Multiple Pellet Boiler Systems

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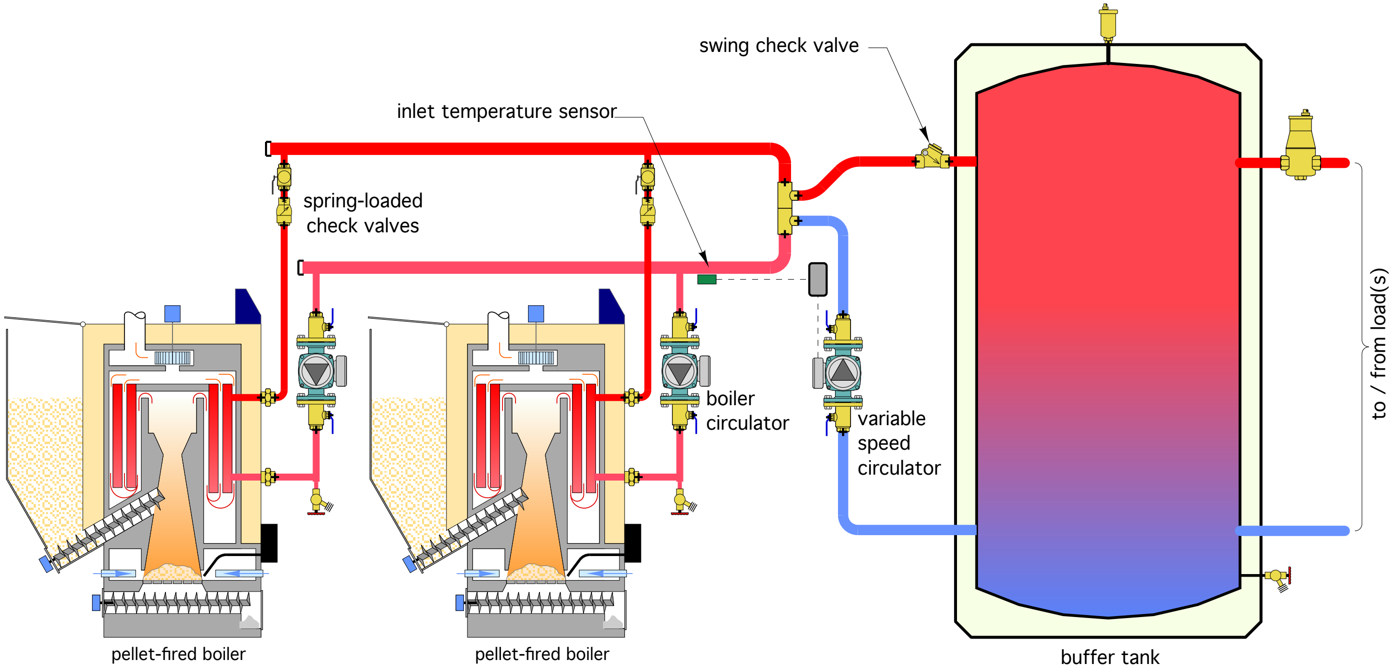
Moderated by:

Sue Dougherty
Clean Heating & Cooling program
NYSERDA
sue.dougherty@nyserda.ny.gov

presented by:

John Siegenthaler, P.E.
Principal, Appropriate Designs
Holland Patent, NY
www.hydronicpros.com



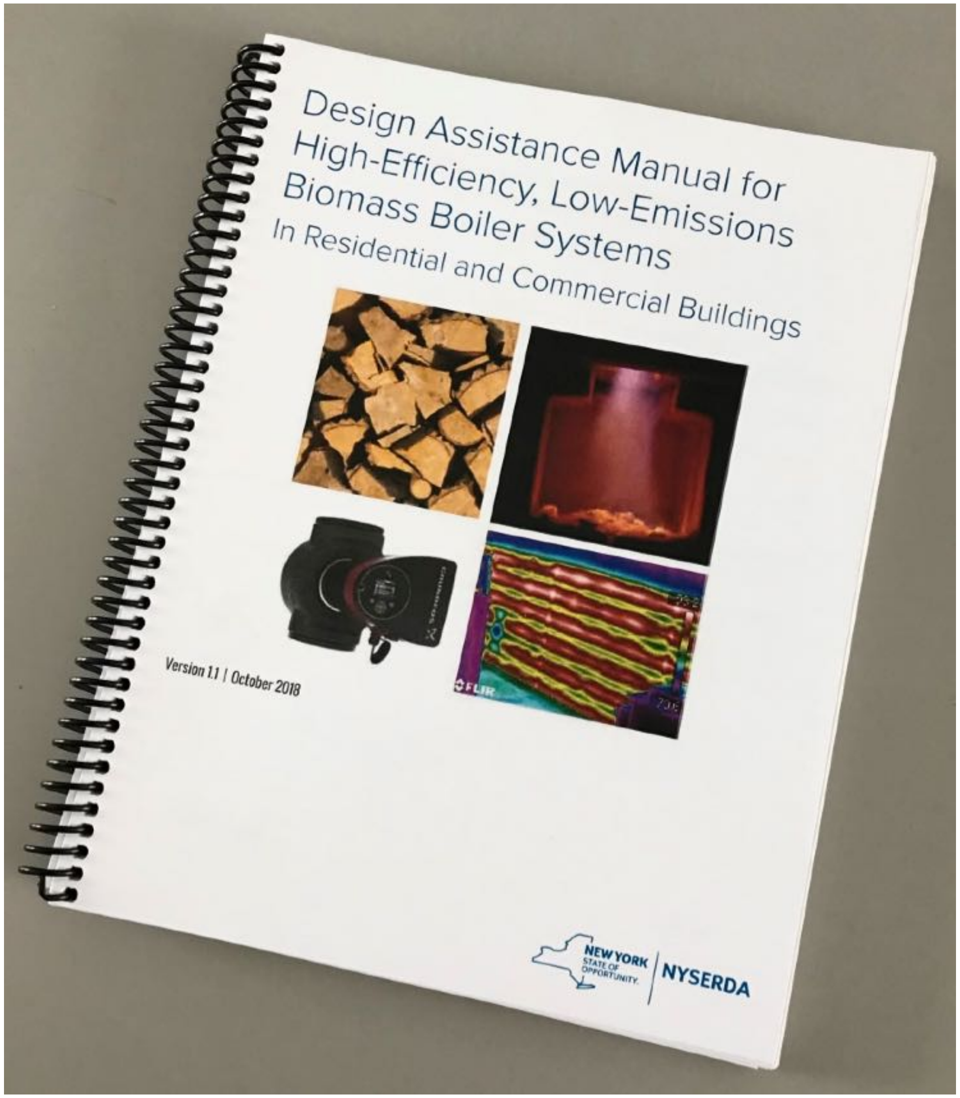
Multiple Pellet Boiler Systems

Description: Just as larger capacity heating systems often use multiple fossil-fuel boilers, it’s possible to build systems around multiple pellet boilers. This webinar shows how such boilers would be piped and controlled. It also discusses concepts such as using pellet boilers of different heating capacity to better match variable heating loads.

Learning Objectives:

- Understand the benefits of multiple boiler systems - in general.
- Understand the benefits of using two or more pellet boilers rather than a single larger boiler.
- Learn how to pipe and control multiple pellet boiler.
- Learn how to integrate a fossil fuel boiler into the system

Design Assistance Manual
for High Efficiency Low Emissions Biomass Boiler Systems



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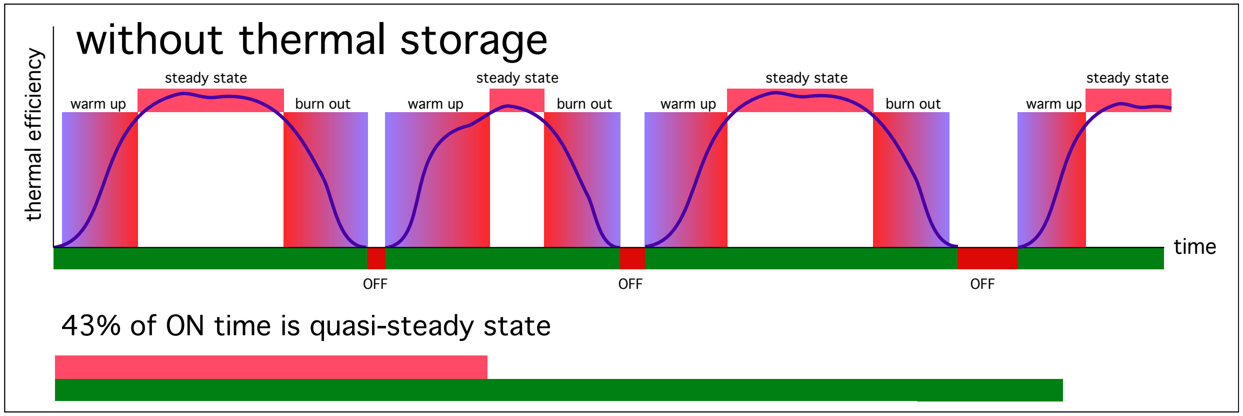
It's available as a FREE downloadable PDF at:

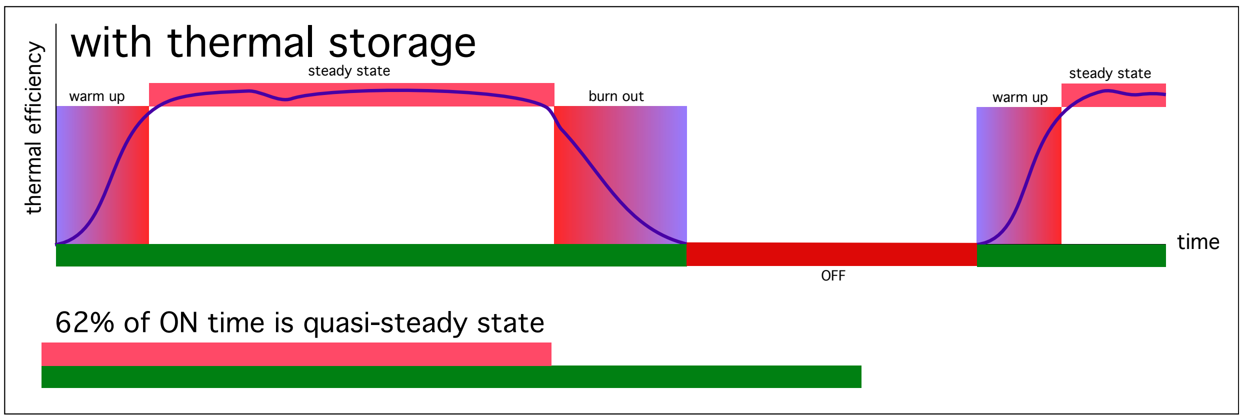
https://www.nyserda.ny.gov/-/media/Files/EERP/Renewables/Biomass/Design-Assistance-Biomass-Boiler.pdf

