HEATING AND COOLING DISTRIBUTION

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AIA Continuing Education Provider

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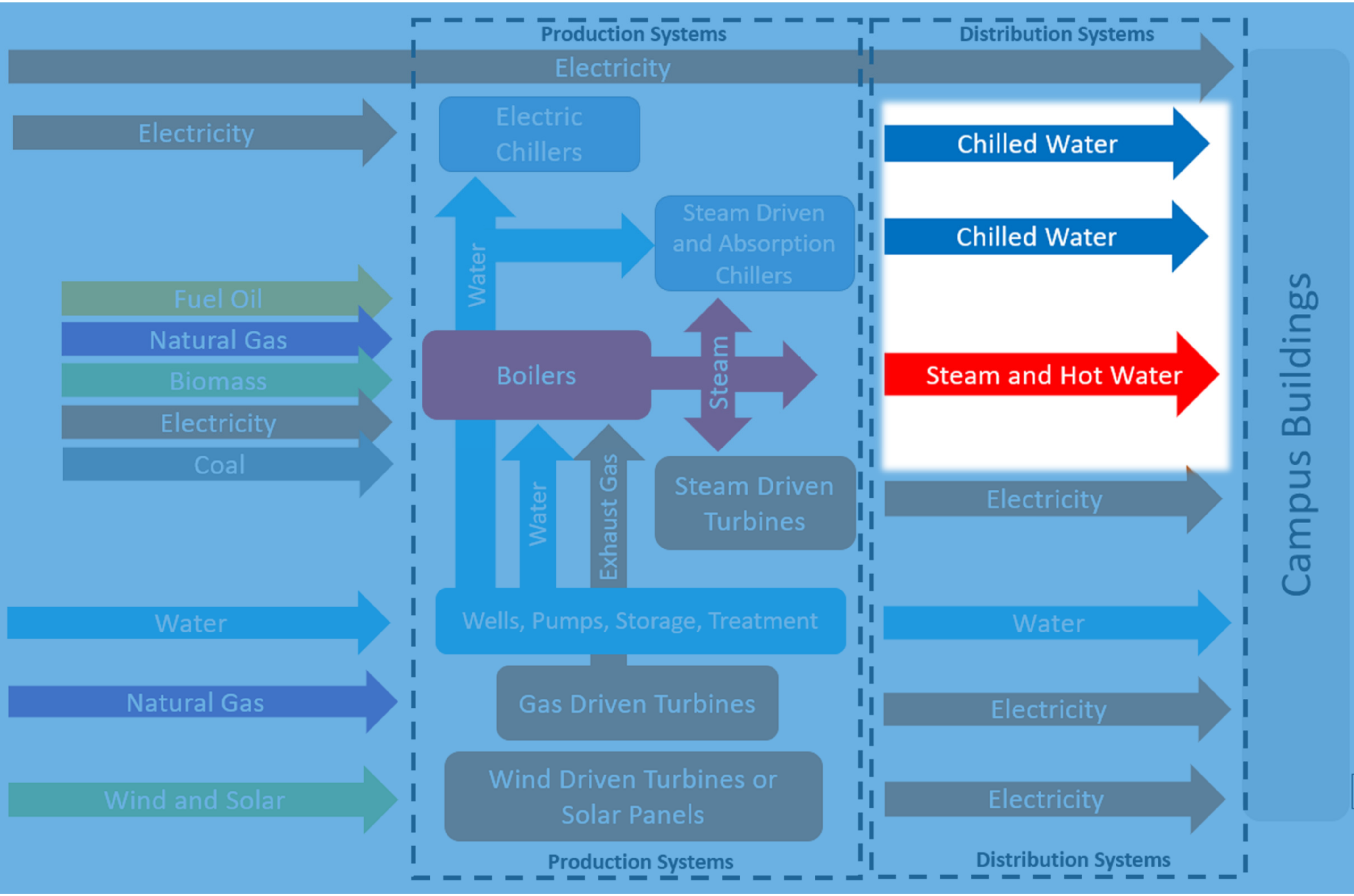
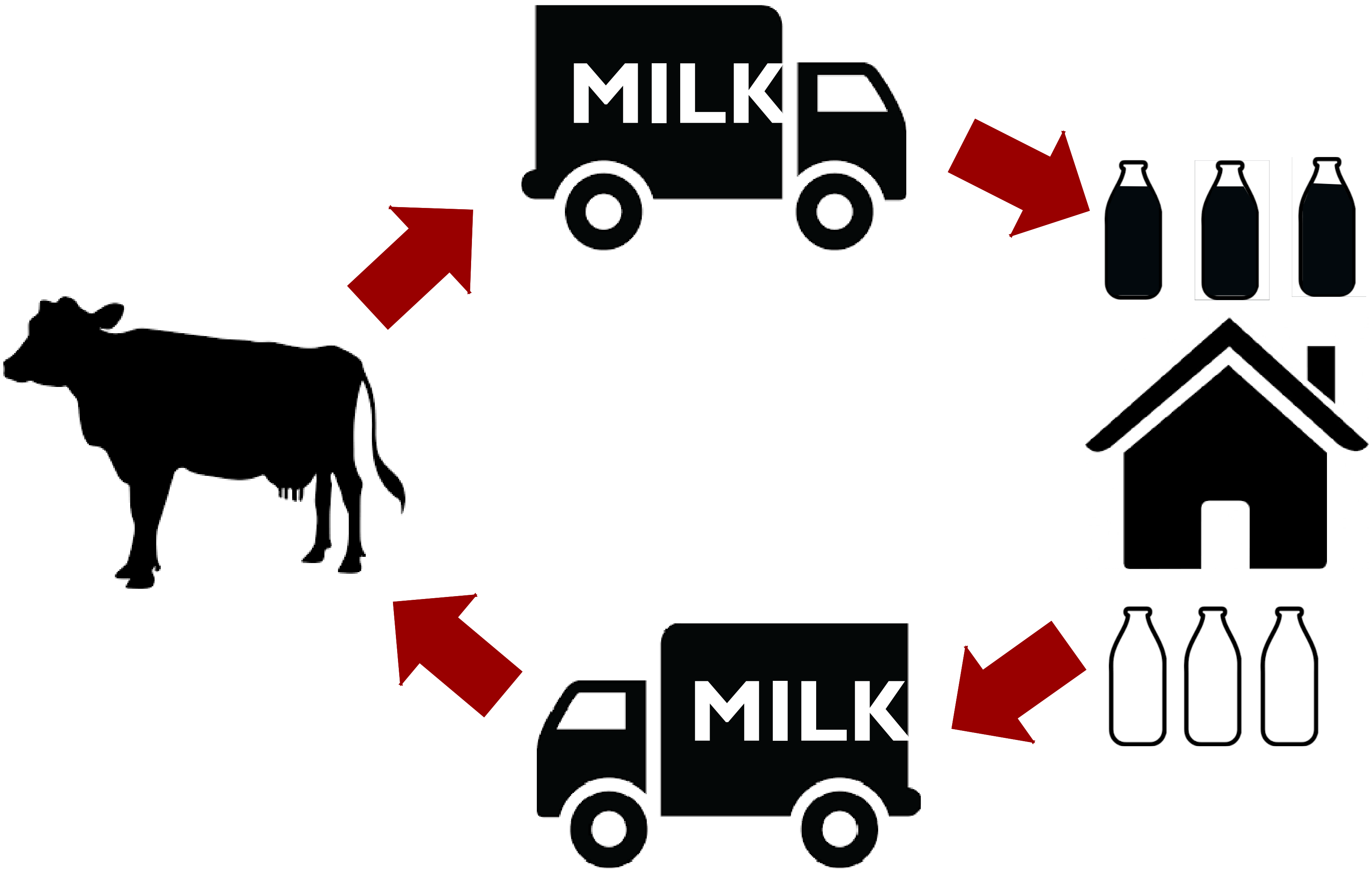
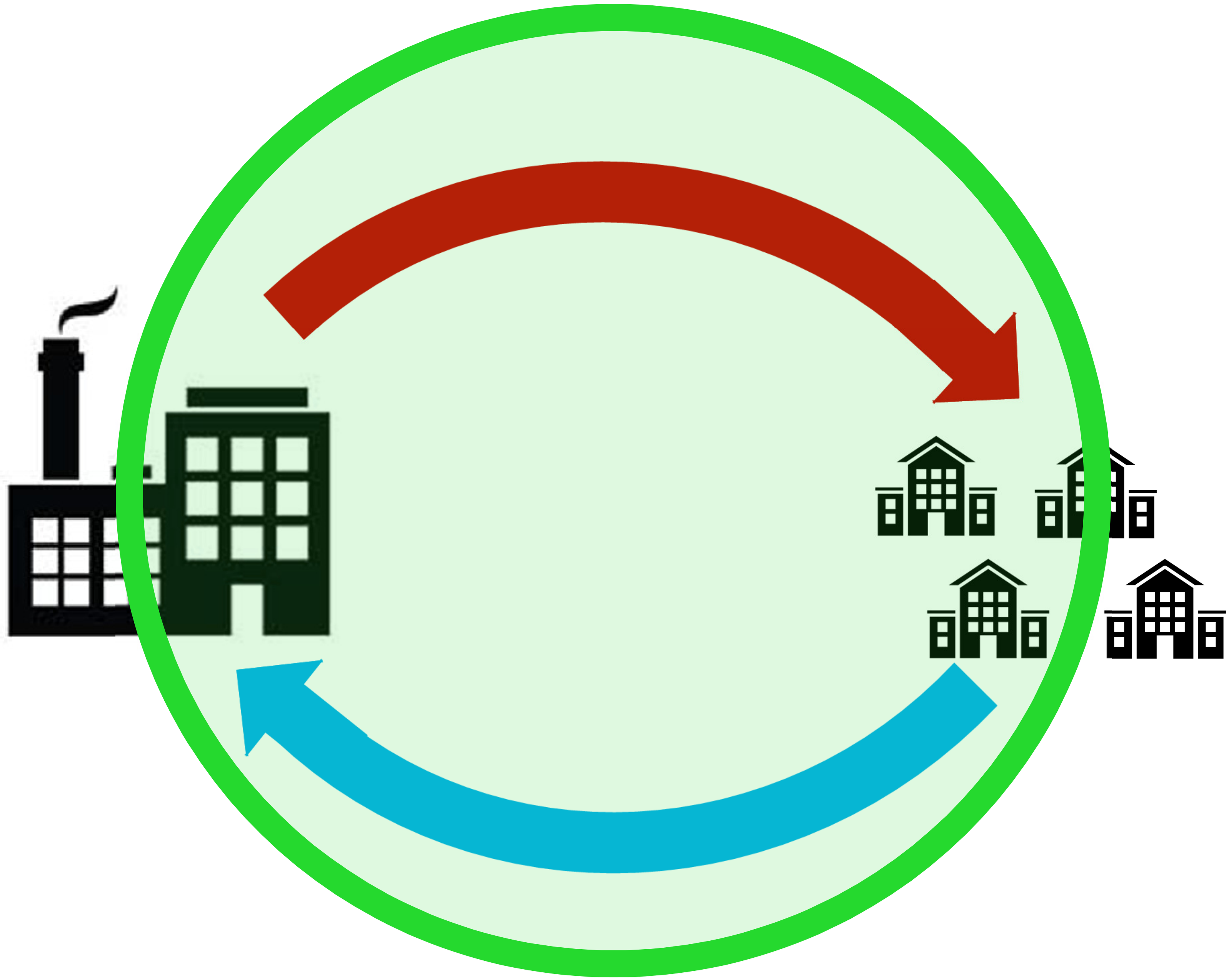
HEATING DISTRIBUTION



