High Efficiency / Low Emission Biomass Boiler Systems

Technology Overview & Lessons Learned

source: ECONOBURN

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High Efficiency / Low Emission Biomass Boiler Systems

Technology Overview & Lessons Learned

Topics:

1. Cordwood gasification boiler systems

   Boilers, systems, key concepts, sizing

2. Pellet boiler systems

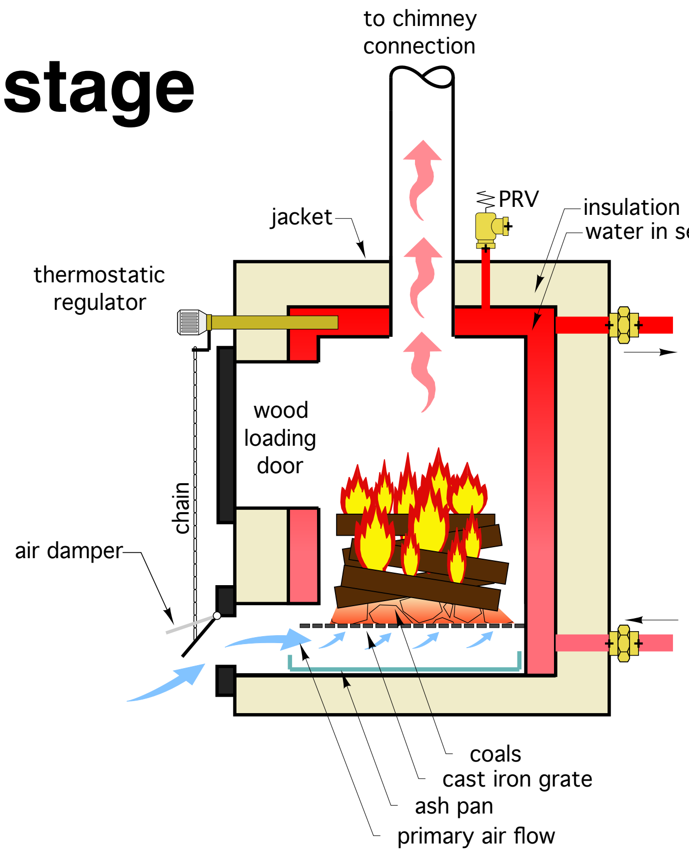
   Boilers, systems, key concepts, sizing

3. Lessons Learned

   Working with heating pros, thermal storage, boiler venting, heat emitters, auxiliary boiler

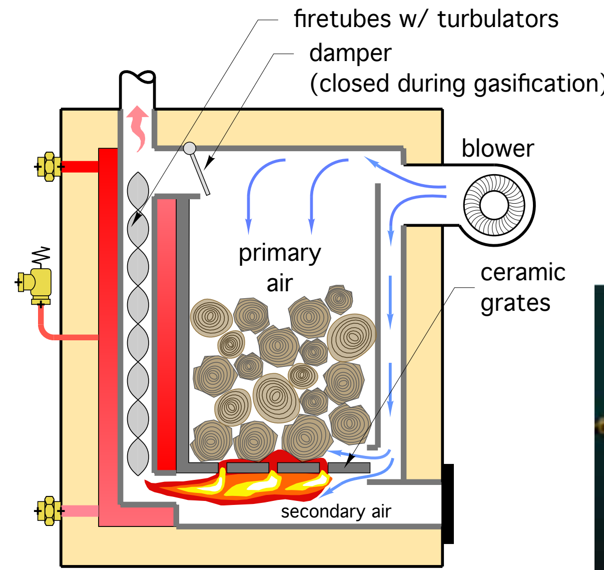
Cordwood-fired *boiler* classifications:

1-stage



- 1-stage combustion (no secondary air)
- significant ash & “clinker” residue

2-stage (gasification)



- 2-stage combustion
- Operate in “batch burn” mode
- Seasonal thermal efficiency 60-70%
- Very little ash or “clinker” residue

Wood gasification boilers

- 2-stage combustion
- Operate in “batch burn” mode
- Seasonal thermal efficiency 60-70%
- Very little ash or “clinker” residue

image courtesy of Econoburn

• For highest efficiency... Burn Hot & Burn fast.

• Don’t attempt to operate with wood moisture content > 20%. The drier the better.

• Heat output often exceeds heating load, so thermal storage is crucial.

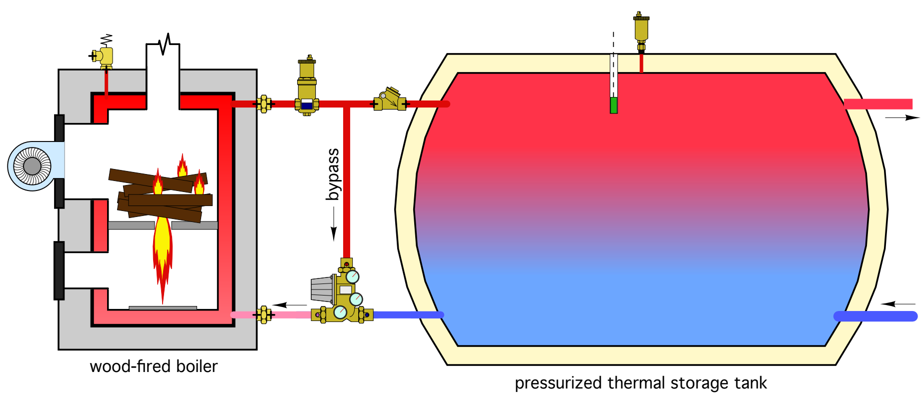


image courtesy of New Horizon Corp.

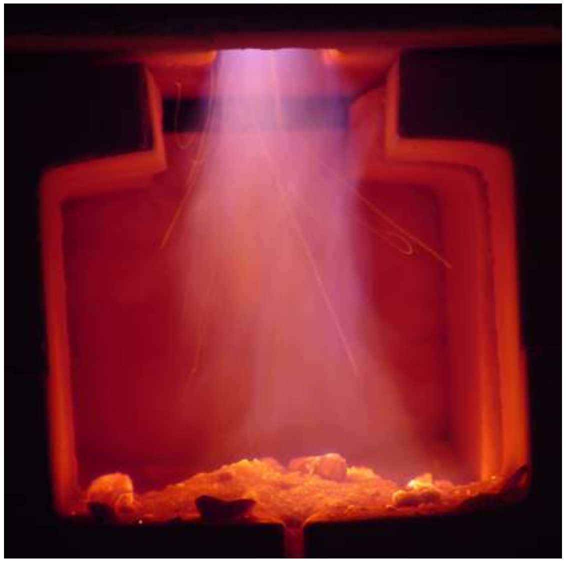


image courtesy of Tarm Biomass

Wood gasification boilers

secondary combustion in lower chamber

video courtesy of Econoburn

A typical system using a cordwood gasification boiler

(using pressurized thermal storage)

