RYAN
BOILERS / HEATING SYSTEM COMPONENTS

Modern Hydronic Designs, Controls, and Condensing Boilers

Matthew Kiemen

Marketing/ Mechanical Engineer

Ryan Company Inc.

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Condensing Boiler Basics

Primary/Secondary

Variable Primary

Control Strategies

Summary

Boiler Efficiency Classifications

- **Standard Efficiency (80-84%)**
  - Kewanee, Burnham, Cleaver Brooks, Bryan, LES, Hurst, Slant Fin, Ray Pak, Superior
- **Mid Efficiency (85-88%)**
  - Lochinvar, Thermal Solutions

NON - CONDENSING

- **High Efficiency (90+%)**
  - Fulton, Aerco, Viessmann, Lochinvar, Aldrich

CONDENSING

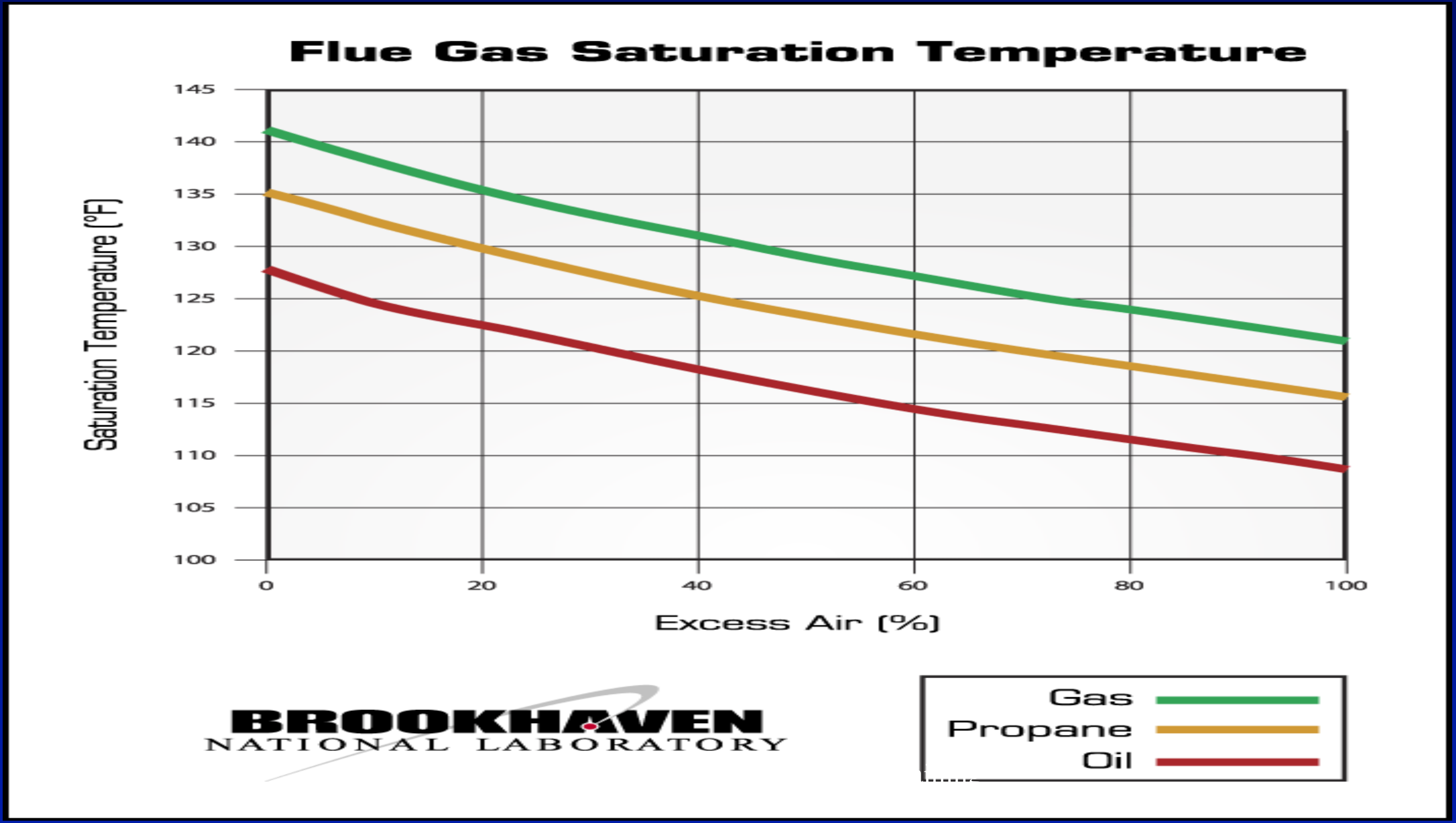
Condensing Boiler Basics

- **A condensing boiler recovers heat from flue gas condensate**
  - NOT steam condensate
- **Condensing represents opportunity for increased efficiency (Operate > 89%)**
- **Specific operating conditions are necessary for a boiler to operate at optimal efficiencies**

Flue Gas Condensate

- **Flue (exhaust) gas condensation is a process where the temperature of the flue gas cools below its water dew point.**
  - Water vapor is a by-product of the gas fired combustion process
  - Flue gases change phase from a gas to a liquid
  - In a condensing boiler, the phase change happens inside the heat exchanger of the boiler itself

Flue Gas Condensate



Flue Gas Condensate

- **Why is condensate important?**
  - Condensation process provides significant energy that is made available to the application (instead of being wasted in the exhaust gases).

- **Latent Heat – Energy associated with the change of phase (gas to liquid)**

- **Flue Gas Condensate has 1,000 BTU/lb**
  - 1 Gallon = 8,340 BTU

Defining a Condensing Boiler

- To operate at efficiencies >88.6%, a boiler must experience flue gas condensation
- Condensing can occur in any fuel fired boiler, however not all boilers will survive
- Flue gas condensate is slightly acidic
- Heat exchanger design and materials of construction are critical
- Liquid condensate needs a means of leaving the boiler vessel

Condensing Boiler Designs

- Fireside design & material suitable for condensation
- Cast Iron, Carbon Steel and Copper are not suitable for Condensing

Think About It

Cast Iron, Carbon Steel, & Copper Are Not Suitable For Condensing Boilers

There are various aspects to take into account when selecting or specifying a boiler. The most important consideration for condensing boilers is material construction. Below are two excerpts from ASHRAE Handbook - HVAC Systems and Equipment.

"For maximum reliability and durability over the extended product life, condensing boilers should be constructed from corrosion resistant materials throughout the fireside combustion chamber and heat exchangers." - ASHRAE HVAC Systems & Equipment

"The condensing portion of these boilers requires special material to resist the corrosive effects of the condensing flue gases. Cast iron, carbon steel and copper are not suitable materials for the condensing section of a boiler." - ASHRAE HVAC Systems & Equipment

However, advances in design, controls, and manufacturing have allowed materials such as cast iron to be used where they previously could not be; as with all products, consult the manufacturer for proper application. Commercial boiler installations can be adapted to condensing operation by adding a condensing heat exchanger in the flue gas vent.

For maximum boiler life, use a corrosion resistant material like stainless steel or Cor-Ten (bridge grade steel)

Condensing Boilers Basics

- **Condensing represents opportunity for increasing overall system efficiency**
  - Condensing boilers – thermal efficiency up to 99%
  - Other areas to save operating costs
- **Condensing boilers represent opportunity for decreasing initial capital investment requirements**

Condensing Boilers

- **Condensing represents opportunity for increasing overall system efficiency**
  - Condensing boilers – thermal efficiency up to 99%
  - Other areas to save operating costs
- **Specific operating conditions are necessary for a boiler to operate at optimal efficiencies**
- **Condensing boilers represent opportunity for yearly savings.**
- **How do we achieve thermal efficiency of up to 99%?**

Keys to Condensing

- **Return Water Temperature**
  - Lower water temperatures allow flue gases to cool
  - Flue gas temperature is directly proportional to water temperature
- **Firing Rate (Modulation Point)**
  - Lower firing rate decreases flue gas velocity through the heat exchanger
  - Surface Area: Energy Transfer
- **Effective Control of Modular Boilers**
  - Sequencing and staging logic should be designed specially around condensing boilers

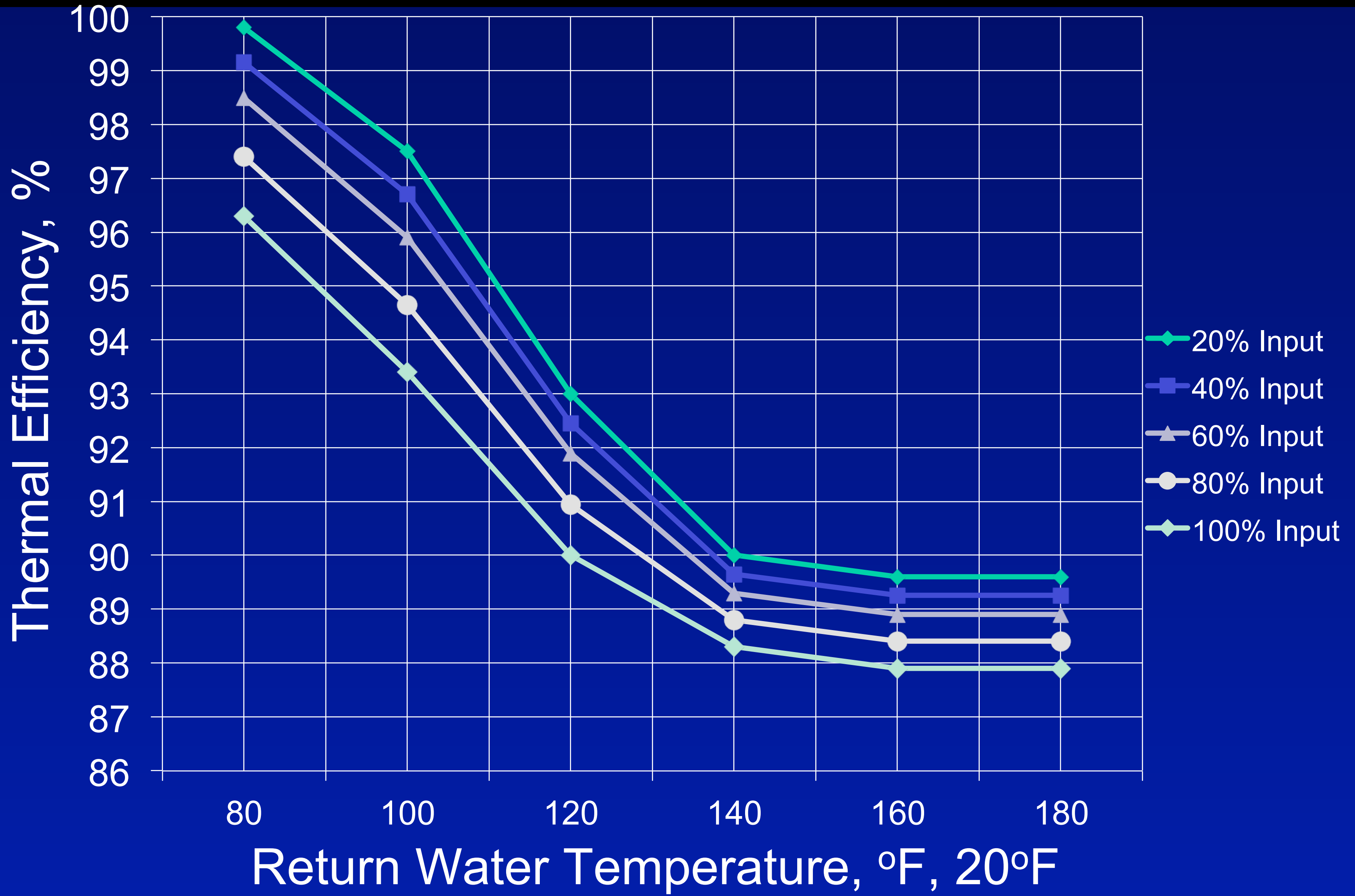
Why Condensing

- **More efficient**
- **Payback quicker on purchased equipment**
- **Uses less energy and natural gas**
- **Energy savings**
- **Cost savings**
- **Rebates**
  - Center point
  - Xcel energy

