Boiler Optimization and Integration

Patterson-Kelley

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Agenda

- Best practices for design, installation, and maintenance for the:
  - Gas piping and gas supply regulator
  - Venting basics for success
  - Hydronic piping system and required accessories
  - Water quality – ALWAYS a wise decision
  - Periodic maintenance
- Boiler Integration with Other Appliances
  - Condensing/Non-Condensing Applications
  - Hot/Cold Hydronic Systems
  - Electric Hybrid Hydronic Applications

Gas Piping

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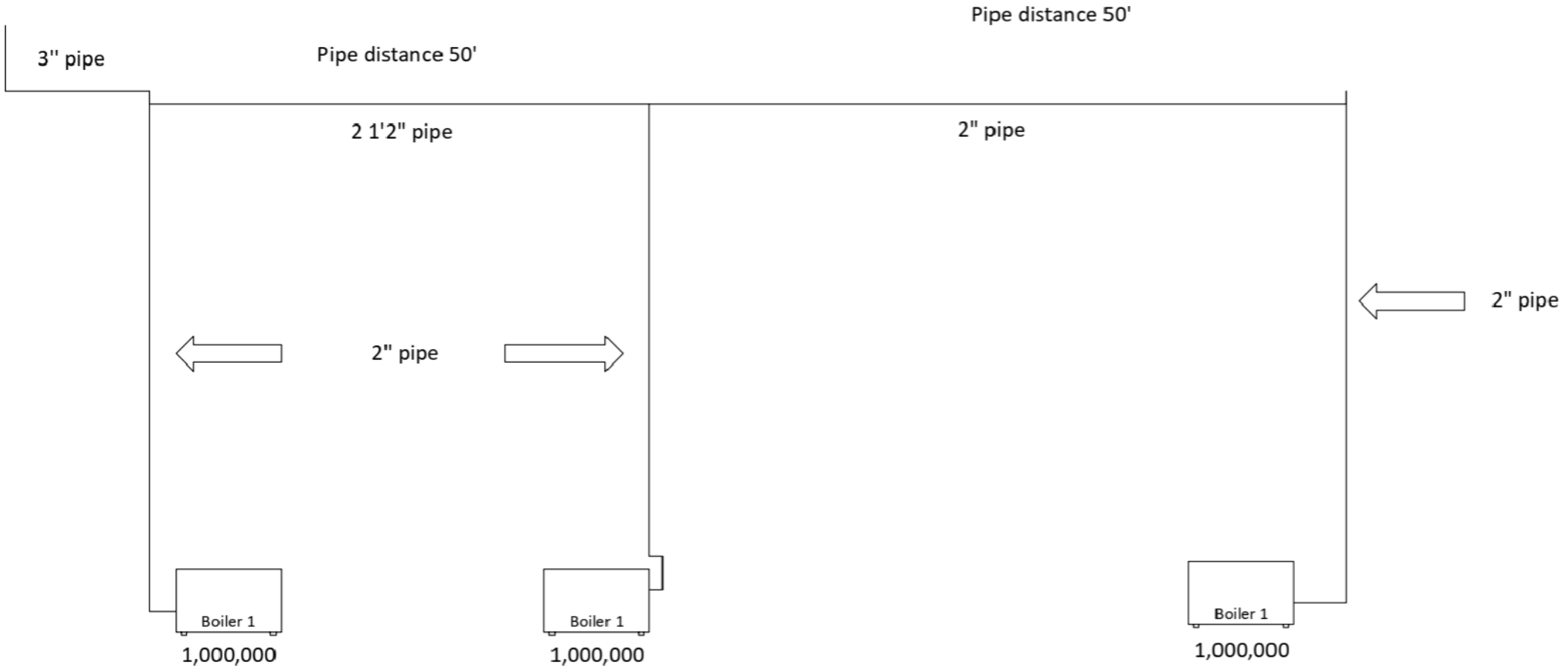
Gas Pipe Sizing vs. Load

Capacity of Pipe (MBH ≈ CFH)							
Pipe Size (in)		Pipe Length (ft)					
Nominal	Inside diameter	10	20	40	80	150	300
1/2"	0.622	120	85	60	42	31	22
3/4"	0.824	272	192	136	96	70	50
1"	1.049	547	387	273	193	141	100
1 1/4"	1.38	1200	849	600	424	310	219
1 1/2"	1.61	1860	1316	930	658	480	340
2"	2.067	3759	2658	1880	1330	971	686
2 1/2"	2.469	6169	4362	3084	2189	1593	1126
3"	3.068	11225	7938	5613	3969	2898	2049
4"	4.026	23479	16602	11740	8301	6062	4287
5"	5.047	42945	30367	21473	15183	11088	7841
6"	6.065	69671	49265	34836	24632	17989	12720
8"	7.981	141832	100290	70916	50145	36621	25895

Example:

Inlet pressure 14"

Inlet pipe 80'



Gas Piping Best Practices

- Pipe between regulator and boiler is your reservoir
- Increase reservoir if distance to boiler from regulator is less than 10'
- Drip leg same size as main gas pipe to boiler
- Regulator orifice sized 10% above maximum input needed
- Vent line should increase one pipe size for every 10’ of distance (more on this later)

Gas Regulator

- Select The Smallest Orifice That Will Handle The Rated Input
- The Pipe Size should be at least one size larger than the Regulator Body Size
  - The pipe should be one size larger than the regulator
    - 1 1/2” regulator body means piping needs to be 2”
- Select The Spring With The Lower Range For Better Accuracy
  - Oversizing is bad

Optimal Gas Regulator

- Adjust The Set Point 5% above Normal Flow
- Direct Operated Regulators Have A Faster Response Than Pilot Operated Regulators
- Piping Up To And Away From Regulators Can Cause Flow Pressure Loss
- Gas pressure drop less than 2”

Gas line

Pressure drop equals volume

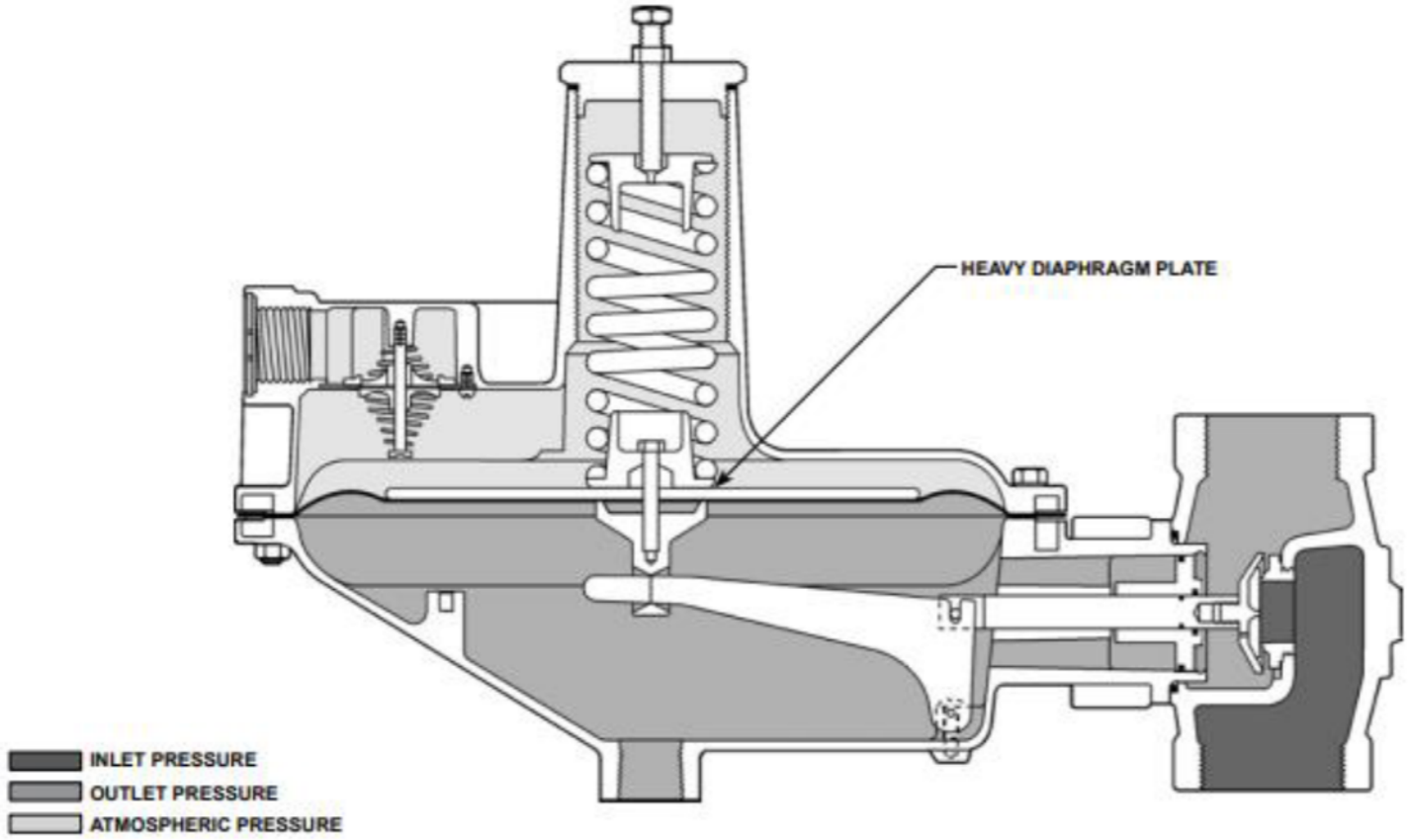
- Lower pressure drop equals higher volume

Pipe Capacity for Natural Gas

Nominal Iron Pipe Size (Inches)	Internal Diameter (Inches)	Equivalent Pipe Length		Maximum Capacity in Cubic Feet of Natural Gas Per Hour Pressure Drop of 0.5" W.C. Equivalent Length of Pipe (in feet)						
		90° Ell (Feet)	Tee (Feet)	20	40	60	80	100	150	200
2	2.067	5.17	10.3	2750	-	-	-	-	-	-
2- 1/2	2.469	6.16	12.3	4350	3000	2400	2050	1850	1500	-
3	3.068	7.67	15.3	7700	5300	4300	3700	3250	2650	2280
4	4.026	10.1	20.2	15800	10900	8800	7500	6700	5500	4600

Gas Regulator Vent Line

- Vent line is to allow regulator diaphragm to move



Gas Regulator Vent Line

- Rule of Thumb only, no available engineering document/calculator, and the ROT varies by regulator manufacturer
- Many regulator manufacturers do not mention the need to upsize the vent pipe due to vent stack resistance
- Examples:
  - For every fifteen feet of straight pipe, run beyond the first ten feet from the regulator increase vent line size 10 nominal pipe size back to the regulator vent connection. 1 pipe elbow = 5 feet of straight pipe run
  - Keep vents open. Do not use small diameter, long vent lines. Use rule of thumb of the next nominal pipe size every 10ft (6.1m) of vent line and 3ft (0.91m) of vent line for every elbow in the line.

