System Diagram Workshop

Introduction

Introduction and Overview

Instructor:

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Senior Engineer

Facility Dynamics Engineering

September 19, 2017

Class Material Location

The slides and other supporting information for the class can be found at:

- http://tinyurl.com/DavidsTrainingMaterials

Materials for this current class are at the top of the page

Materials from previous classes are below that

About using my spreadsheets and other resources:

- They are my tools vs. tools I developed to be used by others
- Use at your own risk; I provide them as a resource for you to use as a starting point
- You still need to understand how it works and fix it if it doesn't work for you

Disclaimer

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Learning Objectives

After completing this course you should be able to:

- Explain and embrace the system concept
- Understand the key concepts behind a system diagram
- Understand the similarities and difference between air and water system diagrams
- Understand how to apply system diagrams to support design, commissioning, and ongoing operation
- Be familiar with the tools available to you to develop system diagrams

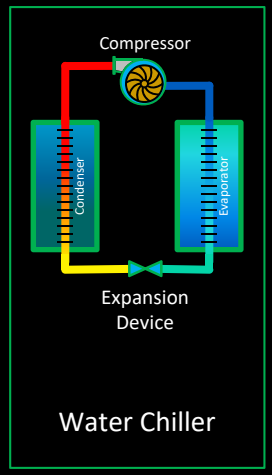
Agenda

- Introduction and Overview to the System Concept
- System Diagram Concepts
  - Key Characteristics
  - Tools and Development Resources
  - Water System Diagrams
  - Air System Diagrams
- Lab Session
  - Identifying System Components (Optional)
  - Looking at a Central Chilled Water Plant
  - Looking at an Air Handling System

The System Concept

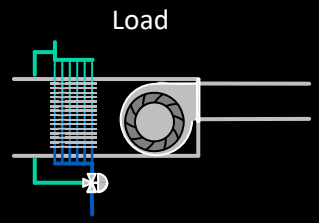
Key to design and commissioning success …

The Chilled Water System



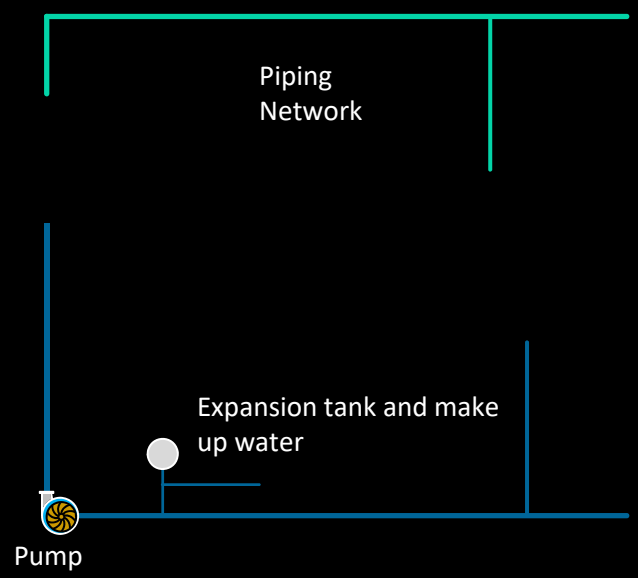
Not just the chiller …

The Chilled Water System



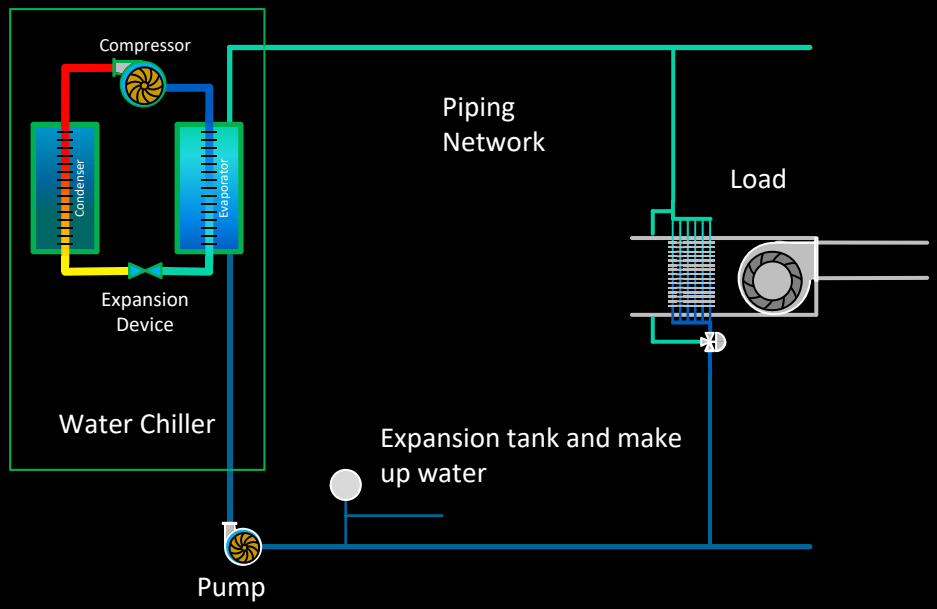
Not just the loads …

The Chilled Water System



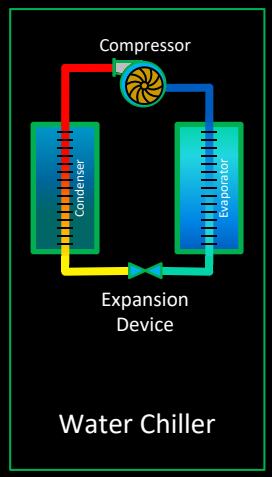
Not just the pumps and piping …

The Chilled Water System



Rather, the integrated, interactive assembly of chiller, pumps, piping and coils and all of their related control elements

The Same Thing is True on the Condenser Side of the Chiller



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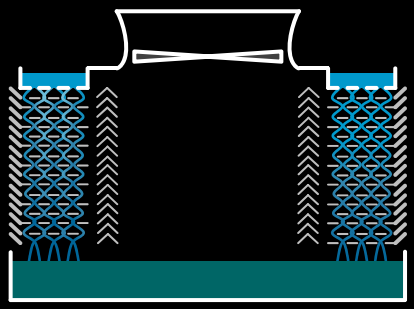

Cooling Tower

Not just the cooling tower …

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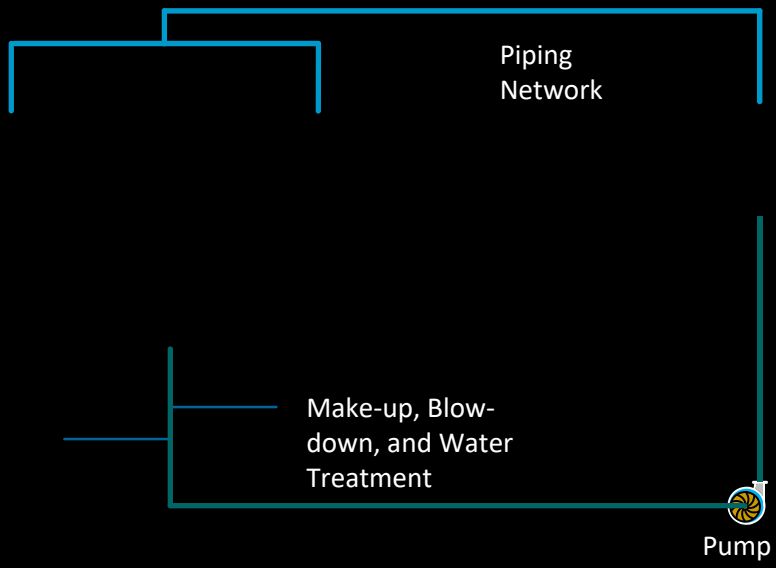

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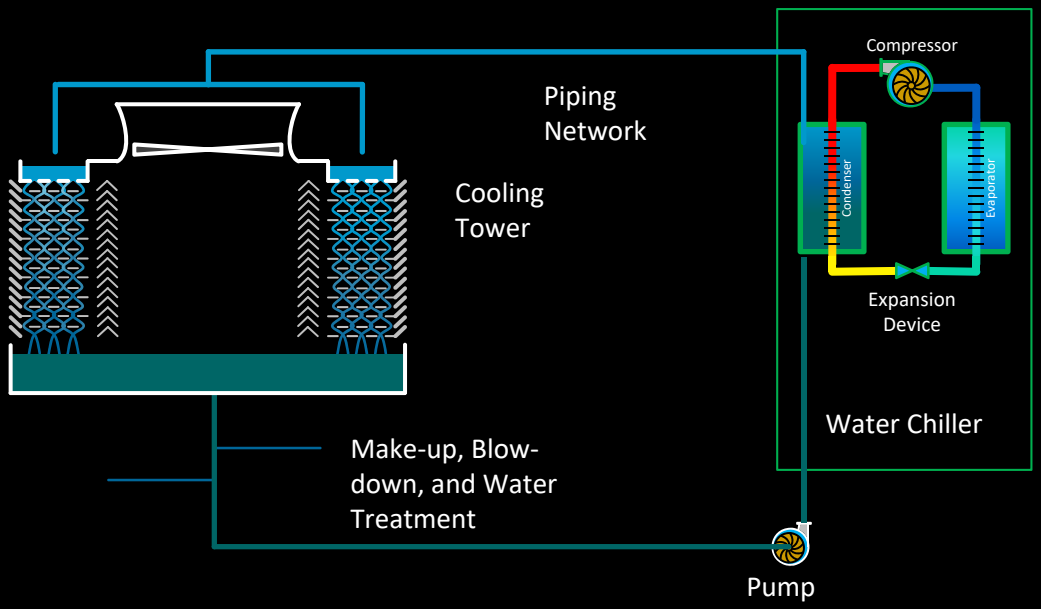
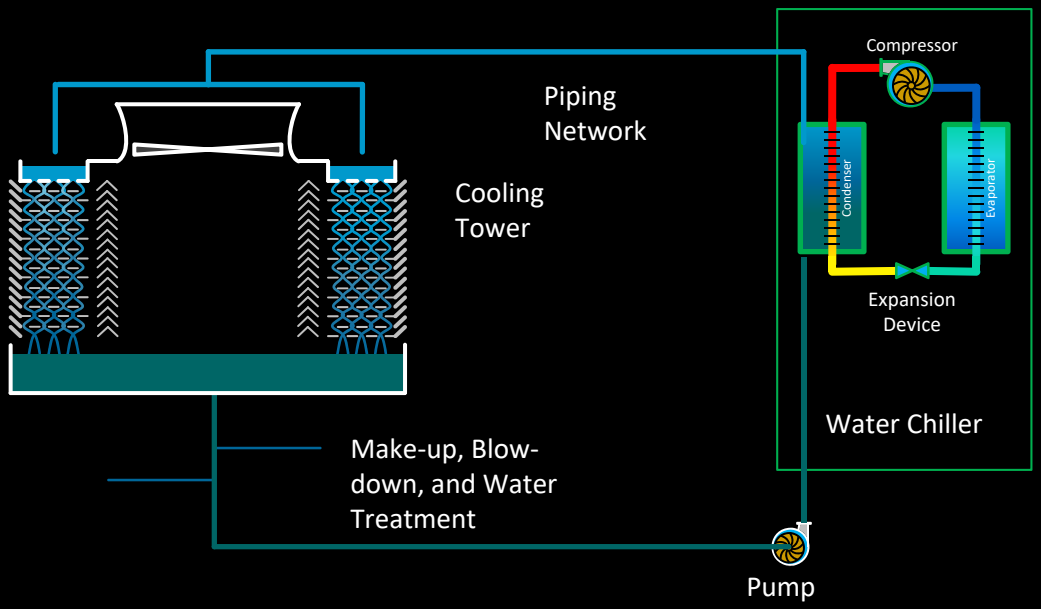


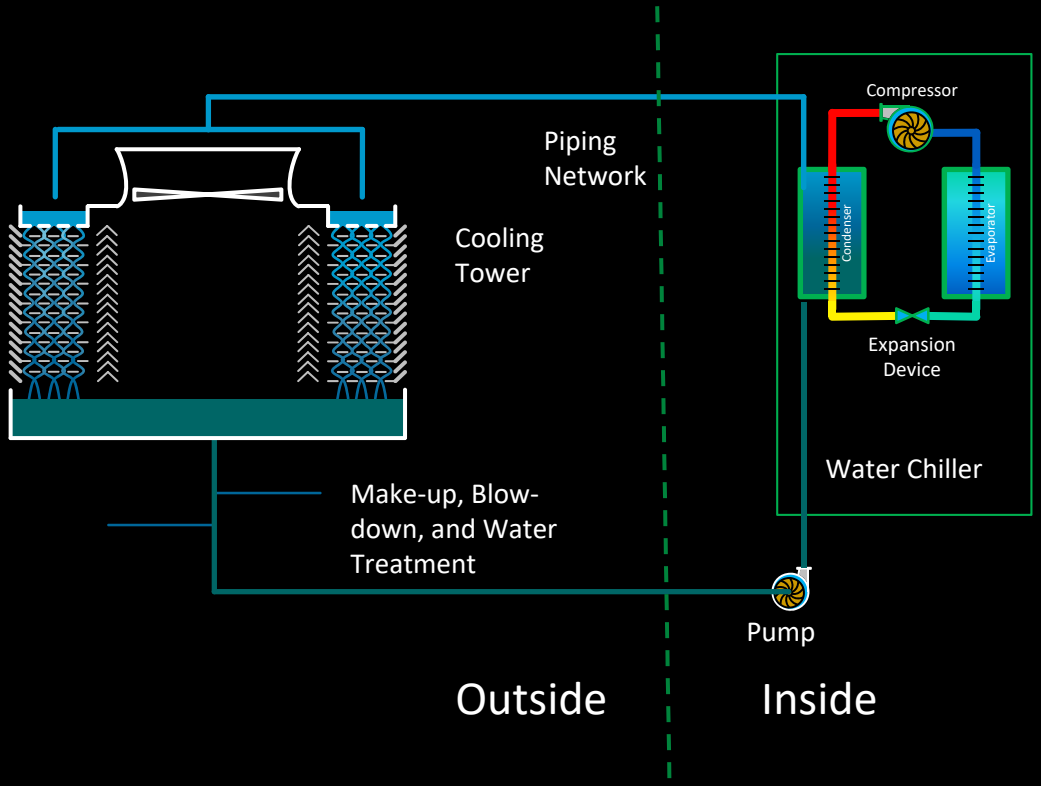
Rather, the integrated, interactive assembly of chiller, pumps, piping and cooling towers and all of their related control elements

What Happens If:

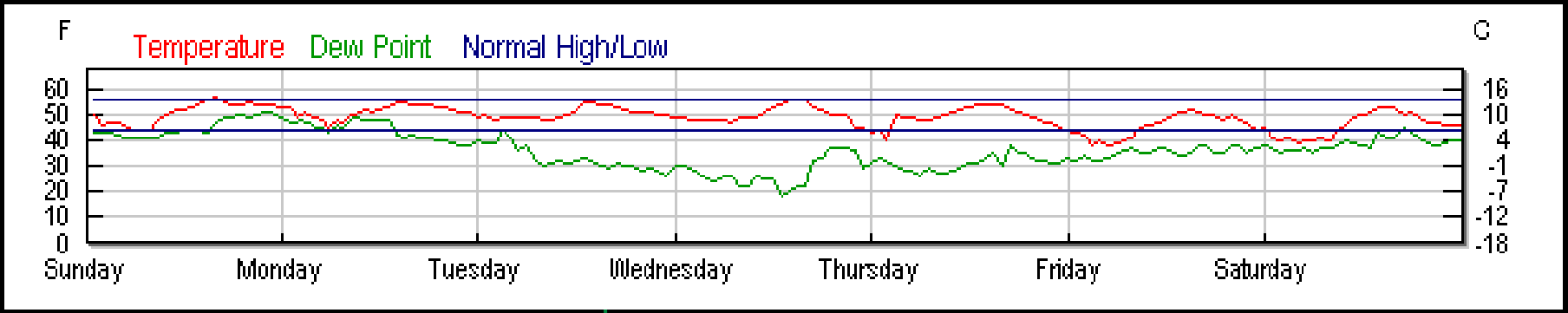


- The cooling tower fan fails?
- The make-up valve leaks?
- We shut down the pump?
- It is physically piped as drawn and:
  - We shut down the pump?
  - We restart the pump?
- The chiller is shut down?
- The blow down valve fails open?
- The blow down valve fails closed?