KEY CONCEPTS:

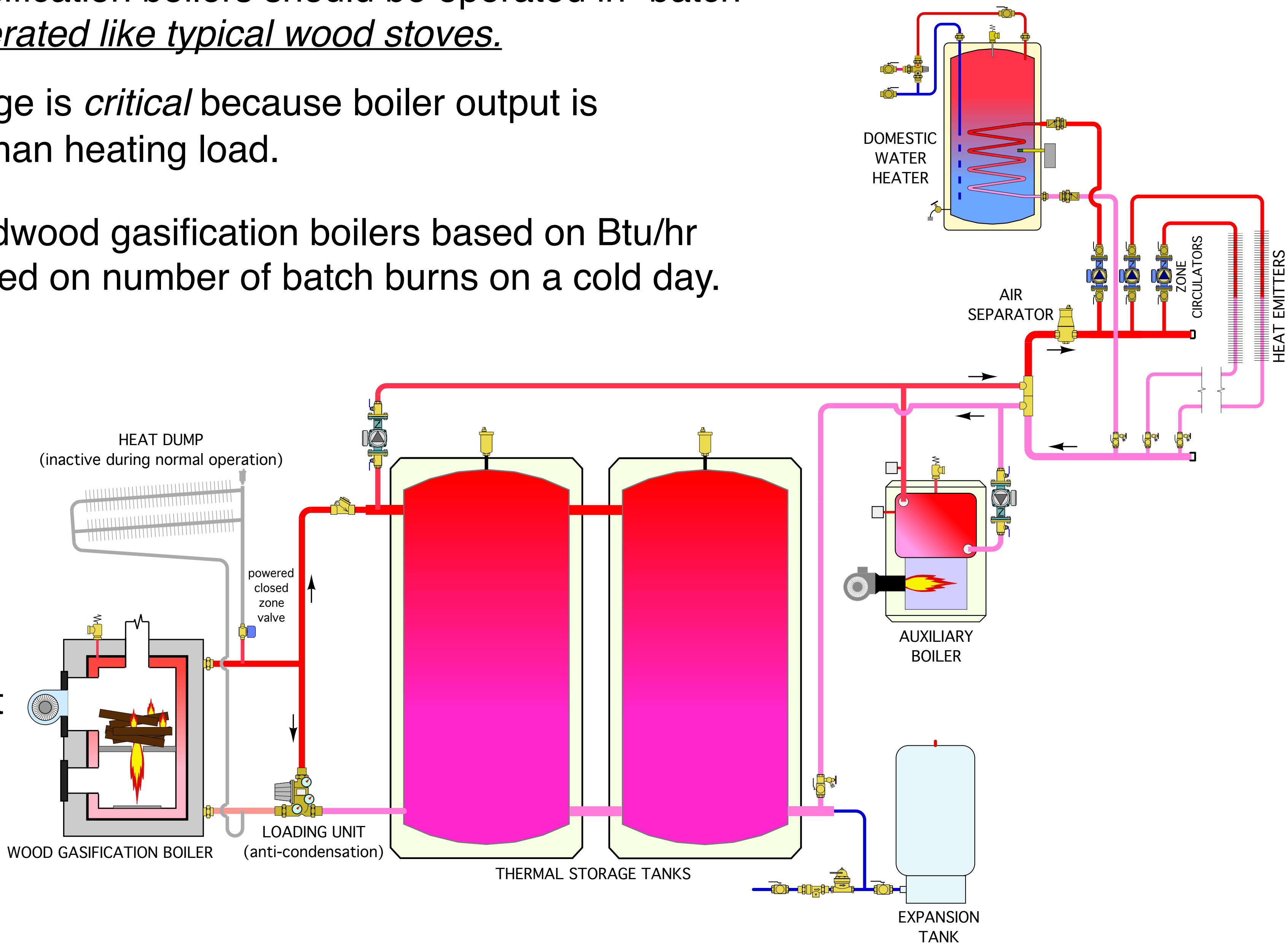
• Cordwood gasification boilers should be operated in “batch burns”, *<u>not operated like typical wood stoves.</u>*

• Thermal storage is *critical* because boiler output is usually higher than heating load.

• Don’t size cordwood gasification boilers based on Btu/hr rating. Size based on number of batch burns on a cold day.

• Always plan for safe dissipation of residual heat during a power outage.

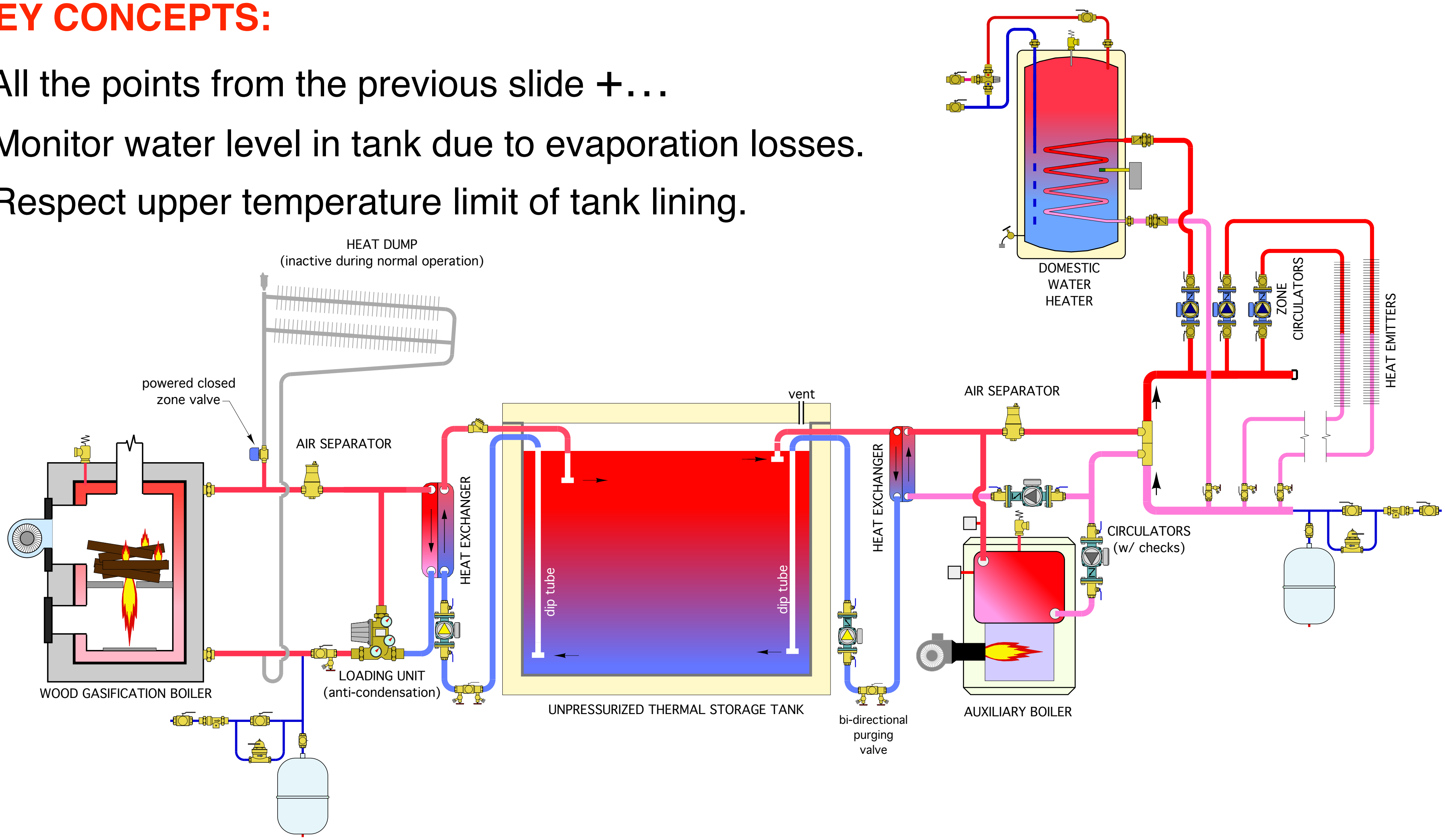
• Always protect boiler from sustained flue gas condensation.



