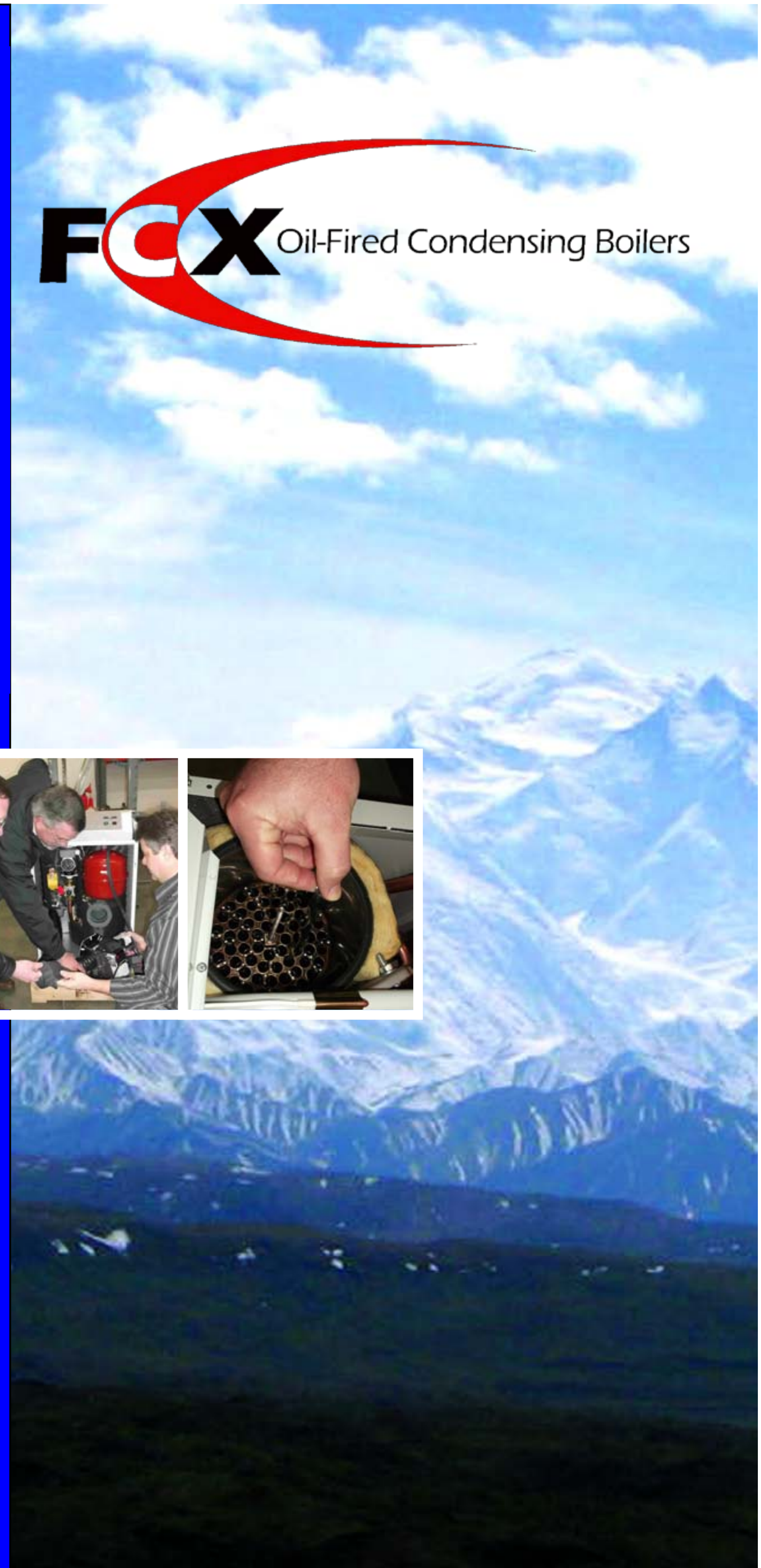
2015 Condensing Boiler Technical Seminar



April 13, 2015
Cold Climate Housing Research Center

1000 Fairbanks Street
Fairbanks, Alaska

Condensing Boiler and Hydronic Technical Seminar
April 13, 2015

Introduction

- Geminox – France's leading manufacturer of steel boilers, part of Bosch Thermotechnologie. http://www.geminox.com/int/instit/instit.asp
- Lucky Distributing – Exclusive importer of the Geminox FCX Oil-Fired Condensing Boiler
- Quintessence Corporation – Fairbanks Master Dealer and Tech rep

Seminar Organization

1. Introduction
2. Breaks – About every hour - Pizza for lunch
3. Condensing Technology – how it works and why it is the most efficient choice
4. Handling the Condensate
5. The FCX and DHW Tanks - Features and Benefits
6. Hydronics - Unique to Condensing
7. New Construction
8. Retrofits
9. Optimization
10. Baseboard homes
11. Testimonials
12. Controls
13. Venting/Stacks
14. Maintenance
15. Website Tour

Condensing Technology

How is heat recovered?
What is condensing?
Why is it more efficient?
Condensing vs. Conventional
Added Benefits
CO2 and Excess Air, Gas vs. Oil
Facts about Conventional Efficiencies
Conclusions
Boiler efficiency comparisons

Handling the Condensate

- Neutralization and Disposal
    - Neutralization – what we used to do
        - Traps - how to do it
        - Is it necessary?
- pH of common household substances
    - Disposal
        - Down the drain
        - Pump it away - pics
        - Cold drains

Actual Measurements
- Lifewater system
- Covered in the new Geminox manual

The FCX Boiler - Features and Benefits

- Most efficient oil-fired boiler sold in the US
- Small footprint, attractive, very quiet
- Two sizes 76 Kbtu and 104 Kbtu (same physical size)
- Riello Burners – the most reliable name in the industry
  - High-pressure pump
  - In-line oil heater
  - Dual air adjustment – coarse and fine
  - Blocked vent safety
- Built-in features:
  - Expansion tank
  - Mixing valve
  - Grundfos pump
  - Plug and play to your manifolds.
  - FCX counter flow
- Two temperature circuits
  - Mixed for low temperature radiant
  - High temperature that does not contaminate the cooler return water with the hot return water
  - The advantage of a separate secondary condenser
- Stack: Less expensive, easily worked plastic, many options
- Additional standard safeties not required for residential boilers
  - High water temperature safety
  - High stack temperature safety
  - SPDT switches on above switches for add on alarms
- Built for radiant heat but works well for baseboard
- Close technical support
- Comprehensive instruction manual
- Efficiency & fuel savings
  - Savings you can expect replacing a conventional boiler – 30% to over 50%
- Gas conversion

DHW Tanks

- Sizes available – 25, 40, 50, & 80 gallon
- Thermometer
- Aquastat
- Special connection for hot recirculation
- Built for low temperature boilers
- Recovery rates & sizing
- Sizing
- Works on 130-140° water

Warranty and Support

- 10 Years for Heat Exchangers and DHW Tanks

- 2 years on other parts
- 2 year standard Riello warranty
- Comprehensive installation manual
- Close technical support to the designer, installer, and serviceman
- Fairbanks – Initial setup and tuning included

Hydronics - Unique to Condensing

- Return Temperatures
  - The key to greater efficiency
  - Return water temperatures must be below 115°F, the threshold where condensing begins
  - Brookhaven Laboratory study has confirmed this
  - 100 °F or less out and 75 to 80 °F return works best
  - 130 °F out and 110 °F provides some condensing
- Do NOT temper the return water
  - Immune to boiler shock
  - No tempering circuits/valves
  - No recirculation pumps
  - No 4-way mixing etc.
  - No Injection recirculation loops
  - The 2nd most important event in condensing boilers
- Pumping
  - The more the better??? – old school
  - Variable Frequency Drive (VFD) – the best way
  - ΔT, ΔP, Mixing Pumps Depends on applications
  - No need for bypass valves
  - Slow, nearly continuous pumping at lower temperatures
  - The pumping can have a great effect on efficiency
- Heat Emitters
  - Floor types
  - High Mass – the best for condensing
  - Lowest temperatures needed
  - Staple Up – don't do it, requires water 30°F greater
  - Radiant Panels – pricey, but probably can use lower temperatures
  - Baseboard
  - Super Baseboard
  - Unit heaters and other low mass
  - The key is lower return water temperature
- Injection Pumping
  - Diagram - What is wrong
  - Diagram – How to fix it
  - Hydraulic separation – necessary or not ???

New Construction

- Radiant Homes – a no-brainer
- Best Floor types

Retrofits

- Options & Limitations
  - Considerations
    - Is the boiler big enough?
    - Can you extract adequate heat from the boiler at lower temperatures?
    - Auxiliary heat sources
    - Old construction Radiant
    - Can you use lower temperatures than now used
  - Factors affecting the need for High water temperatures
    - Poor insulation
    - Bad Windows
    - Air Leaks
    - Few heat emitters
    - Location – Hills or Holes
- Return water temperatures - Ways to drop them
  - Preheat domestic
  - Unit heaters
  - Heat HRV incoming air
  - On dual systems put baseboard through a radiant section
  - Plastic stack robber
  - Remember LOW return water temperatures are the key, not high supply water temperatures.
- Brookhaven National Labs baseboard study
- Baseboard and combo heated homes

Testimonials

- Proof positive boiler comparisons

Controls

- Cold start vs. Hot start
- Reset controls and suitability
  - Temperature
  - Mixing
  - DHW
- Boiler protection
  - Causes for sustained condensing in primary
  - Large structure / lots of high mass emitters
  - Too much throughput
- Recommendations
  - Taco SR50x switching relays are my choice
  - Simple and inexpensive

Venting / Stacks

- Concentric Options
  - Side wall - Up and out
  - Side wall - Straight out
  - Condensate drain tees
- Single Wall Options

Vertical – best choice
Horizontal caution recommended
Back drafting
Even in “sealed” boiler rooms
Manufactured condensate tee
Single wall balanced - Direct connection to boiler
Combustion Air During construction – Consider a Filter
Dirty filters
Back drafting

Maintenance

Cleaning and Inspection
Once a year or every 1000 gallons
Non-condensing mode and sooting
Primary condensing – What to check for
Secondary condensing (washing the tubes
Concentric air tee - need for inspection
Plugged condensate drains
Back drafting
Tuning a condensing boiler
Slides with charts
CO2, O2, CO Levels
Excess Air
New Chart
Smoke

Enhancing Optimizing the Condensing Boiler

White paper

Website Tour

www.fcxalaska.com

Informational and Technical Website

End of Presentation

Tour of CCHRC Facility if time permits ???

