Low Temperature Heating

Applications and Economics

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130 F Max

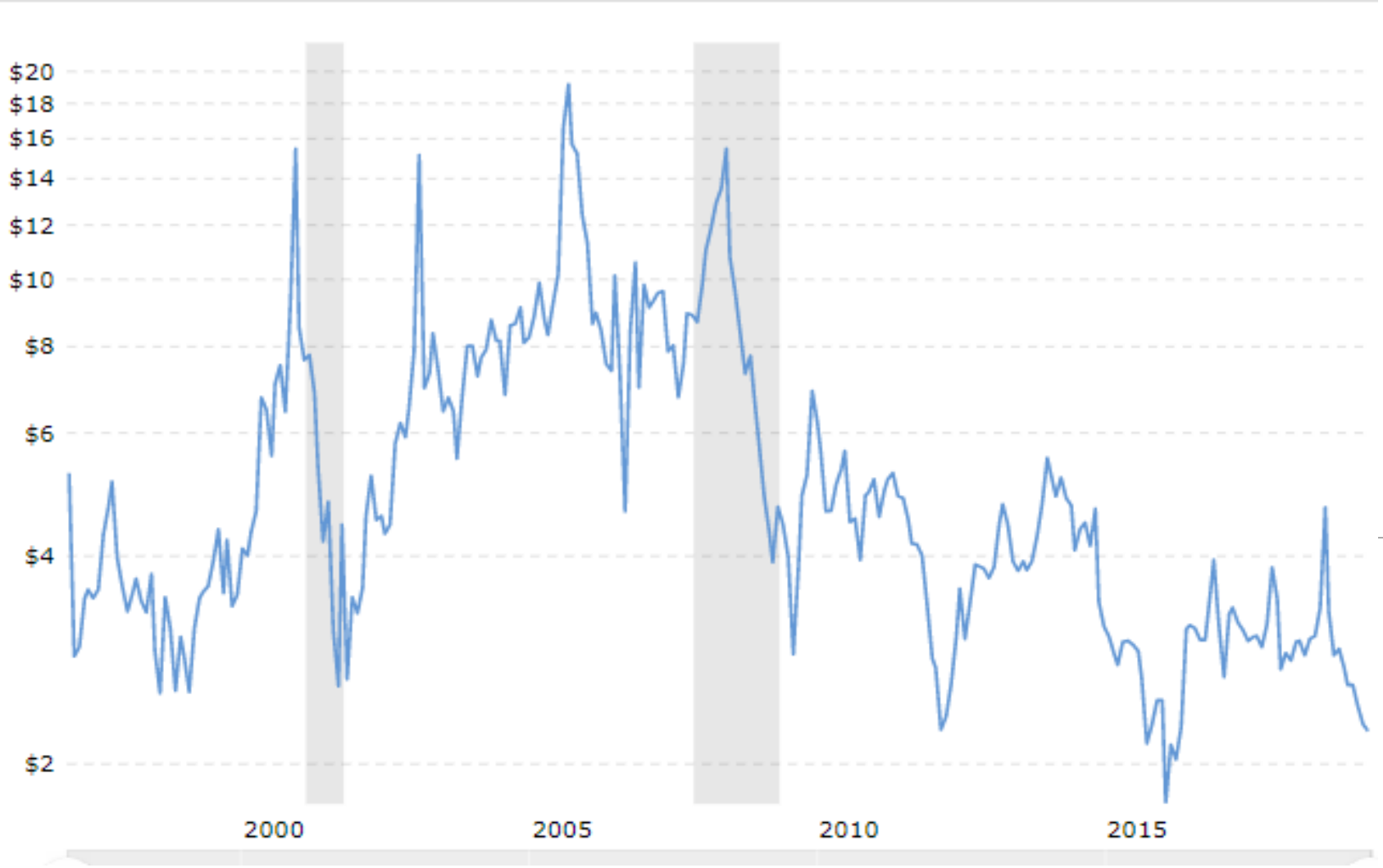
USGBC Data

39% of total US energy goes into non-residential buildings.

Gas for heating is about 60% of energy used in a building

Gas for heating is about **¼ of total energy used in the US.**

Historic Natural Gas Pricing




Green Valley Elementary School
New Albany, Indiana

The (Inadvertent) Greening of Green Valley Elementary

"Environmental Equity" project

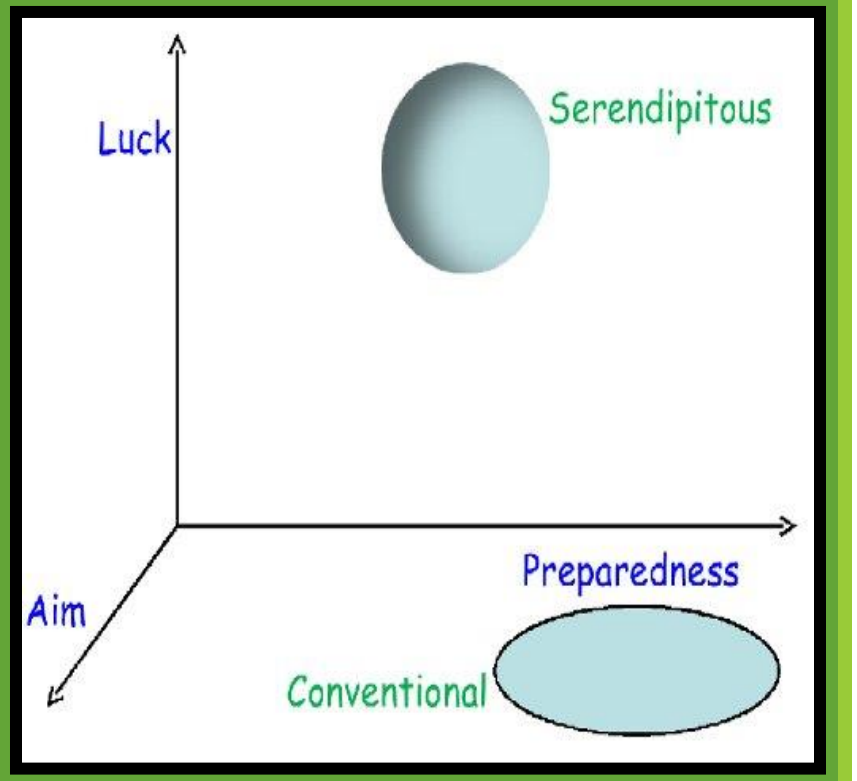
- Add air conditioning
- Very limited budget

From the scrap heap of history, the modern

2-Pipe System

- Using a coil selected for cooling/dehumidifying to heat
  - You don't need much water and it doesn't need to be very hot.
- Hence, low temperature heat from condensing boilers.

