x12"	30"x11"	33"x11"	35"x10"	40"x10"
21"	WxH	19"x19"	21"x17"	24"x16"	26"x15"	28"x14"	29"x13"	30"x12"	33"x12"	33"x11"	39"x11"	40"x10"
22"	WxH	20"x20"	23"x18"	26"x17"	26"x15"	28"x14"	32"x14"	33"x13"	36"x13"	36"x12"	39"x11"	44"x11"
23"	WxH	21"x21"	24"x19"	26"x17"	28"x16"	30"x15"	32"x14"	35"x14"	36"x13"	39"x13"	42"x12"	44"x11"
24"	WxH	22"x22"	25"x20"	27"x18"	30"x17"	32"x16"	34"x15"	35"x14"	39"x14"	39"x13"	42"x12"	48"x12"
25"	WxH	23"x23"	25"x20"	29"x19"	30"x17"	32"x16"	36"x16"	38"x15"	39"x14"	42"x14"	46"x13"	48"x12"
26"	WxH	24"x24"	26"x21"	30"x20"	32"x18"	34"x16"	36"x16"	38"x15"	41"x15"	42"x14"	46"x13"	52"x13"
27"	WxH	25"x25"	28"x22"	30"x20"	33"x19"	36"x18"	38"x17"	40"x16"	41"x15"	45"x15"	49"x14"	52"x13"
28"	WxH	26"x26"	29"x23"	32"x21"	35"x20"	36"x18"	38"x17"	43"x17"	44"x16"	45"x15"	49"x14"	56"x14"
29"	WxH	27"x27"	30"x24"	33"x22"	35"x20"	38"x19"	41"x18"	43"x17"	44"x16"	48"x16"	53"x15"	56"x14"
30"	WxH	27"x27"	31"x25"	35"x23"	37"x21"	40"x20"	43"x19"	45"x18"	47"x17"	48"x16"	53"x15"	60"x15"

STATIC REGAIN METHOD

- Static pressure remains constant throughout the system
- Adjust duct size to obtain equal static pressure and correct air quantity at each outlet
- Most accurate method of sizing with little to no balancing required
- Involves many calculations for each fitting and duct section
- Used for large HVAC air delivery systems

CONSTANT VELOCITY METHOD

- Each section of duct holds the velocity of air constant
- Ducts are sized using a duct calculator called a *Ductulator* and a *velocity scale*
  - Can also be sized using air velocity and the cross-sectional area of the duct
- Method used for sizing exhaust systems or material collection systems
  - Not commonly used for sizing supply or return ducts

CEILING SPACE CONSIDERATIONS

- Contains (not an all-inclusive list)
  - Ductwork and components
  - Structural components
  - Water, sanitary, and storm drainage piping
  - Electrical conduits/trays
  - Fireproofing
  - Sprinkler piping
  - Light fixtures

AIR CONTROL DEVICES - DAMPERS

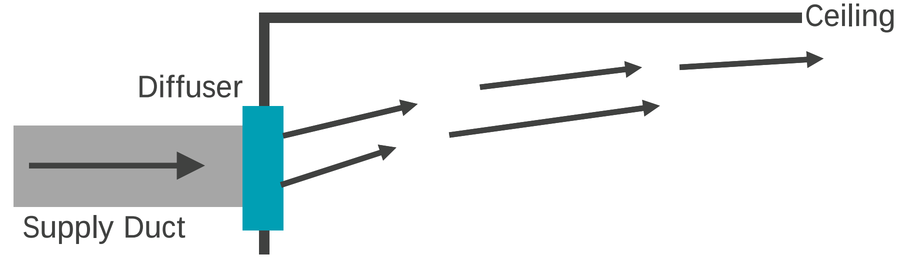
Air Dampers inside AHU

Ductwork Dampers

Installed Motorized Dampers
(Blue control boxes)

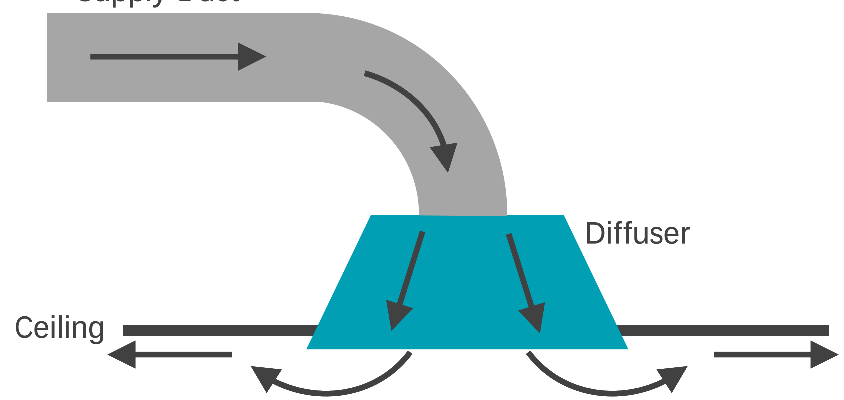
AIR CONTROL DEVICES - DIFFUSERS


Architectural Slot Diffuser (Wall or ceiling)



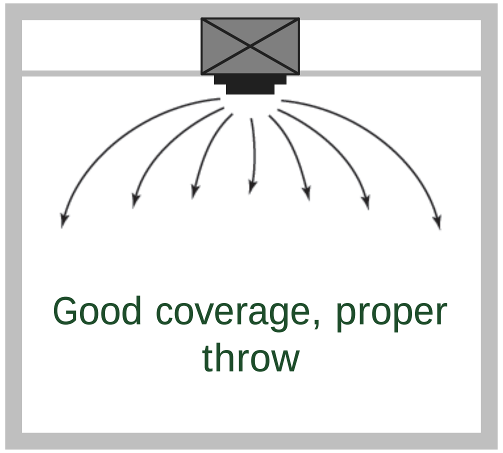
Coandă Effect

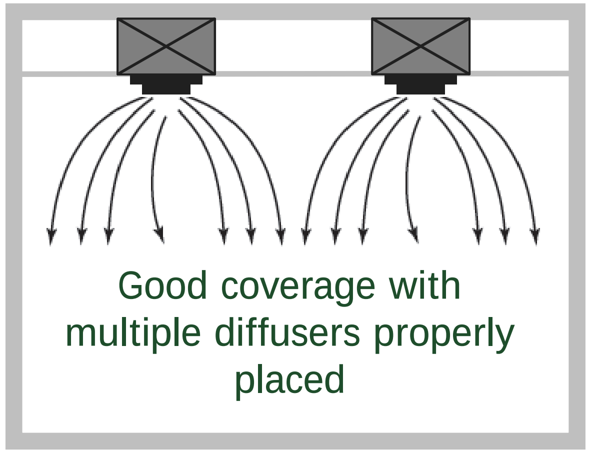
Ceiling Diffuser



AIR DISTRIBUTION PATTERNS

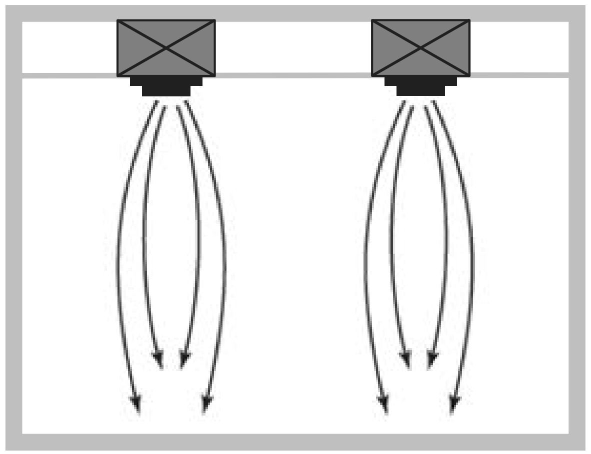
- Air distribution pattern from ceiling air diffusers
  - Good throw and coverage



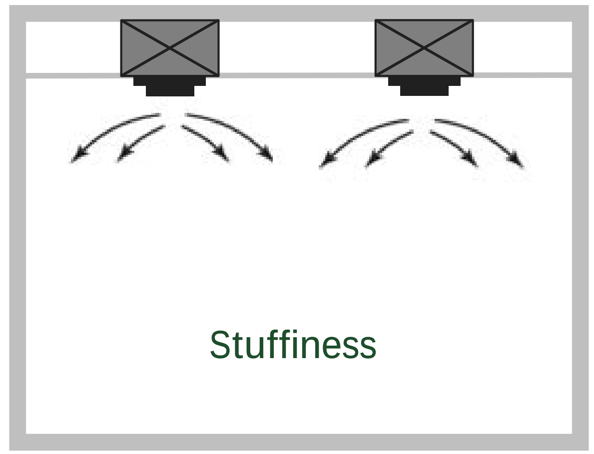


AIR DISTRIBUTION PATTERNS

- Insufficient throw and coverage

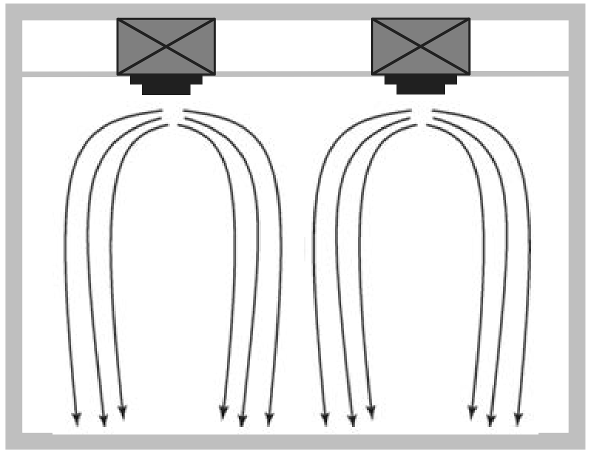


Poor coverage (dumping of air), no throw is apparent

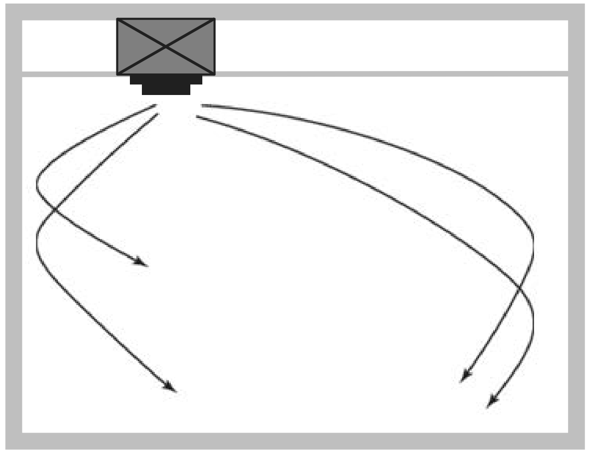


AIR DISTRIBUTION PATTERNS

- Excessive throw and coverage



Drafty



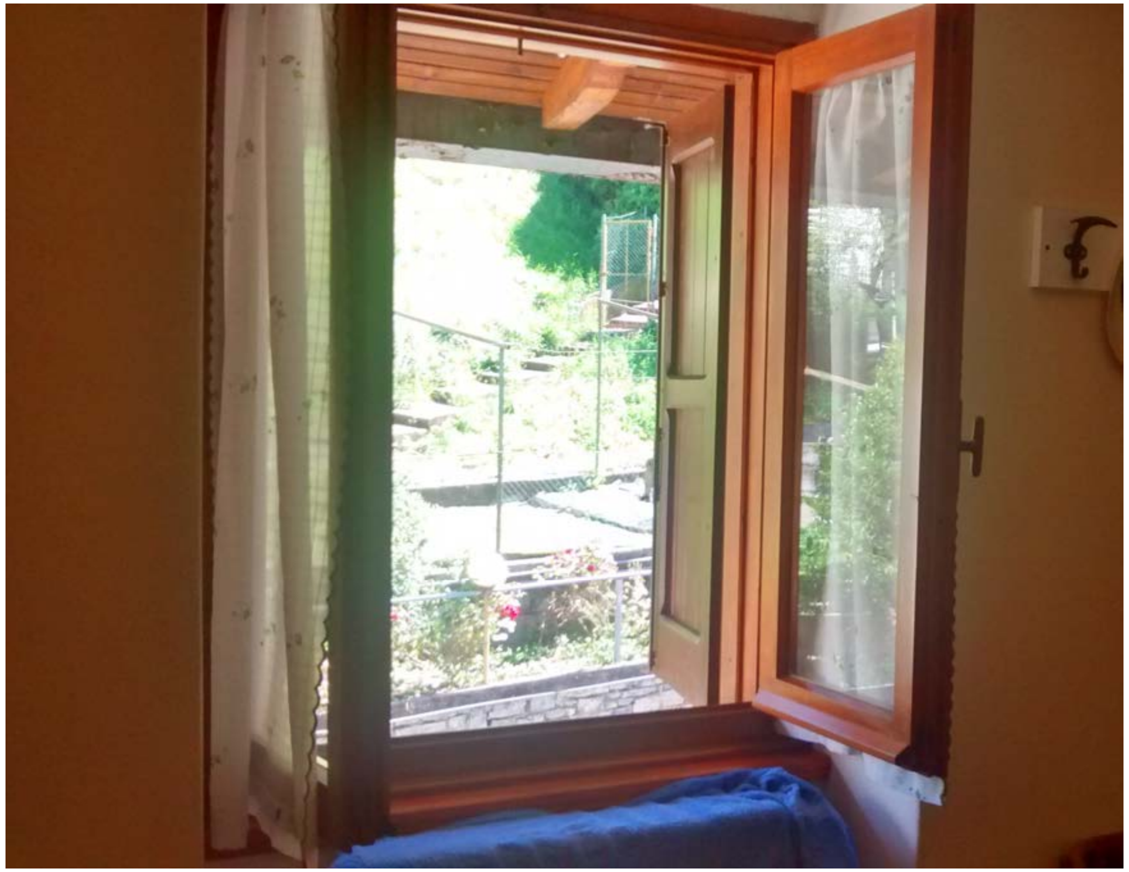
Turbulent

ENERGY RECOVERY FROM EXHAUST

- Most buildings require large amounts of ventilation and therefore have large amounts of conditioned exhaust air.
- Recovery of the heat in the air reduces the ΔT for make-up air
- Several ways to recover this energy
  - Runaround Coils
  - Plate heat exchangers
  - Heat pipes
  - Rotary heat exchangers

NATURAL VENTILATION

- Historically used before AC and fans
- Convection principles used
  - High ceilings
  - Large windows
  - Transoms
  - Cross ventilation
- Arguments against operable windows
  - Windows interfere with AC performance
  - Pipes may freeze if the windows are left open
  - Dust and allergens can enter the building
- Windows can save energy if used correctly



HVAC PLANS AND SPECIFICATIONS

CON 371 – Mechanical and Plumbing Systems

LEARNING OUTCOMES

- By the end of this lesson, students will be able to:
  1. Understand the drawings and information provided in HVAC plans and specifications
  2. Recognize the various HVAC symbols used
  3. Evaluate plans and specifications to determine the details and information of an HVAC system for a project

HVAC PLANS

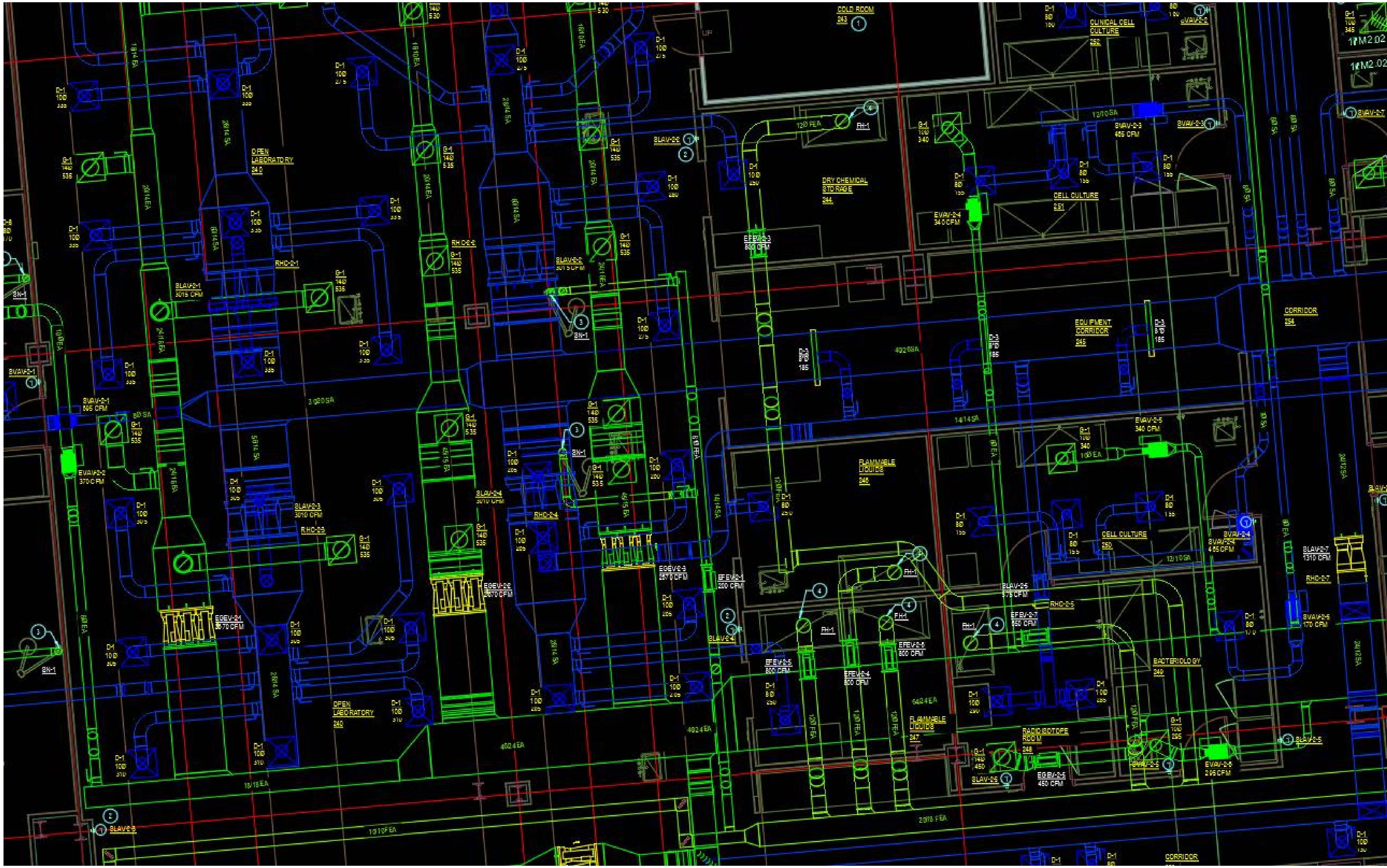
- Listed as “M” documents in a plan set
- Includes:
  - Floor plans
  - Elevation
  - Schedules
  - Details
  - Isometrics
  - Single line (Schematics)
  - Piping & instrumentation diagram (P&ID)

- Mechanical Plan Sets can include (But not limited to):
  - Size, type and layout of ductwork and piping
  - Diffusers, registers, return air grilles, dampers
  - Ductwork and piping insulation
  - HVAC equipment
  - Thermostats and control devices
  - Water and gas connections
  - Ventilation
  - Fans
  - Symbol legend, general notes, specific key notes, special conditions
  - Heating and cooling load summary
  - Heat loss and heat gain calculations

HVAC DUCTWORK FLOOR PLANS

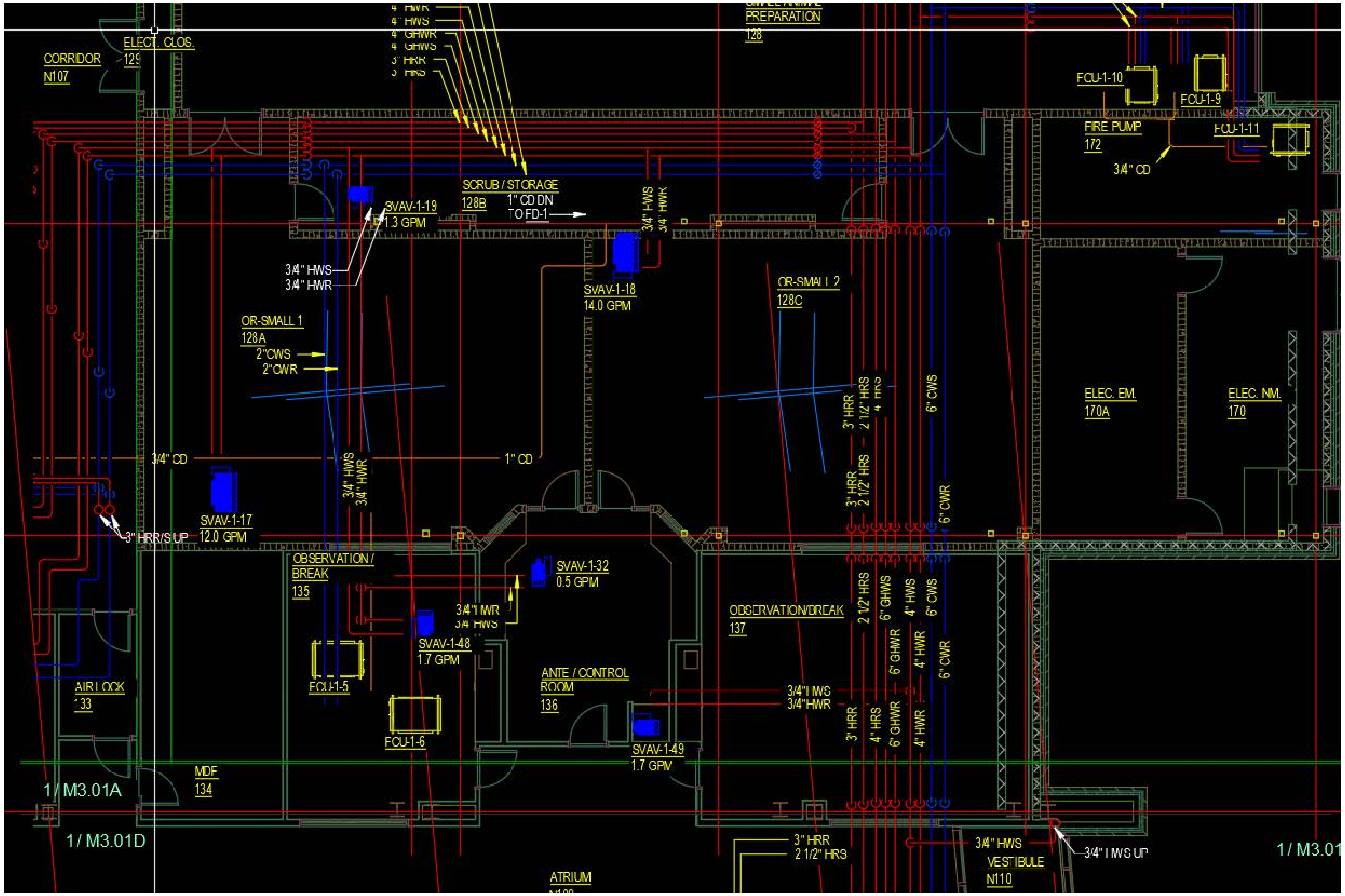
Blue – Supply Air

Green – Exhaust Air

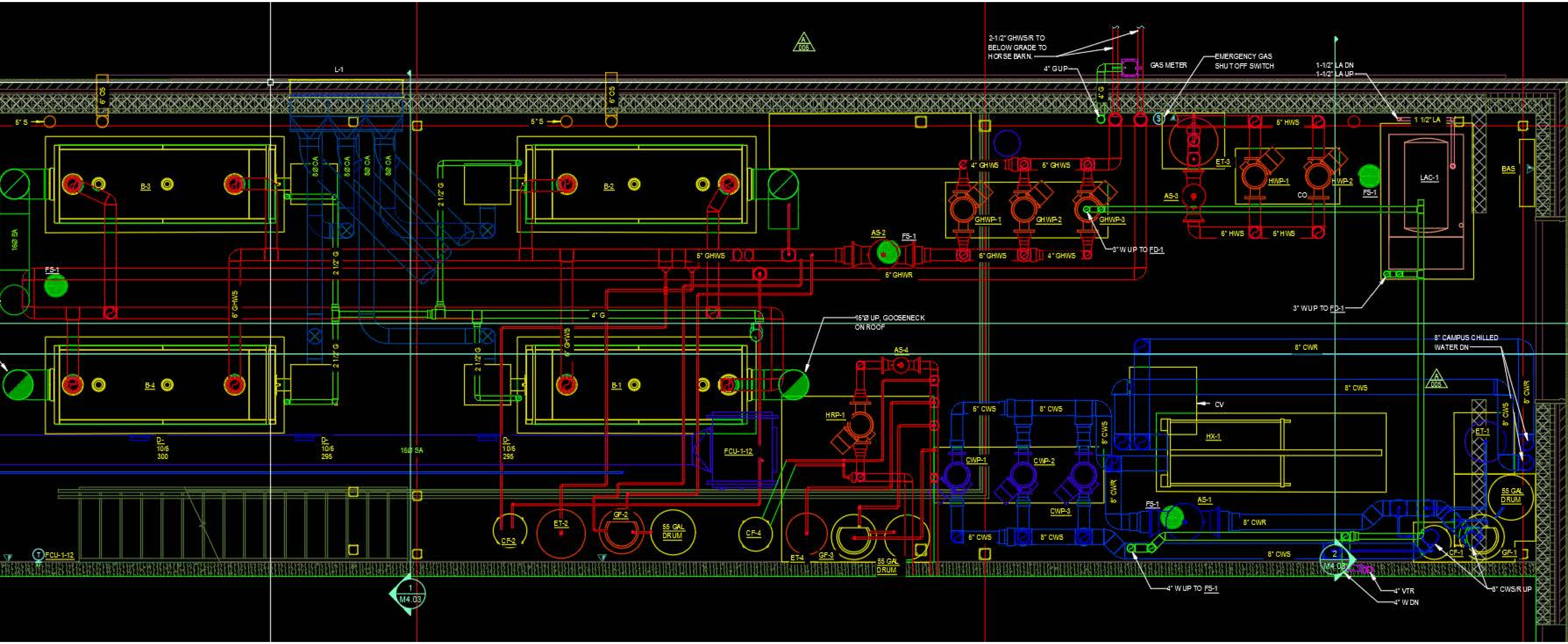


HVAC PIPING FLOOR PLANS

- Blue
  - CWS - Chilled Water Supply
  - CWR - Chilled Water Return
- Red
  - HRS - Heat Recovery Supply
  - HRR – Heat Recovery Return
  - GHWS – Glycol Heating Water Supply
  - GHWR – Glycol Heating Recovery Return
  - HWS – Heating Water Supply
  - HWR – Heating Water Return
- Orange
  - CD - Condensate



MECHANICAL ROOM PLANS



HVAC SPECIFICATIONS

- CSI Division 15 (1995 Masterformat)
  - 15050 Basic Mechanical Materials and Methods
  - 15100 Building Service Piping
  - 15200 Process Piping
  - 15300 Fire Protection Piping
  - 15500 Heat-Generation Equipment
  - 15600 Refrigeration Equipment
  - 15700 HVAC Equipment
  - 15800 Air Distribution
  - 15900 HVAC Instrumentation and Controls
  - 15950 Testing, Adjusting, and Balancing
- CSI Division 23 (2004 Masterformat)
  - 23 00 00 HVAC
  - 23 10 00 Facility Fuel System
  - 23 20 00 HVAC Piping and Pumps
  - 23 30 00 HVAC Air Distribution
  - 23 40 00 HVAC Air Cleaning Devices
  - 23 50 00 Central Heating Equipment
  - 23 60 00 Central Cooling Equipment
  - 23 70 00 Central HVAC Equipment
  - 23 80 00 Decentralized HVAC Equipment

HVAC SPECIFICATIONS

H&L#260.007
cs2 #8-2021
100% CD Date: September 15, 2008

Colorado State University
Industrial Sciences
Building Renovations
Fort Collins, CO.

SECTION 15540

HVAC PUMPS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

A. Extent of HVAC Pumps Work required by this section is indicated o schedules, and by requirements of this section.

B. Types of Pumps specified in this section include the following:

1. In-Line Circulator
2. Frame-Mounted End Suction

C. Pumps furnished as part of factory-fabricated equipment are specified as p assembly in other Division 15 sections.

D. Refer to other Division 15 sections for other work; not work of this section

E. Refer to Division 16 sections for the following work; not work of this secti

1. Power supply wiring from power source to power connection c Contractor shall include starters, disconnects, and required electric where specified as furnished, or factory-installed, by manufacture
2. Interlock wiring between pumps; and between pumps and field devices.
a. Interlock wiring specified as factory-installed is work of th

F. Provide the following Electrical Work as work of this section, complying wit Division 16 sections:

1. Control Wiring between field-installed controls, indicating devices, panels.
a. Control Wiring specified as work of Division 15 for Automa Controls is work of that section.

1.2 QUALITY ASSURANCE

A. Manufacturer's Qualifications: Firms regularly engaged in manufacture centrifugal pumps with characteristics, sizes and capacities required, whos been in satisfactory use in similar service for not less than five (5) years.

B. Codes and Standards:

1. HI Compliance: Design, manufacture, and install HVAC pumps in HI "Hydraulic Institute Standards".

2. UL Compliance: Design, manufacture, and install HVAC pumps in UL 778 "Motor Operated Water Pumps".

HVAC PUMPS

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3. UL and NEMA Compliance: Provide electric motors and compone listed and labeled by Underwriters Laboratories and comply with NEI

C. Certification, Pump Performance: Provide pumps whose performances, u operating conditions, are certified by manufacturer.

1.3 SUBMITTALS

A. Product Data: Submit manufacturer's pump specifications, installation instructions, and current accurate pump characteristic performance curves points clearly indicated.

B. Shop Drawings: Submit manufacturer's assembly-type shop drawings indicati weight loadings, required clearances, and methods of assembly of compone

C. Wiring Diagrams: Submit manufacturer's electrical requirements for power s HVAC pumps. Submit manufacturer's ladder-type wiring diagrams for interlo wiring. Clearly differentiate between portions of wiring that are factory-installe to be field-installed.

D. Record Drawings: At project closeout, submit record drawings of installed sys in accordance with requirements of Division 15.

E. Maintenance Data: Submit maintenance data and parts lists for each type of and accessory; including "trouble-shooting" maintenance guide. Include this data, shop drawings, and wiring diagrams in maintenance manual; in ac requirements of Division 15.

1.4 DELIVERY, STORAGE, AND HANDLING

A. Handle HVAC pumps and components carefully to prevent damage, breakin scoring. Do not install damaged HVAC pumps or components; replace wit

B. Store HVAC pumps and components in clean dry place. Protect from weath water, construction debris, and physical damage.

C. Comply with Manufacturer's rigging and installation instructions for unloading and moving them to final location.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Manufacturer: Subject to compliance with requirements, provide products following:

1. In-Line Circulator Pumps:
a. Bell & Gossett ITT; Fluid Handling Division; Series 80 or 9 No Exceptions

HVAC PUMPS 15540 - 2

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2. Frame-Mounted End Suction Pumps:
a. Armstrong Pumps, Inc.; Series 4030
b. Bell & Gossett ITT; Fluid Handling Division; Series 1510
c. Taco

2.2 PUMPS

A. General: Provide factory-tested pumps, thoroughly cleaned, and painted wi machinery enamel prior to shipment. Type, size, and capacity of each pump schedule. Provide pumps of same type by same manufacturer.

B. Pump motor shall be sized so as not to be overloaded at any point along i specified performance.

C. All pump couplers shall be suitable for both constant speed and variable s

2.3 IN-LINE CIRCULATOR PUMPS

A. General: Provide bronze fitted in line circulator pumps where indicated, an scheduled.

B. Type: Horizontal mount, vertical split case, oil-lubricated, designed for pressure, and 225 degree F (107 degree C) continuous water temperature

C. Body: Cast iron, with flanged suction and discharge and gauge tappings.

D. Shaft: Hardened alloy steel.

E. Bearings: Oil-lubricated bronze journal bearings.

F. Seal: Mechanical, with carbon seal ring and ceramic seat.

G. Motor: Pump motor shall be non-overloading at any point on pump requirements of Section 15040.

H. Coupling: Self-aligning, flexible coupling.

I. Impeller: Brass or Bronze enclosed type, hydraulically and dynamically bala to shaft.

2.4 FRAME-MOUNTED END SUCTION PUMPS

A. General: Provide frame-mounted bronze fitted end suction pumps where i capacities and having characteristics as scheduled.

B. Type: Horizontal mount, single stage, vertical split case, flexible coupling, designed for 175 psi working pressure.

C. Casing: Cast iron, 125 psi ANSI flanges, tappings for gauge and drain con

D. Shaft: Steel with replaceable shaft sleeve.

E. Bearings: Regreaseable sleeve bearings.

HVAC PUMPS

H&L#260.007
cs2 #8-2021
100% CD Date: September 15, 2008

Colorado State University
Industrial Sciences
Building Renovations
Fort Collins, CO.

F. Seal: Mechanical, with carbon seal ring and ceramic seat.

G. Motor: Pump motor shall be non-overloading at any point on pump curve and meet requirements of Section 15040.

H. Impeller: Bronze enclosed type, hydraulically and dynamically balanced, keyed to shaft and secured with locking screw. Assembly components shall be 304 stainless steel.

I. Baseplate: Structural steel with welded cross members, and open grouting area.

J. Coupling: Flexible, capable of absorbing torsional vibration, equipped with coupling guard.

PART 3 - EXECUTION

3.1 INSPECTION

A. Examine areas and conditions under which HVAC pumps are to be installed. Do not proceed with work until unsatisfactory conditions have been corrected in manner acceptable to Installer.

3.2 INSTALLATION OF PUMPS

A. General: Install HVAC pumps where indicated, in accordance with manufacturer's published installation instructions, complying with recognized industry practices to ensure that HVAC pumps comply with requirements and serve intended purposes.

B. Access: Provide access space around HVAC pumps for service as indicated, but in no case less than that recommended by manufacturer.

C. Support: Install base-mounted pumps on minimum of 4-inch high concrete base equal or greater than three (3) times total weight of pump and motor, with anchor bolts poured in place. Set and level pump, grout under pump base with non-shrink grout.

1. Install in-line pumps, supported from piping system.

D. Support: Refer to Division 15 section "Vibration Control" for support and mounting requirements of HVAC pumps.

E. Electrical Wiring: Install electrical devices furnished by manufacturer but not specified to be factory-mounted. Furnish copy of manufacturer's wiring diagram submittal to Electrical Installer.

1. Verify that electrical wiring installation is in accordance with manufacturer's submittal and installation requirements of Division 16 sections. Do not proceed with equipment start-up until wiring installation is acceptable to equipment Installer.

F. Piping Connections: Provide system return connection to inlet strainer with valved bypass to drain. Provide pump discharge connections with check valve, shutoff valve, and balancing valve for each pump.

HVAC PUMPS 15540 - 4

HVAC SPECIFICATIONS

SECTION 23 31 13 - DUCTWORK

1. GENERAL

1.1 SECTION INCLUDES

A. Metal ductwork.

1. Sheet metal materials.
2. Duct liner.
3. Sealant and gaskets.
4. Fasteners.
5. Seismic-restraint devices.
6. Duct cleaning.
7. Duct pressure testing.

B. Insulated flexible ductwork.

C. Louver backpans.

1.2 REFERENCE SECTION 23 05 00 FOR THE FOLLOWING:

A. Quality assurance.

1. Perform Work in accordance with the following standard

a. NFPA 90A - Installation of Air Conditioning and Ve
b. NFPA 90B - Installation of Warm Air Heating and
c. NFPA 91 - Installation of Blower and Exhaust Removal or Conveying.
d. NFPA 96 - Installation of Equipment for the Re Vapors from Commercial Cooking Equipment.
e. SMACNA - HVAC Air Duct Leakage Test Manual.
f. SMACNA – HVAC Duct Construction Standards -
g. SMACNA - Round Industrial Duct Construction St
h. International Mechanical Code, current edition.

B. References.

2. PRODUCTS

2.1 METAL DUCTWORK

A. SINGLE-WALL RECTANGULAR DUCTS AND FITTINGS

1. General Fabrication Requirements: Comply with SMACNA's "HVAC Duc Standards - Metal and Flexible" based on indicated static-pressure class ur indicated.

a. Reference SMACNA figure 2-9 and Drawings to construct gradual tra ductwork changes size or offsets.
b. Provide duct material, gages, reinforcing, and sealing for operating press

2. Transverse Joints: Select joint types and fabricate according to SMACNA' Construction Standards - Metal and Flexible," Figure 2-1, "Rectangular D Joints," for static-pressure class, applicable sealing requirements, materials support intervals, and other provisions in SMACNA's "HVAC Duct Constructi Metal and Flexible."

a. Transverse Duct Connection System

1) Slide on flange system: Ductmate and Ductmate WDCI connectic complete with interlocking angle and duct edge connection systen gasket, cleats, and corner clips. <u>Gasket material shall be chemica material in all fume exhaust ductwork.</u>
2) Formed on flange system: TDC, TDF or equivalent connection sys equivalent. Such flanges shall be constructed as SMACNA T-24 f 25 and 1-37 '85 SMACNA Duct Construction Manual, 1985 Editior

3. Longitudinal Seams: Select seam types and fabricate according to SMACNA Construction Standards - Metal and Flexible," Figure 2-2, "Rectangular Du Seams," for static-pressure class, applicable sealing requirements, materials support intervals, and other provisions in SMACNA's "HVAC Duct Constructi Metal and Flexible."
4. Elbows, Transitions, Offsets, Branch Connections, and Other Duct Constructio and fabricate according to SMACNA's "HVAC Duct Construction Standard Flexible," Chapter 4, "Fittings and Other Construction," for static-pressure cl sealing requirements, materials involved, duct-support intervals, and othe SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

a. Construct T's, and elbows in using radius of not less than 1-1/2 times v centerline. Where mitered rectangular elbows are used or indicated, vanes in accordance with Section 23 33 00.

7. 4 kHz Octave Band: 34

F. Manufacturer: Flexmaster Type 6B or equivalent.

2.3 LOUVER BACKPAN

A. Fabricate in accordance with SMACNA HVAC Duct Construction Standards - Metal and Flexible and NFPA 96.

B. Construct of 18-gage galvanized steel using continuous external welded joints.

C. Welded ductwork is to be welded with filler rod of the same material as the metal that is being welded. Prime coat and paint welded joints with cold galvanized paint.

D. Slope bottom to prevent accumulation of water. Provide drains where shown on drawings.

3. EXECUTION

3.1 GENERAL

A. Install in accordance with manufacturer's instructions; SMACNA HVAC Duct Construction Standards - Metal and Flexible, current edition and International Mechanical Code requirements.

B. Seal ducts in accordance with SMACNA HVAC Duct Construction Standards - Metal and Flexible, current edition.

C. Duct sizes are inside clear dimensions. For lined ducts, maintain sizes inside lining.

D. Duct transition from round to rectangular and vise versa shall be made with rectangular to round duct transition fitting.

E. Provide flange-type joint at transverse joints or seal as specified. All transverse joints shall be inspected by the Owner prior to insulating ductwork.

3.2 DUCT INSTALLATION

A. Drawing plans, schematics, and diagrams indicate general location and arrangement of duct system. Indicated duct locations, configurations, and arrangements were used to size ducts and calculate friction loss for air-handling equipment sizing and for other design considerations. Install duct systems as indicated unless deviations to layout are approved on Shop Drawings and Coordination Drawings.

B. Install round and flat-oval ducts in maximum practical lengths.

a. Install round in lengths not less than 10 feet, unless interrupted by fittings.

HEATING PIPING SYSTEM SYMBOLS

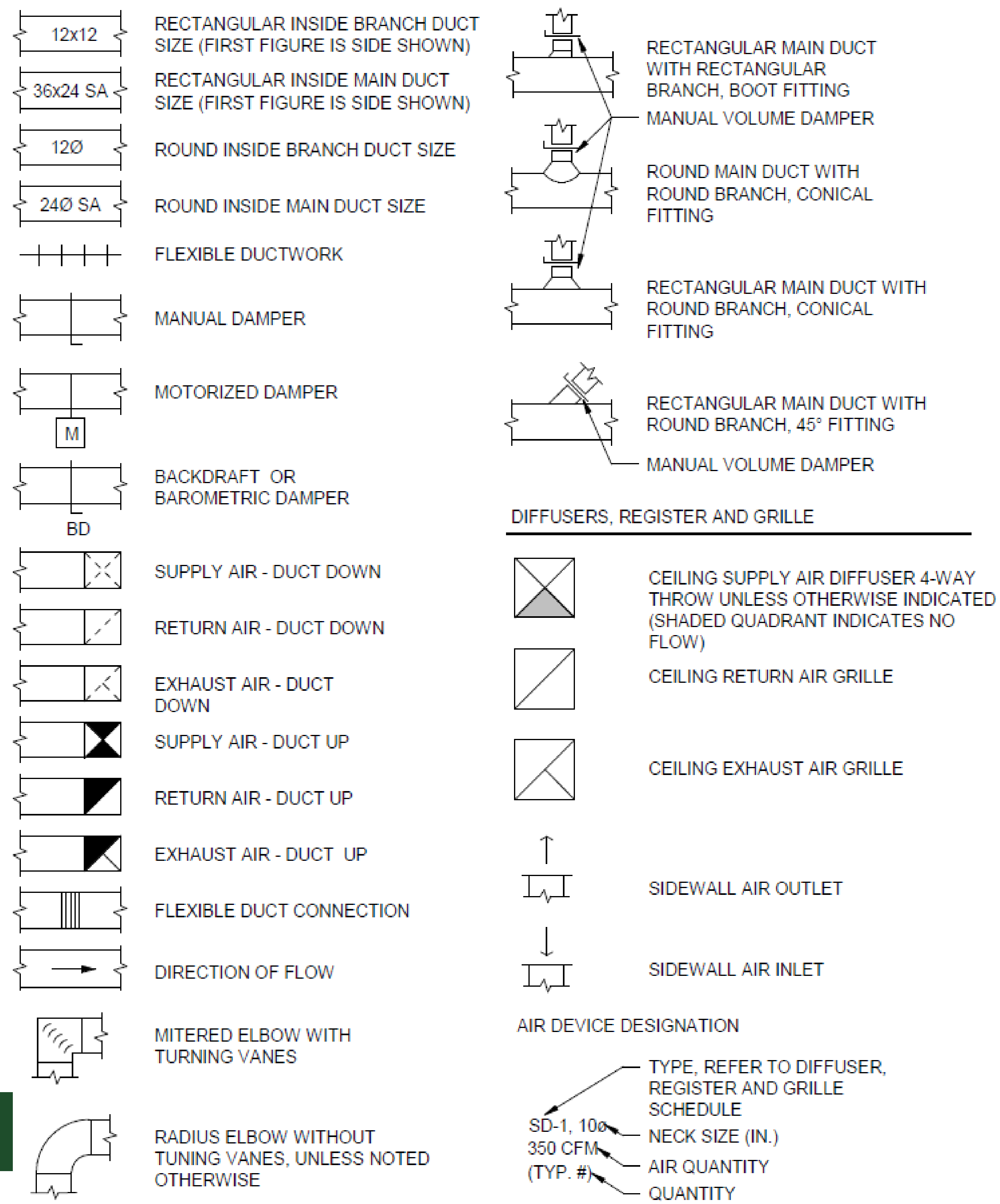
HEATING PIPING

Description	Symbol	Description	Symbol
High pressure steam supply	——HPS——	Make up water	—— MU ——
Medium pressure steam supply	——MPS——	Air relief line	—— V ——
Low pressure steam supply	——LPS——	Fuel oil suction	——FOS——
High pressure steam steam return	— —HPR— —	Fuel oil return	——FOR——
Medium pressure steam return	— — MPR — —	Fuel oil vent	——FOV——
Low pressure steam return	— —LPR — —	Compressed air	—— A ——
Boiler blow off	—— BD ——	Hot water heating supply	—— HWS——
Condensate or vacuum pump discharge	——VPD——	Hot water heating return	— —HWR— —
Feedwater pump discharge	——PPD——		

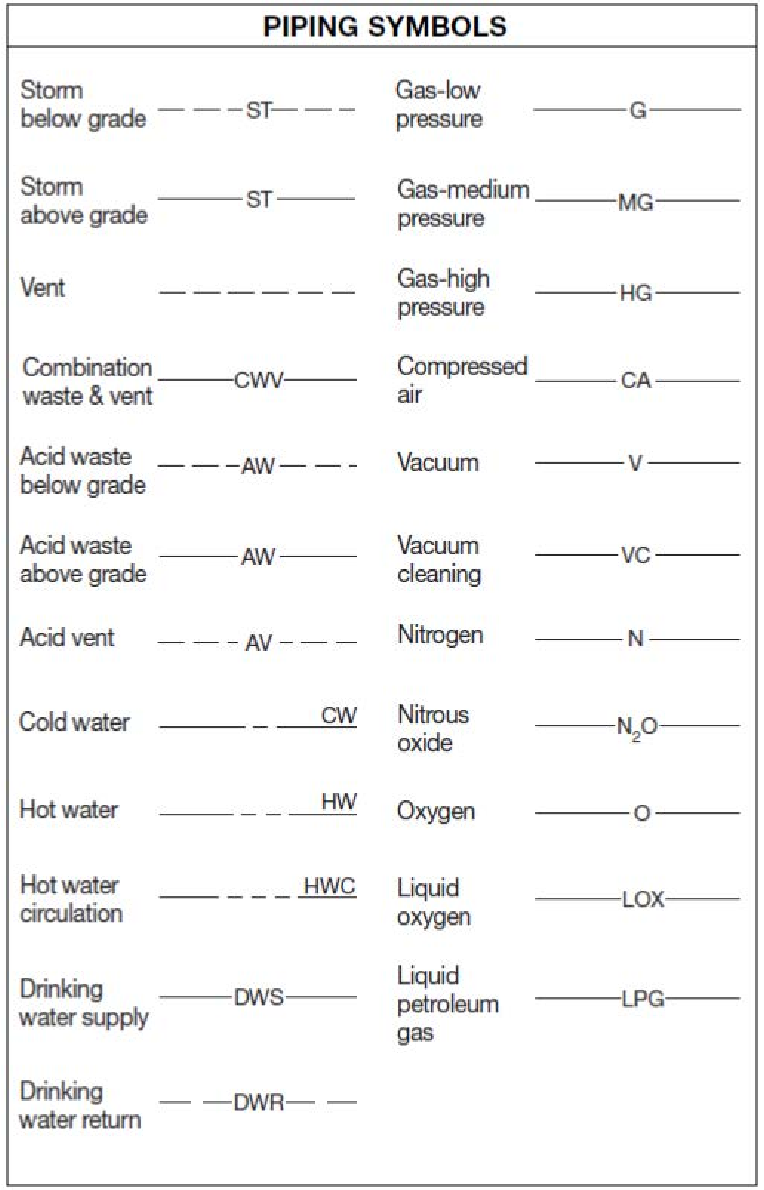
COOLING PIPING SYSTEM SYMBOLS

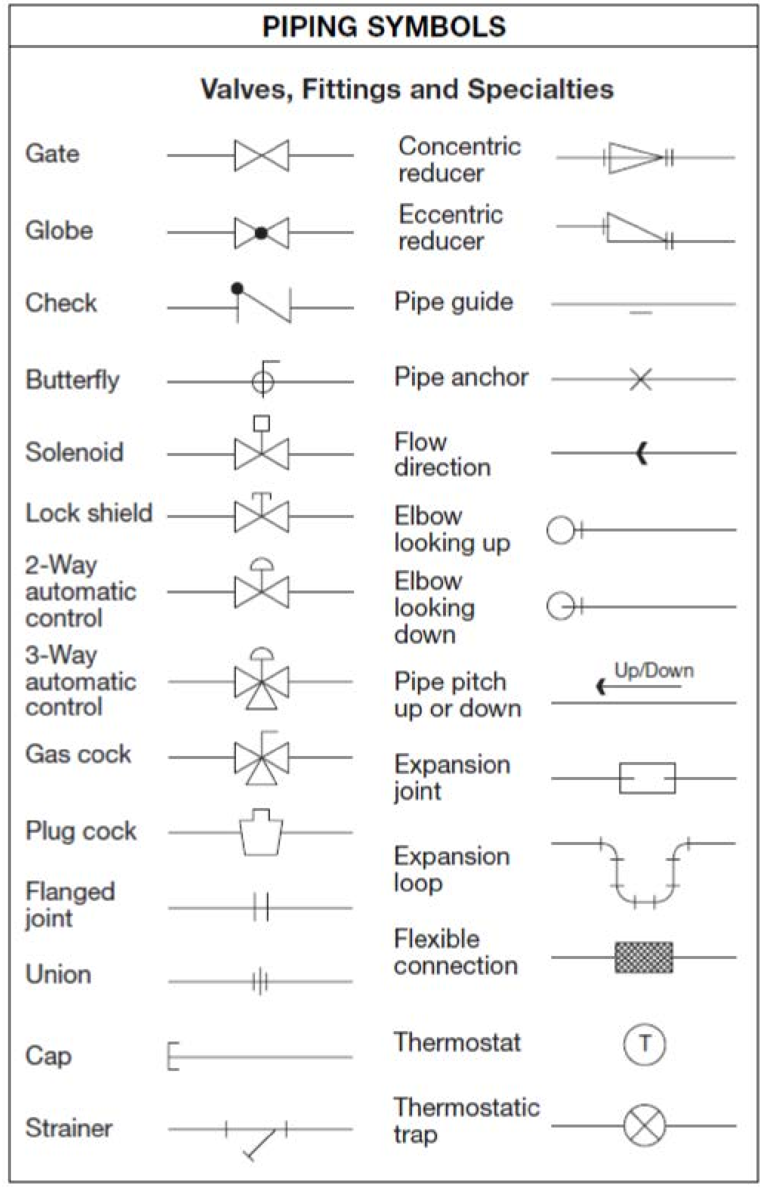
AIR CONDITIONING PIPING			
Refrigerant liquid	—— RL ——	Chilled water return	— — CWR — —
Refrigerant hot gas	—— RHG ——	Make up water	—— MU ——
Refrigerant suction	—— RS ——	Humidification line	—— H ——
Condenser water supply	—— CS ——	Drain	—— D ——
Condenser water return	— — CR — —	Brine supply	—— B ——
Chilled water supply	—— CWS ——	Brine return	—— BR ——

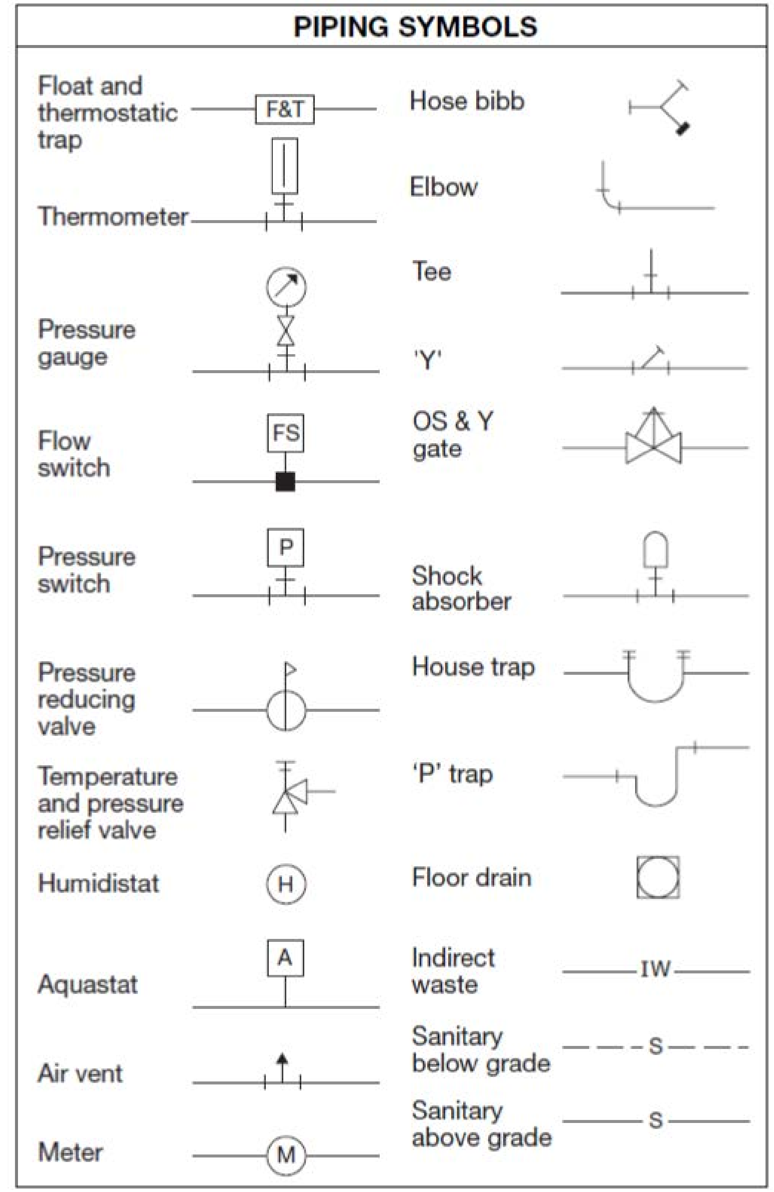
DUCTWORK SYMBOLS



PIPING SYSTEM SYMBOLS







CONTROLS SYMBOLS

	CONTROL DAMPER
M	PNEUMATIC MAIN
EPT	ELECTRIC PNEUMATIC TRANSDUCER
SD	SMOKE DETECTOR
CO	CARBON MONOXIDE DETECTOR
CO2	CARBON DIOXIDE DETECTOR
AM	AIR FLOW MEASURING STATION
T	TEMPERATURE SENSOR
FPS	FLOW PROVING SWITCH PADDLE TYPE
CSR	CURRENT SENSING RELAY
R	RELAY
DPS	DIFFERENTIAL PRESSURE SWITCH
DPT	DIFFERENTIAL PRESSURE TRANSMITTER
	FLUID FLOW MEASURING DEVICE
FMT	FLUID FLOW TRANSMITTER
FPS	FLOW PROVING SWITCH DIFFERENTIAL PRESSURE
SPD	SPEED INDICATION
FS	FLOW SENSOR
AS	STRAP ON AQUASTAT
AFT	AIR FLOW TRANSMITTER
OS	OCCUPANCY SENSOR
ES	DAMPER ACTUATOR END SWITCH
H	HUMIDITY SENSOR
A	GENERAL ALARM
	CONTACT
HL HL LL LL	HIGH-LOW TEMPERATURE THERMOSTAT
DPT	DIFFERENTIAL PRESSURE TRANSMITTER
CP	CONTROL PANEL - MOUNT CONTROL PANEL AT 4'8" ABOVE FLOOR TO CENTER OF CONTROL PANEL
EPO	EMERGENCY POWER OFF SWITCH - MOUNT BOTTOM AT 4'-0" ABOVE FLOOR
BPO	BOILER POWER OFF SWITCH - MOUNT BOTTOM AT 4'-0" ABOVE FLOOR
OR	MANUAL OVERRIDE SWITCH - MOUNT BOTTOM AT 4'-0" ABOVE FLOOR
FA	FIRE ALARM CONTROL MODULE
S	START/STOP

CONTROLS SYMBOLS

Symbol	Description
T	SPACE TEMPERATURE SENSOR - MOUNT BOTTOM AT X'-X" ABOVE FLOOR
OS	SPACE OCCUPANCY SENSOR - COORDINATE WITH ELECTRICAL
DP	SPACE DIFFERENTIAL PRESSURE SENSOR.
CO	SPACE CARBON MONOXIDE SENSOR
C	SPACE CARBON DIOXIDE SENSOR - MOUNT BOTTOM AT X'-X" ABOVE FLOOR
O2	OXYGEN SENSOR
T	SPACE THERMOSTAT - MOUNT BOTTOM AT X'-X" ABOVE FLOOR
T	UNIT MOUNTED THERMOSTAT
DI	DIGITAL INPUT
DO	DIGITAL OUTPUT
AI	ANALOG INPUT
AO	ANALOG OUTPUT
//	ELECTRICAL WIRING CONDUCTORS AS REQUIRED
- - - - -	INTERLOCK WIRING

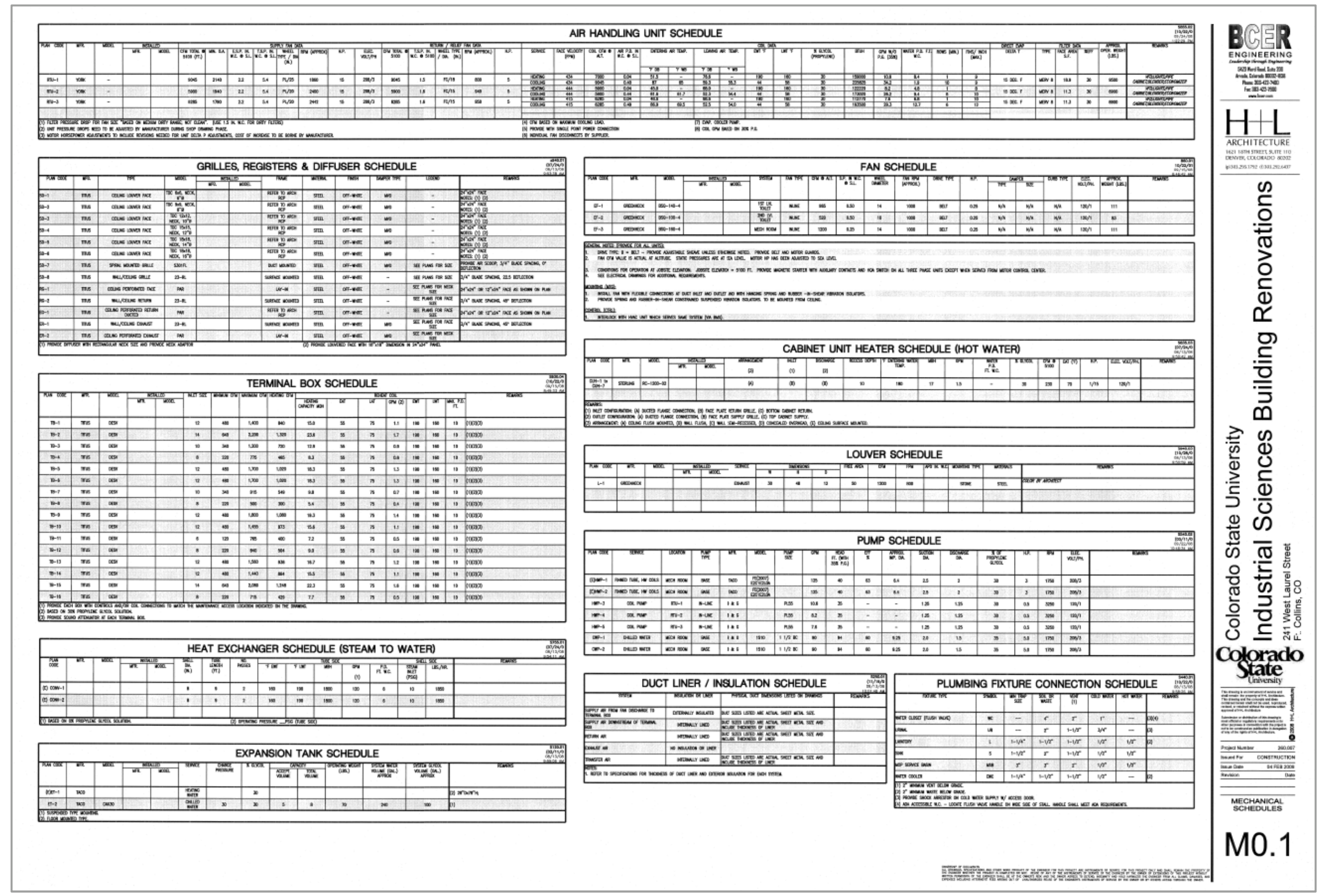
Symbol	Description
C NC NO	THREE WAY CONTROL VALVE
	TWO WAY CONTROL VALVE
STARTER	STARTER
VSD	VARIABLE SPEED MOTOR CONTROLLER
VFD	VARIABLE SPEED MOTOR CONTROLLER
UVC	ULTRAVIOLET CONTROLLER
H C	HOT WATER HEATING COIL
C C	CHILLED WATER COOLING COIL
	FILTER

MECHANICAL ABBREVIATIONS

AC	AIR COMPRESSOR
ADJ	ADJUSTABLE
AFF	ABOVE FINISHED FLOOR
AHU	AIR HANDLING UNIT
AMPS	AMPERES
AS	AIR SEPARATOR
ATC	ACOUSTICAL TILE CEILING
AV	AIR VENT
B	BOILER
BAS	BUILDING AUTOMATION SYSTEM
BBH	BASEBOARD HYDRONIC HEATER
BDD	BACK DRAFT DAMPER
BHP	BRAKE HORSPOWER
BMS	BUILDING MANAGEMENT SYSTEM
BP	BOILER PUMP
BTU	BRITISH THERMAL UNIT
BTUH	BTU PER HOUR
9	
CC	COOLING COIL
CD	CONDENSATE DRAIN
CFH	CUBIC FEET PER HOUR
CFM	CUBIC FEET PER MINUTE
CH	CHILLER
CHWP	CHILLED WATER PUMP
CHWR	CHILLED WATER RETURN
CHWS	CHILLED WATER SUPPLY
CO	CARBON MONOXIDE
CO2	CARBON DIOXIDE
COND	CONDENSATE
CRAC	COMPUTER ROOM AIR CONDITIONING
CRU	CONDENSATE RECOVERY UNIT
CT	COOLING TOWER
CUH	CABINET UNIT HEATER
CW	DOMESTIC COLD WATER
CWP	CONDENSER WATER PUMP
CWR	CONDENSER WATER RETURN
CWS	CONDENSER WATER SUPPLY
DB	DRY BULB
dB	DECIBELS
DDC	DIRECT DIGITALCONTROL
DEG	DEGREES
DEG F	DEGREES FAHRENHEIT
DN	DOWN
DXE	DOMESTIC HOT WATER HEAT EXCHANGER
EA	EXHAUST AIR
EAT	ENTERING AIR TEMPERATURE
EAU	EXHAUST AIR UNIT
EDB	ENTERING DRY BULB TEMPERATURE
EF	EXHAUST FAN
EG	EXHAUST GRILLE
EMCS	ENERGY MANAGEMENT CONTROL SYSTEM
ERV	ENERGY RERCOVERY VENTILATOR
ESP	EXTERNAL STATIC PRESSURE
ET	EXPANSION TANK
EWB	ENTERING WET BULB TEMPERATURE
EWT	ENTERING WATER TEMPERATURE
F	DEGREES FAHRENHEIT
F&T	FLOAT AND THERMOSTATIC STEAM TRAP
FCU	FAN COIL UNIT
FD	FIRE DAMPER
FF	FINAL FILTER
FILL	FILL LINE
FLA	FULL LOAD AMPS
FPM	FEET PER MINUTE
FPVAV	FAN POWERED VARIABLE AIR VOLUME UNIT
FSD	FIRE SMOKE DAMPER
FT	FLASH TANK
FT	FEET
FT HD	FEET HEAD
FTU	FAN TERMINAL UNIT
GA	GAUGE
GC	GENERAL CONTRACTOR
GF	GLYCOL FEEDER DOSING PUMP
GPM	GALLONS PER MINUTE
HC	HEATING COIL
HP	HORSEPOWER
HP	HEAT PUMP
HR	HOUR
HRCP	HEAT RECOVERY PUMP
HUM	STEAM HUMIDIFICATION UNIT
HWP	HEATING WATER CIRCULATION PUMP
HWR	HEATING WATER RETURN
HWS	HEATING WATER SUPPLY
HX	HEAT EXCHANGER
Hz	HERTZ
IAQ	INDOOR AIR QUALITY
IB	INVERTED BUCKET TRAP
IF	INTERMEDIATE FILTER
IN W.G.	INCHES OF WATER GAUGE
kPa	KILOPASCALS
kW	KILOWATT
L	LOUVER
LAT	LEAVING AIR TEMPERATURE
LDB	LEAVING DRY BULB TEMPERATURE
LRA	LOCKED ROTOR AMPS
LS	LINEAR SLOT SUPPLY DIFFUSER
LVG	LEAVING
LWB	LEAVING WET BULB TEMPERATURE
LWT	LEAVING WATER TEMPERATUTE
MAX	MAXIMUM
MBH	THOUSAND BTU PER HOUR
MC	MECHANICAL CONTRACTOR
MCA	MINIMUM CIRCUIT AMPACITY
MIN	MINIMUM
MUA	MAKE-UP AIR
MZ	MULTI-ZONE
NC	NORMALLY CLOSED
NO	NORMALLY OPEN
NTS	NOT TO SCCALE
OA	OUTSIDE AIR
OAT	OUTSIDE AIR TEMPERATURE
P	PUMP
Pa	PASCALS
PD	PRESSURE DROP
PF	PRE FILTER
PH	PHASE
PHC	HYDRONIC PREHEAT COIL
PPE	PERSONAL PROTECTIVE EQUIPMENT
PPM	PARTS PER MILLION
PRV	PRESSURE REDUCING VALVE
PSI	POUNDS PER SQUARE INCH
PSIG	PSI GUAGE
RA	RETURN AIR
RAD	REFRIGERATED AIR DRYER
RF	RETURN AIR FAN
RG	RETURN GRILLE
RH	RELATIVE HUMIDITY
RH	RELIEF HOOD
RHC	REHEAT COIL
RLA	RUNNING LOAD AMPS
RPM	REVOLUTIONS PER MINUTE
SA	SUPPLY AIR
SA	SUPPLY ATTENUATOR
SCBA	SELF CONTAINED BREATHING APPARATUS
SD	SUPPLY DIFFUSER
SF	SUPPLY FAN
SG	SUPPLY GRILLE
SP	STATIC PRESSURE
SR	SUPPLY REGISTER
ST	STEAM TRAP
TDH	TOTAL DYNAMIC HEAD
TEMP	TEMPERATURE
TG	TRANSFER GRILLE
TSP	TOTAL STATIC PRESSURE
TYP	TYPICAL
UH	UNIT HEATER
UMCS	UTILITY MONITORING AND CONTROL SYSTEM
UNO	UNLESS NOTED OTHERWISE
UPS	UNINTERRUPTED POWER SUPPLY
V	VOLTS
VAV	VARIABLE AIR VOLUME UNIT
WB	WET BULB TEMPERATURE
WC	WATER COLUMN
WG	WATER GUAGE

MECHANICAL SCHEDULES

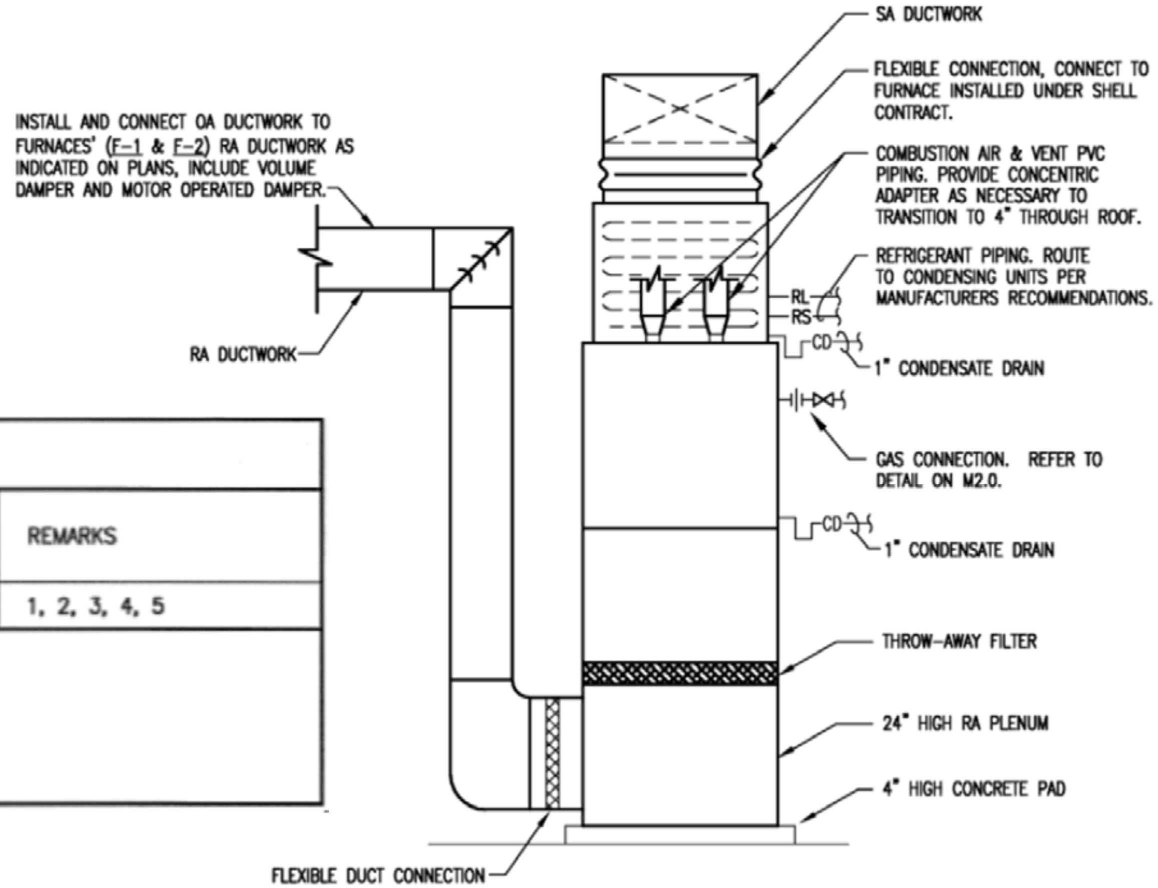
- Schedules provide details on the primary equipment and materials used in the HVAC system
  - Air Handling Units
  - Terminal Box Units
  - Grilles, Registers, Diffusers
  - Heat Exchangers
  - Expansion tanks
  - Fans
  - Pumps
  - Louvers
  - Duct Liner/Insulation
  - Others



MECHANICAL SCHEDULES

GAS-FIRED UNIT HEATER SCHEDULE									
DESIGNATION	INPUT MBH	OUTPUT MBH	CFM	H.P.	VOLTS/PHASE	FLA	MANUFACTURER	MODEL	REMARKS
GUH-1	45	37	629	1/4	120/1ø	3.6	REZNOR	UDAP-45	1, 2, 3, 4, 5

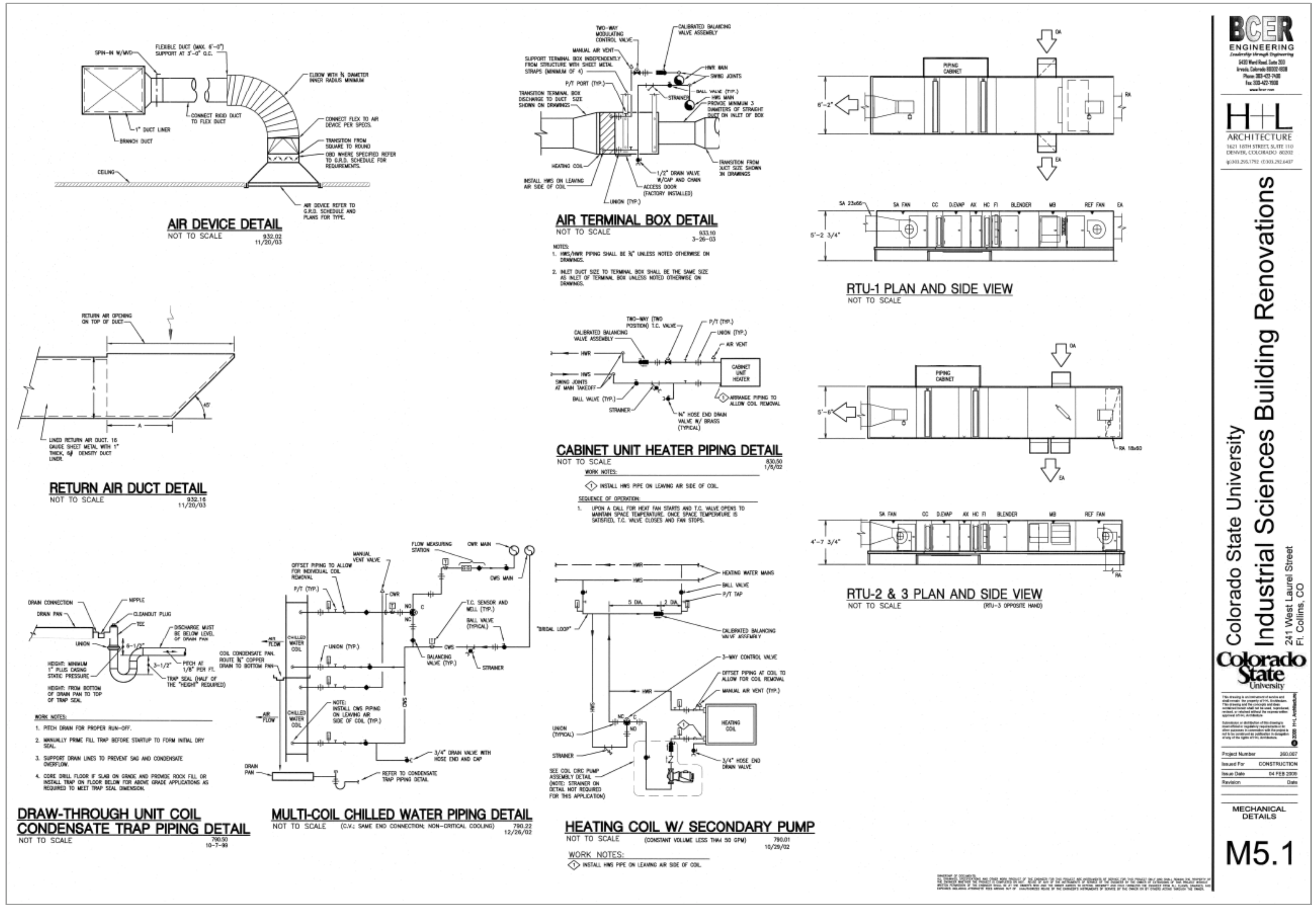
NOTES
1. SPARK IGNITION
2. PROVIDE VENT CAP
3. PROVIDE THERMOSTAT
4. PROVIDE DISCONNECT SWITCH
5. POWER VENT



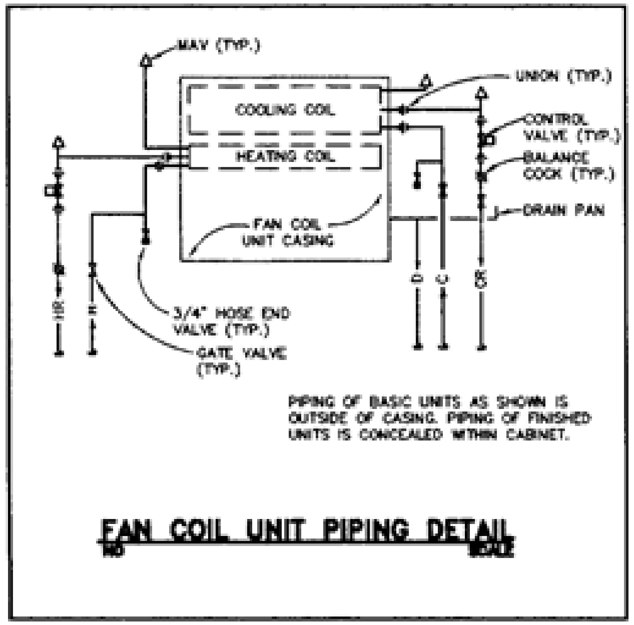
UPFLOW FURNACE DETAIL
N.T.S.