FCX Oil-Fired Condensing Boiler

CONDENSING BOILER TECHNOLOGY

Principles involved, and why it offers the
most efficient solution
in residential and commercial heating.

James Romersberger
Quintessence Corporation
www.FCXalaska.com

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Lucky Distributing – Exclusive importer of the Geminox FCX Oil-Fired Condensing Boiler

John Jansen – President & CEO
Bill McConaughy **– Sales Alaska / Canada**

Quintessence Corporation – Fairbanks Master Dealer and Tech Support

Jim Romersberger – President
Special Technical Representative

Institutional

To get to know Bosch Thermotechnologie better

Bosch Thermotechnologie is currently the principal French constructor of steel boilers.

The Bosch Thermotechnologie Saint-Thégonnec plant, in Brittany, each year produces over 50,000 boilers, ensuring every phase on-site from conception through to fabrication, from the technical studies to the product assemblies.

Bosch Thermotechnologie exports every year to 12 different countries.

With more than 20 years of experience in the condensation domain, Bosch Thermotechnologie benefits from a universally recognized expertise in the most technologically progressive markets, due to its THRi and Docéane ranges of constant modulation gas condensation boilers.

At the cutting edge of new fabrication techniques, engaged in a rigorous quality approach, the products of Bosch Thermotechnologie offer a high degree of reliability and benefit from ISO 9001 certification.

Seminar Organization

1. Introduction
2. Breaks – About every hour, Pizza for lunch
3. Condensing Technology and Hydronics – how it works and why it is the most efficient choice
4. The FCX and DHW Tanks - Features and Benefits
5. Hydronics - Return Water, Tempering, Pumping, Heat Emitters, Injection Pumping, Baseboard, Handling the Condensate, Controls, Maintenance
6. Break, Coffee, Donuts, Hands on – examine the features discussed
7. New Construction, Retrofits, Testimonials, Warranty and Support
8. Venting/Stacks
9. Optimization
10. Website Tour, Hands on

Condensing Technology

How Heat is Recovered?

There are Two Processes by which heat is recovered from the burning of fuel.

Reduction of the burn temperature (sensible heat). Oil burns at about 4000° F, the stack temperature normally is about 350° F. Further reduction leads to the 2nd Process.

Recovering of the latent heat of vaporization (latent from the Greek root word meaning hidden). This is the condensing part.

Condensing Technology

What is Condensing?

The products of combustion consist primarily of <u>CO_2</u> and <u>Water Vapor.</u>

Condensing refers to the cooling of the stack gasses to the point where the water vapor condenses into liquid. It does <u>not</u> refer to the water circulating in the boiler.

Condensing Technology

How does Condensing Make for Greater Efficiency?

- **When water changes state from a gas to a liquid (goes from a <u>gas at 212°</u> to <u>liquid at 212°</u>), it gives off heat that is absorbed by the water in the boiler. Think of it as just the opposite of adding heat to make water boil.**

- **This process recovers the latent (hidden) heat of vaporization, takes place in the condenser, and is added back into the Boiler water.**

- ***<u>The net result is greater efficiency</u>.***

Condensing vs. Conventional

- Lower Temperatures
- Why is condensing bad for conventional boilers
- How and why condensing occurs

Condensing Technology

Added benefits

Lower Temperatures

Condensing boilers are defined by:

- Lower Stack Temperatures (80° to 175°)
- Lower water supply temperatures (100° to 120°)
- Lower water return temperatures (75° to 100°)

Non-condensing conventional boilers have stack temperatures of **350° to 500° F**, and return water temperatures of about **130° F** in order not to condense.

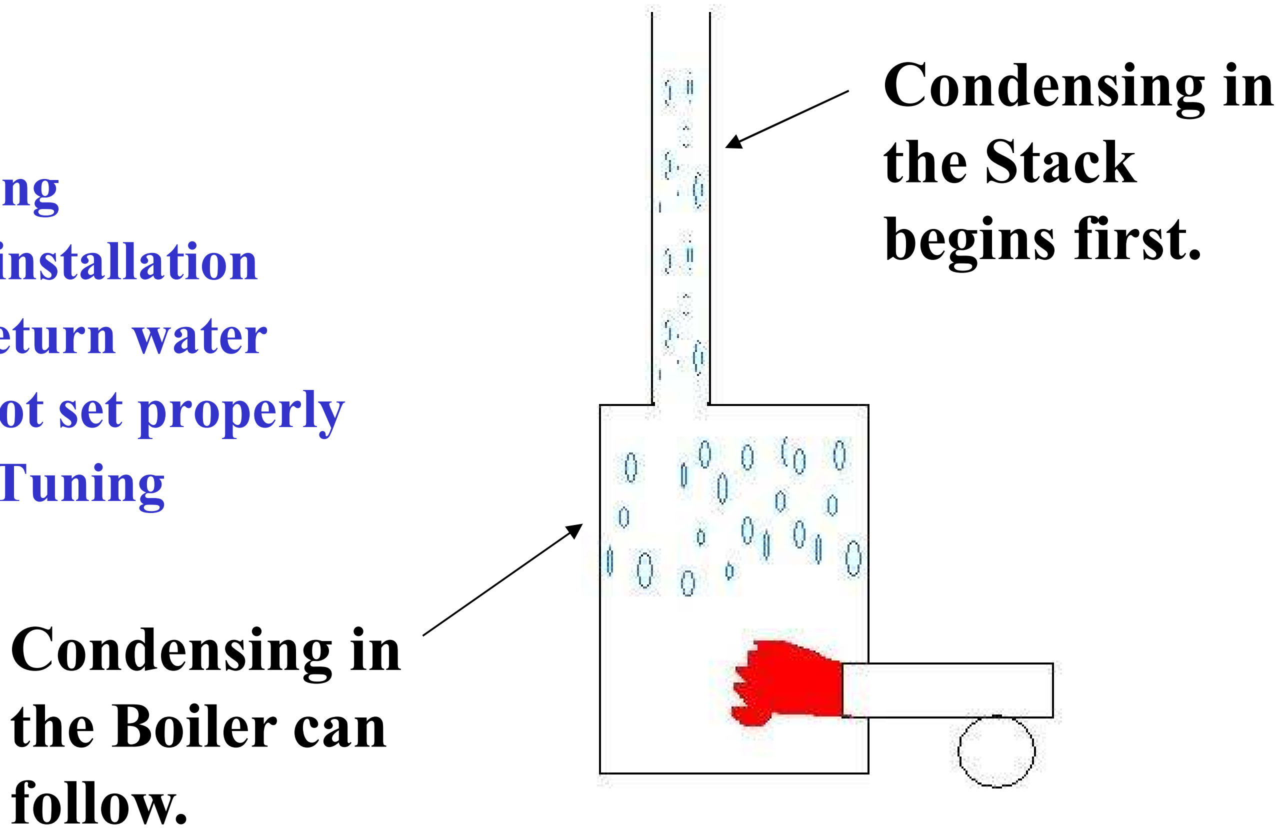
Any heat up the stack is LOST

Condensing Technology
Why is Condensing Bad for Conventional Boilers?

- It's the nature of the condensate, it is slightly acidic.
- Measured values around Fairbanks are about pH 4.
- The stack can be destroyed in year or less, creating a fire hazard. Note that the stainless steel in Metalbestos types of stacks will also fail, because not all stainless steels are created equal.
- Life expectancy of the boiler will be greatly reduced.
- Conventional boilers are not designed to condense.

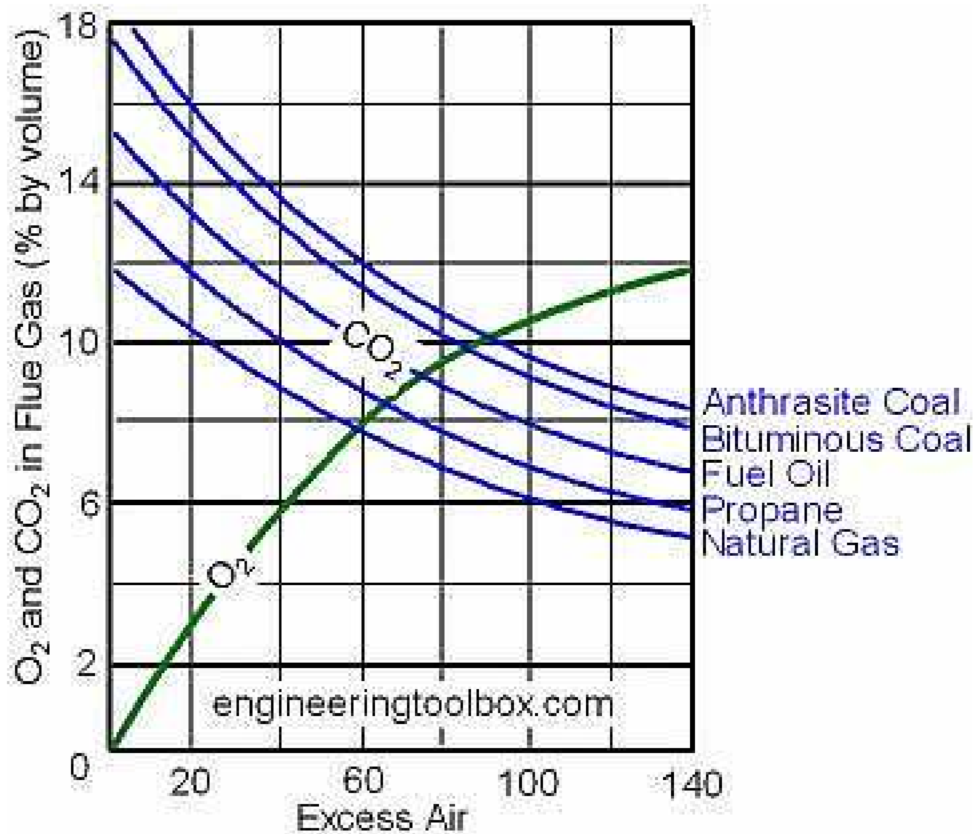
Causes for Condensing Conventional Boilers