Gas Regulator Vent Line

- Vent line is to allow regulator diaphragm to move and to allow gas to vent through the pipe should the diaphragm rupture
- Increase 1 pipe diameter for every 10’ of vent line, add 3’ to the overall equivalent length of the line for every elbow or change of direction.
- Every 10’ of run requires the vent line to increase one pipe diameter
  - Do not have the pipe increase on pipe diameter every 10 feet, the vent line needs to be sized for the LARGEST pipe size all the way from termination back to the regulator
  - Example:
    40’ of straight vent run equivalent on a 3/4” regulator vent port means that all 40 feet need to be 1 1/2” pipe, of any type acceptable, from the regulator to the termination point

    (40 – 10)/10 = 3X the vent size, ¾” to 1” is 1X, 1” to 1 ¼” is 2X, 1 ¼” to 1 ½” is 3X

Gas line “Rules of Thumb”

Regulator outlet to boiler input distance of at least 10 feet

- Best practice - appropriately sized line with as few fittings as possible, fittings add equivalent length

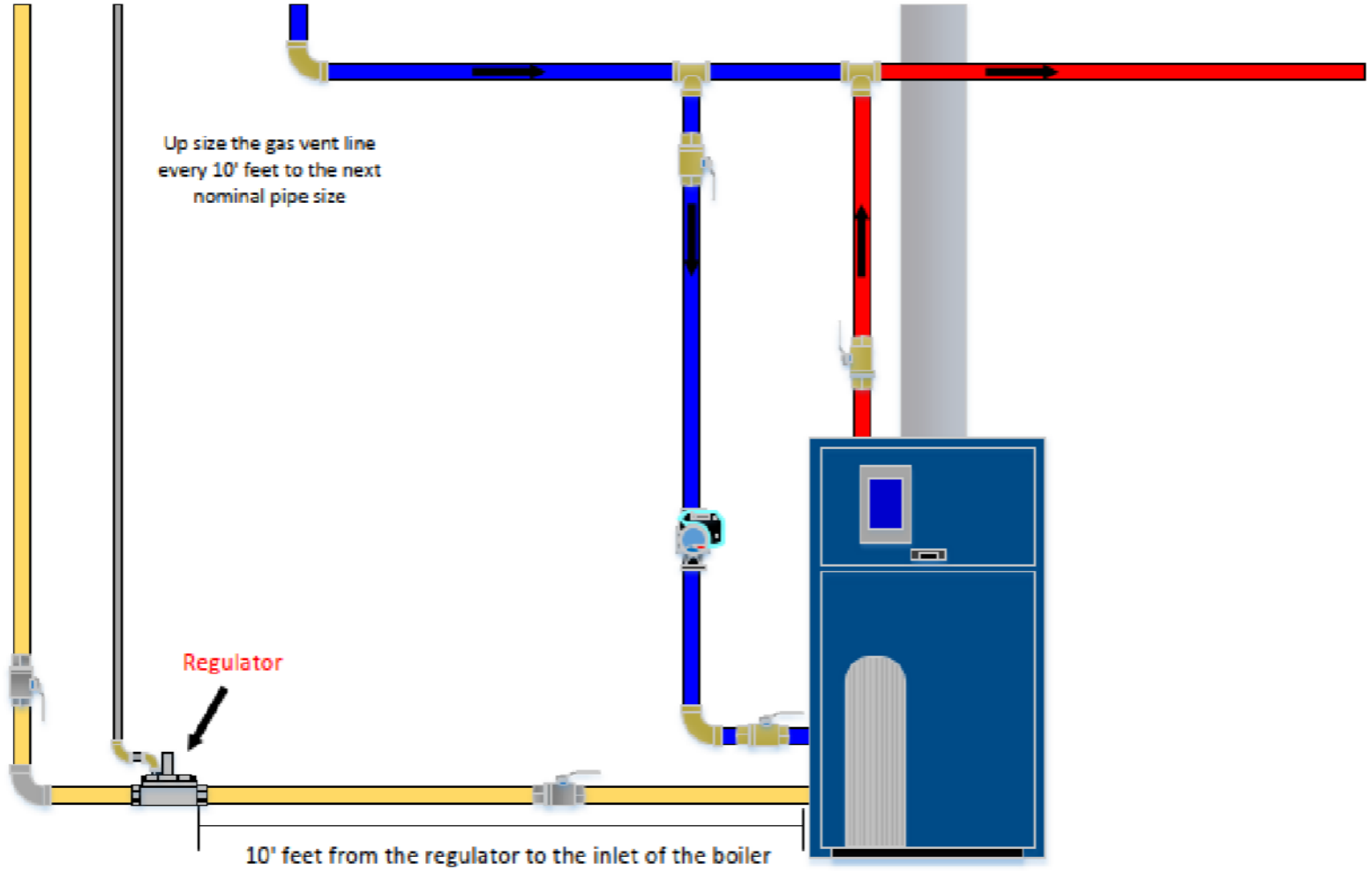
Regulator on each boiler

- Best practice - you can use multiple small regulators that are sized for the application as opposed to one large regulator that will respond slowly

Increase gas inlet piping size

- Boiler gas inlet size is piping size (common, but wrong)
- Larger pipe creates more reservoir volume

Gas line “Rules of Thumb” (Cont.)




HOT WATER SUPPLY
HOT WATER RETURN
NATURAL GAS
NATURAL GAS

Venting

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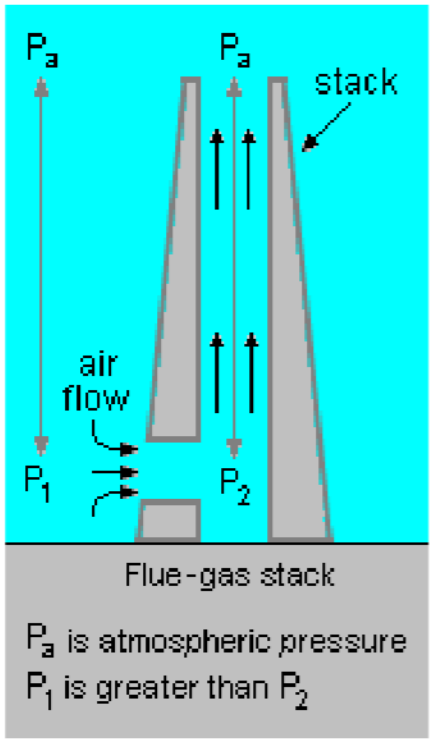
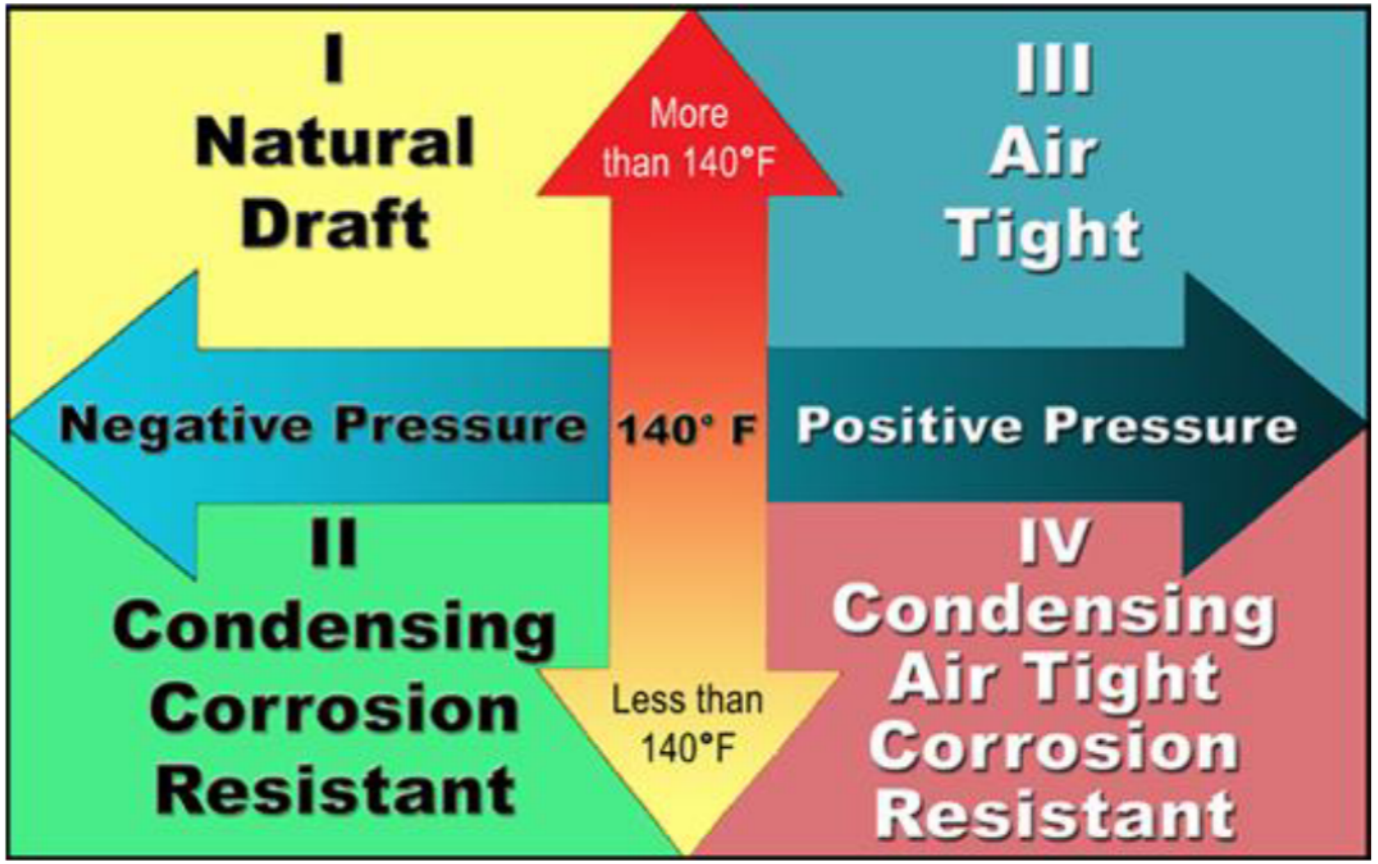
Venting

- Important to understand venting category
  - Not all are interchangeable





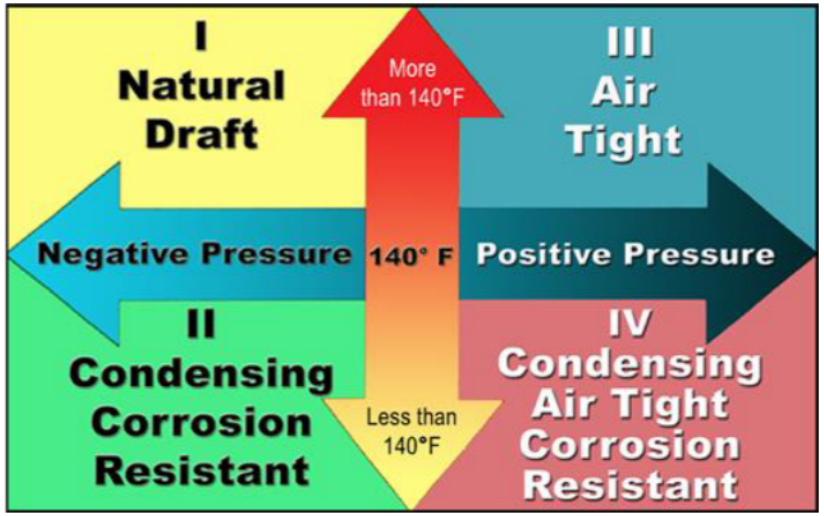
Gas Regulator Vent Line

Category I. **An appliance that operates with a non-positive vent static pressure and with a vent gas temperature that avoids excessive condensate production in the vent.**

Category II. **An appliance that operates with a non-positive vent static pressure and with a vent gas temperature that is capable of causing excessive condensate production in the vent.**

Category III. An appliance that operates with a positive vent static pressure and with a vent gas temperature that avoids excessive condensate production in the vent

Category IV **An appliance that operates with a positive vent static pressure and with a vent gas temperature that is capable of causing excessive condensate production in the vent.**



Pressure zone issues

- Important to have intake and exhaust on sealed combustion system in same pressure zone
- If in different zones it can create erratic pressures which can extinguish a flame or pull it off the burner