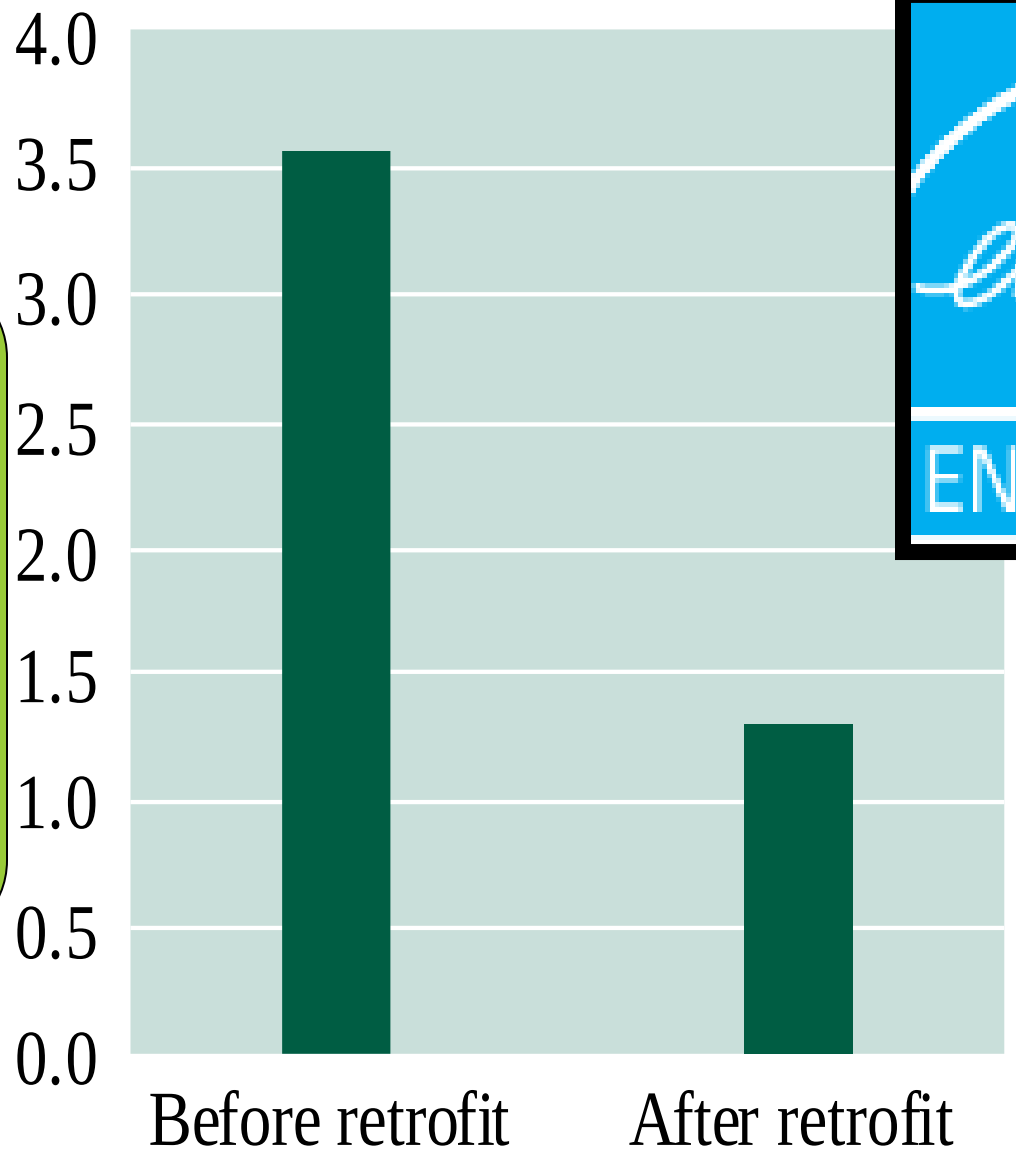
Serendipity



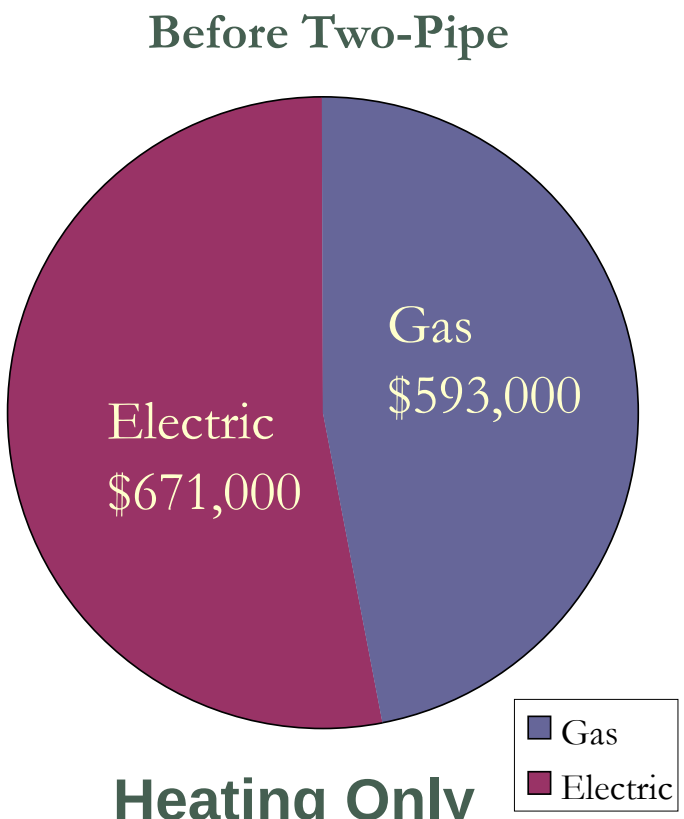
We were looking for a solution that fit the budget and solved the age-old comfort complaints without compromising IAQ.

We achieved all the above and **significant** efficiency gains.

Therms per Heating Degree Day



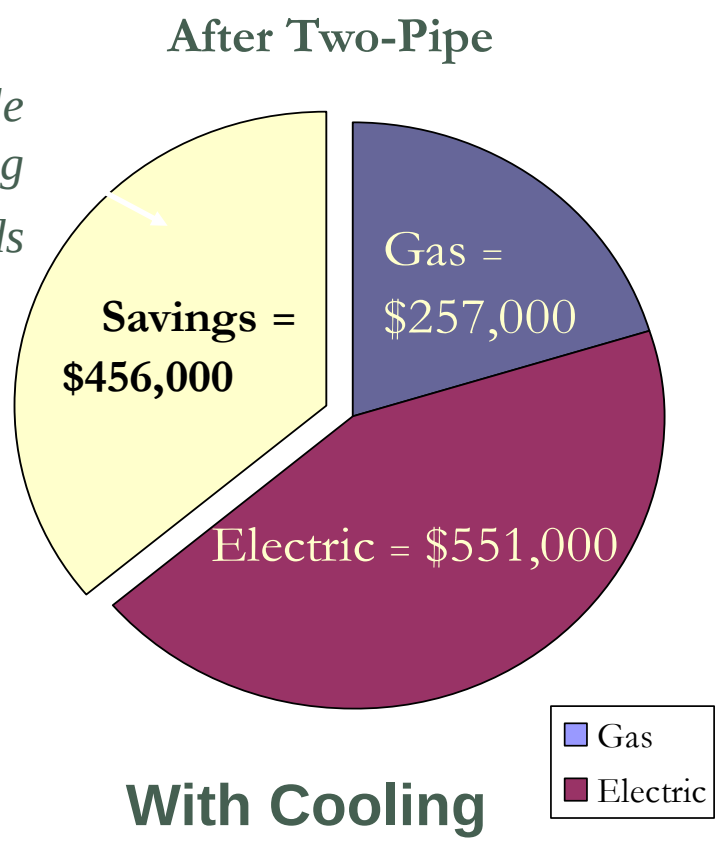
20 School Buildings



Heating Only

$1,264,000

Now available for educating kids



With Cooling

$808,000

As-Found Boilers

Typically, 2 per building at 60-75% of anticipated peak

All had energy management controls

All were well maintained

Mix of fire-tube, water-tube, no natural draft

Average age 25 years

10 were LP (5 PSIG) steam

10 were 180F HW, with reset schedule

New Design

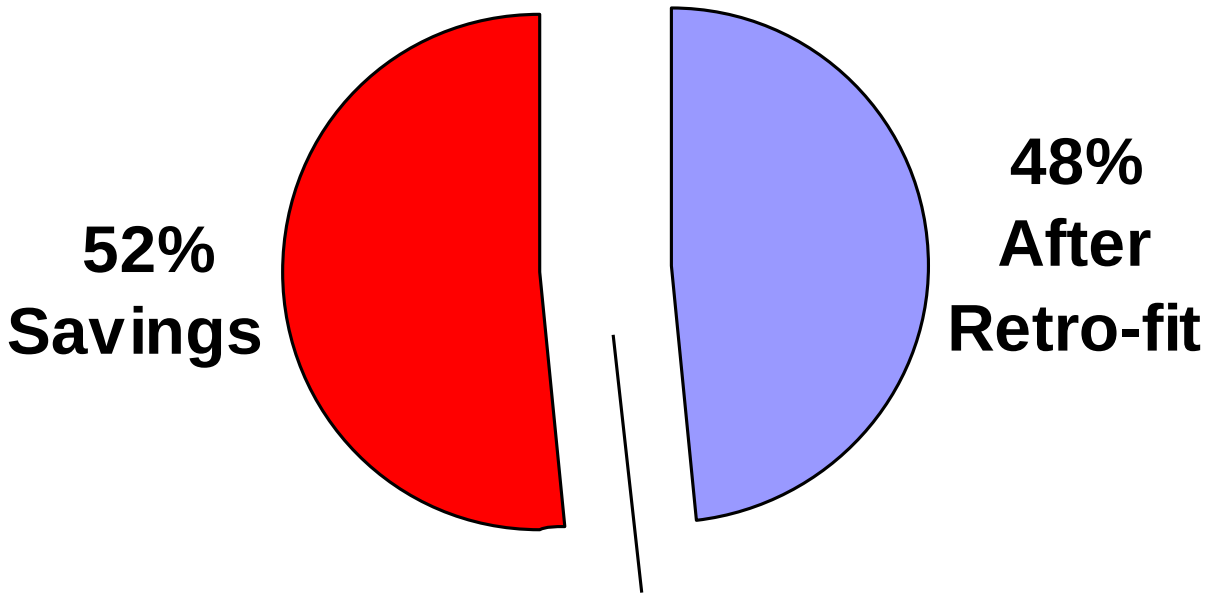
True condensing boilers

130F max temperature at OAT below 20F

Reset versus outside air temperature to 90F at OAT above 60F

N + 1 redundancy

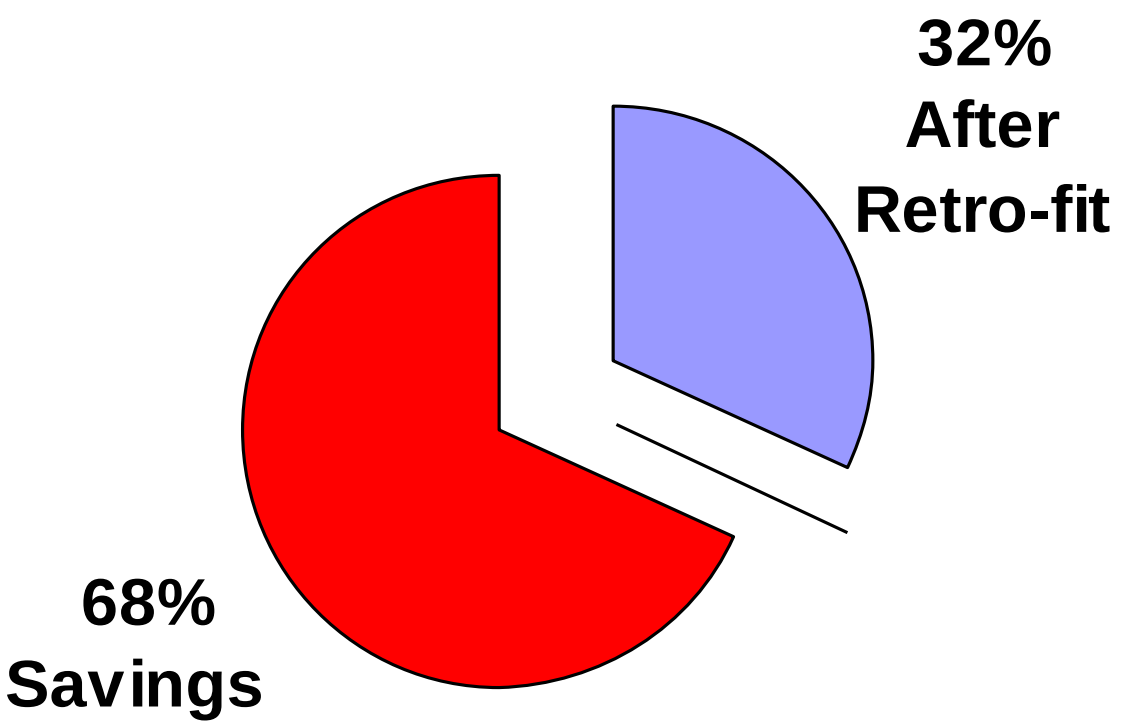
180F to Low Temp HW



Low Temperature:

HW Supply (HWS) = 90F at 60F OAT ;
reset to HWS = 130F at OAT<20F

Steam to Low Temp HW



Low Temperature:

HW Supply (HWS) = 90F at 60F OAT ;
reset to HWS = 130F at OAT<20F

Steam or HT hot water = 75 to 80%

Base efficiency hot water boilers = 80 to 83%

Mid-efficiency = 83 to 88%

Condensing boilers = 88 to 95%

How is efficiency defined?

