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VARIABLE FLOW CHILLER PLANT DESIGN

Julian R. de Bullet

ASHRAE Distinguished Lecturer

President, deBullet Consulting

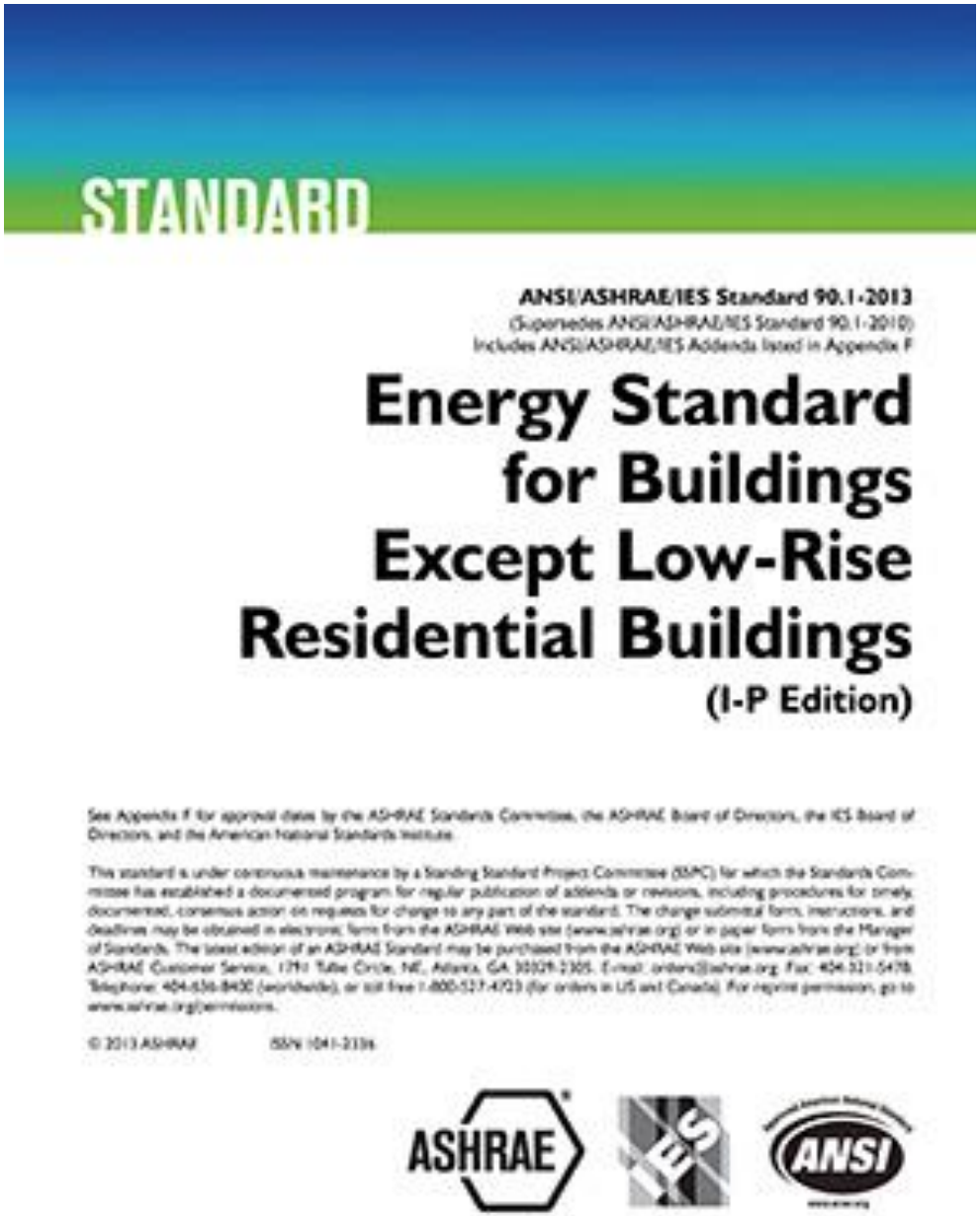
703-483-0179

julian@debullet.com

Carrier
United Technologies
turn to the experts

Why Optimized Design?

- **Buildings In The US Consume 39% Of Our Total Energy**
- **70% Of Our Electricity Annually**
- **5 Billion Gallons Potable Water Per Day For Toilets**
- **Typical Construction Generates 2.5 lbs. Of Solid Waste Per Square Foot**
- **High Performance Building Practices Can Reduce These Negative Environmental Impacts**


STANDARD
ANSI/ASHRAE/IES Standard 90.1-2013
(Supersedes ANSI/ASHRAE/IES Standard 90.1-2010)
Includes ANSI/ASHRAE/IES Addenda listed in Appendix F
Energy Standard for Buildings Except Low-Rise Residential Buildings
(I-P Edition)
See Appendix F for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, the IES Board of Directors, and the American National Standards Institute.
This standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the standard. The change submittal forms, instructions, and deadlines may be obtained in electronic form from the ASHRAE Web site (www.ashrae.org) or in paper form from the Manager of Standards. The latest edition of an ASHRAE Standard may be purchased from the ASHRAE Web site (www.ashrae.org) or from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: orders@ashrae.org. Fax: 404-321-5478. Telephone: 404-636-8400 (worldwide), or toll free 1-800-527-4723 (for orders in US and Canada). For reprint permission, go to www.ashrae.org/permissions.
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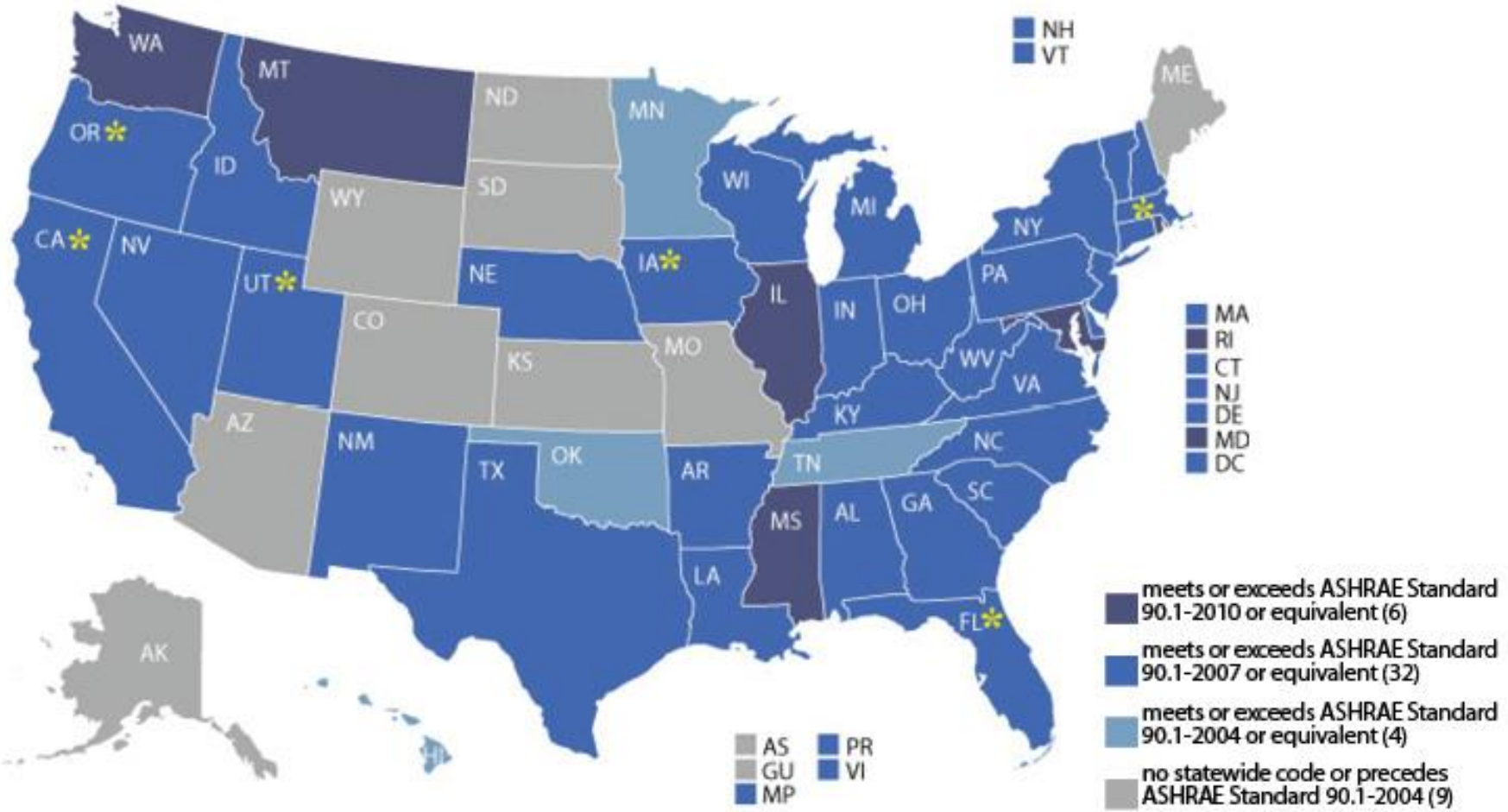
AS OF APRIL 1, 2014



