



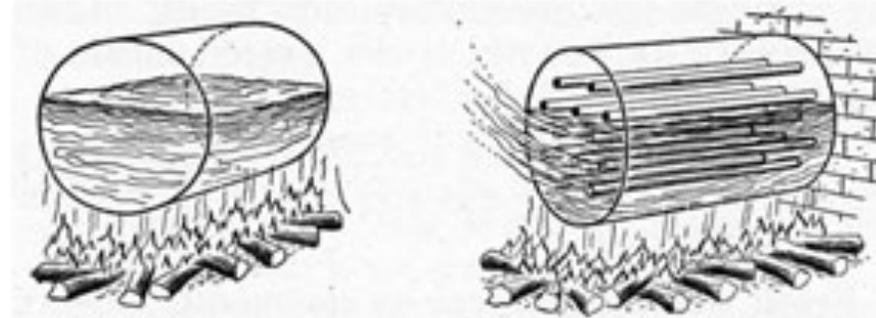
Steam vs. Hot Water Pros vs. Cons

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What is a Boiler?

- **Boiler (*n*) = An enclosed vessel in which water is heated by combustible fuels, electricity, or nuclear power and circulated, either as hot water or as steam, for heating or power applications.**

- **Boiler Basics**
 - **Why Steam**
- **Condensing Boilers**
 - **Summary**



SIMPLE BOILER AND SIMPLE
FIRETUBE BOILER

- A Boiler is a closed vessel in which water, under pressure, is transformed into steam by the application of heat. In the boiler furnace, the chemical energy in the fuel is converted to heat and it is the function of the boiler to transfer this heat to the contained water in the most efficient manner. The heat is transferred to the boiler water through radiation, conduction and convection. The relative percentage of each is dependent upon the type and design of the boiler and the type of fuel.

Boiler Comparison

	STD	MID	HIGH / CONDENSING
Efficiency	80-84%	85-88%	90+%
Min RWT	140°F	140°F	≤50°F
Fuels	Gas/Oil	Gas Only	Gas/Oil*
Physical Size	Large	Small	Small
Venting Type	Cat I or III	Cat I, II, III or IV	Cat IV
Venting Size	Med - Large	Med	Small
Longevity	40+ Yrs	10+ Yrs	15+ Yrs

* Does not condense when firing on oil.

Boiler Types



- **Cast Iron**
- **Steel Firetube**
 - Firebox
 - Scotch
 - Scotchbox
 - Vertical
- **Steel Watertube**
 - D Type
 - S Type
 - A Type
 - O Type
- **Flexible Watertube**
- **Copper Fin Tube**
 - Vertical
 - Horizontal
- **Electric**
- **Thermal Fluid**
- **Condensing**

Boiler Efficiency Classifications

- **Standard Efficiency (80-84%)**
 - Kewanee, Burnham, Cleaver Brooks, Bryan, Aldrich, Hurst, Slant Fin, Ray Pak, Superior
- **Mid Efficiency (85-88%)**
 - Lochinvar, Thermal Solutions
- **High Efficiency (90+%)**
 - Fulton, Aerco, Viessmann, Lochinvar, Aldrich



NON - CONDENSING



CONDENSING

Determine System Config

- **Quantity of Units**
- **Modular System**
- **Base Load System**

Select Units

- **Type**
- **Medium**
- **Efficiency**
- **Cost**
- **Brand**
- **Space Constraints**
- **Venting Constraints**
- **Operating Parameters**
- **Fuels**
- **Included Features**

Select Units

- **Space Constraints**
 - Physical Size of Unit
 - Unit Clearances
 - Service Accessibility

Select Units

- **Venting Constraints**
 - Configuration
 - Vertical
 - Sidewall
 - Size
 - Distance

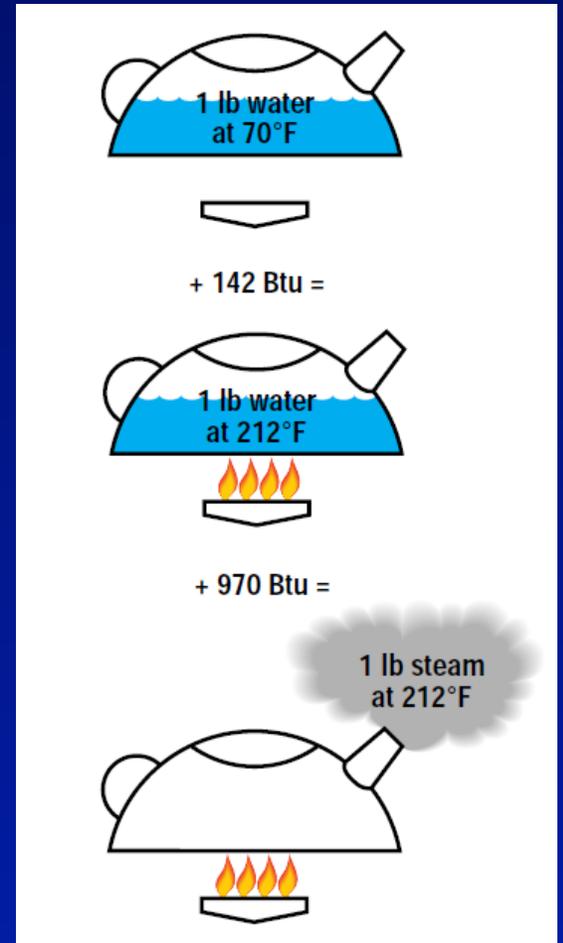
Select Units

- **Operating Parameters**
 - Flow Rates (Min & Max)
 - Min Return Water Temp
 - Max Discharge Temp
 - Max Delta T
 - Max Operating Pressure
 - Operating Electrical Load

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Why Steam?

- **Steam contains more energy per pound than Hot Water or Thermal Fluid**
 - One pound of Steam contains 1,150 BTU/lb. @ 0 PSIG and 212°F
 - Heat available from phase change
 - One pound of Hot Water contains 180 BTU/lb. @ 212°F
 - One pound of Thermal Fluid contains 183 BTU/lb. @ 300°F
- **Does not require a pump to carry energy. Steam uses pressure differential to transport energy**



Steam System Design

Five sub-components:

- Means to generate steam-boiler
- Means to deliver steam to load (piping, valves, etc.)
- Means to collect condensate and feed back to boiler
- Means to remove solids from the boiler
- Means to preserve the pressure vessel and system – water treatment, preheated boiler feed water and deaerator

Sizing a Steam Boiler

- **Many Steam boilers are undersized for the actual NET load**
- **Determine the BTU required for the heat load**
- **Add losses for the piping, distribution, etc.**
- **Correct for the operating pressure of the boiler**
- **Correct for the feedwater temperature of the boiler**

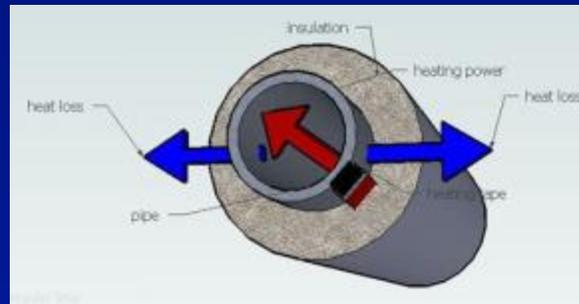
Sizing a Steam Boiler

$$\begin{array}{c} \text{Calculated Load} \\ \text{(BTU/HR)} \end{array} \times \begin{array}{c} \text{Pick-Up Factor} \\ \text{(1.33)} \end{array} = \begin{array}{c} \text{Gross Load} \\ \text{BTU/HR} \end{array}$$



