Hydronic Systems

BASIC HYDRONIC SYSTEM DESIGN

Terminal Units
- Fan Coils, Chilled Beams,
- Finned Tube, Radiant, etc.

Generation Equipment
- Boilers, Chillers, Cooling
- Towers, WWHPs, etc.

Primary Pumps
- P-1 & P-2

Secondary Pumps
- P-B-1 & P-B-2

Decoupler
- Closely Spaced Tees

Expansion Tank

Air / Dirt Separator

Distribution Piping
REFERRING TO PUMPS

HEATING

COOLING

AIR/DIRT SEPARATORS

- Air Vents at High Points
- Reduce Fluid Velocity
- Change Fluid Direction
- Reduce Pressure (Tangential)
- Coalescence (Microbubble)
EXPANSION TANKS

- Control pressure, control problems
- Expansion tanks control thermal expansion and contraction of system fluid
  - Establish the point of “no pressure change”.

DECOUPLING

- Eliminate pump interference
  - Avoid pumping through another pump

- Different flows needed in same piping system
  - Chillers and condensing boilers require min flow rates

- Different temperatures needed in same piping system
  - 180F for DHW
  - 120F for radiant
DECOUPLERS

Closely Spaced Tees  Hydraulic Separator  Buffer Tank (depends)

CLOSELY SPACED TEES

Distance Between Tees as Short as Possible (Tee to Tee).
Pressure Drop Between Tees Will Determine Flow to Terminal Unit

WATER ALWAYSollowS PATH OF LEAST RESISTANCE
HYDRAULIC SEPARATORS

Increasing pipe size reduces velocity and creates area of very low pressure drop

“BUFFER” TANKS

Purpose: increase the amount of fluid in a system to prevent the short cycling of chillers, boilers, etc.
**END SUCTION PUMPS**

- **End Suction Pumps**
  - Most Popular Style
  - Suction / Discharge at 90°
  - Split coupled allows servicing without disturbing pipe connections

![Base Mounted, Split Coupled](image1)

![Foot Mounted, Close Coupled](image2)

**IN-LINE PUMPS**

- **In-Line Pumps**
  - Suction / Discharge are In-Line
  - Differentiated by shaft orientation
  - Pipe supported, not fixed to structure

![Horizontal In-Line](image3)

![Vertical In-Line](image4)
**SPLIT CASE PUMPS**

- **Split Case**
  - Two sets of bearings to support shaft
  - Allows Access to both seals without moving motor or disturbing piping
  - *Up to 1,500 HP*

![Horizontal Split Case](image1)
![Vertical Split Case](image2)

**VERTICAL TURBINES**

- **Vertical Lineshaft Turbine**
  - Designed to Lift Liquid from Sump / Tank
  - Motor and Impeller are separated
  - Impellers “Push” better than “Pull”
  - Cooling Tower Sumps

![Vertical Lineshaft Turbine](image3)
NEW “SMART” PUMPS

- Speed varies without sensors
- High Efficiency ECM
  - Electronically Commutated Motor
  - A.k.a. DC Brushless Motor
- Integral VFD
- Sophisticated Electronics
- Residential to Light Commercial

CENTRIFUGAL PUMPS
AFFINITY LAWS

The Pump Affinity Laws are a series of relationships relating:

Flow (GPM)
Head (HEAD)
Horsepower (BHP)
RPM Speed (RPM)
Impeller Dia. (DIA)

Allow designers to estimate pump performance under different conditions
AFFINITY LAW #1

- GPM varies with RPM
  - Pump speeds up, flow increases
  - Pump slows down, flow decreases

\[ GPM_2 = GPM_1 \times \left( \frac{RPM_2}{RPM_1} \right) \]

- GPM varies with DIA
  - Large diameter impellers move more flow
  - Small diameter impellers move less flow

\[ GPM_2 = GPM_1 \times \left( \frac{DIA_2}{DIA_1} \right) \]
AFFINITY LAW #2

- HEAD varies as the square of the RPM
- Pump speeds up, head increases exponentially
- Pump slows down, head decreases exponentially

\[
\text{HEAD}_2 = \text{HEAD}_1 \times \left(\frac{\text{RPM}_2}{\text{RPM}_1}\right)^2
\]
AFFINITY LAW #3

- BHP* varies as a cube of RPM
  - Pump speeds up, BHP increases by cube
  - Pump slows down, BHP decreases by cube

\[ BHP_2 = BHP_1 \times \left( \frac{RPM_2}{RPM_1} \right)^3 \]

*BHP = Brake Horsepower is the actual power required to rotate the pump shaft. It is the portion of the motor HP that does the work.*

**AFFINITY LAWS**

Reducing Speed by Half:

<table>
<thead>
<tr>
<th>Change in RPM (or DIA)</th>
<th>Change in GPM</th>
<th>Change in HEAD</th>
<th>Change in BHP</th>
</tr>
</thead>
<tbody>
<tr>
<td>x 1/2</td>
<td>x 1/2</td>
<td>x 1/4</td>
<td>x 1/8</td>
</tr>
</tbody>
</table>

Doubling Speed:

<table>
<thead>
<tr>
<th>Change in RPM (or DIA)</th>
<th>Change in GPM</th>
<th>Change in HEAD</th>
<th>Change in BHP</th>
</tr>
</thead>
<tbody>
<tr>
<td>x 2</td>
<td>x 2</td>
<td>x 4</td>
<td>x 8</td>
</tr>
</tbody>
</table>
AFFINITY LAWS