Operating objectives for pellet boilers

1. High thermal efficiency
2. Minimal particulate emissions

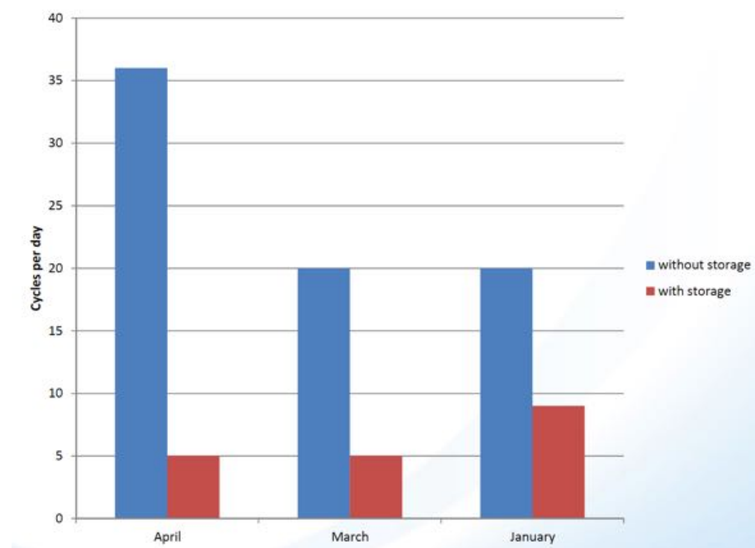
Pellet boilers attain their highest thermal efficiency, and lowest emissions, when **operated for long (multiple hour) burn cycles.**





Suggested design objective: 3 hour run / start

25 kW (85,300 btu/hr) rated pellet boiler supplying a heating load profile typical of an upstate NY house, with and without a 119 gallon



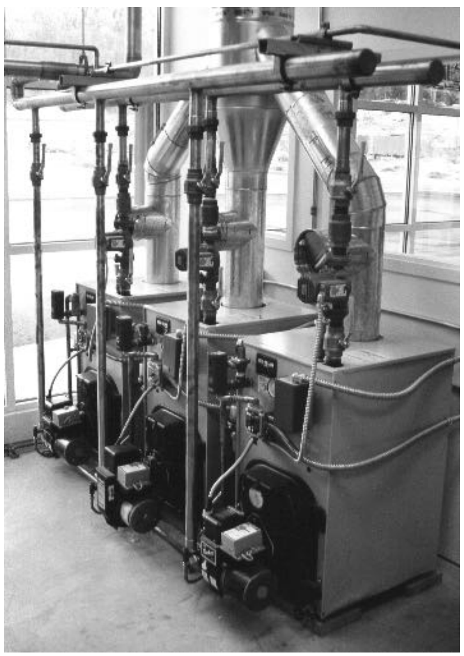
Brookhaven National Laboratory & Dr. Thomas

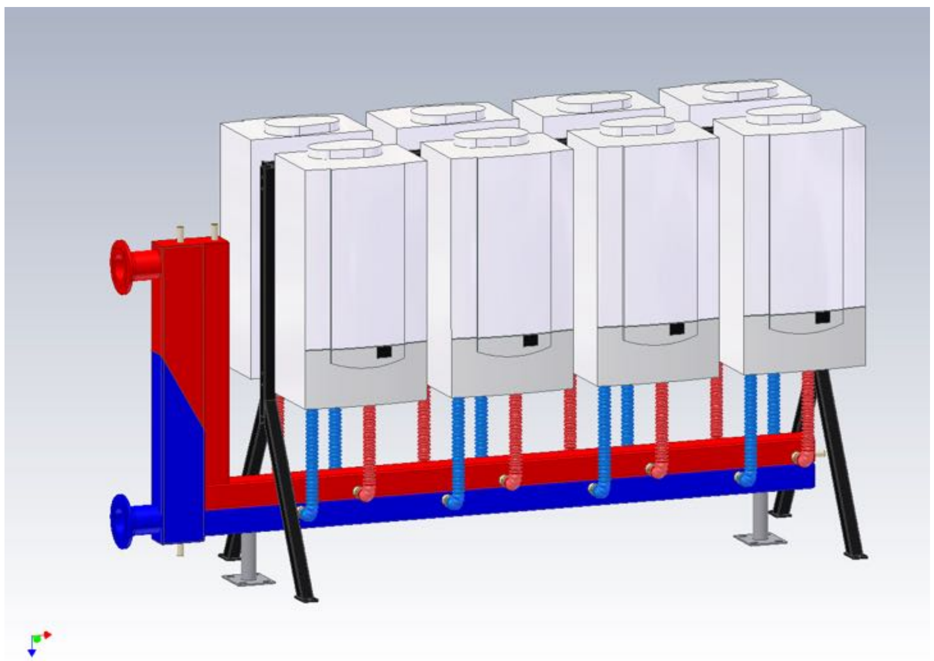
Multiple boiler systems have been around for several decades. The underlying concept is simple:

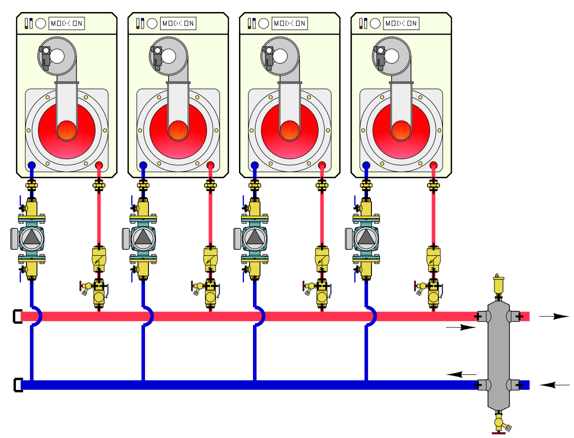
- Divide the total heating load among two or more independently controlled boilers, and operate only the boiler(s) necessary to meet the current load.

- Each boiler represents a “stage” of heat input.

- An intelligent controller determines what boiler stages need to operate to maintain the current target temperature.



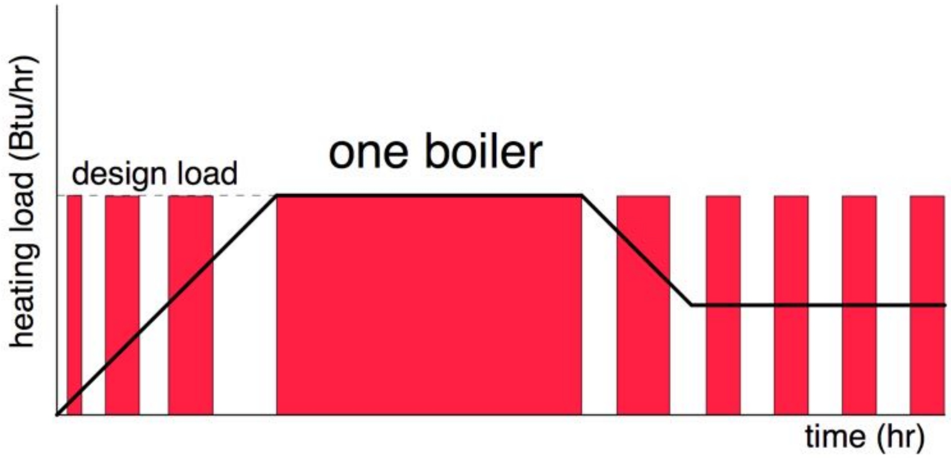


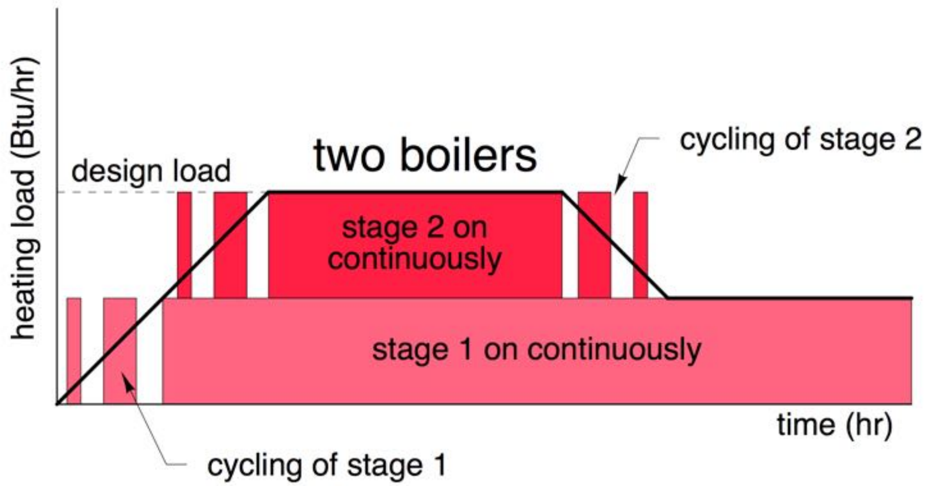


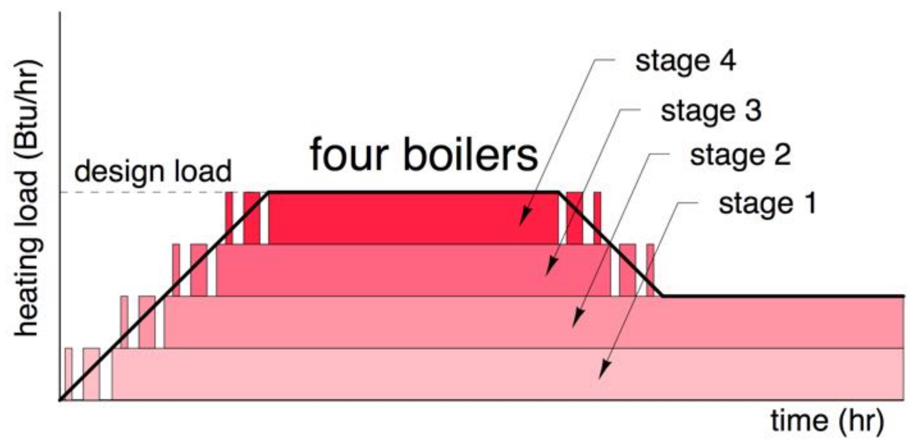
Benefits of multiple boiler systems

1. Better able to match output to load
2. High thermal efficiency under partial loads
3. Redundancy if one boiler is out of service
4. Smaller / lighter boilers to install

The more stages, the better the boiler system can track the load.