NET Load

X



Piping and
Pick-Up

=

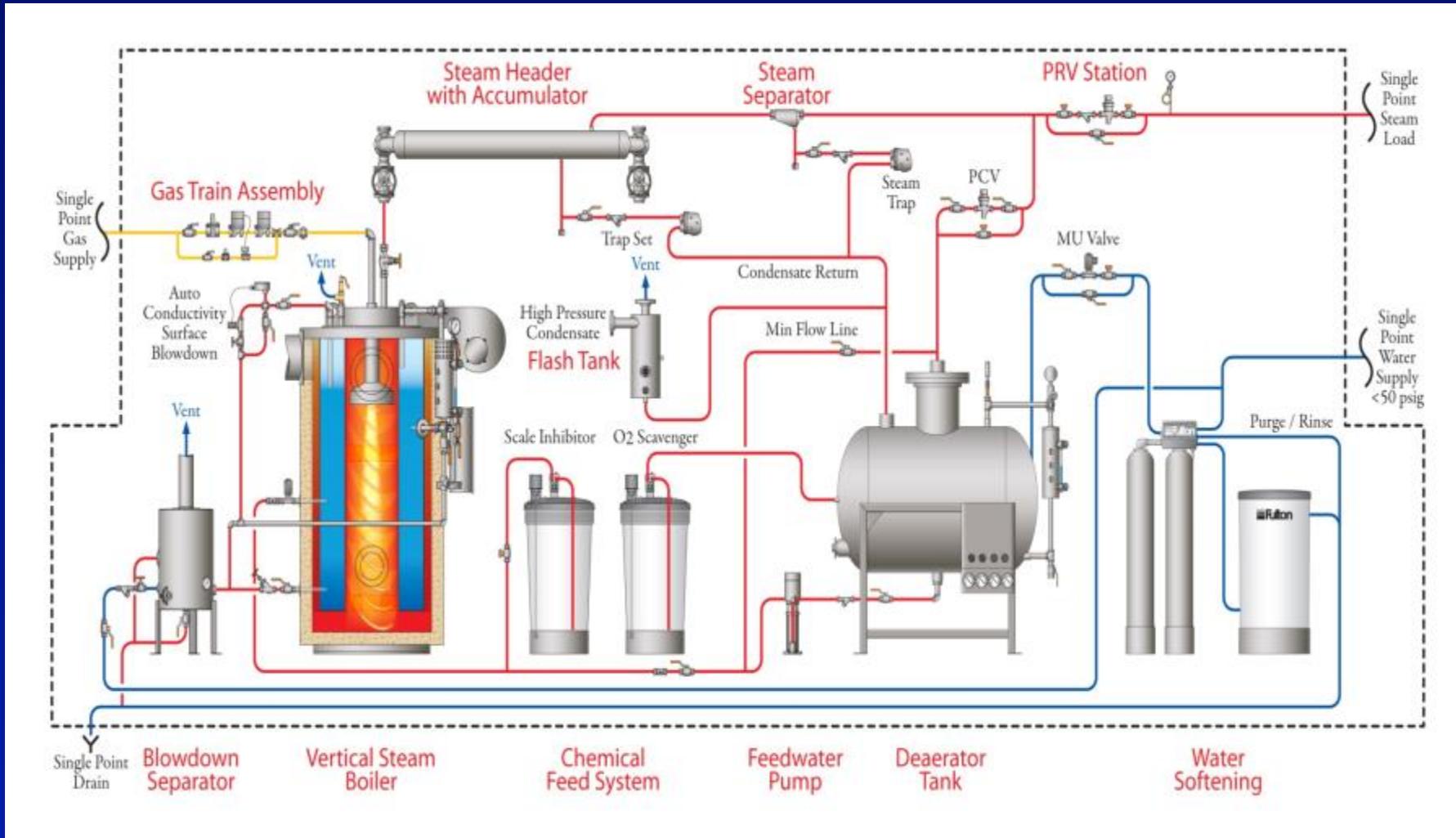


Gross Load

The Ideal Steam Boiler

- **High Mass Pressure Vessel – Durability**
- **High Mass Water Volume - Ability to react to load swings**
 - *Lessen the impact of rapid de-pressurization*
- **Small Footprint**
- **Quick Start up – Save Time**
- **Large Steam Disengagement Area - High Steam Quality**
 - *Acceptable velocity and minimal carryover*
- **Large Furnace Volume – Low Primary Heat Release**
- **Ability to Handle Poor Water Quality – Durability & Steam Quality; reduce impact of scale**
- **High Efficiency – Lower Operating Cost & Corrosion**
- **Low Initial Capital Cost**

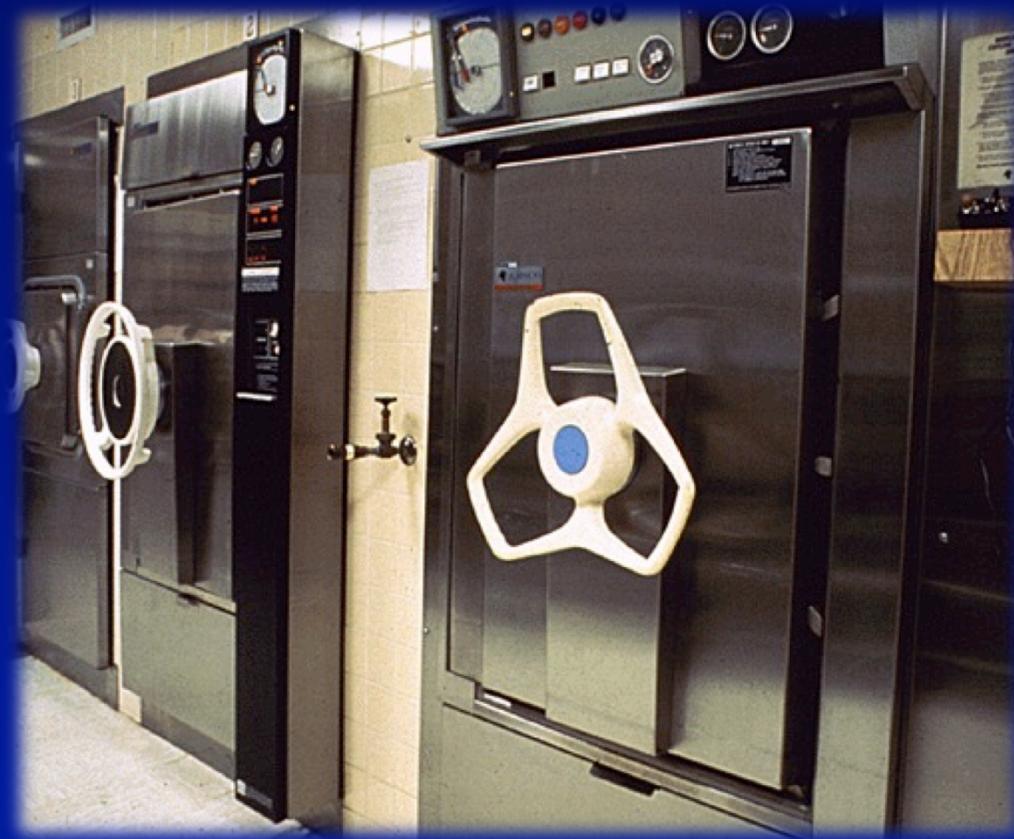
Steam System Design



Applications

- **Hospitals**

- Sterilization
- Autoclaves
- Humidification



Applications

- **Food Processing - bakeries, jacketed vessels, direct injection, dairies, micro breweries**



Other Applications

- **Laundry & Dry Cleaning**
- **Jacketed Kettles**
- **Steam Tunnels**
- **Bottling**