Cordwood gasification boiler system w/ *unpressurized* thermal storage

KEY CONCEPTS:

- All the points from the previous slide +…
- Monitor water level in tank due to evaporation losses.
- Respect upper temperature limit of tank lining.



- External heat exchangers provide more predictable heat transfer relative to coils in tank.
- Use stainless steel circulators for moving water in/out of tank.
- Design controls so heat from auxiliary boiler is not inadvertently sent into thermal storage.

Don’t size a wood gasification boiler based on its BTU/hr rating!

These boilers *should* operate as “batch burners,” not the way a wood stove is typically fired.

The sizing of a wood-gasification boiler is based on the number of firing cycles the owner is comfortable with during a very cold day.

2 to 3 firing cycles during coldest winter day is common.

1 very cold day requires

2 sequential mild days (spring / fall) requires

Thermal Storage Tank Sizing for wood-gasification boilers

single unpressurized tank

2 coupled pressurized tanks

The minimum volume of thermal storage is determined by the certification test EPA M-28 Wood Hydronic Heater – Partial Thermal Storage test that was developed by BNL and adopted by EPA.

The formula below determines thermal storage tank volume based on absorbing ***95% of the heat released from burning a full charge of firewood, without any concurrent heating load.***

$$v = \frac{701(w)(n)}{\Delta T}$$

Where:
v = required thermal storage tank volume (gallons)
w = weight of firewood that can be loaded in the combustion chamber (lb)
n = average efficiency of the combustion process (decimal percent)
ΔT = temperature rise of the tank based on absorbing all heat from the combustion (°F)
701 = a constant based on the heating fuel value associated with 20% moisture content firewood.

Thermal Storage Tank Sizing for wood-gasification boilers

Example: Assume that the firebox of a wood-gasification boiler, when fully loaded, can hold 65 pounds of seasoned firewood (20% m.c.). The boiler's average combustion efficiency ***for a complete burn cycle*** is 70%. Determine the thermal storage tank volume needed assuming the water in the tank will rise 60 °F as it absorbs 95% of the heat generated by burning the full charge of wood.

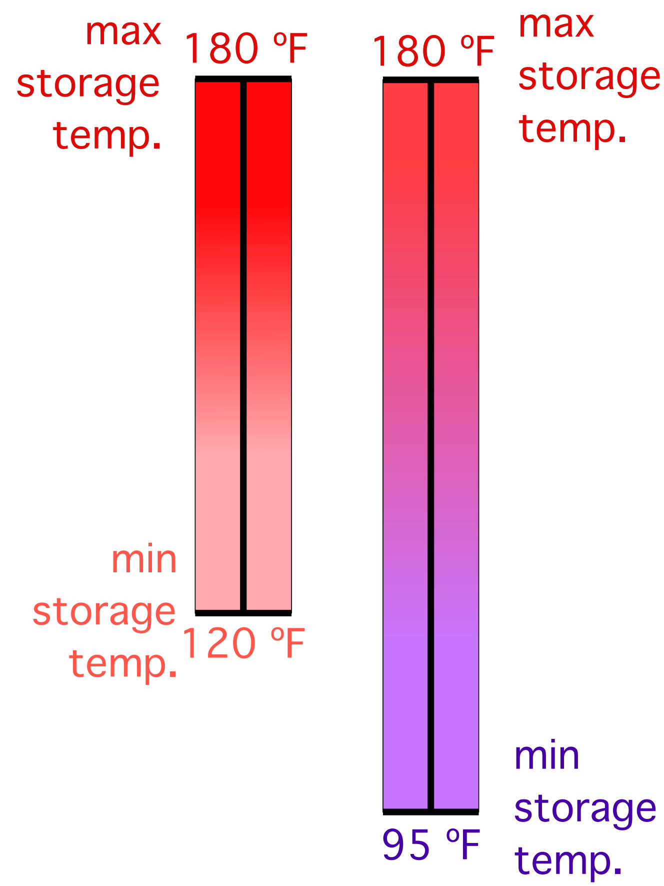
Solution: Putting the data into the formula yields:

$$v = \frac{701(w)(n)}{\Delta T} = \frac{701(65)(0.70)}{60} = 532\,gallons$$

This result shows that a substantial tank volume may be required in systems using wood-gasification boilers.

This volume can be achieved with a single tank, or by combining multiple tanks piped in parallel.