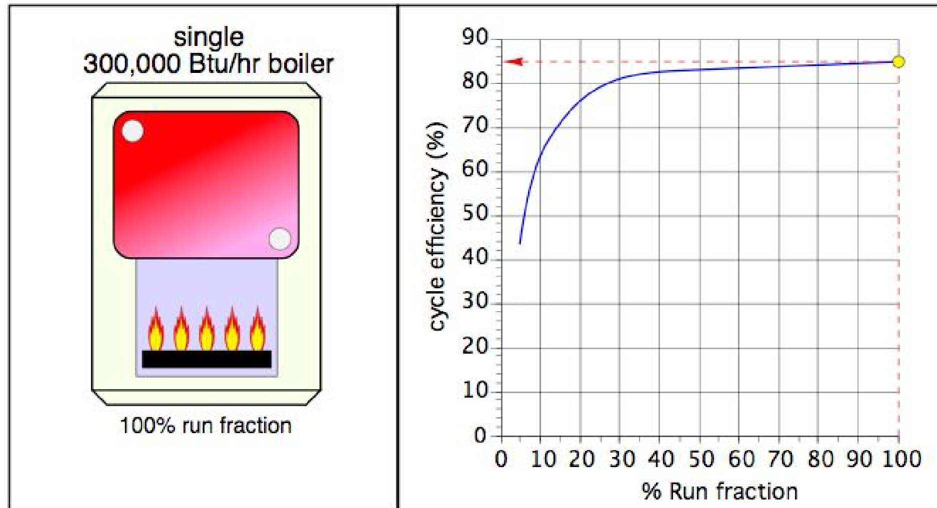




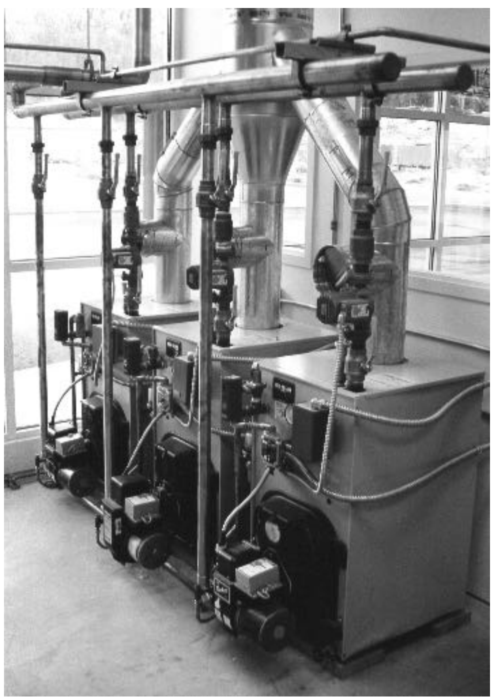
Consider two boiler options:

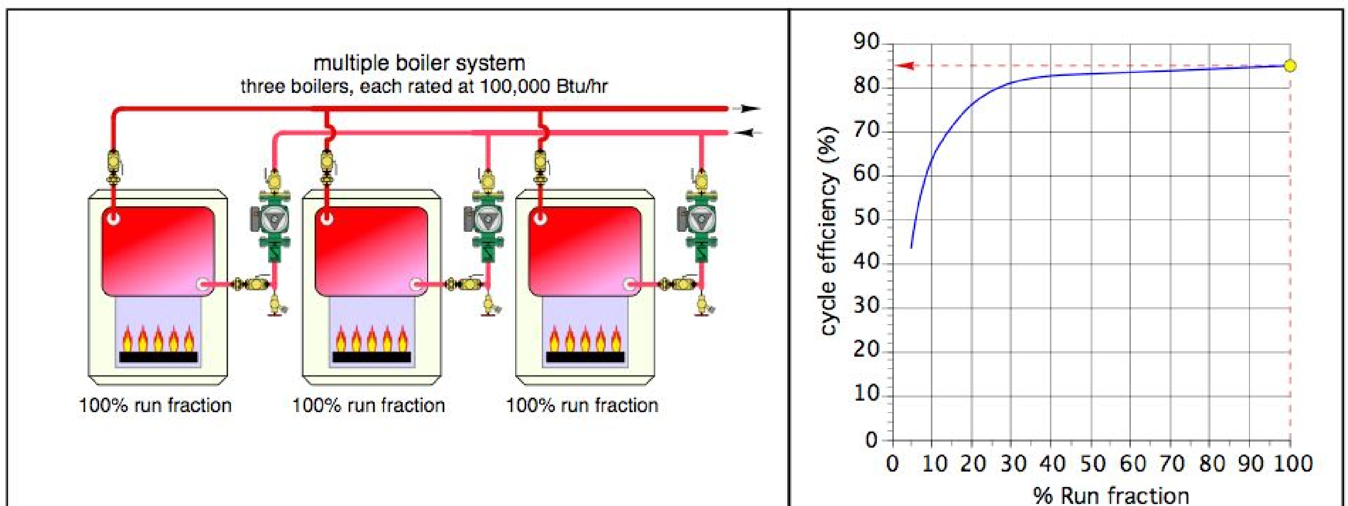
- A single 300,000 Btu/hr conventional boiler
- Three, 100,000 Btu/hr boiler with identical performance

At full load (300,000 Btu/hr) they have essentially identical performance (cycle efficiencies both equal 85%).



Load = 300,000 Btu/hr / Cycle efficiency = 85%



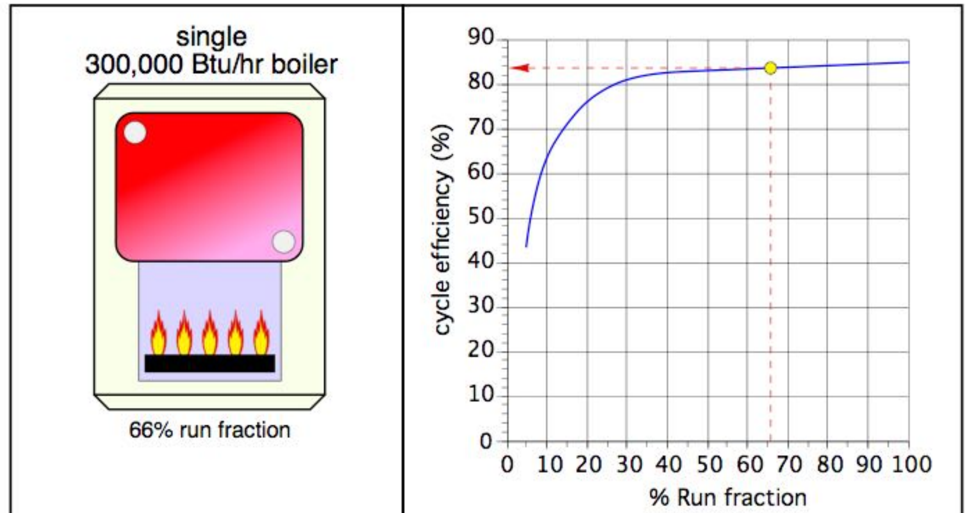


Load = 300,000 Btu/hr / Cycle efficiency = 85%

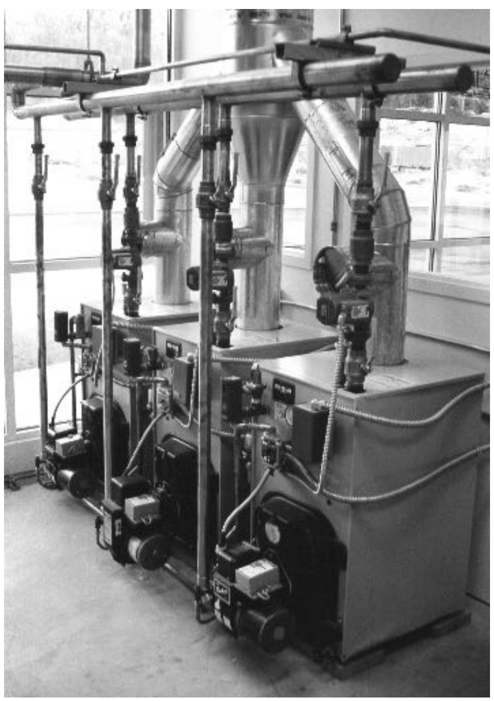
Consider two boiler options:

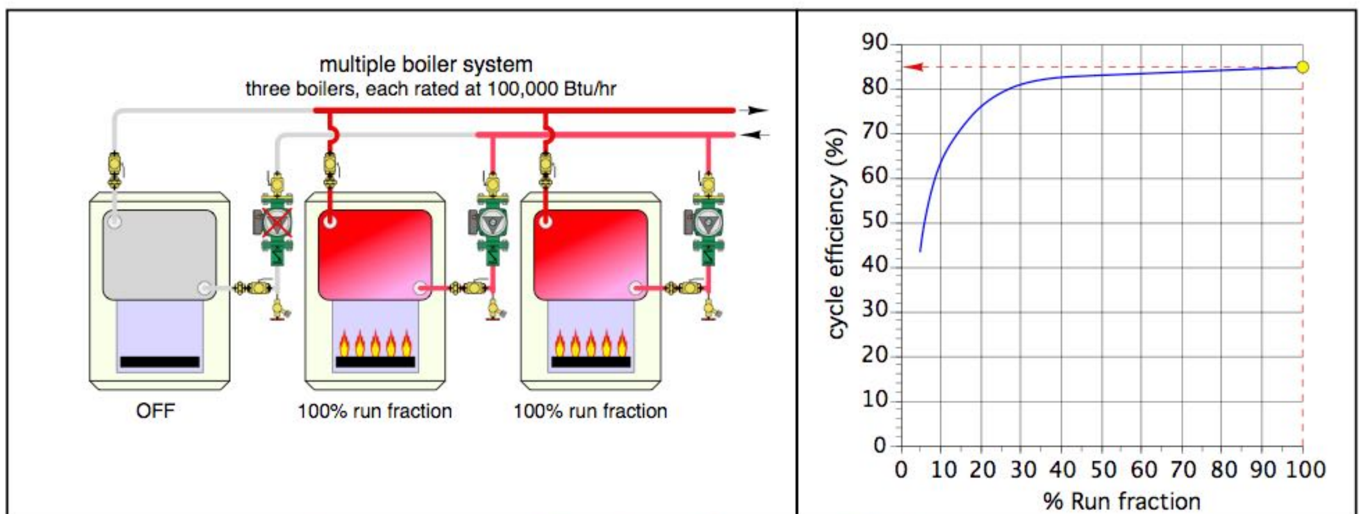
- A single 300,000 Btu/hr conventional boiler
- Three, 100,000 Btu/hr boiler with identical performance

At 200,000 Btu/hr there is a small Difference in cycle efficiencies (83% versus 85%).