- **Most Importantly Building Heat**



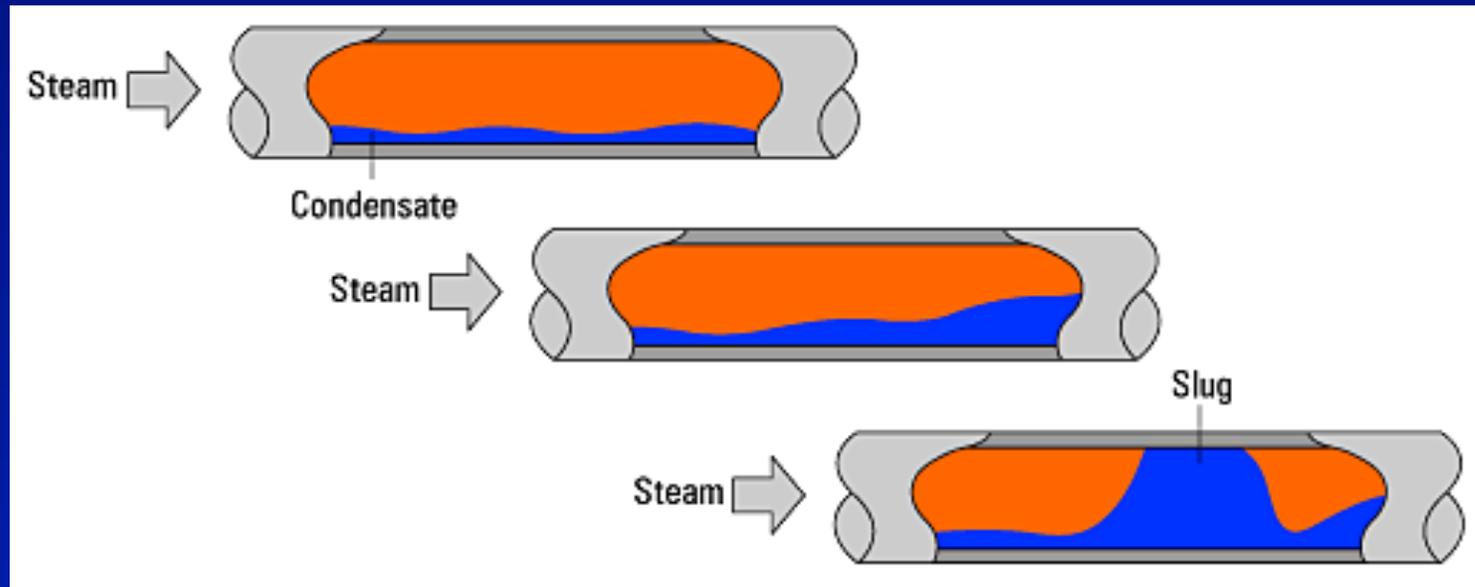
Challenges with Steam

- **Can be sized wrong often**
- **Proper height and room needed for Steam header**
- **Need to properly drain condensate**
- **Some Steam boilers require a big footprint**
- **Boiler license is needed**
- **Can become expensive if additional equipment is needed**
 - Deaerator
 - Boiler Feed system
 - Blowdown tank

Need to Properly Drain Condensate

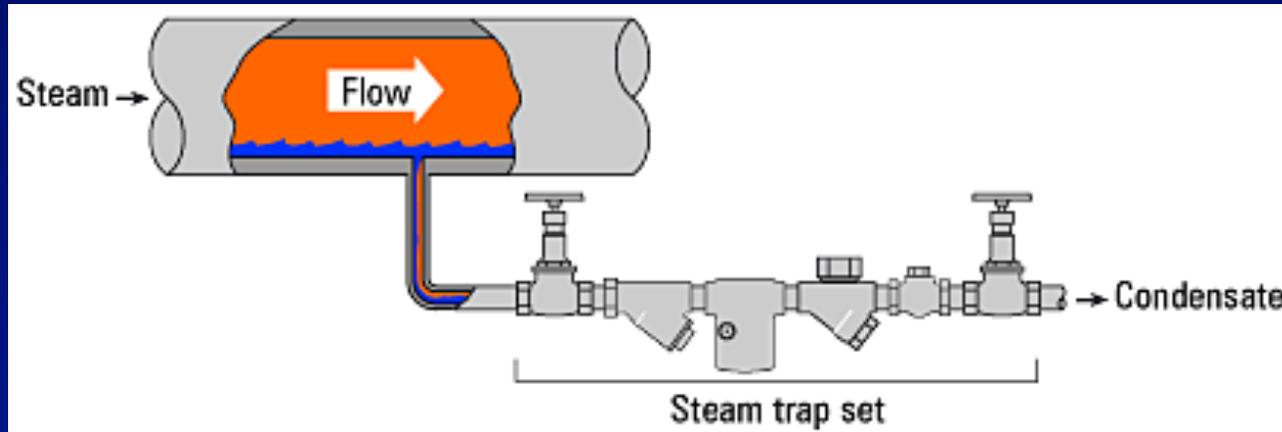
- **Steam trapping**

- It is important that condensate is removed from the steam header as soon as it forms. For this reason a properly sized drip leg with appropriate steam trap must be installed at the end of the header to avoid water hammer.

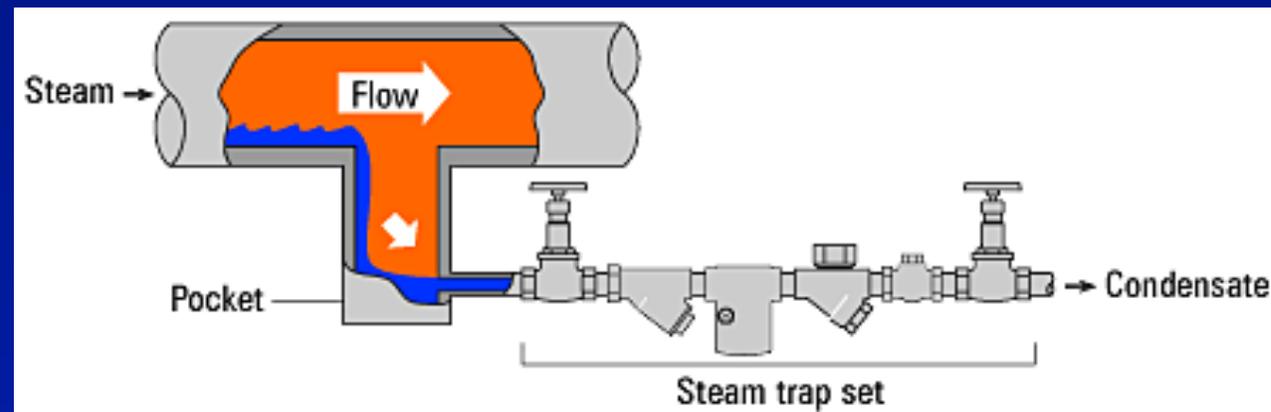


Need to Properly Drain Condensate

- Steam trapping/Drip Legs



Incorrect



Correct

- **Boiler Basics**
 - **Why Steam**
- **Condensing Boilers**
 - **Summary**

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

- **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

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

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

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

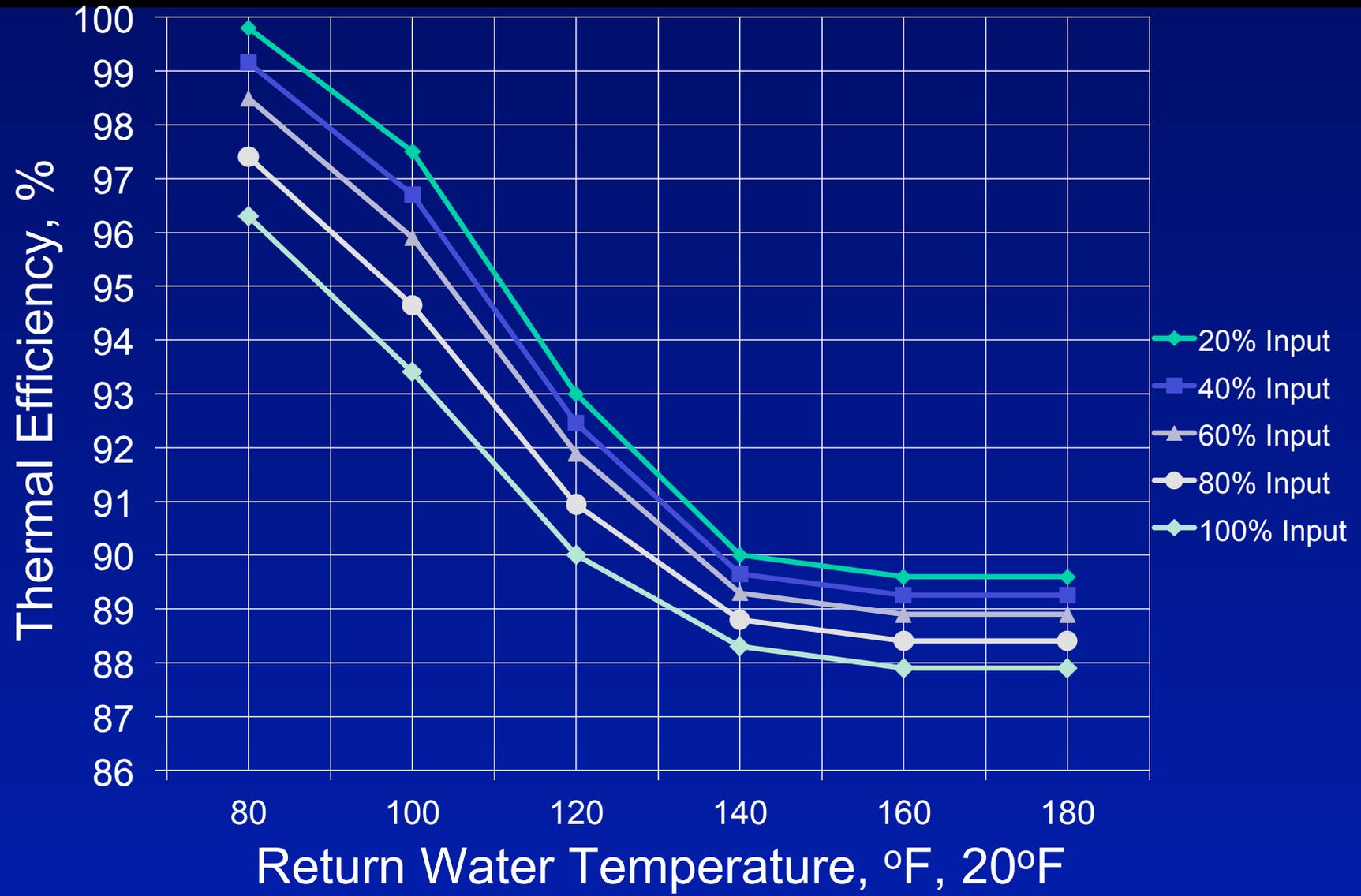
- **Return Water Temperature**
 - Lower water temperatures allow flue gases to cool
 - Flue gas temperature is directly proportional to water temperature
- **Firing Rate (Modulation Point)**
 - Lower firing rate decreases flue gas velocity through the heat exchanger
 - Surface Area: Energy Transfer
-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

