Case study: A pellet boiler system for a highway garage

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July 1, 2021
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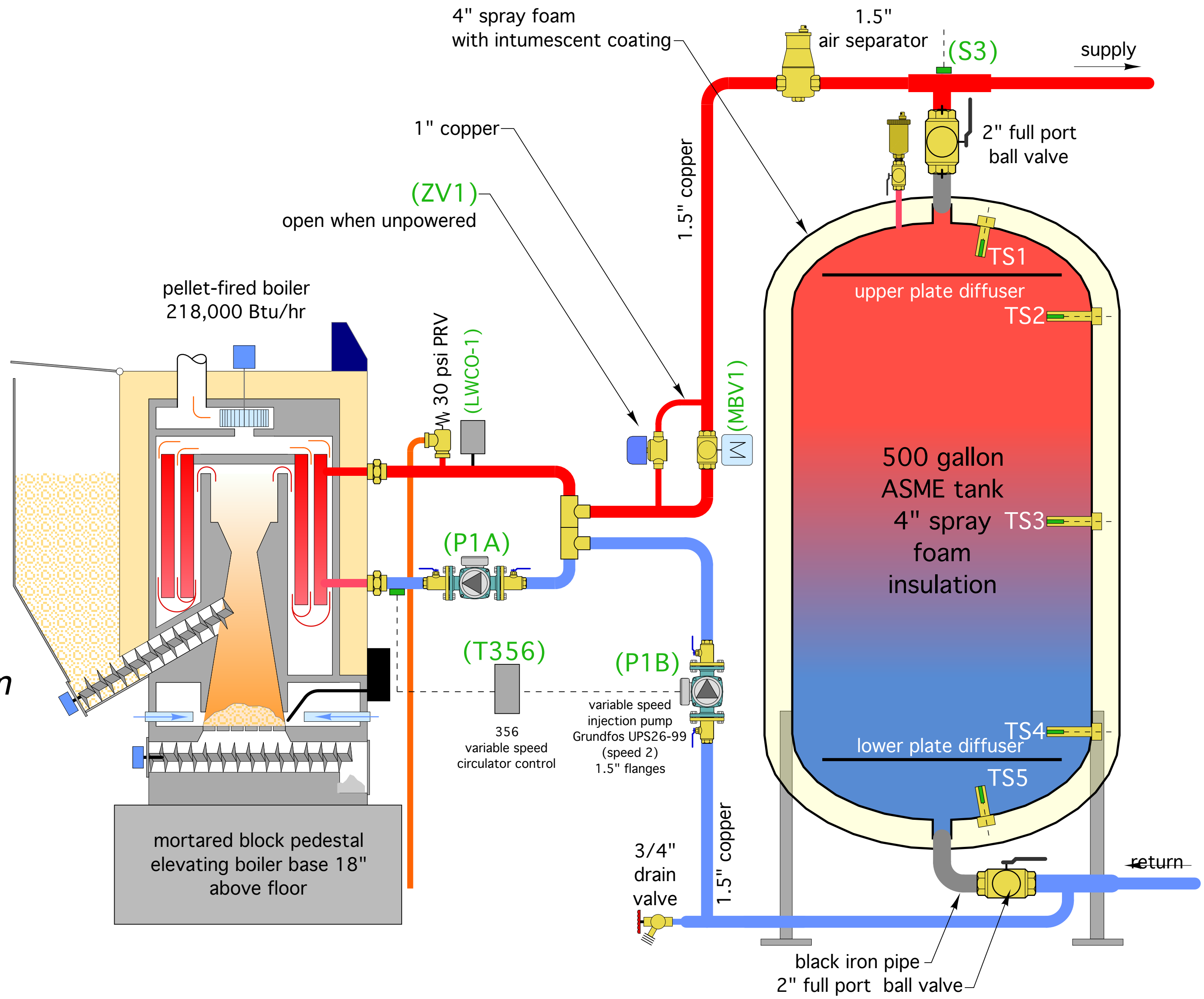

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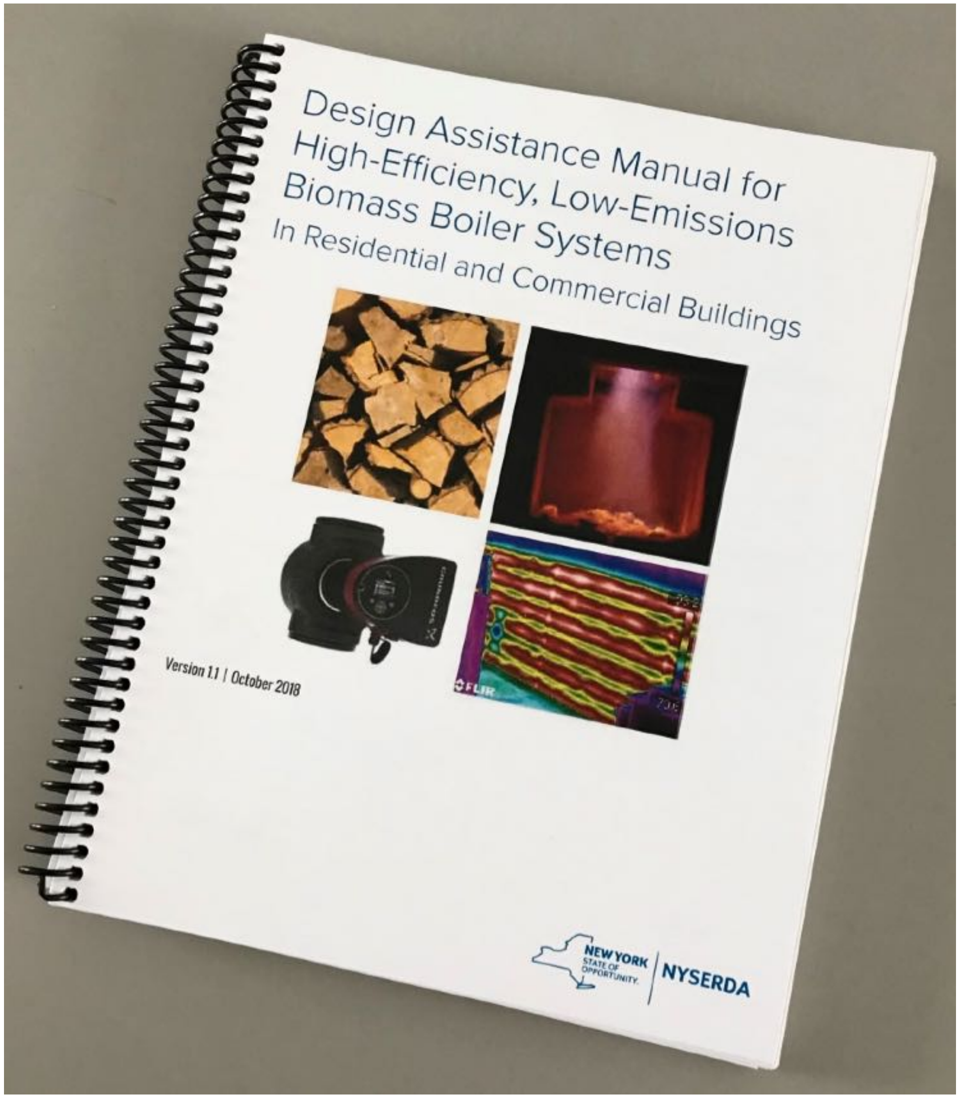
Case study: A pellet boiler system for a highway garage