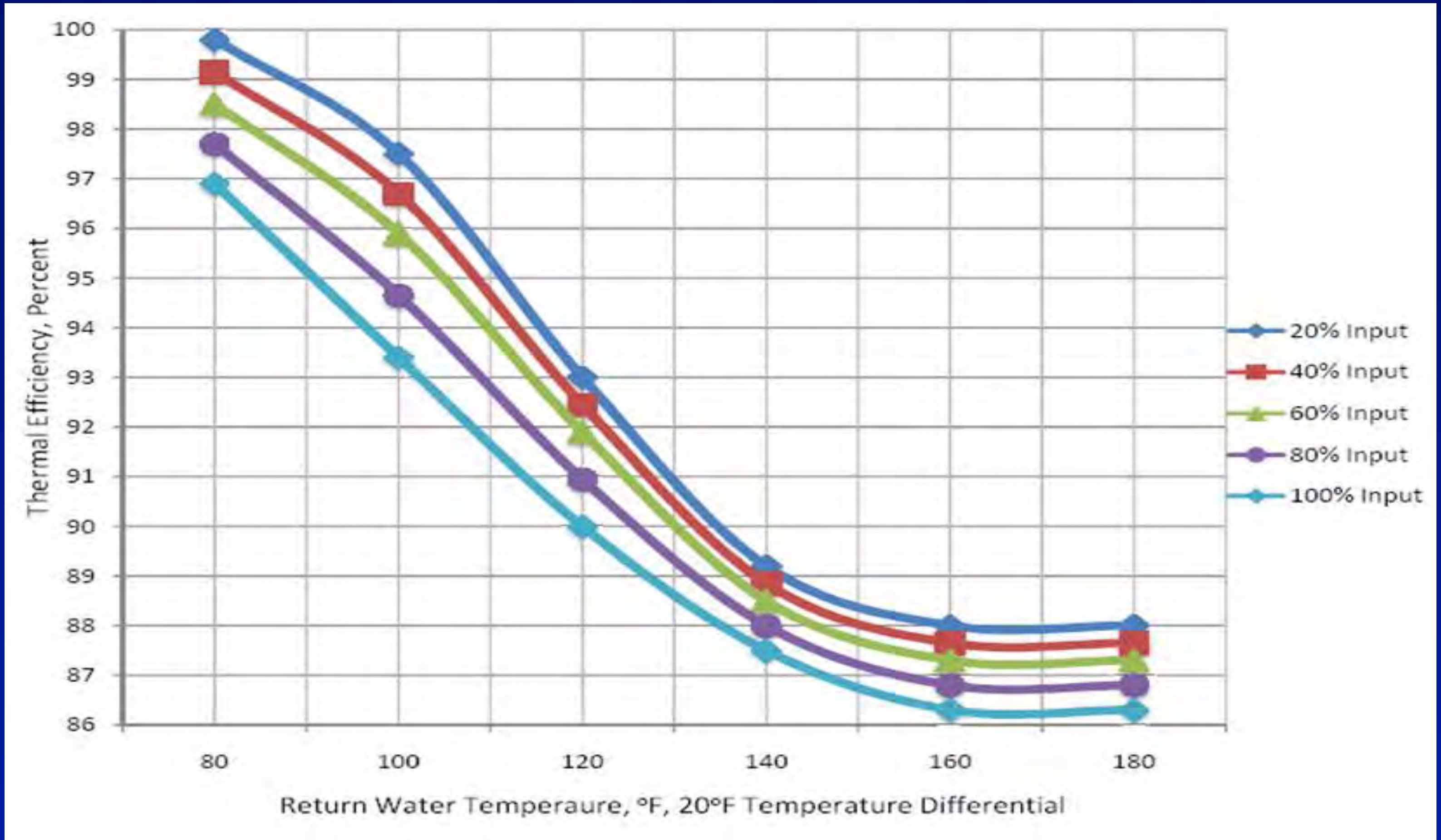
Xcel Energy℠

CenterPoint™ Energy

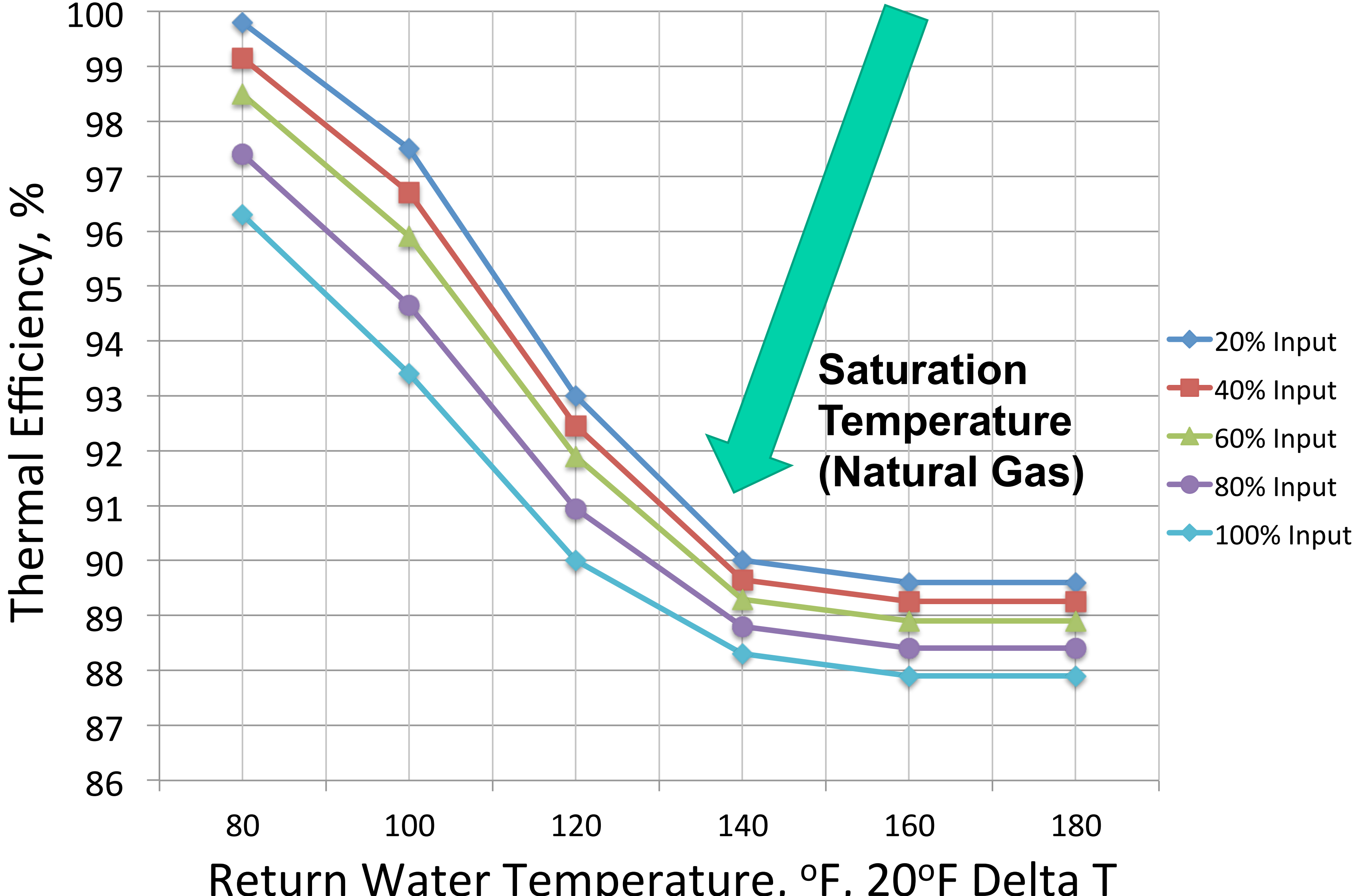
Efficiency Curve for Condensing Boiler



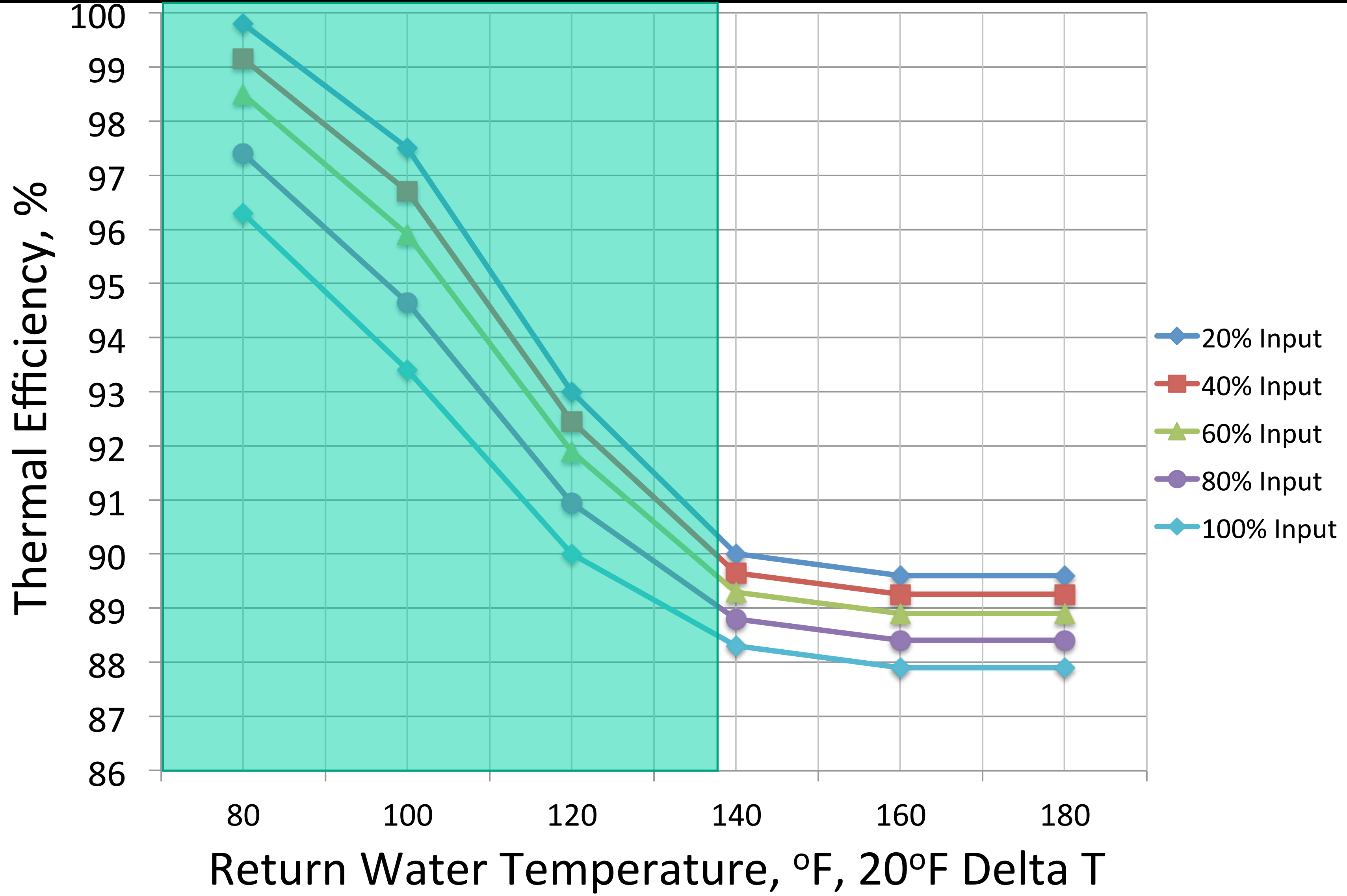
Condensing Boilers



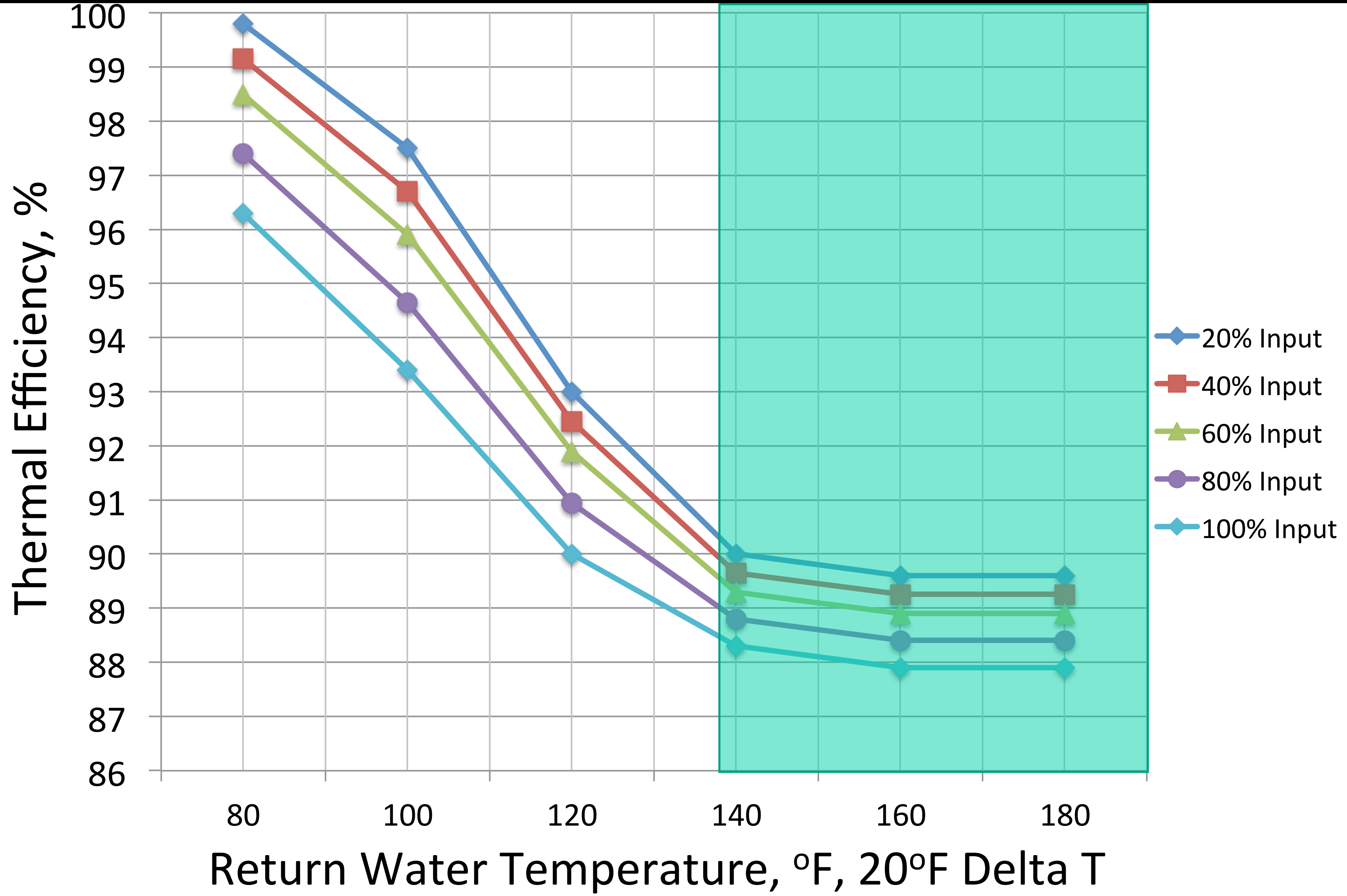
Efficiency Curve for Condensing Boilers



Efficiency Curve for Condensing Boiler



Efficiency Curve for Condensing Boiler



Low RWT

- **Designed for low temperature operation (RWT ≤ 140°F)**

2004 ASHRAE Handbook – HVAC Systems and Equipment

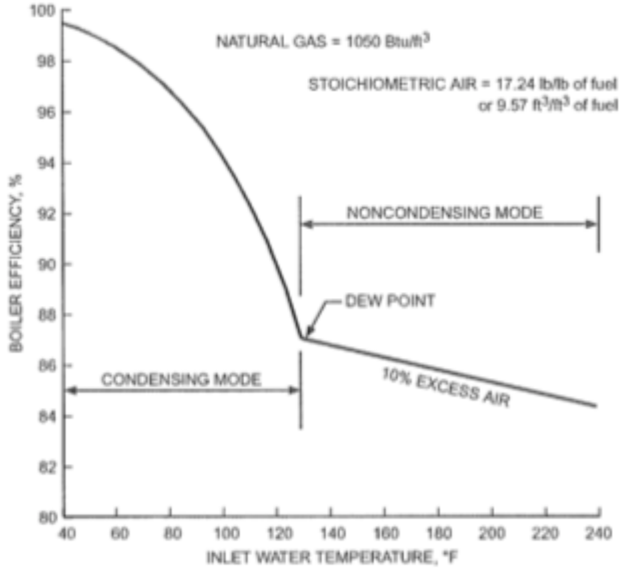
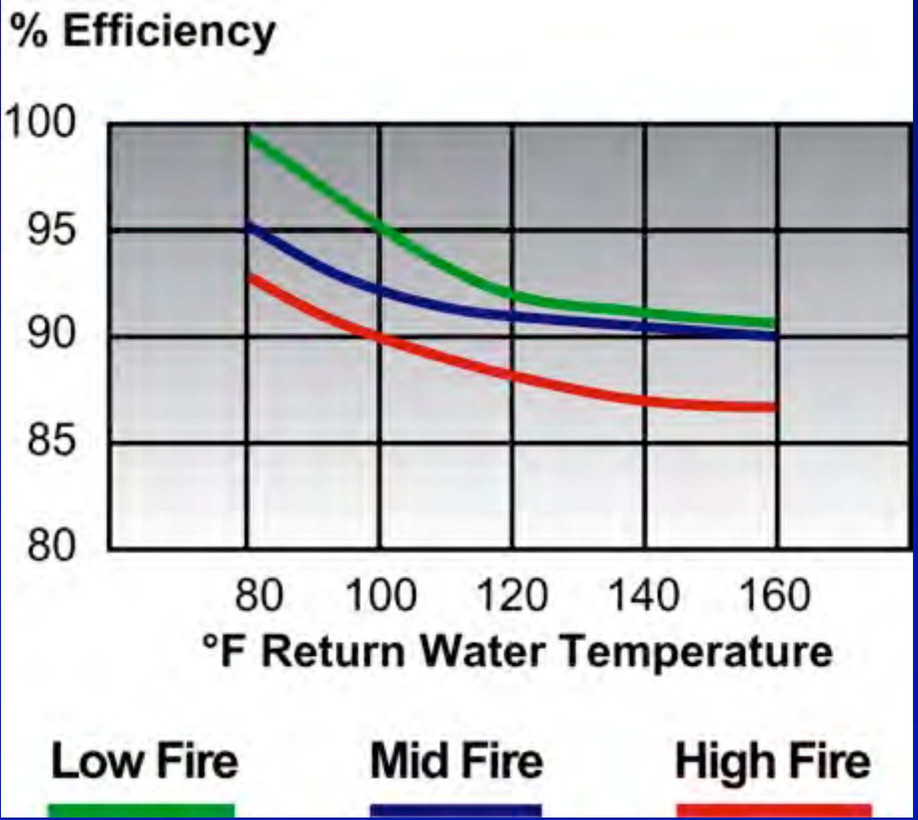


Fig. 5 Effect of Inlet Water Temperature on Efficiency of Condensing Boilers



Condensing Boilers

- **Consider system designs that:**
  - Realistically achieve the efficiency that condensing boilers are capable of operating at
  - Decrease overall system energy usage
    - Multiple factors can be evaluated
      - Piping considerations
      - Control strategies

Thermal Efficiency Savings Potential with Condensing Boilers

- **Example heating system in:**
  - 4,000,000 BTU/hr design day load
  - Seasonal efficiency improvement from 80% to 95%, annual natural gas costs based on $1.00/Therm and average monthly temperatures for heating season:
    - 80% - $79,500
    - 95% - $67,000
    - **ANNUAL SAVINGS: $12,500**
- **But how do we achieve the increased efficiency and what other improvements can be made?**

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Condensing Boiler Basics

Primary/Secondary

Variable Primary

Control Strategies

Summary

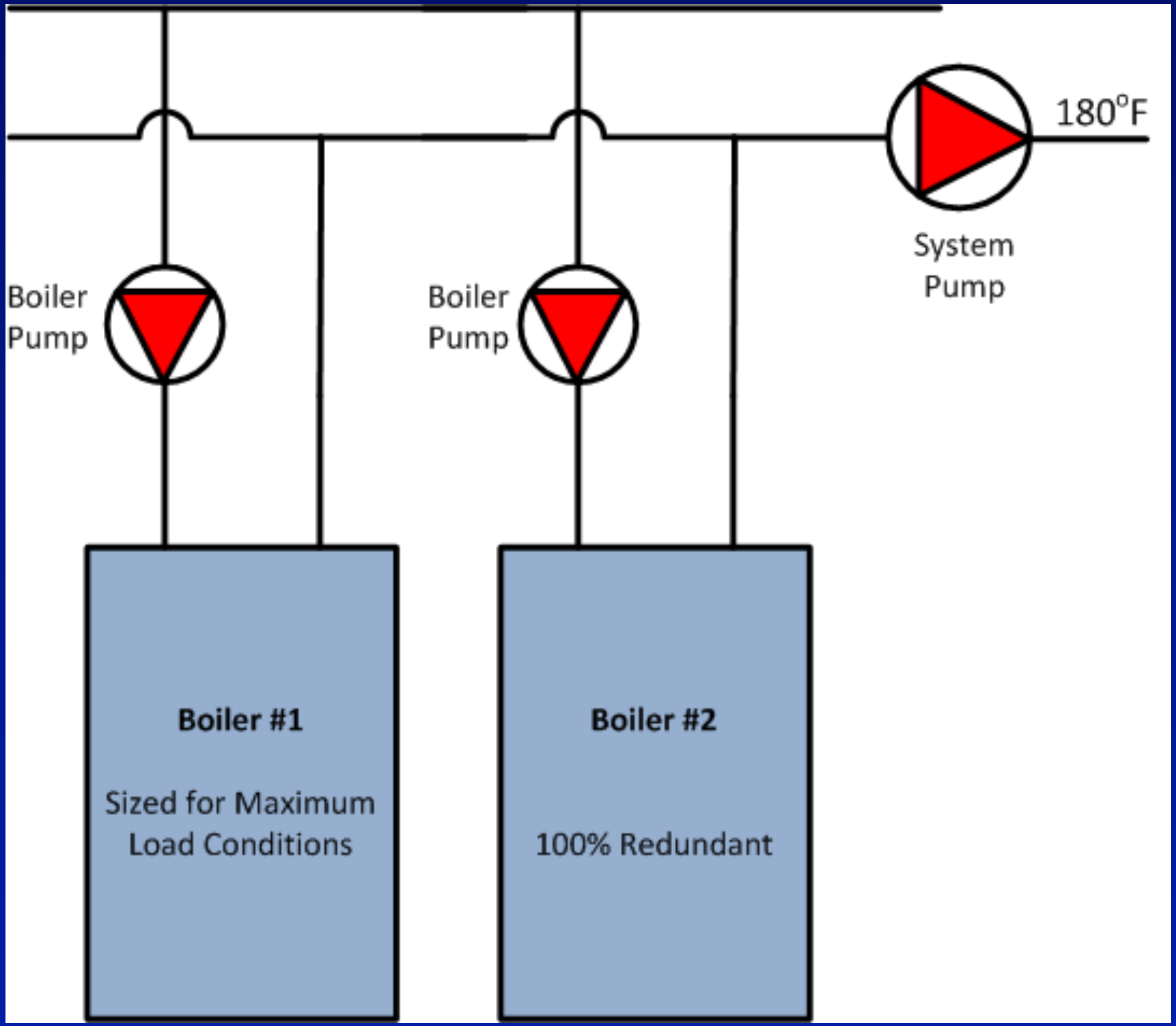
Historical Designs

- 180°F hydronic loop set points
- Primary/secondary pumping
- Protecting boilers from condensing and thermal shock
- Calculate "design day" load, select one large boiler, put in a second boiler for redundancy.
- ***We can design modern systems that do not have to address any of the above!***

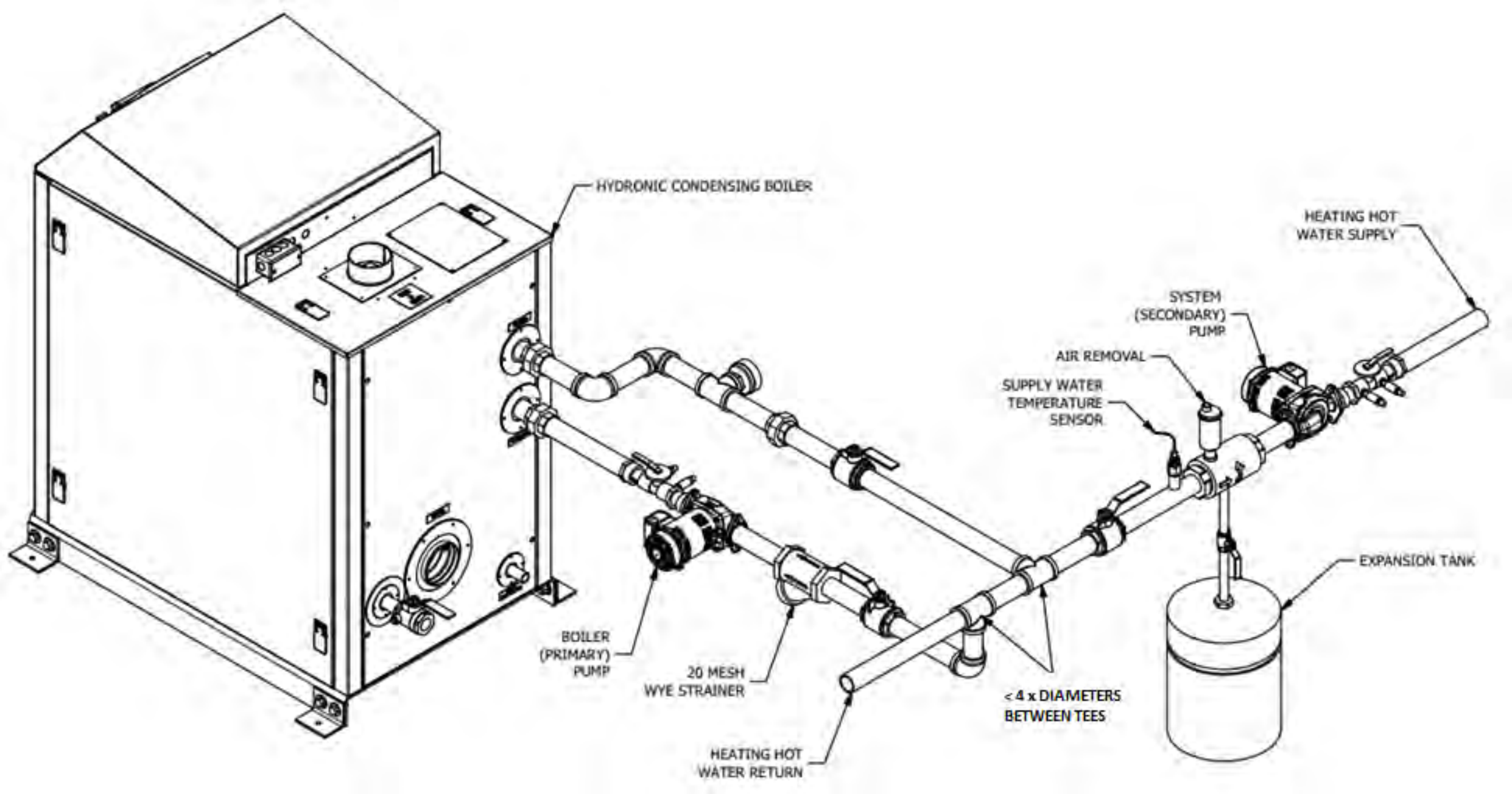
Primary/Secondary Arrangements
The Applications

- **Decouples boiler and system loops**
- **Used in traditional systems to protect non-condensing boilers from low return water temperatures and low flow**
- **Used in modern systems to protect low-mass, low-volume condensing boilers from:**
  - Thermal Shock
  - Low or No Flow (Localized Boiling, Scaling)
  - Excessive Flow (Erosion)

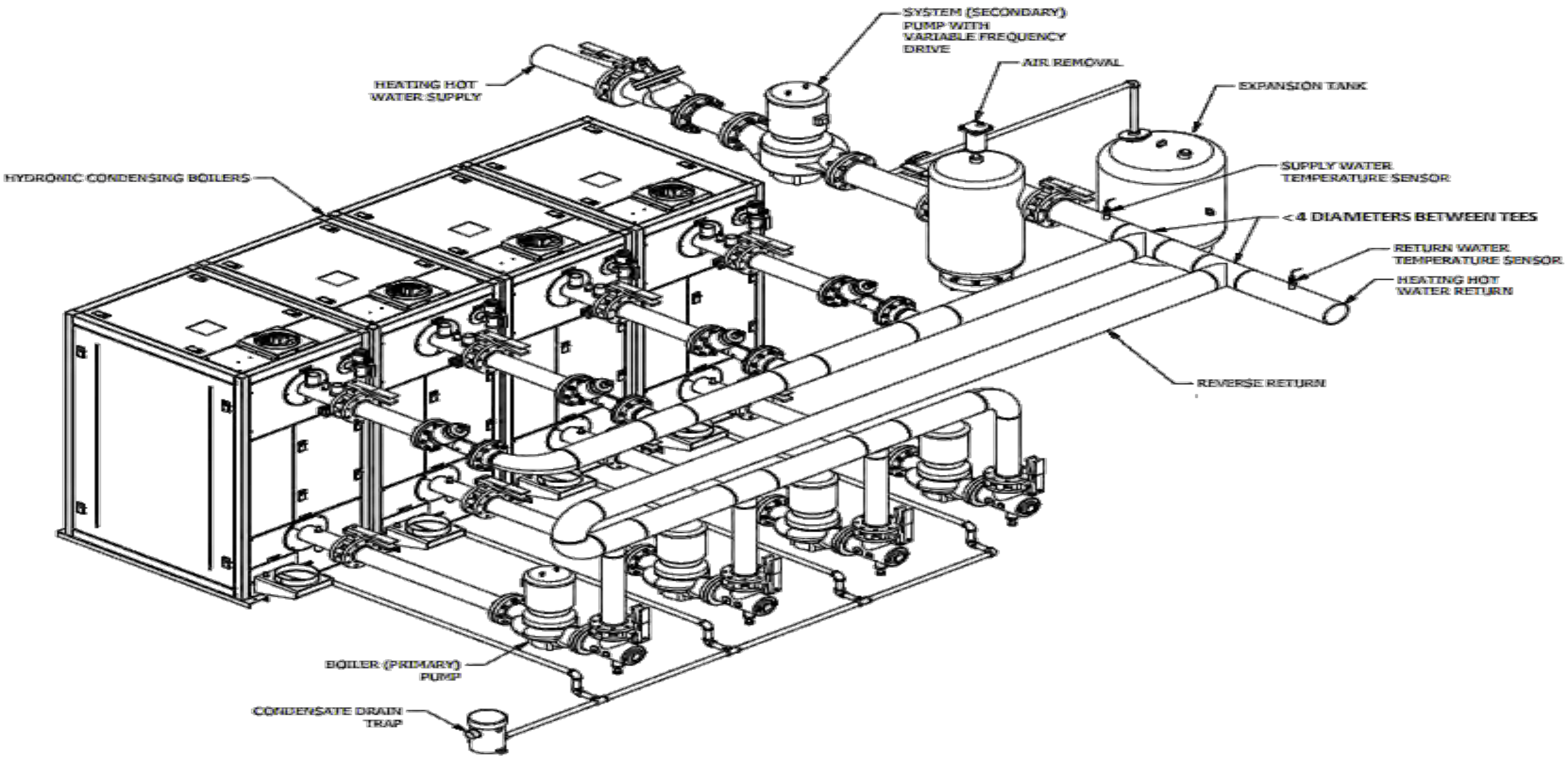
P&ID of Traditional Non-Condensing System