Why Condensing

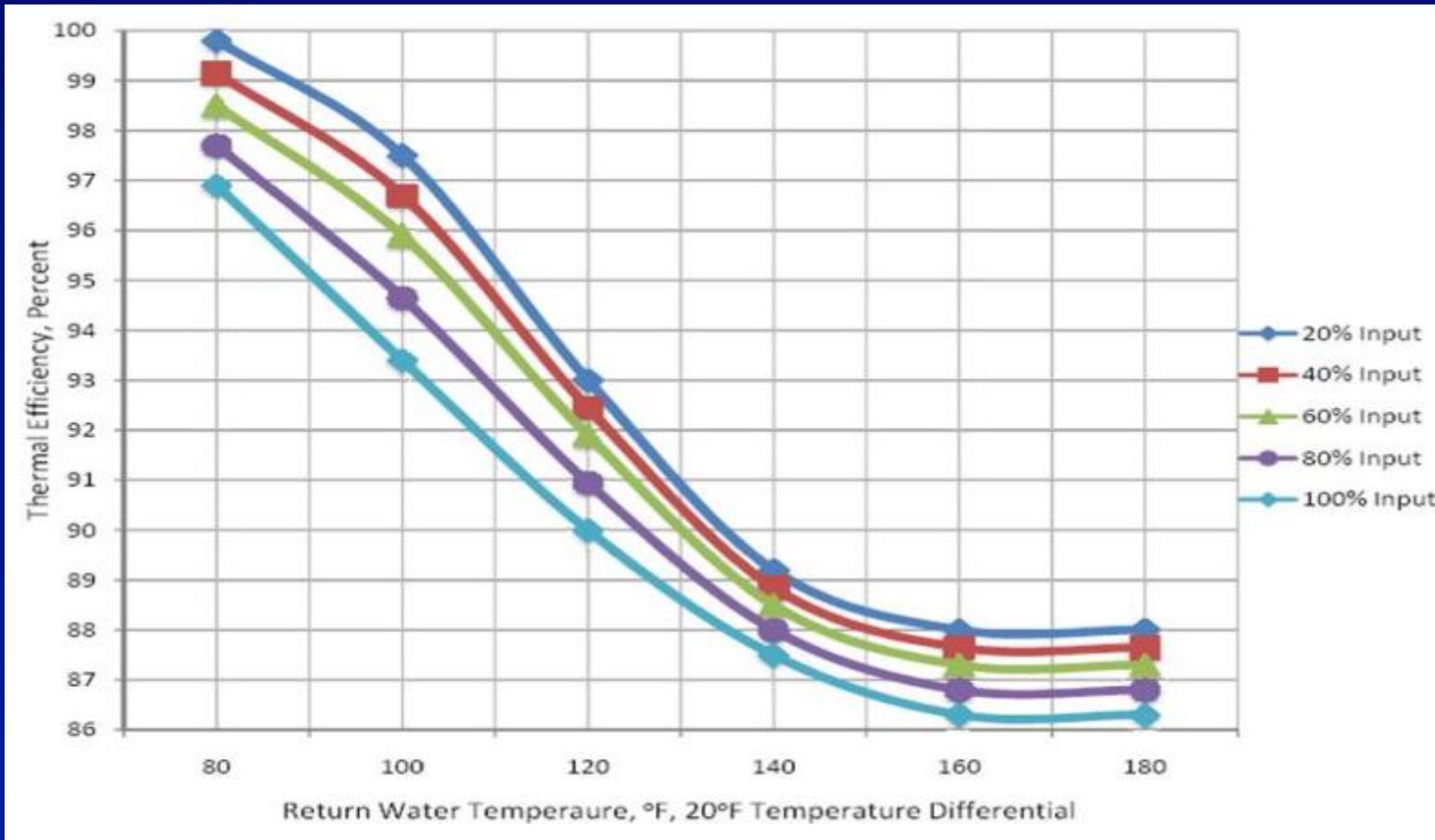
- More efficient
- Payback quicker on purchased equipment
- Uses less energy and natural gas
- Energy savings
- Cost savings
- Rebates
 - CenterPoint
 - Xcel energy