HEATING/COOLING A CAMPUS

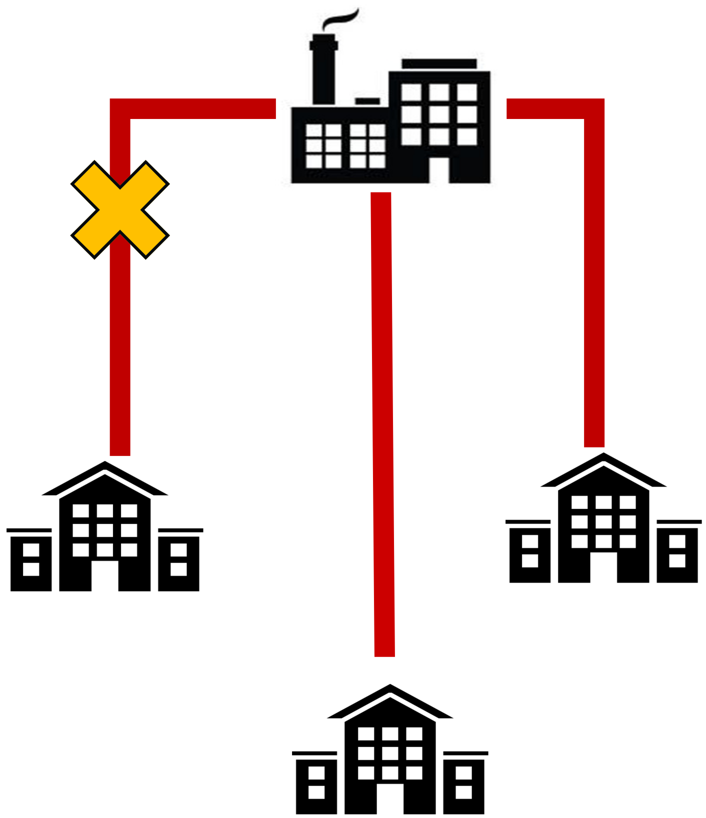




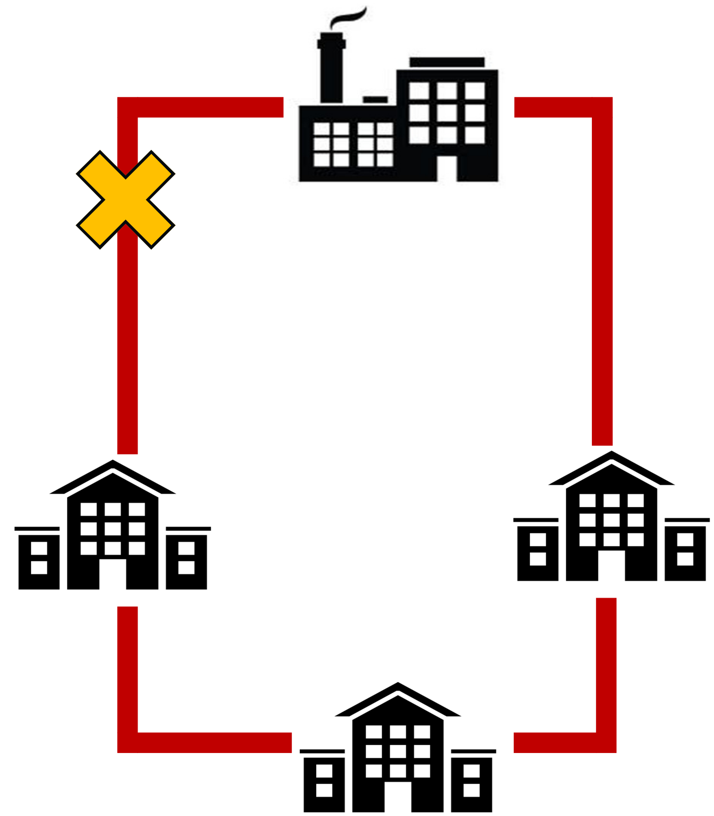
OVERVIEW

- Radial or Looped
- How Pipe Fails
- Steam or Hot Water
- Pipe Materials
- Direct Buried or Tunnel
- Costs
- Design Considerations

RADIAL OR LOOPED



Radial



Looped

HOW PIPE FAILS

Corrosion
Expansion
Water Hammer
Excavation

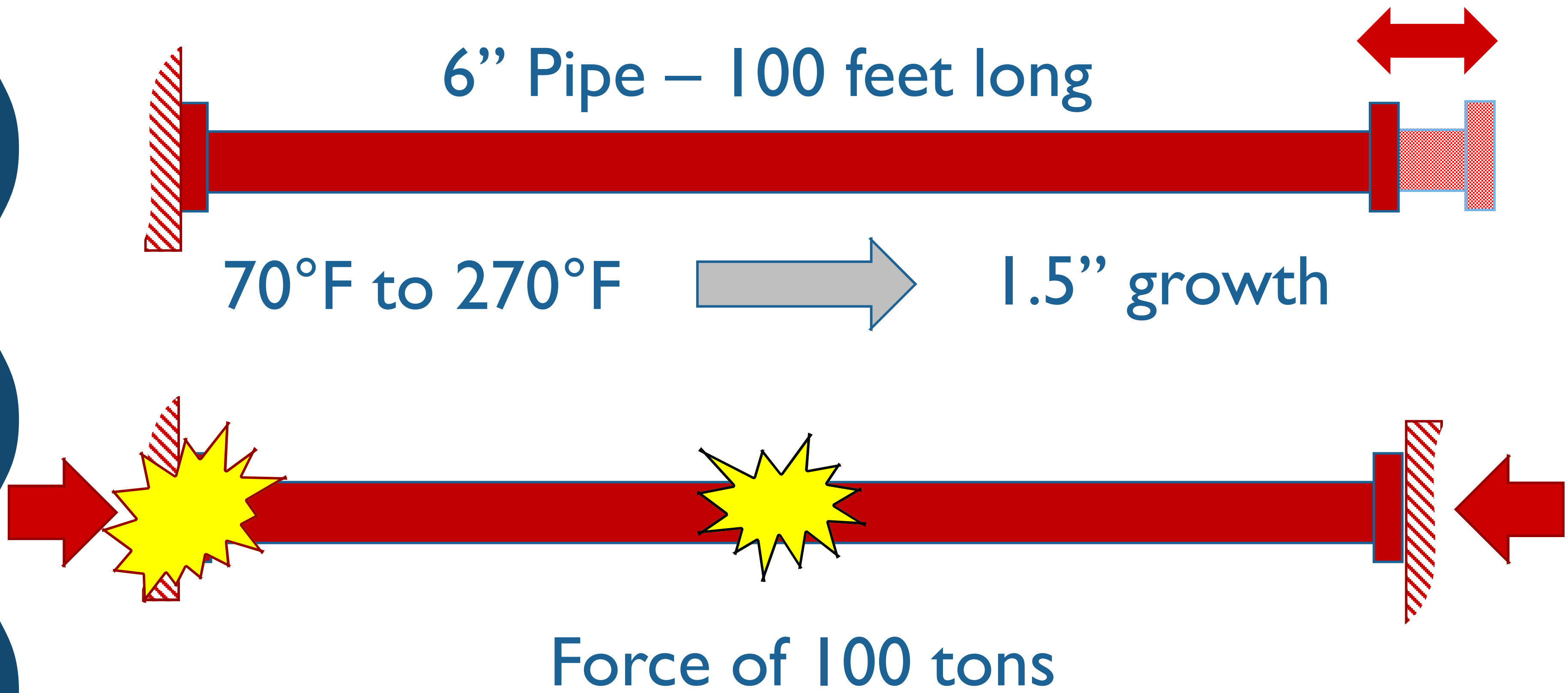
CORROSION

External and Internal

Water + Iron + Oxygen = Rust

Solution:
No Water,
No Iron, or
No Oxygen

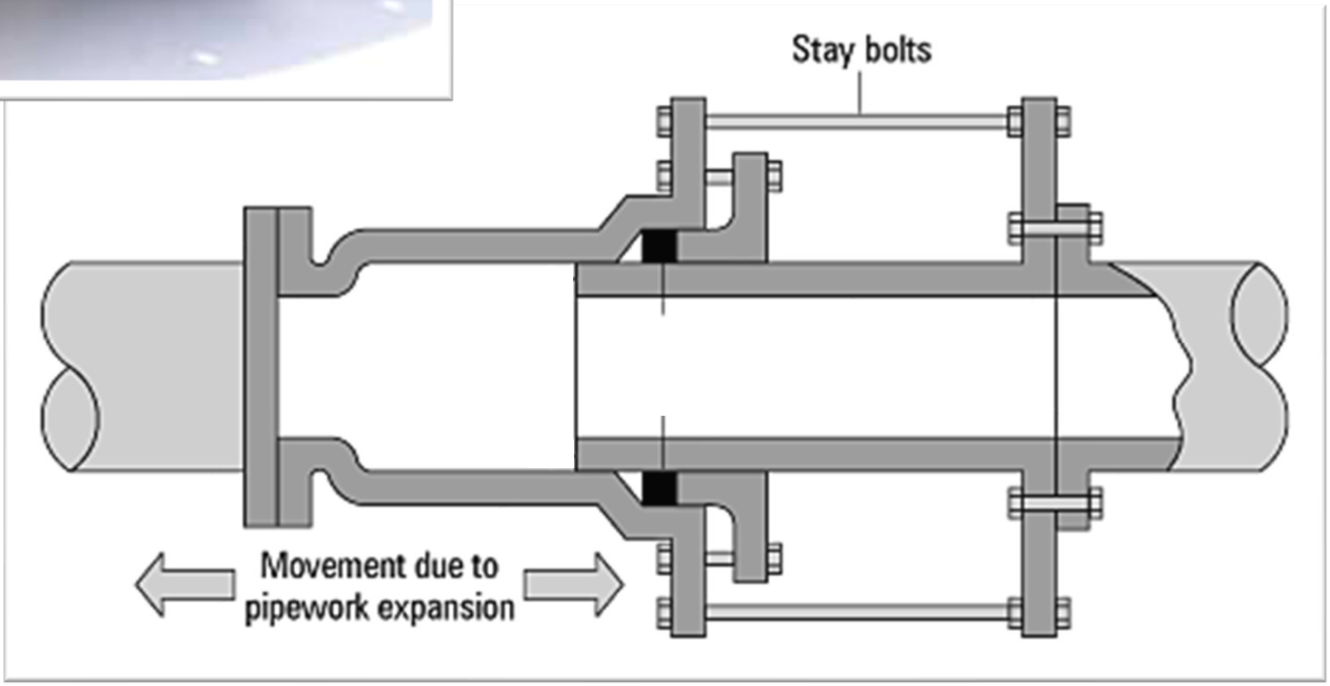
EXPANSION



Solution:

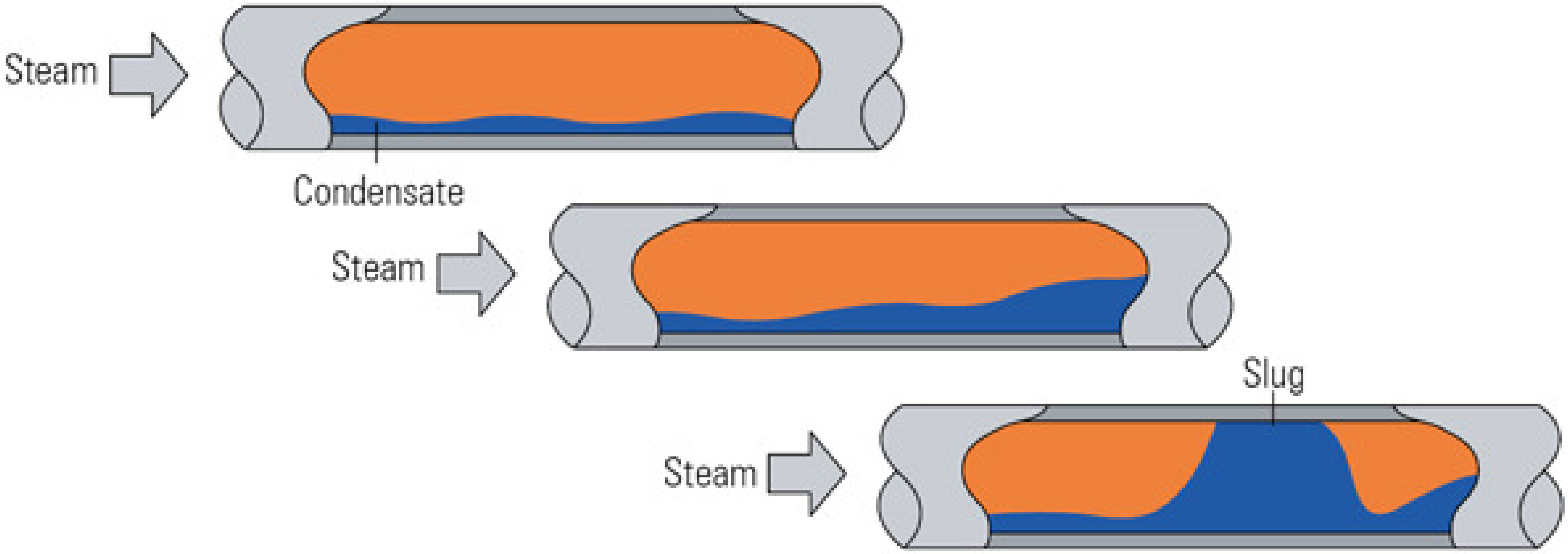
Add Flexibility

EXPANSION



EXPANSION

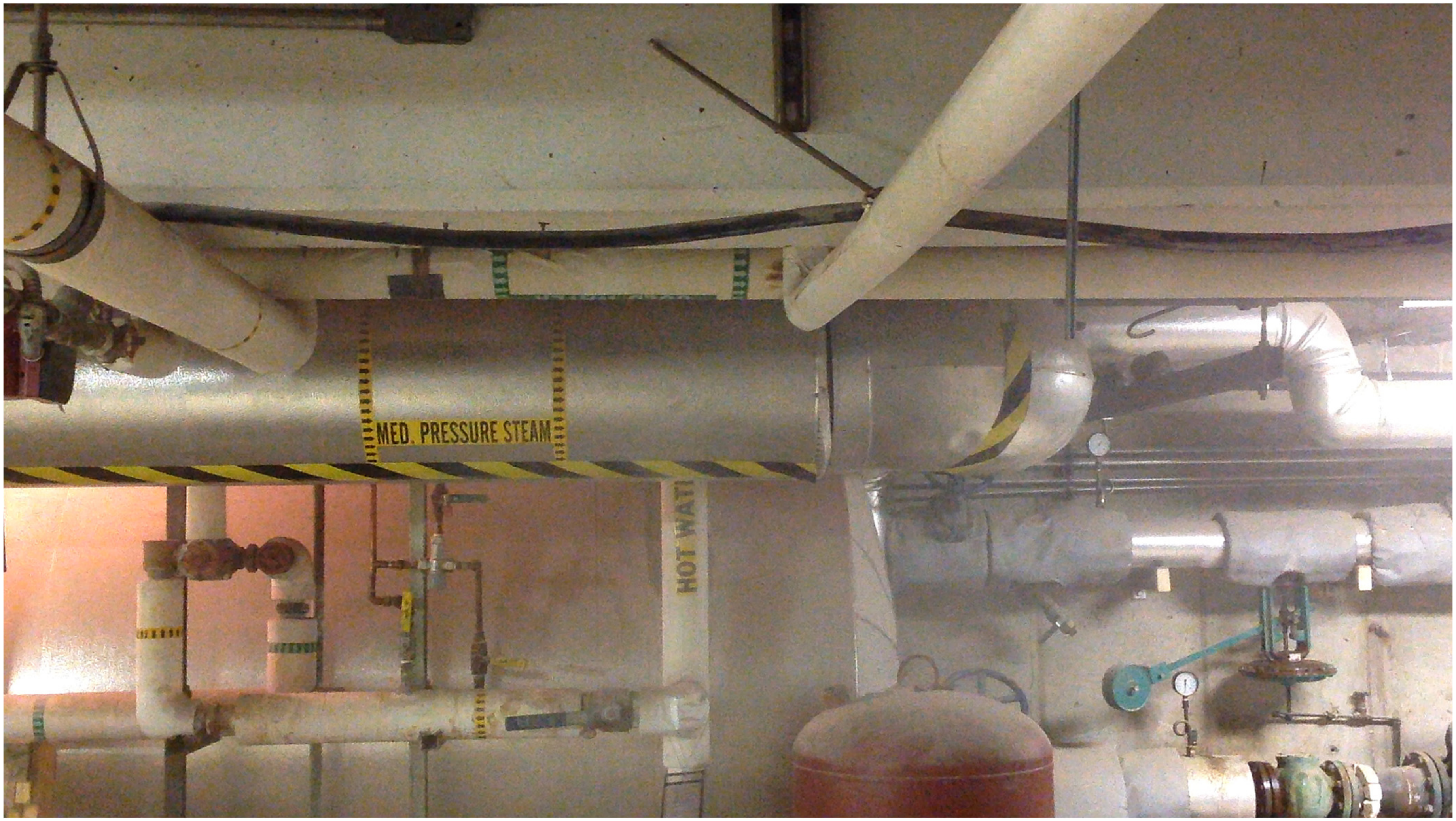
STEAM INDUCED WATER HAMMER



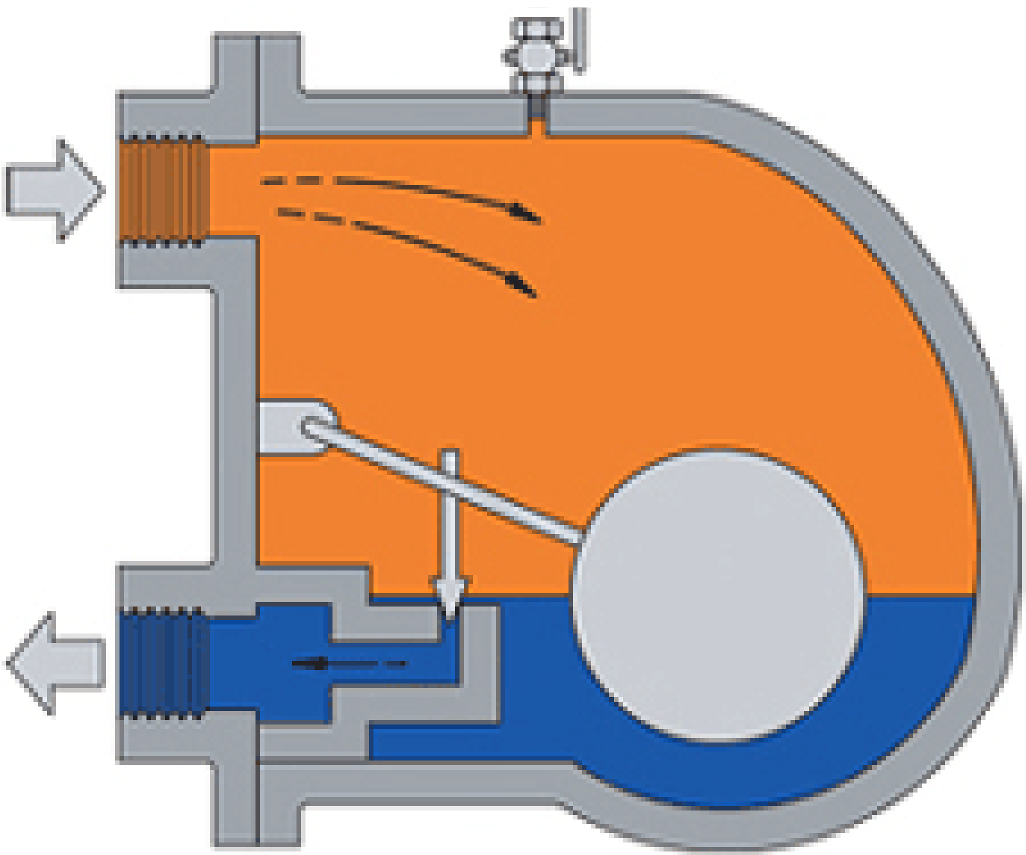
Solution:

Remove condensate from steam line

STEAM INDUCED WATER HAMMER



STEAM INDUCED WATER HAMMER



Traps

Float

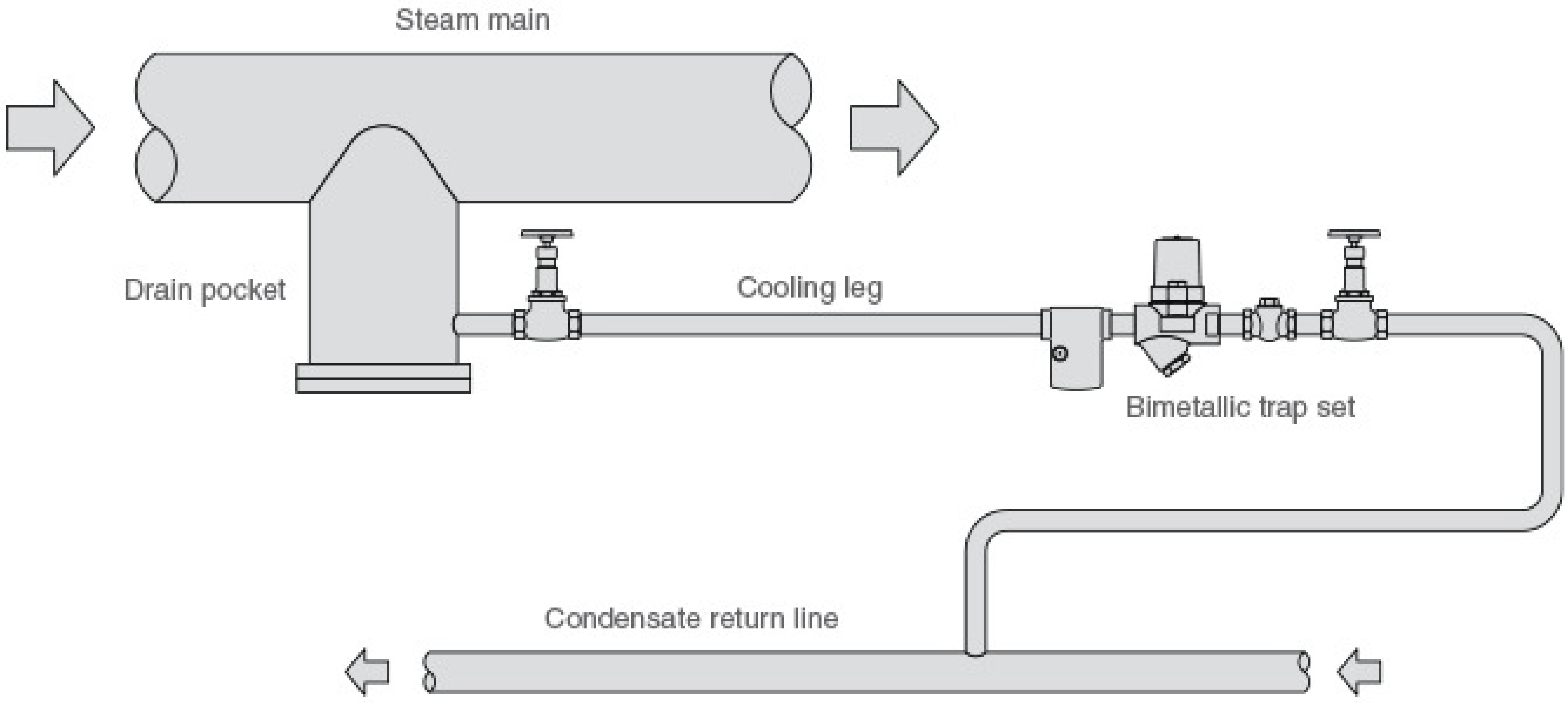
Inverted Bucket

Thermostatic

Thermodynamic

Nozzle

STEAM TRAPS



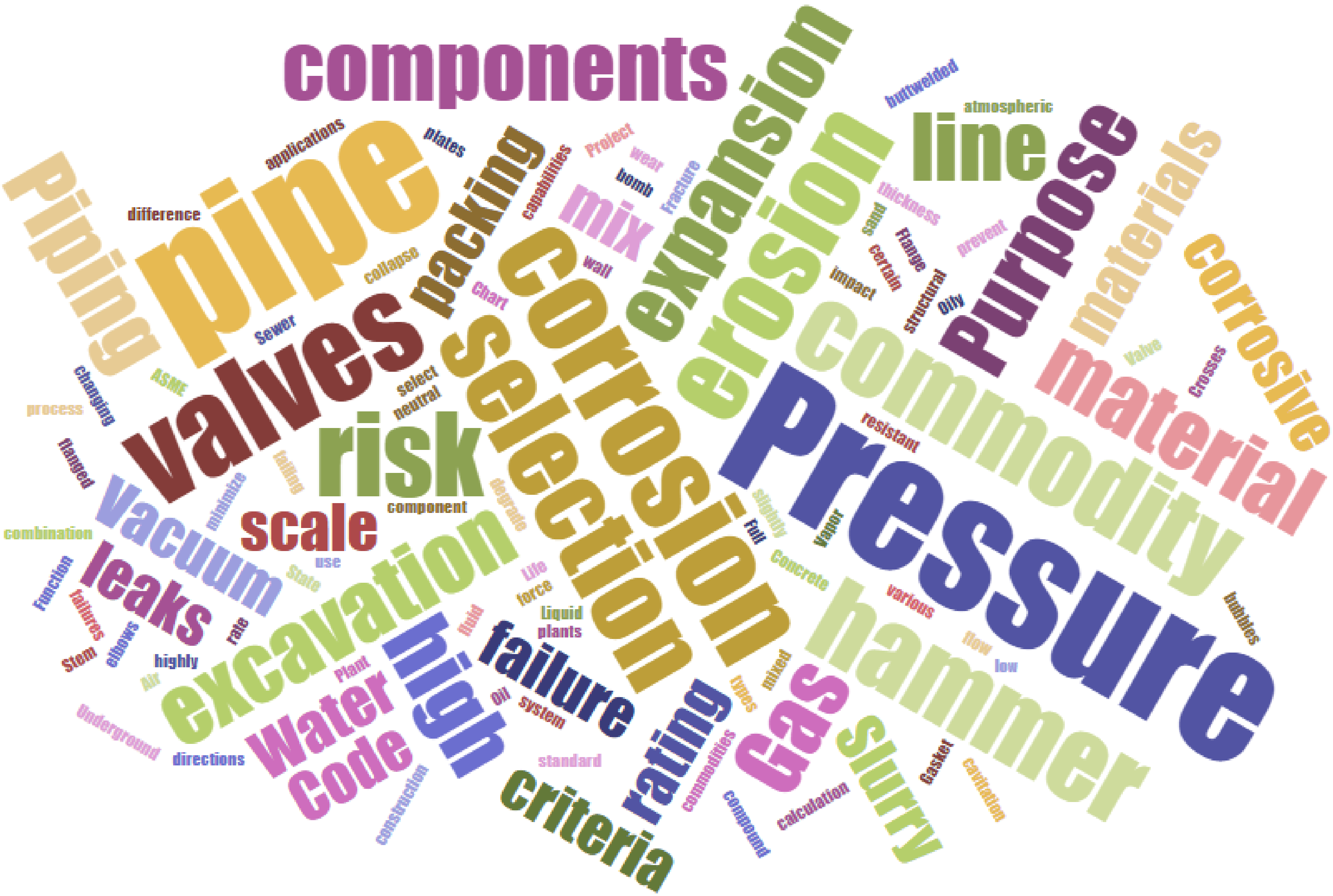
Steam main
Drain pocket
Cooling leg
Bimetallic trap set
Condensate return line

STEAM INDUCED WATER HAMMER

EXCAVATION

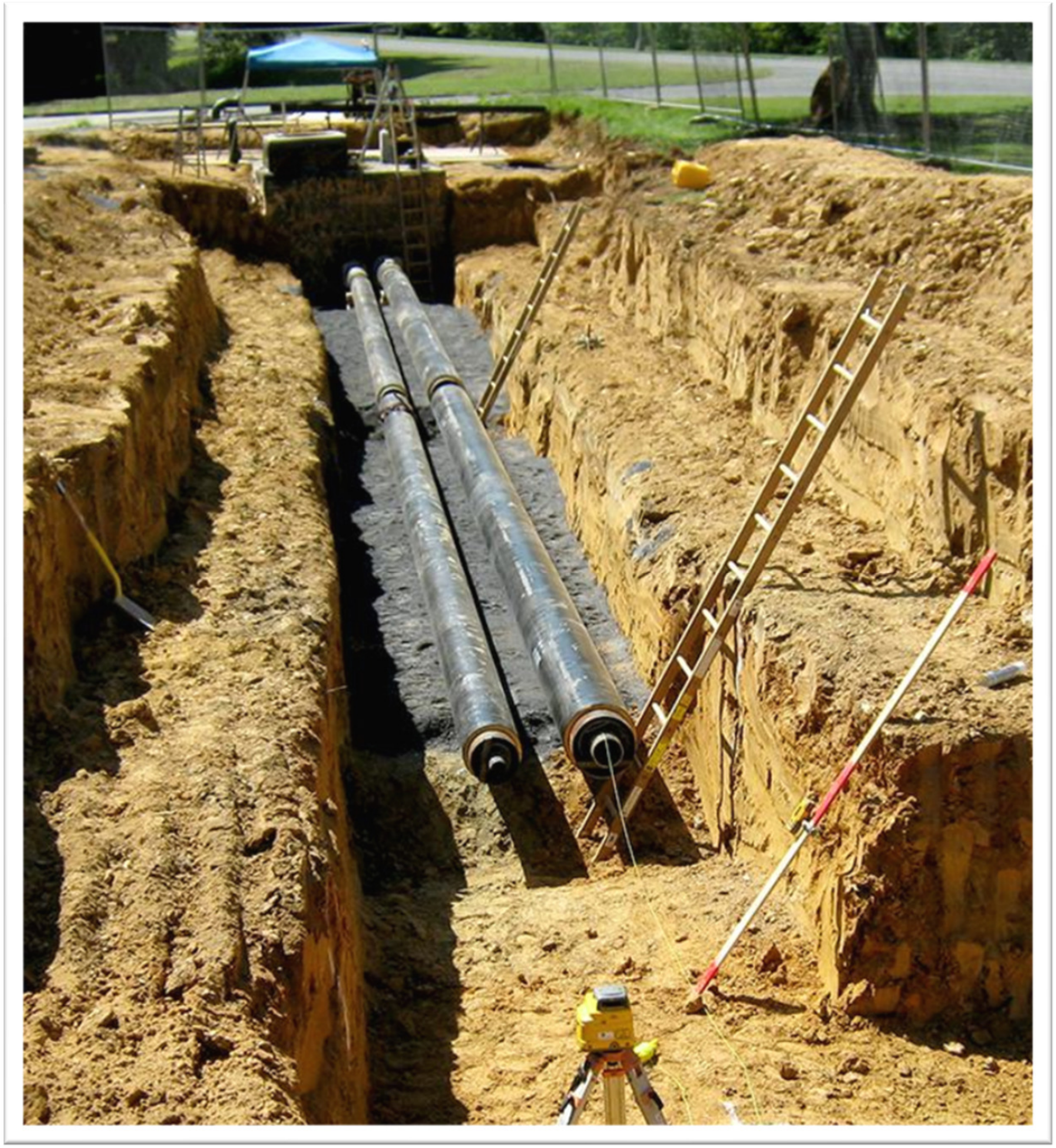
Know what's **below.**
Call before you dig.

PIPE



components
pipe
Piping
valves
packing
Corrosion
selection
expansion
erosion
line
Purpose
materials
corrosive
Commodity
Pressure
material
risk
scale
Vacuum
leaks
excavation
high
failure
Water
Code
rating
criteria
Gas
slurry
hammer
mix
applications
plates
difference
collapse
Sewer
select
neutral
ASME
process
changing
flanged
minimize
falling
component
combination
use
State
Function
failures
rate
elbows
Stem
highly
Air
Underground
directions
construction
Plant
oil
system
fluid
Life
force
Liquid
plants
standard
degrade
capabilities
Project
wear
bomb
Fracture
wall
Chart
buttwelded
atmospheric
thickness
Sand
flange
certain
impact
prevent
structural
Oily
Valve
crosses
resistant
slightly
Full
Vapor
Concrete
various
flow
low
bubbles
mixed
types
commodities
compound
calculation
Gasket
cavitation

