Automated Network Sizing

add-on module for AFT Fathom™ 11

Quick Start Guide | Metric Units

Dynamic solutions for a fluid world ™

Applied Flow Technology

AFT Fathom™ ANS Module

Quick Start Guide

Metric Units

AFT Fathom Version 11

Automated Network Sizing Module

Applied Flow Technology

Dynamic solutions for a fluid world ™

CAUTION!

AFT Fathom is a sophisticated pipe flow analysis program designed for qualified engineers with experience in pipe flow analysis and should not be used by untrained individuals. AFT Fathom is intended solely as an aide for pipe flow analysis engineers and not as a replacement for other design and analysis methods, including hand calculations and sound engineering judgment. All data generated by AFT Fathom should be independently verified with other engineering methods.

AFT Fathom is designed to be used only by persons who possess a level of knowledge consistent with that obtained in an undergraduate engineering course in the analysis of pipe system fluid mechanics and is familiar with standard industry practice in pipe flow analysis.

AFT Fathom is intended to be used only within the boundaries of its engineering assumptions. The user should consult the AFT Fathom internal help files for a discussion of all engineering assumptions made by AFT Fathom.

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Contents

CHAPTER 1

Introducing AFT Fathom ANS Module

Welcome to the AFT Fathom™ ANS module, Applied Flow Technology's powerful pipe and duct system automated sizing tool. With the ANS module you can automatically size all pipes or ducts in a system to minimize monetary cost, weight, volume, or surface area. In addition, you can concurrently size the pumps and pipes to obtain the absolute lowest cost system that satisfies your design requirements. Finally, by including non-recurring and recurring costs, you can size pipe and duct systems to minimize life cycle costs over some specified duration.

How the AFT Fathom ANS module works

The AFT Fathom ANS module consists of three basic elements: the Graphical Interface, the Hydraulic Solver, and the Automated Sizing Engine. Figure 1.1 shows the relationship between the three.

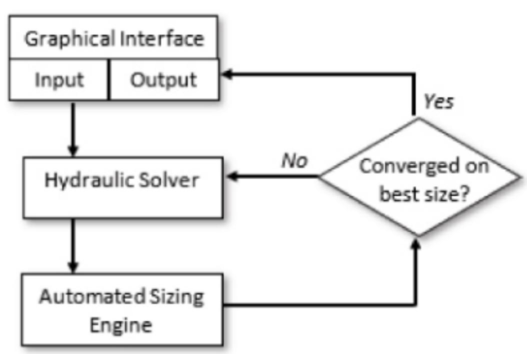

Figure 1.1 ANS module main component flow chart

The Hydraulic Solver obtains a balanced hydraulic solution for a specific pipe or duct system. The Automated Sizing Engine then modifies the design, and the Hydraulic Solver evaluates the modified design. The Automated Sizing Engine continues this process until it is satisfied that no further design improvements are possible. At this point, the Automated Sizing Engine has converged on a design, and the resulting sized design is then sent back to the Graphical Interface where it is displayed to the user.

The Hydraulic Solver, which functions as the prime mover in performing an engineering analysis (e.g., AFT Fathom™), becomes a subroutine called by the Automated Sizing Engine. The Automated Sizing Engine is the prime mover in the ANS module.

The Automated Sizing Engine employed by the ANS module uses state-of-the-art numerical searching technology licensed from a leading developer in this field. This technology has been used for many years in engineering design, with extensive use in structural finite element analysis.

Analysis vs. design

Analysis

Traditional piping system engineering has employed pipe flow *analysis*. Engineering analysis is the process of using accepted calculation methods to predict the behavior of a given system. These calculation methods may be manual, or automated in a computer program.

The weakness of analytical methods for design is that they require the specification of the system before the methods are applied. Specifically, the pipe or duct sizes, pumps, valves and other equipment must be specified in order to perform the calculation.

However, when a new pipe system is being designed, these parameters are not known. To use the analytical methods, the engineer must guess at the pipe sizes and required equipment, perform the analysis, then modify his or her original selections as necessary.

The analytical methods are used iteratively to arrive at a final design.

Design

A design-oriented approach to piping system engineering allows the selection parameters to be variables. Rather than specifying pipe diameters, the engineer solves for pipe diameters by specifying the flows and pressures (and other design requirements) and using these to select the appropriate pipes which minimize the overall system weight, volume or monetary cost.

Within certain limits engineers do this with traditional analytical methods. However, the number of design tradeoffs that can be considered is limited and the tradeoffs considered are indirectly tied to weight, volume or monetary cost.

The ANS module offers a true design-oriented approach to piping system engineering by using advanced automated sizing methods to evaluate competing designs vs. weight, volume or cost, and select the best design. The analysis method (i.e., the Hydraulic Solver) is called repeatedly by the ANS module in an effort to identify design improvements (i.e., improvements that reduce weight, volume or monetary cost).

Weight, volume and monetary cost are all costs

In the English language we usually associate the word "cost" with money. However, in engineering that does not have to always be the case. If an engineer is designing an aircraft, for example, minimizing weight is essential. In that respect extra weight is a "cost".

To simplify discussion in this guide, and to avoid needless repetition, the word "cost" will be used to represent any of the parameters an engineer may wish to minimize. In the ANS module, this can be weight, volume, surface area or monetary cost. When discussing issues specifically related to monetary cost, the words "monetary cost" will be used unless the context is otherwise clear that the discussion refers to "monetary cost".

Cost-based automated sizing vs. cost estimating

The ANS module is *not* a cost estimating tool. Rather, it offers a rational and automated approach for comparing potential pipe or duct system designs using the common denominator of cost. It is the pipe or duct system design that the ANS module obtains that is of immense value, not the process of cost estimating.

AFT Fathom ANS module design capabilities

The AFT Fathom ANS module can be used to size a wide variety of engineering systems.

Types of systems that can be sized

- Piping, ducting and tubing systems
- Open and closed (recirculating) systems
- Network systems that branch or loop, with no limit on the number of loops
- Pressure fed systems and gravity fed systems
- Pumped systems, including multiple pumps in parallel or in series
- Pumps with variable speed, controlled pressure, controlled flow and viscosity corrections
- Systems with pressure and/or flow control valves
- Systems with valves closed and pumps turned off
- Systems with heat transfer and energy balance
- Systems with variable density and viscosity
- Systems with non-Newtonian fluid behavior

Types of automated sizing parameters available

- Pipe size
- Pipe velocity, pressure gradient, pressure, flow and temperature
- Pump head rise, NPSH margin, proximity to BEP (Best Efficiency Point), power and others
- Control valve pressure drop and open percentage

ANS module primary window

When the ANS module is activated in AFT Fathom several changes are made to the interface, though the main impact is the addition of a sixth Primary Window, the Sizing window. The Sizing window allows for the sizing and (optionally) cost settings to be configured for the model. When the model is set to perform sizing, input information in the Workspace and Model Data windows for the components being sized is used for initial guesses. Components which are not being sized are treated as constants for the automated network sizing.

Automated sizing terminology

General automated sizing terminology applied to pipe systems is as follows:

Design requirements

There are numerous design requirements in the ANS module. Common requirements are pipe velocity, control valve pressure drop, pump Net Positive Suction Head (NPSH) margin and proximity to Best Efficiency Point (BEP).

Active and inactive design requirements

An active Design Requirement is a requirement which has a direct impact on the solution, whereas an inactive Design Requirement is a passive requirement which does not impact the solution. If an active requirement is removed, the ANS module will find a different solution, whereas removing an inactive requirement will not affect the solution.

Consider a case where several Design Requirements are set for the velocity in a pipe. One may set the maximum to 5 meters/sec, and the minimum to 1 meter/sec. If the final pipe velocity were 4.9 meters/sec, the maximum velocity Design Requirement would be active because the final value of the velocity is at or near the maximum velocity. On the other hand, the 4.9 meters/sec pipe velocity is far away from the 1 meter/sec minimum. If we remove the minimum velocity Design Requirement, the result will still be an actual pipe velocity of 4.9 meters/sec. Thus, the minimum velocity Design Requirement is inactive and does not influence the selected pipe size. On the other hand, if one removed the 5 meters/sec maximum velocity Design Requirement, the actual velocity would probably increase above 5 meters/sec, thus resulting in a different pipe size.

