



U.S. Department of Energy
Energy Efficiency and Renewable Energy

Mechanical Systems - Enhancing Technologies

High Performance Heating Systems

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Question:

- **Who likes to save money?**
- **Who believes “simple” is better?**
- **Who doesn't like to save money?**
- **Who believes “complicated” is better?**



Chelmsford High School - 33% Saving a Year!

After 25 years the existing cast iron boilers were replaced with a 10 million BTU/hr. high efficiency boiler plant. The boiler plant has a total input in five (5) independent units.

After a complete year of operation, the system reduced fuel consumption 33% based on the owners figures.



Marblehead High School - 30% Saving a Year

This high school was designed around a 40°F temperature differential to take advantage of the condensing operation of high efficiency boilers.

Burning only and exactly the fuel needed, the high efficiency boiler plant is projected to save 30% or more of the energy used with a conventional heating boiler plant.

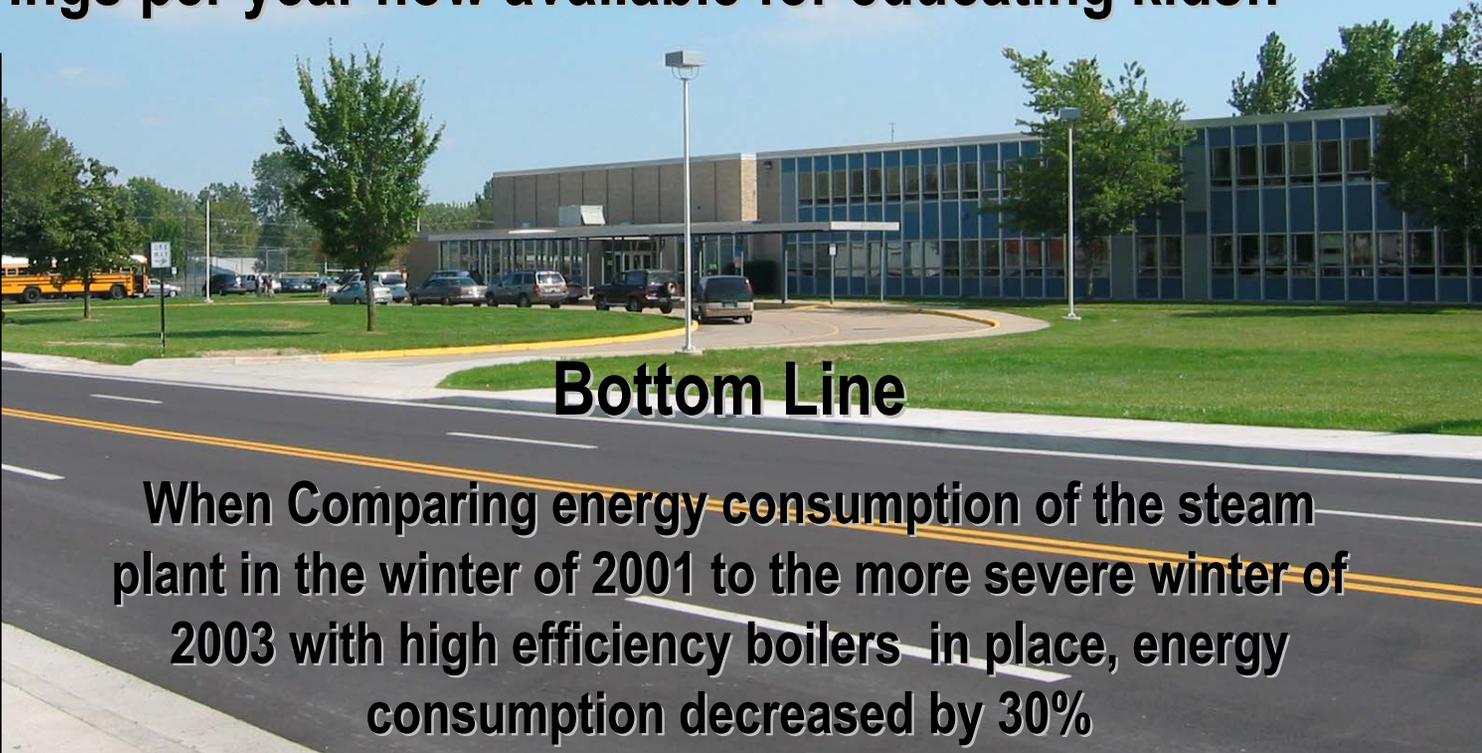




Geyer Middle School, IN

Geyer Simplifies their heating system by eliminating two (2) 42 year old large steam boilers and converted the system to hot water and installed high efficiency hot water boilers

30% Savings per year now available for educating kids!!