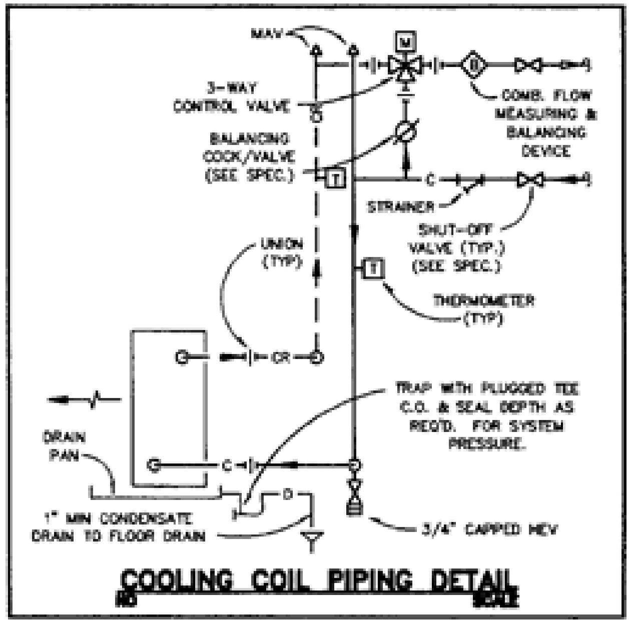
MECHANICAL DETAILS

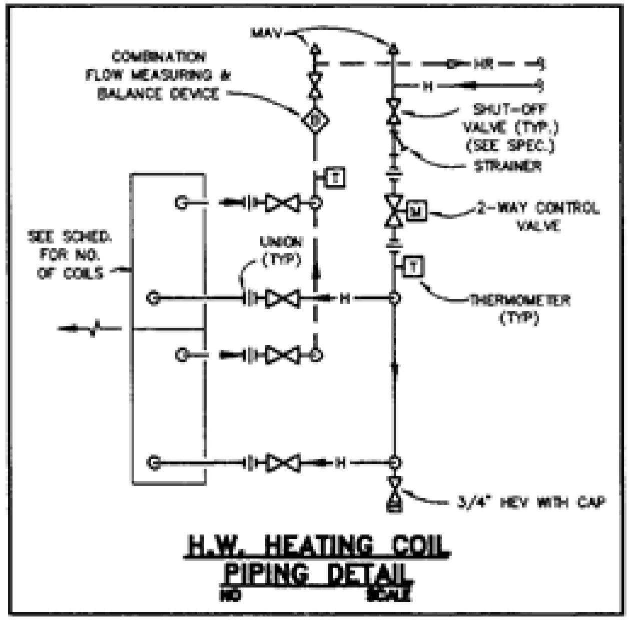
- Complete design with finer details for critical components of the HVAC system
  - Can be scaled to provide closer details



PIPING DETAILS







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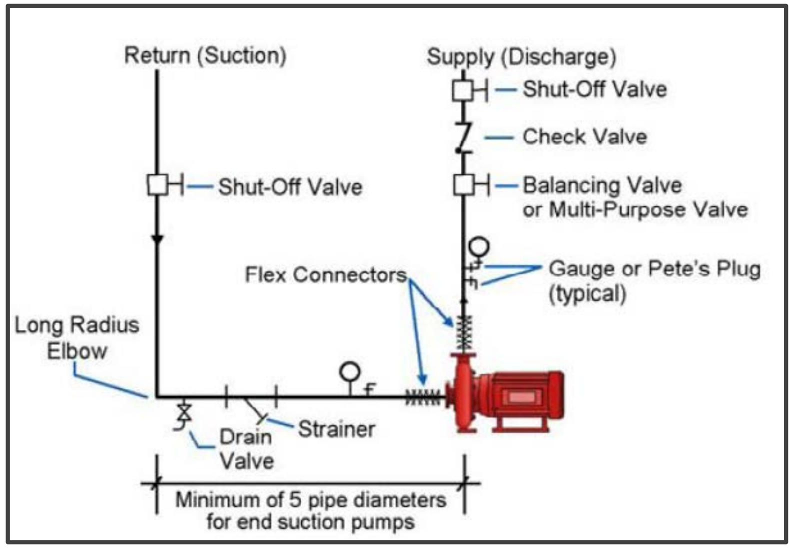
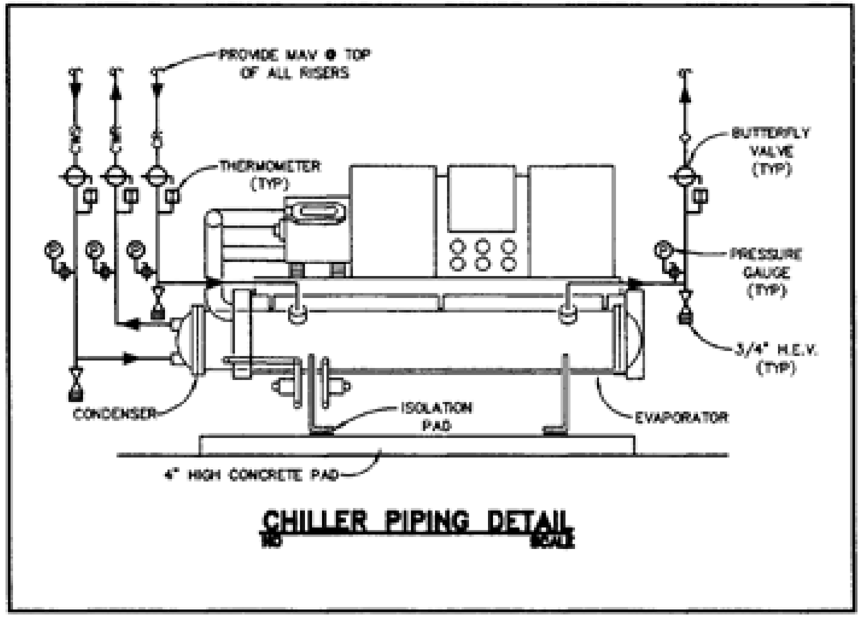
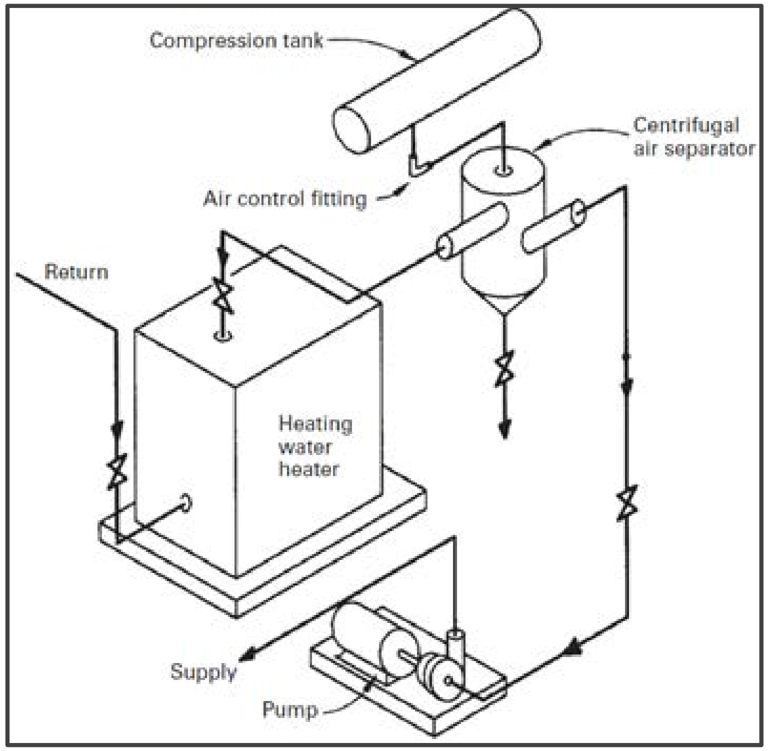


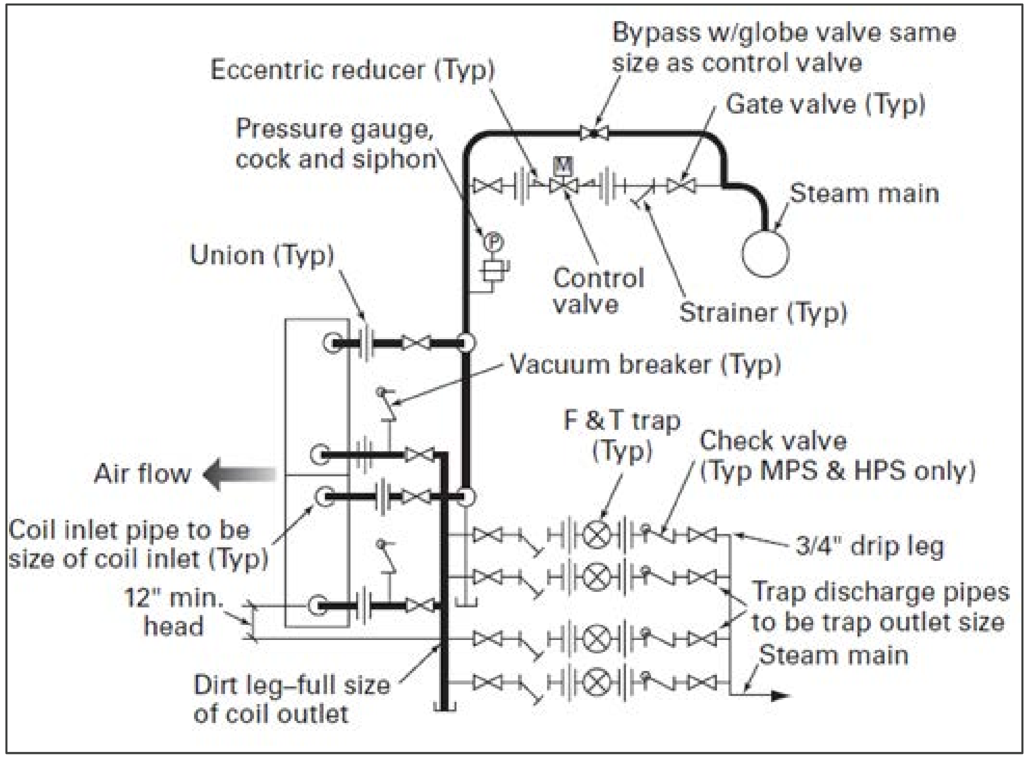
Pump Piping Detail



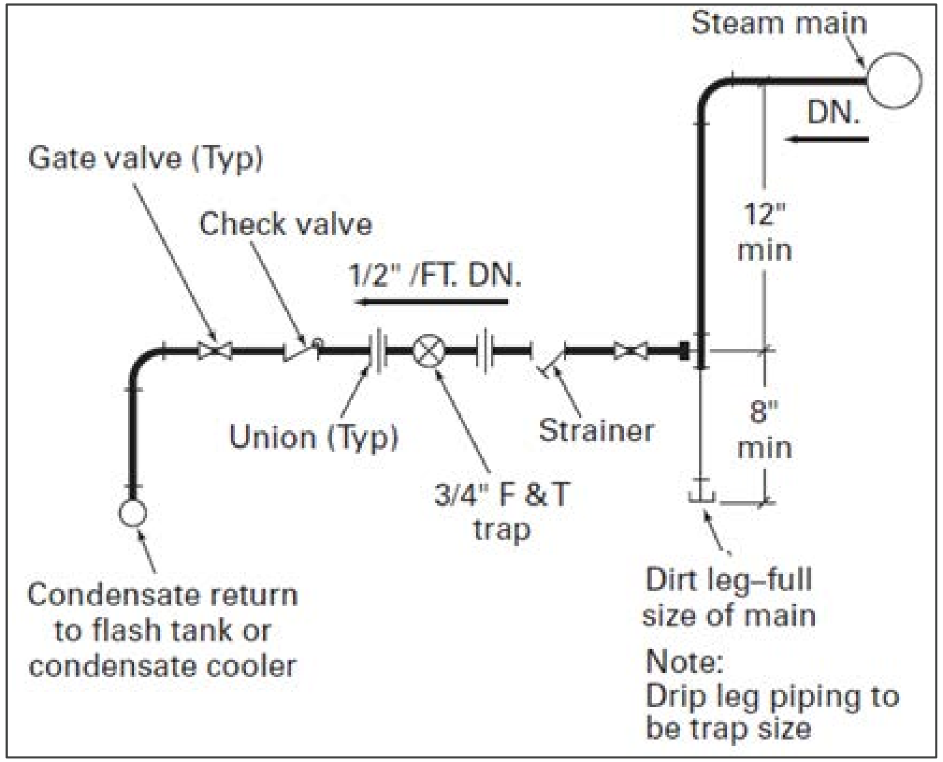


Air Separator and Compression Tank Detail

STEAM AND CONDENSATE PIPING DETAILS

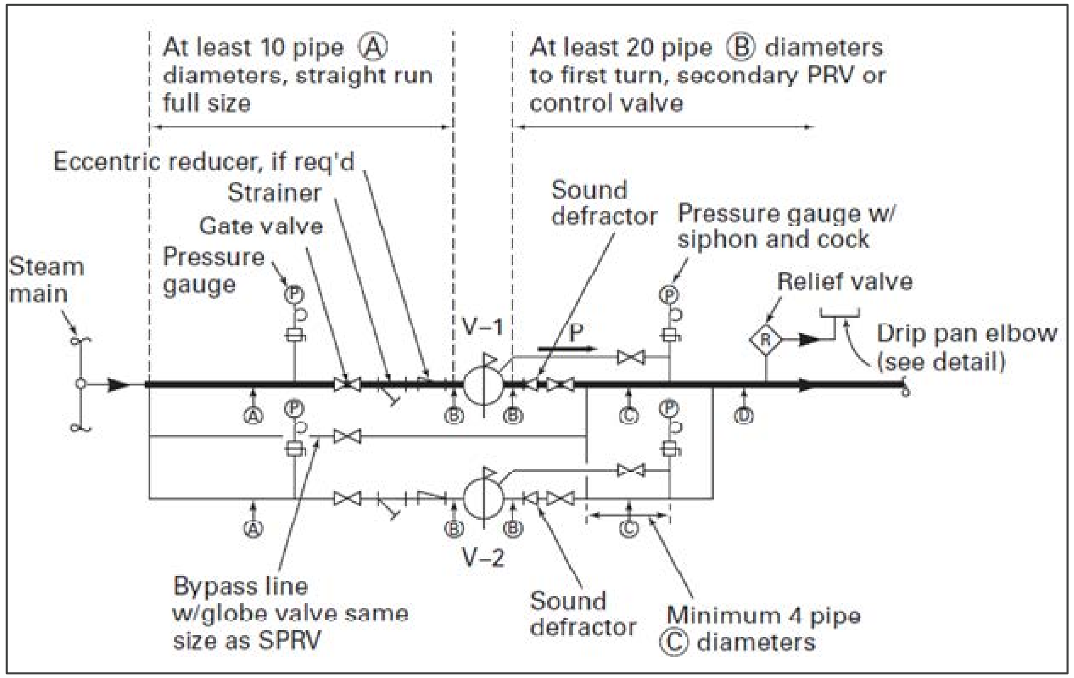


Steam Heating Coil Piping Detail

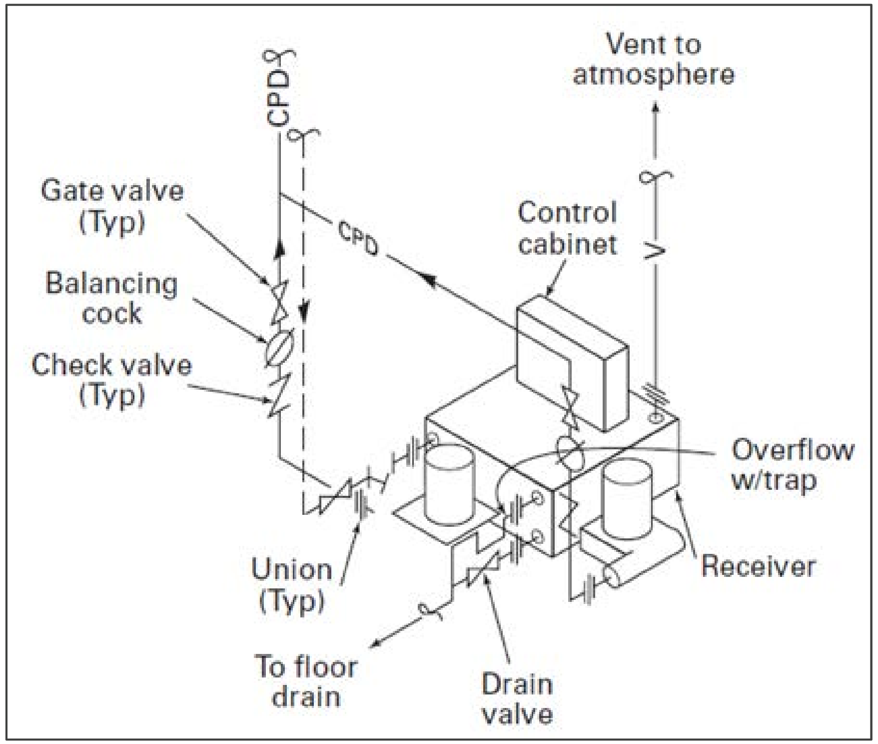


Steam Drip Leg Detail (Medium and High pressure systems)

STEAM AND CONDENSATE PIPING DETAILS

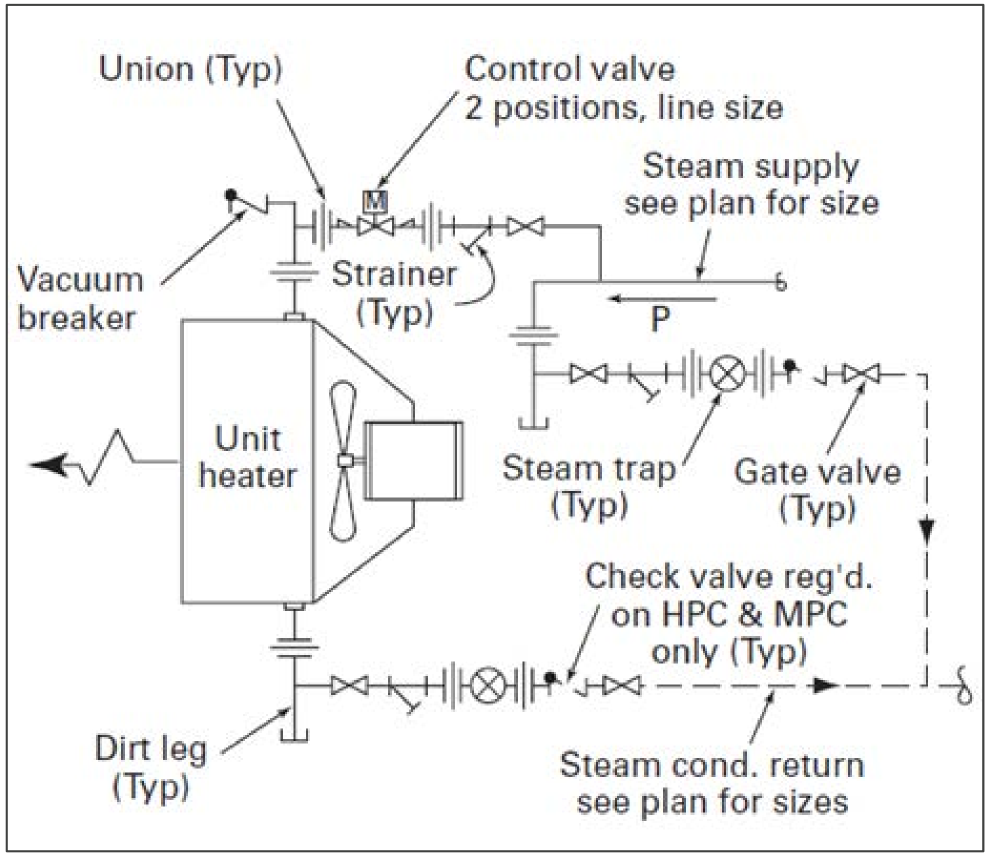


Steam Pressure-Reducing Valve and Relief Valve



Duplex Condensate Pump Piping Detail

STEAM AND CONDENSATE PIPING DETAILS

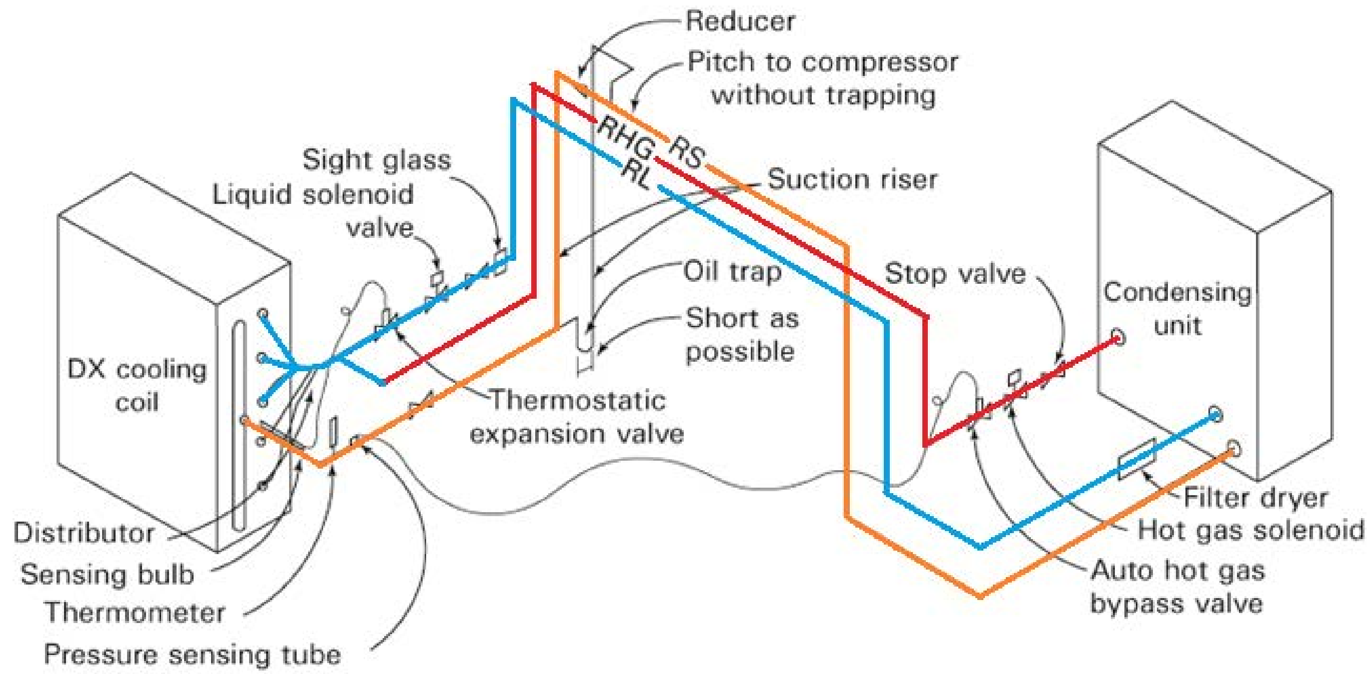


Steam Unit Heater Piping Detail

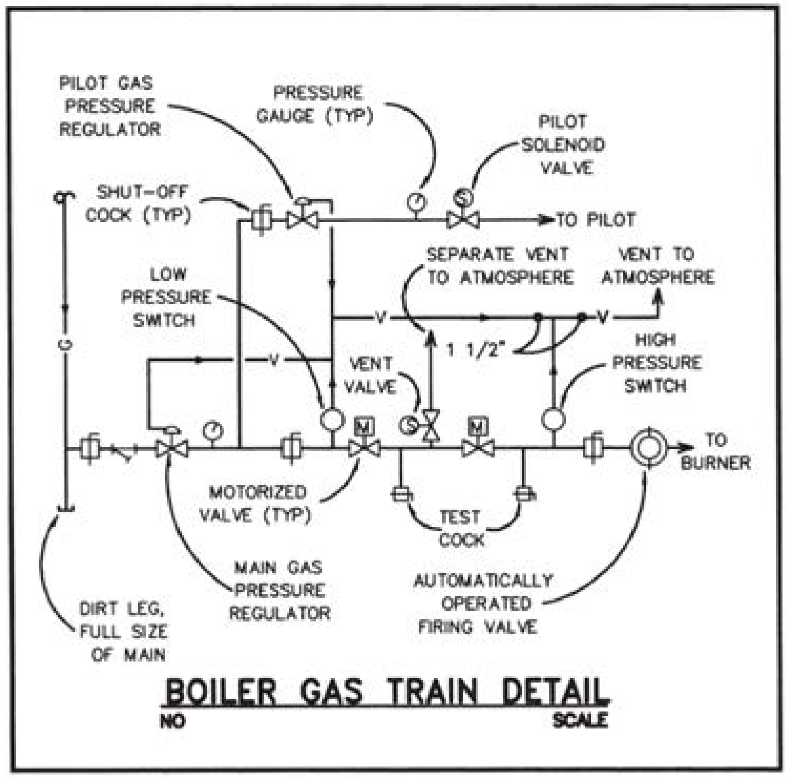
REFRIGERANT PIPING DETAIL

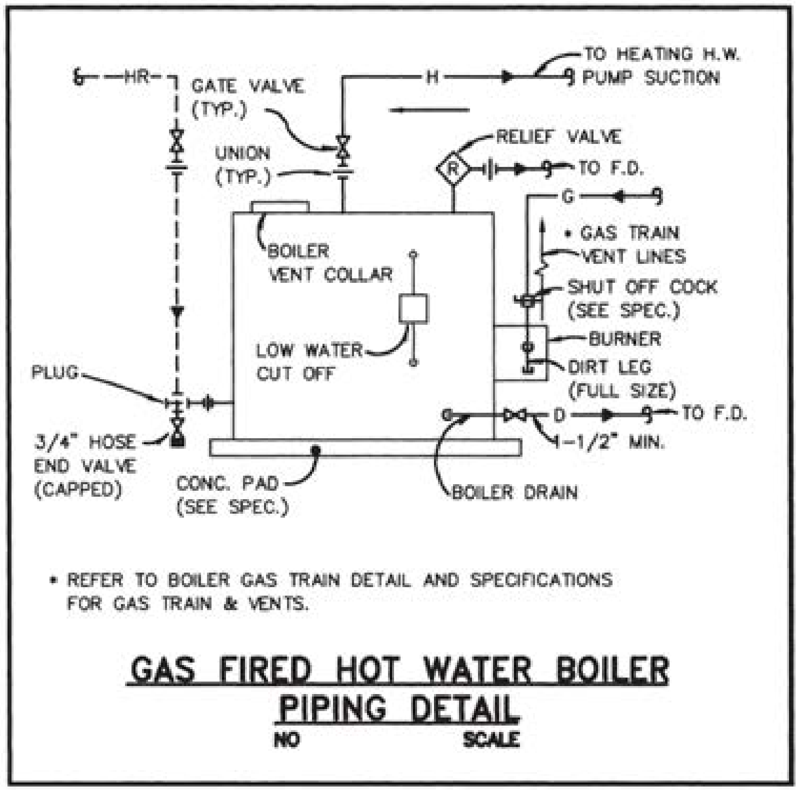
- Direct Expansion System
  - RS – Refrigerant cold suction line
  - RHG – Refrigerant hot gas line
  - RL – Refrigerant liquid line

- Copper, brass, or steel piping
- Joint-soldier, brazed, special screwed connector

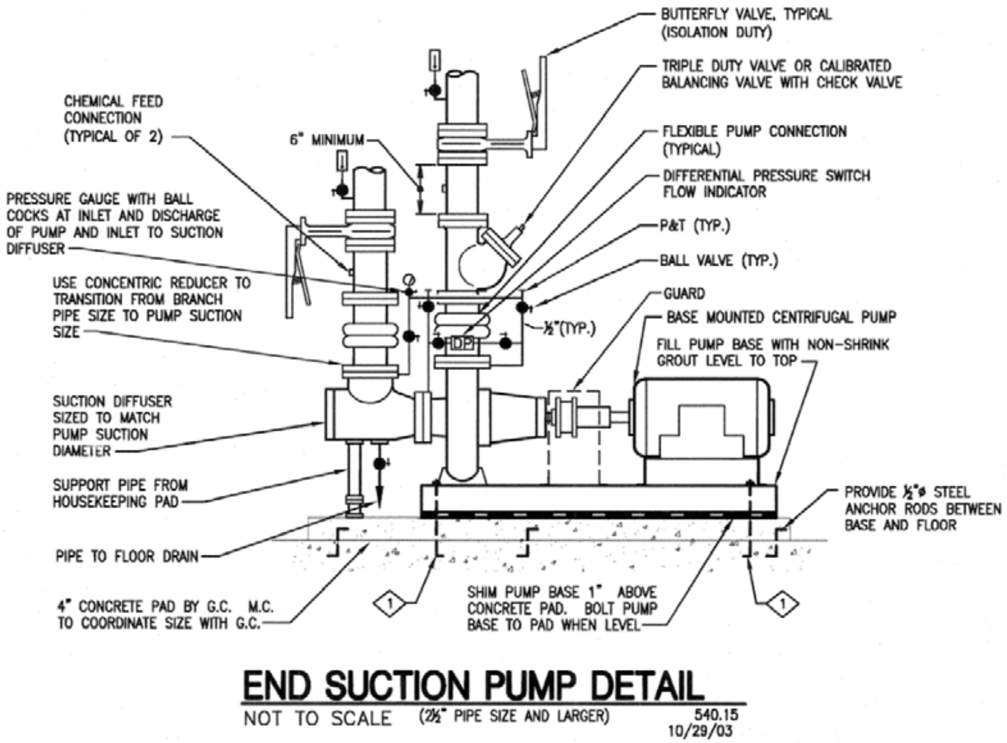


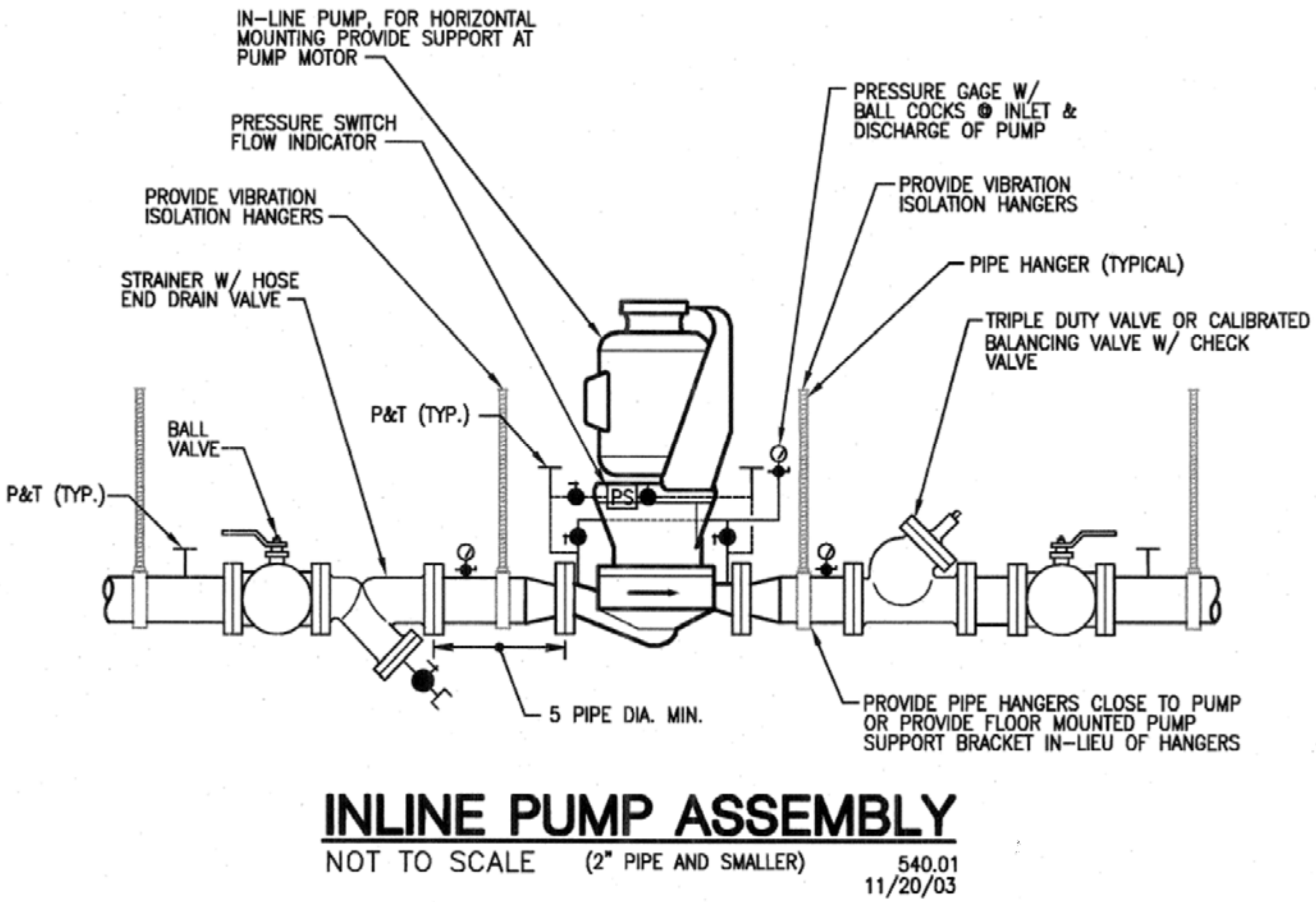
GAS PIPING DETAIL



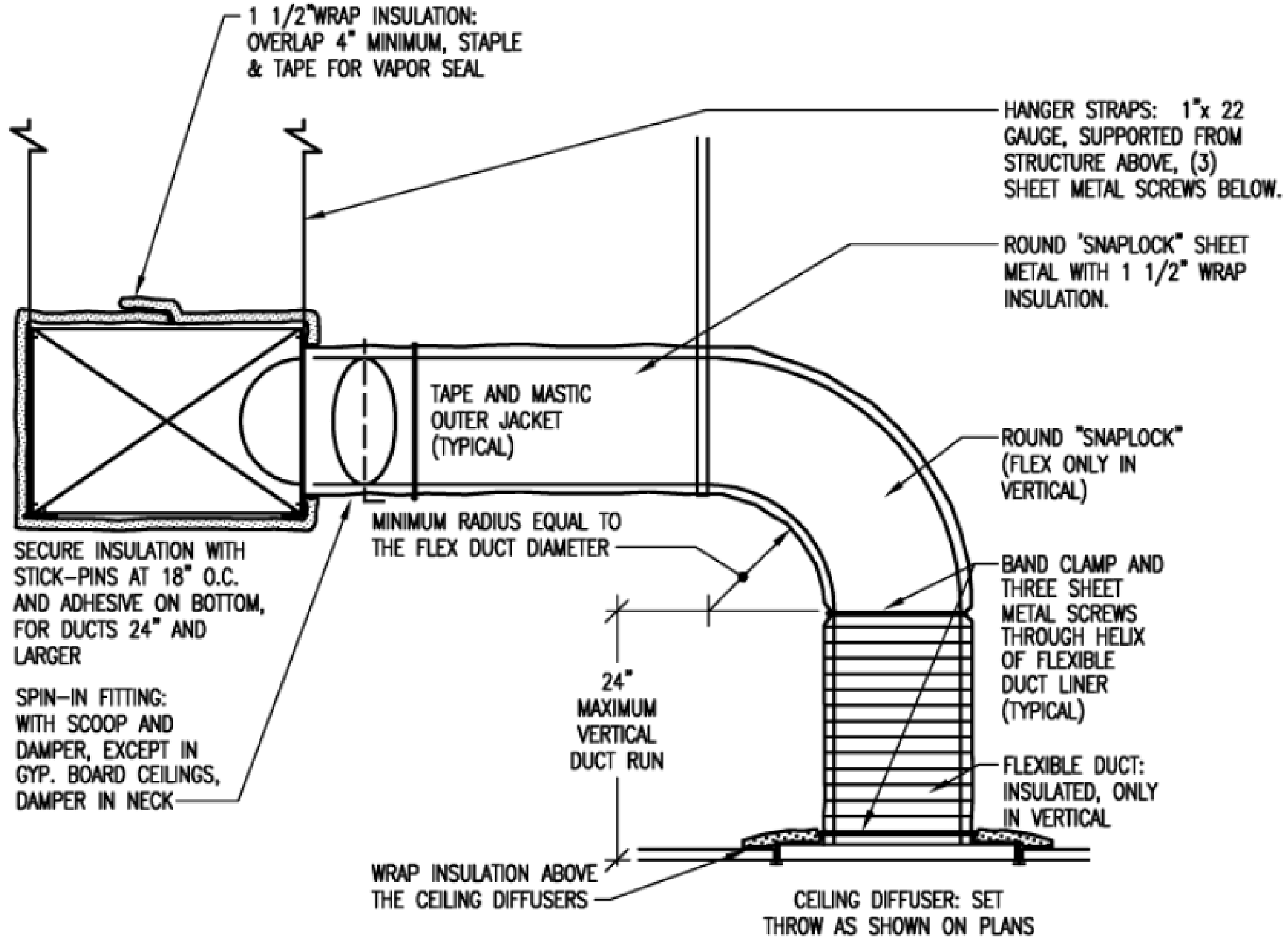


PUMP DETAILS



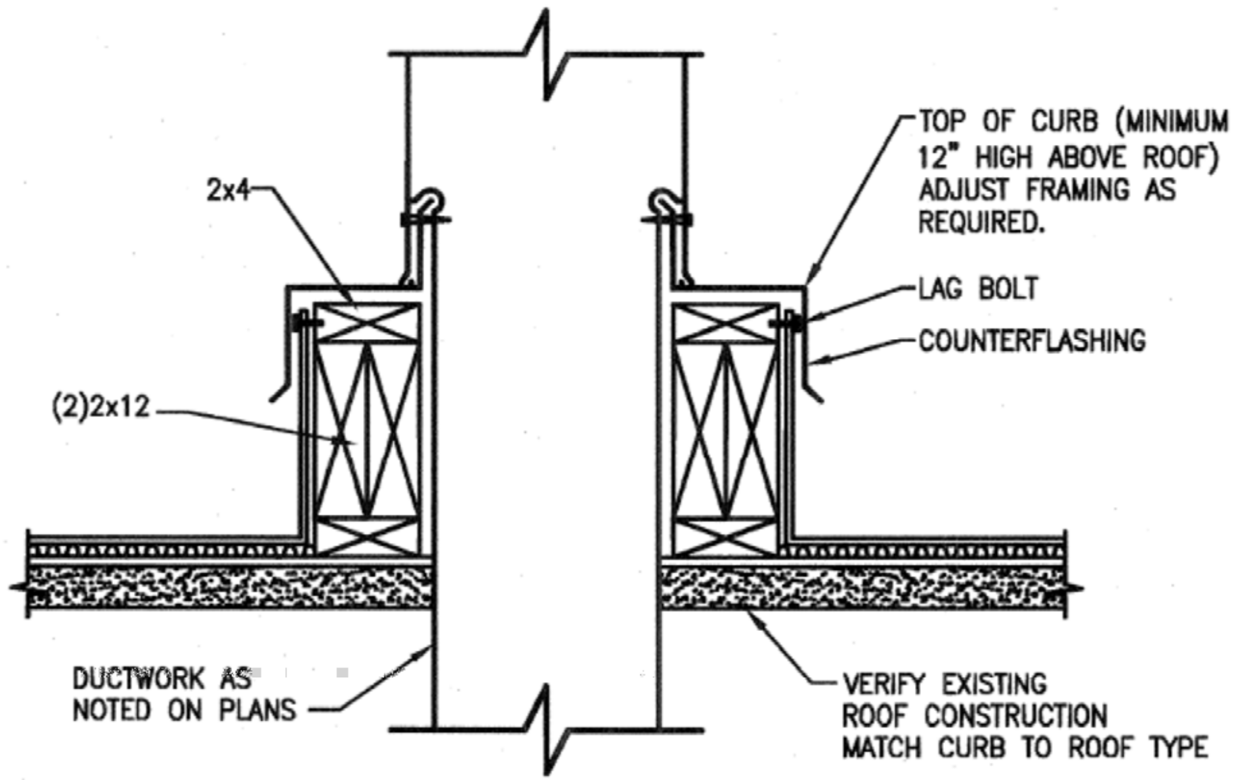


DIFFUSER DETAILS



CEILING DIFFUSER CONNECTION DETAIL (LAY-IN CEILING)
NTS

DUCT ROOF PENETRATION DETAIL



RECTANGULAR DUCT ROOF PENETRATION DETAIL

NOT TO SCALE

891.01
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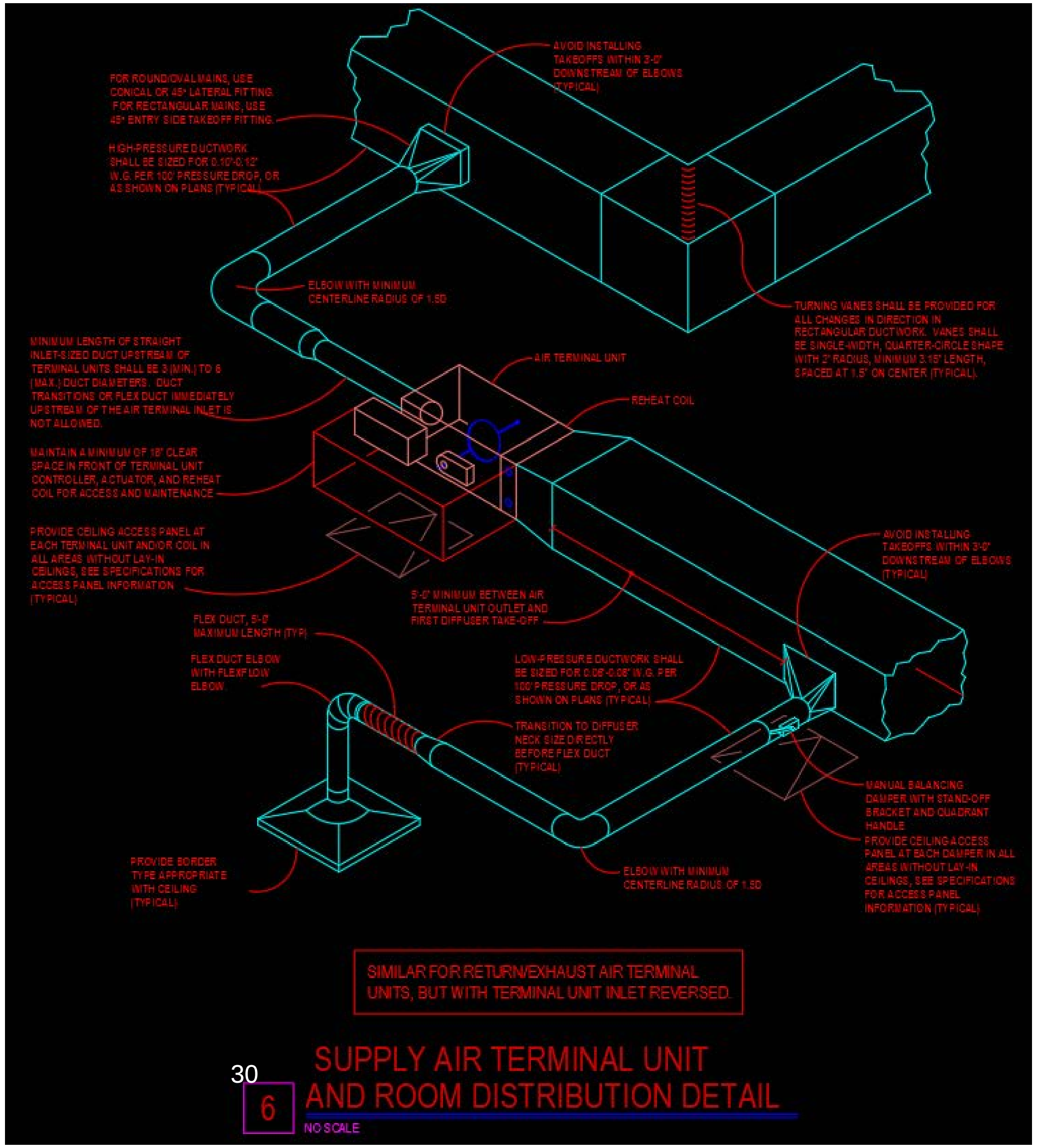
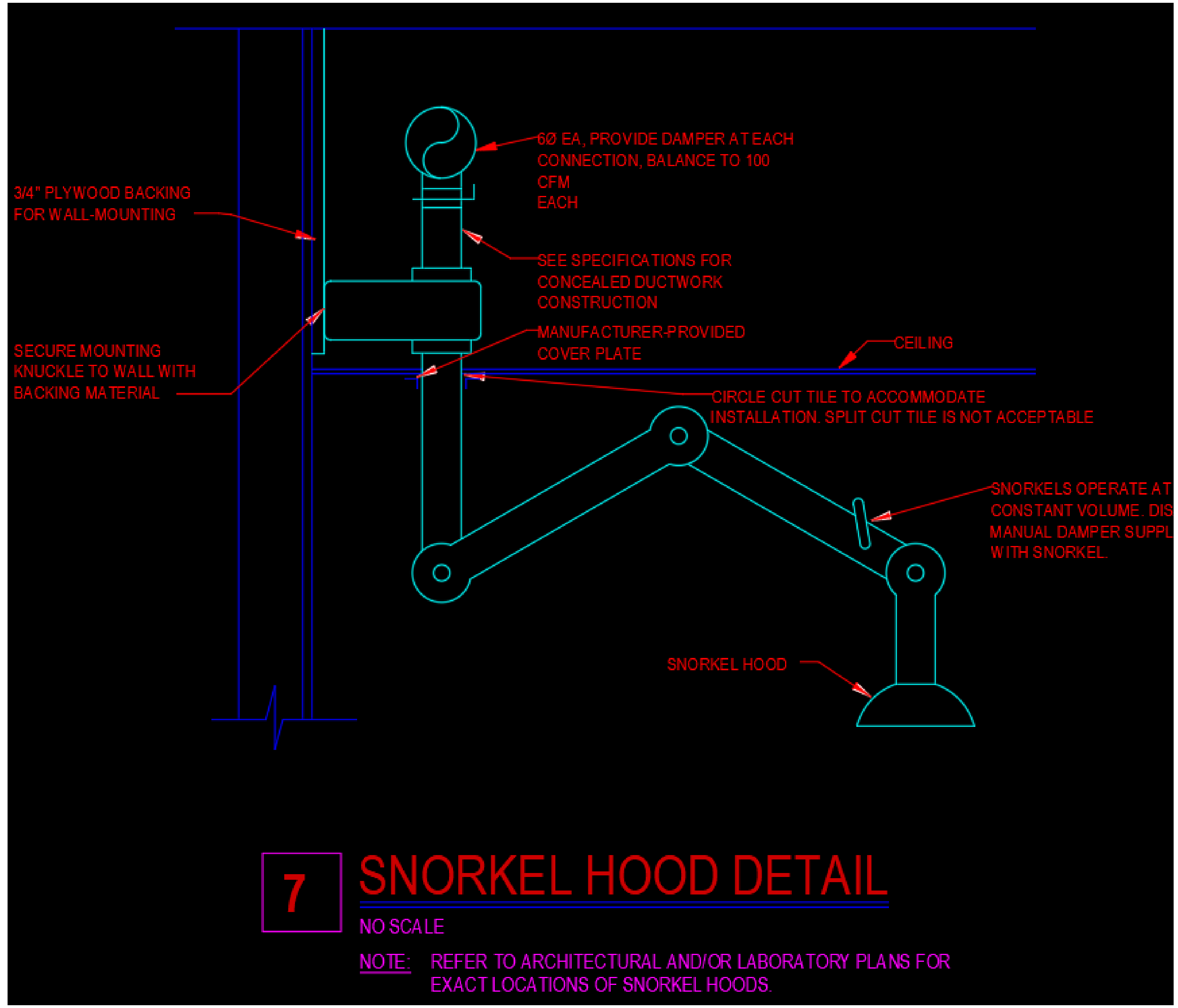
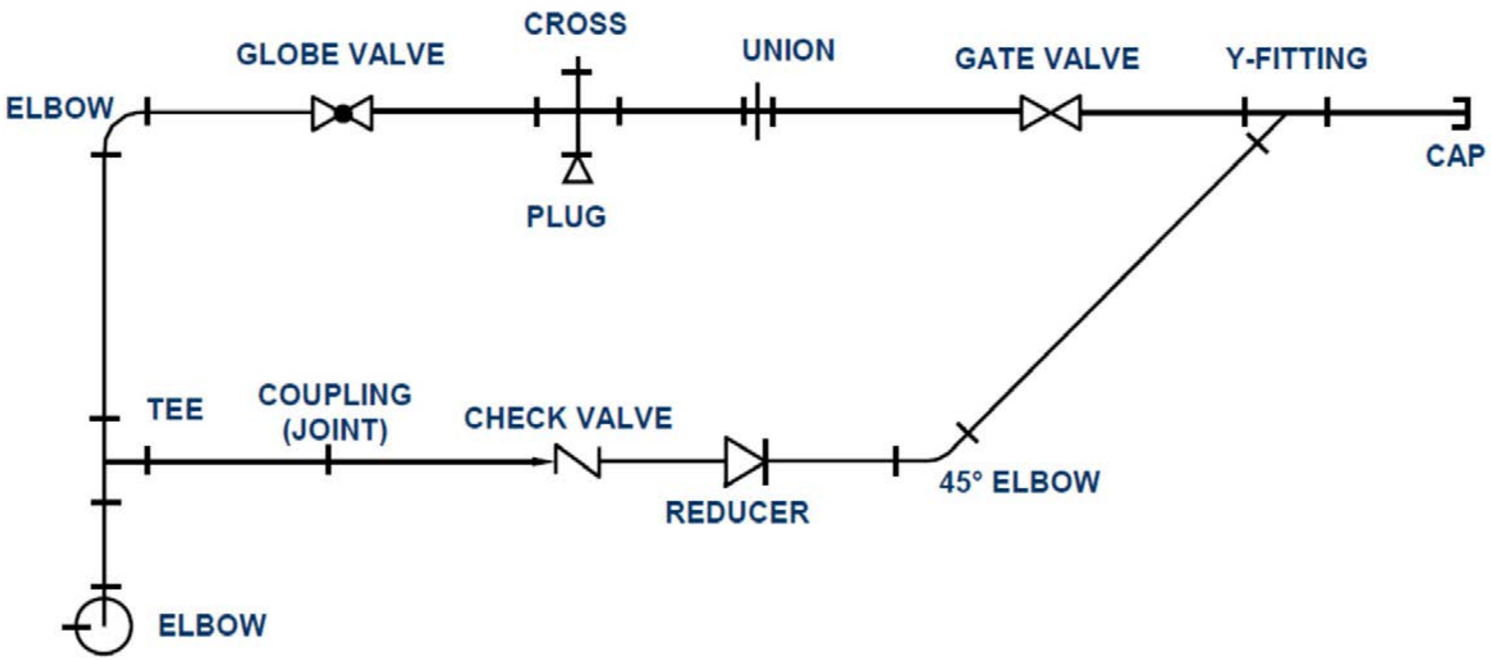
SUPPLY AIR AND SNORKEL HOOD DETAILS



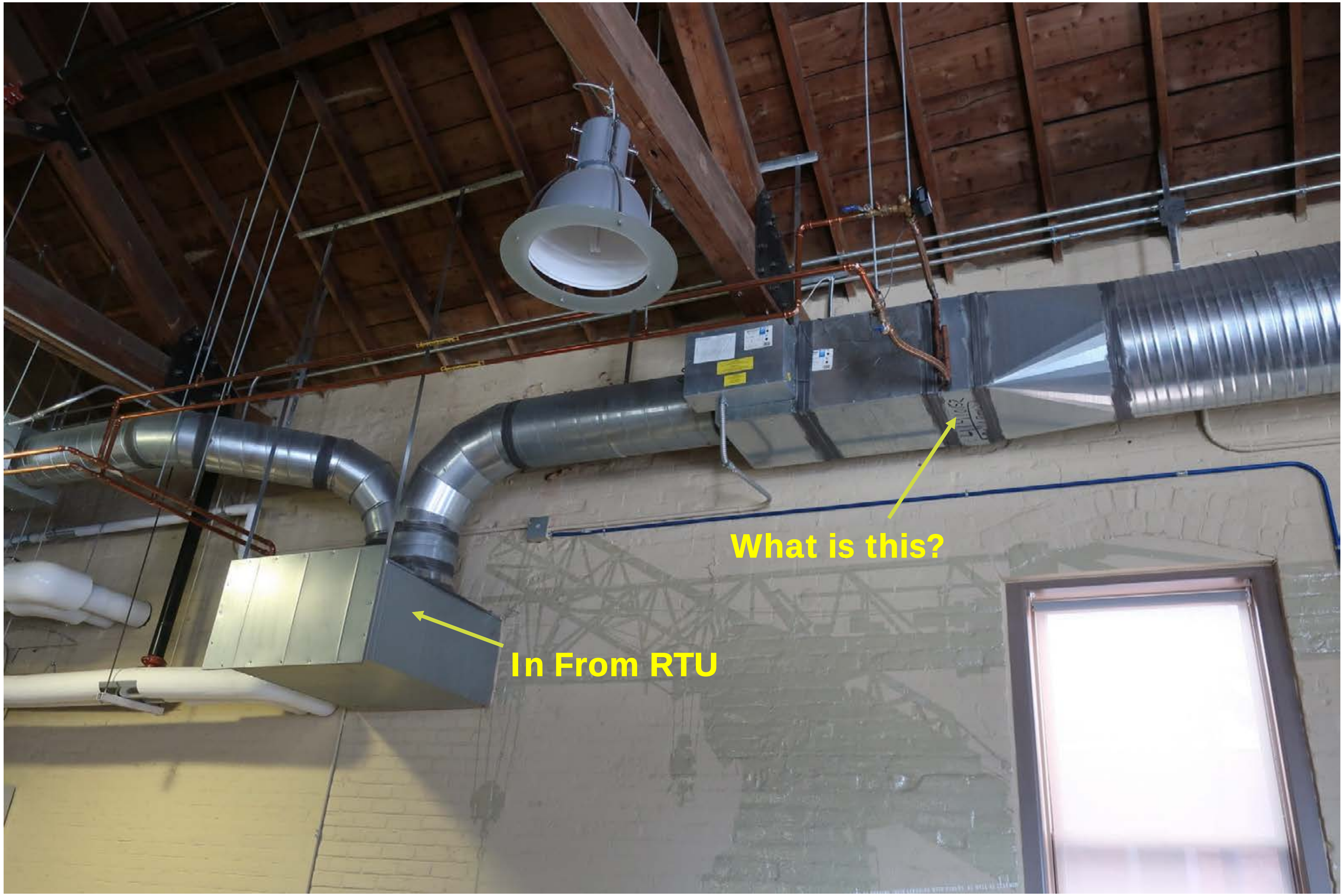


SINGLE LINE (SCHEMATICS)

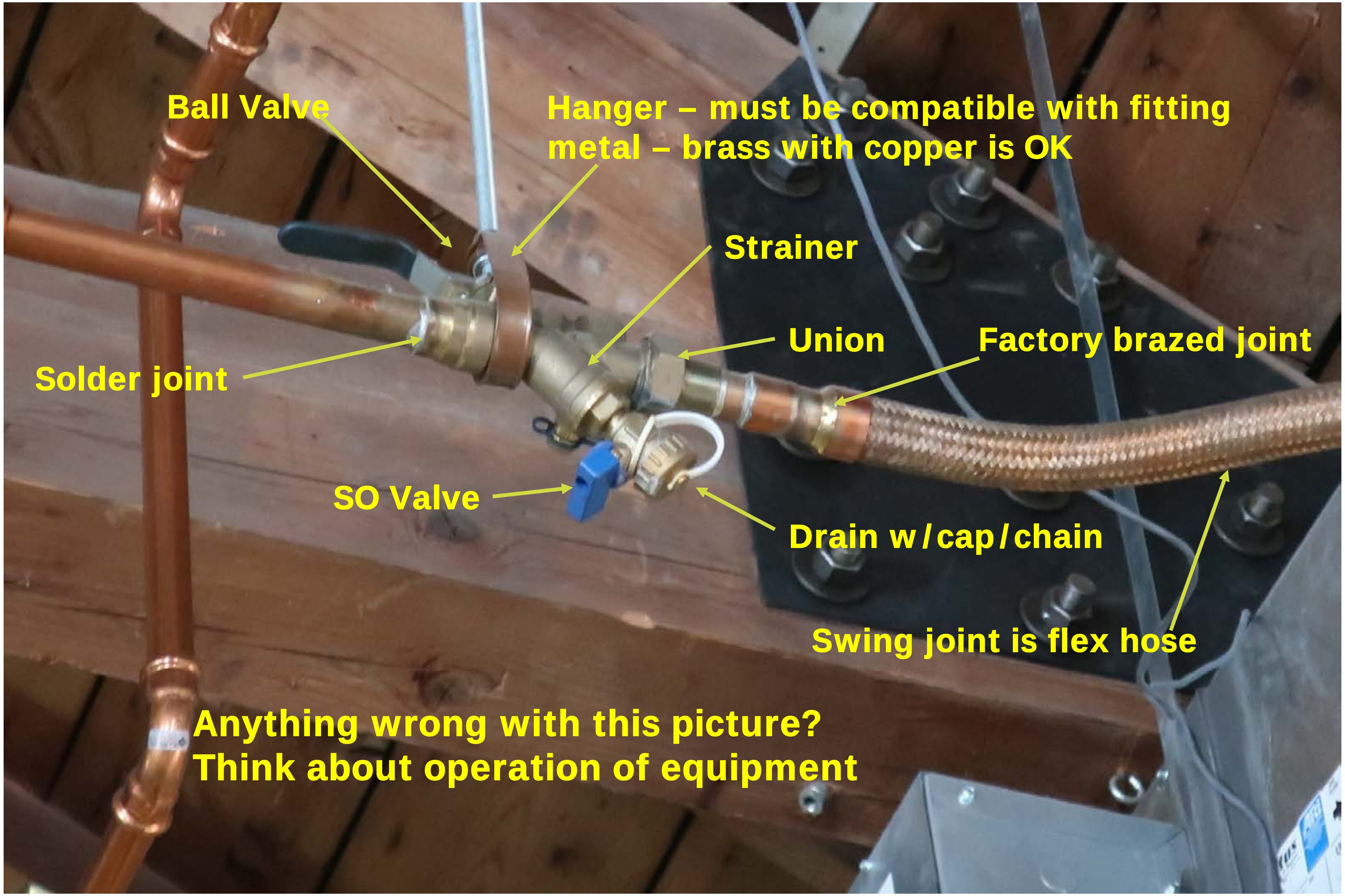
- All piping shown as a single line, regardless of pipe size
- System equipment represented by standard symbols

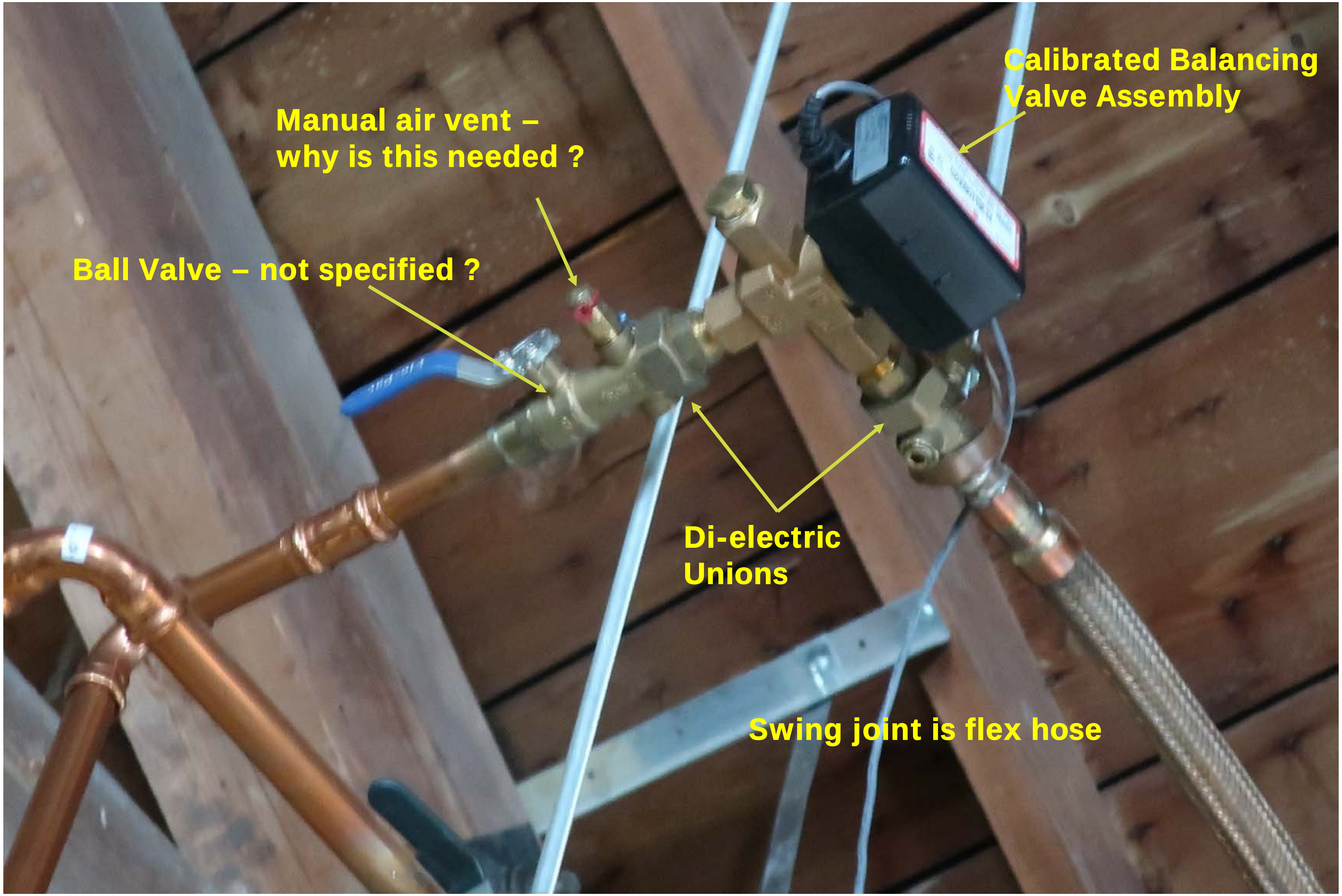


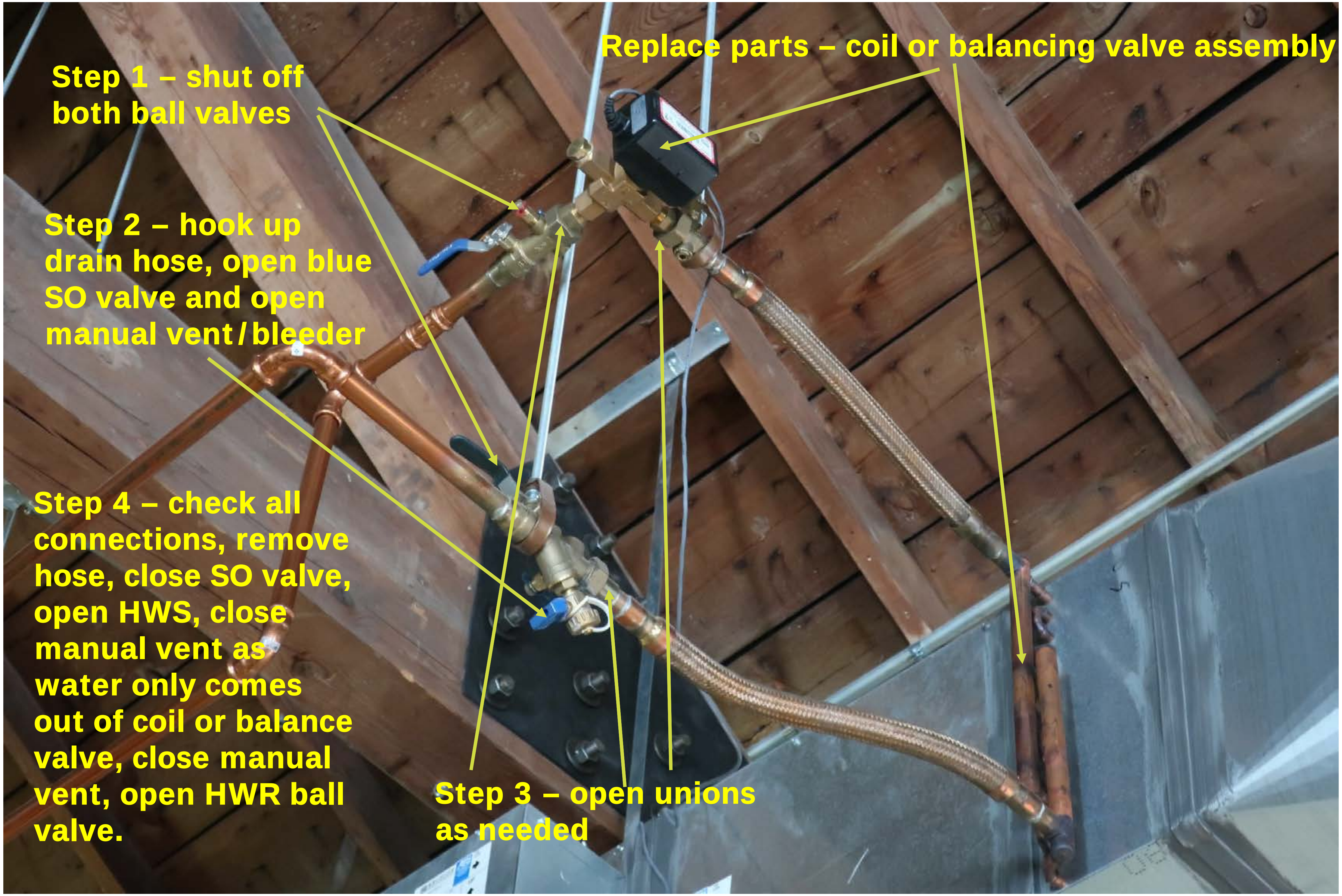
Inside
Room 122




Which is HW supply ?
Is this plumbed correctly?


Ball Valve
Hanger – must be compatible with fitting metal – brass with copper is OK
Strainer
Union
Factory brazed joint
Solder joint
SO Valve
Drain w/cap/chain
Swing joint is flex hose
Anything wrong with this picture?
Think about operation of equipment


Calibrated Balancing
Valve Assembly
Manual air vent –
why is this needed ?
Ball Valve – not specified ?
Di-electric
Unions
Swing joint is flex hose


Replace parts – coil or balancing valve assembly
Step 1 – shut off both ball valves
Step 2 – hook up drain hose, open blue SO valve and open manual vent / bleeder
Step 4 – check all connections, remove hose, close SO valve, open HWS, close manual vent as water only comes out of coil or balance valve, close manual vent, open HWR ball valve.
Step 3 – open unions as needed

HVAC PLANS AND SPECIFICATIONS

CON 371 – Mechanical and Plumbing Systems

LEARNING OUTCOMES

- By the end of this lesson, students will be able to:
    1. Understand the drawings and information provided in HVAC plans and specifications
    2. Recognize the various HVAC symbols used
    3. Evaluate plans and specifications to determine the details and information of an HVAC system for a project

HVAC PLANS

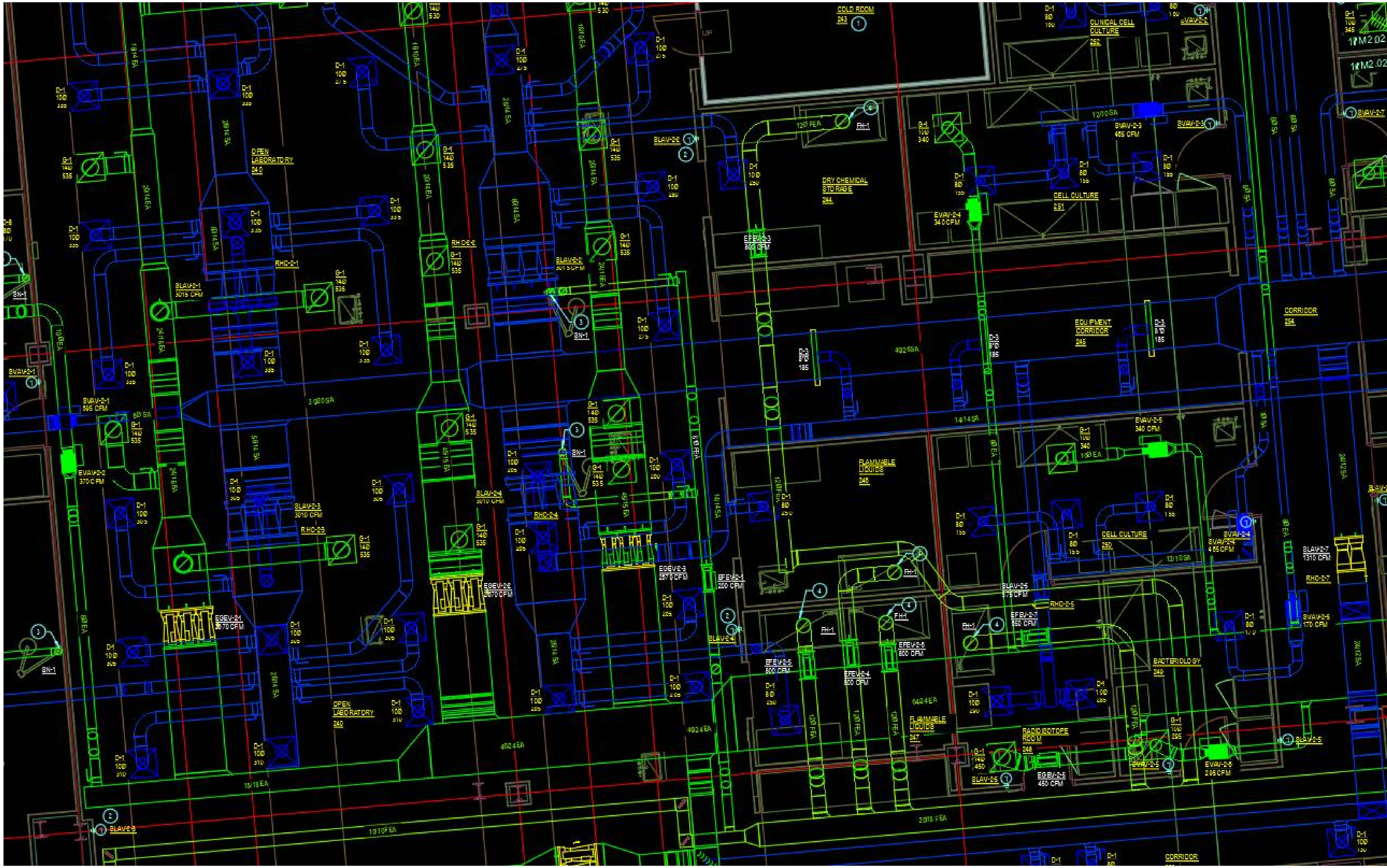
- Listed as “M” documents in a plan set
- Includes:
  - Floor plans
  - Elevation
  - Schedules
  - Details
  - Isometrics
  - Single line (Schematics)
  - Piping & instrumentation diagram (P&ID)

- Mechanical Plan Sets can include (But not limited to):
  - Size, type and layout of ductwork and piping
  - Diffusers, registers, return air grilles, dampers
  - Ductwork and piping insulation
  - HVAC equipment
  - Thermostats and control devices
  - Water and gas connections
  - Ventilation
  - Fans
  - Symbol legend, general notes, specific key notes, special conditions
  - Heating and cooling load summary
  - Heat loss and heat gain calculations

HVAC DUCTWORK FLOOR PLANS

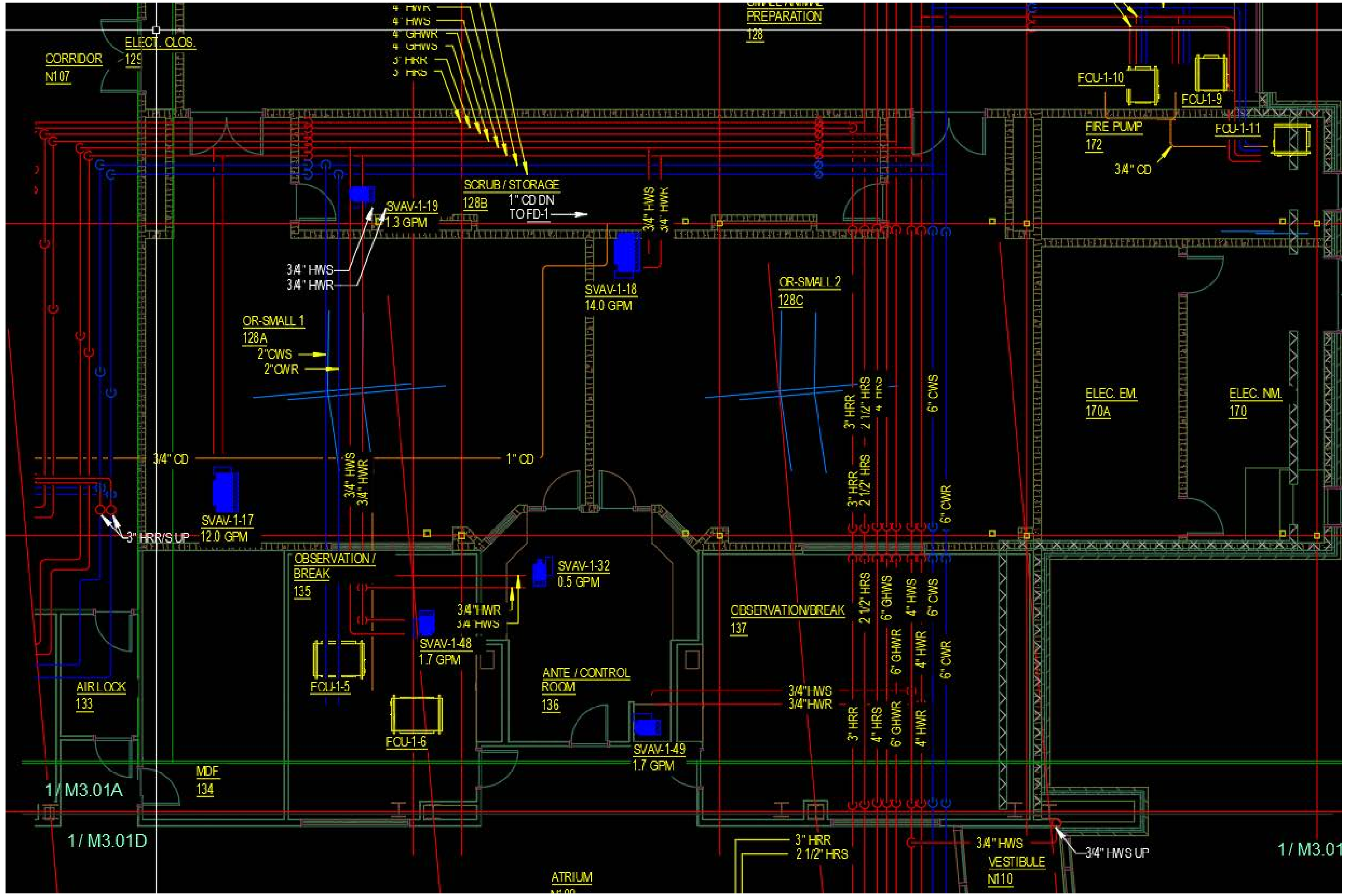
Blue – Supply Air

Green – Exhaust Air

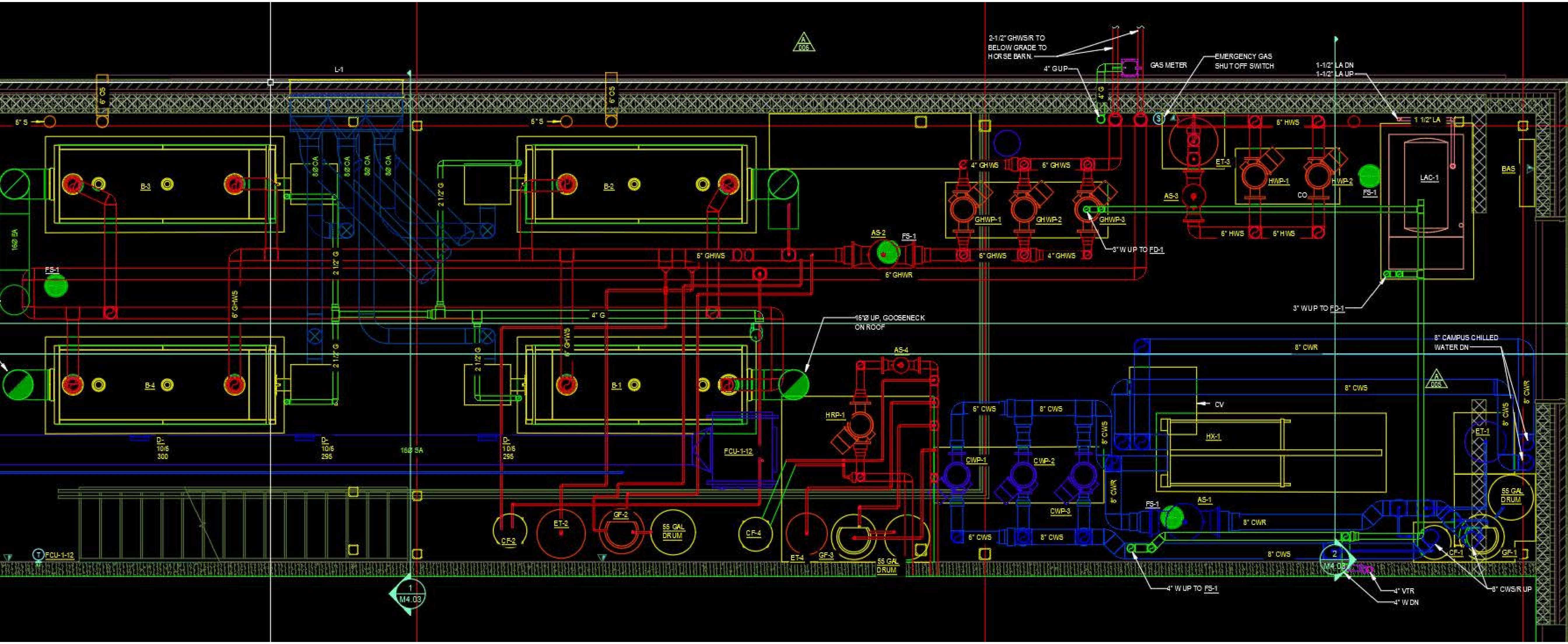


HVAC PIPING FLOOR PLANS

- Blue
  - CWS - Chilled Water Supply
  - CWR - Chilled Water Return
- Red
  - HRS - Heat Recovery Supply
  - HRR – Heat Recovery Return
  - GHWS – Glycol Heating Water Supply
  - GHWR – Glycol Heating Recovery Return
  - HWS – Heating Water Supply
  - HWR – Heating Water Return
- Orange
  - CD - Condensate



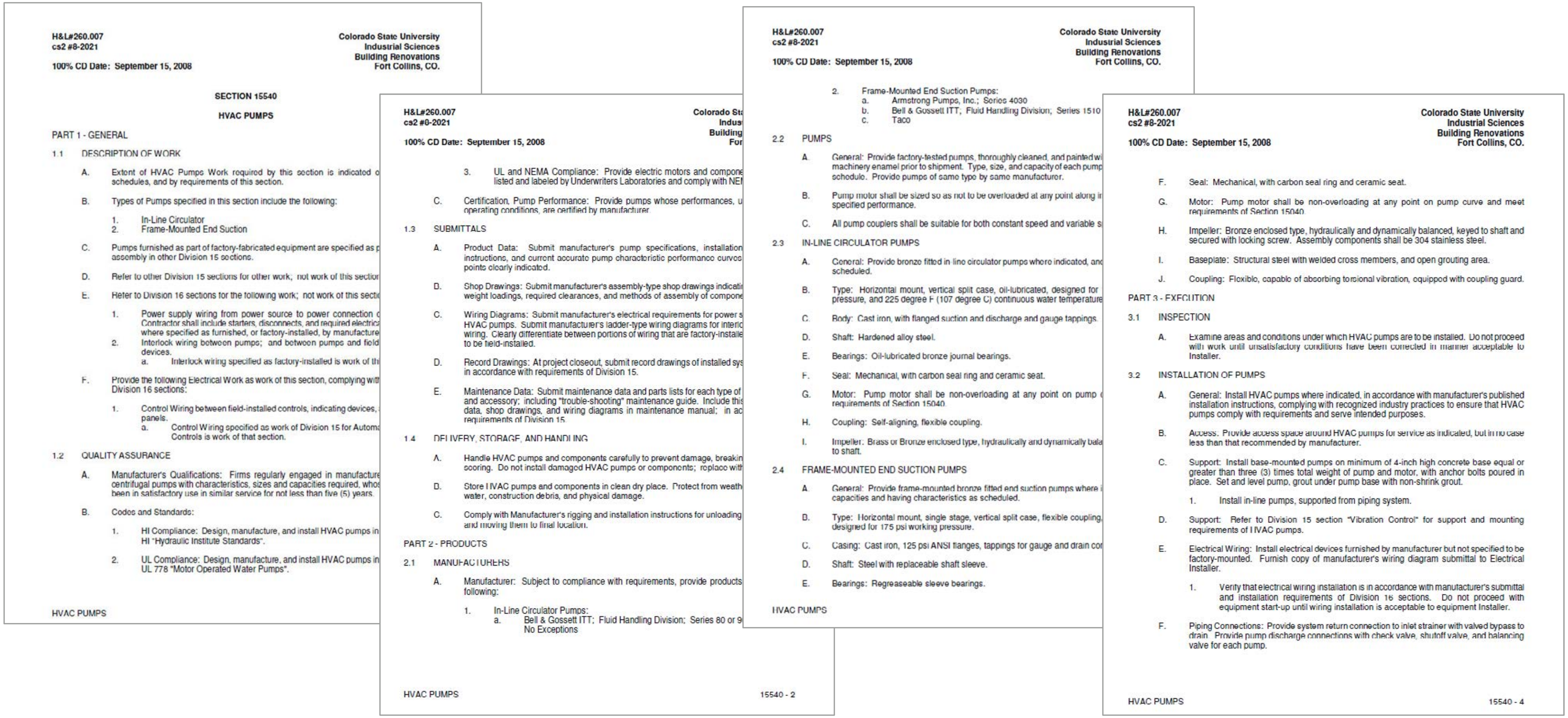
MECHANICAL ROOM PLANS



HVAC SPECIFICATIONS

- CSI Division 15 (1995 Masterformat)
  - 15050 Basic Mechanical Materials and Methods
  - 15100 Building Service Piping
  - 15200 Process Piping
  - 15300 Fire Protection Piping
  - 15500 Heat-Generation Equipment
  - 15600 Refrigeration Equipment
  - 15700 HVAC Equipment
  - 15800 Air Distribution
  - 15900 HVAC Instrumentation and Controls
  - 15950 Testing, Adjusting, and Balancing
- CSI Division 23 (2004 Masterformat)
  - 23 00 00 HVAC
  - 23 10 00 Facility Fuel System
  - 23 20 00 HVAC Piping and Pumps
  - 23 30 00 HVAC Air Distribution
  - 23 40 00 HVAC Air Cleaning Devices
  - 23 50 00 Central Heating Equipment
  - 23 60 00 Central Cooling Equipment
  - 23 70 00 Central HVAC Equipment
  - 23 80 00 Decentralized HVAC Equipment

HVAC SPECIFICATIONS



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SECTION 15540

HVAC PUMPS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

A. Extent of HVAC Pumps Work required by this section is indicated o schedules, and by requirements of this section.

B. Types of Pumps specified in this section include the following:

1. In-Line Circulator
2. Frame-Mounted End Suction

C. Pumps furnished as part of factory-fabricated equipment are specified as p assembly in other Division 15 sections.

D. Refer to other Division 15 sections for other work; not work of this section

E. Refer to Division 16 sections for the following work; not work of this secti

1. Power supply wiring from power source to power connection c Contractor shall include starters, disconnects, and required electric where specified as furnished, or factory-installed, by manufacture
2. Interlock wiring between pumps; and between pumps and field devices.
   a. Interlock wiring specified as factory-installed is work of th

F. Provide the following Electrical Work as work of this section, complying wit Division 16 sections:

1. Control Wiring between field-installed controls, indicating devices, panels.
   a. Control Wiring specified as work of Division 15 for Automa Controls is work of that section.

1.2 QUALITY ASSURANCE

A. Manufacturer's Qualifications: Firms regularly engaged in manufacture centrifugal pumps with characteristics, sizes and capacities required, whos been in satisfactory use in similar service for not less than five (5) years.

B. Codes and Standards:

1. HI Compliance: Design, manufacture, and install HVAC pumps in HI "Hydraulic Institute Standards".
2. UL Compliance: Design, manufacture, and install HVAC pumps in UL 778 "Motor Operated Water Pumps".

HVAC PUMPS

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3. UL and NEMA Compliance: Provide electric motors and compone listed and labeled by Underwriters Laboratories and comply with NE

C. Certification, Pump Performance: Provide pumps whose performances, u operating conditions, are certified by manufacturer.

1.3 SUBMITTALS

A. Product Data: Submit manufacturer's pump specifications, installation instructions, and current accurate pump characteristic performance curves points clearly indicated.

B. Shop Drawings: Submit manufacturer's assembly-type shop drawings indicati weight loadings, required clearances, and methods of assembly of compone

C. Wiring Diagrams: Submit manufacturer's electrical requirements for power s HVAC pumps. Submit manufacturer's ladder-type wiring diagrams for interl wiring. Clearly differentiate between portions of wiring that are factory-installe to be field-installed.

D. Record Drawings: At project closeout, submit record drawings of installed sys in accordance with requirements of Division 15.

E. Maintenance Data: Submit maintenance data and parts lists for each type of and accessory; including "trouble-shooting" maintenance guide. Include this data, shop drawings, and wiring diagrams in maintenance manual; in ac requirements of Division 15.

1.4 DELIVERY, STORAGE, AND HANDLING

A. Handle HVAC pumps and components carefully to prevent damage, breakin scoring. Do not install damaged HVAC pumps or components; replace wit

B. Store HVAC pumps and components in clean dry place. Protect from weath water, construction debris, and physical damage.

C. Comply with Manufacturer's rigging and installation instructions for unloading and moving them to final location.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Manufacturer: Subject to compliance with requirements, provide products following:

1. In-Line Circulator Pumps:
   a. Bell & Gossett ITT; Fluid Handling Division; Series 80 or 9 No Exceptions

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2. Frame-Mounted End Suction Pumps:
   a. Armstrong Pumps, Inc.; Series 4030
   b. Bell & Gossett ITT; Fluid Handling Division; Series 1510
   c. Taco

2.2 PUMPS

A. General: Provide factory-tested pumps, thoroughly cleaned, and painted wi machinery enamel prior to shipment. Type, size, and capacity of each pump schedule. Provide pumps of same type by same manufacturer.

B. Pump motor shall be sized so as not to be overloaded at any point along i specified performance.

C. All pump couplers shall be suitable for both constant speed and variable s

2.3 IN-LINE CIRCULATOR PUMPS

A. General: Provide bronze fitted in line circulator pumps where indicated, and scheduled.

B. Type: Horizontal mount, vertical split case, oil-lubricated, designed for pressure, and 225 degree F (107 degree C) continuous water temperature

C. Body: Cast iron, with flanged suction and discharge and gauge tappings.

D. Shaft: Hardened alloy steel.

E. Bearings: Oil-lubricated bronze journal bearings.

F. Seal: Mechanical, with carbon seal ring and ceramic seat.

G. Motor: Pump motor shall be non-overloading at any point on pump requirements of Section 15040.

H. Coupling: Self-aligning, flexible coupling.

I. Impeller: Brass or Bronze enclosed type, hydraulically and dynamically bala to shaft.

2.4 FRAME-MOUNTED END SUCTION PUMPS

A. General: Provide frame-mounted bronze fitted end suction pumps where i capacities and having characteristics as scheduled.

B. Type: Horizontal mount, single stage, vertical split case, flexible coupling, designed for 175 psi working pressure.

C. Casing: Cast iron, 125 psi ANSI flanges, tappings for gauge and drain co

D. Shaft: Steel with replaceable shaft sleeve.

E. Bearings: Regreaseable sleeve bearings.

HVAC PUMPS

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F. Seal: Mechanical, with carbon seal ring and ceramic seat.

G. Motor: Pump motor shall be non-overloading at any point on pump curve and meet requirements of Section 15040.

H. Impeller: Bronze enclosed type, hydraulically and dynamically balanced, keyed to shaft and secured with locking screw. Assembly components shall be 304 stainless steel.

I. Baseplate: Structural steel with welded cross members, and open grouting area.

J. Coupling: Flexible, capable of absorbing torsional vibration, equipped with coupling guard.

PART 3 - EXECUTION

3.1 INSPECTION

A. Examine areas and conditions under which HVAC pumps are to be installed. Do not proceed with work until unsatisfactory conditions have been corrected in manner acceptable to Installer.

3.2 INSTALLATION OF PUMPS

A. General: Install HVAC pumps where indicated, in accordance with manufacturer's published installation instructions, complying with recognized industry practices to ensure that HVAC pumps comply with requirements and serve intended purposes.

B. Access: Provide access space around HVAC pumps for service as indicated, but in no case less than that recommended by manufacturer.

C. Support: Install base-mounted pumps on minimum of 4-inch high concrete base equal or greater than three (3) times total weight of pump and motor, with anchor bolts poured in place. Set and level pump, grout under pump base with non-shrink grout.

1. Install in-line pumps, supported from piping system.

D. Support: Refer to Division 15 section "Vibration Control" for support and mounting requirements of HVAC pumps.

E. Electrical Wiring: Install electrical devices furnished by manufacturer but not specified to be factory-mounted. Furnish copy of manufacturer's wiring diagram submittal to Electrical Installer.

1. Verify that electrical wiring installation is in accordance with manufacturer's submittal and installation requirements of Division 16 sections. Do not proceed with equipment start-up until wiring installation is acceptable to equipment Installer.

F. Piping Connections: Provide system return connection to inlet strainer with valved bypass to drain. Provide pump discharge connections with check valve, shutoff valve, and balancing valve for each pump.

HVAC PUMPS 15540 - 4

HVAC SPECIFICATIONS

SECTION 23 31 13 - DUCTWORK

1. GENERAL

1.1 SECTION INCLUDES

A. Metal ductwork.

1. Sheet metal materials.
2. Duct liner.
3. Sealant and gaskets.
4. Fasteners.
5. Seismic-restraint devices.
6. Duct cleaning.
7. Duct pressure testing.

B. Insulated flexible ductwork.

C. Louver backpans.

1.2 REFERENCE SECTION 23 05 00 FOR THE FOLLOWING:

A. Quality assurance.

1. Perform Work in accordance with the following standard

a. NFPA 90A - Installation of Air Conditioning and Ve
b. NFPA 90B - Installation of Warm Air Heating and
c. NFPA 91 - Installation of Blower and Exhaust Removal or Conveying.
d. NFPA 96 - Installation of Equipment for the Re Vapors from Commercial Cooking Equipment.
e. SMACNA - HVAC Air Duct Leakage Test Manual.
f. SMACNA – HVAC Duct Construction Standards -
g. SMACNA - Round Industrial Duct Construction St
h. International Mechanical Code, current edition.

B. References.

2. PRODUCTS

2.1 METAL DUCTWORK

A. SINGLE-WALL RECTANGULAR DUCTS AND FITTINGS

1. General Fabrication Requirements: Comply with SMACNA's "HVAC Duc Standards - Metal and Flexible" based on indicated static-pressure class ur indicated.

a. Reference SMACNA figure 2-9 and Drawings to construct gradual tra ductwork changes size or offsets.
b. Provide duct material, gages, reinforcing, and sealing for operating press

2. Transverse Joints: Select joint types and fabricate according to SMACNA' Construction Standards - Metal and Flexible," Figure 2-1, "Rectangular D Joints," for static-pressure class, applicable sealing requirements, materials support intervals, and other provisions in SMACNA's "HVAC Duct Constructi Metal and Flexible."

a. Transverse Duct Connection System

1) Slide on flange system: Ductmate and Ductmate WDCI connectic complete with interlocking angle and duct edge connection system gasket, cleats, and corner clips. <u>Gasket material shall be chemica material in all fume exhaust ductwork.</u>
2) Formed on flange system: TDC, TDF or equivalent connection sys equivalent. Such flanges shall be constructed as SMACNA T-24 f 25 and 1-37 '85 SMACNA Duct Construction Manual, 1985 Editior

3. Longitudinal Seams: Select seam types and fabricate according to SMACNA Construction Standards - Metal and Flexible," Figure 2-2, "Rectangular Du Seams," for static-pressure class, applicable sealing requirements, materials support intervals, and other provisions in SMACNA's "HVAC Duct Constructi Metal and Flexible."

4. Elbows, Transitions, Offsets, Branch Connections, and Other Duct Constructio and fabricate according to SMACNA's "HVAC Duct Construction Standard Flexible," Chapter 4, "Fittings and Other Construction," for static-pressure cl sealing requirements, materials involved, duct-support intervals, and othe SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

a. Construct T's, and elbows in using radius of not less than 1-1/2 times v centerline. Where mitered rectangular elbows are used or indicated, vanes in accordance with Section 23 33 00.

7. 4 kHz Octave Band: 34

F. Manufacturer: Flexmaster Type 6B or equivalent.

2.3 LOUVER BACKPAN

A. Fabricate in accordance with SMACNA HVAC Duct Construction Standards - Metal and Flexible and NFPA 96.

B. Construct of 18-gage galvanized steel using continuous external welded joints.

C. Welded ductwork is to be welded with filler rod of the same material as the metal that is being welded. Prime coat and paint welded joints with cold galvanized paint.

D. Slope bottom to prevent accumulation of water. Provide drains where shown on drawings.

3. EXECUTION

3.1 GENERAL

A. Install in accordance with manufacturer's instructions; SMACNA HVAC Duct Construction Standards - Metal and Flexible, current edition and International Mechanical Code requirements.

B. Seal ducts in accordance with SMACNA HVAC Duct Construction Standards - Metal and Flexible, current edition.

C. Duct sizes are inside clear dimensions. For lined ducts, maintain sizes inside lining.

D. Duct transition from round to rectangular and vise versa shall be made with rectangular to round duct transition fitting.

E. Provide flange-type joint at transverse joints or seal as specified. All transverse joints shall be inspected by the Owner prior to insulating ductwork.

3.2 DUCT INSTALLATION

A. Drawing plans, schematics, and diagrams indicate general location and arrangement of duct system. Indicated duct locations, configurations, and arrangements were used to size ducts and calculate friction loss for air-handling equipment sizing and for other design considerations. Install duct systems as indicated unless deviations to layout are approved on Shop Drawings and Coordination Drawings.

B. Install round and flat-oval ducts in maximum practical lengths.

a. Install round in lengths not less than 10 feet, unless interrupted by fittings.