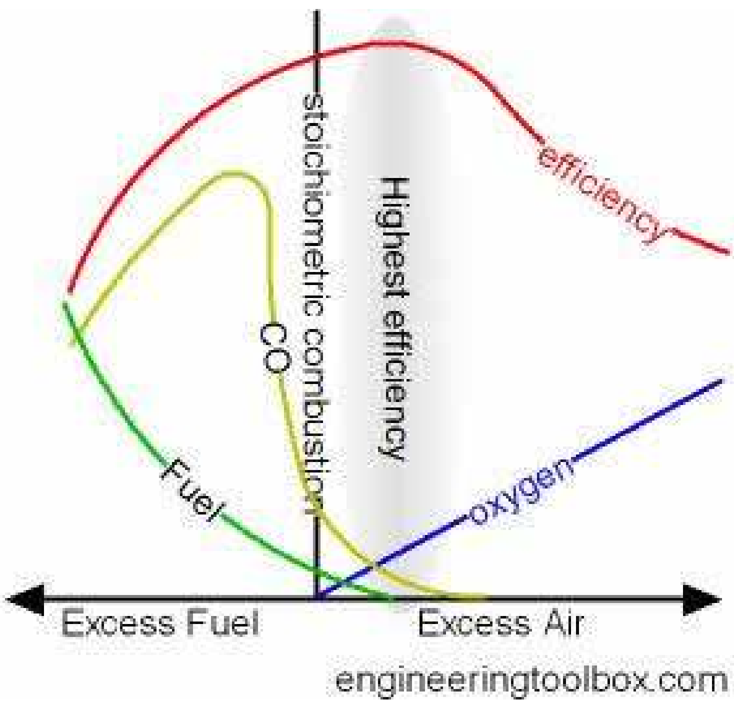
- Note that any boiler can be made to condense
- Causes
  - Under Firing
  - Improper installation
  - Too cool return water
  - Controls not set properly
  - Improper Tuning



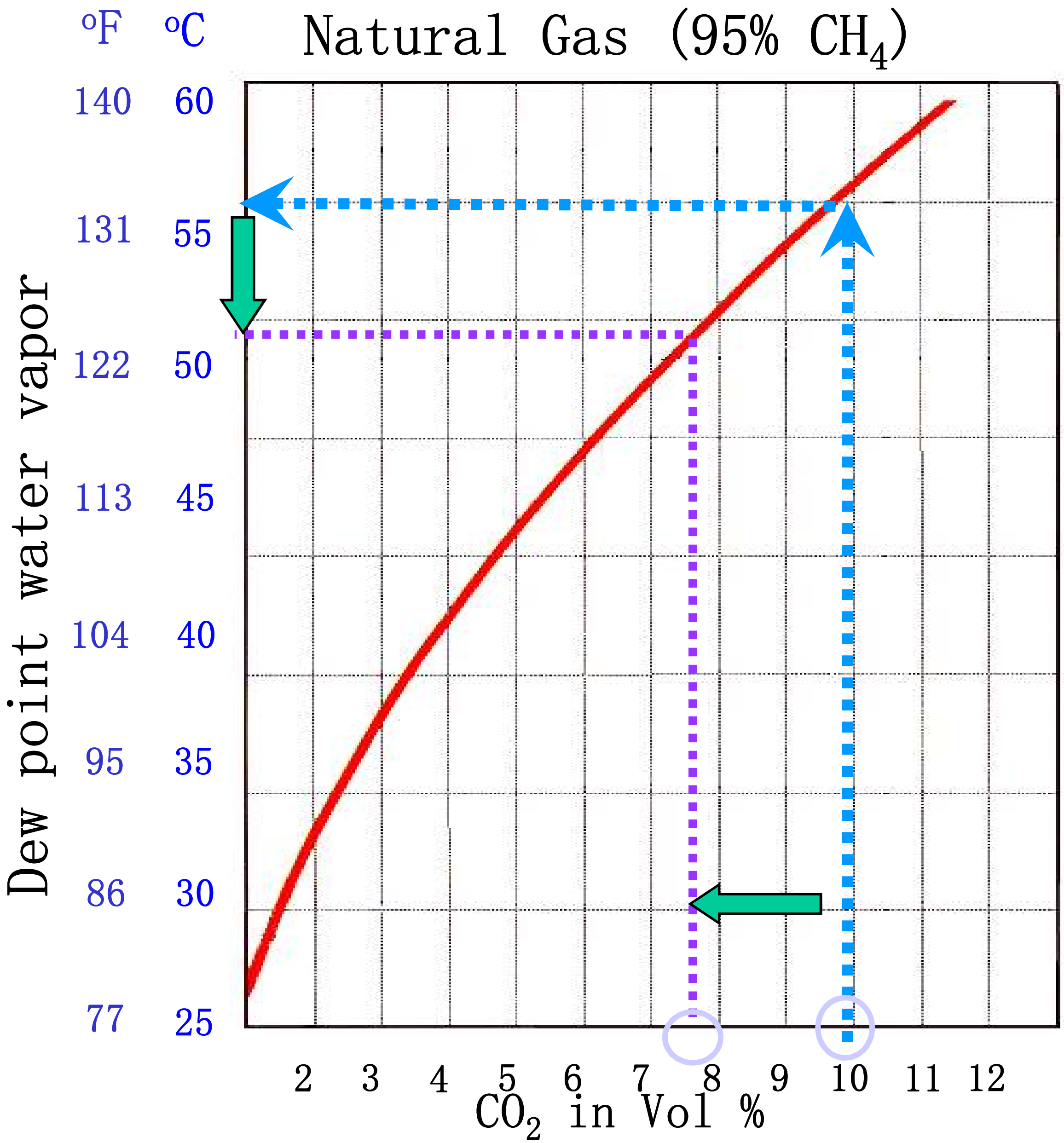
Condensing in a Boiler

CO2 vs. Excess Air





WATER VAPOR DEW POINT



CO_2% of flue gas influences dew point temperature

Higher CO_2
=Higher Dew point
=More Condensation

Lower CO_2
=Lower Dew point
=Less Condensation

Some Interesting Observations

- Stack Temperatures vs. Boiler Design
- Insulated Stacks
- Conclusions

Condensing Technology

Conventional Boilers – a few FACTS

Fact – Any conventional boiler can be made 5% to 10% more efficient by making it condense. But if this is done, the acidic condensate will destroy them.

Fact – Conventional boilers are designed to run hotter in order not to condense. Efficiency is Secondary

Fact – **The primary purpose of the very expensive insulated stove pipe is designed to hold the heat in so the flue gases won't condense.**

Fact – The hotter the boiler, the less efficient it runs, and…

Any Heat up the Stack is LOST

Condensing Technology

Conclusions

Lower temperatures mean greater efficiency

Every degree you lower the stack temperature increases both the <u>sensible heat</u> recovery (*from lower stack temperatures*) and the <u>latent heat</u> recovery (*from the condensing effect*). Lowered temperatures are directly translated to $$$ saved.

THE BOTTOM LINE

Any heat up the stack is LOST

Stack Materials

- Stack temperatures are so low that plastic is used.
- Zero Clearance to Combustibles.
- Huge Savings in both Materials & Labor

Boiler Efficiency Comparisons

The Cheek Test

If You Dare

At the exhaust of the boiler, see how long you can can hold your cheek on the stack.

Handling
the
Condensate

Handling the Condensate

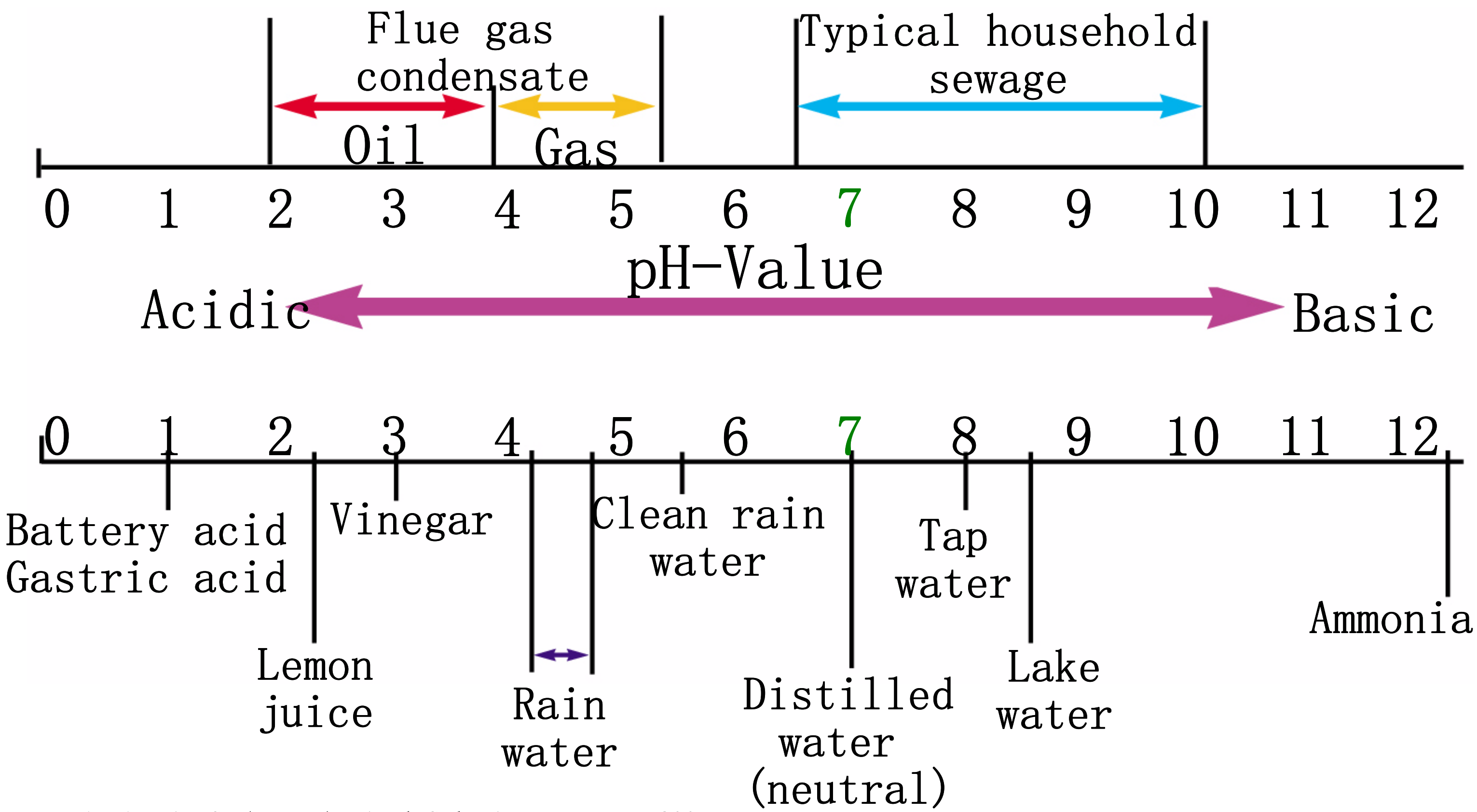
Neutralization and Disposal

- **Neutralization**
  - Traps - how to do it
  - Is it necessary?
- **Disposal**
  - Down the drain
  - Pump it away
  - Cold drains

Handling the Condensate

pH VALUES OF VARIOUS FLUIDS

Condensate – the NON-Issue



ASHRAY Presentation by Jim Cooke Mechanical Solutions NW, Nov 2005

Handling the Condensate

Actual Measurements after several months indicate a ph level of 7.0 Neutral.