Description: Large slab-on-grade buildings are ideal candidates for combining a pellet boiler system with floor heating. This webinar will show the details for a system designed to heat a 13,000 square foot highway garage, including system piping, combustion air supply, thermal storage, controls, and a staged modulating/condensing auxiliary boiler system. The concepts shown are scaleable and repeatable for similar structures.

Learning Objectives:

- Understand why slab on grade buildings are well suited to pellet boiler systems.
- Learn how the thermal storage tank is piped and temperature monitored.
- Learn how the controls for injection mixing and modulating aux boilers are coordinated.
- Understand way continuous circulation through floor heating circuits is beneficial in this type of building.

Design Assistance Manual
for High Efficiency Low Emissions Biomass Boiler Systems



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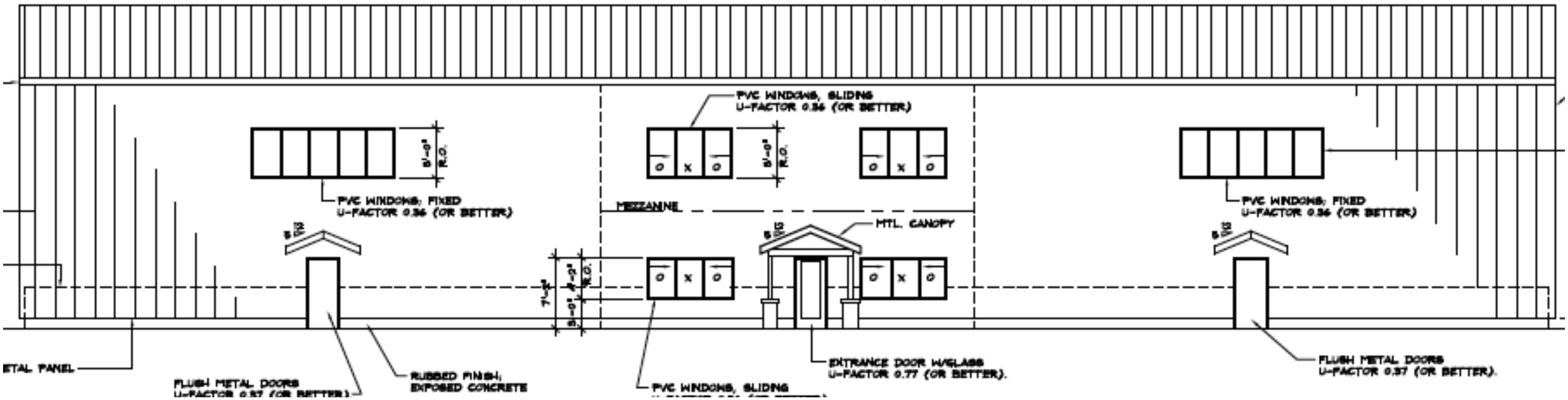
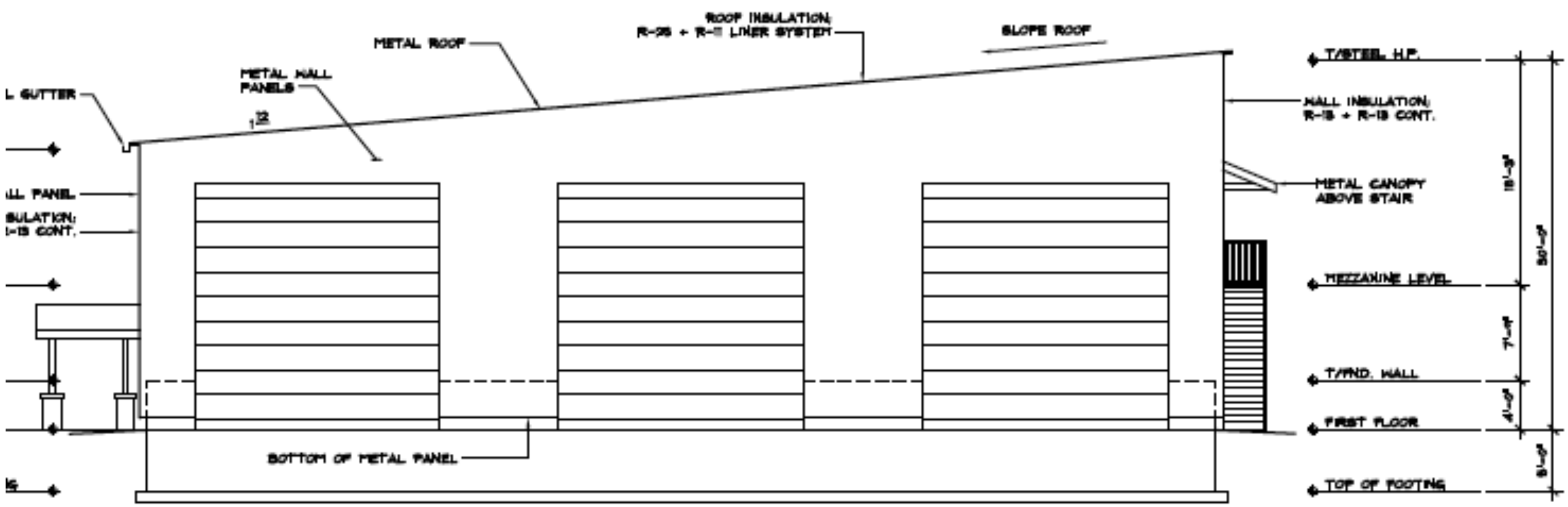
It’s available as a FREE downloadable PDF at:

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

A town highway garage, in rural upstate NY

<u>Fully planned but not yet under construction….</u>





Design objectives of the heating system:

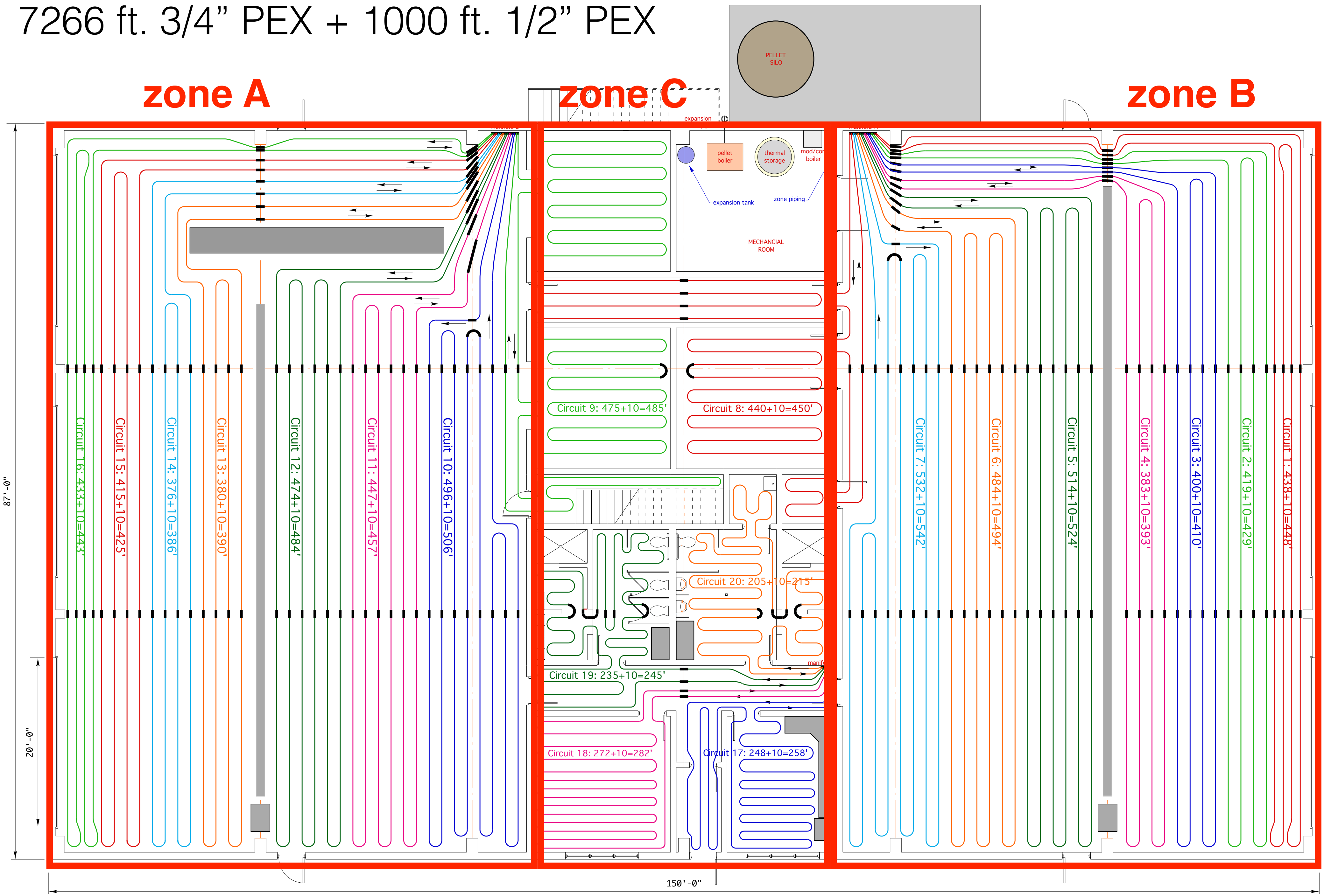
- Comfortable and economical heating of building (dry floors…)
- Preferential use of pellets over propane
- Automatic switching to propane if pellet boiler is down
- *Installable* by contractors with minimal previous experience
- *Serviceable* by local HVAC companies
- Use residential / light commercial scale hardware where possible
- Achieve long operating cycles of the pellet boiler
- Use constant circulation in floor circuits to prevent low temperature area near late overhead doors.
- Provide separate zoning of garage areas from offices, break room, etc.
- Provide exterior pellet storage for safety and space savings
- Create detailed documentation to ensure long service life
- Meet all criteria for NYSERDA's Renewable Heat NY incentive program

Project details:

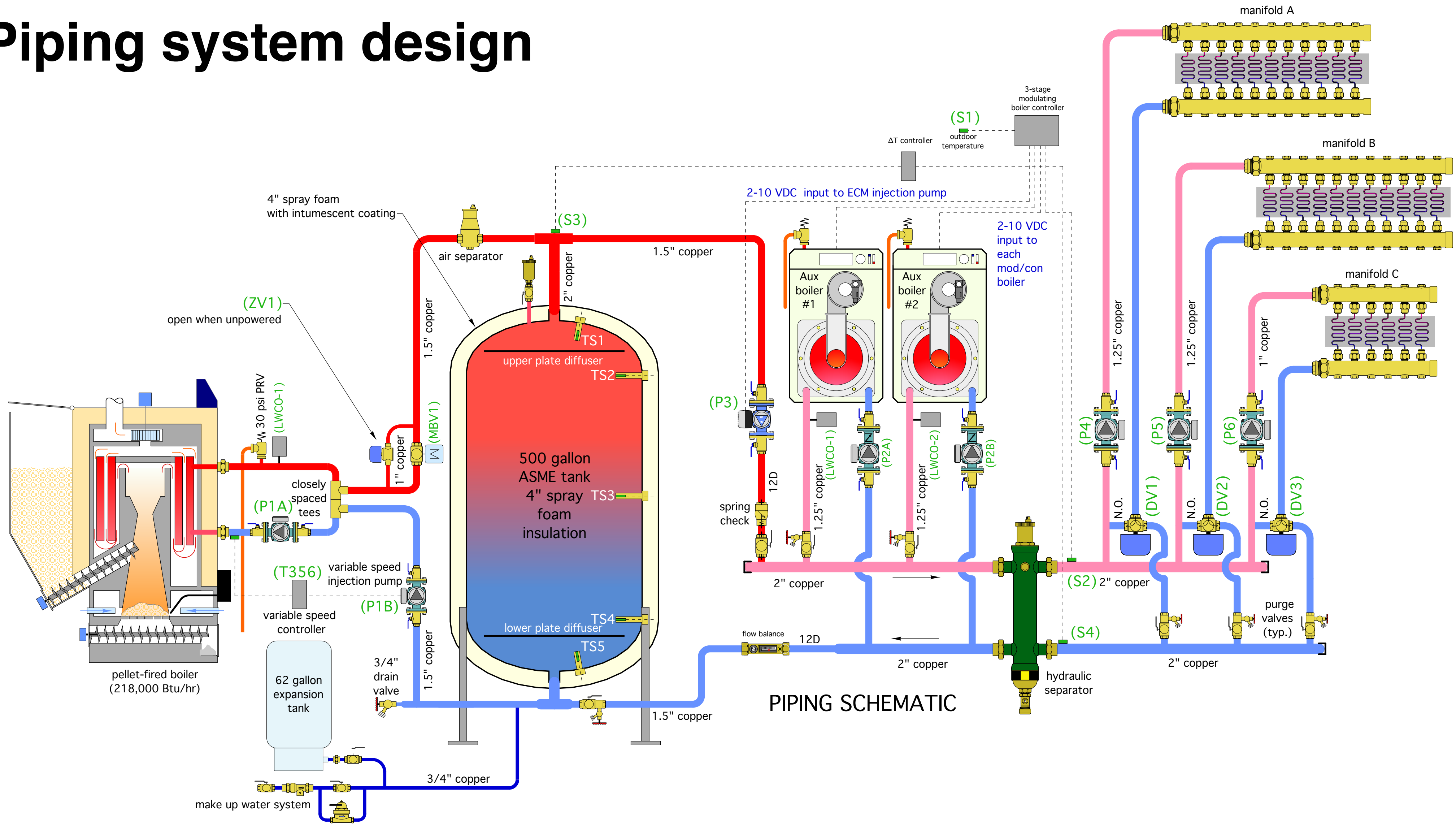
- 320,000 Btu/hr building design load @70 ºF design ΔT, (-5ºF ambient)
- 8” concrete slab (13,000 ft^2 / 608 tons) w/ 2”/60 psi polystyrene insulation
- Each truck bay is a zone (2 large zones)
- Office, break room, bathrooms separate zone
- 218,000 Btu/hr Pellet boiler as primary heat source (68% of design load)
- 2, propane-fueled mod/con boilers at 185,000 Btu/hr output each as supplemental and back up heat sources
- Truck bays use 3/4” PEX tubing at mostly 18” spacing
- Office, break room, bathrooms use 1/2” tubing at 12” spacing
- 41 yard^3 (22 ton capacity) galvanized steel pellet silo
- 500 gallon ASME rated thermal storage tank with R-24 insulation
- Supply water temperature to floor circuits @ design load = 110 ºF
- Estimated seasonal heating energy = 537 MMBtu/yr, 42 tons of pellets
- Estimated installed cost $110,000, (expect $32,000 NYSERDA rebate)