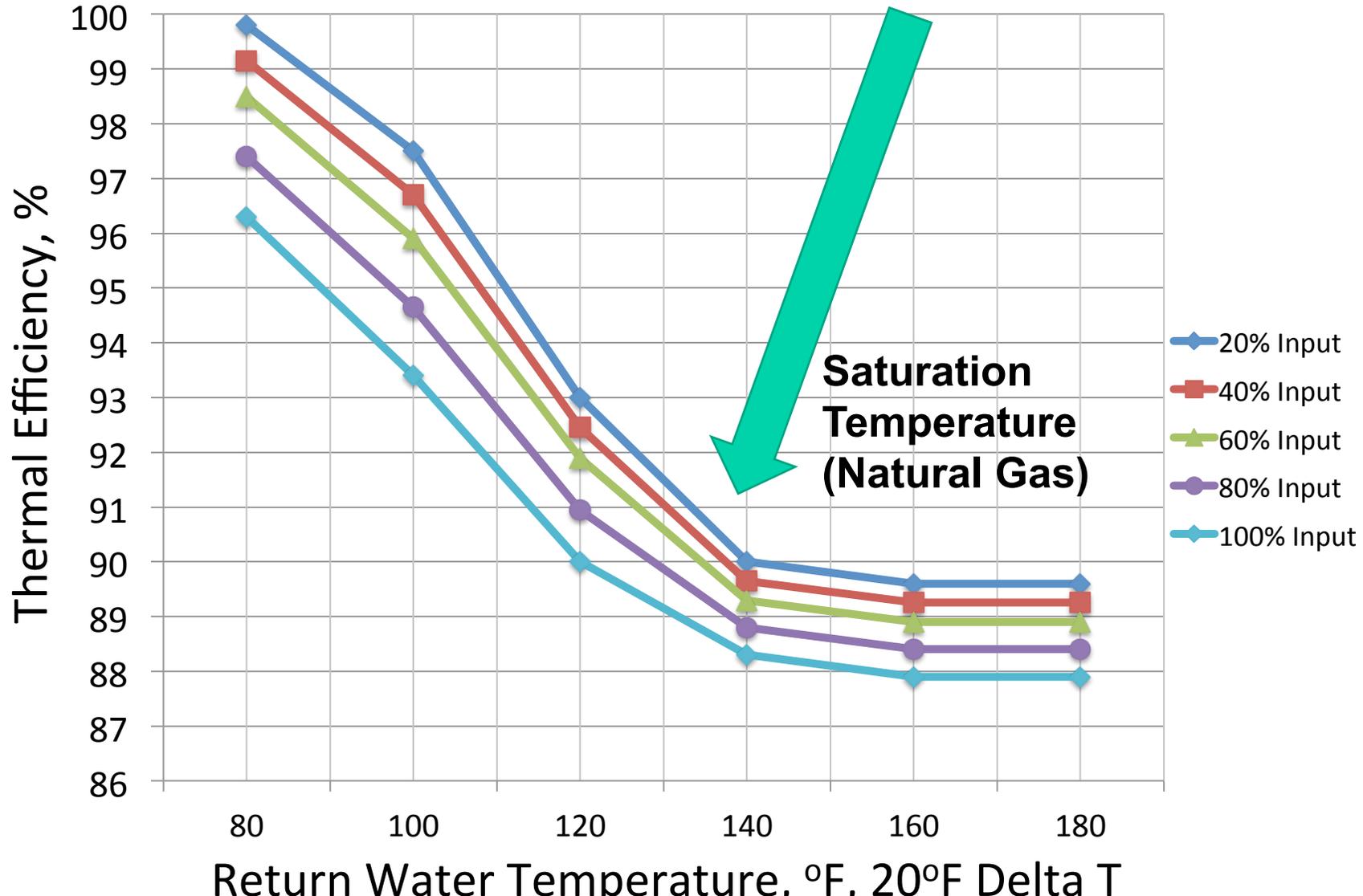
Efficiency Curve for Condensing Boiler



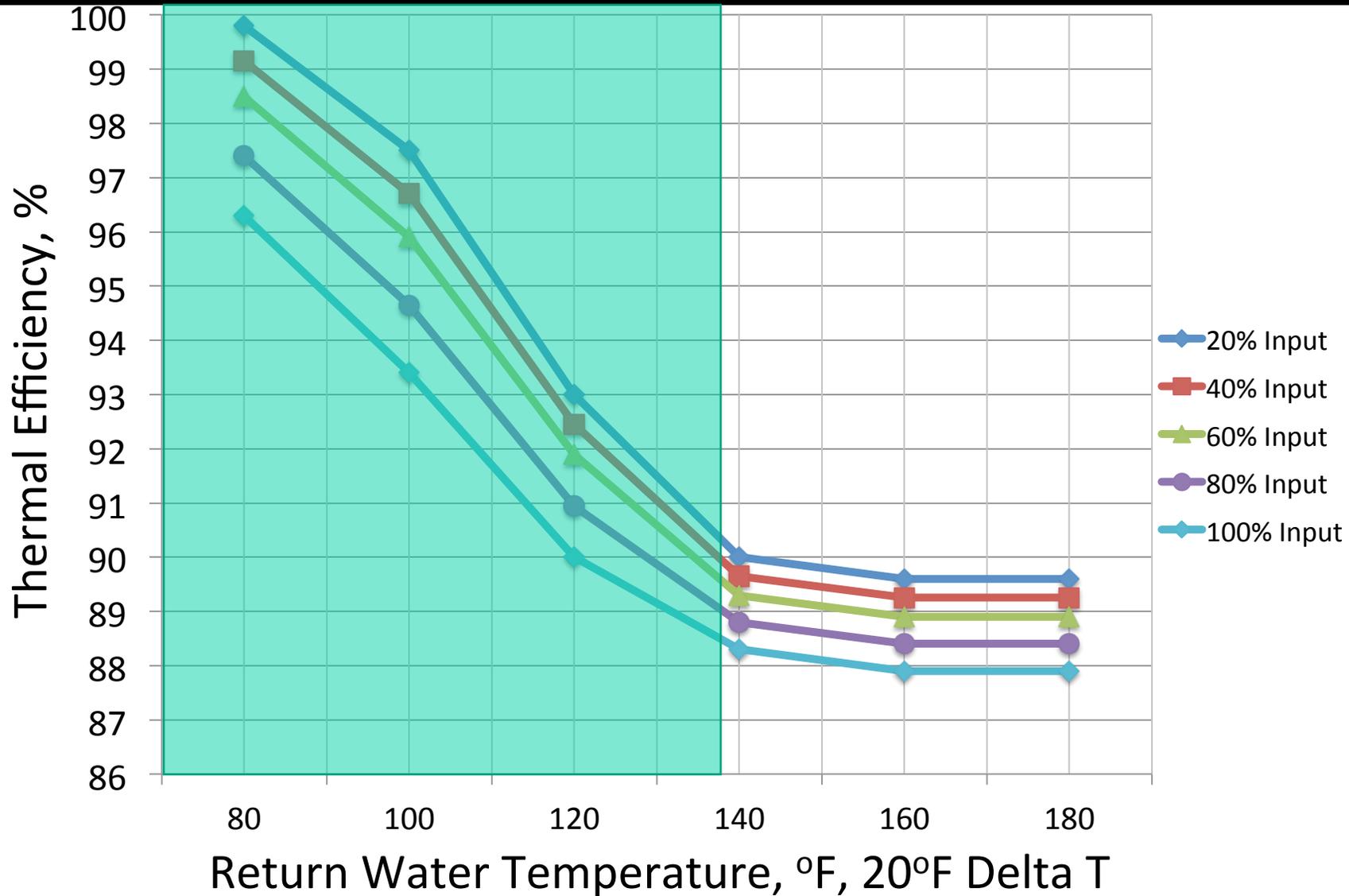
Condensing Boilers



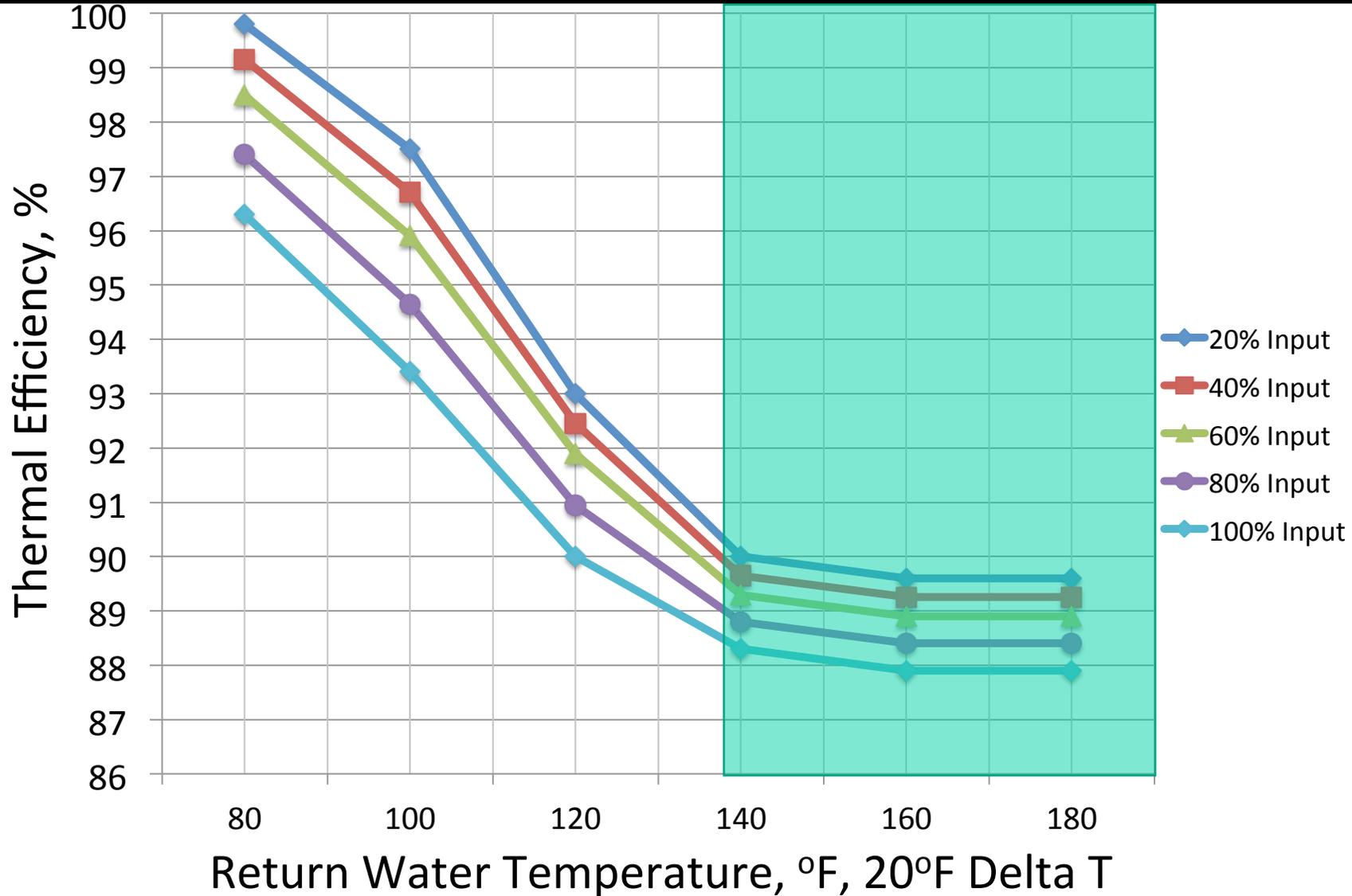
Efficiency Curve for Condensing Boilers



Efficiency Curve for Condensing Boiler



Efficiency Curve for Condensing Boiler