DIRECT BURIED PIPE



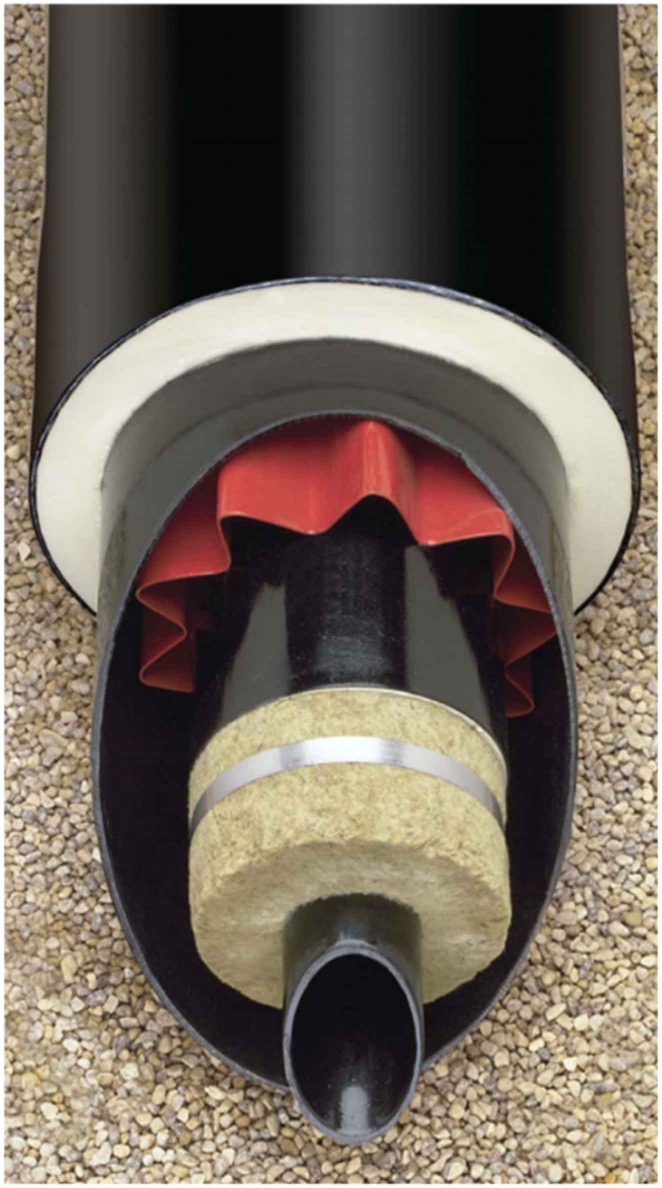
STEEL

High Temp. = Steel

- Corrosion
+ Expansion
+ Water Hammer
- Excavation

$500 - $1,000/ft

DIRECT BURIED PIPE - STEEL



DIRECT BURIED PIPE

PLASTIC

Low Temperature:
Plastic is an option

+ Corrosion
+ Expansion
+ Water Hammer
- **Excavation?**

$400 - $700/ft

TUNNELS

+ Corrosion
+ Expansion
+ Water Hammer
+ Excavation

$4,000 - $7,000/ft

SHALLOW TRENCH

+ Corrosion
+ Expansion
+ Water Hammer
+ Excavation

$2,000 - $3,000/ft

COMPARISON

Direct-Buried

+ Simple and fast
+ Lowest cost

- Less reliable
- More disruption

Tunnel

+ High reliability
+ No disruption

- Very expensive
- Low flexibility

Shallow Trench

+ Good reliability
+ Low disruption

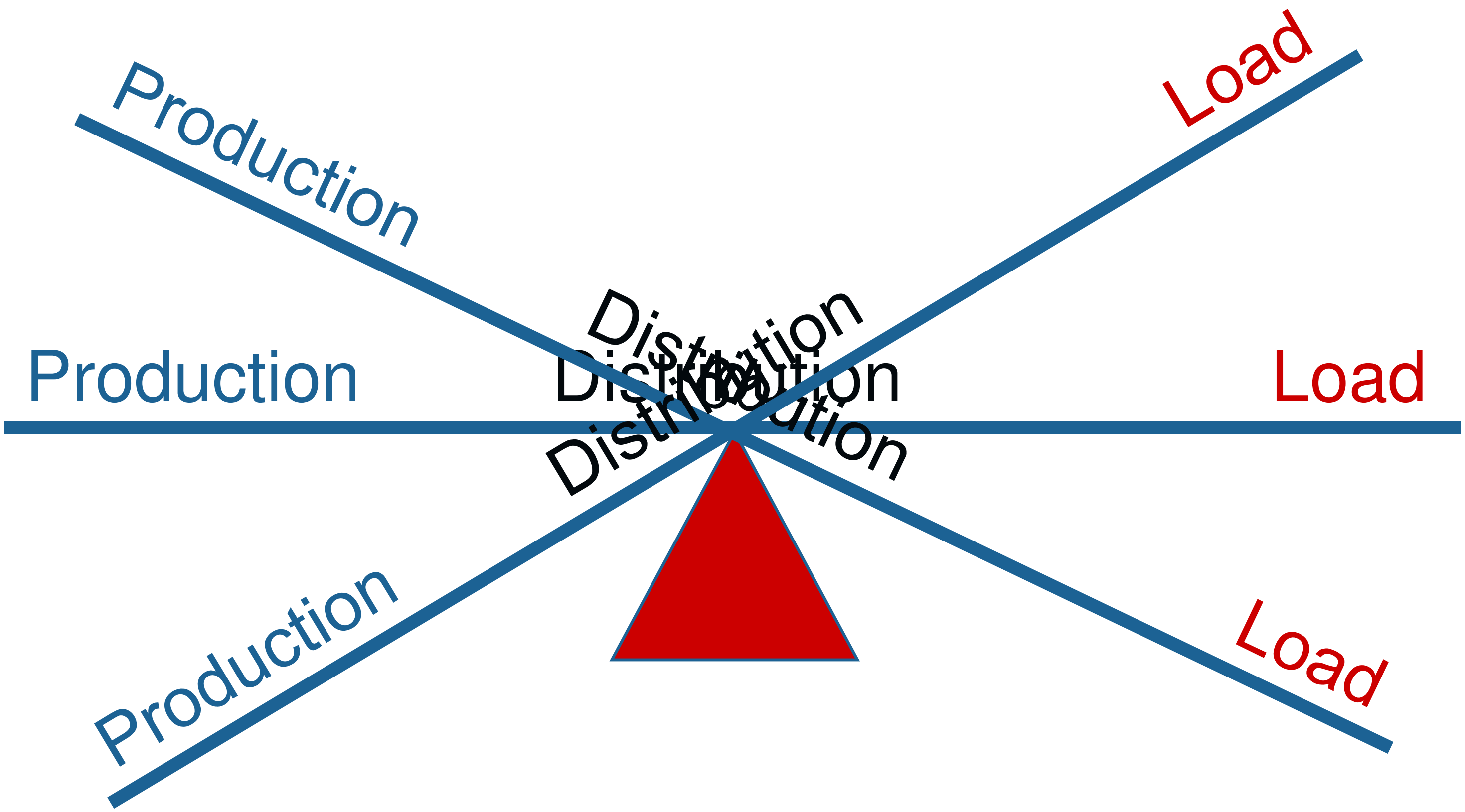
- Expensive
- Low flexibility

DISTRIBUTION DESIGN

- System Concepts
  - Definitions
  - Basic Formulae
    - ΔT
  - Hydraulic Profile
- System Components
- System Configurations

WORDS OF WISDOM

It's not how much you've got; it's whether you can use it.

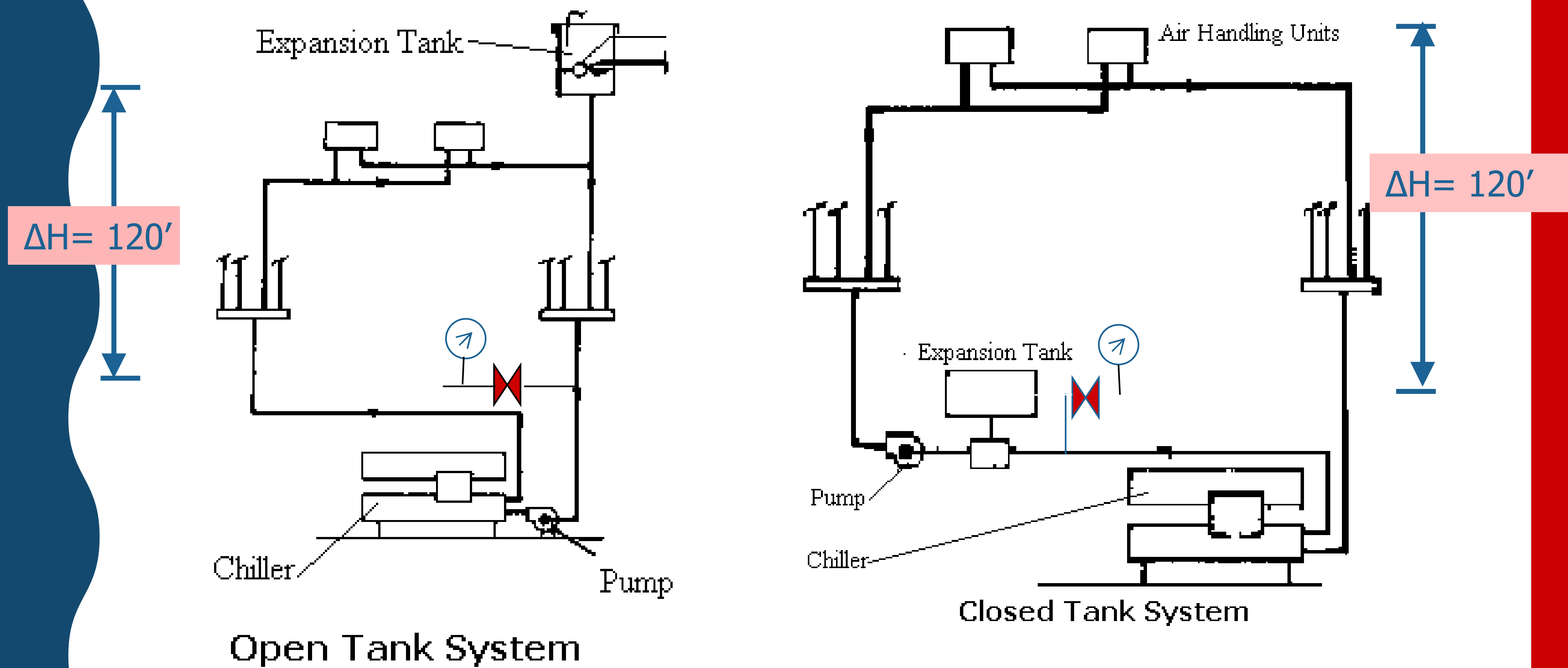


DEFINITIONS

- System (Static/Fill) Pressure: The non-flowing pressure to which the system must be filled to assure flooding of the highest device.
  - System pressure is usually set so that there is at least 5 psig measured at the highest device in the system.

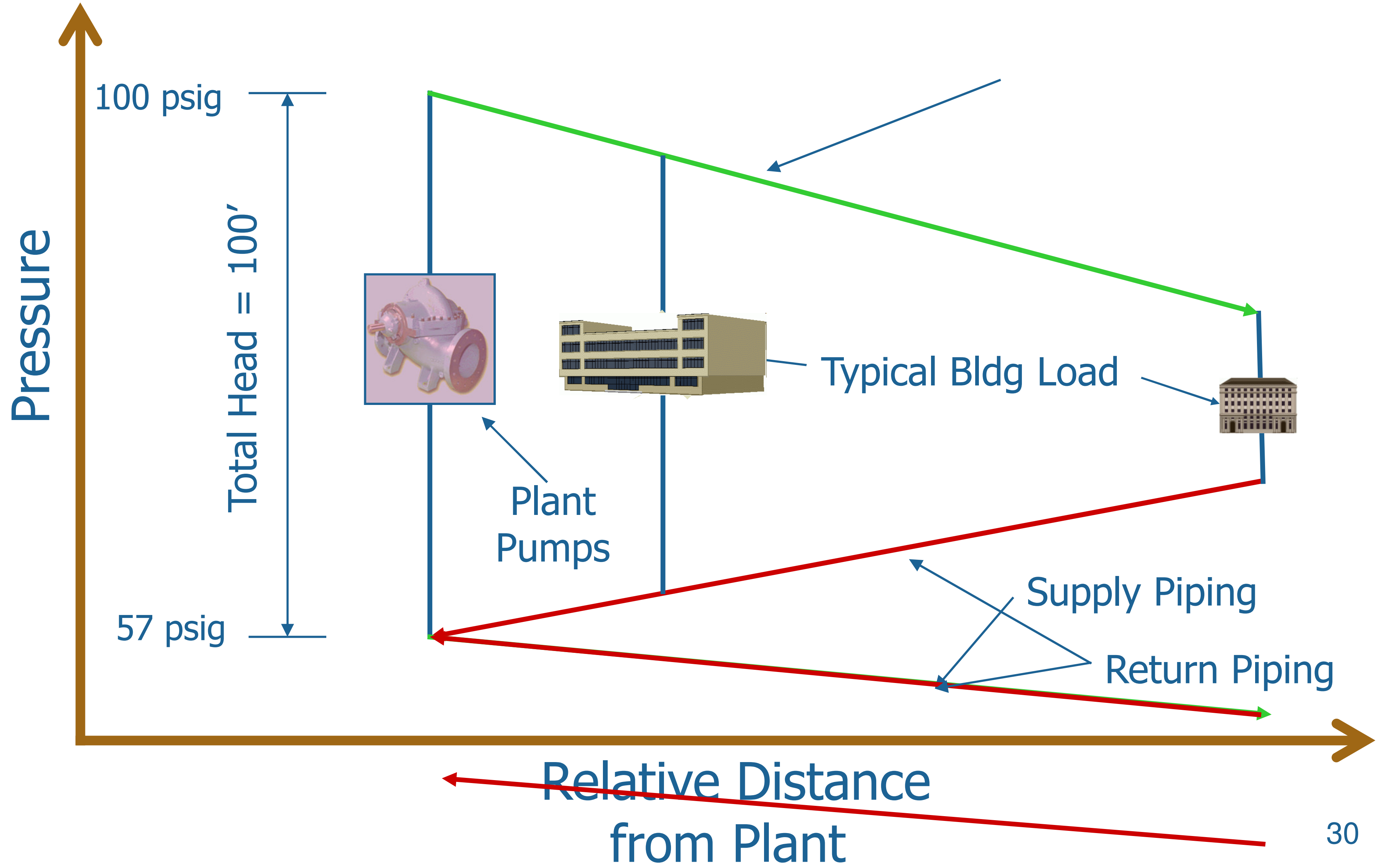
- Dynamic Pressure:
  - The flowing pressure the system pumps must develop to overcome the friction due to piping, coils, valves, fittings, and other devices in the system at a given flow rate.
  - Head loss, measured in feet of head = 2.31 ft. W.C./psi (.434 psi/ft)
- Design Pressure
  - The dynamic pressure the system pumps must develop at the *maximum* flow in the system.
  - The *differential* pressure between the supply and return piping at the pump, i.e. the **total head**