Unless required by code this is not really necessary.

Covered in the Geminox Manual.

Twin Boilers - Lifewater Shop, Office, & Appts - 8000 SF

The FCX Oil-Fired Condensing Boiler

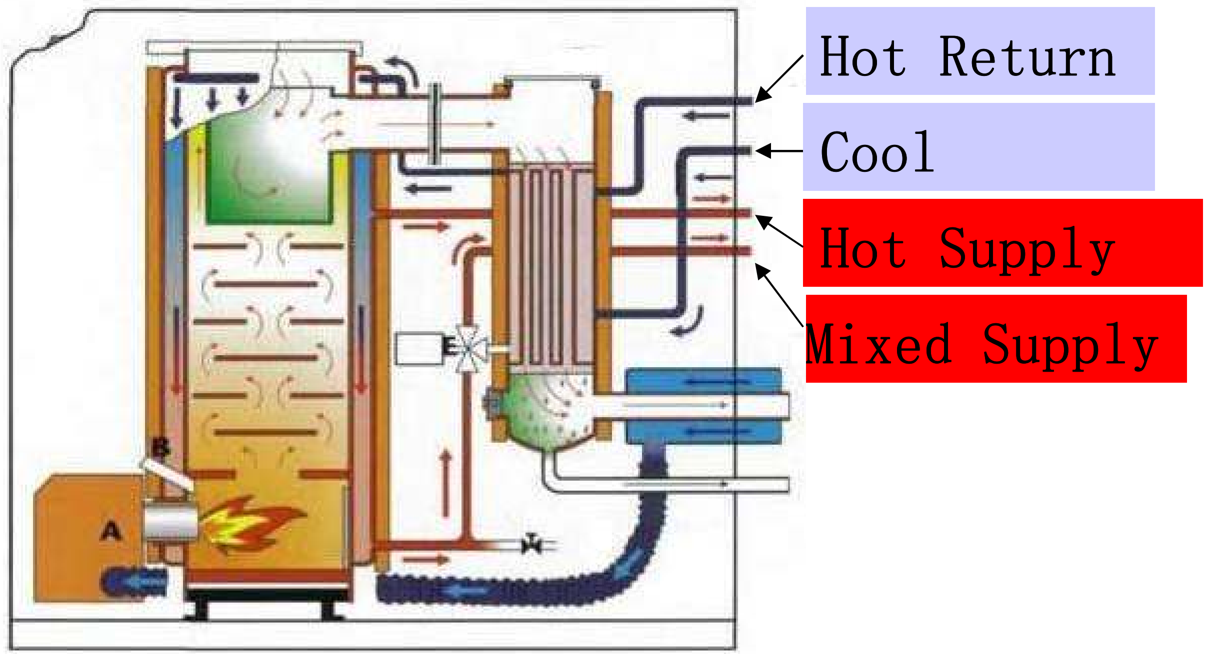
FCX Oil-Fired Condensing Boiler

92-97% Efficient

The Most Efficient Oil-Fired Boiler

Counter Flow Heat Exchanger

Counter Flow
Heat Exchanger



1. Combustion gasses rise thru the <u>Primary</u> and continue down through the <u>Condenser</u> and then to the flue.
2. Water flows counter to the direction of the gasses and enters the bottom of the condenser.
3. The flue gas is cooled enough to condense, and this adds the latent heat of vaporization into the water.

The FCX Boiler

Features and Benefits - 1

- Small footprint, attractive, very quiet
- Two sizes 76 Kbtu and 104 Kbtu Output
- Riello Burners – the most reliable name in the Industry
    - High pressure pump
    - In-line oil heater
    - Dual air adjustments – coarse & fine
    - Blocked vent safety

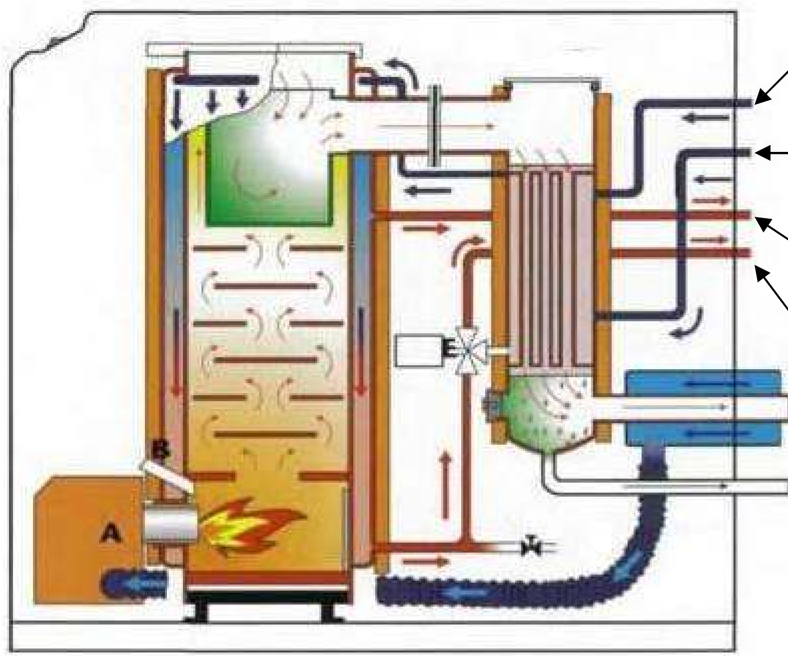
The FCX Boiler

Features and Benefits -2

- Built-in features:
  - Expansion tank
  - Mixing valve
  - Grundfos pump
  - Plug and play to your manifolds.
- Two Temperature circuits
  - Mixed for low temperature radiant
  - High temperature that does not contaminate the cooler return water with the hot return water.
  - The advantage of a separate secondary condenser

Counter Flow Heat Exchanger

Counter Flow
Heat Exchanger



Hot Return

Cool

Hot Supply

Mixed Supply

1. Combustion gasses rise thru the Primary and continue down through the Condenser and then to the flue.
2. Water flows counter to the direction of the gasses and enters the bottom of the condenser.
3. The flue gas is cooled enough to condense, and this adds the latent heat of vaporization into the water.

The FCX Boiler

Features and Benefits - 3

- Stack: Less expensive, easily worked plastic, many options
- Additional standard safeties not required for residential boilers
  - High water temperature safety
  - High stack temperature safety
  - SPDT switches on above safeties for add on alarms
- Built for radiant heat, but can work with baseboard
- Close technical support to the designer, installer, and servicer
- Comprehensive Installation Manual

The FCX Boiler

Features and Benefits - 4

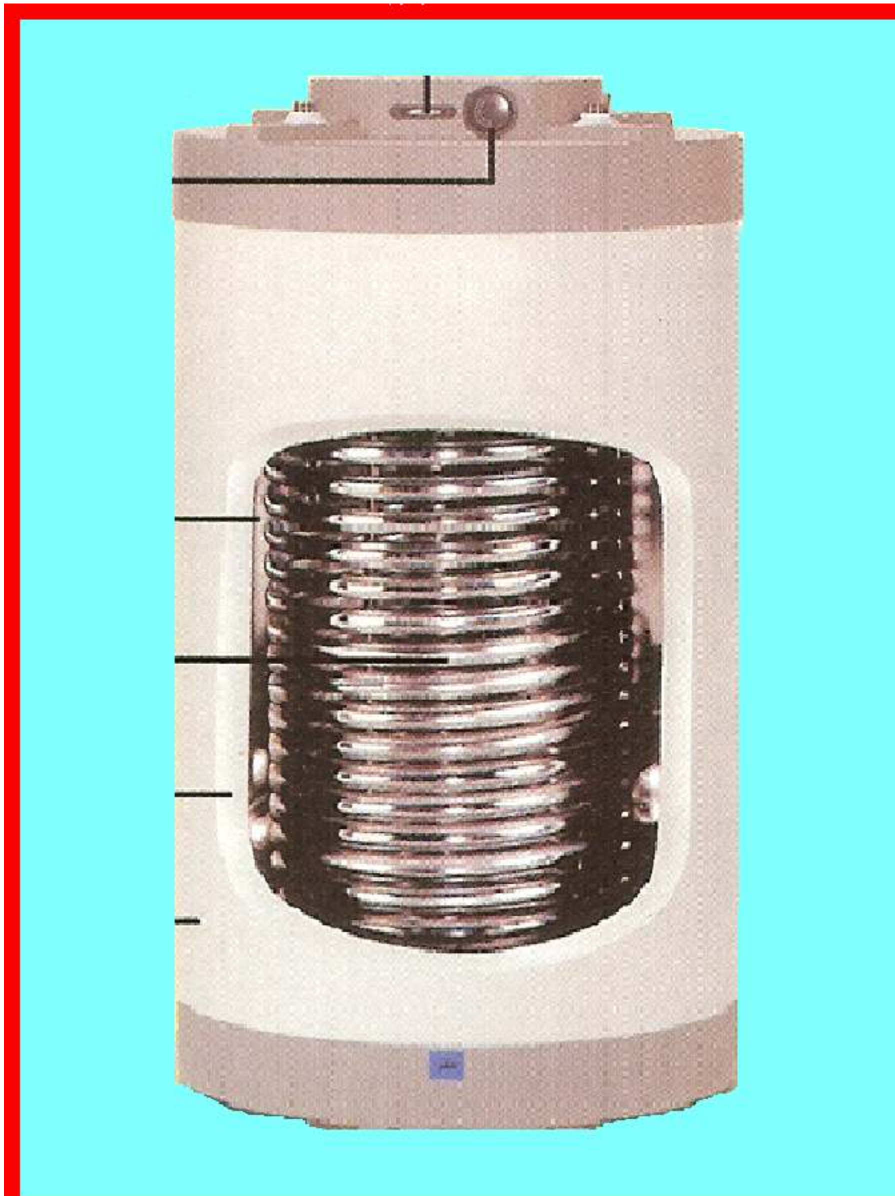
- **Efficiency & Fuel Savings**
- **Savings you can expect replacing a conventional boiler**

30% to over 50%

What about gas conversion?