Objective

This is the goal of the analysis in the system. Typically, the Objective is to minimize monetary cost either directly using monetary cost data, or indirectly by minimizing parameters such as pipe weight. As the ANS module varies the pipe sizes, the objective value (cost, weight, etc.) varies. The Automated Sizing Engine searches for combinations of pipe sizes that achieve the objective by comparing these variations.

Continuous vs. discrete sizing

Discrete data is a set of data which lists explicit values that can be used, such as a set of pipe sizes within a given schedule. Continuous data is a set of data that includes all values between the given minimum and maximum, such as percent open values for a valve.

Generally, the desired sizing within the ANS module is discrete, since commercial pipe sizes must be chosen from a set of specific sizes. However, since it is much easier to minimize values using a continuous solution, many methods in the ANS module will first implement continuous sizing, then use this solution to find a nearby discrete solution for the system. Note that this is not as simple as just choosing the closest discrete value around the continuous minimum. Good searching algorithms like those used in the ANS module will consider values that are more than one discrete size from the continuous value.

Common size groups

The automated sizing process takes longer as the number of pipes being independently sized increases. Frequently there are groups of pipes in a system which would ideally be the same size for design purposes, or must be the same size by virtue of their location in the system. To link the sizes for pipes together one can create *Common Size Groups*. When one places pipes into a Common Size Group, one is saying that the group of pipes must all have the same pipe size, and be the same material and schedule, class, or type. A Common Size Group thus consolidates the individual pipes that are part of that group to a single pipe size for that group.

Feasible and infeasible designs

A feasible design is one which satisfies all Design Requirements, while an infeasible design does not satisfy one or more Design Requirements. There are many ways you can create a model that has no feasible solution. For example, connect a pipe to an Assigned Pressure junction set to 15 bar. Then place a Design Requirement on the pipe that it cannot have a pressure greater than 10 bar. Since the pipe is connected to an Assigned Pressure junction at 15 bar, there is no way for it to satisfy the 10 bar Design Requirement. Thus, no feasible solution exists.

Candidate sets

A Candidate Set is a collection of potential sizes that will be considered for the sizing calculations. Each pipe being sized in the system must have one Candidate Set assigned to it. If continuous sizing is being performed, only the minimum and maximum pipe sizes in the Candidate Set will be used to bound the continuous sizing.

CHAPTER 2

Weight Sizing Example

This example shows how to use the ANS module to perform a non-monetary automated sizing on a system. Parameters such as pipe weight or volume frequently relate closely to the actual pipe cost and are easier to set up than monetary cost based automated sizing. This makes them useful for approximating an initial design. Further, on some systems such as aircraft, marine vessels or automobiles, minimizing weight may be the primary goal.

This example demonstrates minimizing the *pipe weight* in a system.

Topics covered

- Non-monetary parameter automated sizing
- Creating Common Size Groups
- Defining Candidate Sets
- Control Valve Design Requirements

Required knowledge

No prior knowledge is required for this example. However, users who are completely new to AFT Fathom are advised to first complete the AFT Fathom Quick Start Guide examples. There, one will see how to use basic features for conventional pipe flow modeling. This example focuses on the automatic sizing features in the ANS module.

Model file

This example uses the following file, which is installed in the Examples folder as part of the AFT Fathom installation:

- *Metric - Control Valve - ANS.fth* - AFT Fathom model file

- This example is also provided in English units in the "*US - Control Valve – ANS.fth*" model file.

This example will require you to build the model from scratch to familiarize you with the steps required to build a complete model in AFT Fathom. Therefore, use this example model file as a reference only.

Problem statement

The example is for a fluid transfer system that feeds water from an elevated reservoir at 12 meters to a lower reservoir at 3 meters. A control valve is used to control the flow rate at 70 m3/hr and can be placed anywhere within the line, though it must have a minimum pressure drop of 82 kPa. For simplicity, we will locate the flow control valve at the midpoint of the 120 meter pipeline.

The pipeline uses STD Steel - ANSI pipe in the size range from 1-12 inches.

Step 1. Start AFT Fathom

From the Start Menu, choose AFT Products and AFT Fathom.

Activate the ANS module from the Startup Window by checking the box next to the ANS module. Alternatively, it can be activated from the Add-on Modules button at the bottom of the Quick Access Panel, or from the Activate Modules option in the Tools menu.

Once the ANS module has been activated, check that it is enabled for use by going to Automated Sizing under the Analysis menu and selecting Network as shown in Figure 2.1. This should be done automatically by AFT Fathom when the module is activated.

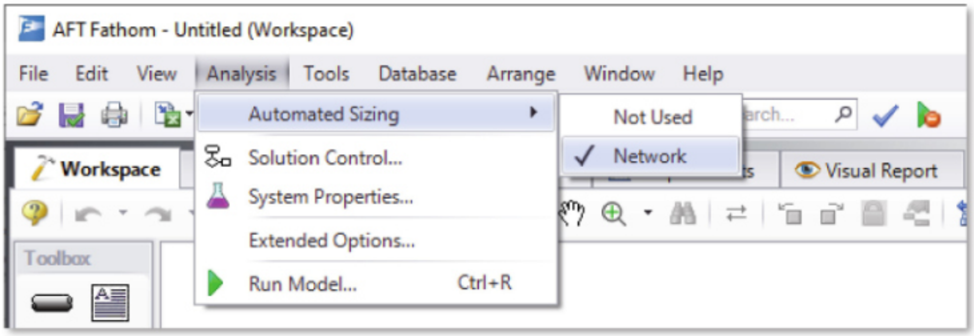

Figure 2.1 **Enabling the ANS module for use. The Automated Sizing menu item becomes available when the ANS module has been activated.**

Step 2. Specify system properties

1. Open the System Properties window by selecting System Properties in the Analysis menu.
2. On the Fluid Data tab, select the AFT Standard database and then select "Water at 1 atm" in the Fluids Available in Database list.
3. Click "Add to Model" to select water for use in this model.
4. Now type in 20 deg. C in the fluid temperature box and click "Calculate Properties". This calculates the fluid properties to use in the model.
5. Click OK.

Step 3. Build the model

A. Place the pipes and junctions

At this point, the first two items are completed on the Checklist. The Checklist can be accessed by clicking the checkmark icon on the toolbar or from the View menu and provides a summary of items that must be completed before the model is run. When the ANS module is activated the fourth checklist item changes from "Specify Cost Settings" to "Define All Sizing Input".

For this model the first two items have been completed. The next Checklist item is "Define All Pipes and Junctions". In the Workspace window, assemble the model as shown in Figure 2.2.