Load = 200,000 Btu/hr / Cycle efficiency = 83%



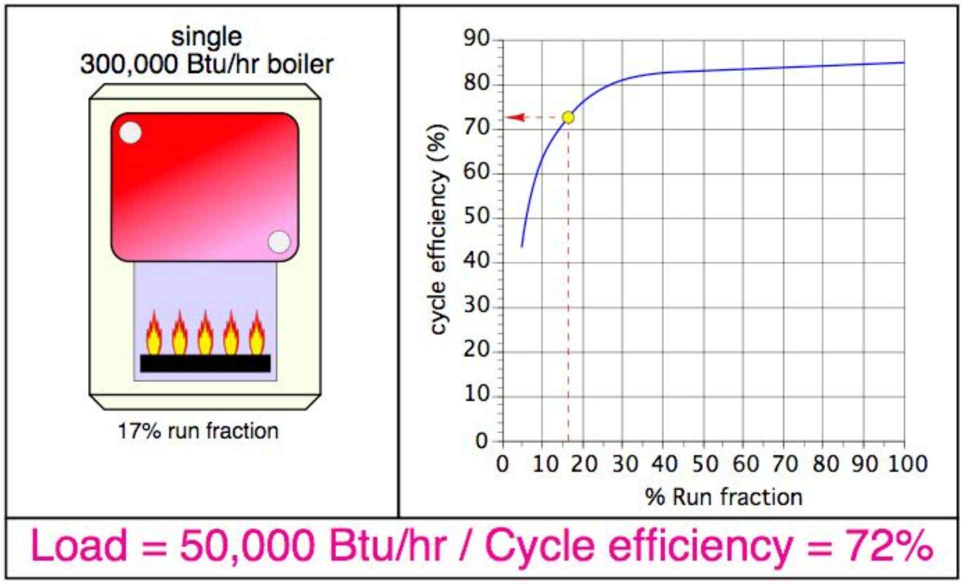


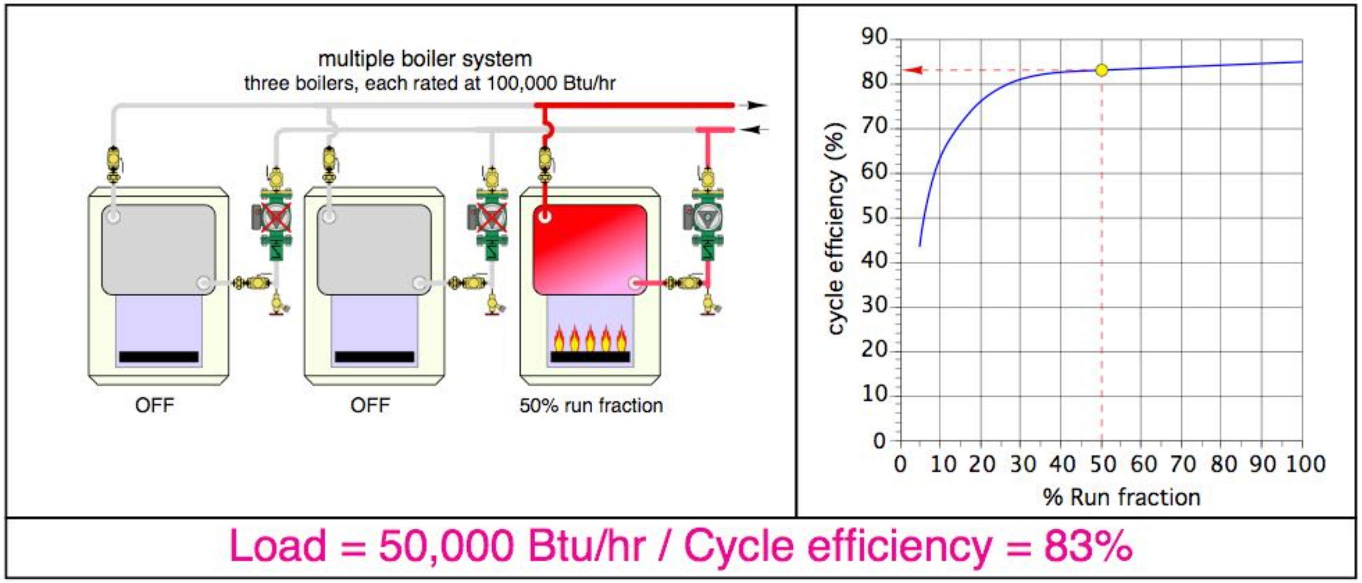
Load = 200,000 Btu/hr / Cycle efficiency = 85%

Consider two boiler options:

- A single 300,000 Btu/hr conventional boiler
- Three, 100,000 Btu/hr boiler with identical performance

At 50,000 Btu/hr there is a large difference in cycle efficiencies (72% versus 83%).





The **benefits** offered by multiple boiler systems include:

•Partial heat delivery if one boiler is down for servicing.

Piping multiple pellet boiler systems

Multiple smaller boilers in a staged arrangement:

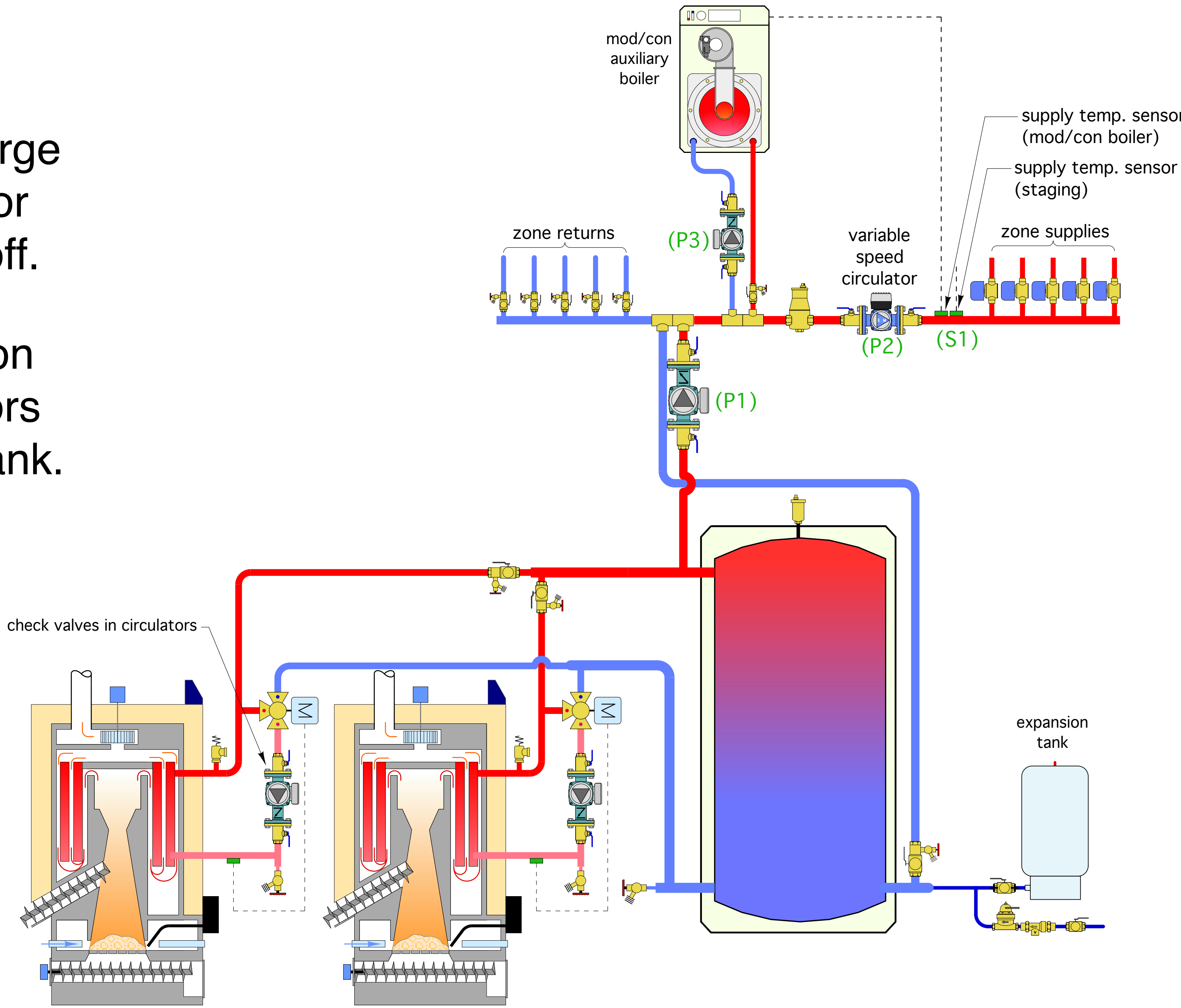
• Flow only through active boiler(s)

• 3-5 minute post purge operation of circulator when boiler turned off.

• Hydraulic separation between all circulators provided by buffer tank.

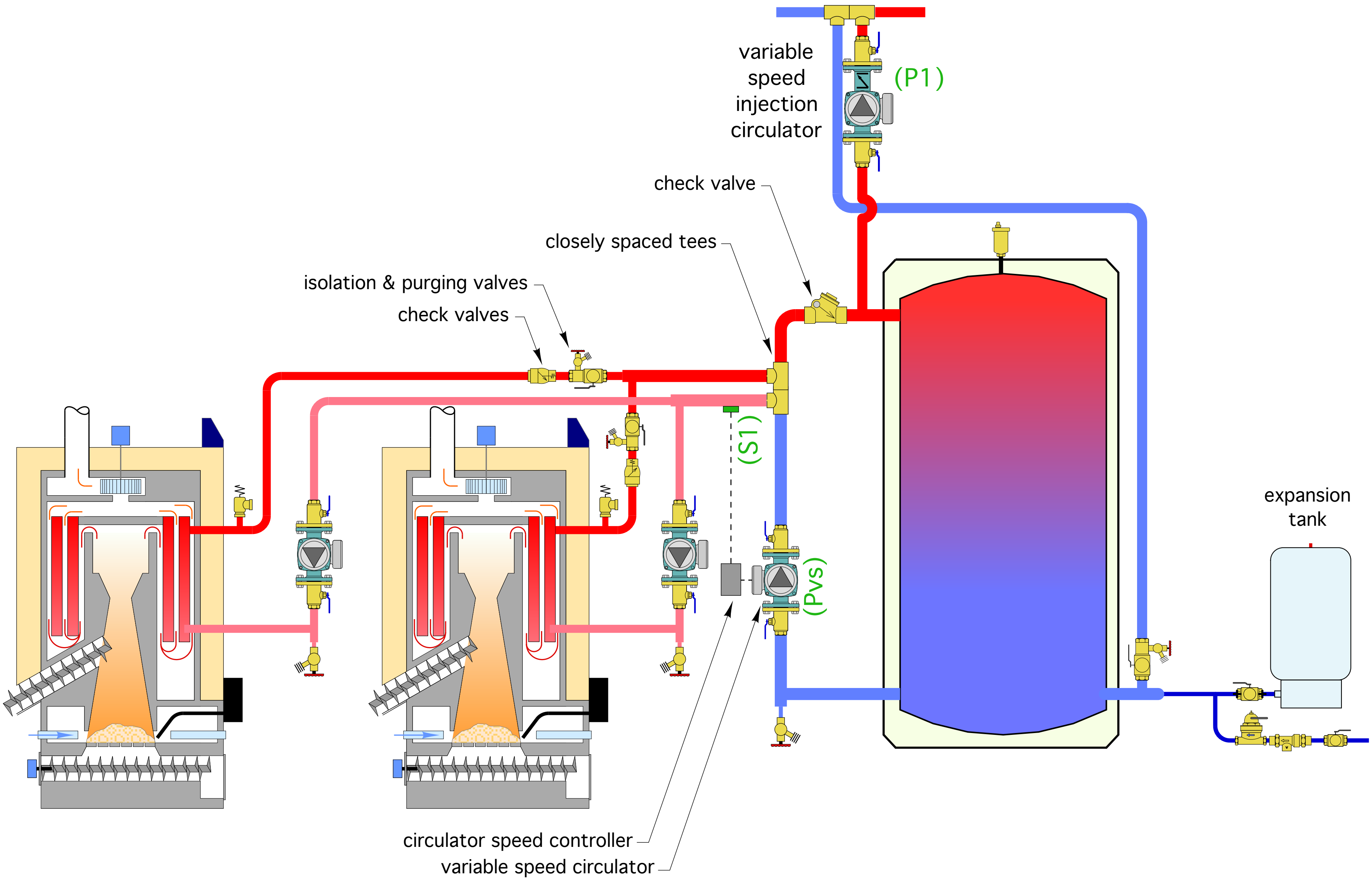
• Individual 3-way motorized mixing valves provide boiler protection.

•Injection mixing for regulating supply water temperature.