Primary/Secondary Piping For Condensing Boilers (Single)

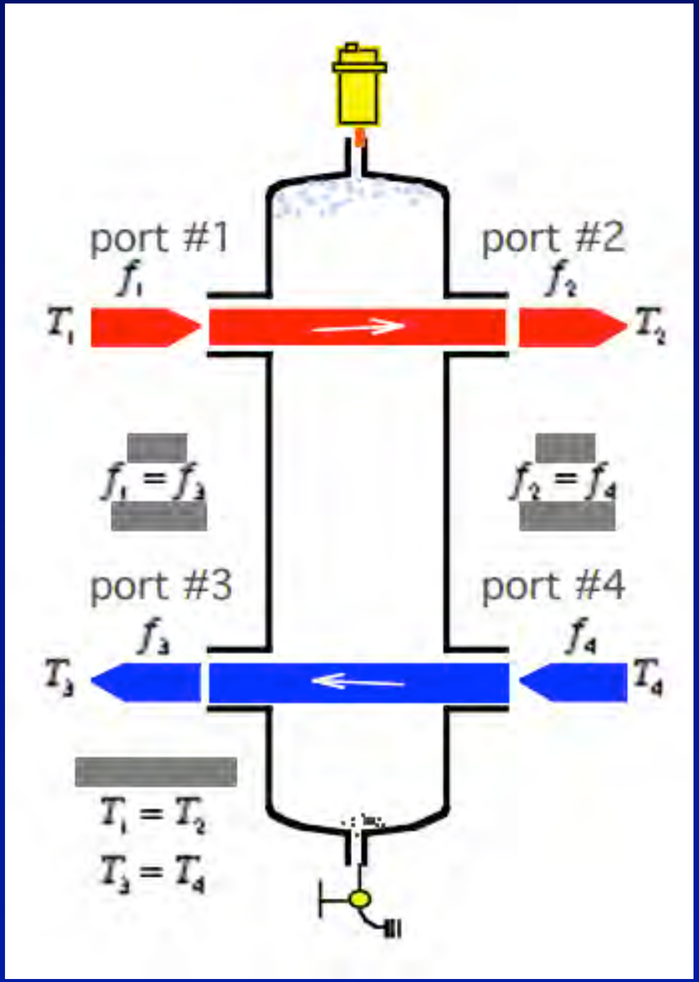


Primary/Secondary Piping For Condensing Boilers (Multiple)



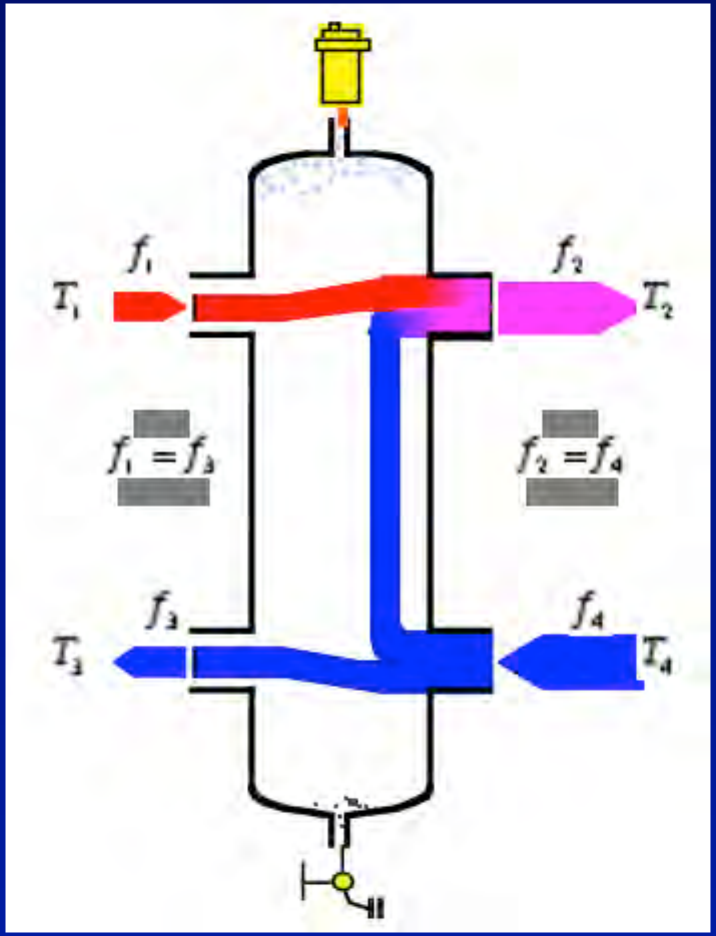
Equal Flow Distribution

- Boiler GPM = System GPM
- Equal system/boiler supply and return temperatures
- This situation is ideal for a condensing boiler
- Very difficult to achieve in practice



System Flow Greater Than Boiler Flow

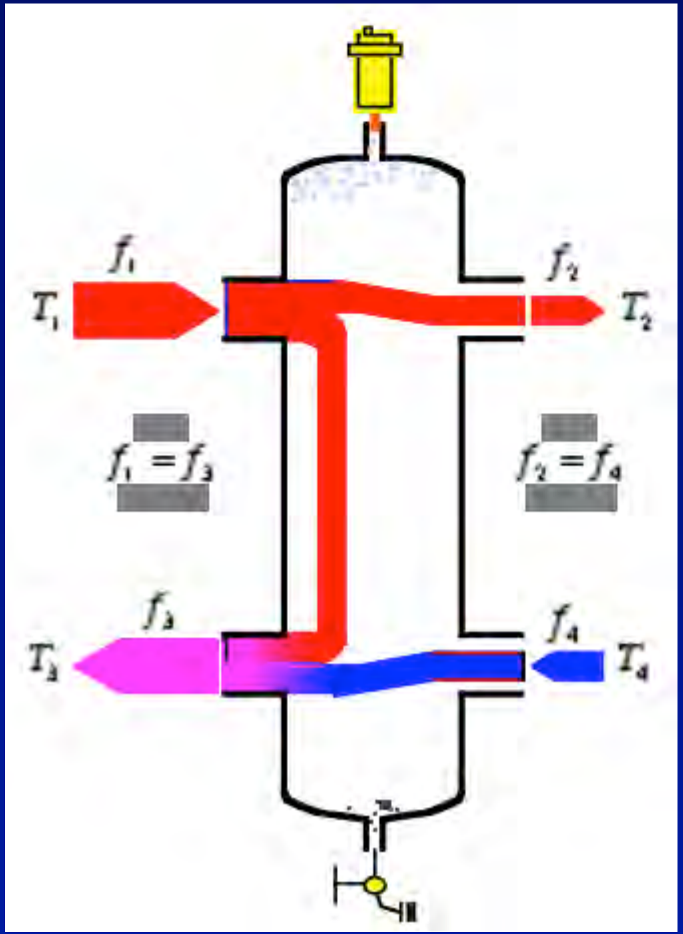
- **Mixing occurs in the manifold**
- **Boiler must modulate higher to meet setpoint demand**
  - Reduced thermal efficiency at higher firing rate
  - May cause nuisance MRHL trips
- **Boiler and system return temperatures are equal**



Boiler Flow Greater Than System Flow

- **Boiler and system supply temperatures are equal**

- **Boiler return temperature is greater than system return temperature**
  - Common on constant speed boiler pump, variable speed system pump applications
  - Reduced thermal efficiencies with higher RWT

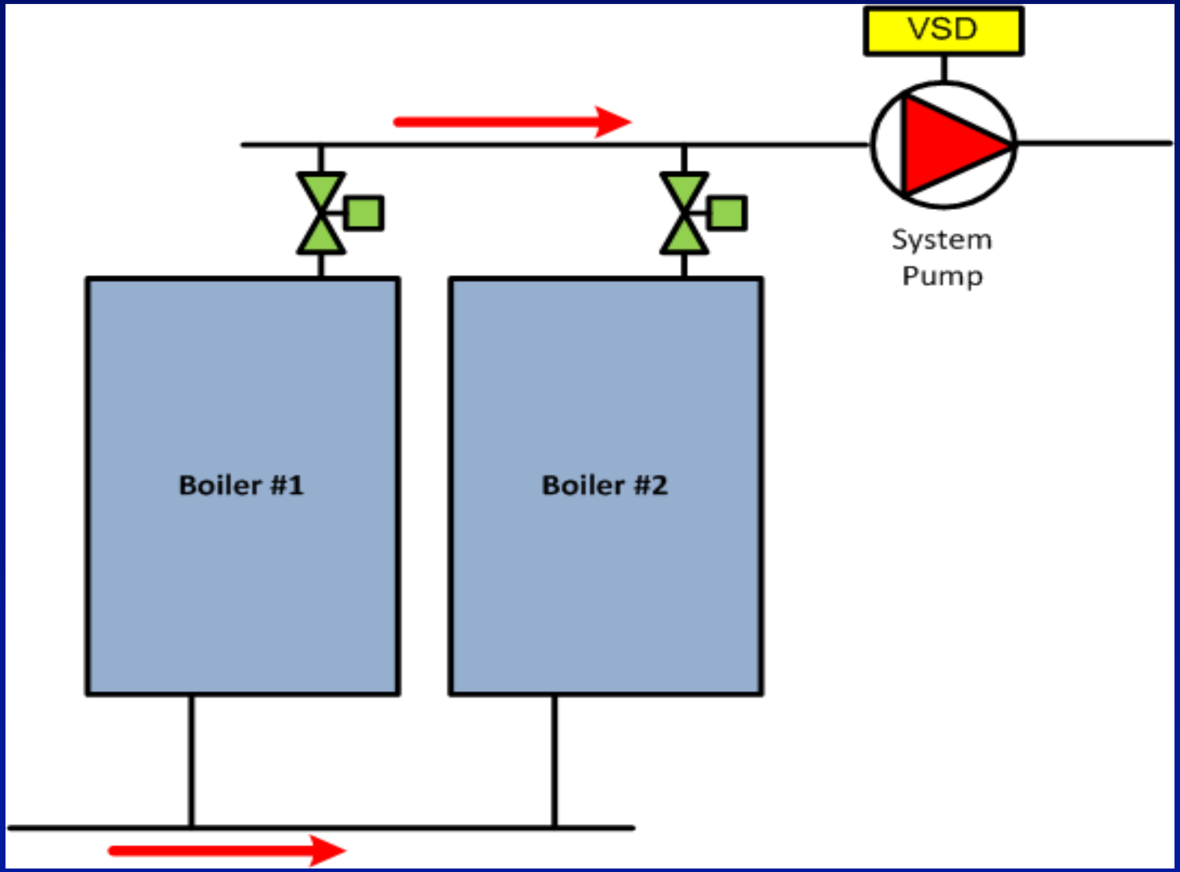


Condensing Boiler Basics
Primary/Secondary
Variable Primary
Control Strategies
Summary

Primary Only Variable Flow
The Basics

- The system pumps are used to provide flow through the boilers
  - No dedicated boiler pumps required!
- Does not require mixing manifolds, hydraulic separators, or heat injection loops (simpler design)
- The coldest water temperatures are always delivered directly to the boiler return water connection (no mixing!)
- The hottest water temperatures are always delivered directly to the system (no mixing!)