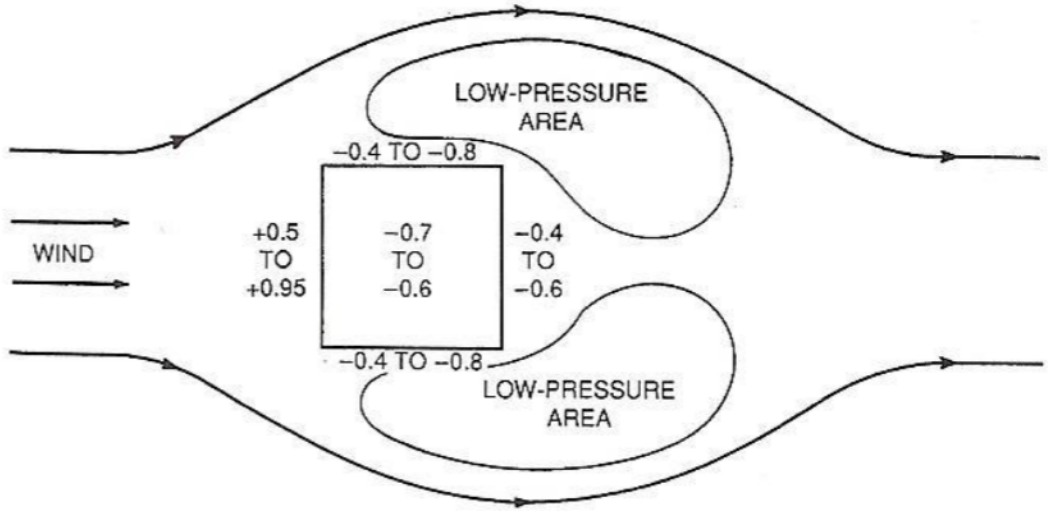
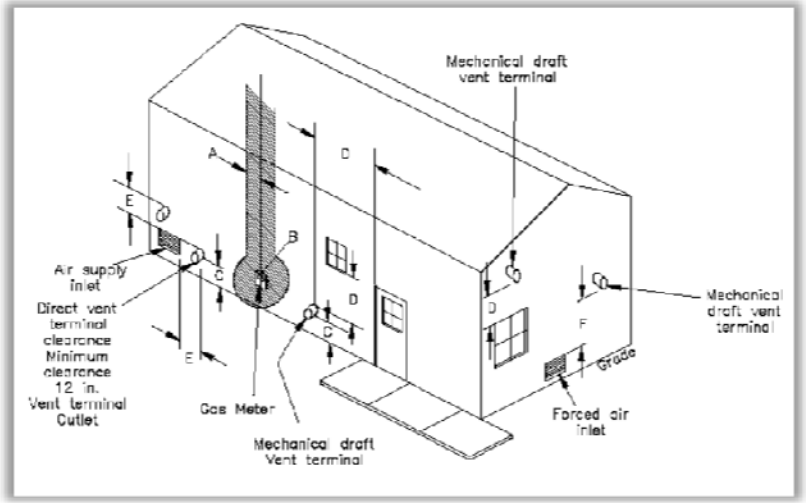
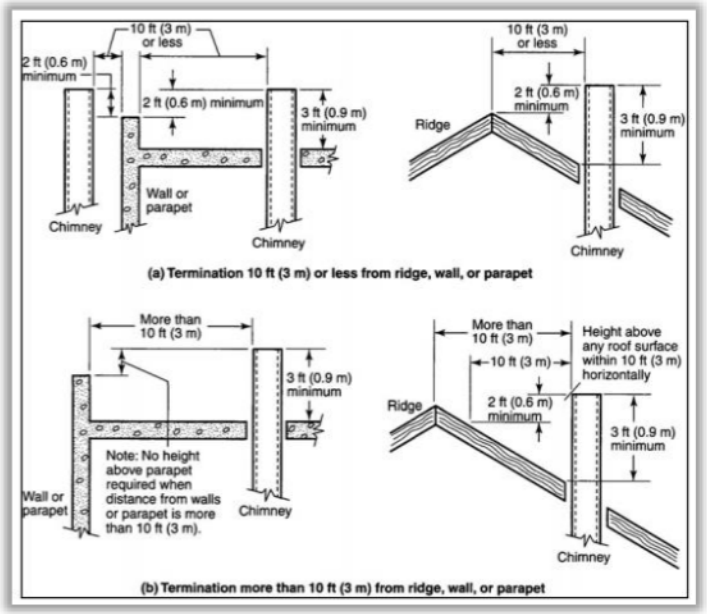


FIGURE 4.4.43 Pressure ratios compared to mean upstream wind velocities.

Venting and Condensing Boilers

- Condensing boilers have VERY specific draft ranges
  - *Typical values -0.05” WC to +0.30” WC*
  - *But it varies by model and manufacturer*
- Vent Stacks MUST be ENGINEERED for the application as all vent types and manufacturers products are different
- Equivalent Lengths is only a starting point and mean very little. The vent must still be designed to meet the applicable draft range





EXISTING CONDITIONS & CODES

Maintenance

- Perform annual equipment maintenance for peak performance following the manufacturer's recommendations
- Routinely check and adjust water quality as needed
- Check, blowdown, and clean boiler supply and system strainers as part of annual maintenance at a minimum
- Flush fire side of heat exchanger to remove any acidic condensate residue
- Test and adjust draft and combustion values to meet the boiler manufacturer's requirements
- If boiler performance relies on stack or other sensors, calibrate or replace the sensors annually or as required.
- Always default to the manufacturer's IOM

Hydronic Systems

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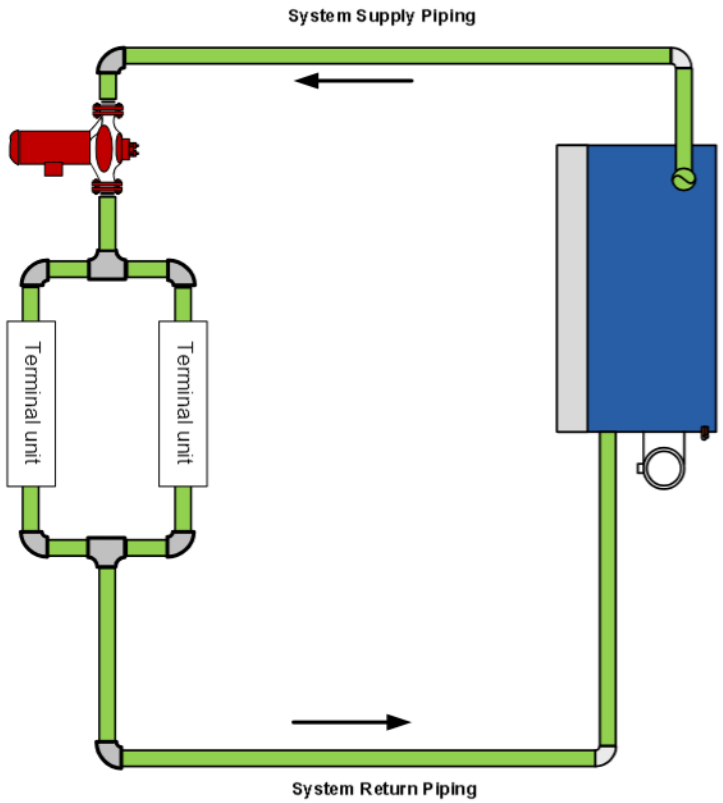
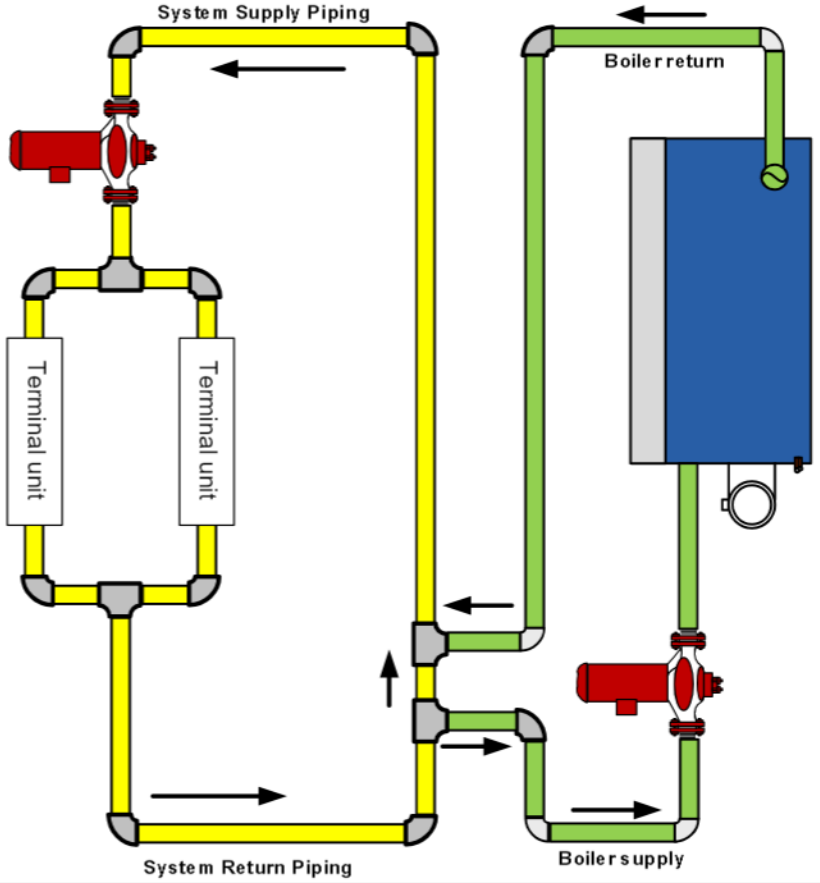
Piping Systems