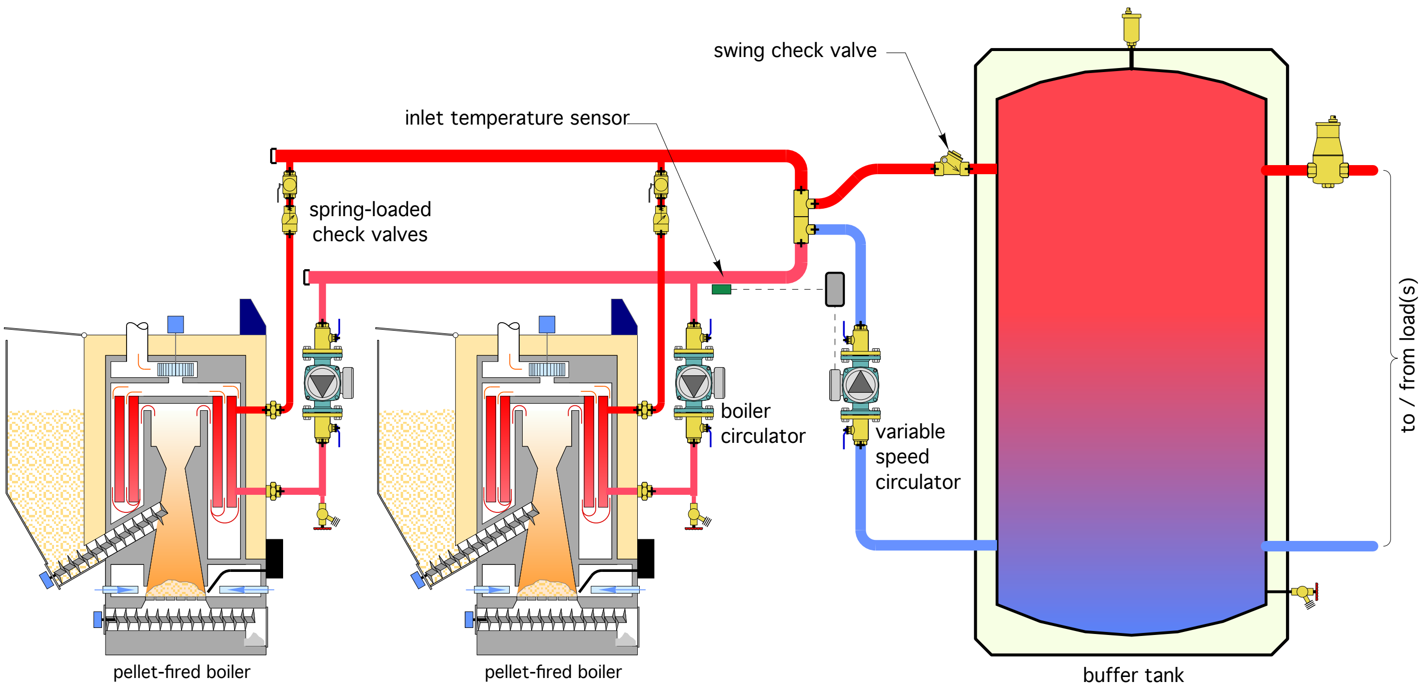
individual 3-way motorized valves for anti-condensation protection

Multiple smaller boilers in a staged arrangement:



- Variable speed circulator operates to provide boiler protection.
- Be sure that all boilers can “communicate” with expansion tank.

Variable speed circulators for anti-condensation control

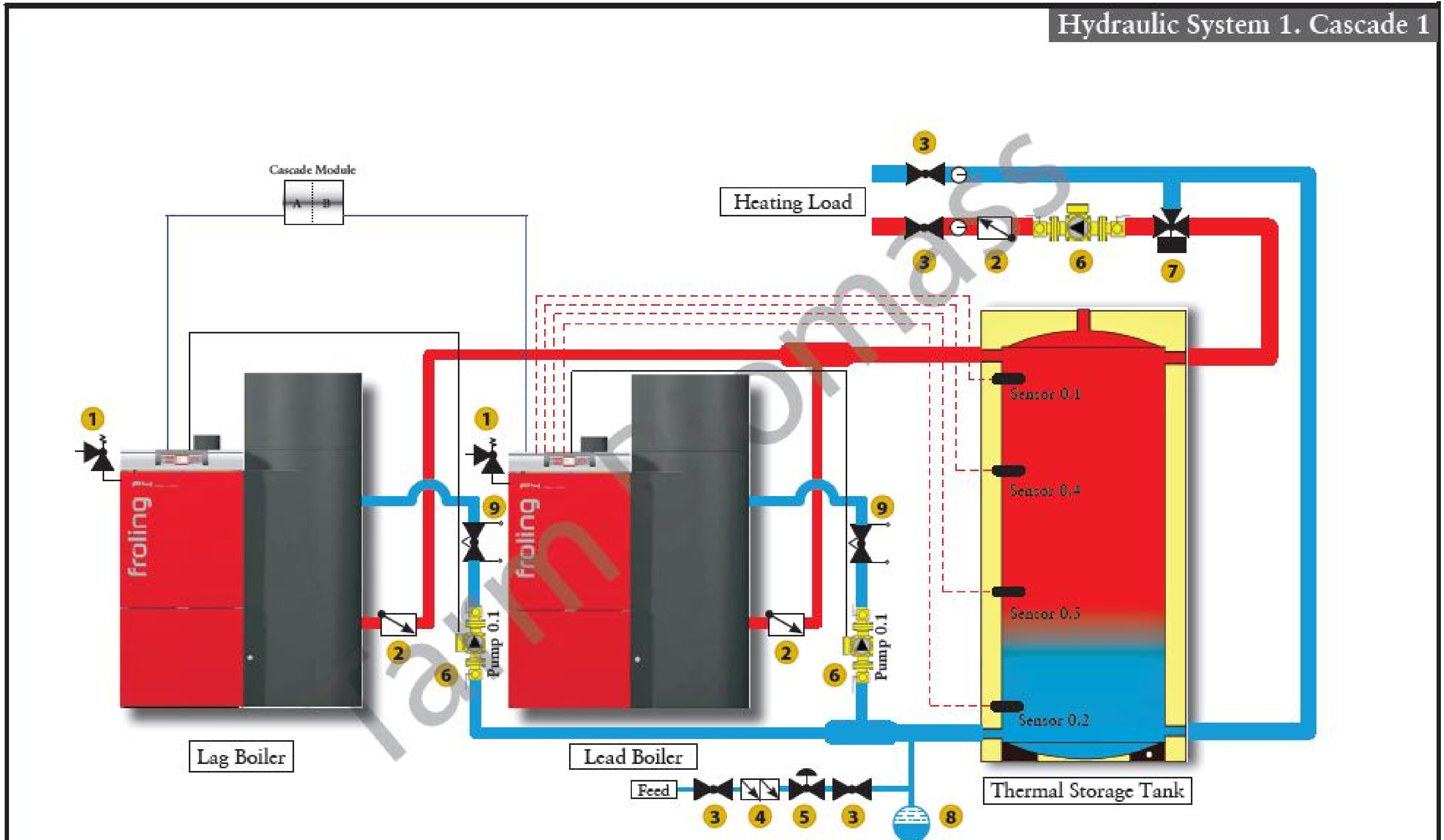


direct connection to temperature sensor

00-VV

2-10 VDC, 4-20 ma speed input

Some boilers have special internal designs combined with variable speed circulator control for anti-condensation protection.



This is only a concept drawing. Final design, installation and code compliance details are the responsibility of the designer/installer of the system.

Key:			
1	Pressure relief valve	6	Circulator
2	Check valve	7	Mixing Valve
3	Isolation valve	8	Expansion tank
4	Back-flow preventer	9	Balancing valve
5	Pressure reducing valve		

TARM BIOMASS
Innovative Leaders in Alternative Heating Solutions

Drawing Name/System Type: Hydraulic System 1.Cascade 1

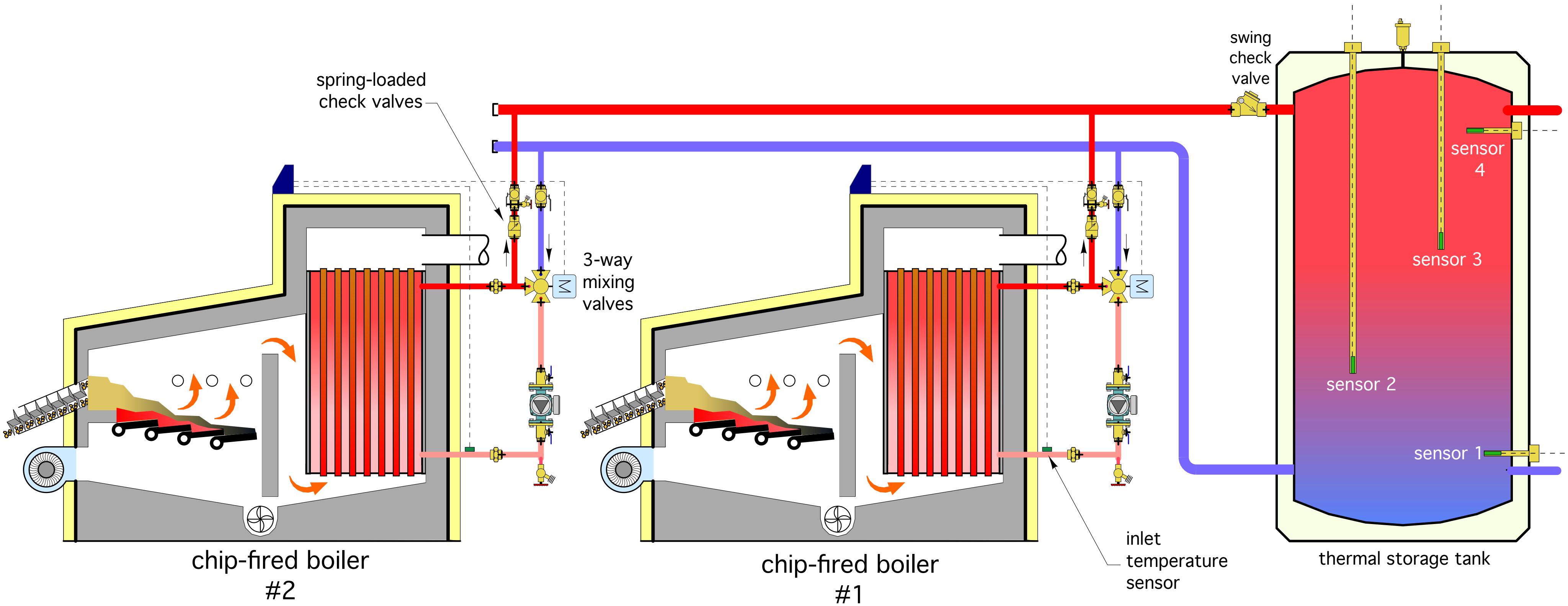
Drawn by: TSP | Date: 6-13-2013

Notes: Two boiler cascaded system.

courtesy of Tarm Biomass

Temperature stacking strategy used with two pellet-fired boilers.

Same strategy as used with multiple pellet-fired boilers.