DWH Tanks

- Sizes Available
  - 25, 40, 50, & 80 Gallon
- Thermometer
- Aquastat
- 100% 316 L Stainless Steel
- Special connection for hot recirculation
- Built for low temperature boilers
- Comparison of recovery rates & Sizing
- Works on 130-140° water



Warranty & Support

10 Years for Heat Exchangers and DHW Tanks

2 years on other parts

2 year Riello warranty

Comprehensive installation manual

Close technical support to the designer, installer, and serviceman

Fairbanks – Initial setup and tuning included

Hydronics Unique To Condensing

Hydronics – Unique to Condensing

**** Return Temperatures*****

- The key to greater efficiency
- Return water temperatures must be below 115°F, the threshold where condensing begins
- Brookhaven Laboratory study has confirmed this
- 100 °F or less out and 75 to 80 °F return works best
- 130 °F out and 110 °F provides some condensing

The single most important event in condensing boilers

Hydronics – Unique to Condensing

Do NOT Temper the Return Water

- Immune to boiler shock
- No tempering circuits/valves
- No circulation pumps
- No 4-way mixing etc.
- No Injection circulation loops

The 2nd most important event in condensing boilers

John Siegenthaler, P.E.

Future-proof hydronic systems

Low water temperatures are the key.

A tradeoff has always existed between the water temperature at which hydronic heat emitters are sized and their cost. The higher the supply water temperature assumed by the designer, the smaller the required heat emitters and the lower their installed cost. This is why the heat output tables on some baseboards did, and in some cases still do, list heat outputs at water temperatures all the way up to 240° F.

Although I've worked with hydronic heating for more than three decades and designed systems around just about every possible heat source, I would be hard-pressed to predict what might be available as hydronic heat sources 25 years from now. Fifty years from now I doubt that I will be predicting anything. Yet I hope that hydronic heating, in some form, will still exist and may even be the dominant method of heat delivery.

Think about it

By the latter half of the 20th century, the North American hydronics industry got used to the fact that some hydronic heat sources could last for several decades. It was not uncommon for a well-applied cast-iron boiler to have a useful life of 30 to 40 years. These boilers usually became technologically obsolete before they were incapable of operating due to some major failure. This was just fine when fuel prices were reasonably cheap and stable, and product development occurred at a somewhat slower pace compared to today. Back then, most Americans cared little about the "box in the basement," provided that it responded when the dial on the T-86 got turned up in the fall.

Today, some fuel costs are approaching 400% of what they were 15 years ago. Predictably, more consumers are now interested in what's happening within that box in the basement. Our industry has responded with a wide spectrum of heat sources from boilers to heat pumps to solar collectors. Still, you won't find many manufacturers suggesting that these heat sources are likely to last more than 20 years.

To attain high thermal efficiency, most of these heat sources need to operate with low-temperature hydronic distribution systems. These include radiant floors, walls and ceilings, panel radiators or some of the newer low-temperature baseboard.

The hardware used in these distribution systems includes a wide range of polymer tubing (e.g., PEX, PEX-AL-PEX, PERT, PERT-AL-PERT, PP-R), as well as copper, steel and aluminum. Other materials used in site-built radiant panels include concrete, poured gypsum underlayment, foam insulation, fiberglass insulation and wood. When properly selected and installed, modern hydronic distribution systems made from these materials should last for many decades, perhaps even as long as the building they are installed in.

Planning ahead

So, based on expected life, it appears inevitable that most of the hydronic *distribution systems* currently being installed will be supplied by different heat sources over their useful life. This raises an obvious question: What can designers do today to ensure that the distribution systems they create are compatible with future heat sources?

The answer should consider the materials used in the system, how the system will be maintained and at what conditions the system will operate.

Regarding materials, most of the present-day polymer tubes, when applied at temperatures and pressures well-below their maximum ratings, should last upwards of 100 years. I've even heard

Hydronics – Unique to Condensing

Pumping

- The more the better??? – old school
- Variable Frequency Drive (VFD) – the best way
- ECM ΔT, ΔP, Mixing Pumps
- Slow, nearly continuous pumping at lower temperatures

The pumping can have a great effect on efficiency

John Siegenthaler, P.E.

Hitting a home run

Your solar combisystem will benefit from this easy-to-install heating system design.

After reading my Solar Design Notebook in **pme**'s October issue, perhaps you formed an opinion about what's the "best" heat emitter for use with solar thermal collectors. That's fine, but remember no heat emitter can deliver optimal performance without an equally well-thought-out distribution system.

Although many potential piping layouts could serve your purpose, one stands out as the simplest, easiest to install and literally most flexible approach. I refer to it as a home-run distribution system. An example of such a system using panel radiators as heat emitters is shown in Figure 1.

> Figure 1.

Photo courtesy of Caleffi North America

Home-run distribution systems start with a manifold station. Usually it's the same type of manifold station that would be used in a radiant floor heating system. In Figure 1, the manifold station is shown in a recessed wall mounting. It also can be mounted horizontally under the floor provided it remains accessible.

Paired runs of 1/2-in. PEX or PEX-AL-PEX tubing provide the supply and return from the manifold station to each heat emitter. The flexibility of this tubing allows it to be routed through most framing cavities much like an electrical cable. This is particularly nice in a retrofit situation where the use of rigid tubing would otherwise require some "Sawzall surgery" to walls, ceilings, etc.

Figure 2 shows a home-run system in schematic form. It adds a thermal storage tank as the heat source and a variable-speed pressure-regulated circulator.

Variable-speed pressure-regulated circulators have been in use for more than a decade in Europe and are now available in North America from companies including Grundfos, Wilo, Taco and Xylem. These circulators all use microprocessor-controlled, electronically commutated motors that can operate over a wide range of speeds and in different control modes depending on the application.

For a home-run system, the circulator would be set to operate in a "*constant differential pressure*" mode. As such, it varies its speed whenever necessary to maintain a constant (installer-set) differential pressure between its inlet and outlet ports. The relationship between the pump curves at different speeds and the various system head loss curves (depending on which zones are active) is shown in Figure 3.

Notice how the yellow dots, which represent hydraulic equilibrium between a given system head loss curve and a given pump curve, all stay on the same horizontal line. This line represents the differential pressure across the manifold of a home-run circuit under design load conditions. Because these points stay on a horizontal line, the differential pressure across the manifold remains constant at this setting regardless of which zones are active. This ensures stable flow rates in all zones at all times.

At full speed, circulators with ECM motors operate on about 50% of the electrical wattage required by standard hydronic circulators of equal capacity. This characteristic, in combination with "intelligent" speed control, delivers annual electrical energy savings of 60% or higher relative to standard wet-rotor circulators. These circulators are quickly raising the performance bar in all types of hydronic systems. Their energy-saving characteristics make them particularly attractive for solar thermal applications where minimizing electrical energy use is a key design goal.

The combination of a home-run distribution system, heat emitters equipped with thermostatic radiator valves and a variable-speed pressure-regulated circulator is a simple yet elegant subsystem for pairing with solar thermal collectors, as well as an auxiliary boiler for those days when the sun isn't shining so brightly.

The thermostatic radiator valves shown on each panel radiator in Figure 2 constantly monitor the air temperature of the room in which the panel is located. If that temperature drops 1° F or more below the TRV's temperature setting, the valve's stem slowly begins

*Note: The views expressed here are strictly those of the author and do not necessarily represent **pme** or BNP Media.*

Hydronics – Unique to Condensing

Heat Emitters

- High Mass – the best for condensing
  - Lowest temperatures needed
- Staple Up – don't do it, requires water 30°F greater water temperature
- Radiant Panels – pricey, but can use lower water temperatures
- Baseboard and Super Baseboard
- Unit Heaters and other low mass

The Key is lower water return temperatures

> Figure 2.

Courtesy of Smith's Environmental Products

Making it happen

Hopefully you're now convinced that low water temperature distribution systems enhance the performance of solar thermal combisystems. *My suggestion is to create your distribution systems so the supply water temperature under design load conditions doesn't exceed 120°F.* With that in mind, let's look at some heat emitters that love to operate under these conditions.

First, it's critically important to understand what determines the water temperature in any hydronic distribution system.

Some designers, including an embarrassingly high percentage of HVAC professionals, think it's the *heat source* that controls the water temperature in a hydronic heating system. This notion stems from the fact many boilers come with a control device that has a dial (or perhaps digital interface) on which the installer "sets" a water temperature. Many think by setting this temperature they are "guaranteeing" the heat source will produce it. This is not the case. The set temperature is only a limit on how high the water temperature leaving the heat source *might* climb.

The water temperature in any hydronic distribution system only climbs high enough for that system to achieve thermal equilibrium – where the rate of heat release from the distribution system exactly balances the rate of heat input from the heat source. Once this condition is achieved, there is no "thermodynamic incentive" for the water temperature to climb higher, and it won't!

It's the design of the hydronic distribution system, including the selection and sizing of the heat emitters, that determines the water temperature at which the system will operate.

Anyone who designs a heating system wants to maximize its thermal efficiency. Today, that means moving away from high water temperatures by specifying heat emitters with larger active surfaces, or other details that increase both convective and radiative heat transfer. This allows thermal equilibrium to occur at relatively low water temperatures during both maximum load and partial load conditions.

Emitter evolution

There are several ways to design modern hydronic distribution systems around the low water temperatures that enhance the performance of renewable energy heat sources.

Let's start with the heat emitters. That term refers to any device intended to remove heat from water flowing through it and release that heat into the room where it is located.

Many building owners in heating-dominated climates are used to the look of fin-tube baseboard. While most don't relish it as a visual enhancement of the room, they understand its purpose and accept it as a necessary part of the building.

The latest development in low temperature fin-tube baseboard is shown in Figure 2 with a product called Heating Edge that is currently made in the UK, but available in North America.

From the outside it looks very similar to other fin-tube baseboard, but what's "under the hood" is very different. Heating Edge baseboard has much larger fins than traditional baseboard. The fin area is about three times larger, almost filling the entire space within the enclosure. It also has *two* ¾-in. copper tubes running through those fins. The tubes can be piped either for parallel flow or in series. In the latter case, the hottest water flows down the upper tube, makes a U-turn at the end and flows back along the lower tube.

Assuming an *average* water temperature of 110°F, this baseboard releases about 290 Btu/hr./ft., when the two pipes are configured for parallel flow and the total flow rate through the element is 1 gpm (0.5 gpm through each tube). This increases to about 345 Btu/hr./ft., with a total flow rate of 4 gpm (e.g. 2 gpm per tube). If the two tubes are configured for series flow (hot along top and return along bottom), the output at 1-gpm flow rate drops about 10%.