What Happens If:



- The cooling system sits idle over a long weekend in San Francisco?
  - Consider the weather pattern
  - Consider centrifugal and absorber condenser water limitations



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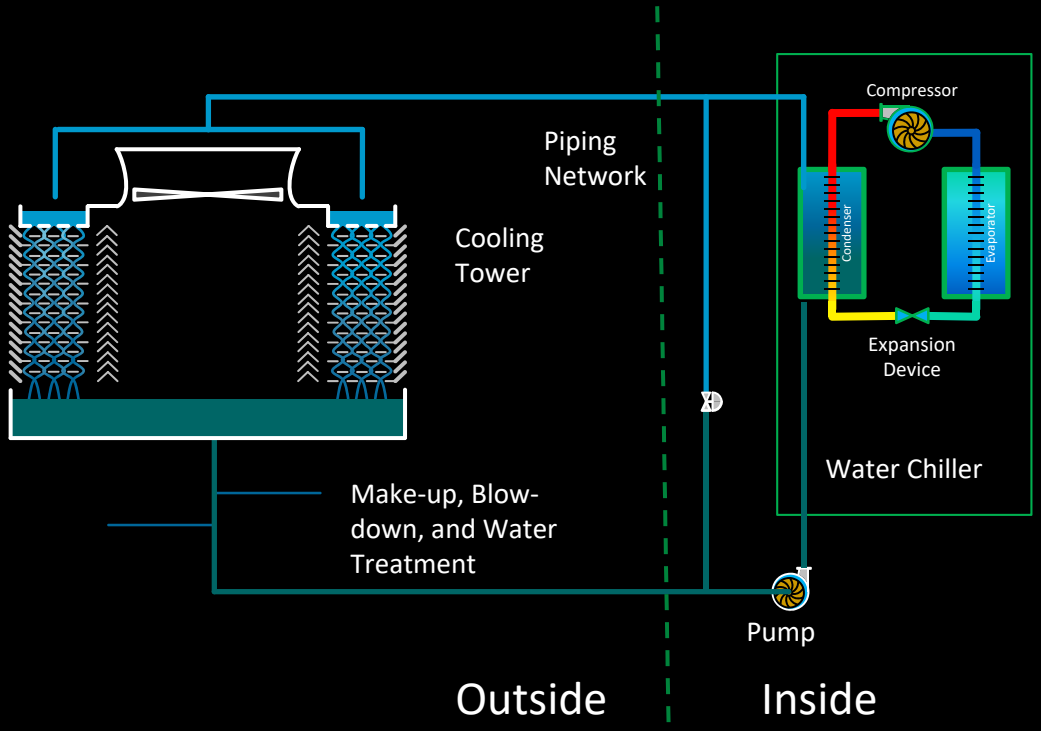
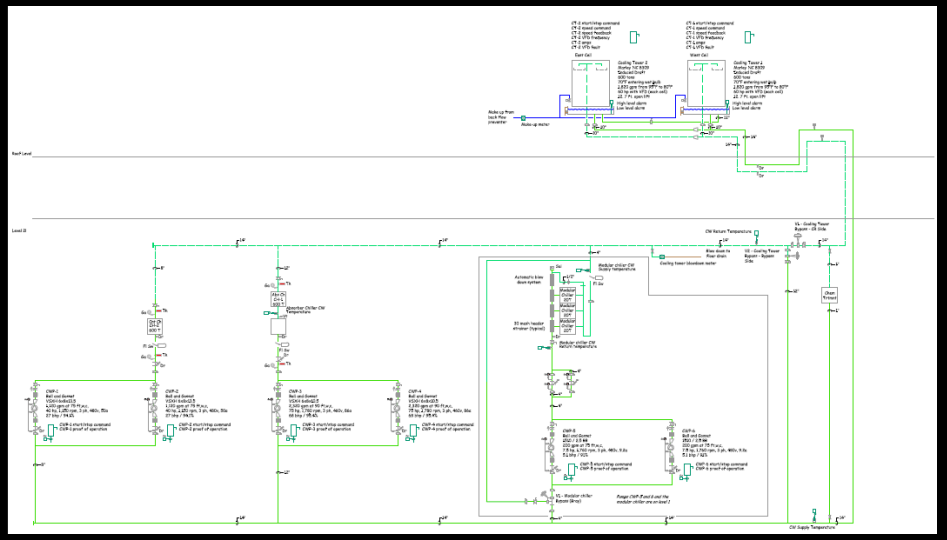


- The cooling system sits idle over a long weekend in San Francisco?
  - Consider the weather pattern for the last year
  - Consider centrifugal and absorber condenser water limitations
- How would you control this arrangement?

Consider the Sensor Location

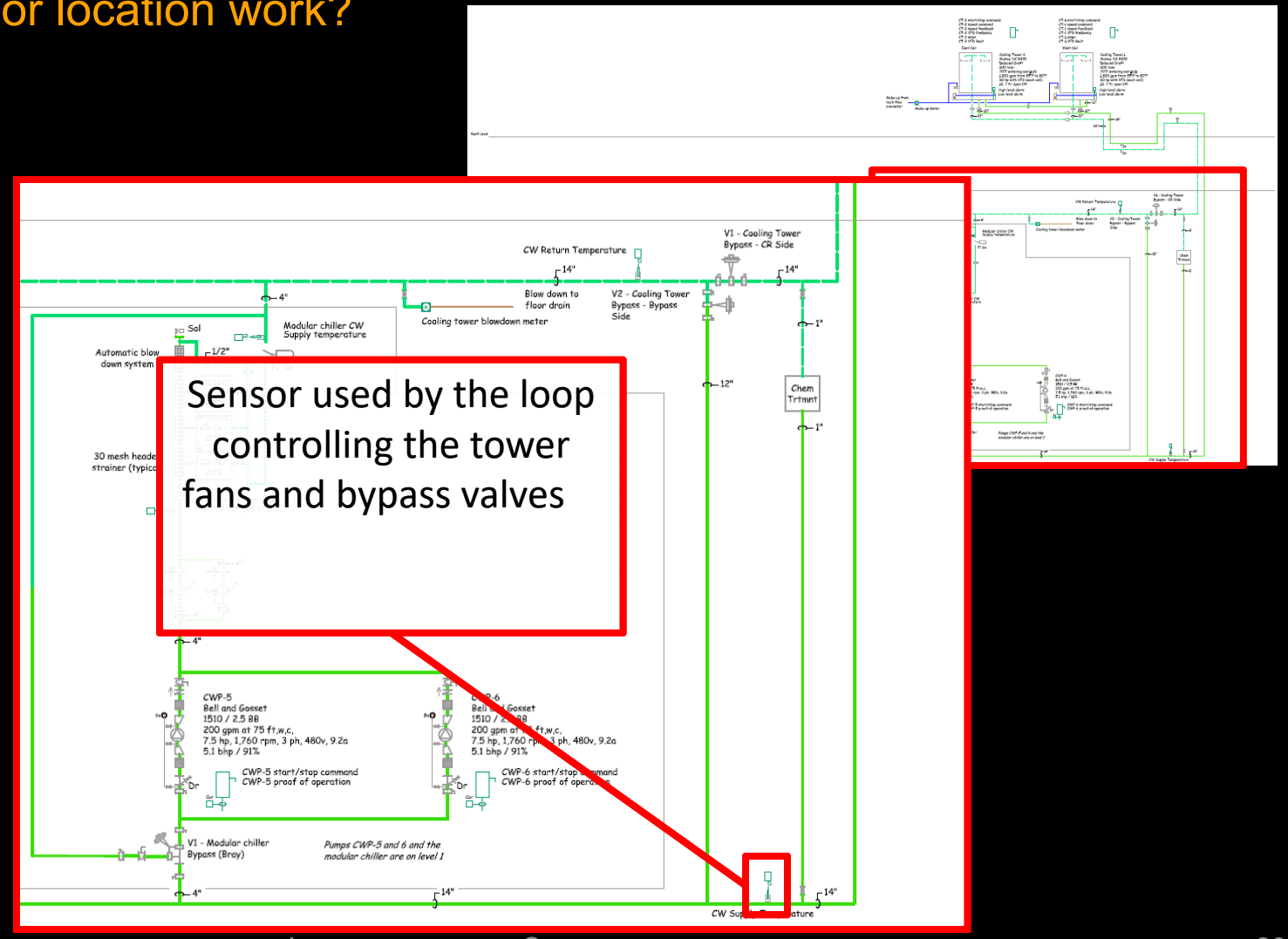
[02-16-10 Condenser Water v3 - Teaching Example.pdf]



Consider the Sensor Location

Sutardja Dia CW System Folder, 02-16-10 Condenser Water v3 - Teaching Example.pdf

Will this sensor location work?



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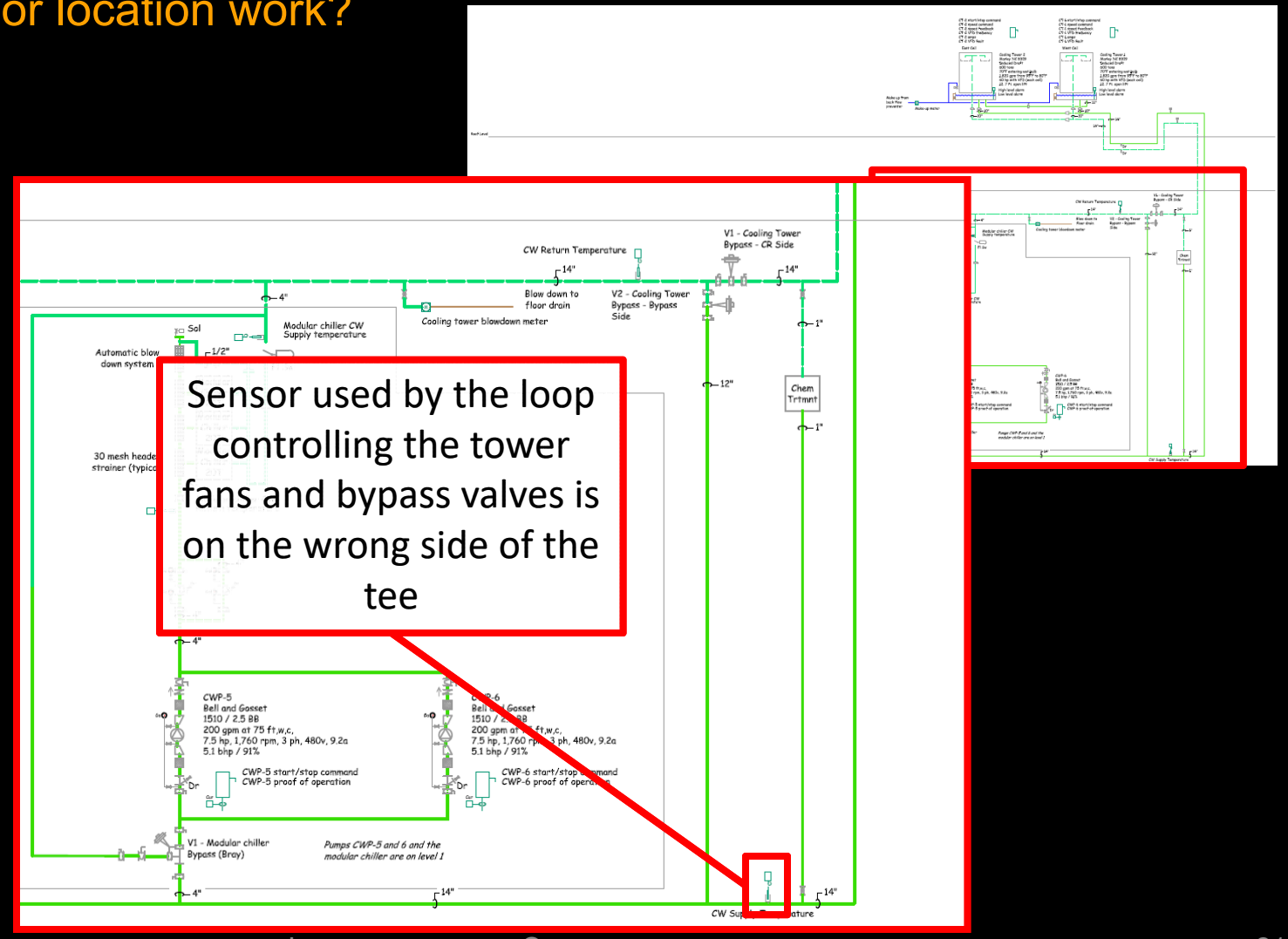
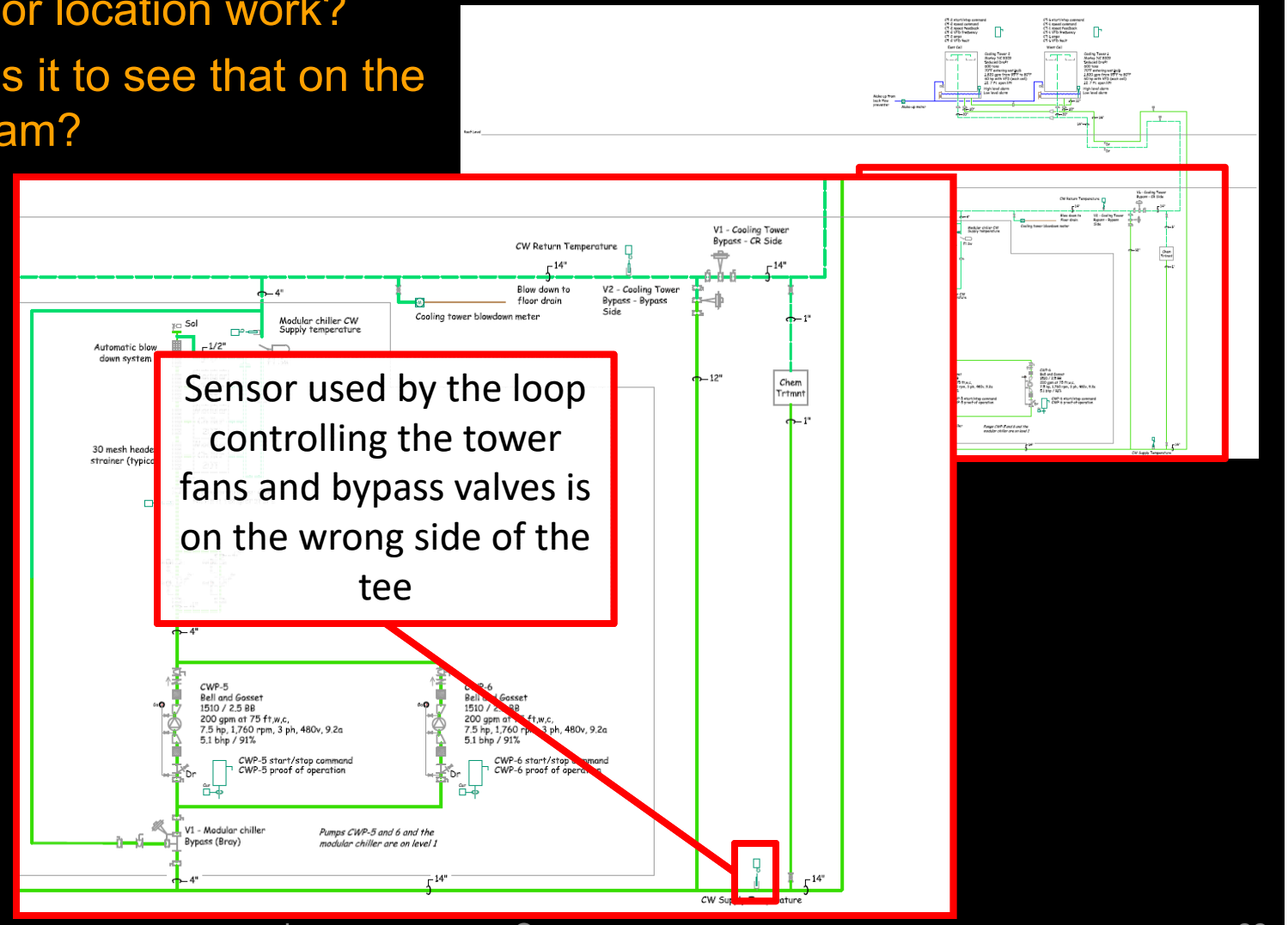


Consider the Sensor Location

[02-16-10 Condenser Water v3 - Teaching Example.pdf]

Will this sensor location work?