Boiler #1 ON if sensor #3 ≤ 120 ºF

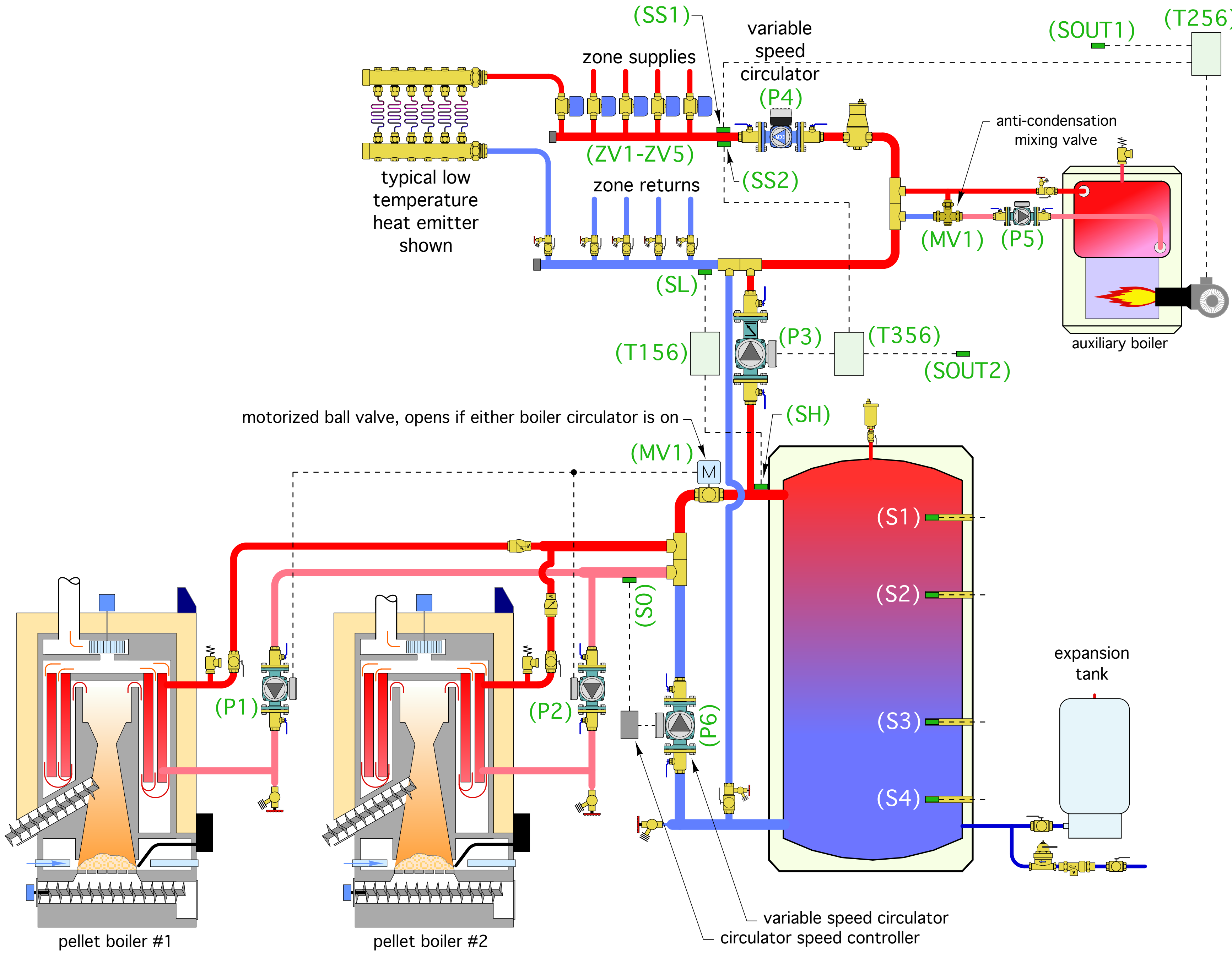
Boiler #2 ON if sensor #4 ≤ 120 ºF

Boiler #2 OFF if sensor #2 ≥ 180 ºF

Boiler #1 OFF if sensor #1 ≥ 180 ºF

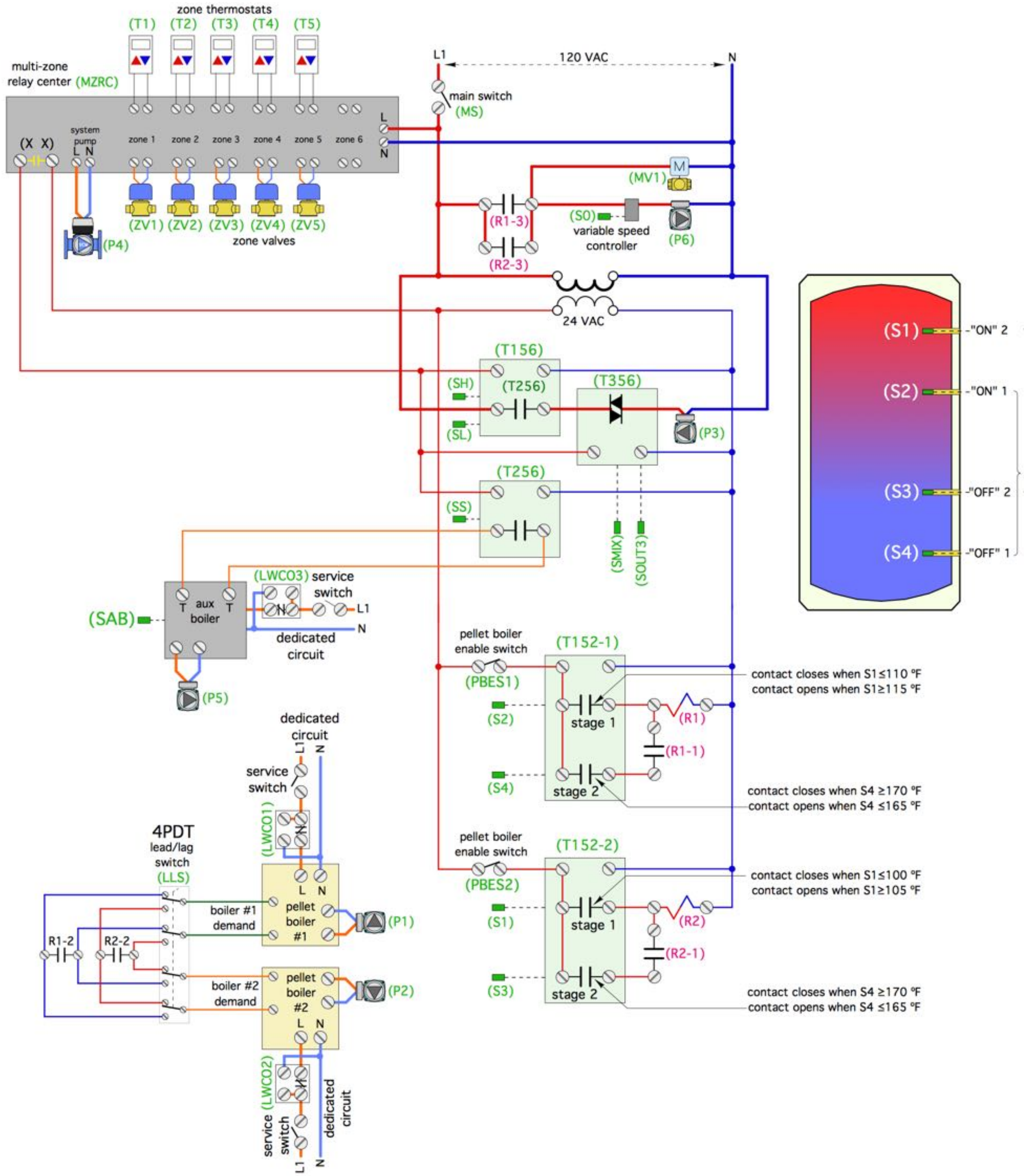
Firing order of boilers is periodically changes to help equalize boiler operating hours.

System #8 from Biomass Design Assistance Manual



System #8 from Biomass Design Assistance Manual

- This systems uses off-the-shelf controllers.
- Equivalent control logic could be created using BAS system.
- Manually operated 4PDT switch used to determine which pellet boiler leads vs. lags.
- Two, 2-stage setpoint controllers used to monitor tank sensor temperature, and provide contact closures for boiler firing.



Description of operation (read this later)

Power supply: Power for each pellet boiler is 120 VAC and supplied from a dedicated circuit. The service switch for each pellet boiler must be closed, and the low-water cutoff (LWCO1, LWCO2) for that boiler must detect water for the boiler to operate. Each pellet boiler also has an "enable switch" (PBES1, PBES2) that must be closed for the boiler to operate.

Power for the auxiliary boiler is 120 VAC and supplied from a dedicated circuit. The service switch for the auxiliary boiler must be closed, and the low-water cutoff (LWCO3) must detect water for the auxiliary boiler to operate.

Power for circulators (P3, P4, P6), the 24 VAC transformer (X1), the multizone relay center (MZRC), zone valves (ZV1-ZV5), temperature controllers (T152-1, T152-2, T156, T256, T356), relay coils (R1, R2), and motorized valve (MV1) is supplied through another 120 VAC dedicated circuit. The main switch (MS) must be closed for these devices to operate.

Pellet boiler operation: Each pellet boiler is operated based on two temperature sensors in the thermal storage tank. As shown in Figure 8-8b, pellet boiler 1 is turned on when the temperature at sensor S2 drops to or below 110ºF. This causes the stage one contacts in the (T152-1) controller to close, passing 24 VAC to relay coil (R1). Relay contact (R1-1) closes to provide a second pathway for 24 VAC to reach coil (R1). That pathway passes through the stage two contact of the (T152-1) controller which closes whenever the temperature at sensor (S4) is less than or equal to 165ºF. Relay contact (R1-2) closes to provide an external demand signal to pellet boiler 1, through the 4PDT switch contacts. Pellet boiler 1 turns on circulator (P1) and initiates its startup sequence. The stage one contacts in (T152-1) open when sensor (S2) reaches 115ºF. However, 24 VAC can still reach relay coil (R1) through the closed stage two contacts of (T152-1) and closed relay contact (R1-1). Pellet boiler 1 continues to operate until the temperature at sensor (S4) reaches 175ºF.

Pellet boiler 2 turns on when and if the temperature at sensor (S1) drops to or below 100ºF. This condition causes the stage one contacts in the dual setpoint controller (T152-2) to close, passing 24 VAC to relay coil (R2). Relay contact (R2-1) closes to provide a second pathway for 24 VAC to reach coil (R2). That pathway passes through the stage two contact of the (T152-2) controller, which are closed whenever the temperature at sensor (S3) is less than or equal to 165ºF. Relay contact (R2-2) closes to provide an external demand signal to pellet boiler 2, through the 4PDT switch contacts. Pellet boiler 2 turns on circulator (P2) and initiates its startup sequence. The stage one contacts in (T152-2) open when sensor (S2) reaches 105ºF. However, 24 VAC can still reach relay coil (R2)through the closed stage two contacts of (T152-2) and closed relay contact (R2-1). Pellet boiler 2 continues to operate until the temperature at sensor (S3) reaches 175ºF.

The 4PDT "lead/lag" switch allows the firing order of the pellet boilers to be reversed. It would typically be switched once or twice per season to allow approximately the same number of run hours on each pellet boiler.