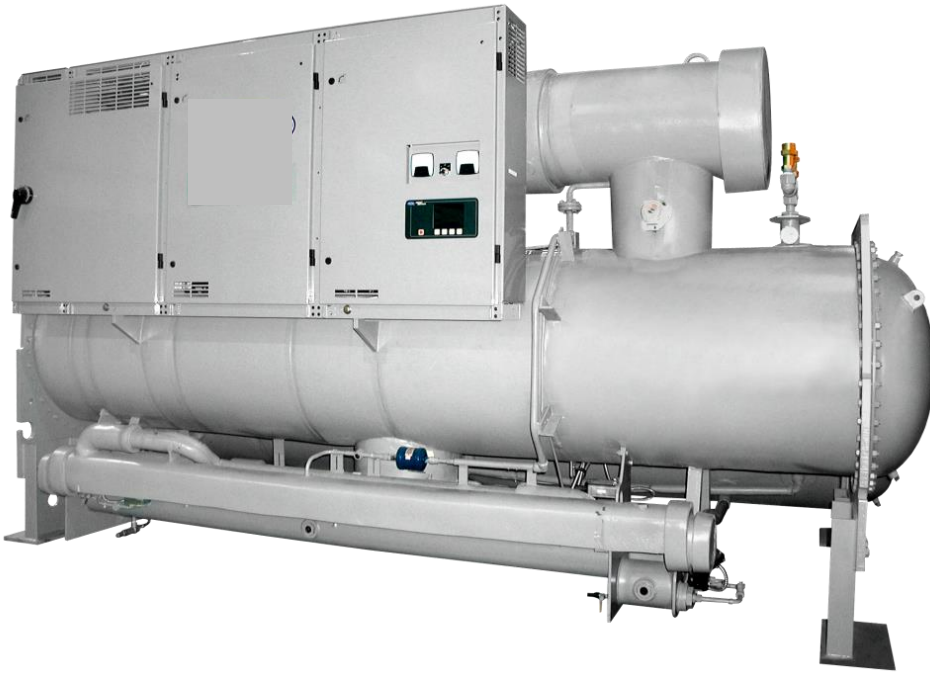
BCAP Dedicated to the adoption, implementation, and advancement of building energy codes

Get all the most up-to-date code status maps and other valuable resources at www.energycodesocean.org

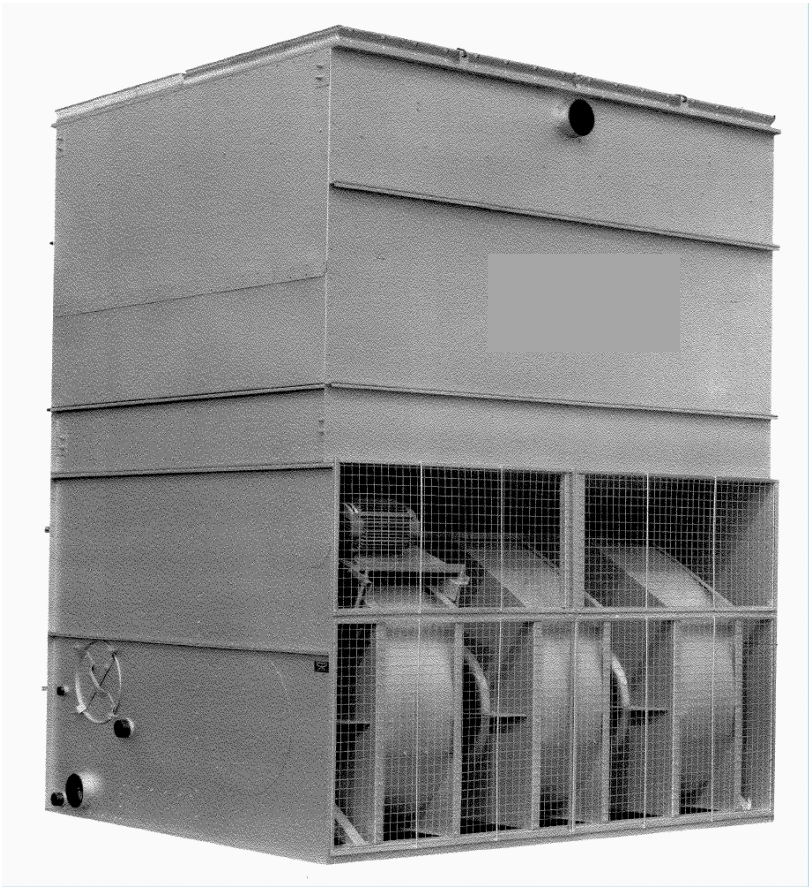
NOTE: These maps reflect only mandatory statewide codes currently in effect.

Chiller Basics

- **Air, Water Or Evaporatively Cooled**
- **Reciprocating, Scroll, Screw Or Centrifugal Compressors**
- **DX or Flooded Evaporators**



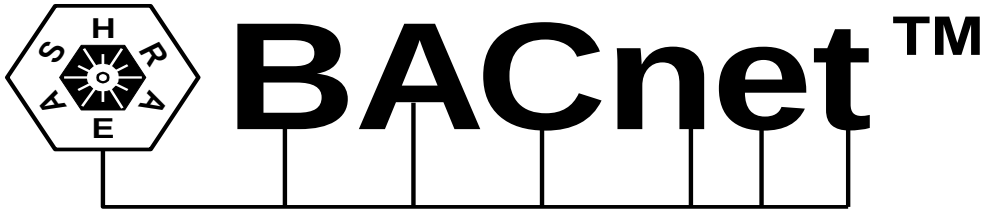
Cooling Tower Basics



Load Basics

- **Chilled Water Coils Transfer Heat From Building Air To Chilled Water**
- **Process Loads**
  - **Cooling Jackets**

HVAC Controls

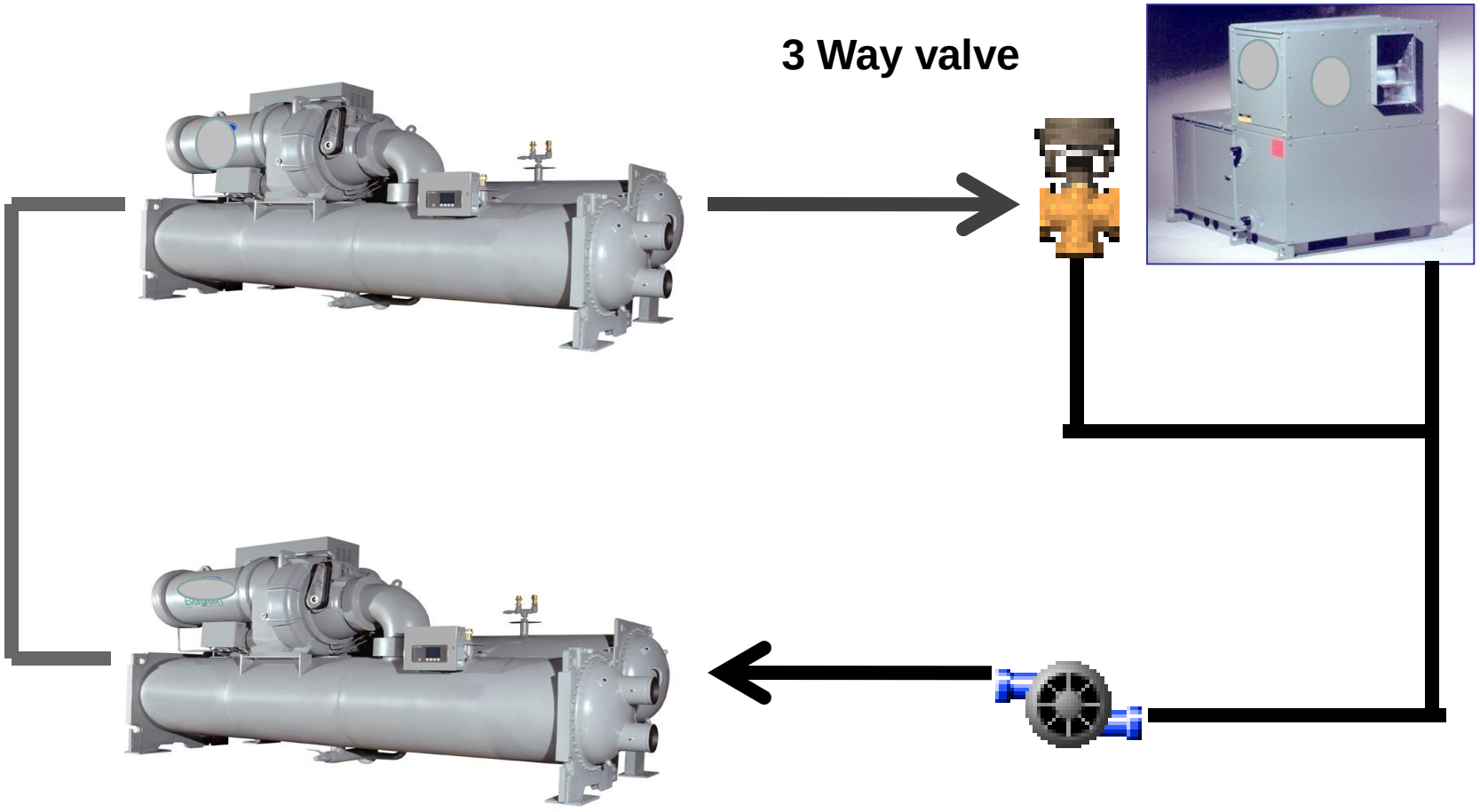


Modbus?