PRIMARY-ONLY



PRIMARY-SECONDARY



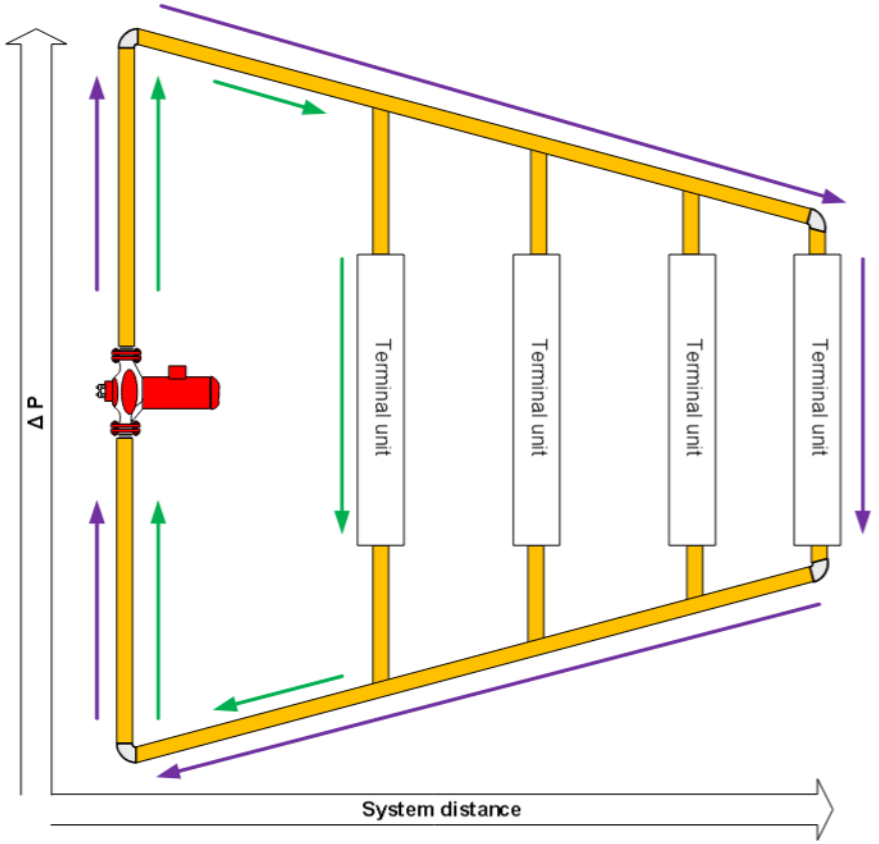
Legend

Primary loop

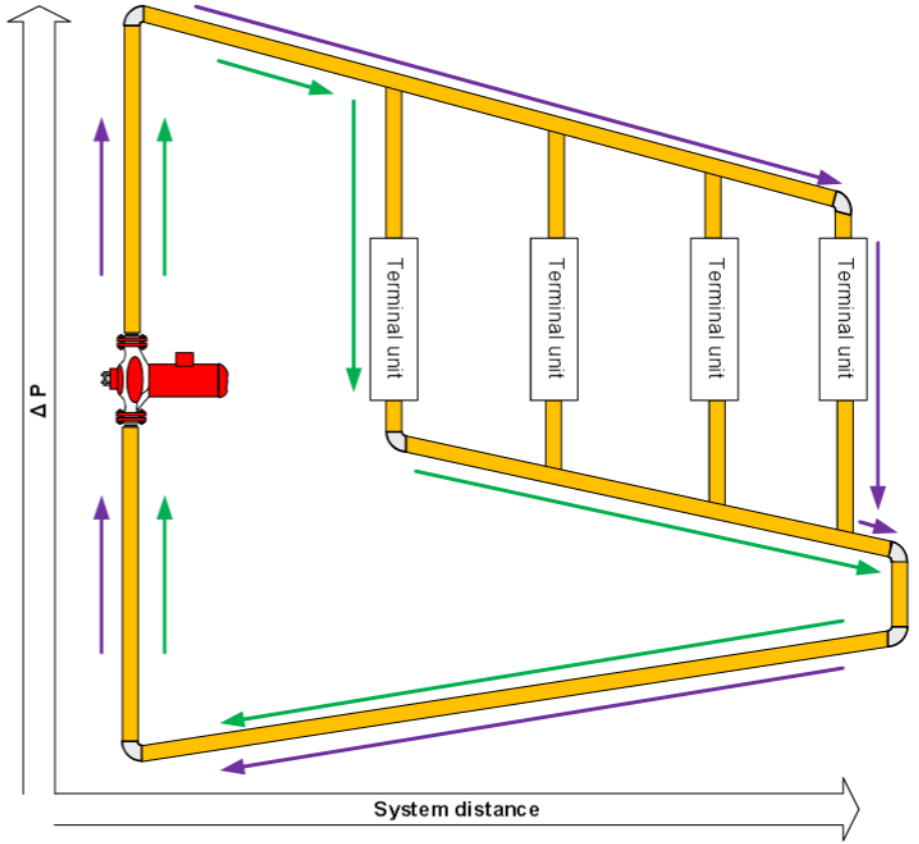
Secondary loop

Defining Piping Techniques: Piping Returns

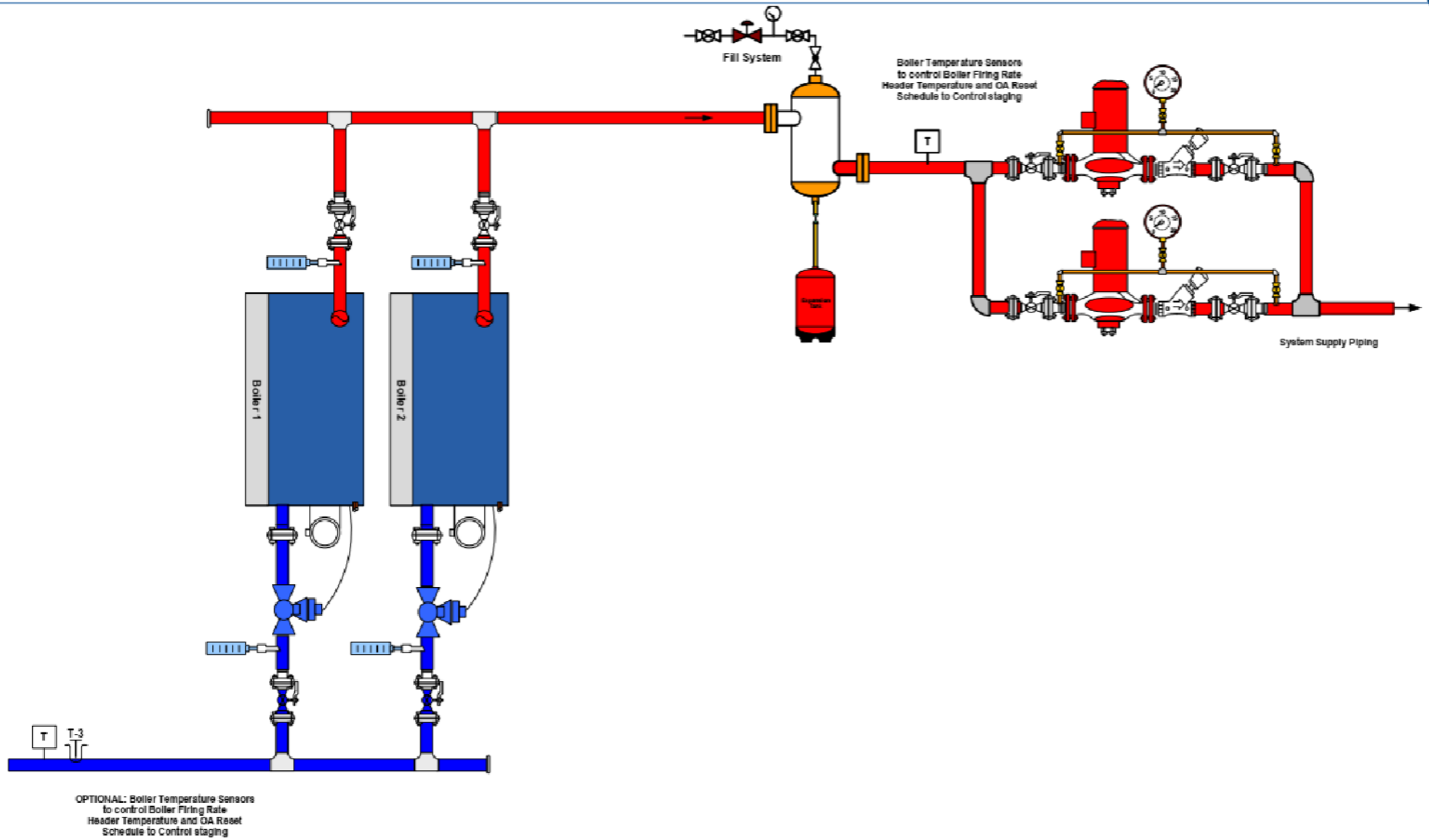
DIRECT RETURN (NOT RECOMMENDED)



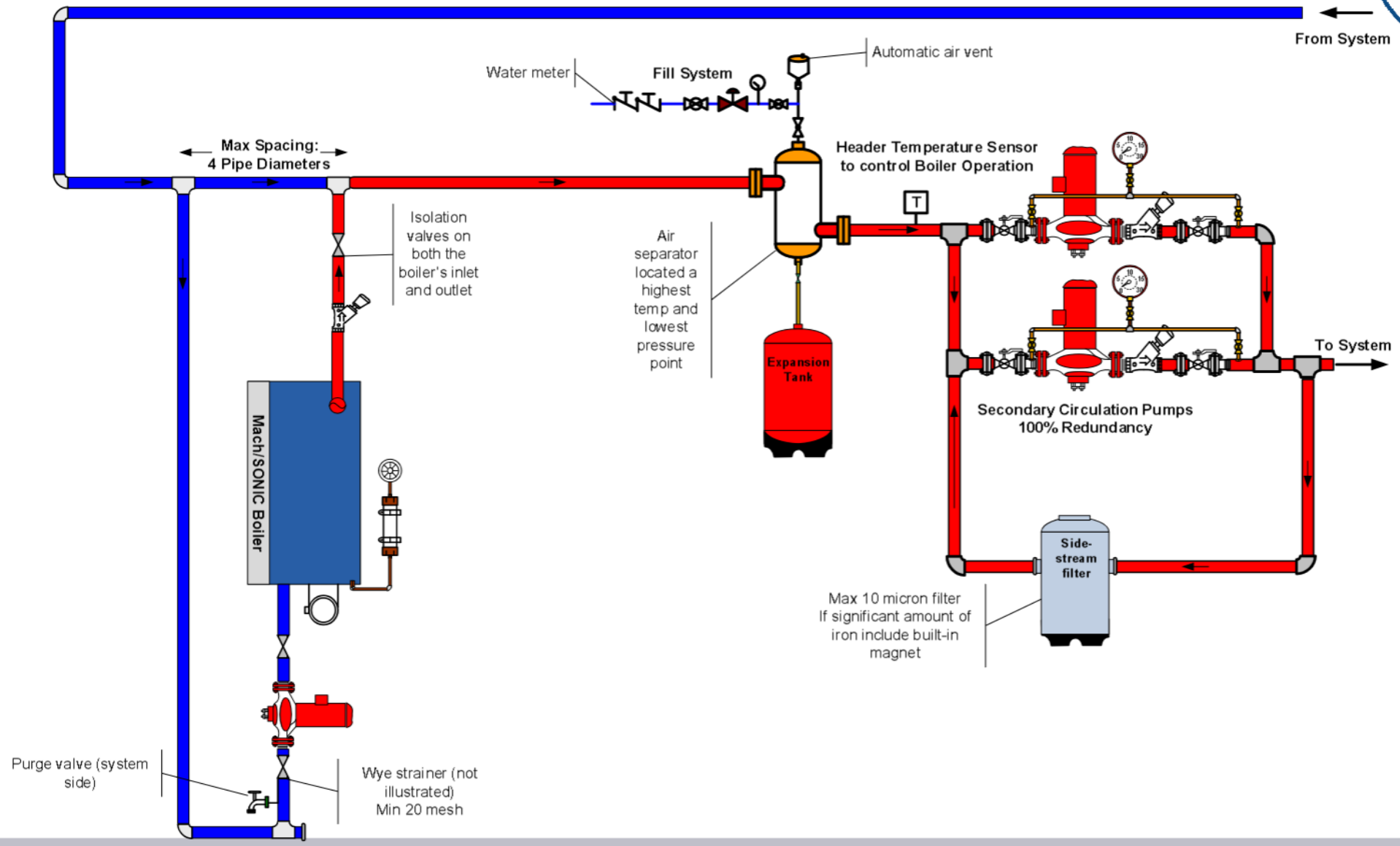
REVERSE RETURN (RECOMMENDED)