Floor heating tubing layout

7266 ft. 3/4” PEX + 1000 ft. 1/2” PEX

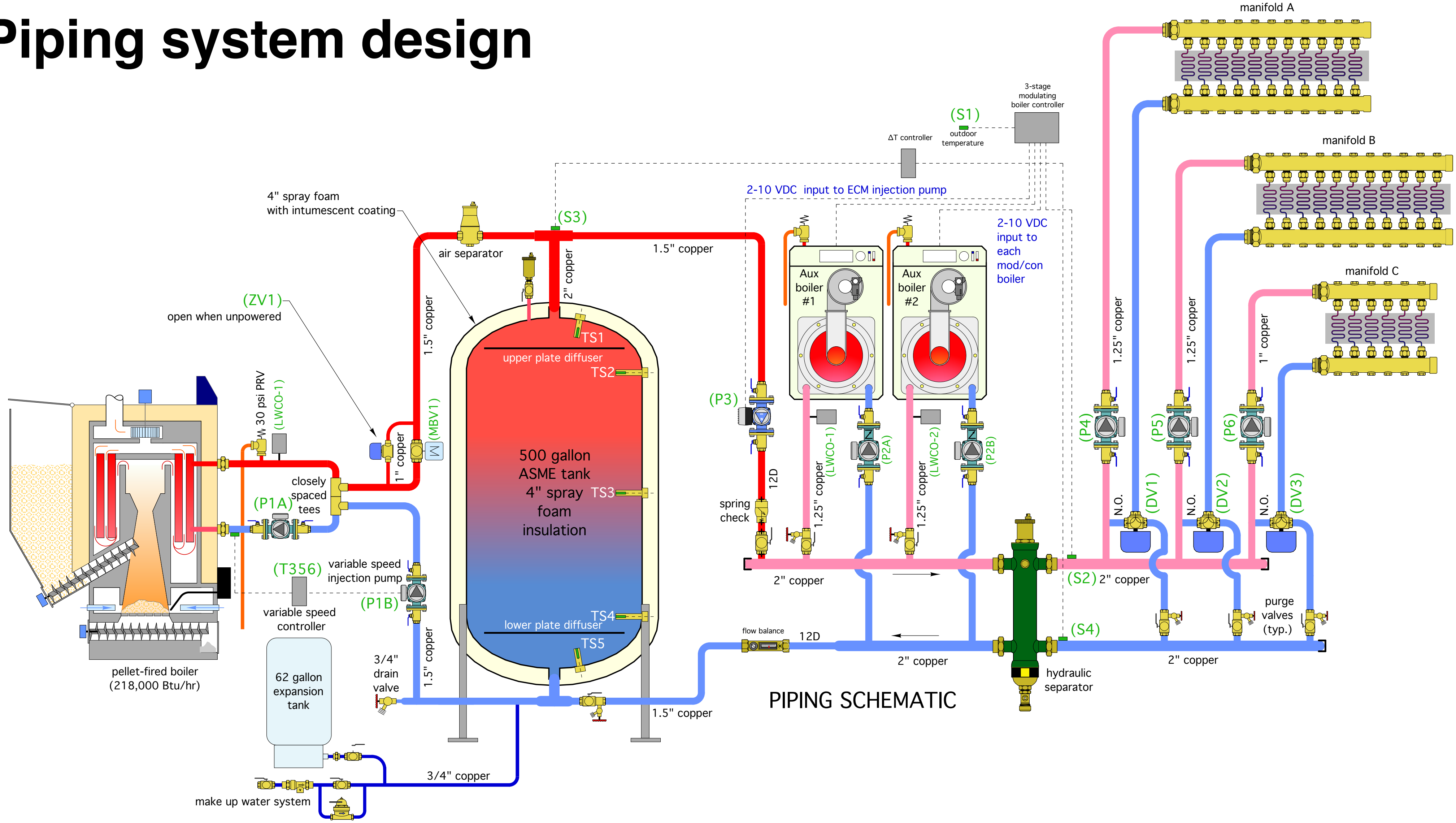


Piping system design



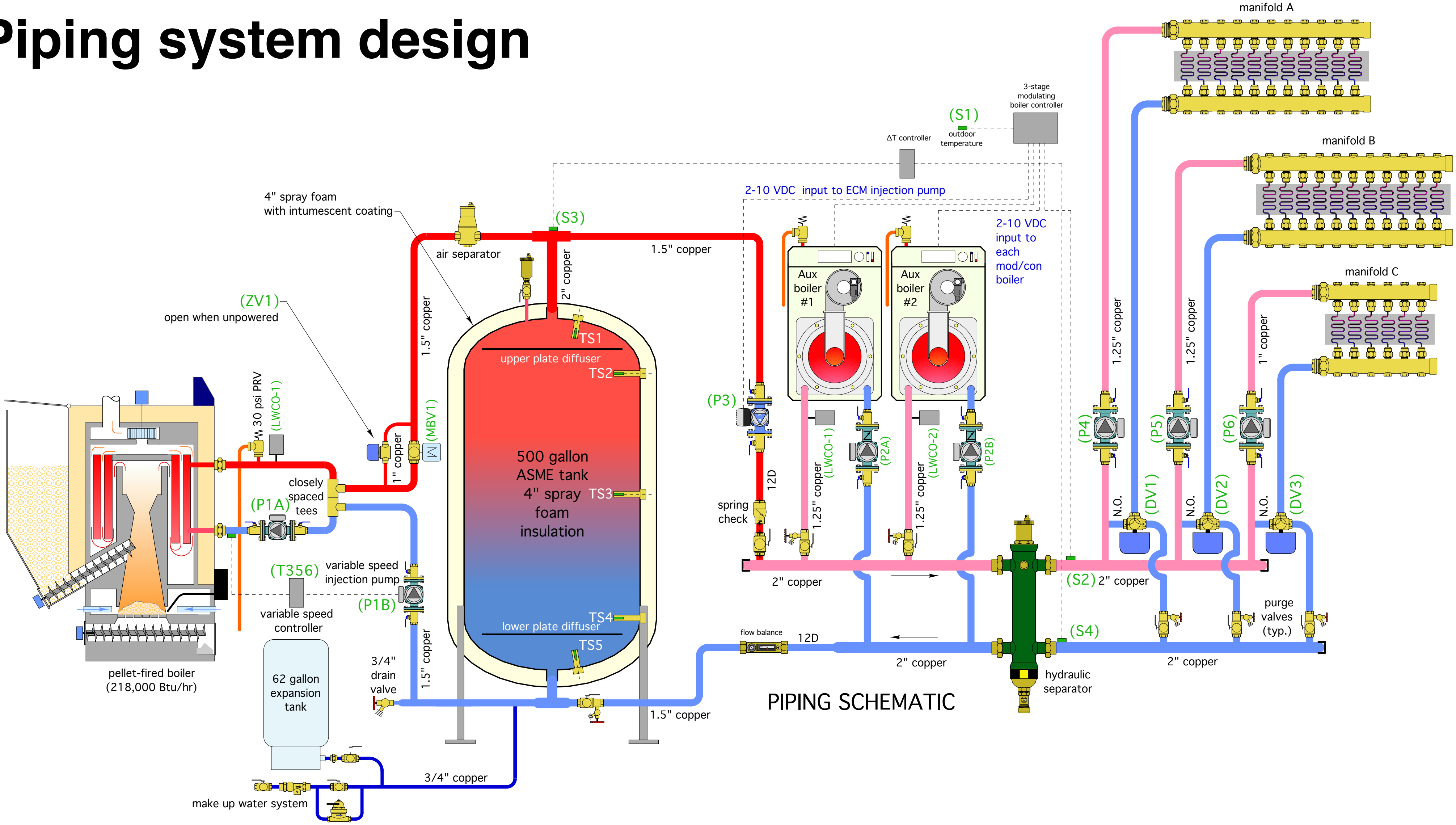
- Constant circulation in floor heating circuits
- Variable speed injection circulator (P3) controlled by 0-10 VDC input
- Each propane boiler has 5:1 modulation, controlled by 0-10 VDC input
- Controller provides fixed 1st stage, and rotating 2nd and 3rd stage