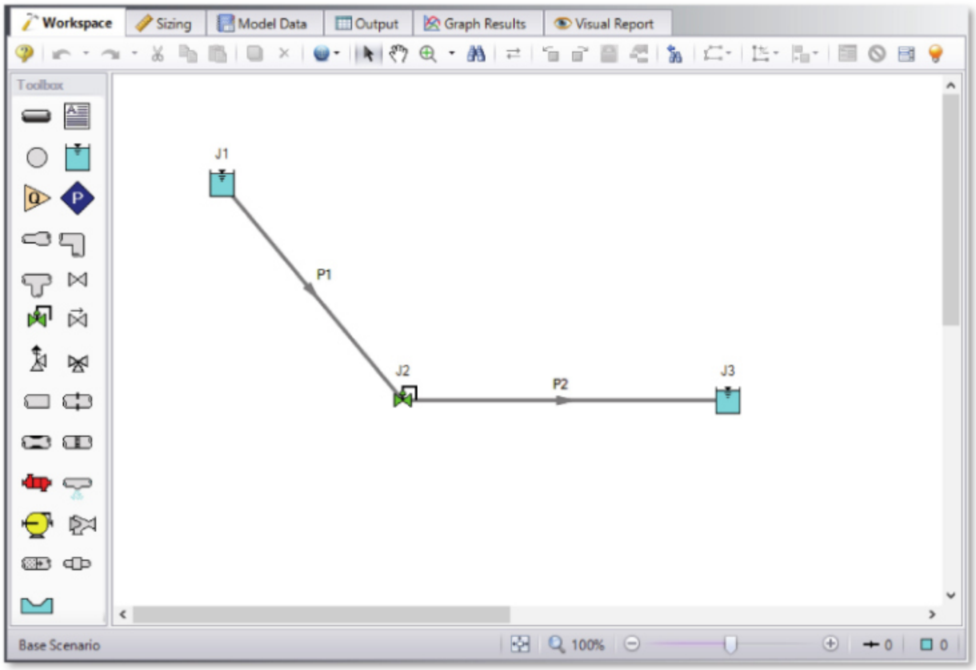

Figure 2.2 Control Valve system layout

B. Enter the junction data

J1 - Reservoir

1. Liquid Surface Elevation = 12 meters
2. Liquid Surface Pressure = 0 barG
3. Pipe Depth = 0 meters

J2 - Control Valve

1. Elevation = 6 meters
2. Valve Type = Flow Control (FCV)
3. Volumetric Flow Rate = 70 m3/hr

J3 - Reservoir

1. Liquid Surface Elevation = 3 meters
2. Liquid Surface Pressure = 0 barG
3. Pipe Depth = 0 meters

C. Enter the pipe data

For this example, we need to find the best pipe size, but we are limited to STD pipe sizes. Now we need to use engineering judgment to take an initial guess at the pipe size for a flow rate of 70 m3/hr. Let's try 4 inch pipe. Specify both the pipes as follows:

1. Pipe Material = Steel – ANSI
2. Size = 4 inches
3. Type = STD (schedule 40)
4. Length = 60 meters
5. Friction Model = Standard

Step 4. Define sizing input

The first three items have now been completed on the Checklist, leaving one last item, "Define All Sizing Input".

In this model we are going to perform sizing to minimize the pipe weight, while maintaining a minimum pressure drop of 82 kPa across the control valve. To do this, first go to the Sizing window by clicking on the Sizing tab, or from the Window menu.

The Sizing window is comprised of multiple panels which can be accessed using the buttons on the Sizing Navigation Panel along the bottom of the window, as shown in Figure 2.3. The sizing panels can be accessed in any order, though it is easiest to enter the information by navigating the panels from left to right, since the input on panels such as the Sizing Objective and the Size and Cost Assignments panels will affect the options available on later panels. Depending on the type of sizing being done, some panels may be disabled or unused.

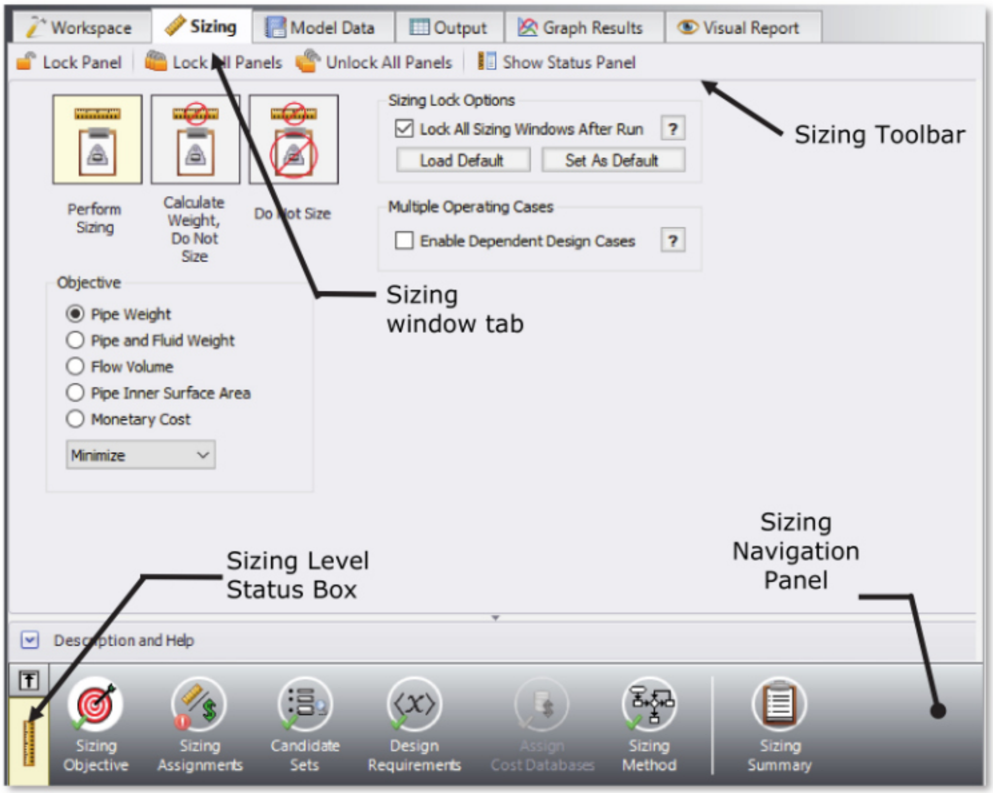

Figure 2.3 Sizing window layout identifying common features

Similar to the Checklist, each panel button contains either a green checkmark or red circle which denotes the completion status of that panel. If the minimum required information is present to run the model, the symbol will be green, whereas the red symbol represents incomplete input. The amount of information required will vary based on whether the sizing is set to Perform Sizing, Calculate Weight/Do Not Size, or Do Not Size. A detailed summary of the items which have been completed and the items which are still incomplete can be seen in the Status Panel.

The type of sizing calculation being performed, also called the Sizing Level, can always be seen on the Sizing Level Status Box on the left of the Sizing Navigation Panel as shown in Figure 2.3. Clicking this box will bring you to the Sizing Objective panel, where the calculation type can be changed. The choice of continuous or discrete sizing is selected on the Sizing Method panel, which is discussed later.

Note that some panels will always be shown as complete since the model can be run without any additional information entered on them, such as the Design Requirements panel. However, in order to find the best system design, it will often be necessary to enter more than the minimum information required by the Solver.

The Lock Panel toggle located on the Sizing Toolbar prevents changes to the current panel when it is enabled. This is primarily useful to prevent editing once a scenario has been run, since any changes that are made to a scenario which has output will cause all output to be erased. By default, all panels will lock after a sizing run is completed, requiring panels to be unlocked before any changes can be made. This setting can be changed on the Sizing Objective panel. All panels can be locked or unlocked simultaneously by using the Lock/Unlock All Panels buttons on the Sizing Toolbar.

A. Sizing objective

The Sizing Objective panel will be displayed by default when the Sizing window is first opened, as shown in Figure 2.3. This panel is used to select the option for calculation and to set the desired Objective.

The first option is "Perform Sizing", which sets up the model to perform the automated sizing calculation. While it is typically desired to run the sizing calculations, the other two selections can be useful in certain cases.

The second option is "Calculate Weight, Do Not Size". This option is useful to find the cost of the initial design, or for troubleshooting. If the objective is set to use monetary cost, this option is similar to running AFT Fathom with the Cost Calculation option turned on.

The last option is "Do Not Size". This is equivalent to performing a regular AFT Fathom analysis without needing to disable the ANS module and potentially lose the entered Sizing settings. This can also be useful to check the feasibility of the initial design before sizing.

- **Select "Perform Sizing"** to begin configuring the sizing run.

The next step is to set a Sizing Objective, which can be monetary cost, or a non-monetary cost such as pipe weight or flow volume. It is easier to perform a non-monetary sizing, since all of the geometry and material information necessary to calculate the pipe weight/volume is already contained in the pipe material databases. A monetary cost objective would require cost information to be obtained and entered into cost databases. For many systems, sizing the system using one of the simpler non-monetary objective options provides a sufficient approximation for minimized cost. In this case, we will be performing a minimization of pipe weight.

- **For the Objective choose "Pipe Weight"** and select the Minimize option from the drop-down list.

B. Sizing assignments

On the Sizing Navigation Panel select the Sizing Assignments button. The Sizing Assignments panel allows the user to define what will be sized in the model, and what will be included in the cost calculation without being sized (in this case, what will be included in the weight, but will not have its weight minimized). Common Size Groups for pipes can be created on this panel as well.

In the Sizing Assignments panel the table can be used to select various options to either “Automatically Size”, or “Do Not Size” each pipe.

If an “Automatically Size” option is selected, the ANS module will treat the pipe diameter as a variable and vary it according to certain criteria that will be discussed shortly.