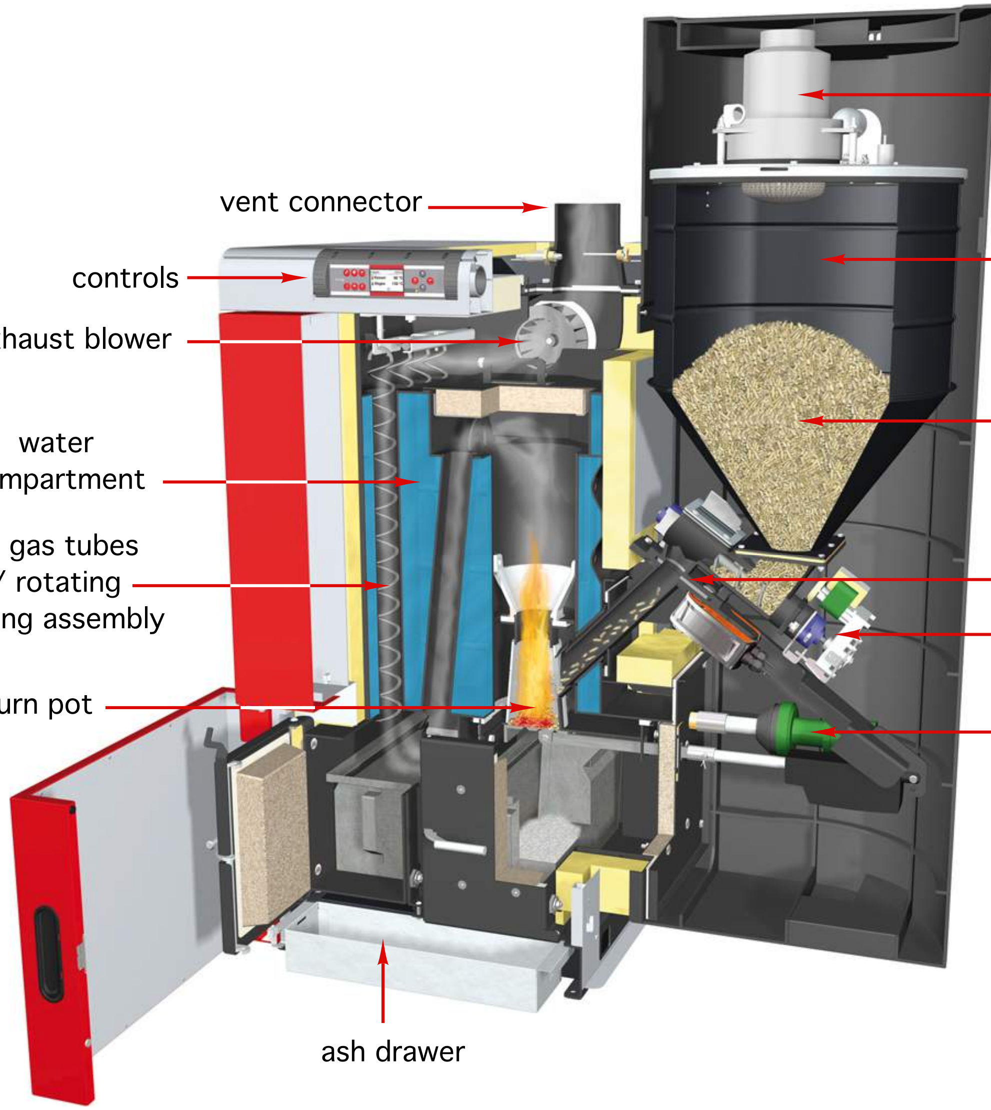
Can reduce the required volume by using a control strategy that widens the temperature cycling range of tank. With the upper temperature typically limited to 175-200 °F, ***the cycling range can be widened by reducing the temperature at which the space-heating distribution system operates.***



ΔT 0f 85°F (180-95) yields 42% more Btu storage per gallon than ΔT of 60 °F (180-120)

High Efficiency Pellet-fired Boilers

image courtesy of Tarm Biomass

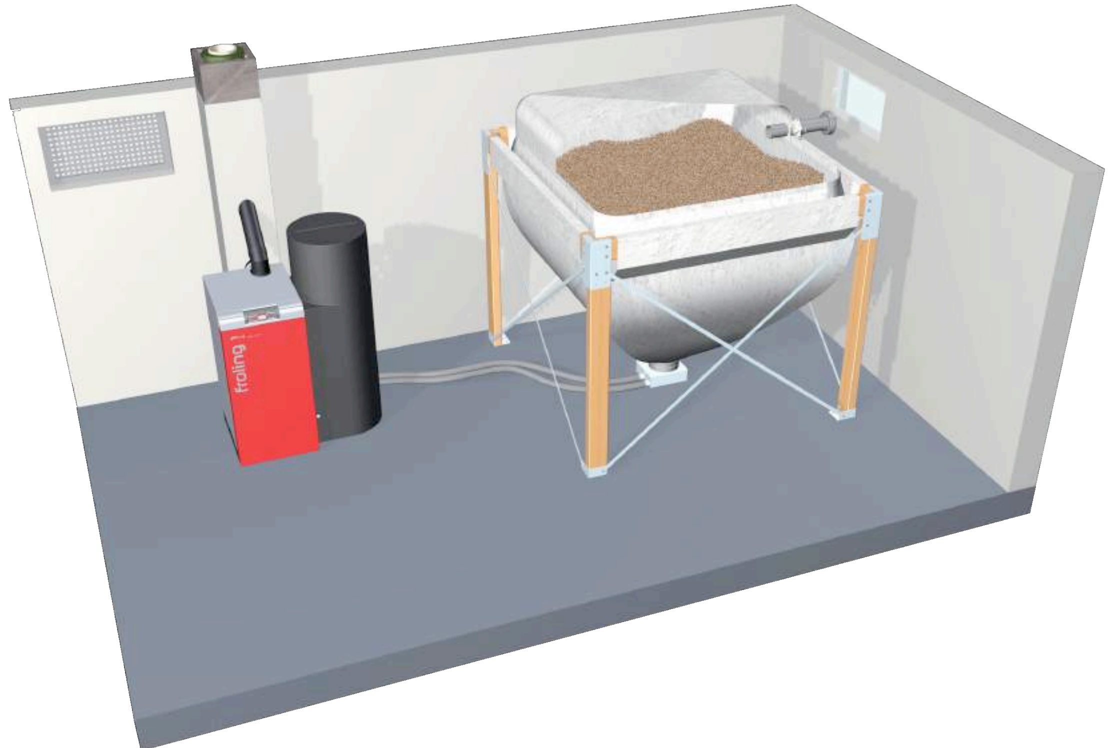


Pellet boilers operated at higher loads, cycle less frequently, and have lower emissions when installed with thermal storage.