Bottom Line

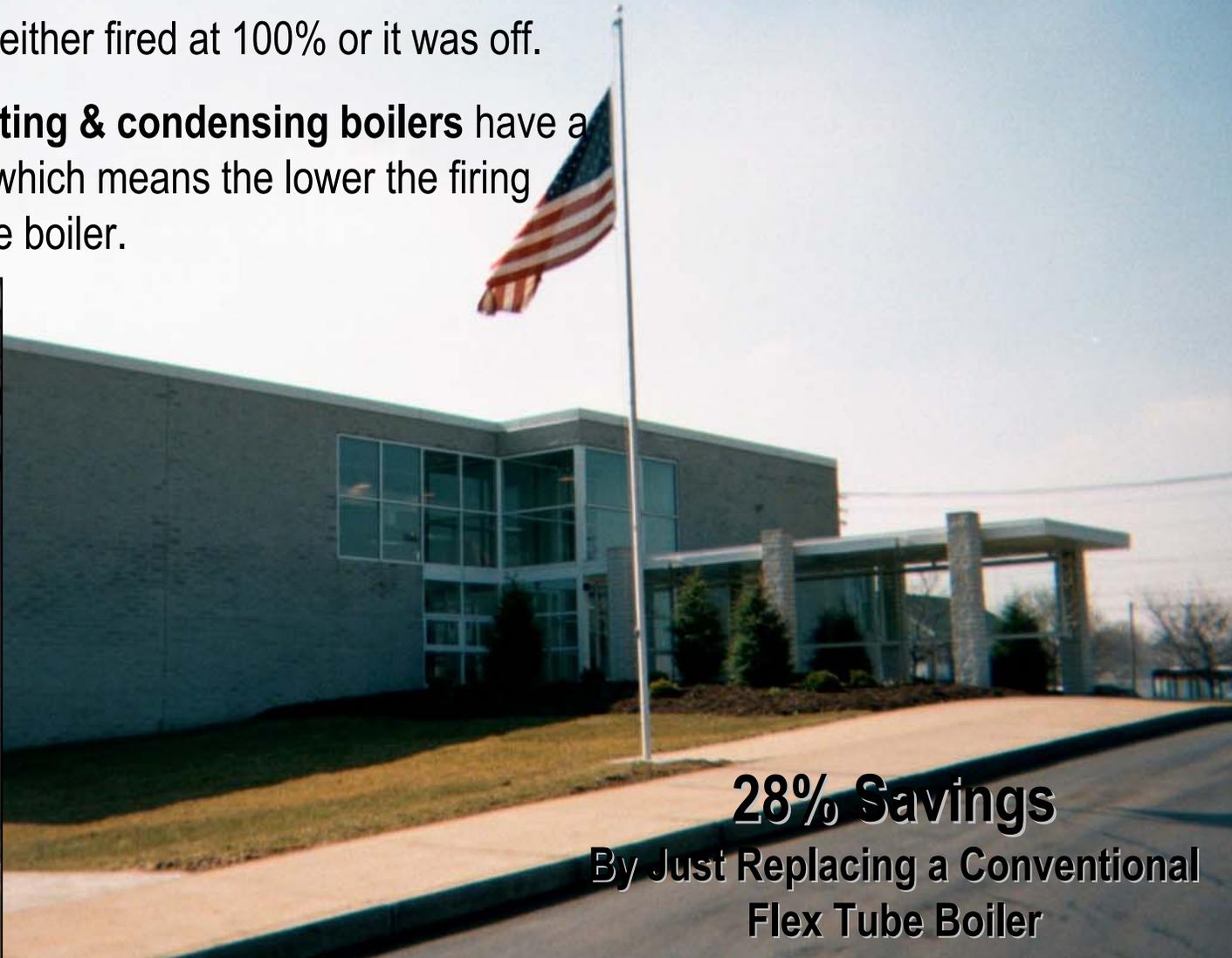
When Comparing energy consumption of the steam plant in the winter of 2001 to the more severe winter of 2003 with high efficiency boilers in place, energy consumption decreased by 30%



Cuyahago County BMR in Ohio

The Old Flex tube boiler either fired at 100% or it was off.

High efficiency modulating & condensing boilers have an inverse efficiency curve which means the lower the firing rate the more efficient the boiler.



28% Savings
By Just Replacing a Conventional
Flex Tube Boiler



Efficiency Definitions

Combustion Efficiency – 100% minus the percent of energy losses at the exhaust (heat, CO₂, free air and water vapor lost up the flue) - Flue Loss Method

Thermal Efficiency – Ratio of energy transferred to water compared to the total energy (gas & electric) consumed

Seasonal Efficiency - Overall Effectiveness of the Boiler Over the Entire Heating Season. Takes into account boiler operation at partial heating loads.



Question:

- **Which one of these efficiency terms could best be used to compare real operating costs for any given Boiler at the gas meter?**
 - ***Combustion (Flue Loss)***
 - ***Thermal***
 - ***Seasonal***



What is Considered a High Efficiency Boiler?