Piping system design



- Pellet boiler can thermosiphon to tank during power outage
- Pellet boiler inlet temperature controlled to 130 °F (anti-condensation)
- Flow through pellet boiler blocked with it is off
- “2-pipe” thermal storage configuration with internal diffuser plates

Piping system design



• Injection pump can only operate if temperature at top of tank ≥ 3°F above return temperature from distribution system

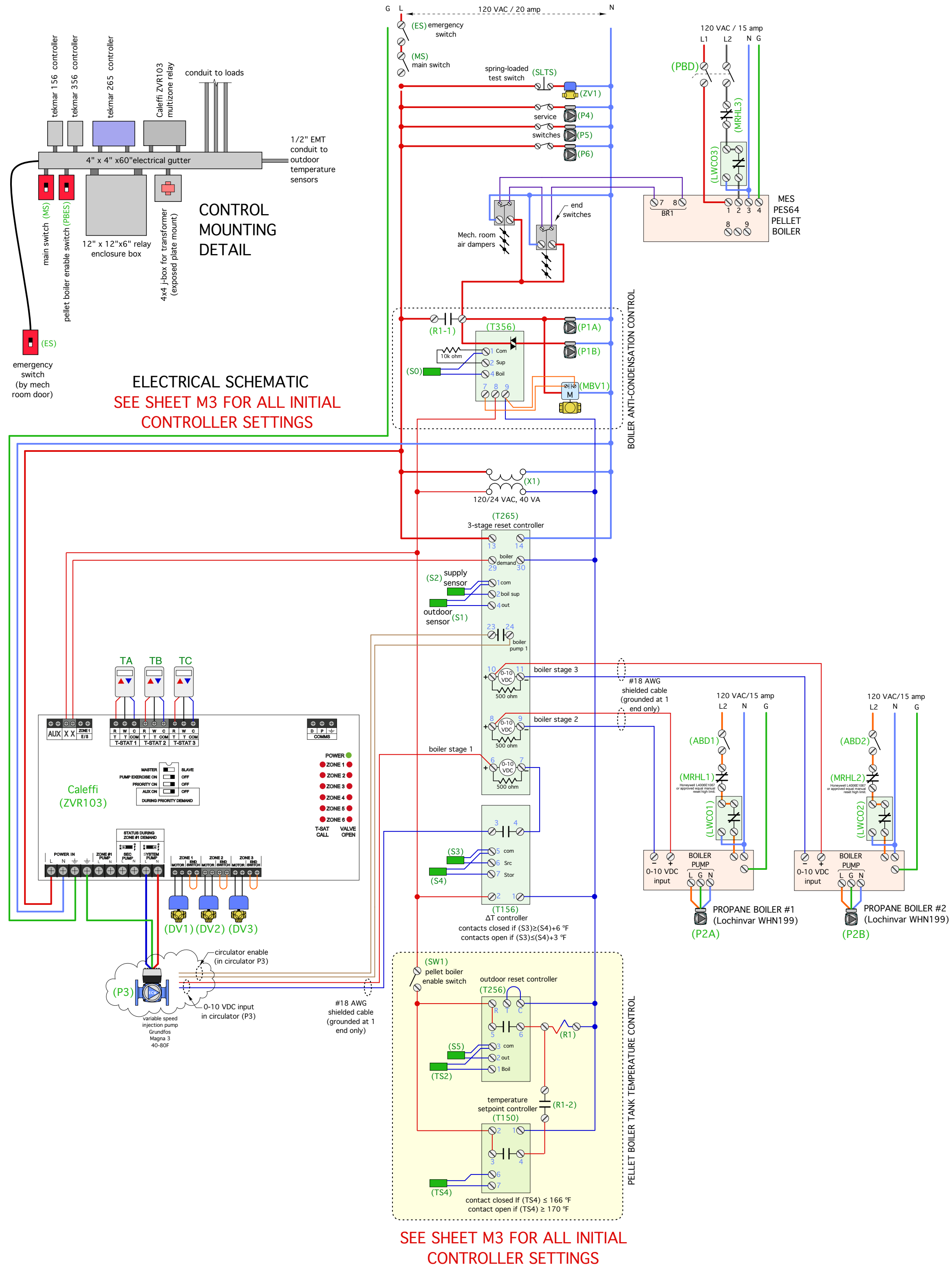
• All circulators are hydraulically separated from each other

• “2-pipe” thermal storage configuration with internal diffuser plates to maintain temperature stratification in tank

Electrical controls

Off-the-shelf controllers

$2,500 total controls hardware cost



Provide detailed description of operation and controller settings

Read later if you like…

DESCRIPTION OF OPERATION:

Power Supply to control circuit: Power to the controller circuit requires that both the emergency switch (ES), located near door of mechanical room, and main switch (MS), located by control panel in mechanical room be closed.

Pellet Boiler Operation: The pellet boiler is controlled based on the temperature at two sensors in the thermal storage tank. Upper tank sensor (TS2) determines when the pellet boiler is turned on. Lower tank sensor (TS4) determines when the pellet boiler is turned off.

The "on" condition for the pellet boiler occurs when the temperature at sensor (TS2) drops slightly below the target temperature, which is continuously calculated based on the outdoor temperature at sensor (S5), and the settings of the outdoor reset controller (T256).

The target temperature at (TS2) is 110 ºF when the outdoor temperature is -5 ºF. This target temperature decreases to a minimum of 80 ºF when the outdoor temperature is 51 ºF or above.

A contact closure in the (T256) controller passes 24 VAC to the coil of relay (R1). Normally open contact (R1-1) closes to supply 120 VAC directly to circulator (P1A), and to the line voltage lead on the tekmar 356 controller (T356) operating circulator (P1B), and to both motorized air dampers. 120 VAC is also supplied through (R1-1) to operate motorized ball valve (MBV1). When the motorized ball valve is fully open, its internal end switch closes passing 24VAC to the low voltage circuits in the (T356) controller

When both motorized air dampers are fully open, their internal end switches close (in series) to provide a completed circuit between terminals 7 and 8 of the PES64 boiler turning it on.