Combustion (thermal) efficiency

Vs.

Overall efficiency

Vs.

Seasonal efficiency (AFUE)

(ASHRAE Handbook S32.6)

How is combustion efficiency measured?

ANSI Z 21.13 - 2000

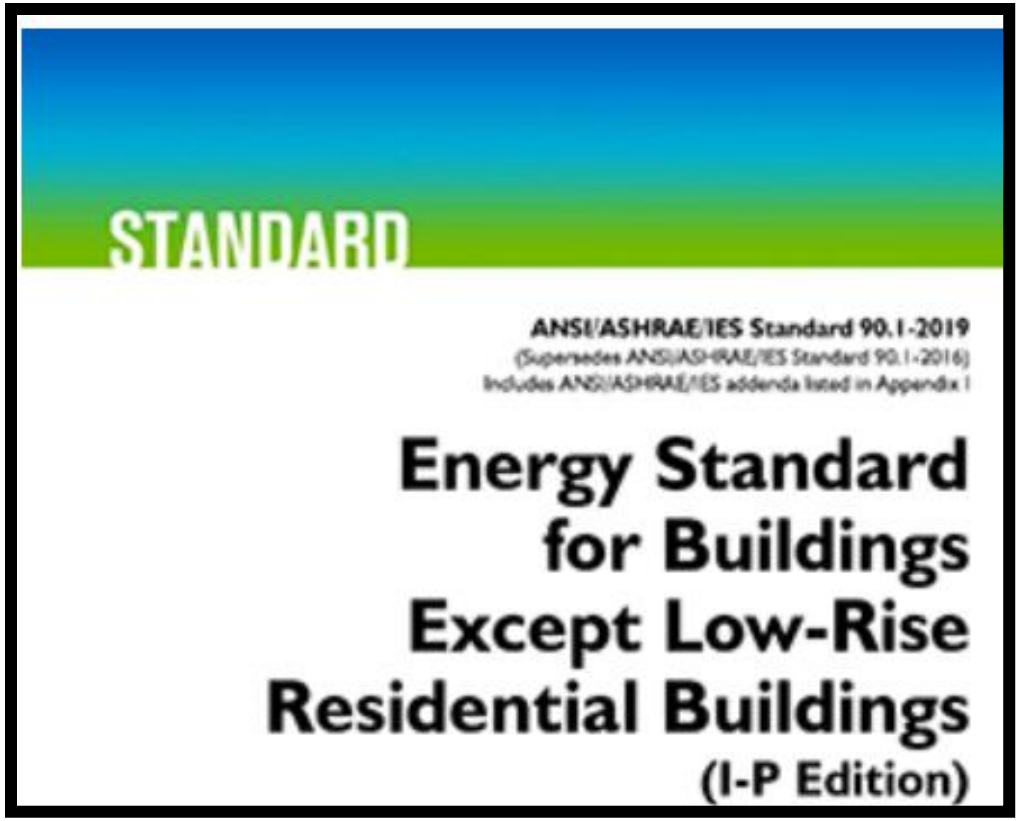
- Steady state operation
- Full load
- 80F entering water

(ASHRAE Std 155P will be more reflective of actual conditions.)

What does ASHRAE say?

Standard 90.1

- Must meet the minimum efficiency requirements of ANSI Z21.13
- Select one for best efficiency at full and part load
- Operate at lowest possible water temperature



What's the lowest temperature?

- From anybody's boiler book…

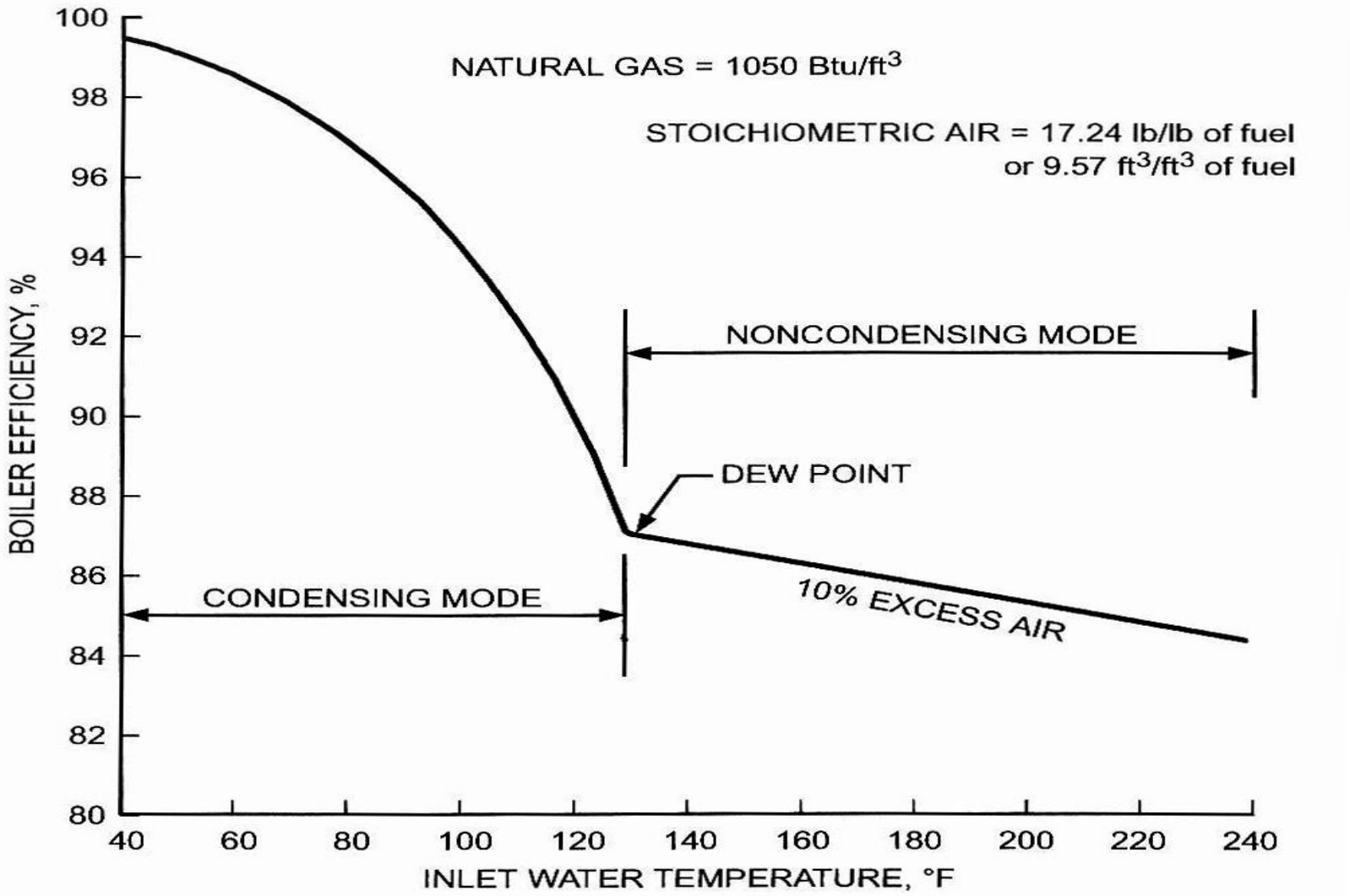
"Warning: Inlet water temps below 140F (60C) can excessively cool the products of combustion in the heat exchanger and flue. Operation is that range may void the warranty."

Hence the "standard" 180F design with O/A reset.

Effect of Inlet Water Temperature

Products of combustion of natural gas are CO2 and H2O.

As the flue gases cool, the latent heat of the water vapor (+/-1,000 BTU/Lb) goes into the process.



It isn’t just the efficiency!

The capacity will go down too!

A boiler rated at 2.0 MBH input and 1.6 MBH output will only be capable of 1.4MBH at 140F EWT.

What isn’t in the calculation?

Jacket losses

Purge losses

Combustion air and flue losses

Pipe losses

Start-up losses

Part load effect

Jacket and Purge Losses

JACKET

The difference between “combustion efficiency” and “overall efficiency”, about 2 – 4% lower than combustion efficiency.

PURGE LOSSES

Typically, five minutes at the start of a firing cycle and two minutes at the end of a firing cycle.

Essentially, pre-cooling the boiler internals at the start, and throwing away whatever heat was still in the boiler at the end of the cycle.

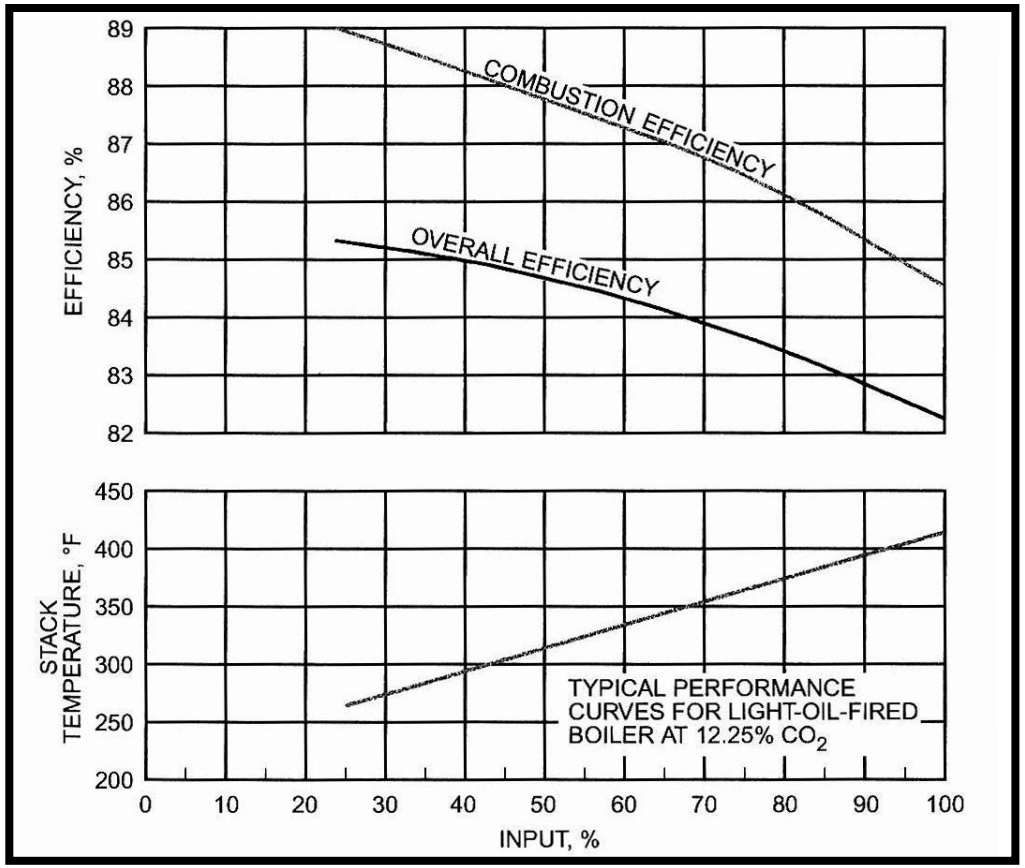
Combustion and Flue Losses

LP Steam…300F

Conventional HW…250F

Low Temp HW…130F

- Added benefit of sealed combustion (No big combustion air louvers)



The Pipes?