HEATING PIPING SYSTEM SYMBOLS

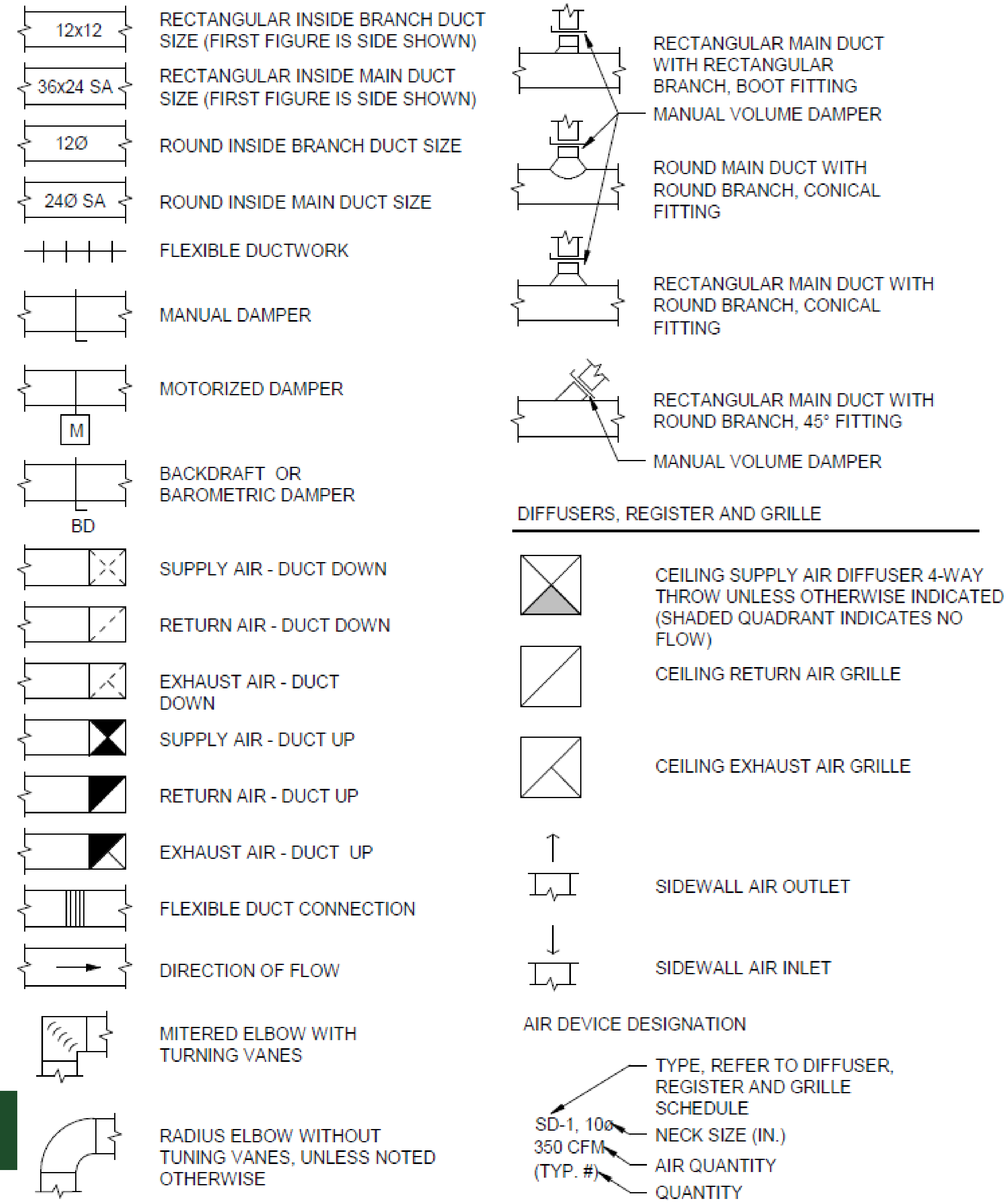
HEATING PIPING

High pressure steam supply	——HPS——	Make up water	—— MU ——
Medium pressure steam supply	——MPS——	Air relief line	—— V ——
Low pressure steam supply	——LPS——	Fuel oil suction	——FOS——
High pressure steam steam return	— —HPR— —	Fuel oil return	——FOR——
Medium pressure steam return	— — MPR — —	Fuel oil vent	——FOV——
Low pressure steam return	— —LPR — —	Compressed air	—— A ——
Boiler blow off	—— BD ——	Hot water heating supply	—— HWS——
Condensate or vacuum pump discharge	——VPD——	Hot water heating return	— — HWR— —
Feedwater pump discharge	——PPD——		

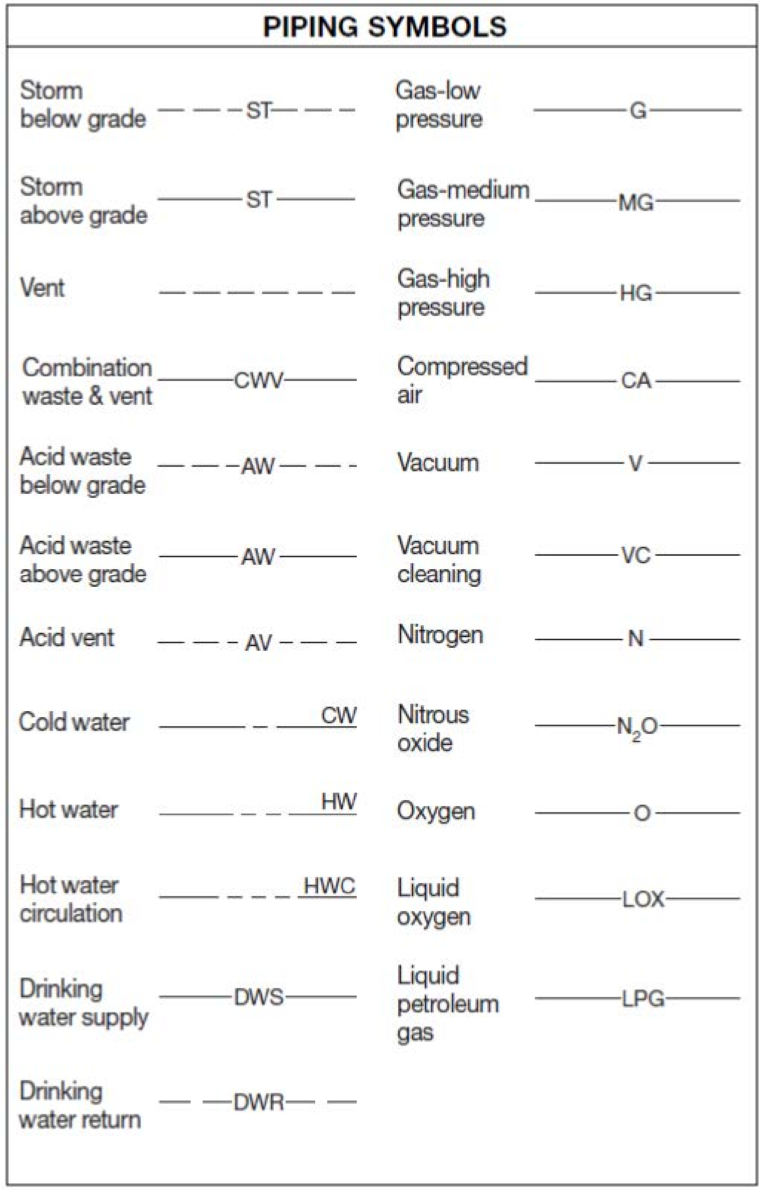
COOLING PIPING SYSTEM SYMBOLS

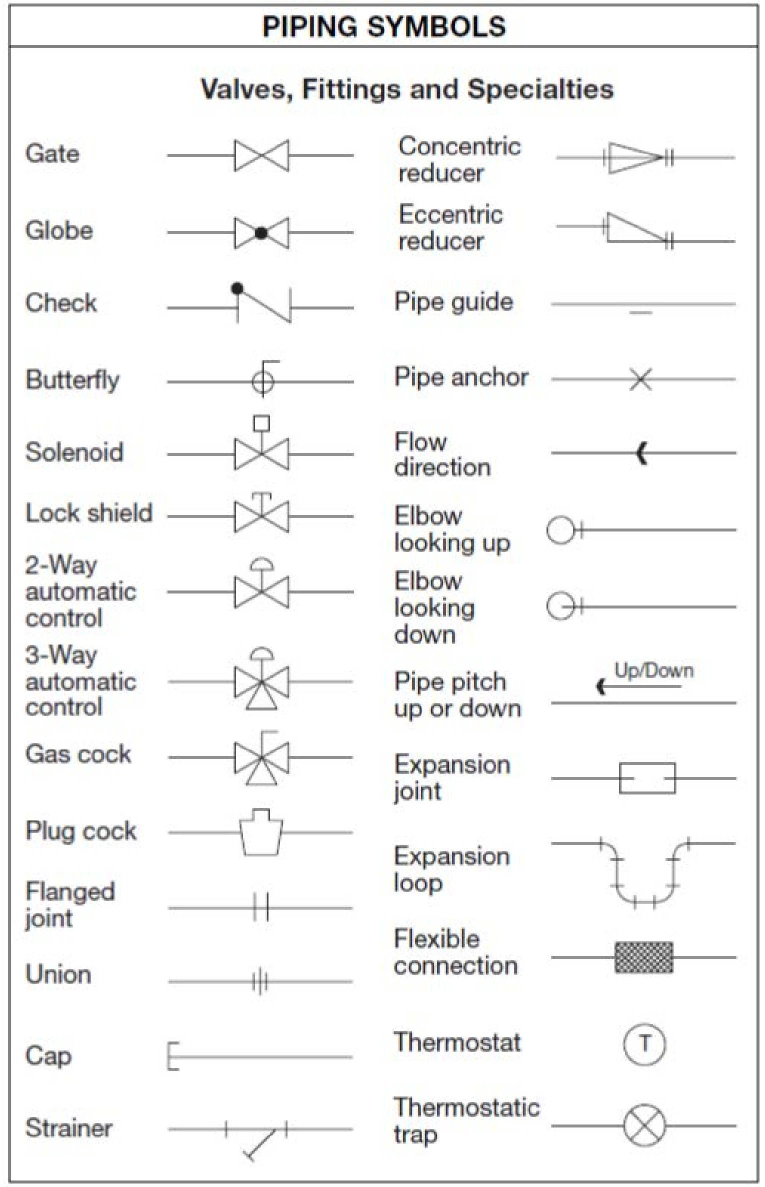
AIR CONDITIONING PIPING			
Refrigerant liquid	—— RL ——	Chilled water return	— — CWR— —
Refrigerant hot gas	—— RHG——	Make up water	—— MU ——
Refrigerant suction	—— RS ——	Humidification line	—— H ——
Condenser water supply	—— CS ——	Drain	—— D ——
Condenser water return	— — CR- — —	Brine supply	—— B ——
Chilled water supply	——CWS——	Brine return	—— BR ——

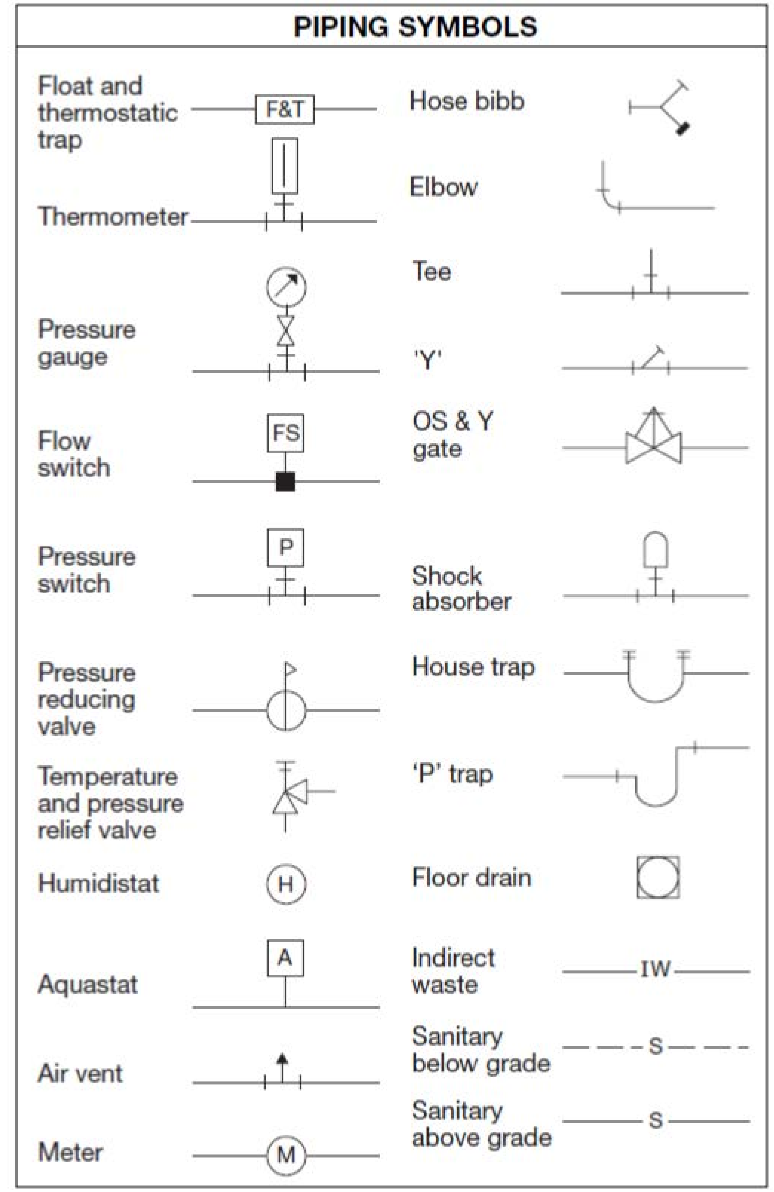
DUCTWORK SYMBOLS



PIPING SYSTEM SYMBOLS







CONTROLS SYMBOLS

Symbol	Description
	CONTROL DAMPER
M	PNEUMATIC MAIN
EPT	ELECTRIC PNEUMATIC TRANSDUCER
SD	SMOKE DETECTOR
CO	CARBON MONOXIDE DETECTOR
CO2	CARBON DIOXIDE DETECTOR
AM	AIR FLOW MEASURING STATION
T	TEMPERATURE SENSOR
FPS	FLOW PROVING SWITCH PADDLE TYPE
CSR	CURRENT SENSING RELAY
R	RELAY
DPS	DIFFERENTIAL PRESSURE SWITCH
DPT	DIFFERENTIAL PRESSURE TRANSMITTER
	FLUID FLOW MEASURING DEVICE
FMT	FLUID FLOW TRANSMITTER
FPS	FLOW PROVING SWITCH DIFFERENTIAL PRESSURE

Symbol	Description
SPD	SPEED INDICATION
FS	FLOW SENSOR
AS	STRAP ON AQUASTAT
AFT	AIR FLOW TRANSMITTER
OS	OCCUPANCY SENSOR
ES	DAMPER ACTUATOR END SWITCH
H	HUMIDITY SENSOR
A	GENERAL ALARM
	CONTACT
HL HL LL LL	HIGH-LOW TEMPERATURE THERMOSTAT
DPT	DIFFERENTIAL PRESSURE TRANSMITTER
CP	CONTROL PANEL - MOUNT CONTROL PANEL AT 4'8" ABOVE FLOOR TO CENTER OF CONTROL PANEL
EPO	EMERGENCY POWER OFF SWITCH - MOUNT BOTTOM AT 4'-0" ABOVE FLOOR
BPO	BOILER POWER OFF SWITCH - MOUNT BOTTOM AT 4'-0" ABOVE FLOOR
OR	MANUAL OVERRIDE SWITCH - MOUNT BOTTOM AT 4'-0" ABOVE FLOOR
FA	FIRE ALARM CONTROL MODULE
S	START/STOP

CONTROLS SYMBOLS

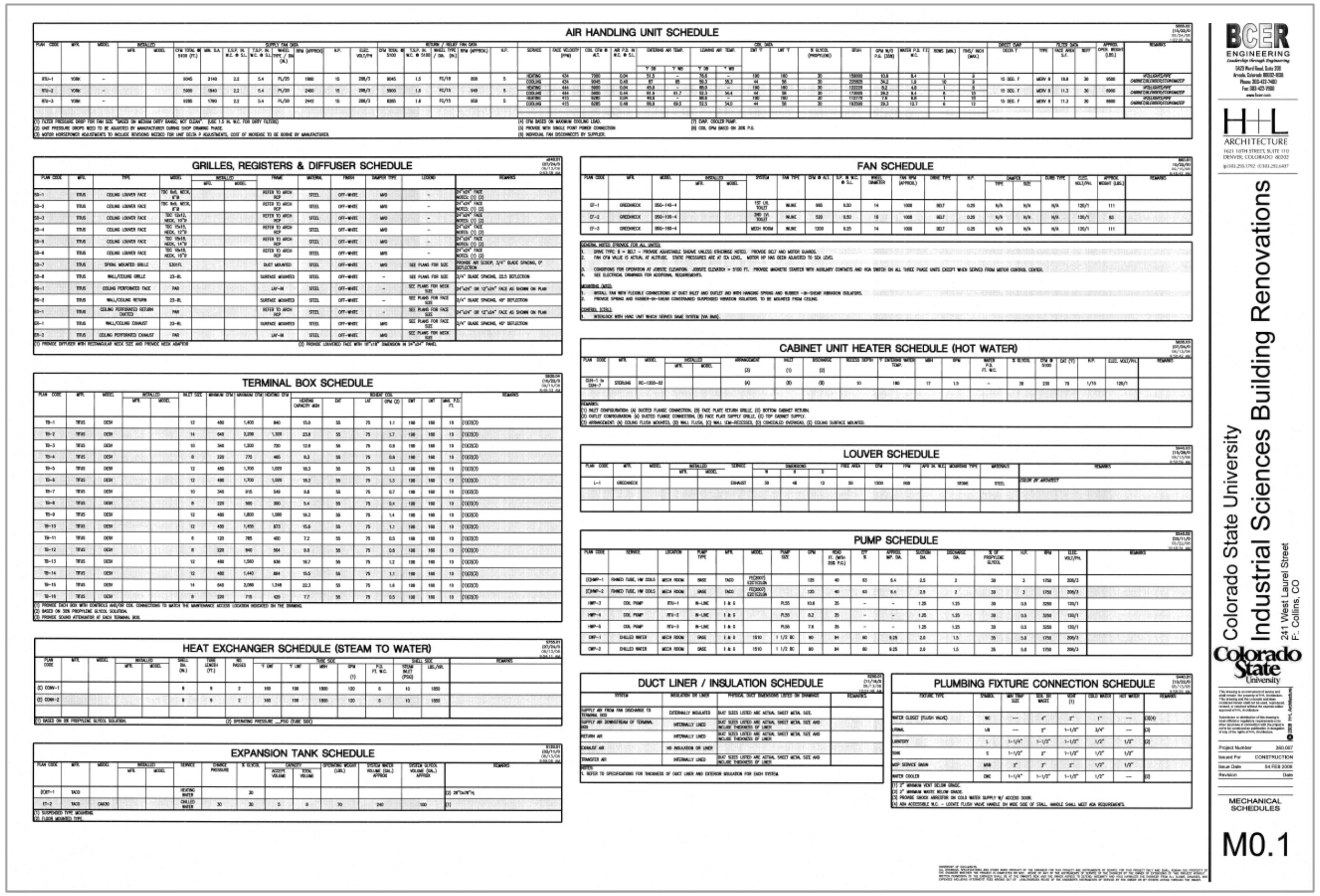
T	SPACE TEMPERATURE SENSOR - MOUNT BOTTOM AT X'-X" ABOVE FLOOR
OS	SPACE OCCUPANCY SENSOR - COORDINATE WITH ELECTRICAL
DP	SPACE DIFFERENTIAL PRESSURE SENSOR.
CO	SPACE CARBON MONOXIDE SENSOR
C	SPACE CARBON DIOXIDE SENSOR - MOUNT BOTTOM AT X'-X" ABOVE FLOOR
O2	OXYGEN SENSOR
T	SPACE THERMOSTAT - MOUNT BOTTOM AT X'-X" ABOVE FLOOR
T	UNIT MOUNTED THERMOSTAT
DI	DIGITAL INPUT
DO	DIGITAL OUTPUT
AI	ANALOG INPUT
AO	ANALOG OUTPUT
//	ELECTRICAL WIRING CONDUCTORS AS REQUIRED
- - - - -	INTERLOCK WIRING
C NC NO	THREE WAY CONTROL VALVE
	TWO WAY CONTROL VALVE
STARTER	STARTER
VSD	VARIABLE SPEED MOTOR CONTROLLER
VFD	VARIABLE SPEED MOTOR CONTROLLER
UVC	ULTRAVIOLET CONTROLLER
H C	HOT WATER HEATING COIL
C C	CHILLED WATER COOLING COIL
	FILTER

MECHANICAL ABBREVIATIONS

AC	AIR COMPRESSOR
ADJ	ADJUSTABLE
AFF	ABOVE FINISHED FLOOR
AHU	AIR HANDLING UNIT
AMPS	AMPERES
AS	AIR SEPARATOR
ATC	ACOUSTICAL TILE CEILING
AV	AIR VENT
B	BOILER
BAS	BUILDING AUTOMATION SYSTEM
BBH	BASEBOARD HYDRONIC HEATER
BDD	BACK DRAFT DAMPER
BHP	BRAKE HORSPOWER
BMS	BUILDING MANAGEMENT SYSTEM
BP	BOILER PUMP
BTU	BRITISH THERMAL UNIT
BTUH	BTU PER HOUR
9	
CC	COOLING COIL
CD	CONDENSATE DRAIN
CFH	CUBIC FEET PER HOUR
CFM	CUBIC FEET PER MINUTE
CH	CHILLER
CHWP	CHILLED WATER PUMP
CHWR	CHILLED WATER RETURN
CHWS	CHILLED WATER SUPPLY
CO	CARBON MONOXIDE
CO2	CARBON DIOXIDE
COND	CONDENSATE
CRAC	COMPUTER ROOM AIR CONDITIONING
CRU	CONDENSATE RECOVERY UNIT
CT	COOLING TOWER
CUH	CABINET UNIT HEATER
CW	DOMESTIC COLD WATER
CWP	CONDENSER WATER PUMP
CWR	CONDENSER WATER RETURN
CWS	CONDENSER WATER SUPPLY
DB	DRY BULB
dB	DECIBELS
DDC	DIRECT DIGITALCONTROL
DEG	DEGREES
DEG F	DEGREES FAHRENHEIT
DN	DOWN
DXE	DOMESTIC HOT WATER HEAT EXCHANGER
EA	EXHAUST AIR
EAT	ENTERING AIR TEMPERATURE
EAU	EXHAUST AIR UNIT
EDB	ENTERING DRY BULB TEMPERATURE
EF	EXHAUST FAN
EG	EXHAUST GRILLE
EMCS	ENERGY MANAGEMENT CONTROL SYSTEM
ERV	ENERGY RERCOVERY VENTILATOR
ESP	EXTERNAL STATIC PRESSURE
ET	EXPANSION TANK
EWB	ENTERING WET BULB TEMPERATURE
EWT	ENTERING WATER TEMPERATURE
F	DEGREES FAHRENHEIT
F&T	FLOAT AND THERMOSTATIC STEAM TRAP
FCU	FAN COIL UNIT
FD	FIRE DAMPER
FF	FINAL FILTER
FILL	FILL LINE
FLA	FULL LOAD AMPS
FPM	FEET PER MINUTE
FPVAV	FAN POWERED VARIABLE AIR VOLUME UNIT
FSD	FIRE SMOKE DAMPER
FT	FLASH TANK
FT	FEET
FT HD	FEET HEAD
FTU	FAN TERMINAL UNIT
GA	GAUGE
GC	GENERAL CONTRACTOR
GF	GLYCOL FEEDER DOSING PUMP
GPM	GALLONS PER MINUTE
HC	HEATING COIL
HP	HORSEPOWER
HP	HEAT PUMP
HR	HOUR
HRCP	HEAT RECOVERY PUMP
HUM	STEAM HUMIDIFICATION UNIT
HWP	HEATING WATER CIRCULATION PUMP
HWR	HEATING WATER RETURN
HWS	HEATING WATER SUPPLY
HX	HEAT EXCHANGER
Hz	HERTZ
IAQ	INDOOR AIR QUALITY
IB	INVERTED BUCKET TRAP
IF	INTERMEDIATE FILTER
IN W.G.	INCHES OF WATER GAUGE
kPa	KILOPASCALS
kW	KILOWATT
L	LOUVER
LAT	LEAVING AIR TEMPERATURE
LDB	LEAVING DRY BULB TEMPERATURE
LRA	LOCKED ROTOR AMPS
LS	LINEAR SLOT SUPPLY DIFFUSER
LVG	LEAVING
LWB	LEAVING WET BULB TEMPERATURE
LWT	LEAVING WATER TEMPERATUTE
MAX	MAXIMUM
MBH	THOUSAND BTU PER HOUR
MC	MECHANICAL CONTRACTOR
MCA	MINIMUM CIRCUIT AMPACITY
MIN	MINIMUM
MUA	MAKE-UP AIR
MZ	MULTI-ZONE
NC	NORMALLY CLOSED
NO	NORMALLY OPEN
NTS	NOT TO SCCALE
OA	OUTSIDE AIR
OAT	OUTSIDE AIR TEMPERATURE
P	PUMP
Pa	PASCALS
PD	PRESSURE DROP
PF	PRE FILTER
PH	PHASE
PHC	HYDRONIC PREHEAT COIL
PPE	PERSONAL PROTECTIVE EQUIPMENT
PPM	PARTS PER MILLION
PRV	PRESSURE REDUCING VALVE
PSI	POUNDS PER SQUARE INCH
PSIG	PSI GUAGE
RA	RETURN AIR
RAD	REFRIGERATED AIR DRYER
RF	RETURN AIR FAN
RG	RETURN GRILLE
RH	RELATIVE HUMIDITY
RH	RELIEF HOOD
RHC	REHEAT COIL
RLA	RUNNING LOAD AMPS
RPM	REVOLUTIONS PER MINUTE
SA	SUPPLY AIR
SA	SUPPLY ATTENUATOR
SCBA	SELF CONTAINED BREATHING APPARATUS
SD	SUPPLY DIFFUSER
SF	SUPPLY FAN
SG	SUPPLY GRILLE
SP	STATIC PRESSURE
SR	SUPPLY REGISTER
ST	STEAM TRAP
TDH	TOTAL DYNAMIC HEAD
TEMP	TEMPERATURE
TG	TRANSFER GRILLE
TSP	TOTAL STATIC PRESSURE
TYP	TYPICAL
UH	UNIT HEATER
UMCS	UTILITY MONITORING AND CONTROL SYSTEM
UNO	UNLESS NOTED OTHERWISE
UPS	UNINTERRUPTED POWER SUPPLY
V	VOLTS
VAV	VARIABLE AIR VOLUME UNIT
WB	WET BULB TEMPERATURE
WC	WATER COLUMN
WG	WATER GUAGE

MECHANICAL SCHEDULES

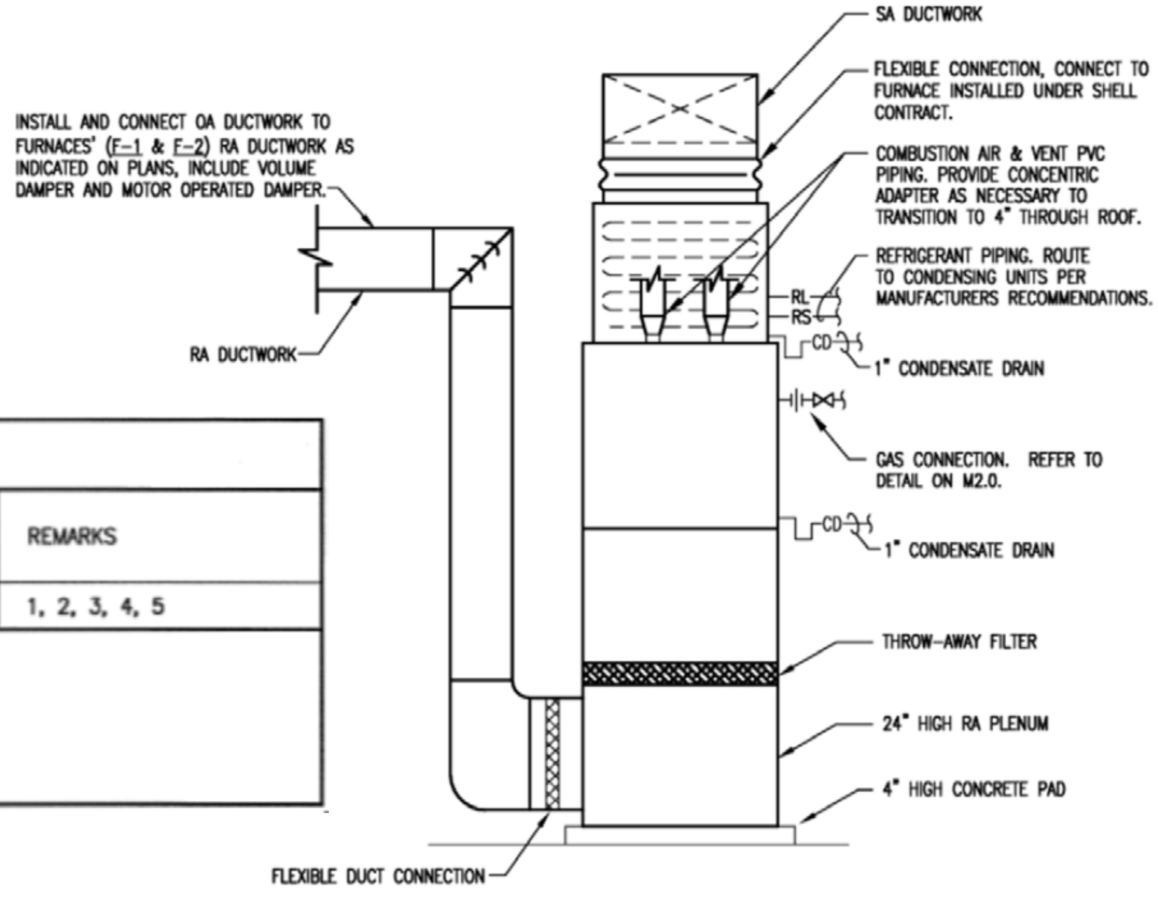
- Schedules provide details on the primary equipment and materials used in the HVAC system
  - Air Handling Units
  - Terminal Box Units
  - Grilles, Registers, Diffusers
  - Heat Exchangers
  - Expansion tanks
  - Fans
  - Pumps
  - Louvers
  - Duct Liner/Insulation
  - Others



MECHANICAL SCHEDULES

GAS-FIRED UNIT HEATER SCHEDULE									
DESIGNATION	INPUT MBH	OUTPUT MBH	CFM	H.P.	VOLTS/PHASE	FLA	MANUFACTURER	MODEL	REMARKS
GUH–1	45	37	629	1/4	120/1ø	3.6	REZNOR	UDAP–45	1, 2, 3, 4, 5

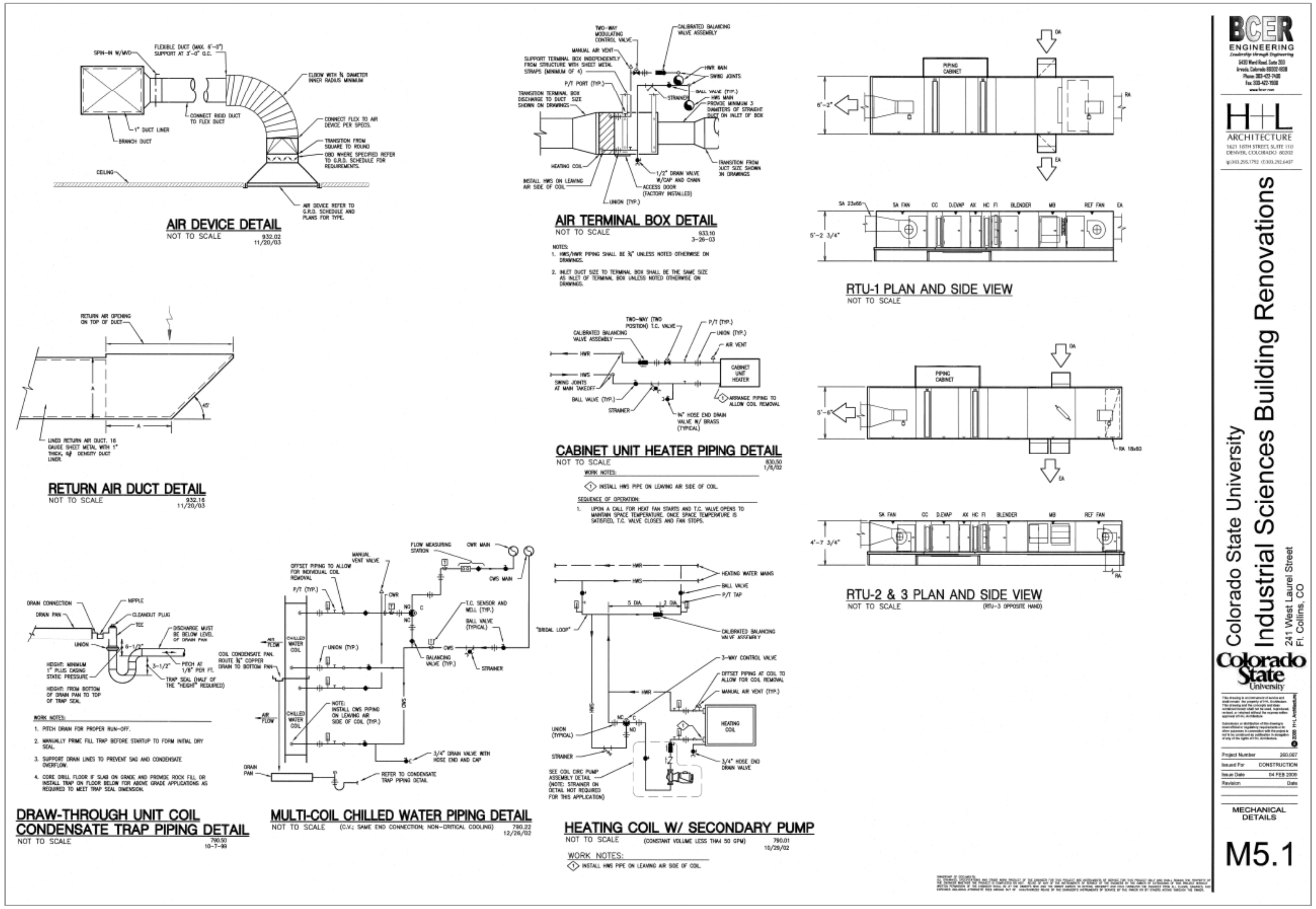
NOTES
1. SPARK IGNITION
2. PROVIDE VENT CAP
3. PROVIDE THERMOSTAT
4. PROVIDE DISCONNECT SWITCH
5. POWER VENT



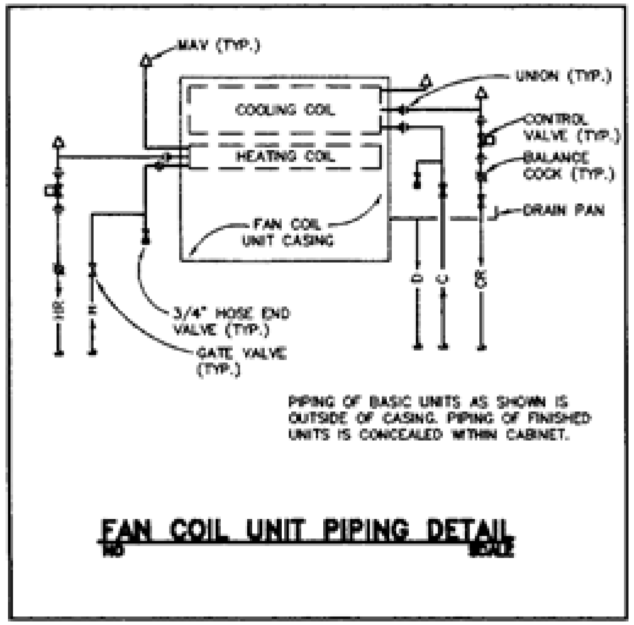
UPFLOW FURNACE DETAIL
N.T.S.

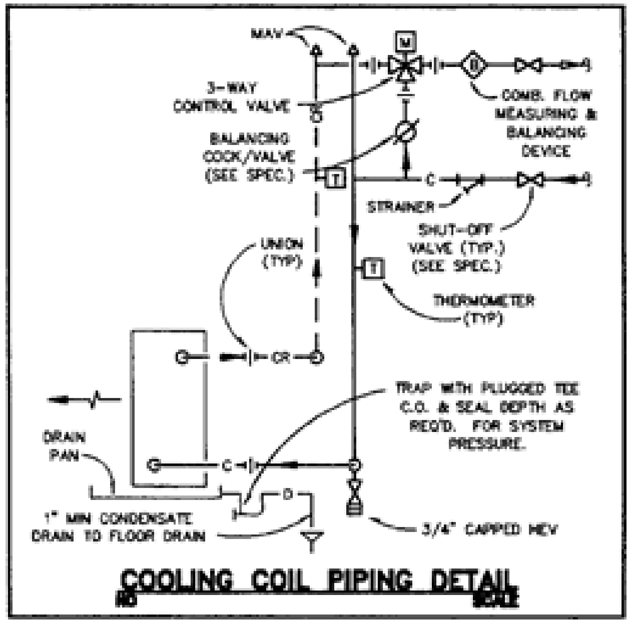
MECHANICAL DETAILS

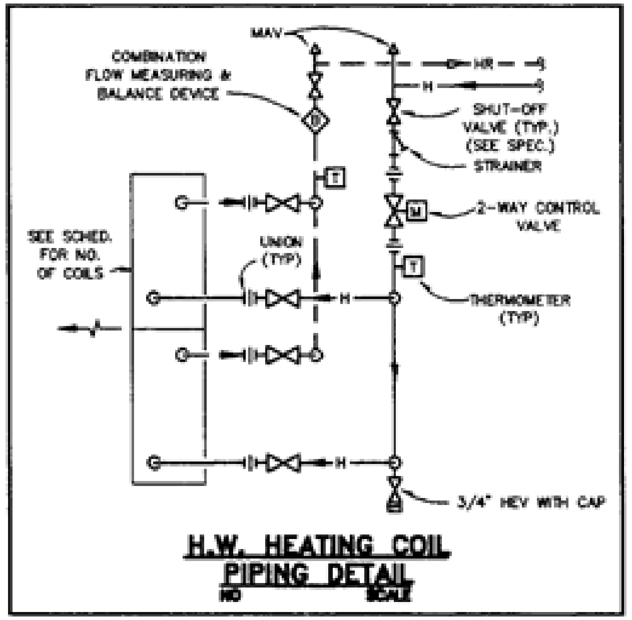
- Complete design with finer details for critical components of the HVAC system
  - Can be scaled to provide closer details



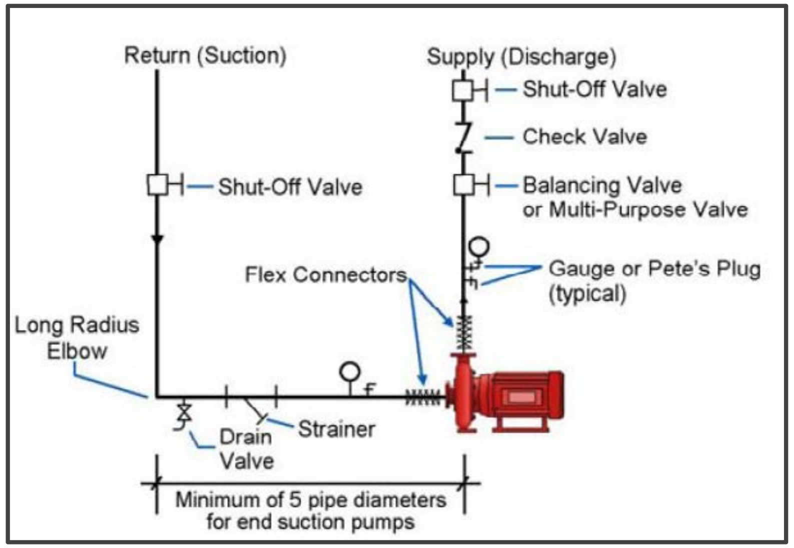
PIPING DETAILS



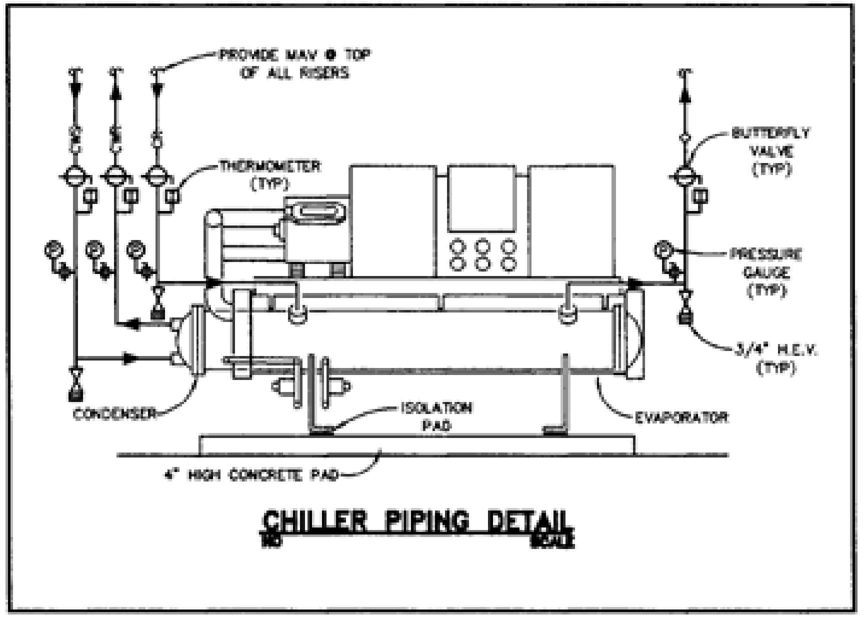


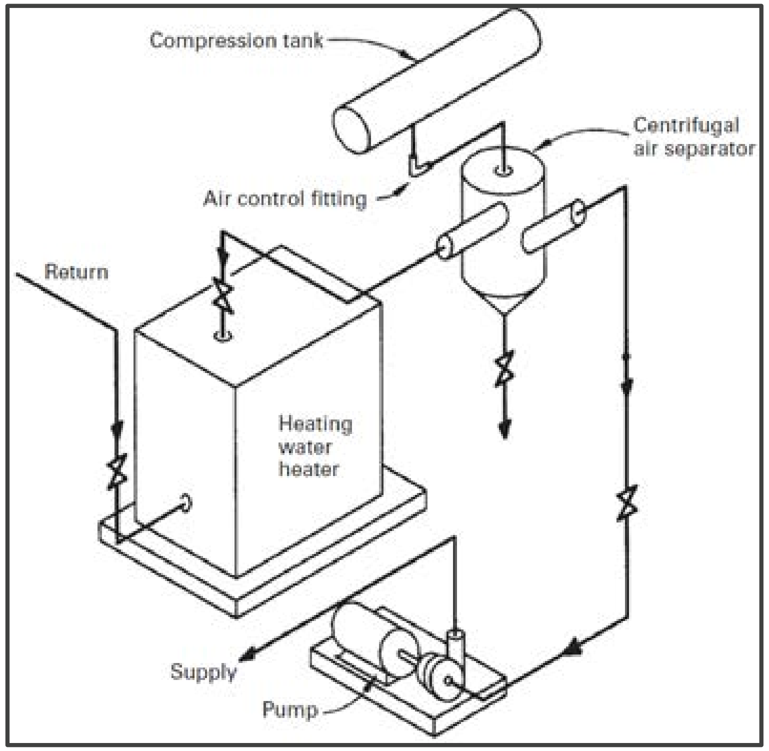


PIPING DETAILS



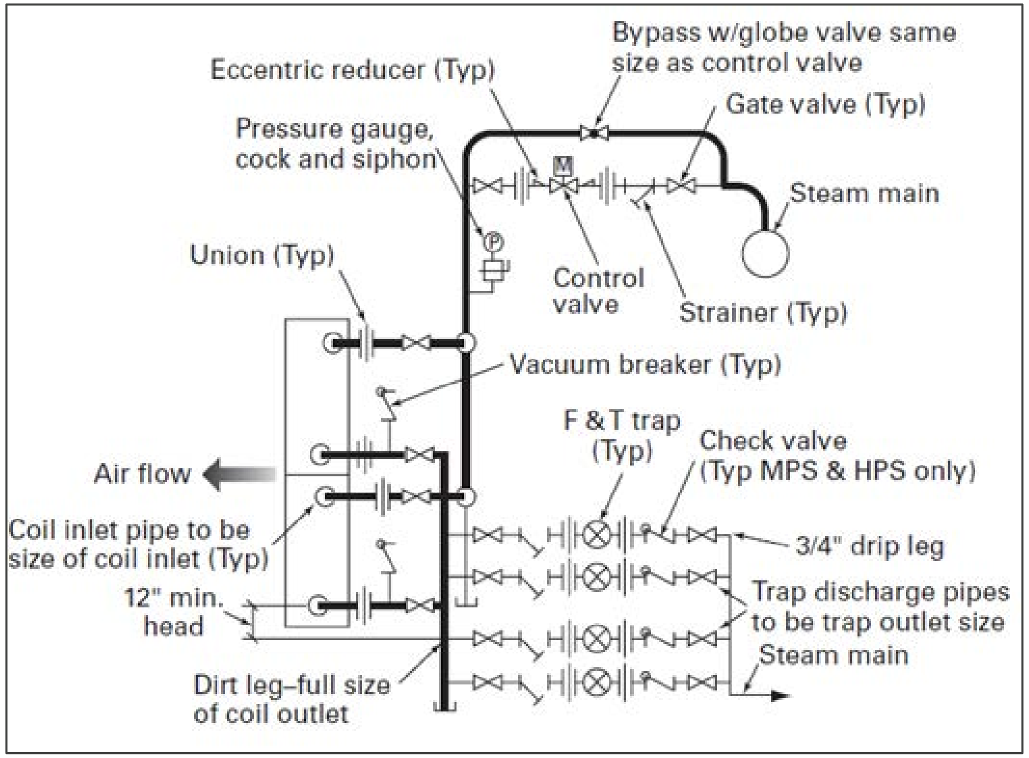
Pump Piping
Detail



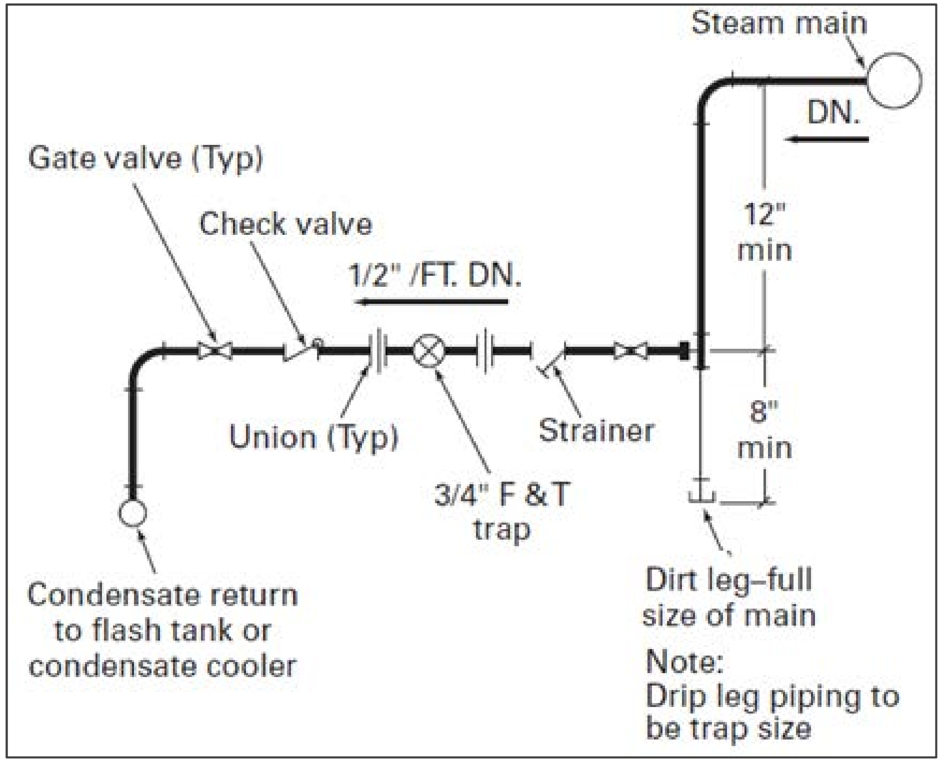


Air Separator and Compression
Tank Detail

STEAM AND CONDENSATE PIPING DETAILS

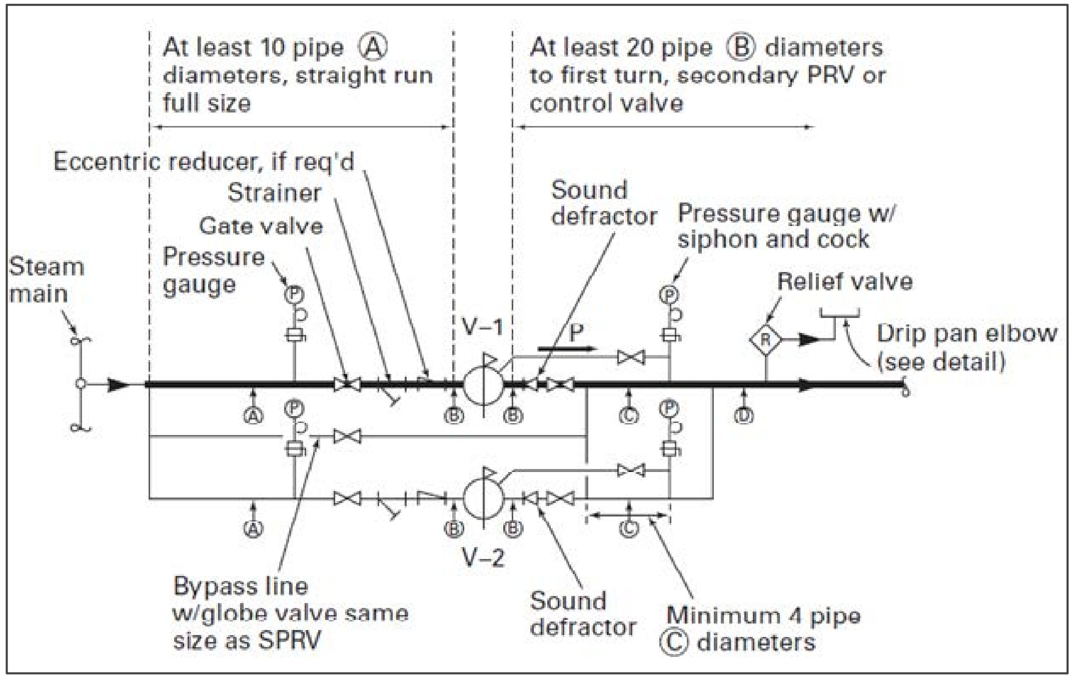


Steam Heating Coil Piping Detail

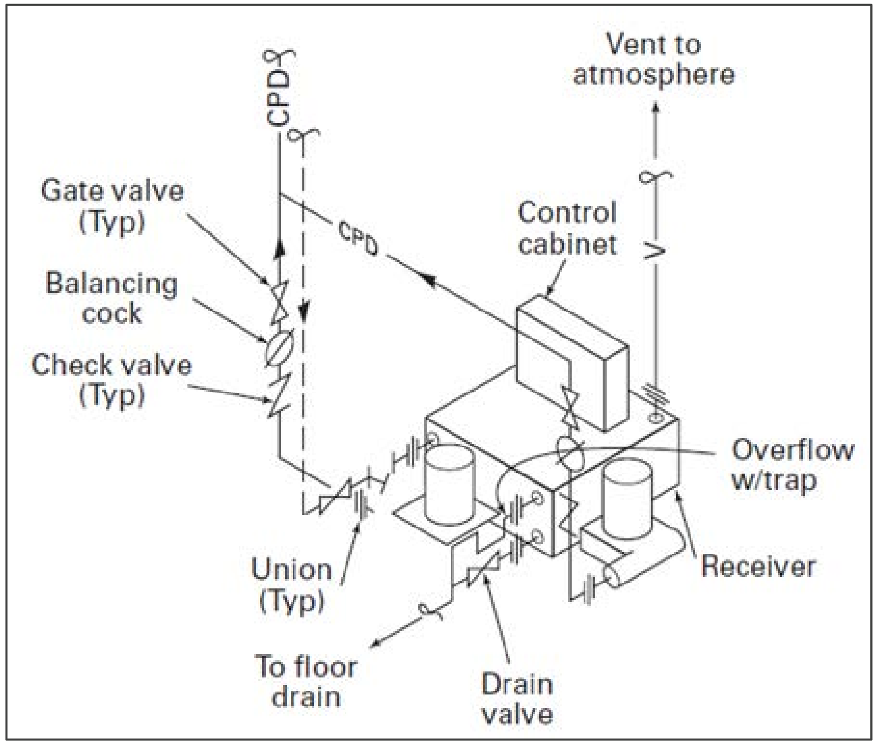


Steam Drip Leg Detail (Medium and High pressure systems)

STEAM AND CONDENSATE PIPING DETAILS

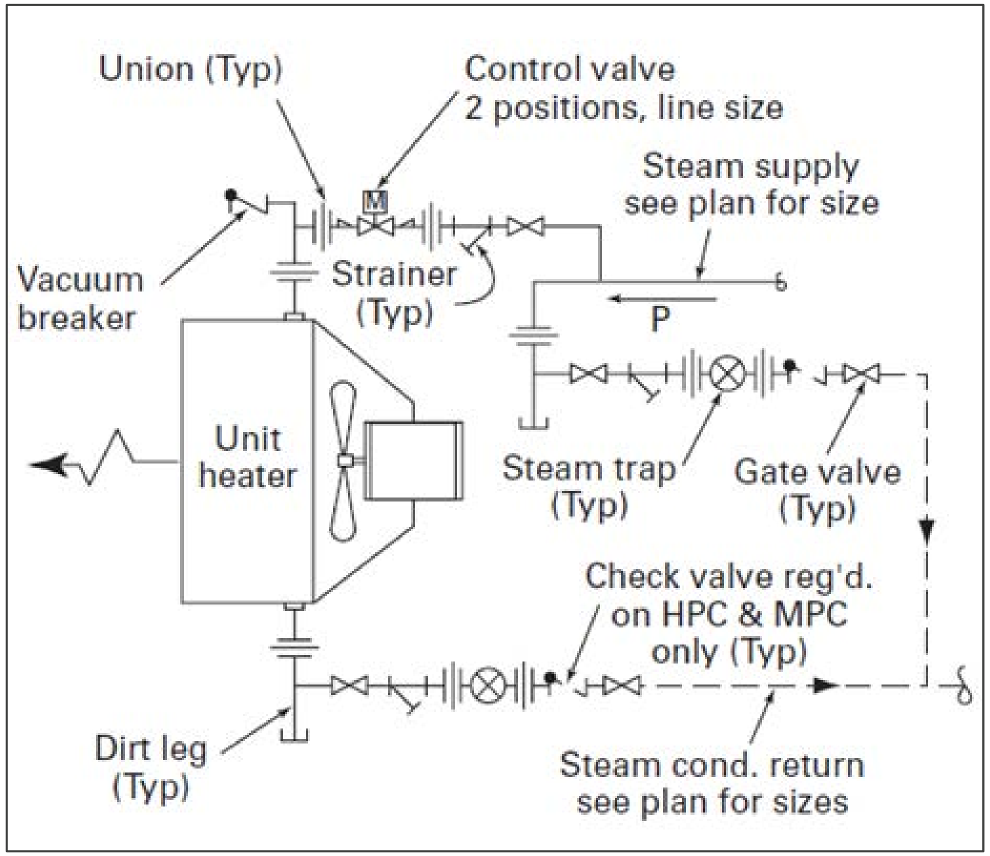


Steam Pressure-Reducing Valve and Relief Valve



Duplex Condensate Pump Piping Detail

STEAM AND CONDENSATE PIPING DETAILS

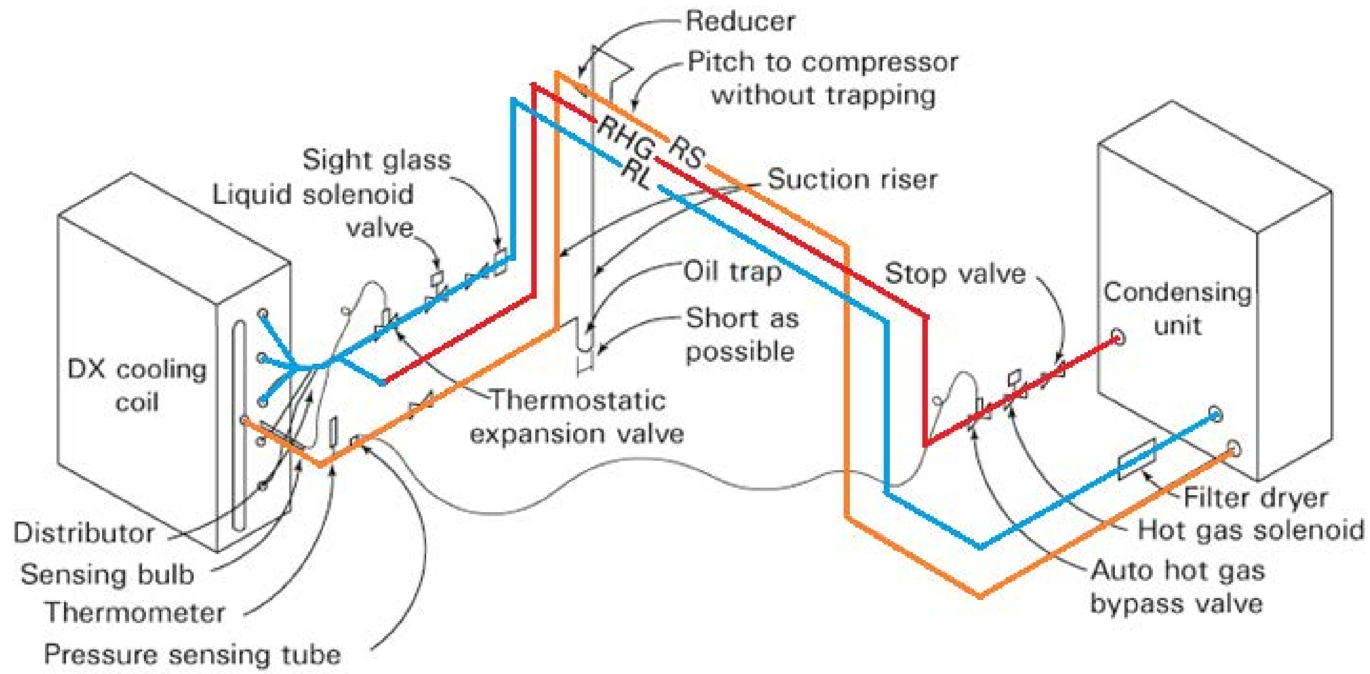


Steam Unit Heater Piping Detail

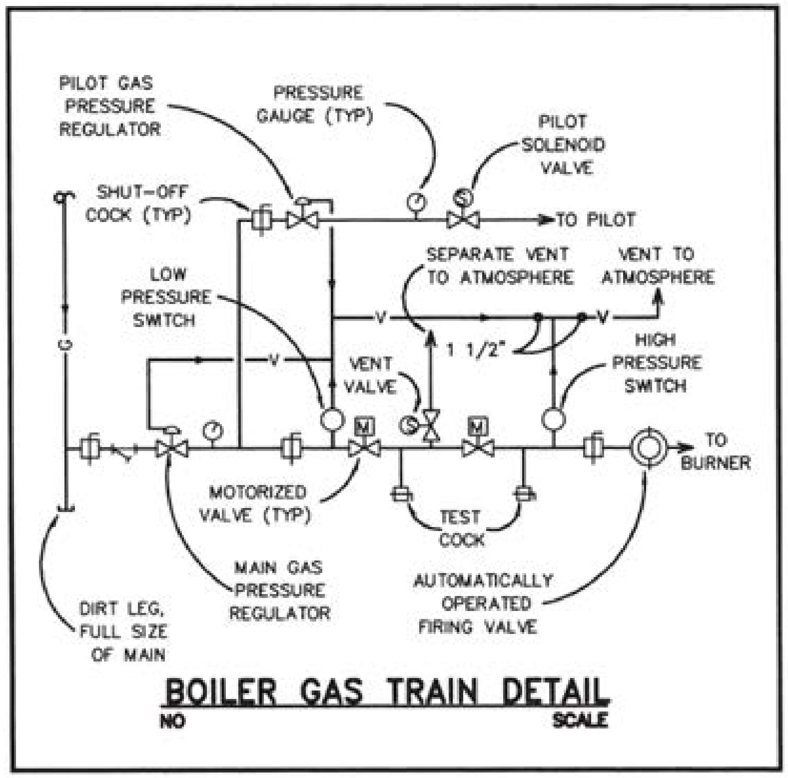
REFRIGERANT PIPING DETAIL

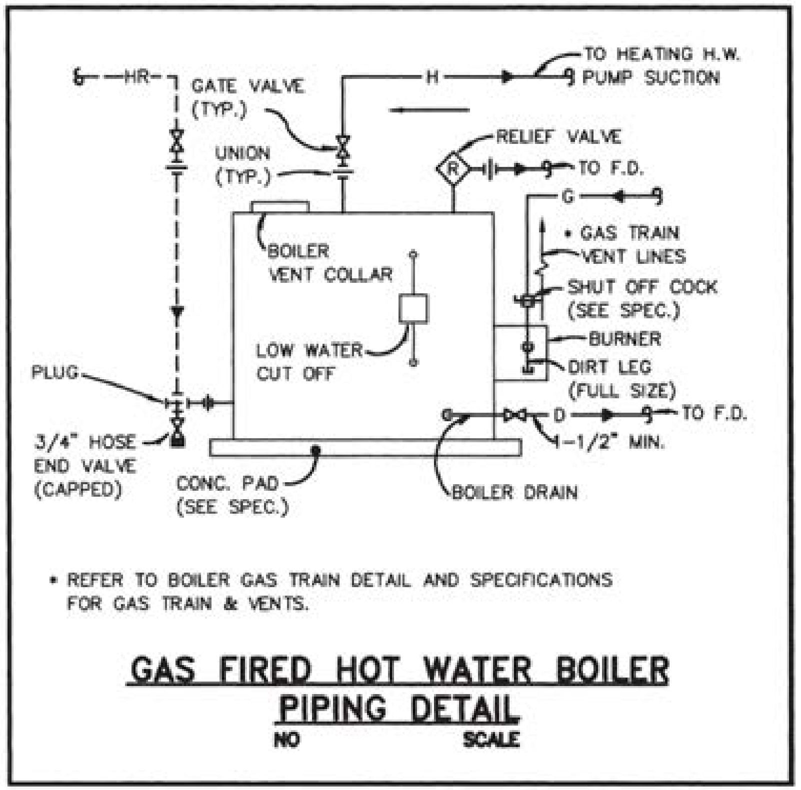
- Direct Expansion System
  - RS – Refrigerant cold suction line
  - RHG – Refrigerant hot gas line
  - RL – Refrigerant liquid line

- Copper, brass, or steel piping
- Joint-soldier, brazed, special screwed connector

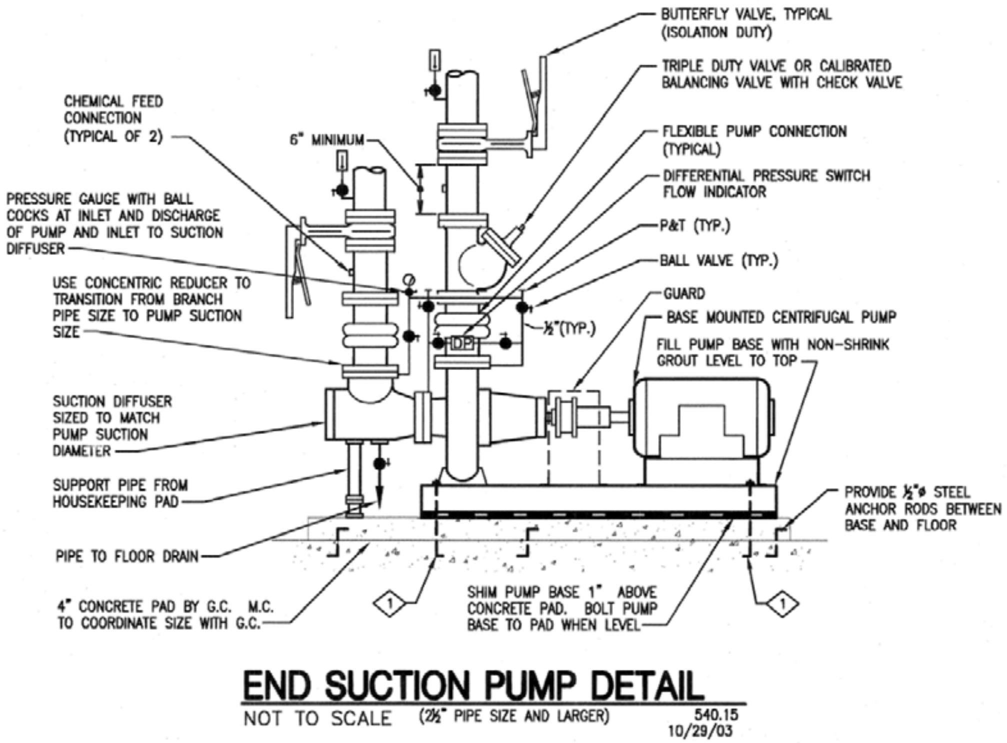


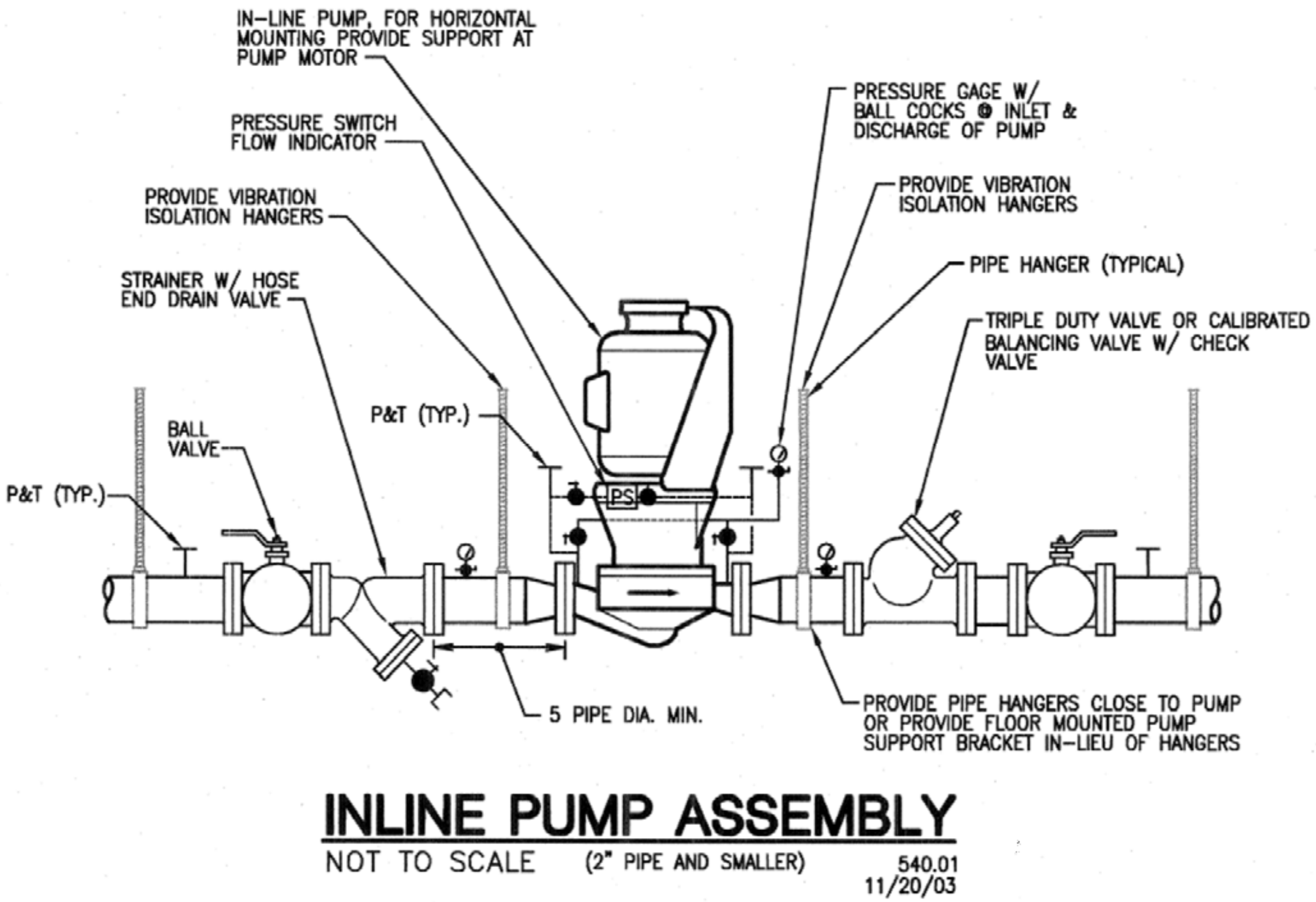
GAS PIPING DETAIL



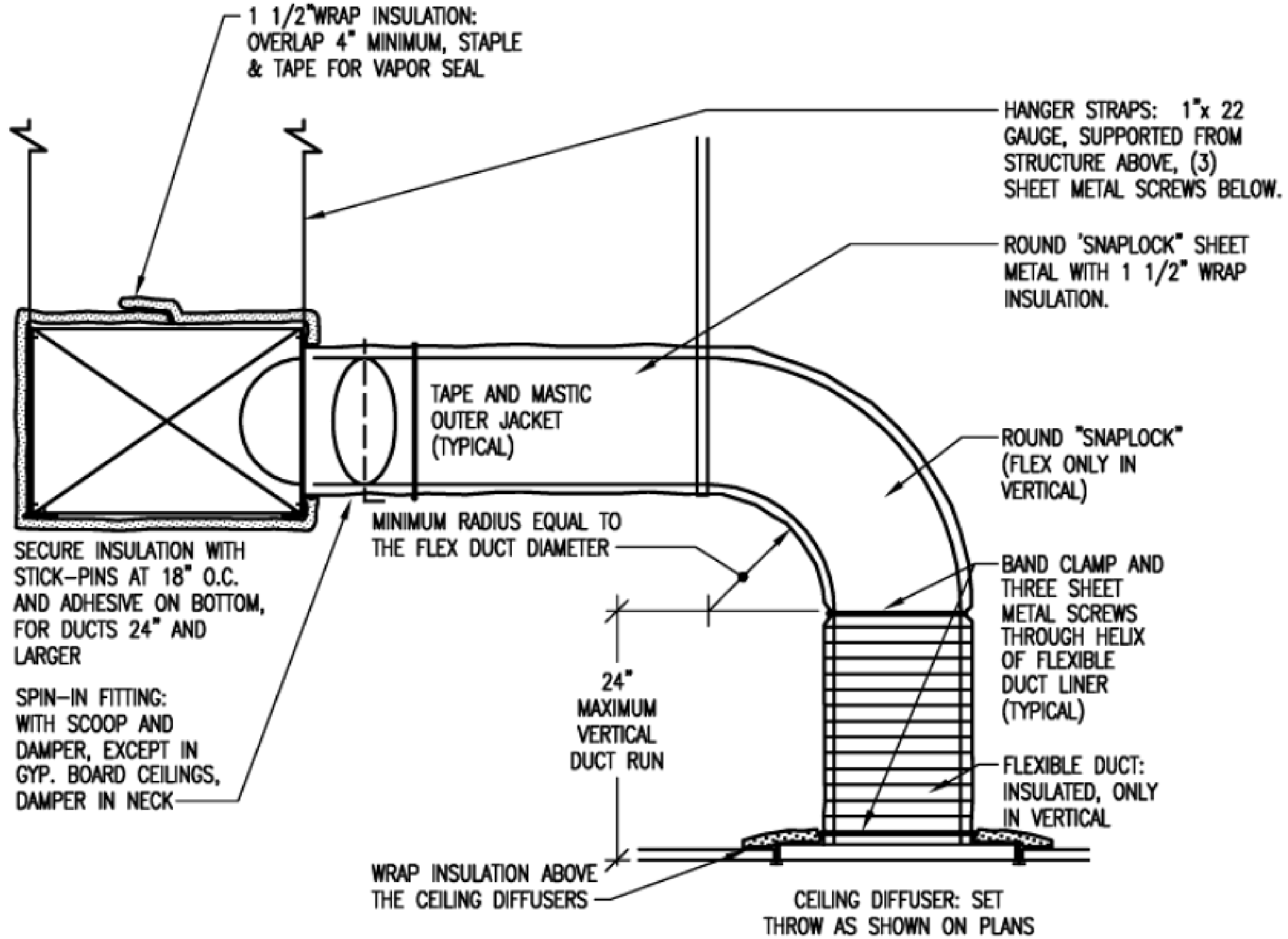


PUMP DETAILS



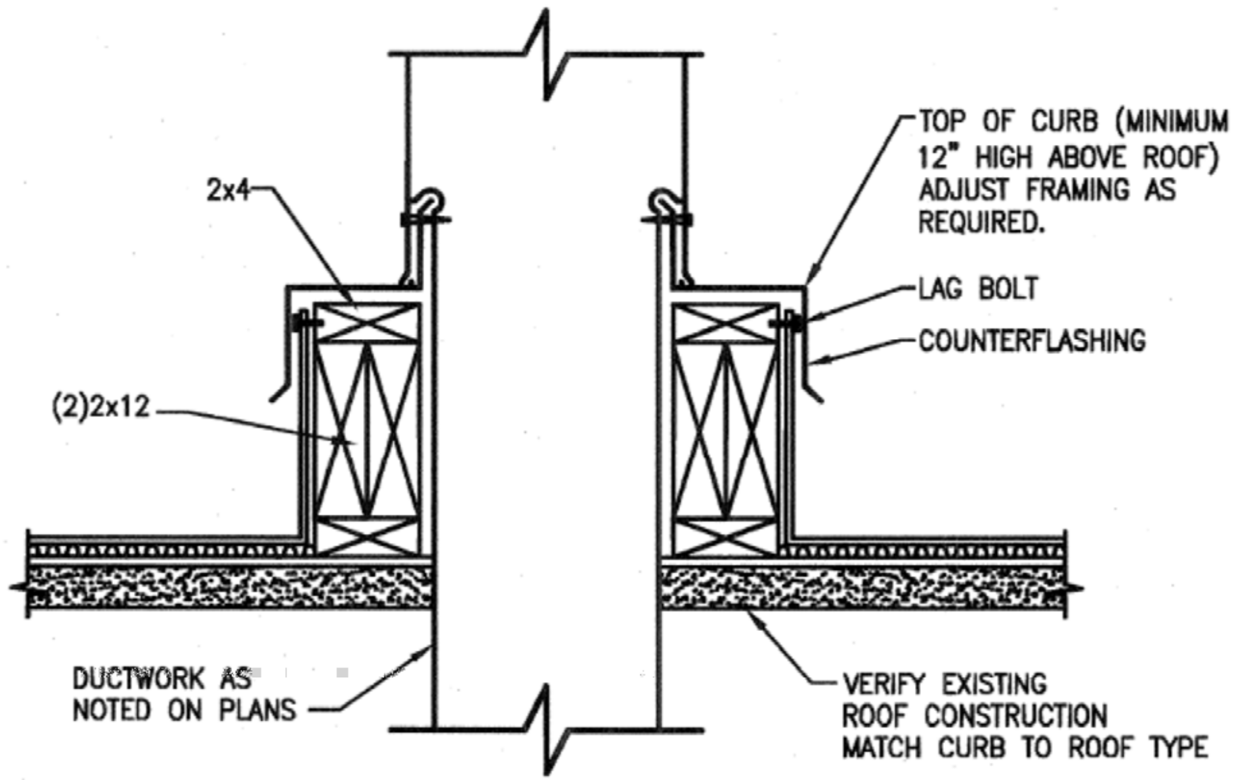


DIFFUSER DETAILS



CEILING DIFFUSER CONNECTION DETAIL (LAY-IN CEILING)
NTS

DUCT ROOF PENETRATION DETAIL

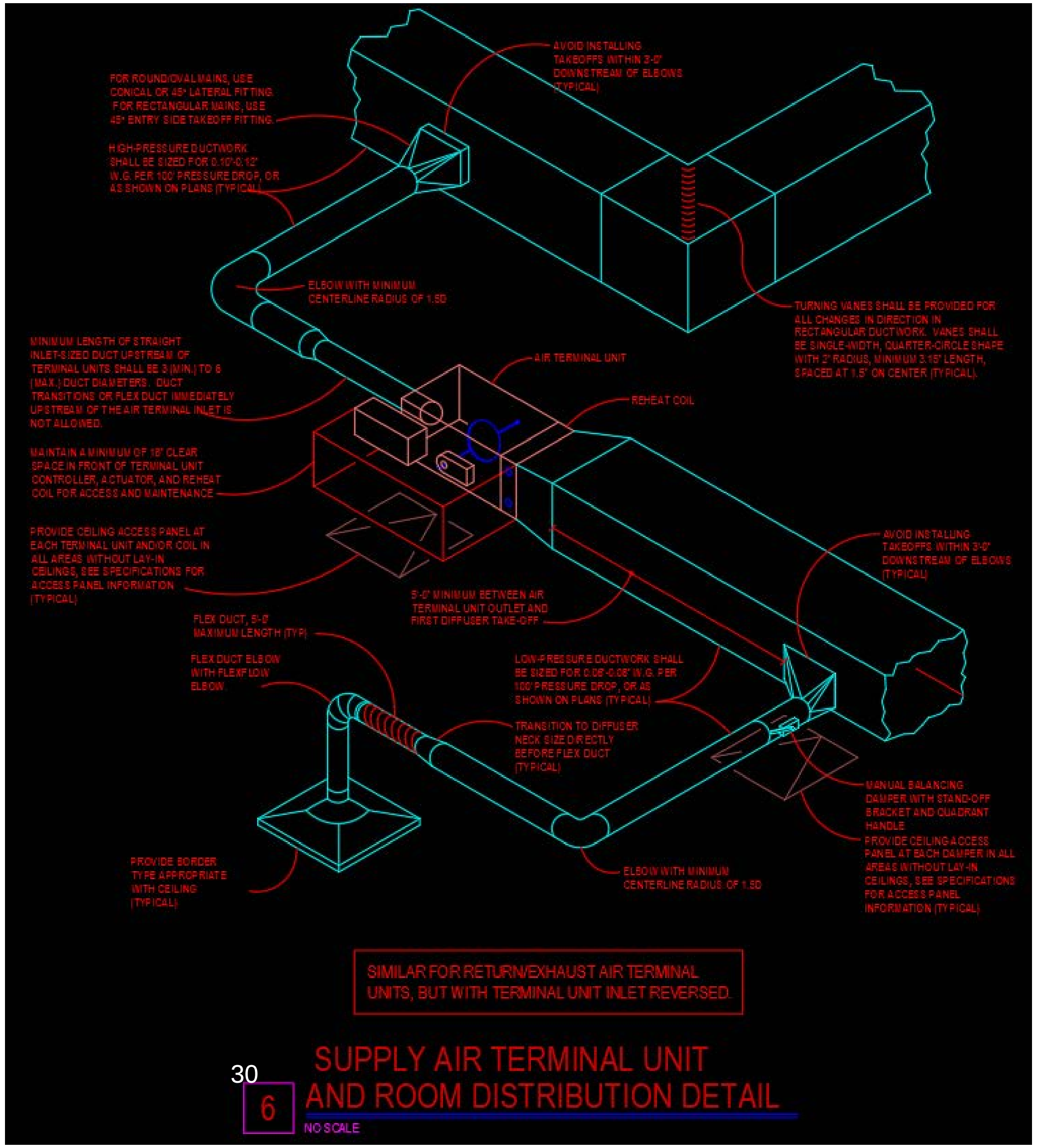


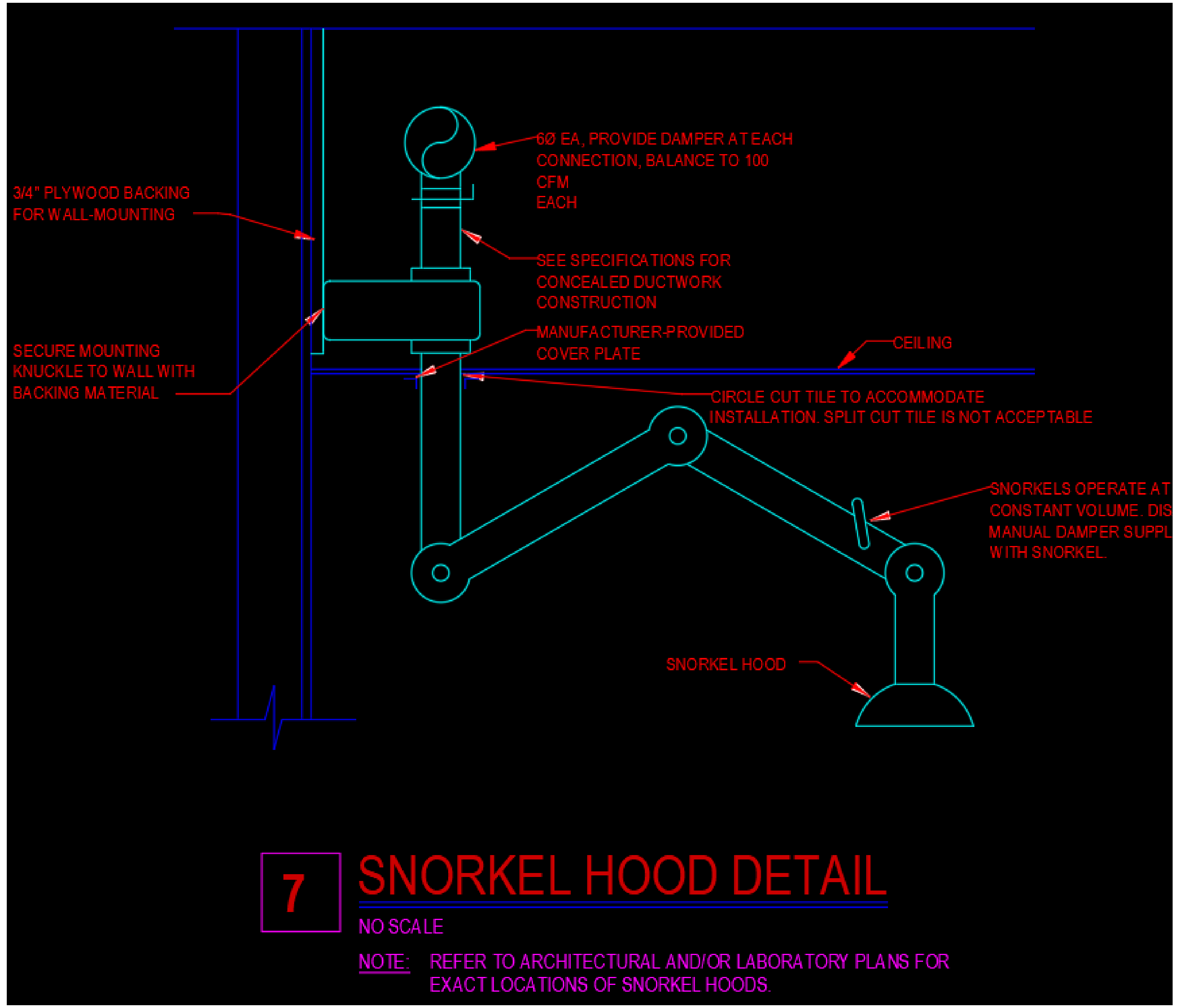
RECTANGULAR DUCT ROOF PENETRATION DETAIL

NOT TO SCALE

891.01
10/30/03

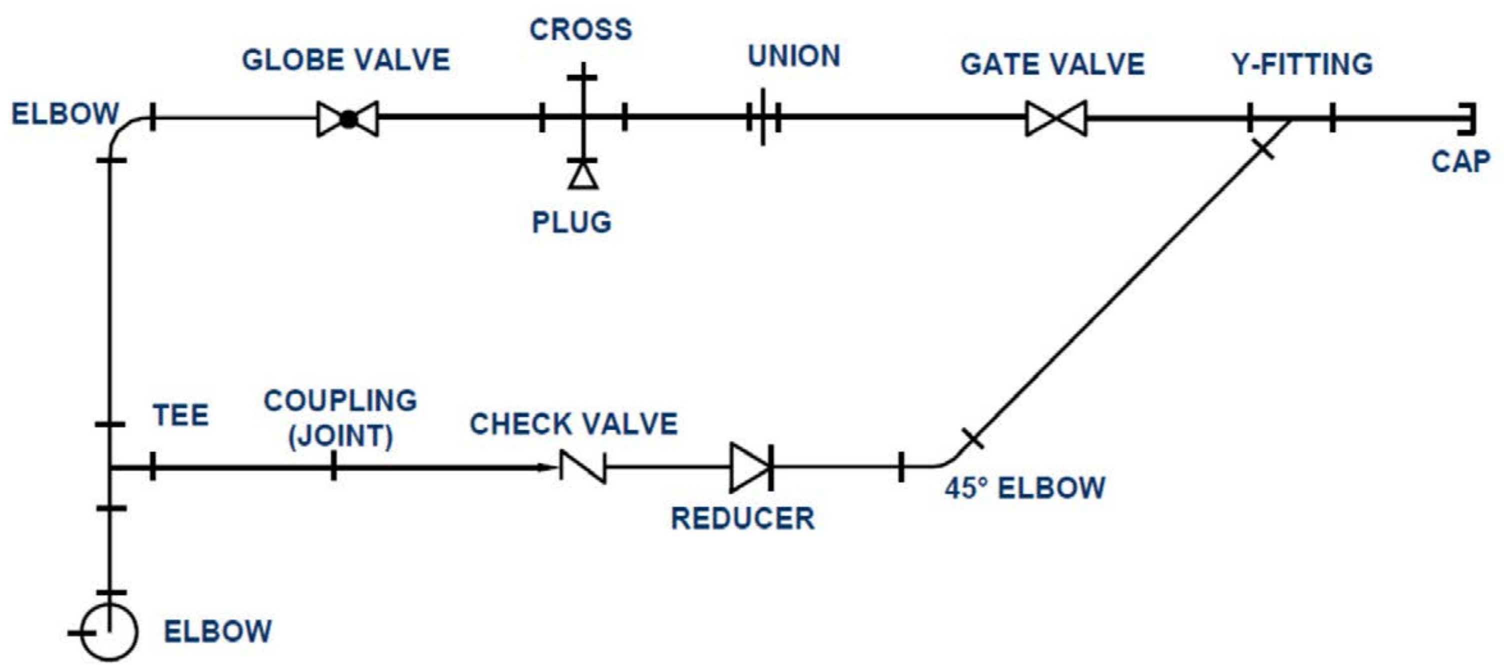
SUPPLY AIR AND SNORKEL HOOD DETAILS



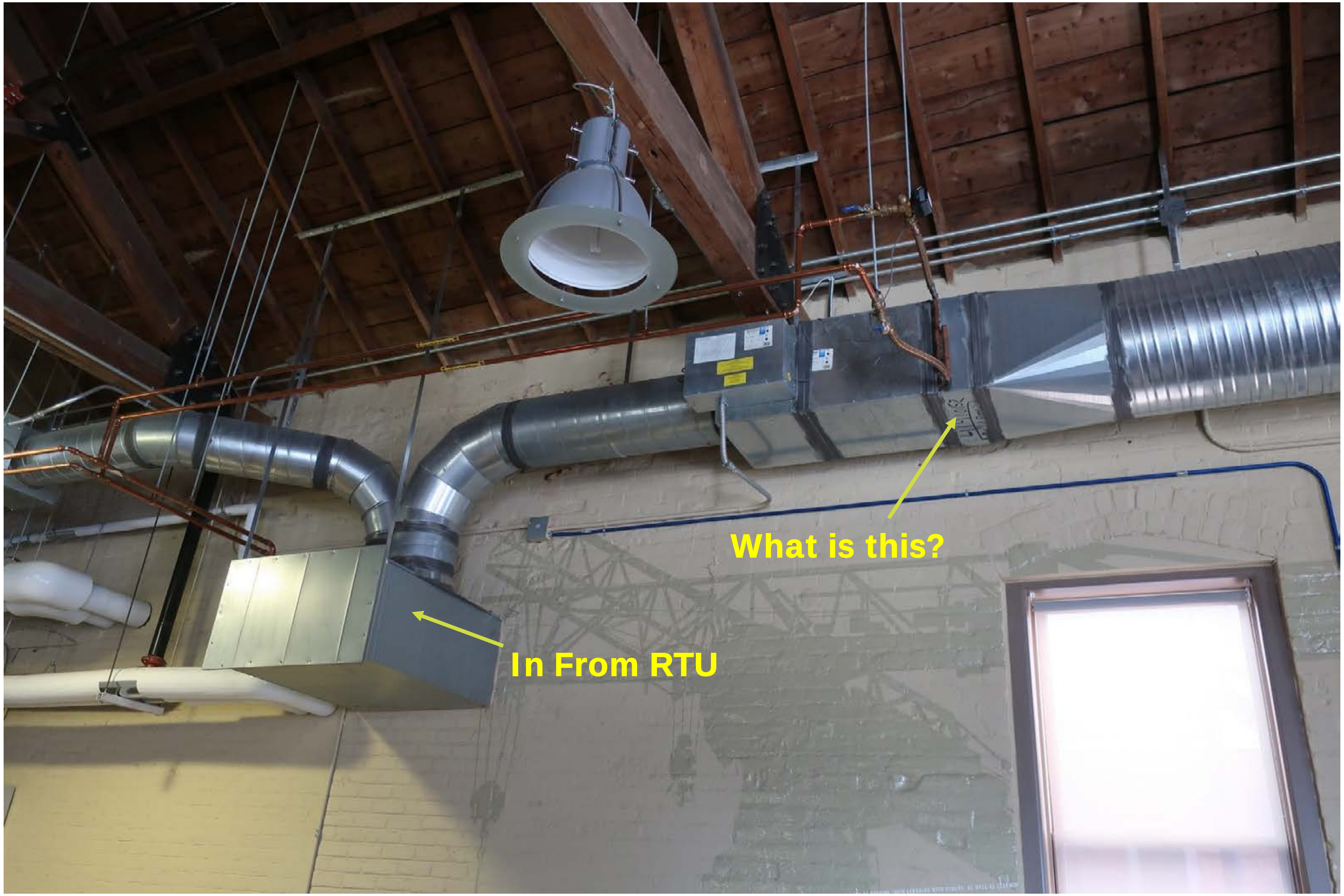


SINGLE LINE (SCHEMATICS)