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

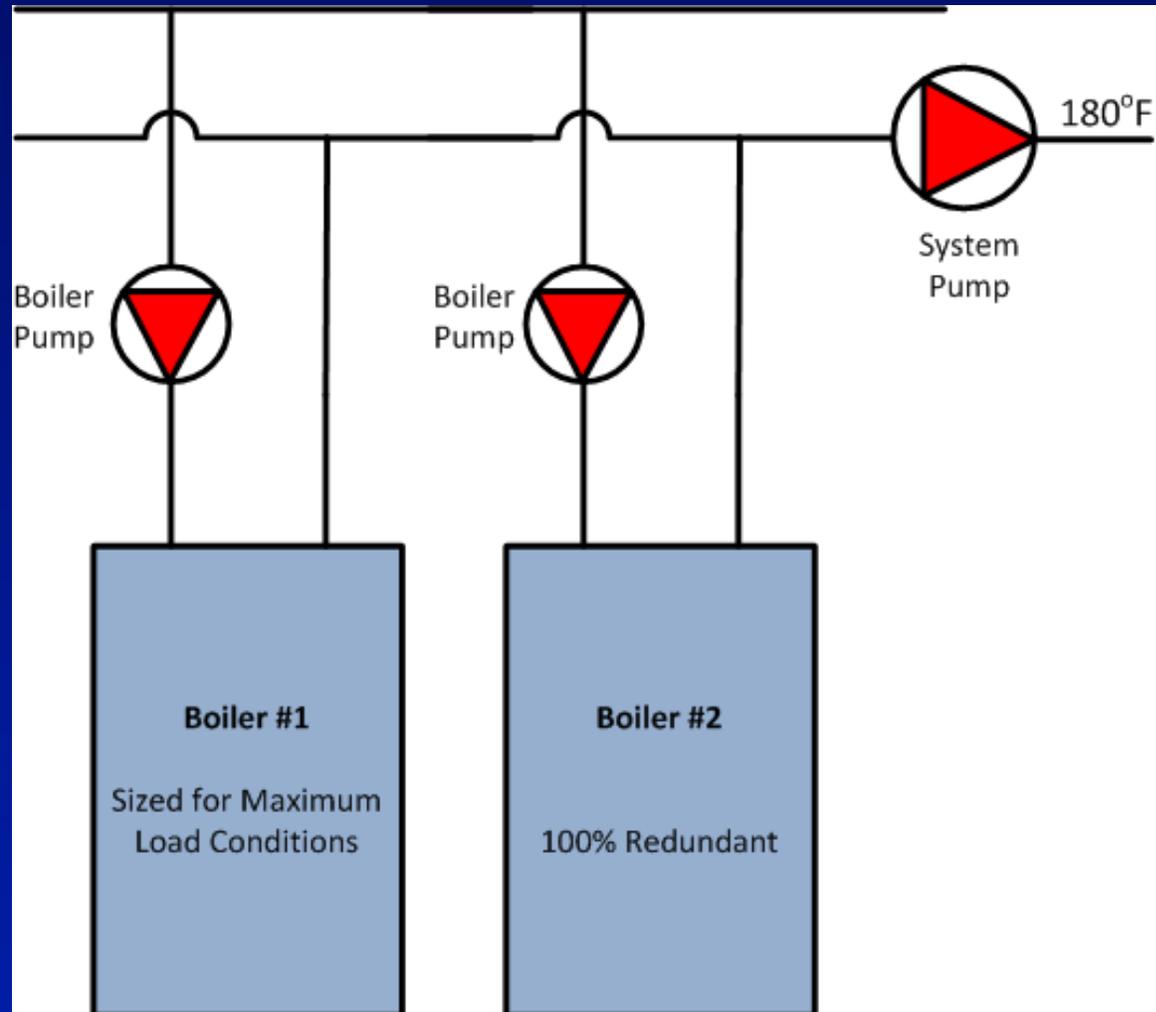
Thermal Efficiency Savings Potential with Condensing Boilers

- **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?**

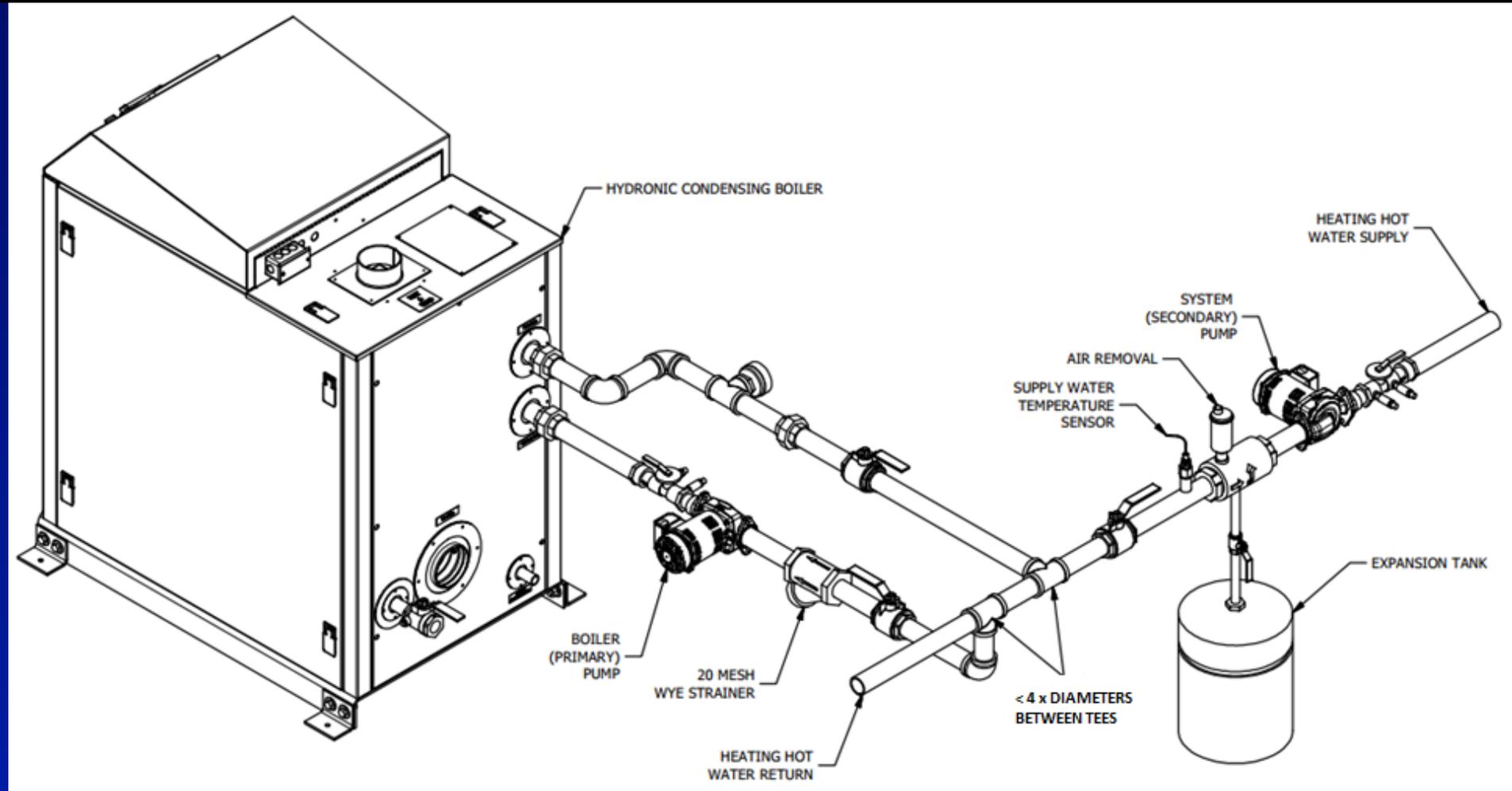
Primary/Secondary Arrangements The Applications