Inside the building

Heat loss from un-insulated 180F pipe ~ 272 BTU/ft

Heat loss from insulated 180F pipe ~ 18 BTU/ft

Heat loss from insulated 130F pipe ~ 9 BTU/ft

At least 1% of an average heating bill and possibly overheating the plenum (VAV systems)

Campus Steam

Line loss = 474,000 BTUs per year (8 months)

Equivalent of entire heating requirement of a 50K SF building

What are we doing?

Trying to heat air to 90 - 100F.

My (your?) new favorite number

130

Max HW Supply Temp, reset vs. OAT

From condensing boilers

Why 130?

If HWS is no higher than 130, HWR will be less than 120 and boilers will always be in condensing mode.

What is a condensing boiler?

- Suitable for low temperature operation, no low limit on EWT
- Metallurgy immune to fire side condensation
- Usually modular, low mass boilers
- Usually high turndown burners

Why condensing boilers?

- Okay with water temps below 140F
- Highest Efficiency at Full and Part Load
- Size
- Simplified piping
- Perfect complement to heat recovery chillers
- Safety

Safety?

180F water = a 3rd degree burn in 1 second

130F water = a 2nd degree burn in 17 seconds

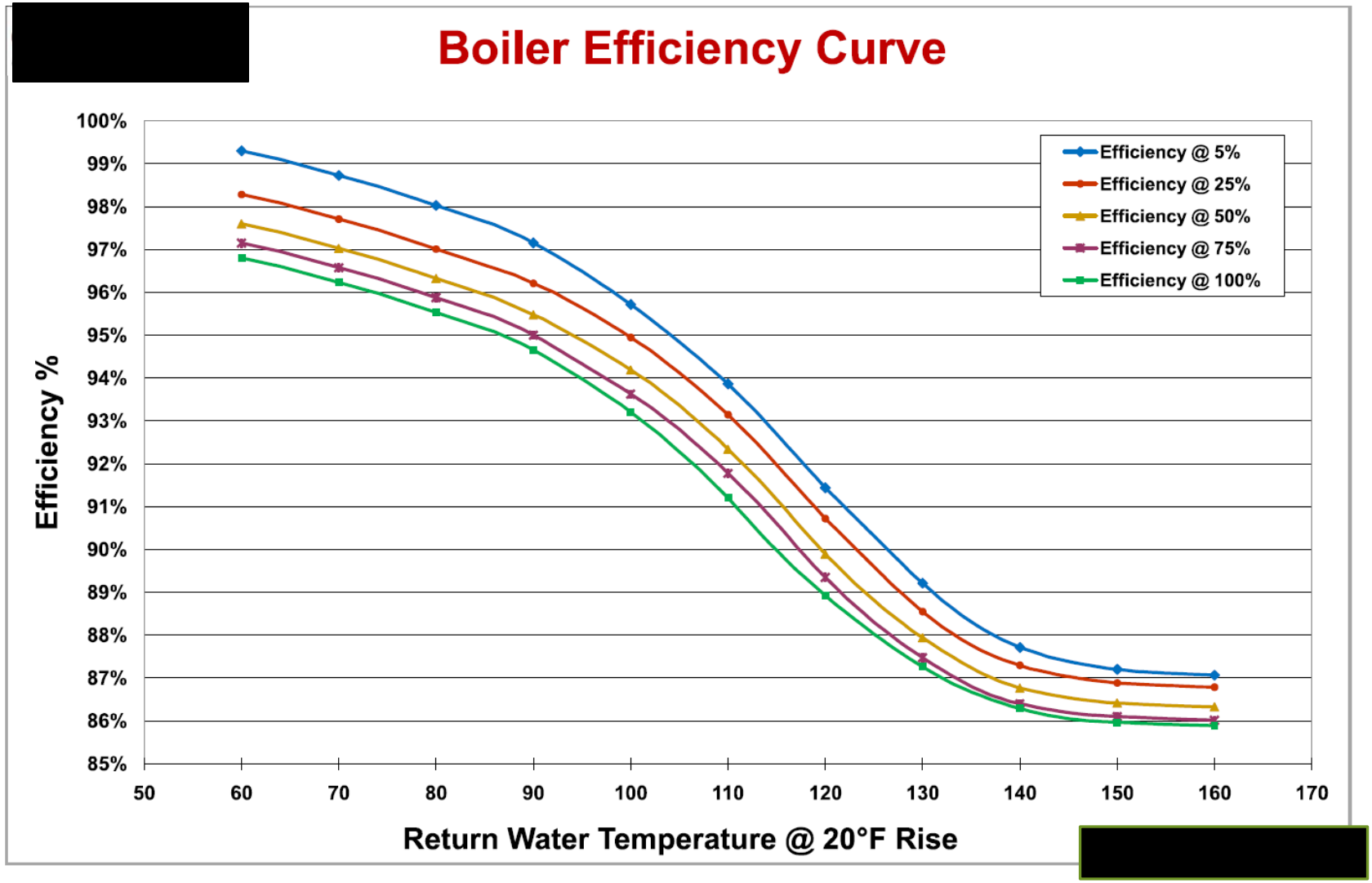
(Shriners' Hospital www.shrinershq.org)

Part Load Effect

Turn-down of at least 10 to 1

This is for a condensing boiler,

I could not find one for a conventional boiler.



Why not condensing boilers?

First cost.

In a retro-fit, the balance of the system isn't designed for low temp heat.

Life expectancy = ???

Some process requirements may need higher temps

What do they cost?

Conventional Boiler (82% eff.) = $5,000 per MMBTU

Condensing Boiler (92% eff.) = $12,000 per MMBTU

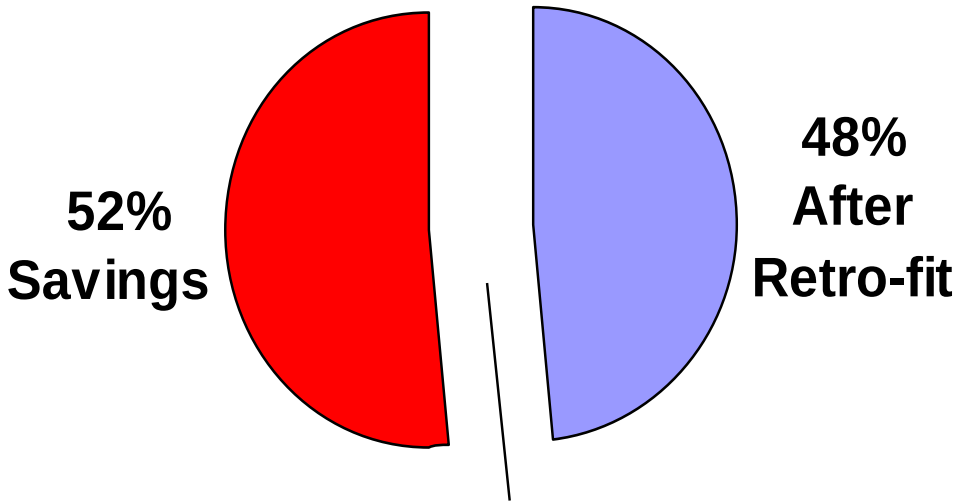
What's the payback?

A school in Indiana costs $1.00 per SF per Year (35% gas, 65% electric) or $0.35 per SF per Year for Gas.

Conversion to Cond boilers = 12% efficiency improvement , down to $0.312 per SF per Year

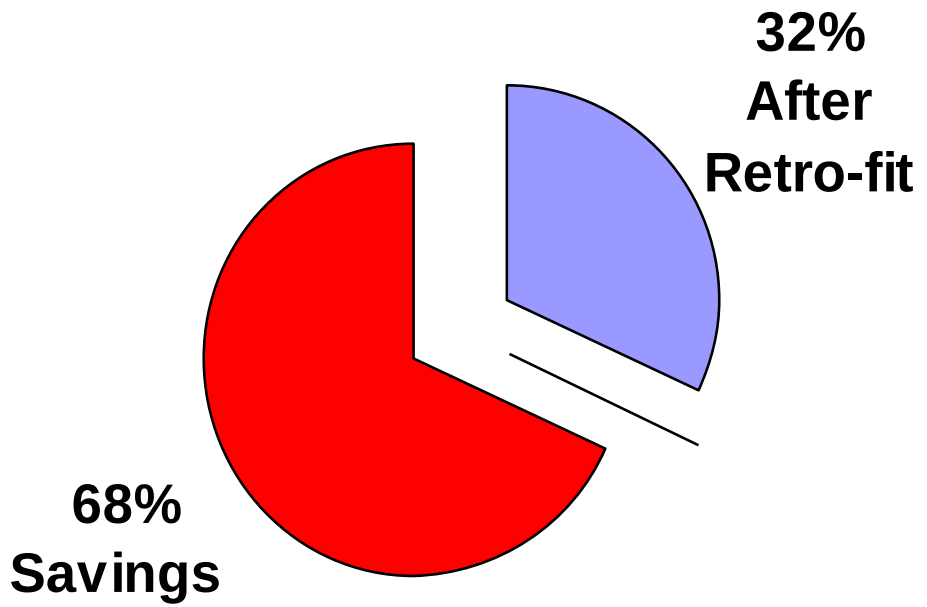
7.4 year simple payback

180F to Low Temp HW



30% better than published

Steam to Low Temp HW



50% better than published

What's the REAL payback?