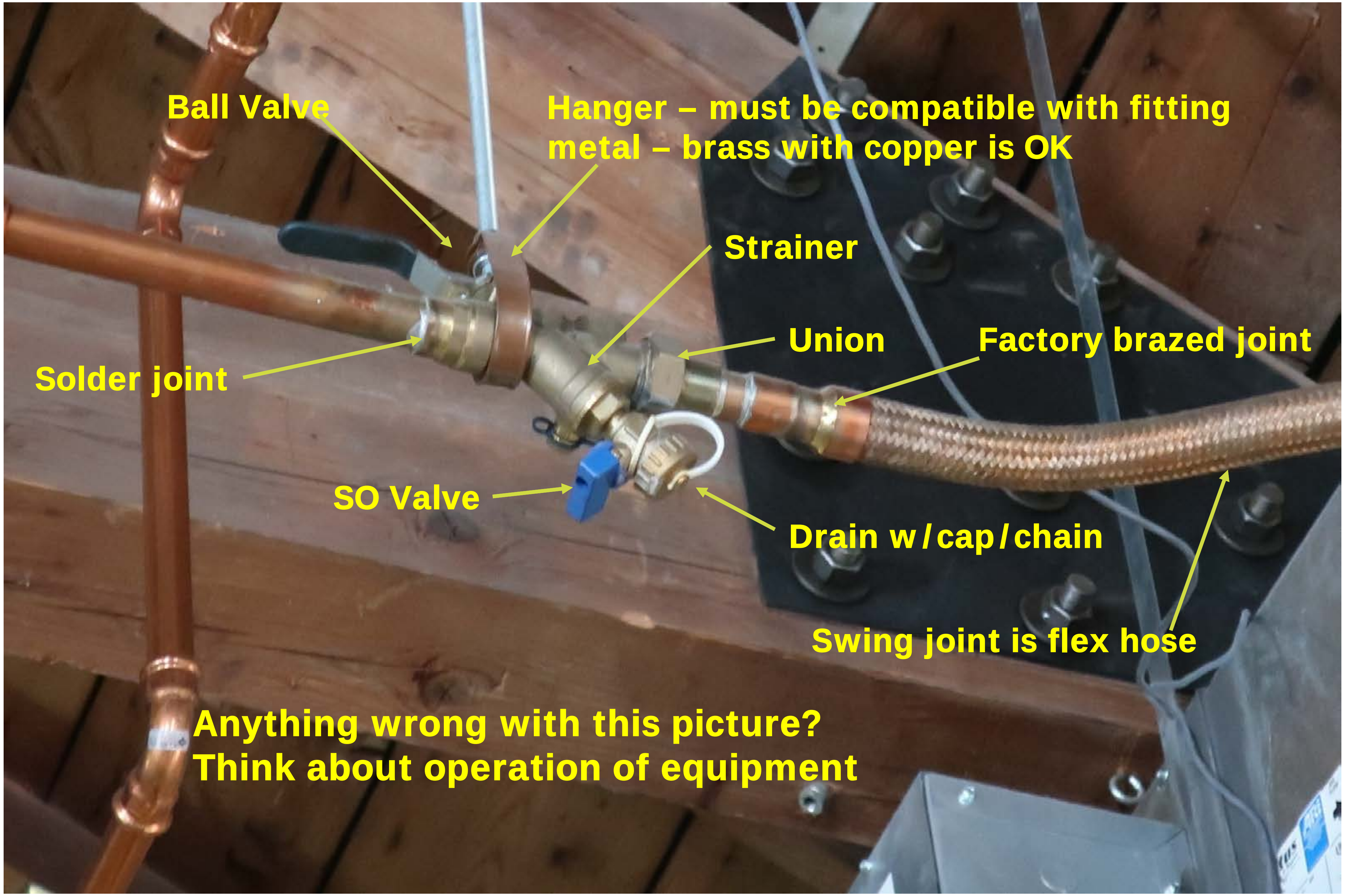
- All piping shown as a single line, regardless of pipe size
- System equipment represented by standard symbols

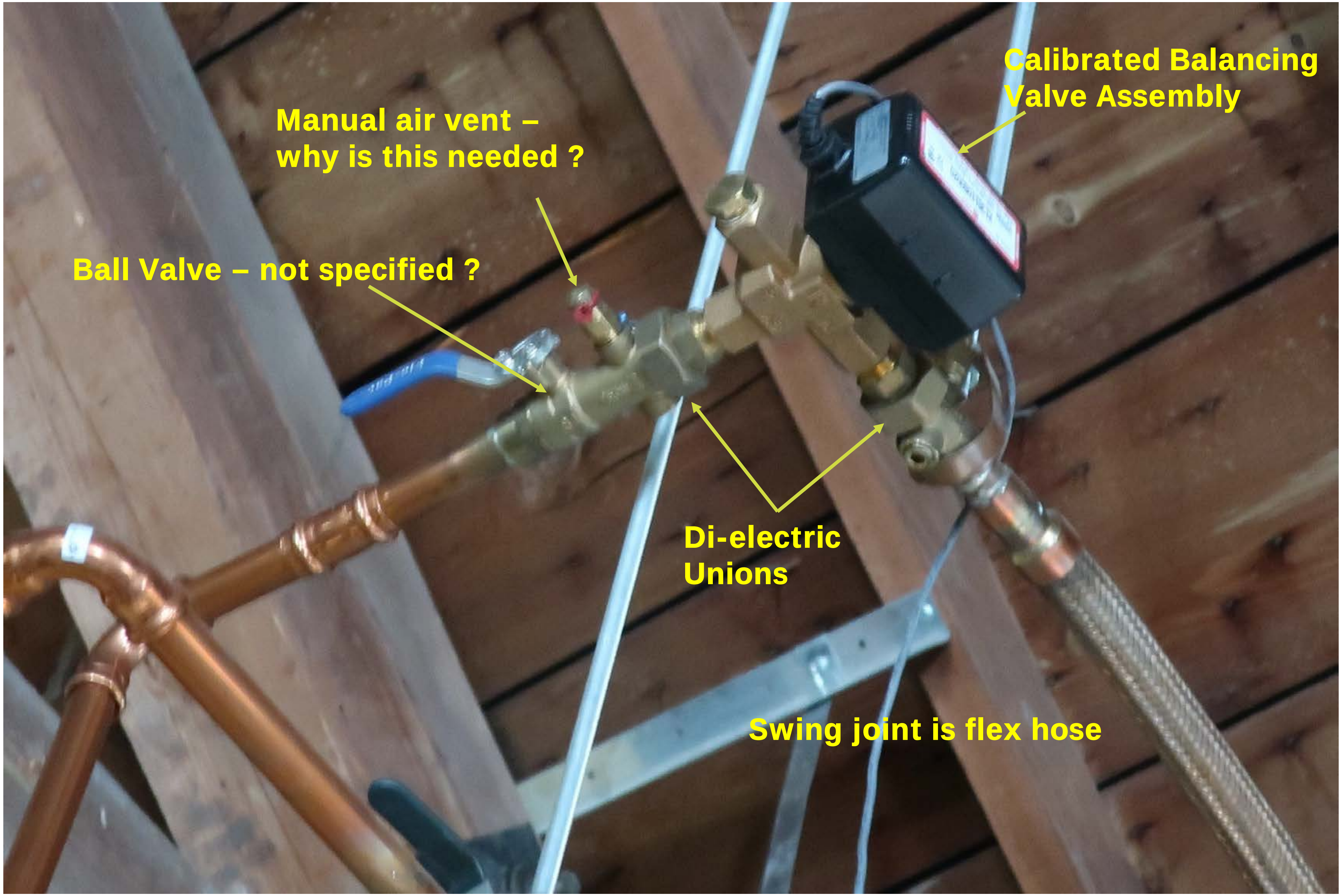


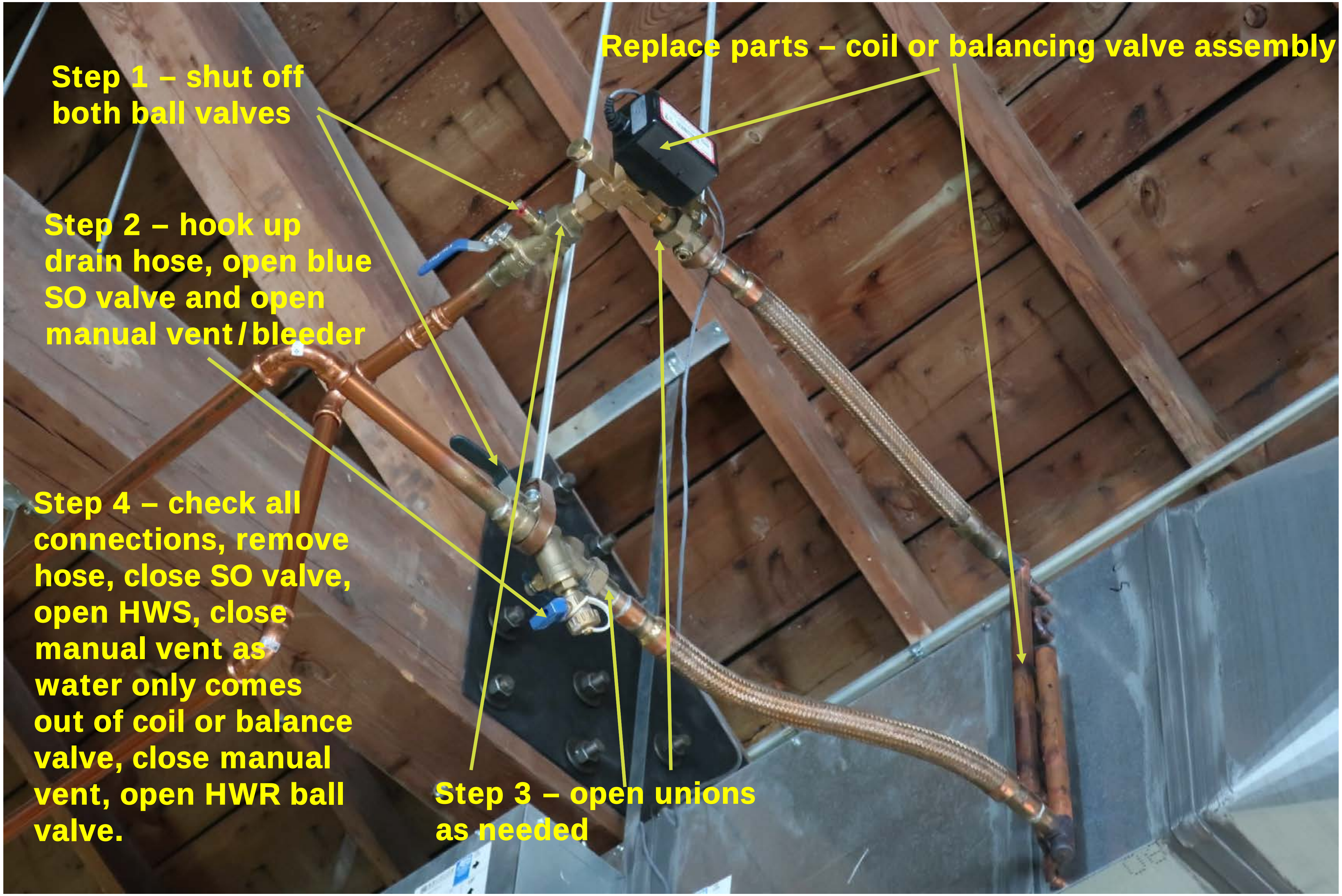
Inside
Room 122




Which is HW supply ?
Is this plumbed correctly?


Ball Valve
Hanger – must be compatible with fitting metal – brass with copper is OK
Strainer
Union
Factory brazed joint
Solder joint
SO Valve
Drain w/cap/chain
Swing joint is flex hose
Anything wrong with this picture?
Think about operation of equipment


Calibrated Balancing
Valve Assembly
Manual air vent –
why is this needed ?
Ball Valve – not specified ?
Di-electric
Unions
Swing joint is flex hose


Replace parts – coil or balancing valve assembly
Step 1 – shut off both ball valves
Step 2 – hook up drain hose, open blue SO valve and open manual vent / bleeder
Step 4 – check all connections, remove hose, close SO valve, open HWS, close manual vent as water only comes out of coil or balance valve, close manual vent, open HWR ball valve.
Step 3 – open unions as needed

DOMESTIC WATER SYSTEMS

CON 371 – Mechanical and Plumbing Systems

LEARNING OUTCOMES

- By the end of this lesson, students will be able to:
  1. Describe the characteristics and quality of water
  2. Discuss water purification and filtration systems
  3. Recognize the common domestic water system loads
  4. Analyze pressure needs for a water distribution system

PLUMBING SYSTEMS

- **Water Supply, Distribution, Treatment, Quality, Temperature**
- Selection and Installation of Plumbing Fixtures and Drainage Devices
- Waste Collection, Treatment, and Disposal
- Storm Water Collection, Retention, and Disposal

- Building Water Supply needed for:
  - Domestic Water
  - Hydronic System
  - Food Service
  - Pools
  - Landscaping
  - Processes/Research
  - Fire protection

WATER SOURCE

Potable Water

- Generally provided from a public water system
  - Lakes, reservoirs, rivers
- Collected in tanks or cisterns for later use
  - Rain water collected in cisterns and used for watering landscaping

Groundwater

- Water that has filtered through the ground to form an aquifer
  - Common water source in rural areas (Wells)
- Typically pumped faster than recharge
  - Depletes underground aquifers
- Water table depth equates to the depth of the well
  - Distance of water table from the surface

DOMESTIC WATER USAGE

Usage	Demand, GPM	Total Consumption, gal
Shower, 5 min	2–6	10–30
Bath, in tub	5–15	25–30
Dishwashing, residential	1–2	10–15
Dishwashing, commercial	10–30	50–200
Clothes washer, residential	2–4	10–50

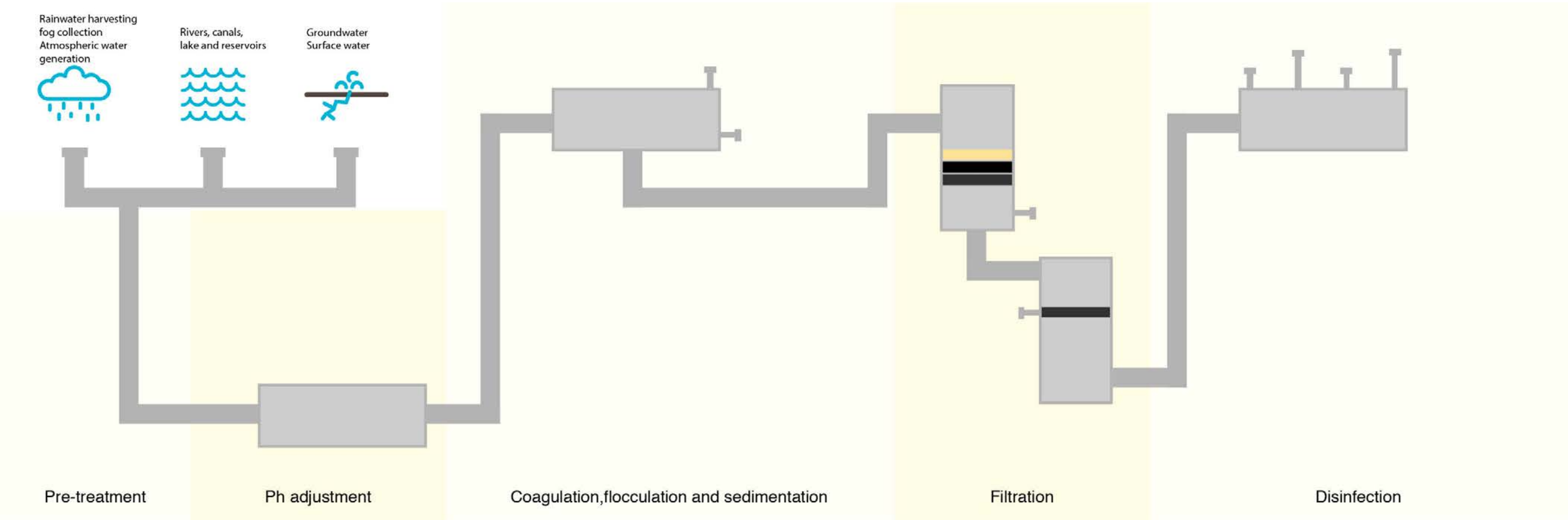
Total Consumption per use

- If you take 300 showers annually, how much water is used?

$$\left(\frac{300\ showers}{yr}\right) \times \left(\frac{20\ gallons}{shower}\right) = 6{,}000\ Gal/yr$$

EXAMPLE

DOMESTIC WATER TREATMENT



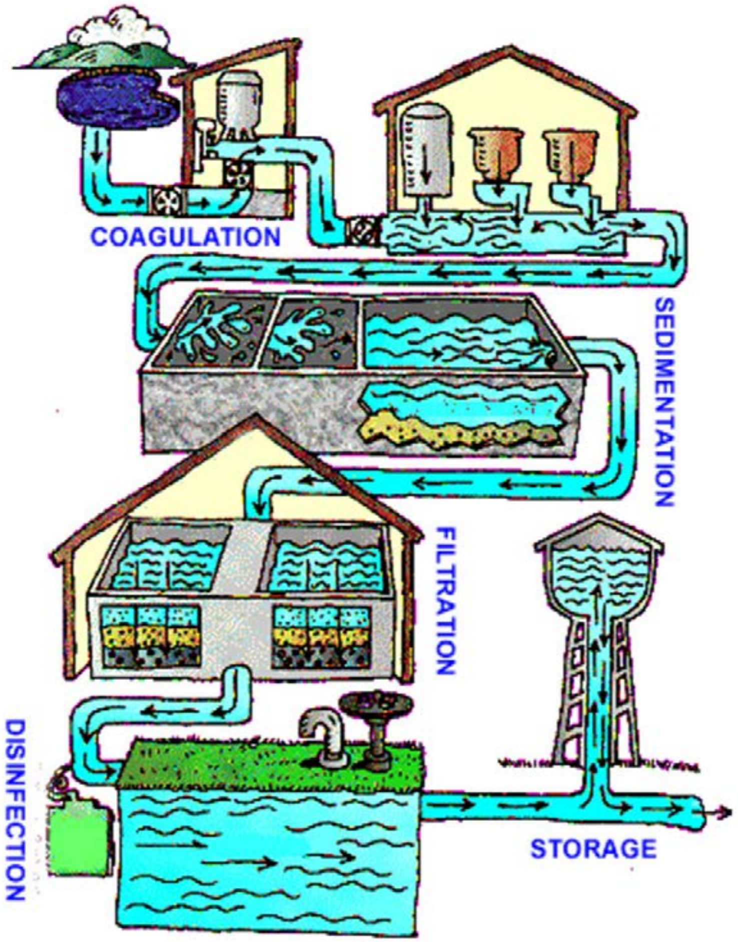
Treating domestic water for consumption limits the amount of suspended solids, dissolved solids, and bacteria/radioactive materials in the water

WATER TREATMENTS FOR SUSPENDED SOLIDS

- Sedimentation
  - Removes suspended solids
  - Reduces turbidity (Clarity of water)

- Coagulation (or flocculation “floc”)
  - Removes suspended solids using chemicals (e.g., hydrated aluminum sulfate)
  - Reduces turbidity and improves color and taste

- Filtration
  - Removes suspended matter using porous materials as a filter
  - Improves turbidity, potability, color, and taste



Public Domain Photo courtesy of the Environmental Protection Agency

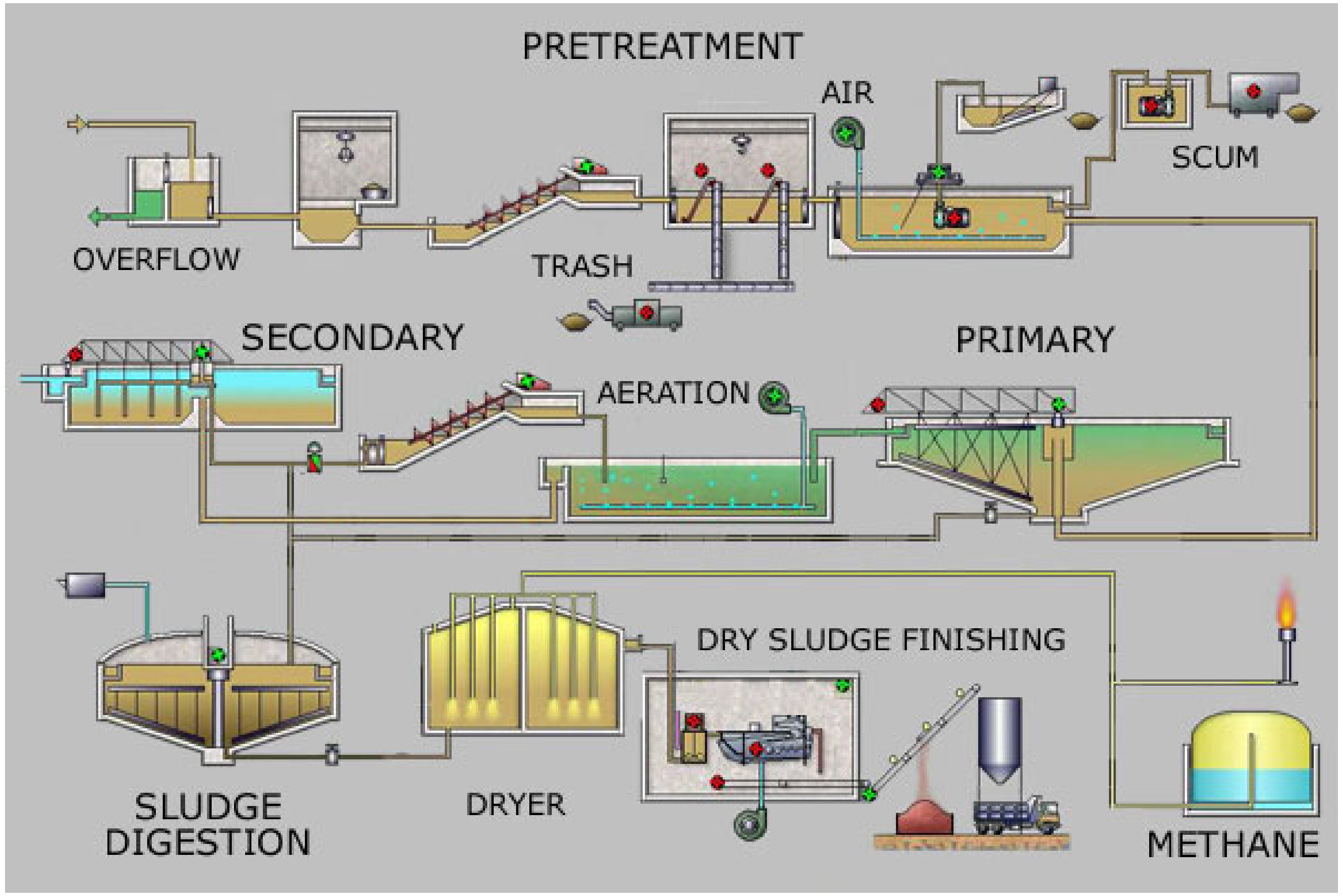
WATER TREATMENTS FOR DISSOLVED SOLIDS

- Disinfection
  - Use of chlorine to destroy the enzymatic process of bacteria
  - Improves quality
- Aeration
  - Oxygen is added to water
  - Oxidizes impurities and improves color and taste
- Fluoridation
  - Prevents tooth decay

Common Dissolved Solids found in Water	
Sulfates	Iron
Nitrates	Manganese
Sodium	Calcium carbonate

CDC Reading:
Community Water Treatment

WASTEWATER TREATMENT



WATER QUALITY

Water purification systems

- Removal of dissolved solids
  - Calcium
  - Salt
  - Chlorine
- Types
  - Deionization
  - Reverse osmosis (RO)
  - Distillation
  - Desalinization

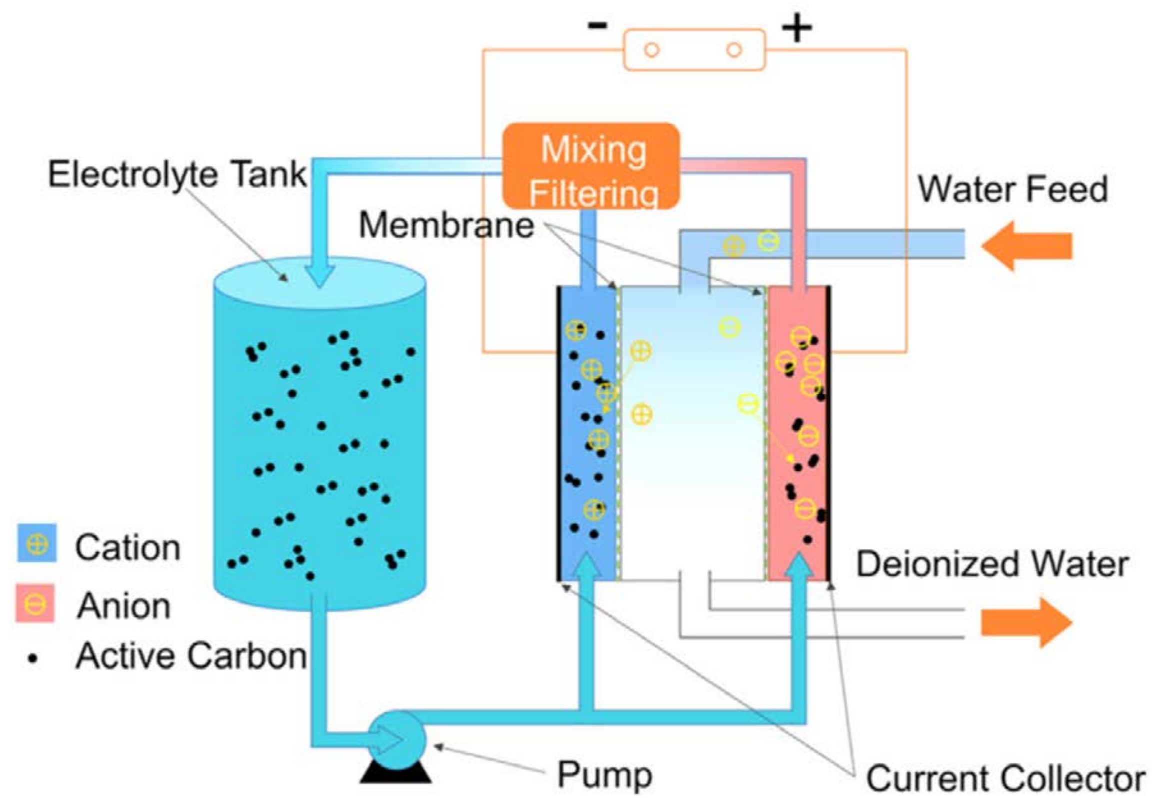
Expensive systems

Water filtration systems

- Removal of undissolved (suspended) solids
  - Dirt
  - Debris
  - Suspended matter

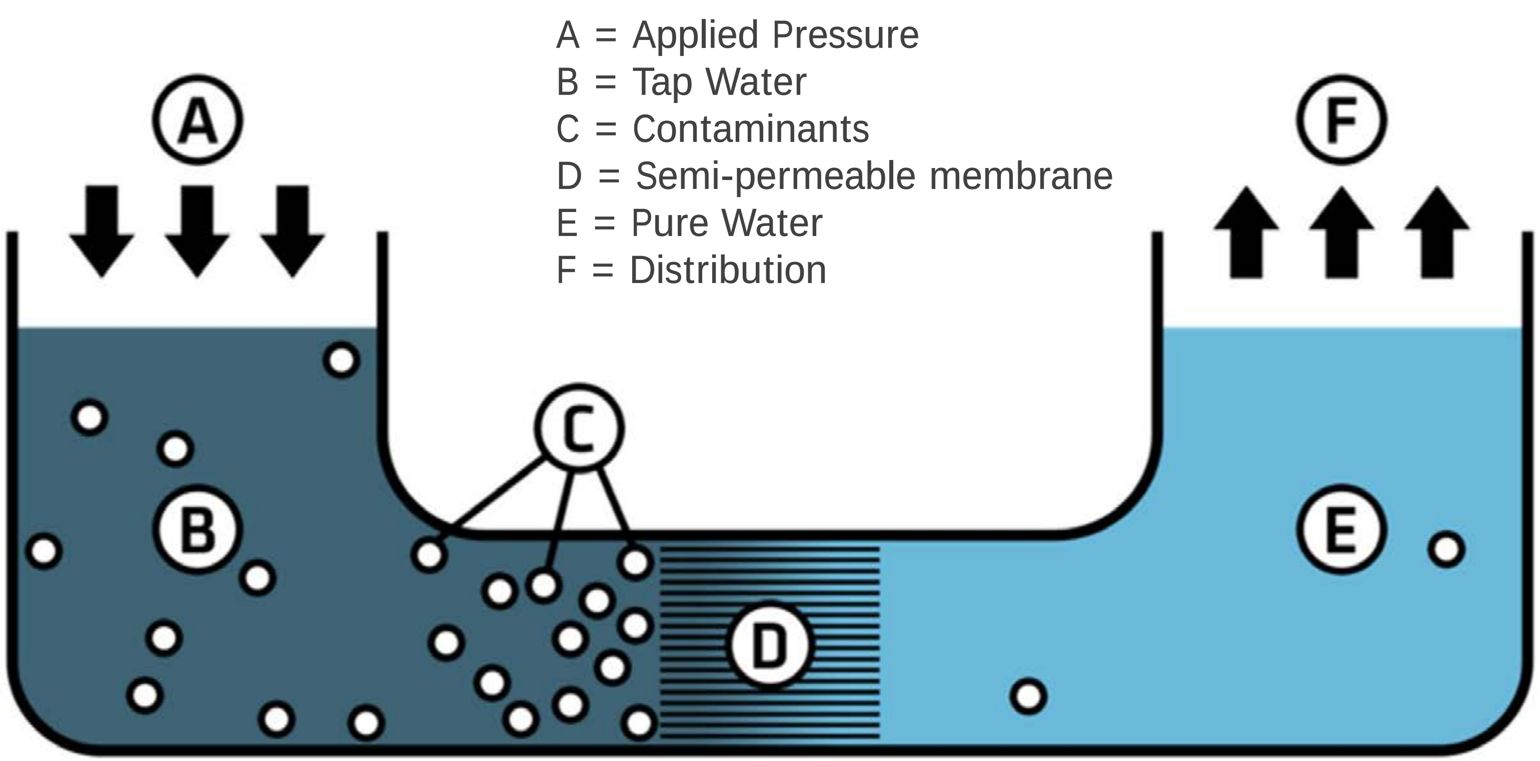
DEIONIZATION

- Resins absorb cations and anions
  - Cations: Calcium, Sodium, Potassium, Iron
  - Anions: Carbonates, Sulfates, Chlorides, Silica
- Reduces hardness and mineral content
- Can produce the most pure water



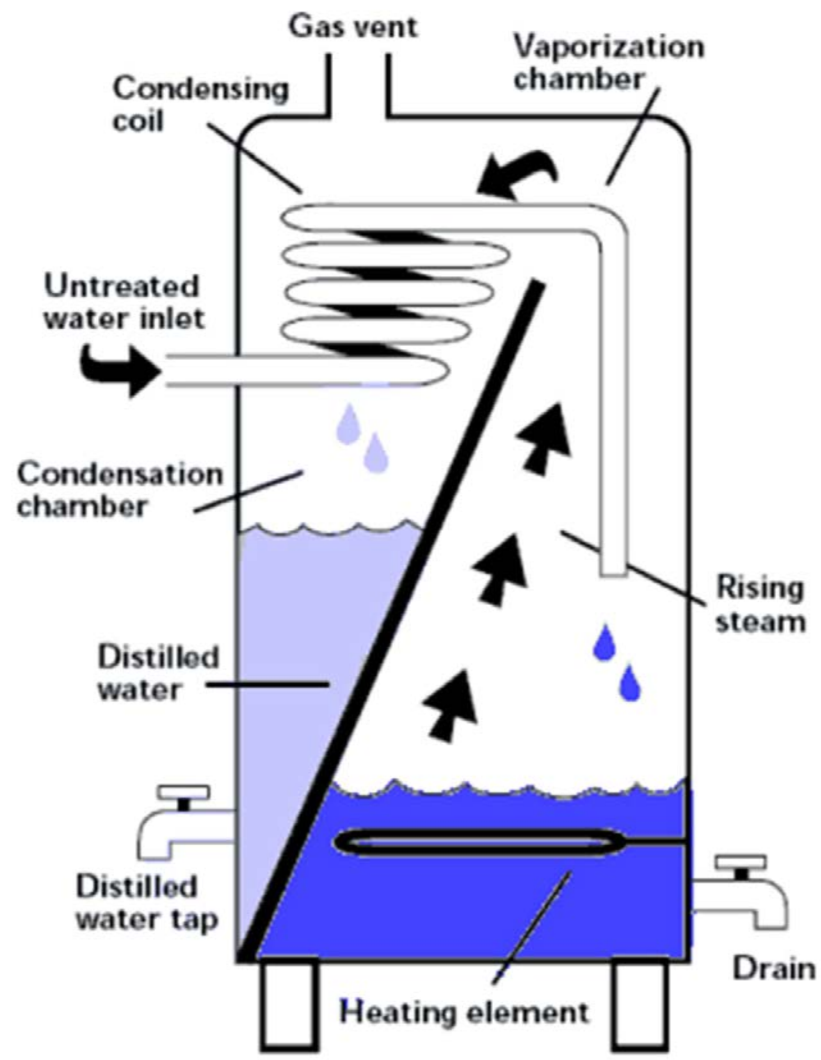
REVERSE OSMOSIS (RO)

- Natural Phenomenon: Principle of diffusion



DISTILLATION

- Water heated to a vapor and then condensed
- Condensed water is highly purified as impurities removed in the evaporation-condensation cycle
- Requires more energy than RO and deionization



WATER FILTRATION SYSTEMS

- Used to improve turbidity
- Types:
  - Sand filters
    - Graduated layers of minerals/sand
    - Efficient to operate
  - Diatomaceous earth filters
    - Fine mineral powder (Silica)
    - Compact size

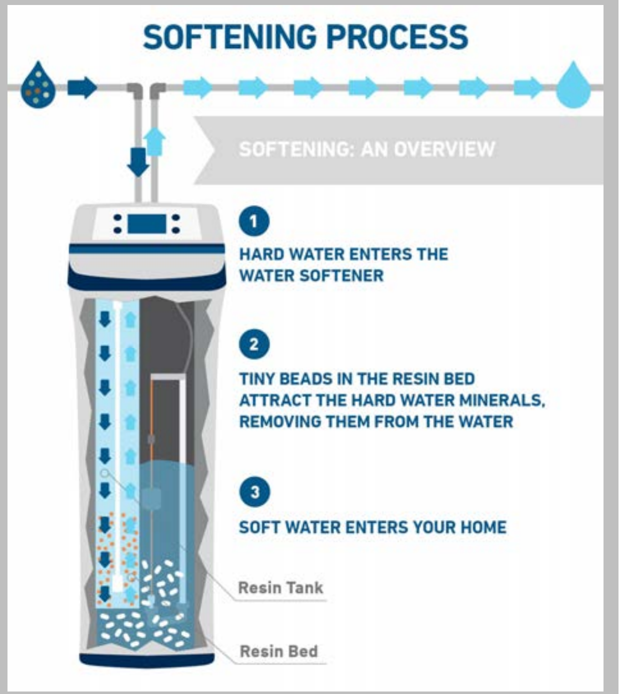
WATER SOFTENING

Calcium Carbonate Causes Water Hardness

- Desirable <200 ppm
  - Less than 100 ppm: Soft water
  - 100 – 200 ppm: Reasonably soft
  - 200 – 300 ppm: Average hardness
  - 300 – 400 ppm: Very hard
  - Over 400 ppm: Extremely hard
- Too hard
  - Reduces efficiency of heat exchangers
  - More soap required to produce lather
  - Causes rings in bathtubs and sinks
  - Chemical deposits in pipes (Scaling)
  - Poor laundry results
  - Hard water not considered detrimental to health

Zeolite System

- Exchange of Ca or Mg ions (negative ions) with Na ions (positive ions)
- Resin tank contains ion-exchange resins
- Brine tank contains sodium solution to re-charge resins
- Hard water passes through resins and removes Ca and Mg ions



DOMESTIC WATER SYSTEM LOADS

- Plumbing fixtures
- Food services
- Laundry
- Hydronic system
- Landscaping
- Pools
- Research/medical
- Fire protection

All water loads for these services must be accounted for in the design of the domestic water system

PLUMBING FIXTURES

- Depends on the number and type of fixtures installed
- Fixtures assigned water supply fixture units (wsfu) rating
  - Fixtures and fixture units will be discussed in detail in the next lesson

FOOD SERVICES

- Varies between residential and commercial equipment
- Water demand associated with sinks and dishwashers
  - Sinks accounted for in the plumbing fixture units
  - Need to consider dishwasher loads
    - 10-15 gallons per wash for residential (Corresponds to 2-3 GPM)
    - 10x greater for commercial dishwashers

Note: DW Loads commonly obtained from manufacturer

LAUNDRY

- Varies between residential and commercial equipment
  - 20-40 gallons per wash for residential (Corresponds to 4-6 GPM)
  - Commercial loads provided by manufacturer

HYDRONIC SYSTEMS

- Typical systems are closed-loop requiring little to no water replacement
- Exception: Water Cooling Towers
  - Water needed to make up evaporation and drift losses
  - 3-4 GPM needed for each ton of refrigeration required
  - Common to use 1 to 2% make-up rate for evaporation, blown-down, or drift
    - Approximately 0.035 GPM = 2 gallons per ton-hour

Flow rate is quite low, but need to consider the size of water-based cooling systems

HYDRONIC SYSTEMS

- High School Building
  - Utilizes a 50 ton chiller
  - Average load is 65%
  - 4 GPM flow rate per ton
  - System operates 10 hours per day for 225 days

1. Find the water make-up demand for the cooling system

$$Water\ Demand: (50\ tons)\left(\frac{4GPM}{ton}\right)(1.5\%) = 3GPM$$

2. Find the annual consumption

$$Total\ Consumption: (3GPM)(65\%)\left(\frac{60min}{hr}\right)\left(\frac{10hr}{day}\right)\left(\frac{225days}{yr}\right) = 263{,}250\ Gal/yr$$

LANDSCAPING

- Manual watering: 5-15GPM per hose bibb
  - Can be discounted if used during off-peak hours
- Landscaping sprinkler systems
  - ½” piping: 1-10 GPM
  - 1” piping: 10-30 GPM
  - Pressure: 20-60 psi
  - Typically controlled to run during off-peak hours
- Water features (e.g., fountains, reflecting pools)
  - Ranges from 1 to 1,000 GPM
    - Depends on the nozzles used
  - Typically use re-circulation
    - Include 10% makeup capacity

POOLS

World's deepest pool opened in Poland in 2019. Holds 2.1 Million gallons of water!

- Swimming Pools
  - Size of pool dictates the flow rate
  - Typical flow rates are to re-circulate the entire volume of water in 6 to 8 hrs or 3 to 4 time a day
  - Include 1-2% makeup to overcome evaporation, bleed-off, and spillage

RESEARCH/MEDICAL

- Typical research/medical uses:
  - Lab equipment
  - Commercial processes
  - Industrial processes
  - Computer equipment
- Use can be quite high
  - Demands calculated by actual usage

SERVICE WITHIN BUILDINGS

- Due to a principle called hydrostatic pressure, buildings will have water distribution designed as an:
  - Upfeed System
  - Downfeed System
  - Air Pressure System (Hydro-pneumatic)

SERVICE WITHIN BUILDINGS

	Upfeed System	Downfeed System	Air Pressure System
Characteristics	• City supplied water main pressure pushes water up • Serves top floor of facility with adequate pressure	• Uses pumps and valves to move water up to storage tank (top of bldg, multiple floors in a bldg) • Water is then distributed via gravity	• City supplied water main pressure is too low to service the facility adequately • Compressed air used to raise and push water through the system (increases pressure)
Advantages	• No need for pumps or tanks • No additional pressure system needed • Useful for low-rise structures	• Water supply is not affected by peak load hour • Not affected by power interruptions • Time needed to maintain/replace parts does not affect water supply	• Compact pumping unit • Sanitary and air tight water chamber • Smaller diameter pipes • Less initial construction and maintenance costs
Disadvantages	• Incoming pressure may be inadequate for tall buildings • Water supply is affected by peak load hour	• Water is subject to contamination • Higher maintenance costs • Occupies vast amounts of space • Stronger foundation and structure to carry water and tank load	• Water supply is affected by loss of pressure due to power interruptions

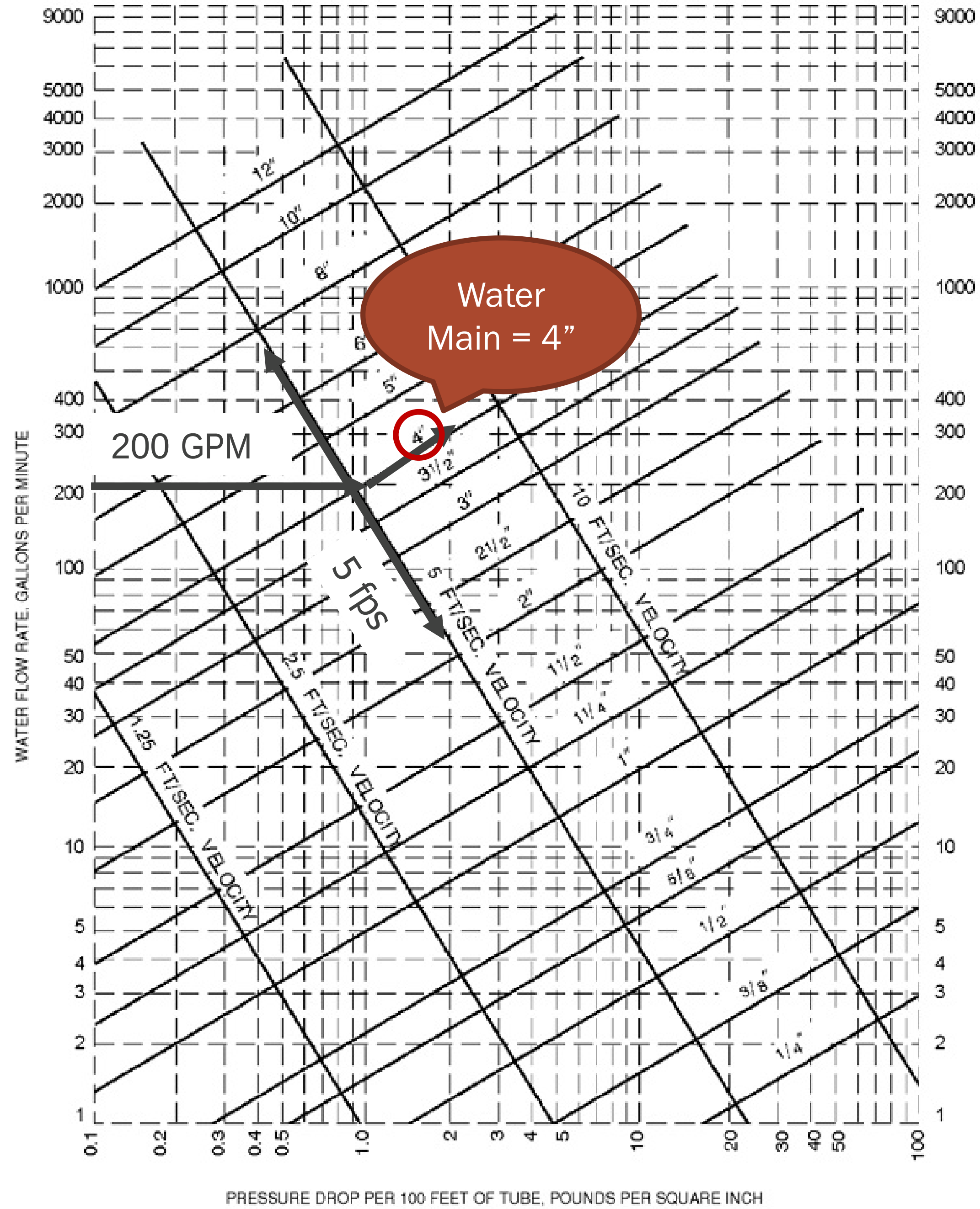
WATER PRESSURE

- Positive pressure establishes flow through the system and fixtures
  - Helps prevent contamination with foul water
- Pressure requirements must overcome:
  - Friction loss
  - Elevation
  - Flow pressure at outlets/equipment

Fixture or Equipment	Minimum Flow Pressure, psi
Lavatory, sink, bathtub, shower, bidet, drinking fountain, water closet (tank)	8–10
Water closet and urinal (flushometer)	20–25
Garden hose, lawn sprinkler, dishwasher, clothes washer	15–20
Commercial dishwasher (self-contained pump)	30–50
Fire protection sprinkler	25–30
Fire hose (1½ in.)	65
Fire hose (2½ in.)	65

WATER PRESSURE

- If the peak demand for a commercial office building is:
  - 200 GPM
  - Flow not to exceed 5 feet per second (ft/sec)
  - Type L Copper
- Find the water main service pipe size needed



PRESSURE LOSS

- Factors that affect pressure loss
  - Starting pressure
    - City Main sufficient or need pump
  - Ending pressure
    - Needed at fixture (e.g. tank water closet requires 15 psi)
  - Friction loss in pipe, fittings, and valves
  - Pressure needed to lift water
    - Remember: Water weighs 62.4 lbs/ft^3

1 psi lifts water approx. 2.3’
Static pressure = 0.433 psi per foot of pipe

PRESSURE LOSS

- A multi-story building has access to a city water main. Ignoring friction and flow pressure at outlets, how many floors will this system effectively serve if the top floor will require 100 psi?
  - Given:
    - 200 psi main
    - 15’ per floor
    - Ignore affects of pipe and fitting friction

$$Vertical\ Pressure\ Available = 200 - 100 = 100\ psi$$

$$Vertical\ Distance = \frac{100\ psi}{0.433\ psi/ft} = 230.95ft$$

$$Number\ of\ floors = \frac{230.95ft}{15ft/floor} = 15.40 \sim 15\ floors$$

1 psi lifts water approx. 2.3’

Static pressure = 0.433 psi per foot of pipe

WATER HEATING SYSTEMS

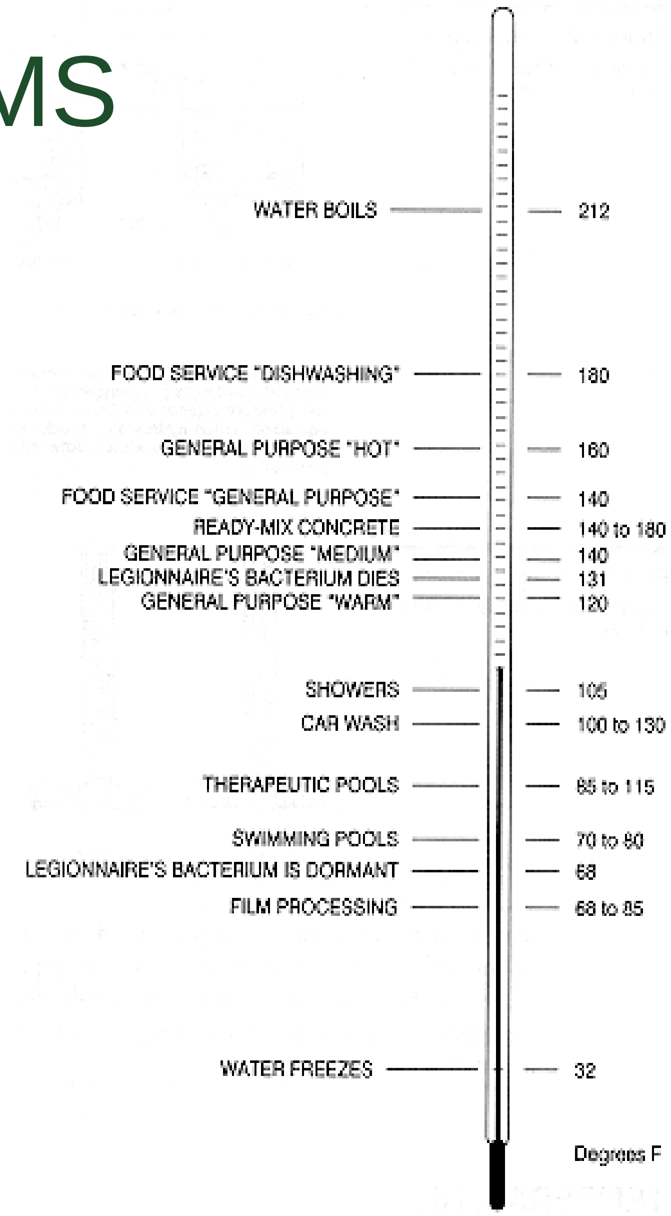
- Hot Water Burns People
- Hot water is corrosive as every 20°F increase in temperature doubles corrosive qualities
  - Due to the minerals found in water

Water Temperature	Minimum Time for 1st Degree Burns	Minimum Time for 2nd or 3rd Degree Burns
111.2 °F	5 hours	7 hours
116.6 °F	5 minutes	45 minutes
118.4 °F	10 minutes	14 minutes
122.0 °F	1 minute	5 minutes
131.0 °F	5 seconds	25 seconds
140.0 °F	2 seconds	5 seconds
149.0 °F	1 second	2 seconds
158.0 °F	Instantaneous	1 second

Water inside residential water heater can reach 150°F, pipes near boilers can be 200°F, uninsulated steam pipes 250°F or more

WATER HEATING SYSTEMS

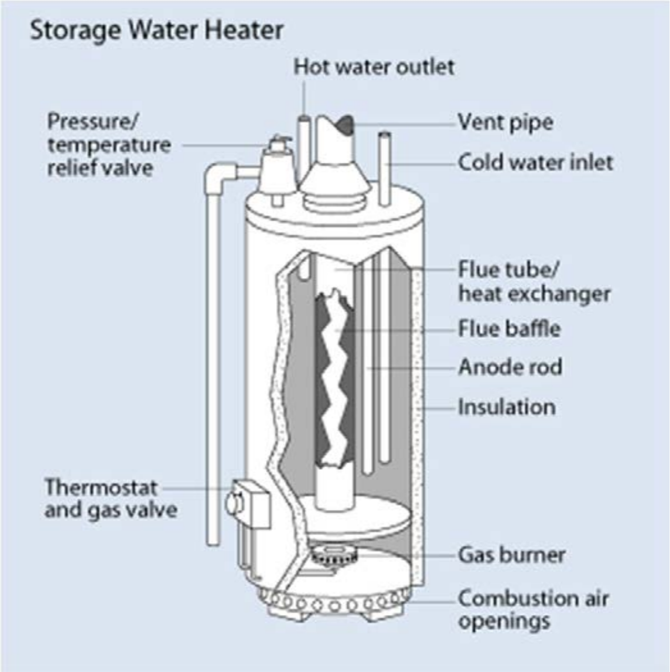
- Bacteria can breed (e.g., pneumonia)
  - Dormant at 68°F
  - Highest point of reproduction 110 – 120°F
  - Water heaters typically reach 130-140°F inside housing
- Recirculation
  - Hot water on demand
  - PFA Station #4 has this
  - So does NESB
- Recovery vs Storage
  - Tank storage (70% usable)
  - Tankless/Instant HW

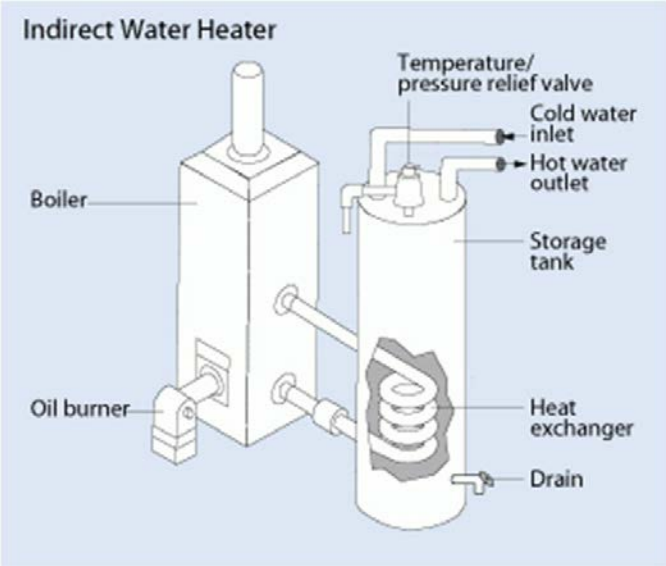


WATER HEATERS

- Classified by fuel sources
  - Natural gas
  - Propane
  - Fuel oil
  - Electric
  - Steam (E.g., NESB)
  - Solar

U.S. Dept of Energy Reading:
Tankless and Indirect Water Heaters



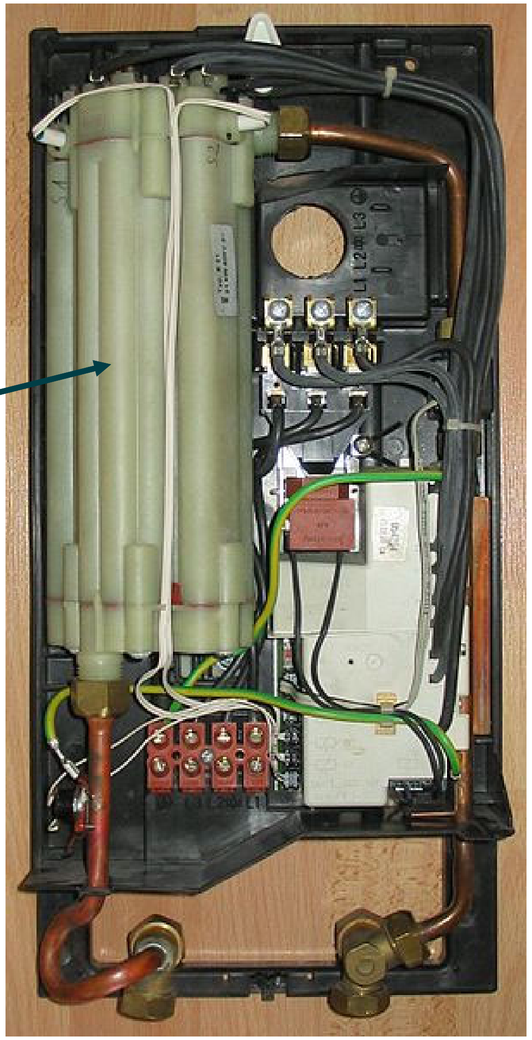


Public Domain Photos courtesy of U.S. Department of Energy

TANKLESS WATER HEATERS

Natural Gas Tankless WH

400V 3-phase Electric Tankless WH



REASONS TO USE TANKLESS WH

- Provides hot water on demand

Reduced Energy Costs

- Hot water always available

Endless Supply of Hot Water

- Tank water heater = 12-15 yrs
- Tankless water heater = 20+ yrs

Longer Lifespan

- Tank water heater: 60” tall x 24” round
- Tankless water heater: 20”x28”x10”

Space Saver

ISOMETRICS

CON 371 Mechanical and Plumbing Systems

LEARNING OUTCOMES

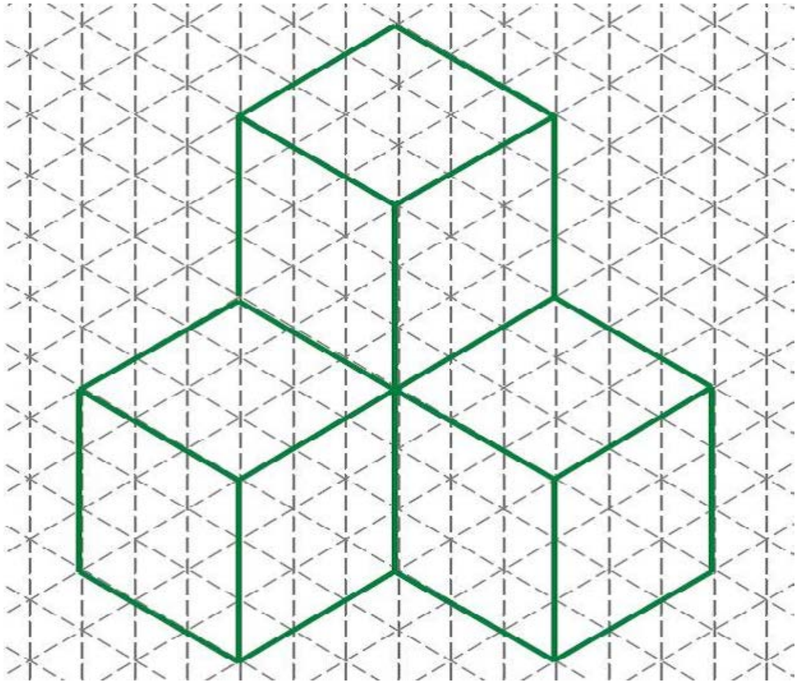
- By the end of this lesson, students will be able to:
  - Define Isometrics and understand Isometric Drawings for Piping Systems
  - Determine and understand the proper layout and symbols used for isometric drawings
  - Draw and build isometric drawings from examples

ISOMETRICS

- An isometric drawing shows three dimensions of an object in one view
- Isometrics are an easy method of drawing 3D images
  - All vertical lines are drawn vertically
  - All horizontal lines are drawn at 30°
- Isometric views place all horizontal lines at 30° angles relative to the horizon
- Vertical lines are always perpendicular to the horizon
- Lines are to scale and remain in proportion to one another

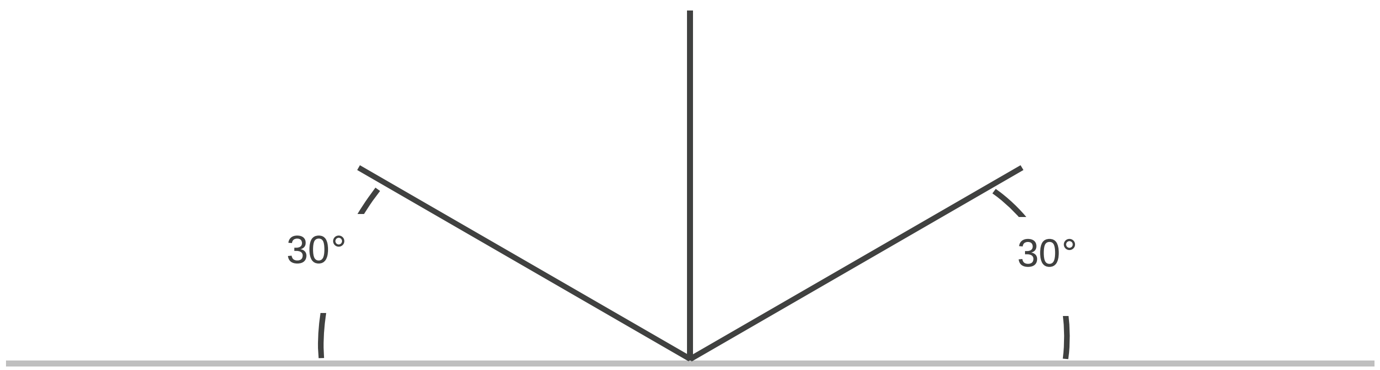
ISOMETRICS

- Used with process piping systems (HVAC, Plumbing, Industrial)
- Can lay out the piping system in a more realistic view
- Sometimes used in lieu of plans and elevations
  - Typically isometrics are used to supplement the plan drawings and specifications
- Used as fabrication and shop drawings for pipe run fabrications
- Provides designers with the ability to calculate angular offsets in the pipe run



ISOMETRICS – LAYOUT

Isometric lines: One vertical and two at 30° from the horizon



- Isometric lines can be measured

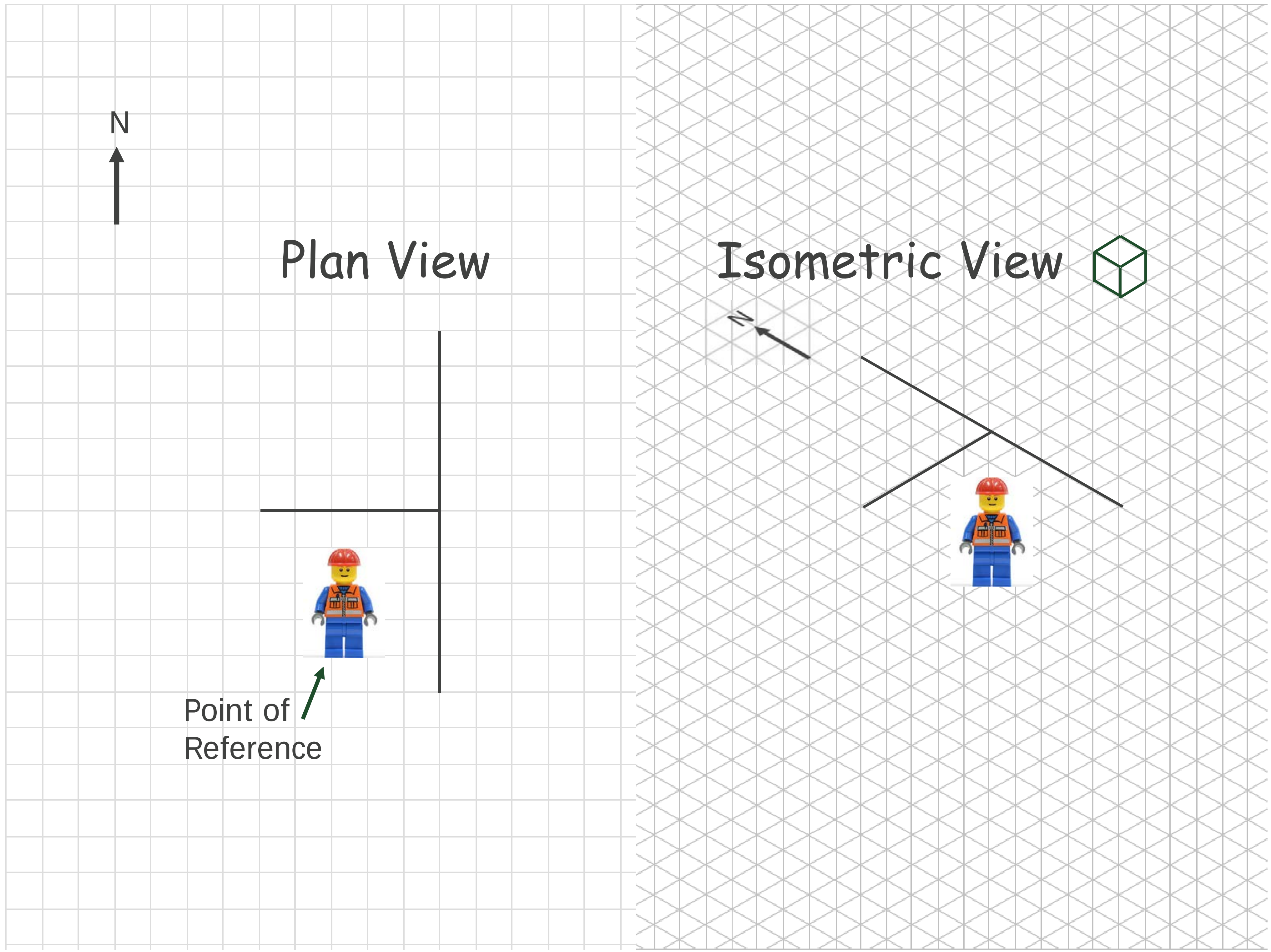
- Non-isometric lines: Lines that are not parallel to the isometric lines and these lines cannot be measured

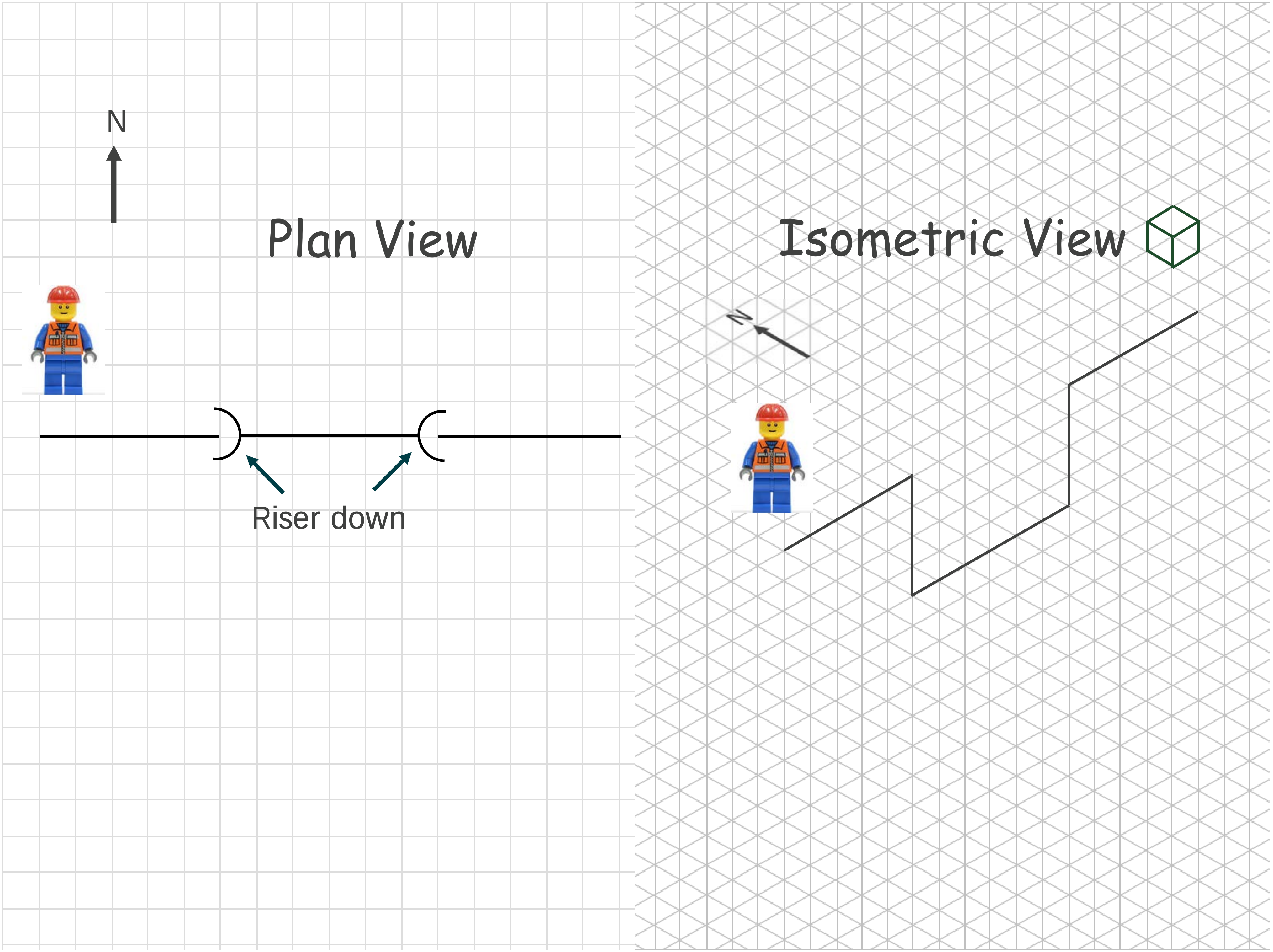
ISOMETRICS – LAYOUT

- It is common to have isometric drawings included with plan set, but not drawn to scale
  - However, pipe lengths should be proportional to the actual dimensions
- Companies sometimes use 11x17 paper, which limits space and proportions may be sacrificed
  - Make sure to check the written dimensions for accuracy

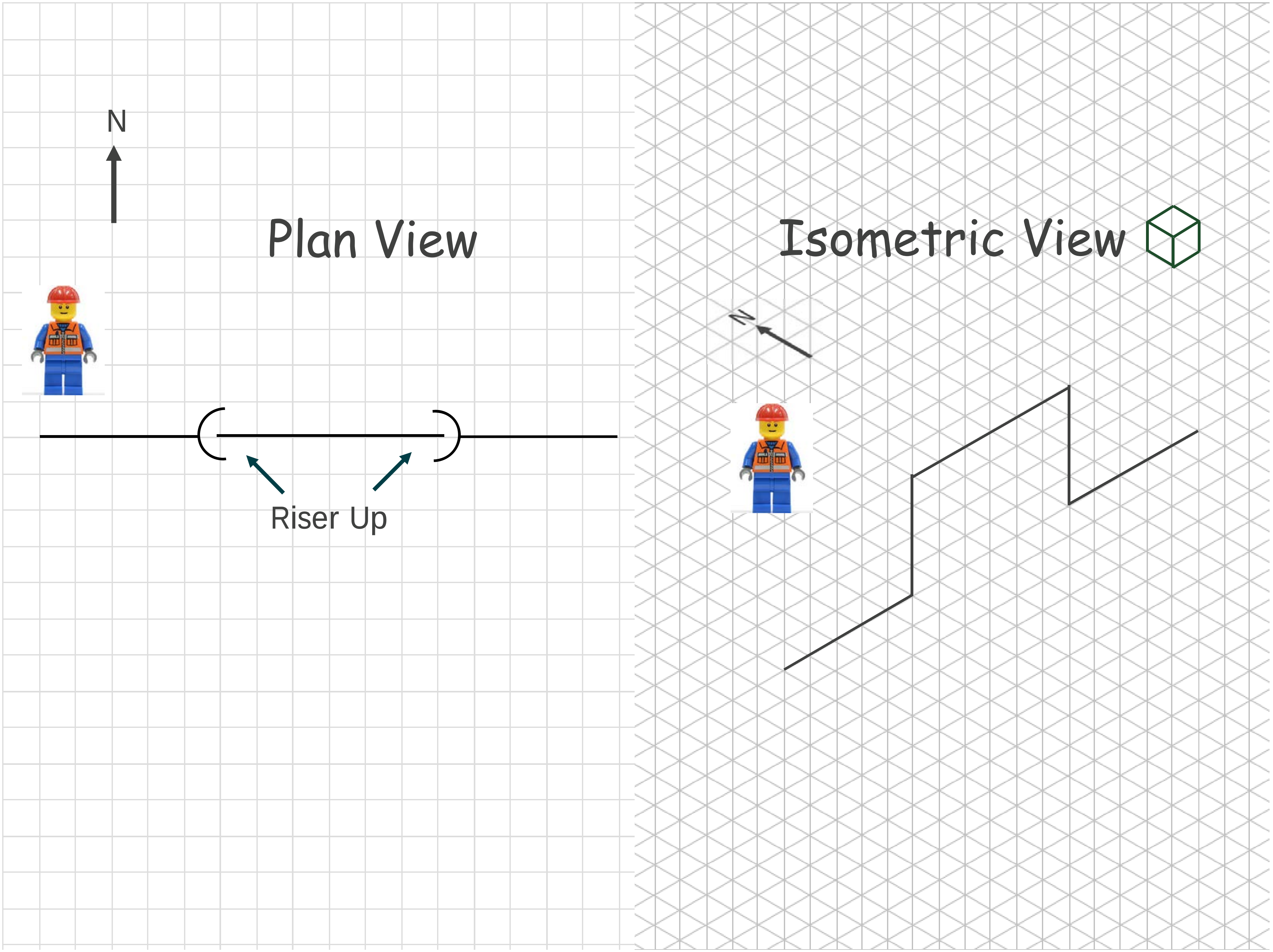
ISOMETRICS – LAYOUT

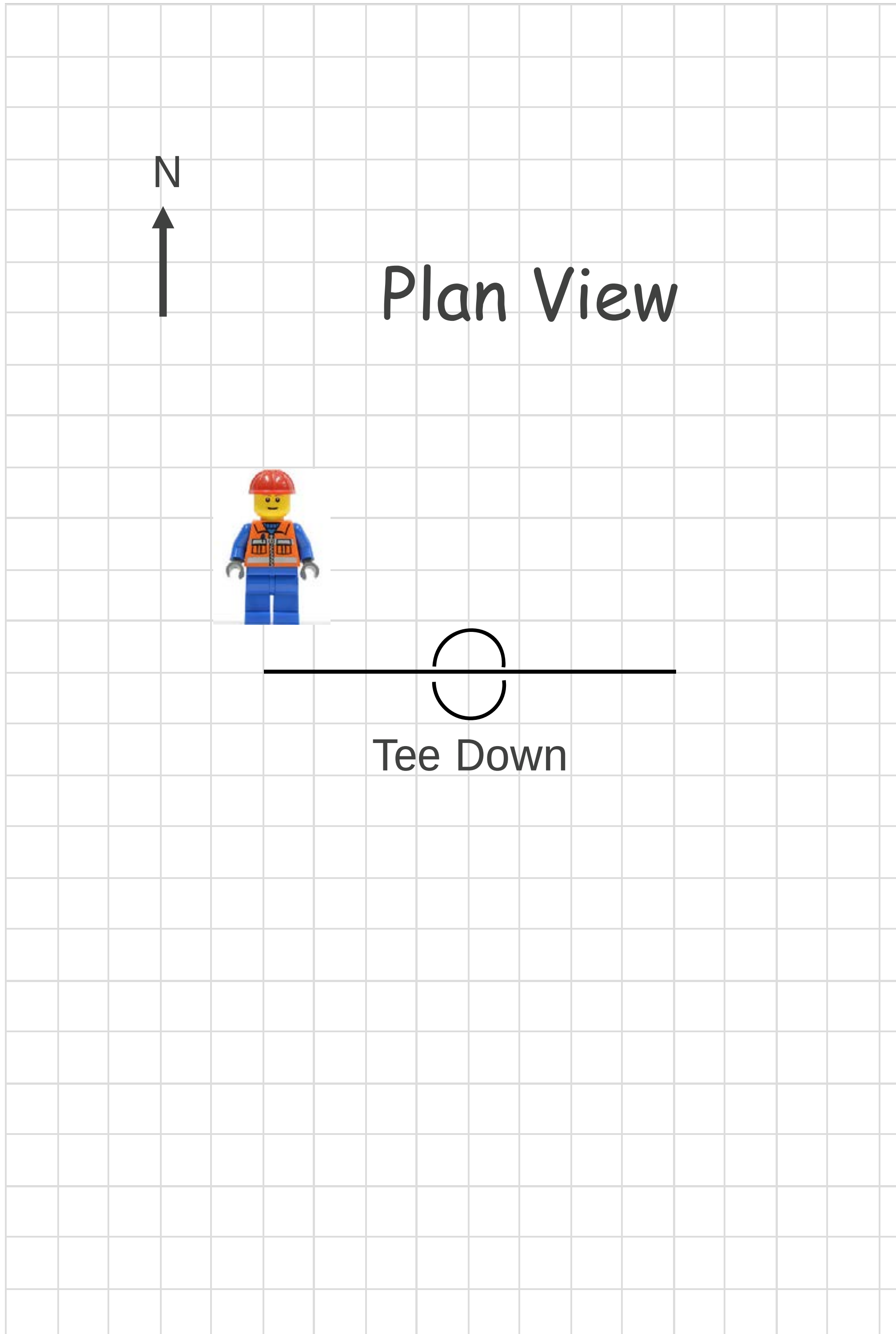
- Location and direction are needed to properly orient the isometric drawing
  - Show north arrow pointing to the upper-right corner of the isometric paper
  - Structural reference points can be shown on isometrics
  - Dimensions should always be shown with points of reference (structures, equipment, etc.)
  - Coordinates are shown for reference