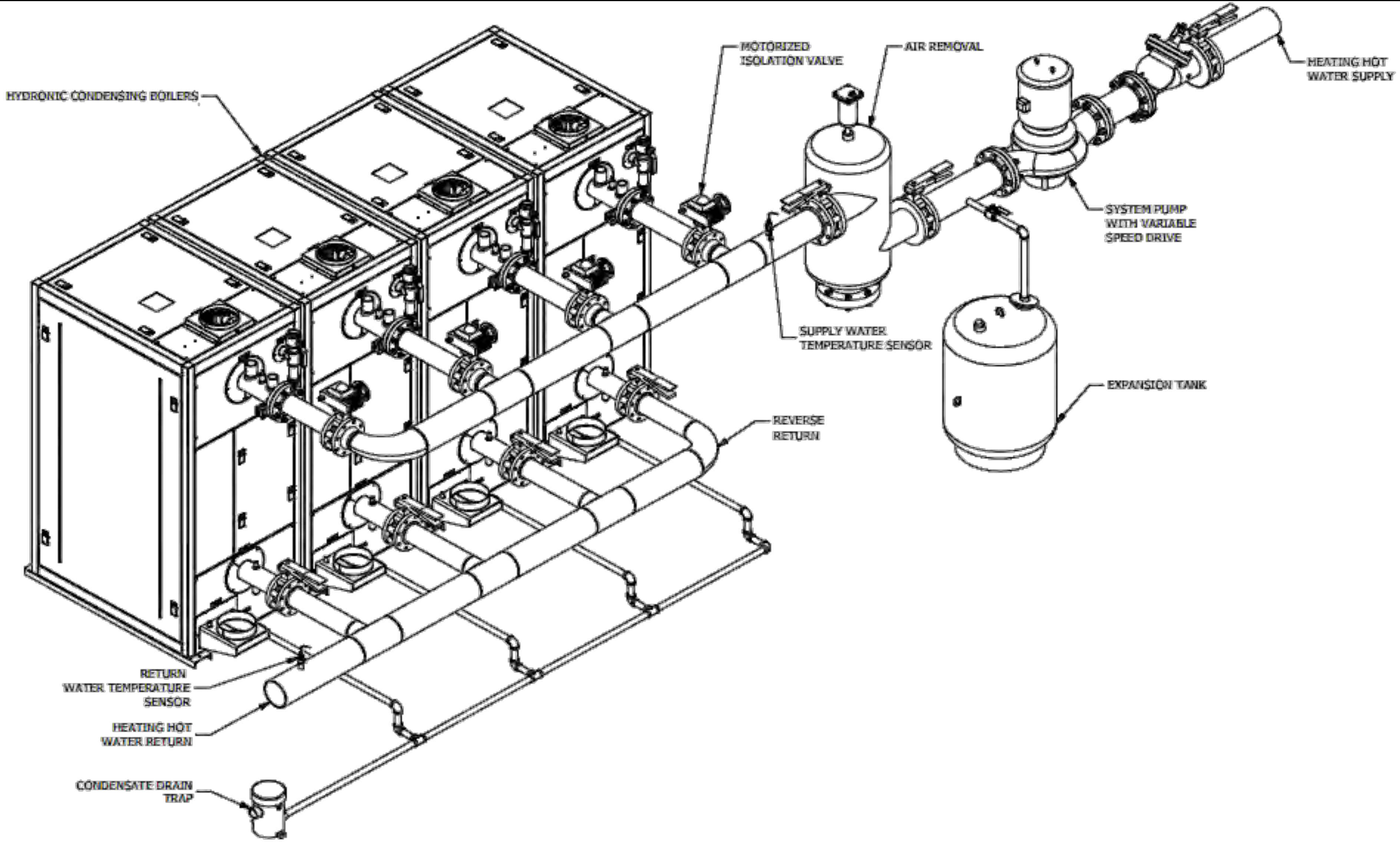
System Flow Directly Through Boilers



Appropriate for high mass & high volume condensing pressure vessel designs.

The boilers used are High Mass and High Volume condensing Pressure Vessels

Primary Only Variable Flow

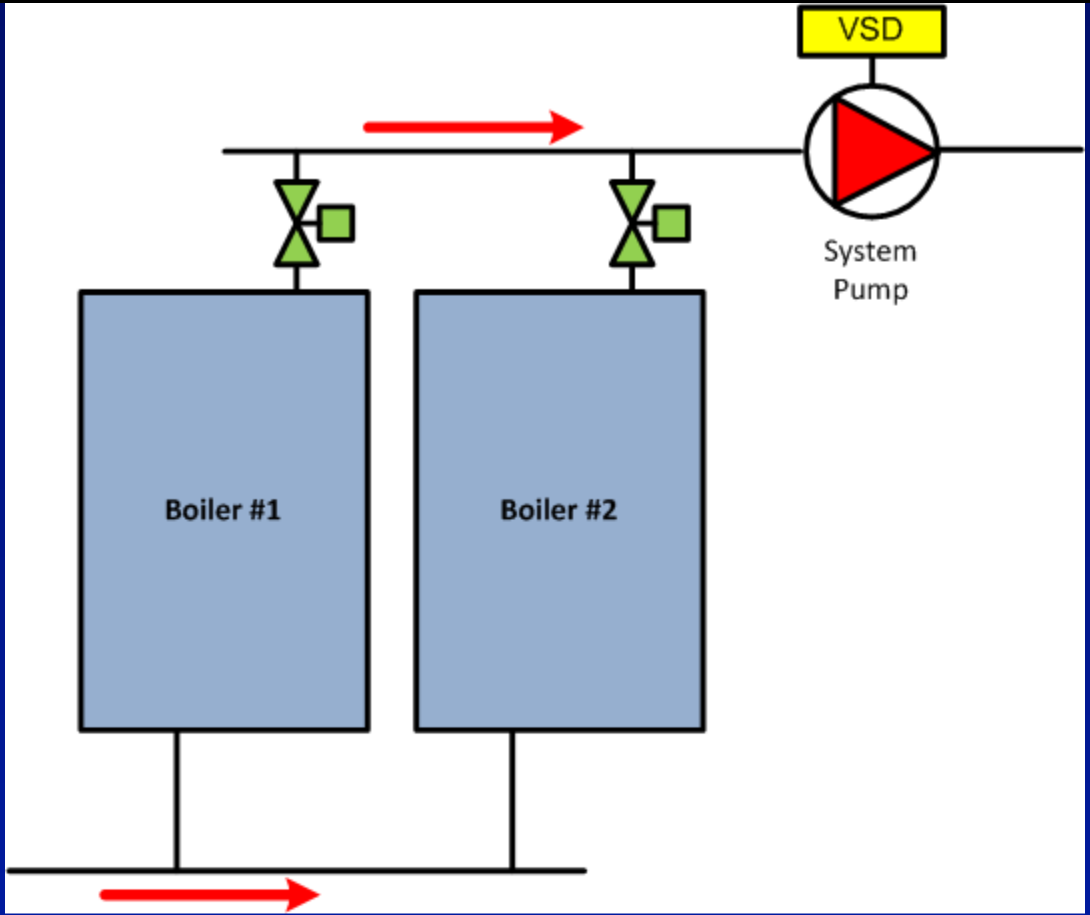


Why Use Motorized Isolation Valves?

- **Only send flow through enabled boilers**
  - Reduces natural draft through idle boilers (heat loss!)
- **Eliminates operating off a mixed temperature**
- **Prevents nuisance high limit trips**
- **Always leave the lead valve open to provide a path of flow**

Control strategy: Boiler enabled, valve open. Boiler disabled, valve closed. Lead boiler always open. Fail open.

- Important to use, install at boiler outlet



Control strategy: Boiler enabled, valve open. Boiler disabled, valve closed. Lead boiler always open. Fail open

Primary Only Variable Flow
The Applications

- **Not every boiler is designed for primary only variable flow applications**

- **The boiler must have:**
  - Flexibility for large variations in flow
  - No minimum return water temperature requirements
  - Low water pressure drop

  High mass and high volume

Advantages of High Volume Condensing Boilers

- **High water volume benefits:**
  - Decreased cycling
  - Tolerance of varying flow and/or no flow conditions
  - No return water temperature requirements
  - Tolerance of water chemistry variances
  - Decreased risk of scaling and/or erosion

Advantages of High Mass Condensing Boilers

- **Conservative designs are less likely to experience:**
  - Thermal shock
  - Cyclic fatigue
  - Premature failures

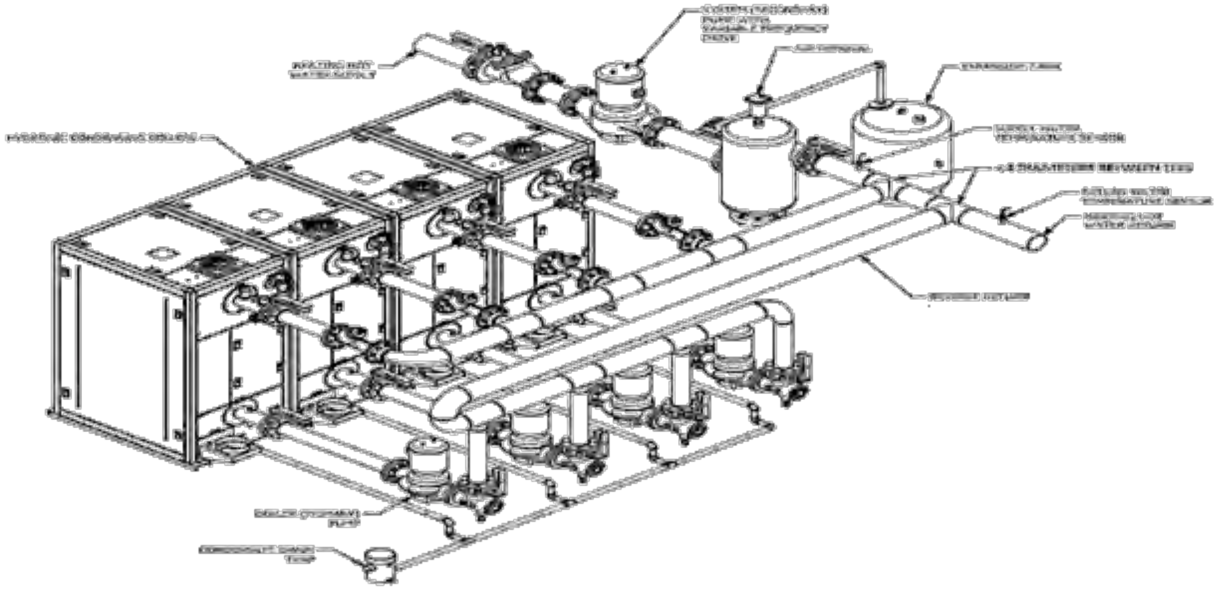
Mass & Volume: Increasing Efficiency

- **Increased overall system efficiency**
- **Low water side pressure drop through boilers**
- **Decreased system energy requirements**
  - No dedicated circulator pump running
  - Energy from boilers is made directly available to the hydronic loop
  - No heat injection loops

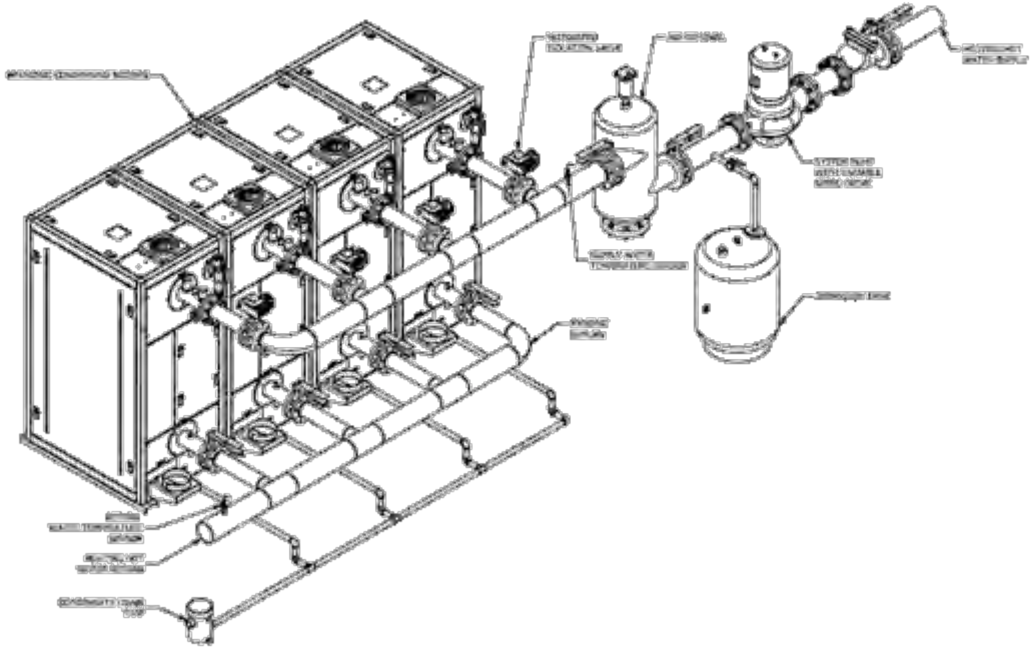
Primary Only Advantages

- **Eliminates boiler pumps, additional piping & valves**
  - Lower installation costs
  - Lower maintenance costs
  - Lower operational (kWh) costs
- **Eliminates mixing to maximize thermal efficiency**
- **Simpler system designs**
- **Smaller boiler plant footprint**