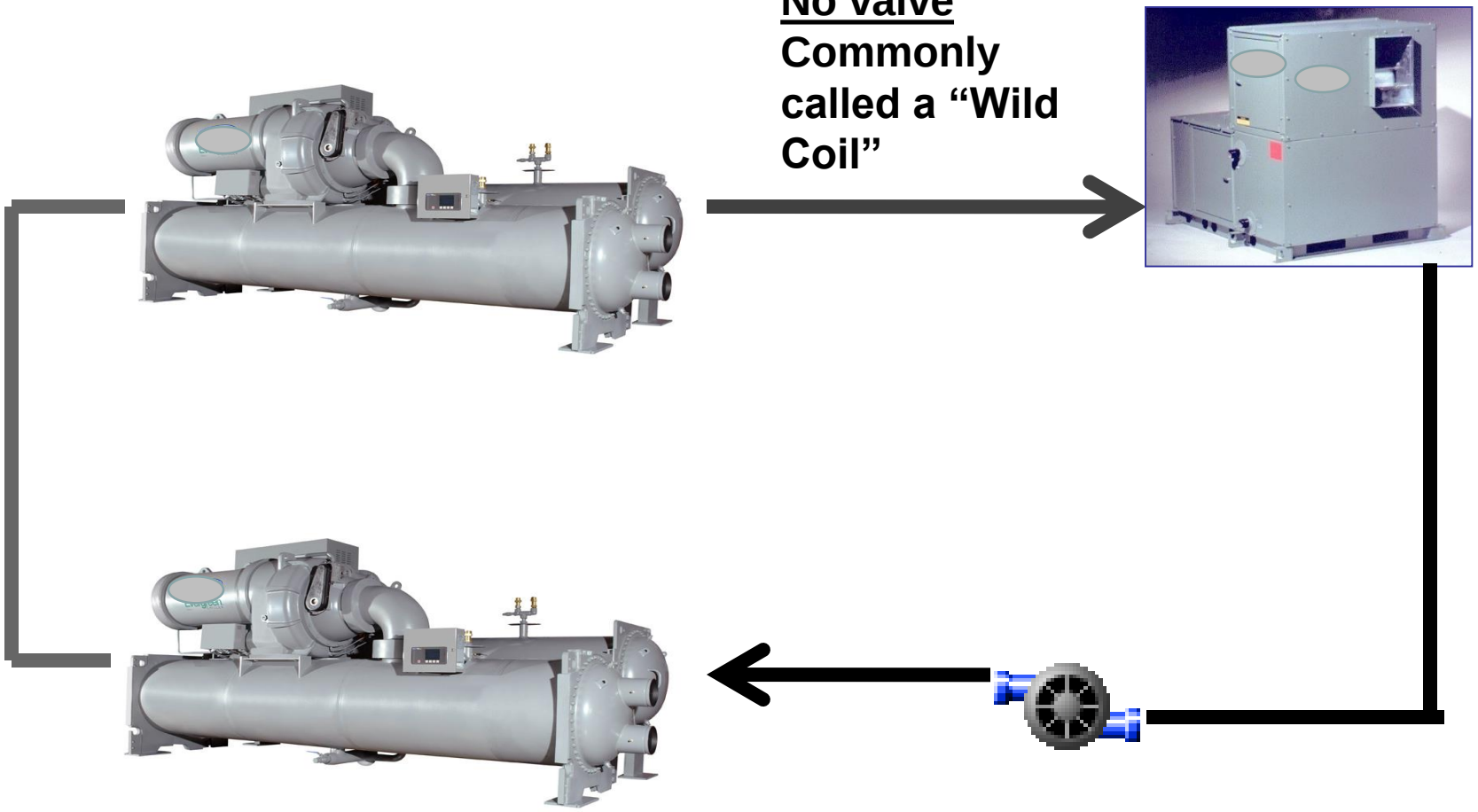
Web-based?

OPEN PROTOCOL IS A NORM!

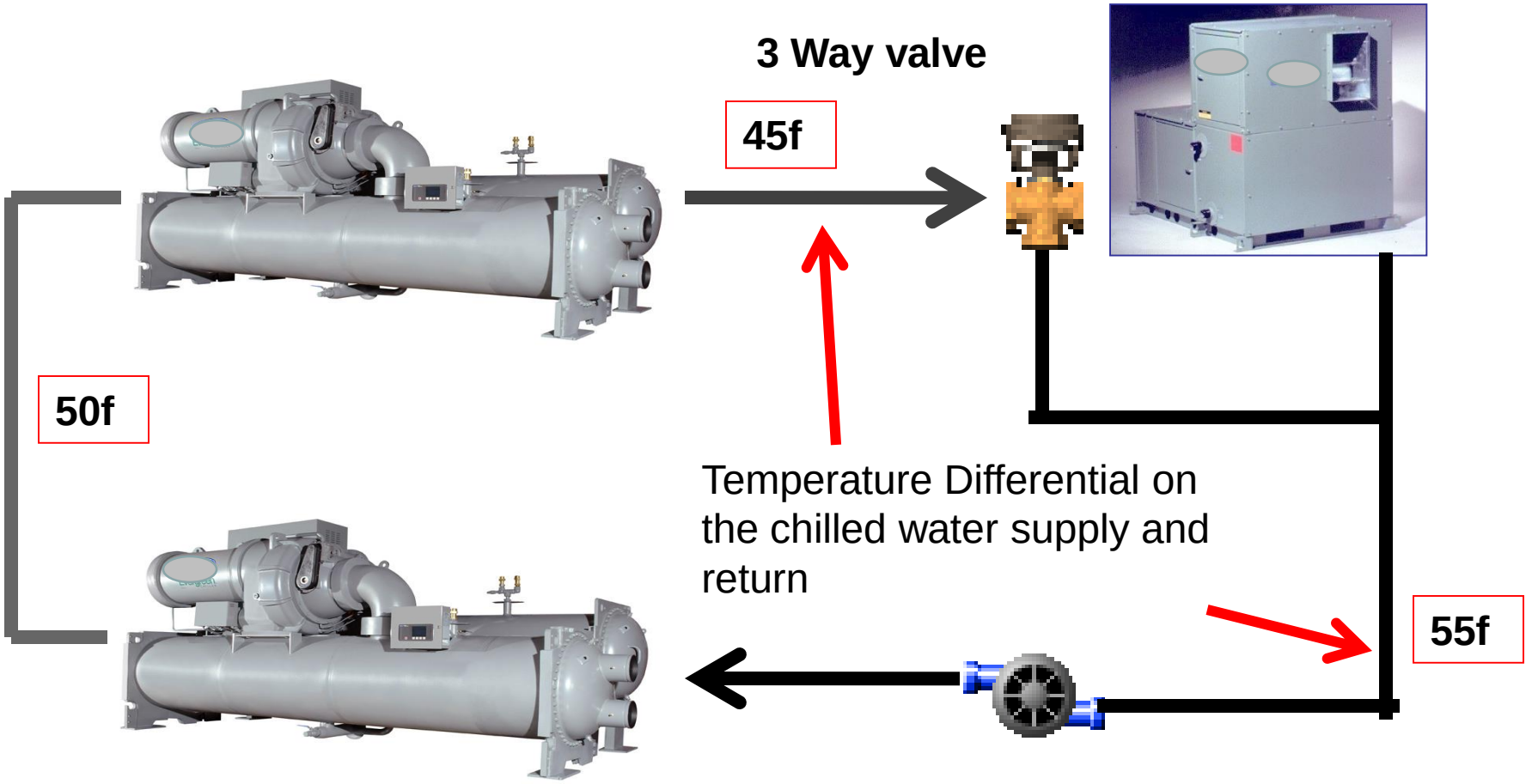
Constant Volume Chilled Water Flow Design



Constant Volume Chilled Water Flow Design



Constant Volume Chilled Water Flow Design



Capacity measurement

Constant Volume Chilled Water Flow Design

- Constant chilled water flow required because of the **three way bypass** valves on each air handler

- Multiple chiller applications require the chillers to be in series for capacity reduction