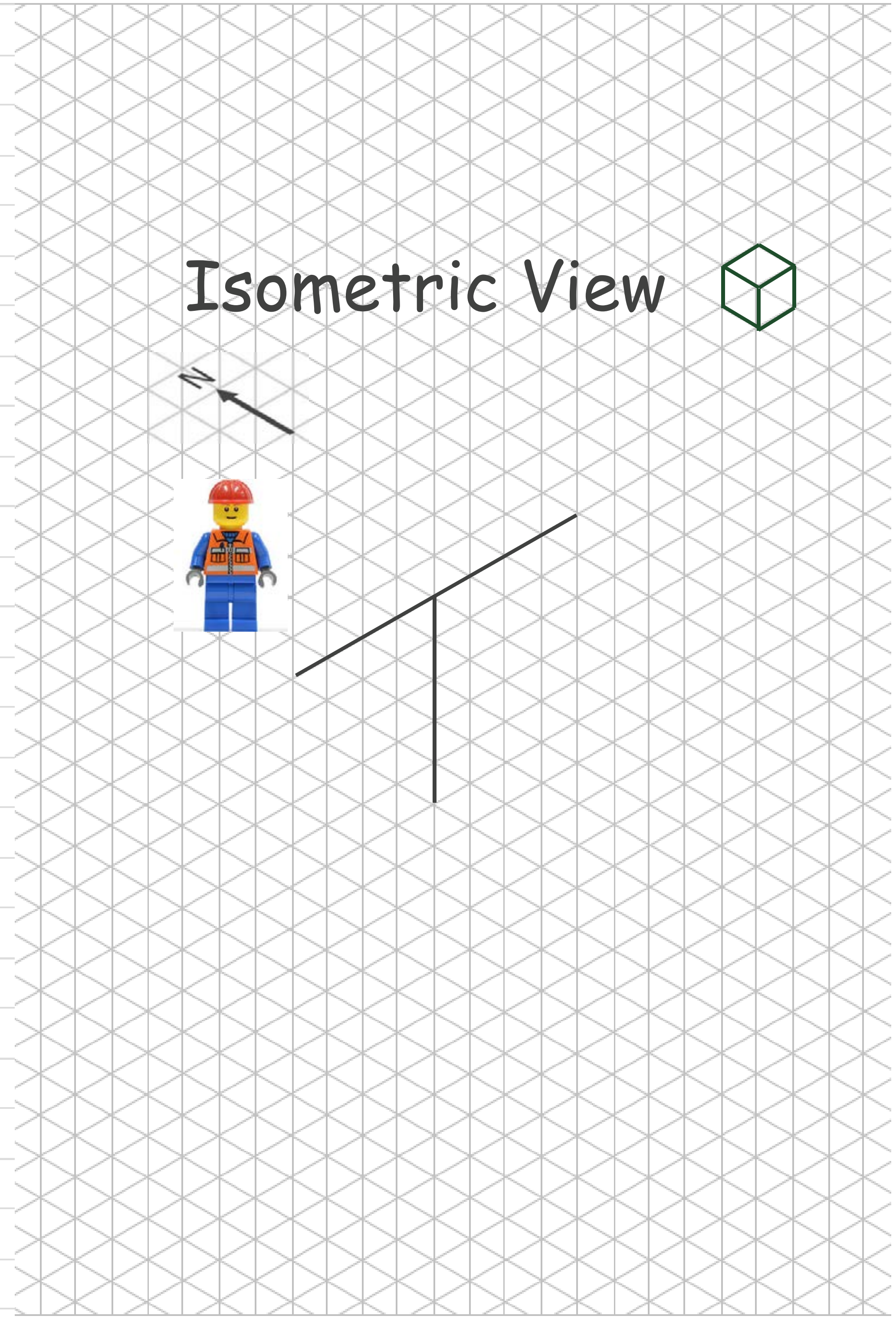

N
Plan View
Point of Reference
Isometric View
N

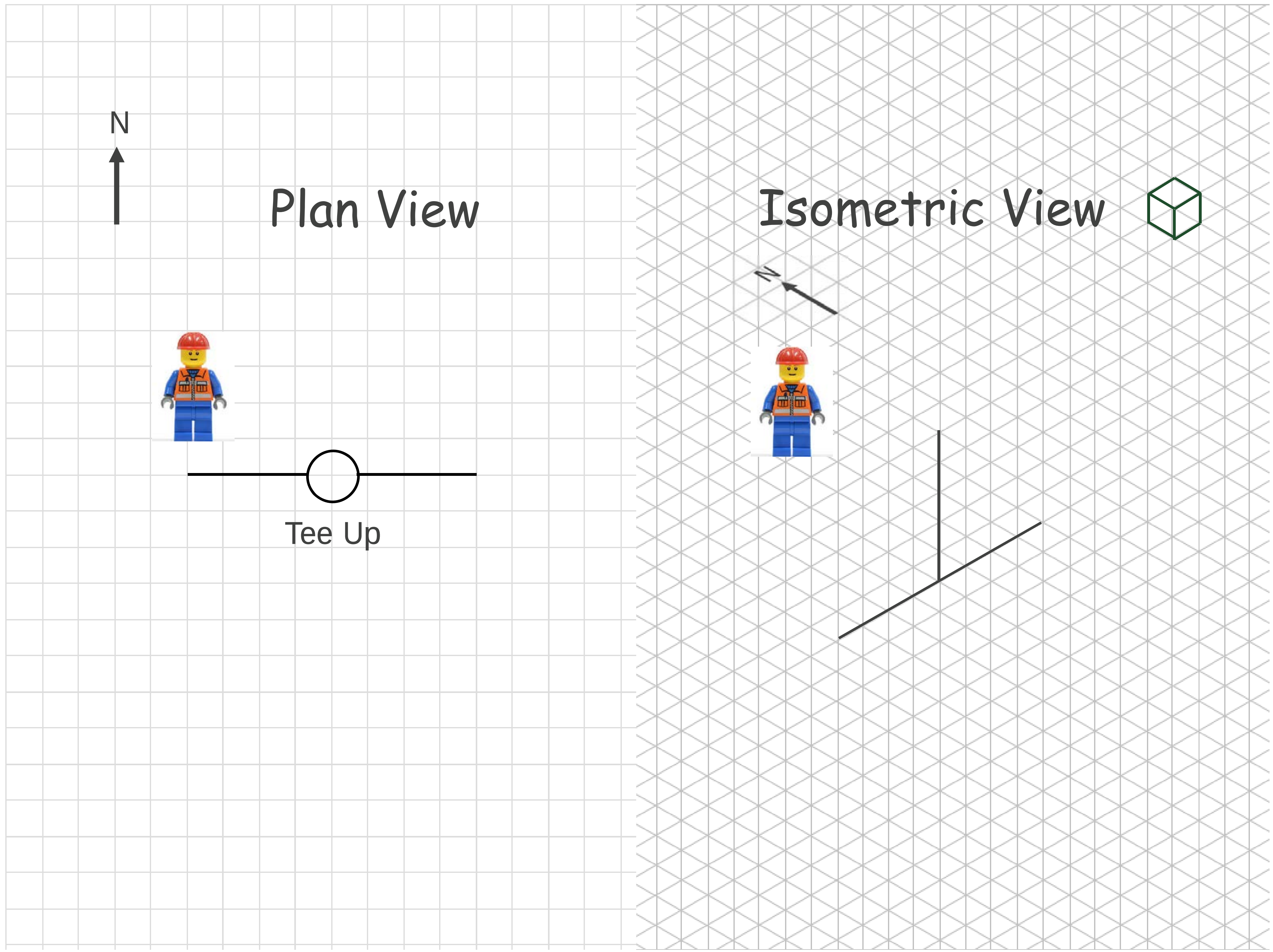


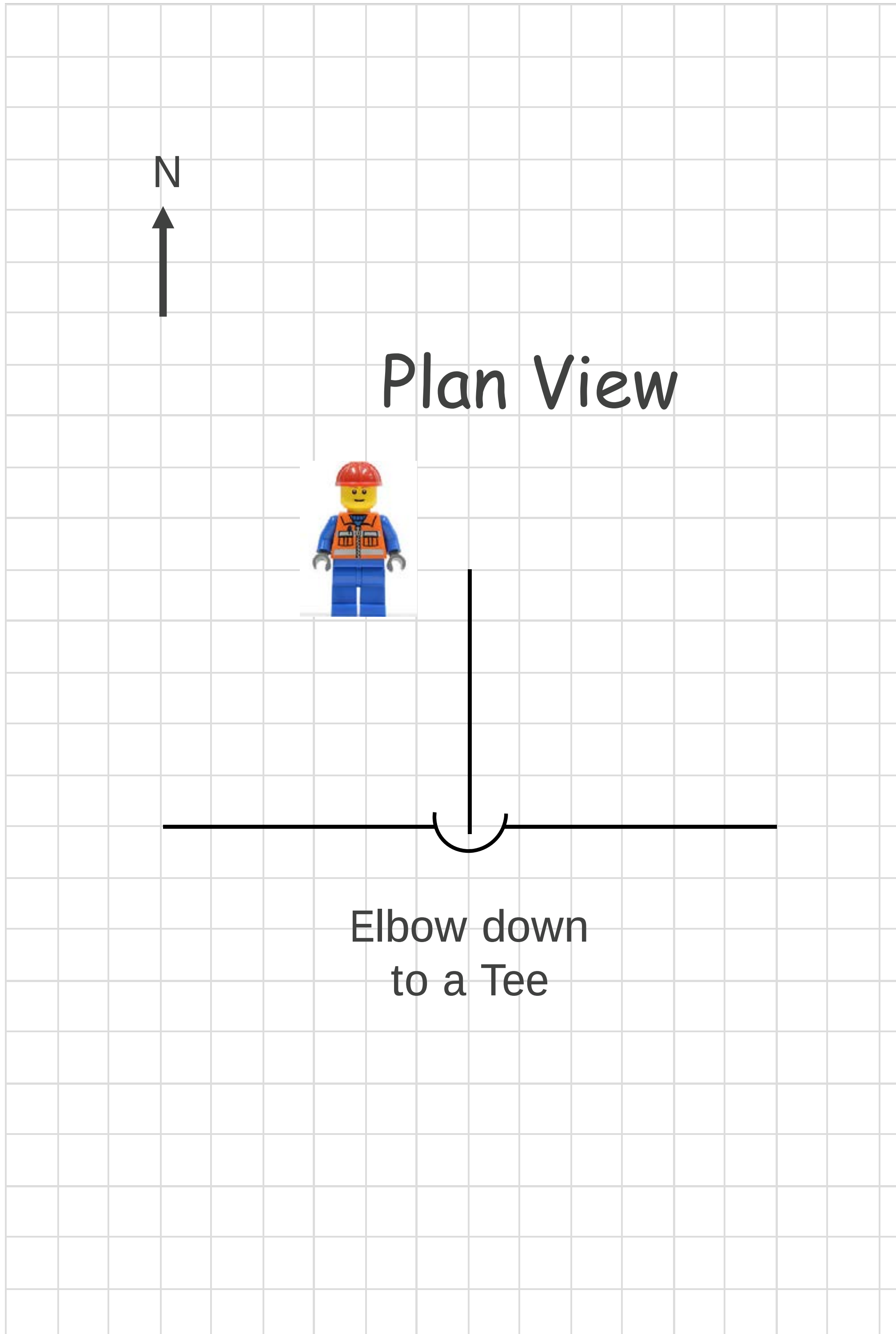
N
Plan View
Riser down
Isometric View
N

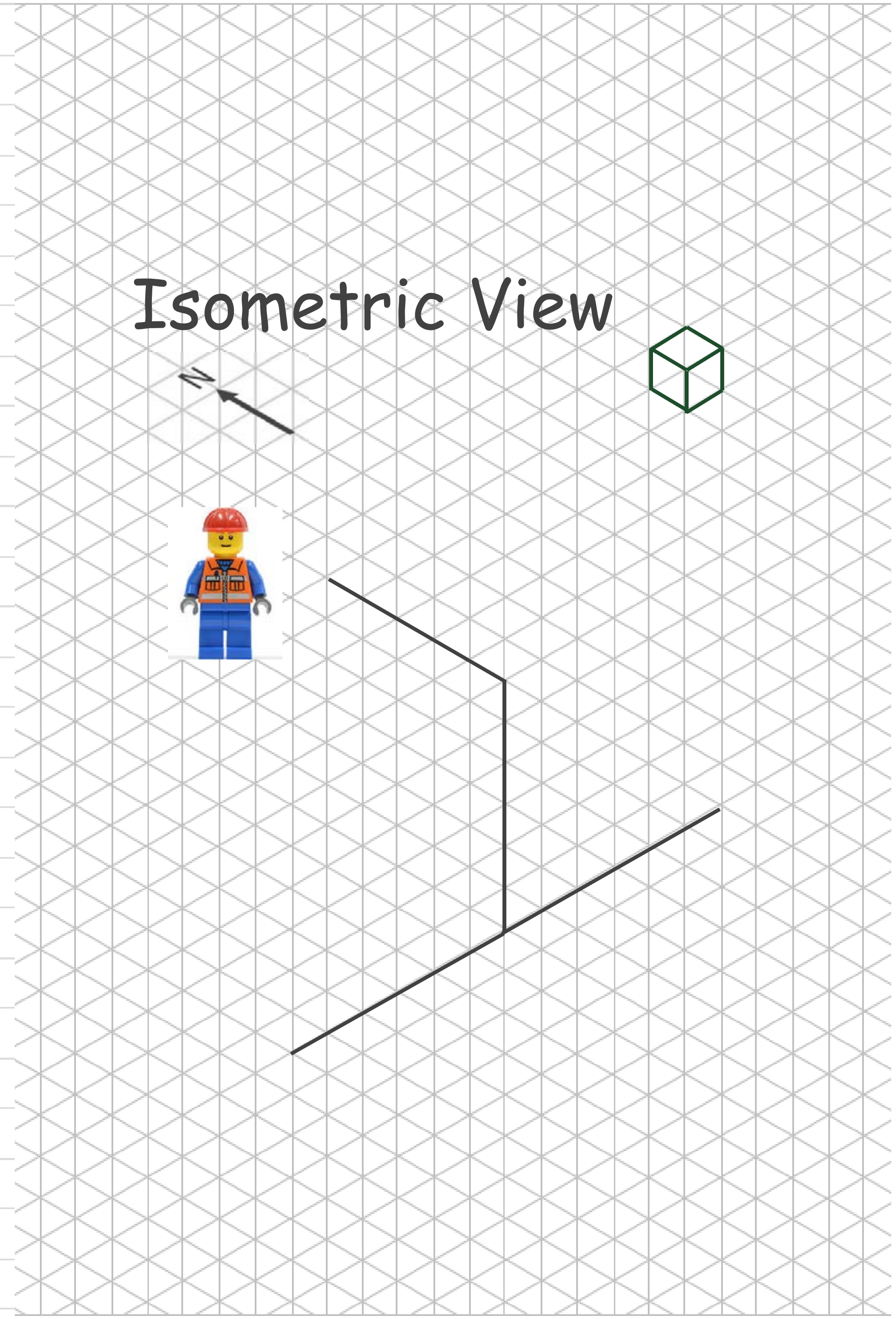

N
Plan View
Riser Up
Isometric View
N

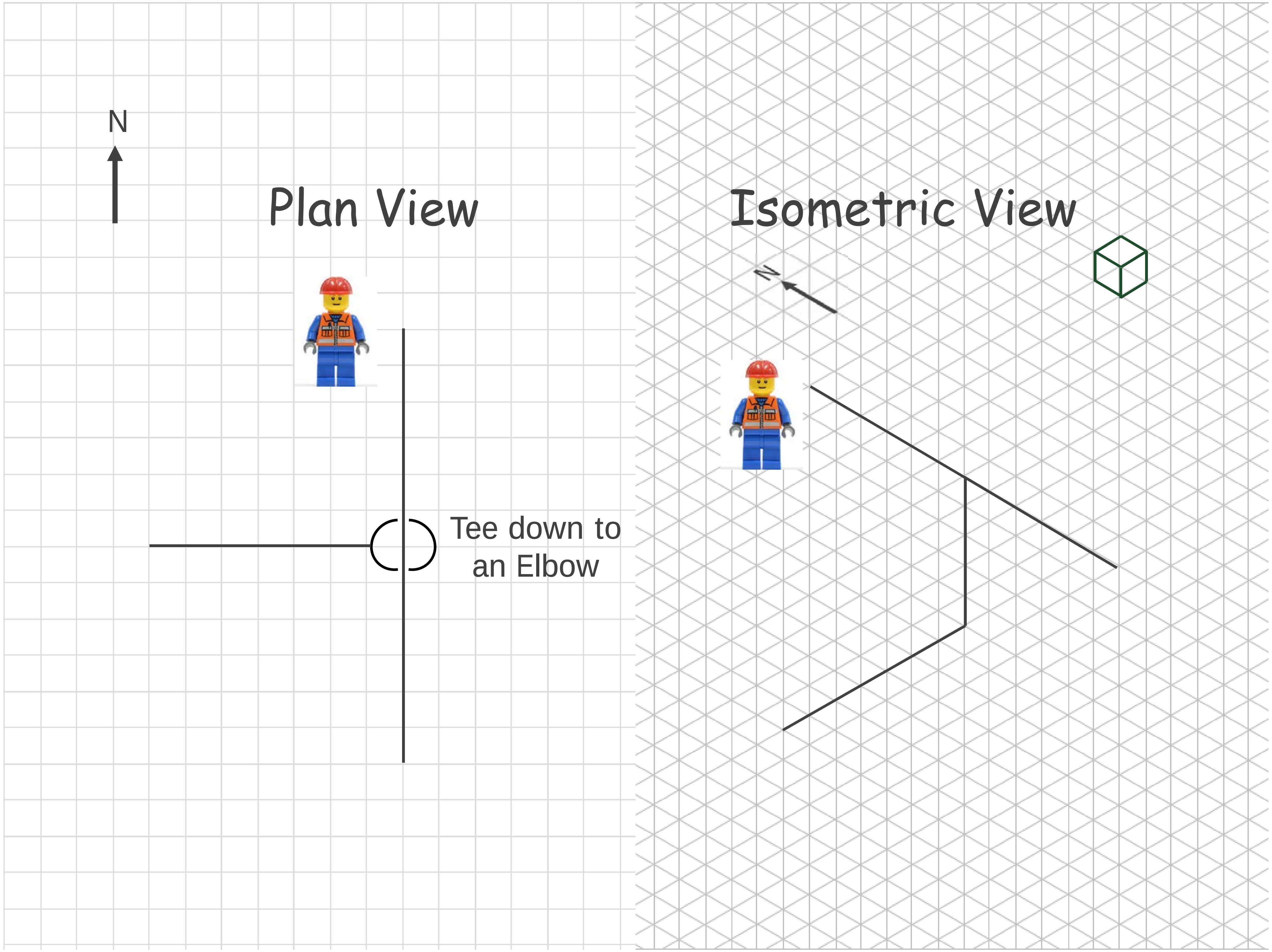

N
Plan View
Tee Down

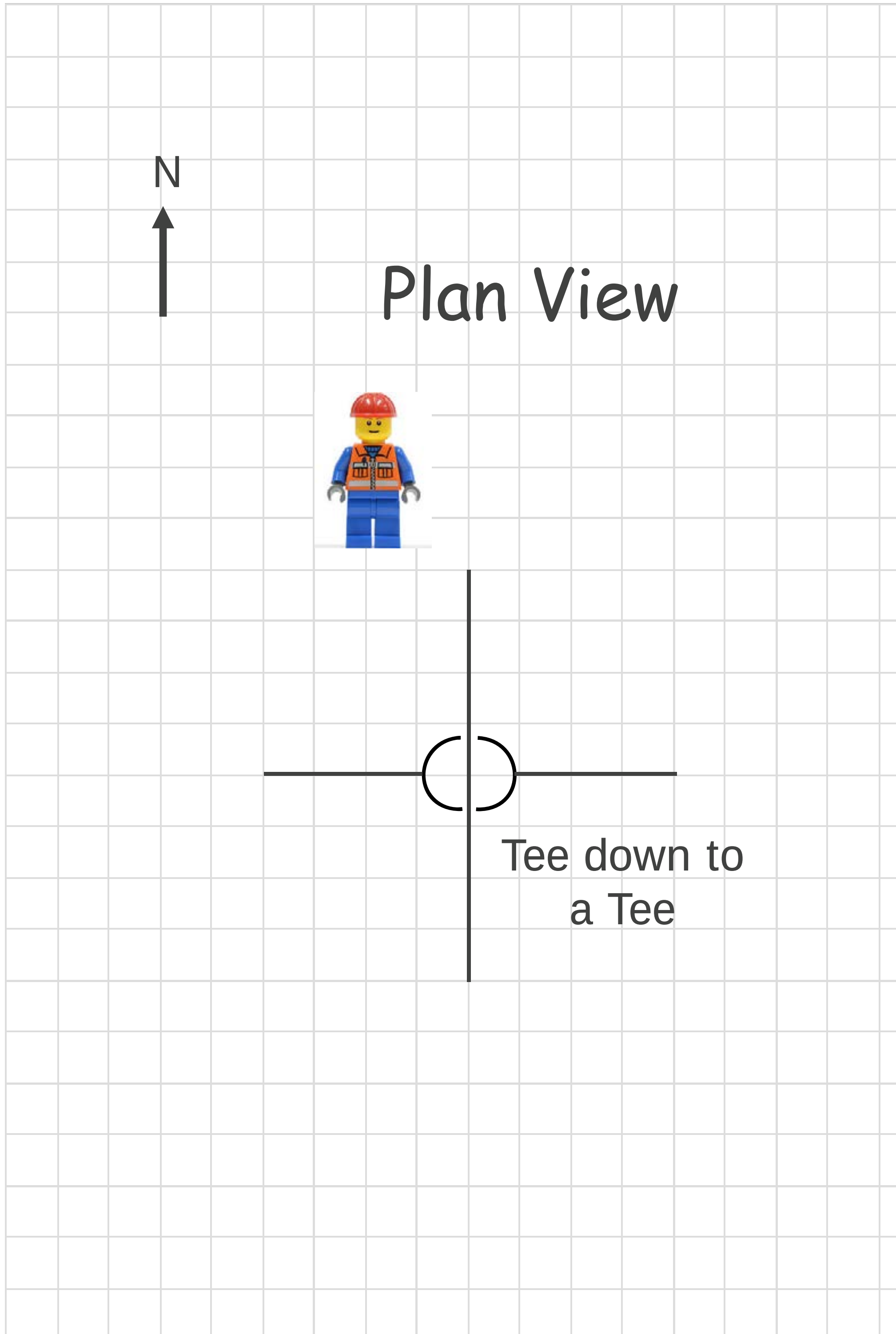

Isometric View
N

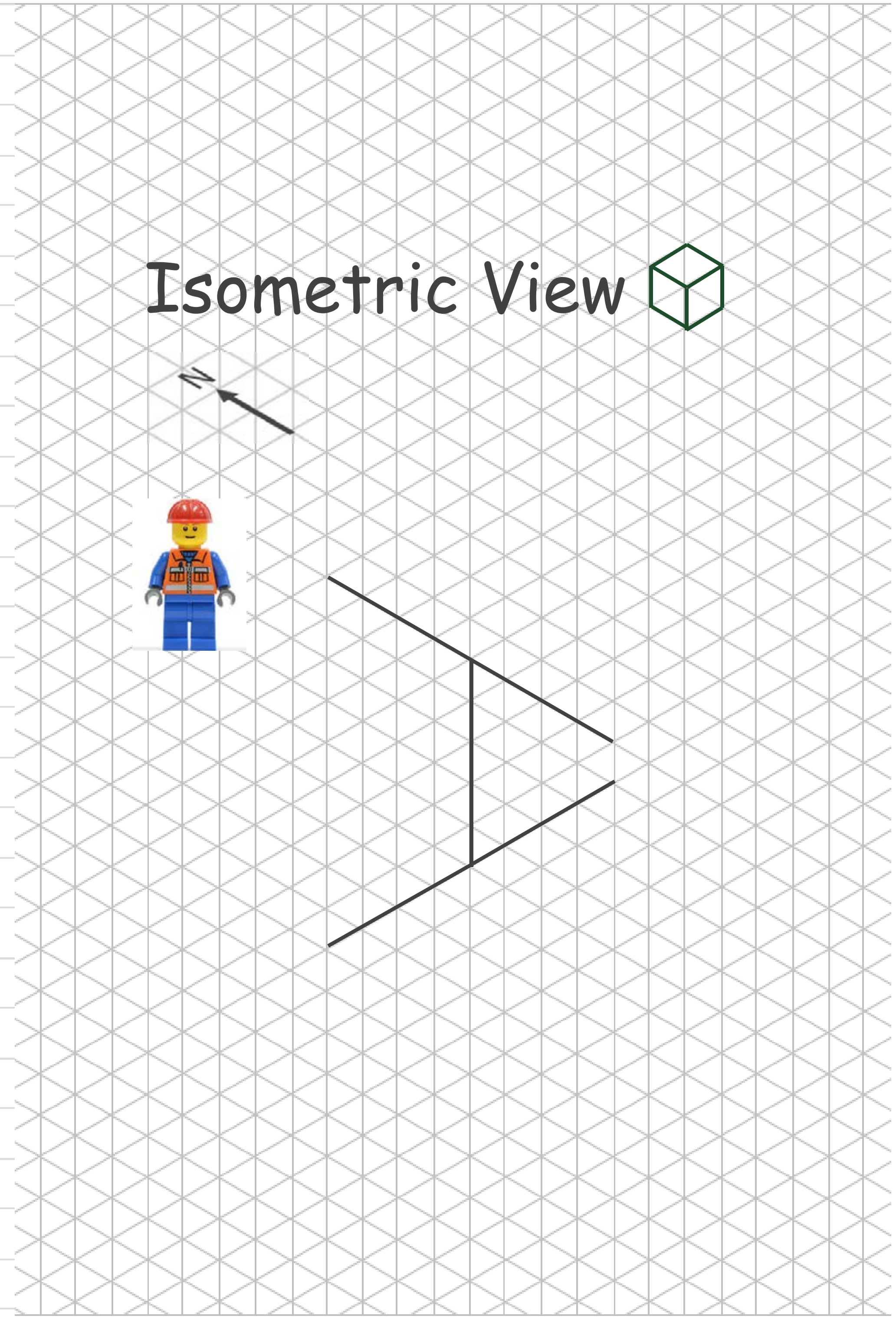

N
Plan View
Tee Up
Isometric View
N


N
Plan View
Elbow down
to a Tee

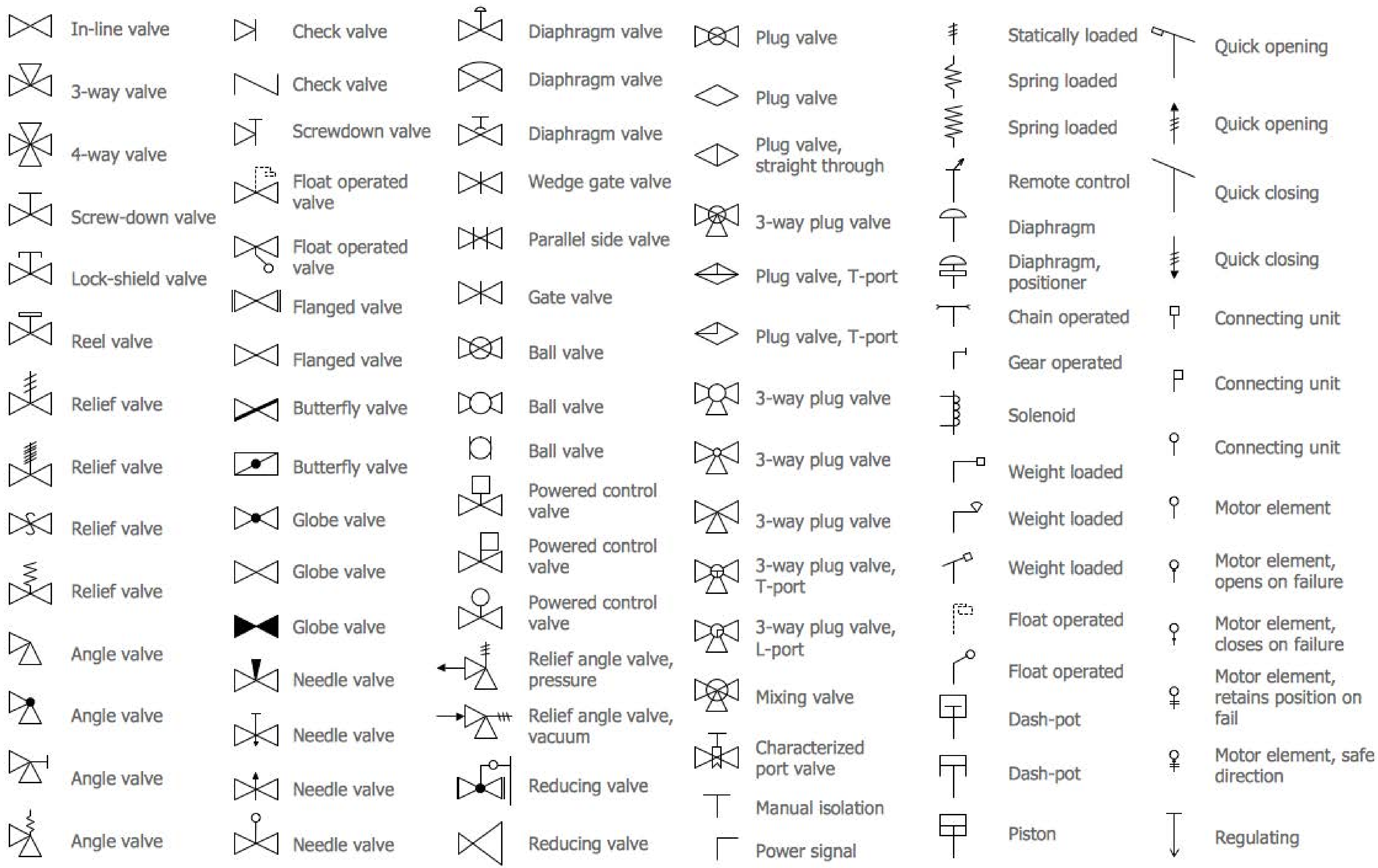

Isometric View
N


N
Plan View
Tee down to
an Elbow
Isometric View
N

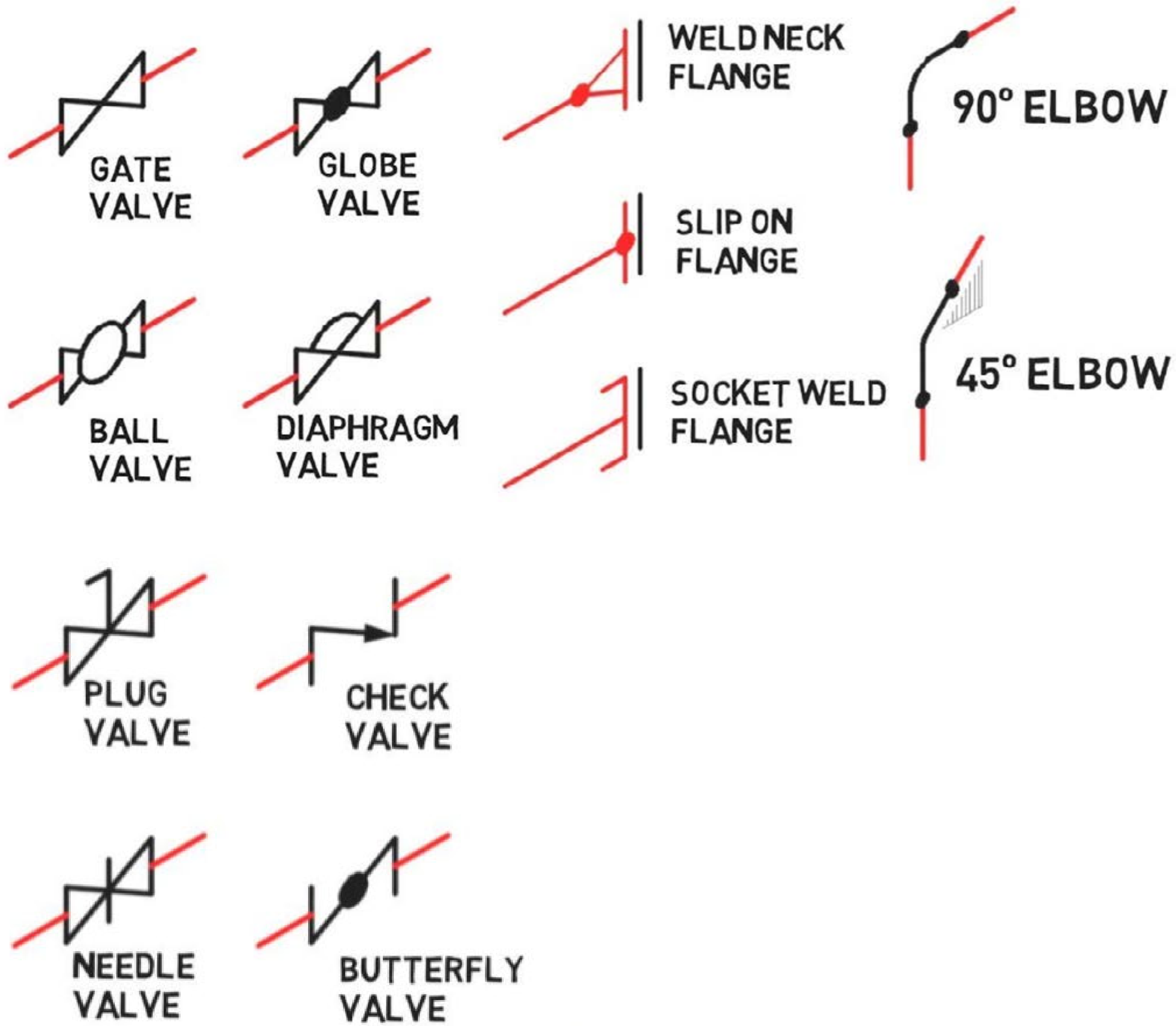

N
Plan View
Tee down to
a Tee


Isometric View
N

SYMBOLS

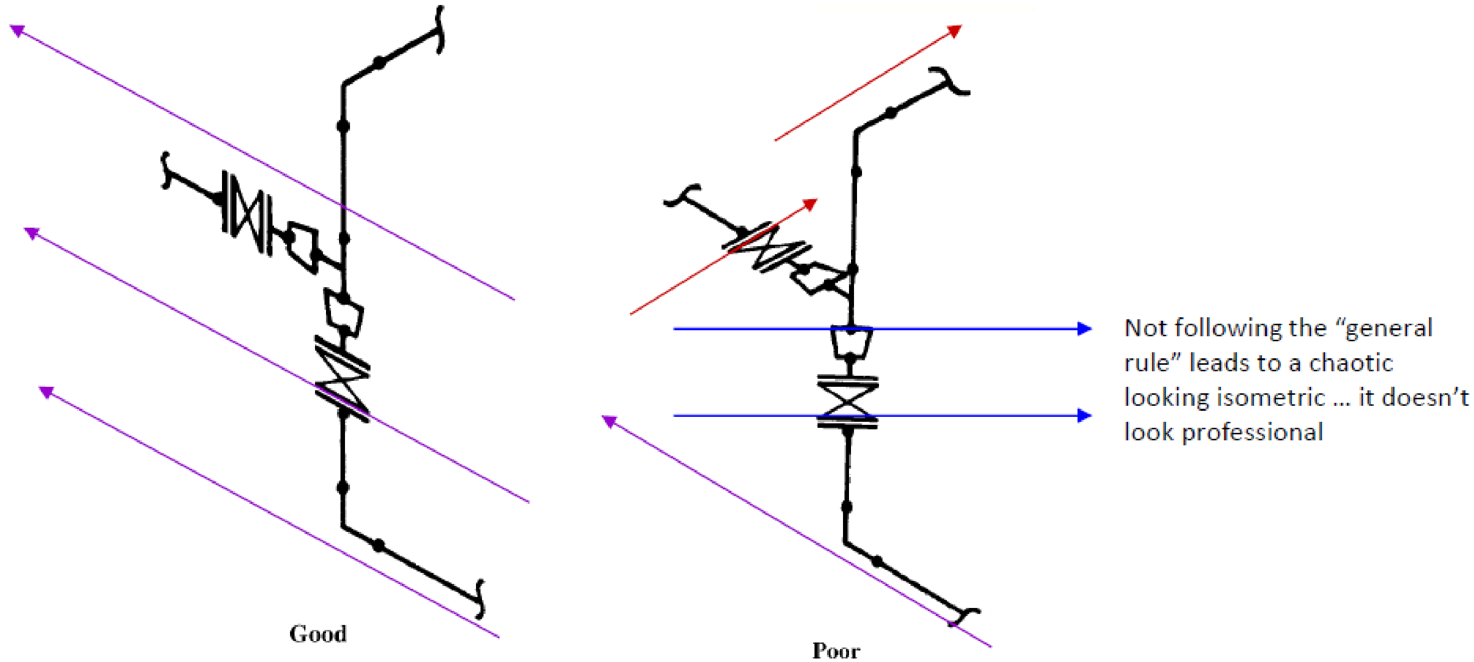

In-line valve
3-way valve
4-way valve
Screw-down valve
Lock-shield valve
Reel valve
Relief valve
Relief valve
Relief valve
Relief valve
Angle valve
Angle valve
Angle valve
Angle valve
Check valve
Check valve
Screwdown valve
Float operated valve
Float operated valve
Flanged valve
Flanged valve
Butterfly valve
Butterfly valve
Globe valve
Globe valve
Globe valve
Needle valve
Needle valve
Needle valve
Needle valve
Diaphragm valve
Diaphragm valve
Diaphragm valve
Wedge gate valve
Parallel side valve
Gate valve
Ball valve
Ball valve
Ball valve
Powered control valve
Powered control valve
Powered control valve
Relief angle valve, pressure
Relief angle valve, vacuum
Reducing valve
Reducing valve
Plug valve
Plug valve
Plug valve, straight through
3-way plug valve
Plug valve, T-port
Plug valve, T-port
3-way plug valve
3-way plug valve
3-way plug valve
3-way plug valve, T-port
3-way plug valve, L-port
Mixing valve
Characterized port valve
Manual isolation
Power signal
Statically loaded
Spring loaded
Spring loaded
Remote control
Diaphragm
Diaphragm, positioner
Chain operated
Gear operated
Solenoid
Weight loaded
Weight loaded
Weight loaded
Float operated
Float operated
Dash-pot
Dash-pot
Piston
Quick opening
Quick opening
Quick closing
Quick closing
Connecting unit
Connecting unit
Connecting unit
Motor element
Motor element, opens on failure
Motor element, closes on failure
Motor element, retains position on fail
Motor element, safe direction
Regulating

SYMBOLS AND ISOMETRIC ORIENTATION

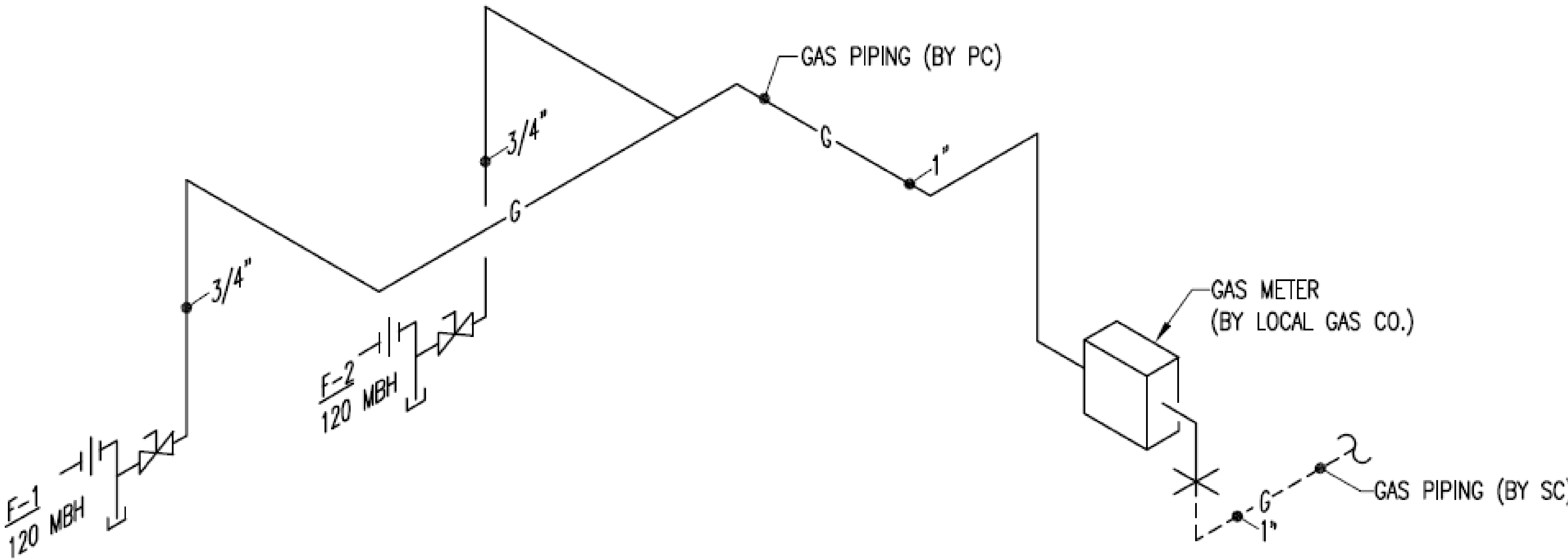


SYMBOLS AND ISOMETRIC ORIENTATION

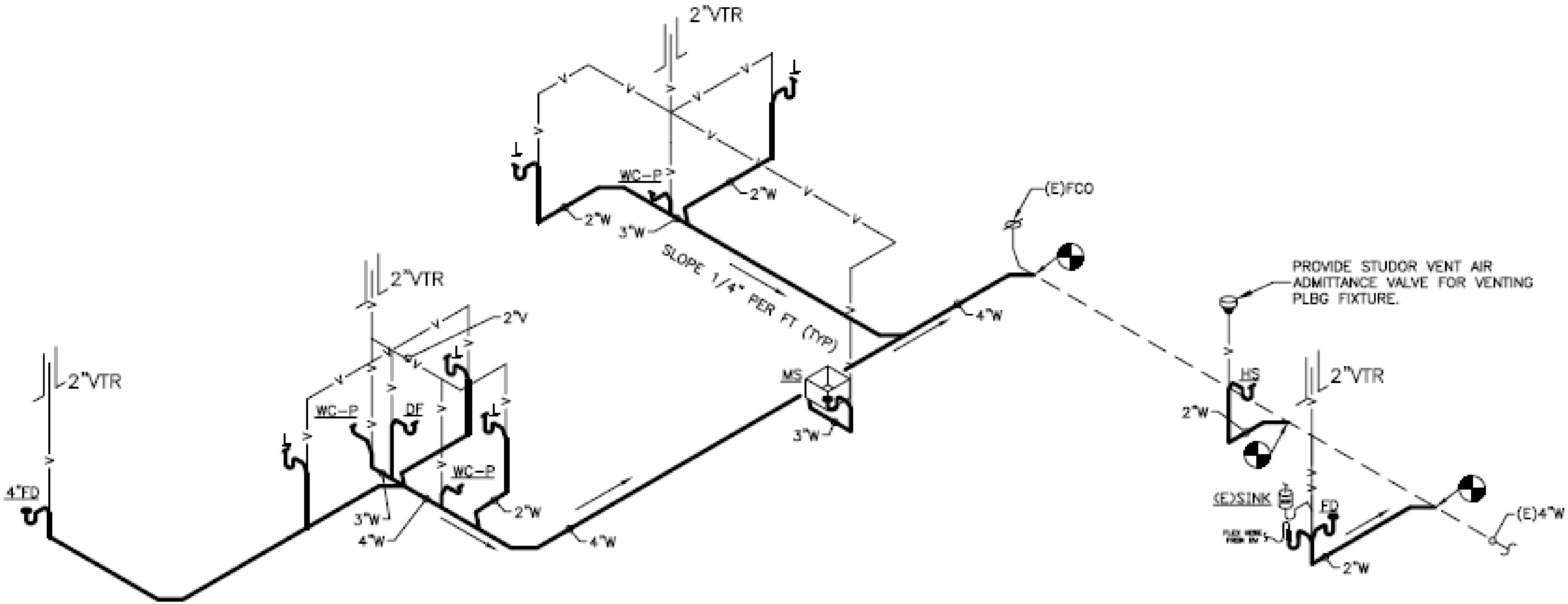
- Important to know that there are good methods and poor methods for orienting fitting and valves
- General rule: Draw fitting/valve so they are parallel to the last direction change or branch in the pipe



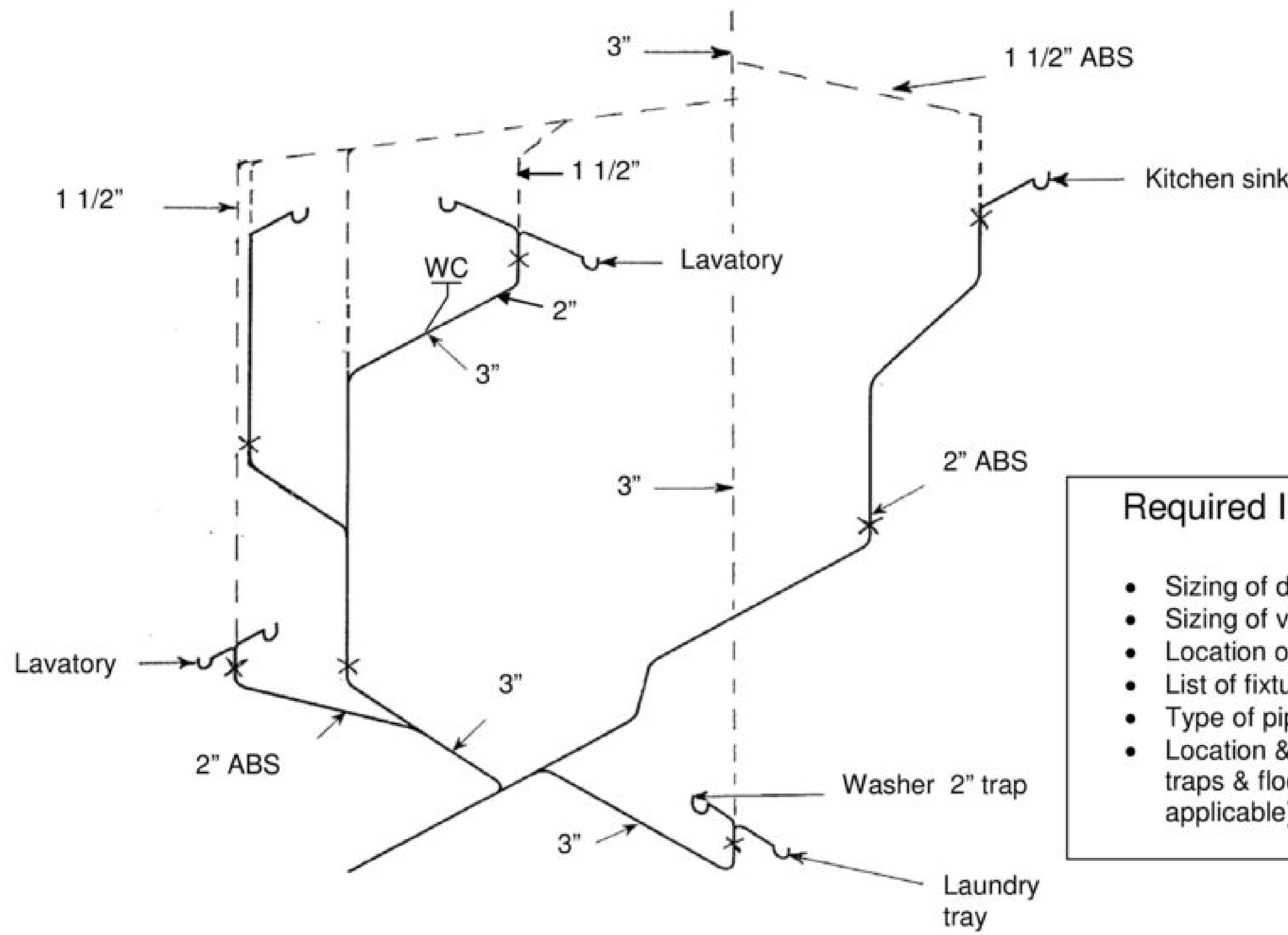
GAS PIPING ISOMETRIC



WASTE & VENT ISOMETRIC



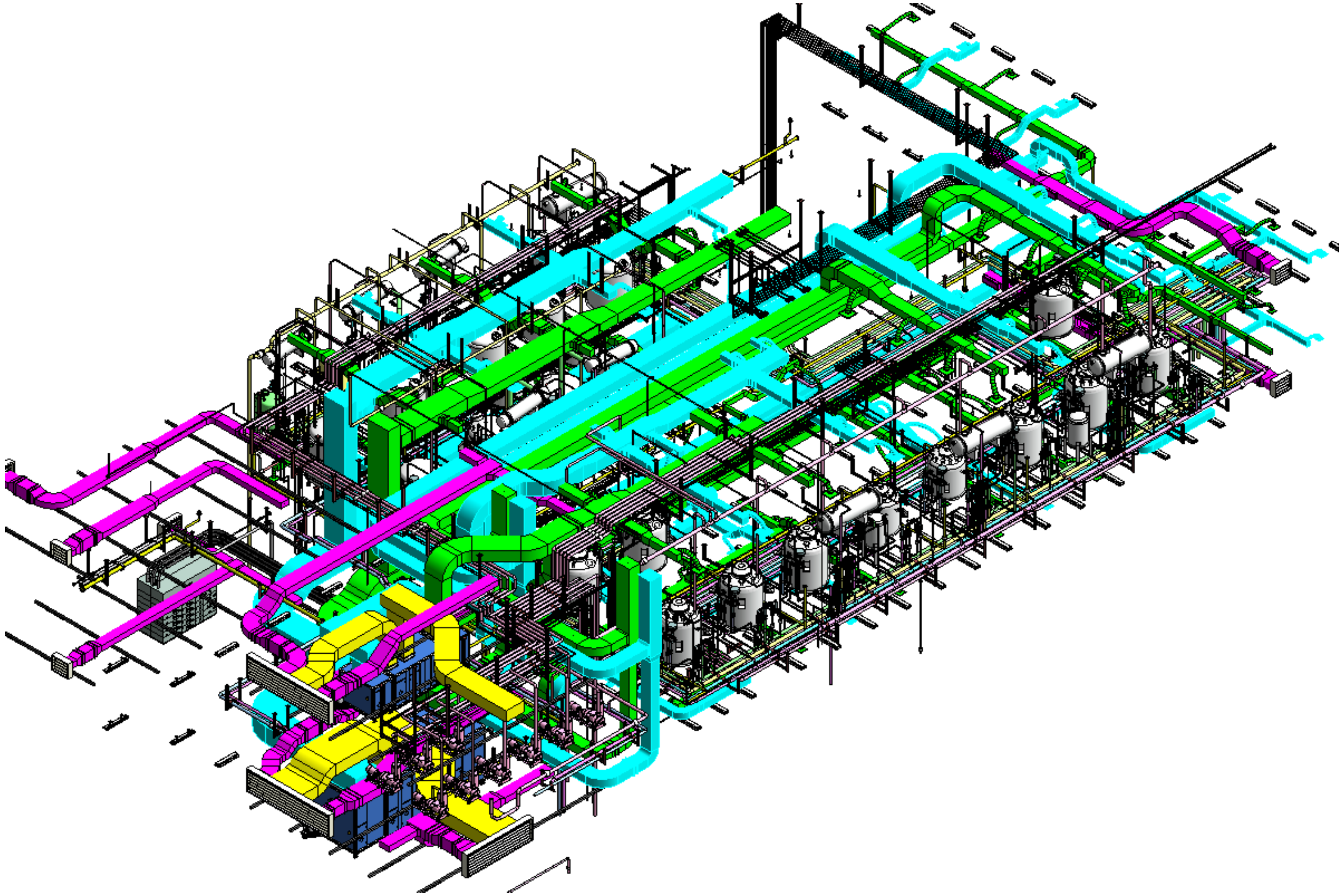
DRAINAGE ISOMETRIC



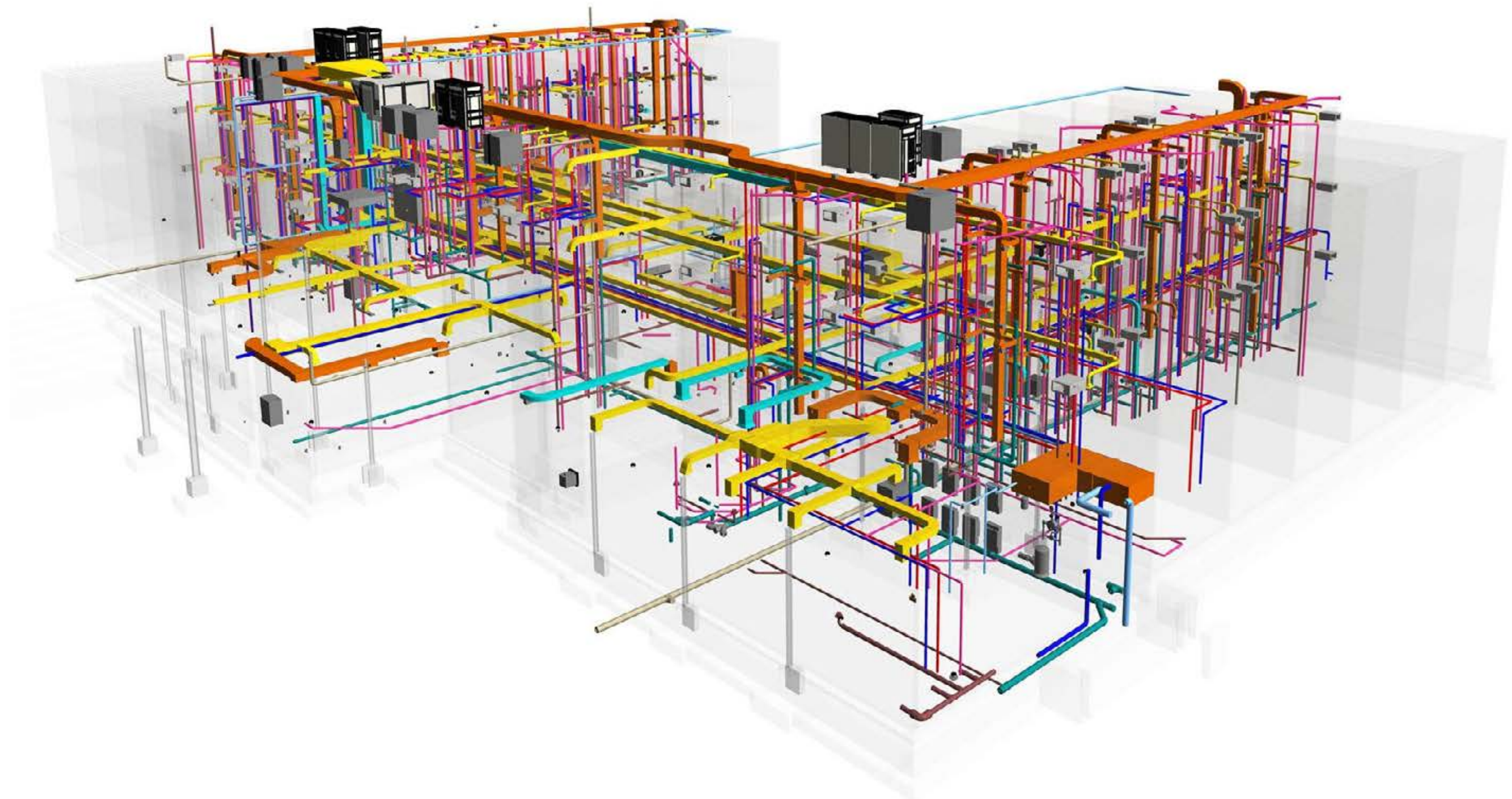
Required Information

- Sizing of drains
- Sizing of vents
- Location of cleanouts – X
- List of fixtures
- Type of piping
- Location & size of grease traps & floor drains (where applicable)

ISOMETRIC 3D MODELING



ISOMETRIC 3D MODELING



HEAVY CIVIL SYSTEMS

CON 371 – Mechanical and Plumbing Systems

LEARNING OUTCOMES

- By the end of this lesson, students will be able to:
  - Understand the Scope and Limitations of 811 and Unknown Utilities
  - Understand the drawings and information provided in site utility plans for construction projects
  - Recognize the various symbols used on the drawings
  - Know how to use the plans to determine the details of Civil sitework projects
  - Understand the broad scope of plumbing/piping for infrastructure systems

CALL UTILITY NOTIFICATION OF COLORADO 811

- Know what's below, CALL before you DIG.
- Call two business days in advance before you dig, grade, or excavate for the marking of underground member utilities
  - Member utilities does not mean "ALL UTILITIES"
- You are responsible for all utilities present that are not marked
- If a utility is not a "member" of the 811 group, how do you know there is a utility present?

HUNTING FOR UTILITIES

- Looking for unknown utilities is a game.
  - Ask more experienced workers in your, and other, companies that are familiar with the area.
  - Go to the local utilities and ask about abandon utility lines in the area (they may be live).
  - Ask local utilities for old maps of the area, not all information may be digitized
  - Always document who, what, when and where as you go through the due diligence process of looking for unmarked utilities.

LOCATE ONCE

- The 811 utility locater is typically a contractor that comes to your site with maps of the member utility locations. They may be from out of State and know little history of construction and utility infrastructure in the area.
- Their job is to mark the Utilities of the “Member” companies.
- **Green** = Sewer & Drain Lines; **Blue** = Water; Yellow = Natural Gas, Oil, Steam, Petroleum, other flammable material; Red = Electrical; Orange = Communication
- The locator tells you there is a distance on either side of the locate mark that you need to hand dig in.
- They typically paint colors, leave small location flags and provide a site map.
- Your job is to determine risks associated with hitting a utility.

CHECK TWICE

- What is the risk of hitting a utility, known or unknown?
  - What does the contract state?
  - Owner responsible for all utilities not located by 811.
  - Your company responsible for all utilities, known or unknown.
- When do you pothole? https://www.youtube.com/watch?v=qye7FIxzRis
  - This depends on your comfort level of understanding the area.
    - Is the area newly developed? →High probability the locations will be accurate.
    - Is the area an older downtown site → High probability that no one has accurate maps.
    - Contract requires you to verify the existing utilities prior to work.

POTHOLE TRUCK

Line Visual with minimal Impact

DEWATERING NEEDED

After placing a ½ mile of 2” UG water line to a rural home, the last 400’ needs to be directional bored under an irrigation ditch. This is the pit where the boring machine will set up to bore.

DEWATERING COMPLETE

With dewatering complete and gravel installed in the bottom of the pit, the boring can start.

DIRECTIONAL BORING

The boring rig needs water to lubricate the bore pipe. Sometimes the water can come from a fire hydrant but you need a special permit and meter to pay for the water. In remote locations it comes from trucks like this.

This small rig will bore a 400’ length to the house and pull a 4” sleeve from the house back to the pit.

It will then pull a 2” water line through the sleeve back to the house.

Note the small diameter of the pipe in the storage area of the machine

DIRECTIONAL BORE EMERGES

The bore head emerges by the house. Note the bore pipe diameter is only 4”. The bore head is guided by a signal box operated by a crew member. This box reads the depth of the head and what line it is tracking. The operator can then signal the bore head to change direction, right, left, up down, etc.

Bore head and pipe

READY TO PULL THE 4” SLEEVE

A pulling head is placed on the pipe. Once the boring is complete the guiding head is not needed.

4” sleeve

Pulling head

DIFFERENT PLUMBING PROJECT TYPES

- Natural Gas and Oil are heavy users of process piping and underground (UG) piping for transport.
- Subdivisions add to the infrastructure needs of a community and require tying into existing or new lines.
  – Many developers put in the subdivision development infrastructure and sell off lots. Others do raw ground to finished building.
- Utility upgrades are always taking place and may be a requirement of the conditions of approval by a planning department;
  – Must do these improvements or can't do the project

NATURAL GAS PROCESSING PLANTS AND PIPE TO GET THE GAS TO THE PLANT

UG GAS PIPE AND PIECES

OTHER BORING EQUIPMENT, BIG!!

Boring 2” – 56” pipe size up to 6,400 ft long

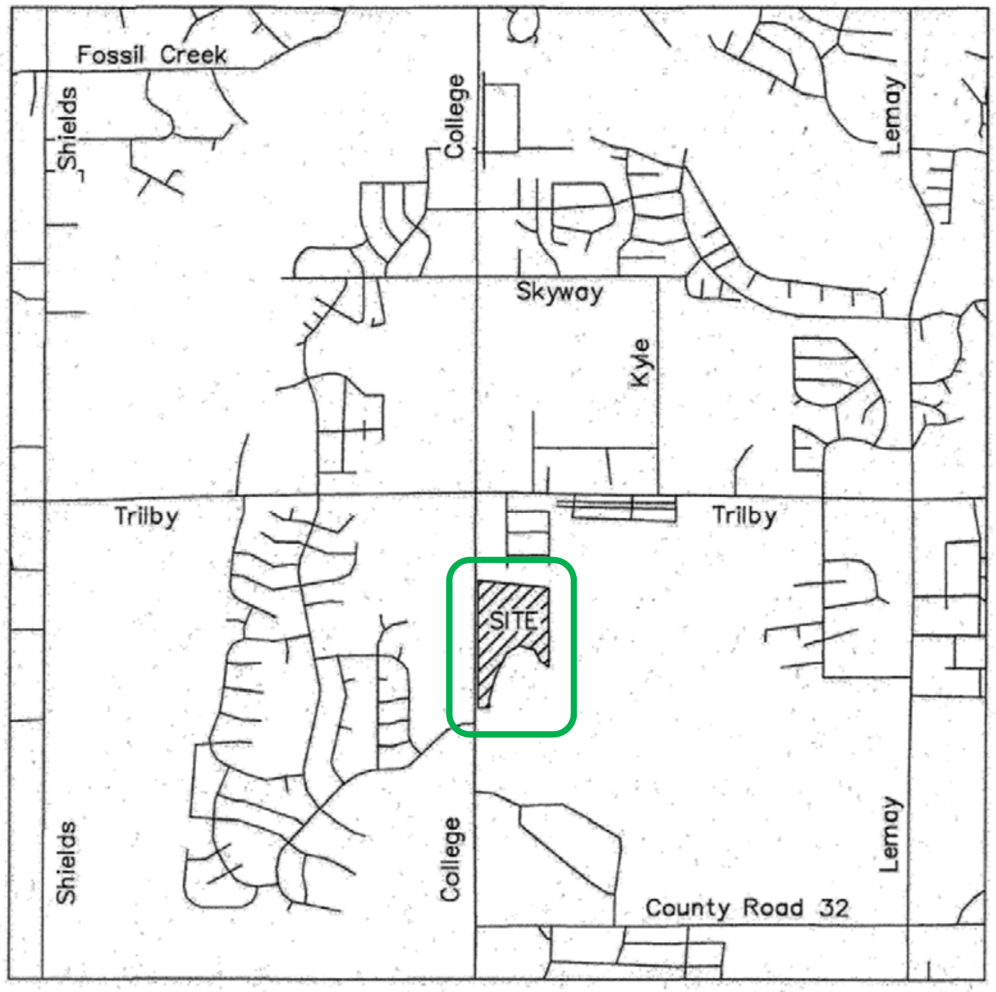
Semi trailer mounted for large projects like oil and gas.

BORING PIPE ON SEMI TRAILER

TRACKED BORING MACHINES

LAKEVIEW ON THE RISE
A SMALL SUBDIVISION PROJECT

- Please take time to acquaint yourself with these PPT slides and the Lakeview on the Rise plans on Canvas. You have an extensive In-class assignment using this material
- This project is close to wetlands, an irrigation ditch and a lake.
- There is an existing building and other improvements to be removed or relocated.



VICINITY MAP

OVERALL UTILITY PLAN: SHEET C-013

UTILITY NOTES:

1. 10' SEPARATION SHALL BE PROVIDED BETWEEN WATER, SANITARY SEWER, AND STORM SEWER LINES.
2. ALL STORM SEWER PIPE SHALL BE CLASS III RCP OR HDPE ADS N-12, WITH WATER TIGHT JOINTS, UNLESS NOTED OTHERWISE.
3. ALL SANITARY SEWER SERVICES SHALL BE SDR 35 PVC WITH ONE 6" PVC SERVICE FOR EACH BUILDING.
4. ALL SANITARY SEWER CLEAN-OUTS SHALL BE TRAFFIC RATED.
5. 2" WATER SERVICES AND METER PITS SHALL BE PROVIDED FOR ALL 12 UNIT BUILDINGS AND 1 $\frac{1}{2}$" WATER SERVICES AND METER PITS FOR ALL 8 UNIT BUILDINGS. THE DEVELOPER MAY CHOOSE TO PRIVATELY SUB-METER BEHIND THE MASTER METER. FINAL SIZING OF ALL METERS AND SERVICES ARE PROVIDED BY THE MEP. CONSTRUCT 4" TAP AND 4" (DIP) FIRELINES A MIN. OF 5 FEET BEYOND THE ROW OR BACK OF WALK IN PRIVATE DRIVES/ PARKING LOTS, AT ALL LOCATIONS. A TRANSITION FROM 4" TO 2" FIRELINE MAY BE MADE AS DESIGNED BY THE MEP.
6. ALL WATERLINES SHALL HAVE A MINIMUM OF 5' OF COVER AND A MAXIMUM OF 6' OF COVER.
7. A KNOX BOX WILL BE REQUIRED TO BE MOUNTED ON THE FRONT OF BUILDINGS EQUIPPED WITH A FIRE SPRINKLER SYSTEM OR FIRE ALARM SYSTEM PER POUDRE FIRE AUTHORITY. EACH BUILDING SHALL ALSO HAVE AN FDC (REMOTE FDC WHERE REQUIRED) AND SHALL BE MOUNTED PER P.F.A. REQUIREMENTS. CONTRACTOR SHALL COORDINATE LOCATION OF KNOX BOX AND FDC WITH POUDRE FIRE AUTHORITY PRIOR TO SPRINKLER PERMITTING.
8. HAZARDOUS MATERIALS: TOXIC, CORROSIVE, OR REACTIVE MATERIALS, OR FLAMMABLE/COMBUSTIBLE LIQUIDS (AS DEFINED IN THE UNIFORM FIRE CODE) IF USED, STORED, OR HANDLED ON SITE, MUST HAVE A HAZARDOUS MATERIALS IMPACT ANALYSIS (HMIA) COMPLETED AND SUPPLIED TO THE PLANNING DEPARTMENT AND THE FIRE DEPARTMENT.
9. ALL FIRELINES AND WATER SERVICE LINES SHALL BE EXTENDED TO 5' OUTSIDE OF THE BUILDING. SEE MEP/ARCH PLANS FOR INTERNAL CONNECTIONS TO BUILDINGS.
10. ALL FIRE HYDRANT CONNECTIONS/ ASSEMBLIES SHALL HAVE AN 8"x 6" SWIVEL TEE W/ 6" GATE VALVE & THRUST BLOCK.
11. ALL ROOF DRAIN COLLECTOR LINES TO STUB 5' FROM BUILDING FOOTPRINT. SEE PLUMBING PLANS FOR ROOF DRAIN CONNECTION DESIGN.
12. BACKWASH FLOW FROM THE PROPOSED SWIMMING POOL IS LIMITED TO 95 GPM.
13. REDUCED BACKFLOW PREVENTION DEVISES SHALL BE INSTALLED ON ALL FIRE SERVICES LINES AND DOMESTIC WATER LINES INSIDE THE BUILDING. REFER TO BUILDING AND PLUMBING PLANS FOR BACKFLOW DEVISES AND DETAILS.
14. PLEASE REFER TO THE PLAT FOR DETAILS ON UTILITY EASEMENTS, EMERGENCY ACCESS EASEMENTS, AND PLATTING FOR THE SITE.
15. CONTRACTOR SHALL INSTALL ALL ROOF DRAINS PRIOR TO INSTALLATION OF DRY UTILITIES.
16. IF CONTRACTOR ENCOUNTERS GROUND WATER DURING CONSTRUCTION THEN CONTRACTOR WILL BE RESPONSIBLE FOR INSTALLING CLAY CUTOFF WALLS ALONG WET UTILITY LINE PER FORT COLLINS REQUIREMENTS AND COORDINATE WITH ENGINEER.

Notes are an important part of understanding what goes underground to support building plumbing systems. Look at the potential liability that contractor has in note 16. Groundwater can be an expensive surprise, but in a site like this you might expect to perform more preliminary testing due to the lake and historical irrigation ditches.

KEYNOTE LEGEND ON SHEET C-013

KEY NOTE LEGEND

1. PROPOSED 6" PVC SSWR SRVC
2. PROPOSED 6" PVC SSWR SRVC CLEANOUT
3. PROPOSED 2" WATER METER SRVC W/ METER PIT & 2" CURB STOP
4. PROPOSED 2" FIRE SERVICE LINE (4" TAP AT MAIN REDUCED TO 2", 5' BEYOND ROW OR BACK OF SIDEWALK IN PRIVATE DRIVES AS DESIGNED BY MEP)
5. PROPOSED FIRE HYDRANT (6" DIP WATER LINE)
6. PROPOSED ROOF DRAIN (TYP) (SEE ROOF DRAIN PLAN FOR DETAILS)
7. PROPOSED 1 ½" WATER METER SRVC W/ METER PIT & 1 ½" CURB STOP
8. PROPOSED FORCE MAIN 4' CLEANOUT MH

This type of information may be provided for the page you are looking at, or for some other page in the plans. In this case it is for the current page and shows you where all the water supply, sewer, UG roof drain, fire protection, and associated required items are located. A page like this gives you a good understanding of the overall layout of the development. Finding this resource first will help you understand the overall scope of the project.

LEGEND

	PROPOSED FORCE MAIN SANITARY SEWER
	PROPOSED 8" PVC SANITARY SEWER W/ MANHOLE
	PROPOSED 8" PVC WATER
	PROPOSED FIRE HYDRANT ASSEMBLY
	PROPOSED STORM SEWER W/ MANHOLE
	PROPOSED TYPE R STORM INLET
	PROPOSED WATER VALVE
	PROPOSED THRUST BLOCK
FO	EXISTING FIBER OPTIC LINE
GAS	EXISTING GAS LINE
W	EXISTING WATER LINE
OHE	EXISTING OVERHEAD POWER LINE
SS	EXISTING SANITARY SEWER LINE
D	EXISTING STORM SEWER LINE
E	EXISTING UNDERGROUND POWER LINE
T	EXISTING UNDERGROUND TELEPHONE LINE
	EXISTING POWER POLE
	EXISTING GUY WIRE
	EXISTING LIGHT POLE
	EXISTING SANITARY SEWER MANHOLE
	EXISTING FIRE HYDRANT
	EXISTING WATER VALVE
	EXISTING WATER METER
	EXISTING WATER MANHOLE
	NATURAL HABITAT BUFFER ZONE

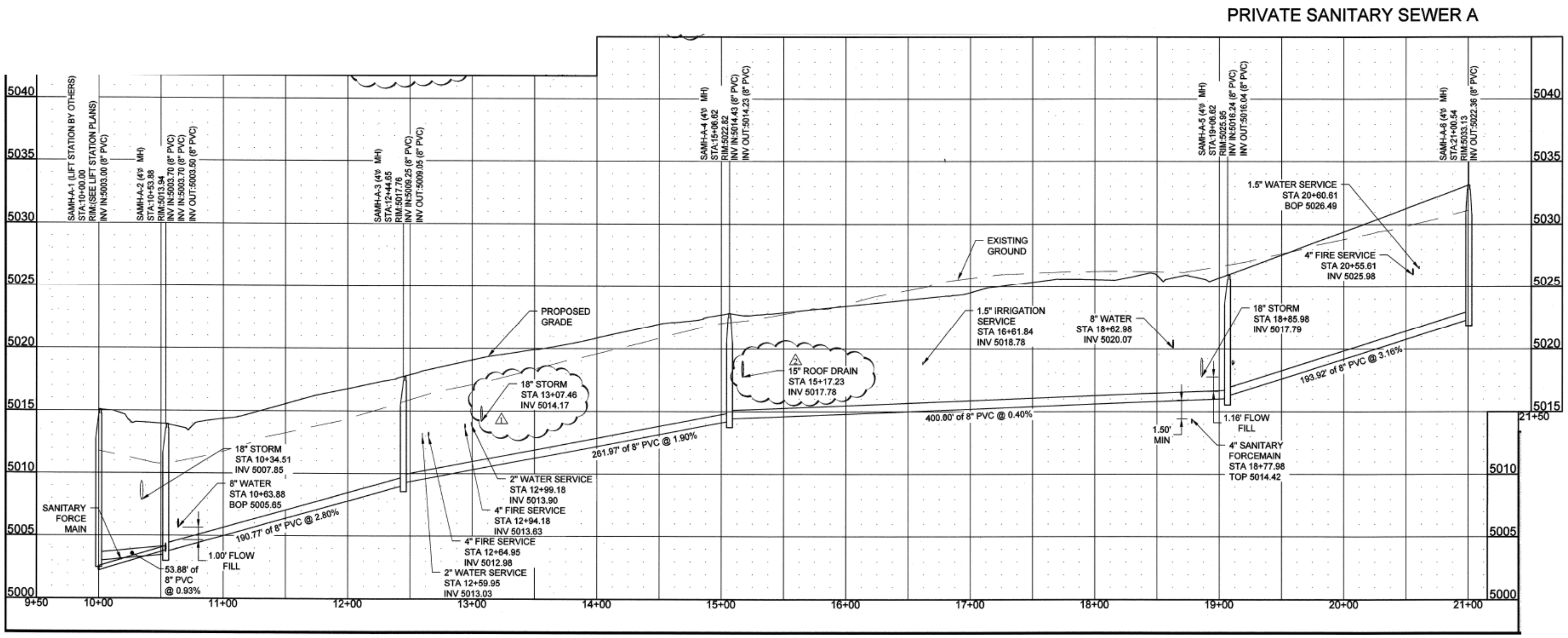
WATER PLANS: NORTH (C-014) AND SOUTH (C-015)

Along with the Overall Utility Plan, water plans help the GC and subcontractor understand the project scope. While the GC relies on the sub to price and perform the job, it is in everyone's best interest for the GC to understand what the requirements for all subcontractors. This information helps inform the GC so they can check the scope during the buyout process. If you review the Legends on each page you will discover several items that you may not be familiar with. If you take the time to learn about them your interactions with the specialty contractor will be more productive and you will build mutual respect and trust much faster. Yard hydrant, type K copper water line, knox box, FDC, thrust block, manhole, etc…….

UTILITY NOTES:

1. 10' SEPARATION SHALL BE PROVIDED BETWEEN WATER, SANITARY SEWER, AND STORM SEWER LINES.
2. ALL STORM SEWER PIPE SHALL BE CLASS III RCP OR HDPE ADS N-12, WITH WATER TIGHT JOINTS, UNLESS NOTED OTHERWISE.
3. ALL SANITARY SEWER SERVICES SHALL BE SDR 35 PVC WITH ONE 6" PVC SERVICE FOR EACH BUILDING.
4. ALL SANITARY SEWER CLEAN-OUTS SHALL BE TRAFFIC RATED.
5. 2" WATER SERVICES AND METER PITS SHALL BE PROVIDED FOR ALL 12 UNIT BUILDINGS AND 1 $\frac{1}{2}$" WATER SERVICES AND METER PITS FOR ALL 8 UNIT BUILDINGS. THE DEVELOPER MAY CHOOSE TO PRIVATELY SUB-METER BEHIND THE MASTER METER. FINAL SIZING OF ALL METERS AND SERVICES ARE PROVIDED BY THE MEP. CONSTRUCT 4" TAP AND 4" (DIP) FIRELINES A MIN. OF 5 FEET BEYOND THE ROW OR BACK OF WALK IN PRIVATE DRIVES/ PARKING LOTS, AT ALL LOCATIONS. A TRANSITION FROM 4" TO 2" FIRELINE MAY BE MADE AS DESIGNED BY THE MEP.
6. ALL WATERLINES SHALL HAVE A MINIMUM OF 5' OF COVER AND A MAXIMUM OF 6' OF COVER, UNLESS OTHERWISE NOTED.
7. A KNOX BOX WILL BE REQUIRED TO BE MOUNTED ON THE FRONT OF BUILDINGS EQUIPPED WITH A FIRE SPRINKLER SYSTEM OR FIRE ALARM SYSTEM PER POUDRE FIRE AUTHORITY. EACH BUILDING SHALL ALSO HAVE AN FDC (REMOTE FDC WHERE REQUIRED) AND SHALL BE MOUNTED PER P.F.A. REQUIREMENTS. CONTRACTOR SHALL COORDINATE LOCATION OF KNOX BOX AND FDC WITH POUDRE FIRE AUTHORITY PRIOR TO SPRINKLER PERMITTING.
8. HAZARDOUS MATERIALS: TOXIC, CORROSIVE, OR REACTIVE MATERIALS, OR FLAMMABLE/COMBUSTIBLE LIQUIDS (AS DEFINED IN THE UNIFORM FIRE CODE) IF USED, STORED, OR HANDLED ON SITE, MUST HAVE A HAZARDOUS MATERIALS IMPACT ANALYSIS (HMIA) COMPLETED AND SUPPLIED TO THE PLANNING DEPARTMENT AND THE FIRE DEPARTMENT.
9. ALL FIRELINES AND WATER SERVICE LINES SHALL BE EXTENDED TO 5' OUTSIDE OF THE BUILDING. SEE MEP/ARCH PLANS FOR INTERNAL CONNECTIONS TO BUILDINGS. MAINTAIN 18" MIN. CLEARANCE BETWEEN FIRELINES/SERVICE LINES AND THE ROOF DRAINS. SEE ROOF DRAIN PLANS FOR THE ROOF DRAIN INVERT ELEVATIONS.
10. ALL FIRE HYDRANT CONNECTIONS/ ASSEMBLIES SHALL HAVE AN 8"x 6" SWIVEL TEE W/ 6" GATE VALVE & THRUST BLOCK.
11. ALL ROOF DRAIN COLLECTOR LINES TO STUB 5' FROM BUILDING FOOTPRINT. SEE PLUMBING PLANS FOR ROOF DRAIN CONNECTION DESIGN. SEE ROOF DRAIN PLANS C-026 - C-029 FOR ROOF DRAIN DESIGN.
12. BACKWASH FLOW FROM THE PROPOSED SWIMMING POOL IS LIMITED TO 150 GPM.
13. REDUCED BACKFLOW PREVENTION DEVISES SHALL BE INSTALLED ON ALL FIRE SERVICES LINES AND DOMESTIC WATER LINES INSIDE THE BUILDING. REFER TO BUILDING AND PLUMBING PLANS FOR BACKFLOW DEVISES AND DETAILS.
14. PLEASE REFER TO THE PLAT FOR DETAILS ON UTILITY EASEMENTS, EMERGENCY ACCESS EASEMENTS, AND PLATTING FOR THE SITE.

SANITARY SEWER PLAN: SHEETS C-016 – C-018

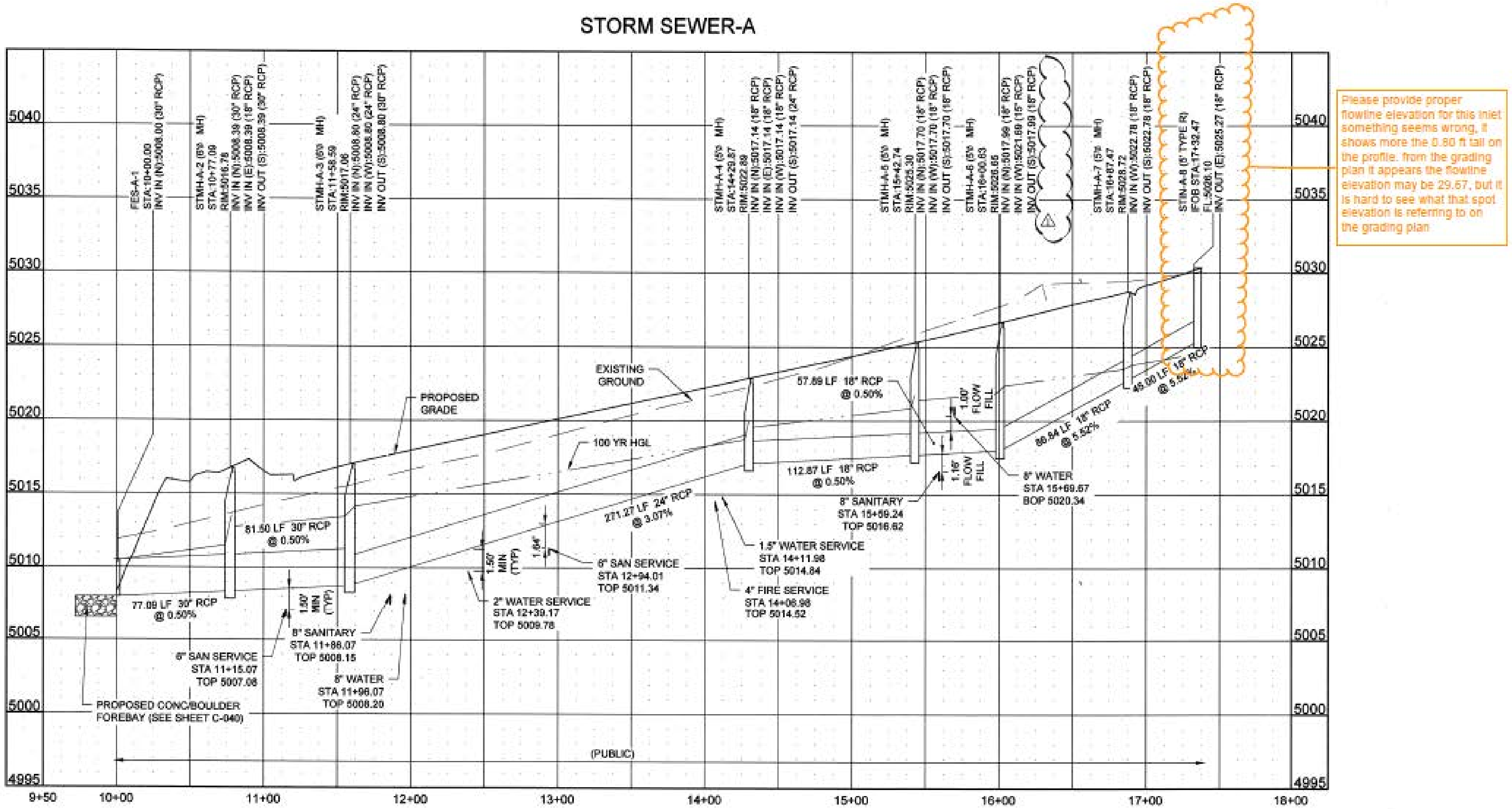


NOTES:

1. SANITARY SEWER SERVICE STATIONING IS BASED ON SEWER LINE ALIGNMENTS.
2. ALL SANITARY SEWER SHALL BE SDR-35 PVC. ALL 6" SERVICES SHALL HAVE TRAFFIC RATED CLEANOUTS.
3. ALL SANITARY SERVICES SHALL BE 6" PVC @ 1.0% (MINIMUM), UNLESS OTHERWISE NOTED.
4. SEE SHEET C-002 FOR ADDITIONAL SEWER NOTES.
5. SEE HORIZONTAL CONTROL PLAN FOR COORDINATE TIES TO PROPERTY CORNERS.
6. CONTRACTOR SHALL LOCATE ALL EXISTING UTILITIES PRIOR TO CONSTRUCTION AND VERIFY HORIZONTAL AND VERTICAL LOCATION OF UTILITY CONNECTION POINTS. NOTIFY ENGINEER OF SIGNIFICANT DISCREPANCIES.
7. SANITARY SEWER FORCE MAIN WILL BE CONSTRUCTED IN A COMMON TRENCH WITH THE GRAVITY SEWER. SEE TRENCH DETAIL ON SHEET C-017.
8. FORCE MAIN SHALL BE C-900 4" FUSIBLE PVC BY UNDERGROUND SOLUTIONS, OR APPROVED ALTERNATIVE.
9. IF CONTRACTOR ENCOUNTERS GROUND WATER DURING CONSTRUCTION THEN CONTRACTOR WILL BE RESPONSIBLE FOR INSTALLING CLAY CUTOFF WALLS ALONG SANITARY LINE PER FORT COLLINS REQUIREMENTS AND COORDINATE WITH ENGINEER.

All aspects of the project typically have overall and detailed sections of the work to be performed. Time spent reviewing the plans and specifications early in the project is time well spent for all parties to the contract.

STORM SEWER PLAN: SHEETS C-019 – C-025

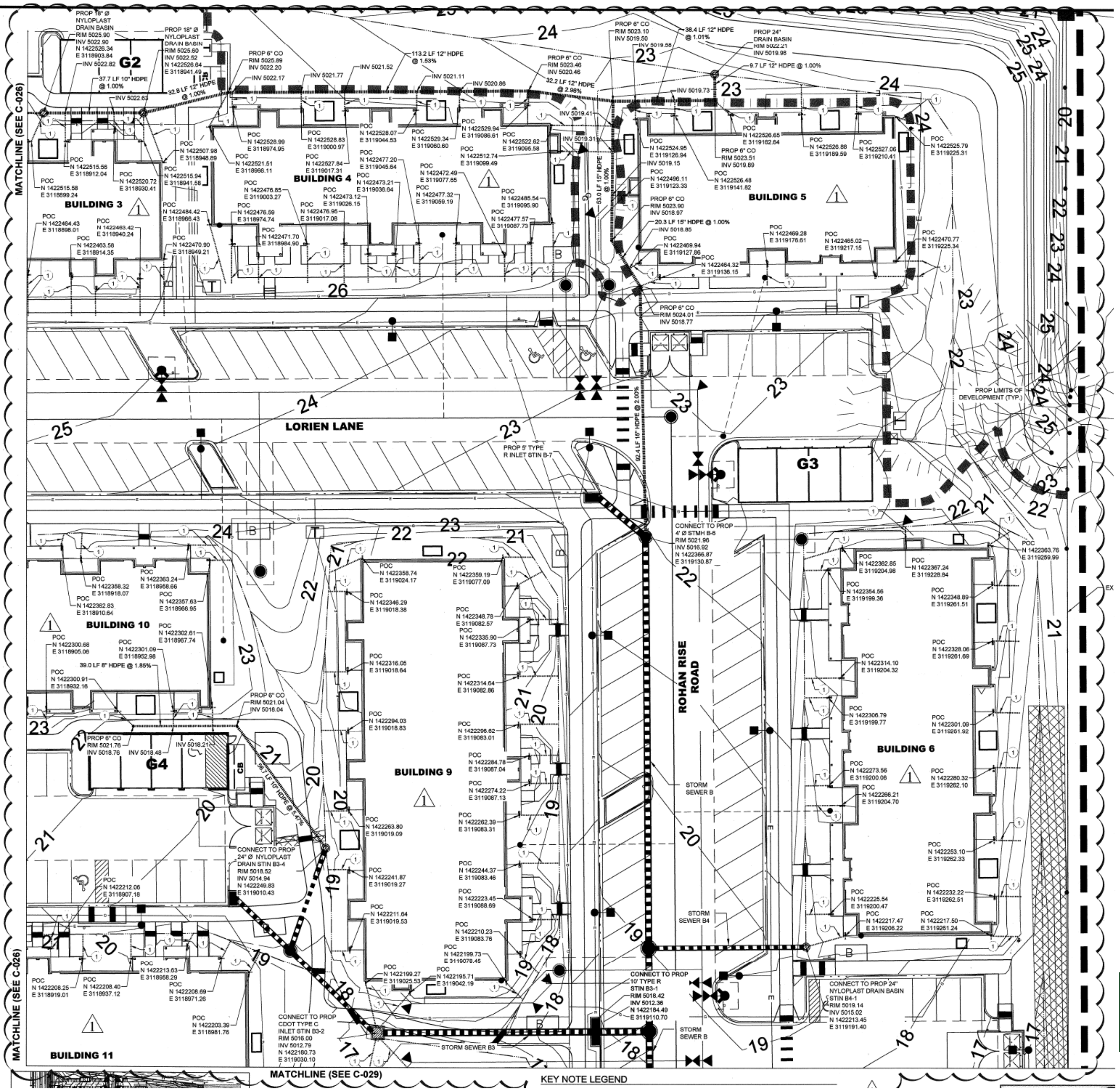


NOTES:

1. PIPES SHALL HAVE A PRESSURE SEAL. RCP JOINT SEALS SHALL COMPLY WITH ASTM C-443.
2. ALL STORM SEWERS SHALL BE CLASS III RCP WITH WATER TIGHT JOINTS. ALL HDPE SHALL BE ADS N-12.
3. ALL COORDINATES GIVEN FOR STORM DRAIN INLETS ARE TO THE INTERSECTION OF THE MIDPOINT OF THE INLET AND FLOWLINE OF THE STREET. ALL OTHER COORDINATES FOR STORM DRAIN STRUCTURES ARE TO END OF PIPE OR CENTER OF MANHOLE. ALL LENGTHS OF STORM PIPE ARE FROM THE CENTER OF MANHOLE OR INSIDE FACE OF THE INLET/STRUCTURE TO THE END OF PIPE. ALL SPECIALLY FABRICATED ACCESS STRUCTURES SHALL PROVIDE A CONTINUOUS VERTICAL ACCESS AT ONE SIDE OF THE PIPE SECTION. SHOP DRAWINGS OF SPECIALLY FABRICATED ACCESS STRUCTURE MUST BE SUBMITTED TO THE ENGINEER FOR APPROVAL AT LEAST TWO WEEKS PRIOR TO CONSTRUCTION.
4. IFOB = INSIDE FACE OF BOX
5. CONTRACTOR SHALL LOCATE ALL EXISTING UTILITIES PRIOR TO CONSTRUCTION AND VERIFY HORIZONTAL AND VERTICAL LOCATION OF EXISTING UTILITIES. NOTIFY ENGINEER OF SIGNIFICANT DISCREPANCIES.

All aspects of the project typically have overall and detailed sections of the work to be performed. Time spent reviewing the plans and specifications early in the project is time well spent for all parties to the contract.

ROOF DRAIN PLAN: SHEETS C-026 – C-027



STREET CUT NOTE:
LIMITS OF STREET CUT ARE APPROXIMATE. FINAL LIMITS ARE TO BE DETERMINED IN THE FIELD BY THE CITY ENGINEERING INSPECTOR. ALL REPAIRS ARE TO BE IN ACCORDANCE WITH THE CITY STREET REPAIR STANDARDS.

KEY NOTE LEGEND

1 ROOF DRAIN EXTENSION OR BURIED 4" ADS STORM LEADER @ 1.00% MIN, TO BE DETERMINED AT TIME OF CONSTRUCTION, IN COORDINATION WITH OWNER.

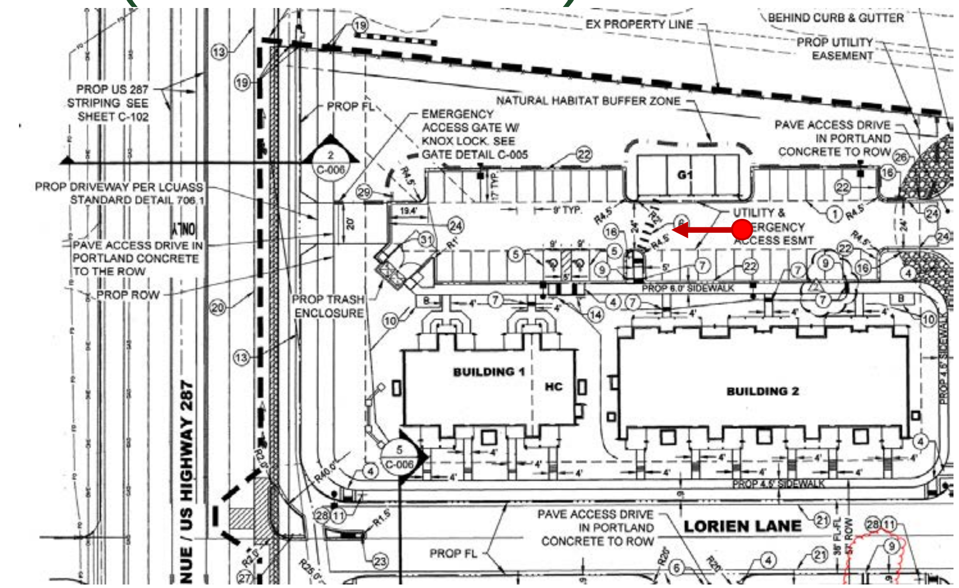
1

NOTES:

1. ALL ROOF DRAIN COLLECTOR LINES TO STUB 5' FROM BUILDING FOOTPRINT. SEE PLUMBING PLANS FOR ROOF DRAIN CONNECTION DESIGN.
2. POC = POINT OF CONNECTION
3. CONTRACTOR SHALL INSTALL ALL ROOF DRAINS PRIOR TO INSTALLATION OF DRY UTILITIES.
4. IF CONTRACTOR ENCOUNTERS GROUND WATER DURING CONSTRUCTION THEN CONTRACTOR WILL BE RESPONSIBLE FOR INSTALLING CLAY CUTOFF WALLS ALONG ROOF DRAIN LINE PER FORT COLLINS REQUIREMENTS AND COORDINATE WITH ENGINEER.

All aspects of the project typically have overall and detailed sections of the work to be performed. Time spent reviewing the plans and specifications early in the project is time well spent for all parties to the contract.

LAKEVIEW ON THE RISE (SHEET C-004)

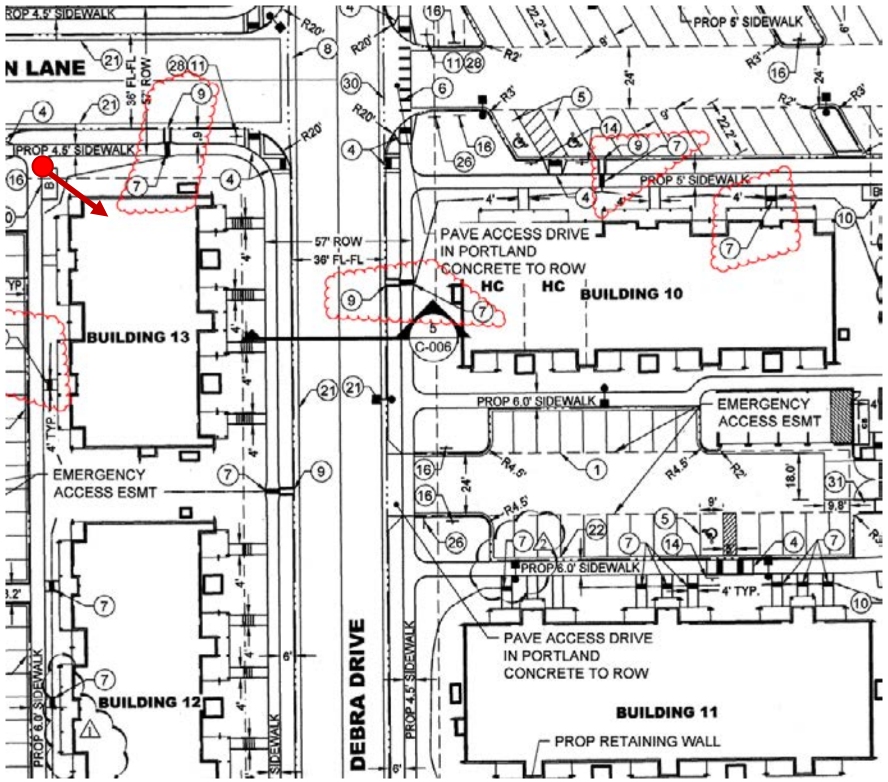


Standing in parking lot on the north side of Building 2 looking West towards US Hwy 287. Notice all the curb and gutter is in and the base course of asphalt is laid. This tells us that the UG water and sewer lines are installed and approved by the jurisdiction having control over that inspection process.