How hard was it to see that on the system diagram?



Consider the Sensor Location

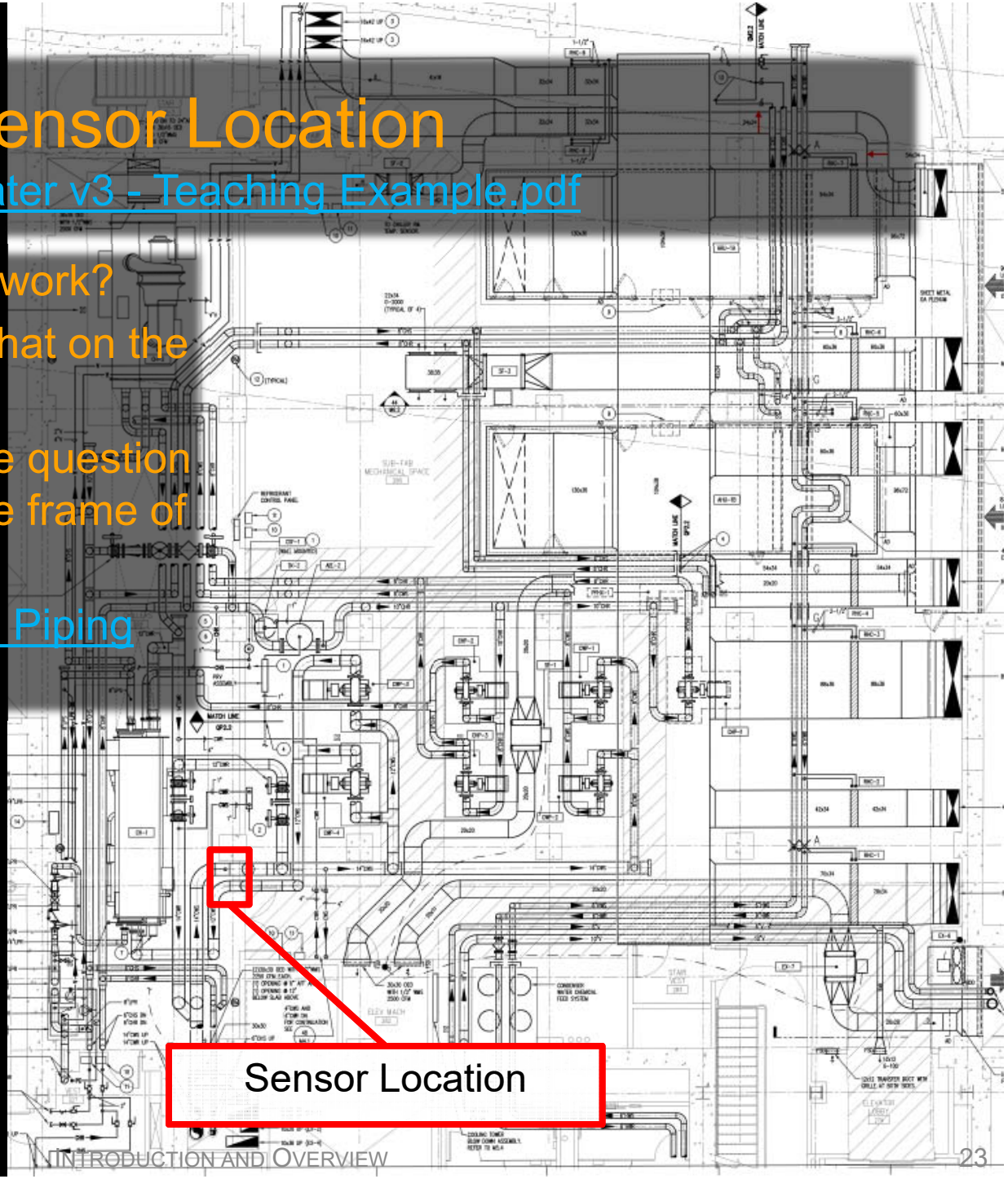
02-16-10 Condenser Water v3 - Teaching Example.pdf

Will this sensor location work?

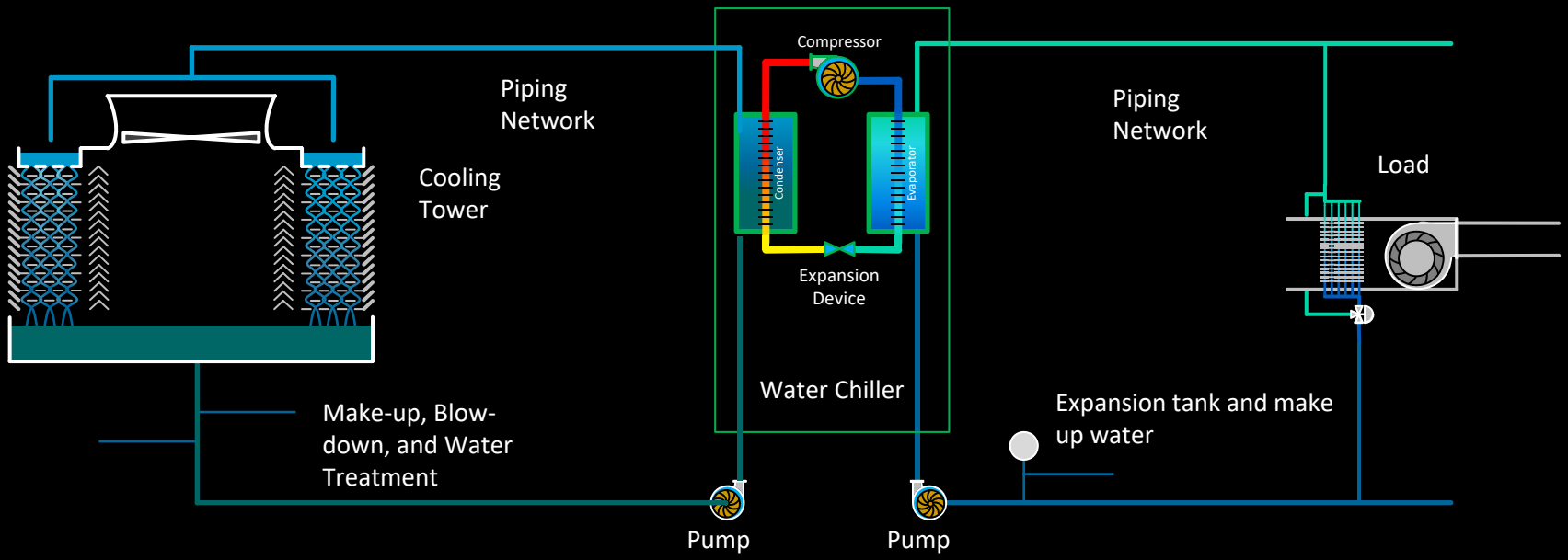
How hard was it to see that on the system diagram?

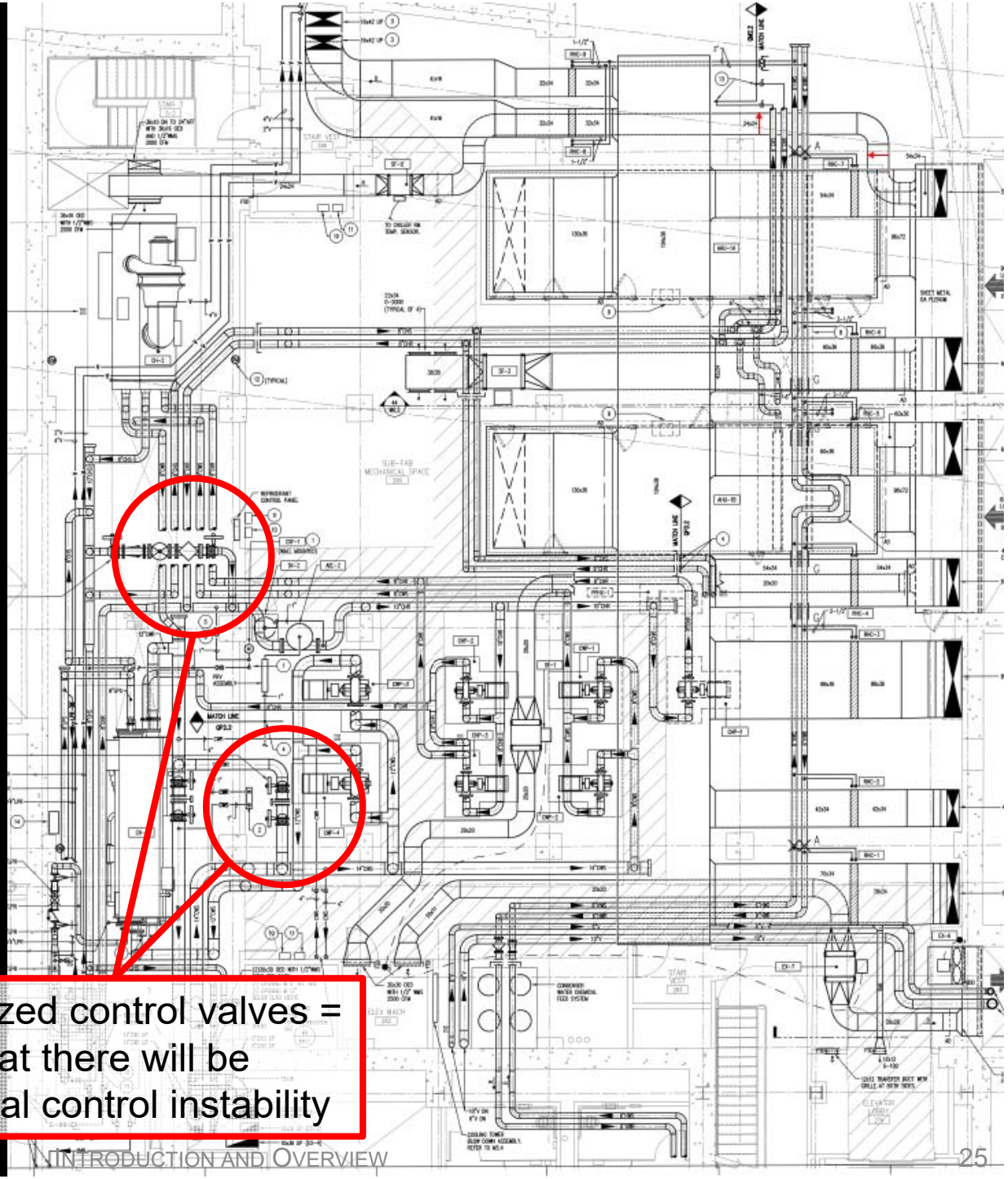
Ask yourselves the same question using this diagram as the frame of reference

(Main Mechanical Room Piping Plan.pdf)