Fill Pressure, Makeup, and Expansion



System Pressure = .434 psi/ft X 120’ + 5 = **57 psig**

SYSTEM HYDRAULIC PROFILE



BASIC FORMULAE

$$Q_{BTUH} \approx GPM \times \Delta T$$

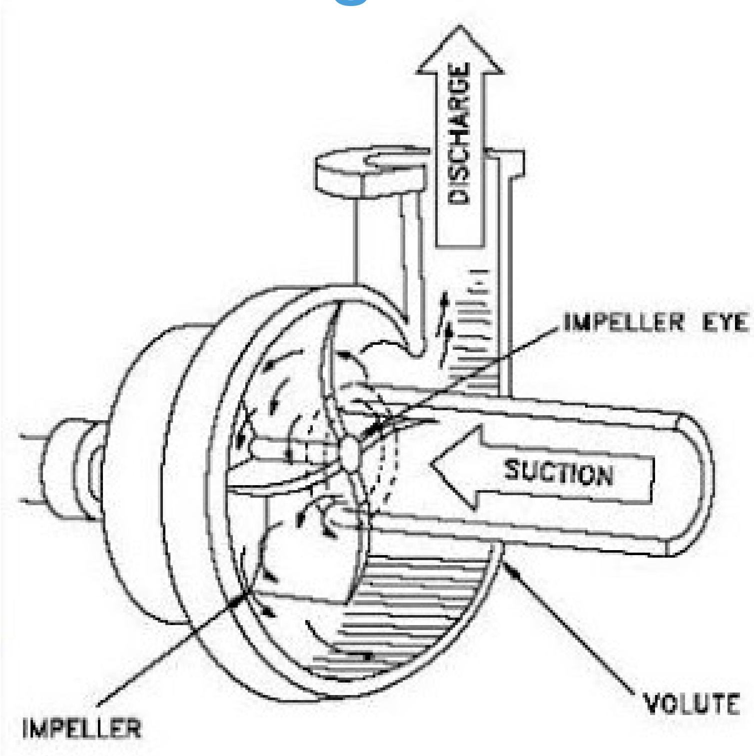
ΔT = temperature difference between supply and return

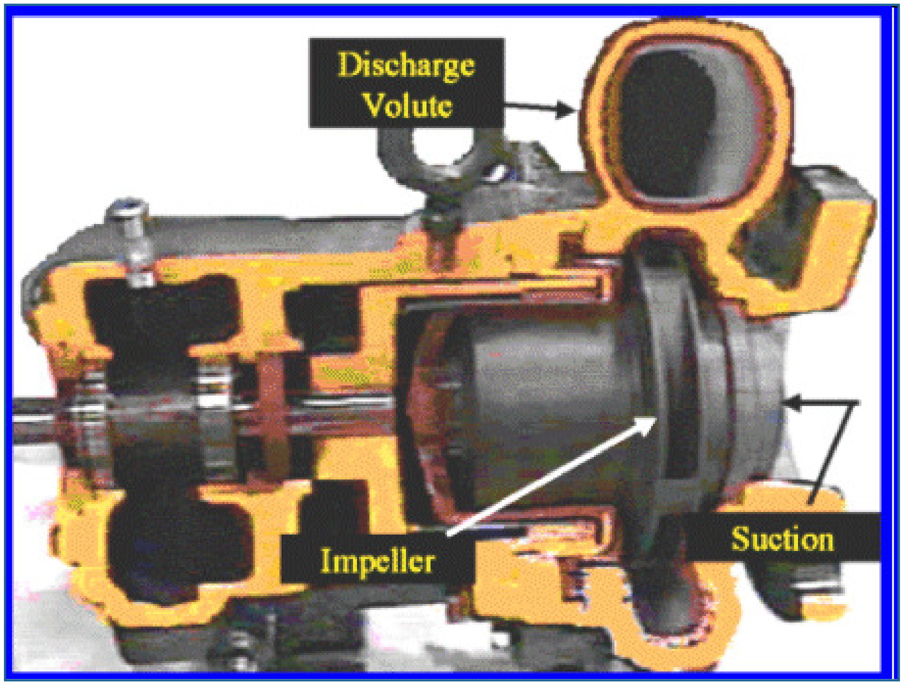
SYSTEM COMPONENTS

- Pumps/ Piping
  - Parallel Pumping
  - Series Pumping
  - Variable Speed Pumping
- Effect of ΔT on Pump Energy
- Effect of ΔT on Pump Flow
- Effect of ΔT on Dynamic Pressure

PUMPS

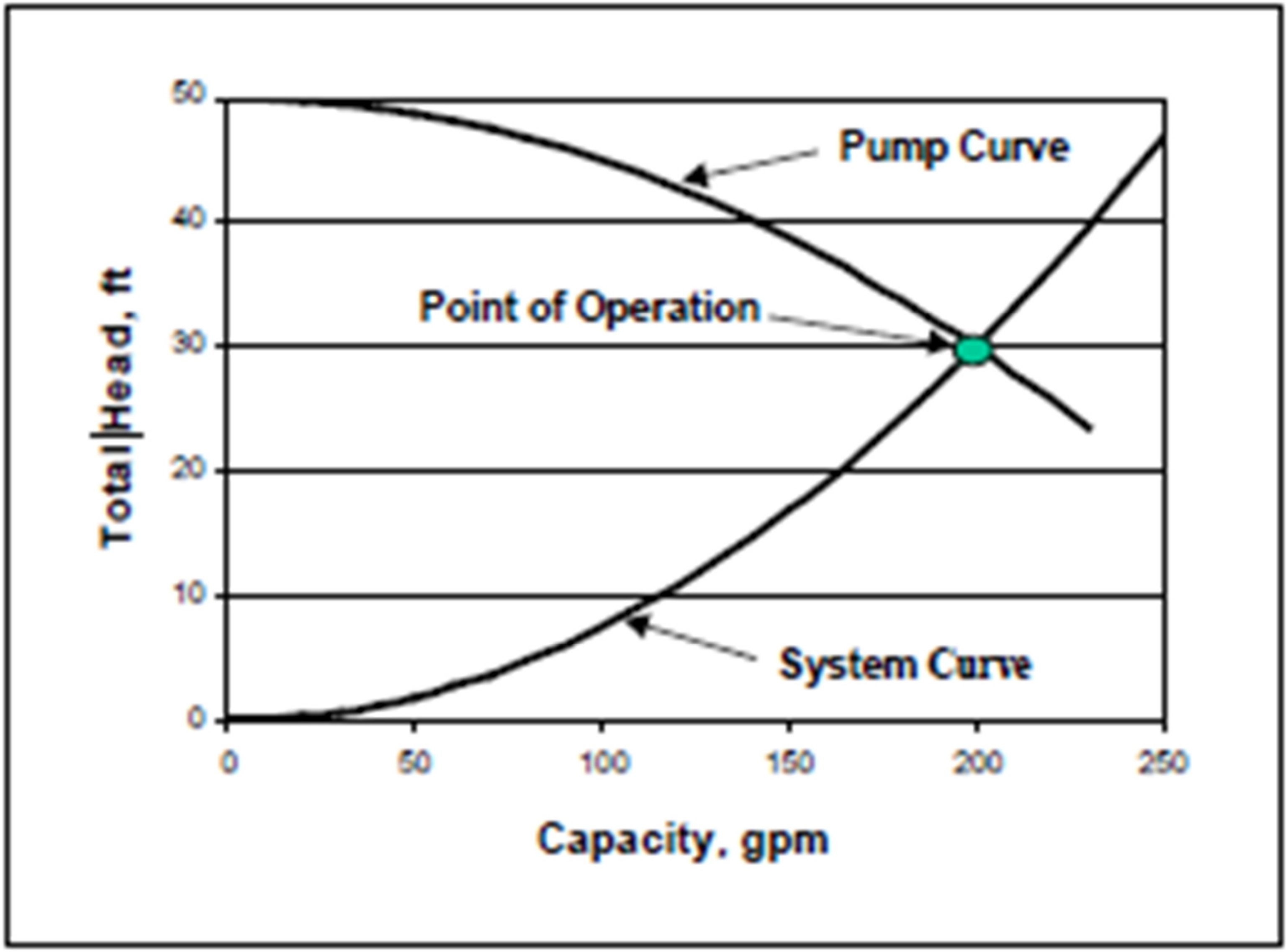
- Driving force to move water in piping
- Provide pressure and flow
- Primary type
  - Centrifugal



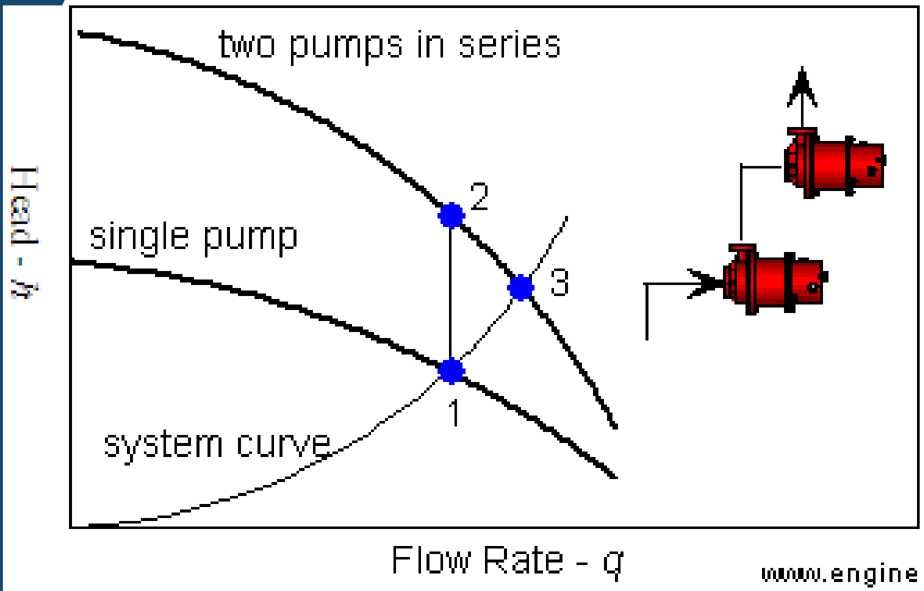


SYSTEM CURVE

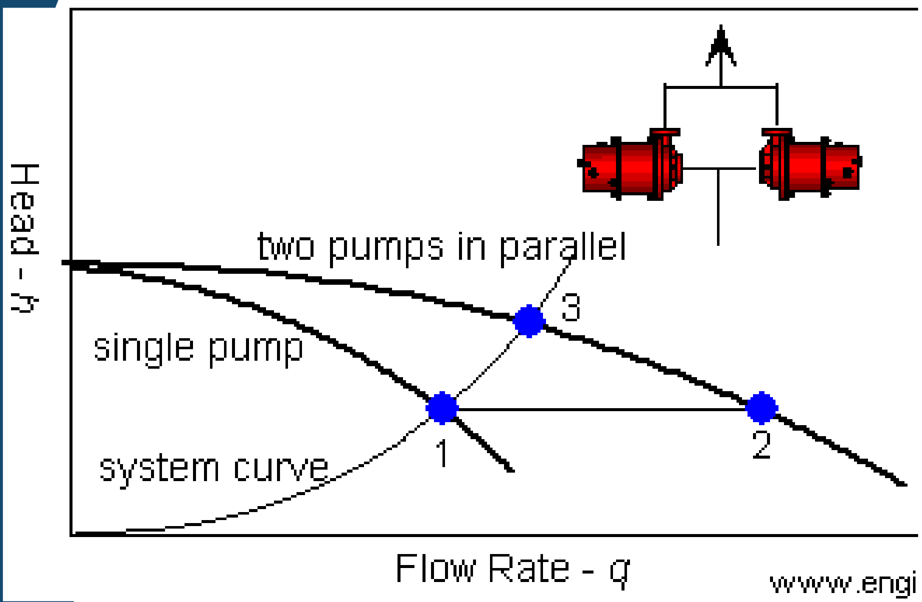
The system curve is a plot of friction losses (in head or pressure) for a piping system versus flow rate



MULTIPLE PUMPS



Centrifugal pump in series are used to overcome larger system head loss than one pump can handle alone. For two identical pumps in series the head will be twice the head of a single pump at the same flow rate. With constant flowrate, the combined head moves from 1 to 2. In practice the combined head and flow moves along the system curve to 3.