Pellet boiler anti-condensation protection: When either pellet boiler is firing, relay contacts (R1-3) or (R2-3) pass 120 VAC to the variable speed controller for circulator (P3) and to the actuator of motorized valve (MV1). Motorized valve (MV1) opens to allow flow from the pellet boilers to reach the upper tank header. The variable speed controller keeps circulator (P3) off until the temperature of water returning to the pellet boilers measured at sensor (S0) has reached 130ºF. It then increases the speed of circulator (P3), reaching full speed when the temperature at sensor (S0) has reached 140ºF or higher.

Auxiliary boiler operation: Whenever there is a heating demand, the (T256) controller monitors the supply water temperature to the distribution system at sensor (SS1). The auxiliary boiler and its associated circulator (P5) are turned on when the supply water temperature at sensor (SS1) drops 5ºF below the target supply water temperature, based on the current outdoor temperature and the settings of the (T256) controller. The auxiliary boiler continues to operate until the supply water temperature at sensor (SS1) is 5ºF above the target temperature and as long as one or more zone thermostats are calling for heat. When low-temperature heat emitters are used, the auxiliary boiler needs to be protected against sustained flue-gas condensation. This is done using a thermostatic mixing valve (MV1), as shown in Figure 8-8a. When the return water temperature from the heat emitters are consistently above 130ºF consistently, this mixing valve is not needed.

Heat transfer from biomass subsystem to distribution: When one or more zone thermostats call for heat, 24 VAC is passed through the (X X) contacts of the multizone relay center (MZRC) to power on differential temperature controller (T156) and injection mixing controller (T356). The (T156) measures the temperature of the upper tank header at sensor (SH) and the temperature on the return side of the distribution system at sensor (SL). It closes its contacts when the temperature at (SH) is at least 6ºF above the temperature at (SL). It opens its contacts when the temperature at (SH) is 3ºF or less above the temperature at (SL). This control action ensures that circulator (P3) will only be allowed to operate when the biomass portion of the system can make a positive energy contribution to the distribution system.
The 120 VAC pass through the closed contact of the (T156) to the (T356) injection mixing controller. The (T356) measures the outdoor temperature at sensor (SOUT2) and uses this temperature along with its settings to calculate the target supply water temperature at sensor (SS2). It then varies the speed of circulator (P3) to inject hot water from the biomass portion of the system into the distribution system so that the temperature at sensor (SS2) is directed toward the target temperature. This allows full-outdoor reset control of the supply water temperature to the heat emitters.

Space heating distribution system operation: On a call for heating from any zone thermostat (T1, T2, T3, T4, T5), the associated zone valve (ZV1, ZV2, ZV3, ZV4, ZV5) is turned on the by the multizone relay center (MZRC). Circulator (P4) is turned on and operates in a preset constant differential pressure mode.

Suggested initial controller settings (read this later)

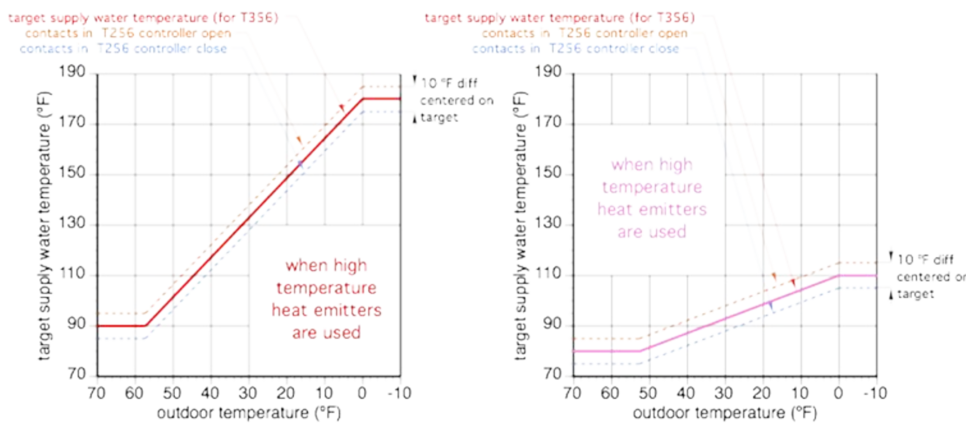
Suggested initial controller settings: Figure 8-8c shows suggested outdoor reset settings for the (T256) and (T356) controllers.

The following suggested initial controller settings assume low-temperature heat emitters that require a supply temperature of 110ºF under design load conditions (0ºF outdoor temperature).

- Stage one contacts in T152-1 controller: Monitor's tank sensor S2 contacts close at 110ºF, open at 115ºF
- Stage two contacts in T152-1 controller: Monitor's tank sensor S4 contacts close at 165ºF, open at 170ºF.
- Stage one contacts in T152-2 controller: Monitor's tank sensor S1 contacts close at 100ºF, open at 105ºF
- Stage two contacts in T152-2 controller: Monitor's tank sensor S4 contacts close at 165ºF, open at 170ºF
- Injection mixing controller (T356) settings:
  - No-load condition: 70ºF supply water temperature when outdoor temperature is 70ºF
  - Design load condition: 110ºF supply water temperature when outdoor temperature is 0ºF or lower
  - Minimum supply water temperature = 80ºF
  - Maximum supply water temperature = 110ºF
- Outdoor reset controller for auxiliary boiler (T256) setting:
  - No-load condition: 70ºF supply water temperature when outdoor temperature is 70ºF
  - Design load condition: 110ºF supply water temperature when outdoor temperature is 0ºF or lower
  - Differential = 10ºF, centered on target temperature
  - Minimum supply water temperature = 80ºF
- Pellet boiler settings:
  - High-limit temperature = 200ºF
  - Other setting as per boiler manufacturer's recommendations
- Oil-fired boiler high-limit controller setting: 200ºF
- Anti-condensation mixing valve setting for (MV1): 130ºF
- Anti-condensation circulator speed controller settings
  - Circulator P6 off when sensor (S0) temperature ≤ 130ºF
  - Circulator P6 at full speed with (S0) temperature ≥ 140ºF
- Circulator (P4) setting:

  Constant differential pressure at the required ΔP with all zone valves open

Suggested outdoor reset settings for T256 and T356 controllers in system 8



Venting multiple pellet boiler systems

These 3 pellet boilers are common vented

Potential for backdrafting through unfired boilers.

Better to use separate chimney and draft regulator on each boiler

pellet boiler plant at RayBrook NY

positive pressure sealing

draft regulator by Tigerholm

Four Froling boilers at NH industrial facility

- 500,000 Btu/hr each
- Can burn wood chips or pellets

Approximate installed system costs:

Material Storage & Handling for Chips and Pellets: $160,000

Boilers: $220,000

Venting: $20,000

Buffer Tank: $20,000

Piping, Fittings & Valves: $30,000

Insulation: $25,000

Labor Costs: $75,000

Total = $550,000

Multiple pellet boiler system RayBrook, NY

Multiple pellet boiler system at RayBrook

100KW 200KW 200KW

Multiple pellet boiler system at RayBrook

Firing order

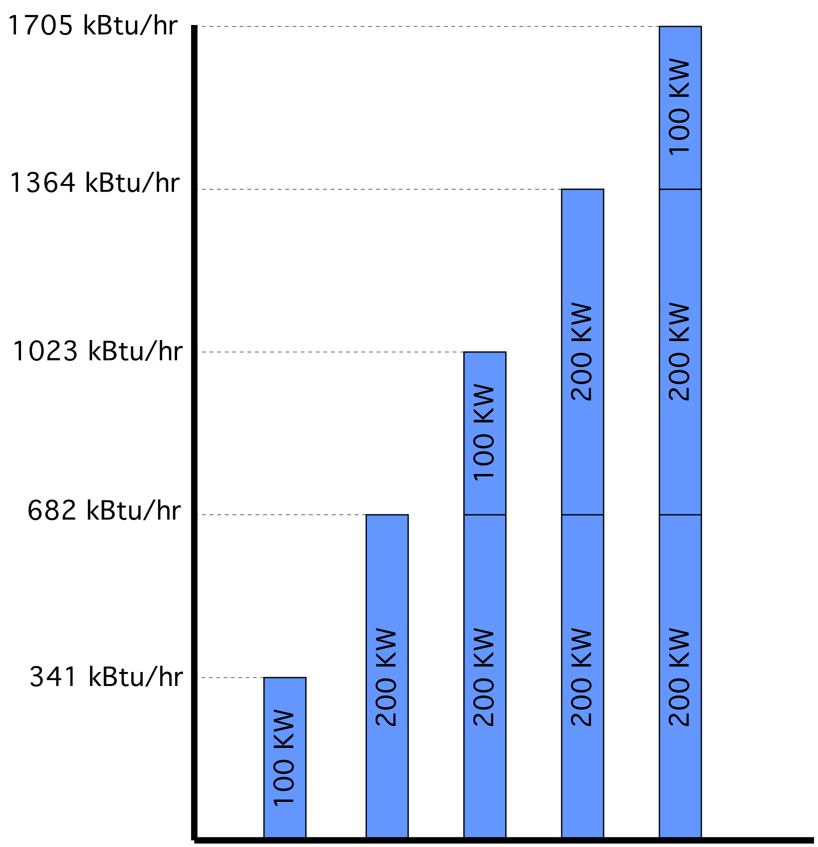
100 KW

200 KW

100 KW + 200 KW

200 KW + 200 KW

100 KW + 200 KW + 200 KW



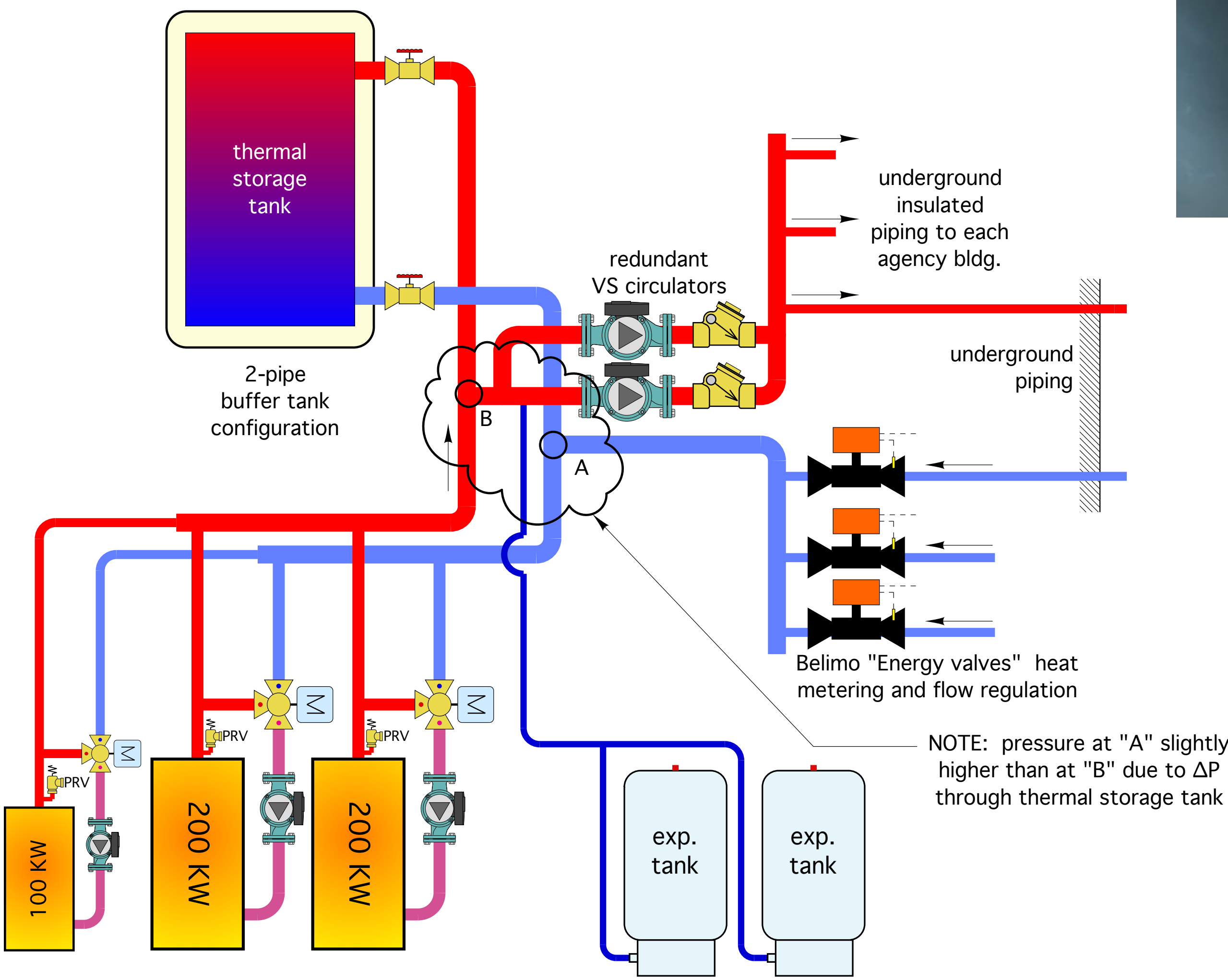
Boiler firing is based on *measured* total building load

Multiple pellet boiler system at RayBrook

Btu meters
1 for each building

Original design of multiple boiler system

The issue: When a pellet boiler turns off it's 3-way anti-condensation valve is fully open to the system. This allow flow of heated water through the unfired boiler.



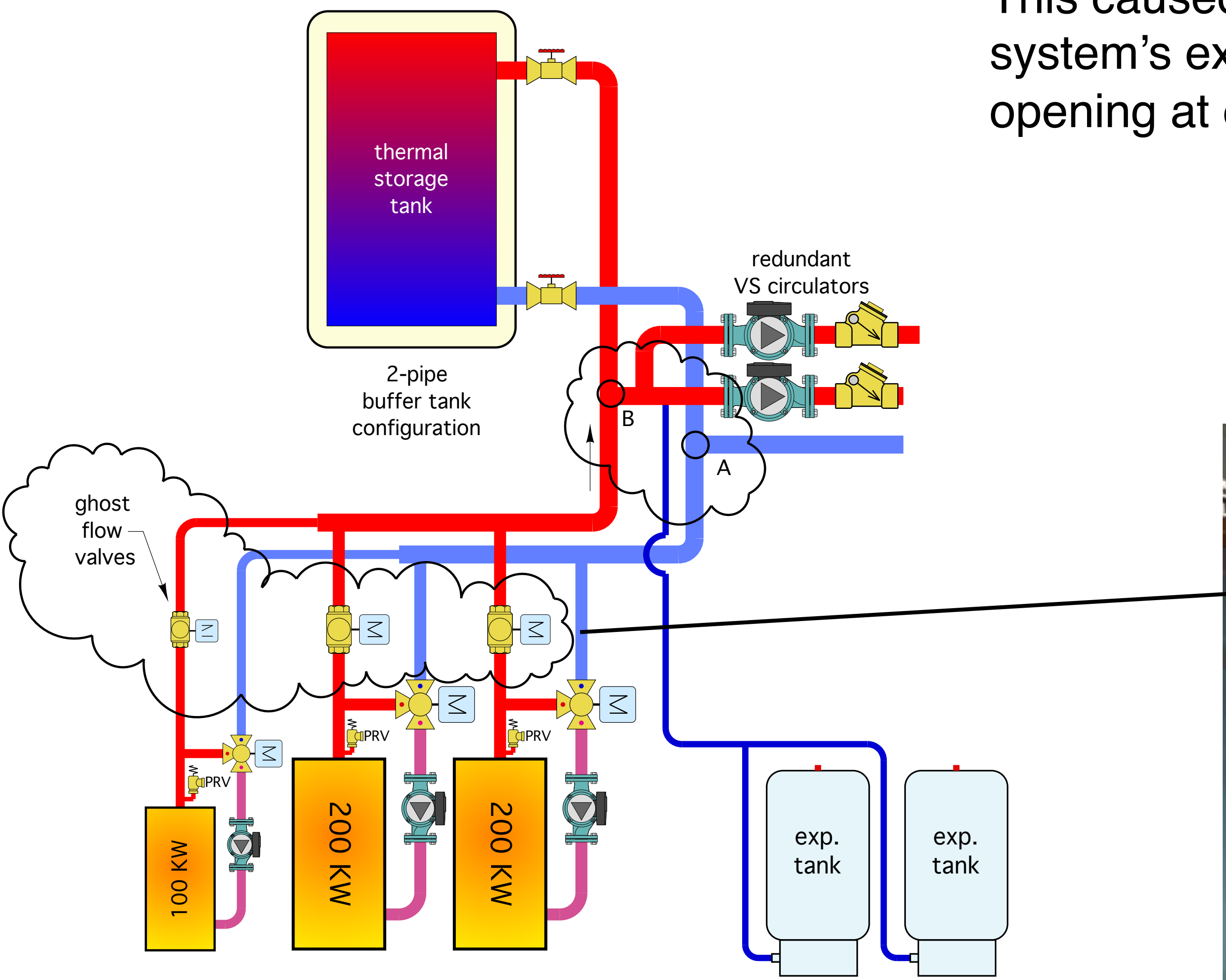
The “fix” implemented

motorized 2-way valves were installed on supplied side of each pellet boiler.

At start up the anti-condensation valve on each boiler is fully closed.

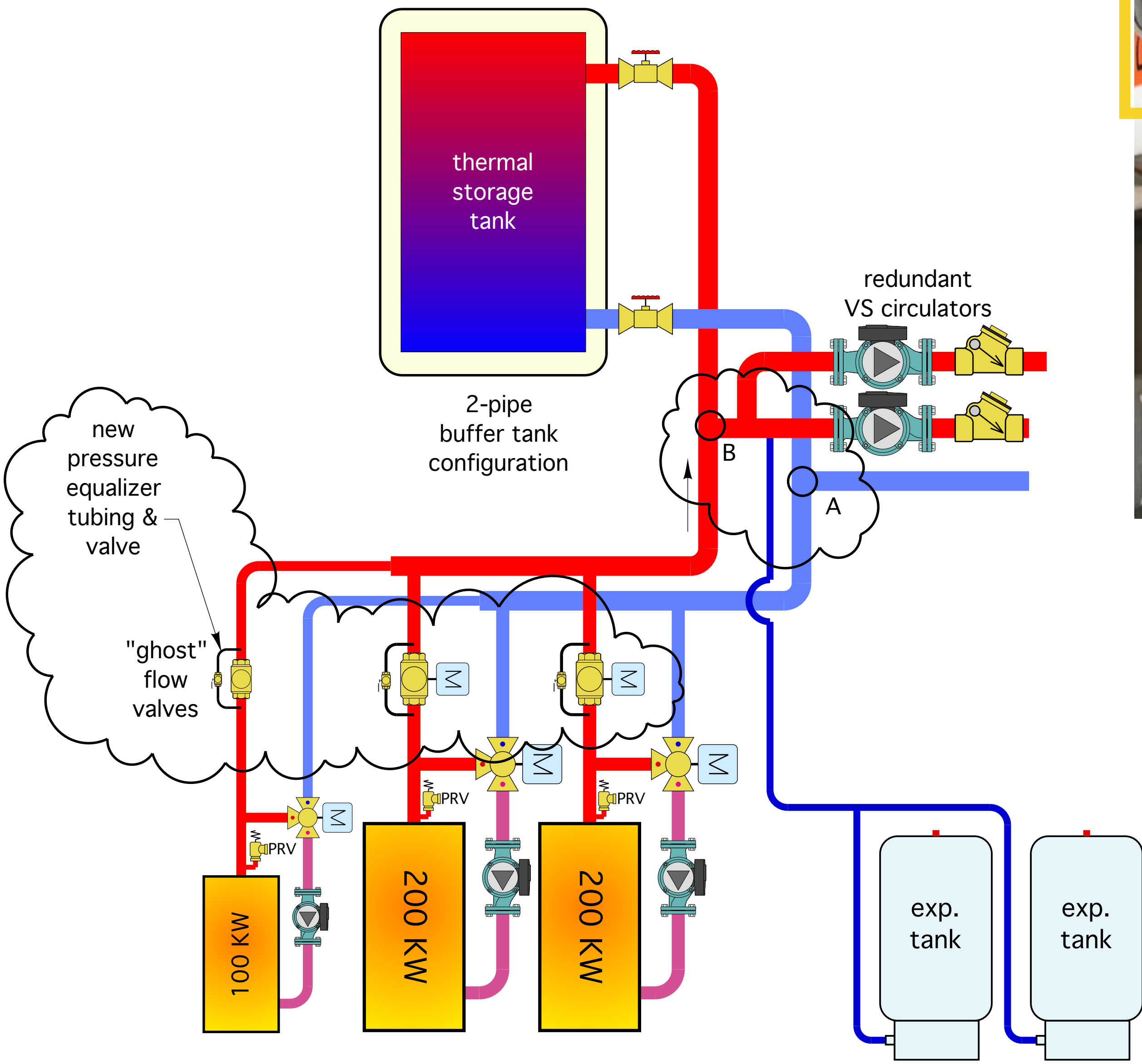
The motorized 2-way would not open until the boiler warmed up and its circulator turned on.

This caused the boiler to be isolated from the system’s expansion tank - leading to the PRV opening at each cold start.



Fixing the Fix…

A very small bypass pipe and valve was installed around the 2-way valve to allow pressure equalization with very tiny flow



Thanks for attending this series of webinars.

October 14, 2021

Title: Adapting a pellet boiler to a forced air heating system

Description: The majority of houses in NY have forced air heating systems supplied by furnaces operating on fossil fuels. The webinar shows how a pellet boiler could be integrated into those systems to displace much of the fossil fuel used for space heating, and provide domestic hot water.

November 18, 2021

Title: Case study: Designing from scratch: What's possible when a pellet boiler is planned into new building construction

Description: Many of the previous webinars have focussed on adapting a pellet boiler into an existing hydronic heating system. This webinar describes an unfettered design development when a pellet boiler is incorporated into new construction. Details that leverage low temperature distribution systems, and optimal configuration of thermal storage for providing space heating and domestic hot water.

All of these webinars will be posted on NYSERDA's Renewable Heat NY website - under "training opportunities" link.

QUESTIONS ?