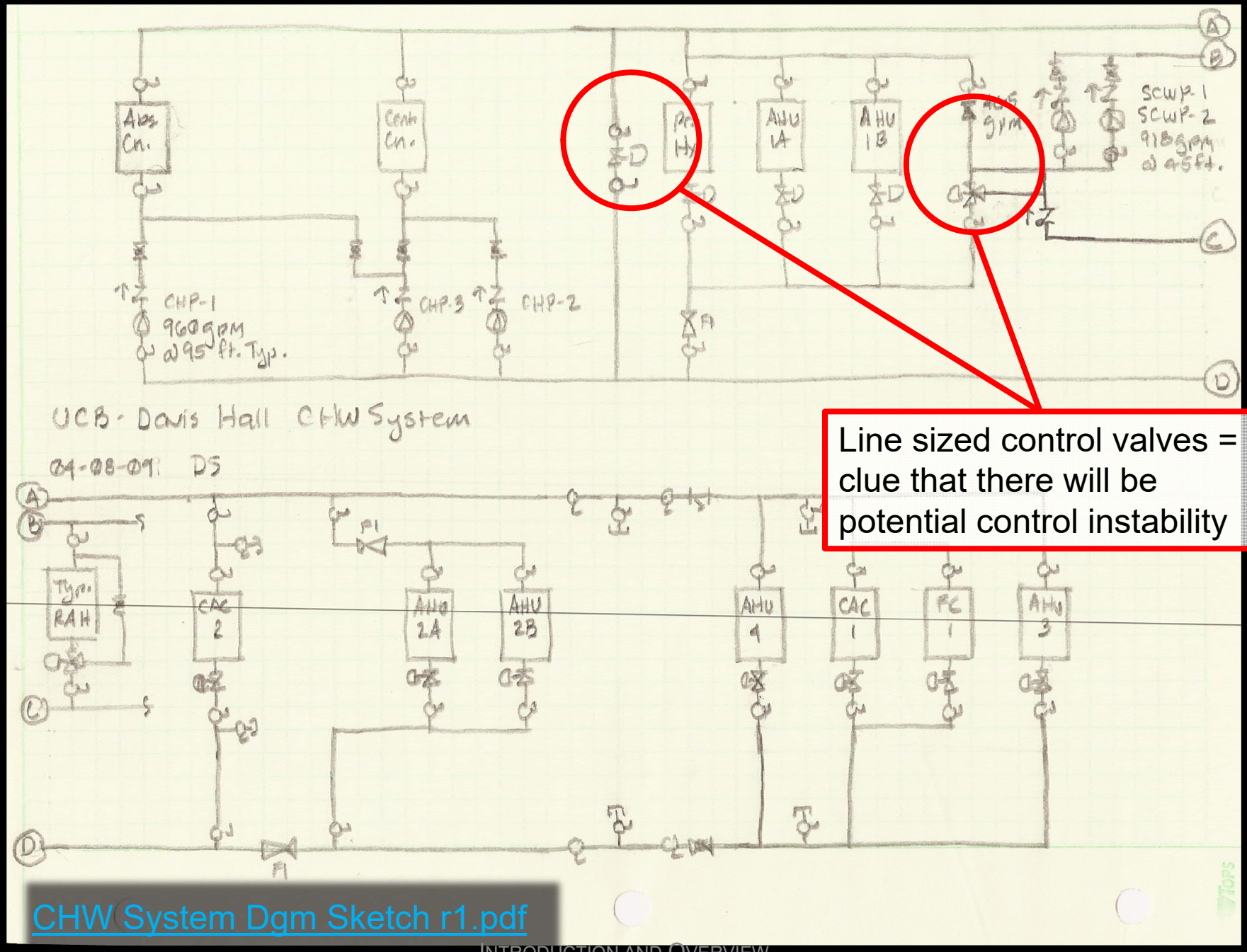


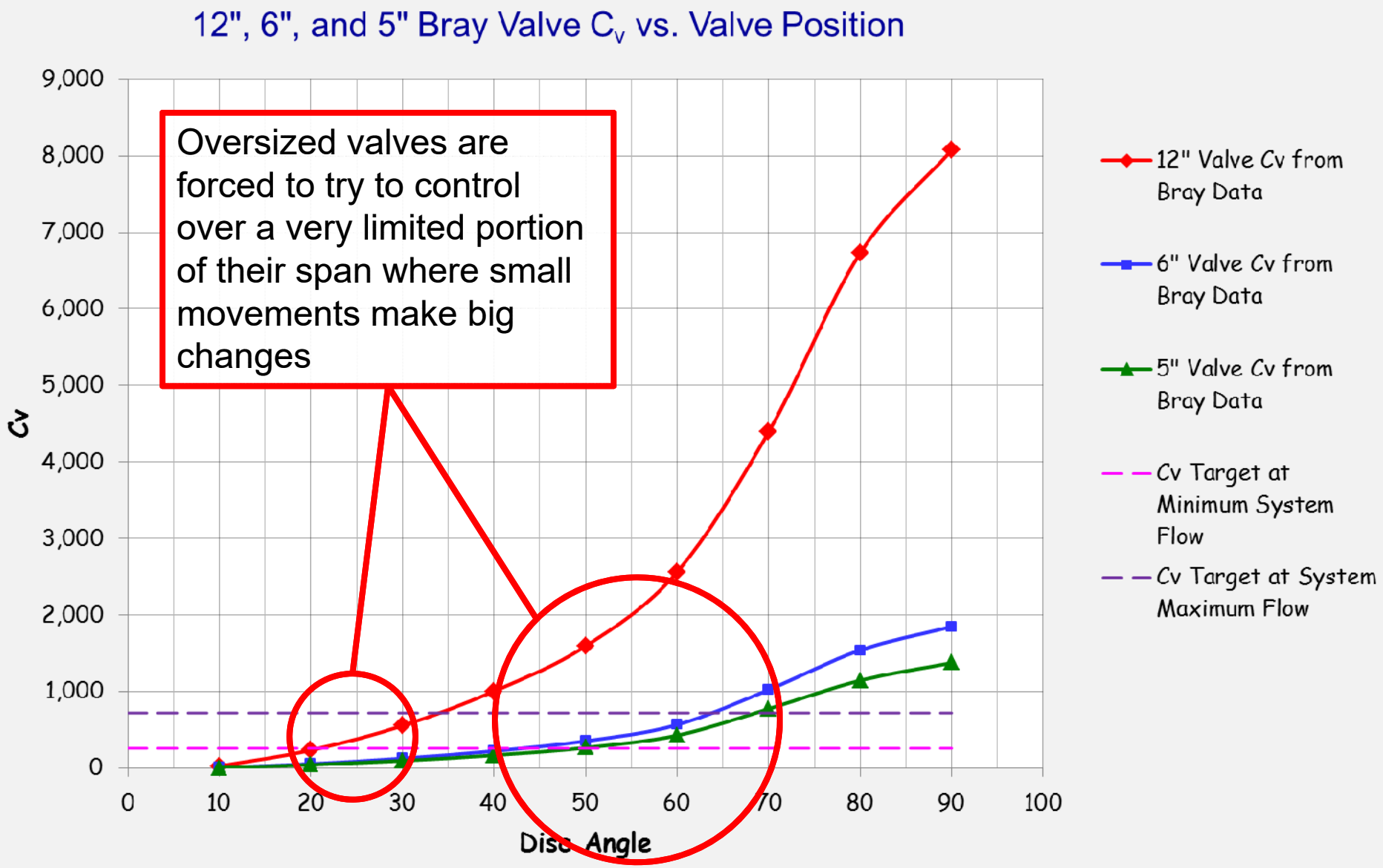
What Happens if the Discharge Temperature Control Loop on a Load Becomes Unstable?

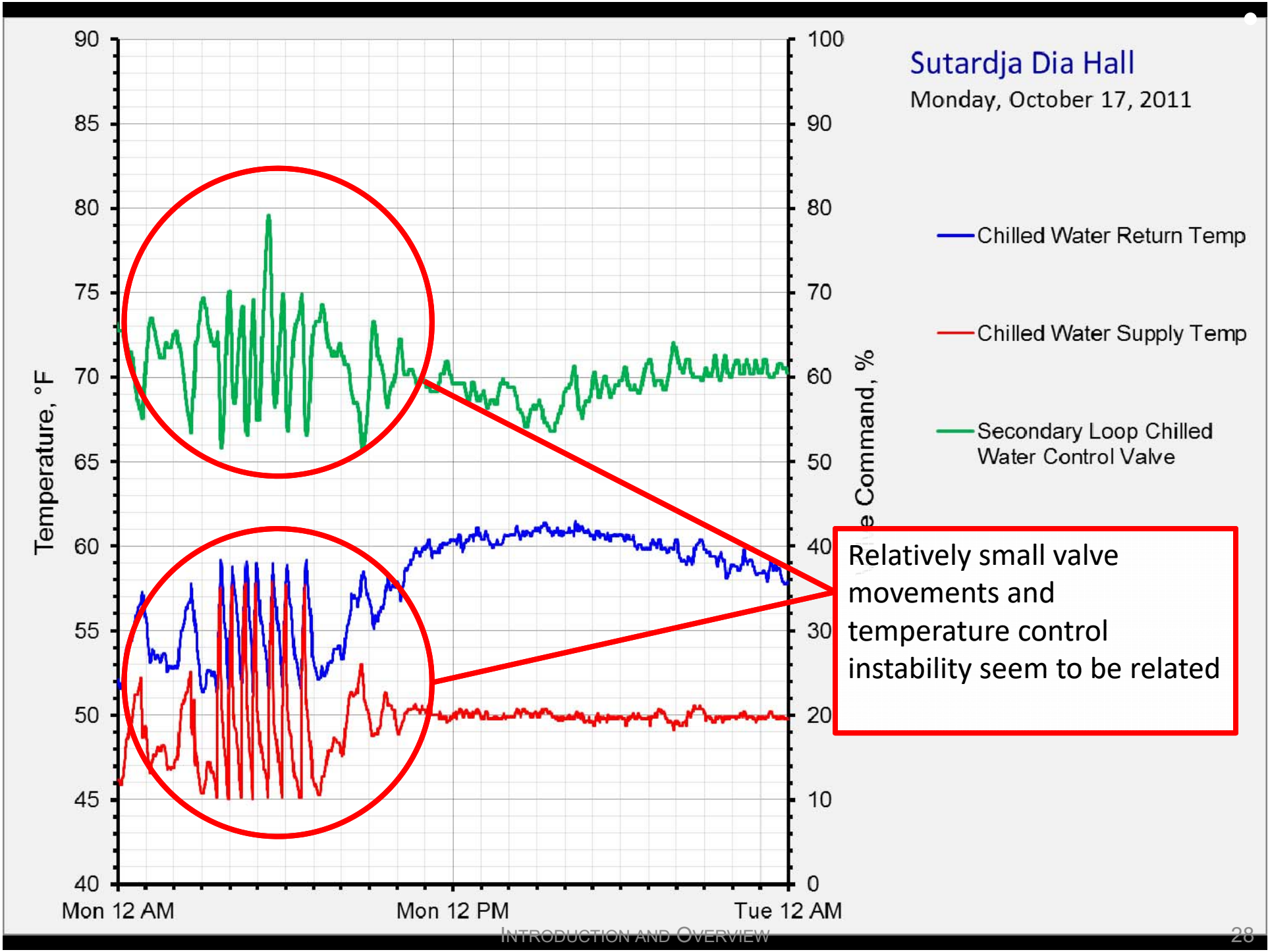




Line sized control valves = clue that there will be potential control instability


CHP-1
960 GPM
@ 95 ft. Typ.
CHP-3
CHP-2
SCWP-1
SCWP-2
UCB - Davis Hall CHW System
04-08-09 DS
Line sized control valves = clue that there will be potential control instability
CHW System Dgm Sketch r1.pdf


12", 6", and 5" Bray Valve C_v vs. Valve Position
Oversized valves are forced to try to control over a very limited portion of their span where small movements make big changes
Cv
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0
10
20
30
40
50
60
70
80
90
100
Disc Angle
12" Valve Cv from Bray Data
6" Valve Cv from Bray Data
5" Valve Cv from Bray Data
Cv Target at Minimum System Flow
Cv Target at System Maximum Flow


Sutardja Dia Hall
Monday, October 17, 2011
Chilled Water Return Temp
Chilled Water Supply Temp
Secondary Loop Chilled Water Control Valve
Temperature, °F
Command, %
90
85
80
75
70
65
60
55
50
45
40
100
90
80
70
60
50
40
30
20
10
0
Mon 12 AM
Mon 12 PM
Tue 12 AM
Relatively small valve movements and temperature control instability seem to be related

Temperature Control Instability Means:

For the Centrifugal

- Rapid entering water temperature changes
- Rapid leaving water temperature changes
- Rapid cycling
  - 12,000 hours
  - 11,000 starts
- Inability to fine tune the control system
  - Hot gas bypass operation at 300 tons instead of 600 tons

For the Absorber

- Rapid entering water temperature changes
- Rapid leaving water temperature changes
- Something that happens to fast to bother with
- Fine tune? You're lucking its even running

Short Cycling = Serious Problem

- Centrifugal Chiller
  - Motor overheating
  - Poor lubrication
  - Starter wear and tear
  - Premature failure
- Absorption Chiller
  - Won't short cycle (meaning long off cycle)
  - Solidification
- Clean Room (Mission Critical Load)
  - Unstable CHW temperatures = loss of process control
  - Unstable CHW temperatures = damage to expensive equipment

Balancing Energy with Mission and Capital Investments

- University Setting = Cutting Edge Research
- Cutting Edge Experiments = Valuable Data and Hardware
- Chiller Service Calls =
  - Down time
  - No redundancy
  - $1,200 - $3,200 a day for labor plus parts
- Chiller Replacement =
  - Down time
  - No redundancy
  - $610,000 for the chiller
  - $725,000 for installation

Images used with permission, courtesy Precision Air Systems, www.precisionairsystemsinc.com

Protecting the Mission and Investment

Eliminate the Instability as Soon as Possible

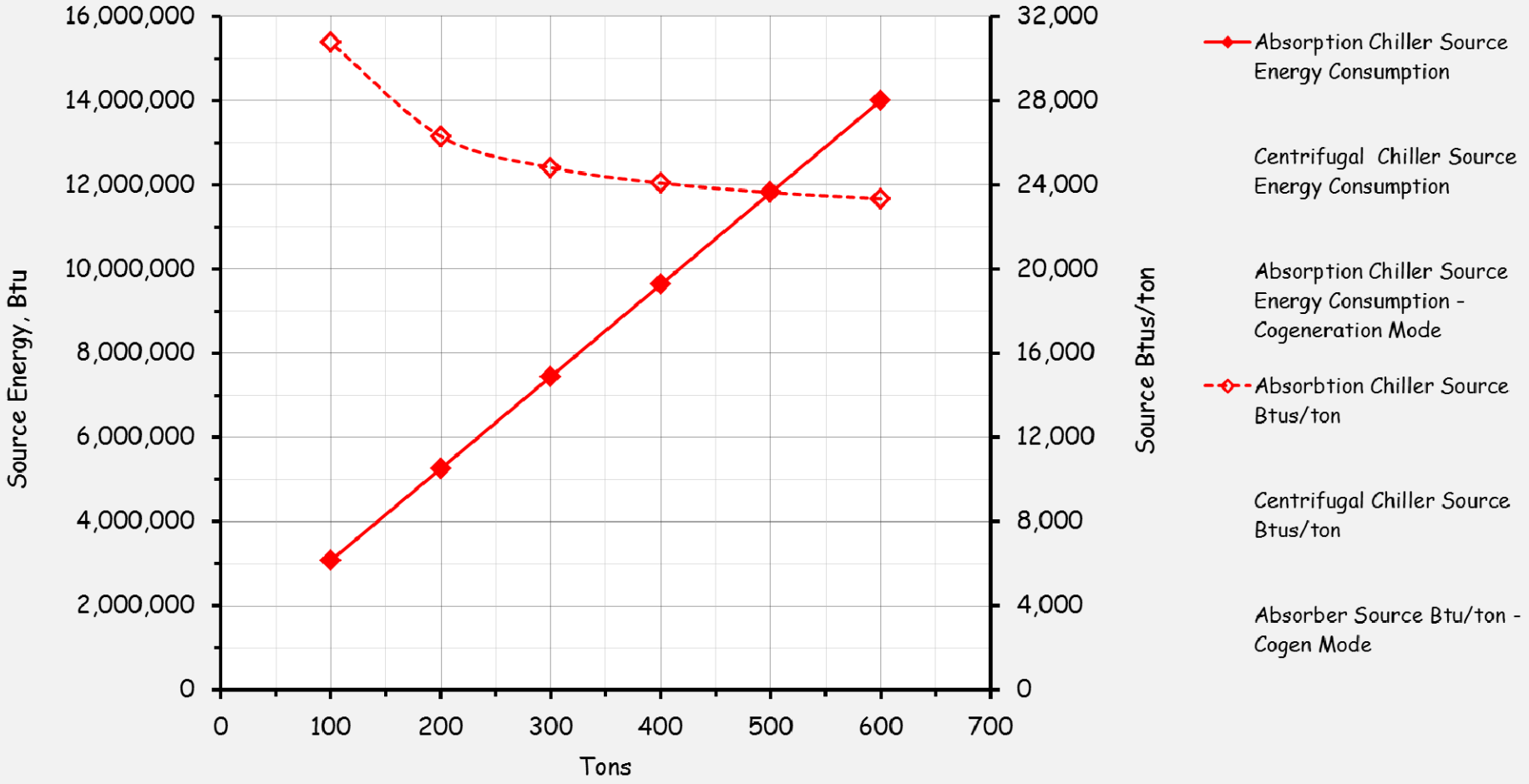
- Eliminate schedules to minimize turn down requirements
- Eliminate economizers to ensure a load on the plant