A school in Indiana costs $1.00 per SF per Year (35% gas, 65% electric) or $0.35 per SF per Year (Gas)

Conversion to Cond boilers = 50% efficiency improvement , down to $0.175 per SF per Year

1.6 year simple payback

Many load models do not reflect this reality!

Conclusion:

"…the old standard can be significantly improved…if a building is to be heated hydronically, use low temperature water from condensing boilers."

Boiler System Efficiency

By **Thomas H. Durkin, P.E.,** Member ASHRAE

When natural gas cost $0.40 per therm* (1999), even a poorly designed boiler system would have positive payback. Hurricane Katrina changed that.

According to the Energy Information Administration (www.iea.doe.gov), the cost of natural gas has increased 50% in the U.S. since last fall (due to Hurricane Katrina) and 200% in the last seven years. Electricity has increased only 20% in the same time frame (central Indiana). Winter 2006 natural gas cost as much as $1.40 per therm (100,000 Btu) and electricity costs around $0.07/kWh (3,413 Btu). The electric cost equates to $2.05 per therm.

In the simplest terms, when comparing condensing boiler/low-temperature heat and conventional boilers, if the boiler cannot deliver heat to the space at an efficiency of at least 68%, then the boiler has zero payback vs. straight resistance electric heat, which is (theoretically) 100% efficient. This represents a large shift in engineers' approach to heating systems.

Some would argue, probably correctly, that the entire national energy picture is in flux, and that the cost of electricity is artificially low compared to natural gas. Conversely, the cost of natural gas may be artificially high because of the hurricane damage to the gas drilling rigs in the Gulf of Mexico. In Indiana, most of the new electric power generation is gas-fired peaking plants, which likely will create a ripple effect on electric costs.

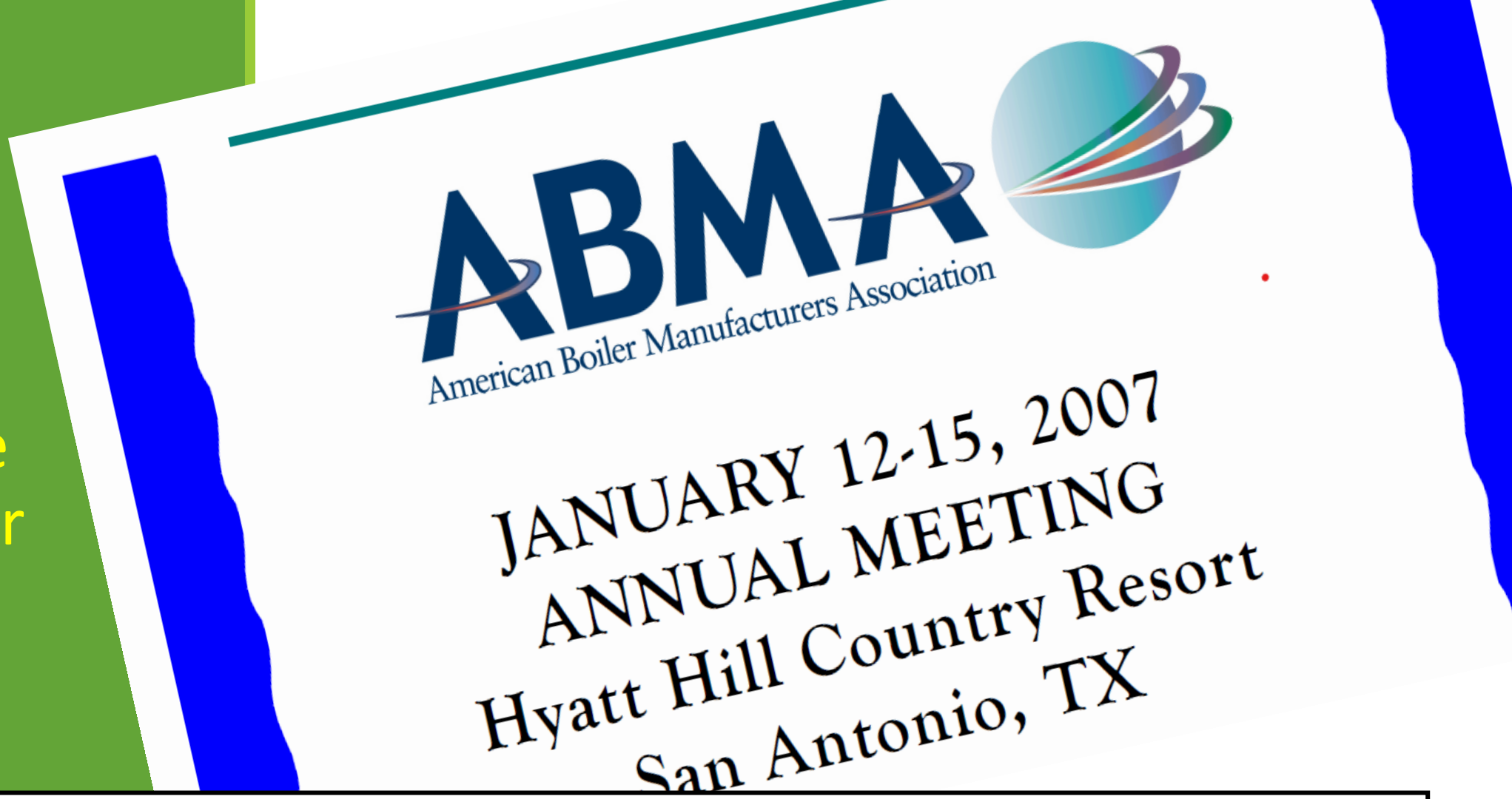
This snapshot makes it seem that gas-fired boilers are a marginal investment, and that boilers burning fuel oil at $2.80 per gallon (139,000 Btu/$2.01 per therm) or propane at $2 per gallon (91,600 Btu/$2.18 per therm) will cost significantly more than straight resis-

About the Author

Thomas H. Durkin, P.E., is director of engineering at Veazey Parrott Durkin & Shoulders in Indianapolis.

*therm = 105.5 MJ

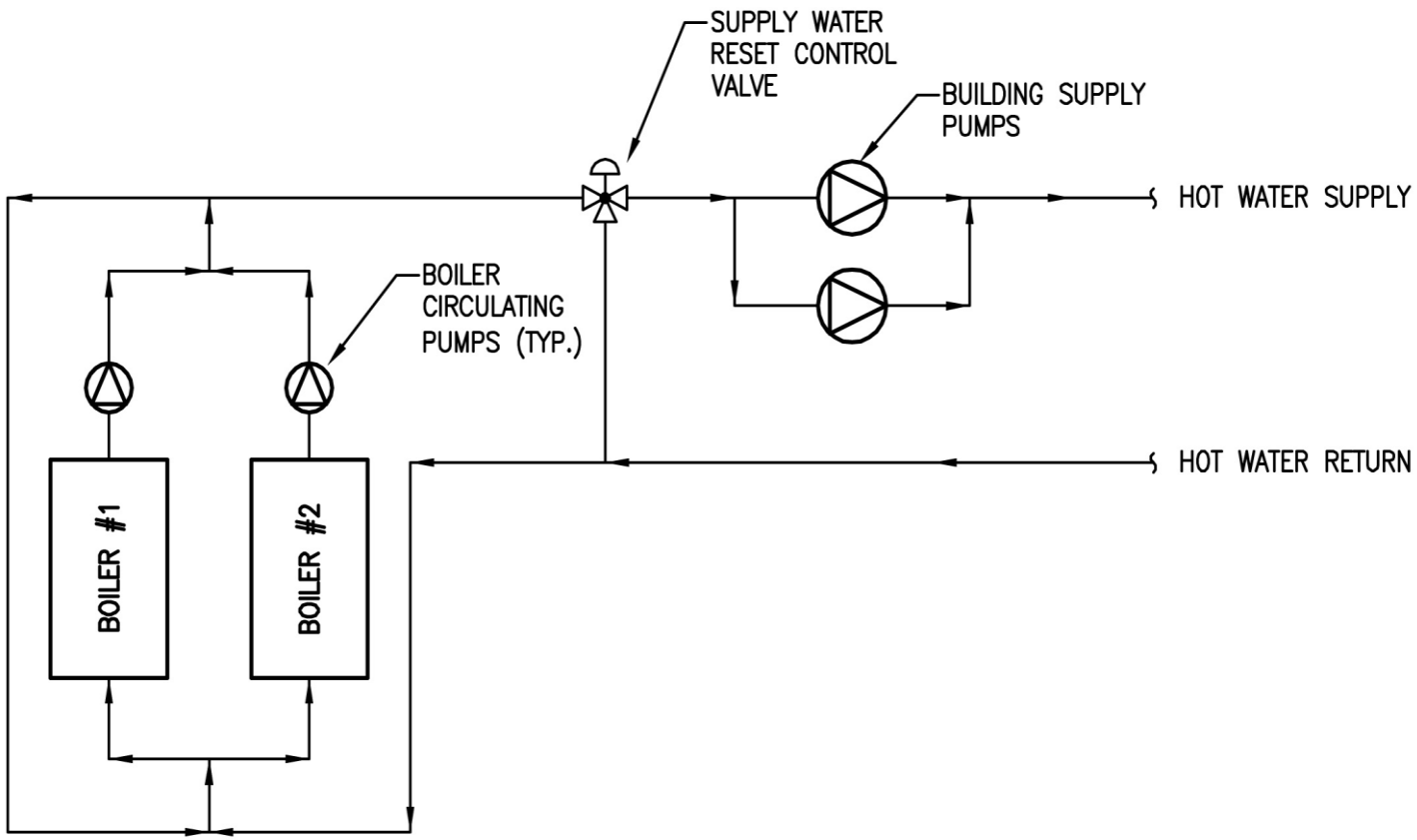
They made me an offer I couldn't refuse…