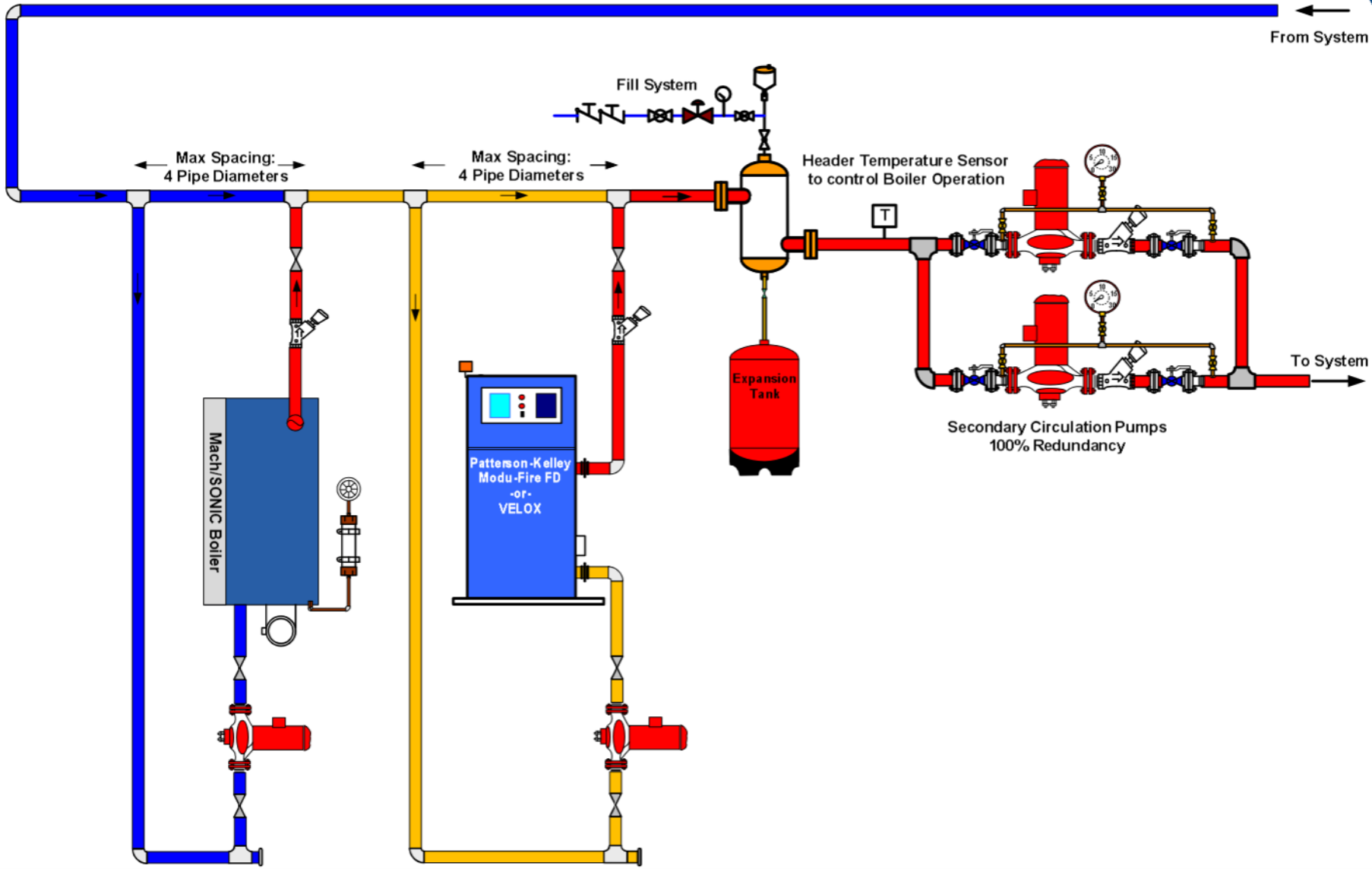
Primary-Only Systems



Primary-Secondary Systems



Primary-Secondary Hybrid Systems:



Air Separator Types

Inline

Good For Small Systems; Less Than Ideal For Most Applications

Tangential

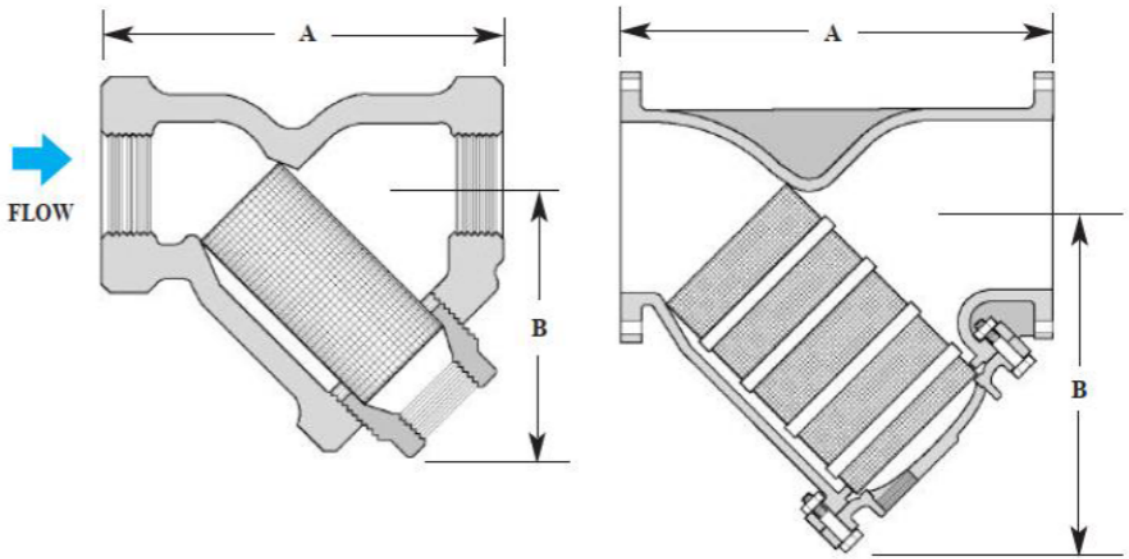
Good Option If System Maintains Designed Flow Rates; Operation Suffers As Flow Rates Drop

Micro-Bubbler

Preferred: Excellent Performance Regardless of Flow Rate

Boiler Filtration

- 3/64” screen opening recommended, max size 20 mesh
- Install prior to boiler return
- Prevents large particles, foreign debris, etc. from entering and obstructing flow or heat transfer through the boiler’s heat exchanger



Let's Talk Boilers For A Minute

- The bottom line is, they heat water provided all the ancillary systems are designed, installed, and maintained properly

- Let's briefly discuss:
  - Redundancy options for design and installation
  - Hybrid applications for maximizing efficiency
  - Owner peace of mind

Redundancy discussion

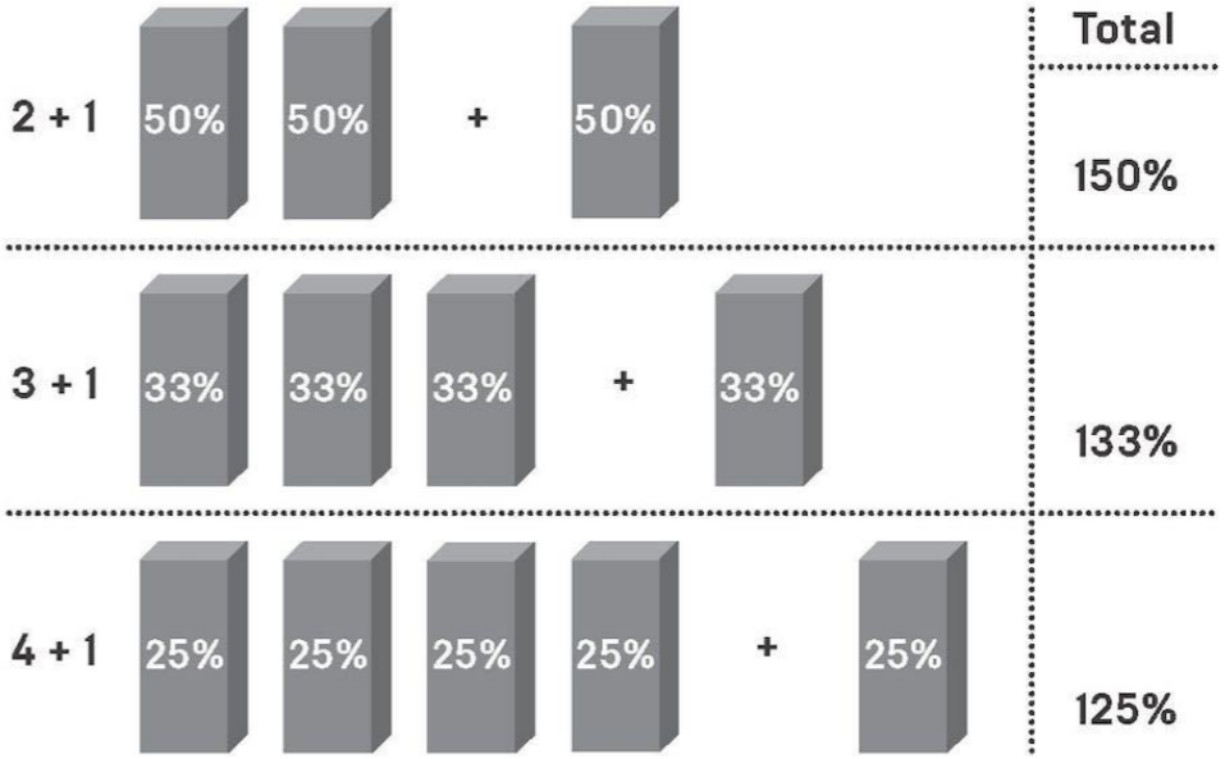
2,000 MBH peak load

2 + 1 = 3 @ 1,000 MBH

3 + 1 = 4 @ 650 MBH

4 + 1 = 5 @ 500 MBH

N + 1 is the lowest total installed cost of the above options, but is it necessary?



BIN DATA with Redundancy in mind

Avg T	BIN	to	Range	TOT	J	F	M	A	M	J	J	A	S	O	N	D	% TOT	% CUM	% LOAD
63	62		64	335				23	45	46	40	45	102	23	11		5.22	5.22	2.78
61	60		62	308				20	45	45	48	40	59	40	10	1	4.80	10.02	5.56
59	58		60	200				17	39	33	13	42	36	16	3	1	3.12	13.14	8.33
57	56		58	273	4		4	29	71	36	22	21	32	45	8	1	4.26	17.40	11.11
55	54		56	351	8	4	6	38	68	32	10	17	46	89	31	2	5.47	22.87	13.89
53	52		54	285	5	3	28	46	42	16	6	2	38	51	47	1	4.44	27.32	16.67
51	50		52	232	2	3	16	35	38	11	1		32	64	27	3	3.62	30.93	19.44
49	48		50	238	1	7	18	52	22	5			33	42	47	11	3.71	34.64	22.22
47	46		48	258		4	27	45	23	1			28	58	51	21	4.02	38.67	25.00
45	44		46	227	2	2	30	55	22				8	53	39	16	3.54	42.20	27.78
43	42		44	287	4	5	69	76	24				12	48	30	19	4.47	46.68	30.56
41	40		42	180	3	8	56	42	10				5	26	15	15	2.81	49.49	33.33
39	38		40	273	8	20	50	50	32				4	40	41	28	4.26	53.74	36.11
37	36		38	337	24	23	80	46	20				4	41	60	39	5.25	59.00	38.89
35	34		36	257	24	31	39	28	11					18	59	47	4.01	63.00	41.67
33	32		34	313	46	50	53	8	4					10	69	73	4.88	67.88	44.44
31	30		32	360	50	62	71	9						9	68	91	5.61	73.50	47.22
29	28		30	298	44	79	45	12						4	49	65	4.65	78.14	50.00
27	26		28	187	45	32	34	6							22	48	2.92	81.06	52.78
25	24		26	207	85	28	28								13	53	3.23	84.28	55.56
23	22		24	142	62	24	32								1	23	2.21	86.50	58.33
21	20		22	180	45	45	30								7	53	2.81	89.30	61.11
19	18		20	155	37	47	17								1	53	2.42	91.72	63.89
17	16		18	105	38	33	7									27	1.64	93.36	66.67
15	14		16	113	38	47	3									25	1.76	95.12	69.44
13	12		14	85	46	22	1									16	1.33	96.45	72.22
11	10		12	54	18	31										5	0.84	97.29	75.00
9	8		10	52	21	26										5	0.81	98.10	77.78
7	6		8	38	22	14										2	0.59	98.69	80.56
5	4		6	21	17	4											0.33	99.02	83.33
3	2		4	16	12	4											0.25	99.27	86.11
1	0		2	17	14	3											0.27	99.53	88.89
-1	-2		0	13	9	4											0.20	99.73	91.67
-3	-4		-2	13	6	7											0.20	99.94	94.44
-5	-6		-4	4	4												0.06	100.00	97.22
-7	-8		-6														0.00	100.00	100.00