The (T356) monitors the temperature of water entering the pellet boiler. When this temperature rises to 140 ºF, the (T356) begins to ramp up the speed of circulator (P1B), which transports heat from the pellet boiler recirculation loop to thermal storage or load. The speed of circulator (P1B) increases as the return water temperature rises above 140 ºF, and slows to a very low speed if the return water temperature decreases below 140 ºF.

24 VAC also passes through the closed contact of the (T150) setpoint controller, through contact (R1-2). This contact maintains 24 VAC to relay coil (R1) after the contacts in the (T256) controller open as the tank temperature begins to rise.

The pellet boiler continues to operate until the temperature at tank sensor (TS4) rises to 170 ºF. This causes the contacts in the (T150) controller to open, interrupting 24 VAC to relay (R1), and turning off the pellet boiler, circulators (P1A) and (P1B), and the (T356) controller. The motorized ball valve (MBV1) also closes using its internal spring return mechanism. This prevents flow through the pellet boiler when it is off.

Zone valve (ZV1) remains closed whenever the master switch is on, and electrical power is available to the system. During a power outage (ZV1) opens to allow passive thermosiphoning between the pellet boiler and thermal storage tank. A spring-loaded test switch (SLTS) can be periodically pushed to interrupt 120 VAC power to zone valve (ZV1) to test its operation.

Heat Input to Distribution System: There are three stages of heat input to the distribution system. All three stages are controlled by the tekmar modulating boiler controller (T265). This controller is turned on by a call from any of the three zone thermostats (T1, T2, T3).

When any thermostat calls for heat, 24 VAC from transformer (X1) passes through the (X X) contacts in the (ZVR103) multi-zone relay center to terminal 29 on the (T265) controller. This turns the (T265) on in outdoor reset mode. The (T265) controller measures outdoor temperature at sensor (S1) and uses this reading along with its settings to calculate the target supply water temperature to the distribution system. It compares this calculated target temperature to the measured temperature at sensor (S2). If the measured temperature at (S2) is slightly below the target temperature, the (T265) uses its first stage 0-10 VDC output to ramp up the speed of circulator (P3). Stage 1 output is fixed as the lead stage.

Injection circulator (P3) is enabled to operate by the closure of relay contact (23/24) in the (T265) controller. This contact closure occurs whenever the (T265) initiates stage 1 operation. The speed of circulator (P3) is determined by the 0-10 VDC signal supplied by the (T265) controller.

If the temperature at sensor (S2) cannot be maintained by injection of hot water from thermal storage and/or the pellet boiler, a 0-10 VDC output from stage 2 and 3 of the (T265) controller activates to provide modulated heat input from auxiliary boilers 1 and 2. Stages 2 and 3 periodically rotate operating order so as to provide approximately equal run time for auxiliary boilers 1 and 2.

Prevention of Inadvertent heat flow into thermal storage: Heating of the thermal storage tank by the auxiliary boilers is prevented by continuously measuring the difference between the temperature on the piping at the top of the thermal storage tank at sensor (S3), and the temperature returning from the distribution system at sensor (S4). If (S3) ≥ (S4) + 6 ºF, the normally open contact in the tekmar differential temperature controller (T156) is closed allowing the 0-10 VDC speed control signal from the stage 1 output of the (T265) controller to operate circulator (P3). If (S3) ≤ (S4)+3 ºF the contact in the (T156) controller opens to prevent circulator (P3) from operating. This allows the thermal storage tank to contribute heat to the distribution system whenever possible, but prevents heat produced by the auxiliary boilers from heating thermal storage.

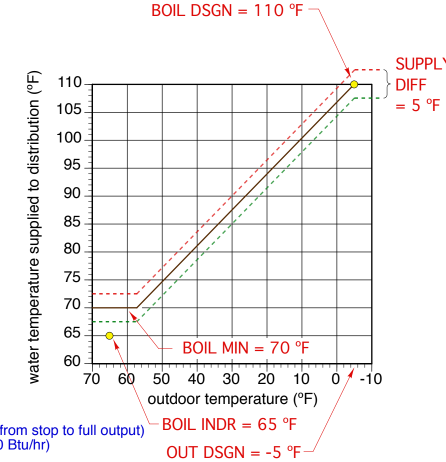
All heat input to the distribution system passes through the hydraulic separator, which isolates the pressure dynamics of the injection circulator. and the auxiliary boiler circulators from the distribution circulators.

Heating distribution: All three radiant floor heating zones operate with constant circulation. This improves heat distribution across the floor areas, and helps protect the high heat loss areas of the slab, near the overhead doors, from potential freezing. Circulators (P4) (P5) and (P6) operate whenever the main switch of the heating system is closed. Each of these circulators is supplied with 120 VAC though a normally-closed service switch.

Diverter valves (DV1) (DV2) and (DV3) are off whenever their associated zone thermostat is not calling for heat. In this mode they route flow returning from each radiant floor zone back to the supply manifold for that zone, and thus provide no heat input to the zone. When a zone thermostat (T1) (T2) or (T3) call for heat, 24 VAC is supplied to the actuator of the associated diverter valve. This routes flow returning from that zone back to the hydraulic separator, and passes heated water to the zone. Verify proper operation so that N.O. port is open when actuator is off.

Initial settings for tekmar 265 controller:
DIP Switch settings:
DIP switch 1: set to ADVANCED
DIP switch 2: set to STAND ALONE
DIP switch 3: set to ALERT
DIP switch 4: set to OFF
DIP switch 5: set to SEQUENTIAL
DIP switch 6: set to OFF
DIP switch 7: set to ROTATE
DIP switch 8: set to FIXED LEAD
DIP switch 9: set to FIRST ON / LAST OFF

ROOM OCC = 65 ºF
ROOM UNOCC = 65 ºF
BOOST = OFF
BOILER 1 = Au
BOILER 2 = Au
BOILER 3 = Au
OUT DSGN = -5 ºF
TERM = 1
BOIL INDR = 65 ºF
BOIL DSGN = 110 ºF
BOIL MIN = 70 ºF
BOIL MAX = 110 ºF
BOIL DIFF = 5 ºF
DLY /// = 0 (damper delay)
STG DLY = Au