OPEN MEETING – COMMERCIAL SYSTEMS GROUP – *Open to All Annual Meeting Registrants Having An Interest*

- Roundtable Market Discussion
- Speaker: *"Staying Relevant In A Green Era"*
  Tom Durkin, PE, Veazey Parrott Durkin & Shoulders

A Typical Conventional Boiler System



Variable speed building pumps

Reset HW supply temp, 3-way valve controls

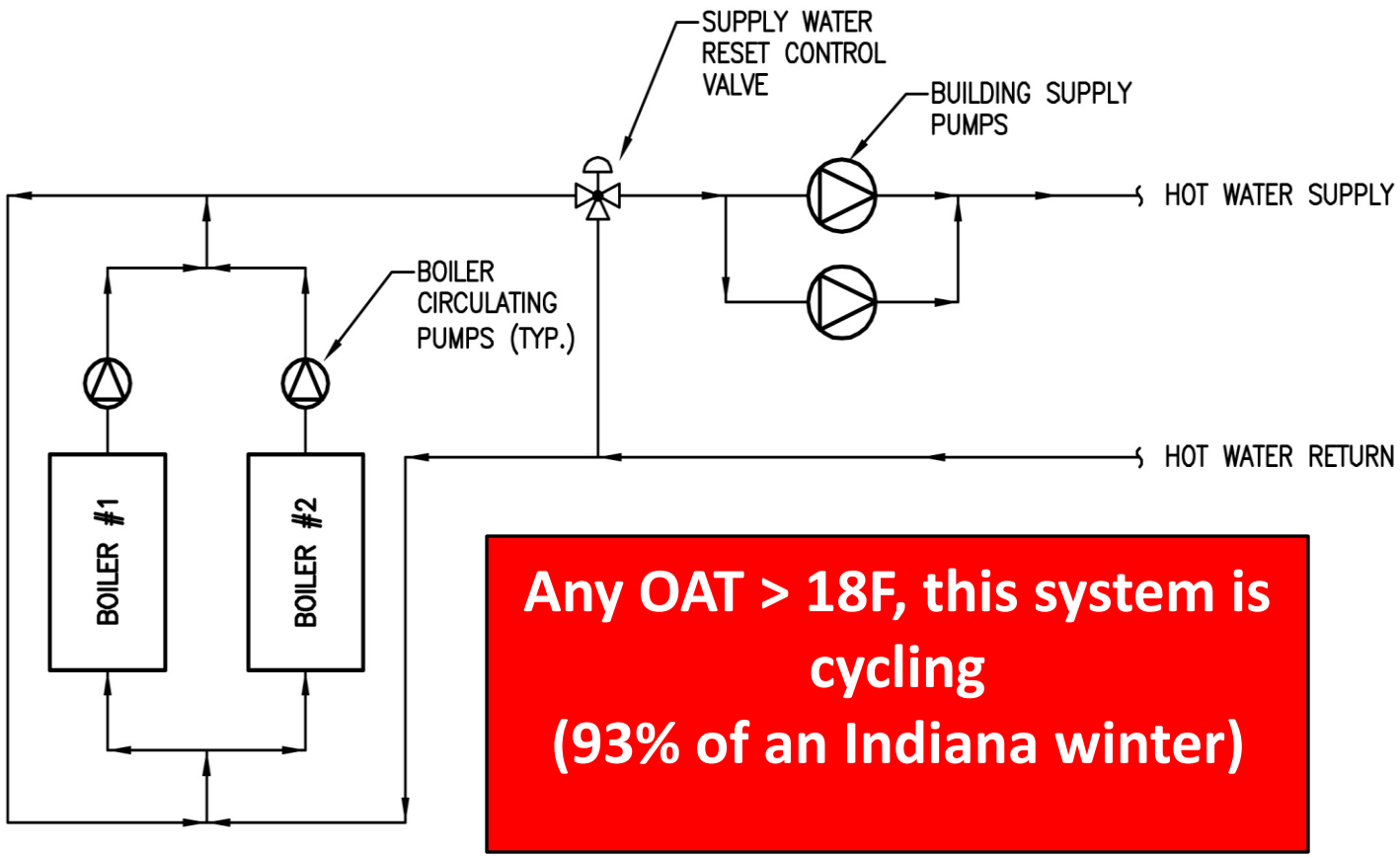
Boilers sized for 75% of peak demand

4:1 turn down on boiler

20F Delta-T system design

Low Delta-T on building loop, 15F average

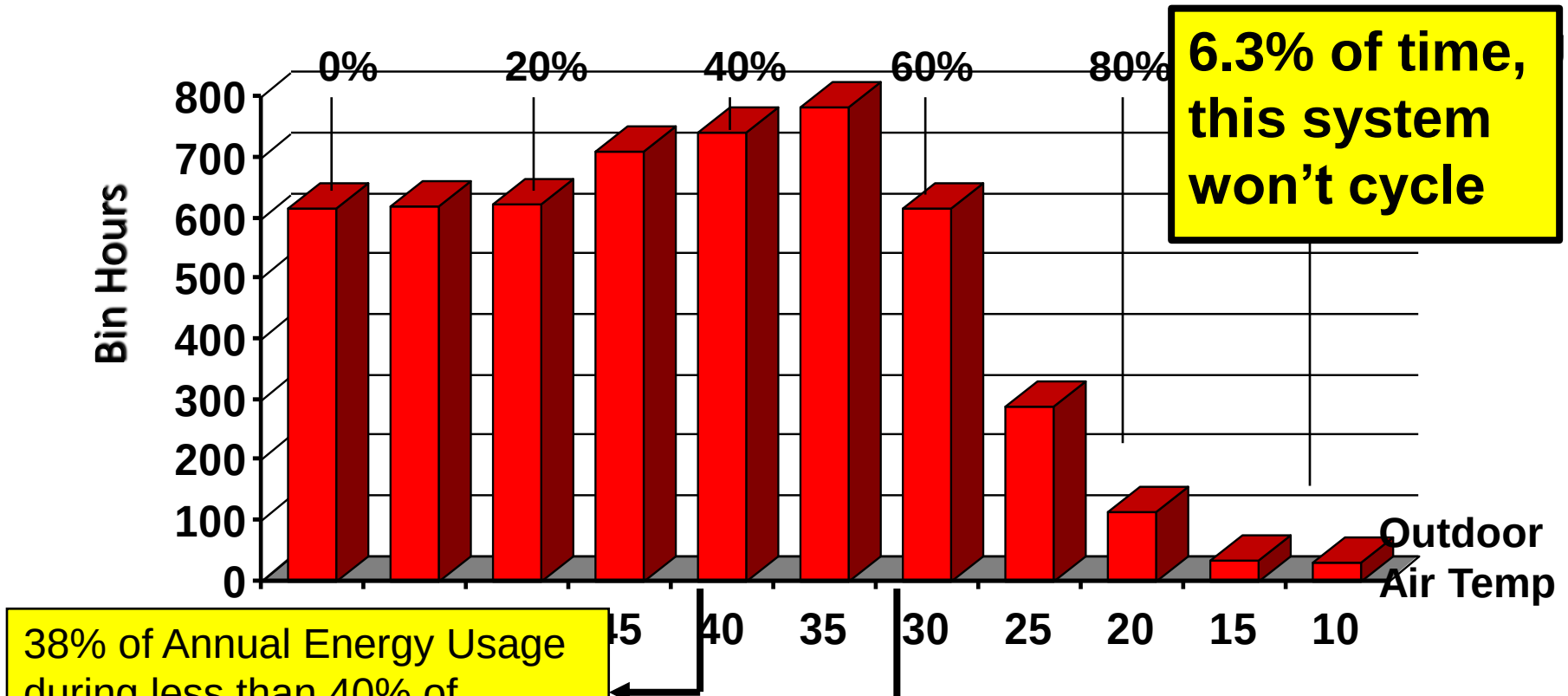
A Typical Conventional Boiler System



Any OAT > 18F, this system is cycling
(93% of an Indiana winter)

- Variable speed building pumps
- Reset HW supply temp, 3-way valve controls
- Boilers sized for 75% of peak demand
- 4:1 turn down on boiler
- 20F Delta-T system design
- Low Delta-T on building loop, 15F average

Part Load Effect



38% of Annual Energy Usage during less than 40% of Building Heating Load

80% of Annual Energy Usage during less than 60% of Building Heating Load (above 30F outdoor air temp.)

Part Load and Turndown

When a boiler cycles, there is a pre-purge and post-purge.