The vertical white PVC pipe is the rough-in for the building plumbing systems. The foundations are SOG due to the water table, soils, and existing conditions.

NORTH SIDE OF BLDG. 13, LOOKING SE TO BLDG. 10 BEING FRAMED AND BLDG. 11 WHICH IS DRIED IN

(SHEET C-004)

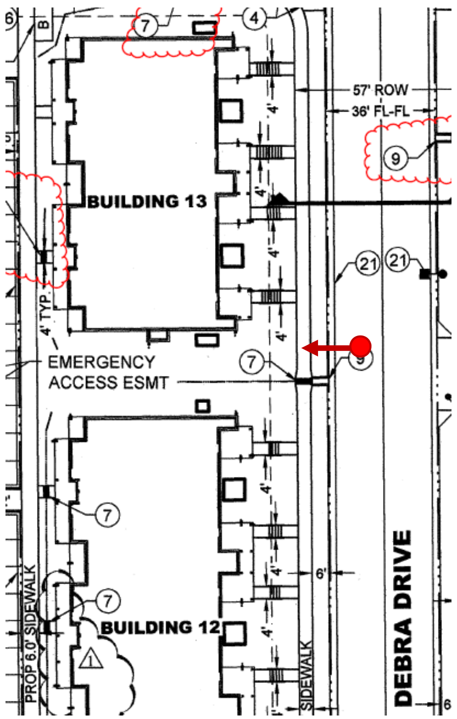


Note bent rebar from foundation walls telling us that the stem walls for the building are in place. The rough UG plumbing within the building is what you are seeing sticking up.

The greenish rigid insulation is for the first two feet of the foundation for Energy codes.

LOOKING WEST FROM DEBRA DR. TO BLDG. 13

(SHEET C-004)

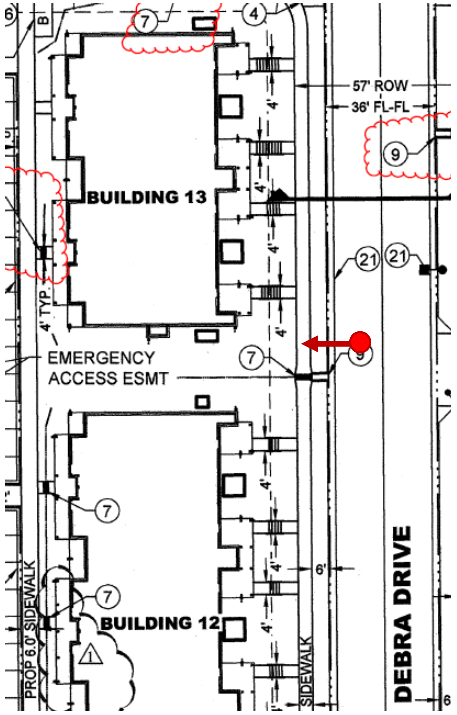


The open hole has two vertical pipes. If you look at where they connect to the Horizontal Line you will see an opposed WYE fitting. This enables a plumber to snake the line away from, or towards the building in the event of a clog. It is also code that this be within 10’ of the building foundation.

The pipe is connecting multiple units to the UG sanitary sewer, foreground, under the survey stake. Note the exposed foundation insulation and backfill required. Think Schedule sequencing among several trades.

CLOSE-UP OF PREVIOUS PPT SLIDE

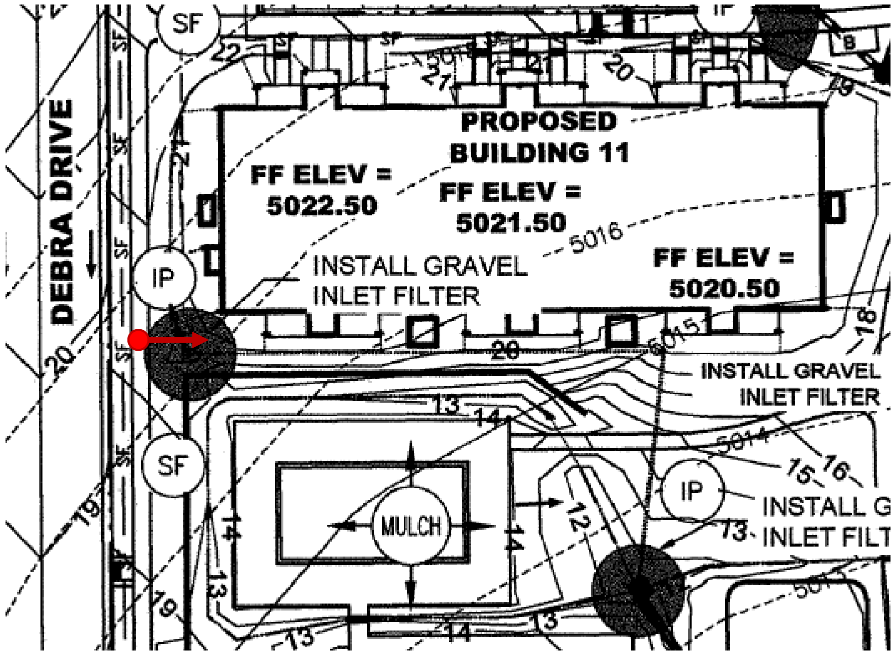
(SHEET C-004)



Note the pea gravel in the bottom of the trench as bedding for the DWV pipe. This is similar to the requirements for most UG piping, not just in a subdivision.

The black tubes under the orange tarp at the bottom of the trench are for ground thawing so the SOG can be placed in winter without freeze thaw concerns.

SW CORNER OF BLDG. 11, IP (SHEET C-007) SHOWN AS 12' DRAINAGE BASIN (SHEET C-013)

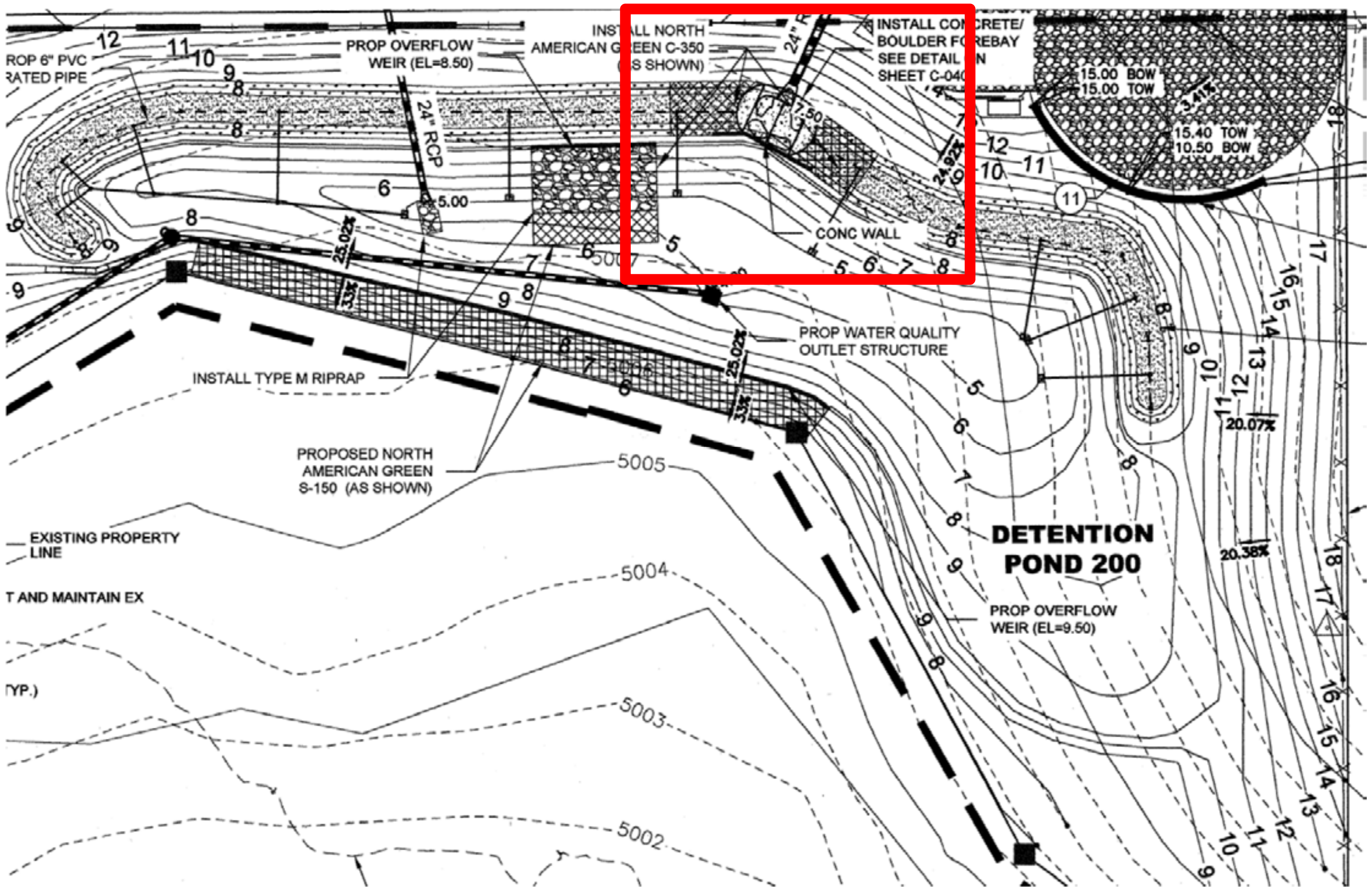


Note the green vertical drain pipe. As it turns to horizontal it becomes the white DWV Note 6 on page C-013 says this will have a minimum of 5' and maximum of 6' cover.

The silt fencing also matches the drawing requirement on C-007

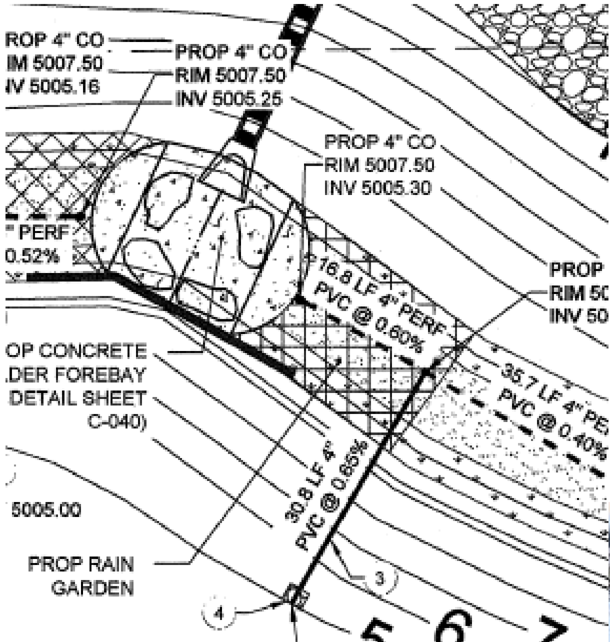
EXCERPT FROM SHEET C-011 PROVIDING CONTEXT FOR THE FOLLOWING PPT SLIDE

This shows detention pond 200 for storm water management. Lakeview sits on a lake and undesignated wetlands. This required a lot of planning with the City of Fort Collins to ensure that water quality was maintained post construction. The detention ponds serve to filter out particulate matter prior to discharge into the existing lake. While this is not is the scope of a normal plumbing contractor, it is integral to making the subdivision work and is closely aligned to the topic of storm water management, a plumbing scope area.



LOOKING SOUTH FROM ELEV 18 ON THE SOUTH SIDE OF BLDG. 8. LOOKING AT THE FOREBAY AND STORM SEWER (SHEET C-029)

FOREBAY IS DETAILED ON SHEET C-040

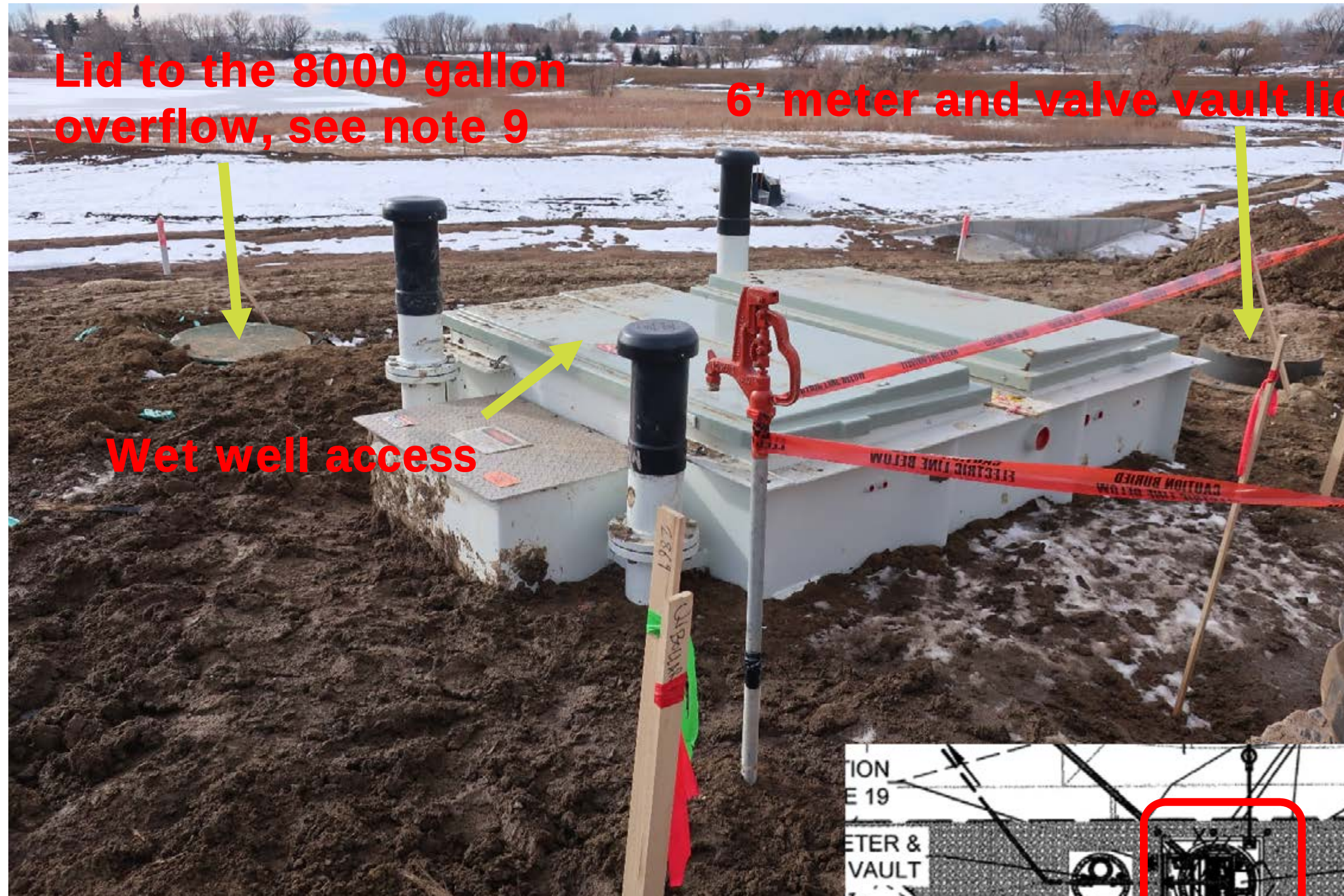


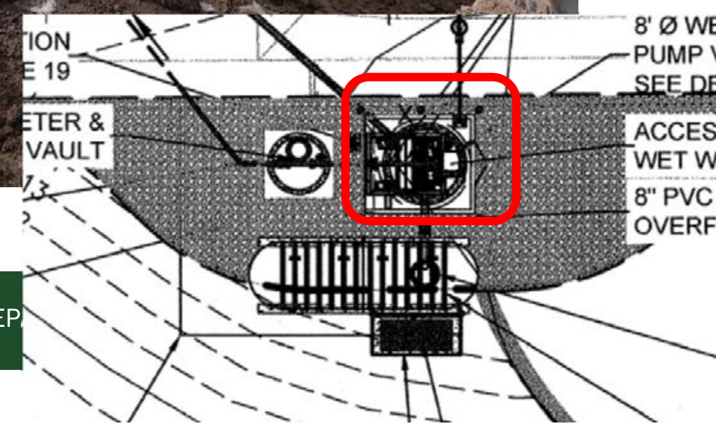
33

Note the gravel in proximity to the rain garden Forebay. See detail notes on Sheet C-040, both for Concrete/boulder Forebay pond and rain garden Basin detail.

ON SHEET SS01, TOP OF PAGE, THERE IS A SITE PLAN VIEW OF THE SANITARY SEWER LIFT STATION, PICTURED HERE

This project does not have a gravity flow to the sanitary sewer system so it needs a lift station to pump sewage to the nearest sewer main that uses gravity flow to a treatment facility. The sewer main between the lift station and the gravity line is called a forced main; pressure from the lift station makes waste flow uphill. This is similar to a vault in a individual sewage disposal system for a single family dwelling where the sewage is either pumped from a vault to a truck for disposal or pumped to a leach field for percolation into the soil. See also the enlarged detail for the components on sheet SS01, bottom half of page.

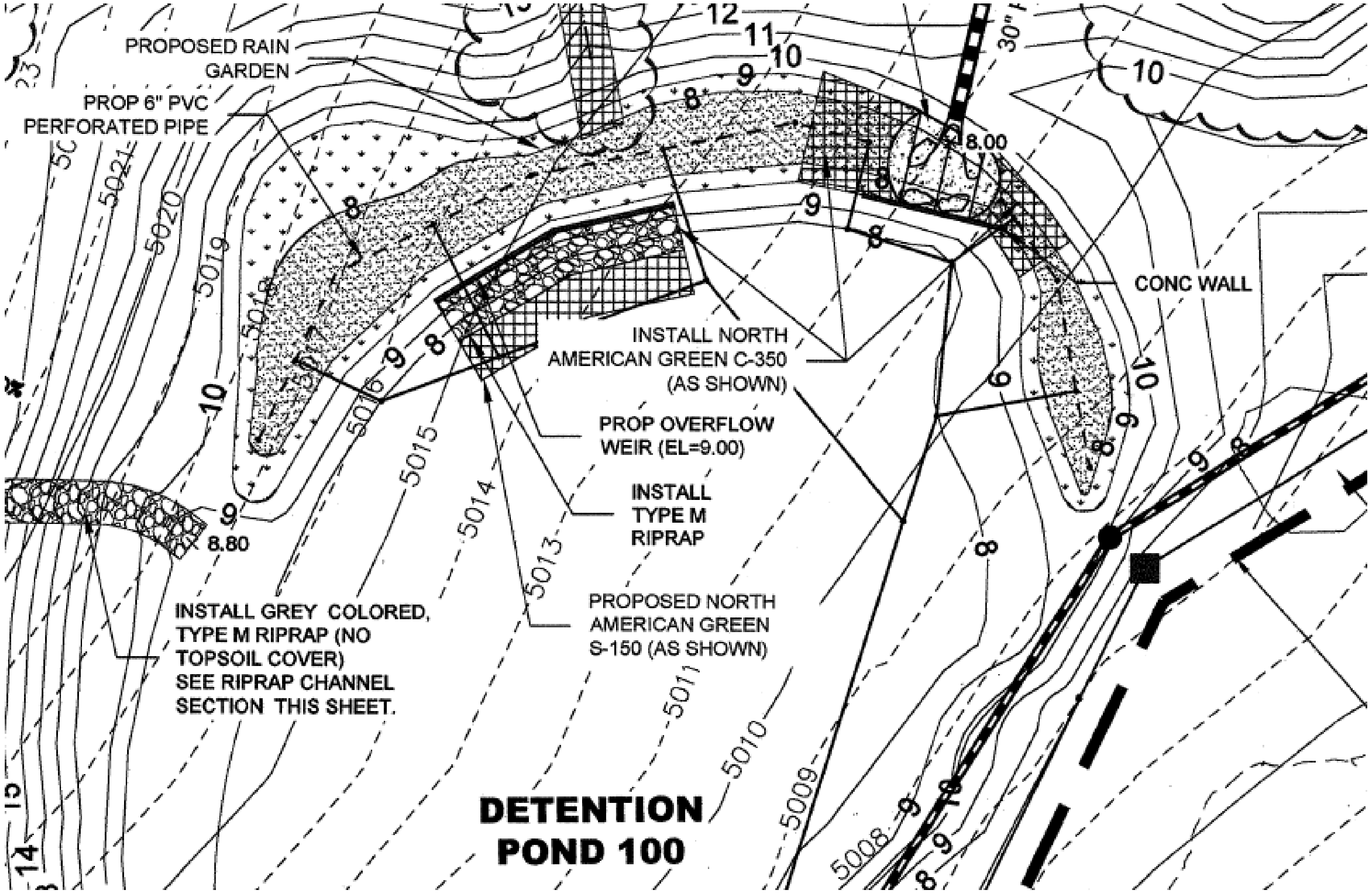




VIEW LOOKING EAST OF LIFT STATION AND UTILITIES

DETENTION POND 100, PROVIDES CONTEXT FOR NEXT TWO PPT SLIDES

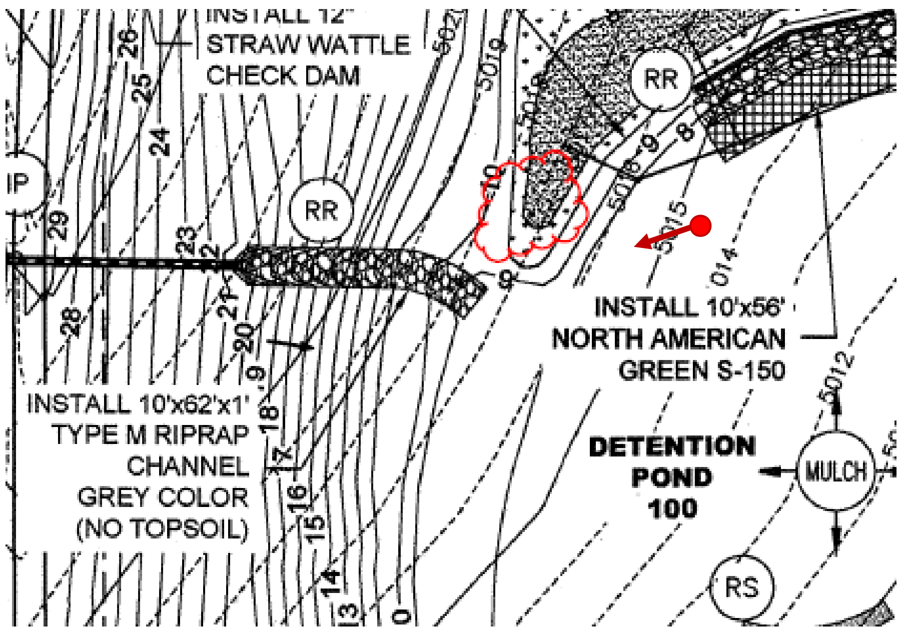
Detention pond 100 (Sheet C-011), provides for enhanced water quality from highway 287 drainage as well as Lakeview development storm water runoff. The following PPT slides show the riprap and the forebay areas.



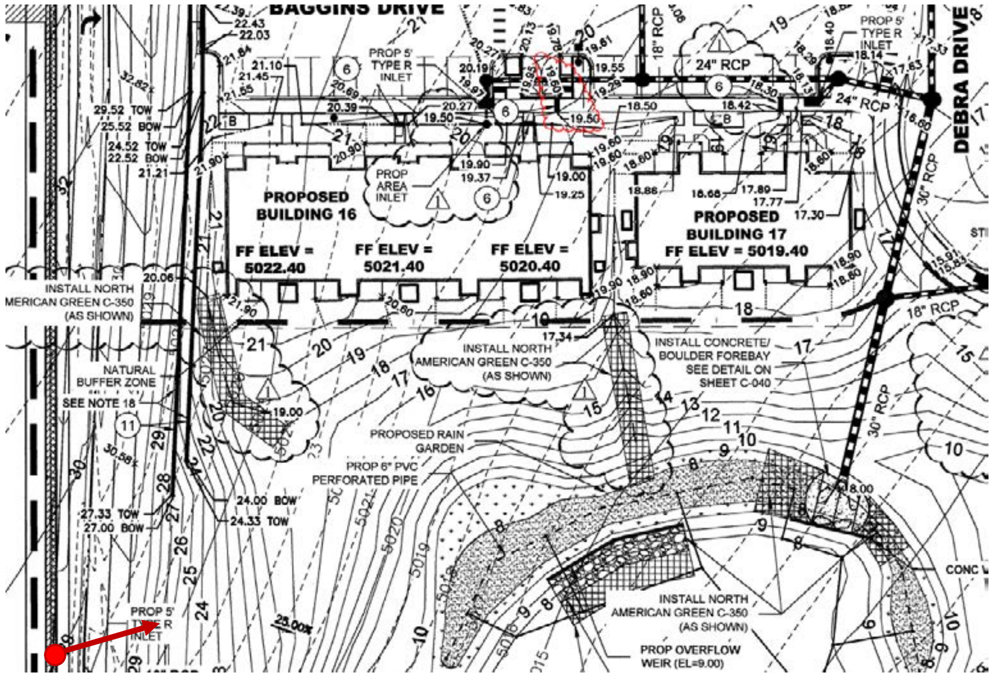
LOOKING WEST AT 10'X62'X1' TYPE-M RIPRAP (RR) CHANNEL NEXT TO US HWY 287 (SHEET C-007)

The white PVC underdrain pipe is discussed in notes 8 and 9 on Sheet C-007.

The RR is part of the storm sewer system the 287 area and the underdrain pipe is part of the development storm sewer to enhance water quality.



STANDING ON HWY 287 LOOKING NE TO THE 30” RCP OUTLET COMING SOUTH FROM DEBRA DRIVE AND THE INTERSECTION OF STONEY BROOK RD (SHEET C-011)



30” RCP outlet
Concrete wall and Forebay area

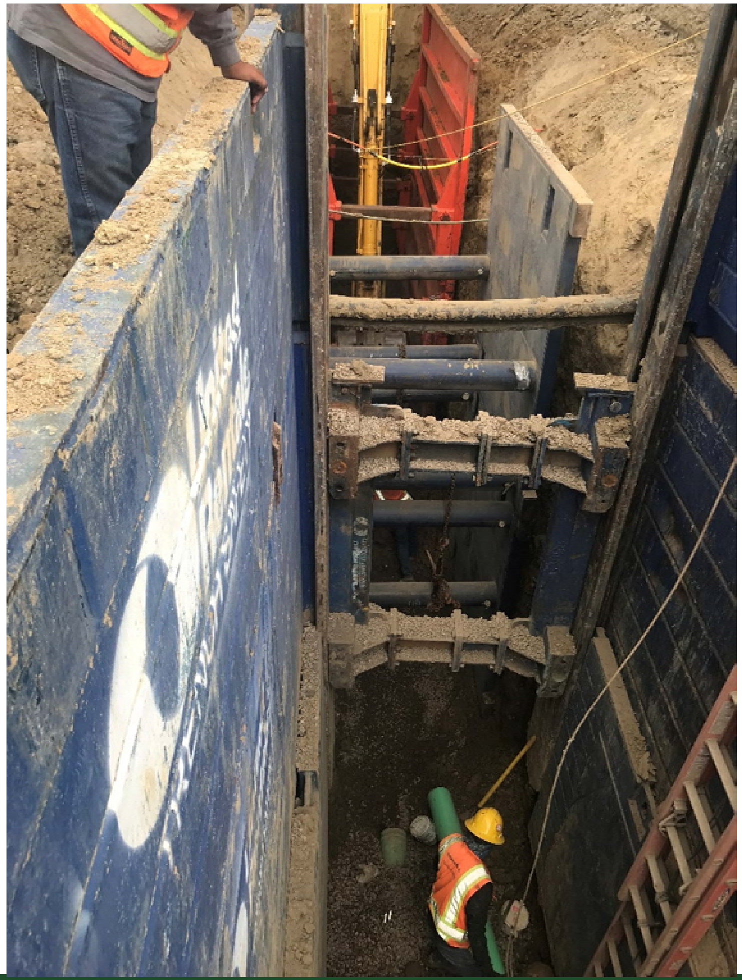
You can see the outlet of the 30” RCP and the Concrete wall in the foreground. This exits into a proposed rain garden. There is a concrete forebay at the mouth of the outlet, see sheet C-040 for details. This is part of the storm sewer system to protect the existing Robert Benson Lake water quality.

? UG DWV, WHERE DOES IT GO ONCE IT LEAVES THE BUILDING?

String, dirt, boxes, glue, mud; what else is there to make sure a plumbing project runs smoothly?

Left shows larger excavation of DWV from a building. Right shows a close-up of the pipe right below the mini excavator. There is a lot of dirt moved on a project once the foundations are in place; SOG or SOG in a basement. Think schedule, compaction, pipe under footings, pressure testing prior to backfill, inspections, and proper placement of the vertical risers.

ANSWER. DWV GOES DEEP TO CONNECT TO A SEWER MAINLINE. IT IS NOT UNCOMMON FOR MAINLINE TO BE 12’ OR DEEPER UNDERGROUND. NOTE THE DEPTH OF THE TRENCH IN THE CENTER PICTURE, APPROXIMATELY 20’.



ON SITE SEWAGE DISPOSAL SYSTEMS
“SEPTIC SYSTEM”

- Not all buildings are located in close proximity to a public sewer.
- Sewage disposal can be through vault, tank and leach field, other specialized system.
- Vault – holding tank that needs to be pumped periodically and transported to a sewage disposal facility. Typically low first cost, high operating costs.
- Septic tank and leach field. Typically high first cost and low operating cost.
- Always check the current regulations to determine/validate what is permitted.
- Regulations can be at the state, county, or local level and may be influenced by federal clean water regulations.

ENGINEERED DOSED SEWER SYSTEM
CM CARES PROJECT

Pressurized dosing pipes

Mined 150 yds of native soil from neighbor to meet engineers soil specifications

Infiltrators, number based on engineers design.

READY FOR TANK DELIVERY

Future forced main up to leach field.

SETTING SEPTIC TANKS ON CM CARES PROJECT

Pressure pump in pumping tank
disconnect and wiring for control panel.

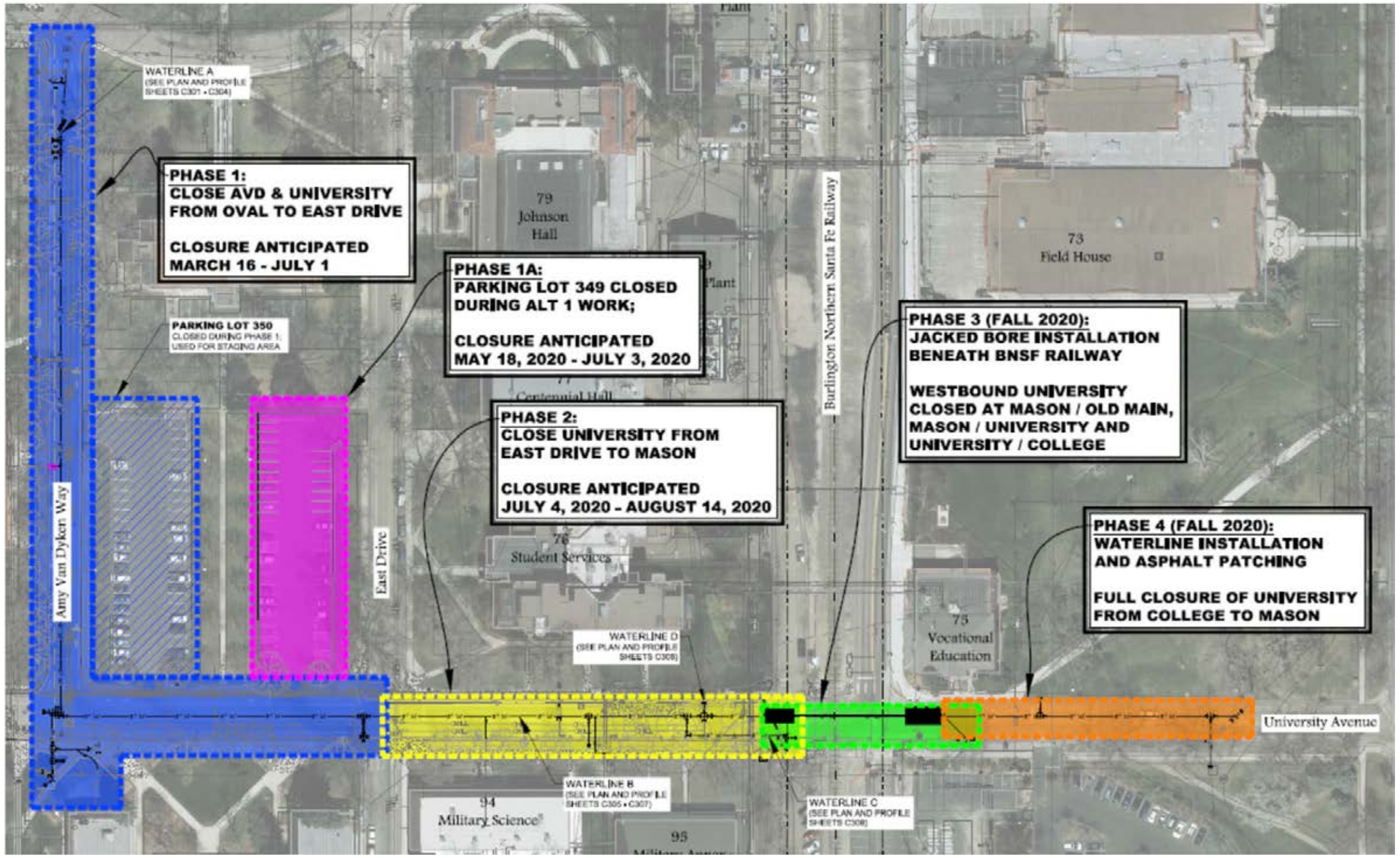
Pumping tank risers

Holding tank risers

GRAVITY FED LEACH FIELD MANIFOLD FROM DUAL CHAMBER TANK AND INFILTRATORS

PHASING REPLACEMENT WATERLINE PROJECT – CSU INFRASTRUCTURE UPGRADE

Project phasing provide flexibility for the owner and the contractor. The owner may be managing a budget and waiting to see how the bids come in to see how much work can be accomplished. The contractor can bid all or part and use economies of scale to entice the owner to do the entire project now. The phasing also allows for street closures to be planned to limit traffic disruption.



CONSIDERATIONS TO PLAN FOR WHEN DOING WATER AND SEWER UTILITY WORK IN A PUBLIC RIGHT OF WAY (ROW)

- Traffic control plan – typically done by a subcontractor that knows the local requirements. They also may provide signage, cones and flaggers.
- What arrangements are made for local traffic, emergency access, and where detours will be.
- ROW work permits – typically comes from the government having jurisdiction over the ROW. They want to know how long the project will take.

PLUMBING PLANS AND SPECIFICATIONS

CON 371 – Mechanical and Plumbing Systems

LEARNING OUTCOMES

- By the end of this lesson, students will be able to:
  1. Understand the drawings and information provided in Plumbing plans and specifications
  2. Recognize the various Plumbing symbols used, and not all symbols are correct or included
  3. Know how to use the plans and specifications to determine the details and information of a Plumbing system for a project

SOME COMMON PLUMBING SYSTEMS

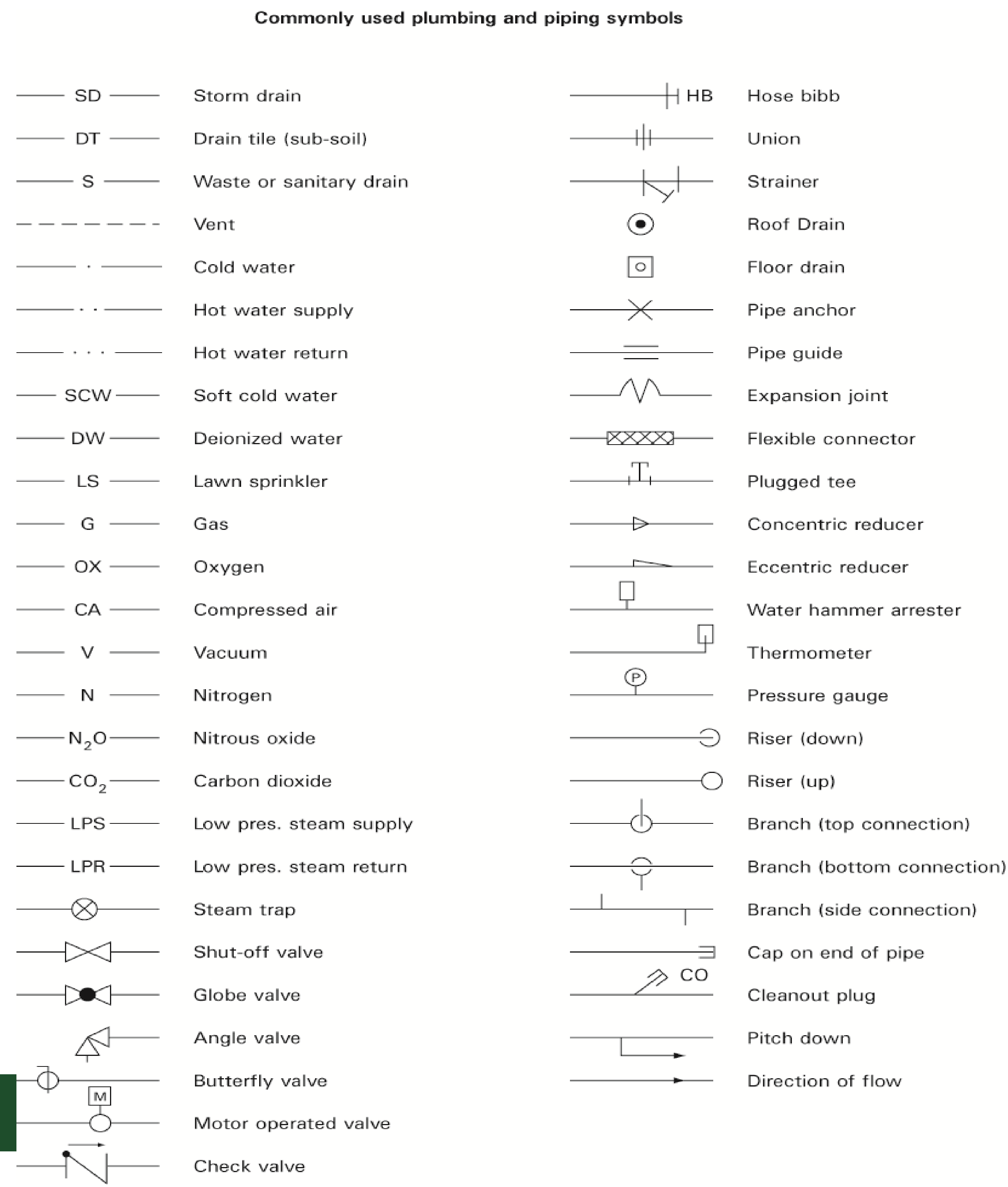
- Domestic water
  - Hot, cold, tempered, filtered, treated
- Waste water
  - Drainage, waste, and vent (DWV)
- Grey water recycling
  - Flushing and irrigation
- Fixtures, drains, pipes, and specialty equipment
- Roof drains and piping
- Rain water capture
  - Flushing and irrigation
- Fuel gas and fuel oil piping
- Compressed air systems
- Medical gas systems
  - Oxygen, medical air, vacuum, nitrogen, nitrous oxide
  - Medical air compressors and vacuum pumps
  - Outlets, valves, and alarms
- Fire protection
- Lawn irrigation

PLUMBING PLANS

- Listed as “P” or sometimes “M” sheets in a plan set
- Includes:
  - Floor plans
  - Elevations
  - Schedules
  - Isometrics
  - Details
  - Riser Diagrams
  - Schematics

- Plumbing plan sets details:
  - Domestic water
  - DWV
  - Gas piping
  - Size, type, and layout of piping
  - Fixtures, Faucets, and Equipment
  - Piping insulation
  - Water, drainage, and gas connections
  - Symbol legend, general notes, and specific key notes
  - Plumbing Schedules
  - Fixture Units

PLUMBING SYMBOLS



FROM HERE ON THE INFORMATION PRESENTED IS FROM THE CSU TRANSLATIONAL MEDICINE INSTITUTE (TMI) PLANS AND SPECIFICATIONS

CSU TMI PROJECT

- We are using the CSU Transitional Medicine Institute (TMI) Plans and Specs for this lesson. You have access to these on Canvas and we will be using them as a reference throughout the rest of this lesson and the In-class exercise you will complete after this lesson.
- The remainder of the presentation is organized as follows:
  - Overview of the plan layout and how the information is presented at the overall project level
  - Focus by floor and specific area of each floor
    - Project broken up by floor and by areas A, B, C, D as well as subareas designated as A1, A2, etc.
  - Presentation of a specific floor area, risers, details, and schematics to provide a better conceptual understanding of the project

HOW TO APPROACH THE CSU TMI PLANS

- Read the Index if Applicable
- Look at the bottom RH corner of the pages for topical headings.
  - P2.00.A1 – P2.03.D2 pages denote the zones on each floor due to the size and complexity of the project.
  - Pages P3.01 – P3.10 denote the Water Supply Risers
  - Pages P3.11 – P3.20 – denote the Waste & Vent Risers
  - Pages P4.01 – P4.03 – denote Piping Schematics
  - Pages P5.01 – P5.02 – denote Plumbing Details
  - Pages P6.01 – P6.04 – denote Plumbing Schedules –

NOTE: Some pages say “superseded” on them and show the updated plans page prior to that page, they both have the same topical heading for clarity.

ABBREVIATIONS, SYMBOLS & NOTES

- As previously discussed there are no sets of perfect plans and specifications, TMI is no exception. Lets look at a few examples.
- What is shown on page P0.00 for a 4" floor drain?
- This is what is shown on P2.00.A4 for a 3" floor drain

It is not uncommon to find drawing conventions differ from the abbreviations page to what is used in the plans. In any cases you will need to review the P drawings in detail to understand what the abbreviations stand for.

HOW THE TMI "P" PLANS ARE ORGANIZED

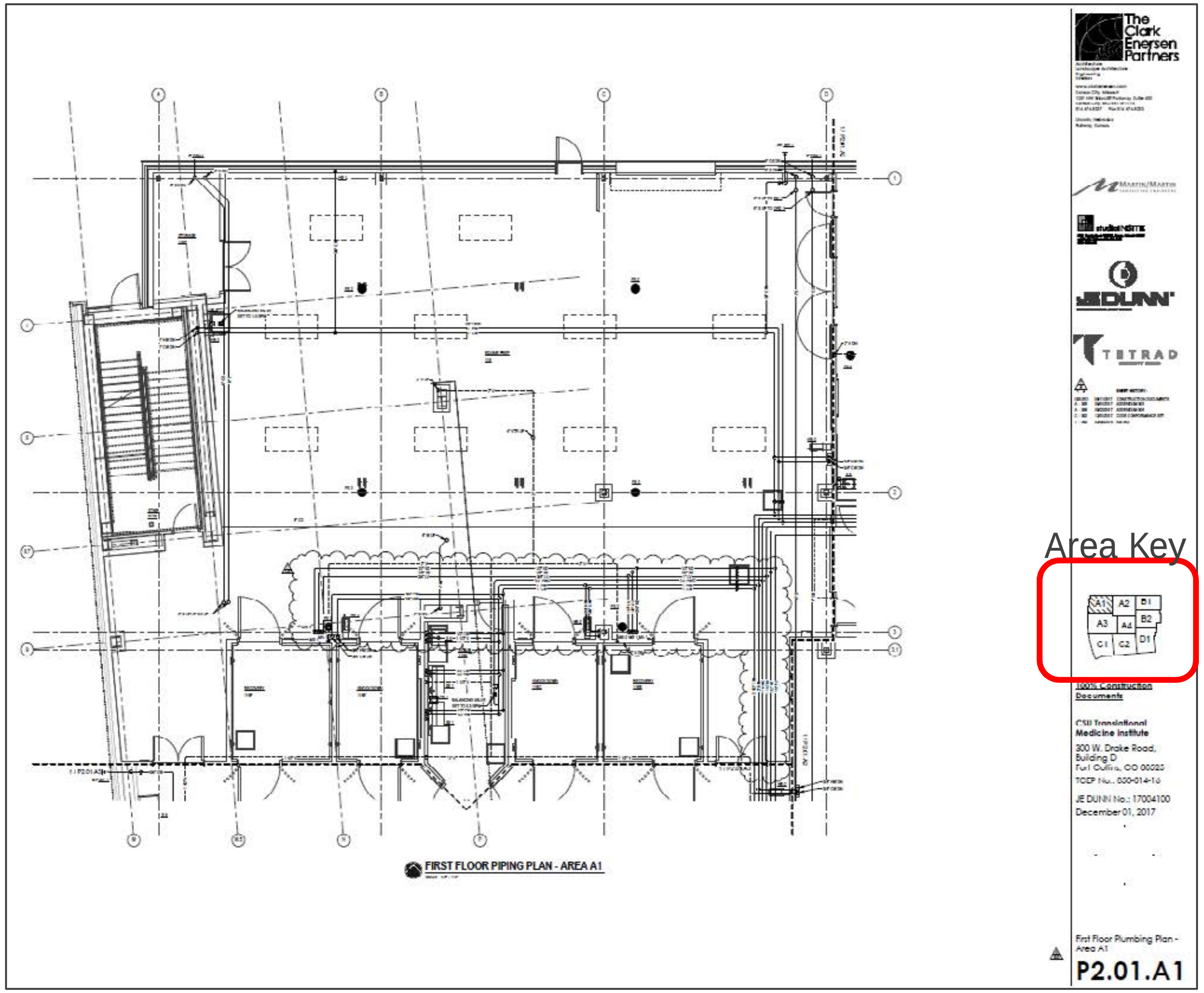
- TMI project has three floors, each with very different uses
- Not all floors have the same footprint as the floor below it
  - In the right hand margins of the TMI drawings there is a plan view grid (Area Key) showing what grid section of the floor the current drawing is referring to
- TMI has up to nine grid areas on a floor
  - Spend time to understand how the drawings for each grid area link to adjacent grid areas on the same floor and floors above or below
- As you work through the In-class exercise this understanding will help

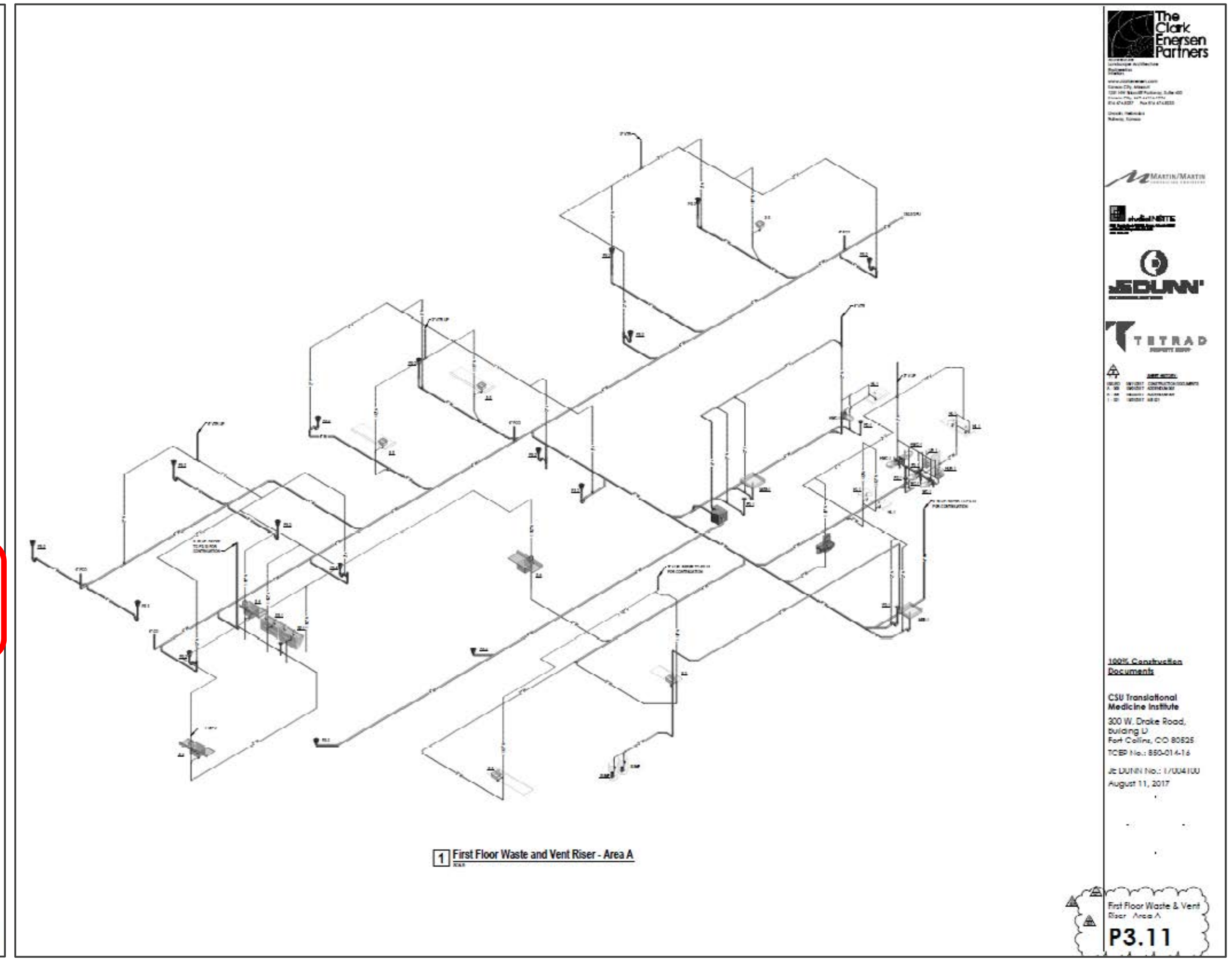
HOW THE TOPICAL HEADINGS RELATE BY FLOOR & BY AREA

- The following all relate to grid area “A1” or “A”. Sometimes the information includes all of an area and you need to determine what is being shown by the information
  - P2.00.A1 shows the A1 zone below floor plumbing plan, for reference only
  - P2.01.A1 shows the same zone (A1) for the first floor plumbing plan
  - P2.02.A1 shows the same zone (A1) for the second floor plumbing plan
  - P2.03.A1 shows the same zone (A1) for the third floor plumbing plan
  - P3.01 shows the first floor plumbing supply riser for area A. This could include all four A areas, a quick visual check of key components will verify this.
  - P3.05 shows the second floor plumbing supply riser for area A
  - P3.11 shows the first floor waste & vent riser for area A
  - P3.15 shows the second floor waste & vent riser for area A
  - P3.18 shows the third floor waste & vent riser for area A

FIRST FLOOR PLUMBING PLAN – AREA A1

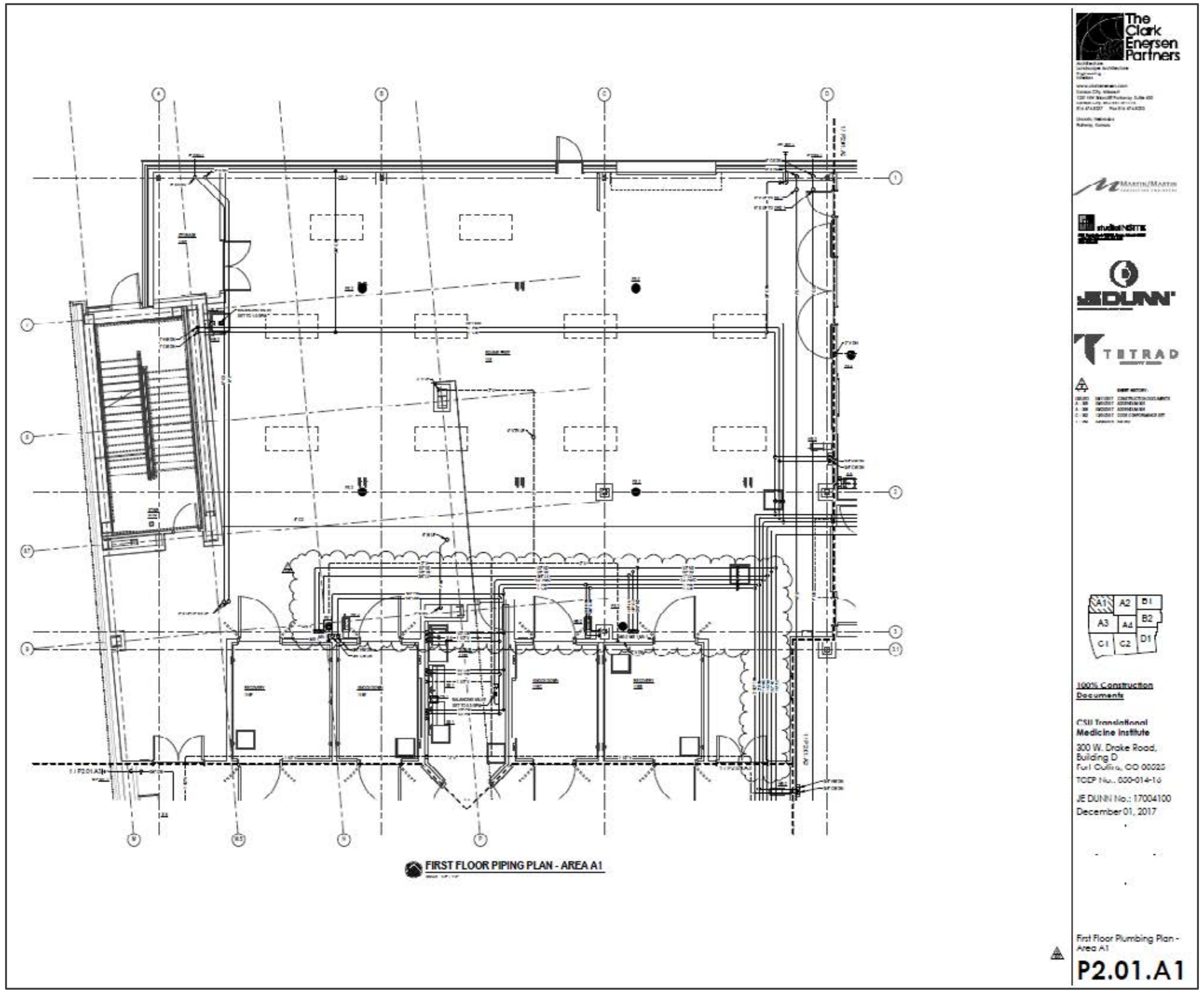
FIRST FLOOR WASTE & VENT RISER – AREA A

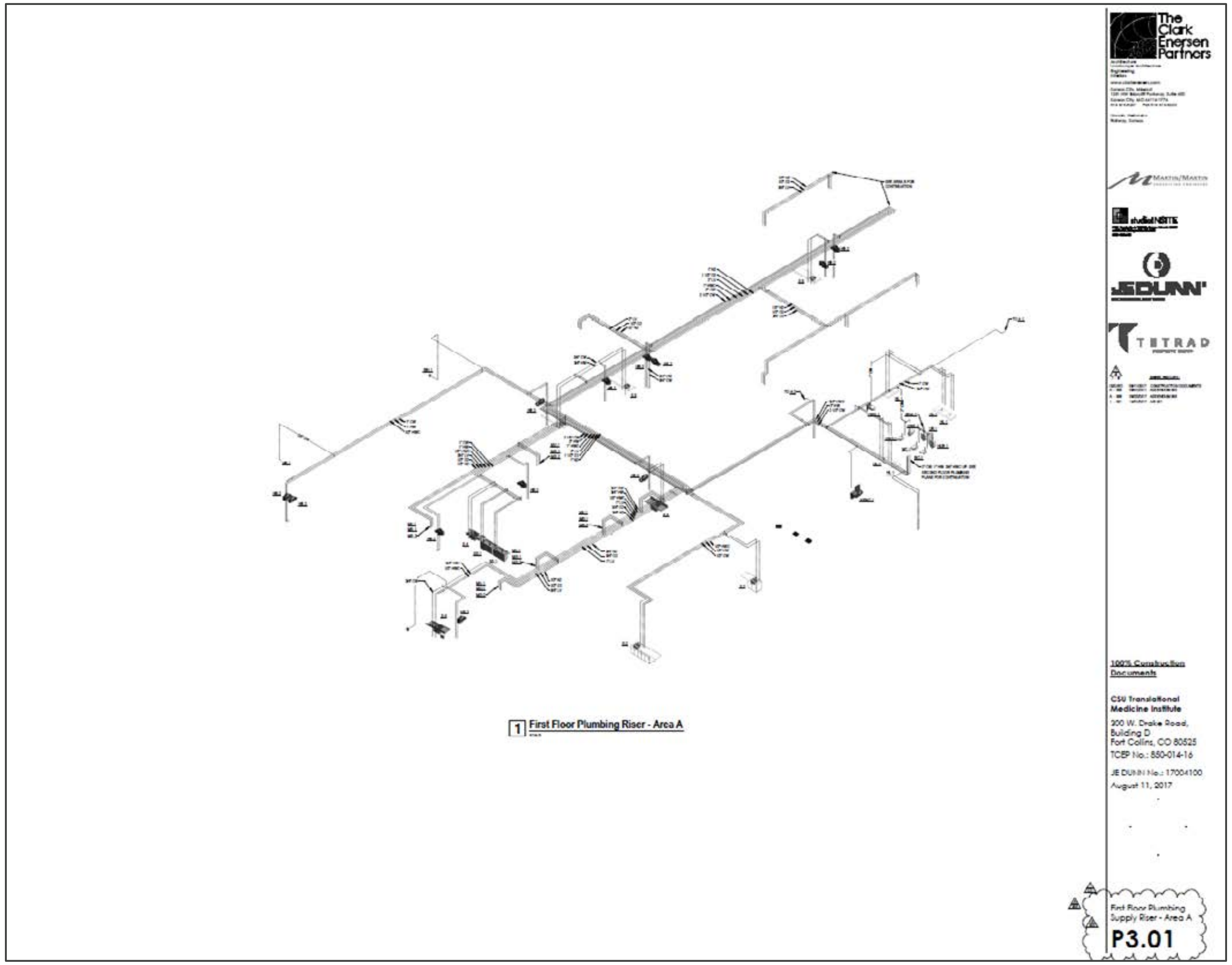




FIRST FLOOR PLUMBING PLAN – AREA A1

FIRST FLOOR PLUMBING SUPPLY RISER – AREA A

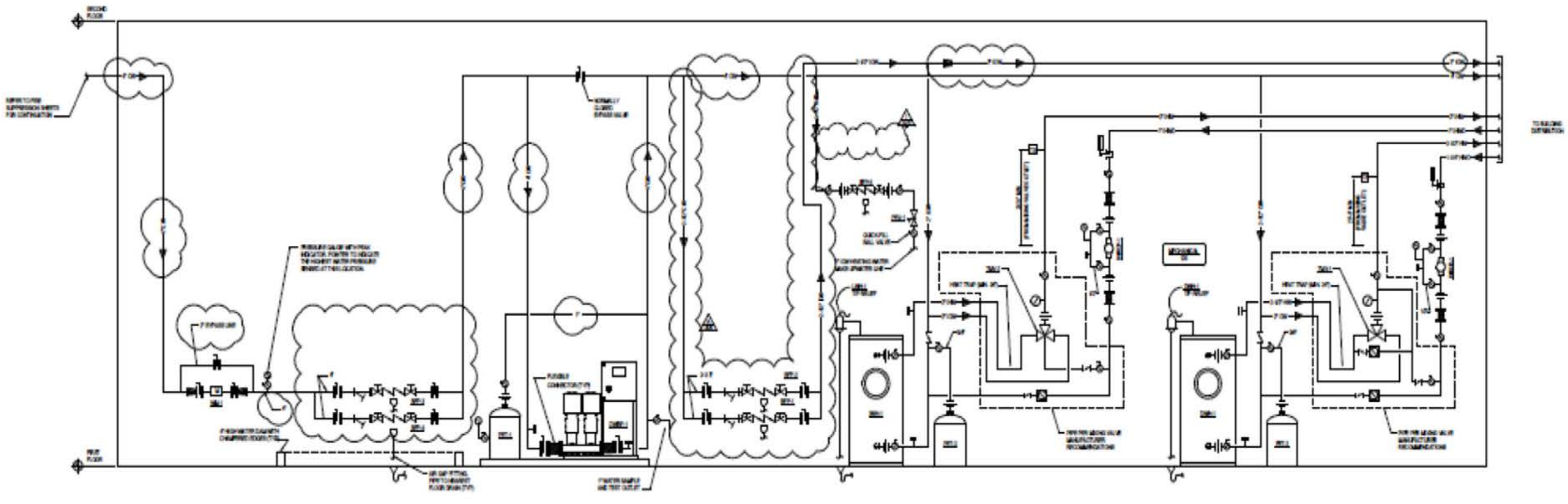




TOPICAL HEADING ADDITIONAL INFORMATION

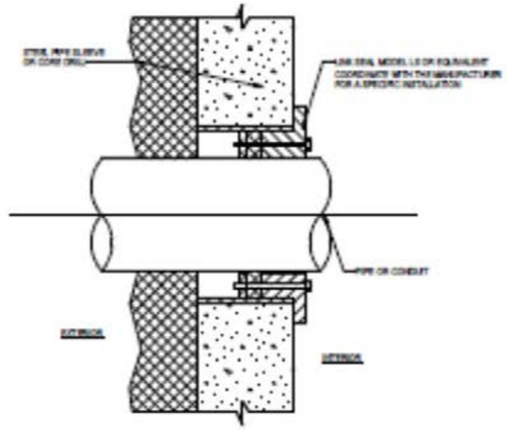
- P4.01 shows the water system piping schematics
- P4.02 shows the Laboratory piping system schematics
- P4.03 shows the natural gas piping system schematic
- P5.01 shows plumbing details, underfloor details, for reference only.
- P5.02 shows plumbing details
- P6.01 shows plumbing schedules, underfloor details, for reference only
- P6.02 – P6.04 shows plumbing schedules

P4.01 THE WATER SYSTEM PIPING SCHEMATICS FOR SINGLE BOOSTER PUMP

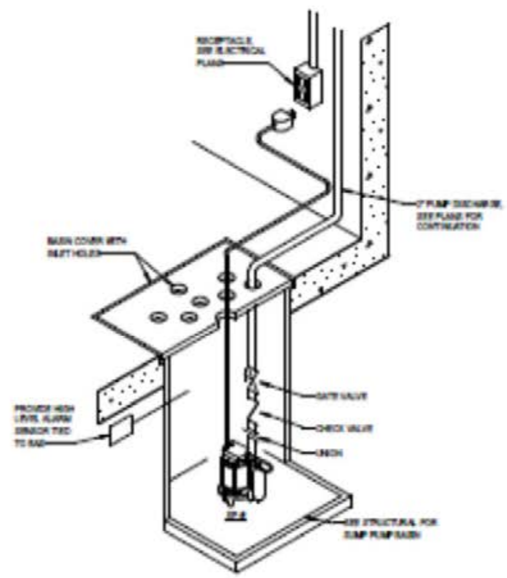


1 WATER SYSTEMS PIPING SCHEMATIC: SINGLE BOOSTER PUMP OPTION

P5.01 SHOWS PLUMBING DETAILS, UNDERFLOOR DETAILS, FOR REFERENCE ONLY

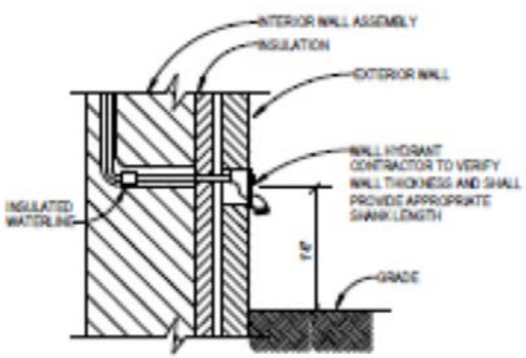


2 SLEEVE/SEAL THRU WALL BELOW GRADE
NO SCALE

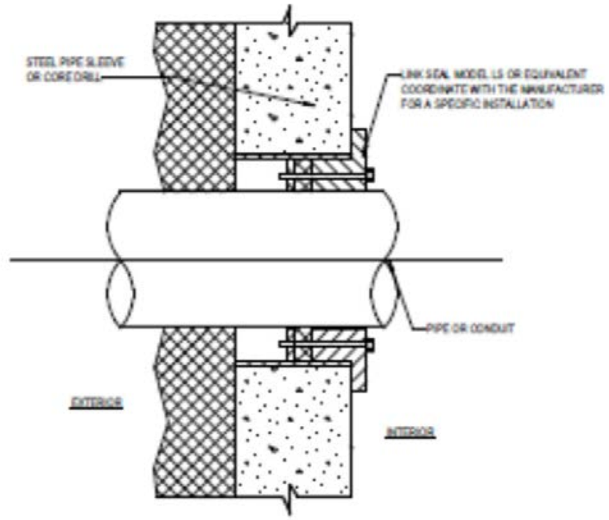


3 ELEVATOR SUMP PUMP DETAIL
NO SCALE

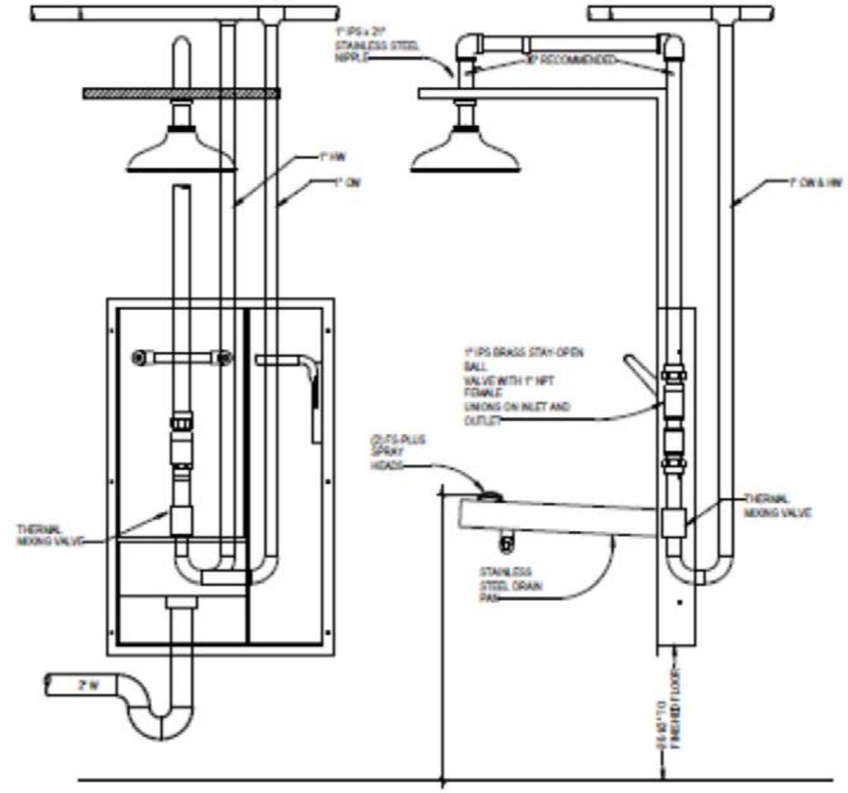
PLUMBING DETAILS



8 **WALL HYDRANT**
NO SCALE



2 **SLEEVE/SEAL THRU WALL BELOW GRADE**
NO SCALE



4 **RECESSED EMERGENCY SAFETY STATION DETAIL**
NO SCALE

P6.02 – P6.04 SHOWS PLUMBING SCHEDULES PLUMBING FIXTURE, ACCESSORY, AND CONNECTION

PLUMBING FIXTURE, ACCESSORY, AND CONNECTION SCHEDULE

MARK:	FUNCTION:		MANUFACTURER AND MODEL:	WASTE:	VENT:	HW:	CW:
SS-1	SCRUB SINK	SINK: FAUCET: TRAP: DRAIN: SUPPLIES:	JUST J-4820 OR APPROVED EQUIVALENT SCRUB SINK , 48" X 20" OVERALL DIMENSIONS, (1) 47" X 16-1/2" 8" DEEP BOWLS, 14 GAUGE, 304 STAINLESS STEEL CONSTRUCTION WITH DRAIN PUNCH FOR J-35-FS DRAIN JUST JS-10 OR EQUIVALENT, SINGLE HOLE, 8-1/2" CAST BRASS SPOUT, 2.5 GPM OUTLET, TEMPERATURE LIMITER, CHROME PLATED WITH JUST JKV-400 KNEE OPERATOR MINIMUM 17 GAUGE CHROME PLATED CAST BODY WITH ESCUTCHEON. INCLUDED WITH SINK CHROME PLATED LOOSE KEYSTOP VALVES WITH LOCK SHIELD CAP AND DEEP ESCUTCHEON PLATES.	1-1/2"	1-1/2"	1/2"	1/2"
MSB-1	MOP SERVICE BASIN	SINK: FAUCET:	FIAT MODEL MSB-2424 OR EQUIVALENT. MOLDED STONE, 24" X 24" X 10" SIZE. PROVIDE COMBINATION DOME STRAINER WITH LINT BASKET, DRAIN BODY. PROVIDE MOP & HOSE HANGER & STAINLESS STEEL WALL GUARDS. MOEN COMMERCIAL MODEL 8124 OR EQUIVALENT. CHROME PLATED 10-1/4" SPOUT WITH VACUUM BREAKER, WALL MOUNTING BRACKET, PAIL HOOK AND 2-1/2" LEVER HANDLES.	3"	2"	1/2"	1/2"
SH-1	SHOWER (HANDICAPPED ACCESSIBLE)	MIXING VALVE: SUPPLIES: DRAIN:	POWERS MODEL E710000100 OR APPROVED EQUIVALENT. THERMAL MIXING (SET TO 110%%DF), 1.5 GPM HANDWASHER ON 24" CHROME ADA WALL GRAB BAR SYSTEM. INTEGRAL TO SHOWER PAN. SEE ARCH. DRAWINGS	2"	1-1/2"	1/2"	1/2"
TMV-3	TEMPERING VALVE	MIXING VALVE:	WATER SAVER MODEL AP3600 OR EQUIVALENT, THERMOSTATIC MIXING VALVE (FACTORY SET TO 85 DEGREES) FOR SINGLE EMERGENCY EYE WASH. UNIT SHALL INCLUDE A BUILT-IN COLD WATER BY-PASS, ROUGH BRONZE FINISH, SOLID BIMETAL THERMOSTAT, LOCKING TEMPERATURE REGULATOR W/ LIMIT STOP FACTORY SET FOR 90 DEG, INTEGRAL CHECK STOPS, AND DIAL THERMOMETER. UNIT SHALL HAVE A FLOW RANGE OF 0.5-6 GPM WITH A MAXIMUM PRESSURE LOSS OF 20 PSI AND COME WITH A FULL 1 YEAR WARRANTY. UNIT SHALL BE CERTIFIED TO ASSE 1071. UNIT SHALL BE CERTIFIED TO MEET LOW LEAD REQUIREMENTS OF WETTED SURFACE AREA CONTAINING LESS THAN 0.25% LEAD BY WEIGHT.			1/2"	1/2"
OD-1	OVERFLOW ROOF DRAIN	DRAIN:	JAY R. SMITH MODEL 1070-CID OR EQUIVALENT, CAST IRON BODY AND DOME, ROOF CLAMPING COLLAR, GRAVEL GUARD AND UNDERDECK CLAMP AND 2" DAM, 16" DIAMETER, SEE PLANS FOR SIZE				
RD-1	ROOF DRAIN	DRAIN:	JAY R. SMITH MODEL 1010Y OR EQUIVALENT, CAST IRON BODY AND DOME, ROOF CLAMPING COLLAR, GRAVEL GUARD, UNDERDECK CLAMP, SUMP RECEIVER, SEE PLANS FOR SIZE				
WB-1	WALL BOX	WALL BOX:	GUY GRAY WB200HA OR EQUIVALENT, GALVANIZED METAL WASHING MACHINE OUTLET BOX WITH PROVIDED SINGLE LEVER VALVE AND HAMMER ARRESTERS, PROVIDE CHECK VALVE ON EACH OUTLET.				1/2"
WCO-1	WALL CLEANOUT	CLEANOUT:	JAY R. SMITH MODEL 4530 SERIES. CLEANOUT T FOR CONCEALED DRAINAGE PIPE GASKET SEAL, BRONZE PLUG, STAINLESS STEEL WALL COVER	(SEE PLANS)			
WH-1	WALL HYDRANT (FREEZEPROOF)	HYDRANT:	WOODFORD MODEL 67 OR EQUIVALENT. BRASS VALVE BODY, CHROME, ANTI-SIPHON VACUUM BREAKER, LOOSE KEY OPERATION SEE NOTE PLUMBING SCHEDULE NOTE #3.				3/4"
WHA-1	WATER HAMMER ARRESTOR	ARRESTOR:	J.R. SMITH HYDROTOL 5010 OR EQUIVALENT. STAINLESS STEEL CONSTRUCTION, PRE-CHARGED COMPRESSION CHAMBER, NON-TOXIC HYDRAULIC FLUID, IN-LINE DESIGN WITH THREADED NIPPLE CONNECTION. SIZE AND INSTALL PER THE PLUMBING AND DRAINAGE INSTITUTE (PDI-WH 201)				

REFER TO ARCHITECTURAL INTERIOR ELEVATIONS FOR FIXTURE MOUNTING HEIGHTS OR MOUNT AT MANUFACTURERS RECOMMENDED HEIGHTS.

PLUMBING SCHEDULE NOTES:

1) MINIMUM SIZE OF UNDER SLAB WASTE/VENT SHALL BE 2".

2) ALL HANDICAPPED LAVATORIES SHALL BE INSTALLED WITH P-TRAP AND SUPPLY INSULATION. PROVIDE TRUEBRO MODEL 102 OR EQUIVALENT P-TRAP INSULATION. HOT AND COLD WATER VALVES AND SUPPLY SHALL BE INSULATED WITH CLOSED CELL VINYL, 3/16" WALL THICKNESS, K-VALUE OF 1.17.

3) CONTRACTOR SHALL VERIFY ALL WALL THICKNESSES AND SHALL ORDER APPROPRIATE OPERATING ROD ASSEMBLIES AS REQUIRED

IMPORTANT NUANCES

- The abbreviations on the first page are not all inclusive
- Some abbreviations may not refer to the first page, but to some item on the plumbing schedules at the back of the P drawings
  - HL-2 on P2.00.D1 is not on the abbreviations page, it is not on P6.0s with HL-1, so an RFI would be needed to see what it was compared to HL-1 on that page
- Make sure that you do not forget to read the notes on all pages
- The drawings you have show contractor markups in red where they questioned the drawings based on past experience or trade custom

FAMILIARIZE YOURSELF WITH THE MATERIALS, AVAILABILITY OF FIXTURES AND SCOPE

- What do the fixtures look like?
- Are there standard fixtures or are they special order with cost premiums?
- What part of the scope is the MEP contractor and what part is noted as belonging to others?
- Are there references to “manufactures instructions” on the plans or in the specifications?
- Do the plans or specifications define start-up procedures, do they agree?

HOW TO LEARN ABOUT FIXTURES

- One of the issues you may find as you look at plumbing plans is what are the fixtures that are being used and what do they do
- In many cases you can look at the broader context of the situation for some guidance
  - Look at P2.02.C2, find the dry chemical storage room (244). In this room look for FH-1. What is this piece of equipment?
- Turn to your schedules, P6.03 and find FH-1. It is a Fume Hood.
  - In context this makes sense as dry chemicals give off fumes. The hood vents these. Also note the scope shift to the mechanical (CSI Division 23) contractor
- While we do not have a model number, you could look online to learn more about fume hoods

WHAT SOME OF THE PARTS LOOK LIKE

- Neutralization Tank – NT-1
  - The most common and cost effective method of **neutralization is** the process where **acidic** chemical waste **is** brought into contact with calcium carbonate in the form of limestone chips. The calcium carbonate undergoes a chemical reaction with the waste flow which **is** then discharged into the sewer at acceptable pH levels.

WHAT SOME OF THE PARTS LOOK LIKE

HEWC-1: Electric water cooler with bottle filler (Handicap accessible)

You can find this fixture on P6.02. There is a manufacturer and model number given. With this you can access retail price, distributors, installation instructions, etc.

This type of research in invaluable on the jobsite when talking to the MEP sub, framers, electricians, etc. As a GC, knowledge about all your trades and what they do makes your project run smoother with less items on the punch list

SCHEDULE EXAMPLE FROM THE TMI PROJECT – P6.01

PLUMBING FIXTURE, ACCESSORY, AND CONNECTION SCHEDULE

MARK:	FUNCTION:		MANUFACTURER AND MODEL:	WASTE:	VENT:
FCO-1	FLOOR CLEANOUT	CLEANOUT:	JAY R. SMITH MODEL 4031 SERIES. CAST IRON CLEANOUT, ROUND ADJUSTABLE SCORIATED SECURED NICKEL BRONZE TOP, FLASHING FLANGE WITH FLASHING CLAMP, BRONZE PLUG.	(SEE PLANS)	
FD-1	FLOOR DRAIN	DRAIN:	WADE MODEL 1103STD5. CAST IRON BODY WITH FLANGE, INTEGRAL REVERSIBLE FLASHING COLLAR, SEEPAGE OPENINGS, 5" TOP SIZE, NICKEL BRONZE STRAINER. PROVIDE WITH TRAP SEAL.	(SEE PLANS)	(SEE PLANS) (SEE NOTE 1)
FD-2	FLOOR DRAIN	DRAIN:	WADE MODEL 1100-SS-STDSS. STAINLESS STEEL BODY WITH FLANGE, INTEGRAL REVERSIBLE FLASHING COLLAR, SEEPAGE OPENINGS, 5" TOP SIZE, STAINLESS STEEL STRAINER. PROVIDE WITH TRAP SEAL.	(SEE PLANS)	(SEE PLANS) (SEE NOTE 1)
FS-1	FLOOR SINK	DRAIN:	JOSAM 49580A-NB. CAST IRON BODY WITH FLANGE, INTEGRAL REVERSIBLE COLLAR, SEEPAGE OPENINGS, 10" DEEP, 12" ROUND WITH 3/4 GRATE, NICKEL BRONZE TOP WITH CAST IRON DOME STRAINER. PROVIDE WITH TRAP SEAL.	4"	2"
FS-2	FLOOR SINK	DRAIN:	JOSAM MODEL 42630 OR EQUIVALENT 12" ROUND 304 STAINLESS STEEL FLOOR SINK, 6" SUMP DEPTH. ANTI-TILT SKIRTED GRATE WITH PERFORATIONS OUTLET. AND BOTTOM NO-HUB OUTLET. PROVIDE WITH SS DOME BOTTOM STRAINER, AND SS SEDIMENT BUCKET.	(SEE PLANS)	(SEE PLANS) (SEE NOTE 1)
OI-1	OIL INTERCEPTOR	INTERCEPTOR:	JOSAM 60506-EST-8 OR EQUIVALENT STEEL INTERCEPTOR WITH INTEGRAL STORAGE COMPARTMENT. PROVIDE WITH DIAMOND PLATE COVER, SEDIMENT BASKET, EXTENSION TO FINISHED FLOOR PROVIDE GRADE RINGS AS REQUIRED.	4"	2"

REFER TO ARCHITECTURAL INTERIOR ELEVATIONS FOR FIXTURE MOUNTING HEIGHTS OR MOUNT AT MANUFACTURERS RECOMMENDED HEIGHTS.

PLUMBING SCHEDULE NOTES:

1) MINIMUM SIZE OF UNDER SLAB WASTE/VENT SHALL BE 2".

PLUMBING SPECIFICATIONS, TMI DENOTES PROJECT SPECIFIC NUMBER/CATEGORY USE

- CSI Division 15 (1995 Masterformat)
  - 15050 Basic Mechanical Materials and Methods
  - 15100 Building Service Piping
  - 15200 Process Piping
  - 15300 Fire Protection Piping
  - 15500 Heat-Generation Equipment
  - 15600 Refrigeration Equipment
  - 15700 HVAC Equipment
  - 15800 Air Distribution
  - 15900 HVAC Instrumentation and Controls
  - 15950 Testing, Adjusting, and Balancing
- CSI Division 22 (2004 Masterformat)
  - 22 05 00 Basic Plumbing Requirements
  - 22 10 00 Plumbing Piping (TMI)
  - 22 21 23 Plumbing Pumps (TMI)
  - 22 20 00 Unassigned
  - 22 30 00 Plumbing Equipment
  - 22 40 00 Plumbing Fixtures
  - 22 50 00 Pool & Fountain Plumbing Sys
  - 22 61 00 Gas & Vacuum Sys for Labs (TMI)
  - 22 70 00 Unassigned
  - 22 80 00 Unassigned

HOW TO USE THE SPECIFICATIONS

- The specifications should be reviewed at a high level prior to bidding
  - During the bidding process the specifications should be reviewed at the detail level to ensure no cost or quality related requirement is overlooked
- As you initially work through the plans you should also review each section of the specifications as they relate to the focus of the scope of work
- Specification review is just as important as the estimate and schedule components of a bid, it impacts both areas

THE ROLE OF SPECIFICATIONS

- Like the plans, the specifications are broken into topical areas
  - The Basic Plumbing Requirements section 22 05 00 and relay important information to the contractor.
- Division 1 is referenced as well and is applicable to all sections of Division 22
- If the contractor fails to ask for clarification on an issue, the contract requires that the more expensive method will be used
- The contractor is responsible for all permits and fees

PLUMBING SPECIFICATIONS – TMI

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TCEP Project No.: 850-014-16
JE Dunn Project No.: 17004100

SECTION 22 05 00 - BASIC PLUMBING REQUIREMENTS

1. GENERAL

1.1 SECTION INCLUDES

A. This section describes Basic Mechanical Requirements required to provide for a complete installation of all mechanical systems for this project. This section shall apply to all other Division 22 specification sections as well as all work shown on the drawings.

B. It is the intent of the Mechanical Division of the Specifications that all mechanical work specified herein be coordinated as required with the work of all other Divisions of the Specifications and Drawings so that all installations operate as designed.

C. All systems shall be completely assembled, tested, adjusted and demonstrated to be ready for operation to the satisfaction of the Owner's representative.

D. The Contractor shall note that, in some cases, piping as shown on the Drawings provide general location and routing information only. The Contractor shall be responsible for providing interference-free systems with proper clearance to facilities and equipment.

E. Where the word "provide" is used, it shall mean "furnish and install" unless otherwise noted or specified.

F. Note that the words "mechanical" and "plumbing" are used interchangeably throughout the Division 22 and 23 specification sections.

1.2 RELATED SECTIONS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 1 specification sections, apply to work of this section and all other sections of Division 22.

1.3 DESCRIPTION OF WORK

A. The work included under this section consists of providing all labor, materials, supervision, and construction procedures necessary for the installation of the complete mechanical systems required by these specifications and/or shown on the drawings of the contract.

B. The Contract Drawings are shown in part diagrammatic intended to convey the scope of work, indicating the intended general arrangement of equipment, piping fixtures, etc. The Contractor shall follow the drawings in laying out work and verify clearances for the installation of the materials and equipment based on the dimensions of actual equipment furnished. Whenever a question exists as to the exact intended location of outlets or equipment, obtain instructions from the Architect/Engineer before proceeding with the work.

BASIC PLUMBING REQUIREMENTS 22 05 00 - 1

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SECTION 220513 – ELECTRICAL REQUIREMNTS FOR PLUMBING EQUIPMENT

1. GENERAL

1.1 SECTION INCLUDES

A. Electrical Requirements for:

1. Motors
2. Starters, Electrical Devices, and Wiring
3. Manual Motor Starters
4. Motor Connections
5. Capacitors
6. Safety Switches

1.2 REFERENCE SECTION 22 05 00 FOR THE FOLLOWING:

A. Quality assurance.

1. Electrical components and materials shall be UL labeled and listed.

B. References.

1. The design, manufacture, testing and method of installation of all equipment and materials furnished under the requirements of this specification section shall conform to the following:

a. AFBMA 9 – Load Ratings and Fatigue Life for Ball Bearings.
b. AFBMA 11 – Load Ratings and Fatigue Life for Roller Bearings.
c. ANSI/IEEE 112 – Test Procedure for Polyphase Induction Motors and Generators.
d. ANSI/NEMA Standard MG 1 – Motors and Generators.
e. ANSI/NFPA 70 - National Electrical Code.
f. NEMA Standard ICS 2 – Industrial Control Devices, Controllers, and Assemblies.
g. NEMA Standard 250 – Enclosures for Electrical Equipment.
h. NEMA Standard KS 1 – Enclosed Switches.

C. Submittals.

1. No separate submittal is required. Submit product data for motors, starters, and other electrical components with submittal data required for the equipment for which it serves, or as required by the individual equipment specification sections.

D. Operation and maintenance manuals.

E. Project record documents.

F. Delivery, storage, and holding

ELECTRICAL REQUIREMENTS FOR PLUMBING EQUIPMENT 22 05 13 - 1

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SECTION 22 08 00 – COMMISSIONING OF PLUMBING

1. GENERAL

1.1 DESCRIPTION

A. Commissioning is a systematic process of ensuring that all building systems perform interactively according to the owner's project requirements and operational needs. The commissioning process shall encompass and coordinate the traditionally separate functions of system documentation, equipment startup, control system calibration, testing adjusting and balancing, performance testing and training. Commissioning during the construction phase is intended to achieve the following specific objectives:

1. Verify that applicable equipment and systems are installed according to the manufacturer's recommendations and to industry accepted minimum standards and that they receive adequate operational checkout by installing contractors.
2. Verify and document proper functional performance of equipment and systems.
3. Verify that O&M documentation left on site is complete.
4. Verify that the Owner's operating personnel are adequately trained.