Conventional Efficiency: 80 - 83%

Mid Efficiency: 84 - 88%

High Efficiency: 89% and up (condensing)



Condensing

Captures "*latent heat*" for +90 + % efficiency by installing product with incoming water temperatures significantly below 140°F
(warranty coverage)



What Defines Condensing Boilers?

Condensing

The 'regain' of energy that occurs when water vapor found in flue gas changes state (condenses), becoming a liquid.

1 pound of condensate = 970 BTUs

When condensing occurs within the heat exchanger, the additional energy (heat) is transferred to the boiler water.

Why Condensing Occurs

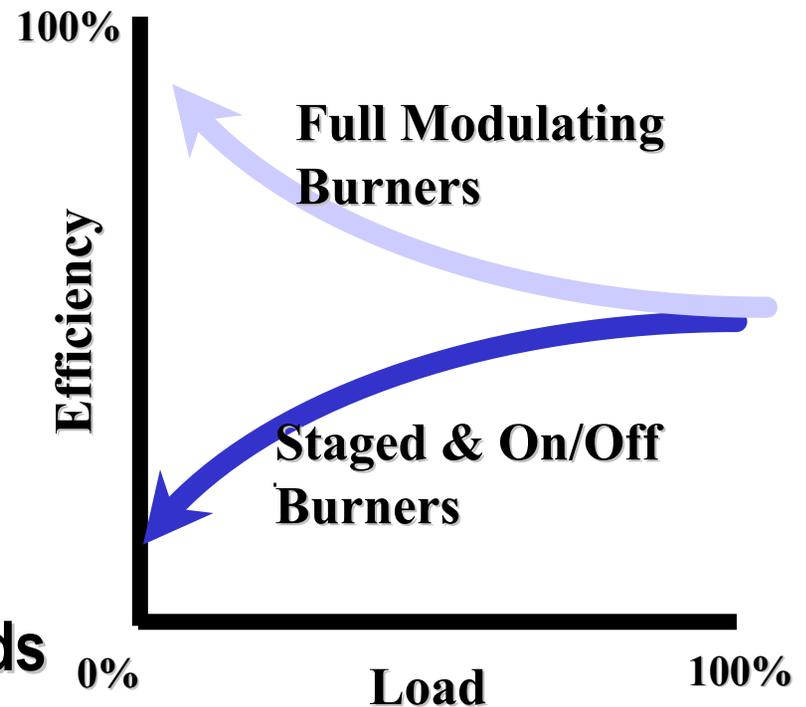
When flue gas drops below its dewpoint ~ 135°F condensing occurs. Cool water surrounding the heat exchanger "cools" flue gases within.

In general, you cannot achieve thermal efficiencies in excess of 87% without some condensing occurring.



Why Modulate the Fuel/Air Input?

- **Turndown Increases Efficiency**
Eliminates *Cycling* Losses
No Energy Waste
- **Match Energy Input**
to Actual Heating Load
No Energy Waste
- **Precise Temp Control at All Loads**
Maximize System Efficiency
& Simplify Building Controls





Thermal Efficiency Rating

$$\text{BTU/hr} = 500 \times \text{Delta T} \times \text{GPM}$$

Thermal Efficiency Measurement: (Energy out/Energy in) x 100

But...

Test Conditions Require:

- 80°F inlet water temperature**
- 180°F outlet water temperature**
- 100% Firing Rate (full capacity)**
- 30-minute test period after “full soak”**