- Capacity measurement is with the chilled water temperature differential

Advantages to this design-

- **Ease of control**

Disadvantages to this design-

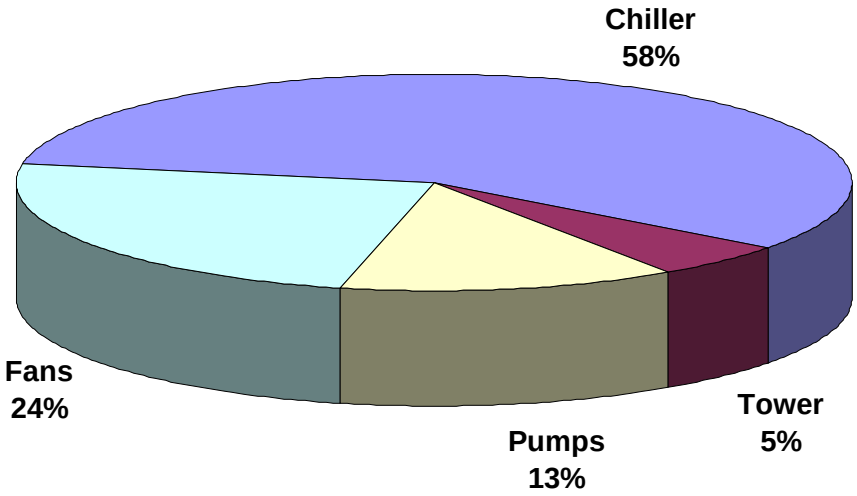
- Increased installation cost because of parallel piping required to allow for service or isolation of one unit

- Low fluid velocities

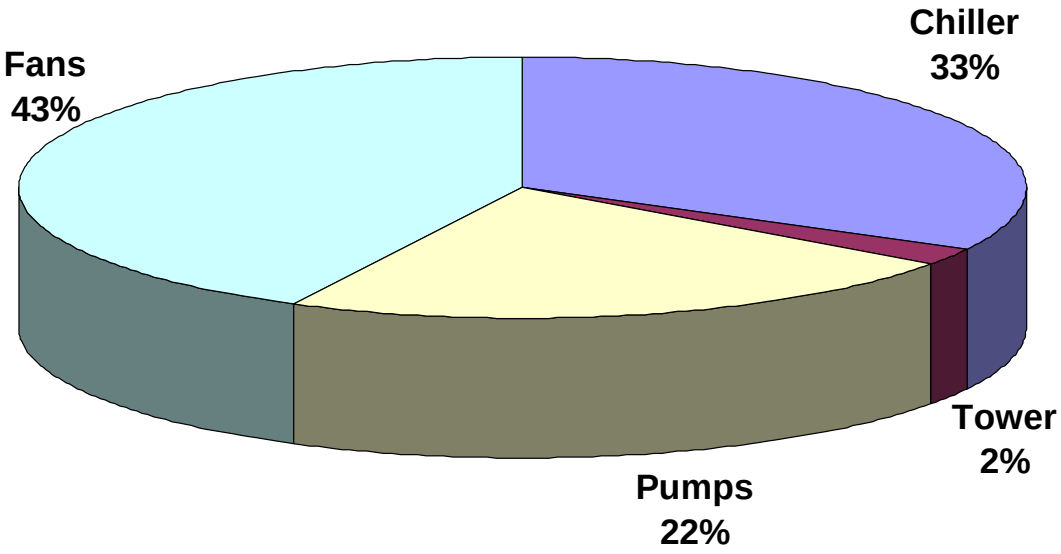
- Chillers with different lift and mass flow capabilities

- **Matching or balancing the load of two chillers**

Full Load Vs. Annual Load



Design Performance



Annual Energy Usage

HVAC - Prescriptive Method (Section 6)

Hydronic Systems (6.3.4)!!!!!

- Variable Flow Required For Systems Over 10 HP (6.4.3.1)
  - Modulate Down To 50%
- Exceptions
  - Where Minimum Flow Is Less Than Flow Required By Equipment And < 75HP
- Individual Variable Flow Pumps
  > 100 Feet *And* 50 hp Motor
  - 30% Design Wattage At 50% Flow
  - Controlled As A Function Of Flow Or Pressure Differential

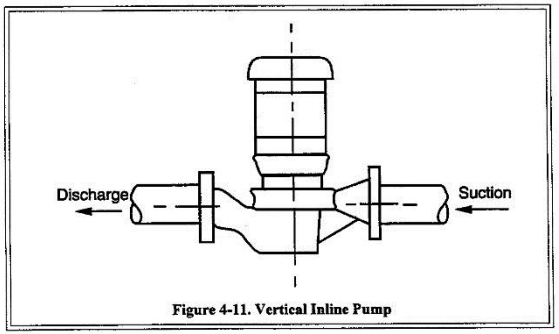
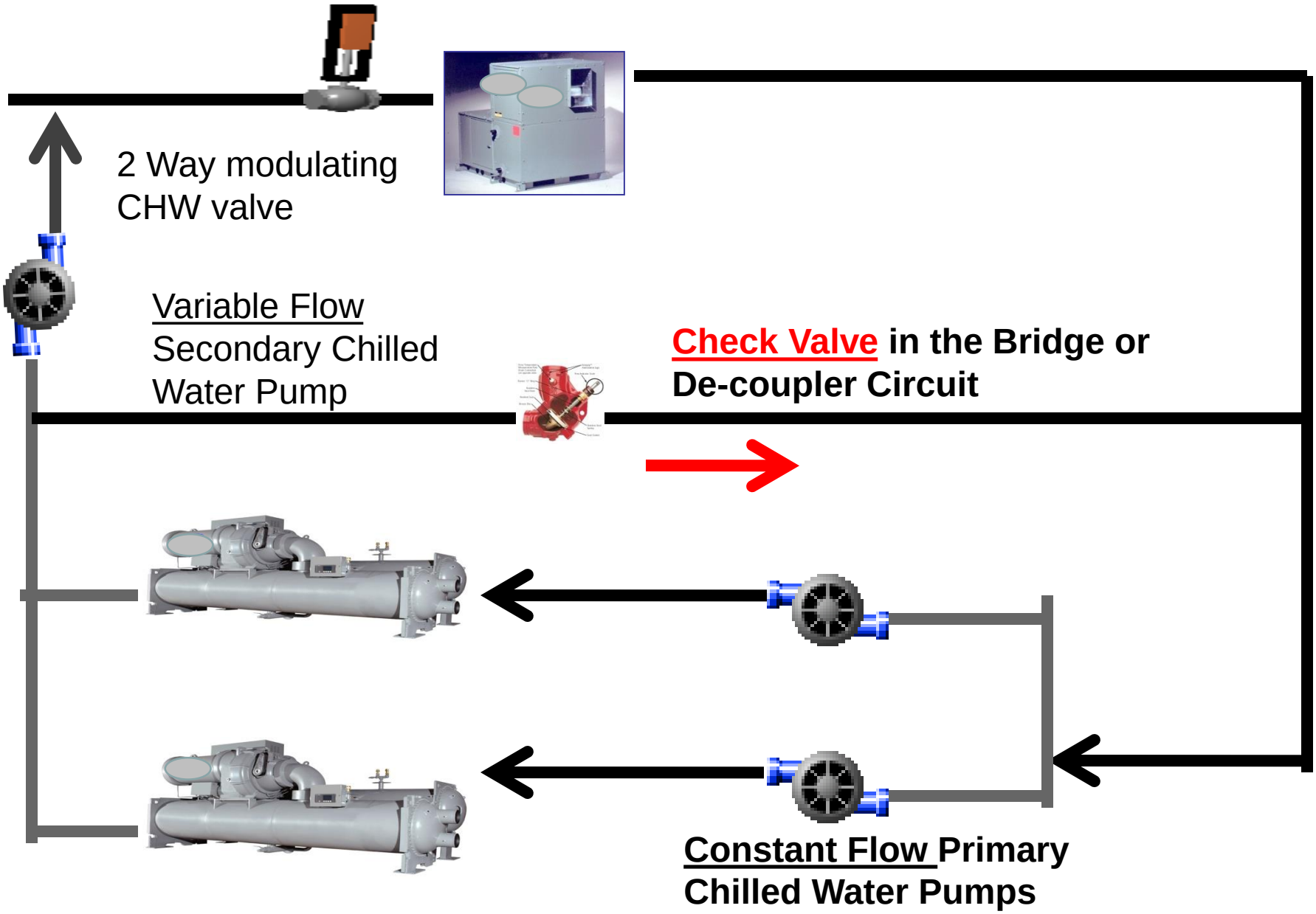
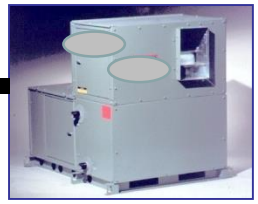


