Hydronics – Step By Step

[Image: Architectural plans with pencils and a calculator]
Heat Loss Example

- 10 x 15 room, 9’ ceilings
  - Indoor design temp: 70
  - Outdoor design temp: 0
  - 2 outside walls –
    Inf. Fac. = 0.018
  - No heat above or below
  - U-Value = 1 ÷ R-Value
  - Window R-Value: 2.77 –
    U-Value = 0.36
  - R-19 in walls – U-Value = 0.05
  - R-38 in ceiling – U-Value = 0.02
  - R-19 in floor – U-Value = 0.05
- Infiltration = 10 L x 15 W x 9 H x 70 DTD x 0.018 Inf. fac. = 1,701 BTUH
  - Windows = 60 x 70 DTD x 0.36 U = 1,512 BTUH
  - Walls = 165 Net Area x 70 DTD x 0.05 U = 578 BTUH
  - Ceiling = 10 L x 15 W x 70 DTD x 0.02 U = 210 BTUH
  - Floor = 10 L x 15 W x 70 DTD x 0.05 U = 525 BTUH
- Total Heat Load = 4,526 BTUH
Boiler Sizing Terms

• What’s the difference between DOE capacity and I-B-R Net Output? **DOE capacity** is a federal rating, and assumes the boiler is installed in a heated space and that all jacket and piping losses are usable and help offset the heating load. **NET IBR rating** assumes the boiler is installed in an unheated area, such as an unheated basement or garage, and that all jacket losses and piping losses are wasted. The **NET IBR rating** is an automatic 15% reduction of the DOE output.

• What is “pickup” allowance? **IBR** includes “pickup” in the 15% output reduction of the DOE output. Pickup allows for the heating up of cold cast-iron boiler sections and cold steel pipe. Both need to heat up before heat can be delivered to radiators. Newer mod-con boilers usually have only a DOE rating and have no pickup allowance since they are very low mass and heat up relatively quickly compared to a cast iron boiler.
Point Of No Pressure Change

• Where is the “point of no pressure change? It’s the point in the system where the expansion tank connects to the piping. It’s the one point in the system where the circulator can’t change the system pressure.

• What 3 things can change the system pressure at this point?
  1. Add or remove water from the system
  2. Add or remove air from the tank
  3. Heat the water so it expands

• What happens if the circulator is placed BEFORE the expansion tank? The circulator’s pressure differential will show itself as a negative as opposed to a positive, lowering the overall system pressure and creating noise and air control problems.

• After the expansion tank? The circulator will show its pressure differential as a positive, adding to the overall system pressure and keeping air under control and keeping the system quiet.
Centrifugal Pump

- Create a Pressure differential
- High pressure goes to Low pressure

- Why is it a circulator and not a pump? It uses its pressure differential to create flow in a closed loop system. It doesn’t lift, as a well pump does.
How The Water Moves

- Water enters through the *Eye of the impeller*.
- How is velocity added? *Vanes slap water from eye outward into the volute.*
- How does impeller thickness impact performance? *The thicker the impeller, the more flow a circulator can create.*
- How does impeller diameter impact performance? *The wider the impeller, the more pressure the circulator can create.*
- How does speed impact performance? *The faster the impeller, the more flow and head a circulator can create.*
- What’s the difference between open and closed vane impellers? *Open vane impellers are used in high flow, low head circulators; closed vane impellers are used in low flow, higher head circulators.*
What is “head loss?”
A term to express pressure drop in a closed loop system.

What produces head loss? Friction of the water rubbing against the pipe as it flows through the system.

1 PSI of pressure drop = 2.31 feet of head.

Does height of the building influence head loss? No.