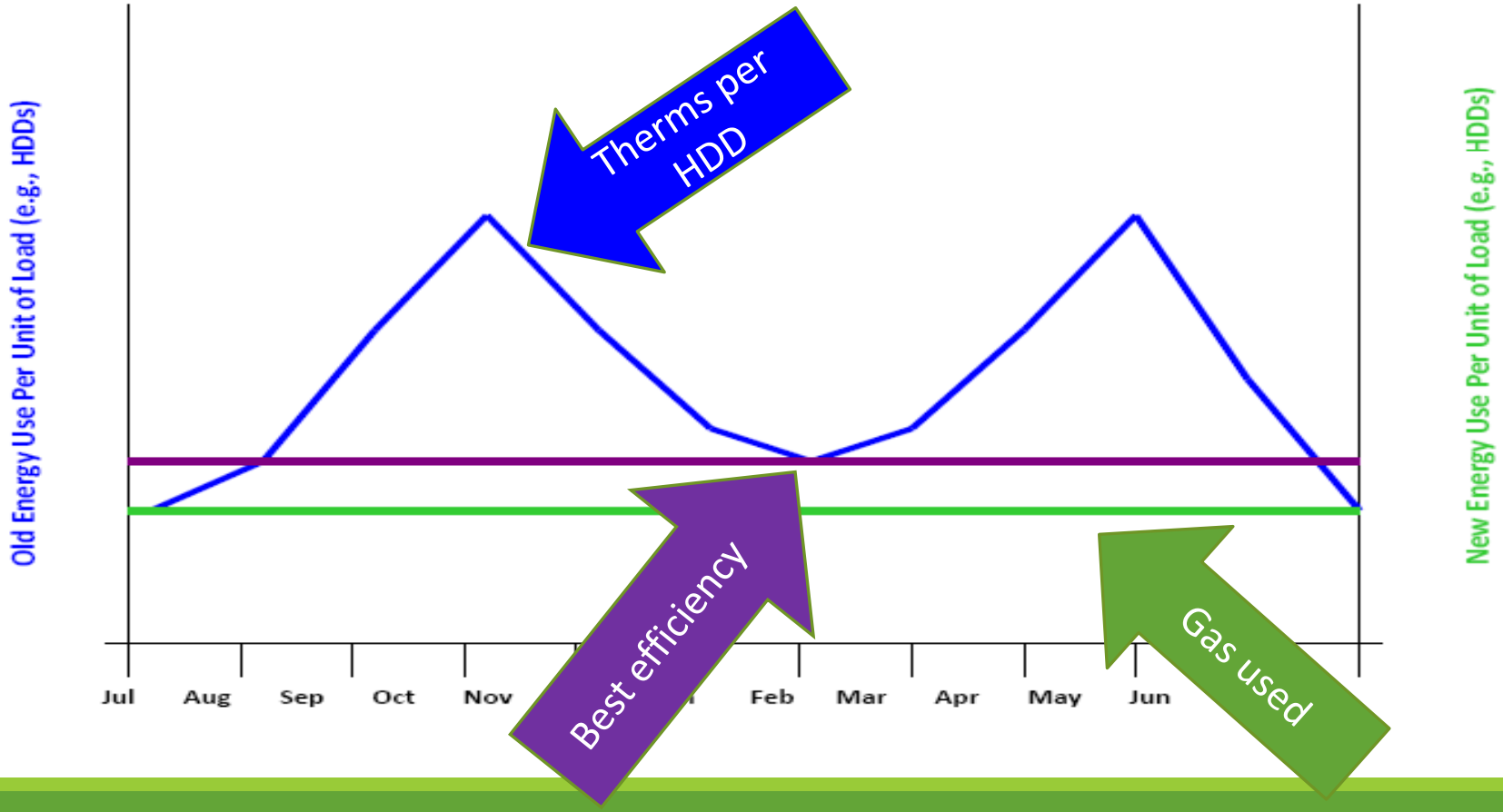
Both are significant energy wasters.

Cycle Efficiency Curve (Nichols-McKeegan Curve)

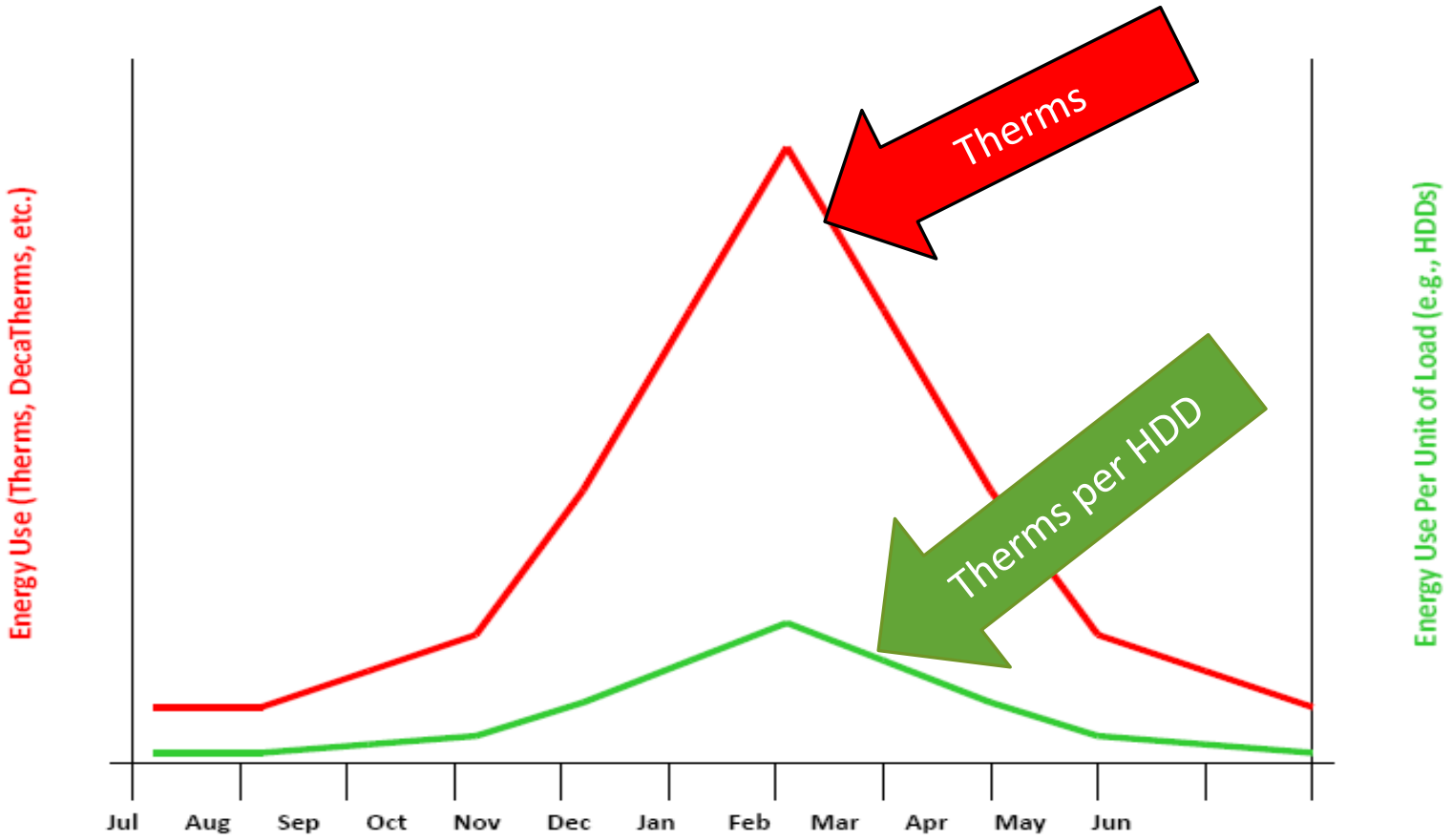
Therms per heating degree day (HDD) plotted by month for heating season

- An easy check on how efficient your entire heating system is, not just the boiler.
- A measure of system efficiency versus component efficiency

Therms per HDD (theory)



An ideal curve…



Therms per HDD Analysis

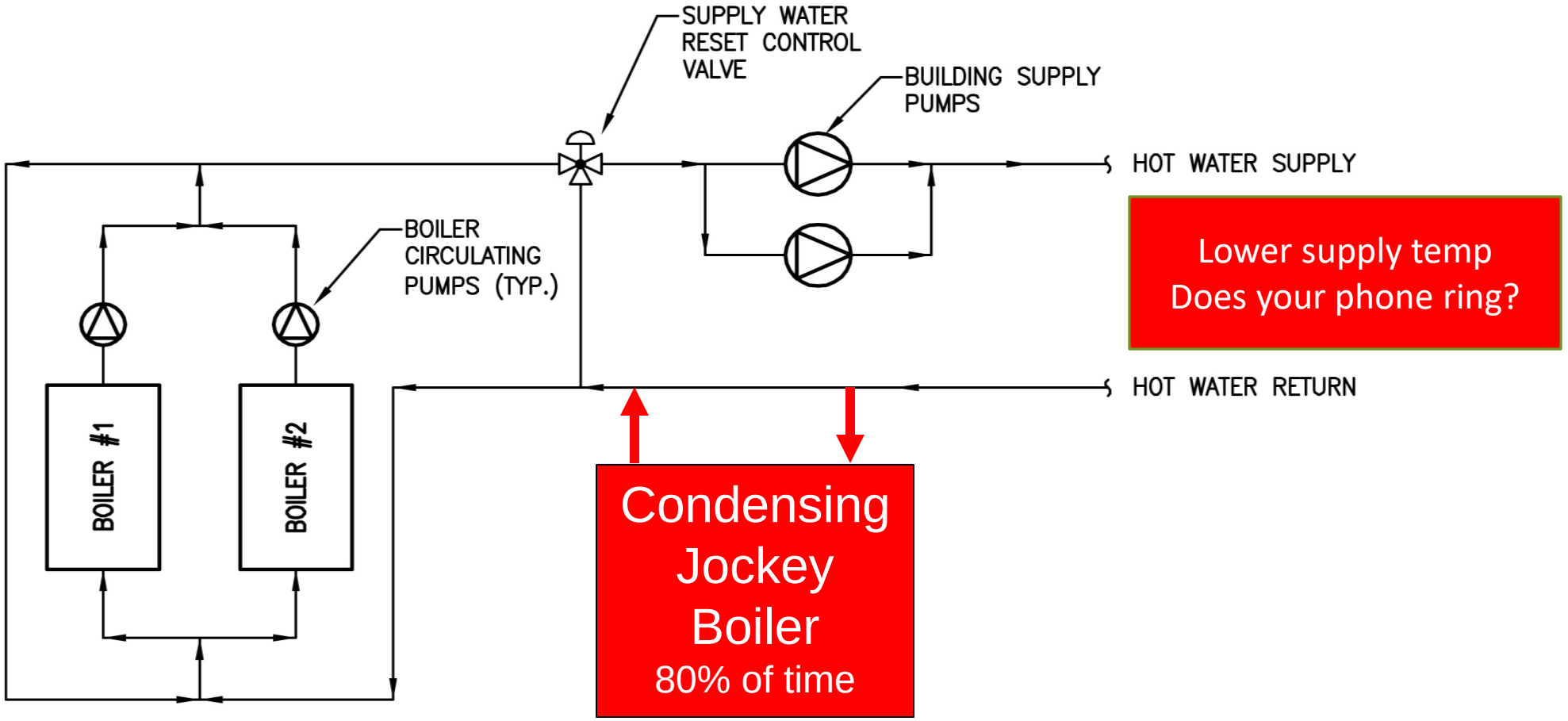
Month	Therms	$	$/Therm	HDD	Therms/HDD
May	3349	$2878	$0.86	158	21.20
April	5332	$4568	$0.86	371	14.37
March	7042	$6027	$0.86	435	16.19
February	7823	$5515	$0.70	1149	6.81
January	7748	$5462	$0.70	1422	5.54
December	7170	$5056	$0.71	983	7.29
November	3981	$2468	$0.62	731	5.45
Total	42,445			5,249	8.09

Potential savings

33% of gas

$11,920/7-months

How do we fix it?