Figure 4-11. Vertical Inline Pump

Primary/Secondary Chilled Water Flow Design



Primary/Secondary Chilled Water Flow Design



Pressure differential transmitter

Secondary Chilled Water Supply Temperature

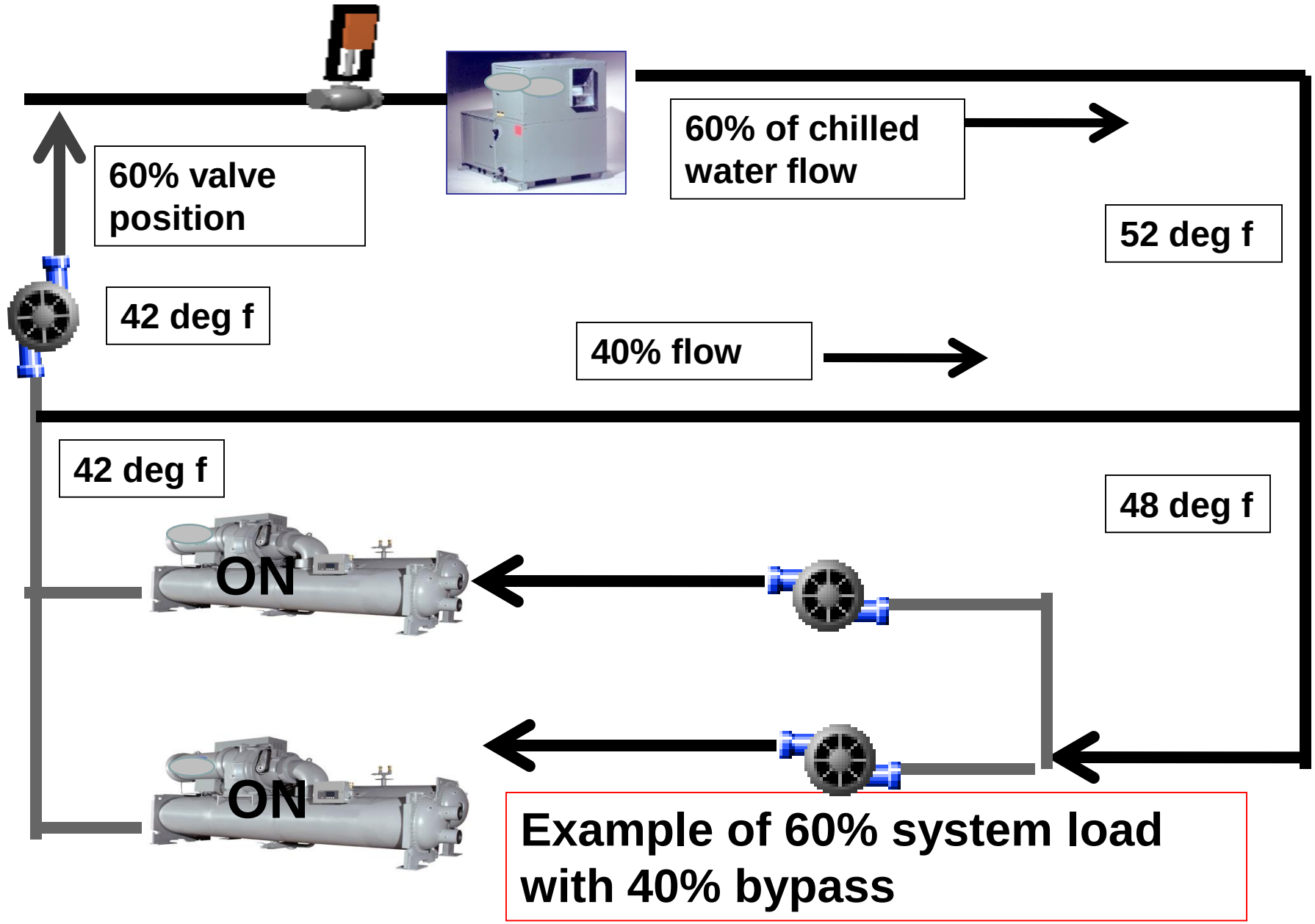
Secondary Chilled Water Return Temperature

Secondary Chilled Water Flow Meter

Bridge or De-coupler temperature sensor or bi-directional flow meter

Measurement devices required for system capacity

Primary/Secondary Chilled Water Flow Design



Primary/Secondary Design

- **Pros**
- **Variable Flow Through Secondary Loop**
- **Stable Constant Flow through Chillers**

- **Cons**
- **Complexity**
- **Low Delta T Syndrome**
- **Stepped Primary Flow**
  - **(More Pump Work Than Variable Primary Flow)**

Low Delta T-Definition

A Condition Whereby a Low Chilled Water Return Temperature Causes an Excessive Amount of Chilled Water to Circulate to Meet System Cooling Loads and Chillers Receiving the Low Temperature CHR CANNOT be Loaded to Their Design Capacity

Low Delta T Syndrome

Low Delta T Symptoms And Solutions

- **3 Way Valves**
  - **Don’t Use Them**
- **Supply Air Set points Lowered Beyond Design**
  - **Valves Go Wide Open - No Control**
  - **Ensure Valves Are Tracking**
- **Valves Not Closed When Not Required**
  - **Ensure Valves Close When AHU Not In Use**
- **All System Components Not Designed For Same Delta T**

Low Delta T Syndrome

Low Delta T Symptoms And Solutions Cont'd

- **Coils And Valves Not Properly Selected**
  - **Select Correctly**
- **Coils Piped "Backwards"**
  - **Coils Must Be Piped So Water Is Counterflow To Air**
- **Improper Tertiary Piping**
  - **Ensure Tertiary Setpoint Is Above Chilled Water Setpoint**
- **Dirty Coils- Clean the Coils**

Low Delta T Syndrome

Low Delta T Retrofit Solutions Cont'd

- **VFD Chillers**
  - **Excellent Part Load Performance Allows Two Chillers To Operate More Efficiently Even With Parasitic Losses**
- **Oversize Primary Pumps**
  - **Oversized Primary Pumps With VFDs Can Over Pump Chillers And Avoid Starting Additional Machines**
- **Variable Primary Flow**
  - **Easily Accommodates Over Pumping Chillers**

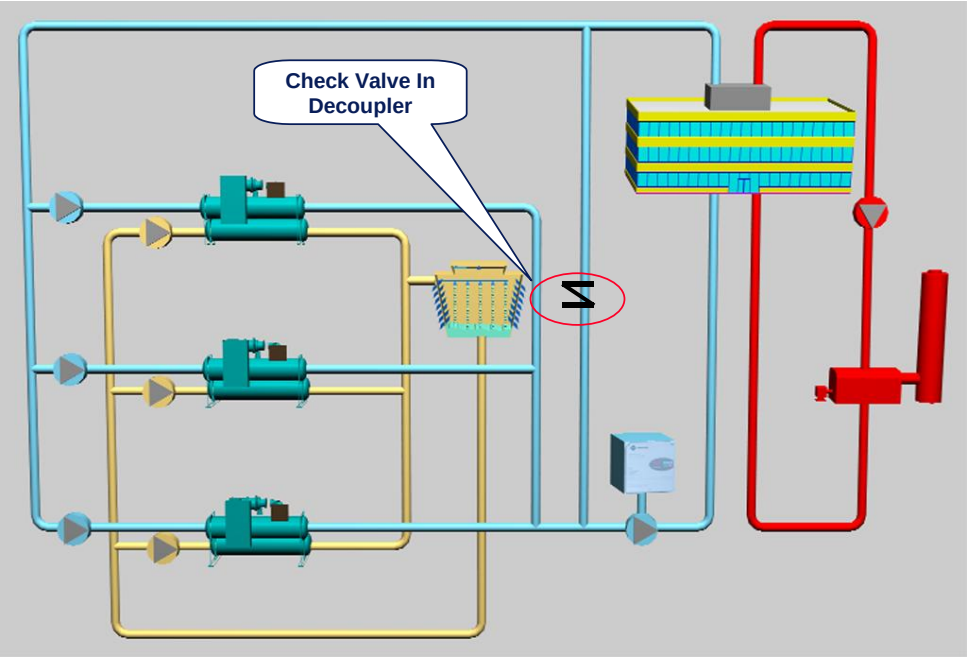
Low Delta T Syndrome

Low Delta T Retrofit Solutions Cont'd

- **Reduce Delta T On Primary Side**
  - **Larger Pumps And Piping Will Increase Capital Cost**
  - **Penalty At Full Load**
- **Add Flow Control Valves At Each Coil**
  - **Ensures Terminal Device Doesn't Exceed Design Flow**
  - **Space Cooling Not Satisfied**
  - **Increase System Pressure Drop**
  - **Adds Cost**

Low Delta T Syndrome

Low Delta T Retrofit Solutions ?