1.2 RELATED WORK

A. All installation, testing and start-up procedures and documentation requirements specified within Division 22.

B. Section 01 91 13 – General Commissioning Requirements.

C. Section 23 08 00 – Commissioining of HVAC.

D. Section 26 08 00 – Commissioning of Electrical

1.3 ABBREVIATIONS AND DEFINITIONS

A. A/E: Design Professional

B. ASI: Architectural Supplemental Instruction

C. BAS: Building Automation System

D. CxA: Commissioning Authority

E. CC: Controls Contractor

F. Cx: Commissioning

COMMISSIONING OF PLUMBING 22 08 00 - 1

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PLUMBING SPECIFICATIONS – TMI

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SECTION 22 21 23 - PLUMBING PUMPS

1. GENERAL

1.1 SECTION INCLUDES

A. Domestic and industrial water booster pump packages.

B. In-line circulators.

1.2 REFERENCE SECTION 22 05 00 FOR THE FOLLOWING:

A. References.

B. Performance requirements.

1. Ensure pumps operate at specified system fluid temperatures without vapor binding and cavitation, are non-overloading in parallel or individual operation, and operate within ± 10 percent of scheduled performance and published operating curve.

C. Submittals.

D. Operation and maintenance data.

E. Qualifications.

F. Delivery, storage and handling.

G. Extra materials.

1. Provide one set of mechanical seals and gaskets for each pump.

H. Warranty

1. Products included in this specification section shall have a 1-year warranty.

2. PRODUCTS

2.1 DOMESTIC AND INDUSTRIAL WATER BOOSTER PUMP PACKAGES

A. See pump schedule on drawings for requirements.

PLUMBING PUMPS 22 21 23 - 1

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SECTION 22 30 00 - PLUMBING EQUIPMENT

1. GENERAL

1.1 SECTION INCLUDES

A. Domestic and industrial water heaters.

B. Thermal mixing valves.

1.2 REFERENCE SECTION 22 05 00 FOR THE FOLLOWING GUIDELINES

A. References

B. Submittals

1.3 QUALITY ASSURANCE

A. See Section 22 05 00.

B. Perform Work in accordance with State and Local standards.

C. Provide pumps with manufacturer's name, model number, and rating/capacity identified.

D. Ensure products and installations of specified products are in conformance with recommendations and requirements of the following organizations:

1. National Sanitation Foundation (NSF).
2. American Society of Mechanical Engineers (ASME).
3. National Board of Boiler and Pressure Vessel Inspectors (NBBPVI).
4. National Electrical Manufacturers' Association (NEMA).
5. Underwriters Laboratories (UL).

E. Ensure pumps operate at specified system fluid temperatures without vapor binding and cavitations, are non-overloading in parallel or individual operation; operate within 25 percent of midpoint of published maximum efficiency curve.

1.4 COORDINATION

A. Coordinate sizes and locations of concrete bases with actual equipment provided.

2. PRODUCTS

2.1 Refer to Plumbing Equipment Schedules for performance requirements.

PLUMBING EQUIPMENT 22 30 00 - 1

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SECTION 22 10 00 - PLUMBING PIPING

1. GENERAL

1.1 SECTION INCLUDES

A. Pipe and pipe fittings.

B. Valves.

C. Sanitary waste and vent piping system.

D. Acid waste and vent piping system.

E. Water piping systems.

F. Storm water piping system.

G. Natural gas piping system.

1.2 REFERENCE SECTION 23 05 00 FOR THE FOLLOWING:

A. Quality assurance.

1. Valves: Manufacturer's name and pressure rating marked on valve body.

B. References

C. Submittals

D. Operation and maintenance manuals.

1. AWWA C651 disinfection report.
2. Valve schedule.

E. Project record documents

1. All valves shall be numbered with a brass tag and a schedule shall be submitted with valve number, purpose, location, and normal operating position. Valve schedule shall be incorporated into the as-built drawings, mounted in a protected form in mechanical rooms, and in the O&M manual.

F. Delivery, storage, and handling.

PLUMBING PIPING 22 10 00 - 1

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MECHANICAL SUSTAINABILITY: MOBY ARENA GEO-X PROJECT SITE VISIT

CON 371 – Mechanical and Plumbing Systems

LEARNING OUTCOMES

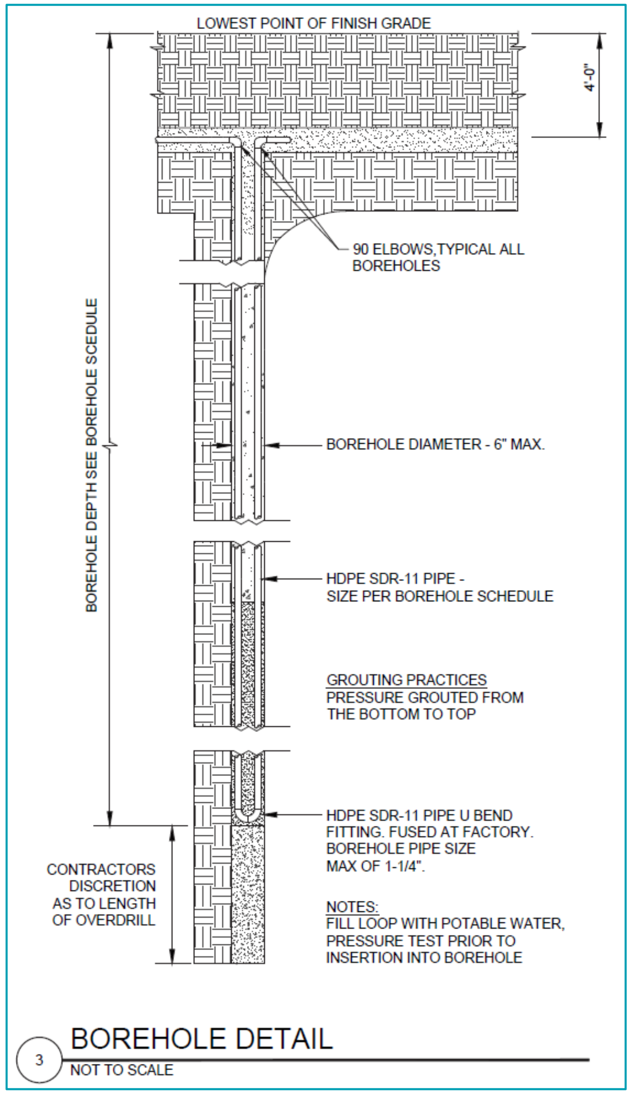
- By the end of this lesson, students will be able to:
  - Review the drawings and information provided in the Geothermal Borefield Plans for the Moby Arena Geo-X project on the CSU Campus
  - Recognize the issues involved with selective demolition, and mechanical and plumbing upgrades to an existing building built in the 1960's
  - Understand the installation process for a large geothermal heating and cooling system

WHAT ARE GEOTHERMAL HEAT PUMPS?

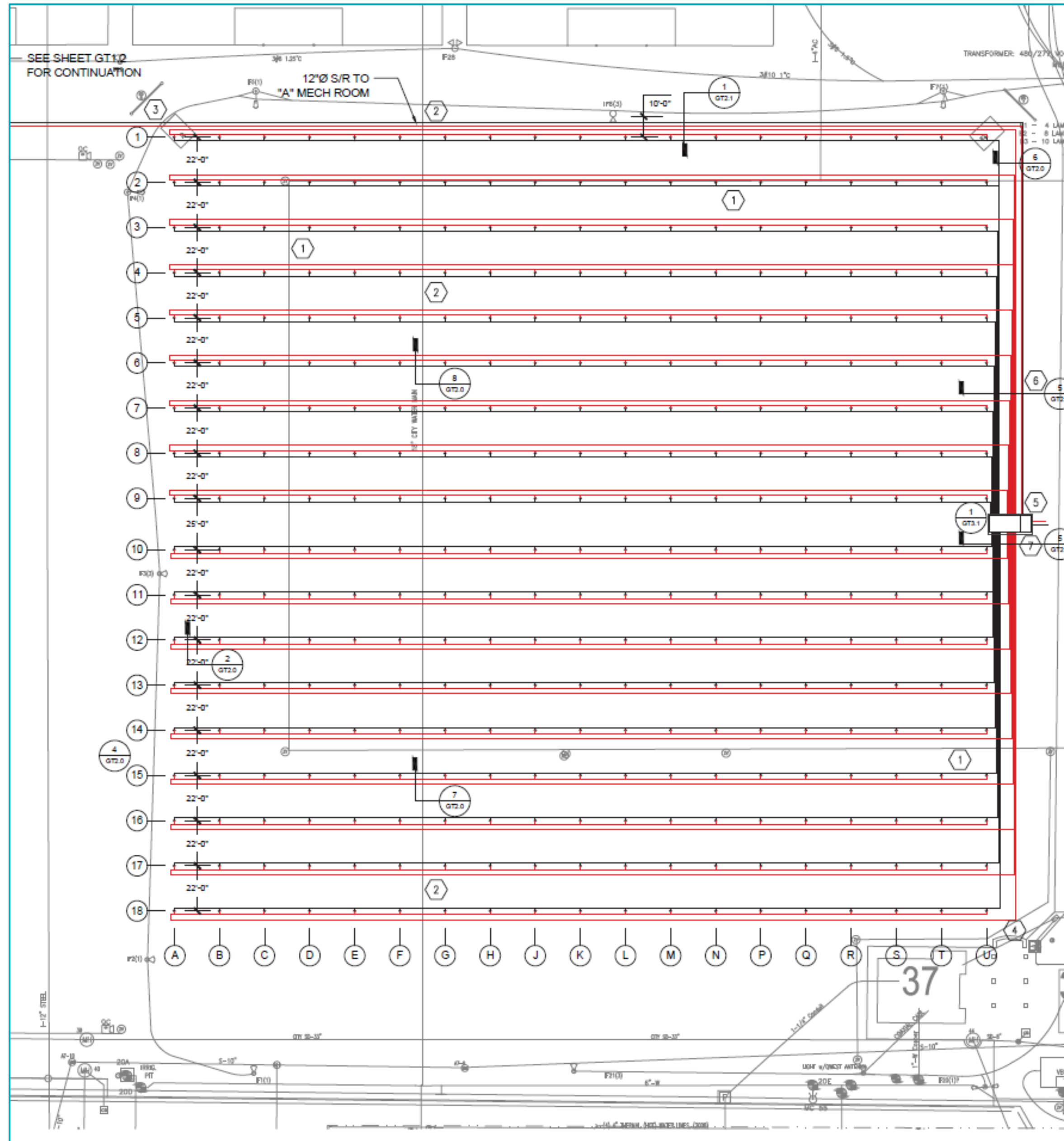
- GHPs transfer heat to and from the ground for heating and cooling purposes in homes and buildings
- GHPs use sub-surface heat to transfer heat to/from a building
- Sub-surface heat stays constant and helps lower the delta-T
- GHPs can be 30-60% more efficient than traditional heating and cooling split-systems

WHAT ARE GEOTHERMAL HEAT PUMPS?

- Right, red lines, is the borefield layout; 342 wells (Sheet GT1.0)
- Center is the borehole detail; 550’ deep (Sheet GT2.0)
- **[Energy 101: Geothermal Heat Pumps (YouTube video)]**



BOREHOLE DETAIL
NOT TO SCALE



1 MOBY GEOTHERMAL HEAT EXCHANGER SITE PLAN

MOBY GEO-X DESCRIPTION OF WORK

The scope of this project includes upgrading various areas of the Moby Complex with geothermal systems. This will require the selective demolition of pipe related to the existing system as well as existing ceilings, walls, and some floor penetrations. Where demolition occurs, new building elements will be constructed to match the existing adjacent locations. Any demolished elements that require a fire rating will be replaced with a system match the fire rating.

Two mechanical rooms (AN114 and A115B) will require 1 hour rated partitions at the interior walls due to the equipment in them. As required per the International Building Code Table 509, any furnace room where any piece of equipment is over 400,000 BTU per hour input requires a 1 hour rating or provide an automatic sprinkler system. There currently is no existing sprinkler system and as a result the walls and penetrations through them will be 1 hour rated. These are existing walls constructed of 10" thick cast in place concrete. It is understood that these walls provide the required 1 hour rating per the International Building Code Tablel 721.1(2). Any penetrations through the walls of these rooms are required to maintain that rating. In addition, the doors into these rooms will have a 90 minute rating.

In addition, a new 85 square foot electrical room will be constructed adjacent to the exterior wall of mechanical room AN114. This electrical room will have two exits directly to the exterior of the building.

GEOTHERMAL BOREFIELD GENERAL NOTES

(SHEET GT0.0)

1. All ground heat exchanger work shall be installed only by an international ground source heat pump association (IGSHPA) accredited or IGSHPA/NATE certified contractor. Contractor shall maintain copies of said documents on file at job site during construction for one (1) site drilling superintendent and one (1) site fusion headering superintendent and shall maintain current status with IGSHPA registrations. Submissions are required, see specifications for documentation requirements.
2. All ground heat exchanger installation work shall conform to all standards and procedures set forth by the international ground source heat pump association (IGSHPA) and local governing agencies.
3. Contractor shall contact utility location service prior to any excavation to mark underground utilities.
4. Contractor shall be responsible for repairing any damage that occurs during drilling to any utilities that are shown on any drawings included in the project or have been identified in the utility locate. If the contractor damages any lines that have not been identified in either drawings or by the locate, then the owner is responsible for repairs.
5. All pipe turns shall not be less than the minimum bend radius of the pipe manufacturer's specifications, except with use of 90°f elbow pipe fittings
6. All HDPE piping connections shall be fused by a qualified IGSHPA contractor and performed in accordance to ASTM d2657. Electrofusion joints are not acceptable.
7. Provide metallic locating tape over all ground heat exchanger piping for underground surveying and marking. Marking tape shall be buried minimum of 6“ below grade for piping in all trenches. Tracer wire shall be in continuous length for each run of nonmetallic pipe. Provide tracer wire system with locator device for locating borefield.
8. All borehole spacing shall be no less than ±1 foot of specified borehole spacing in borehole schedule. Final borehole locations shall be surveyed. Surveyed locations shall be submitted to engineer for approval prior to backfilling and/or compaction of trenches. In the event borehole spacings are not properly maintained, loop contractor shall be responsible for providing additional number of boreholes at their specified depth to match the number of boreholes that do not meet the spacing requirements.

GEOTHERMAL BOREFIELD GENERAL NOTES

(SHEET GT0.0)

9. Drilling contractor shall be responsible for maintaining individual borehole circuit installation for the specified length of the borehole. In the event individual circuits do not maintain specified depth, drilling contractor shall be responsible for notifying engineer of record prior to taking action. Engineer of record shall determine final course of action.
10. Ground loop contractor shall be responsible for ground loop system fill, flush, and purging, and antifreeze mixing (25% propylene glycol).
11. Ground loop contractor shall coordinate with testing, adjusting, and balancing (TAB) contractor for final flow balance of each header circuit where required flow balance devices are shown. Flow balancing requirements of each circuit at header manifold shall be executed by TAB contractor. General TAB contractor requirements shall be outlined in mechanical specification.
12. All borehole piping stub-ups shall be properly capped and sealed. Duct tape is not allowed and is not considered acceptable sealing method.
13. Excavation contractor shall backfill trench with coarse sand 6" above and below piping in the event rocks or other debris are present that are greater than 1" in size. Trench cuttings shall be separated between fines and shall be separated from larger debris such that excavation contractor may backfill entire trench with the fines of trench cuttings, hydrating as necessary for compaction requirements of parking lot or landscaping. Once covered 6" above, all larger debris cuttings can be used.
14. Excavation contractor shall compact all trench areas shall be to 90% compaction to prevent pipe damage in traffic and non-traffic areas.
15. Contractor shall follow specification sections 23 57 33, 23 57 33.16 and 23 57 33.19.

STARTING BOREFIELD WELLS

TYPICAL DRILL RIG

Pipe handling cable. In some of the videos you can see this in use

Borepipe

1110’ roll of well pipe

Guide rod for well pipe and grouting tube

RIG AND SUPPORT EQUIPMENT

Green pipe removing spoils from bore

Shaker table
You can see this in operation in one of the videos

Circular pipe rack

Bore spoils from shaker table

Liquid containment box

White hose supplying boring water

PLACING LAST SECTION OF PIPE TO REACH 550FT DEPTH

Last pipe to hit the required depth

Water storage tanks

SPECIALIZED EQUIPMENT

Track mounted spool reel for unrolling well pipe. One of many different styles seen on this project.

1-¼" EARTH LOOP PIPE

Note the length is exactly twice the depth of the bore. This is special order material so it could be a long lead item.

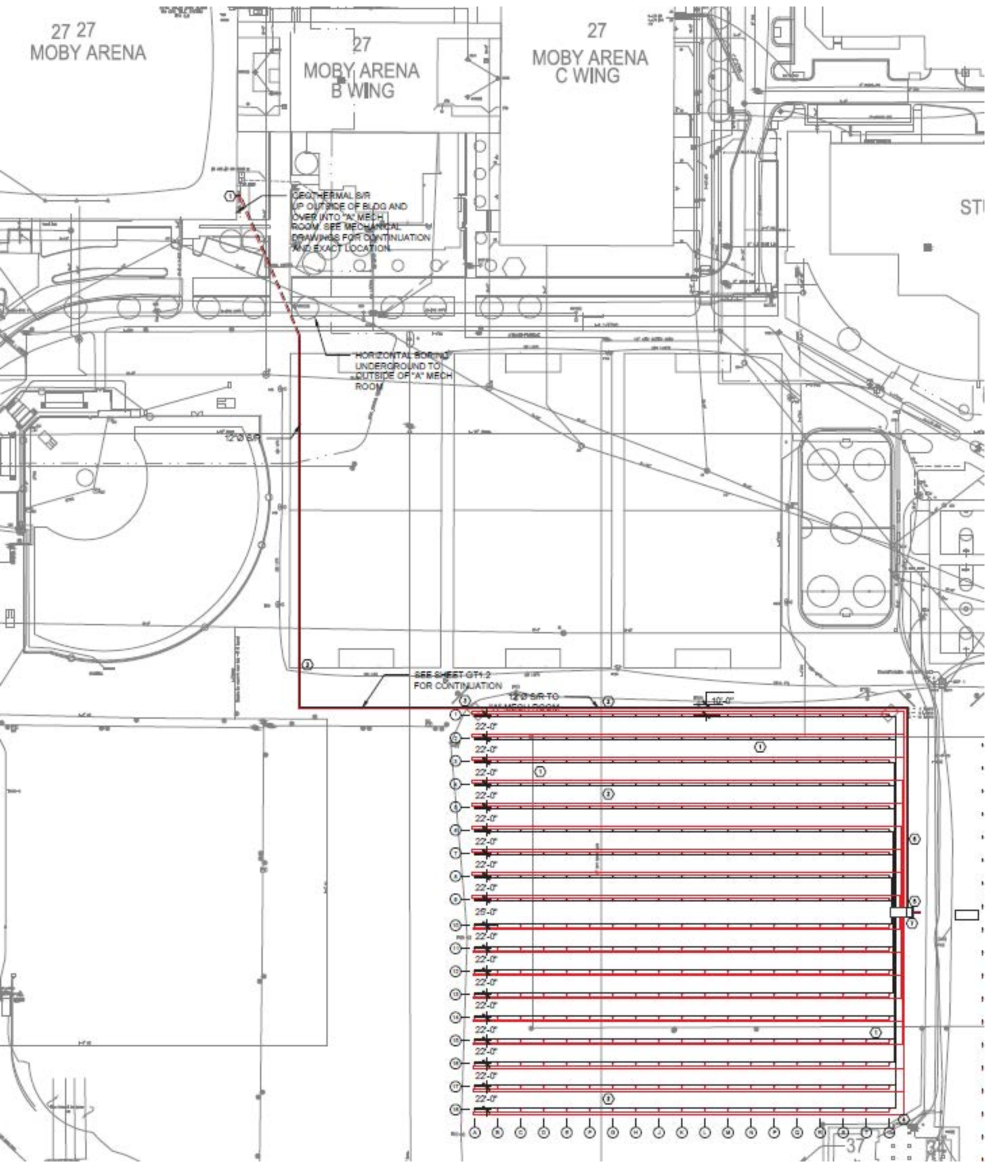
MISCELLANEOUS DRILLING SUPPLIES

Diamond studded drill bit, industrial diamonds, but still expensive.

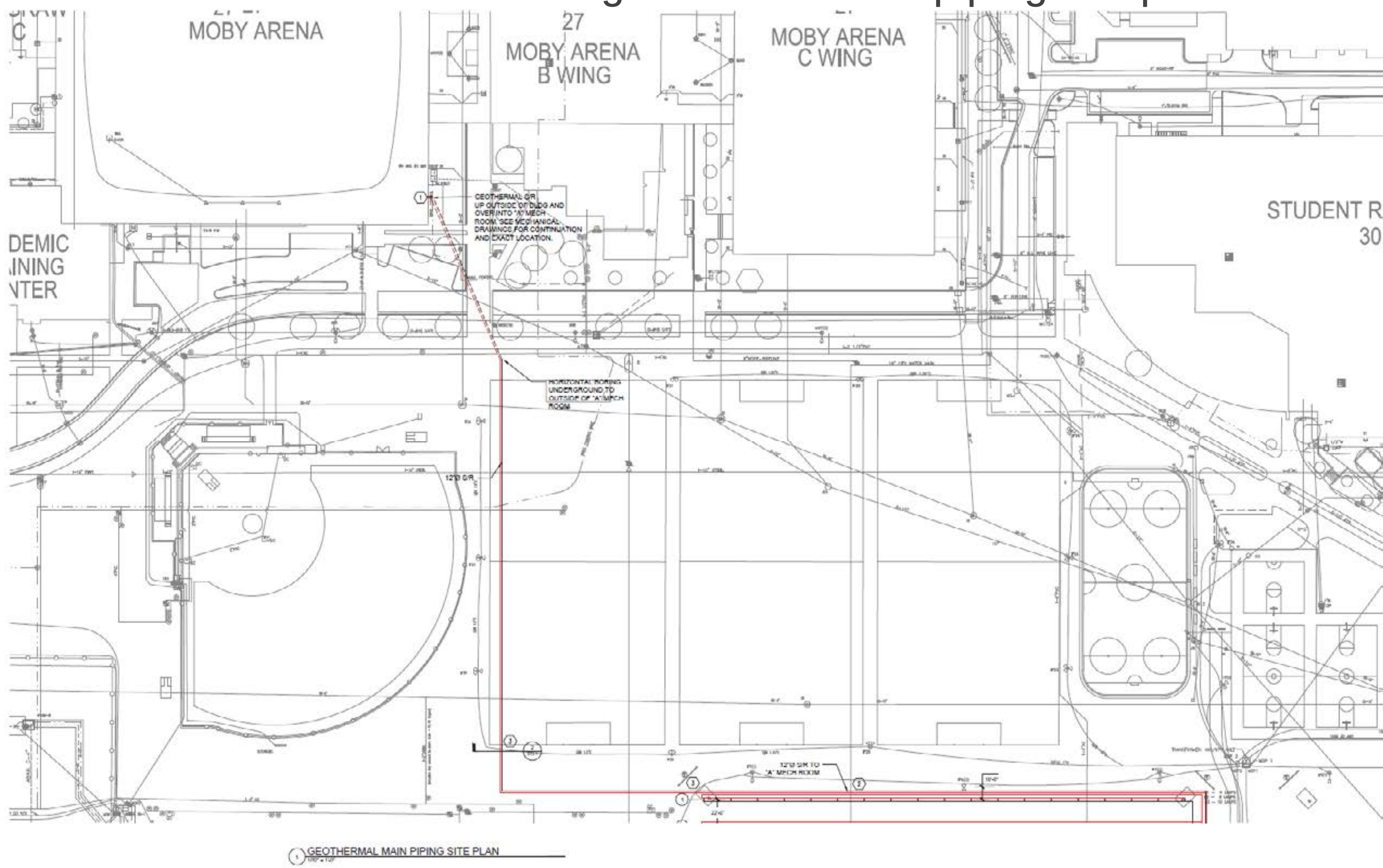
DRY MIX GROUT

FROM THE FIELD TO THE MOBY COMPLEX

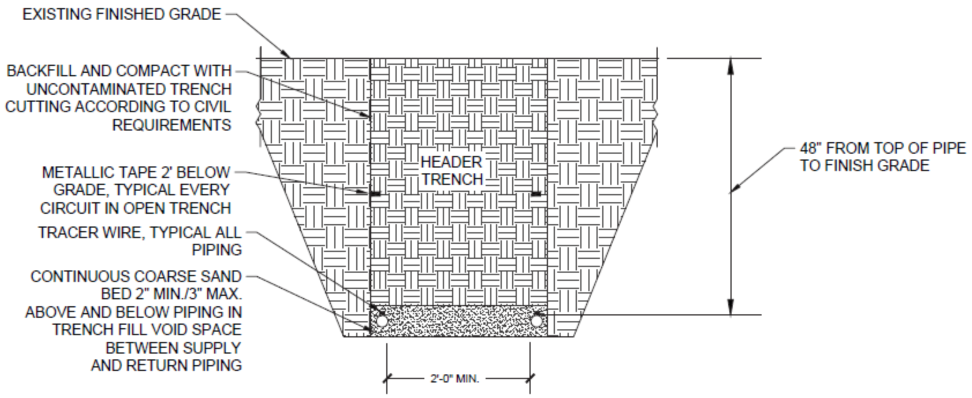
GT1.0 shows the overall heat exchanger site plan



GT1.2 shows the geothermal main piping site plan

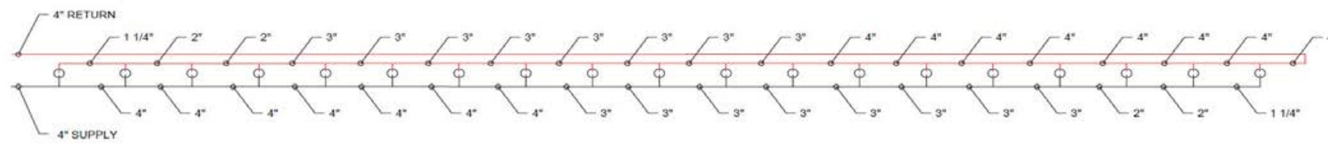


TRENCH AND MANIFOLD DETAILS

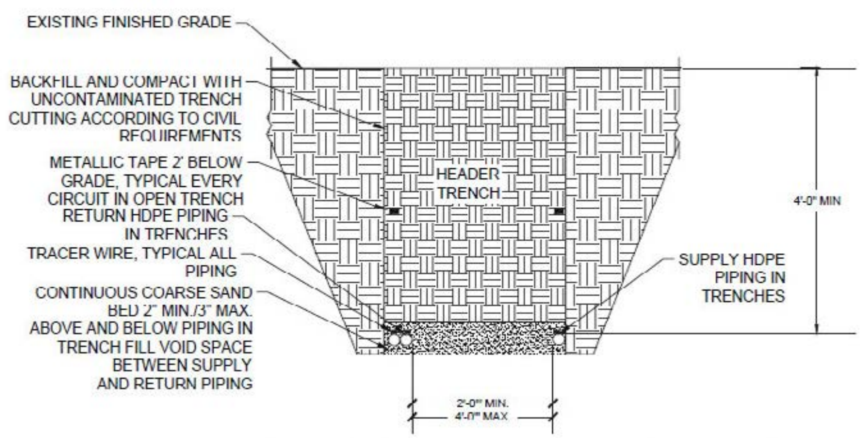


1 TYPICAL TRENCH PIPING DEPTH DETAIL
NOT TO SCALE

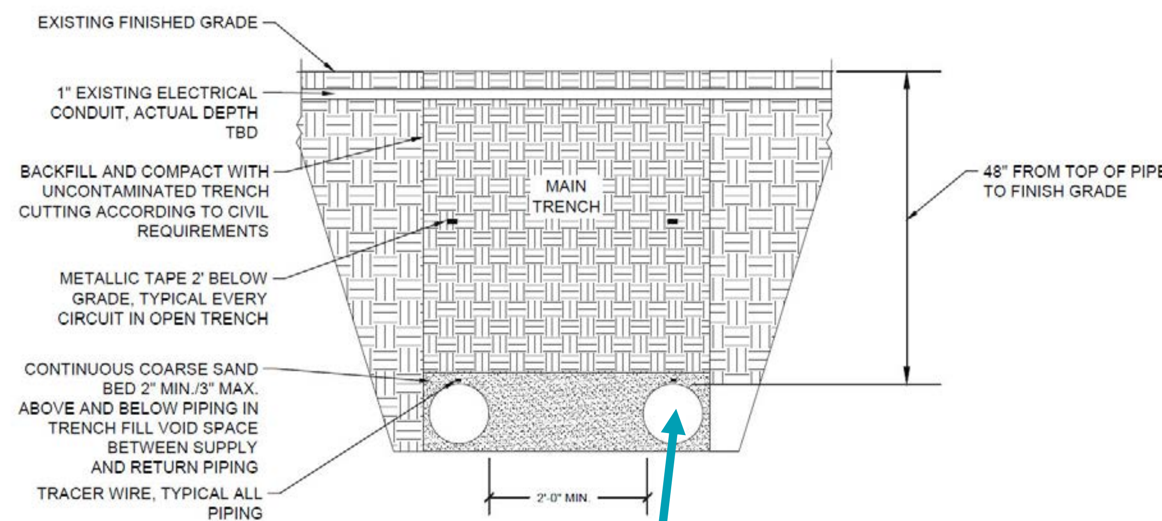
The 342 wells are connected to a manifold by row and area



4 TYPICAL HEADER DETAIL
NOT TO SCALE



2 TYPICAL CIRCUIT TRENCH SECTION DETAIL
NOT TO SCALE



2 TYPICAL MAIN PIPING DEPTH DETAIL
NOT TO SCALE

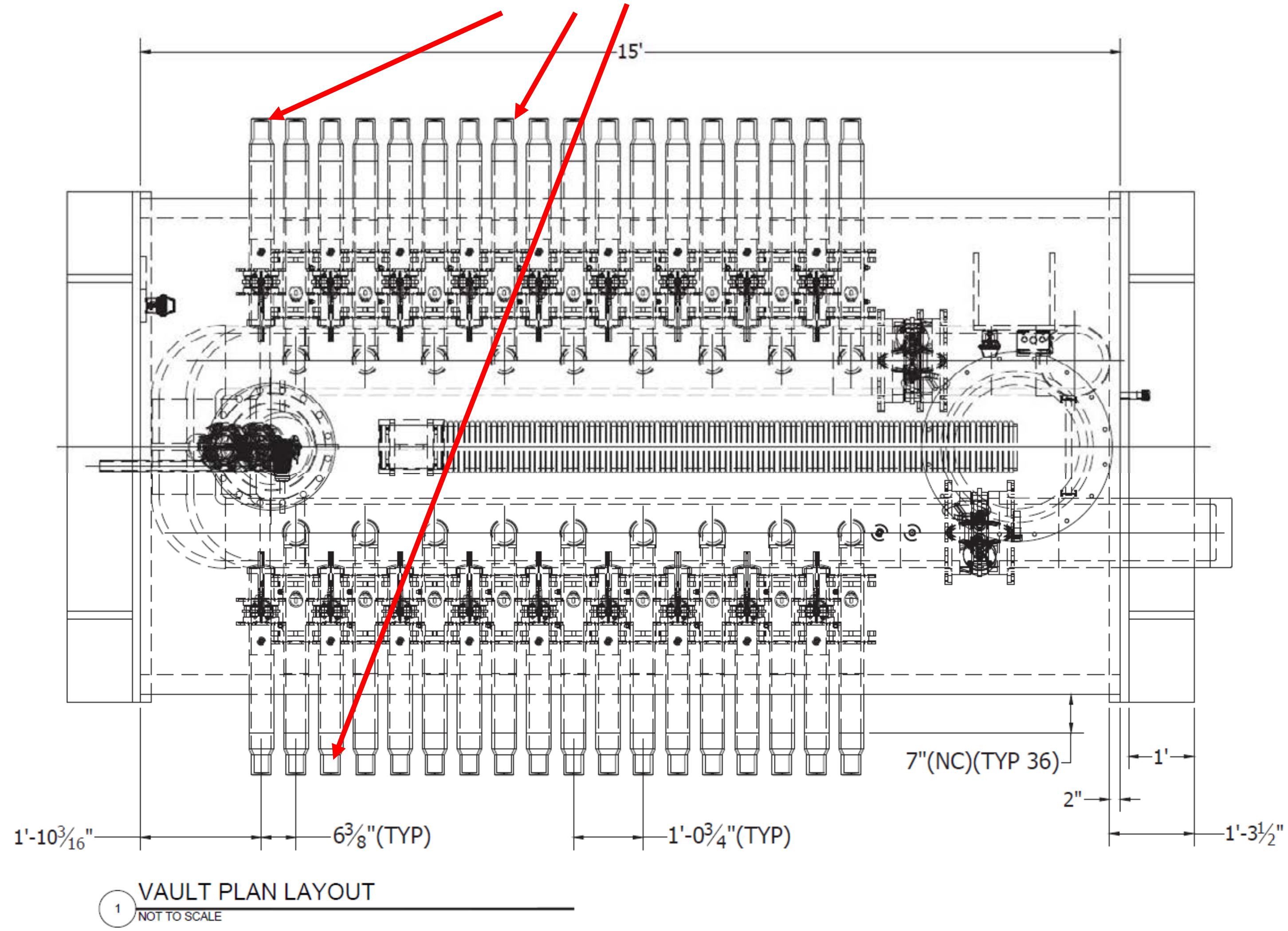
GT2.0 and GT2.1 shows Geothermal trench and Manifold details

Main lines to Moby are 12” diameter

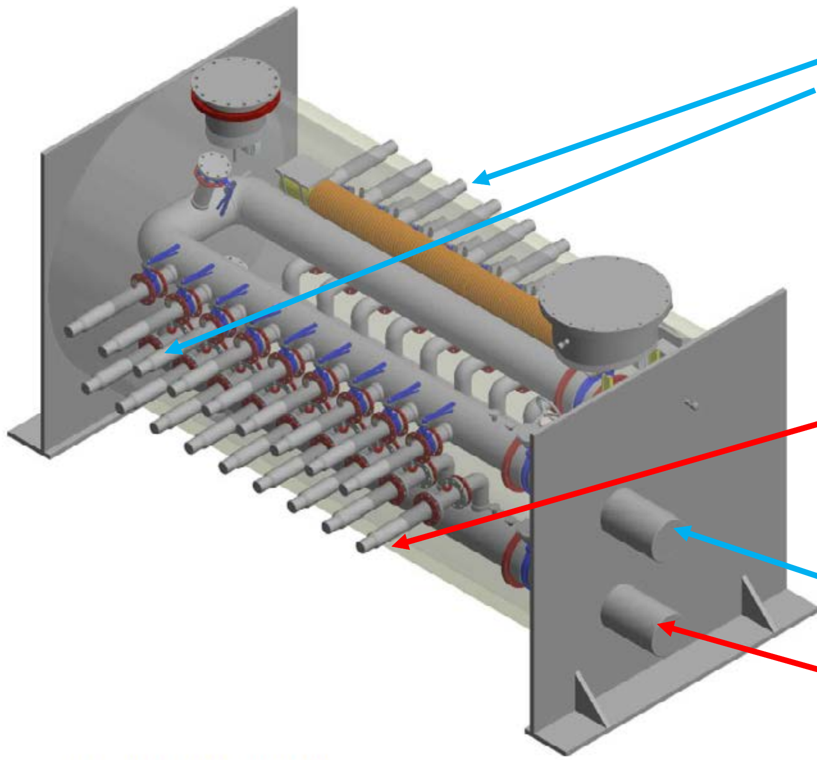
UG VAULT PLAN VIEW

- There are 18 header connections to each side of the manifold
  - 9 up and 9 down
  - One for supply to Moby and one for return flows to the field (see next slide)
- There are 18 rows of wells and each row has 19 wells (342 total) which are connected by one of the various trench details on sheet GT2.1
- Once the wells are connected to the header the water flows to Moby in 12” UG lines

Header connections on manifold



GEOTHERMAL VAULT DETAILS

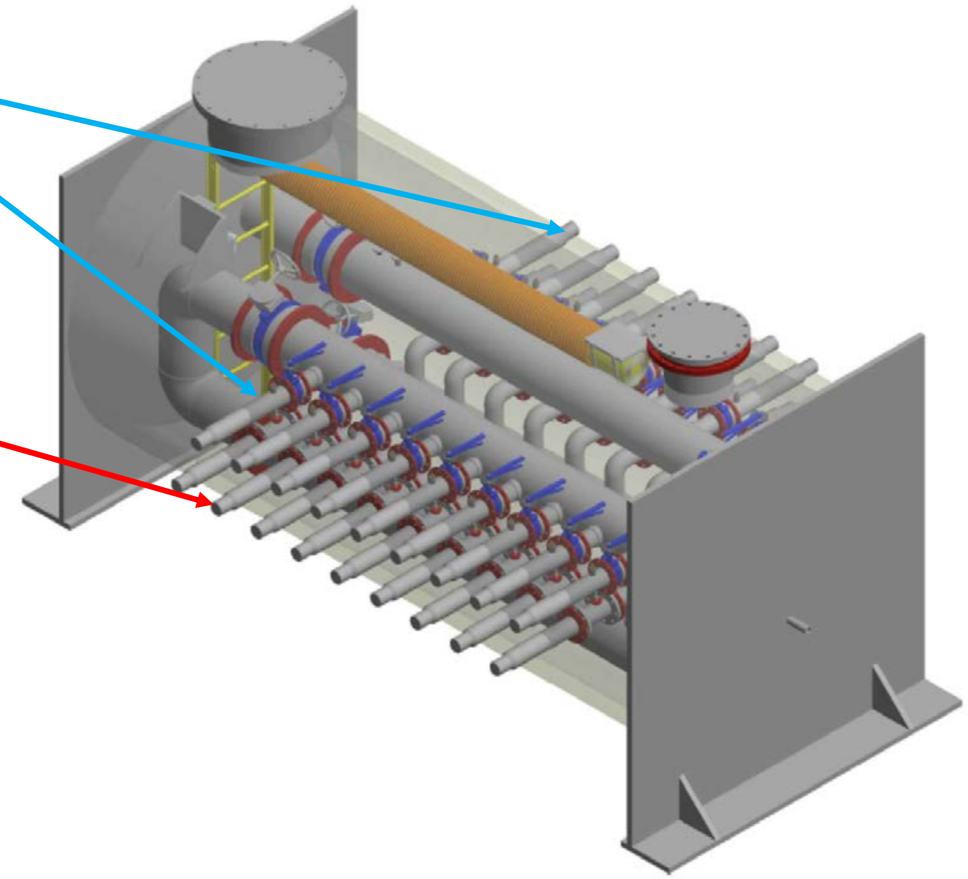


2 LEFT SIDE VAULT RENDERING
NOT TO SCALE

Outflows to the field

Inflows from field

Moby Return
Moby Supply
Red = hot water
Blue = cold water



2 RIGHT SIDE VAULT RENDERING
NOT TO SCALE

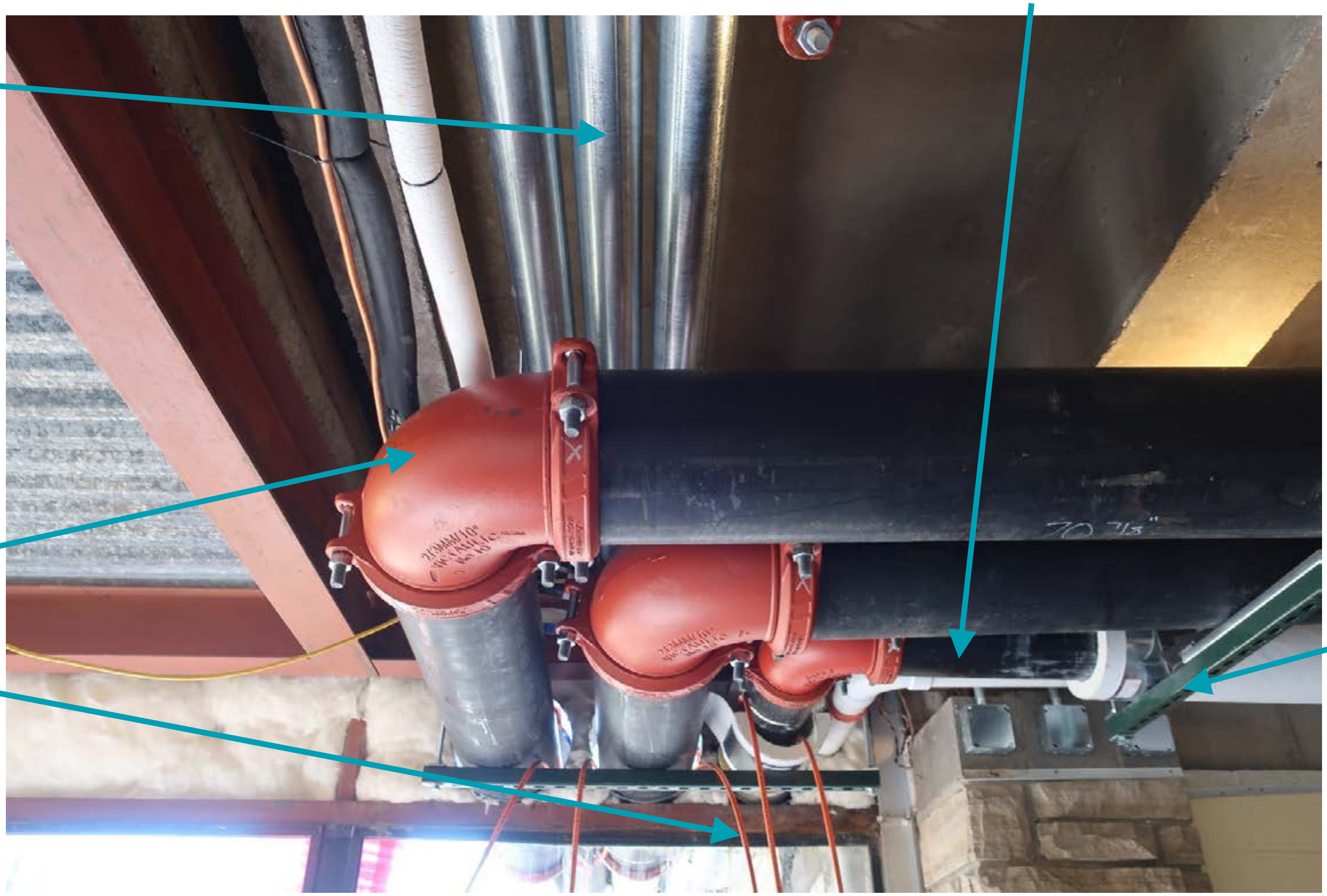
MOBY DEMO FOR UPGRADES

Pink paint indicates demolition items

NEW PIPING TO CONNECT GEO-X FIELD TO MOBY

New 6” water/glycol pipe

New 4” electrical conduit to new electrical room where chillers were previously located



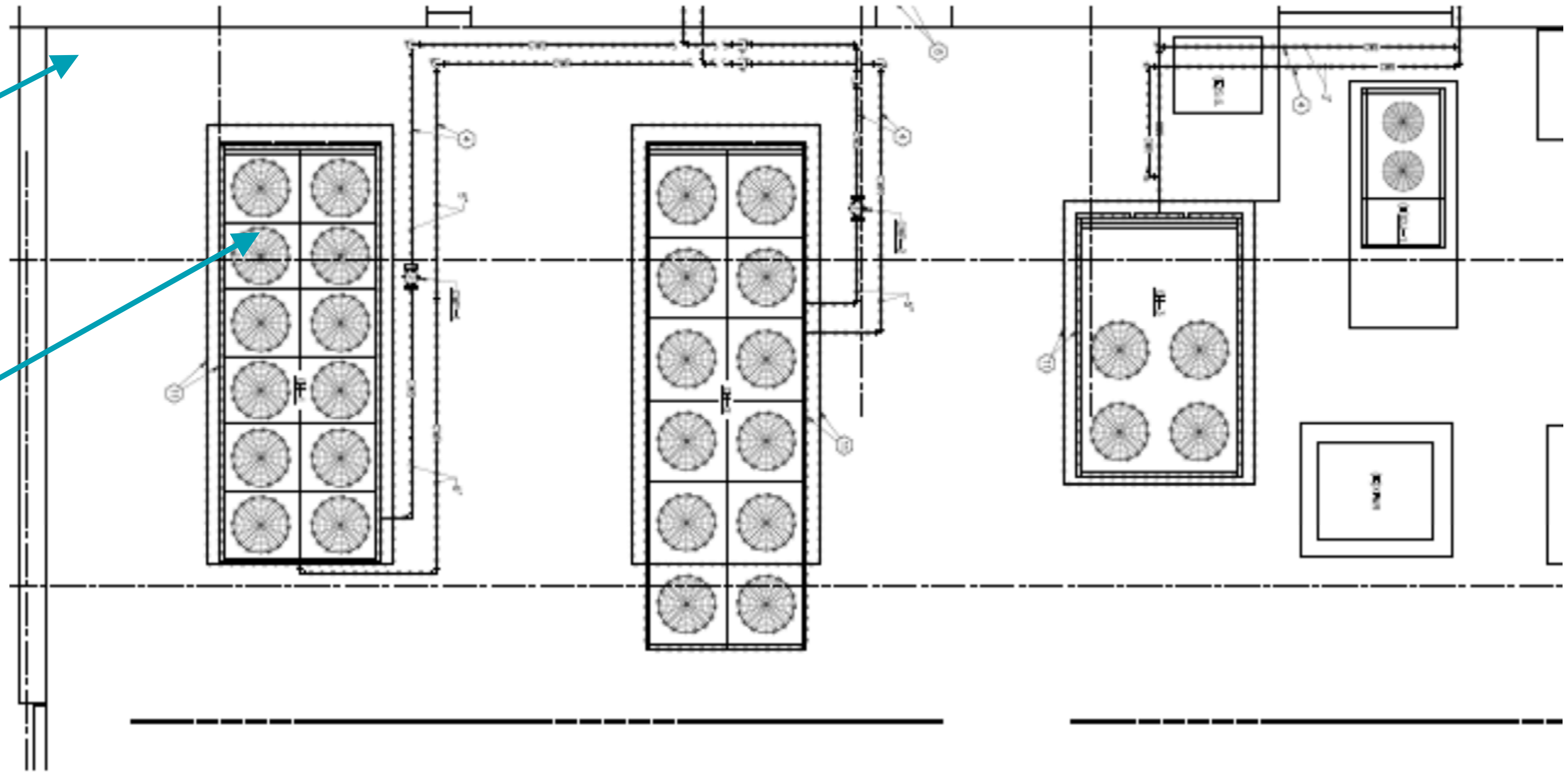
2 - New 10” water/glycol supply lines out to field. The orange wires hanging below is heat tape as they run outside in the soffit of the building

New Unistrut support for added pipe support

M-510 HVAC DEMO PLAN VIEW

This is where the 3 new 4” electrical conduits come out on next slide

Where mini-excavator is sitting on next slide



OLD CHILLER PADS, NEW ELECTRICAL ROOM

3- 4” new electrical conduits for new electrical room

Old Chiller Pads (3), new electrical room

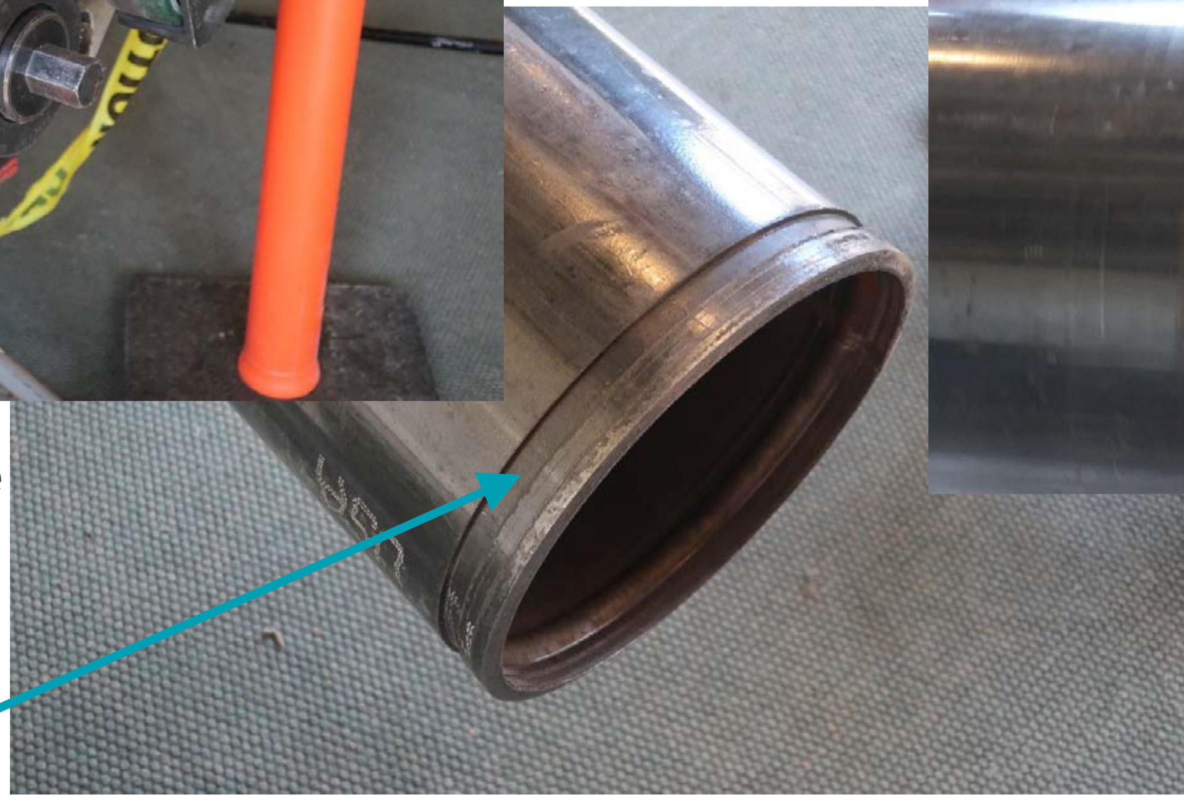
PARTIAL INSULATION AND PRESSURE TEST

Pipe insulation and identification labels started

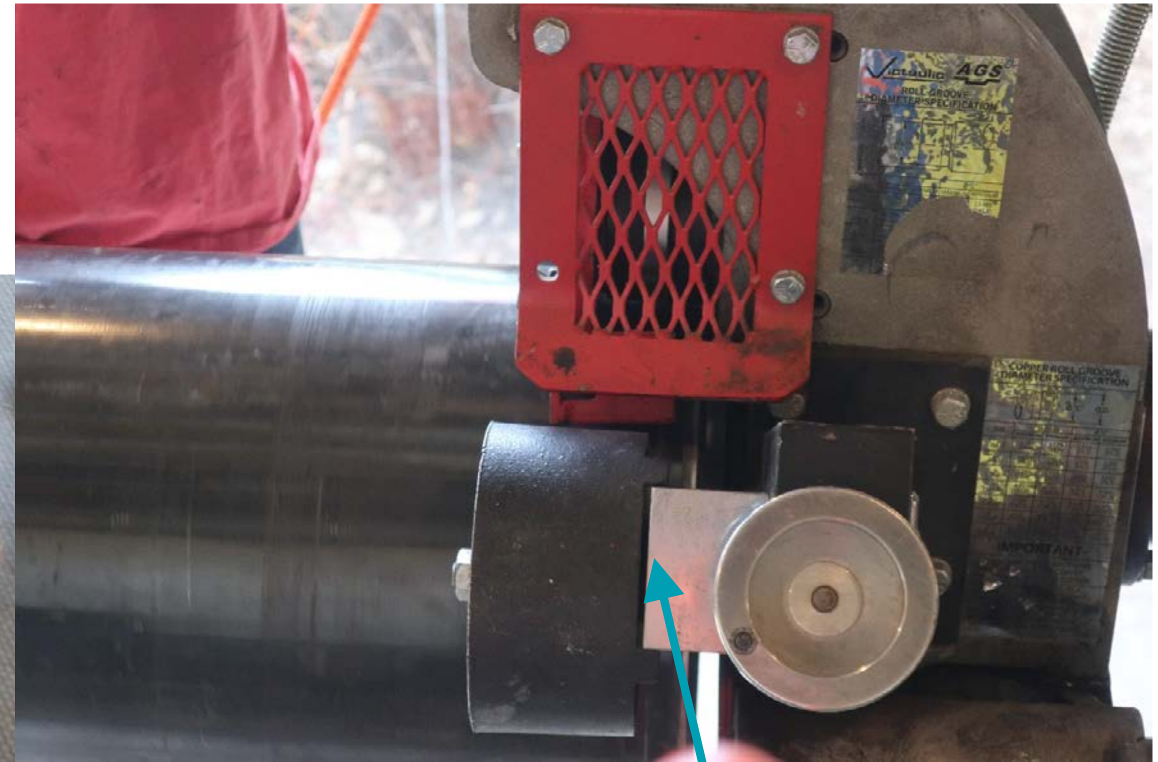
Red tape indicates pressure test in in process. Do not touch!

SITE MADE PIPE FOR VICTAULIC CONNECTORS

Pipe grooving machine



Groove for Red Victaulic connector



Pipe being grooved

SITE WELDED NATURAL GAS PIPE

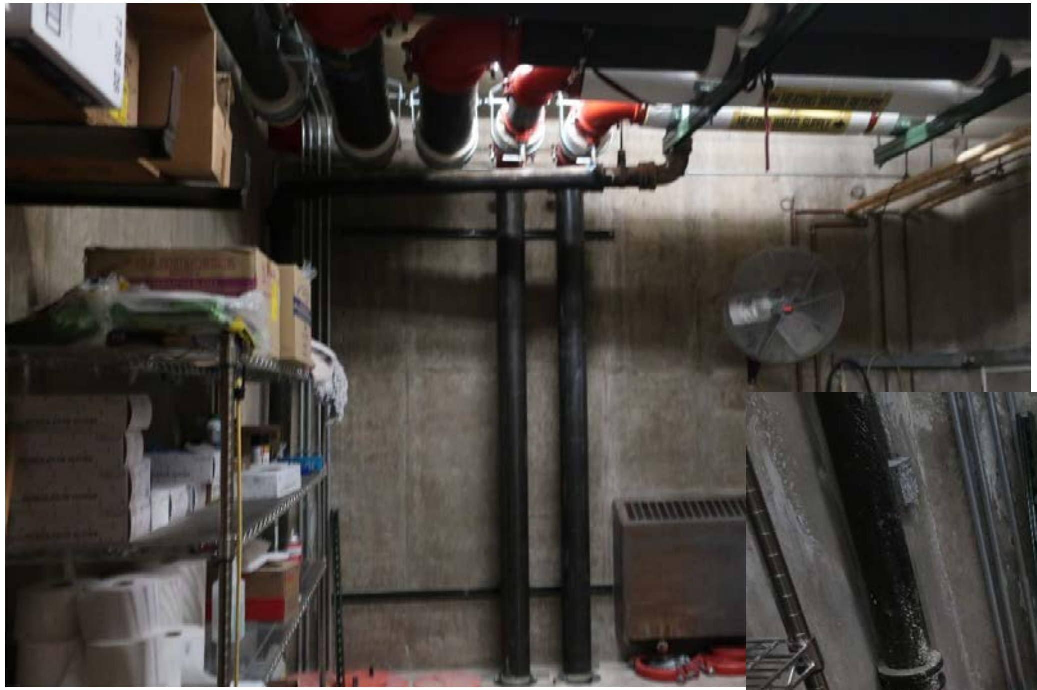
PIPE SUPPORTS

Unistrut and rigid hangers are used

REINFORCEMENT FOR THE UNISTRUT SUPPORT

- This bracket was field made to provide additional support to the Unistrut support
  - It goes from wall to wall
  - The pipe sizes being supported are (from left to right): 6”, 10”, 10”, 6”, 6”
- Once filled with water there is a lot of weight
- All five of these pipes are going through new bores in the existing wall structure

NEW PIPING IN CUSTODIAL RM. AN 116



New bore holes

New Unistrut support

TIGHT SPACE

10” elbow

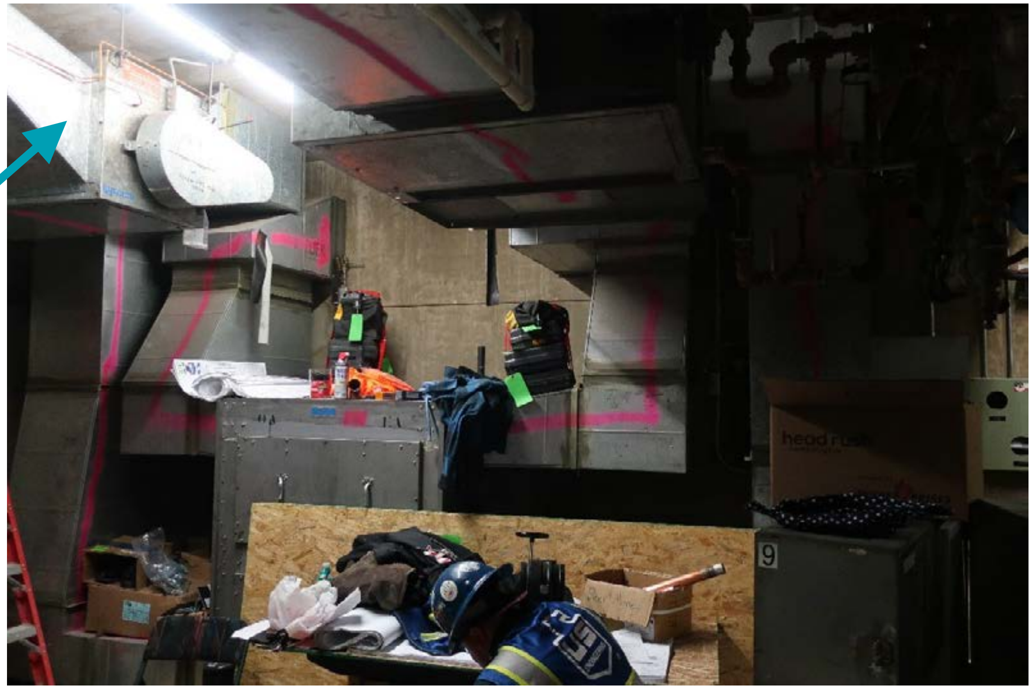
Note the drop ceiling grid pieces on the wall. The goal is to hide all the new pipe in the same ceiling space.

INSIDE STORAGE AN 118

New cores in wall

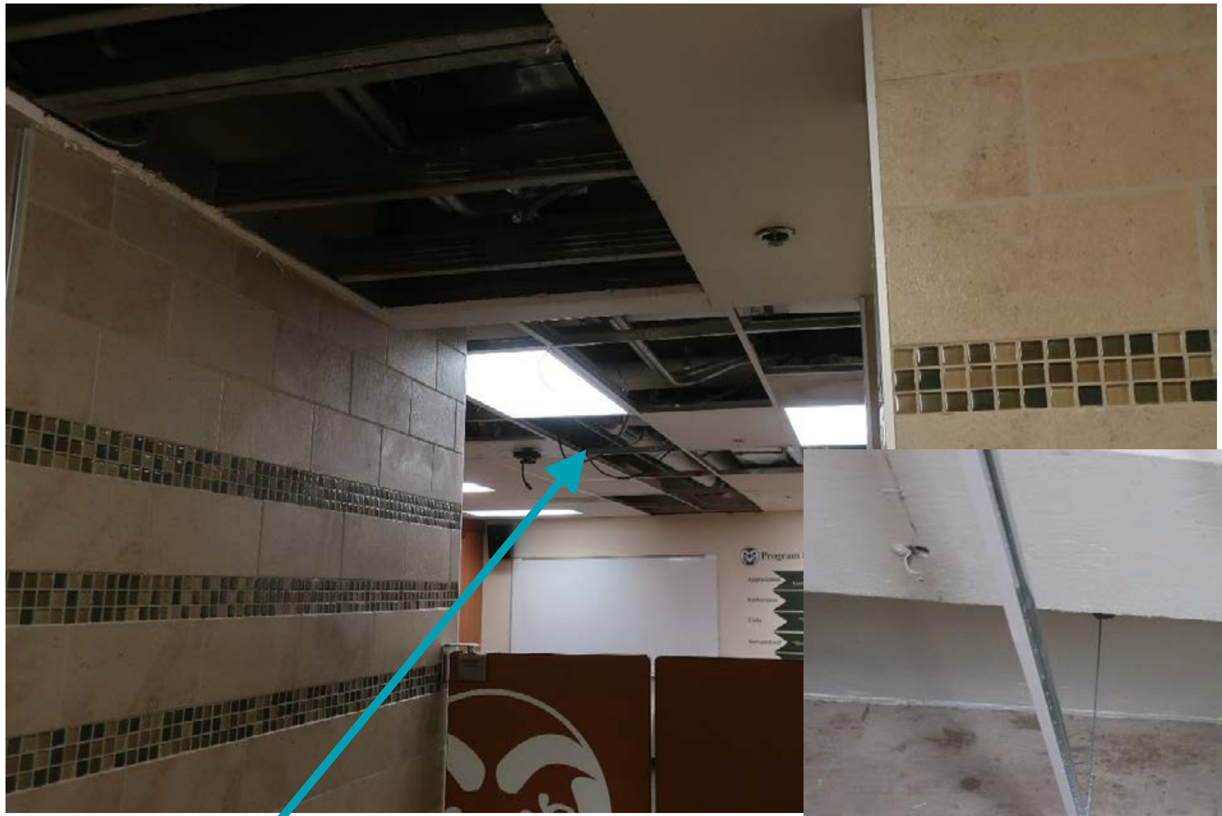
New pipe installed and covered for protection

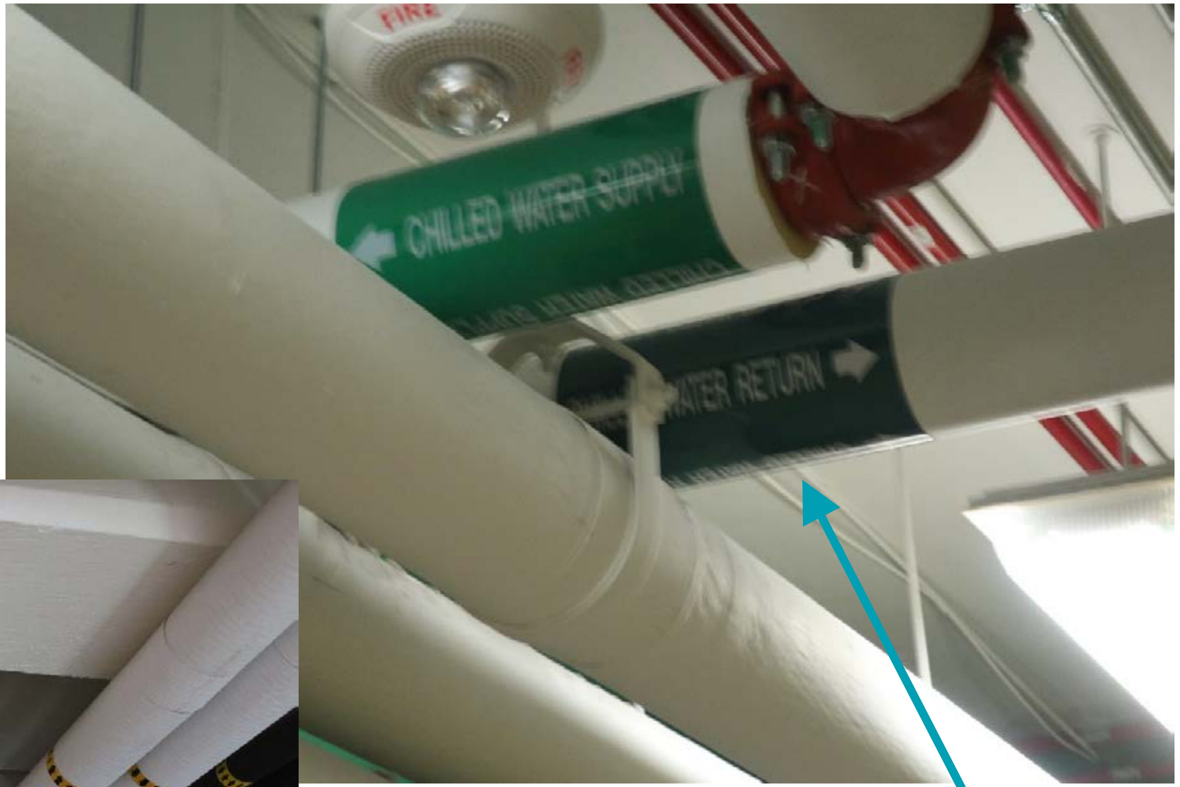
Pink paint denotes demo areas



The existing equipment is in the way so it needs to go

INSIDE A147

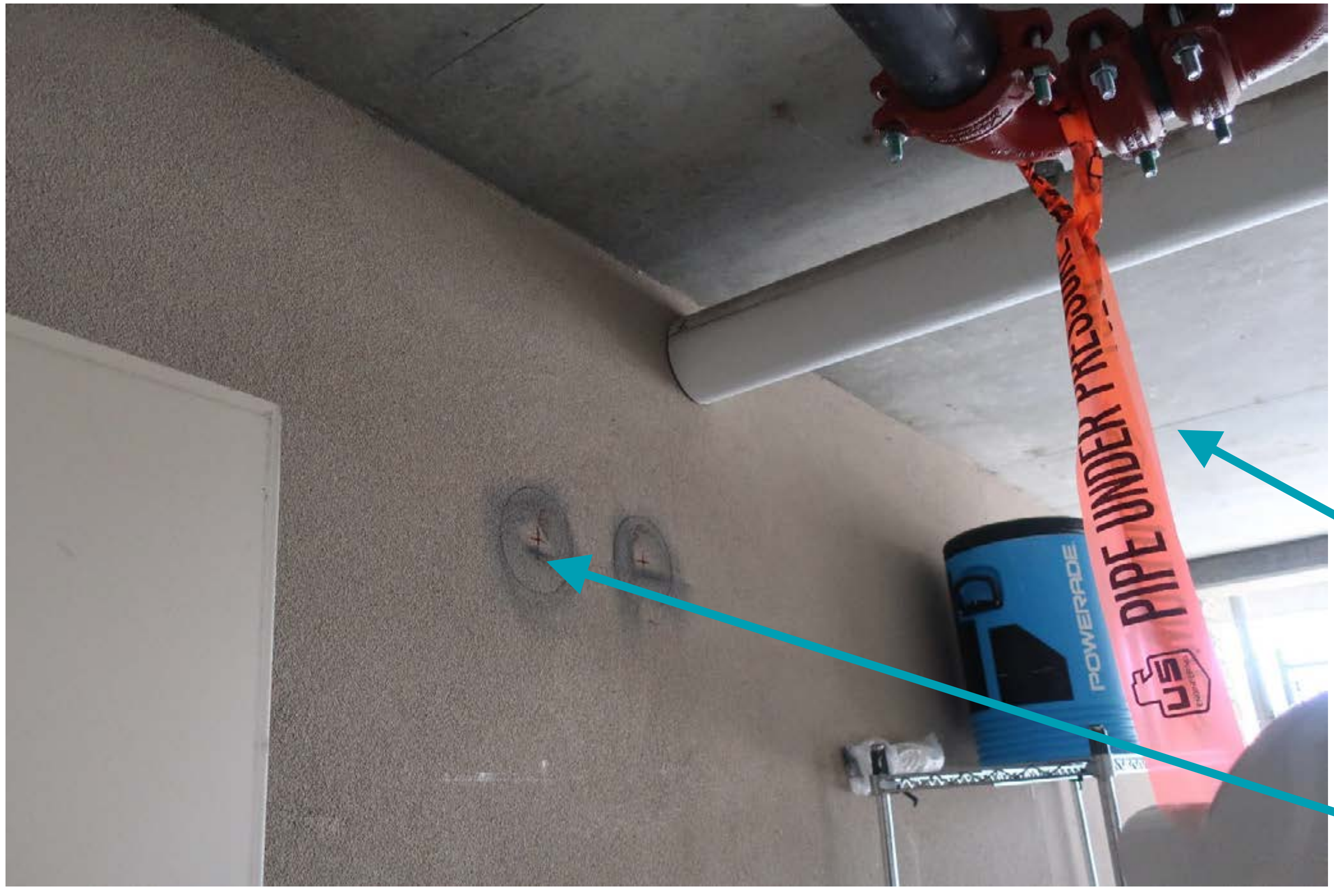




Not much demo here due to grid ceiling

New wall core and finished product. Note the quality of the work.

INSIDE ICE STORAGE A 142A



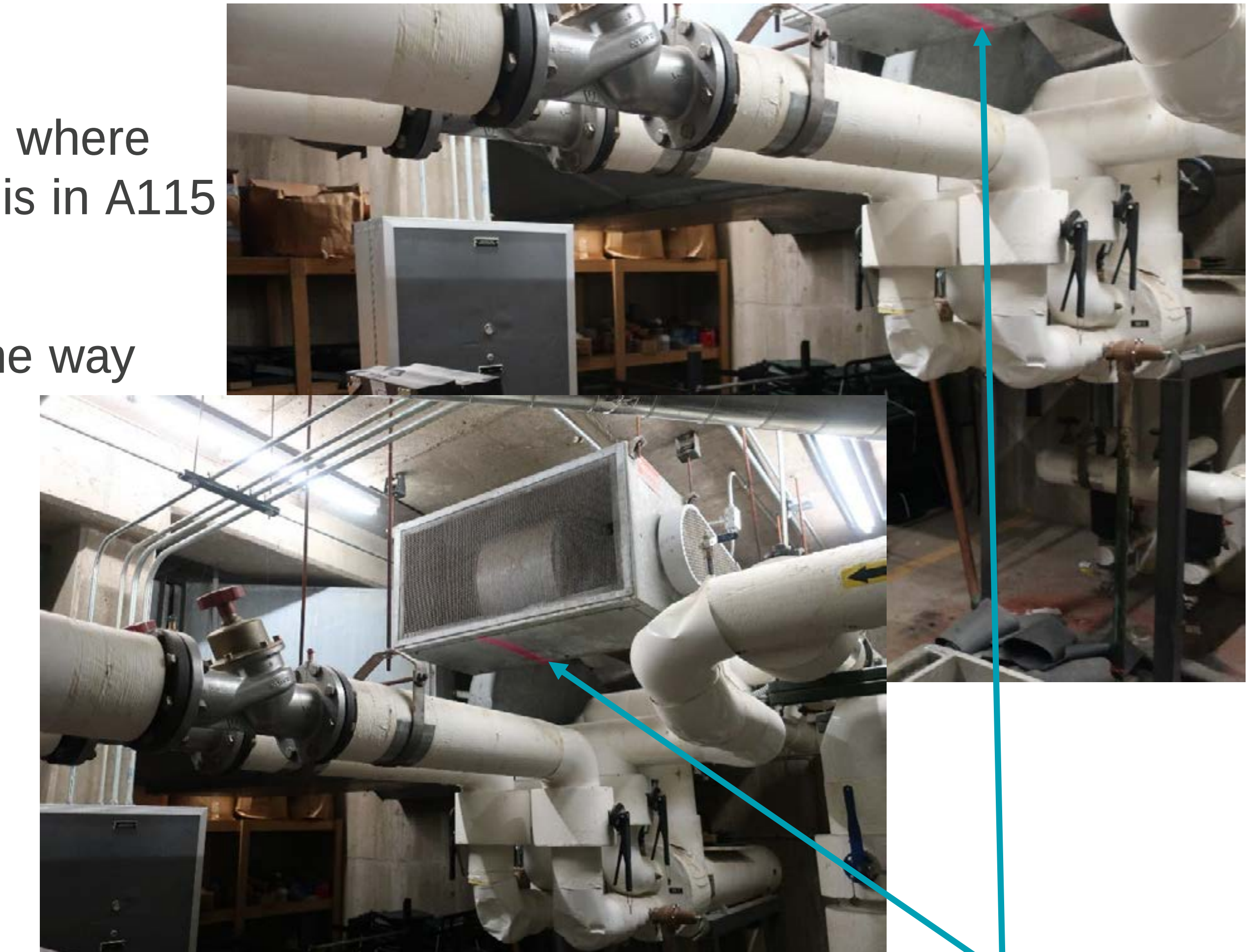
Pipe under pressure test.

New borings marked

LAUNDRY A 115 AND 115 B, THE OTHER SIDE OF THE WALL

Pipe goes where that duct is in A115

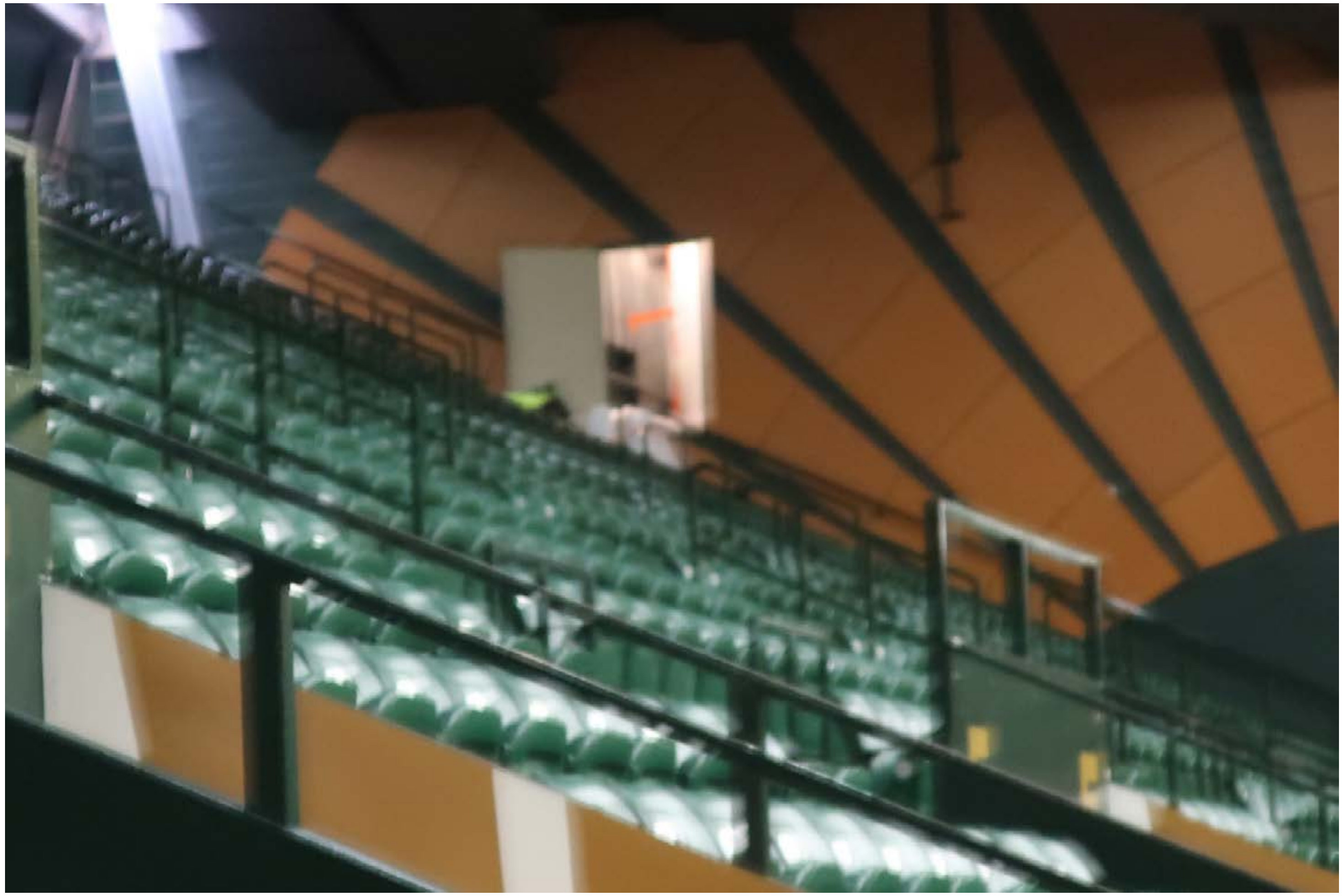
Stuff in the way



115 B shows where that duct goes, pink is to be demo'd

WHERE IT ENDS

- Inside the arena there are several small doors on the east and west ends of the upper level seating areas
- Behind these doors is where the air handlers are for the arena
- The conditioned air from the geo-x project will help fans stay comfortable for years to come



BEHIND THE DOOR

Tenting for demolition to make connections to the arena air handlers.

Arena Air handlers, 10-12’ in height

ADDITIONAL DUCT IN THE ARENA CEILING

PLUMBING SYSTEMS & QUALITY CONTROL

CON 371 – Mechanical and Plumbing Systems

LEARNING OUTCOMES

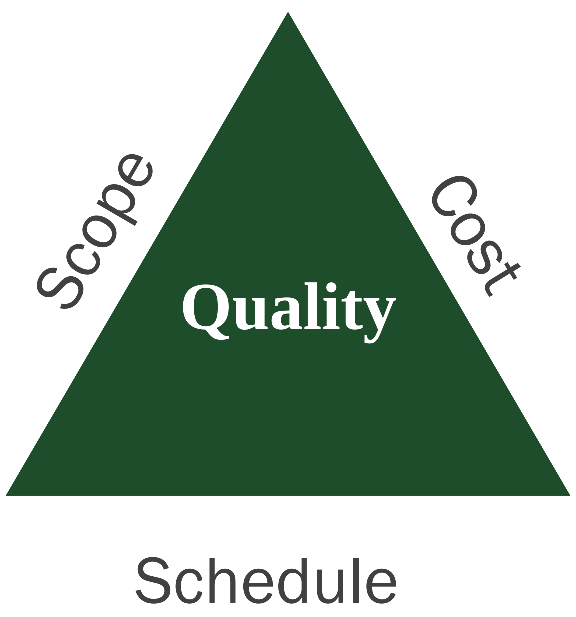
- By the end of this lesson, students will be able to:
  - Recognize the importance of quality control for plumbing systems
  - Evaluate quality control specifications for plumbing systems, equipment, fixtures, and components

QUALITY CONTROL

- Today's Lesson – Plumbing Systems & Quality Control
- This PPT is updated from the QC PPT for HVAC
- There are many similarities between the two presentations, HVAC & Plumbing, but there are also subtle, but important, differences.
- An example of these differences is found in 1.8 References, Div 22 has 3 additional referenced standards. Missing these may result in failure to meet the contract requirements.
- There are also cases where the Division 22 written requirements reference other incorrect divisions. This results from using cut and paste to make one size specs fit all projects.

CONSTRUCTION QUALITY

- Quality in construction is more than supplying the right materials:
  - High level of workmanship
  - Finishing within budget
  - Finishing on time
  - Reducing or eliminating rework
  - Enforcing safety
  - No claims or litigation
  - Customer satisfaction



QUALITY CONTROL

- The actions and considerations necessary to assess and adjust production and construction processes so as to regulate the level of quality being produced in the end product
- Involves monitoring specific project results to comply with required standards
  - Results are both product results (e.g., deliverables) and management results (e.g., cost and schedule performance)
  - Interrelates with cost, schedule, procurement, risk, value engineering, safety, productivity, etc.

TYPES OF QUALITY CONTROL

Performance Specifications	Design Specifications	Submittals	Inspections
• Heating capacity • Concrete strength • Grade of lumber	• Type of tile • Façade finish	• Shop drawings • Cut sheets • Mockups • Scale models • Samples	• Building codes • Laws and regulations • Materials testing

PLUMBING QUALITY CONTROL

- When does quality control start in the Plumbing, division 22/15, scope of work (any division)?
- What other divisions does the GC need to pay attention to for Plumbing work? Remember that Division one (1) is always referenced as a related division, as are others. Is this cross-reference correct?
- Read the specification section(s) to understand your (from your perspective) responsibility for the finished product.
  - GC perspective
  - Underground utility perspective
  - MEP perspective
  - Steel erector perspective
  - Concrete contractor perspective
  - Framer perspective
  - Mason perspective
  - Other subcontractors as warranted perspective

ESTABLISHING A QUALITY CONTROL PROCEDURE

- Where do you start?
  - Drawings
  - Project Manual
  - Past projects
  - Discussions with Mechanical subcontractors
  - Discussions with Owner
  - Discussion with Equipment Manufactures
  - Discussion with Architect/Engineer
  - Discussion with Mechanical System Designer/engineer
  - GC, Subcontractors, tiered subcontractors
  - All the above

REVIEW THE PROJECT MANUAL

- What does the Contract Require? “Communicate Early and Often” Matt Powell RK Mechanical*
  - Review the General section of Division 22/15
  - Make a list of Major Themes
    - Identify all systems, material types and equipment required to complete the project.
    - Identify specific installation qualifications, training requirements and schedule.*
    - Develop a project specific Material Handling, Quality Assurance and test plan.*
    - Quality Control Checklists will be used to track area/room specific deficiencies.*
    - All deficiencies need to include a responsible party and resolution date.
    - Planning Meetings.*
    - Initial Inspections.
    - Sustained Quality Assurance.
    - Pre Start up, Start up, Pre-commissioning and Commissioning.
  - Sub-detail the Major Themes as necessitated

A PROBLEM DOES NOT BELONG TO ONE ENTITY

1.4 Questions and Interpretation (22 06 00-2)*

A. If questions arise during the bidding process regarding the meaning of any portion of the contract documents, the prospective bidder shall submit the questions to the Architect/Engineer for clarification. Any definitive interpretation or clarification of the contract documents will be published by addenda, properly issued to each person holding documents, prior to the bid date. Verbal interpretation or explanation not issued in the form of an addendum shall not be considered part of the bidding documents. When submitting questions for clarification, adequate time for issuance and delivery of addenda must be allowed.

B. The *Architect/Engineer shall be the sole judge regarding interpretations* of conflicts within contract documents.

QUALITY ASSURANCE IN THE SPECIFICATIONS

(SECTION 22 05 00-3, 1.7 QUALITY ASSURANCE)

A. Installers shall have *at least 2 years of successful installation experience* on projects with mechanical installation work similar to that required by the project. All equipment and materials shall be *installed in a neat and workmanlike manner* and shall be aligned, leveled, and adjusted for satisfactory operation, unless noted otherwise in other mechanical sections.

B. Manufacturer of equipment and materials must be regularly engaged in the manufacture of the specified equipment and material with similar construction and capacities and whose *products have been in satisfactory use in similar service for not less that five (5) years*, unless noted otherwise in other Mechanical Sections.

C. Qualify welding processes and operators for structural steel according to AWS D1.1. "Structural Welding Code - Steel.

D. Quality welding processes and operators for piping according to ASME "Boiler and Pressure Vessel Code," Section IX, "Welding and Brazing Qualifications."

QUALITY ASSURANCE IN THE SPECIFICATIONS

(SECTION 22 05 00-3, 1.7 QUALITY ASSURANCE)

E. Comply with provisions of ASME B31 Series "Code for Pressure Piping”, including all addenda.

F. Contractor *signed welder certificate(s) shall be submitted*. *Certify that each welder has passed AWS qualification tests for the welding processes involved and that certification is current*. A record shall be maintained on the job site showing the date and results of qualification tests for each welder employed on the job. *One certified copy of the qualification test for each welder so employed shall be furnished to the Owner’s representative*.

G. For all the refrigerant work/service required by this project, *all refrigerant technicians shall be EPA/ASHRAE 34 certified for corresponding classification type I, II, III and/or IV*.

SPECIFICATIONS CONFORM TO SPECIFIC REFERENCES

(SECTION 22 05 00-3, 1.8 REFERENCES)

The design, manufacture, testing, and method of installation of all equipment and materials furnished under the requirements of this specification shall conform to the following as applicable:

1. Safety and Health Regulations for Construction.
2. Occupational Safety and Health Standards, National Consensus Standards and Established Federal Standards.
3. ABMA - American Boiler Manufacturers Association.
4. ACCA - Air Conditioning Contractors of America.
5. ACGIH - American Conference of Governmental Industrial Hygienists.
6. ADC - Air Diffusion Council.
7. AGA - American Gas Association.
8. AIHA - American Industrial Hygiene Association.
9. AMCA - Air Movement and Control Association.
10. ANSI - American National Standards Institute.
11. ARI - Air-Conditioning and Refrigeration Institute.
12. ASA - Acoustical Society of American.
13. ASHRAE - American Society of Heating, Refrigerating, and Air-Conditioning Engineers.
14. ASME - The American Society of Mechanical Engineers.
15. ASTM - American Society of Testing and Materials.

SPECIFICATIONS CONFORM TO SPECIFIC REFERENCES
(SECTION 22 05 00-4, 1.8 REFERENCES)

The design, manufacture, testing, and method of installation of all equipment and materials furnished under the requirements of this specification shall conform to the following as applicable:

16. BOCA – Building Officials and Code Administrators International.
17. CABO – Council of American Building Officials.
18. CAGI - Compressed Air and Gas Institute.
19. CTI - Cooling Tower Institute.
20. EJMA - Expansion Joint Manufacturers Association.
21. ETL - Engineering Tests Laboratory.
22. HEI - Heat Exchange Institute.
23. HI - Hydraulic Institute.
24. HYD I - Hydronics Institute.
25. IAPMO – International Association of Plumbing and Mechanical Officials.
26. ICBO - International Conference of Building Officials.
27. ICC – International Code Council.
28. NEBB - National Environmental Balancing Bureau.
29. NEC - National Electrical Code.
30. NEMA - National Electrical Manufacturers Association.
31. NFPA - National Fire Protection Association.
32. NSF - National Sanitation Foundation.
33. SAE - Society of Automatic Engineers.
34. SMACNA - Sheet Metal and Air Conditioning Contractors' National Association.
35. TEMA - Tubular Exchanger Manufacturers Association.
36. UL - Underwriters Laboratories, Inc.
37. International Plumbing Code.
38. International Mechanical Code.
39. Other governing, state, and local codes that apply.

ADDITIONAL REQUIREMENTS
(SECTION 22 05 00)

- 1.9 Submittals – 22 05 00-4 / 22 05 00-12
  – Coordination Drawings – 22 05 00-13 and 22 05 00-14
- 1.10 Substitutes – 22 05 00-8
- 1.11 Warranty – 22 05 00-10
- 1.12 Close Out and Operation Instructions – 22 05 00-10 and 22 05 00-11
- 1.13 Record Documents 22 05 00-11
- 1.14 Maintenance Manuals 22 05 00-12

22 05 00 SECTION - 3. EXECUTION

- Subtle but important differences from HVAC
  - 3.1 Delivery, Storage and Handling
  - 3.2 Rough-In
  - 3.3 Coordination
  - 3.4 Plumbing Installations
  - 3.5 Accessibility
  - 3.6 Lubrication and Tools
  - 3.7 Piping Systems Pressure Testing
  - 3.8 General Contractor – Mechanical Extent of Work
  - 3.9 Electrical – Plumbing Extent of Work

EXECUTION EXAMPLES IN THE SPECS

22 05 00-18 D. Concrete Bases

1. Division 22 Contractor is to notify the General Contractor prior to submitting his bid, the number, size and location of all mechanical equipment bases. The Division 22 Contractor shall be liable for all associated costs to install the mechanical equipment bases upon failure to notify the General Contractor prior to bid submission.