In a new system, typically all pipes will be desired to be sized and included in the cost calculation (in this case, the cost is being calculated in terms of weight). If you are instead analyzing the possible replacement of existing pipes, it may be better to choose “Include in Weight if Size Changes”. This will allow the weight to only be calculated for pipes if they change size, since using the existing pipes will incur no new costs.

If “Do Not Size” is selected, the pipe will retain the settings currently set in the Workspace. Why would one choose to not size a pipe? There could be a number of reasons, but one good reason is that the pipe represents a pipe in an existing system and the design does not allow the replacement of that pipe with a new one. Therefore, its diameter is fixed, and sizing the pipe would be incorrect.

Another reason may be if a certain size is necessary for the design due to certain requirements, in which case the pipe cost can be included without sizing the pipe by choosing “Include in Weight”.

This model is a new system, so all pipes will be sized and included in the cost (weight).

- **Select "Always Include in Weight"** next to each of the pipes.

For this system it is required that both pipes be the same size. We will need to add both pipes to a Common Size Group to specify this as follows:

1. Click the "New" button above Pipe Grouping, and specify a name (e.g. "Main Pipes")
2. A new section will now appear with the "Main Pipes" group listed under Common Size Groups. Add both pipes to this group by clicking the corresponding radio buttons (Figure 2.4).

Now that the pipes are both in a Common Size Group, the ANS module will force them to have the same diameter, rather than allowing them to be varied separately.

For larger models, multiple Common Size Groups can be created as desired. Selection tools are available at the bottom of the window to help assign multiple pipes to a Common Size Group at once. Pipes can only be assigned to a group once they are set to use one of the "Automatically Size" options.

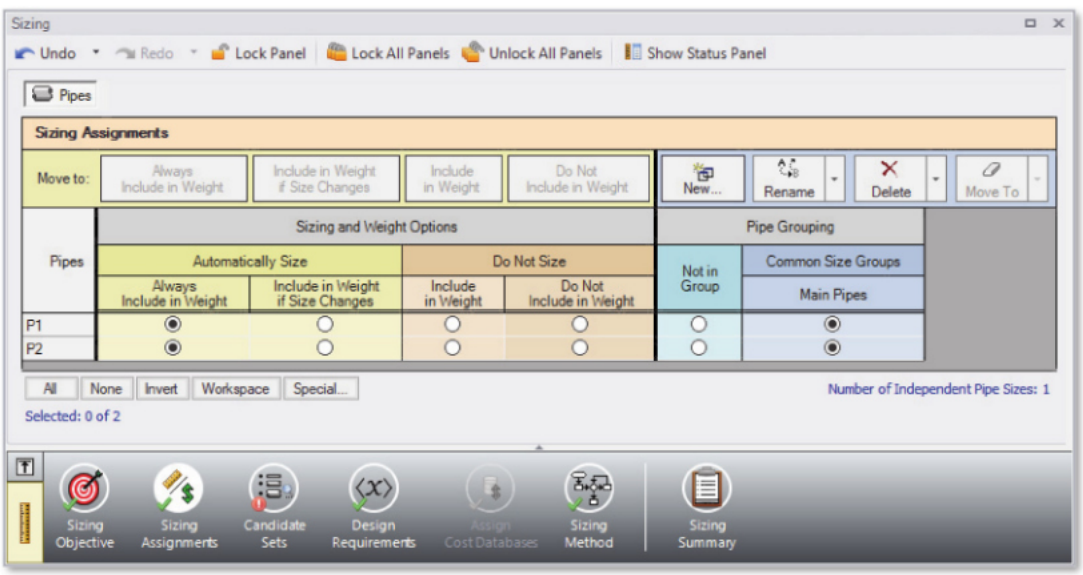

Figure 2.4 Pipes P1 and P2 settings in the Sizing Assignments panel

C. Candidate sets

Click on the Candidate Sets button to open the Candidate Sets panel.

To select a specific pipe size, the ANS module needs a list of potential sizes from which to choose. This list is called a *Candidate Set*. A specific pipe can only access one Candidate Set, but a specific Candidate Set can be accessed by any number of pipes.

So as not to limit the sizing unnecessarily, the Candidate Sets should include both smaller and larger pipes than your anticipated final size. If you make the Candidate Set too small, you may limit the ability of the ANS module to find the best sizing. It is better to make the Candidate Set too large than too small. Experience in applying the ANS module to actual systems will help you choose appropriate Candidate Sets. If after obtaining a solution you find that one or more of the sized pipes is at the extreme of the Candidate Set, a warning will appear and recommend that the defined Candidate Set be expanded.

To create a Candidate Set, do the following:

1. Under Define Candidate Sets, click the New button.
2. Give the set a name (e.g., "STD Pipes") and click OK.
3. From the drop-down list choose Steel - ANSI.
4. In the bottom of the Select Pipe Sizes window, check that the Sort option "Type, Schedule, Class" is selected.
5. In the Available Material Sizes and Types on the left, expand the STD pipe sizes list.
6. Double-click each of the sizes from 1 to 12 inches to add them to the list on the right, or use the “add” button (Figure 2.5).
7. In the Select Pipe Sizes window, click the OK button.

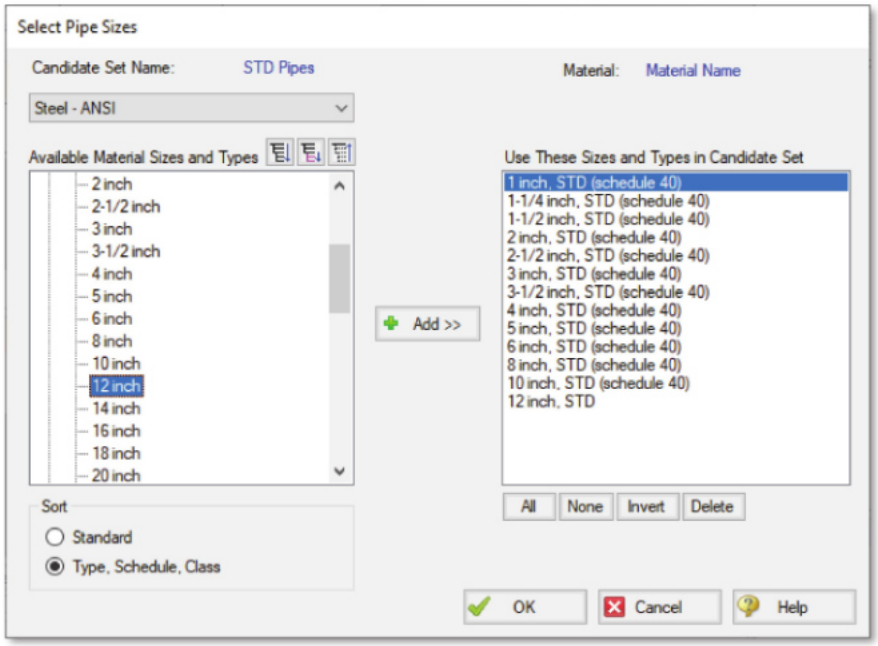

Figure 2.5 Select Pipe Sizes window with STD Steel-ANSI pipe sizes added for 1”-12”

The "STD Pipes" set will now appear. However, we still need to define which pipes will use this Candidate Set during the automated sizing. By necessity, a Common Size Group will use one Candidate Set for all pipes within the group, since all pipes in the group must be the same size, so there is only one item to assign the set to.

➢ **Under Assign Candidate Sets to Pipes, set the "Main Pipes" Common Size Group** to use the "STD Pipes" Candidate Set. The Candidate Sets are now fully defined and assigned to the appropriate pipes, as can be seen in Figure 2.6.

Once a Candidate Set is assigned, the list of available pipe sizes on the Pipe Properties window in the Workspace is restricted to pipe sizes in that Candidate Set. In Figure 2.7 you can see the area normally described as "Size" is now described as "Size (From Common Size Group)". If the initial pipe sizes defined in the pipes were not included in the assigned Candidate Set, the ANS module will change the pipes in the Workspace to a pipe size from the defined Candidate Set.