- **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)

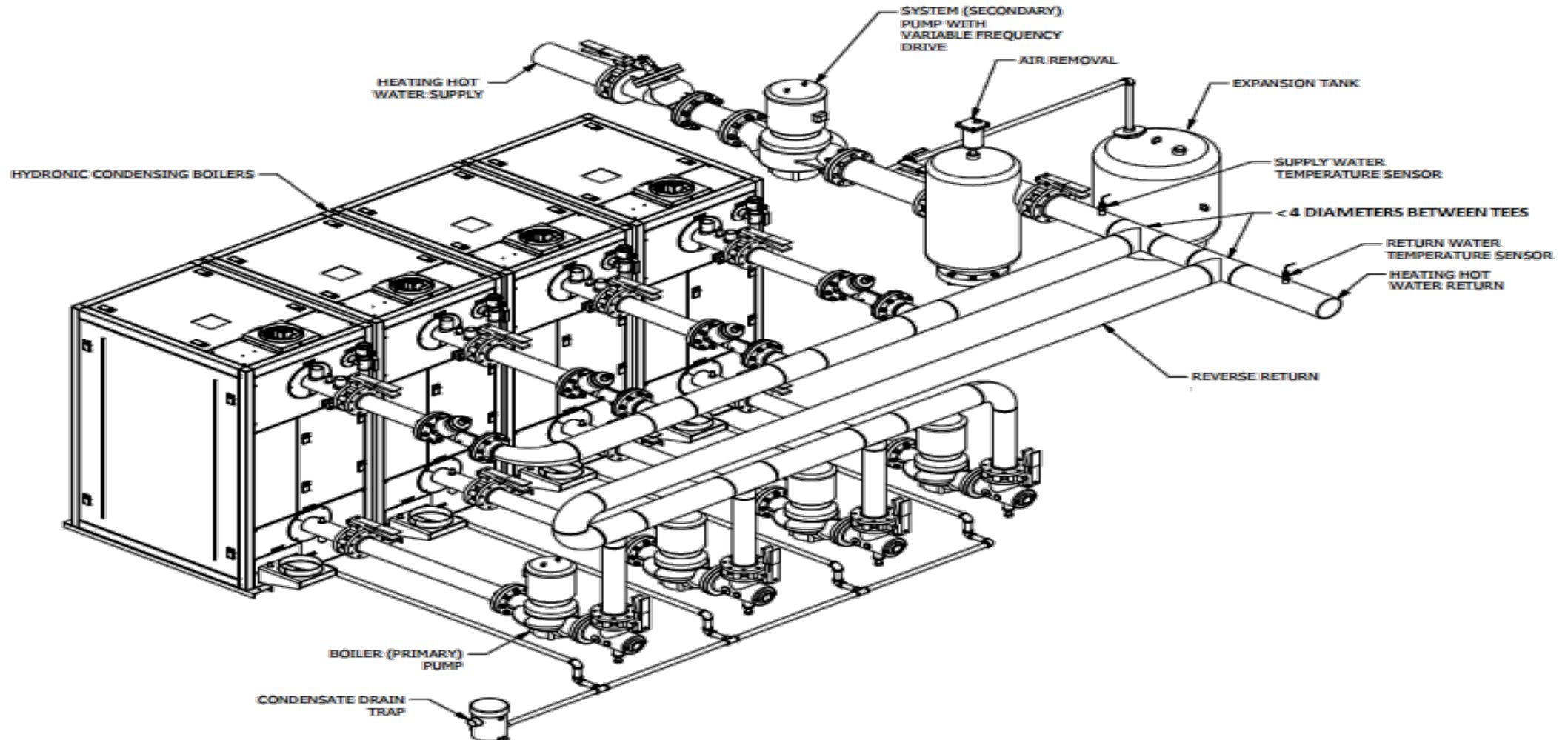
P&ID of Traditional Non-Condensing System



Primary/Secondary Piping For Condensing Boilers (Single)



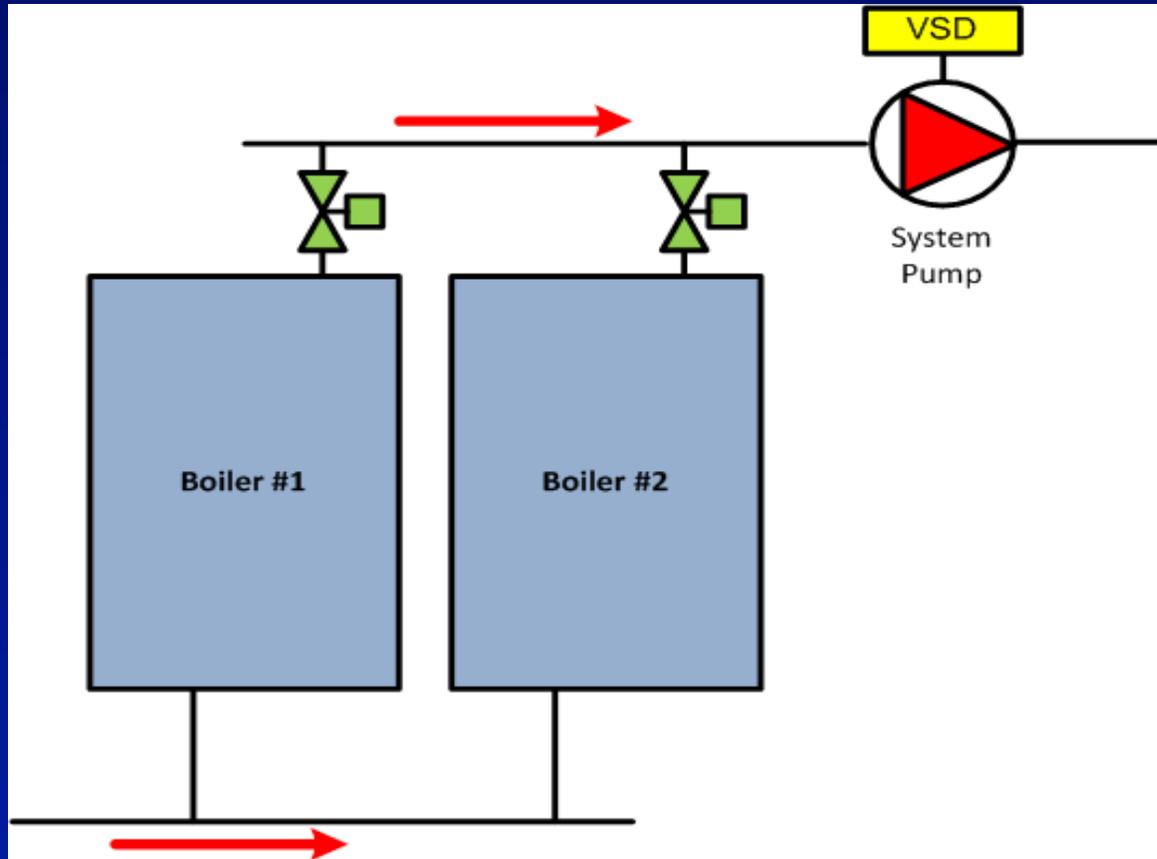
Primary/Secondary Piping For Condensing Boilers (Multiple)



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!**)