Operate the absorption chiller only

- More tolerant of instability

Chiller Source Energy Consumption for One Hour at Different Load Conditions

Includes all Auxiliary Energy Except Cooling Tower Fans



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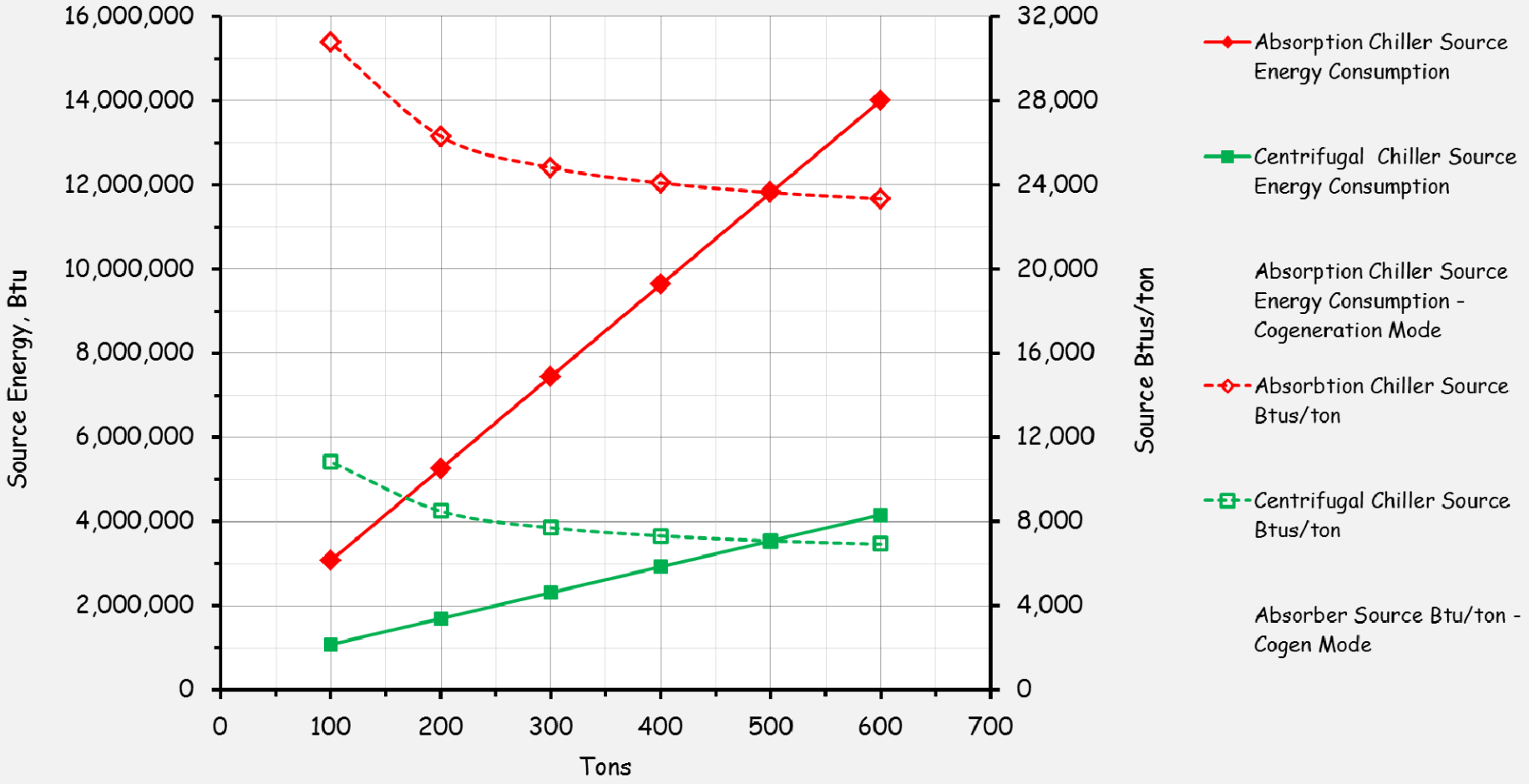
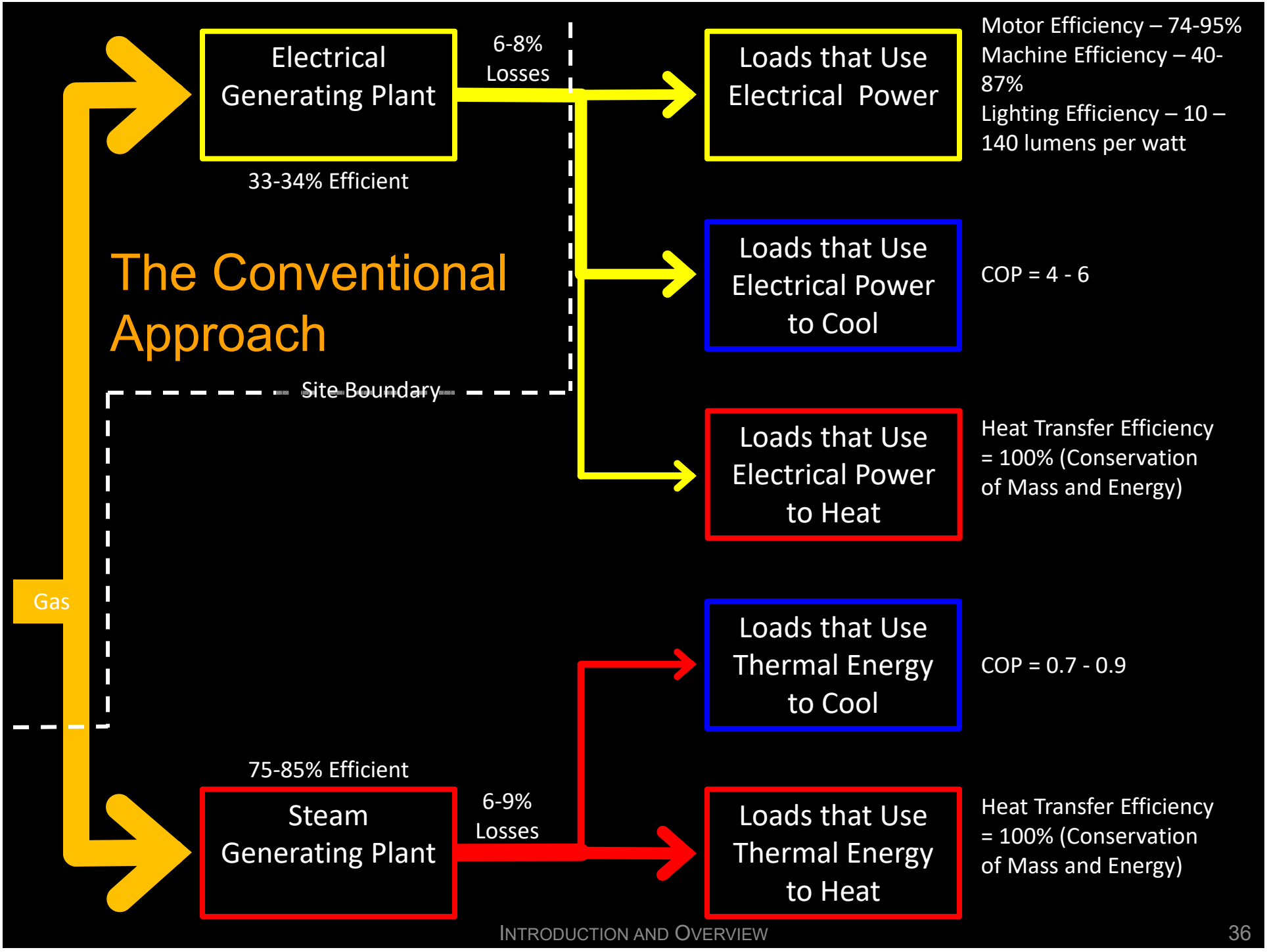


Source Energy Consumption and Site Cost to Produce 600 tons for One Hour				
Item	Absorption Chiller, Btu		Centrifugal Chiller, Btu	
	Source Btu	$	Source Btu	$
Refrigeration Process Source Energy	13,114,286	$76.11	3,693,399	$35.40
Chilled Water Pumping Energy	241,896	$2.32	241,896	$2.32
Condenser Water Pumping Energy	513,084	$4.92	220,693	$2.12
Absorber, Generator, and Evaporator Pump Energy	135,633	$1.30	N/A	$0.00
Oil Pump	N/A	$0.00	5,837	$0.06
TOTAL for 600 tons for One Hour	14,004,899	$84.65	4,161,826	$39.89
Heat to be Rejected at the Cooling Tower	17,485,714		8,408,202	


Electrical Generating Plant
6-8% Losses
33-34% Efficient
Loads that Use Electrical Power
Motor Efficiency – 74-95%
Machine Efficiency – 40-87%
Lighting Efficiency – 10 – 140 lumens per watt
The Conventional Approach
Loads that Use Electrical Power to Cool
COP = 4 - 6
Site Boundary
Loads that Use Electrical Power to Heat
Heat Transfer Efficiency = 100% (Conservation of Mass and Energy)
Gas
Loads that Use Thermal Energy to Cool
COP = 0.7 - 0.9
75-85% Efficient
Steam Generating Plant
6-9% Losses
Loads that Use Thermal Energy to Heat
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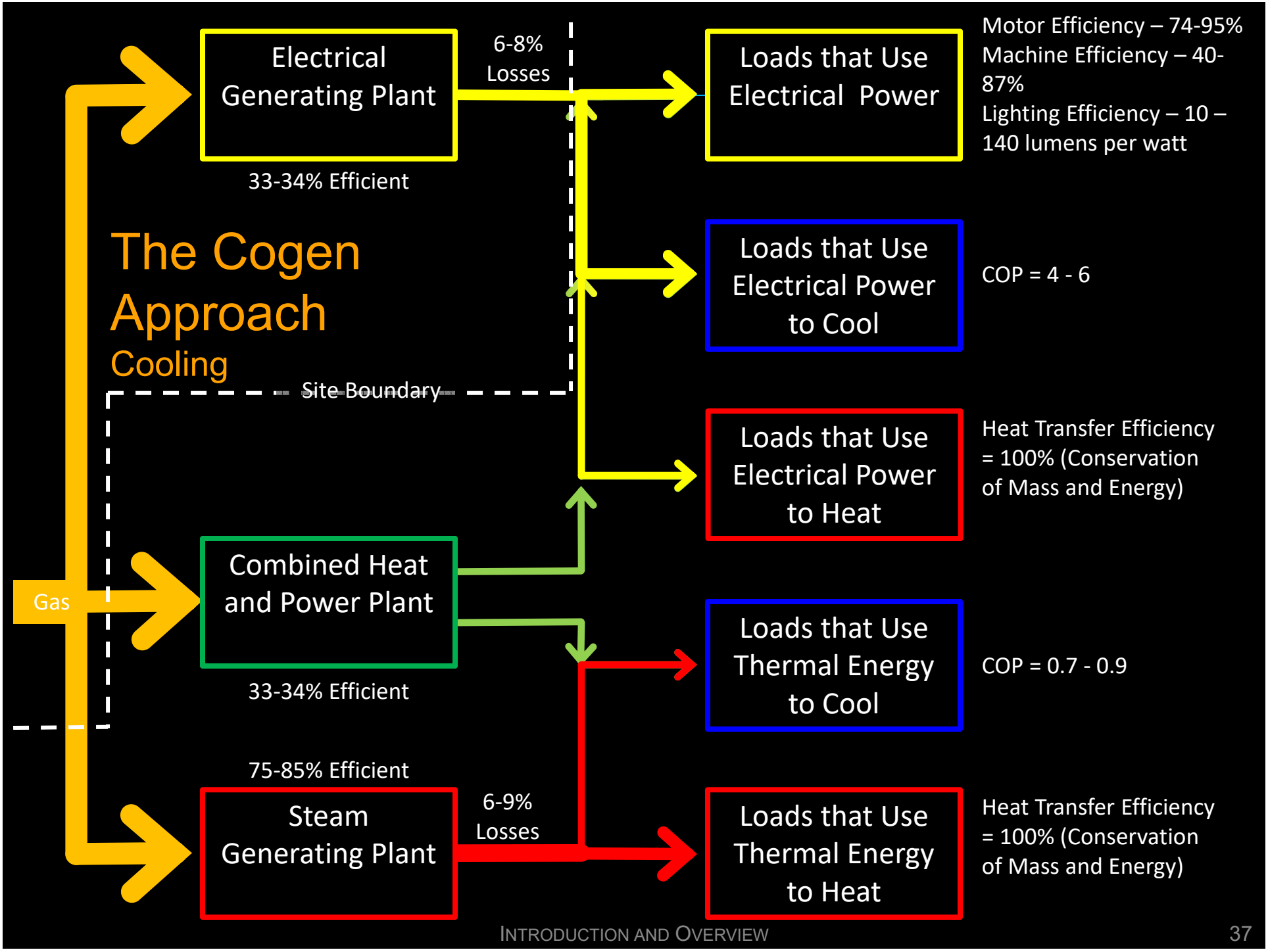
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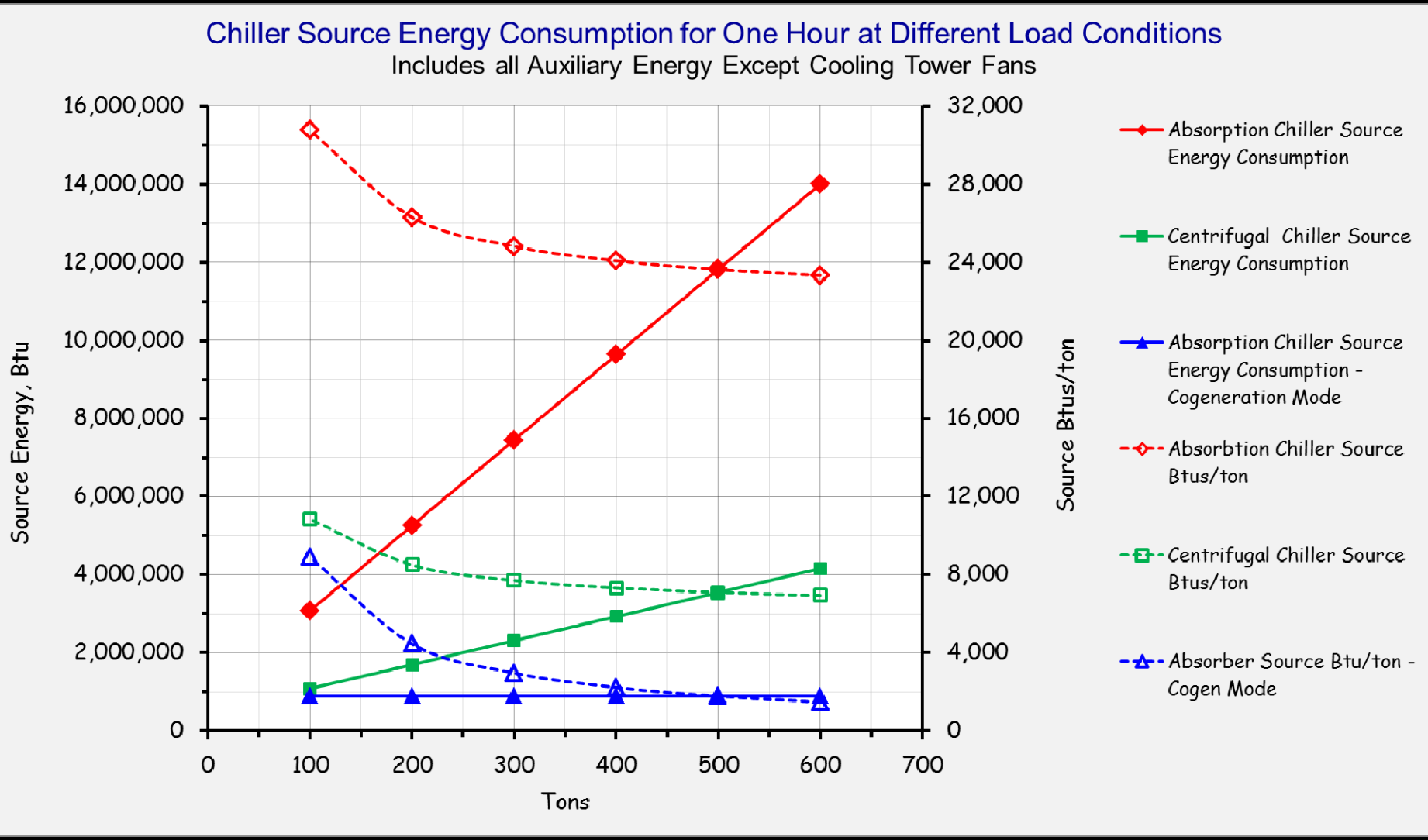
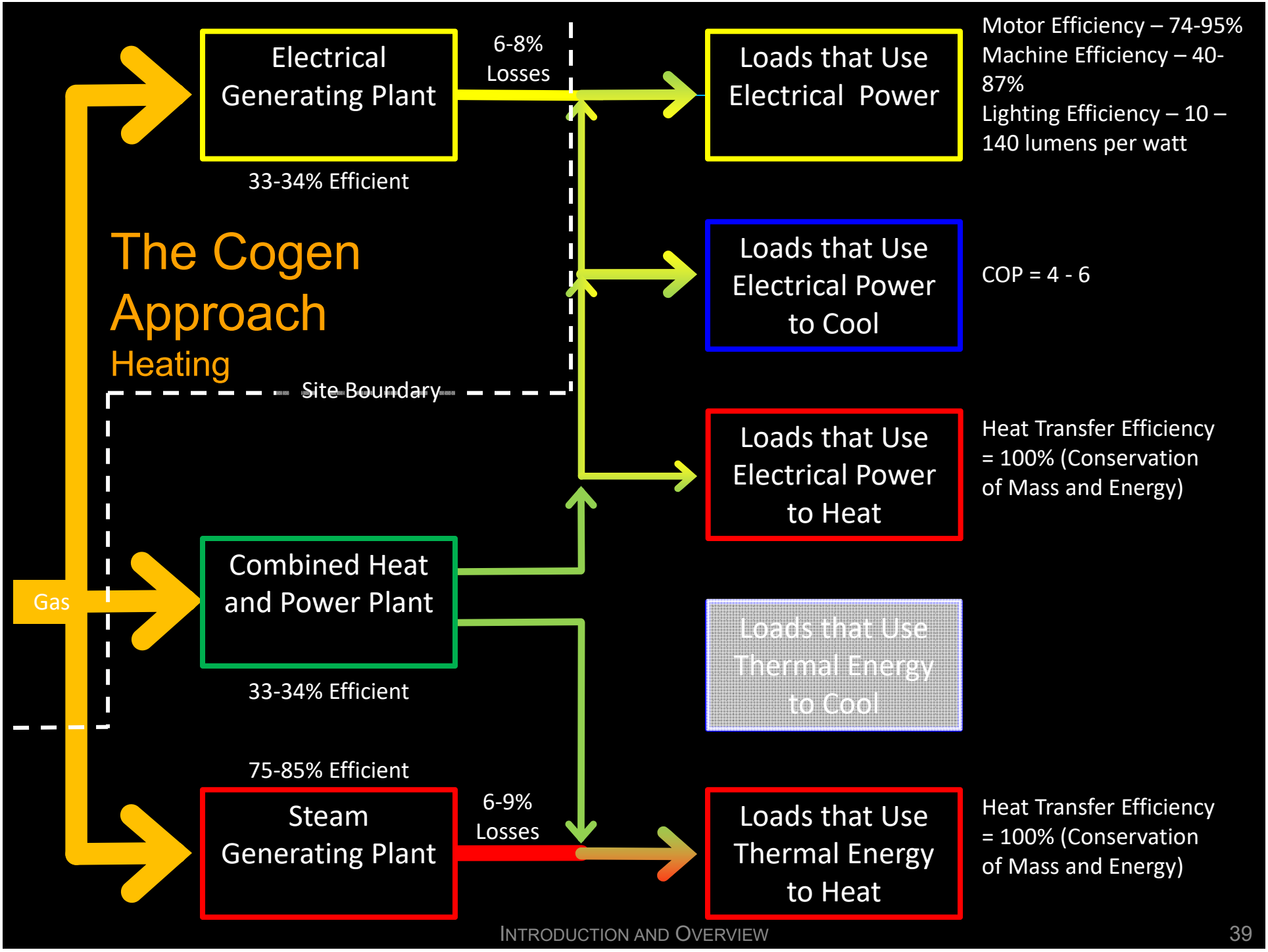