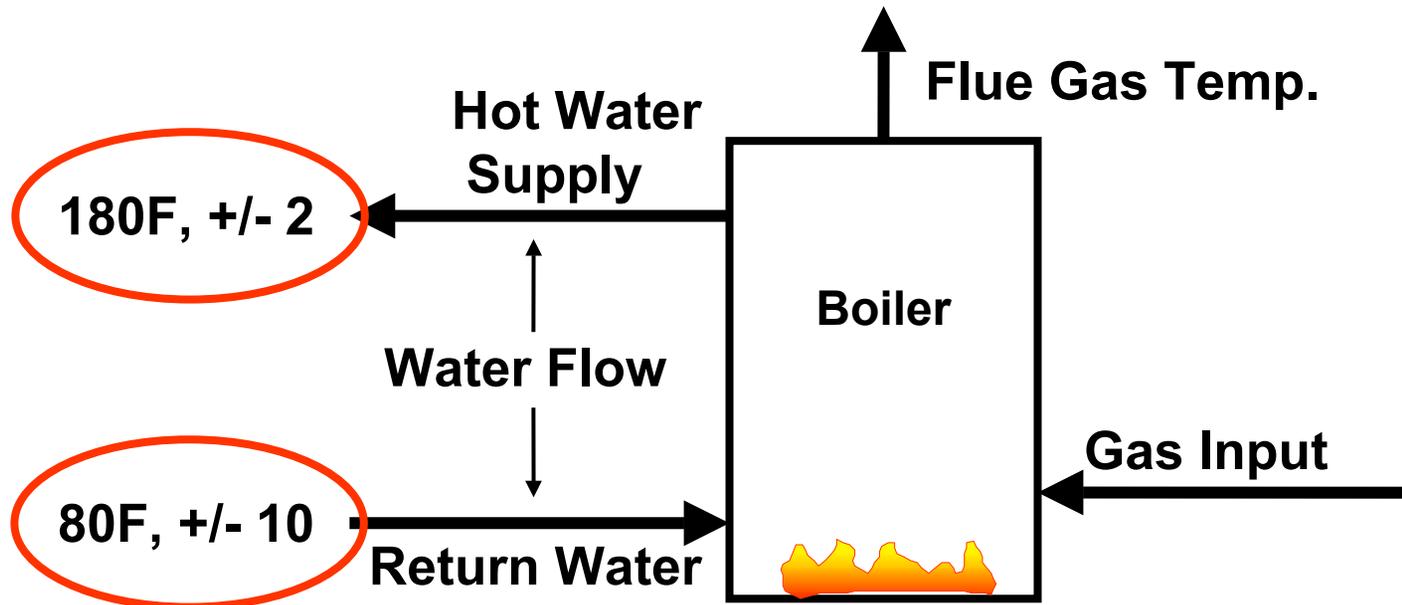
This is NOT representative of typical heating applications!



ANSI Z21.13-2000: Thermal Efficiency Test

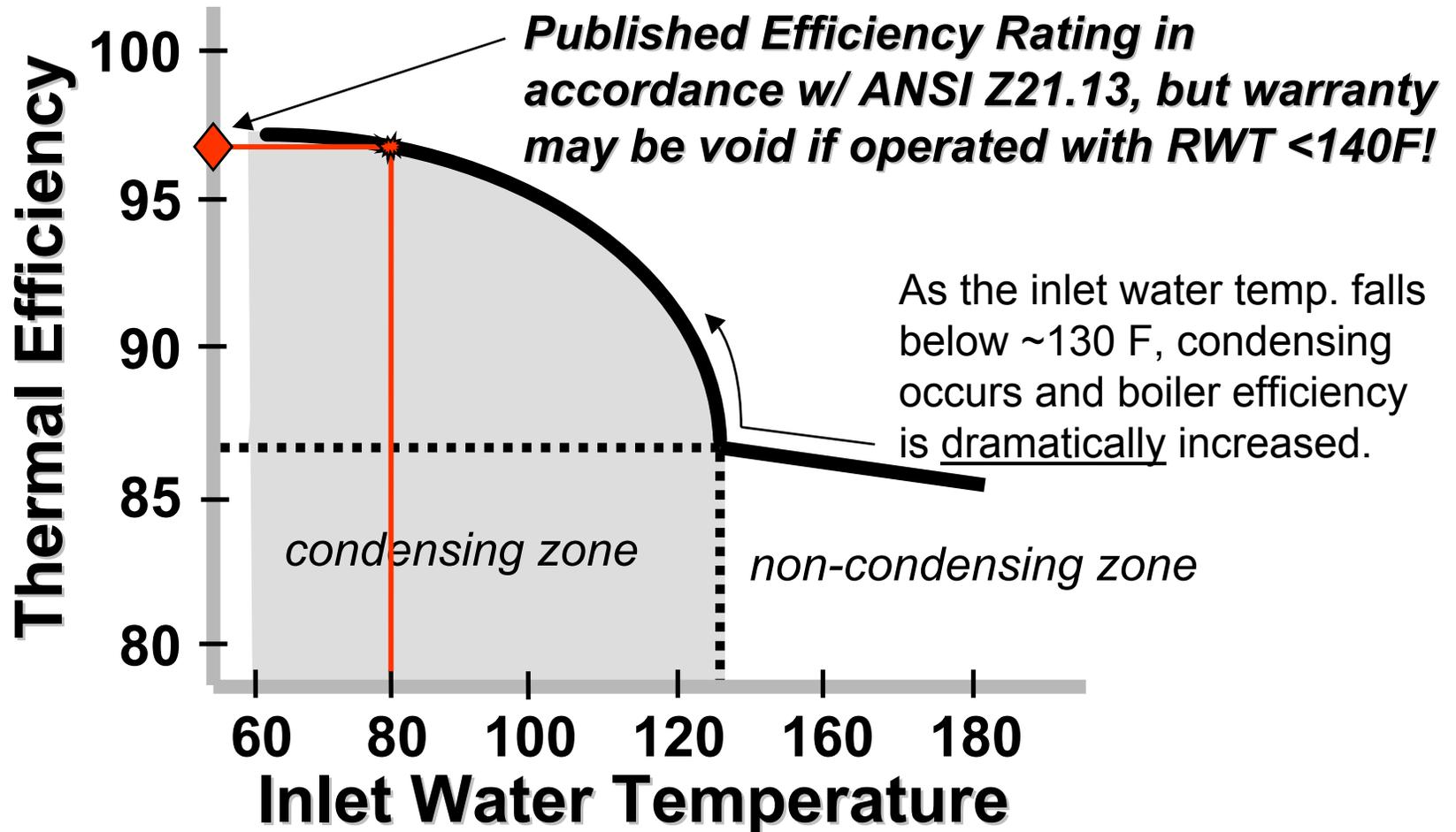
300,000 Btu/h to 12,500,000 Btu/h
Test Boiler at Full Capacity