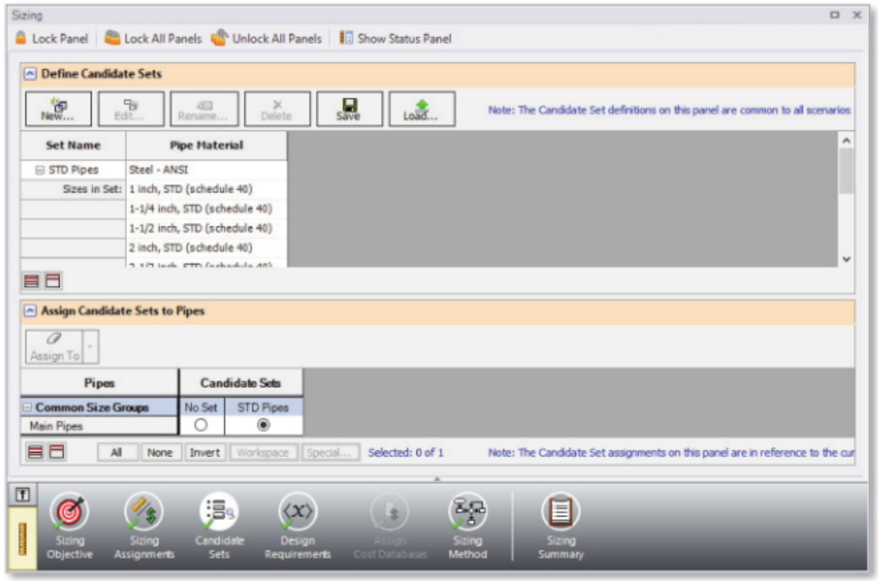

Figure 2.6 Candidate Sets panel fully defined for the model

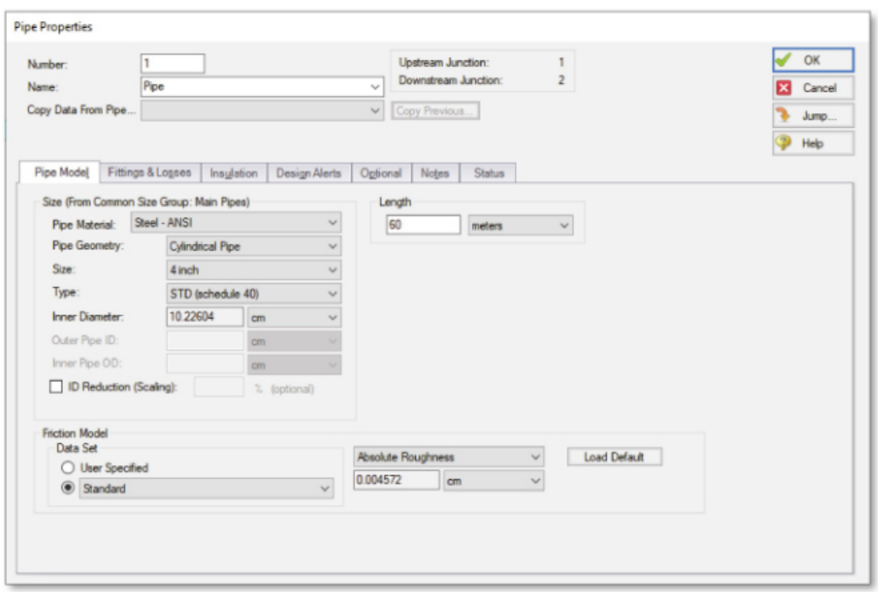

Figure 2.7 Pipe Properties Window after having a Candidate Set assigned to it – pipe size selections are limited to those in the Common Size Group

D. Design requirements

Select the Design Requirements button. This panel is used to define restrictions on the final solution by applying Design Requirements to the system.

For this model we only have one Design Requirement, which is for the minimum pressure drop across the Control Valve. To define this requirement:

1. Select the Control Valves button at the top of the window.
2. Click the New button under Define Control Valve Design Requirements.
3. Enter a name when prompted (e.g., "Min Pressure Drop").
4. Next to "Min Pressure Drop" in the table, select Pressure Drop Static as the Parameter.
5. Choose Minimum for Max/Min, and enter 82 kPa

Now that the Design Requirement is defined, it needs to be assigned to the appropriate junction.

➢ **Check the box next to the Control Valve Junction J2** in the "Assign Design Requirements to Control Valves" section. The Design Requirements panel should now appear as shown in Figure 2.8.

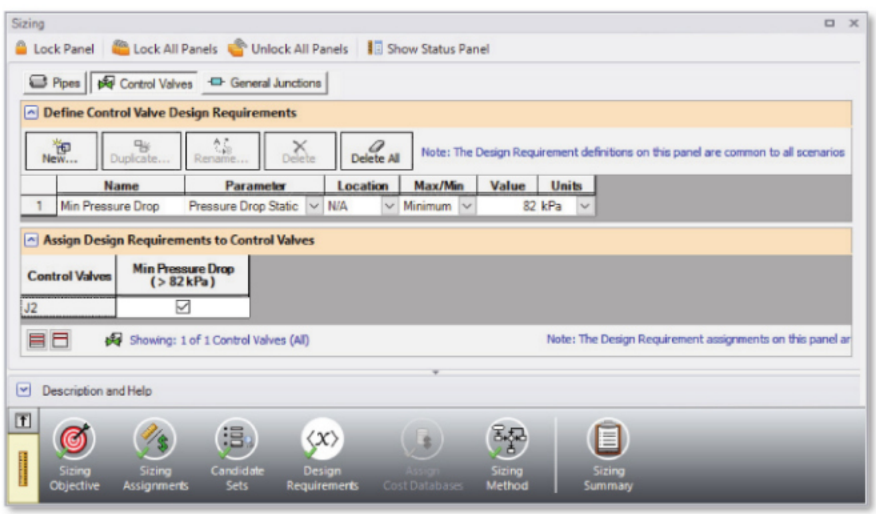

Figure 2.8 Minimum pressure drop requirement defined for the control valve

Note: It is strongly recommended that all control valves have a Design Requirement specified for the minimum pressure drop/head, or the maximum Cv/percent open at the valve. If no Design Requirements are applied, the ANS module will allow the control valve to control to any pressure required to meet the control setpoint, even if this requires the control valve to add pressure to the system for design purposes. To avoid this behavior in the final solution, a Design Requirement should be applied.

E. Assign cost databases

This panel is only used to assign the necessary monetary cost information when Monetary Cost is chosen as part of the Sizing Objective. In this case this button is disabled since we are minimizing pipe weight.

F. Sizing method

Select the Sizing Method button from the Sizing Navigation Panel.

The Sizing Method panel defines the calculation methods to be used for sizing the system. The User has the option to select whether discrete or continuous sizing will be used, and which method will be applied.

If Continuous Sizing is selected, the ANS module will use the minimum and maximum Candidate Set sizes as boundaries. It will then calculate the ideal hydraulic diameter for the pipes being sized, which will likely not match any of the possible chosen commercial sizes. While this is not useful as a final solution, this may be helpful as a baseline to check the final solution using the provided discrete methods. For this model, make sure Discrete Sizing is selected.

For the Search Method, the ideal method will often change based on the number of independent pipe sizes (number of pipes not in group & Common Size Groups in sizing), number of Design Requirements, and feasibility of the initial system design. The Help file provides more information on the strengths and weaknesses of each method. It is generally recommended to run the sizing with more than one method, as it is often not obvious which method will be most effective for each system.

For a simple model such as this one, the MMFD or SQP method should be appropriate since there is only one Design Requirement, and only one pipe size is being varied. Choose the default “Modified Method of Feasible Directions (MMFD)”.

Step 5. Run the automated sizing

We are now in a position to run the automated sizing. Before doing so, take a moment to consider what this model is trying to accomplish. The pipe P1 and P2 sizes will be selected together from the "STD Pipes" candidate set such that their weight is minimized while still obtaining a minimum 82 kPa pressure drop across the control valve.

To begin sizing the system select Run from the Analysis menu. While the model is running, the Solution Progress window shows the "Sizing Calls to Solver". This is how many times a complete hydraulic analysis was run.

The Solver also displays the Current Cost and Best Feasible Cost, which will display the last calculated value for the cost, as well as the Best Feasible Cost which has been found so far (Figure 2.9). The Solver will continue to iterate using the defined method to find a global minimum. For most methods, the Solver will first perform a continuous sizing, then perform discrete sizing based on the continuous solution, though this is not always the case.