Compare The Heating Plant size

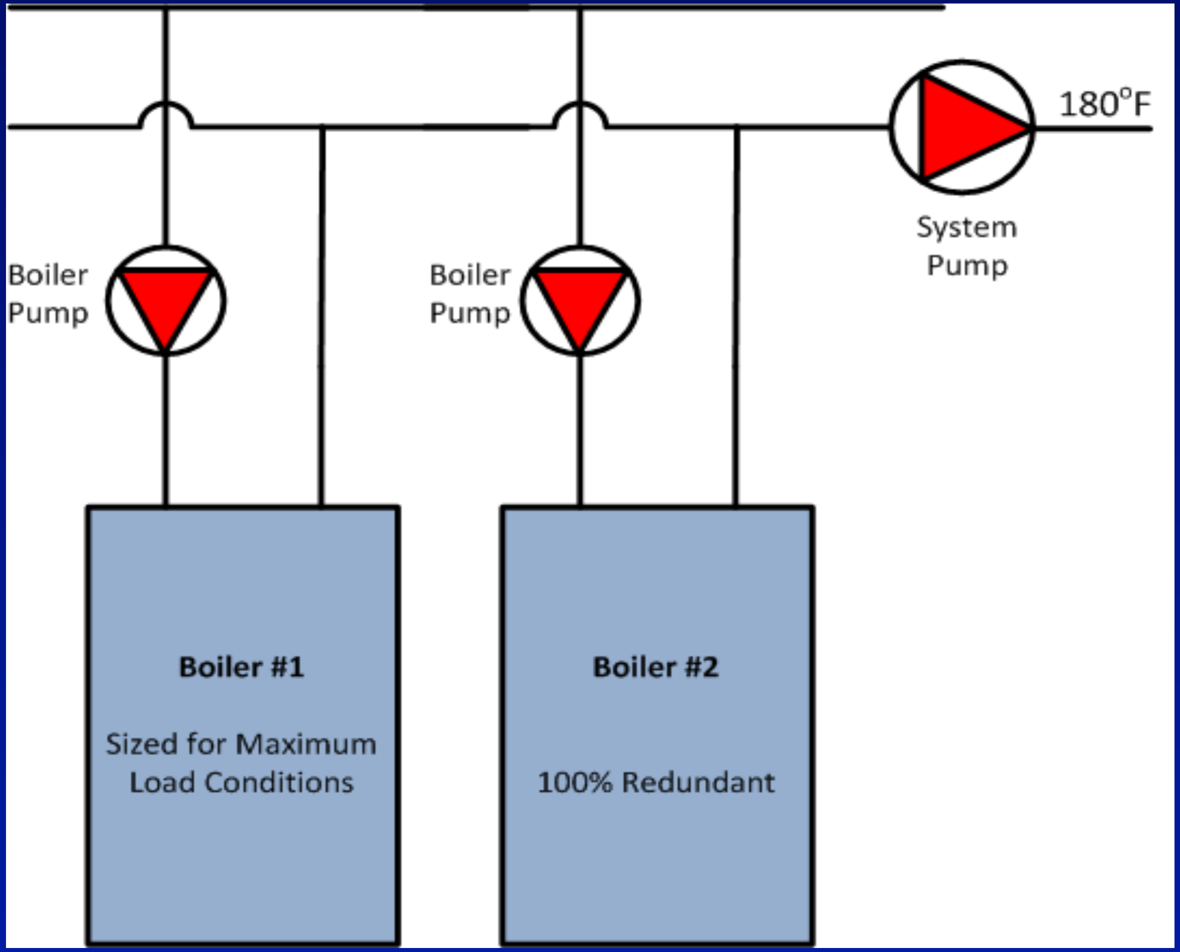


Primary/ Secondary Design

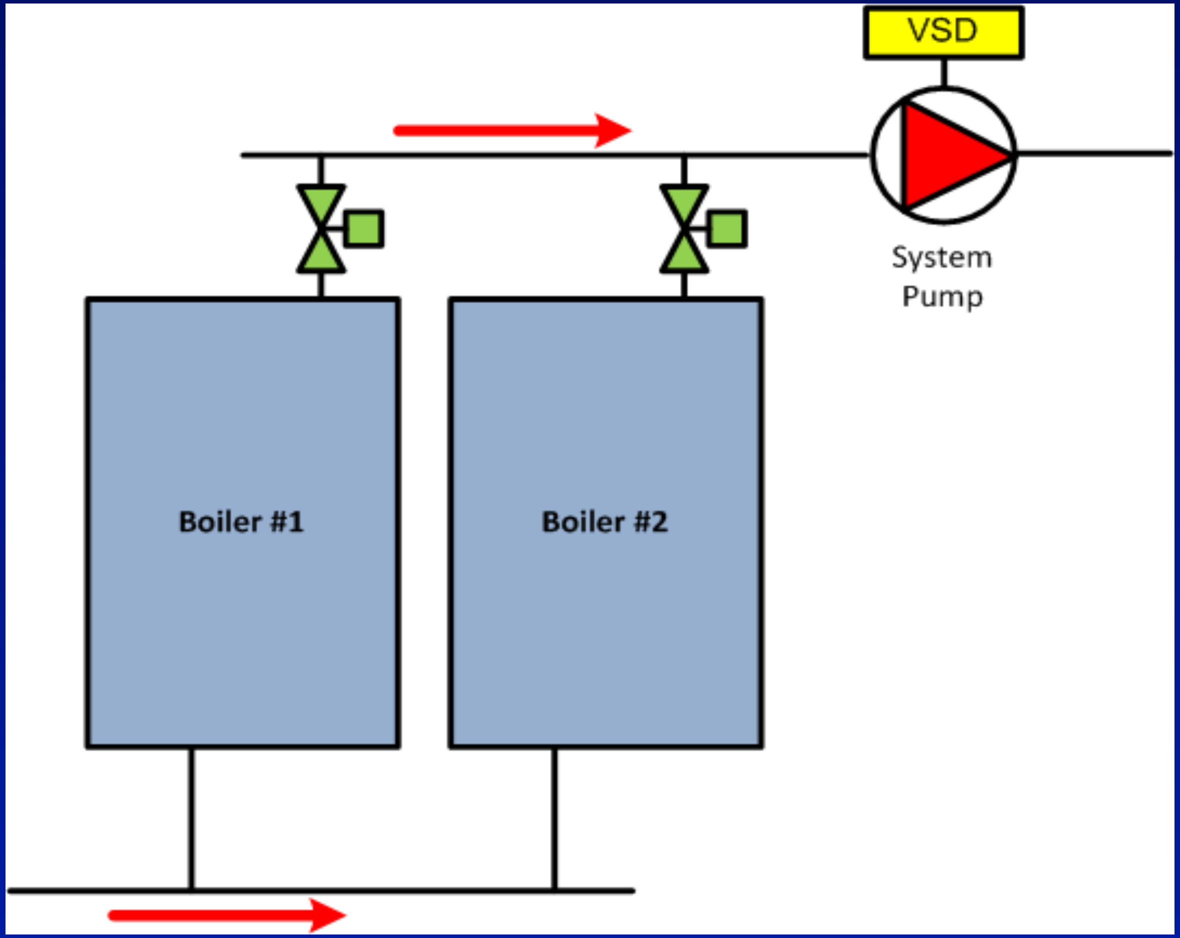


Full Flow or Primary Only Design

Compare The Design



Primary/ Secondary Piping



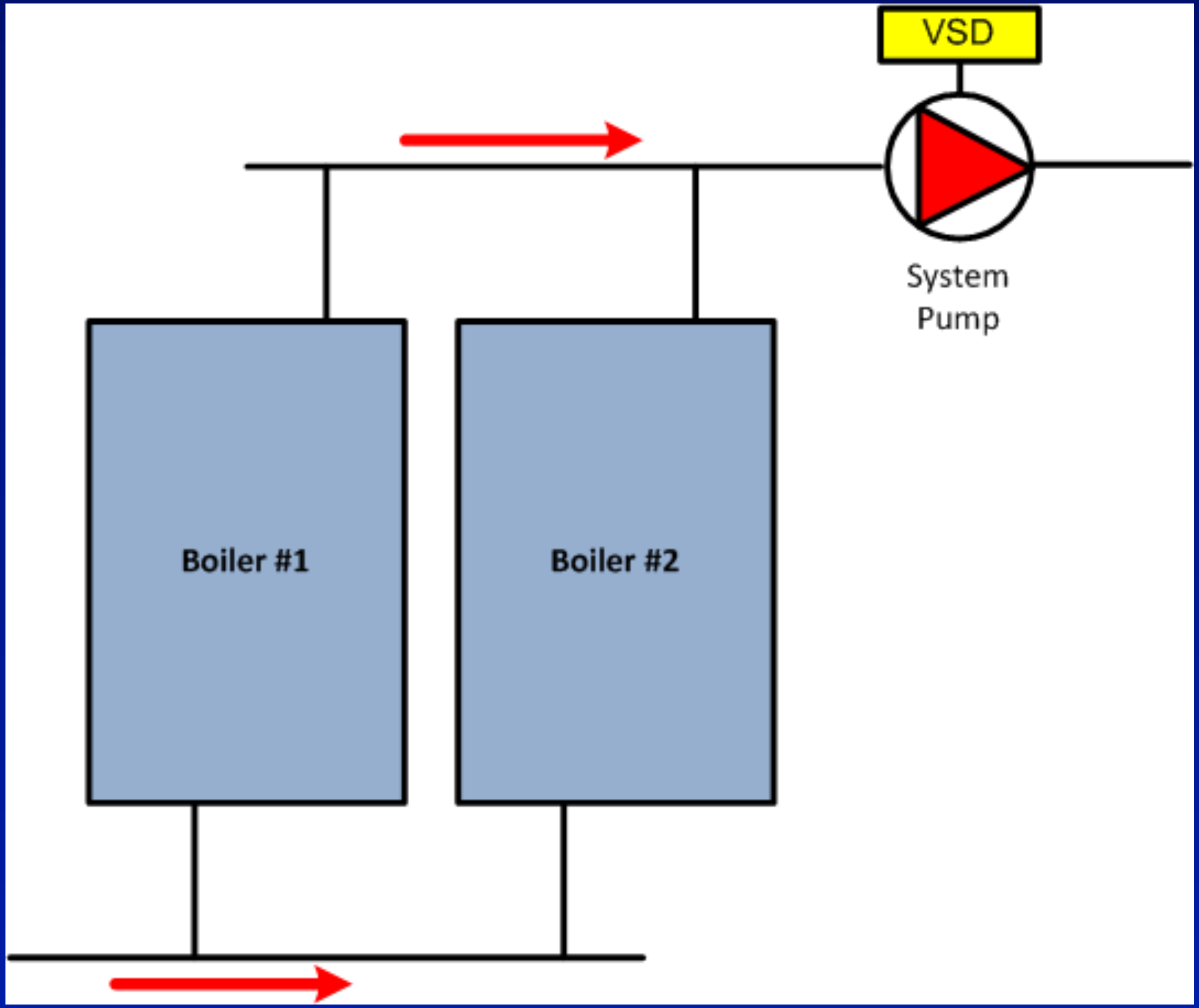
Primary only (Full Flow)

Increasing System Efficiency

Variable Speed Drives

System Pumps

Primary Only with VSD



Why use Variable Speed Drives?

- **VSD controls the speed of a motor**
  – Varies with changing electrical power supplied to the motor

- **Decreased pump and system operating costs**

- **Typical operating turndown of a drive is 3:1**
  – Pump affinity laws are used to calculate volume capacity, head or power consumption in pumps when changing speed (rpm).
  – Amp draw of the motor will be reduced

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Condensing Boiler Basics
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Variable Primary
Control Strategies
Summary

Control Strategies

- **Number and type of boilers**
- **Outdoor reset schedule**
- **Number of pumps, VSD’s**
- **Number and load requirements of zones**
- ***A sophisticated sequencing system should be able to control boilers, pumps and the speed of the VSD’s***

BMS System/Controls Contractor

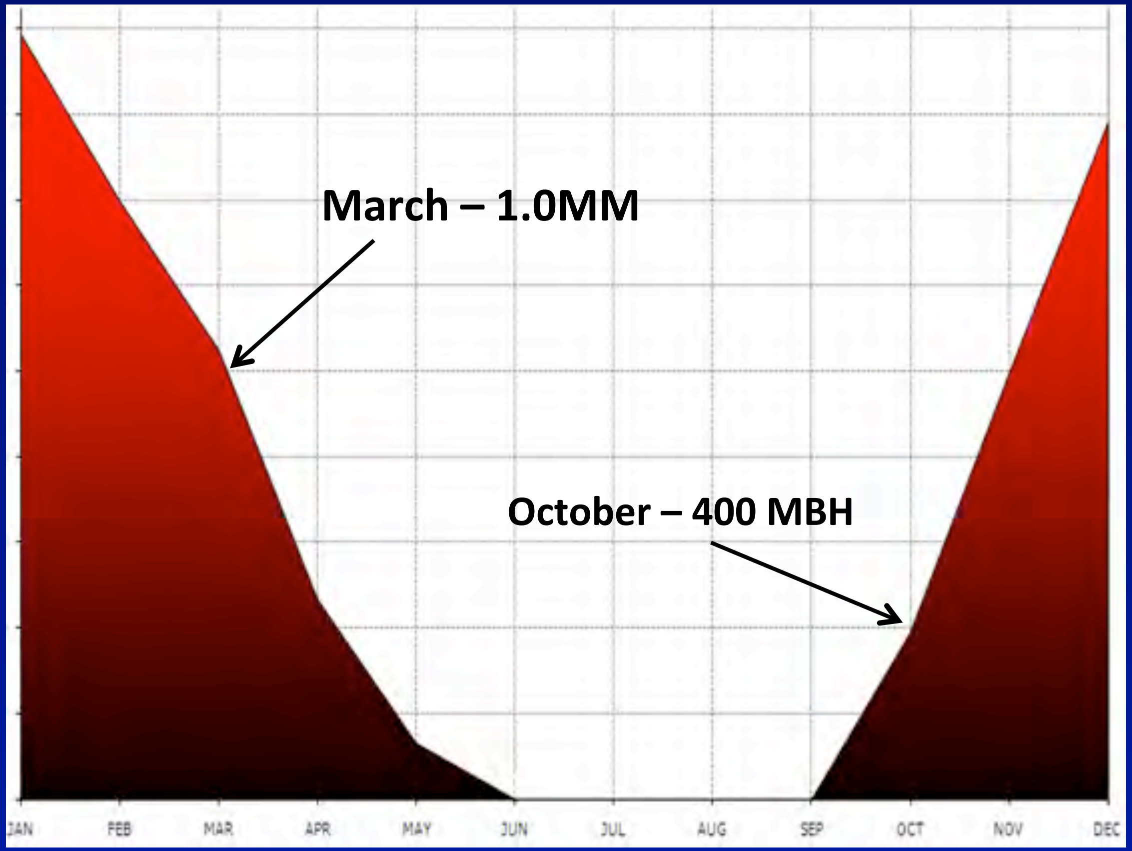
- Operate boilers at low fire
- Incorporate delays between boiler stages
- Equal run time on all boilers
- Ownership of boiler control