$$\text{Thermal Efficiency} = (\text{Energy Out} / \text{Energy In}) \times 100$$





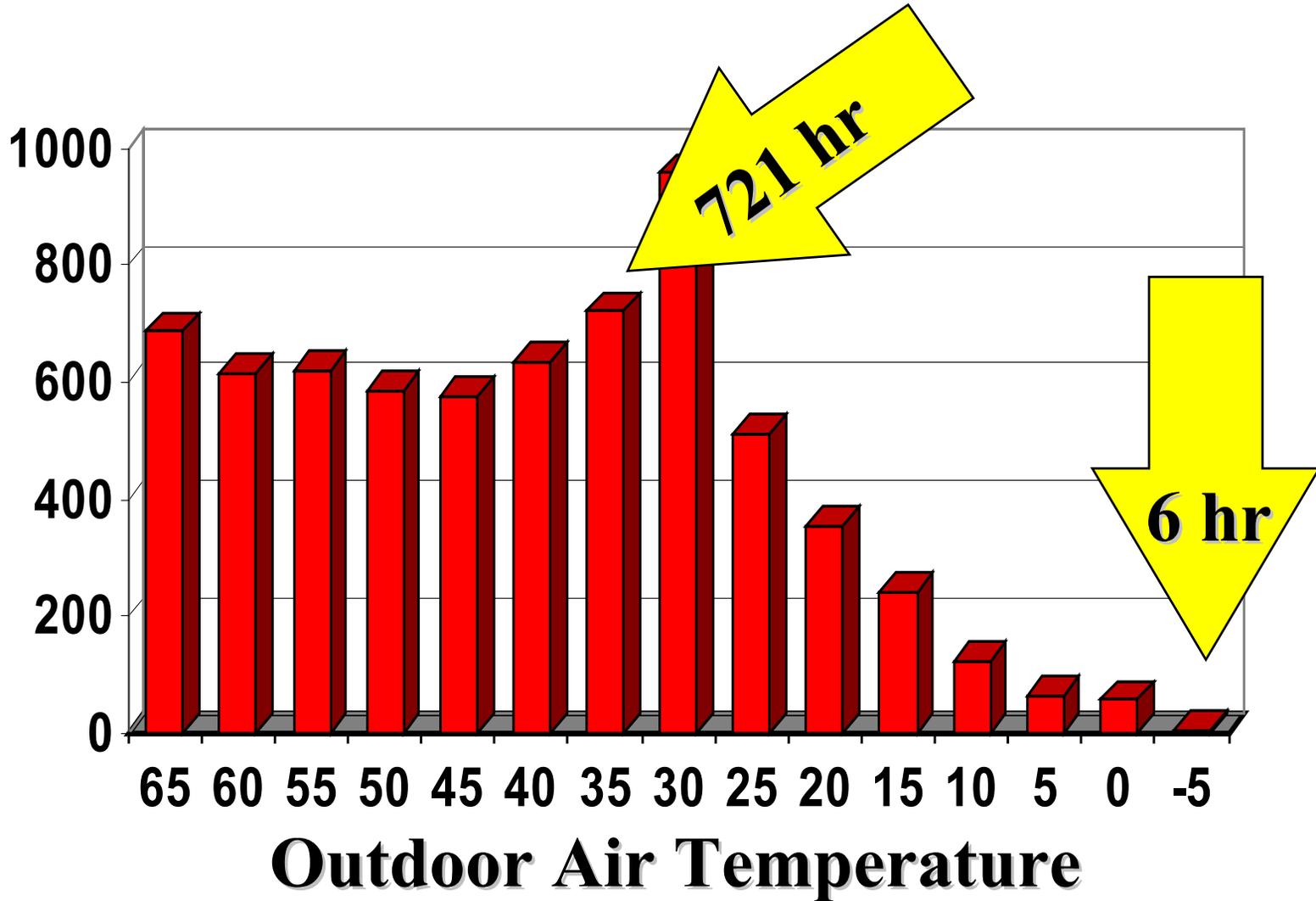
Inlet Water Temp Effect on Boiler Efficiency





