Hydronic Systems

BASIC HYDRONIC SYSTEM DESIGN

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

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

Decoupler
Closely Spaced Tees

Expansion Tank

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

Air / Dirt Separator

Primary Pumps
P-1 & P-2

Distribution Piping

1
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”.

![Expansion Tanks Images]

Full Acceptance
Bladder type

Partial Acceptance
Bladder type

Partial Acceptance
Diaphragm type

CENTRIFUGAL PUMP
COMPONENTS

- Bearing Frame Assembly
- Casing / Volute
- Motor
- Discharge
- Suction
- Drain Pan
- Base
- Coupler w/Guard
CENTRIFUGAL PUMP COMPONENTS

- Impeller
- Bearing Frame Assembly
- Woods Dura-Flex Coupler
- Mechanical Seal
- Pump Shaft
- Motor
- Motor Shaft

COUPLER

Woods Dura-Flex Coupler
BEARING ASSEMBLY

Bearing Frame Assembly

MECHANICAL SEAL

John Crane (Type 21) mechanical seal
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  Foot Mounted, Close Coupled

IN-LINE PUMPS

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

Horizontal In-Line  Vertical In-Line
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

Vertical Split Case

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

Horizontal Split Case

Vertical Lineshaft Turbine
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

TYPICAL CAPACITIES

<table>
<thead>
<tr>
<th>TYPE</th>
<th>GPM</th>
<th>HD (FT.)</th>
<th>HP</th>
<th>RPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>HORIZ. IN-LINE</td>
<td>20 – 375</td>
<td>10 - 75</td>
<td>¼ - 3</td>
<td>1760, 3500</td>
</tr>
<tr>
<td>END SUCTION</td>
<td>40 – 4,000</td>
<td>10 - 400</td>
<td>½ - 200</td>
<td>1160, 1760, 3500</td>
</tr>
<tr>
<td>VERTICAL IN-LINE</td>
<td>40 – 12,000</td>
<td>10 - 400</td>
<td>¼ - 600</td>
<td>1160, 1760, 3500</td>
</tr>
<tr>
<td>SPLIT CASE</td>
<td>100 – 18,000</td>
<td>20 - 500</td>
<td>3 – 1,500</td>
<td>1160, 1760, 3500</td>
</tr>
<tr>
<td>VERTICAL TURBINE</td>
<td>20 – 6,000</td>
<td>10 - 150</td>
<td>½ - 150</td>
<td>1160, 1760</td>
</tr>
</tbody>
</table>
Pumps create Differential Pressure (ΔP)

Water Flows From Higher Pressure to Lower Pressure

The ΔP Induces Flow Against System Resistance

In an Open System the ΔP also Induces Lift Against Atmospheric Pressure and Gravity

CENTRIFUGAL PUMP
BASIC OPERATION

- Impeller spin accelerates the liquid radially
- Liquid forced to the outside of the impeller
- Cutwater diverts liquid out through the discharge
- Impeller eye is point of lowest pressure
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

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**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 #1

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

\[
HEAD_2 = HEAD_1 \times \left(\frac{RPM_2}{RPM_1}\right)^2
\]
AFFINITY LAW #2

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

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?

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

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

\[
BHP_2 = 12.5 \, HP \, (@880 \, RPM)
\]
**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>

**“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

Pump Curves
**Pump Curves**

PUMP CAN ONLY OPERATE ON ITS CURVE

**IMPELLER CURVES**

FLOW (GPM)

HEAD (FT)

- 13"
- 12"
- 11"
- 10"

**System Curve**

FLOW = \text{HEAD}^2

(Y = X^2)

FLOW (GPM)

SYSTEM CURVE (PARABOLA)
Horsepower Curves

PUMP OPERATES WHERE SYSTEM AND IMPELLER CURVES INTERSECT

IMPELLER CURVE

SYSTEM CURVE (PARABOLA)

OPERATING POINT

HP CURVES

FLOW (GPM)

HEAD (FT)

100

200

20

15

10

Parallel Pumping
Correct Selection

GPM IS ADDITIVE, HEAD REMAINS THE SAME

SYSTEM CURVE

IMPELLER CURVES

P1 or P2

P1 + P2

2 PUMPS ON OPERATING POINT

1 PUMP ON OPERATING POINT

STATIC HEAD
Parallel Pumping Incorrect Selection

GPM is additive, head remains the same

One pump running does not intersect with system curve
Result = No Flow

Hydronic Piping Systems

- Direct Return System
- Reverse Return System
- Primary-Secondary Pumping System
- Injection Pumping System
- Series Pump System
- Zone Pumping System
- Single Pipe System
Direct Return (First In/First Out)

- **Advantages**
  - Shorter Pipe Runs
    - Lower first cost
    - Lower pump head
  - Disadvantages
    - Poor Comfort
      - Does not insure adequate flow to all terminal units
    - Not Self Balancing
      - Balance valves and balancing required

Reverse Return
(First In/Last Out)

- **Advantages**
  - Improved Comfort
    - Greater assurance of adequate flow to all terminal units all times
  - Self Balancing
- **Disadvantages**
  - Longer Pipe Runs
    - Higher first cost
    - Higher pump head
Primary-Secondary

- Advantages
  - Improved Comfort
    - Reduced complexity of balancing
  - Lower Operating Cost
    - Reduced pump horsepower by separating zones with different loads, operating temperatures, or pipe length
- Disadvantages
  - Increased Number of Pumps and First Cost

DECOUPLING

Distance Between Tees as Short as Possible (Tee to Tee). Pressure Drop Between Tees Will Determine Flow in Secondary Circuit when Secondary Pump is Off

WATER ALWAYS FOLLOWS PATH OF LEAST RESISTANCE
Single Pipe

- **Advantages**
  - **Maximum Comfort**
    - Insures adequate flow to all terminal units at all times
  - **Self-balancing**
  - **Lower First Cost**
    - Eliminate control valves, balance valves, balancing, pipe and fittings

- **Disadvantages**
  - Requires accounting for temperature cascade to provide adequate capacity of terminal units.

Injection Pumping

- **Advantages**
  - **Lower Operating Cost**
    - Operate secondary systems at optimum operating temperatures
  - **Lower First Cost**
    - Use one primary boiler system for multiple secondary systems requiring different operating temperatures.

- **Disadvantages**
  - Increased Number of Pumps and First Cost
Injection Pumping – Another Look!

Zone Loop
Injection
Building Loop

Advantages
- Lower Operating Cost
  - Reduced pump horsepower by separating zones with different loads

Disadvantages
- Increased Number of Pumps and First Cost
- Operation of Pumps Affects Flow in Other Circuits
  - Pumps are not decoupled
  - Increased complexity of balancing

Series Pumping System

Advantages
- Lower Operating Cost
  - Reduced pump horsepower by separating zones with different loads

Disadvantages
- Increased Number of Pumps and First Cost
- Operation of Pumps Affects Flow in Other Circuits
  - Pumps are not decoupled
  - Increased complexity of balancing
Zone Pumping

**Advantages**
- Lower Operating Cost
  - Reduced pump horsepower by separating zones with different loads

**Disadvantages**
- Increased Number of Pumps and First Cost
- Operation of Pumps Affects Flow in Other Circuits
  - Increased complexity of balancing

Single Pipe

**Single Pipe System**
- Independent Decoupled Secondary Circuits for all Terminal Units
- Use Circulators Instead of Valves

**No Control Valves**
- Control Zone Temperature with Circulators Only
  - On/Off or Variable Speed

**No Balance Valves**
- Self Balancing
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
Thank You!