Centrifugal pumps in parallel are used to overcome larger volume flows than one pump can handle alone. For two identical pumps in parallel the flowrate, will double (moving from 1 to 2) compared to a single pump if head is kept constant. In practice the combined head and volume flow moves along the system curve as indicated from 1 to 3.

VARYING PUMP SPEED

$Q_{BTUH} \approx \text{GPM} \times \Delta\text{T}$

Affinity Laws:

If speed is decreased by 10%,

<u>Law 1</u>: Flow is Proportional to Shaft Speed.

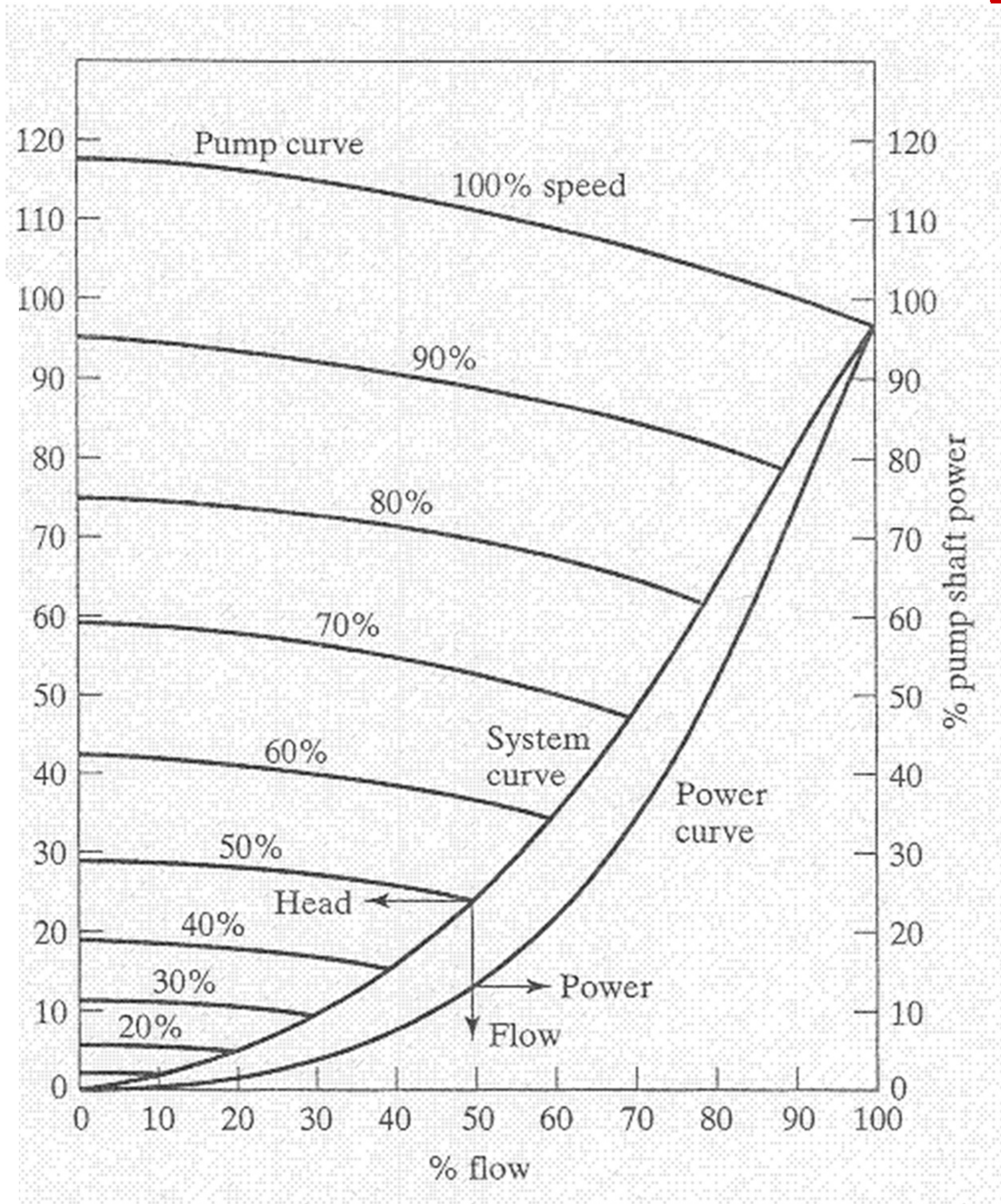
Flow is decreased by 10%

<u>Law 2</u>: Pressure is Proportional to the Square of Shaft Speed.

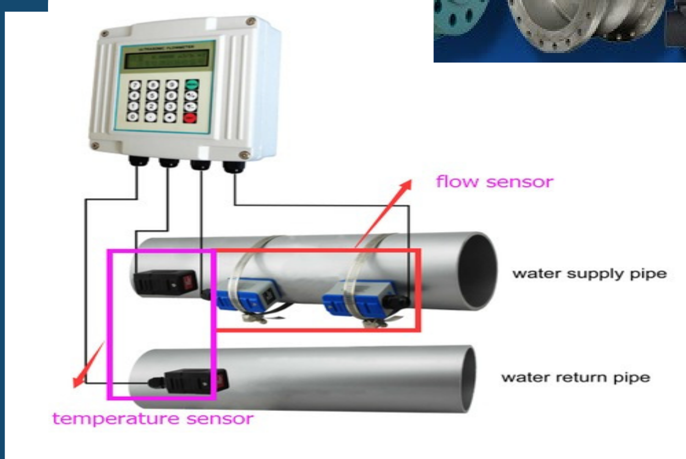
Pressure is decreased by ~18% ($1-.90^2$)

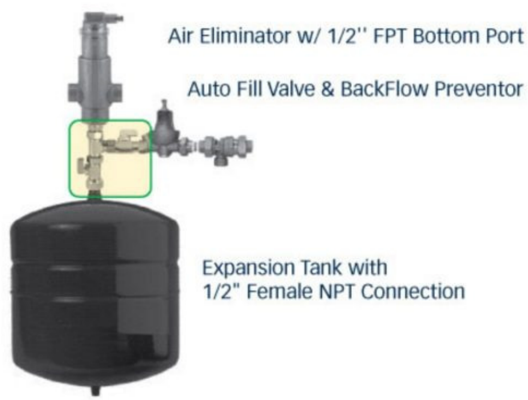
<u>Law 3</u>: Power is Proportional to the Cube of Shaft Speed.

Power is decreased by ~27% ($1-.90^3$)