Chiller Source Energy Consumption for One Hour at Different Load Conditions
Includes all Auxiliary Energy Except Cooling Tower Fans
Source Energy, Btu
16,000,000
14,000,000
12,000,000
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
0
Source Btus/ton
32,000
28,000
24,000
20,000
16,000
12,000
8,000
4,000
0
0
100
200
300
400
500
600
700
Tons
Absorption Chiller Source Energy Consumption
Centrifugal Chiller Source Energy Consumption
Absorption Chiller Source Energy Consumption - Cogeneration Mode
Absorbtion Chiller Source Btus/ton
Centrifugal Chiller Source Btus/ton
Absorber Source Btu/ton - Cogen Mode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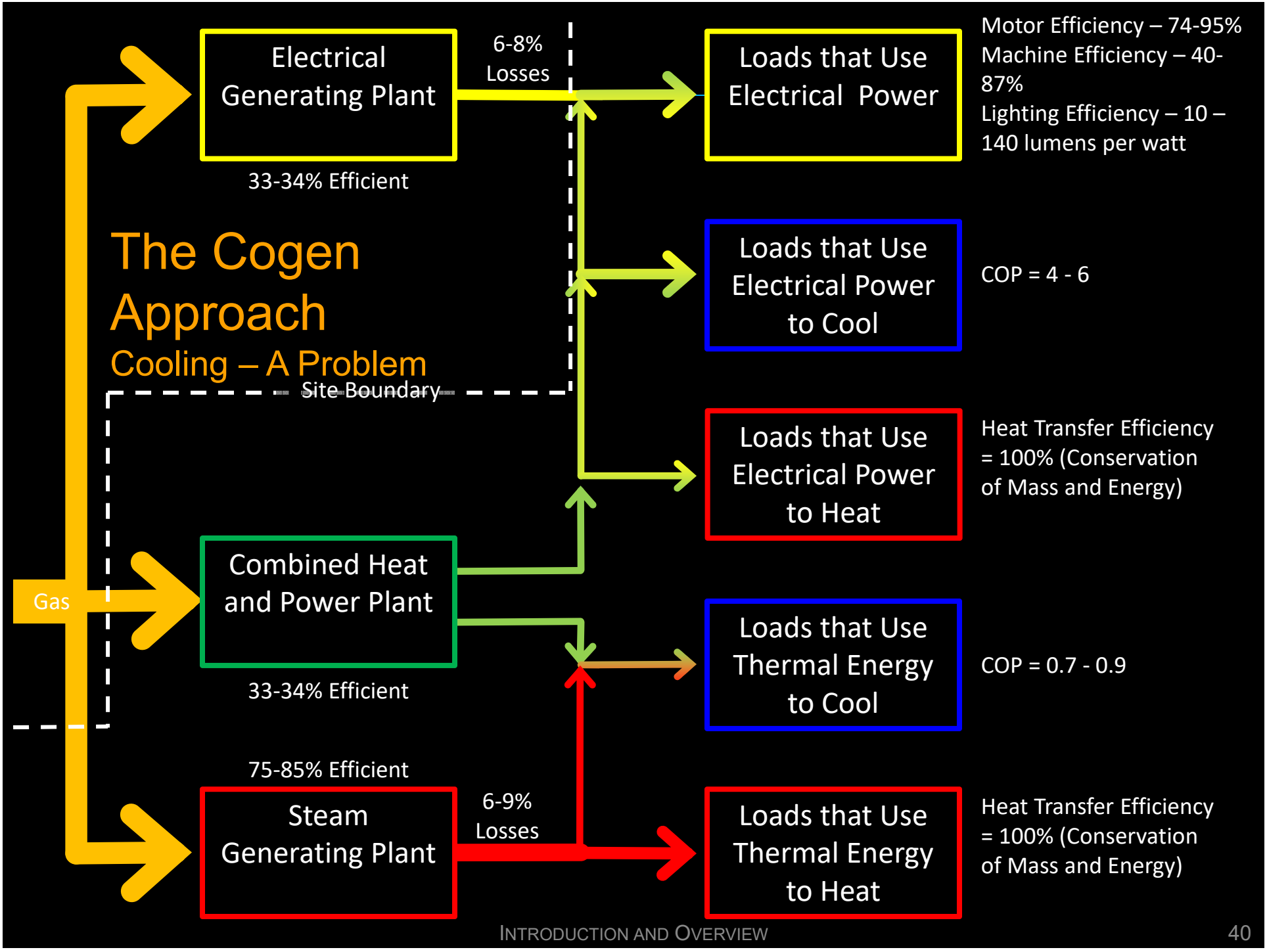
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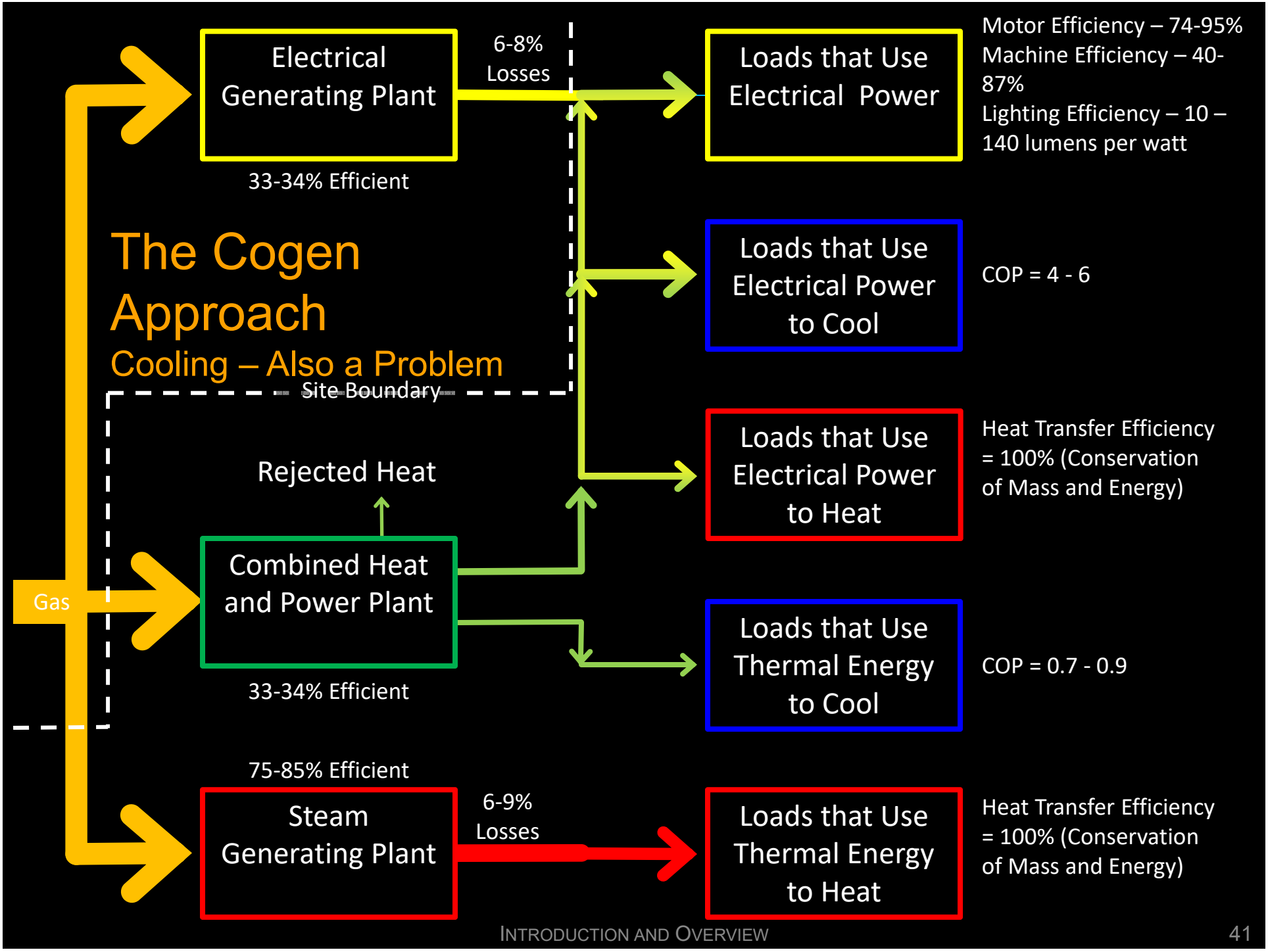
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Site Boundary
Rejected Heat
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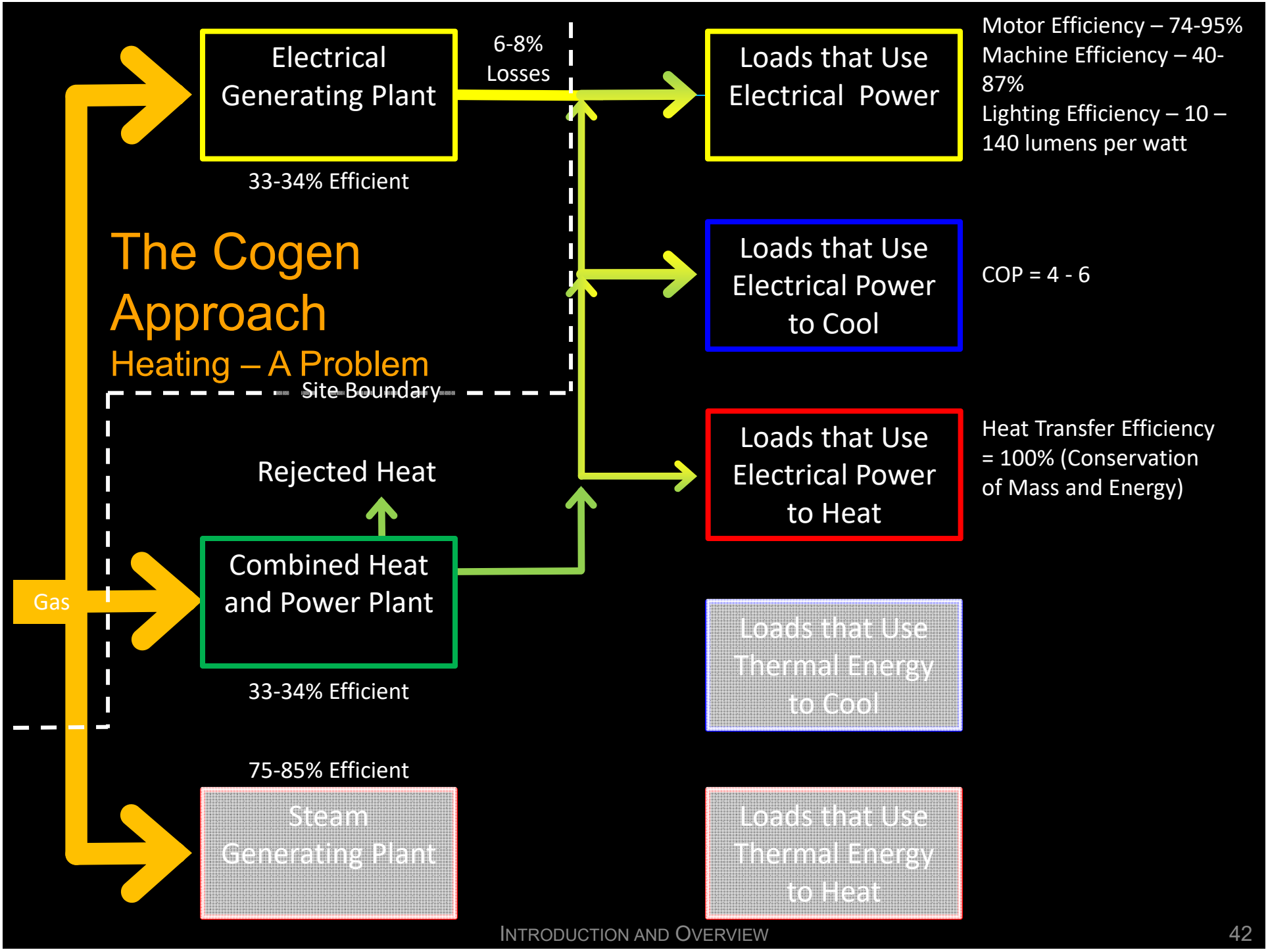
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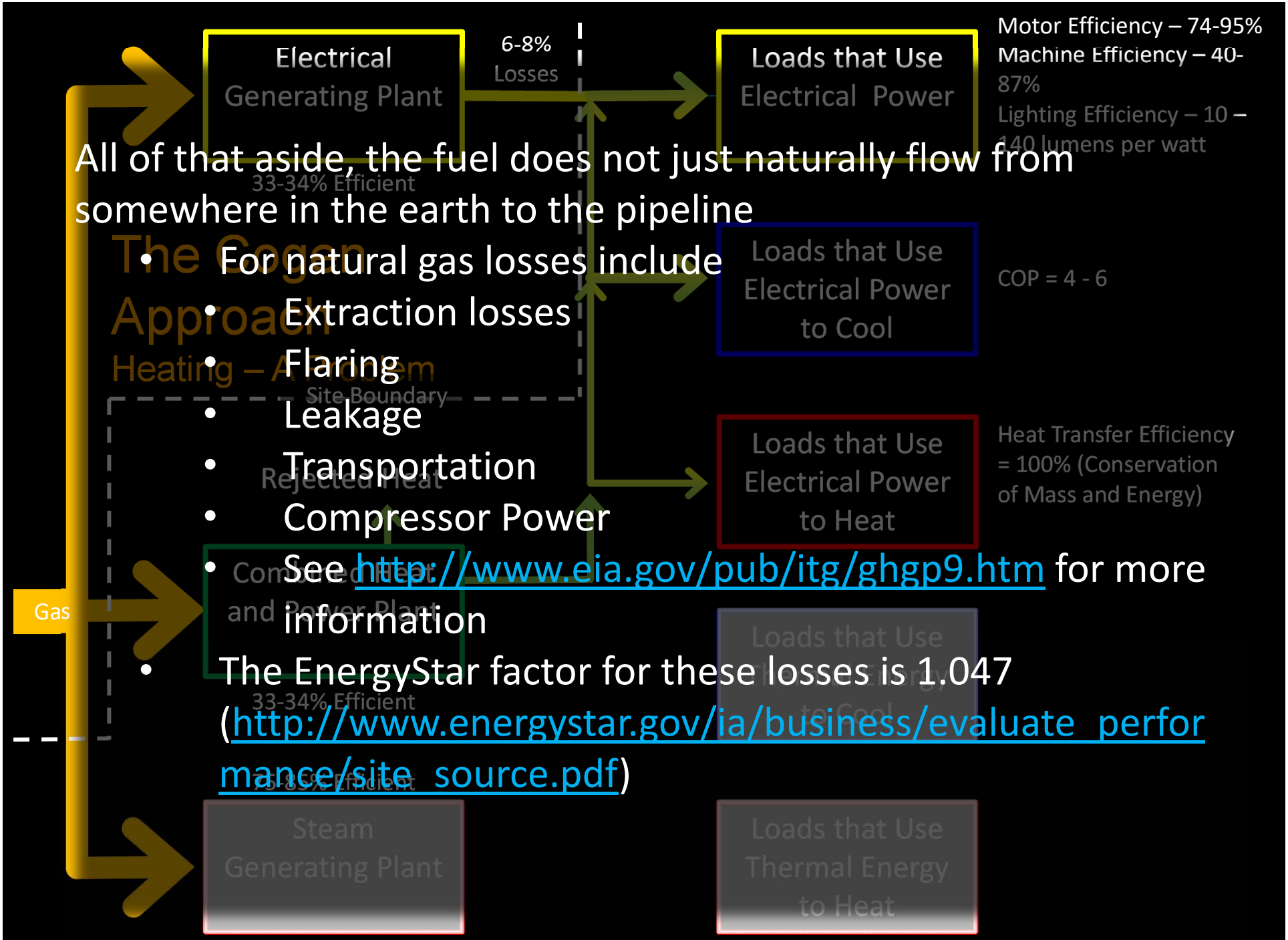
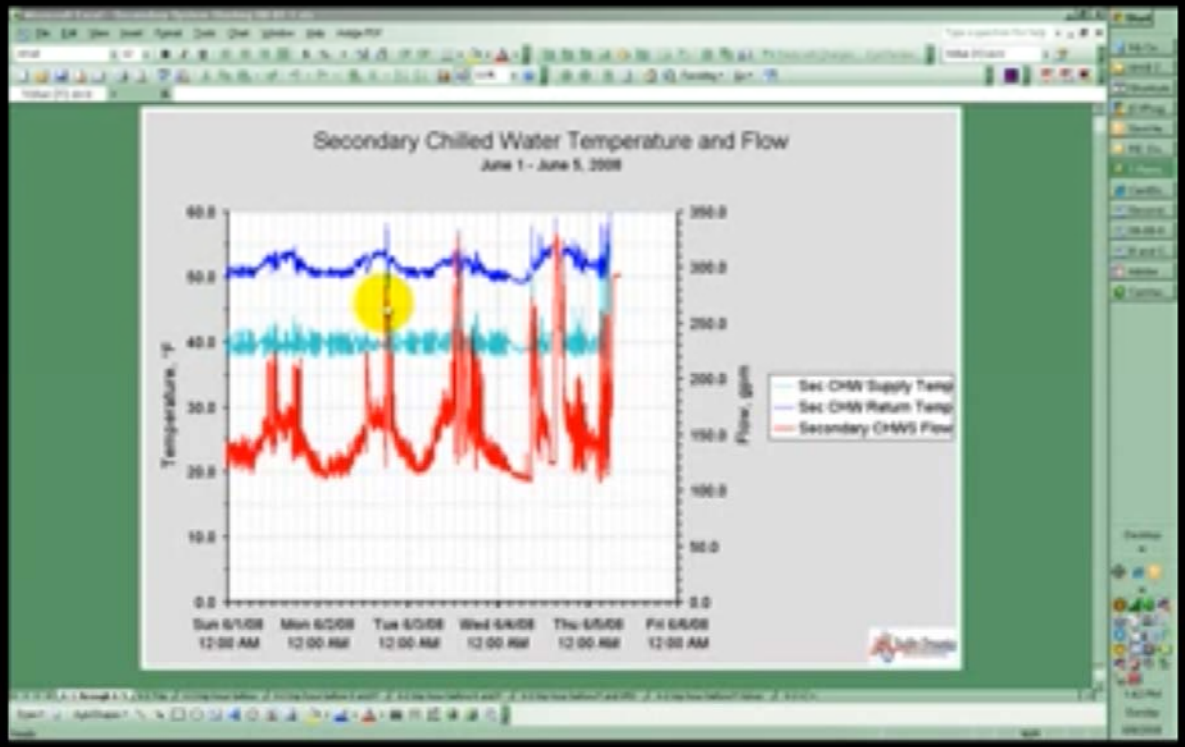