Note: For complex systems using the Genetic Algorithm Sizing Method, the solution can be paused and accepted at any time by using the Pause button, then selecting “Accept Sizing” under Other Actions. This allows the user to accept the best current solution, rather than continuing to search for the global minimum.

When the sizing has completed, click the Output button to display the results.

Step 6. Review automated sizing results

The Cost Report tab in the General Output section shows a total weight of 5,099 kg, while each pipe has a weight of 2550 kg (Figure 2.10). This makes sense since the pipes have equivalent length and a common diameter due to the fact that they are in a Common Size Group.

The Sizing tab in the Pipe Output section shows the ideal pipe size was found to be 8 inch for the pipes when sized together.

The CV Design Requirements tab shows that the 82 kPa minimum pressure drop is satisfied - the pressure drop for 8 inch pipe was 86.11 kPa. Note that the Design Requirement result is highlighted in blue, indicating that the Design Requirement was active during the continuous solution, but the discrete solution was outside of a certain tolerance from the continuous solution. Yellow highlighting will be used if the Design Requirement is active in the final solution, and the discrete solution is within a close tolerance to the continuous solution.

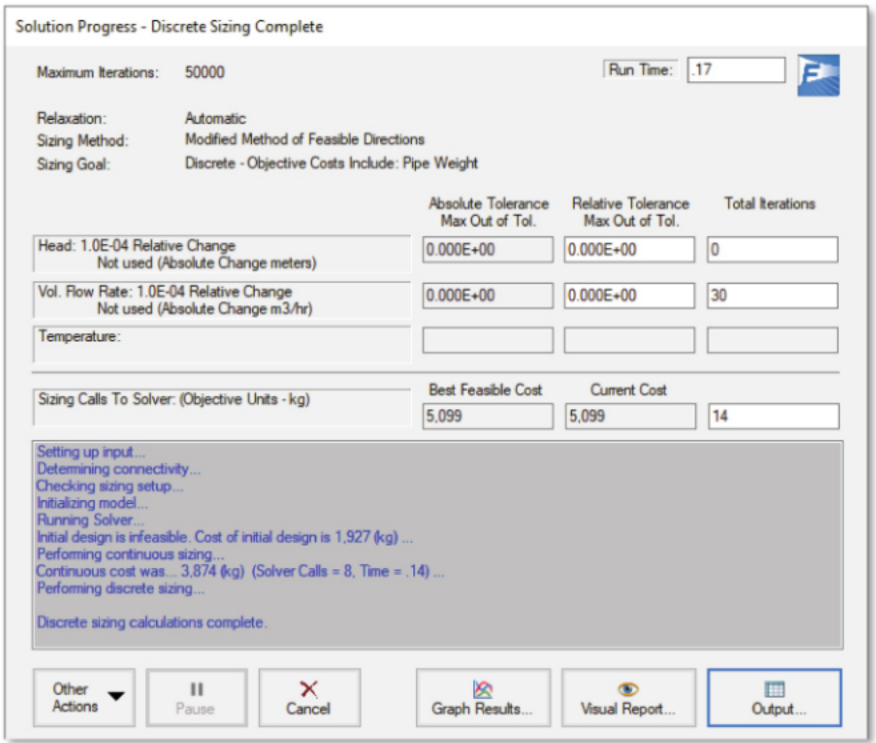

Figure 2.9 The Solution Progress window shows the progress of the AFT Fathom Solver and the ANS module

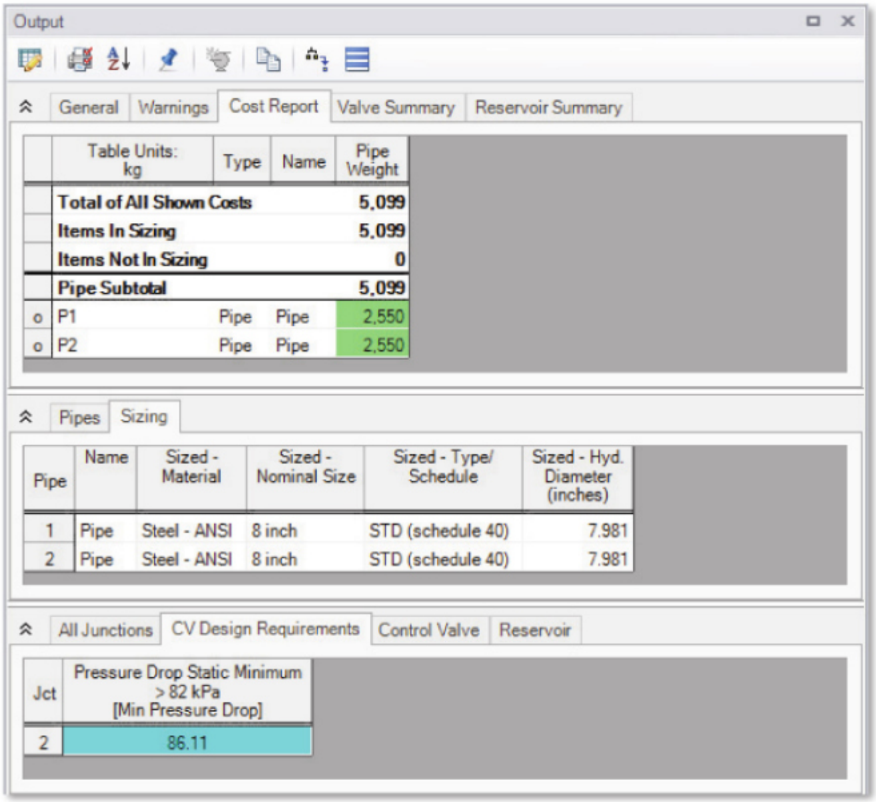

Figure 2.10 The Output window shows the hydraulic results of the sized system, plus the sizing results. The blue color for the CV Design Requirement indicates this Design Requirement is "Active".

Conclusions

This example demonstrates the automated sizing capabilities of the ANS module for a simple system with a single Design Requirement. Sizing for non-monetary objectives such as pipe weight is fast and easy to implement.

CHAPTER 3

Initial and Life Cycle Cost Sizing

This example demonstrates some key features by using the ANS module to size a cooling water system for cost.

Topics covered

- How to connect and use existing engineering and cost databases
- Sizing for Initial or Life Cycle Cost and using Initial Cost Limits
- Process to size a pump, and sizing piping for the chosen pump
- Interpreting Cost Reports

Required knowledge

This example assumes that the user has some familiarity with AFT Fathom and the ANS module such as placing junctions, connecting pipes, entering pipe and junction properties, and creating and using Candidate Sets and Design Requirements. Refer to the Weight Sizing Example in Chapter 2 for more information on these topics.

Model files

This example uses the following files, which are installed in the Examples folder as part of the AFT Fathom installation:

- *Metric - Sizing Cooling System – ANS.fth* - AFT Fathom model file
- *Cooling System ANS.dat* - component engineering database
- *Cooling System ANS.cst* - cost database associated with “Cooling System ANS.dat”
- *STD Steel Pipe 1in-36in.cst* - cost database for STD steel

Problem statement

This example uses an existing model to investigate three automated sizing cases:

1. Size system for *initial cost* with a 10-year system life
2. Size system for *life cycle cost* with a 10-year system life
3. Size system for *life cycle cost* with an initial cost limit for a 10-year system life

Step 1. Start AFT Fathom

From the Start Menu, choose AFT Products and AFT Fathom.

Enable the ANS module from the Startup Menu by checking the box next to the ANS module. Alternatively, the ANS module can be activated from the Add-on Modules button at the bottom of the Quick Access Panel, or from the Activate Modules option in the Tools menu.

Step 2. Open model file

For this example, we will be starting from a pre-built model file that is fully defined for a normal AFT Fathom run. We will add automated sizing settings to find a more cost-effective design. From either the startup screen or the File menu, browse to the model file name shown above and copy it to a new location. The Workspace should appear as shown in Figure 3.1.