Principles of Cycle Efficiency Improvement

- Peak heating loads occur very rarely.
- Boiler plant must “load match”… operate efficiently no matter how mild the weather or small the load.
- It is easier to achieve high cycle efficiency with low mass boilers rather than high mass boilers.

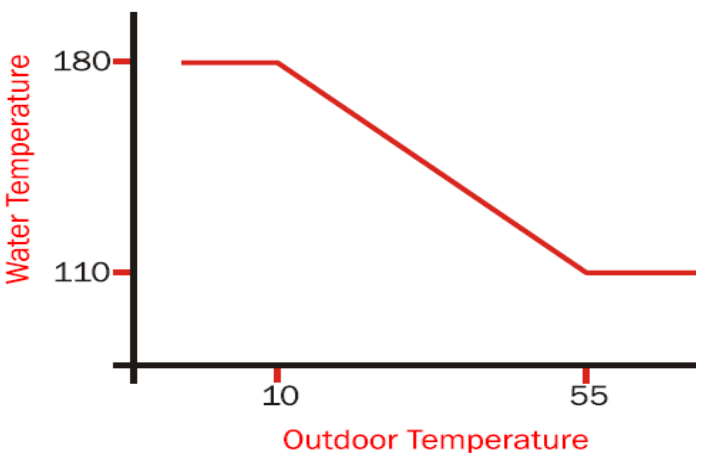
Healthy Heating Systems

The bottom line on cycle efficiency…

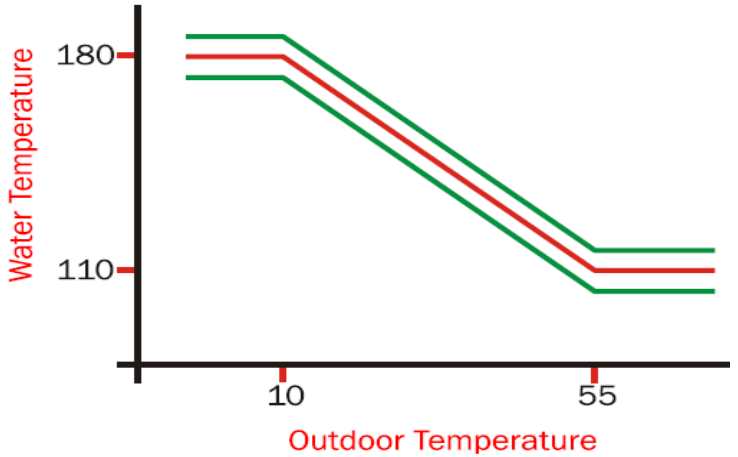
- Starts per hour? One per day is good.
- What's the real turndown? Not as % of boiler capacity, but as a % of actual (not peak) load.
  - Traditional boiler: 4:1
  - Condensing boiler: 25:1
- How is it being controlled? Wide dead band on supply temp.

HW Supply Reset Schedules

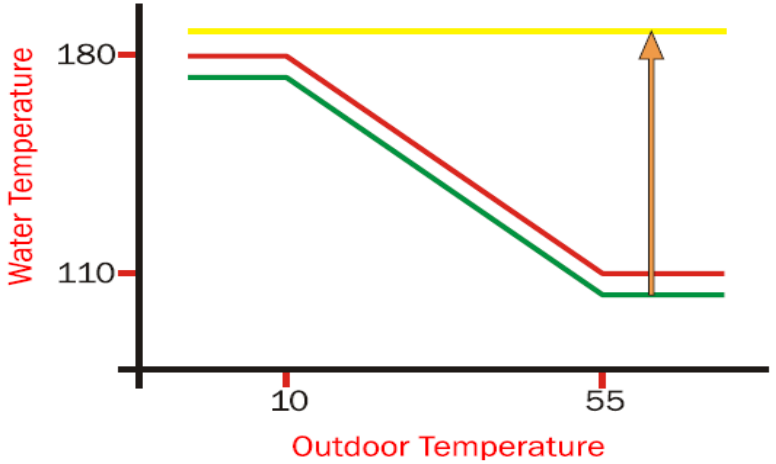
(if we can't get feedback from the building)



Typical



Better: +/- 10F dead band

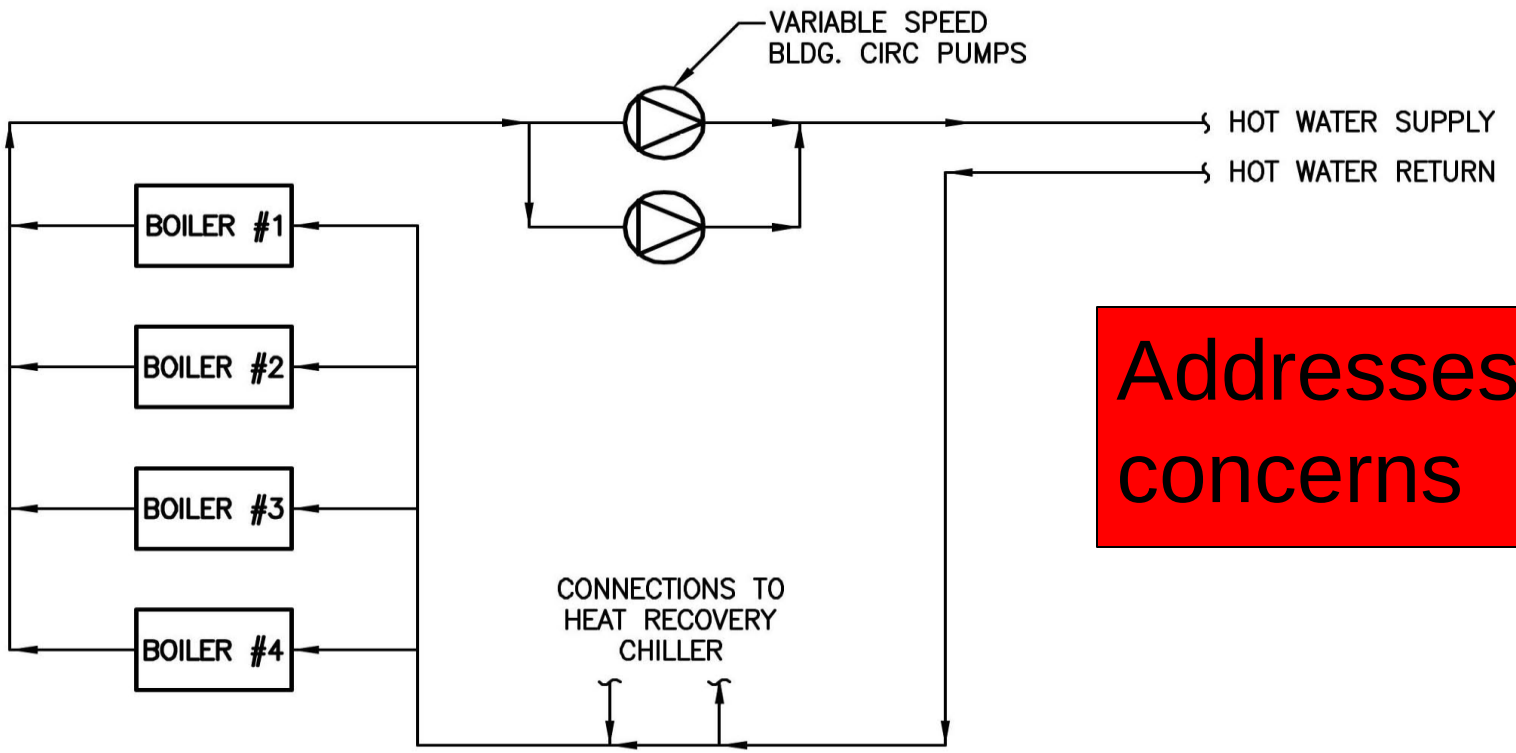


Recommended: once it starts, let it run.

Minimize the number of starts.

(Few numbers we work with matter less than HW supply temp)

Condensing Boiler Arrangement



Addresses all concerns

In the Building, what has to change?

Pumps, piping and valves are the same (20F Delta-T)

Coils have to be deeper, 3 or 4 row versus 1 or 2 row
($300 per AHU, $30 per VAV)

AHU's require additional static ~ 0.10 in.

VAV boxes require additional static downstream ~ 0.25 in.

Radiation and convection may need fan assist

Any other benefits?

- Boiler room gets smaller
- Piping gets simpler
- Fewer pumps
- No boiler room louvers, easy venting
- Minimized start-up losses
- Better turn-down
- Safety
- Quieter

Any limitations?

- In retro-fits, what's the **threshold of pain**
- 3rd party boiler controls
- Some are not true condensing boilers
- Some have high internal pressure drops
- Boiler minimum flow
  - Avoid the noise

How Low Can You Go?

My (your?) new favorite number

130

Max HW Supply Temp, reset vs. OAT

From condensing boilers

Expanded Applications

Integration with:

- Heat Recovery Chillers
- Geothermal Central Systems

You'll know you're on the right track when…

The gas company changes the meter.

Twice.

Friday
October 10, 1997
Bloomington, Indiana

The Herald-Times
REGION

Ambulance runs / C3
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C Section

Schools' new heat, air mean savings

Elementary schools' new systems use less gas

By Sean O'Brien
H-T Staff Writer

" When the board voted to do this, our primary goal was that all kids attend air-conditioned schools. It was great that we could save money at the same time. "

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