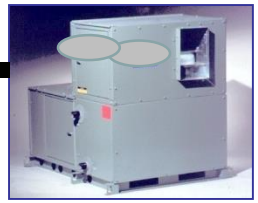
- Check Valve Puts Pumps In Series
- Potentially Over-pump Chiller
- Can Starve Building
- Doesn’t Fix Real Problem

Variable Primary Flow Design

General

- Primary Pump Operates When Chilled Water Required
- Condenser Pump And Tower Operate When Chiller Operates
- 2 Way Valves
  - Diversity To Flow
- Works With Single, Series And Parallel Chillers

Variable Primary Chilled Water Flow Design



2 Way modulating
CHW valve

Minimum flow bypass

Pressure differential transmitter across each chiller evaporator to operate the minimum flow bypass

Measurement devices required to control the chillers

Variable Primary Chilled Water Flow Design

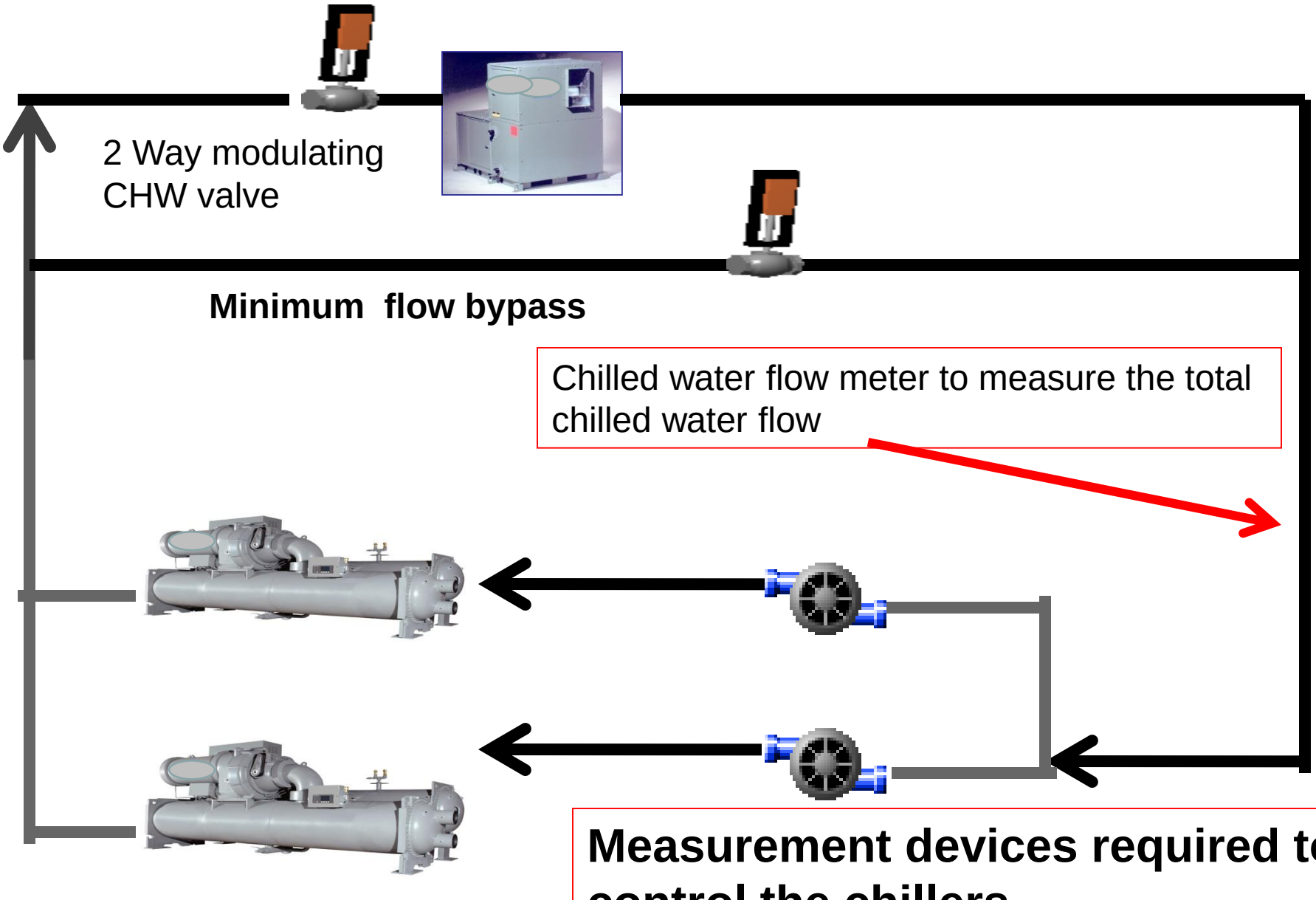
2 Way modulating
CHW valve

Minimum flow bypass

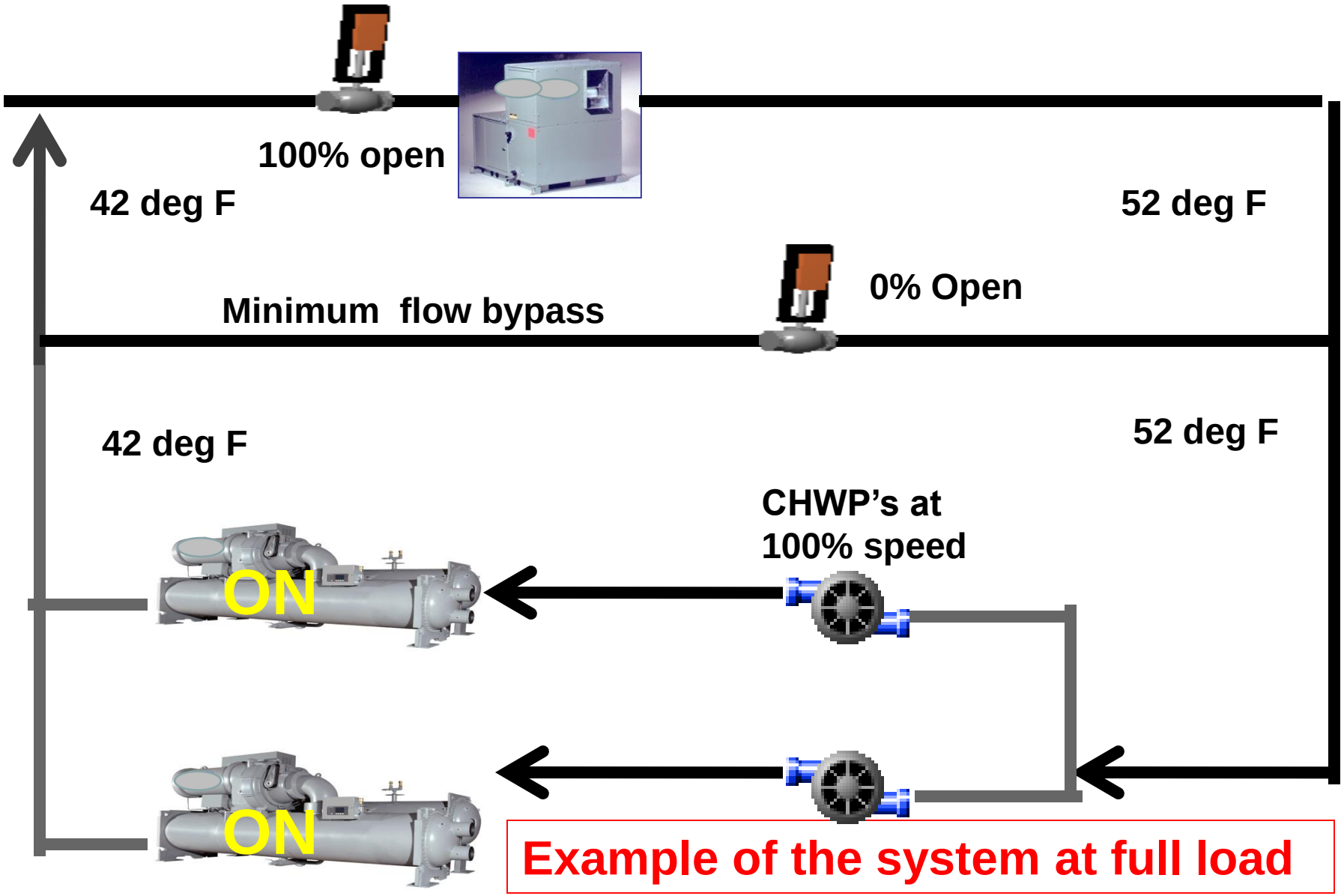
Pressure differential transmitter across the chilled water header to control the chilled water pump speed