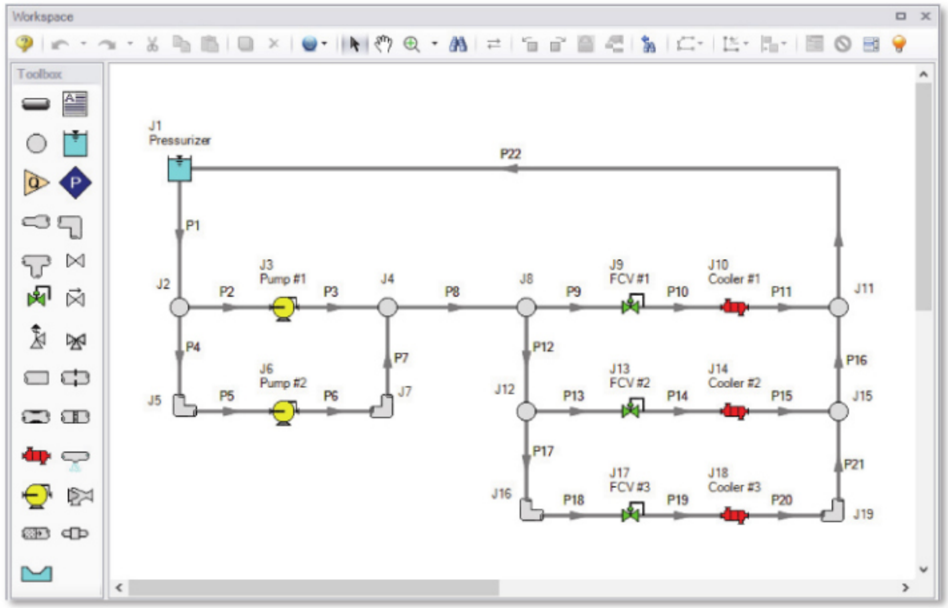

Figure 3.1 Cooling System example model

Sizing systems with pumps

A centrifugal pump can be modeled with either the Pump Curve or as a fixed flow rate or pressure/head as the Sizing option. Generally if a specific pump has been identified, the Pump Curve type would be chosen, whereas the Sizing option is useful during the selection stage in order to identify the pumping requirements for the system. In some cases, even though the specific pump has not been chosen, several candidate pumps are available. For this third case it would be best to model each candidate pump with a pump curve using separate scenarios for each pump.

Pump model in this system

The pumps in our cooling water case are both set as Sizing at fixed flows of 680 m3/hr. In order to allow the pumps to be defined as fixed flows, the flow control valve at J17 has been defined at a fixed pressure drop of 35 kPa. This model thus represents a first cut model where, based on the first cut results, the two pumps will become actual pumps with pump curves, and control valve J17 will become a flow control valve controlling to 450 m3/hr, similar to control valves J9 and J13.

As already stated, when a pump is modeled as a fixed flow, it is not a specific pump from a specific manufacturer. Thus, the costs for the pump can only be approximated. To a first approximation, it should be possible to estimate the non-recurring cost (i.e., material and installation cost) for the pump as a function of power requirements. For instance, a typical one kilowatt pump (of specific configuration and materials of construction for a given flowrate) may cost $2500, and a ten kilowatt may cost $5000. Other typical costs for different power requirements can be approximated. The actual cost for the pump will, of course, highly depend on the application. As AFT Fathom evaluates different combinations of pipe sizes, each combination will require a certain power from the pump. With a cost assigned to this power, the ANS module can account for this over the life of the system. Later in this chapter, we will look at the costs for the pumps in our example cooling water network.

In addition to non-recurring costs, recurring costs can also be estimated. Specifically, the cost of the power used by the pump over a period of time (which the ANS module calls the "system life") can be determined. All AFT Fathom needs is an overall pump efficiency to determine the actual power from the ideal power. Again, since we do not have a specific pump selected yet, the efficiency can only be approximated. The ANS module calls this the "nominal efficiency”. In addition, users can provide a "nominal NPSHR".

A step-by-step method of pump selection proceeds in two phases. The steps are outlined in the Help System.

Step 3. Review model settings

The model is already defined, but we need to review and complete the sizing settings before running the analysis. In the Analysis menu check that Automated Sizing is set to Network, then go to the Sizing window by clicking the tab.

A. Sizing objective

The Sizing Objective panel should be displayed by default.

To begin we will first need to choose the calculation option, so select “Perform Sizing”.

As explained previously, a non-monetary parameter such as weight could be chosen to simplify the sizing. However, there are a few downsides to this method, as this does not allow one to include pump and other junction initial costs for the sizing. Additionally, recurring costs cannot be calculated using non-monetary cost. To more thoroughly size the pumps in this system we will need to minimize monetary cost directly.

- **Select Monetary Cost as the Objective** and select Minimize from the drop-down list.

With the Monetary Cost selected, the options to minimize monetary cost will appear displayed in a table, along with several options to the side that will activate depending on the cost types being analyzed. Several common analysis types can be selected in the list box above the table to automatically configure the table.

- **From the list box choose "Size for Initial Cost, Show Energy Costs"**. This will set the table to include material and installation costs in the Sizing Objective and will calculate the energy costs without including them in the Objective, as can be seen in Figure 3.2. This will allow us to size for the initial costs and include the energy costs for comparison when we later size the system for life cycle cost (initial costs and recurring costs combined).

Since the energy costs are included in the cost calculation, users must provide a System Life and, optionally, interest and inflation rates to calculate the present value of the recurring costs.

- **Enter 10 years for the System Life**, with 0% for the interest and inflation rates.

The source of the energy costs must also be defined. Simple energy costs can be entered here, or it can be specified that energy costs come from Energy Cost Databases, which would need to be added on the Assign Cost Databases panel. An Energy Cost Database allows variable energy costs to be used to account for varying prices during different times of day, different seasons, etc.

- **Choose "Use this Energy Cost Information"**, with a cost of 0.11 U.S. Dollars per kW-hr. Note this assumes the pump will run all day, every day, for the entire 10 years.

The Sizing Objective panel should now appear as shown in Figure 3.2.

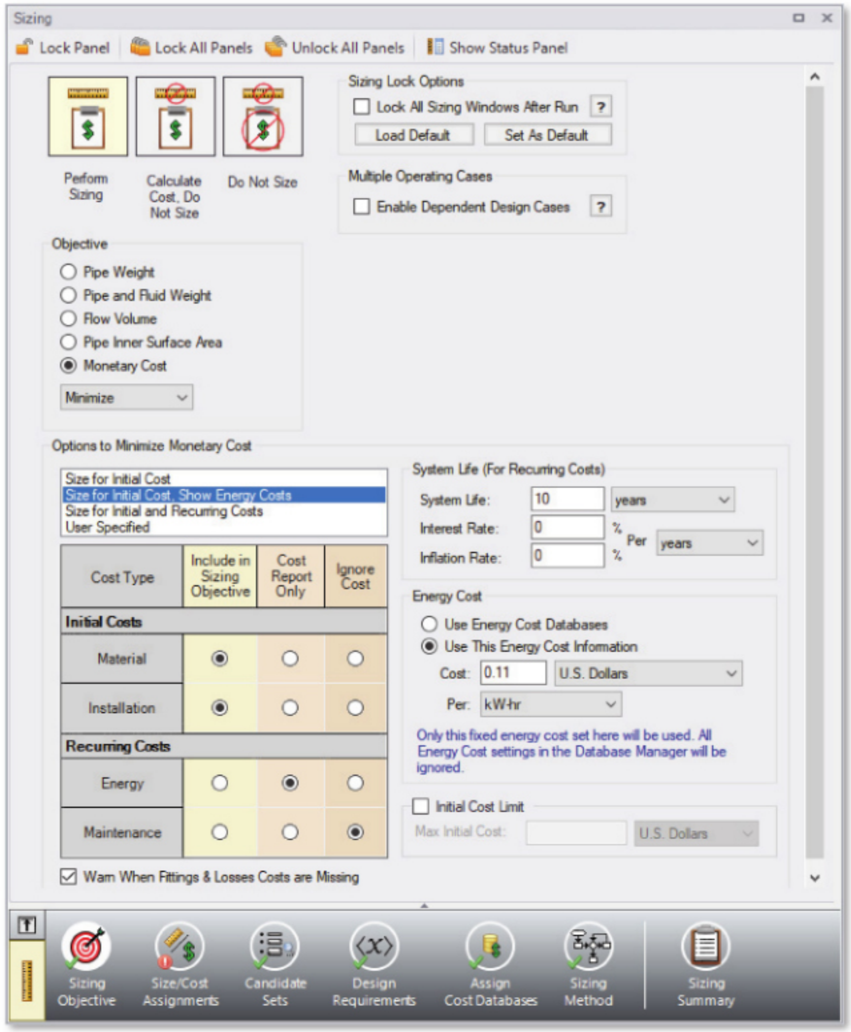

Figure 3.2 Sizing Objective panel setup for an Initial Cost analysis

B. Size/Cost assignments

On the Sizing Navigation Panel select the Size/Cost Assignments button. For this example we are sizing both the pipes and pumps for a new system, so we will need to calculate and minimize cost for all related components in the model.