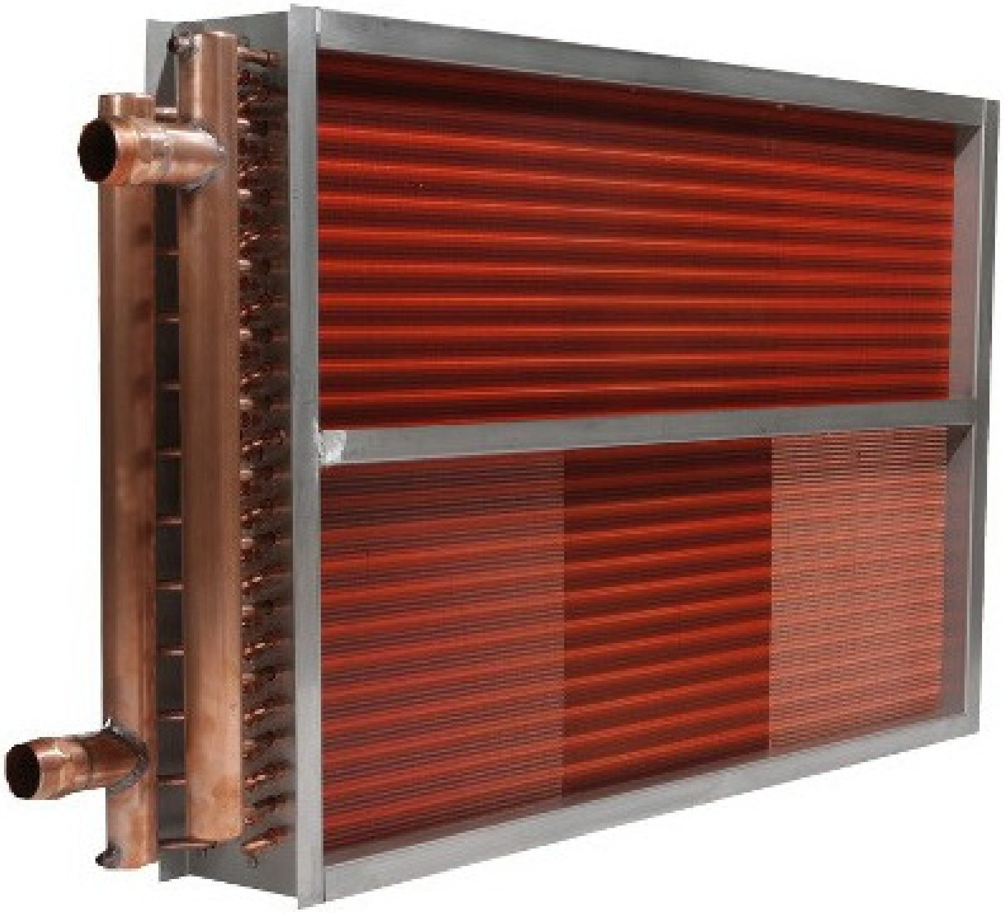


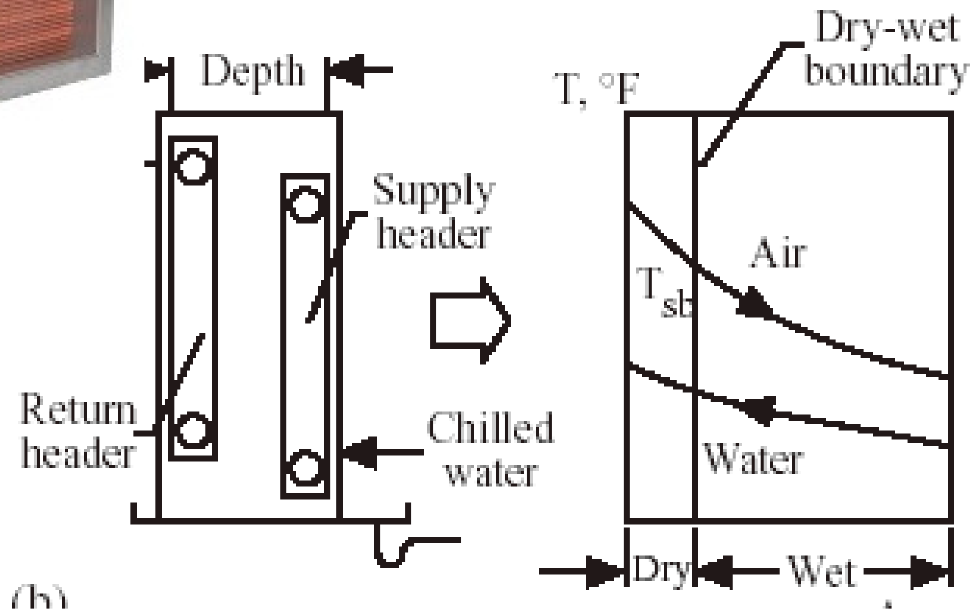
PIPING SYSTEM





CHILLED WATER COILS





DYNAMIC PRESSURE VS ∆T

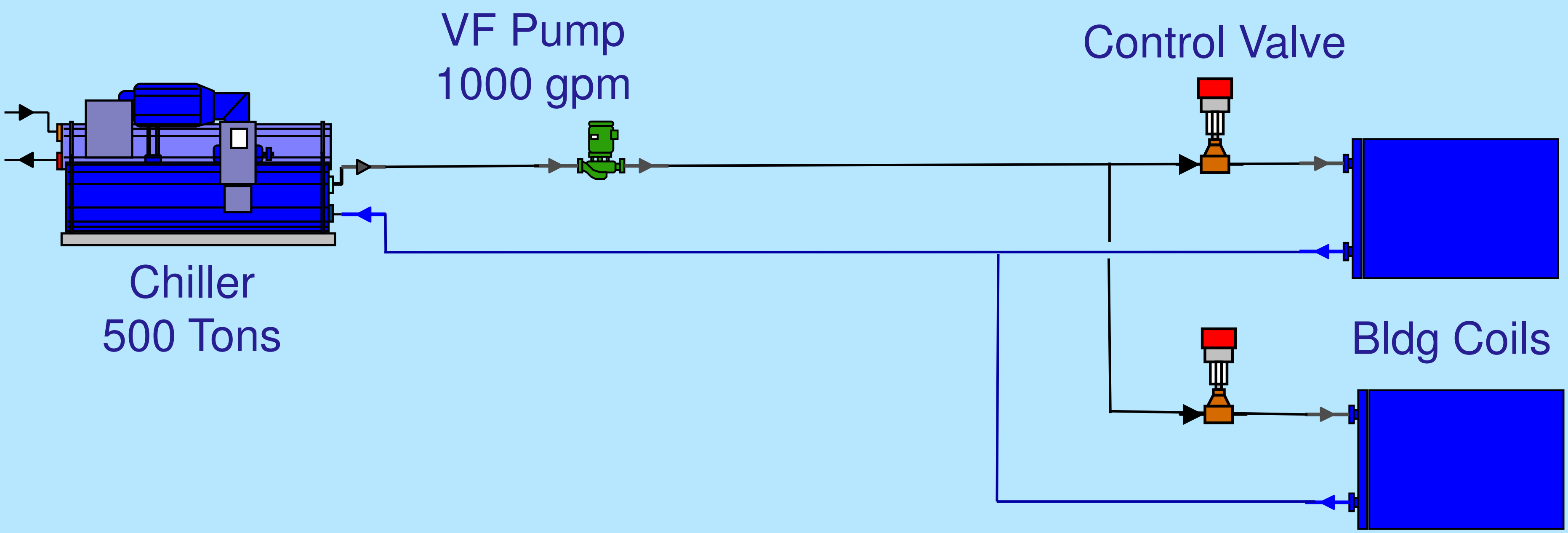
$$Q_{BTUH} \approx \mathrm{GPM} \times \Delta\mathrm{T}$$

- Increasing supply-to-return differential temperature requires less flow for same heat transferred
- Less flow in a given pipe system results in lower velocity
- Lower velocity equals lower friction and lower pressure loss
- Lower pressure and flow equals lower energy

Three Rules for Chilled Water System Optimization

Reduce Flow
Reduce Flow
Reduce Flow

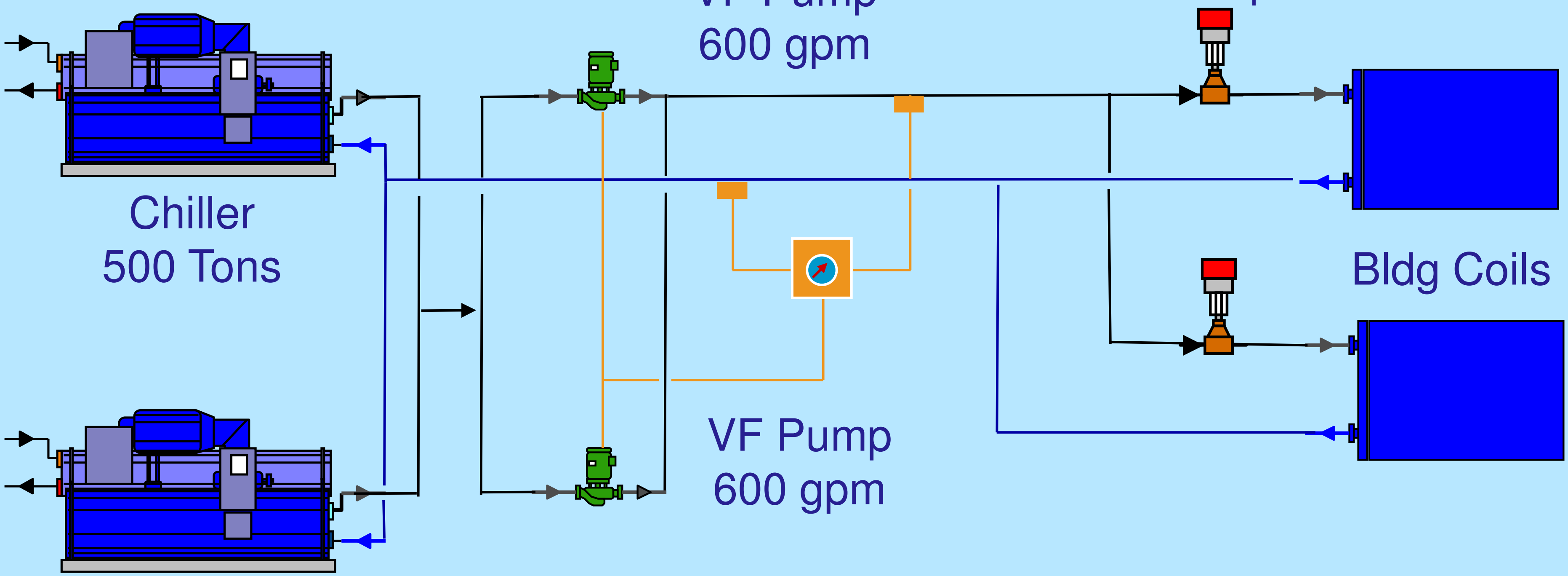
Variable Primary Only
(One unit on)



Load equals 1 chiller = 1000 gpm @ 12°F ΔT = 500 Tons

Variable Primary Only (Two units on)

QUESTION: Can we improve this scheme?



Chiller and flow staging accomplished by measurement of ΔP between supply and return at selected location

Load equals 1.2 chillers = 600 Tons = 1200 gpm @ 12°F ΔT

EFFECT OF ∆T ON PIPE CAPACITY & COST

CHILLED WATER PIPING CAPACITY

PIPE SIZE VS. TONS (BLDG. SQ. FT.) PER WATER SIDE TEMPERATURE DIFFERENTIAL — TONS (1,000 FT²) — CAPACITY AREA

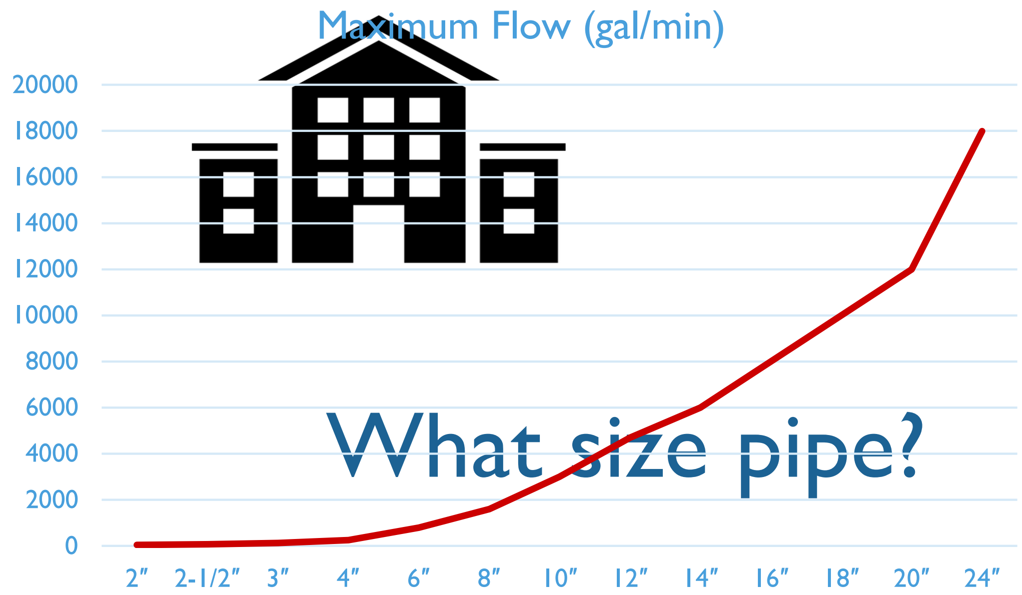
DIRECT BURIED PIPE		WATER SIDE TEMPERATURE RISE, T∆ GPM/TON						
PIPE DIAMETER (IN)	GPM VEL FT/100 FT HP COST	10° F 2.4	12° F 2.06	14° F 1.7	16° F 1.5	18° F 1.33	20° F 1.20	24° F 1.0
[illegible]	60,000 GPM [illegible] 400 HP $2,500/LF	25,000 (7,500)	30,000 (9,000)	35,000 (10,500)	40,000 (12,000)	45,000 (13,500)	50,000 (15,000)	60,000 (18,000)
42"	40,000 GPM 9.2 FPS 0.8'/100' 200 HP $2,200/LF	16,000 (4,800)	20,000 (6,000)	24,000 (7,200)	27,000 (8,000)	30,000 (9,000)	34,000 (10,000)	40,000 (12,000)
36"	30,000 GPM [illegible] 200 HP $2,000/LF	12,500 (3,800)	15,000 (4,500)	17,500 (5,300)	20,000 (6,000)	22,500 (6,800)	25,000 (7,500)	30,000 (9,000)
30"	20,000 GPM [illegible] 150 HP $1,500/LF	8,000 ([illegible])	10,000 (3,000)	12,000 (3,600)	13,000 (4,000)	15,000 (4,500)	17,000 (5,000)	20,000 (6,000)
24"	[illegible] 8.5 FPS 1.3'/100' 120 HP $1,300/LF	5,000 (1,500)	6,000 (1,800)	7,000 (2,100)	8,000 (2,400)	9,000 (2,700)	10,000 (3,000)	12,000 (3,600)
18"	7,000 GPM 9.5 FPS 2.0'/100' 100 HP $1,000/LF	3,000 (900)	3,500 (1,050)	4,000 (1,200)	4,600 (1,400)	5,200 (1,600)	6,000 (1,800)	7,000 (2,100)
16"	5,000 GPM 9.0 FPS 2.8'/100' 100 HP $800/LF	2,000 (600)	2,500 (750)	3,000 (900)	3,500 (1,050)	3,800 (1,100)	4,000 (1,200)	5,000 (1,500)
14"	4,000 GPM 9.5 FPS 3.0'/100' 100 HP $700/LF	1,700 (500)	2,000 (600)	2,400 (720)	2,700 (800)	3,000 (900)	3,400 (1,000)	4,000 (1,200)
12"	3,000 GPM 8.7 FPS 3.8'/100' 75 HP $650/LF	1,250 (380)	1,500 (450)	1,800 (540)	2,000 (600)	2,300 (680)	2,500 (750)	3,000 (900)
10"	2,000 GPM 8.0 FPS 3.1'/100' 40 HP $500/LF	800 (240)	1,000 (300)	1,200 (360)	1,300 (400)	1,500 (450)	1,700 (500)	2,000 (600)
8"	1,200 GPM 7.7 FPS 4.0'/100' 35 HP $400/LF	500 (150)	600 (180)	700 (200)	800 (240)	900 (270)	1,000 (300)	1,200 (360)
6"	600 GPM 6.7 FPS 4.0'/100' 20 HP $300/LF	250 (75)	300 (90)	350 (100)	400 (120)	450 (140)	500 (150)	600 (180)
4"	200 GPM 5.0 FPS 4.0'/100' 5 HP $200/LF	80 (24)	100 (30)	120 (36)	130 (40)	150 (45)	170 (50)	200 (60)

Assume you need 1,000' of pipe for a load of 2,000 Tons:

- With a 10F ∆T, 4,800 GPM is required
  - 16 " pipe, $800,000
- With a 16F ∆T, 3,000 GPM is required
  - 12" pipe, $650,000

PIPE CAPACITY

100,000 GSF
1,000 feet



<u>125 psig system</u>

4" pipe - $400,000 (100,000 GSF)

10" pipe - $500,000 (1,200,000 GSF)

+25% Cost = +1200% capacity

QUESTIONS?

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