Why? It’s a circulator, not a pump. It’s a closed loop system and the weight of the water coming back down the return side acts as a counterbalance. The circulator acts more like the motor on a Ferris wheel.
Sizing A Circulator

• Gotta do the **math**!
• Must do a **room** by **room heat loss**
• Universal hydronics formula
  – \( GPM = \frac{\text{BTUH}}{\Delta T} \times 500 \)

• Headloss
  – Zone length \( \times 1.5 \) = total **developed** length
  – Multiplier accounts for **valves** and **fittings**
  – Developed length \( \times 0.04 \) = head loss
  – 4 feet of head for every 100 feet of pipe
Let’s Do One...

- **Pipe sizing:**
  - 2-4 GPM = \( \frac{3}{4} \)” M, 4-9 GPM = 1’ M
  - 8-14 GPM = 1¼” M, 14-22 GPM = 1½” M

- **Size the zone piping:**
  - 27,000 BTUH load, 20\(^0\) \( \Delta T \), 100% water

- **GPM** = \(\frac{27,000}{\Delta T \times 500}\) GPM = 2.7

- **What size pipe?** 1”

- **Total run length:** 80 feet
  - 80 x 1.5 = 120’ total developed length
  - 120’ x .04 = 4.8 feet of head
Pick A “00”

Which one Taco 007
Multi-Temp, Multi-Load Systems
Planning, piping and controlling

Taco®
What Are You Looking For?

• Boiler piping should be….
  1. understandable
  2. Repeatable
  3. Simple

• What piping arrangement best fits these requirements? Primary-secondary

• Why? Perfect for multi-temp, multi-load jobs, keeps secondary outlets hydraulically isolated
Some Anatomy

Primary Loop

Primary circulator

Secondary circulator

Closely spaced tees

Secondary Loop
Closely Spaced Tees

• Why is Tee spacing important? *Keeps pressure drop between tees to a minimum – prevents accidental flow through secondary*

• What if the Tee’s are too far apart? *More likely to get accidental flow through the secondary*

• What goes into a tee, must come out of a tee…
Sizing The Primary

• GPM = BTUH ÷ ΔT x 500
• Pipe sizing guidelines:
  – 2-4 GPM = ¾”, 4-9 GPM = 1”
  – 8-14 GPM = 1¼”, 14-22 GPM = 1½”
• Head loss calculation:
  – Measure length in feet
  – Multiply by 1.5
  – Multiply by .04
• Exercise:
  – 75,000 BTUH load
  – 20° ΔT
  – 30’ long primary
• Primary flow rate 7.5 gpm
• Primary pipe size 1”
• Primary head loss 1.8’
• Primary circulator *Taco 007*
Size The Secondary

- 35,000 BTUH baseboard
- GPM = 3.5
- Secondary pipe size = \( \frac{3}{4} \)"
- Head loss
  - Secondary run 120’
  - \( 120 \times 1.5 = 180 \)
  - \( 180 \times 0.04 = 7.2’ \)
  - Secondary head loss = 7.2

- Secondary circulator
  - 3.5 GPM @ 7.2’
  - Taco 007
What Goes Into A Tee…

\[ A + B = C \]

\[ (F_A \times T_A) + (F_B \times T_B) = (F_C \times T_C) \]

\[ (4 \times 180) + (3.5 \times 160) = 7.5x \]

\[ 720 + 560 = 7.5x \]

\[ 1280 = 7.5x \]

\[ 171 = x \]
How ‘Bout Some Radiant?

- **30,000 BTUH**
  - 141° SW<sub>T</sub>, 10° ΔT
  - RFH RW<sub>T</sub> 131 degrees
  - RFH flow rate 6 GPM
  - RFH supply pipe 1”
  - Primary Temp (from previous) 171 degrees

- **Injection Flow Rate**
  - GPM = \( \frac{30,000}{40 \times 500} \)
  - GPM = 1.5
  - Injection pipe size = ½”
Keys to Injection Mixing

- **Tee spacing:** 6” or 4 pipe diameters
- **Why?** Hydraulically isolate secondary from primary to prevent accidental flow from one to the other
- **How many inches before and after tee set?** 6 inches
- **Why?** To prevent momentum flow from primary into secondary
- **How big should the thermal trap be?** 1 foot minimum
- **What kind of valve is used on the return injection leg?** Globe valve
What’s Left In The Primary?

\[ (F_A \times T_A) + (F_B \times T_B) = (F_C \times T_C) \]

\[ (6 \times 171) + (1.5 \times 131) = 7.5x \]

\[ 1026 + 197 = 7.5x \]

\[ 1223 = 7.5x \]

\[ 163 = x \]
Some More Radiant?