Measurement devices required to control the chillers

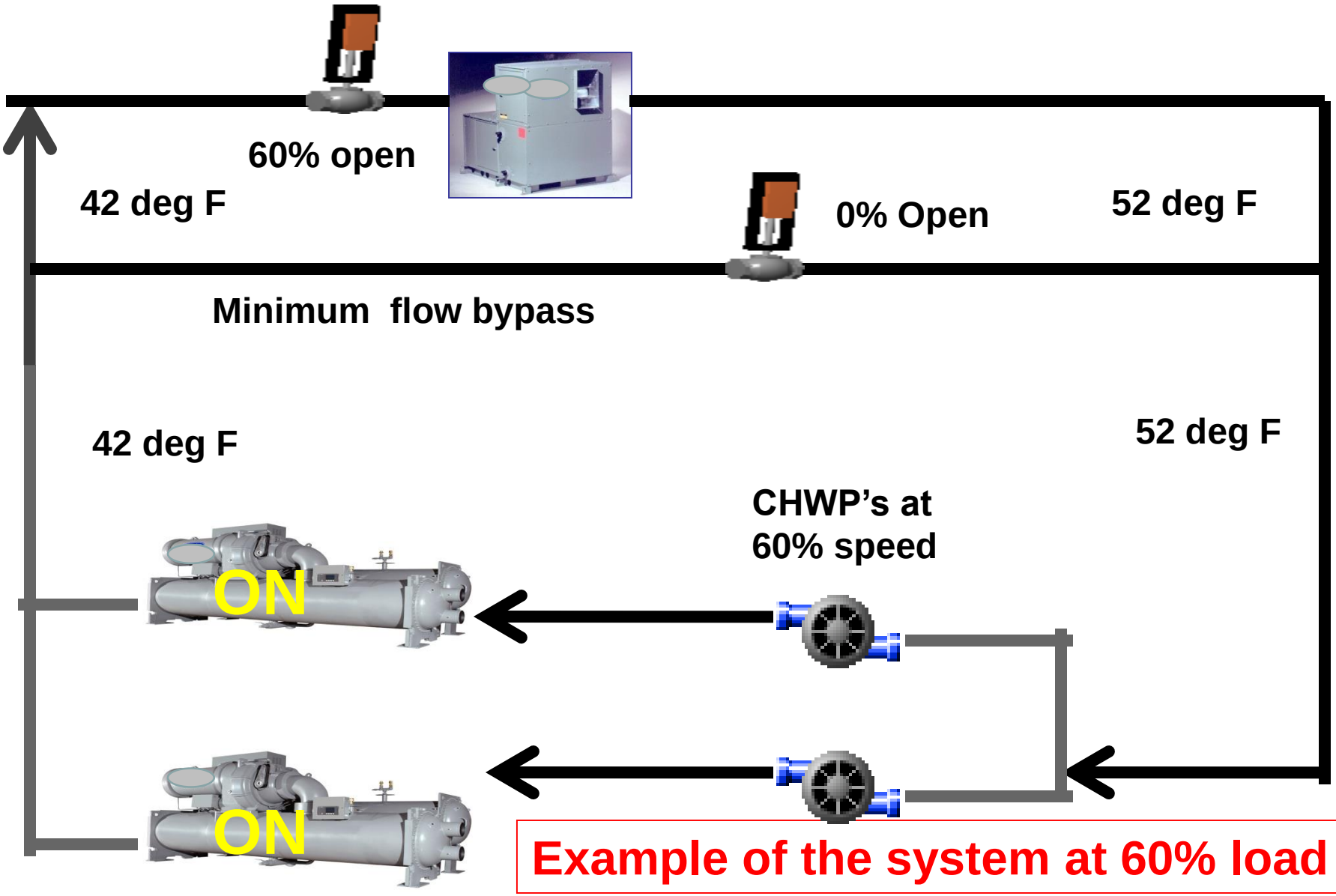
Variable Primary Chilled Water Flow Design



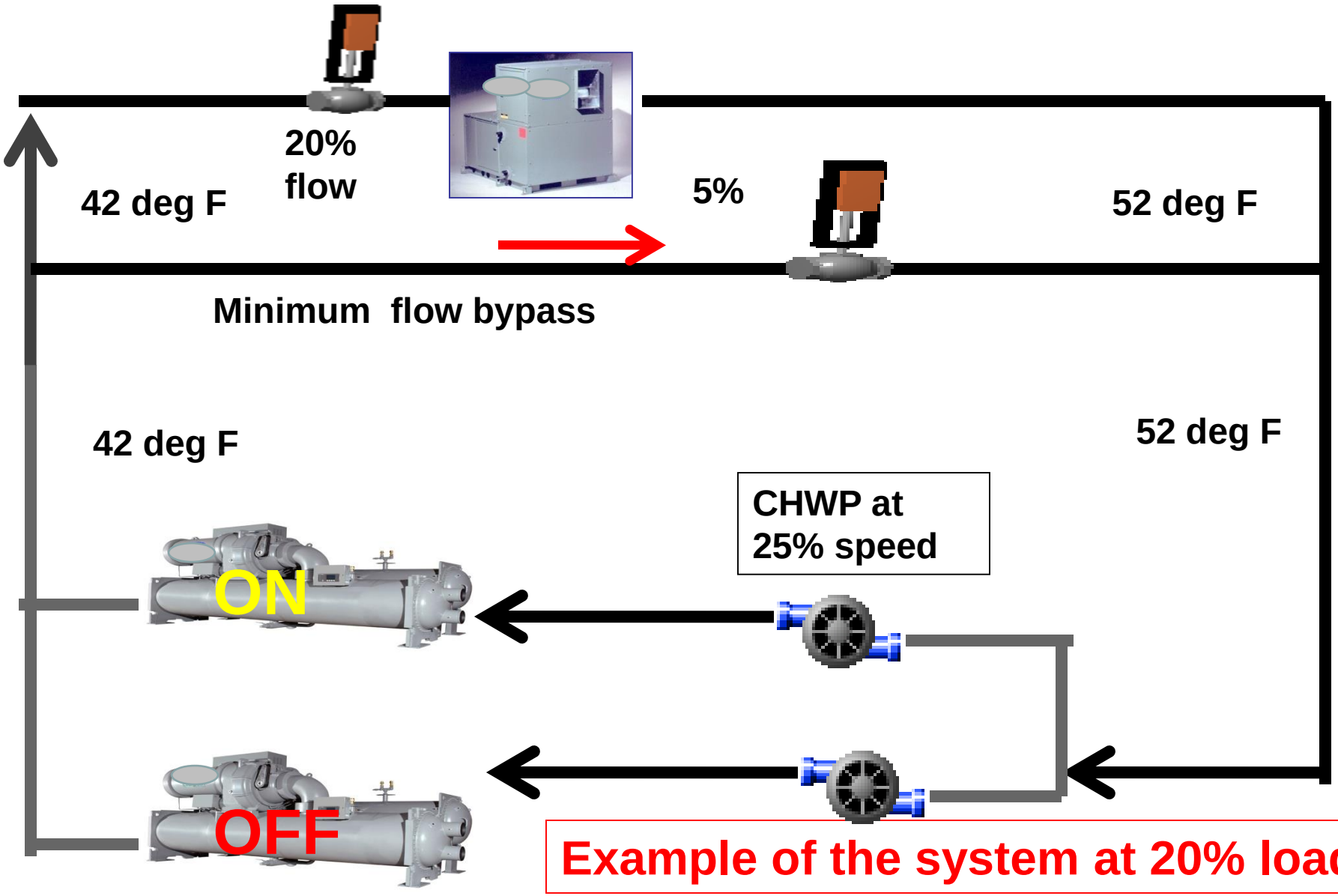
Variable Primary Chilled Water Flow Design



Variable Primary Chilled Water Flow Design

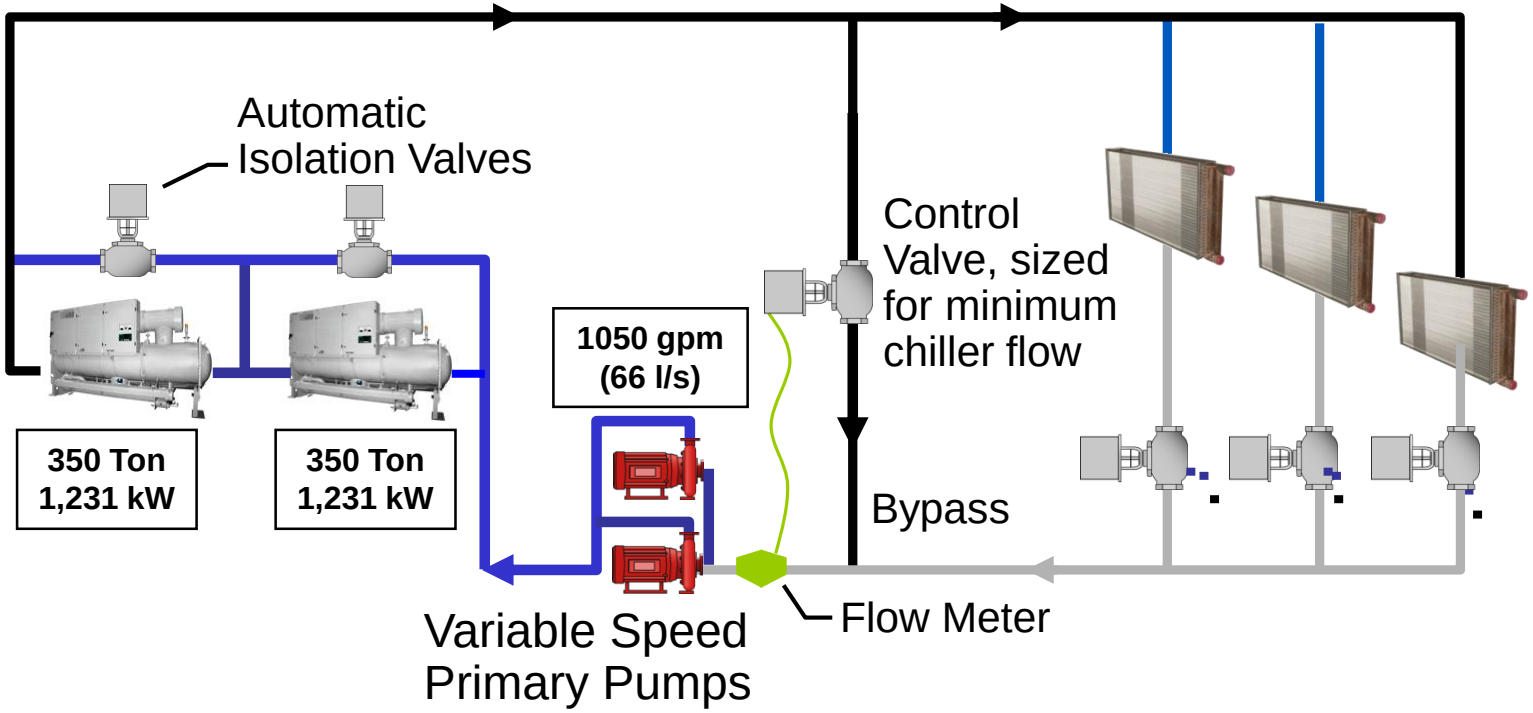


Variable Primary Chilled Water Flow Design



2 × 350 TON, VARIABLE PRIMARY

Building Load 100% (700 Tons, 2462 kW)