How much HP is required to operate a 100 HP, 1760 RPM motor at half speed?

\[ BHP_2 = BHP_1 \times \left( \frac{RPM_2}{RPM_1} \right)^3 \]

\[ BHP_2 = 100 \text{ HP} \times \left( \frac{880 \text{ RPM}}{1760 \text{ RPM}} \right)^3 \]

\[ BHP_2 = 12.5 \text{ HP (@880 RPM)} \]

“Getting Into the Flow”

“the application of VFDs to constant speed pumps is now the fastest growing segment of the commercial pumping industry, a trend that improves (system) performance and efficiency…”
WHY VFDs on PUMPS

- **Soft Start**
  - Same cost as a motor starter
  - Gentler on motors
  - Reduces inrush current

- **Balancing without multi-purpose valve**
  - Significant energy saving opportunity

- **Variable Flow**
  - Flow varies according to demand
  - Ultimate energy savings

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**AFFINITY LAWS**

<table>
<thead>
<tr>
<th>RPM</th>
<th>GPM</th>
<th>HEAD</th>
<th>BHP</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>90%</td>
<td>90%</td>
<td>81%</td>
<td>72%</td>
</tr>
<tr>
<td>75%</td>
<td>75%</td>
<td>56%</td>
<td>42%</td>
</tr>
<tr>
<td>50%</td>
<td>50%</td>
<td>25%</td>
<td>12.5%</td>
</tr>
<tr>
<td>25%</td>
<td>25%</td>
<td>6%</td>
<td>1.2%</td>
</tr>
</tbody>
</table>
The main goal of the building loop(s) is to distribute the correct amount of water to satisfy the load.

It must first accurately monitor the system for changes in load dynamics.

Secondly, it must respond to these load changes with the “correct” amount of flow.

Variable Speed Pumping

Differential Pressure
System pressure changes as control valves respond to load. Challenge is to estimate how to respond to maximize energy savings.
Typical of systems with control valves.

Differential Temperature
Fluid temperatures change precisely as demand rises and falls.
Typical of One Pipe systems with circulators
Differential Pressure Transmitter Installation

DP Transmitter may be wall mounted or pipe stand mounted.

Orientation of DP XMTR and pipes has no effect on performance.

Gauges can be rotated for best viewing.

Determining Set Point

The sensor must keep enough pressure differential across the supply and return to “push” the design capacity flow through the coil and control valve.

Setpoint = Sum of coil pressure drop + control valve pressure drop at design conditions (17’).

3 psi (7’) PD

10’ PD
How Many $\Delta$P Transmitters?

Quantity: Three sensors can provide a very accurate picture of system demand.

- One for the longest run
  (Student dorm or remote part of East Campus)
- One for the dominant load
  (New basketball arena in Central Campus)
- One for another zone
  (Boss’s office)

For buildings with a very asymmetric layout, other sensors may be added to monitor each zone.

Location of $\Delta$P Transmitters

With the proper setpoints, both of these locations are acceptable, however …
Location of $\Delta P$ Transmitters

Efficiencies are affected dramatically!

Typical $\Delta P$ Transmitters
ΔP Transmitters - Example

As the Delta-T falls below setpoint, the pumps slow down. As the Delta-T rises above setpoint, the pumps speed up. Remember that BTUH = GPM x ΔT x 500
Temperature Sensors

Delta-T lends itself to even more cost effective variable speed pumping. The issues associated with placement and of Delta-P sensors are replaced with simplicity of thermisters. As few as two $20 thermistors can provide even more energy efficient operation than ΔP

ΔT Example
Next Generation Green Piping Systems

- Integrated Piping Systems
  - Heating / Cooling / Fire Protection (Condenser Water)
    - Trade Names – Tri Water
  - Cooling / Fire Protection (Chilled Water)
    - Trade Names – Total Comfort Solution, Ultimate Comfort Systems
  - Cooling / Domestic Cold Water (Chilled Water)
    - Trade Names – Total Comfort Solution
  - Heating / Domestic Hot Water (Hot Water)
    - Trade Names – Aqua Therm, Hydro Heat, Total Comfort Solution, Ultimate Comfort Systems
  - Less Materials

Next Generation Green Piping Systems

Single Pipe LoadMatch® HVAC/Fire Protection Integrated Piping Main
Rouges and Saints
Picture Gallery
No Pipe Hangers

Suction Diffuser Support, BUT...

Inertia Base Should Extend Under The Suction Diffuser
Motor Support Not Required Here

Note:
Never support an inline pump motor with a pipe hanger. Can cause misalignment and coupler failure and eventual bearing failure.
No Pressure Gauge Across Pump
Not Enough Straight Pipe Diameters
No Suction Diffuser Support
Weight On Flex/Pump
No Gauge Across Pump
Pump Base Is Grouted
Vertical In-line Installation

Fig. A1.4 With additional pipe supports
Weight On Flex/Pump

Pipe not supported. Weight distorting flex connector.
Wrong Coupler in Variable Speed Application

OLD STYLE COUPLER

Woods Sure-Flex Coupler (old style)
Overall good installation but the devil is in the details

Power wiring placing large side load on very tall assembly
Cast iron pump installed on domestic water heating system

Result: Electrolysis & Corrosion

What NOT To Do!

- 600 GPM / 30 HP pump deadheaded for 30 hours
What NOT To Do!

Affects of Fluid Heating

- This was a chilled water pump. It was operated with the valves closed for about an hour.

- Photo Courtesy of Don Casada-Diagnostic Solutions, LLC.

Thank You!