- 10,000 BTUH
  - $113^0$ SW$_T$, $10^0 \Delta T$
  - RFH RW$_T$ 103 degrees
  - RFH flow rate 2 GPM
  - RFH supply pipe $\frac{3}{4}''$
  - Primary Temp (from previous) 163 degrees

- Injection Flow Rate
  - $\text{GPM} = \frac{10,000}{60 \times 500}$
  - $\text{GPM} = 0.33$
  - Injection pipe size = $\frac{1}{2}''$
What’s Left In The Primary?

$7.5 \text{ GPM} @ 163^\circ$  $7.17 \text{ GPM} @ 164^\circ$  $7.5 \text{ GPM} @ 160^\circ$

$0.33 \text{ GPM} @ 163^\circ$  $0.33 \text{ GPM} @ 103^\circ$

$(F_A \times T_A) + (F_B \times T_B) = (F_C \times T_C)$

$(7.17 \times 164) + (0.33 \times 95) = 7.5x$

$1169 + 34 = 7.5x$

$1203 = 7.5x$

$160 = x$
The Reset Ratio

- Reset ratio = \[
\frac{\text{Mix Design Temp} - 72^0}{72^0 - \text{Design Outdoor Temp}}
\]

- Example:
  - Mix Des. Temp: 145
  - Out Des. Temp: -10
  - What is the reset ratio? 0.9

- What does the reset ratio mean? For every one degree drop in outdoor temperature, the system water temperature will increase 9/10ths of a degree.
Don’t Forget The Indirect!

- Why isn’t the indirect piped primary-secondary? *Easier DHW priority – kill primary circulator; don’t have to run primary circulator or primary loop in summer time.*

- What prevents backwards flow through primary when DHW calls? *IFC in the primary circulator – or else a flowcheck after primary circulator or before DHW return*
Expandable Relays

- In this application, where is Master/Slave switch set? **Master**
- Where is Mode switch set? **Reset**
- Why is primary circulator wired to ZR? **So it will fire when ANY zone calls – even zones on slave relays**
- Connect the boiler to the relay **XX End Switch terminals to TT on the boiler control**
- How do we get DHW priority? **Flip priority switch to on, use Zone 4 for DHW circulator**
- How do you connect master to slaves? **Daisy chain 1-2-3-4 terminals in upper right**
Plug In Power Port Cards

- Explain the uses:
  - Post Purge Card: Runs priority zone as dump zone – takes excess heat from boiler and dumps it into indirect. Lowers standby losses.

  Pump Exercise Card: Runs circulators at scheduled intervals during off-season to prevent possible seize up. Also reduces freeze up risk during heating season by running circulators periodically.

  Priority Protection Card: Provide time limit for DHW priority mode. Returns power to heating zones after one hour of priority operation. This prevents freeze ups in case of priority zone malfunction.
Radiant Mixing Block

• List three benefits of the Radiant Mixing Block: 
  *Piped/wired means faster installation; Piping easier – only 4 connections, fewer mistakes; Easier wiring – fewer mistakes – neater job.*

• What does it replace? 
  *Field piped injection mixing station, injection circulator, radiant system circulator, extra control and lots of labor.*

• How many zones can it handle? *As many as needed. Zoning is done independently – RMB can deliver a single water temperature.*

  In a primary-secondary piping arrangement, which water temperatures should be taken off the primary first? *Always take the highest water temp off the primary first. The primary temp will drop as more secondaries are taken off.*
2-Way Injection