Consider a 12-ft. by 16-ft. room in a well-insulated home with a maximum heating load of 15 Btu/hr./ft.[2] The room's maximum heating load is thus 2,880 Btu/hr. This could be handled by a 10-ft. length of Heating Edge baseboard operating at an *average water temperature of 110°F* and 1-gpm flow rate. To produce equivalent output, a 10-ft. length of conventional residential baseboard would require an average water temperature of about 150°F. The latter temperature would dramatically lower the efficiency of solar thermal collectors.

Radiant panel solutions

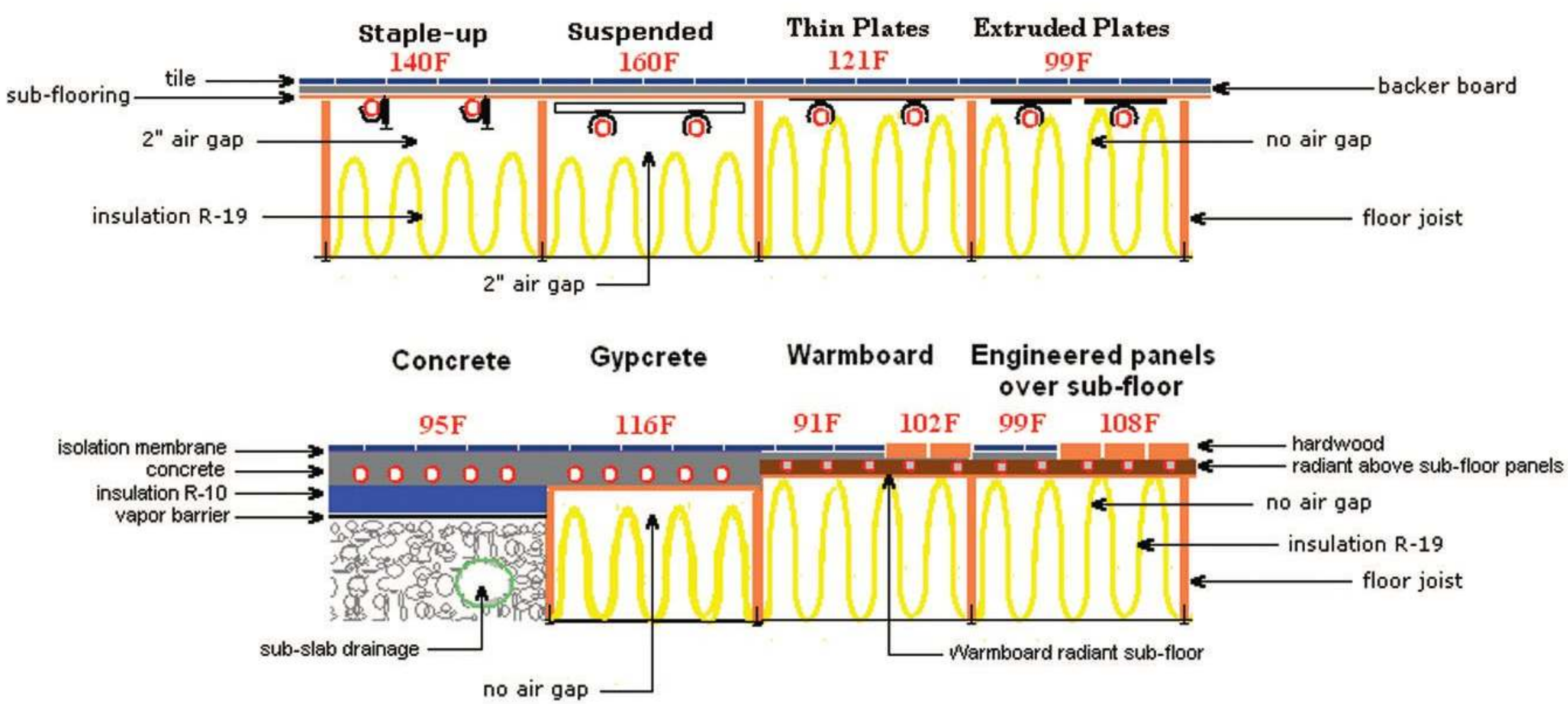
The key to achieving low water temperature operation is using heat emitters with large heated surface areas. The greater the heated surface area, the lower the required water temperature for a given rate of heat output.

By embedding tubing in floors, walls and ceilings, it's possible to create very large heat surfaces within a room. Radiant floor heating is undoubtedly the best-known form of radiant panel heating. It can be installed in several proven ways that allow it to operate at relatively low water temperatures.

Typical Floor Types

The Major Factor: "The lower the systems temperature requirements, the better the overall system-wide efficiency, which will ensure the lowest possible operating costs for fuel and power." [and the Most Condensing and Lowest Stack Temperatures]

Water temperatures required to meet the required 80F floor surface temperature.



Drawing by Dave Yates

A PERFECT MARRIAGE

Comfort and economy of operation are linked with well-designed and properly installed hydronic radiant floor systems.

Providing thermal comfort by transferring energy from point-of-source to point-of-use in hydronic (water-based) systems is achieved by a wide variety of radiant-floor installation methods and each requires varying degrees of water temperature to deliver the same results. The radiant floor temperature boundary for human comfort revolves around maintaining a floor surface temperature below 85° F.

The human body loses heat in four basic ways: radiantly (your body radiates heat); convectively (air currents); conductively (direct contact — barefoot on an unheated tile floor); and perspiration (latent heat of evaporation). Skin surface temperature averages 85°. A floor surface temperature above 85° upsets the balance between the four and will cause people to be uncomfortably warm.

A general misconception about radiant floor warming is that the 85° design limitation was required to protect hardwood flooring. If that was true, hardwood floors heated to well above 100° while baking in direct solar gain would be easily and permanently damaged!

Radiant floors are often a perfect marriage with all types of hardwood floor coverings and all available floor surface materials are compatible with hydronic radiant heating. Modern hydronic radiant design programs provide the system designer with the ability to "install" virtually any type of floor covering over the radiant floor panel, which provides an ability to determine compatibility and the required water delivery temperatures to offset the heat loss.

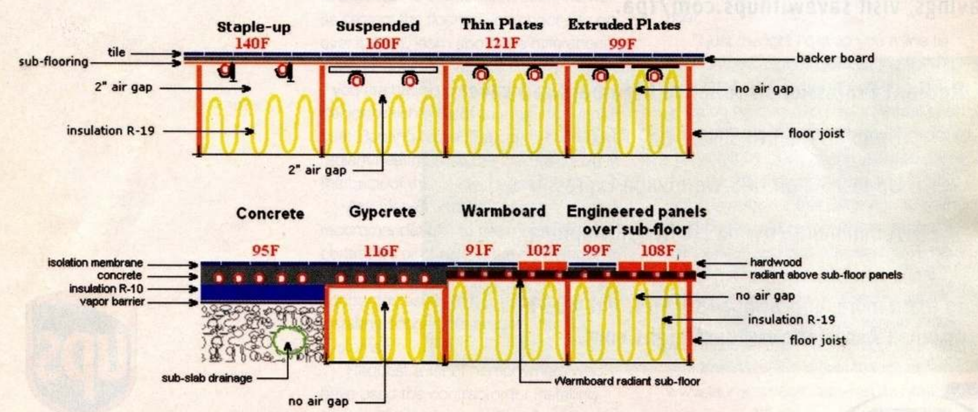
It is not unusual for room-by-room designs to require a wide variety of water delivery temperatures. Numerous reliable methods are available to precisely control multiple-temperature delivery from a single-temperature source or from blended systems where multiple- and varying-temperature energy sources are incorporated.

Comfort and economy of operation are inexorably linked with well-designed and installed hydronic radiant floor systems. Low-temperature designs offer the greatest opportunity to blend a wide variety of energy sources, maintain peak operating efficiencies (especially true for geothermal or air-to-water heat pumps), and to incorporate alternative energy sources such as wind, solar photovoltaic and solar thermal. The lower the system's temperature requirements, the better the overall system-wide efficiency, which will ensure the lowest possible operating costs for fuel and power.

The majority of hydronic radiant systems, certainly the better-designed ones, will employ a control strategy that will alter water temperature based upon whatever Mother Nature is giving us outside. The building's heat loss will be greater as outdoor air temperatures fall. Conversely, system water delivery temperature will be increased to transport more comfort-energy to the radiant floors — the colder it gets outdoors, the hotter the water.

How hot depends on the installation method used for the floors, the materials between the radiant tubing and/or panels and the room served, the desired

