Size Matters:
Picking the Right Size of Piping System Components

April 13, 2017
Did You Know?

- Pump systems account for ~25% of electric motor energy consumption and **20 – 60% of total electrical energy usage** in various industrial, water, and wastewater treatment facilities
  - “U.S. Industrial Motor Systems Opportunities Market Assessment”
  - U.S. Department of Energy, Oak Ridge National Lab, Xenergy, Inc.
Workshop Agenda

- **How to Size:**
  - Pipes, Pumps, Valves, Orifice plates, and Heat exchangers

- **Cost Calculations**
  - Energy costs
    - Effect of control valves vs. VFDs on energy costs
  - Full system costs

- **Minimizing costs**
  - What to minimize? First costs vs. life cycle costs?

- **Q&A**
Sizing a Pipe Example

- **Determine pipe size for system below to limit velocity to 6 ft/sec**
  - Pump water from 10 ft elevation up a hill to a reservoir at a 200 ft elevation

- Water @ 70 degrees F
- Flow requirement is 500 GPM
- Total pipe length is 1000 feet
- Pump elevation = 0 feet
Sizing a Pump Example

- Now that the pipes for the previous system have been sized in order to limit the velocity, **Determine the pump head and power (ideal) in order to size the pump**

Which pump curve should I use?
Sizing Pipes, Valves, & Orifice Plates with Control Valves

- Determine the nominal pipe size, corresponding valve Cv, & equivalent orifice diameter for the below gravity flow system

- Water flows from 40 ft to 10 ft
- Desired flow is 250 gpm
- Control valve must have at least 8 psi drop to ensure control over lifetime of system

- Water system at 70 degrees
- The total pipe length is 200 feet
- Nominal Steel – ANSI pipe sizes are required
Sizing a Heat Exchanger

Start with desired HX outlet temperature to determine heat rate.

Switch to real HX model and adjust parameters accordingly (use GSC).
Performing Cost Calculations with AFT Fathom & AFT Arrow

- AFT Fathom/Arrow can calculate the following costs
  - Material Costs (non-recurring)
  - Installation Costs (non-recurring)
  - Maintenance Costs (recurring)
  - Energy Costs (recurring)
- Cost can be applied to junctions, pipes, and fittings & losses
- Costs calculated effectively with engineering databases (*.DAT) and cost databases (*.CST)
- All cost databases must associate to an engineering database
- Multiple cost databases can exist for a single engineering database
  - i.e., different vendors costs, different currencies, etc.
Cost and Engineering Database Relationship

Fathom Model

Connected Databases
Available Databases
Database Manager

Engineering Database #1
- Cost Database #1A
- Cost Database #1B
- Cost Database #1C

Engineering Database #2
- Cost Database #2A
- Cost Database #2B
- Cost Database #2C

Engineering Database #3
- Cost Database #3A
- Cost Database #3B
- Cost Database #3C

Cost and Engineering Database Relationship
Enabling Cost Calculations

- Specify cost calculations to perform from Analysis menu
  - Pump Energy Only will only calculate pumps energy costs
  - “Calculate” option allows calculation of multiple cost types
    • Material, Installation, Maintenance, & Energy
Define Cost Settings from Analysis Menu

- **Cost Calculations**:
  - Do Not Calculate Costs
  - Calculate Costs

- **Energy Cost**:
  - Use Energy Cost Databases
    - Use This Energy Cost Information
      - Cost: 
      - Per: kW-hr
  - Only this fixed energy cost set here will be used. All Energy Cost settings in the Database Manager will be ignored.

- **Cost Definitions**:
  - Monetary Cost
    - Material
    - Installation
    - Maintenance
    - Operation/Energy

- **Cost Time Period**:
  - System Life: years
  - Interest Rate: % Per years
  - Inflation Rate: % Per years

- **Always Warn for Incomplete Pipe Subcomponent Costs**

- OK, Cancel, Help
Pump Energy Cost Savings Using VFDs Instead of Control Valves

What are the energy cost savings in using VFDs instead of flow control valves for off-peak hour conditions (i.e., 1000 gpm thru each heat exchanger) for one year?
AFT Fathom Cost Calculation Walk-Thrus

- AFT Fathom cost calculation examples demonstrated today are available in the AFT Fathom Examples Help File.
Basic Cost Calculation Example

- “Cost Calculation – Beginner” in Fathom Examples Help File
- Determine HX system cost over 10 year period
  - Include Material, Installation, and Energy Costs

Databases Used:
- One pre-built engineering database
- Two pre-built cost databases

*Heat transfer is enabled in this example
Basic Cost Calculation Example Procedure

- Enable Cost Calculations from Analysis menu & define Cost Settings
  - $0.06 per kW-hr, Enable Material, Installation, Operation/Energy
  - 10 year system life
- Add steel-ANSI piping cost database with database manager
- Add Controlled HX Temp Example Components.dat file for system component engineering data
- Add Controlled HX Temp Example.cst cost database file for system component costs
- Specify pipes and junctions to be included in cost report
- Run model and evaluate system costs
Advanced Cost Calculation Example

- “Plant Cooling Cost Calculation” – FTH Examples Help File
- Determine initial & life cycle system cost over 10 year period
  - Include Material, Installation, & Energy Costs

**Databases Used:**
- Two pre-built engineering databases
  - Steel-ANSI Pipe Material Database
  - Plant Cooling.dat
- Three cost databases built from scratch