- How does 2-way valve injection work? **2-way valve opens and closes to provide injection mixing/reset to radiant. Radiant circulator overcomes headloss through valve, injection piping. Globe valve needed on RFH bypass piping to provide pressure drop to encourage water to return to primary when RFH circulator is running.**

- Size the following:
  - 30,000 BTUH radiant, $10^0 \Delta T$
  - $180^0$ primary, $130^0$ radiant supply
  - Radiant GPM: **6 GPM**  Pipe A: **1”**
  - Injection GPM: **1.2 GPM**  Pipe B/Valve: **1/2”**

*Hint: GPM = BTUH/$\Delta T \times 500$*
“Moose-Antler” Piping

• When would you use “Moose-antler” piping?
  *When using a modulating-condensing boiler – this will ensure lowest possible return water temps.*

• How is this primary-secondary? *Closely spaced tees at boiler supply and return into primary.*

• Why is boiler pump sizing important? *Mod-cons have very high head loss heat exchangers – require high head circulators.*
The Evolution Of Radiant Mixing

Companion Workbook - Valves
Why Mix?

- CI boilers need to be protected from *low return water temperatures* to prevent *flue gas condensation*.
- Minimum return water temp for CI boiler *135 degrees*.
- Mod/Con boilers with *multi-temp, multi-load systems* may need further mixing.
3-Way Tempering Valve

- **Fixed** water temperature

- MUST ZONE radiant system properly/aggressively. Why? *To prevent rooms with different water temp requirements, floor coverings and heat loads from over or underheating*

- What is Cv? *A measure of pressure loss through a valve at a given flow rate*

- Why does it matter? **Critical element in circulator sizing**
A System Sizing Problem

30,000 BTUH
- Flow rate @ $10^0 \Delta T \ 6 \text{ GPM}$
- Pipe size 1’
- Radiant tube head loss – 5’
- Total pipe run – 60 feet
- Pipe head loss 3.6’
- 1” 3-way valve Cv – 3.8
- Valve head loss 5.8’
- Total head loss 14.4’
- Circulator 0014

Formulas:
- $GPM = \frac{BTUH}{(\Delta T \times 500)}$
- $\text{Pipe head loss} = \text{Total run} \times 1.5 \times .04$
- $\text{Valve head loss} = (\text{Flow} \div \text{Cv})^2 \times 2.31$

Pipe Sizing Guidelines
- 2-4 GPM = $\frac{3}{4}”$; 4-8/9 GPM = 1”
- 8-14 GPM = $1\frac{1}{4}”$; 14-22 GPM = $1\frac{1}{2}”$
A System Sizing Problem

Formulas:
\[ \text{GPM} = \frac{\text{BTUH}}{\Delta T \times 500} \]
Pipe head loss = Total run x 1.5 x .04
Valve head loss = \((\text{Flow} \div \text{Cv})^2 \times 2.31\)

Pipe Sizing Guidelines
- 2-4 GPM = \(\frac{3}{4}\)"
- 4-8/9 GPM = 1"
- 8-14 GPM = 1\(\frac{1}{4}\)"
- 14-22 GPM = 1\(\frac{1}{2}\)"

37,000 BTUH
- Flow rate @ 20° DT 3.7 GPM
- Pipe size \(\frac{3}{4}\)"
- Radiant tube head loss – 2.2’
- Total pipe run – 48 feet
- 1” iValve Cv – 3
- iValve head loss 3.3 feet
- Total head loss 9.1 feet
- Circulator Taco 007
A System Sizing Problem

Formulas:
- GPM = BTUH ÷ (ΔT x 500)
- Pipe head loss = Total run x 1.5 x 0.04
- Valve head loss = (Flow ÷ Cv)^2 x 2.31

Pipe Sizing Guidelines
- 2-4 GPM = 3/4"; 4-8/9 GPM = 1"
- 8-14 GPM = 1¼"; 14-22 GPM = 1½"