~80% of Heating Season 50% of the heating degree hours are at warmer temps

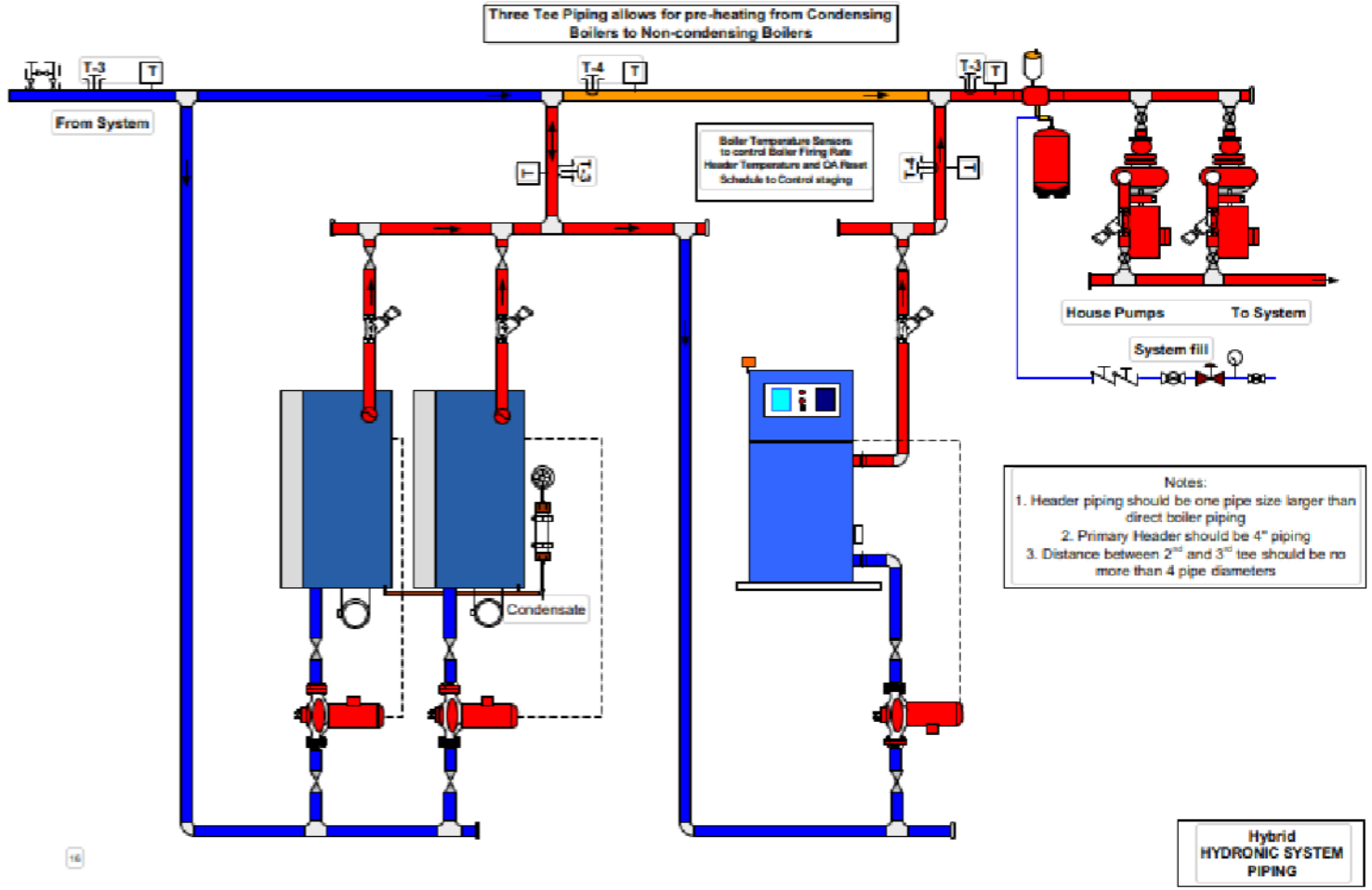
Wilkes-Barre, PA

Redundancy Options

- For Hospitals and Healthcare – N + 1, or greater
- For Industry – N +1, or greater, likely greater if downtime causes disruptions
- For Schools and Commercial – perhaps different approaches to consider
- 2,000 MBH peak load – design for all three to cover the load. Three 750 MBH boilers, two operational at high fire, provides 1,500 MBH input if one boiler is out of service
- Downside is 20% of the heating season, during the coldest peak periods, two boilers would not serve the load per our data. (Review BIN Data for the actual site)
- Upside is lower initial costs for equipment and installation due to smaller boiler sizes
- Two boilers at 1,000 MBH, one at a lower MBH
- Downside is parts and piping are not interchangeable between all boilers and if a larger boiler is down the load is not satisfied during peak periods.
- Most owners do not like this approach unless a very low flow is needed for reheat

Condensing & Non-Condensing Solution

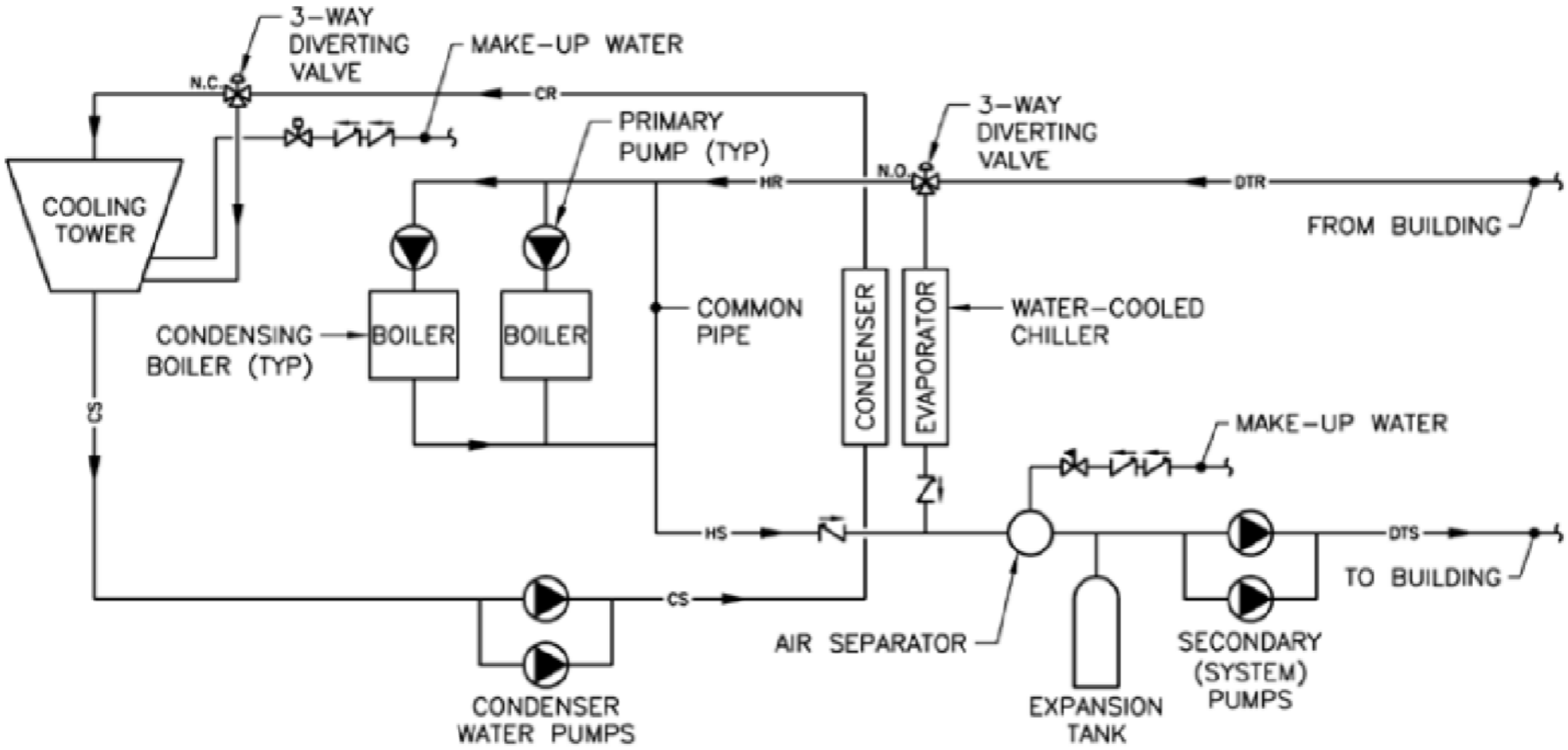
- Another option may be to design the load to use non-condensing and condensing boilers in tandem to maximize the efficiency during the shoulder season.
- The condensing boilers can supply the non-condensing boilers and the controls operate to maximize efficiency.
- Designs are site specific, just like every other hydronic system



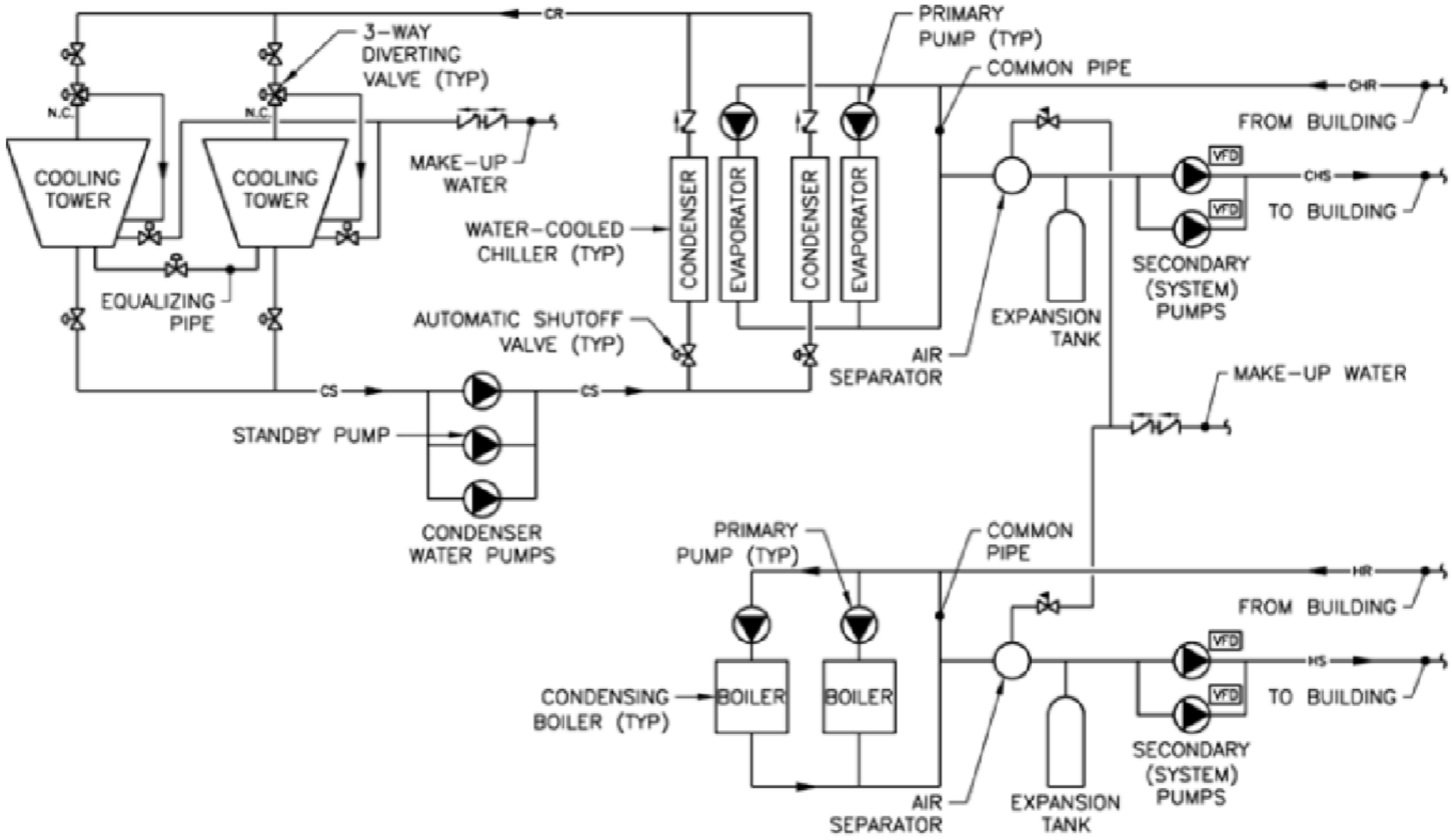
Additional Options for Owner Peace of Mind