**Cost Databases to Build Include:**
- Material/Install costs for pipes
- Material/Install costs for fittings
- Material/Install costs for pumps
## Plant Cooling System Costs

### Steel – ANSI Schedule 20 Pipe Material & Installation Costs

<table>
<thead>
<tr>
<th>Nominal Size (inches)</th>
<th>Material Cost (dollars/foot)</th>
<th>Installation Cost (dollars/foot)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>10.50</td>
<td>24.00</td>
</tr>
<tr>
<td>14</td>
<td>22.50</td>
<td>51.50</td>
</tr>
<tr>
<td>18</td>
<td>27.40</td>
<td>70.00</td>
</tr>
<tr>
<td>20</td>
<td>35.40</td>
<td>85.50</td>
</tr>
<tr>
<td>24</td>
<td>40.00</td>
<td>96.50</td>
</tr>
<tr>
<td>28</td>
<td>58.00</td>
<td>110.00</td>
</tr>
<tr>
<td>30</td>
<td>60.00</td>
<td>129.00</td>
</tr>
</tbody>
</table>

### 90 deg Elbow Material & Installation Cost (Sch20, 8” – 34”)

<table>
<thead>
<tr>
<th>Nominal Size (inches)</th>
<th>Material Cost (dollars/foot)</th>
<th>Installation Cost (dollars/foot)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.125</td>
<td>68.00</td>
<td>185.50</td>
</tr>
<tr>
<td>12.25</td>
<td>151.50</td>
<td>298.00</td>
</tr>
<tr>
<td>17.376</td>
<td>262.50</td>
<td>446.00</td>
</tr>
<tr>
<td>23.25</td>
<td>373.50</td>
<td>595.00</td>
</tr>
<tr>
<td>29.00</td>
<td>484.50</td>
<td>744.00</td>
</tr>
<tr>
<td>33.00</td>
<td>558.50</td>
<td>843.00</td>
</tr>
</tbody>
</table>

*Costs for 90 deg elbows are entered as cost scale tables

### Cooling Tower Circulation Pump Costs

<table>
<thead>
<tr>
<th>Material Cost (dollars/pump)</th>
<th>Installation Cost (dollars/pump)</th>
</tr>
</thead>
<tbody>
<tr>
<td>28,500</td>
<td>12,500</td>
</tr>
</tbody>
</table>
Advanced Cost Calculation Database Relationship

- Pipe Material & Installation Costs
  - Steel – ANSI Pipe material Database

- Pipe Fittings & Losses Material & Installation Costs
  - AFT Default Internal Database (This is where loss factor information is kept for the Fittings & Losses tab in pipe window)

- Pump Material & Installation Costs
  - Plant Cooling Engineering Database
Intelligent System Sizing

- Cost calculation capabilities of AFT Fathom & AFT Arrow are powerful & useful to fully understand system costs
- However, it is **NOT ENOUGH** to simply know the costs
  - Primary job of the engineer is to design a system in which these costs will be **MINIMIZED**
- Minimizing costs of a system requires significant iteration on system input parameters in order to:
  - Reduce costs
  - Delivery system requirements
  - Stay within design constraints
- How does one know if they found the true “minimum” cost?
  - By running out of project design time & picking the lowest cost system design they found
Intelligent System Sizing (2)

- No one has enough time or resources to be able to search & determine the true “minimum” system cost or energy usage
- This requires a powerful tool that can perform thousands of iterations to determine a true minimum cost of a system
  - The tool needs to perform these calculations in a reasonable amount of time
- Applied Flow Technology has had this powerful tool available for over 10 years and is built off of AFT Fathom & AFT Arrow’s powerful hydraulic calculation engines
- This “Intelligent System Sizing” tool is available through:
  - AFT Mercury (incompressible flow systems)
  - AFT Titan (compressible flow systems)
AFT Mercury™ 7
AFT Titan™ 4

- Intelligent System Sizing
- Models and designs pipe network systems
- Automatically selects best pipe & component sizes to minimize initial or life cycle cost, size or weight using
- Ability to apply multiple constraints to pipes and junctions
- Cost optimization may include:
  - non-recurring costs (materials and installation)
  - recurring costs (energy and maintenance) including time varying cost (energy costs varying with time)
- Offers customizable engineering and cost databases

See AFT Technical Papers on AFT Mercury:
Automatic Pipeline Sizing Example

- Consider a 1000 ft long piping system requiring 8000 GPM
  - Pump flow = 8000 GPM ; Pump Efficiency = 65%
  - Assumed pipe friction factor = 0.015
  - Energy Rate = $0.01 per kW-hr ; 5 year system live

- Determine pipe size to minimize initial non-recurring cost
  - Material & installation costs considered

- Determine pipe size to minimize life cycle cost
  - Material, installation, & pump energy costs considered
Two new modules for AFT Fathom 9 & AFT Arrow 6 will be available soon!

- Automated Network Sizing (ANS) module
- Automated Pipeline Sizing (APS) module

ANS & APS modules very similar to AFT Mercury & AFT Titan for calculation & functionality

- ANS & APS modules will contain the powerful capabilities of AFT Mercury & AFT Titan and will be expanded, improved, & fully integrated into AFT Fathom & AFT Arrow!
- Stay tuned for these new modules available soon!!
Questions?