41,000 BTUH
- Pri. flow rate; 20^o ΔT **4.1 GPM**
- Sec. flow rate; 10^o ΔT **8.2 GPM**
- Pipe size **1″**
- Radiant tube head loss – 4.7'
- Total pipe run – 22 feet
- 4 way valve size **3/4″**
- Valve head loss **3.3 feet**
- Total head loss **9.3 feet**
- Circulator **Taco 008**
A System Sizing Problem

**Formulas:**
- \[ \text{GPM} = \frac{\text{BTUH}}{\Delta T \times 500} \]
- \[ \text{Pipe head loss} = \text{Total run} \times 1.5 \times 0.04 \]
- \[ \text{Valve head loss} = (\text{Flow} ÷ \text{Cv})^2 \times 2.31 \]

**2-Way iValve Cv:**
- \( \frac{1}{2} \)" = 4.9; \( \frac{3}{4} \)" = 10.3
- 1" = 8.9

**Pipe Sizing Guidelines**
- 2-4 GPM = \( \frac{3}{4} \)"; 4-8/9 GPM = 1"
- 8-14 GPM = \( \frac{1}{4} \)"; 14-22 GPM = \( \frac{1}{2} \)"

35,000 BTUH
- Flow rate; \( 10^0 \Delta T \) **7 GPM**
- Pipe size **1"**
- Radiant tube head loss – 3.8’
- Total pipe run – 31 feet
- Primary Temp – 180°
- Radiant Supply Temp -- 120°
- Injection Flow Rate **1 GPM**
- 2 way valve size **\( \frac{1}{2} \)"**
- Valve head loss **0.1 feet**
- Total head loss **5.8 feet**
- Circulator **Taco 007**
Circulator Selection For Radiant

The right circulator for the right job
Flow & Head Loss

- **High flow, low head loss** fits most **fin tube baseboard** applications.

- **Why?** **Baseboard zones are large with high BTU requirements, but piped with ¾” copper – relatively low head loss**

- **Flat** curve circulators work best with zone valves.

- **Why?** **Large changes in flow, as happens when zone valves close when zones are satisfied, create relatively small changes in head pressure**
Radiant’s A Little Different…

• Radiant is typically low to medium flow and high head.

• Why? Long runs of small diameter PEX tubing; smaller tubing between joists; long distribution runs to remote manifolds; glycol and mixing valves add pressure drop to systems.

• How do you calculate head loss for copper S&R piping? Measure length, multiply by 1.5 for total developed length, then multiply by .04.

• For PEX? Consult manufacturer’s pressure loss charts and guidelines.
Calculating S&R Head Loss - Copper

- **M1** – 4 GPM @ 7’ head; 65’ S&R piping
  - Pipe size ¾”
  - Additional head 4’
  - Totals 4 GPM @ 11’
  - Circulator 008

- **M2** - 6 GPM @ 12’ head; 38’ S&R piping
  - Pipe size 1”
  - Additional head 2.3’
  - Totals 6 GPM @ 14.3’
  - Circulator 0014

- **M3** – 3 GPM @ 9’ head’ 110’ S&R piping
  - Pipe size ¾”
  - Additional head 6.6’
  - Totals 3 GPM @ 15.6’
  - Circulator 0014

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**Head loss for copper**

- Total run x 1.5 = developed length
- Developed length x .04 = total head
What About A 3-Speed?

- M1 totals \(4 \text{ GPM @ 11'}\) Speed Medium
- M2 totals \(6 \text{ GPM @ 14.3'}\) Speed High
- M3 totals \(3 \text{ GPM @ 15.6'}\) Speed Medium
OOR 3-Speed – Tale Of The Tape

• Why is starting torque important? *Helps overcome service issues due to idle/off time resulting from dirt or iron oxide fouling/seizing up the cartridge*

• Why are 3 separate motor windings important? *Each speed has its own winding – so if one burns up, there are two other functioning winding to keep circulator working*

• Why is a high flow IFC important? *Doesn’t impact the performance curves very much, so you get full service even with IFC in place.*