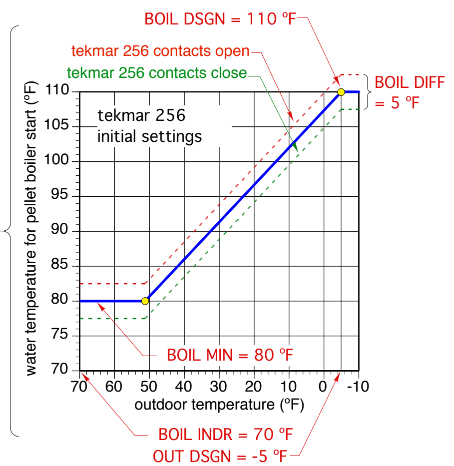
FDLY 1 = 0:30 (30 seconds fire delay)
BOIL MASS 1 = 3 (high mass)
MOTR 1 = 10 (10 seconds to ramp stage 1 from stop to full output)
MIN 1=1 (minimum output boiler 1 = 10,000 Btu/hr)
MAX 1 = 20 (200,000 Btu/hr)
BOIL 1 modulation = 0:20 (0-20 ma output)
MIN 1 % modulation = 0
MAX 1 % modulation = 100
PURG BOIL PUMP 1 = OFF

FDLY 2 = 0:05 (5 seconds fire delay)
BOIL MASS 2 = 1 (low mass)
MOTR 2 = 30 (30 seconds to ramp stage 1 from stop to full output)
MIN 2=4 (minimum output boiler 2 = 40,000 Btu/hr)
MAX 2 = 20 (200,000 Btu/hr)
BOIL 2 modulation = 0:20 (0-20 ma output)
MIN 2 % modulation = 0
MAX 2 % modulation = 100
PURG BOIL PUMP 2 = OFF

FDLY 3 = 0:05 (5 seconds fire delay)
BOIL MASS 3 = 1 (low mass)
MOTR 3 = 30 (30 seconds to ramp stage 1 from stop to full output)
MIN 3=4 (minimum output boiler 2 = 40,000 Btu/hr)
MAX 3 = 20 (200,000 Btu/hr)
BOIL 3 modulation = 0:20 (0-20 ma output)
MIN 3 % modulation = 0
MAX 3 % modulation = 100
PURG BOIL PUMP 3 = OFF

DHW mode: set to OFF
SETP = 1
SETP OCC = OFF
SETP UNOCC = OFF
Priority override = OFF
WWSD OCC = 60 ºF
WWSD UNOCC = 60 ºF
Primary pump purge = OFF
Boiler alert = 20
ºF/ºC = ºF

Tekmar 256 initial settings:
ROOM OCC = 70 ºF
ROOM UNOCC = 70 ºF
OUTDR DSGN = -5 ºF
BOIL INDR = 70 ºF
BOIL DSGN = 110 ºF
BOIL MIN = 80 ºF
BOIL DIFF = 5 ºF
WWSD OCC = 70 ºF
WWSD UNOCC = 70 ºF
ºF/ºC = ºF
TERMINAL UNIT = 1



Tekmar 156 initial settings:
ΔT setpoint = 6 ºF
ΔT differential = 3 ºF
storage max = 210 ºF
source minimum = 90 ºF
ºC/ºF = ºF

Tekmar 150 initial settings:
PWM DIP switch = OFF
setpoint = 168 ºF
differential = 4 ºF
heat/cool = heat
ºC/ºF = ºF

ZVR103 DIP switch settings:
master/slave = master
pump exercise = OFF
priority = OFF
AUX on during priority = OFF

Manual reset high limit settings:
MRHL1 = 200 ºF
MRHL2 = 200 ºF
MRHL3 = 210 ºF

RHNY Incentives

<table>
<tr><th>Program</th><th>System Type</th><th colspan="2">Installation Incentive</th><th colspan="3">Additional Incentive</th></tr>
<tr><td rowspan="3">Small Biomass Boiler</td><td>Advanced Cordwood Boiler
with Thermal Storage</td><td colspan="2">25% installed cost
($7,000 maximum)</td><td>-</td><td rowspan="5">Recycling

$5,000/unit for old indoor/ outdoor wood boiler
<u>or</u>
$2,500/unit for old wood furnace</td><td>-</td></tr>
<tr><td rowspan="2">Small Pellet Boiler
with Thermal Storage</td><td>≤120 kBtu/h
(35 kW)</td><td>45% installed cost
($16,000 maximum)</td><td rowspan="4">Thermal Storage Adder

$5/gal for each gal above the minimum thermal storage requirement</td><td>-</td></tr>
<tr><td>≤300 kBtu/h
(88 kW)</td><td>45% installed cost
($36,000 maximum)</td><td>-</td></tr>
<tr><td rowspan="2">Large Biomass Boiler</td><td>Large Pellet Boiler
with Thermal Storage</td><td rowspan="2">>300 kBtu/h
(88 kW)</td><td>65% installed cost
($325,000 maximum)</td><td rowspan="2">Emission Control System

$40,000</td></tr>
<tr><td>Tandem Pellet Boiler
with Thermal Storage</td><td>75% installed cost
($450,000 maximum)</td></tr>
<tr><td>Residential Pellet Stove</td><td>Pellet Stove</td><td colspan="2">$1,500
($2,000 for income qualified residents)</td><td>-</td><td>Recycling

$500
(income qualified residents only)</td><td>-</td></tr>
</table>

LMI Incentives - Boilers

<table>
<tr><th>Program</th><th colspan="2">System Type</th><th>Market Rate Installation Incentive</th><th>LMI Installation Incentive</th></tr>
<tr><td rowspan="2">Small Biomass Boiler</td><td colspan="2">Advanced Cordwood Boiler with Thermal Storage</td><td>25% installed cost ($7,000 maximum)</td><td>65% installed cost ($18,000 maximum)</td></tr>
<tr><td>Small Pellet Boiler with Thermal Storage</td><td>≤120 kBtu/h (35 kW)</td><td>45% installed cost ($16,000 maximum)</td><td>65% installed cost ($23,000 maximum)</td></tr>
</table>

For more information:

- “Google” Renewable Heat NY
- contact Sue Dougherty at NYSERDA sue.dougherty@nyserda.ny.gov

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Thanks for attending this series of webinars.

September 2021

Title: 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.

October 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 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 ?