Design Day

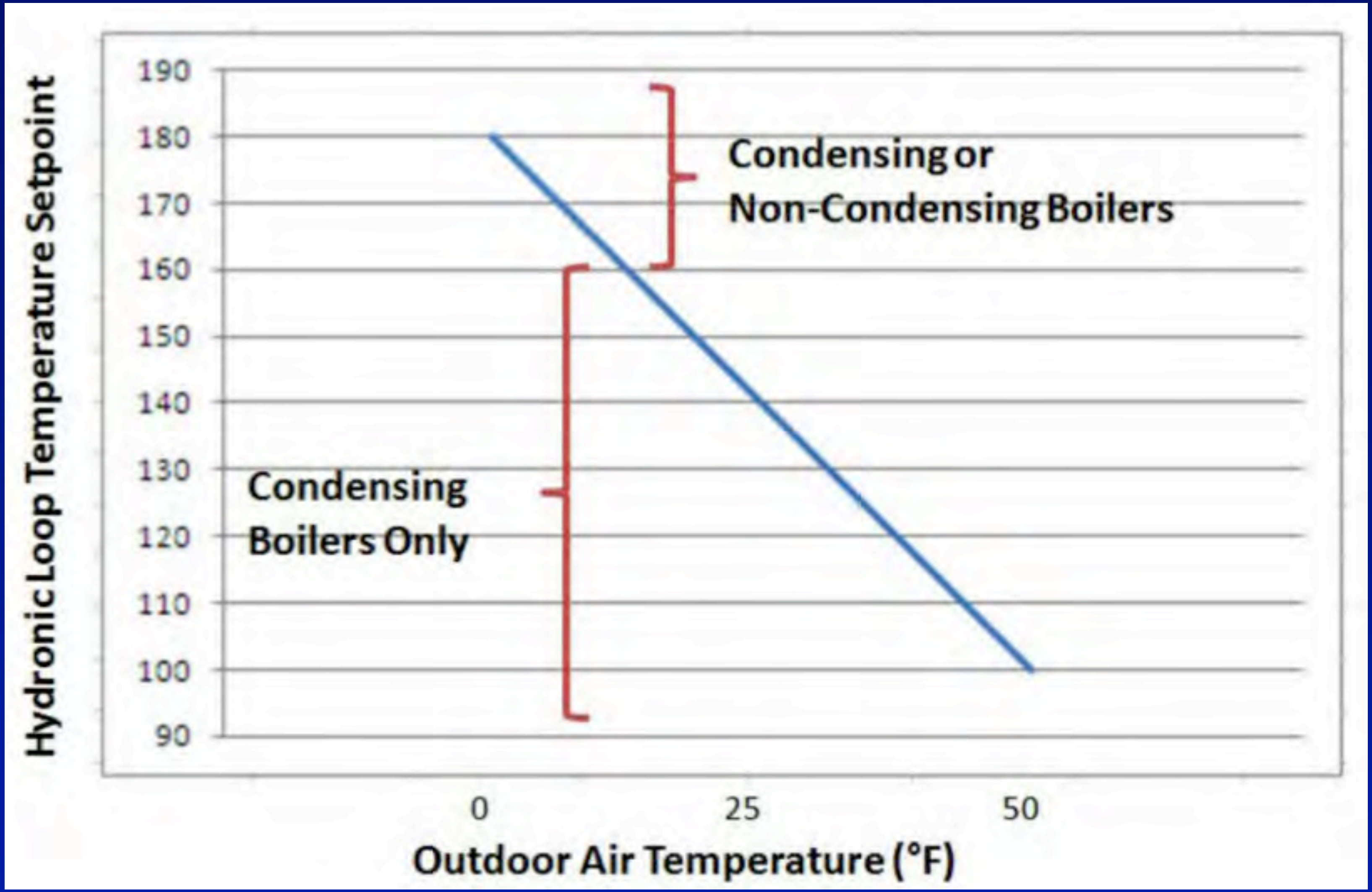
Actual
Shoulder Loads

Seasonal Building Heating Load

- Design Day Temperatures.
  - 4.0MM BTU/Hr.
- Make sure that there are plenty of BTUs available for worst case scenario.
- How often do Design Days occur?



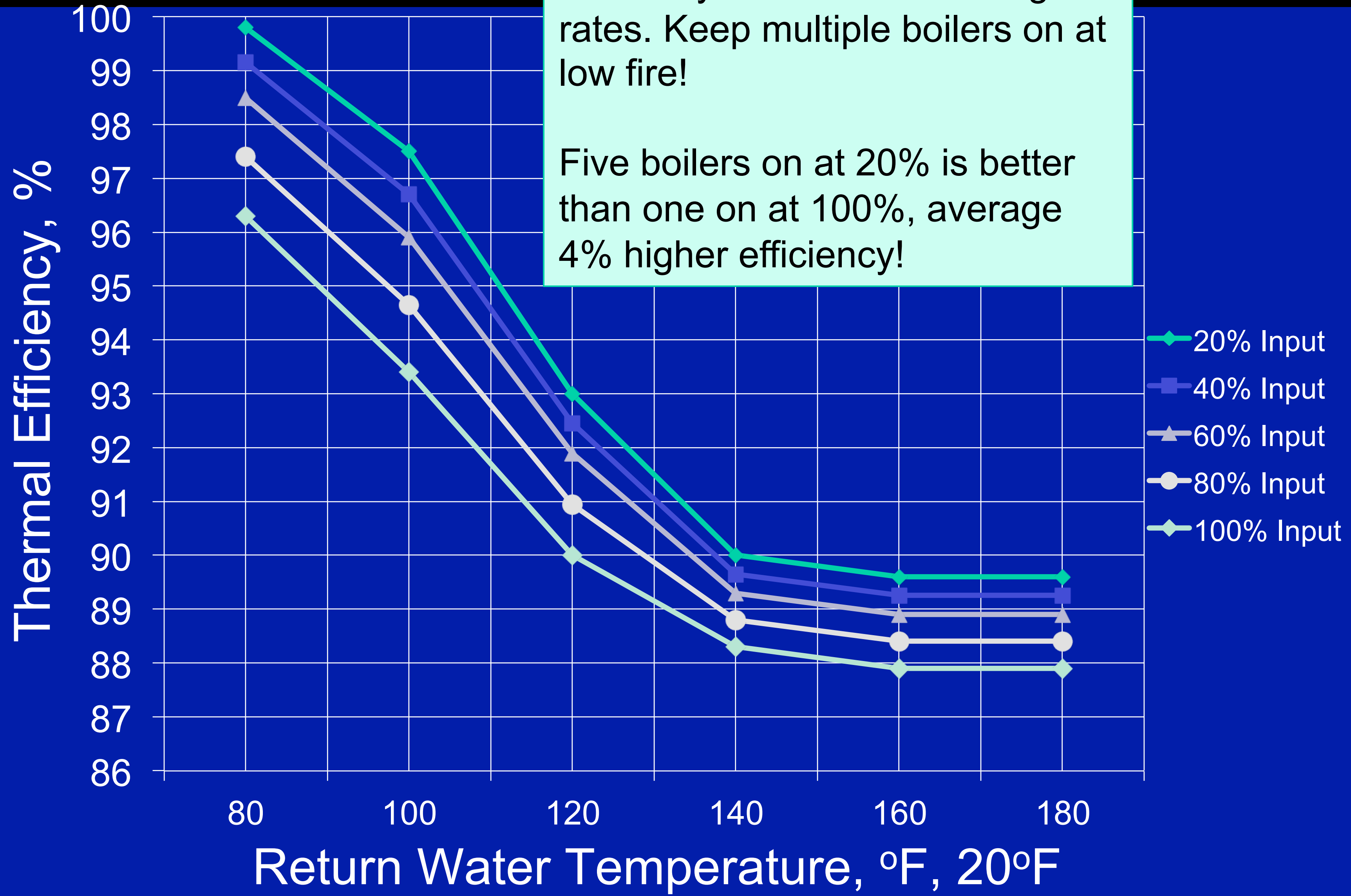
Outdoor Reset Schedule



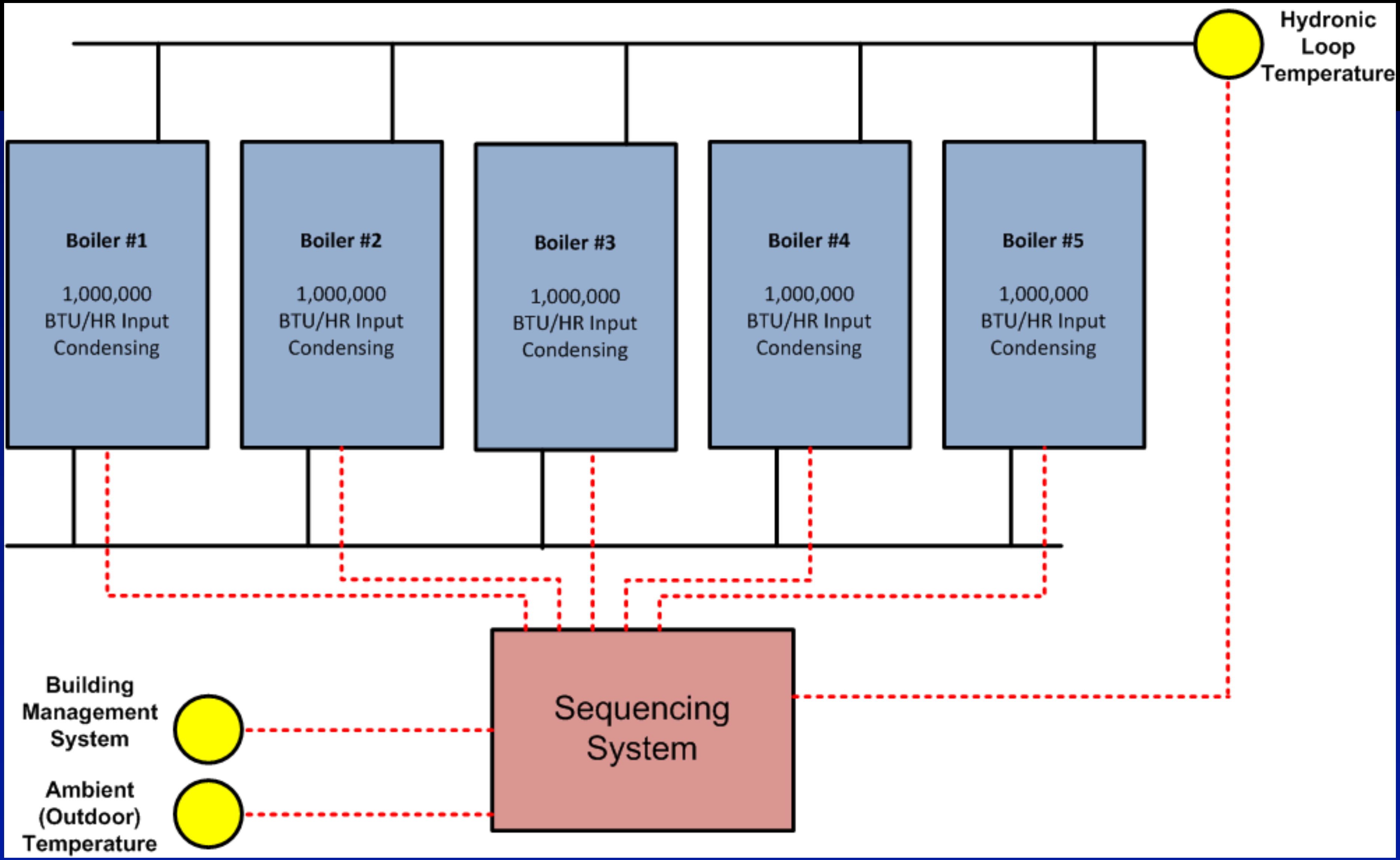
Controlling Condensing Boilers

Condensing boilers operate more efficiently at their lowest firing rates. Keep multiple boilers on at low fire!

Five boilers on at 20% is better than one on at 100%, average 4% higher efficiency!