- Stock Parts - The best solution for most Owners
- Suggestion for critical sites would be a spare blower and ample supply of annual maintenance kits
- There is no planned obsolescence by most boiler manufacturers

Application Cooling and Heating (2-Pipe)



Application Cooling and Heating (4-Pipe)



Electric Hybrid Boiler Systems

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ELECTRIC HYBRID/DUAL FUEL BOILER SYSTEMS

- **Commercial boiler installations featuring both high efficiency condensing boilers and/or standard efficiency non-condensing boilers with an electrified appliance counterpart.**

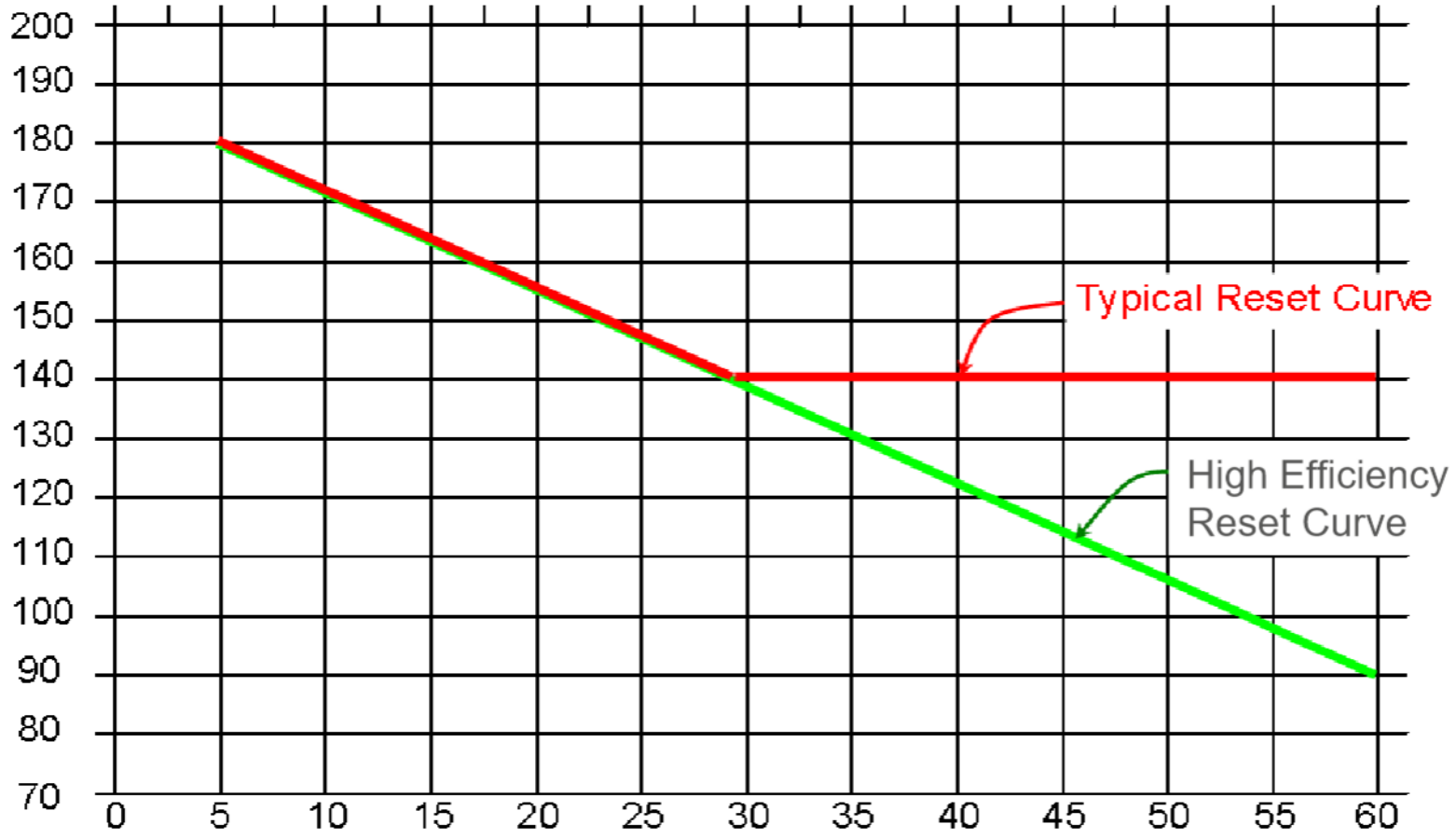
- **The electric heat pump(s) take the lead position and are given priority operation throughout the majority of the heating season.**
  - ✓ *The electric heat pumps are fully utilized when the system supply temperature is below 130°F.*

- **The boiler(s) take the lag position and are primarily reserved for the coldest days of the heating season.**
  - ✓ *The non-condensing boiler(s) are fully utilized when the system supply temperature is above 130°F.*

HYBRID BOILER SYSTEM OBJECTIVES

- **Reduce the equipment cost by balancing the load between heat pump technology and boilers.**
- **Normalize the equipment costs – pay a slight premium for heat pump capabilities but avoid overpaying.**
  - ✓ *Heat Pumps: Approximately $60 - $100+ per MBTUH*
  - ✓ *Boilers: Approximately $13- $33 per MBTUH*
- **Leverage the overall system modulation/turndown to eliminate short-cycling of the boiler equipment.**
- **Establish an extended Outdoor Air Reset curve to promote the use of the high efficiency equipment.**
- **Provide suitable equipment redundancy.**

HYBRID BOILER SYSTEM STRATEGY



HYBRID BOILER SYSTEM STRATEGY

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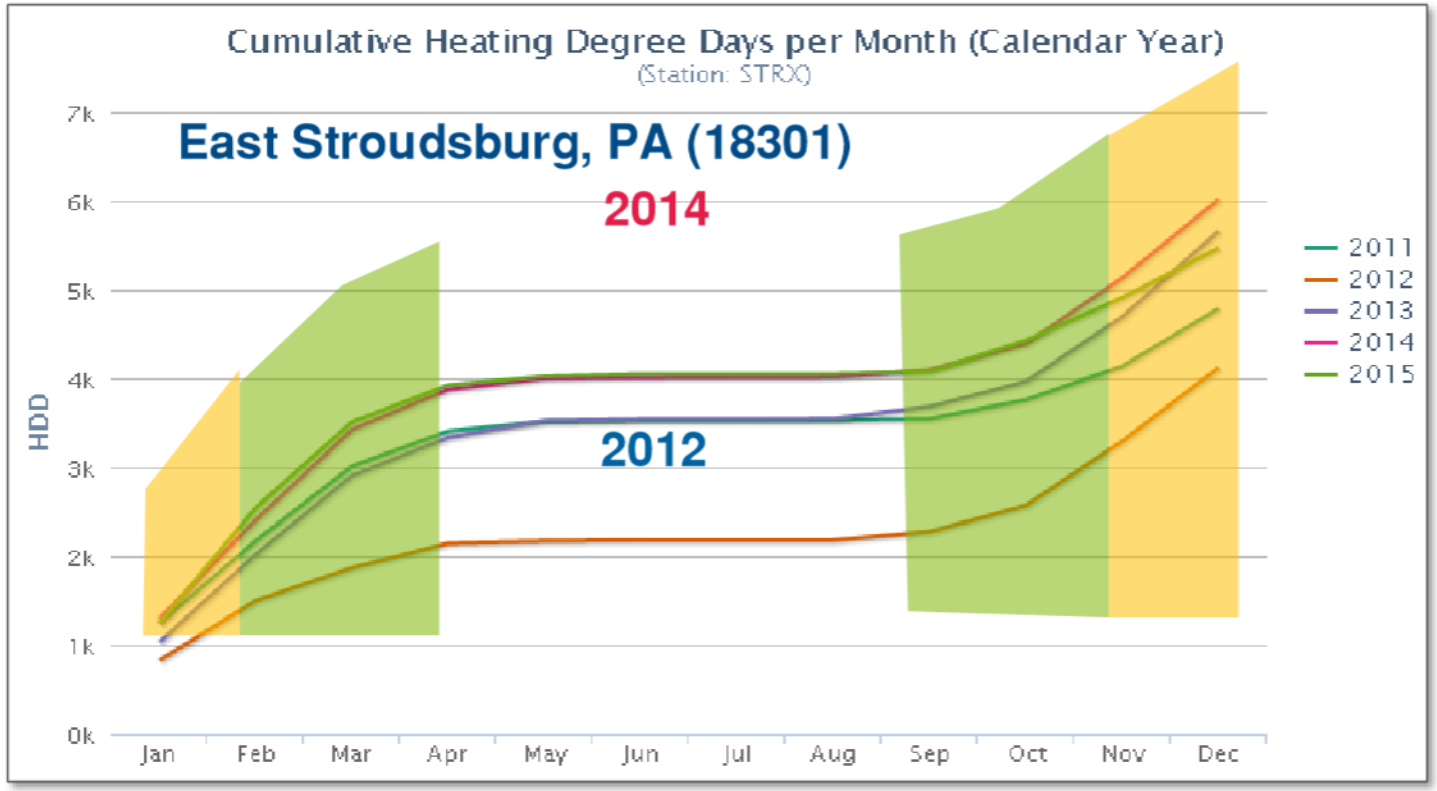
63	62		64	335				23	45	46	40	45	102	23	11		5.22	5.22	2.78
61	60		62	308				20	45	45	48	40	59	40	10	1	4.80	10.02	5.56
59	58		60	200				17	39	33	13	42	36	16	3	1	3.12	13.14	8.33
57	56		58	273	4		4	29	71	36	22	21	32	45	8	1	4.26	17.40	11.11
55	54		56	351	8	4	6	38	68	32	10	17	46	89	31	2	5.47	22.87	13.89
53	52		54	285	5	3	28	46	42	16	6	2	38	51	47	1	4.44	27.32	16.67
51	50		52	232	2	3	16	35	38	11	1		32	64	27	3	3.62	30.93	19.44
49	48		50	238	1	7	18	52	22	5			33	42	47	11	3.71	34.64	22.22
47	46		48	258		4	27	45	23	1			28	58	51	21	4.02	38.67	25.00
45	44		46	227	2	2	30	55	22				8	53	39	16	3.54	42.20	27.78
43	42		44	287	4	5	69	76	24				12	48	30	19	4.47	46.68	30.56
41	40		42	180	3	8	56	42	10				5	26	15	15	2.81	49.49	33.33
39	38		40	273	8	20	50	50	32				4	40	41	28	4.26	53.74	36.11
37	36		38	337	24	23	80	46	20				4	41	60	39	5.25	59.00	38.89
35	34		36	257	24	31	39	28	11					18	59	47	4.01	63.00	41.67
33	32		34	313	46	50	53	8	4					10	69	73	4.88	67.88	44.44
31	30		32	360	50	62	71	9						9	68	91	5.61	73.50	47.22
29	28		30	298	44	79	45	12						4	49	65	4.65	78.14	50.00
27	26		28	187	45	32	34	6							22	48	2.92	81.06	52.78
25	24		26	207	65	28	28								13	53	3.23	84.28	55.56
23	22		24	142	62	24	32								1	23	2.21	86.50	58.33
21	20		22	160	45	45	30								7	53	2.81	89.30	61.11
19	18		20	155	37	47	17								1	53	2.42	91.72	63.89
17	16		18	105	38	33	7									27	1.64	93.36	66.67
15	14		16	113	38	47	3									25	1.76	95.12	69.44
13	12		14	85	46	22	1									16	1.33	96.45	72.22
11	10		12	54	18	31										5	0.84	97.29	75.00
9	8		10	52	21	26										5	0.81	98.10	77.78
7	6		8	38	22	14										2	0.59	98.69	80.56
5	4		6	21	17	4											0.33	99.02	83.33
3	2		4	16	12	4											0.25	99.27	86.11
1	0		2	17	14	3											0.27	99.53	88.89
-1	-2		0	13	9	4											0.20	99.73	91.67
-3	-4		-2	13	6	7											0.20	99.94	94.44
-5	-6		-4	4	4												0.06	100.00	97.22
-7	-8		-6														0.00	100.00	100.00