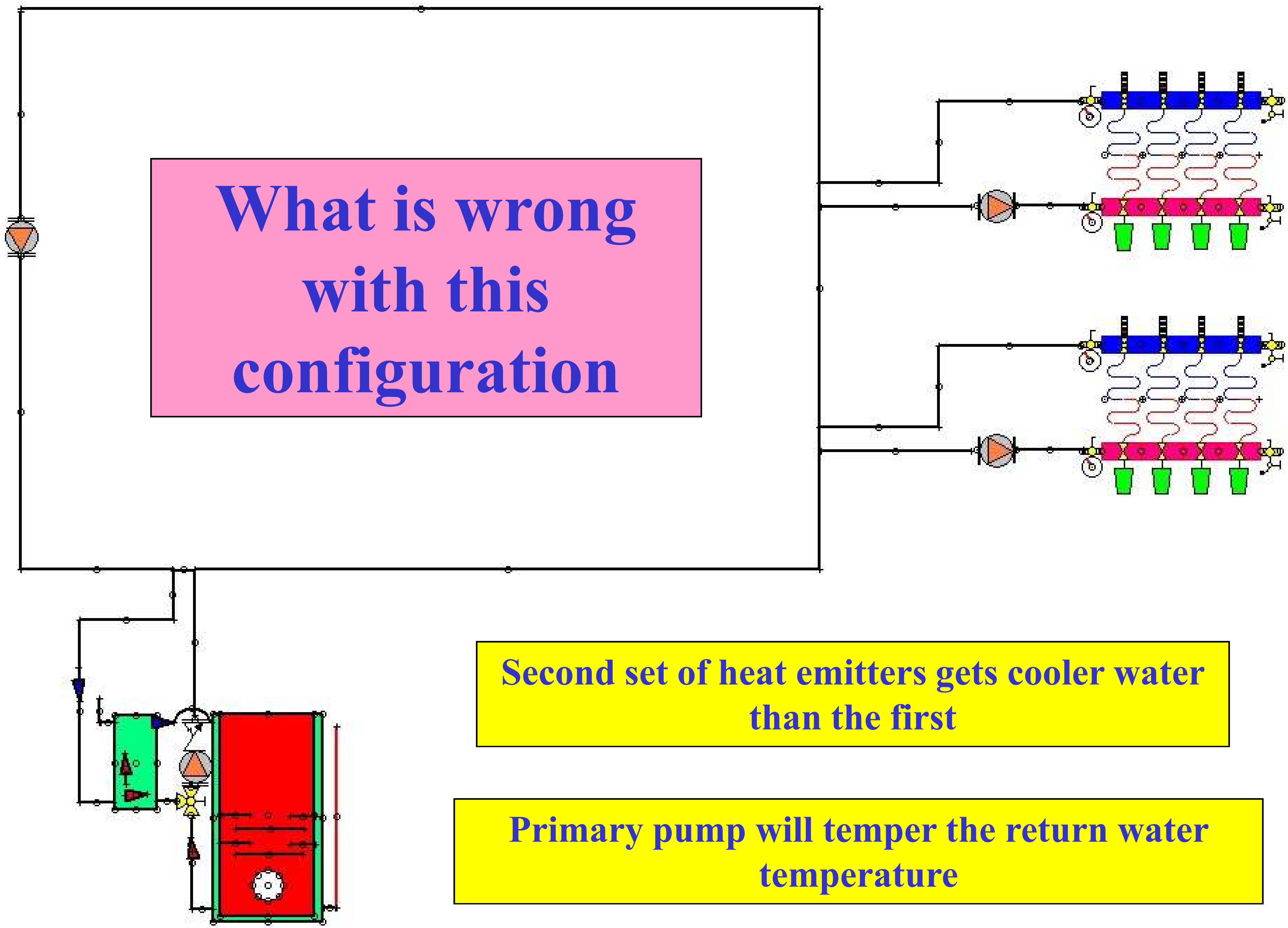
Water temperatures required to meet the required 80F floor surface temperature.



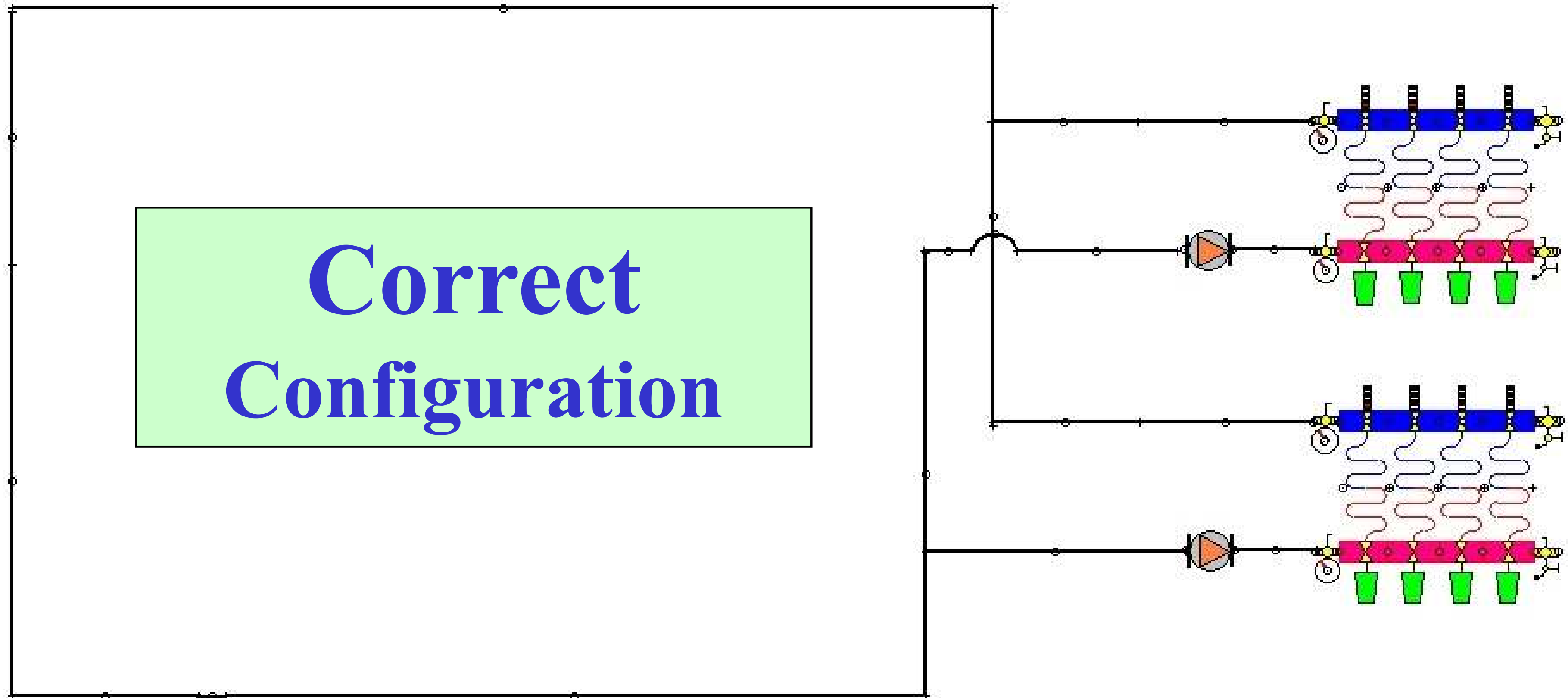
Drawing by Dave Yates

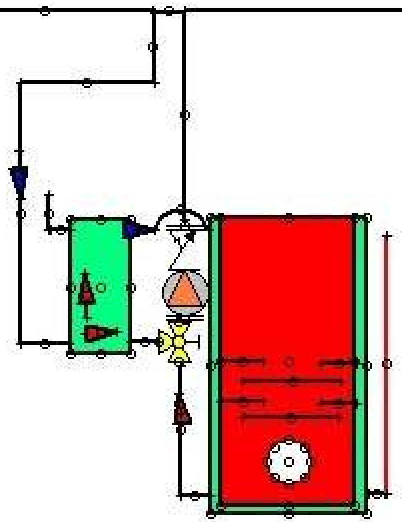
Hydronics – Unique to Condensing

Considerations for Injection Pumping


What is wrong with this configuration
Second set of heat emitters gets cooler water than the first
Primary pump will temper the return water temperature

Correct Configuration





Second set of heat emitters are now in parallel – both receiving the same temperature water.

Caution – the supply pump can still over pump the delivery pumps causing tempering of the return water.

Solution is to use an ECM ΔT pump.

New Construction

- **No Brainer**

Typical Floor Types

The Major Factor: "The lower the systems temperature requirements, the better the overall system-wide efficiency, which will ensure the lowest possible operating costs for fuel and power." [and the Most Condensing and Lowest Stack Temperatures]

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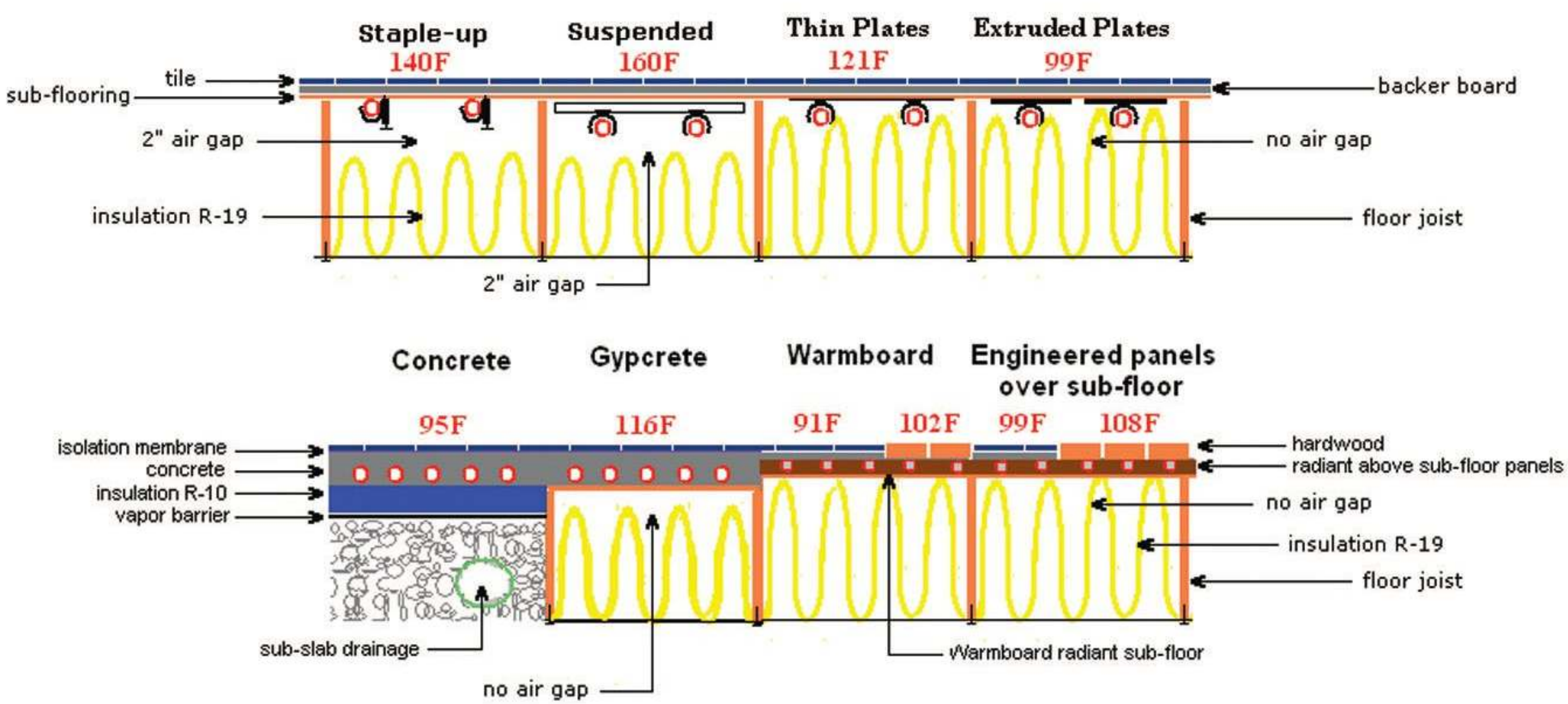