All of that aside, the fuel does not just naturally flow from somewhere in the earth to the pipeline

- For natural gas losses include
  - Extraction losses
  - Flaring
  - Leakage
  - Transportation
  - Compressor Power
  - See http://www.eia.gov/pub/itg/ghgp9.htm for more information
- The EnergyStar factor for these losses is 1.047 (http://www.energystar.gov/ia/business/evaluate_performance/site_source.pdf)

Another Intricate Example that Happens Totally Inside a Building

The Ripple Effects of an Unstable Control Loop



http://youtu.be/I0vIMAOcQLA

Our Bottom Lines

- *Lack of system integration can waste energy and other resources*
- *Lack of system integration can trigger nuisance (or worse) problems*
- *Problems in one system can ripple out to other systems*

Our Bottom Lines

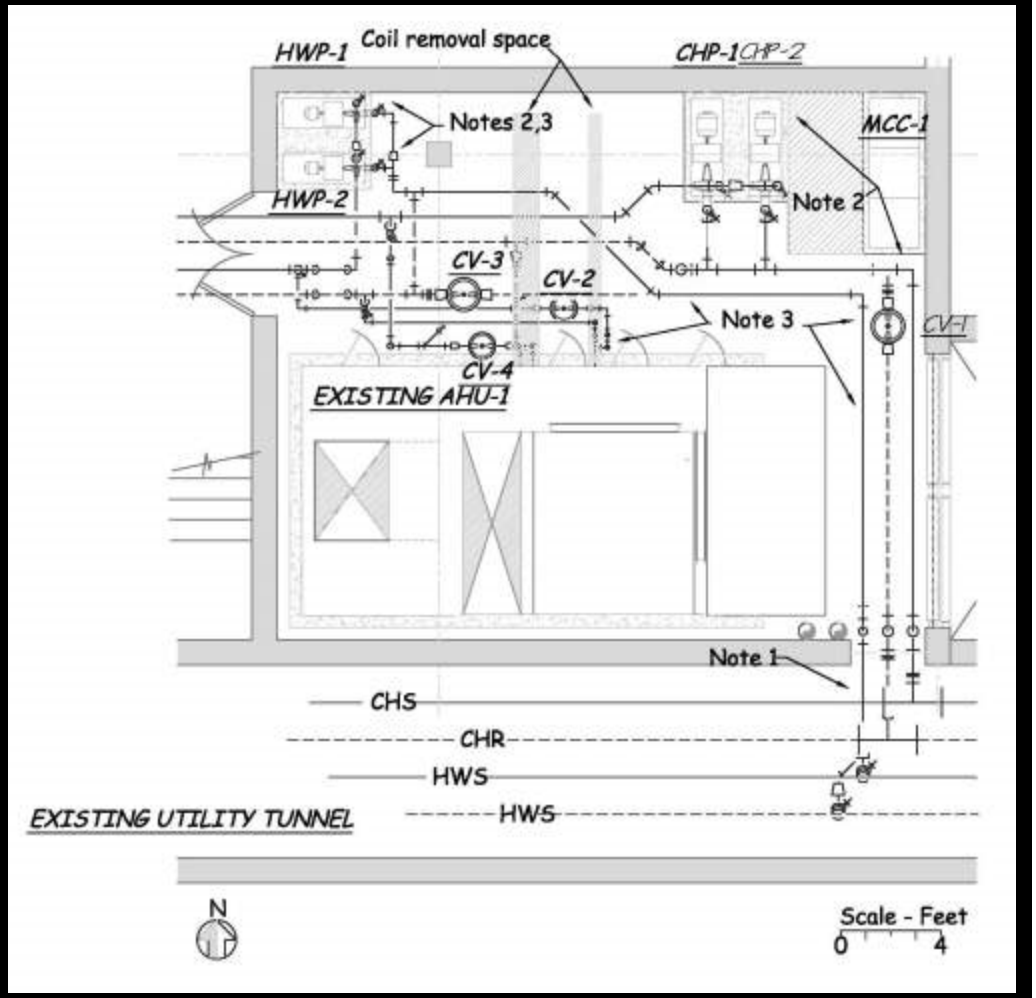
- *Lack of system integration can waste energy and other resources*
- *Lack of system integration can trigger nuisance (or worse) problems*
- *Problems in one system can ripple out to other systems* **and cause really big problems**
- *We need a tool that can help us see the big picture and understand system level and system to system interactions*

Little tiny

Floor Plans

Common Construction Document Mechanism

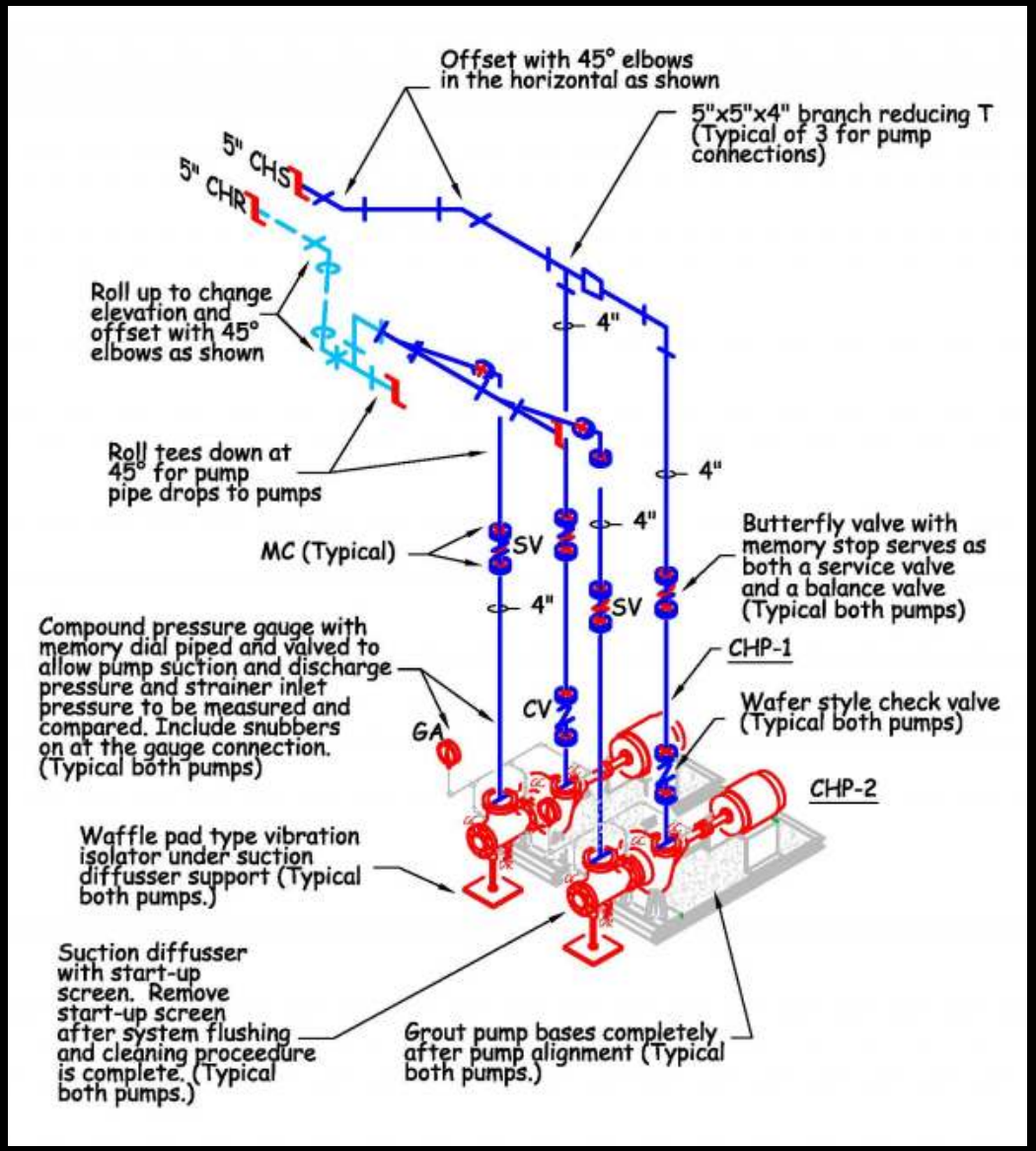
- Depict real world dimensional relationships
- (Can) show if things will fit
- (Can) show fittings required to make things fit and imply related pressure drops
- Three dimensional reality portrayed in two dimensions
- Not intended to convey the design in a schematic arrangement