Indoor Pellet Storage

NOTE: Due to concerns over CO outgassing, Renewable Heat NY does not allow indoor pellet storage.

image courtesy of Tarm Biomass



Bag silos: 1-7 tons capacity

image courtesy of Maine Energy Systems

image courtesy of Pellergy

outdoor pellet storage

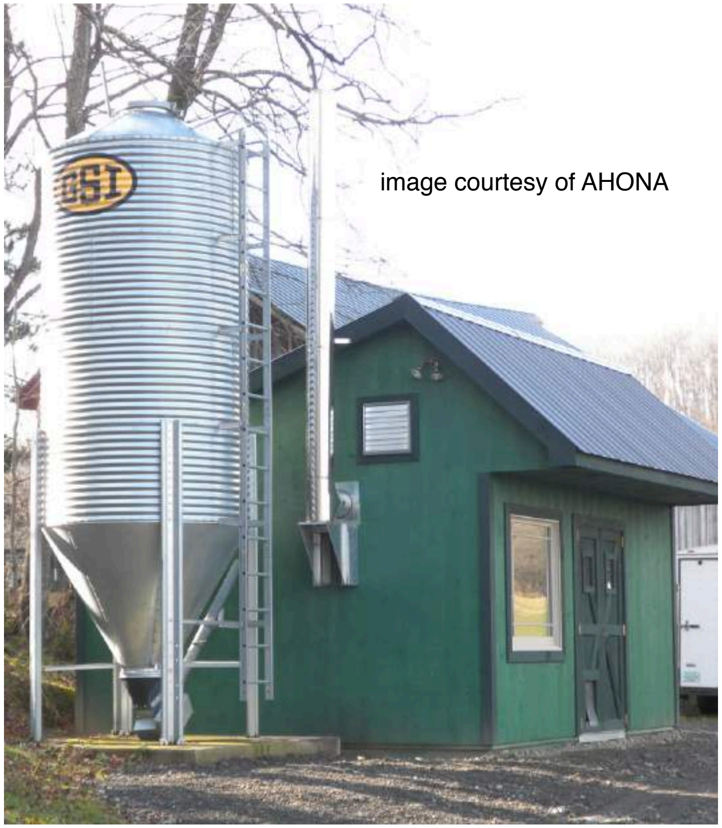


image courtesy of AHONA

Polydome silo 8.5 ton capacity)

Outdoor storage by Vincent’s Fuel Service

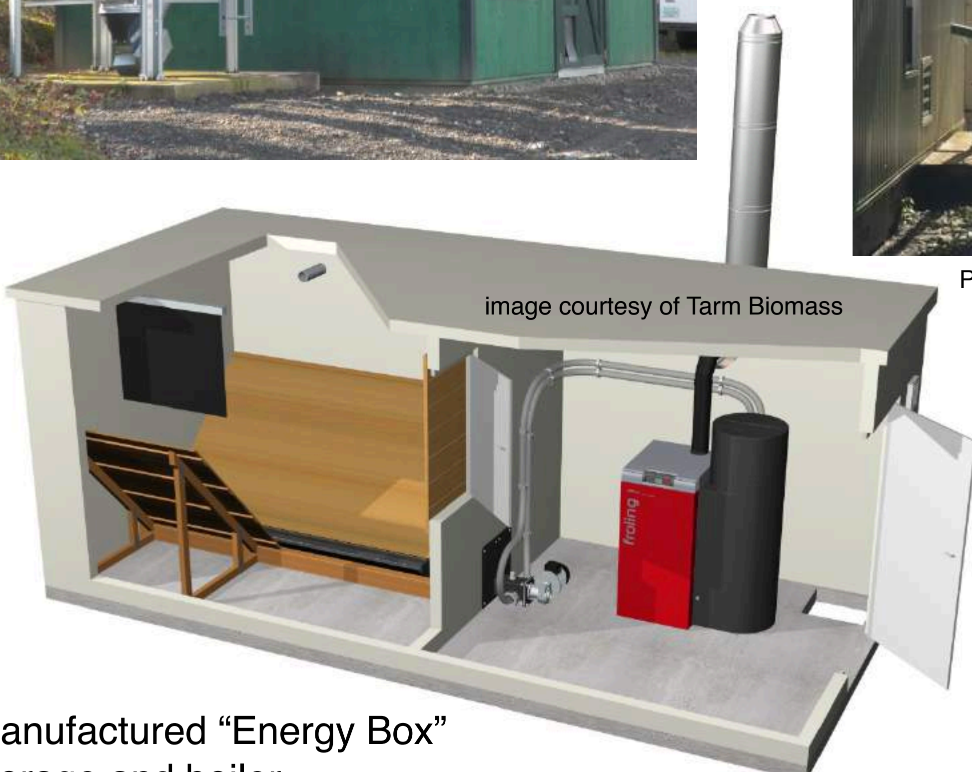


image courtesy of Tarm Biomass

Manufactured “Energy Box”
storage and boiler

A typical system using a pellet boiler

KEY CONCEPTS:

• Thermal storage is needed in most applications.

• To be effective, the thermal storage tank needs to "swing" through the widest possible temperature change.

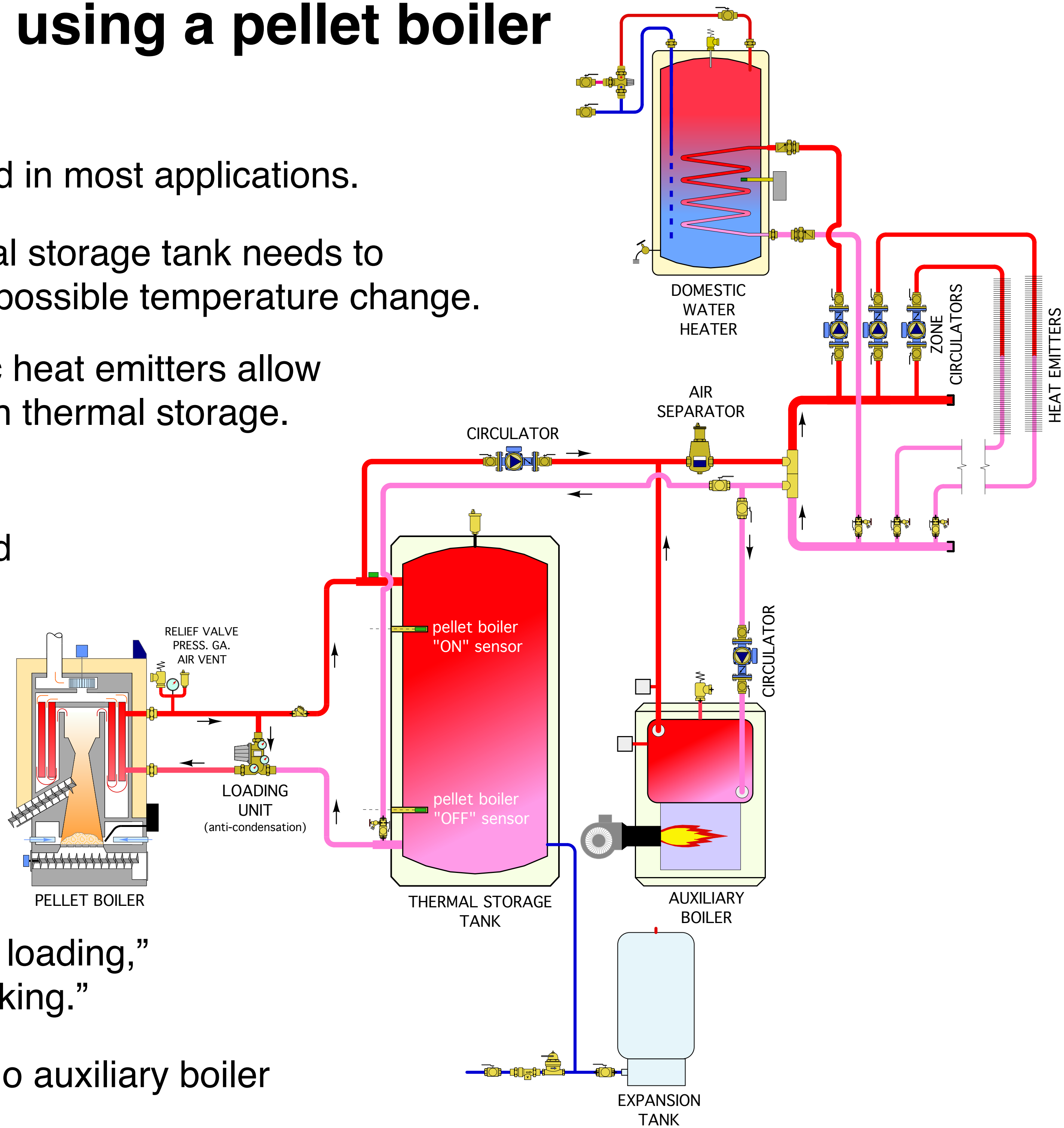
• Low temperature hydronic heat emitters allow wider temperature swings in thermal storage.