Drawing by Dave Yates

What Every New System Should Have

- **A Condensing Boiler**
- **Radiant Floors or Low Temperature Emitters (example Heating Edge)**
- **Controls that allow the boiler to go cold when there is no call for heat**
- **Smart Pump (ECM/VFD) that can control flow and/or temperature**

Retrofits

Options & Limitations

Considerations:

- Is the boiler big enough?
- Can you extract adequate heat from the boiler at lower temperatures?
- Auxiliary heat sources
- Old construction radiant – it will generally work if high mass, not with staple-up
- Can you use lower water temperatures

Factors Affecting the Need for High Water Temperatures

Factors:

- Poor insulation
- Bad Windows
- Air Leaks
- Few heat emitters
- Location – Hills or Holes

Enhancing and Optimization Of Condensing Boilers

By

James Romersberger

7/16/12

Dropping the Stack
and
Return Water Temperatures

Very Important Note:

Not all the return water needs to be reduced in temperature, ONLY the part that goes through the condenser

- **Preheating domestic water with the return**
- **Preheating HRV air**
- **Unit heaters in series**
- **Series plumbing - Baseboard feeding slab or baseboard feeding a cold baseboard area such as a garage**
- **Reduced mixed output temperatures result in reduced returns**
- **Reduced pumping speeds (increases ΔT)**
- **Add an after-condenser to a single heat exchanger system**
- **Add another after-condenser for DHW well water**
- **Add a stack robber (condensing in the stack is as effective as condensing in a condenser if the heat is recovered). Open stacks (not walled in) or vented chases allow for heat recovery.**

BROOKHAVEN NATIONAL LABORATORY

BNL-73314-2004-IR

Hydronic Baseboard Thermal Distribution System with Outdoor Reset Control to Enable the Use of a Condensing Boiler

Dr. Thomas A. Butcher

October, 2004

Baseboard Home #1

My Home:

- 3,000 SF heated, 2,000 shop and basement built into a hill, with residual heat only
- 2x8 walls with blown-in fiberglass, and triple pane windows, 1000 ft elevation
- 108 ft baseboard, no radiant, no unit heaters, pumping 120 to 130 °F water
- All return water goes through a DHW heat exchanger gets 10 °F temperature
- 35 ft x 4 inch plastic stack serves as stack robber, 80 to 120 °F exit flue temperature, depending on burn cycle
- Bacharach measurements: at boiler 91.5%, at top of 3rd floor exit 96%
- 53 gallon Burnham DHW indirect heater on Zone no priority – never out of hot water
- House Heat Recovery – adequate, no setback used

Baseboard Home #2

Chris Swaim:

- 1,545 SF + 900 SF Garage, all heated
- 2 x 6 walls with fiberglass batts, double pane windows, 650 ft elevation
- 151 ft baseboard, no radiant, unit heater in garage
- 4 inch plastic stack retrofitted in a 8” metalbestos stack
- FCX 22 pumping 120 °F to 150 °F water
- Geminox BS50 DHW indirect heater on separate pump – never out of hot water
- Grundfoss Alpha on baseboard
- House Heat Recovery – No setback used, increases temperature manually when needed
- Plans to install radiant in sunken living room
- Reduced fuel consumption by 50%

Baseboard Home #3

Flory and Cathy Shalk:

- 2,400 SF 800 SF per level, 2 story living, 800 SF crawl space all heated
- 2 x 6 walls with fiberglass batts, and double pane windows, 950 ft elevation
- 126 ft baseboard, no radiant, no garage
- Concentric sidewall vented
- FCX 22 pumping 120 °F to 140 °F water
- Geminox BS50 DHW indirect heater on separate pump
- Taco Bumble Bee pump on baseboard
- House Heat Recovery – No setback used

A Case For Multi-Heaters

Bob Tsigonis:

- 4000 SF 100% actively heated
- 12” (2 x 4 offset, 12 “ fiberglass) walls with blown-in fiberglass, and triple pane windows.
- Radiant basement, garage, entryway. Baseboard in lower bedrooms, forced air for main living area, unit heater in garage.
- FCX 30 boiler running temperature 130 °F
- 4 inch plastic stack retrofitted in a 8” metalbestos stack
- DHW indirect heater on Zone, no priority – never out of hot water
- House Heat Recovery – good

Before and After

Buckland

Insulated foam raft foundation, integrated truss combines floor, walls and roof into a single piece for easy framing, polyurethane spray foam, diagonal ridge roof, metal siding.

FCX 22 and 25 gal indirect DHW

Heating coil located in air handler, HRV provides delivery to rooms. By design, no heat can be provided unless HRV is in operation.

All controls, piping, gages etc. mounted on boiler and DWH with gasketed fittings provides easy shipping and simple assembly.

Habit for Humanity - Baseboard

Habit for Humanity - Baseboard

Testimonials

Proof Positive Boiler Comparisons

How Can This Be

Why do Actual Results Differ with AFUE

Standby

- Drafting through the boiler
- Jacket Losses
- Damper Loses
- Over Sizing

Operating

- Short Cycling
- High Stack Temperatures
- Tuning - AFUE vs. Actual, CO2, Excess Air, Stack Temps.
- Boiler Temperatures - 1% loss per 10 degree
- Return Water Temperatures
- Condensing Effect
- Cold Starting
- Side Arms

Controls

Controls

- Cold start vs. Hot start
- Reset controls and suitability
  - Temperature
  - Mixing
  - DHW
- Boiler protection
  - Causes for sustained condensing in primary
  - Large structure / lots of high mass emitters
  - Too much throughput

Recommendations

Taco SR502…506 Series

Or

Equivalent

Simple and inexpensive

Combine with Smart Pump Technology

Venting

Venting / Stacks

Concentric Options - Balanced

- Side Wall - up and out
- Side Wall - straight out
- Vertical
- Condensate drain tees

Single Wall Options

- Vertical – best choice
- Horizontal – caution recommended
- Manufactured condensate tee
- Single Wall balanced – Direct to boiler

Venting / Stacks

Combustion Air

- During construction
- Consider an Air filter

Known Problems

- Clogged air filter
- Back drafting and negative pressures - Even in “sealed” boiler rooms

Maintenance

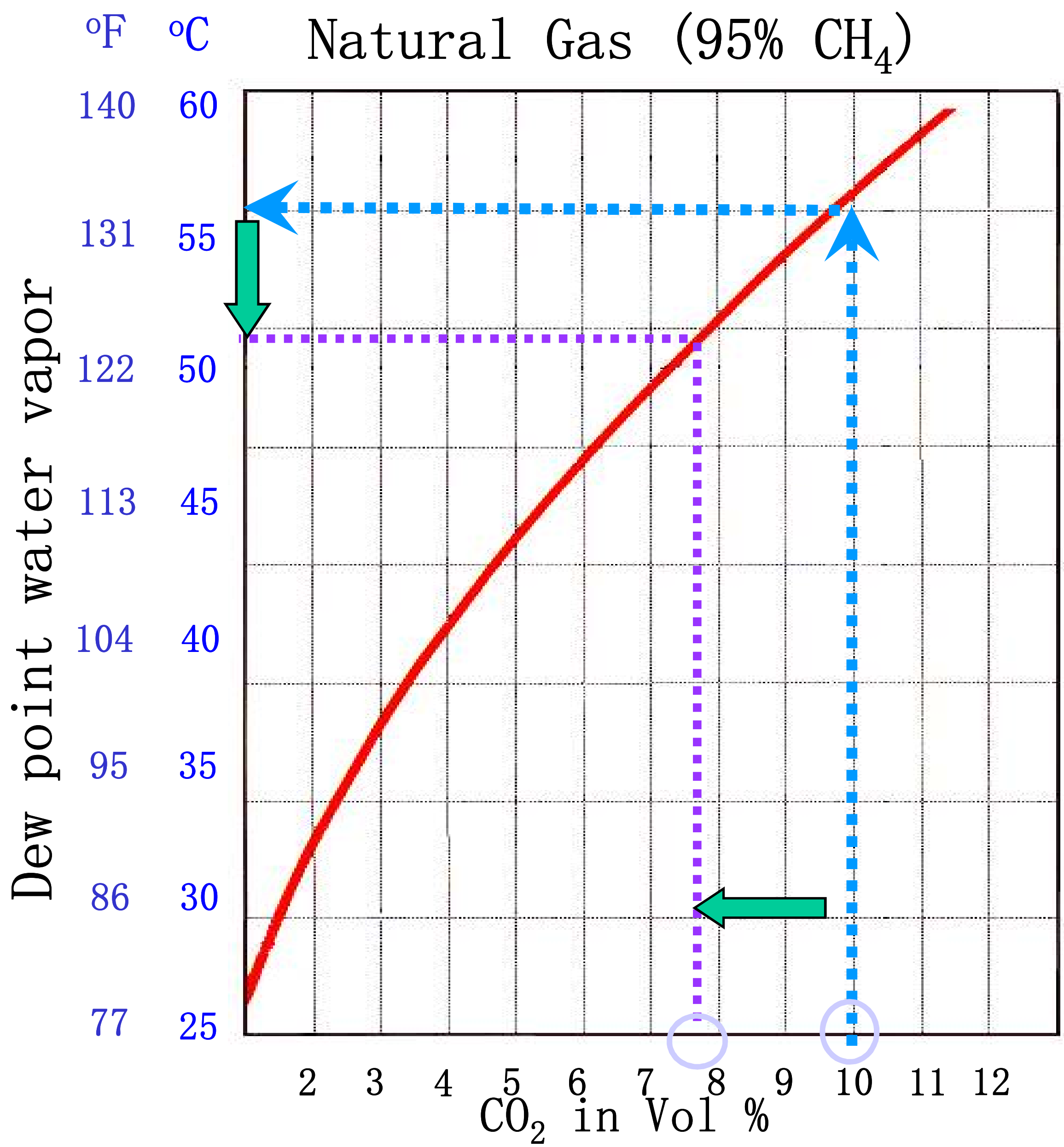
Maintenance
Cleaning and Inspection

- Once a year or every 1000 gallons
- Non-condensing mode and sooting
- Primary condensing – What to check for
- Secondary condensing (washing the tubes)
- Concentric air tee - need for inspection
- Plugged condensate drains
- Back drafting

Maintenance
Tuning a Condensing Boiler

- Slides with charts
- CO_2, O_2, CO Levels
- Excess Air
- Smoke

WATER VAPOR DEW POINT



CO_2% of flue gas influences dew point temperature

Higher CO_2
=Higher Dew point
=More Condensation

Lower CO_2
=Lower Dew point
=Less Condensation

Maintenance

Tuning a Condensing Boiler