Wilkes-Barre, PA

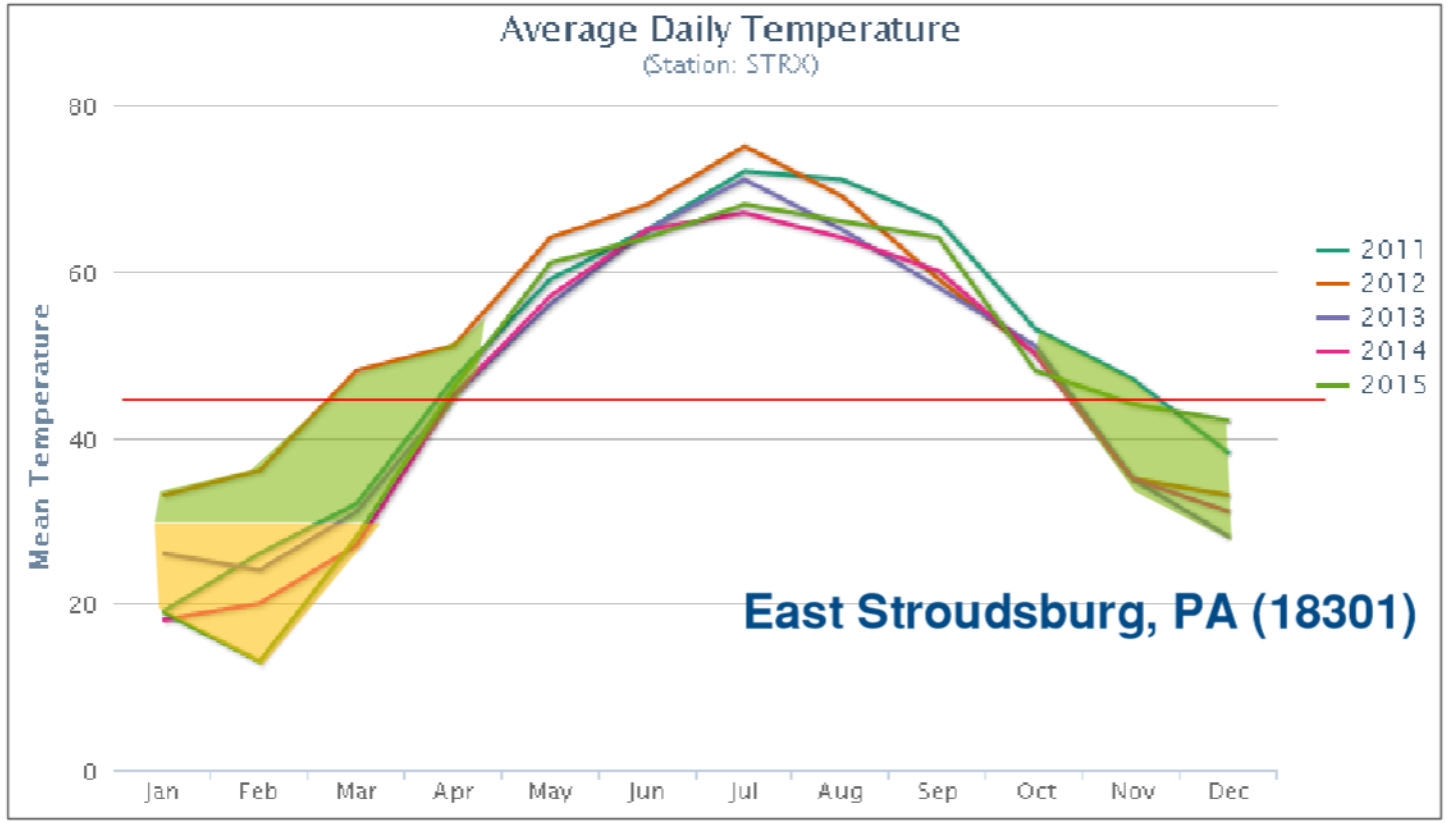
78.14% of Heating Season Can Use Condensing Temperatures in Wilkes-Barre

HYBRID BOILER SYSTEM STRATEGY



Source:
http://www.weatherdatadepot.com/

HYBRID BOILER SYSTEM STRATEGY



Source: http://www.weatherdatadepot.com/

TERMINAL UNITS: BASEBOARD

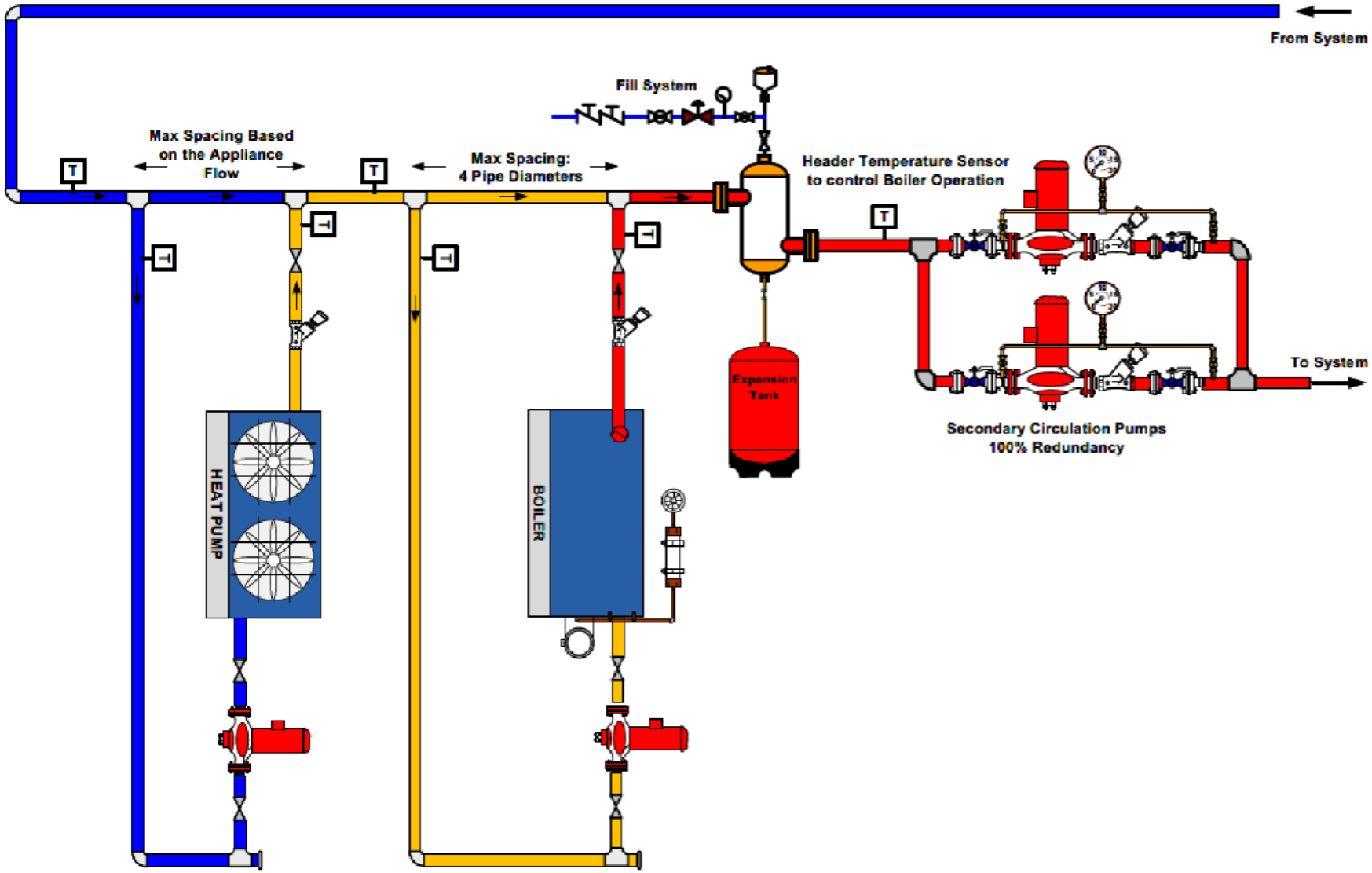
Tube Size & Material	Fin Size & Material	Fins Per Foot	Water Flow	Pressure Drop †	Steam 1 PSI* Btu/Hr. Per Foot	HOT WATER RATINGS* BTU/HR./FT.											
						110°F	120°F	130°F	140°F	150°F	160°F	170°F	180°F	190°F	200°F	210°F	220°F
3/4 copper	"3" x 3¼" x .024 aluminum	48	1 GPM	47	—	230	310	390	480	570	670	770	870	980	1080	1200	1320
			4 GPM	525		250	330	410	500	600	700	810	920	1040	1140	1260	1400
3/4" copper	2¾" x 2½" x .011" aluminum	55	1 GPM	47	—	210	290	360	440	520	610	710	800	900	1000	1100	1220
			4 GPM	525		230	300	380	460	550	650	750	850	960	1060	1170	1290
1" copper	3" x 2½" x .011" aluminum	48	1 GPM	13	—	210	290	360	440	520	610	710	800	900	1000	1100	1220
			4 GPM	145		230	300	380	460	550	650	750	850	960	1060	1170	1290
1-1/4" copper	3" x 3¼" x .020" aluminum	48	1 GPM	6	1160	220	300	370	450	540	640	730	830	940	1040	1140	1260
			4 GPM	63		230	310	390	480	570	670	780	880	990	1100	1210	1340
1-1/4" IPS steel	3" x 3¼" x .028 aluminized steel	48	1 GPM	3	980	190	250	320	390	460	550	630	710	810	890	980	1080
			4 GPM	41		200	270	340	410	490	580	670	750	850	940	1040	1150

NOTE: Approximately 50% Reduction in Heating Capacity from 140°F to 110°F

HYBRID BOILER SYSTEM ESSENTIALS

- **Heat Pump(s) MUST be upstream of boiler(s).**
  - ✓ *Prioritizes electrified equipment*
  - ✓ *Optimizes performance*
- **Control system's temperature sensor MUST be downstream of all appliances in order to measure their contribution to the heating system.**
- **Control system MUST prioritize the heat pump(s).**
- **Control system MUST protect the heat pumps from high incoming (return) water temperatures.**
- **Tune the ODA reset curve for the lowest possible operating temperatures throughout the year based on terminal unit capacities.**

SEQUENTIAL PRIMARY/SECONDARY



Heat Pump Upstream

Boiler Downstream

HYBRID BOILER SYSTEM PERKS

- **Minimize first cost & installation cost by reusing operable equipment:**
  - ✓ *Keep existing operable boilers for backup and redundancy*
  - ✓ *Install heat pumps for priority operation and carbon reduction goals*

- **Opportunities for dual fuel operation / interruptible service:**
  - ✓ *Heat Pumps: Electric*
  - ✓ *Boilers: Natural Gas, Propane Gas, Fuel Oil*

- **Achieve higher system ΔT → Lower return temperatures**
  - ✓ *More condensing opportunities throughout the heating season*

- **Requires relatively simple installation methods with significant fuel savings – excellent ROI potential!**

QUESTIONS?

CONTACT INFORMATION

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