22 05 00-13 B. Coordinate the plumbing work with work of the different trades so that:

1. Interferences between mechanical, electrical, architectural, and structural work, including existing services, will be avoided.
2. Within the limits indicated on the drawings, the maximum practicable space for operation, maintenance repair, removal and testing of mechanical and other equipment will be provided.
3. Pipes, ducts, and similar items, shall be kept as close as possible to ceiling, walls, and columns, to take up a minimum amount of space. Pipes, ducts, and similar items shall be located so that they will not interfere with the intended use of other equipment.

EXAMPLE OF CUTTING AND PASTING DIVISION 23 REQUIREMENTS TO DIVISION 22 (22 05 00-11)

Note the wording referencing Division 23 equipment

1.13 RECORD DOCUMENTS

A. Prepare as-built documents in accordance with the requirements in Division 1 Section "PROJECT CLOSEOUT." In addition to the requirements specified in above, indicate the following installed conditions:

   1. The Plumbing Contractor shall provide the Owner with as-built drawings *for ductwork mains and branches, size and location, for both exterior and interior; locations of dampers and other control devices; filters, boxes, and terminal units* and indicate all devices requiring periodic maintenance or repair, such as control power transformers, LACS panels/routers, field controllers, duct static pressure sensors, piping pressure sensors, etc.

MEP SCHEDULING

CON 371 – Mechanical and Plumbing Systems

LEARNING OUTCOMES

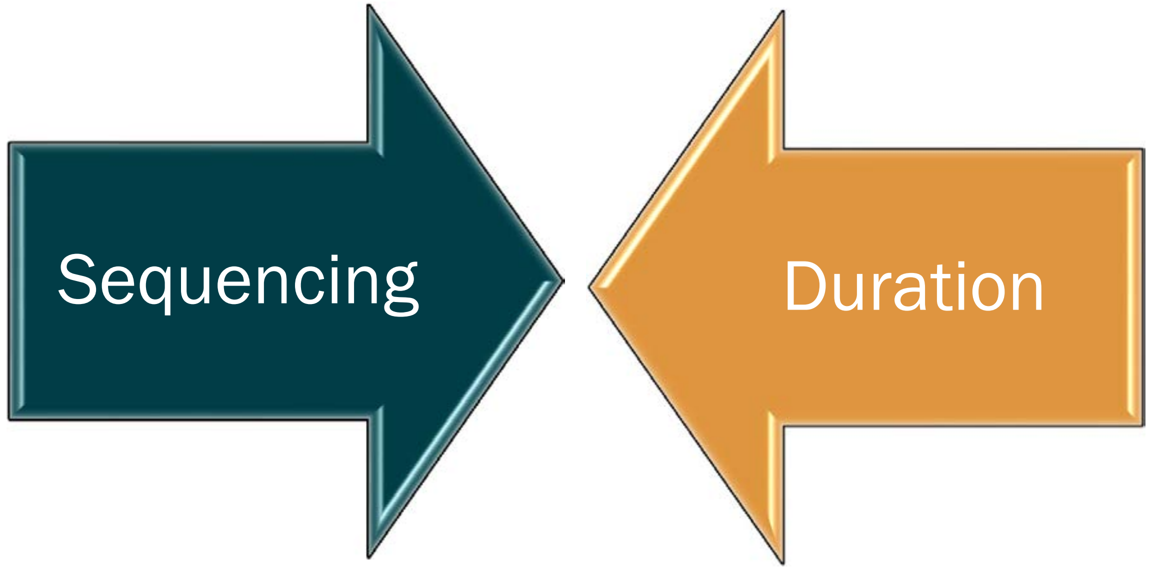
- By the end of this lesson, students will be able to:
  - Understand the project management for mechanical and plumbing systems in a building
  - Discuss approaches to scheduling and the role and responsibilities of the mechanical contractor in regards to project scheduling

PROJECT ELEMENTS

- A starting point
- An ending point
- A deliverable

A finite duration

OBJECTIVE OF SCHEDULING



- Proper scheduling can:
  - Increase productivity
  - Manage resources
  - Strengthen project documentation
  - Be a feedback mechanism for estimating

APPROACHES TO SCHEDULING

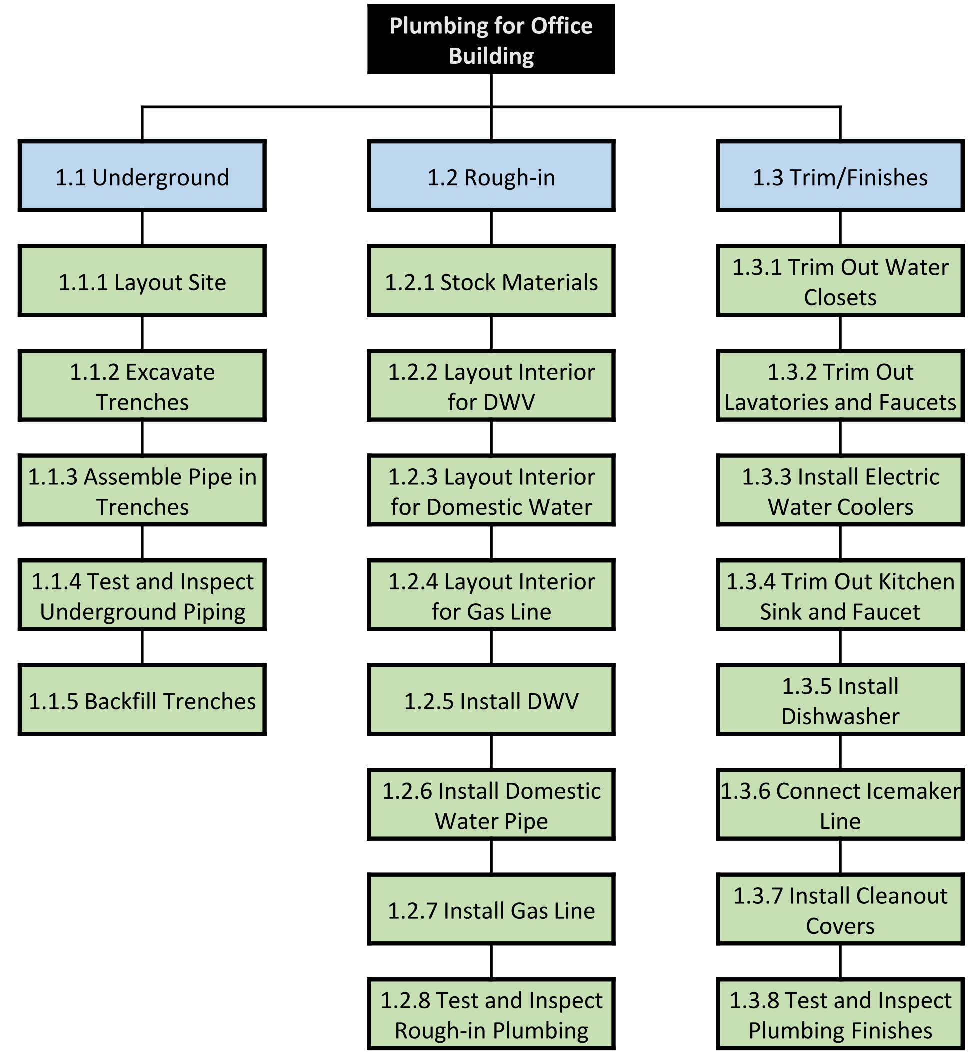
- Work breakdown structure (WBS)
- Check sheets / list of activities
- Bar charts (Gantt Schedules)
- Scheduling network diagrams
- Critical path method (CPM)
- Program evaluation and review technique (PERT)
- Linear schedules

WORK BREAKDOWN STRUCTURE

- A WBS is a systematic way to describe components of a project schedule
- Developing the WBS begins with the definition of the major systems or components of a project
- Each system is then defined in greater and greater detail
  - Until there exists a discrete or measurable piece of work and a single responsibility = work packages
- Work packages can be viewed as mini projects that are contained within the entire project

WORK BREAKDOWN STRUCTURE

- On a typical construction project the WBS consists of numerous items
  - The more complex a project, the more items in a WBS



DETERMINING ACTIVITY DURATIONS

- Total Project Duration is a collective schedule of activities durations
- Quantity Surveying/Takeoff
- Production rates estimates

Activity Duration = Quantity / Production rate

- *"Expert" input*
  - *Senior estimator*
  - *Superintendent*
- *Records from past jobs*
- *Reference guides, e.g. R.S. Means*
- *Activity analysis*
- *Subcontractors*

CREW HOURS / CREW DAYS

- The time required for an activity is the quantity divided by the production rate, E.g.,

$$Crew\ hours = \frac{4{,}000\ cubic\ yards}{80\ cubic\ yards/hour} = 50\ hrs$$

- This value may be rounded to whole days in the schedule
- Fixed time for other tasks such as transporting equipment, maintenance, etc. may be added

REFERENCE GUIDES

- RS-Means Building Construction Cost Data
  - Provides Daily Output for defined crews in units/day for a wide range of construction activities
  - Often considered to be pessimistic/conservative

00 | Cast-In-Place Concrete

10 | Structural Concrete		CREW	DAILY OUTPUT	LABOR-HOURS	UNIT	2006 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P	
24" diameter, minimum reinforcing	R033053 -10	C-14A	51.85	3.857	C.Y.	223	137	13.90	373.90	475	240
Average reinforcing			27.06	7.391		400	263	26.50	689.50	885	

If we have 450 CY of structural concrete to place with minimum reinforcing, what is the daily output and the total duration for this activity?

EXAMPLE

$$\text{Daily Output} = 51.85\ \text{CY/day}$$

$$\text{Crew Days} = \frac{450\ \text{CY}}{51.85\ \mathit{cubic\ yards/Day}} = 8.67\ \text{days} \rightarrow 9\text{days}$$

SCHEDULES

- Baseline Schedule
- Mechanical Contractor schedule
- Mechanical worker-power loading schedule
- Mechanical short-term schedule
- Submittals / materials and equipment purchasing

BASELINE SCHEDULE

- Includes all trades
- Civil and Architectural trades generally have the greatest detail
- Often only “milestone” based
- Mechanical tasks usually broad or general in nature
  - Underground, rough-in, trim

	Start	Finish	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Site Utilities	10/31/14	12/30/14																				
Well Fields	01/30/15	04/09/15																				
Sidewalks, Lighting, Paving, Signage	04/10/15	11/19/15																				
Track & Tennis Court Surfacing	09/24/15	11/16/15																				
Final Grading, Seeding & Landscaping	01/08/16	04/15/16																				
Foundations	10/31/14	01/26/15																				
Structure & Shell	01/16/15	09/24/15																				
Roof & Skylights	05/15/15	07/23/15																				
Underground MEP	01/30/15	04/17/15																				
Concrete Slabs on Grade	04/02/15	06/18/15																				
MEP Rough-in	03/01/15	09/19/15																				
Interior Walls	06/15/15	11/02/15																				
Finishes & MEP Fixtures	09/11/15	04/08/16																				
Punchlist	03/19/16	04/15/16																				

BASELINE SCHEDULE

- Must be reasonable and realistic
- Consider the following:
  - Working conditions
  - Weather
  - Size and complexity of the project
  - Codes and regulations
  - Location of, and access to, the site
  - Labor markets
  - Equipment and material availability
  - Deliveries
  - Other project specific conditions

- What are the risks that a Mechanical Contractor should consider?
  - Completion date
  - Liquidated damages
  - Material and equipment deliveries
  - Escalation clauses
  - Stacking of trades
  - Milestone dates
  - Start/stop
  - Crew size change
  - Dilution of crews
  - Learning curve loss
  - Dilution of supervision
  - Logistics
  - Morale & attitude

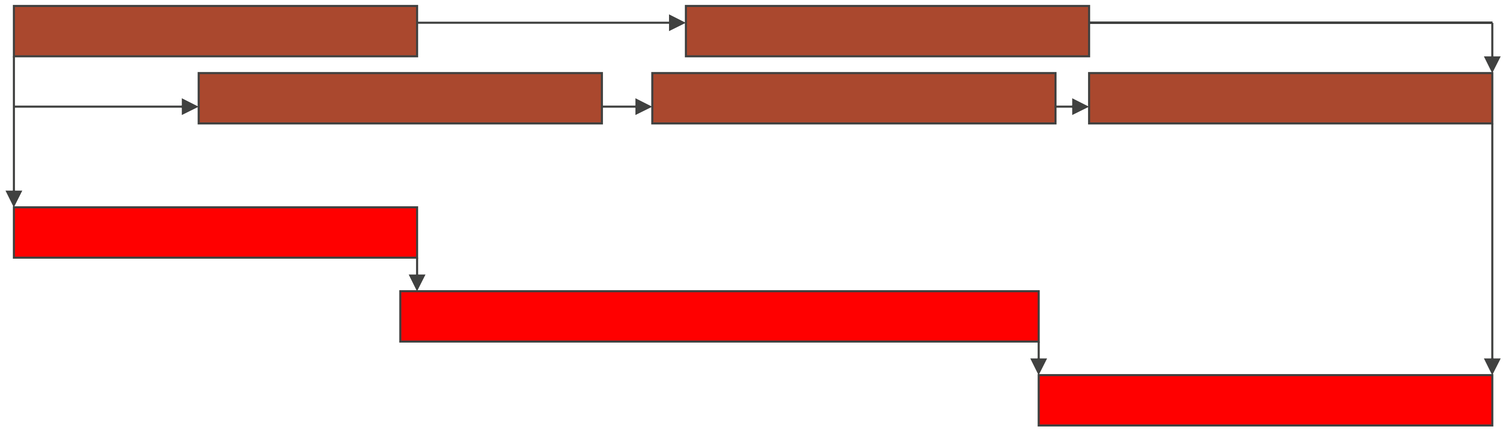
ASSEMBLE THE MECHANICAL SCHEDULE

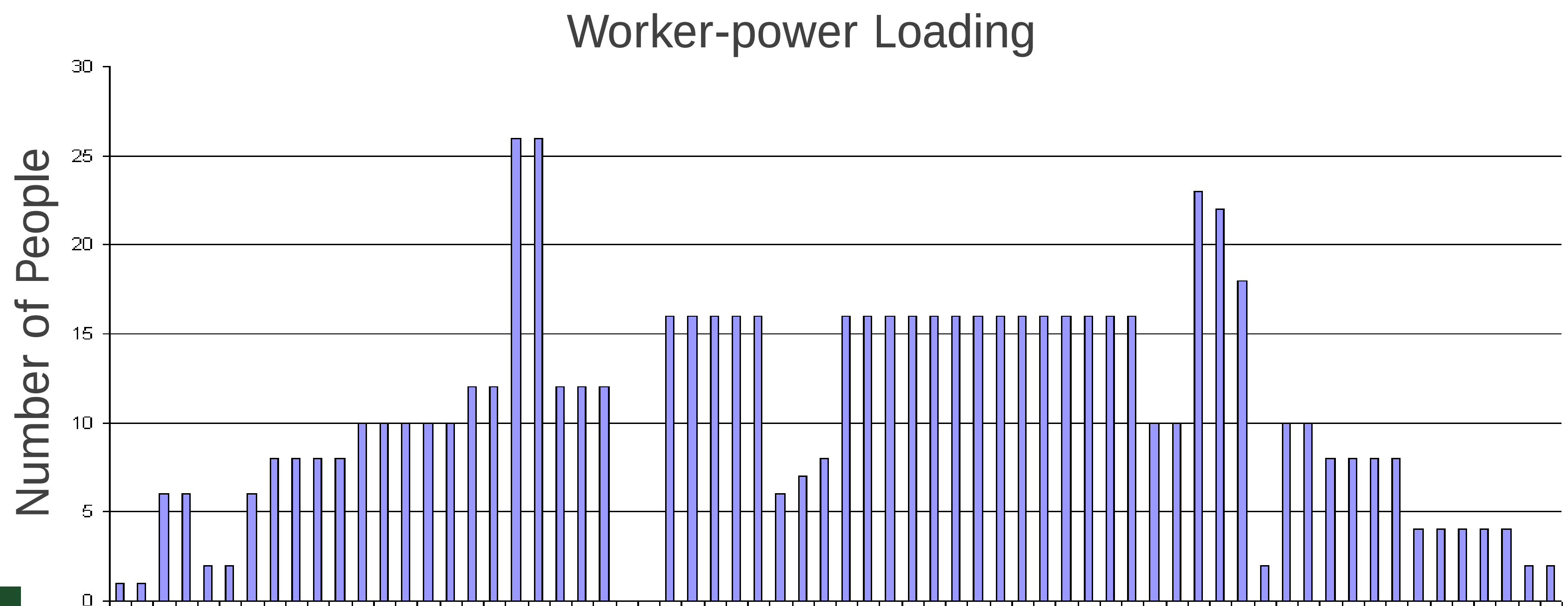
- Basic Guidelines, but <u>ALWAYS</u> Check contract for requirements!
  - Use CPM (Industry standard)
  - Labor-loaded schedule (Know your resources)
  - Activities must very closely resemble labor coding tasks
  - Based on the Area/Zone/Phase of the project
  - Must be joint effort between Mechanical Contractor and GC project team
  - Consider other trades and coordination
  - Must be logical, reasonable and constructible
  - Float for any activity should be less than 30 days
  - Activity duration less than 30 days provides more details
  - Worker-hours per activity should be less than 1,000 but more than 200

WORKER-POWER LOADING CHART

- Goals
  - Ensures the project always has enough of the right people
  - Avoid unnecessary fluctuations
- Often a juggling act
  - Too many resources in one area at one time decreases productivity and negatively impacts relationships of the trades on site (Trade stacking)
  - Too few resources can seem as though the project is inactive (Aloha Fridays)
- Worker-Power needs impacts cash flow and contract billing

RESOURCE LOADING





RESOURCE LEVELING

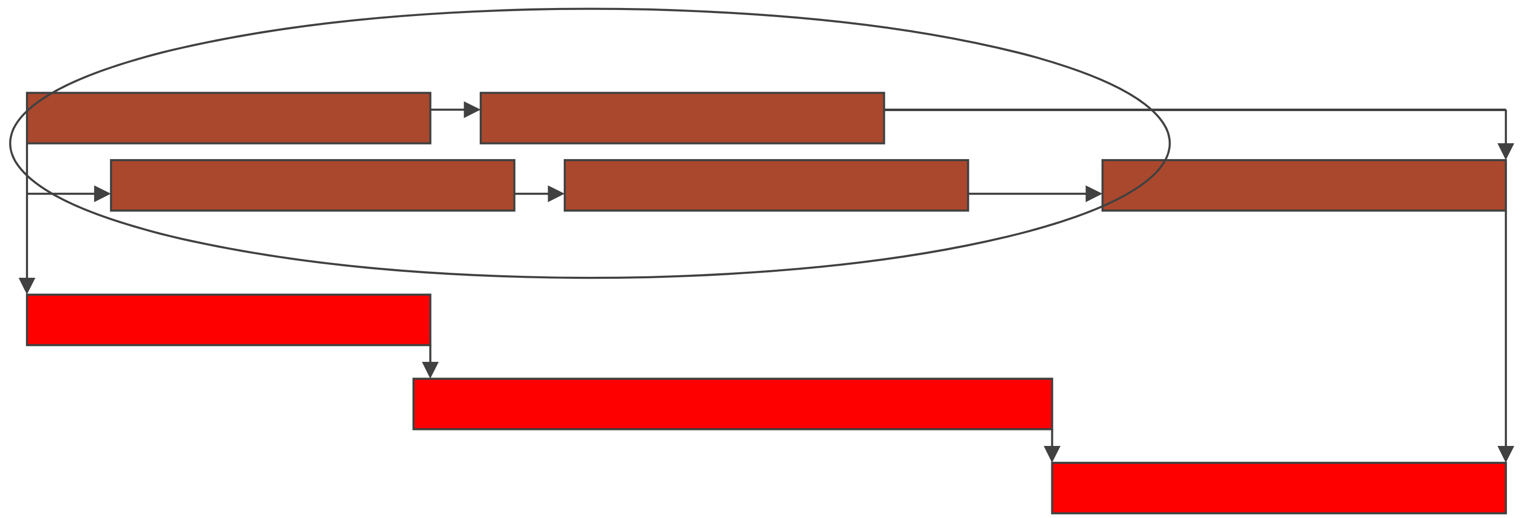
- Resource leveling is used when there are not enough resources available to start all activities at their early start date
  - Where loading is to plan resource needs, leveling is based on the availability of those resource needs

How do we level resources?

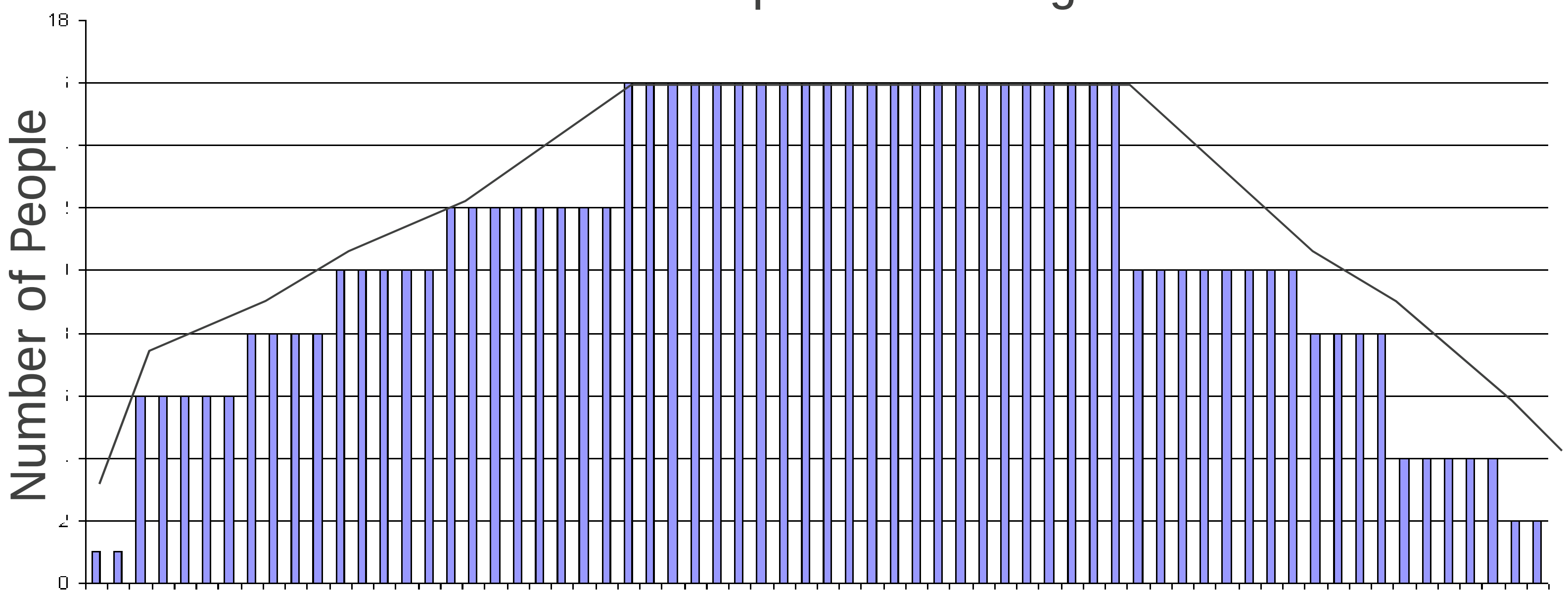
- The objective is to smooth (level) the resource usage over time

The leveling process is accomplished by *shifting only the non-critical activities*, preferably within their float

RESOURCE LEVELING



Worker-power Loading



SHORT INTERVAL SCHEDULES

- Focus on short term outcomes
  - What are we going to do for the next 2 or 3 weeks?
  - How many workers will be required to do it?
  - What tools/materials/equipment do we need to do it?
  - What needs to be done by other trades so we can do it?
  - What does the overall mechanical schedule say we should be doing?

SHORT INTERVAL SCHEDULES (SIS)

- Prepared jointly by PM and project foreman
- Submitted/communicated weekly to the GC,CM, or Owner
- Compare and measure each SIS schedule against the overall project schedule and the labor cost control system

Activity	Crew	Hours to Complete	Duration (Days)	Mon 3/26	Tue 3/27	Wed 3/28	Thu 3/29	Fri 3/30	Sat 3/31	Sun 4/1	Mon 4/2	Tue 4/3	Wed 4/4	Thu 4/5	Fri 4/6	Sat 4/7	Sun 4/8
Area 1: 1st Floor Waste & Vent - Finish Rough-in	John / Nick	64	4	X	X	X	X										
Area 2: 1st Floor Waste & Vent - Rough-in	John / Nick	128	8					X			X	X	X	X	X		
Area 1: 1st Floor Domestic Water - Finish Rough-in	Jamie	24	3	X	X	X											
Area 2: 1st Floor Domestic Water - Rough-in	Jamie	64	8				X	X			X	X	X	X	X		
Area 3: Stock and Layout - Start Rough-in	Jamie / John / Nick	24	1												X		

SUBMITTALS / EQUIPMENT AND MATERIAL PURCHASING

What are the dates that equipment/materials are required on site based on the baseline schedule?

Time to prepare, submit, and gain approval of submittals
- Dictated by the contract
- Impacts ordering of long lead and custom materials and equipment

Time to produce shop drawings
- Part of the submittals process
- Level of detail provided in plan set

Time to fabricate materials/equipment
- In-house fabrication or third party
- Equipment, skids, spools

Time to procure materials/equipment
- Standard or custom
- Various suppliers or proprietary

Time to ship from supplier to site
- Mode of transport: Boat (Least expensive), Rail, Truck, Air (Most expensive), or combination
- Local, regional, national, international

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CON 371 – Mechanical and Plumbing Systems
In-Class Exercise No.1 Worksheet (5 points) - Psychrometrics

Name ____

Using the psychrometric chart, answer the following questions.

1. Find the Relative Humidity for an air/water mixture with 65°F dry bulb temperature and 43°F wet bulb temperature.

2. What is the dry bulb temperature when the wet bulb temperature is 58°F and the relative humidity is 25%? Is this temperature within the Summer Comfort Zone (Blue Shaded Area on the Chart)?

3. When the dry bulb temperature is 70°F at 70% relative humidity, is the wet bulb temperature also 70°F? Is the dew point temperature also 70°F?

4. Find the specific volume of air that has a dry bulb temperature of 35°F and a dew point temperature of 20°F?

5. According to the Chart, to be within the Winter Comfort Zone (Red Shaded Area on the Chart), what is the range of relative humidity?

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CON 371 – Mechanical and Plumbing Systems
In-Class Exercise No.2 Worksheet (5 points) – Choose a Cooling System

Name ____Section___________

Choose a cooling system for each of the different building types provided. Select the system that fits the load and provides the most economical solution for the facility.

Residential: Single Family Home in Dallas, TX (Total Cooling Load: 4.5 Tons)

a. DX split system
b. Variable refrigerant flow heat pump
c. Direct-fired absorption Chiller
d. Evaporative Cooling Swamp Cooler
e. OTHER: ________________________

Large University Classroom Building in San Diego, CA (Total Cooling Load: 200 Tons)

a. Variable refrigerant flow heat pump
b. Air-cooled scroll compression chiller
c. Water-cooled scroll compression chiller
d. Direct-fired absorption chiller
e. OTHER: _________________________

Three-story Apartment Building in Buffalo, NY (Total Cooling Load: 4 tons/unit @ 42 units = 168 Tons)

a. DX split system (for each apartment)
b. Unitary package DX system (for each apartment)
c. Variable Refrigerant flow heat pump (for each apartment)
d. Air-cooled scroll compressor chiller
e. OTHER: ________________________

Technology Research Complex in Las Vegas, NV (Total Cooling Load: 2,300 Tons)

a. Indirect-fired two stage absorption chiller
b. Direct-fired absorption chiller
c. Air-cooled scroll compression chiller
d. Water-cooled centrifugal compression chiller
e. OTHER: ________________________

Natural and Environmental Sciences Building in Fort Collins, CO (Total Cooling Load: 310 Tons)

a. Variable refrigerant heat pump
b. Direct-fired absorption chiller
c. Air-cooled scroll compression chiller
d. Water-cooled centrifugal compression chiller
e. OTHER: ________________________

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CON 371 – Mechanical and Plumbing Systems
In-Class Exercise No.3 Worksheet (20 points) – Heat Loads

Name: ____

Using the spreadsheets on the next three pages to complete the following assignment:

1. Find the total load for the structure described below by calculating conduction and convection loads
2. Calculate the heat load due to conduction.
3. Calculate the convection load due to infiltration and ventilation.

   - Outdoor temperature is 11°F. Indoor design temperature is 72°F. For this exercise, you will need to calculate heat loss through all exterior walls, windows, doors and ceiling.
   - Calculate infiltration as 1.8 air changes per hour. (RCH = 1.8)
   - In addition to the infiltration load, the building needs ventilation at rates of 16 cfm per wallaby and 3 cfm per weasel. There are 64 wallaby and 600 weasels in the building.
   - The building is a three-floor structure and measures 74 x 63 with 12' from finished floor to finished floor.
   - The top floor ceiling is 12' above finished floor and has standard 1/2" wabbit's foot wallboard and is insulated with 18" of wombat fur.
   - The roof structure consists of 28" steel joists, which support corrugated decking made of recycled Walrus tusks. The actual roofing consists of Walleye scales.
   - There is a total of 28 windows per floor, each measuring 8' wide by 6' high.
   - Each wall at street level has two doors measuring 4' by 9'.

Turn to the following pages for your format.

a. Fill in the blanks on page 2
b. Transfer the information from pages 2 to the first five lines of the summary sheet on page 4. Complete the BTUH calculation to determine the building Conduction total Heat loss (BTUH)
c. Fill in the blanks on page 3
d. Transfer the information from page 3 to the summary sheet on page 4.
e. Complete the TOTAL LOAD calculation

Wall area gross =		sf
Windows area =		sf
Doors area =		sf
Top floor ceiling area =		sf

CONDUCTION: total envelope heat loss BTUH

Wall R value	**R-Value**	**Units**	**Quantity (inches)**	**total R-value**	U-Factor u = 1/R
Outside air film value					
wildebeast snout siding					
Weevil Hide sheathing					
2 x 4 studs					
wookie fiber insulation		per/in			
1/2" wabbit's foot wall board		per/in			
Inside air film value					
Total R					

Ceiling R-value	**R-Value**	**Units**	**Quantity (inches)**	**total R-value**	U-Factor u = 1/R
18 "wombat fur		per/in			
1/2" wabbit's foot wall board		per/in			
10" air space		per/in			
Inside air film value					
Outside air film value					
Total R					

Building component	**R-Value**
Wildebeast snout siding	0.81
Weevil Hide sheathing	0.98
Wookie fiber insulation	3.78 per/in
Wombat fur insulation	3.7 per/in
Wabbit's foot wallboard	16.8 per/in
Windows	2.30
Doors	9.00
Inside air film value	0.68
Outside air film value	0.17
Air space	0.72 per/in
Walleye scales	0.00
Walrus tusk	0.00

CONVECTION: gain/loss infiltration **$Q = (C * ACH * V * \Delta T)/60$**

Constant =	1.1	
ACH =	1.8	
V =		
time =	60	
ΔT =		
Q infiltration =		BTUH

OR (Do both methods to check)

Step 1 find cfm

cfm=ACH*V/60

ACH =	1.8
V =	
time =	60
cfm =	

Step 2 use cfm to find Q

$Q = C*cfm*\Delta T$

cfm =		
Constant =	1.1	
ΔT		
Q Infiltration =		BTUH

CONVECTION: ventilation **$Q = 1.1*(cfm/person)(\#persons)*\Delta T$**

	Total Number
Wallaby = 16cfm	
Weasels = 3cfm	

	cfm
	cfm
	cfm total ventilation

Constant =	1.1	
cfm =		
ΔT =		
Q ventilation =		BTUH

SUMMARY SHEET

LOAD CALCULATION for transmission heat loss Q=U*A*ΔT

Component	**R-Value**	**U-Factor**	**AREA sf**	**ΔT**	**BTUH**
Walls (gross)					
Windows					
Doors					
Walls (net)					
Ceiling					
Conduction: total envelope Heat Loss (BTUH)					
Convection: BTUH heat gain/loss due to infiltration					
TOTAL SPACE HEAT LOSS/GAIN (BTUH)					
Convection: BTUH heat gain/loss due to ventilation					
TOTAL LOAD (BTUH)					

Formulas:

1. Conduction (transmission heat loss) $Q = U * A * \Delta T$
2. Infiltration: $Q = 1.1 * cfm * \Delta T$
   CFM = RCH * Vol (ft^3) /60 min/hr
3. Ventilation: $Q = 1.1 * cfm * \Delta T$
   CFM = (cfm/person)*(#persons)

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CON 371 – Mechanical and Plumbing Systems
In-Class Exercise No.4 Worksheet (5 points) – HVAC Delivery Systems

Name ____

Select a delivery system for each of the facilities and spaces described below. There may be more than one system that is acceptable for each facility.

HVAC Delivery Systems		
Forced-air	Single Zone VAV	Baseboard Convectors
Single Zone CV	Multiple Zone VAV	Variable Refrigerant Flow
Single Zone CV Reheat	VAV Reheat	Radiant Panels
CV Terminal Reheat	VAV Dual Duct	Chilled Beams
CV Dual Duct	Fan Terminal Units	Packaged Terminal Air Conditioners
CV Multizone	Fan Coils	

1) 600SF Computer Server Room located in the central area of a high-rise office and tech building in San Francisco, CA. Server room contains processors for a large technology service tenant that occupies half of the building.

Answer: ____

2) 1,800SF single family home, two-story with a full basement, located in Baltimore, MD. Air only system.

Answer: ____

3) 2,500SF Starbucks Coffee located in Portland, ME. It is a standalone structure that includes the serving area, tables and chairs in the customer area, and a kitchen and breakroom in the back. It also has a 500SF conference room that can be reserved by paying customers. System is to be energy efficient.

Answer: ____

4) 5,000SF Academic Steel Structure Laboratory located within a 100,000SF engineering building in Minneapolis, MN and it is a LEED Silver Certified Building. Laboratory is to be used for conducting physics and chemistry experiments. Lab space will require its own system and requires precise temperature and humidity control to conduct experiments.

Answer: ____

5) A 300SF hotel room in a Holiday Inn located in Omaha, NE. Room has a window on its north wall and includes two queen beds, a desk, TV and stand, refrigerator, microwave, and full bathroom.

Answer: ____

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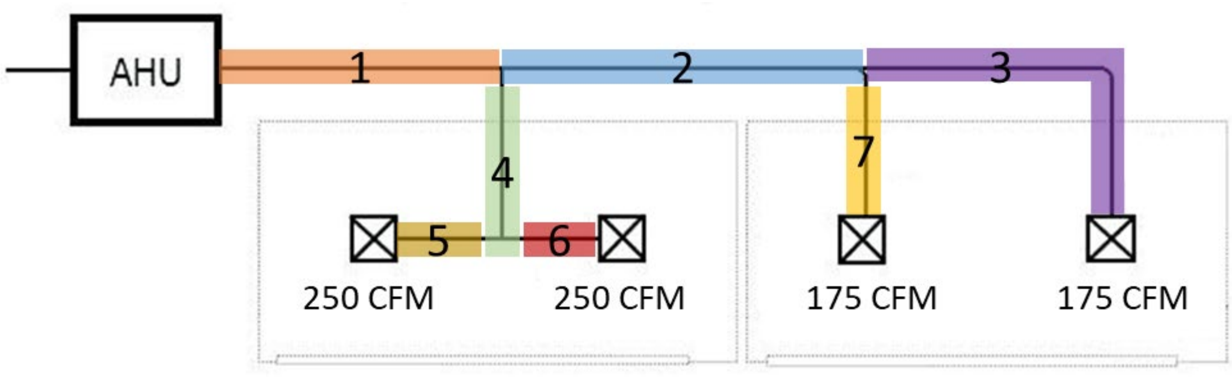
CON 371 – Mechanical and Plumbing Systems
In-Class Exercise No.5 Worksheet (10 points) – HVAC Duct Sizing

Name ____

The floor plan below shows the air delivery system for two zones within a building.

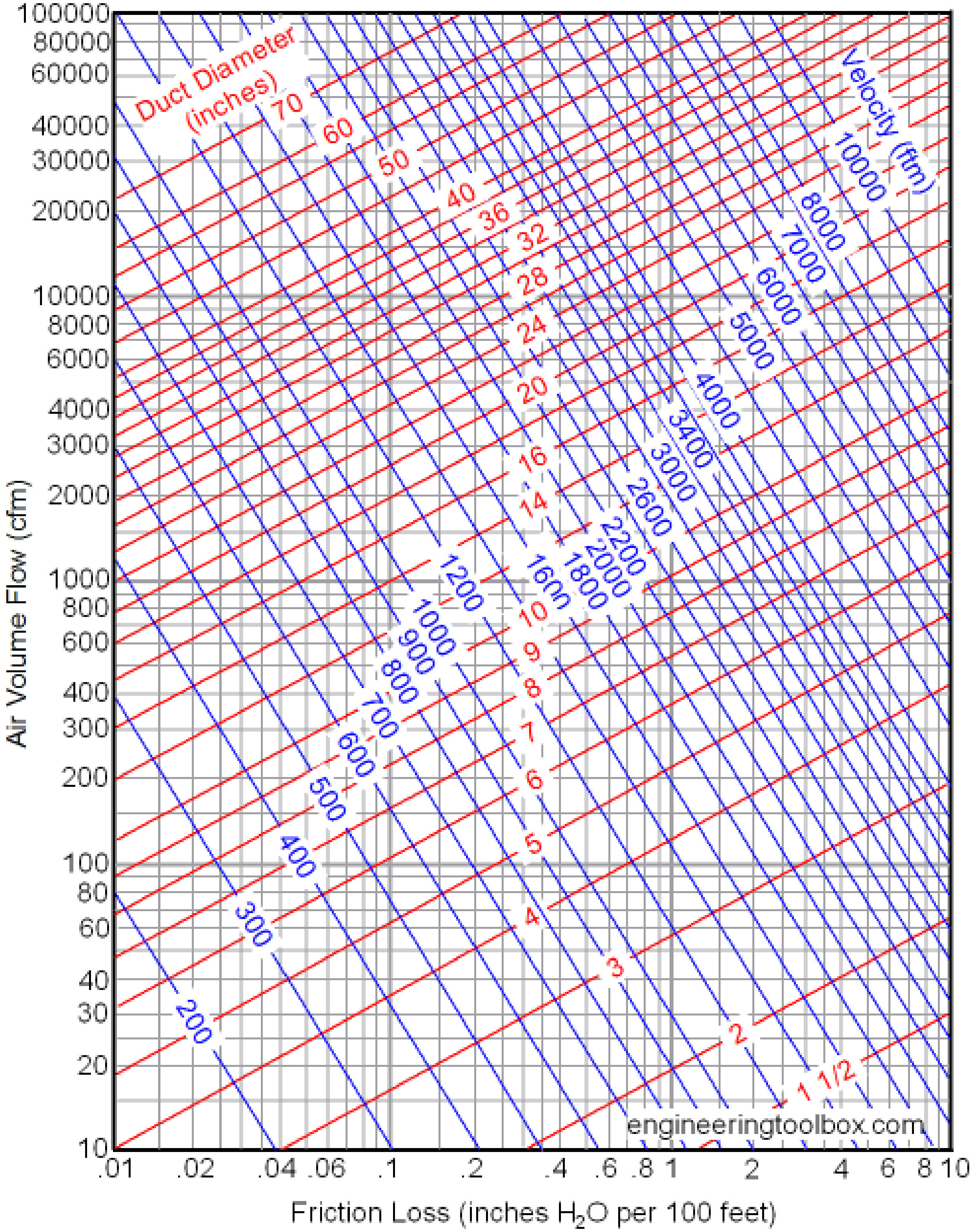


Air Delivery Information:

- Zone 1 requires 500 CFM divided equally between two diffusers
- Zone 2 requires 350 CFM divided equally between two diffusers
- Trunk lines 1 and 2 are to be rectangular ducts that does not exceed 8" in height
- Branch line 4 is to be rectangular duct that does not exceed 8" in height
- Branches 3, 5, 6, and 7 are to be round ducts supplying the diffusers
- The pressure loss per 100ft is to be held at 0.2" w.c. for all ductwork and zones
- Keep rectangular duct as square as possible (aspect ratio of 2 or less)
- Use even numbers for rectangular ductwork sizing (e.g., use 8x6, not 9x7)

Determine the size of each duct section and the associated velocity based on the numbering provided using the equal friction chart:

Duct	Flow Rate (CFM)	Size (inches)	Velocity (FPM)
Trunk 1			
Trunk 2			
Branch 3			
Branch 4			
Branch 5			
Branch 6			
Branch 7			


Duct Diameter (inches)
Velocity (ftm)
Air Volume Flow (cfm)
Friction Loss (inches H2O per 100 feet)
engineeringtoolbox.com
100000
80000
60000
40000
30000
20000
10000
8000
6000
4000
3000
2000
1000
800
600
400
300
200
100
80
60
40
30
20
10
.01
.02
.04
.06
.1
.2
.4
.6
.8
1
2
4
6
8
10
70
60
50
40
36
32
28
24
20
16
14
10
9
8
7
6
5
4
3
2
1 1/2
10000
8000
7000
6000
5000
4000
3400
3000
2600
2200
2000
1800
1600
1200
1000
900
800
700
600
500
400
300
200

Duct Diameter (in)	Rectangular Size (in)	Aspect Ratio										
		1.00	**1.25**	**1.50**	**1.75**	**2.00**	**2.25**	**2.50**	**2.75**	**3.00**	**3.50**	**4.00**
6"	WxH		6"x5"									
7"	WxH	6"x6"	8"x6"									
8"	WxH	7"x7"	9"x7"	9"x6"	11"x6"							
9"	WxH	8"x8"	9"x7"	11"x7"	11"x6"	12"x6"	14"x6"					
10"	WxH	9"x9"	10"x8"	12"x8"	12"x7"	14"x7"	14"x6"	15"x6"	17"x6"			
11"	WxH	10"x10"	11"x9"	12"x8"	14"x8"	14"x7"	16"x7"	18"x7"	17"x6"	18"x6"	21"x6"	
12"	WxH	11"x11"	13"x10"	14"x9"	14"x8"	16"x8"	16"x7"	18"x7"	19"x7"	21"x7"	21"x6"	24"x6"
13"	WxH	12"x12"	14"x11"	15"x10"	16"x9"	18"x9"	18"x8"	20"x8"	19"x7"	21"x7"	25"x7"	24"x6"
14"	WxH	13"x13"	14"x11"	17"x11"	18"x10"	18"x9"	20"x9"	20"x8"	22"x8"	24"x8"	25"x7"	28"x7"
15"	WxH	14"x14"	15"x12"	17"x11"	18"x10"	20"x10"	20"x9"	23"x9"	25"x9"	24"x8"	28"x8"	28"x7"
16"	WxH	15"x15"	16"x13"	18"x12"	19"x11"	20"x10"	23"x10"	23"x9"	25"x9"	27"x9"	28"x8"	32"x8"
17"	WxH	16"x16"	18"x14"	20"x13"	21"x12"	22"x11"	25"x11"	25"x10"	28"x10"	27"x9"	32"x9"	32"x8"
18"	WxH	16"x16"	19"x15"	21"x14"	23"x13"	24"x12"	25"x11”	28"x11"	28"x10"	30"x10"	32"x9"	36"x9"
19"	WxH	17"x17"	20"x16"	21"x14"	23"x13"	24"x12"	27"x12”	28"x11"	30"x11"	30"x10"	35"x10"	36"x9"
20"	WxH	18"x18"	20"x16"	23"x15"	25"x14"	26"x13"	27"x12”	30"x12"	30"x11"	33"x11"	35"x10"	40"x10"
21"	WxH	19"x19"	21"x17"	24"x16"	26"x15"	28"x14"	29"x13"	30"x12"	33"x12"	33"x11"	39"x11"	40"x10"
22"	WxH	20"x20"	23"x18"	26"x17"	26"x15"	28"x14"	32"x14"	33"x13"	36"x13"	36"x12"	39"x11"	44"x11"
23"	WxH	21"x21"	24"x19"	26"x17"	28"x16"	30"x15"	32"x14"	35"x14"	36"x13"	39"x13"	42"x12"	44"x11"
24"	WxH	22"x22"	25"x20"	27"x18"	30"x17"	32"x16"	34"x15"	35"x14"	39"x14"	39"x13"	42"x12"	48"x12"
25"	WxH	23"x23"	25"x20"	29"x19"	30"x17"	32"x16"	36"x16"	38"x15"	39"x14"	42"x14"	46"x13"	48"x12"
26"	WxH	24"x24"	26"x21"	30"x20"	32"x18"	34"x16"	36"x16"	38"x15"	41"x15"	42"x14"	46"x13"	52"x13"
27"	WxH	25"x25"	28"x22"	30"x20"	33"x19"	36"x18"	38"x17"	40"x16"	41"x15"	45"x15"	49"x14"	52"x13"
28"	WxH	26"x26"	29"x23"	32"x21"	35"x20"	36"x18"	38"x17"	43"x17"	44"x16"	45"x15"	49"x14"	56"x14"
29"	WxH	27"x27"	30"x24"	33"x22"	35"x20"	38"x19"	41"x18"	43"x17"	44"x16"	48"x16"	53"x15"	56"x14"
30"	WxH	27"x27"	31"x25"	35"x23"	37"x21"	40"x20"	43"x19"	45"x18"	47"x17"	48"x16"	53"x15"	60"x15"

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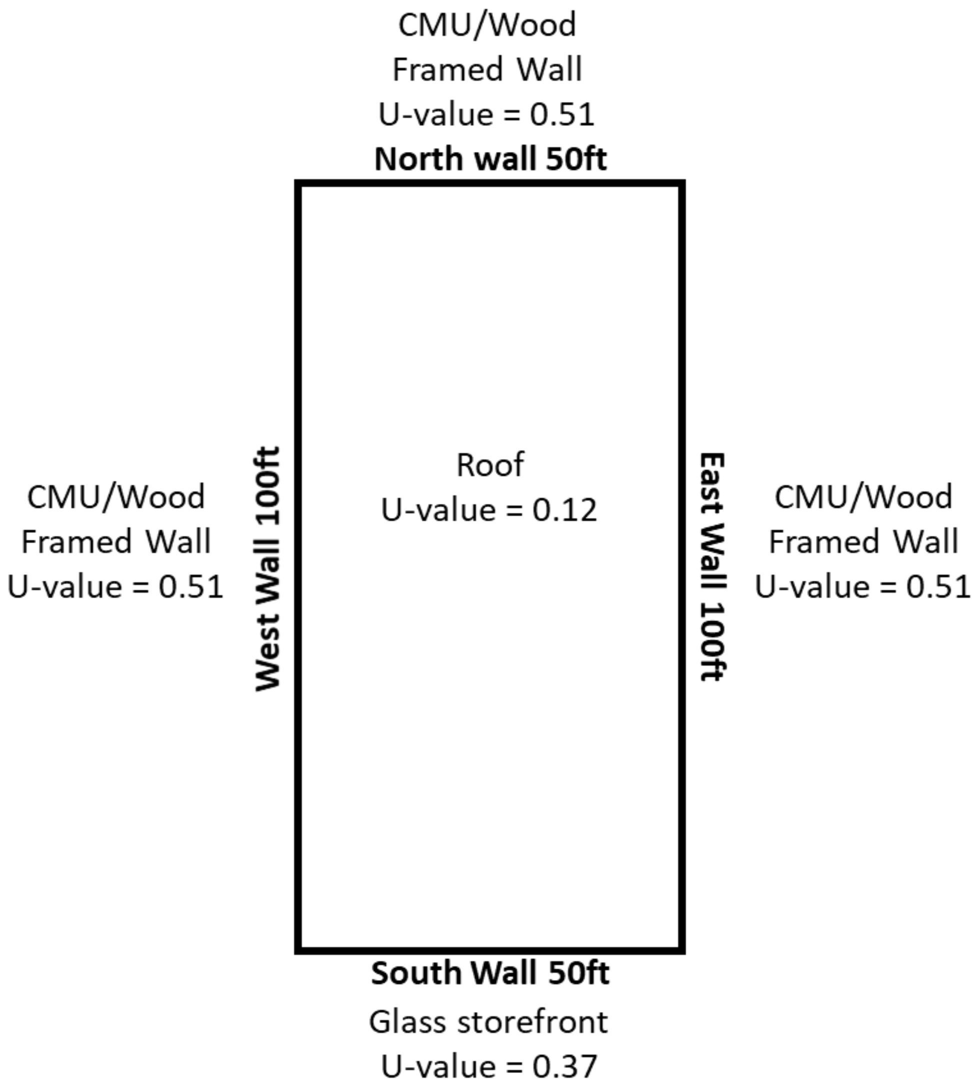
CON 371 - Mechanical and Plumbing Systems
In-Class Exercise No. 6 Worksheet (10 points)

Name ____Section No. _________________

For this exercise, you are to find the pipe size for a hot water and boiler heating system. The information for this system is provided below.

A retail store has dimensions of 100ft x 50ft x 14ft *(L* x *W* x *H).* Three of the walls are CMU block with no windows. The front wall is a glass storefront. The roof is a flat roof with a gray color.



1) Considering just conductance ($Q = U \times A \times TD$) and no humidification, what is the total heat loss (Q) to this building when the outdoor temperature is 25°F and the indoor temperature is to be 72°F? (NOTE: Q is the total load that the boiler is sized for).

	U	A	TD	Q
North Wall				
East Wall				
South Wall				
West Wall				
Roof				
			Total Q	

2) Find the flow rate of the water system based on the boiler information that the temperature exiting the boiler is 175°F and the temperature entering the boiler is 150°F.

$$q = \frac{Q}{500 \times (t_2 - t_1)}$$

Flow rate (q) =______________________________

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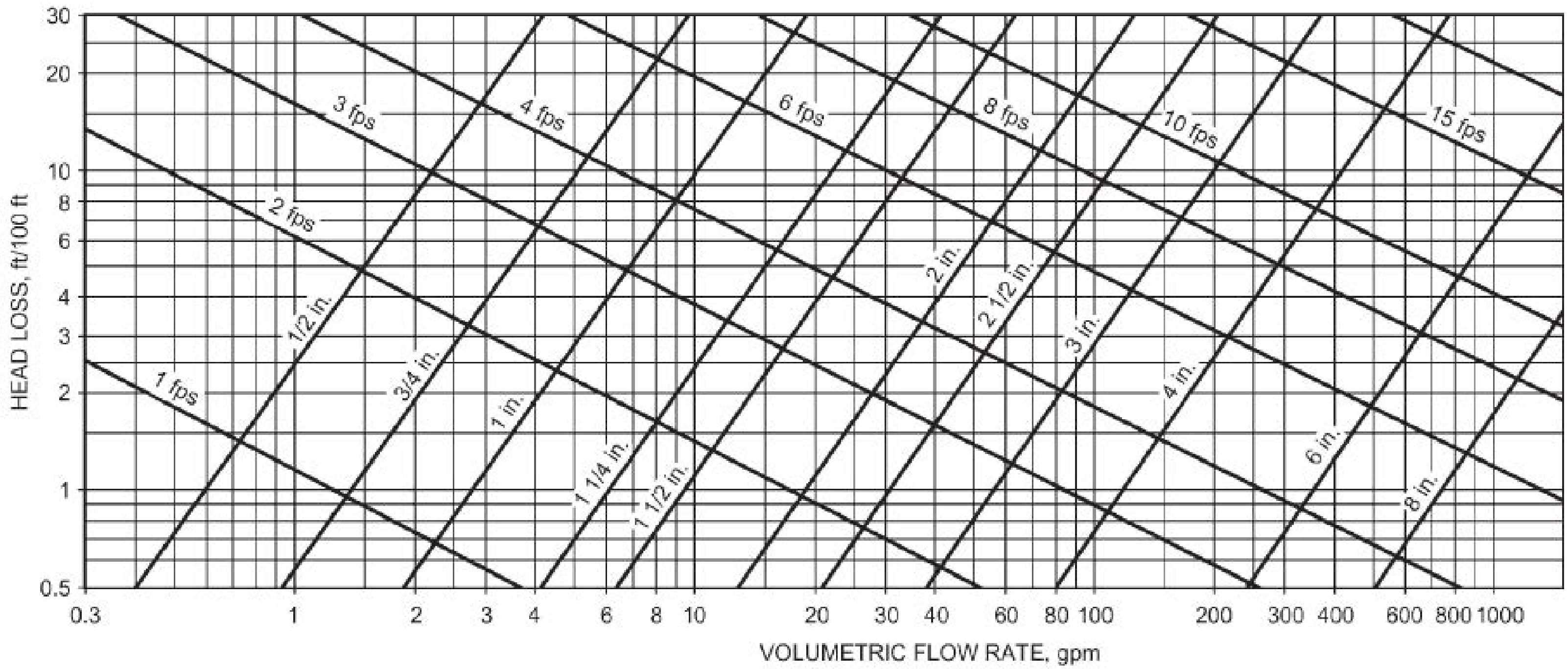
3) Using schedule 80 Carbon (black) steel pipe, what size pipe would be needed based on the flow rate calculated in part 2 and the total head loss of 4ft/l 00ft of pipe?



Pipe size required for Boiler: ______________________________

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CON 371 – Mechanical and Plumbing Systems
In-Class Exercise No. 7 Worksheet (10 points) – HVAC Plans and Specs

Name ____

HVAC Plans and Specs

We will use the mechanical plans for the CSU Precon Building Project. Using the plans, answer the questions below. Make sure to note the plan sheet that you used to find the information.

What is the leaving air temperature (LAT) from terminal box TB-15 located in room 200B?	______ °F	Sheet # ______
What is the water flow rate of the chilled water system pumps?	______ GPM	Sheet # ______
Where are the two heat exchangers (CONV-1 and CONV-2) located (state the floor and room number)?	______	Sheet # ______
What is the GPM being supplied by pumps to the finned-tube hot water (HW) coils?	______ GPM	Sheet # ______
What type of drive and sheave is required for the exhaust fan (EF)?	______	Sheet # ______
What is the sheetmetal gauge thickness required for return air ducts?	______ gauge	Sheet # ______
What is the entering water temperature (EWT) for chilled water flowing through AHU coils?	______ °F	Sheet # ______
What is the steam flow rate through heat exchanger CONV-1?	______ lb/hr	Sheet # ______
How many supply diffusers (SD) are located in Room 122 and what size are the diffusers (in inches)?	______	Sheet # ______
What is the duct size for the return air trunk line connected to branches from Rooms 101 and 102?	______ in	Sheet # ______

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CON 371 – Mechanical and Plumbing Systems
In-Class Exercise No.8 Worksheet (10 points)

Name: ____ Date: ___________

Plumbing Pipe and Joining Methods: Please use a web browser and navigate to http://opus.mcerf.org. Using the information on the website, populate the two tables below for each of the pipe materials listed.

	SYSTEM									
MATERIAL	Chilled Water	Compressed Air	Domestic Water	DWV	Fire Protection	Fuel Gas	Geothermal Heat Pump	Medical Gases	Refrigerant	Steam
ABS										
Carbon Steel										
Cast Iron										
Copper										
CPVC										
Galvanized Steel										
PEX Tubing										
PVC										
Stainless Steel										

	JOINING METHOD									
MATERIAL	CSST	Flanged	Grooved	Heat Fusion Weld	No-Hub Coupling	PEX	Press	Solvent Weld	Threaded	Welding
ABS										
Carbon Steel										
Cast Iron										
Copper										
CPVC										
Galvanized Steel										
PEX Tubing										
PVC										
Stainless Steel										

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CON 371 – Mechanical and Plumbing Systems
In-Class Exercise No.9 Worksheet (20 points)

Plumbing Plans and Specs

We will use the Plumbing plans and Specifications for the CSU TMI Building Project. Both documents are on Canvas. Using the plans & Specs, answer the questions below. Use column one for the answer and the second column for the reference page (either sheet # from the plans or specification section # from the specs) where you found the answer.

QUESTION	RESPONSE		SHEET # or SPEC #
1. Who is the manufacturer and model of MSB-1 sink?	______		______
2. On P2.00.B1, at grid lines H.2 & 2, the note states 3" Waste up to washer. What floor are the washers located on?	______	Floor	______
3. Using the below floor plans find the size of the CW line with a note that refers you to the civil drawings for continuation.	______	Inch	______
4. Is the balancing valve symbol on P2.01.A1 near gridlines P9, the same symbol as shown on the abbreviations page P0.00?	______		______
5. What lab gases are plumbed on the first floor in section A1?	______	inch	______
6. What is the largest size CW line in the building?	______	inch	______
7. On the first floor, area C, what is routed into the base cabinet?	______		______
8. What type of pipe is specified for use in "compressed air, Laboratory Vacuum, and specialty gas"? Think cost increase. Hint section 22 61 13.	______		______
9. What six items are routed in the wall, under the window, on the first floor area C? Up/dn are separate items.	______		______
10. What are 4" RD and 4" OD? You may need to read some of the definitions and work backwards to find this answer.	______		______

11. The "water assure remote monitoring panel" for the Deionized (DI) Water system is provided by whom?

12. What two lines from the third floor, area C, plumbing plan go up to the condensing unit on the roof?

13. On the third floor, Area D2, for the ½" CW DN to the water filter, what needs to be provided between the water filter and icemaker that is made by Watts?

14. What type of metal is the WB-1 made from?

15. Why are there twice as many WC-1 and HWC-1 in the women's rest room on the third floor, area D, than in the men's rest room?

16. What do the sumps serve that are shown on the first floor waste & vent riser plan for area A?

17. In Plumbing Piping, Project Record Documents, what type of "metal" tag is to be used for each valve?

18. All the vertical expansion tanks shown on P6.02 show a factory charge of 55PSIG. Does this meet the standard factory pre-charge requirements shown in the specifications? Hint: look in Plumbing Specialties, the same heading as is on the schedule.

19. HWCP-1 are used in some water distribution systems. How many items (number of numbered lines) need to be performed before and after start-up, as preventative maintenance operations and checks? Hint: look for the specification heading that focuses on pumps.

20. Roof drains (considered plumbing fixtures, products) can cause severe water damage if not installed correctly. Who is responsible for coordinating roof drains with roof types?

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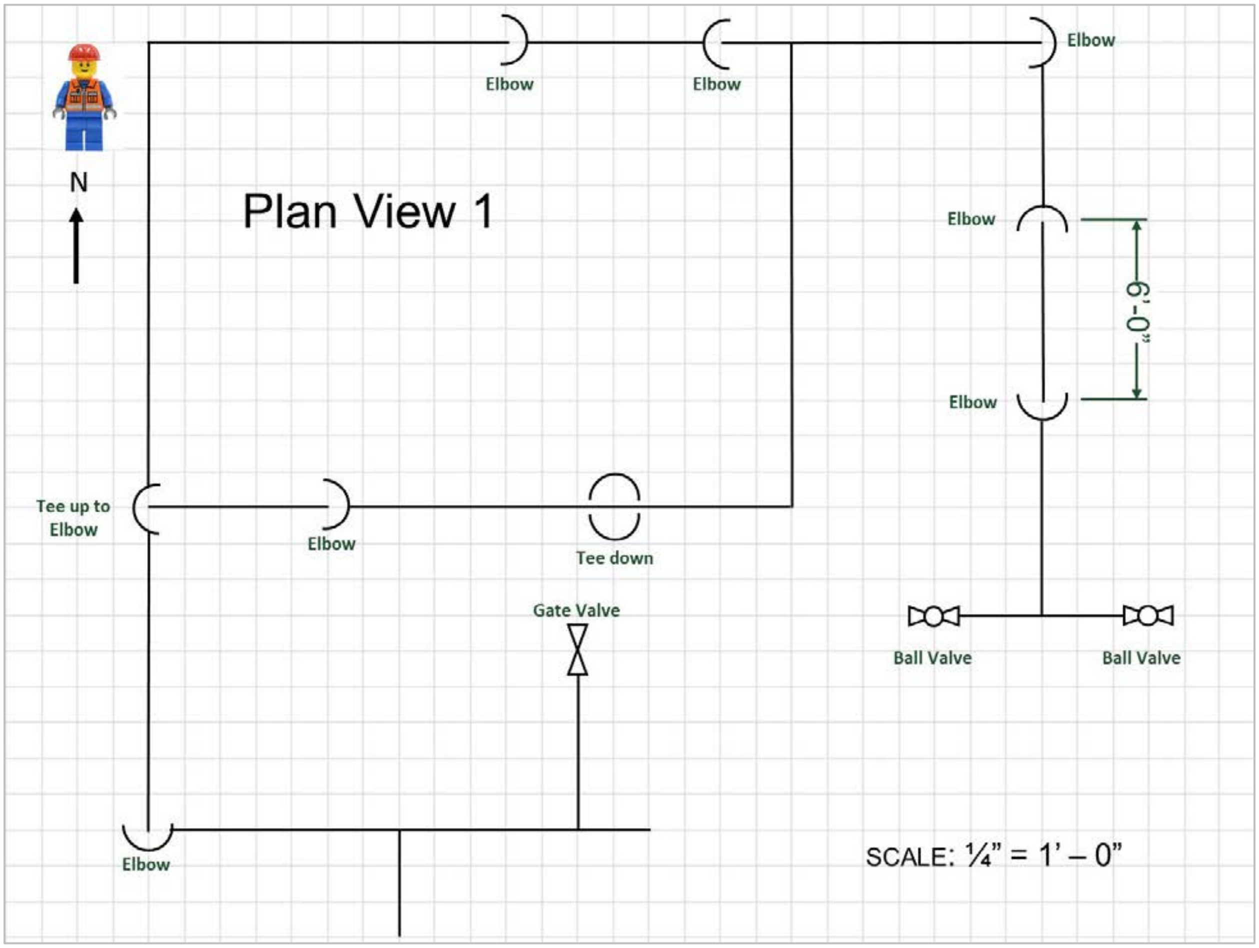
CON 371 – Mechanical and Plumbing Systems
In-Class Exercise No.10 Worksheet (10 points)

Name ____

Isometrics

Review the plan view for the three piping systems show as plan views below. Then, on the following page, draw the Isometric of each system.



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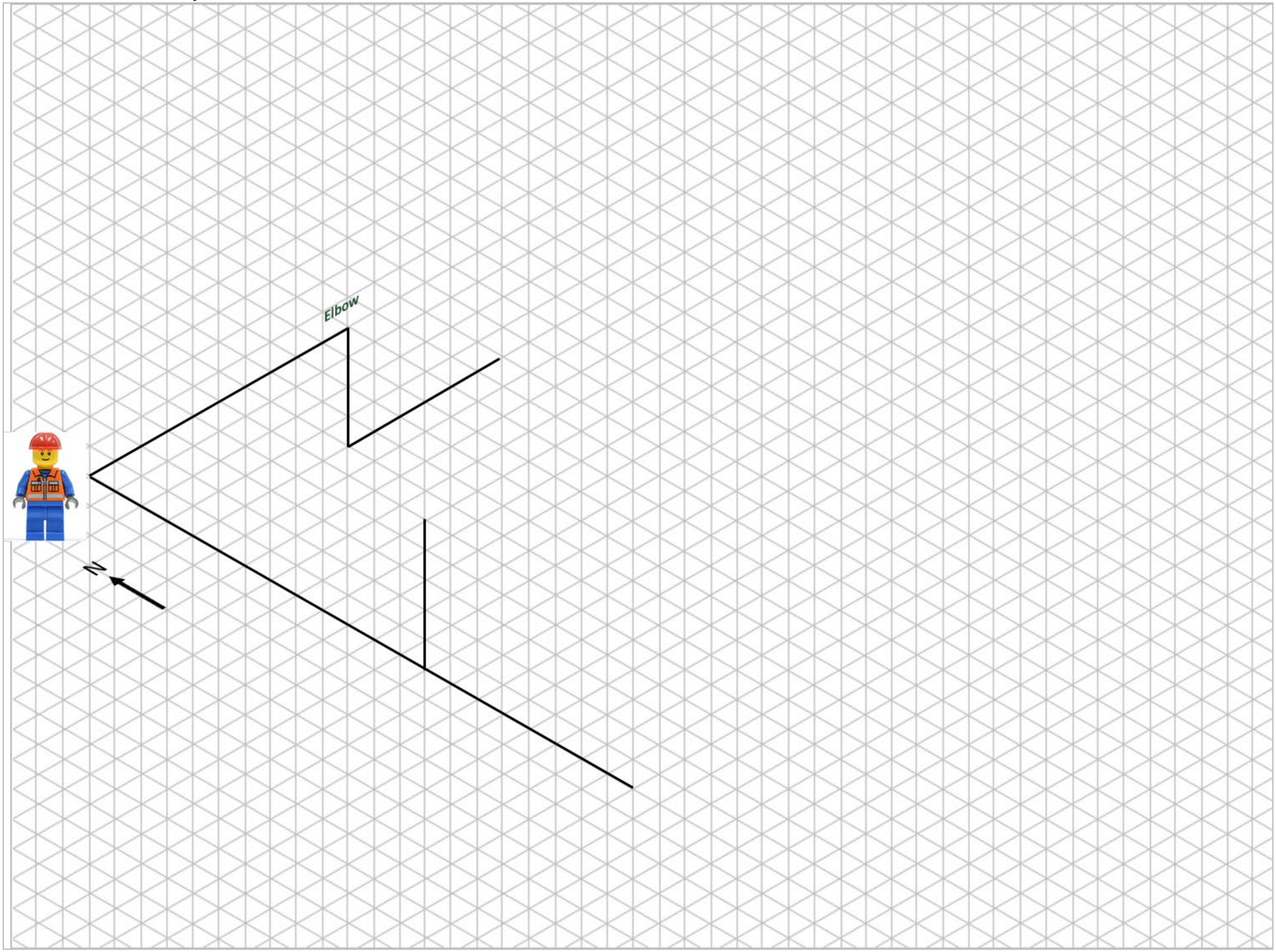
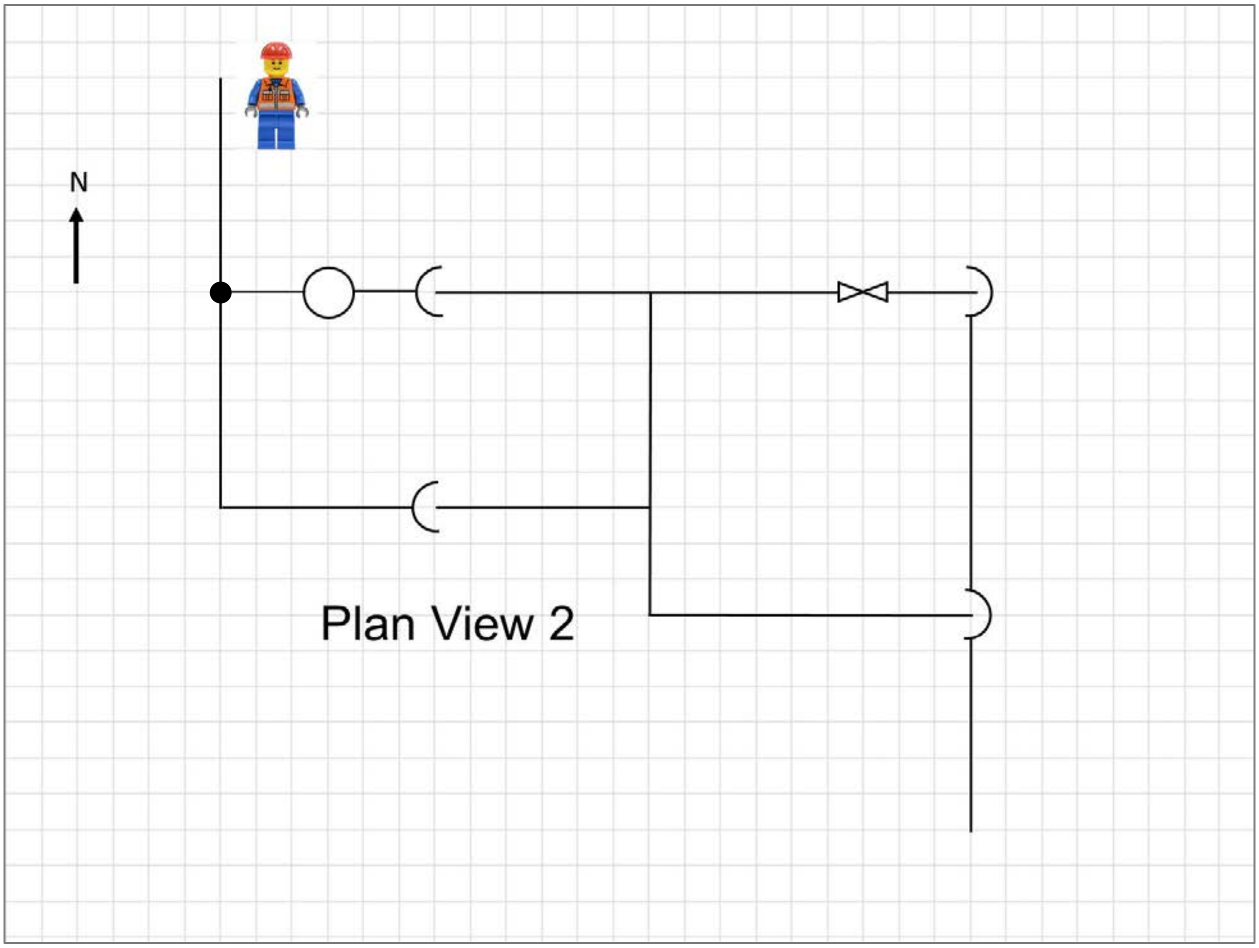
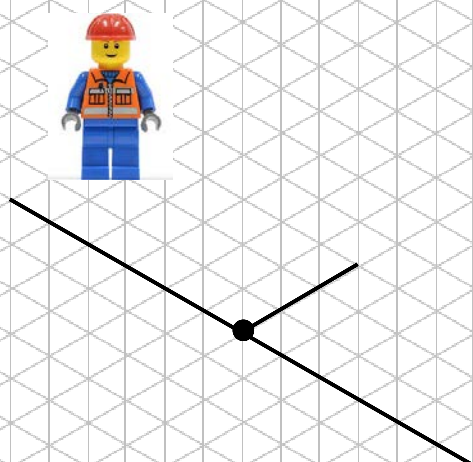
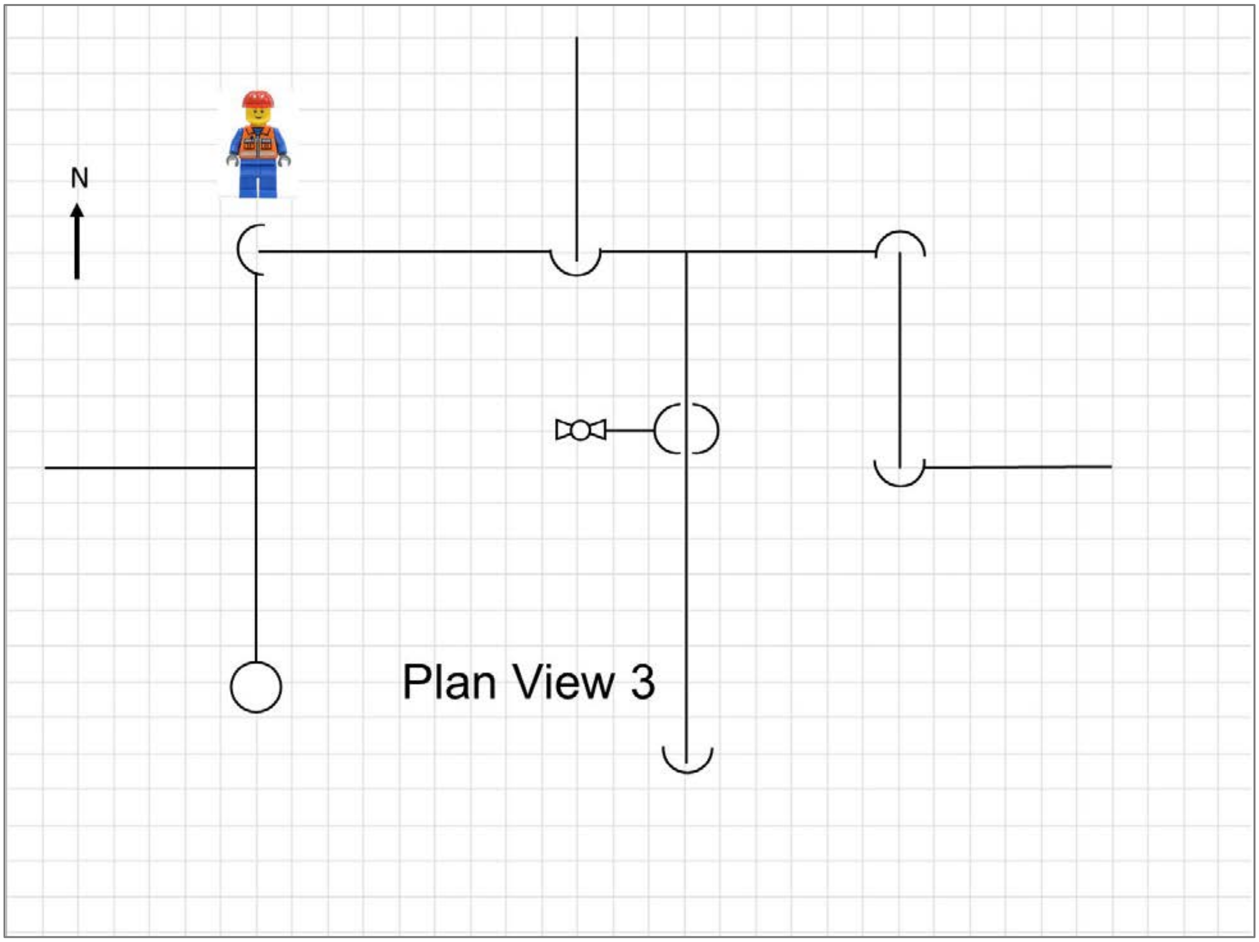



N
Plan View 2




N
Plan View 3

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CON 371 – Mechanical and Plumbing Systems
In-Class Exercise No.11 Worksheet (60 points)

Heavy Civil Plans

We will use the Plumbing plans for the Lakeview on the Rise Project and CSU Shepardson Waterline Replacement project. Both sets of documents are on Canvas. Using the plans, answer the questions below. Use column one for the answer and the second column for the reference page where you found the answer.

QUESTION	RESPONSE		SHEET #
1. Waterline Construction shall conform to what entity(s) standards and specifications?			
2. What referenced entity guidelines does the developer follow when submitting a construction traffic control plan?			
3. What type riprap is installed in Detention Pond 100 on the outlet coming from the development and from US Highway 287?			
4. What schedule PVC pipe is specified for all underdrain pipe?			
5. How many Inlet Protection Area Inlets are shown on the Erosion Control Plan?		ea	
6. What is the elevation of the overflow weir/100 year emergency spillway?		FT	
7. What rating must all sanitary sewer cleanouts have?			
8. How far from buildings do roof drain collector lines need to stub?		FT	
9. On the east side of Debra Dr. between building 10 and 11, what size/dimension is the proposed storm sewer Type R Inlet?		FT	
10. What is the largest size of the RCP on the storm sewer referenced in question 9 above?		IN	

11. What is the size of the force-main leaving the property in the parking lot north of buildings 1 and 2?	____________	IN	____________
12. Where does the force-main is question 11 start at, identify the piece of equipment it attaches to.	____________		____________
13. What size water service is required for 8 unit buildings?	____________	IN	____________
14. What type of copper is specified for 1 ½” and 2” water lines?	____________		____________
15. How many sanitary sewer service lines are required for each building?	____________	ea	____________
16. What is the size of the SS service line in Q 15, and what is the pipe type and rating	____________		____________
17.What is the separation distance between the sanitary sewer, storm sewer and water lines?	____________	FT	____________
18. What is the minimum separation distance between the firelines, service lines and roof drains?	____________	IN	____________
19. What are the requirements for the fire hydrant connections/assembly located on Stoney Brook Road to the south of the community center, marked STA18+03.19?	____________		____________
20. Where water lines are lowered to cross another utility, what is the minimum distance between the two utility lines? Hint, look for a detail.	____________	IN	____________
21. What are the requirements for the tapping saddle for the 8”PVC water line as shown to the west of Baggins Drive between buildings 15 and 16?	____________		____________
22. What size and material is the forcemain made from?	____________		____________
23. All pipes shall have a pressure seal. RPC joint seals shall comply with what ASTM?	____________		____________
24. There is a connection between the roof drain stubs and the collector lines. Where do you find the connection design between these two lines?	____________		____________

25. How much fall is there in the storm sewer on Rohan Rise Road from the elevation given at the radius on Lorien Lane to the east side of building 9 (may not be on storm sewer plans page) and the elevation given at the west side of building 8?

26. Plastic pipe needs to have a tracer wire buried with it so utility locators have something to trace when doing locates. What size copper wire is specified to identify the forcemain? Hint: look at detail drawings.

27. How far from the outlet side of the meter pit must sprinkler connections be? FT

28. Regarding thrust blocks, what is the minimum bearing surface area for a 12" pipe with a 90-degree bend? SF

29. How big is the backup emergency generator installed to ensure that the pumps in the wet well always have power to pump sewage? kW

30. The pumps in the wet well are started and stopped by float switches (they float in liquid as the liquid level rises and falls it turns the pumps in the wet well on or off. At what elevation does the High WSL Alarm go off? Hint: you need to find a detail of the tank under the pumps in the wet well. FT

31. What is the minimum depth of the sealed backflow prevention stainless steel canister associated with the yard hydrant installation?

Questions 32 -40 use the CSU waterline Replacement Plans

QUESTION	RESPONSE		SHEET #
32. How many pot holes were done prior to construction? Hint: look for a table with pot hole information.			
33. What type of coupler is used between the new water line in Amy Van Dyken Way and the 2" copper domestic water service at the Forestry Building?			
34. What parking lot is closed and used as a staging area during Phase 1?			
35. What is the minimum bearing area (SQ. FT.) for 10" pipe with a 22 1/2degree bend?		SF	
36. What specification must the concrete used on a fire hydrant meet?			
37. Who is responsible for locating all underground utilities?			
38. Why is a fire hydrant used as a high point when filling new water main?			
39 If Add Alt 3 STA 1+=23.83 is chosen, what test must be performed prior to making connection?			
40. If either ADD ALT 2 or 3 is used, what type/name of adapter is specified?			

Colorado State University
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CON 371 –Mechanical and Plumbing Systems
In-Class Exercise No.12 Worksheet (20 points)

Sustainability

We will use an abridged set of construction documents for this exercise on a sustainable geothermal system, which are available on Canvas. Using the Plans, answer the questions below. Use column one for the response and the second column for the reference page(s) where you found the answer.

QUESTION	RESPONSE	Page #
1. You are connecting the 12" UG piping from the manifold vault on the east side of the well field to the mechanical room in Moby (AN 118). The pipes are to penetrate the building under what piece of equipment?	______________	______________
2. What type of valve is specified for use when filling/draining the new system (AN 118)?	______________	______________
3. How many GPM does each pump servicing the geothermal system flow?	______________	______________
4. What types of controls do the geothermal system pumps use?	______________	______________
5. There are many new firewall penetrations in Moby as a result of this renovation. What is the stated requirement to seal the pipe through these new penetrations?	______________	______________
6. All HDPE piping connections are to be fused by a qualified IGSHPA contractor. What ASTM is referenced regarding the fusion of this pipe?	______________	______________
7. What is the C/L spacing between the East/West rows of wells?	______________	______________
8. Do the pumps for the geothermal field receive emergency power?	______________	______________
9. What, if any, electrical service is provided to borefield vault one (volts/Amps)?	______________	______________
10. What major city utility main line runs through the borefield (entity name and line size)?	______________	______________
11. Does the fluid flow rate from the field appear to match the flow rate of the pump(s) in AN 118? You will have two pages listed in the right hand column.	______________	______________

12. What does note “3” on the geothermal piping mains require when trenching for the main S/R lines from the field to Moby? ______________ ______________

13. In the borefield, how far below grade is Metallic tape placed, and how often must it be placed? (tell me what is stated for how often) ______________ ______________

14. The geothermal contractor is responsible for pipe entry into the Moby mechanical room. Their responsibility ends at an “H” bridal. How many N.O. valves are there? What does N.O. stand for? ______________ ______________

15. Looking at the “Typical Main Piping Trench Detail” how many tracer wires are shown in this detail? ______________ ______________

16. What is the shown depth from finished grade to the top of the pipe in the borefield? (there is one exception for a utility and it is not part of this question) ______________ ______________

17. When grouting the borehole do you start top down or bottom up? ______________ ______________

18. The vault has many requirements for anchoring. What metal type is used to anchor the HDPE structural brace anchor feet to the concrete pad? What is the W/C ratio of the concrete in the pad? ______________ ______________

19. The main gas ling coming into AN 118, in the first floor of building A, has a pressure reducing valve (PRV), what PSI is it reduced from, and what PSI is the reduction to? ______________ ______________

20. Who is responsible for making repairs to all existing building components that have been affected by the demolition of plumbing systems? ______________ ______________

Colorado State University
Department of Construction Management

CON 371 –Plumbing Systems Quality Control
In-Class Exercise No.13 Worksheet (20 points)

Plumbing Quality Control

We will use the Plumbing Specifications for the CSU TMI Building Project, which is available on Canvas. Using the Specifications, answer the questions below. Use column one for the response and the second column for the reference page where you found the answer. You will need to find the appropriate specification to answer the following series of questions. The first thing you need to do is identify the appropriate section of the specifications. Next look at section headings and then for detailed specifications to answer these questions.

QUESTION	RESPONSE	Section and Page #
1. You are walking down a hall and notice that cellular foam insulation is painted to match the wall color. Is this allowed?		
2. Commissioning is important for QC. What is the sample rate of equipment for plumbing systems during the verification, validation and demonstration process?		
3. For Plumbing Piping, it is typical to test sweat or solder joints. What are the two nondestructive methods mentioned in the specifications to achieve this testing?		
4. Plumbing specialties are just that, specialties. They typically do/provide a specific function that is important. In the case of potable water, there may be regulatory requirements that govern the types of materials that can be used. The specifications call for lead-free materials (0.25% lead by weighted average). What is the referenced standard the specification mentions that needs to be in accordance with?		
5. Some plumbing equipment has electrical requirements. For motors, it important that they be quiet so typically there are several listed requirements the motor must meet. The motors on the TMI project have a “premium efficiency” rating. What standard defines this rating designation?		
6. You are watching a worker insulate piping connected to a boiler. The worker insulated over a nameplate and ASME stamp identifying the boiler. What should the worker have done with the insulation over the nameplate?		

7. Motor starters, Electrical Devices and Wiring are also important to QC. You notice that a 15-horsepower motor is installed, and the tag says, "KVAR size corrects motor power factor to 65%. The 15HP motor has an uncorrected power factor of less than 85% at rated load. Should the motor be accepted for use?

8. To save money on domestic water meters, as you are over budget and trying to catch up, your purchasing agent buys a cast iron meter housing. Will the owner accept this material?

9. Pipe hangers and supports for natural gas piping need to conform to what Fuel Gas Code, as applicable? (list all three)

10. This project has piping that uses Trapeze and clamped systems and need thermal-hanger shield inserts. Your purchasing agent found a deal on half circumference units. Will these pass a QC inspection?

11. The equipment on the roof needs certain supports. In order to decrease weight and not need to replace structural members, you decide not to provide lateral bracing since the load is a dead load. Will this decision pass a QC inspection? Why?

12. When checking on an underground sanitary waste and vent piping (DWV) test, within 5' of the building, you notice that some of the pipe was made in Canada. Does made in Canada meet spec? Why?

13. Backflow preventers are considered a plumbing specialty. You have 30 days from what milestone(s) to certify the backflow preventers operate properly?

14. Plumbing equipment can make up a large part of a project. You have both domestic and industrial water heaters (using natural gas) on your project. When testing Gas pressure what is the maximum inches of W.C. you can have for the gas supply pressure?

15. When installing plumbing equipment, you typically have field quality control measures that you follow. How many test/inspections are listed in the specifications under “field quality control”?

16. What brand WC, Urinal and Lavatories, counter-mounted sinks and laboratory sinks is listed specifically as an unacceptable fixture brand?

17. Your master plumber is out sick with COVID-19. You are working on a compressed air system. The system connections must be brazed. In order to finish the system today you want to use an apprentice for the brazing. What qualifications must they have to perform this function and meet spec?

18. The apprentice finishes the compressed air system in 17 above. What is the pressure specification, minimum and maximum, for testing that system in the field?

19. Who is responsible for cleaning the reverse osmosis system (including piping)?

20. Water hammer arrestors are a plumbing specialty. What is the specification for their installation?

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CON 371 – Mechanical and Plumbing Systems
In-Class Exercise No.14 Worksheet (20 points)

MEP Scheduling

Name: ___________________________________Section:_______

For this exercise, use the quantities for the listed equipment, materials, and fixtures below and the RSMeans packet from Canvas to find the daily output and calculate the duration in days. Complete the Daily Output and Duration Columns below.

	Equipment/Fixtures	Quantity	Unit	Daily Output	Duration (Days)
1)	Fan Coil Units (FCU-1 to FCU-9) Direct Expansion, 3 Ton units	9	ea		
2)	Condensing Units (CU-1 to CU-9) Air Cooled, 3 Ton units	9	ea		
3)	¾" Type L Copper Tubing	684	LF		
4)	Stainless Steel Rectangular Metal Duct Type 304	1,400	lbs		
5)	12" Round Metal Duct Stainless Steel, 26 ga.	467	LF		
6)	Turbine Pumps Cast Iron, 3,000 GPM, 150HP	3	ea		
7)	Finned-Tube Radiation Heaters 21", Two-Tier, Slope Top, 2" Steel Tube	415	LF		
8)	Water Closets (WC-1 to WC-15) Floor Mounted, 1.28 gpf	15	ea		
9)	Lavatories (L-1 to L-30) Vanity Top, Cultured Marble, 25"x22" Single Bowl	30	ea		
10)	Urinals (UR-1 to UR-15) Wall Hung, Siphon Jet	15	ea		