Sequencing System

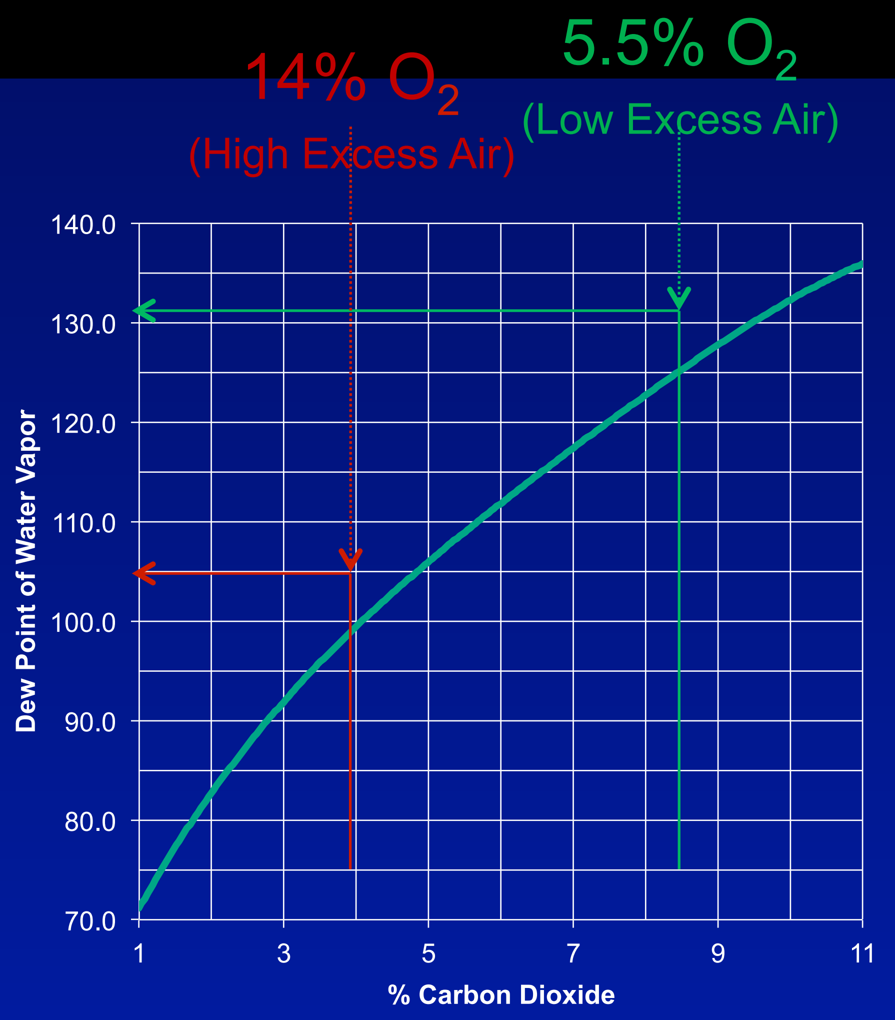


Sequential Modulation
Non-Condensing Horizontal Fire Tube

Parallel Modulation Condensing Boilers

Benefits of Low Excess Air

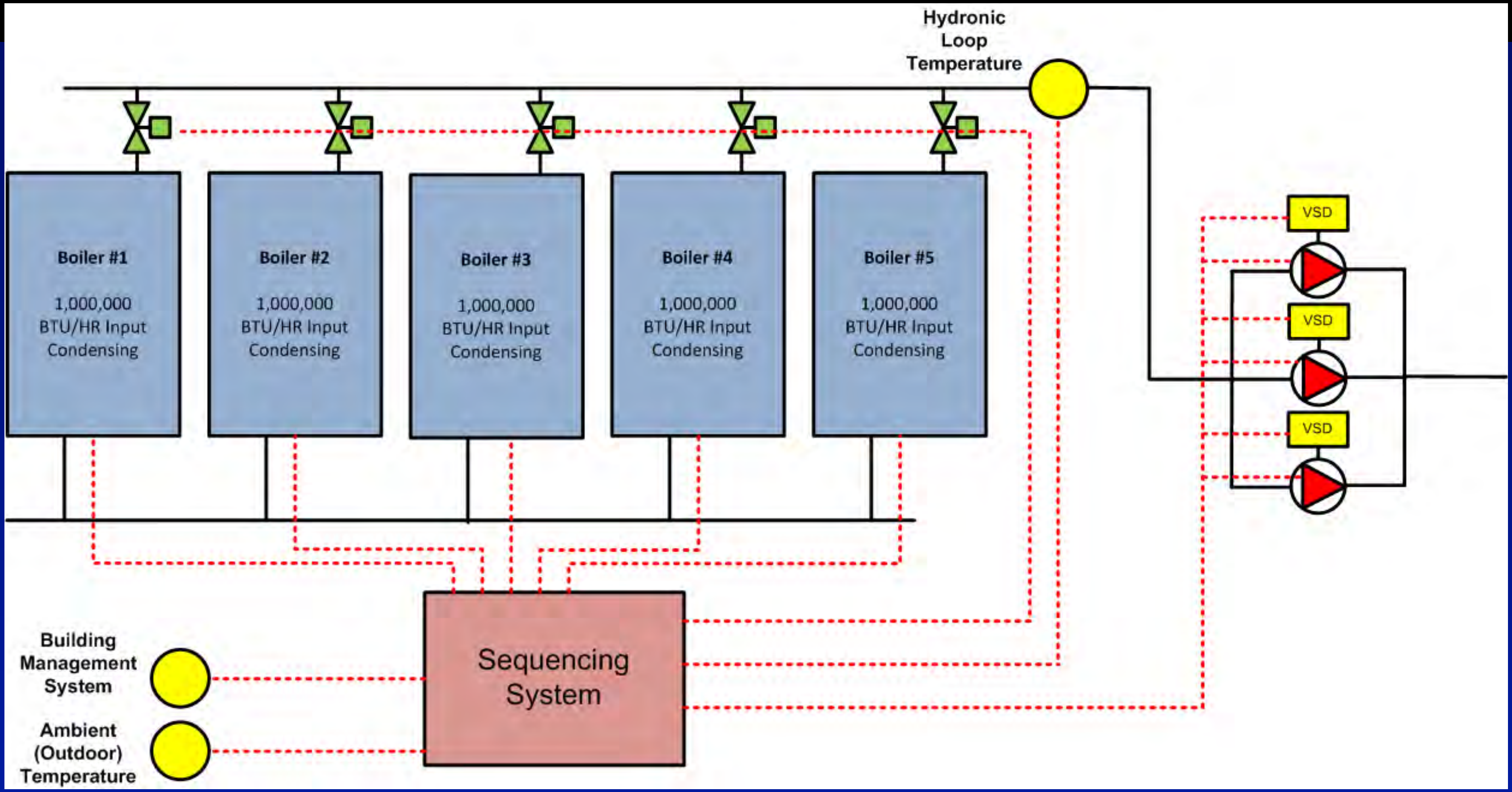
- **Higher Dew Point Temperature**
  - Wider Range of Condensing Operation
- **Higher Combustion Efficiency**
- **Lower Sensible Heat Loss**



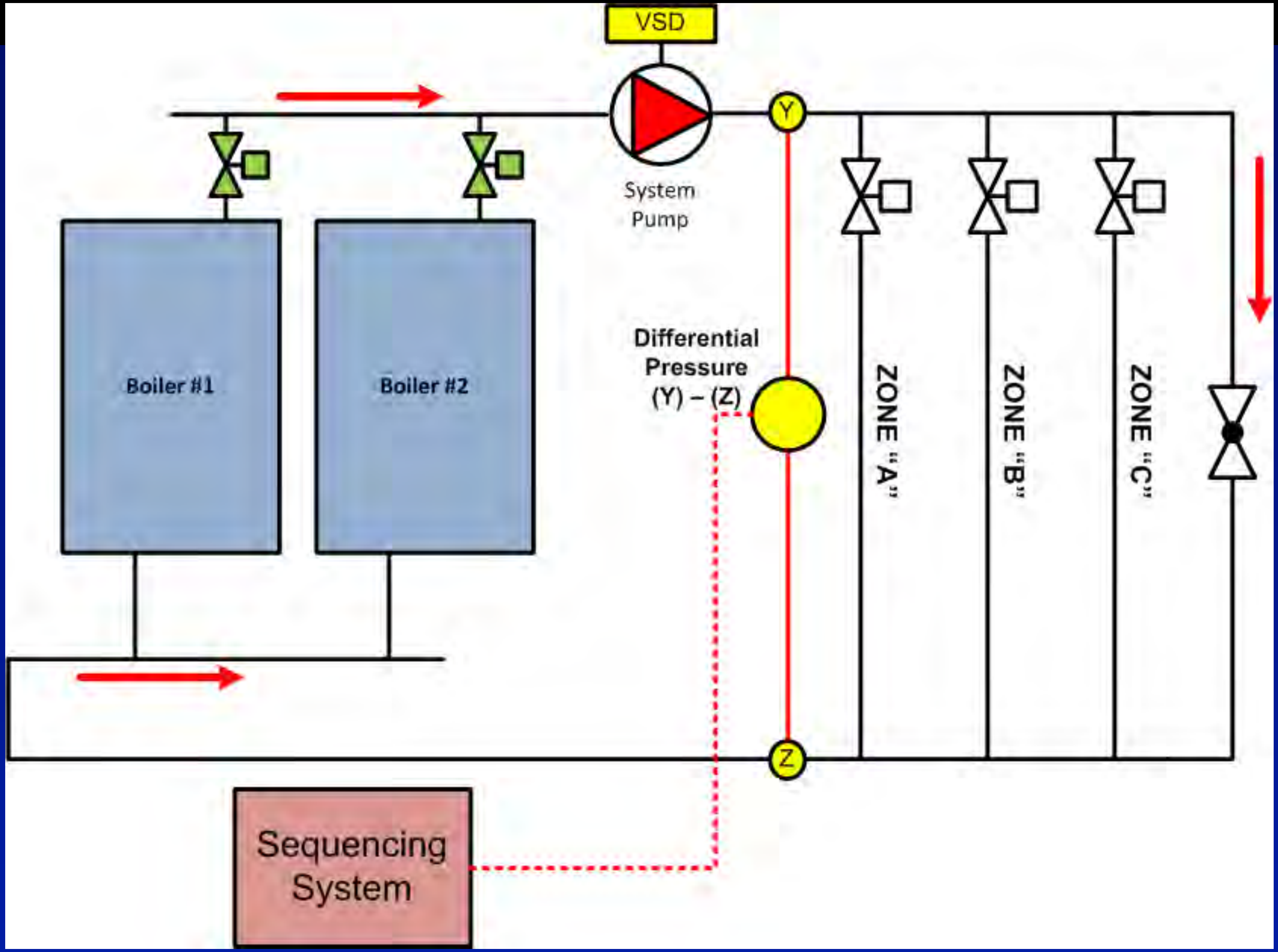
Controlling Pumps and VSD’s

- **The efficiency of a typical motor:**
  - Peaks at about 75% capacity
  - Drops off below 33% capacity
- **Operate multiple pumps between 33% and 75% to maximize motor efficiency.**

Sequencing System



Controlling the VSD's



System Flow and Differential Pressure

- DP measurement tells us how many users are calling for heat (more open zones means less resistance & smaller DP).

- Sequencing system uses flow requirement and loop temperature to determine how many BTU's need to be provided by the boilers.

Financial Impact

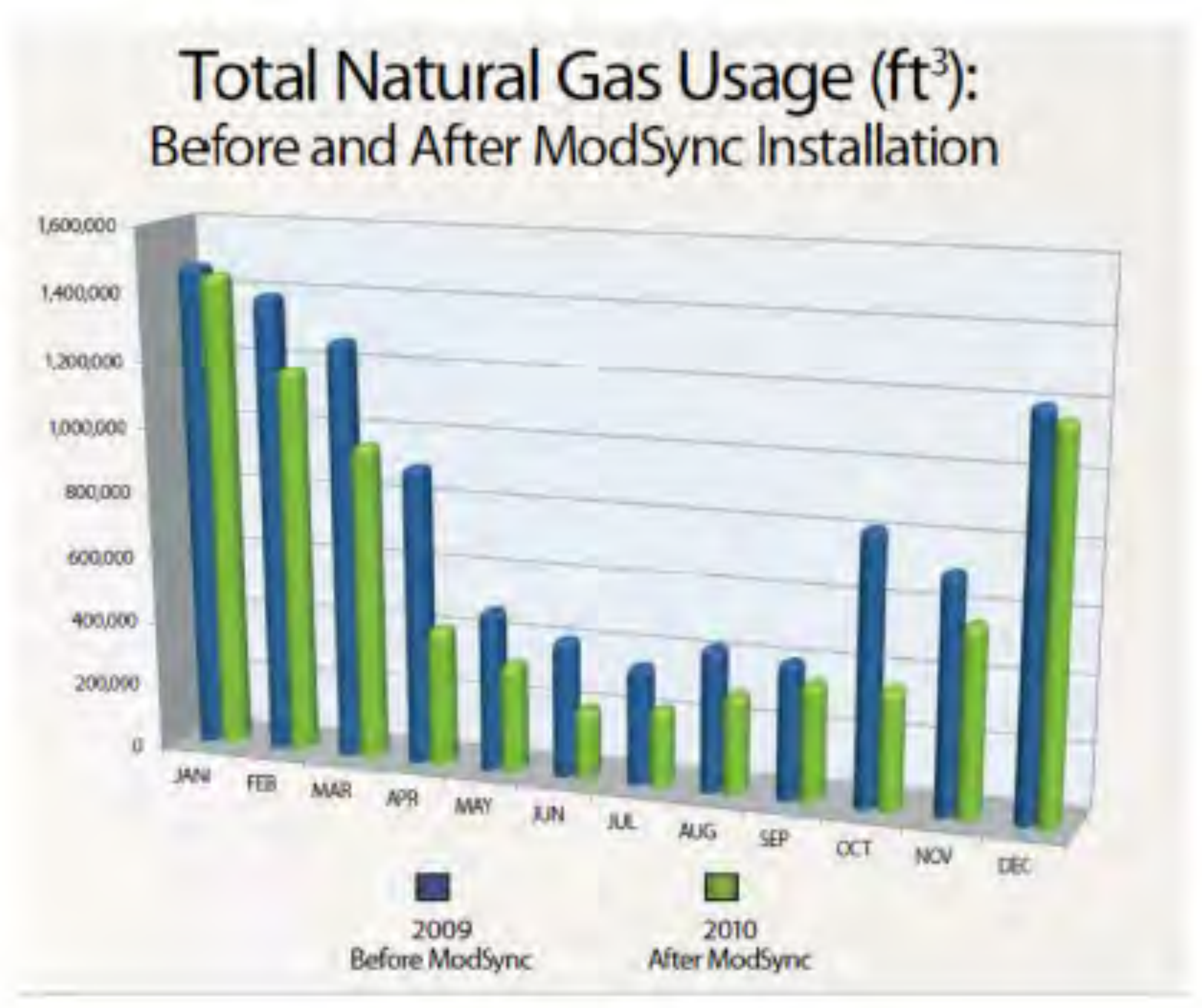
	Primary/Secondary * (2) Non-condensing boilers * 75 HP each * No variable speed drives * Continuous 180°F	**Primary Only** * (5) Condensing boilers * 1,000 MBH each * Variable speed drives * Outdoor reset schedule
Initial Capital Investment	+$12,000 (purchase and install dedicated pumps)	Installing additional boilers (flue stack, fuel piping, drains, etc.)
Operating Costs (Boiler Efficiency, Pump Operation)	+$12,500/yr thermal efficiency +1,500/yr warming up boilers +$1,600/yr operate boiler pumps +$3,000/yr system pumps - no VSD's ***$18,600 annual savings***	Condensing efficiency No boiler pumps VSD's on system pumps

Long Term Investment

- **Lifecycle of a boiler:**
  - Stress on a heat exchanger & pressure vessel is the main component in determining the life cycle of a boiler
  - What causes stress?
    - Cycling (boilers turning on and off)
    - Lack of control strategy
    - Lack of proper maintenance

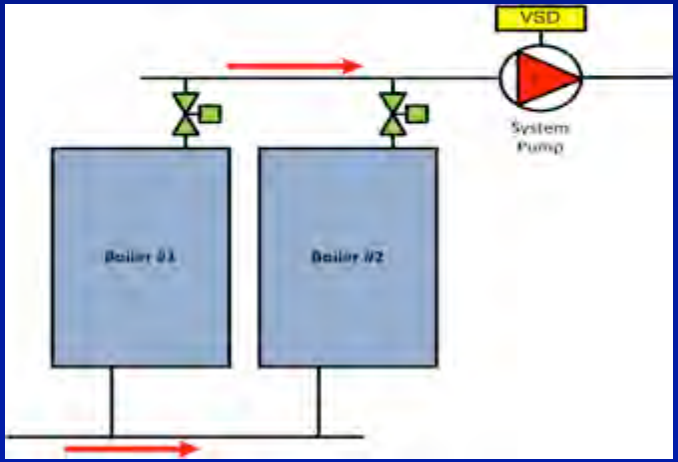
Case Study

- Existing Condensing boiler System with boilers that been installed for 7 years.
- Replaced original control system with a controller based around condensing boilers
- 35% cost reduction
- Decreased cycles from 14,000/ yr to less than 1,000.



Summary

- **There is a New Way to Design your Hydronic Systems**
- **Condensing Boiler Systems are here to stay Lets Take Advantage of all they have to offer.**
- **2 Keys to Condensing Systems**
  - Return Water Temperature
  - Firing Rate
- **Full Flow Design (Primary only) creates additional energy and Cost Savings**
  - Lower installation costs
  - Lower maintenance costs
  - Lower operational (kWh) costs
- **Controls are an Important Factor as well**



Thank You!

Questions?

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Matthew Kiemen
Marketing/ Mechanical Engineer
Direct #: 952-767-7063
Cell #: 612-803-1660
Email: matt@ryancompanyinc.com