• Pellet boilers require protection against sustained flue gas condensation.

• A pellet boiler sized to 60% of design load can supply about 84% of total seasonal heating energy.

• Use pellet boiler for "base loading," and auxiliary boiler for "peaking."

• Can size for peak load if no auxiliary boiler is available.



Lessons Learned: (working with heating pros…)

1. Few heating contractors, and few professional engineers have a solid understanding of the unique characteristics of biomass boilers when they undertake their first system.

2. Don't assume that the designer / installer has a good understanding of modern hydronics technology, or how to apply it in combination with a biomass boiler.

3. Training on the specifics of a program-qualified boiler, AND the design of "balance-of-system" is crucial before allowing heating professionals to design or install biomass boilers within the scope of an incentive program.

4. Incentive programs need provisions for technical review of proposed systems. Key questions to be answered in the submittal are given in later slides.

5. Incentive programs should require system documentation to qualify the design and provide for servicing over the life of the system:

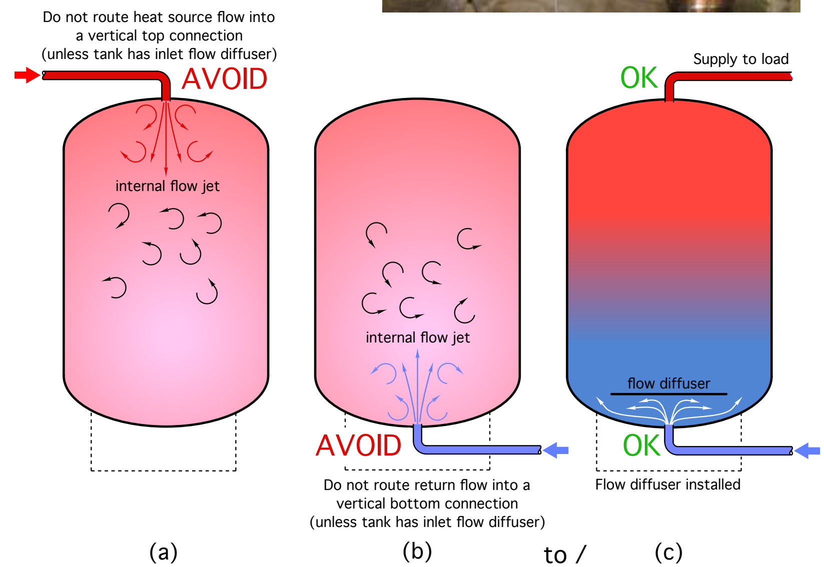
- piping schematic
- electrical / controls schematic
- description of operation

6. Incentive programs need to coordinate the project application with specifics that will be reviewed prior to go ahead on system, and with what the technical inspector should be verifying on site visit. Have everyone using the same information and approach.

Lessons Learned: (thermal storage...)

1. Expect "push back" from some manufacturers or fuel suppliers that thermal storage is not needed. It improves performance for the majority of typical hydronic systems.

2. Just having the required volume and insulation is not enough. Tank needs to be piped correctly to encourage temperature stratification. Avoid vertical flow jets in tank.

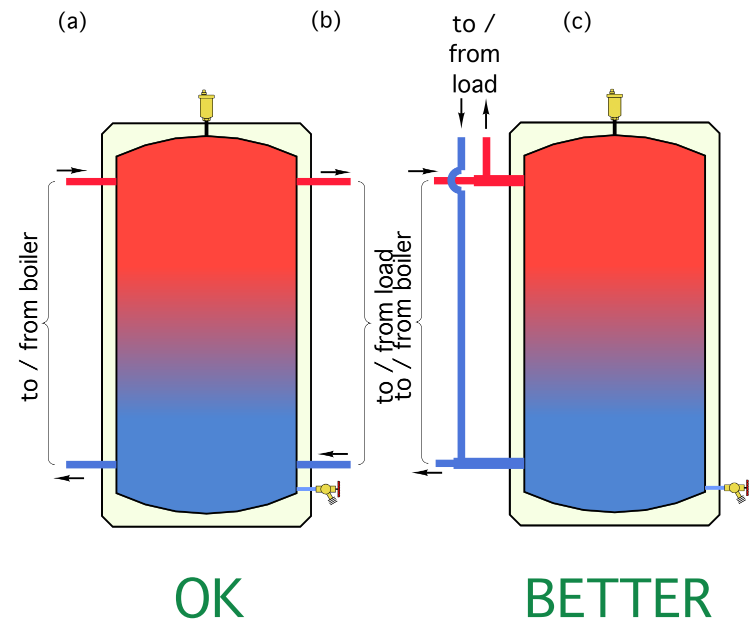


3. A "2-pipe" tank configuration has advantages over a "4-pipe" tank configuration - better stratification.

4. Suggest minimum of R-24 (°F•hr•ft²/Btu) tank insulation. (required for RHNY).

5. Pressure rated tank over 119 gallons need ASME certification.

6. Storage size required by RHNY is minimum 2 gallons per 1000 Btu/hr of pellet boiler rating.



7. Use 2-sensor based "temperature stacking" control logic to maximize heat added to tank on each boiler cycle.

8. specify piping placements that utilize full volume of tank for heat absorption / release.