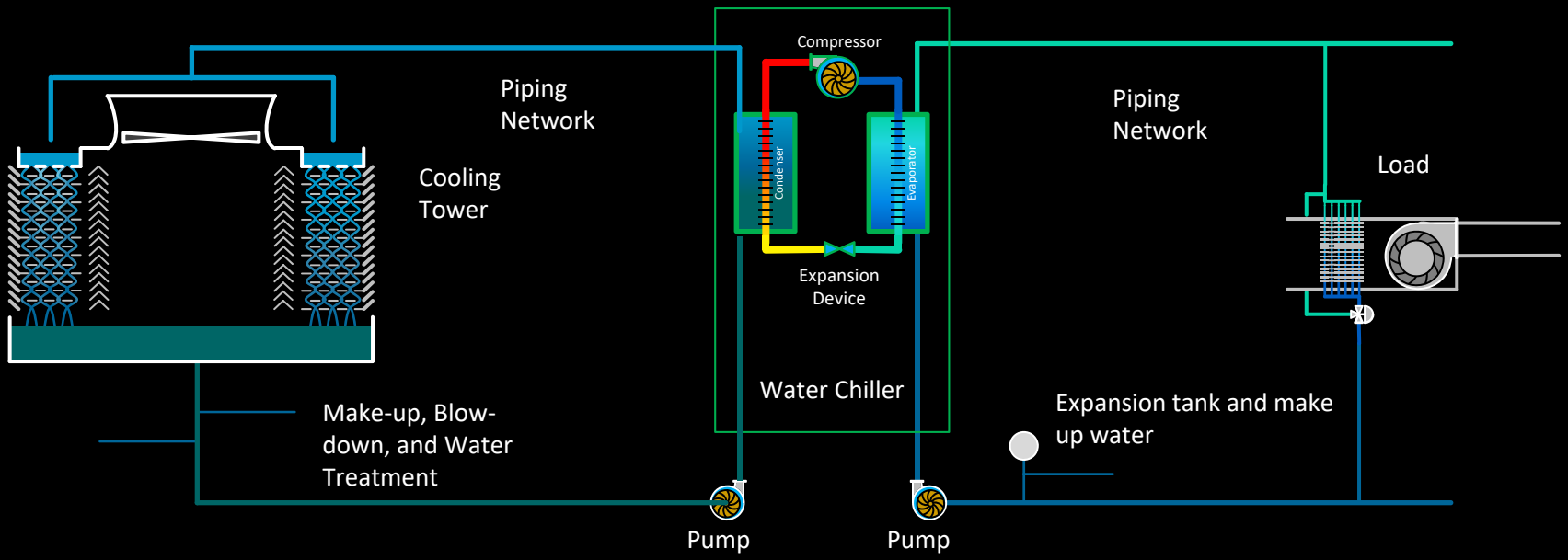
Piping Isometrics

Less Common Construction Document Mechanism

- Bring a three dimensional perspective
- Constructed on isometric projection lines
- Not a true 3D model
- Not intended to convey the design in a schematic arrangement

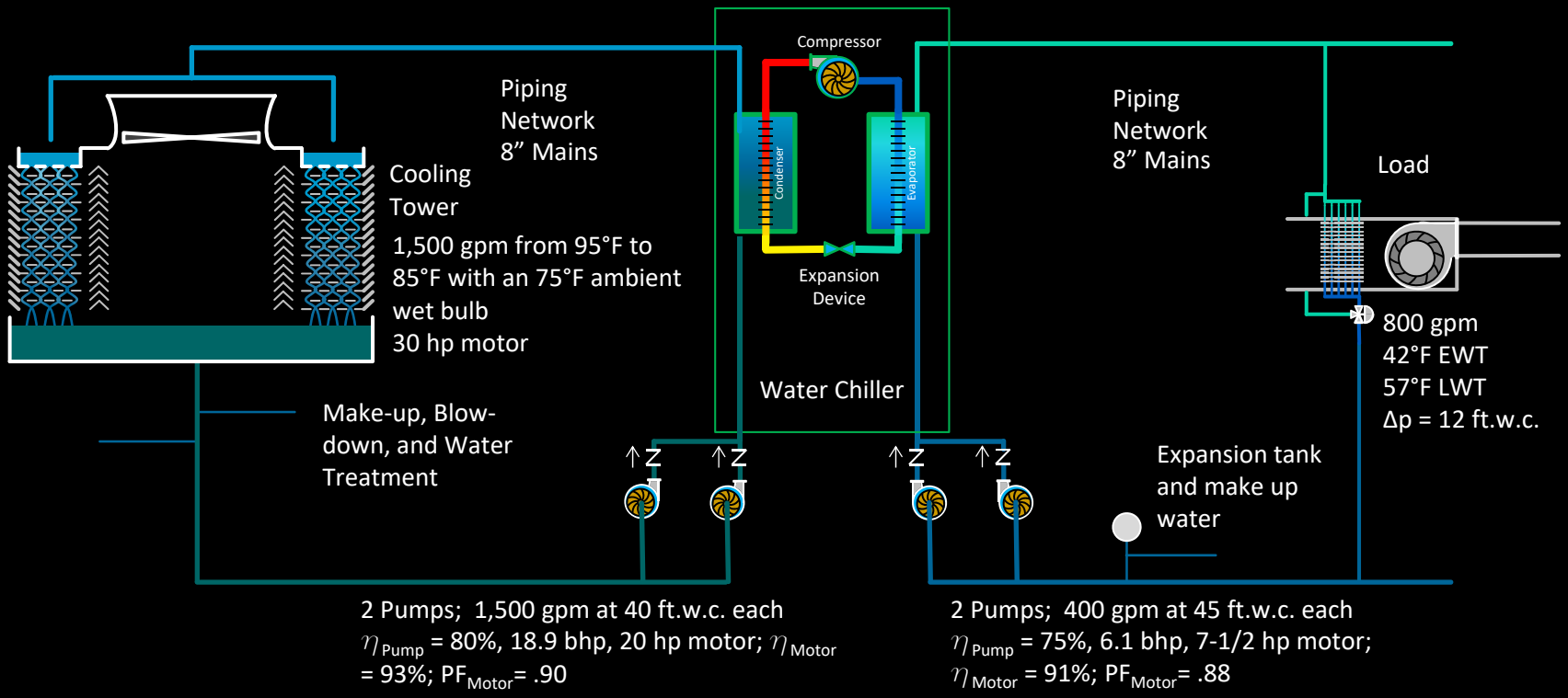


System Diagrams Convey the System Concept



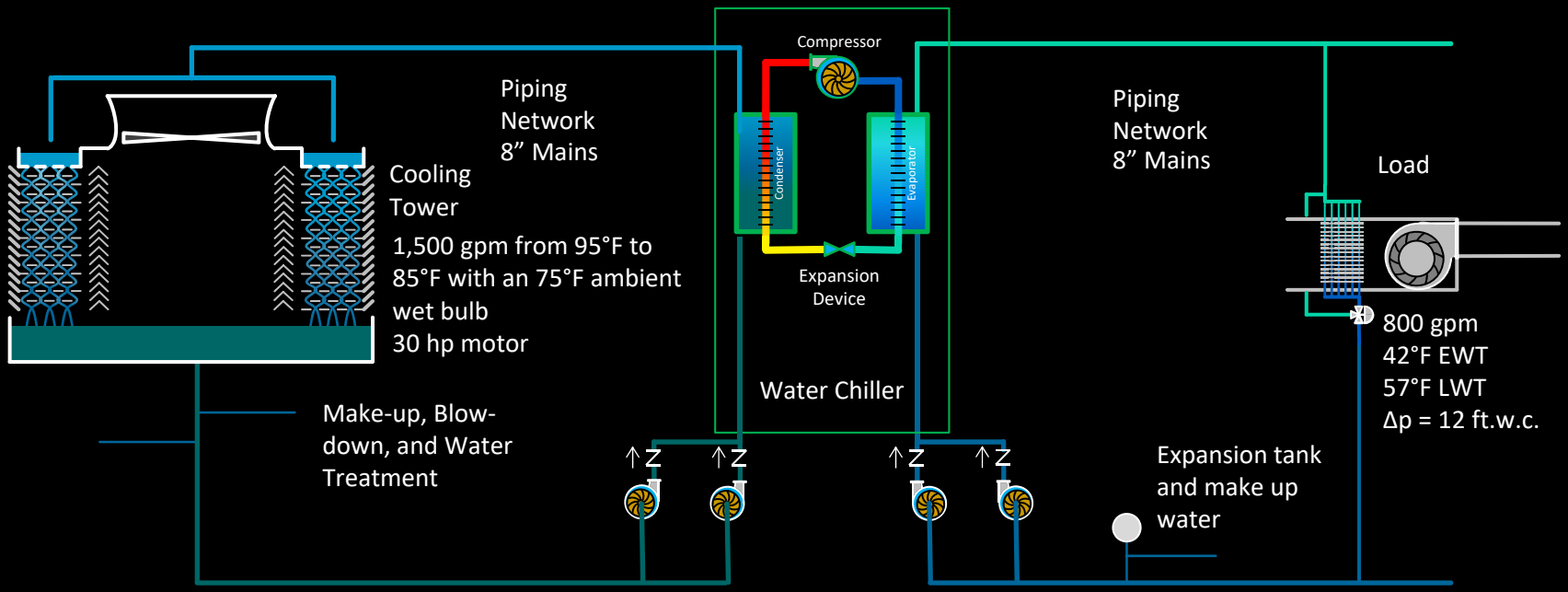
Conveying the system concept is a powerful design tool

System Diagrams Convey the System Concept

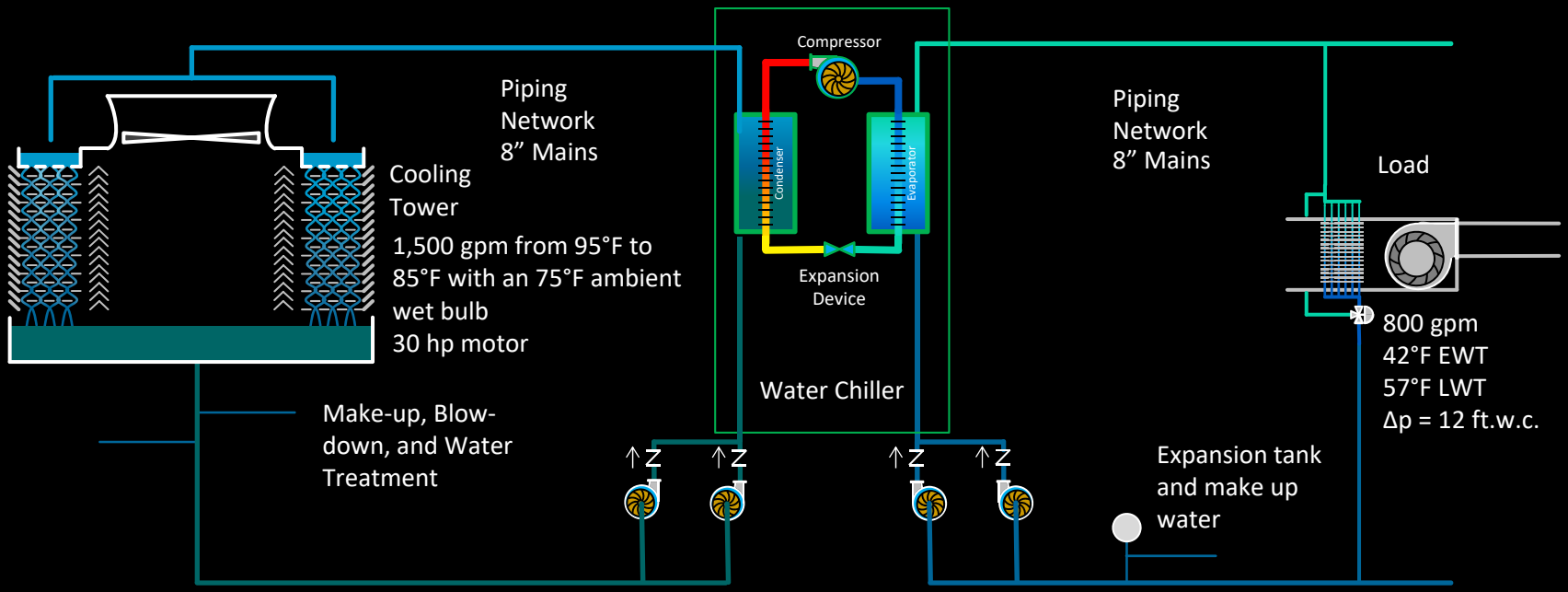


Conveying the system concept is a powerful design tool

Are the Chilled Water Pumps Redundant?



Are the Condenser Water Pumps Redundant?



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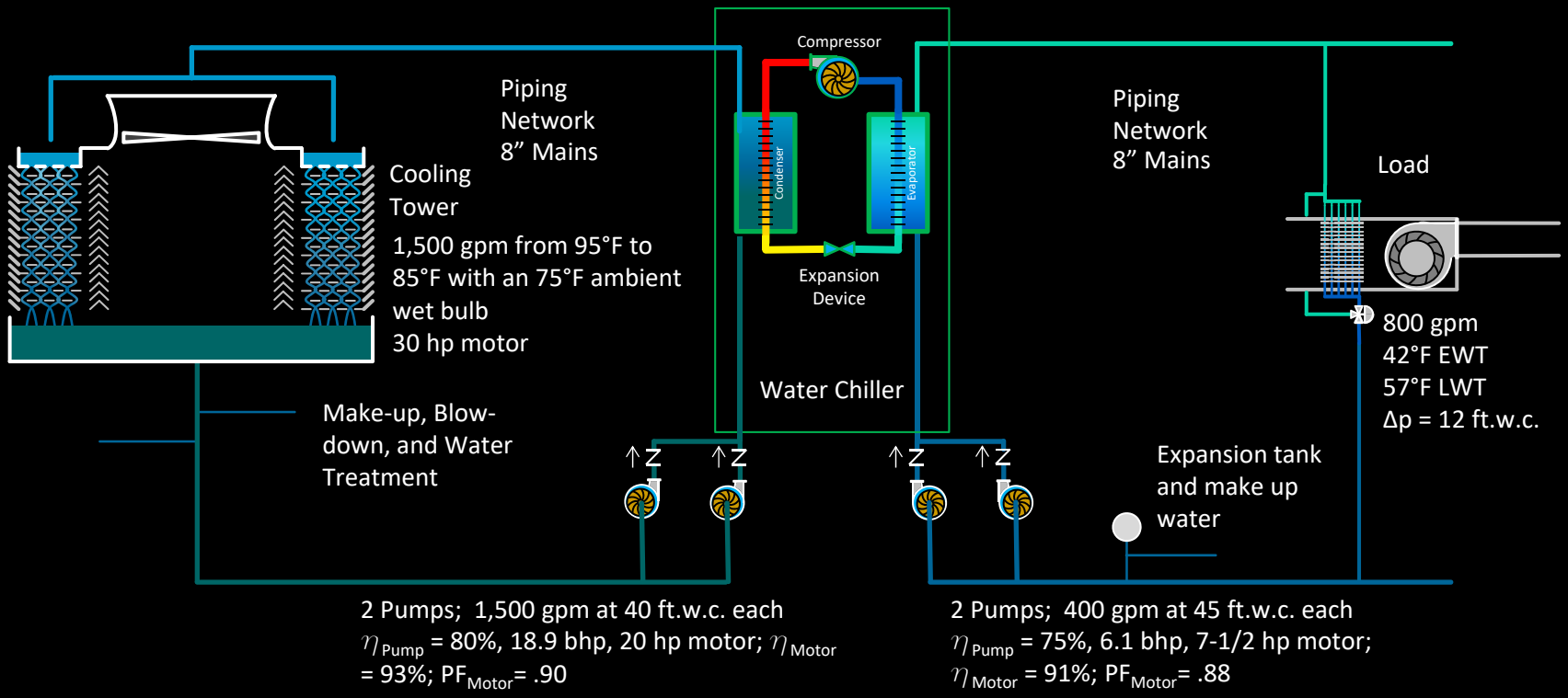

Conveying the system concept is a powerful commissioning tool

System Diagrams Convey the System Concept

Design Tool

Allows the entire system to be seen at once in an orderly, untangled arrangement

- Ensures persistence of intent as plans evolve
- Provides a framework for locating control elements

Allows critical design parameters to be conveyed

- Most engineering decisions can be made at the system diagram stage
- Facilitates inter-discipline communication

Allows configuration details to be conveyed

Cx and Operations Tool

Allows the entire system to be seen at once in an orderly, untangled arrangement

- Allows interactions and integration to be assessed
- Allows trouble-spots to be quickly identified

Allows critical design and performance parameters to be documented

Facilitates:

- Training
- Persistence
- Commissioning
- Troubleshooting