Modern Hydronic System Designs for Condensing Boilers

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Agenda

- Condensing Boiler Basics
- Primary/Secondary Piping Layouts
- Variable/Primary Only Piping Layouts
- Designing Variable/Primary Only Systems
- Hydronic Systems What Not to Do
Historical Hydronic Designs

- 180°F hydronic loop set points
- Primary-secondary piping arrangements
- Protect boilers from condensing and thermal shock
- Calculate “design day” load, select one large boiler, put in a second boiler for redundancy.

- We can design modern systems that do not have to address any of the above!
Condensing Boilers

- Condensing in boilers for hydronic heating systems
  - Flue Gas Condensate (NOT steam condensate)
- Condensing represents opportunity for increased efficiency
- Specific operating conditions are necessary for a boiler to operate at optimal efficiencies
Keys to Condensing

- **Return Water Temperature**
  - Lower water temperatures allow flue gases to cool
  - Flue gas temperature is directly proportional to water temperature

- **Firing Rate (Modulation Point)**
  - Lower firing rate decreases flue gas velocity through the heat exchanger
  - Surface Area: Energy Transfer

- **Effective Control of Modular Boilers**
  - Sequencing and staging logic should be designed specially around condensing boilers
Primary/Secondary Piping Layouts

Hydronic Condensing Boilers
Primary/Secondary Arrangements
The Basics

• Decouples or “hydraulically separates” the primary (boiler) and secondary (system) loops
  – Closely spaced tees or a mixing manifold
• Prevents flow in one circuit from interfering with another
  – Example: As zone valves open, close, or modulate, and as system pumps vary speed, the boiler loop is not impacted.
Primary/Secondary Arrangements
The Applications

• Used in traditional systems to protect non-condensing boilers from low return water temperatures and low flow
• Used in modern systems to protect low-mass, low-volume condensing boilers from:
  – Thermal Shock
  – Low or No Flow (Localized Boiling, Scaling)
  – Excessive Flow (Erosion)
Primary/Secondary Piping For Condensing Boilers (Single)
Equal Flow Distribution

- Boiler GPM = System GPM
- Very little mixing
- Equal system/boiler supply and return temperatures
- This is situation is **ideal** for a condensing boiler
- Very difficult to achieve in practice
System Flow Greater Than Boiler Flow

- Mixing occurs in the manifold
- Boiler must modulate higher to meet setpoint demand
  - Reduced thermal efficiency at higher firing rate
  - May cause nuisance MRHL trips
- Boiler and system return temperatures are equal
Boiler Flow Greater Than System Flow

- Boiler and system supply temperatures are equal
- Boiler return temperature is greater than system return temperature
  - Common on constant speed boiler pump, variable speed system pump applications
  - Reduced thermal efficiencies with higher RWT
Alternative Piping Layouts

Primary Secondary

Variable Primary
Variable Primary Only Piping layouts

Hydronic Condensing Boilers
Primary Only Variable Flow
The Basics

- The system pumps are used to provide flow through the boilers
  - **No dedicated boiler pumps required!**
- Does not require mixing manifolds, hydraulic separators, or heat injection loops
- The coldest water temperatures are always delivered directly to the boiler return water connection
Why Use Motorized Isolation Valves?

- Only send flow through enabled boilers
  - Reduces natural draft through idle boilers (heat loss!)
- Eliminates operating off a mixed temperature
- Prevents nuisance high limit trips
- Always leave the lead valve open to provide a path of flow
Why Use Variable Frequency Drives?

• Why not?
Primary Only Variable Flow

The Applications

• Not every boiler is designed for primary only variable flow applications

• The boiler must have:
  – Flexibility for large variations in flow
  – No minimum return water temperature requirements
  – Low water pressure drop
  – High mass and high volume
Advantages of High Volume Condensing Boilers

- High water volume benefits:
  - Decreased cycling
  - Tolerance of varying flow and/or no flow conditions
  - No return water temperature requirements
  - Tolerance of water chemistry variances
  - Decreased risk of scaling and/or erosion
High Mass Vessels - Condensing Boilers

- Conservative designs are less likely to experience:
  - Thermal shock
  - Cyclic fatigue
  - Premature failures
Primary Only Summary

- Eliminates boiler pumps, additional piping & valves
  - Lower installation costs
  - Lower maintenance costs
  - Lower operational (kWh) costs
- Eliminates mixing to maximize thermal efficiency
- Simpler system designs
- Smaller boiler plant footprint
Designing a Variable Primary System
Designing A Primary Only Variable Flow Hydronic System

- Example System:
  - 3,600,000 BTU/hr design day load
  - 400,000 BTU/hr minimum load
  - 30°F ΔT design
  - Three (3) high mass & high volume condensing boilers
    - 2,000,000 BTU/hr each (N+1 design)
    - Variable speed primary only pumping
    - Multiple heating loads (zones)
Determining Flow Rates

- Some high mass & high volume boilers do not have minimum or maximum flow requirements
  - This means the boiler heat exchanger and pressure vessel will not be damaged in a low or no flow situation
- This does not mean the system will not have flow requirements to provide heat to the users
  - Some flow will always be required to satisfy the building load demand
  - Heat should be consumed at the rate it is delivered
Determining Flow Rates

\[ Q = m \times c_p \times \Delta T \]

- \( Q = \) Heat Load (BTU/hr)
- \( m = \) Mass Flow Rate (lbs/hr)
- \( c_p = \) Specific Heat of Fluid (BTU/lbs \(^\circ\)R)
- \( \Delta T = \) Temperature Differential (\(^\circ\)F)

SIMPLIFIED

\[ FLOW = \frac{LOAD}{500 \times (\Delta T)} \]
Determining Maximum Flow

• In our example:
  – 3,600,000 BTU/hr design day load
  – 30°F design delta-T

\[
FLOW = \frac{3,600,000}{500 \times (30)}
\]

• Design day flow rate:
  – 240 GPM
Determining Minimum Flow

- Consider all zones, minimum building usage before warm weather shutdown
- In our example:
  - 400,000 BTU/hr minimum load
  - 30°F design delta-T

\[
FLOW = \frac{400,000}{500 \times (30)}
\]

- Minimum flow rate:
  - 27 GPM
Determining Setpoint Temperatures

- Use an outdoor reset schedule to lower water temperatures in mild weather

![Graph showing the relationship between outdoor air temperature and hydronic loop setpoint temperature.](image)
Boiler Plant At Design Day

Supply Water @ 180°F

Three Boilers at 70% of Max Input (3600MBH)

Return Water @ 150°F

240 GPM

80 GPM

40 GPM

40 GPM

80 GPM
System Turndown

- **Design Day**
- **Minimum Load Day**
Boiler Plant At Minimum Load

Supply Water @ 100°F

27 GPM

One Boiler at 20% of Max Input (400MBH)

Return Water @ 70°F

10 GPM

10 GPM

7 GPM
What Not To Do
What NOT To Do
What NOT To Do
What NOT To Do

Water Return

Water Supply
What NOT To Do
Thank You!

QUESTIONS?