9. Mount temperature sensors in properly fitting wells, and use thermal grease.

Lessons Learned: (venting…)

1. Sealed / seamless vent connector piping is preferred. It is better at containing flue gases and fly ash, especially at start up.
- *Double wall vent connector piping with stainless steel inner pipe is best*
- *Single wall seamless piping (SS or black painted) is acceptable*
- *Avoid lock-seam galvanized vent connector piping*

2. Seal all joints in vent connector piping joints with high temperature sealant (1000 ºF). Mill-Pac Black is one such sealant. Orange RTV silicone looks terrible…

3. Always fasten vent connector piping together with screws. Use stainless steel screws on any joints in single wall piping.

4. Low thermal mass insulated stainless steel (UL-103 HT) chimneys are preferred over masonry chimneys, especially when the latter is exterior.

5. Install draft regulators that seal against positive pressure. Install in tee at base of vertical vent connector piping.

6. Never vent a biomass boiler and other boiler into same chimney flue.

7. Assure adequate combustion air is supplied to mech room.

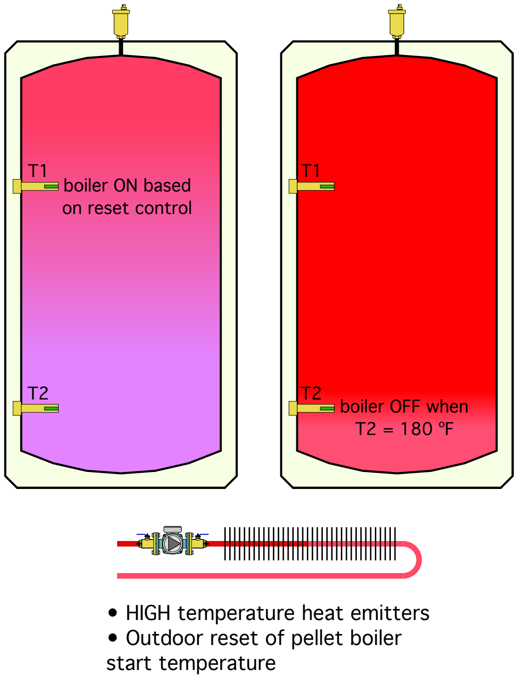
Lessons Learned: (heat delivery…)

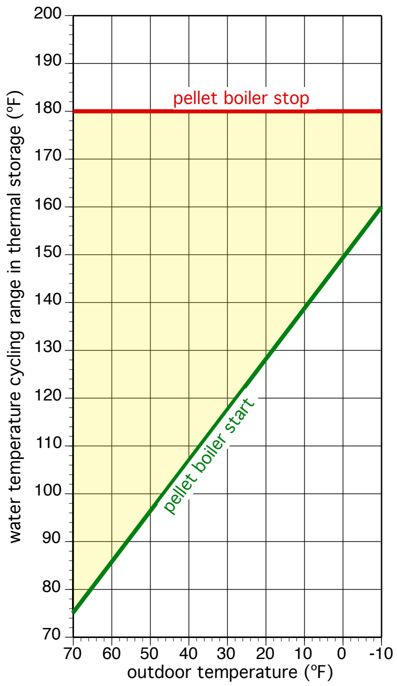
1. Low temperature hydronic heat emitters are preferred. They allow wider temperature cycling of thermal storage, and thus longer boiler burn cycles.

2. Most existing hydronic systems use fin-tube baseboard that was sized around relatively high water temperature at design load conditions.

3. Can add heat emitters to the existing distribution system to reduce the required water temperature. Panel radiators with PEX or PEX-AL-PEX tubing is a good option.

4. Can use outdoor reset control of the pellet boiler “ON” temperature to widen tank temperature swing under partial load conditions.





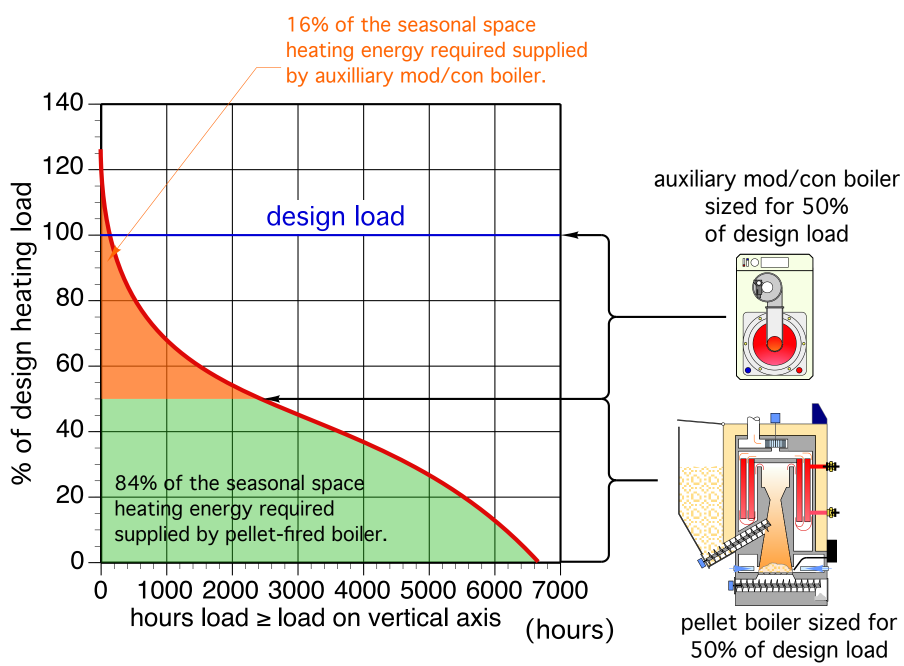
Lessons Learned: (auxiliary boiler…)