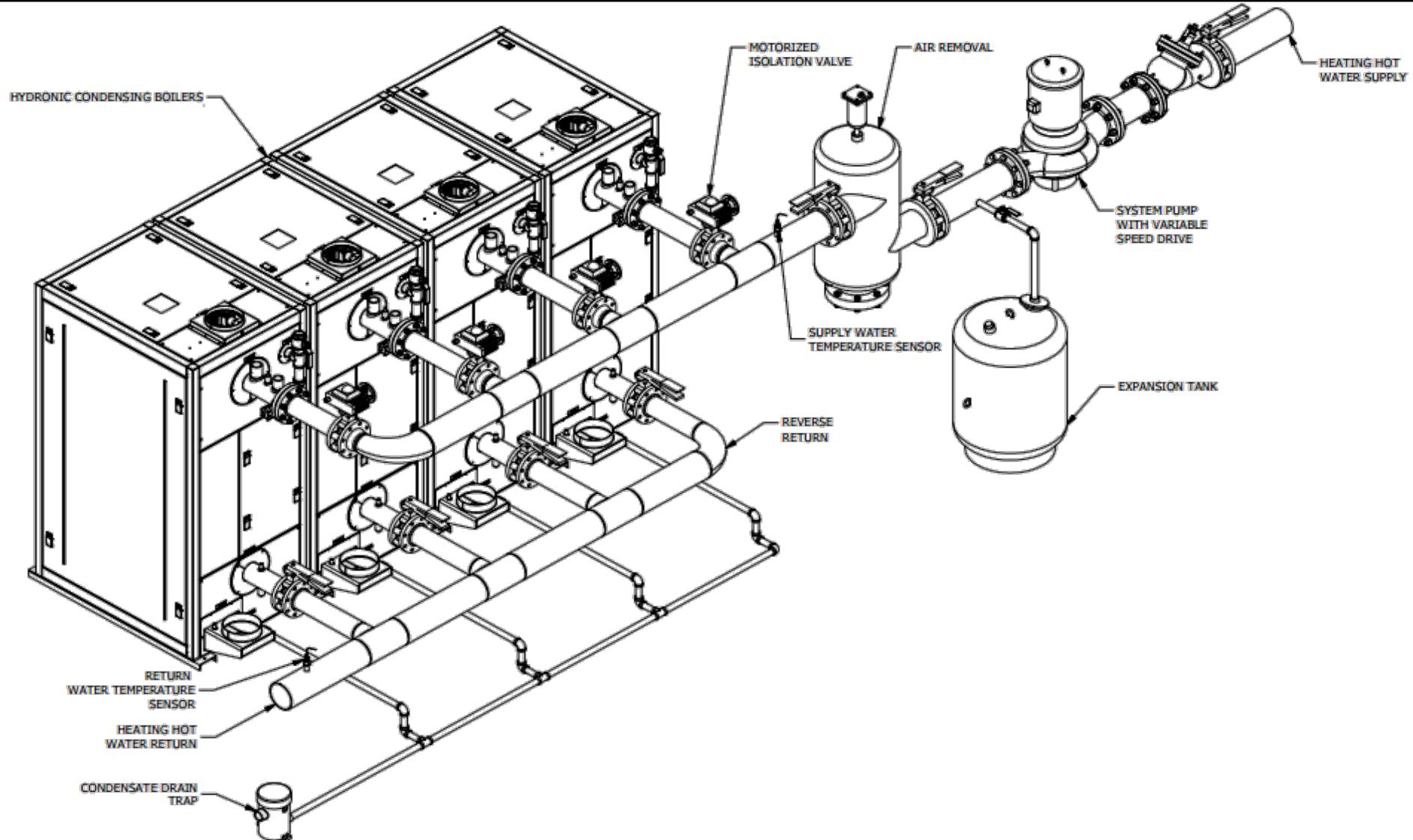
System Flow Directly Through Boilers



*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



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**

Financial Impact

	<u>Primary/Secondary</u>	<u>Primary Only</u>
	<ul style="list-style-type: none"> * (2) Non-condensing boilers * 75 HP each * No variable speed drives * Continuous 180°F 	<ul style="list-style-type: none"> * (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 <u>VSD's</u> <i>\$18,600 annual savings</i>	Condensing efficiency No boiler pumps VSD's on system pumps

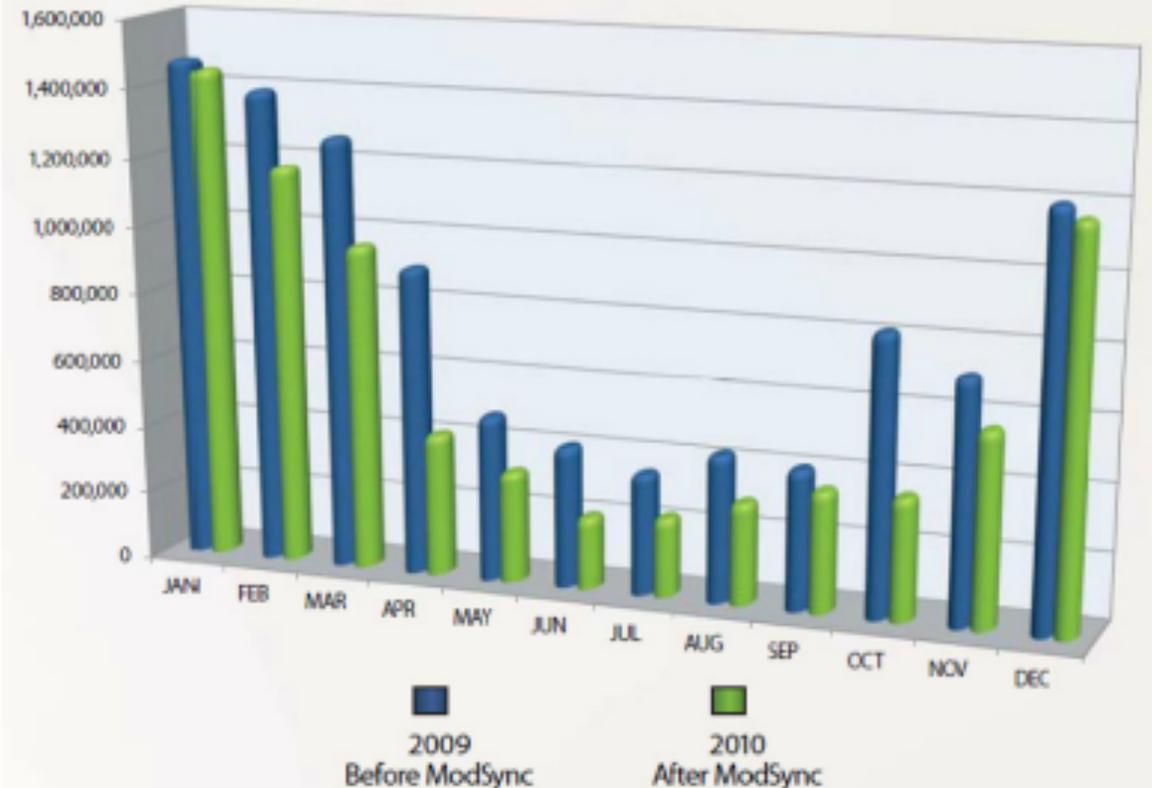
Long Term Investment

- **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

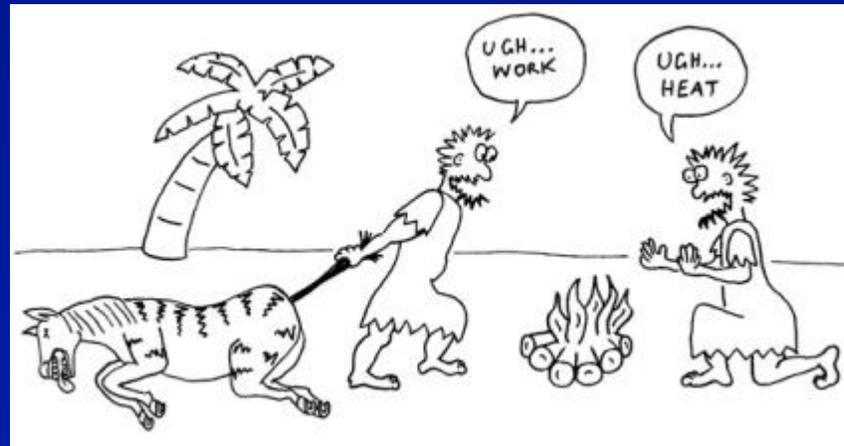
- Existing Condensing boiler System with boilers that been installed for 7 years.
- Replaced original control system with a controller based around condensing boilers
- 35% cost reduction
- Decreased cycles from 14,000/yr to less than 1,000.

Total Natural Gas Usage (ft³):
Before and After ModSync Installation



Summary

- **Condensing Hot water Systems are the now and Future of heating systems**
- **Steam still has its place**
- **Hot water Systems offer a better payback on your heating Systems**
- **Steam Systems require more maintenance generally**
- **Steam systems can potentially be a higher initial investment or can be cheaper up front**



Thank You!

Questions?