700 tons / 2 chillers = 350 tons (1,231 kW) per chiller

When building 100% loaded, entering condenser water = 85F (29.4 C)

Variable Primary Flow Design

- **Design Flowrate Determined by Tube Velocity**
  - **Minimum 1.5 FPS (Based On A Reynolds # Of 7500)**
  - **Maximum 12 FPS**
- **At Typical Conditions, 6-7 FPS**
- **Select Evaporator With More Passes & Higher Pressure Drop**
- **Minimum Flow Typically 50% Or Less Of Design**
- **Bypass Must Be Sized To Maintain Minimum Flow Rate Of Largest Chiller**

Benefits of a variable primary chilled water flow design

- Reduced first cost with the elimination of the secondary chilled water pumps

- Reduced energy cost by the elimination of the constant speed energy on the primary chilled water pumps

- Measurement of capacity with chilled water flow and chilled water temperature differential

- Chillers do not operate in an unloaded condition to generate enough chilled water flow to prevent negative water flow through the de-coupler in a primary secondary design

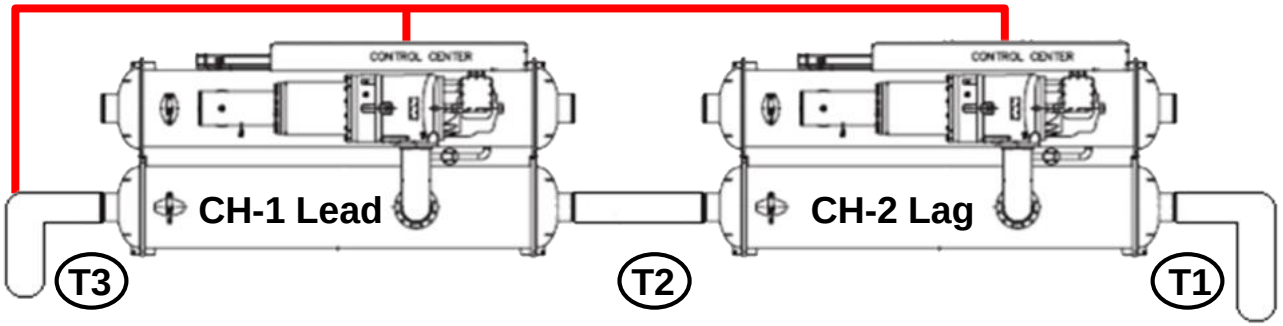
When to consider VPF ?

When:

- **System flow can be reduced by at least 30% of design.**
- **Design affords greater cost savings than a “de-coupled” system.**
- **Operators will understand how the system works and will run it properly.**
- **The system can tolerate a modest variation in supply water temperature.**
- **A single chiller is being replaced and the primary flow can be varied.**

- **Variable Flow can be applied to Parallel as well as Series Flow.**

CHILLER STAGING



Condenser piping not shown

Bypass piping, isolation valves not shown

CH-1 Programmed as lead chiller, CH-2 programmed as lag chiller.

CH-1 loads up until compressor speed indicates 2nd chiller appropriate

Based on compressor speed, CH-1 commands CH-2 to turn on.
Since chillers are in series, pump flows are already established.

CH-1 and CH-2 operate together to regulate T3 to set point.

At appropriate compressor speed, CH-1 commands CH-2 to turn off.

If CH-1 becomes disabled, the on board controls rotate CH-2 as the lead chiller.

CH-2 regulates to the leaving temperature T3 via the sensor.

No Human Intervention Required

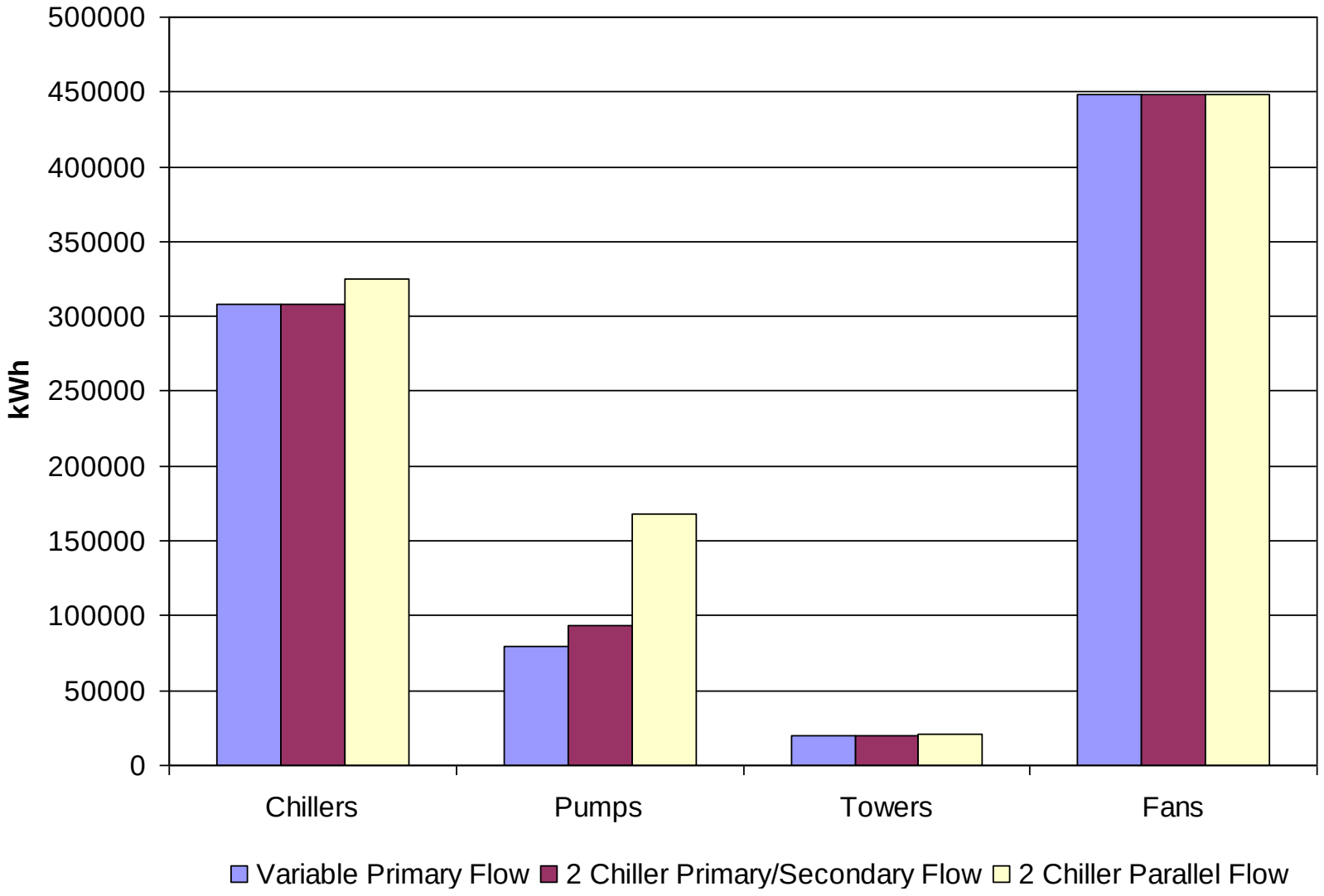
Increasing system reliability in a VPF System

Does the system have the instrumentation in place to control a VPF system?

It is critical that the system have the necessary flow meters, differential pressure sensors, and valves in the system for proper operation.

In addition, these devices should be selected for the system requirements. The accuracy of the instrumentation should be factored into the recommended minimum/maximum water flow limits.

VPF vs. Primary Secondary



More or Less?

According to an ARTI study results, variable primary-only chilled water systems reduced the total annual plant energy by 3 to 8 percent, first cost by 4 to 8 percent, and life cycle cost by 3 to 5 percent relative to conventional constant primary flow/variable secondary flow chilled water systems.

Future Goals

- **Net- Zero Energy Buildings**
  - **Combination of Rising Energy Prices**
  - **Improving Technology**
  - **Concerns about Climate Change**

- **Future Goal of Net-Zero Carbon Emissions**
- **ASHRAE Standard 189, Design of High Performance Green Buildings**

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