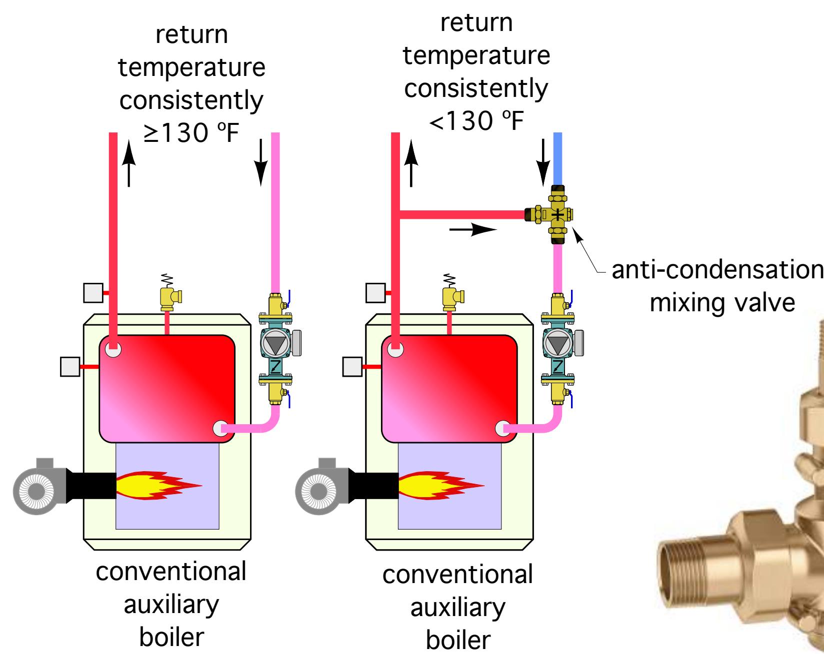
1. Use auxiliary boiler for “peak” loading when / if pellet boiler can’t supply necessary rate of heat delivery.

2. In most systems, configure controls so that heat produced by the auxiliary boiler is not inadvertently back-fed to thermal storage.

3. If existing “auxiliary” boiler is oversized, and system is highly zoned, the auxiliary boiler can be used to heat the upper 20-25% of the thermal storage tank. This can help correct short cycling of the existing boiler.

4. If the supply water temperature will be significantly reduced under partial load, install a mixing valve to protect the existing steel or cast iron boiler from flue gas condensation.





Design questions that should be addressed for biomass boiler systems

Please read through these later....

1. How is the biomass boiler protected against low entering water temperatures that would cause sustained flue gas condensation?

2. If the system uses an auxiliary boiler, how and when do the system's controls call for the auxiliary boiler to operate?

3. If the system allows for *simultaneous* heat flow from the thermal storage tank supplied by the biomass boiler, and the auxiliary boiler, how is heat generated by the auxiliary boiler prevented from being *unintentionally* routed into the thermal storage tank?

4. What is the exact operating logic of the biomass boiler? Is its operation invoked by a heat demand, or does the boiler operate independently of heat demands?

5. How is flue gas leakage prevented during a cold boiler start into a cold chimney?

6. What is the mixing system used between the thermal storage tank and a low temperature distribution system?

7. If the system is zoned and has an auxiliary boiler, How is the auxiliary boiler protected against short cycling when *only the smallest zone* on the system is calling for heat?

8. How is the biomass boiler protected from overheating if a power failure occurs when the boiler is operating at full heat output?

Design questions that should be addressed for biomass boiler systems

Please read through these later....

9. If the system uses an auxiliary boiler, how is it taken “off-line” (e.g., without heated water passing through it) when all heat is being supplied from the biomass boiler?

10. How do the piping connections and inlet flows to the thermal storage tank allow for good thermal stratification? How is mixing within the thermal storage tank prevented?

11. How is heat loss from thermal storage due to thermosiphoning through external piping prevented?

12. What is the temperature cycling range of the thermal storage system under design load conditions. What are the highest and lowest water temperature in the upper portion of the thermal storage tank under design load conditions?

13. What is the minimum supply water temperature at which the heat emitters in the building can provide design load heat output to the building?

14. Are all required safety controls specified for both the biomass boiler and the auxiliary boiler (if present)?

15. Is the required air for combustion and mechanical room ventilation provided?

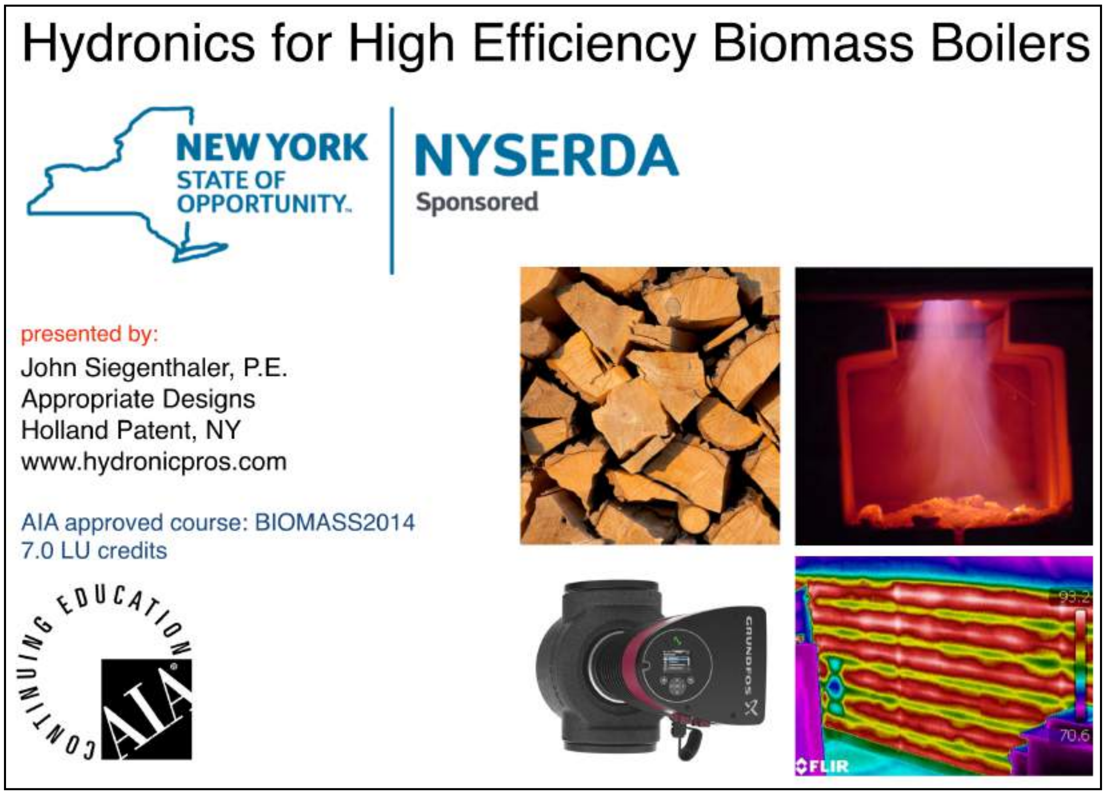
Thanks for attending this session

For more details information download the PDF entitled:
"Hydronics for High Efficiency Biomass Boilers"

https://www.nyserda.ny.gov/-/media/Files/EERP/Renewables/Biomass/biomass-hydronics-training.pdf

Upcoming full-day session: March 30, 2017 TEC-SMART facility, Malta, NY

https://www.regonline.com/registration/Checkin.aspx?EventID=1905534



Questions?

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