ASHRAE Bin Data

Bin Hours





Assume Full Plant Capacity on Coldest Day

2000 MBH load at -5° F

2000MBH x 6 hrs. = 12,000,000 BTUs

That's 120 therms @ \$0.50/therm = \$60

Assume Partial Loads on Other Days

800 MBH load at 30° F

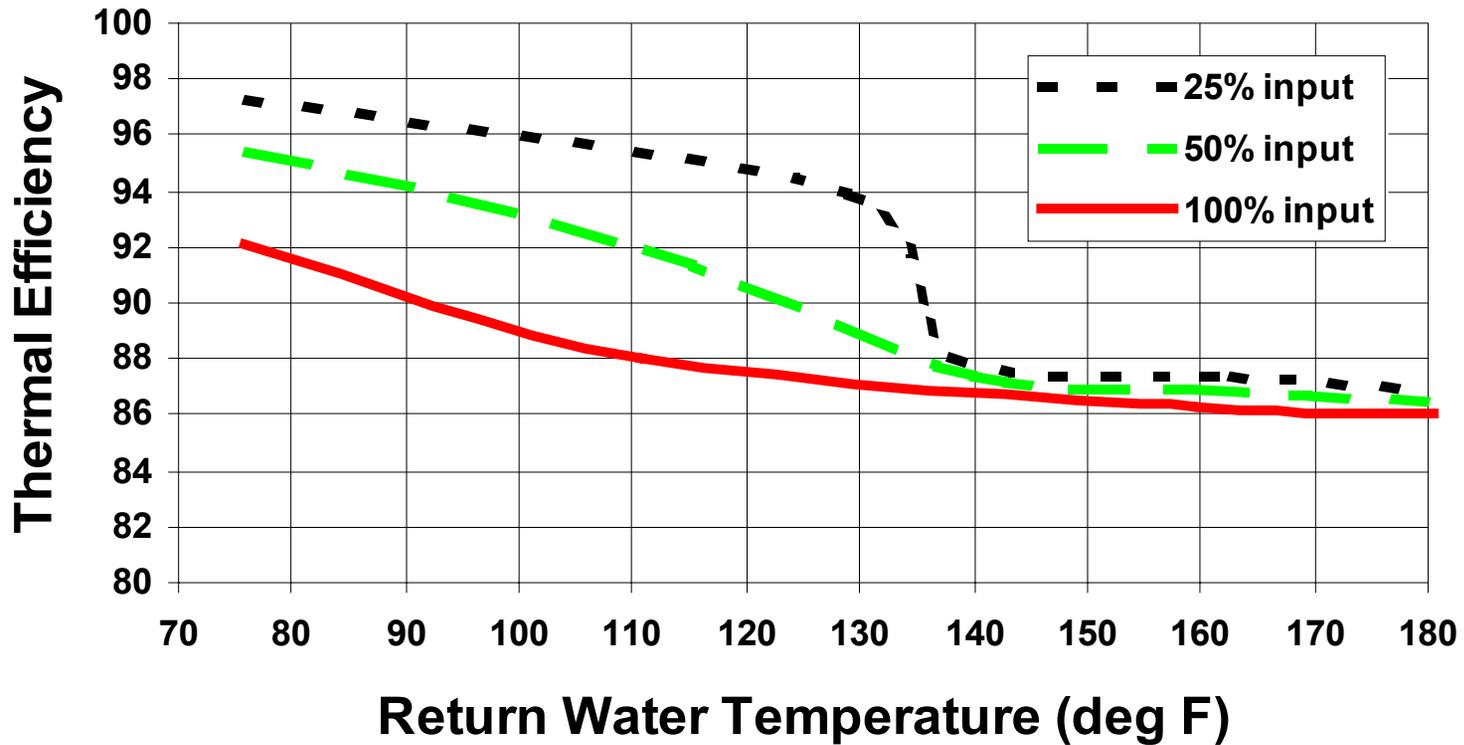
800MBH x 721 hrs. = 576,800,000 BTUs

That's 5768 therms @ \$0.50/therm = \$2884

When should the boiler operate most efficiently?



Full and Part Load Efficiencies





How The Industry Modulates Its Firing Rate

Examples:

Linkages from a
Motorized gas
Valve to a
Damper on the
Exhaust

or

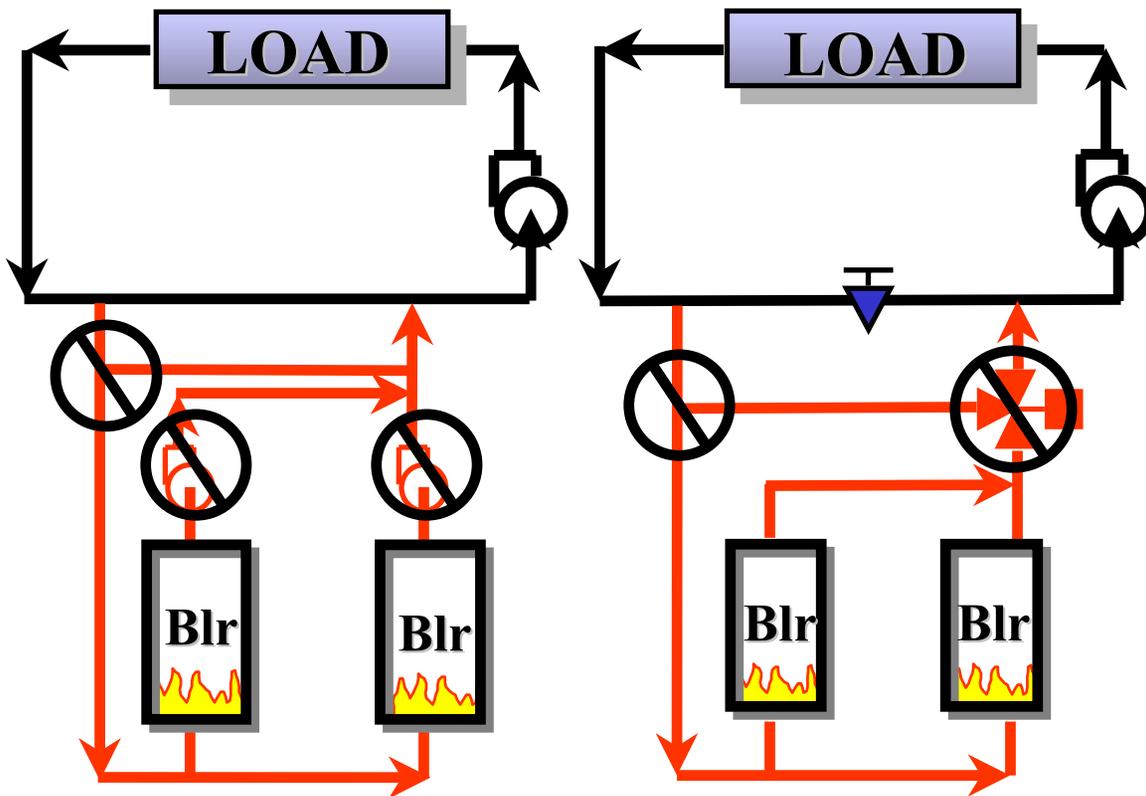
Single Shafted
Motorized
Air/Fuel Valve





Conventional Boiler Piping

Primary/Secondary Pumping or Control Valve

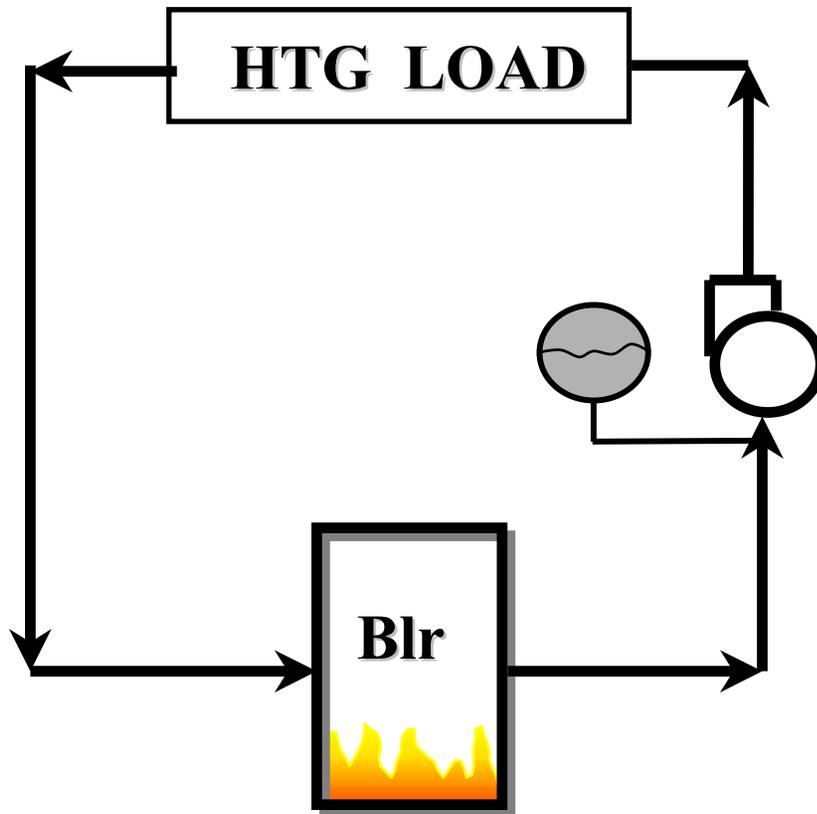


Protect boiler:

- condensing
- thermal shock
- reduce standby losses



High Performance Heating System



Eliminates Auxiliary Components:

❖ **Primary/Secondary Pumping & Controls**

❖ **2, 3 or 4 - Way Valves**

and

Maximize System Efficiency

Maximize Boiler Efficiency

Reduced Installation Cost



Maximizing Heating System Efficiencies

- **Increase Temperature Differential from 20°F to 40°F (or more)**

Result: Smaller pipe size

Lower pump horse power (cost and consumption)

Improved /operation of valves & terminal units means

better control over room temperatures

Lower return water temps to condensing boiler

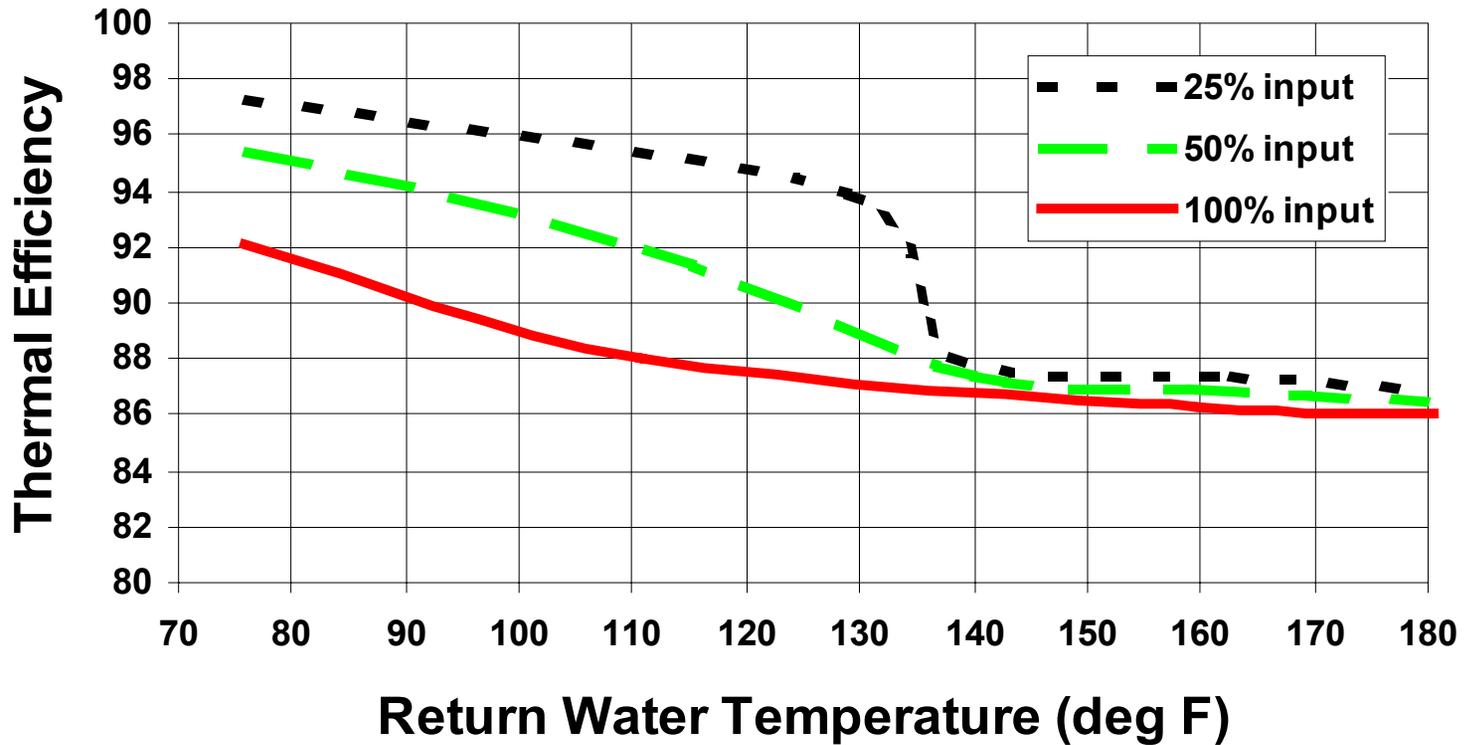
means higher boiler efficiency

- **Variable Speed Pumps**

Result: Energy Efficient, Better room temperature control



Full and Part Load Efficiencies





How Can I Achieve 90%+ Average Seasonal Efficiency?

- **Boiler must condense water vapor in flue gas under operating conditions**
- **Must reduce cycling losses by modulating boiler input at partial load conditions**
- **Must design the system to take advantage of boiler and controls technology**



More Questions for the Industry?

- **Does the boiler modulate? How much? How?**
- **Is the boiler a condensing boiler?**
- **What is the boiler constructed of?**
- **How diverse is the boiler's venting capabilities?**
- **Can I take advantage of the boiler capabilities in my overall heating system?**



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Thank You For Attending This



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