- **Select the Pipes button** and set all pipes to “Always Include in Cost”. See Figure 3.3.

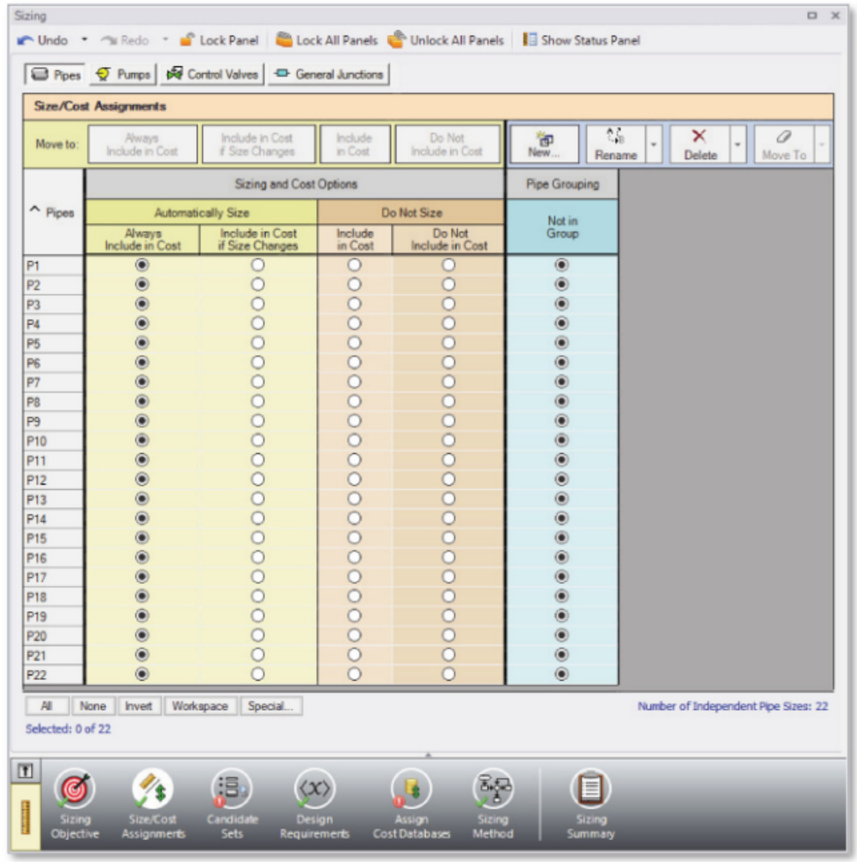

Figure 3.3 Size/Cost Assignments panel with all pipes included in sizing

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Note: The selection tools below the Size and Cost Options table and the Move To buttons above the table can be used to quickly select and assign large groups of pipes simultaneously.

To decrease the run time and reduce complexity, as well as to enforce some design uniformity, it is useful to create Common Size Groups to link the pipes in different sections of the model.

For example, if all the 22 pipes are selected to be "Not In Group", then 22 unique pipe sizes will be selected by the automatic sizing engine. That could potentially mean, for example, different suction pipe diameters in pipes 2 and 5. A similar thing would happen for discharge pipe diameters. If one wanted the suction pipes 2 and 5 to be sized to the same diameter, one would group them into a Common Size Group. To see how this works, in this model all suction and discharge piping for both pumps will be put into a Common Size Group. What this means is that there will be one unique diameter chosen for this group of pipes, rather than potentially six different diameters.

For this system we will define 5 groups to be sized in this model. To set the groups, it is normal to select pipes which must have the same size due to their placement relative to other pipes and junctions, such as pipes at the entrance and exit of valves. In Figure 3.4 we have identified three main sections of the model to begin grouping the pipes.

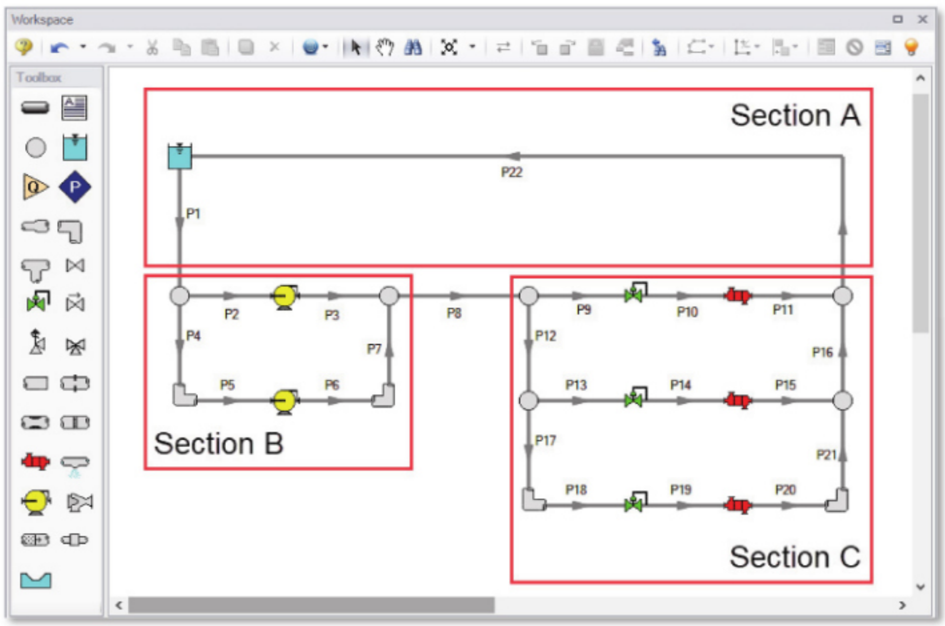


Figure 3.4 Cooling System model with sections identified to make groups

First let's create a "Pressurizer" size group for pipes P1 and P22, which are outlined as section A. The inlet and outlet lines to the pressurizer would logically be identical, though they will not necessarily share a size with other piping in the model.

➢ **Click the "New" button** above the Pipe Grouping section to create the group, and name it "Pressurizer". Select the radio buttons under the "Pressurizer" heading next to P1 and P22 to add them to the group.

Alternatively, the pipes can be selected in the Workspace, then moved to a group by right-clicking the Workspace and selecting the corresponding option from the menu.

Now let's repeat this process for the piping in section B around the pumps and control valves. Since these units are operating in parallel with identical flow rates, we would again expect the pipes in this section to have a common size. Similar to above, create a new group called "Pump Station", and add pipes P2-P7 outlined in Figure 3.4 to the new group.

Lastly consider section C, the piping near the coolers. In this case we have three coolers in parallel, with several header pipes connecting the cooler piping segments. We would expect the piping at the coolers and control valves to have a common size, but the header piping (P12, P16, P17, P21) would likely be larger, so we will group them separately. Create three common size groups as follows:

1. "Cooler Piping" group with pipes P9-P11, P13-P15, and P18-P20
2. "Clr Headers 1" with pipes P12 and P16
3. "Clr Headers 2" with P17 and P21

The completed Size/Cost Assignments can be seen in Figure 3.5, with only pipe P8 left not in a group.

Note: The number of Independent Pipe Sizes in the model can be seen in the bottom right of the Size/Cost Assignments panel, and denotes the number of pipe sizes being independently varied (i.e. the number of Common Size Groups, plus the sized pipes not in a group). This information is useful for choosing Sizing Methods and troubleshooting purposes.

- **Click the Pumps button** to switch to the Pump Size/Cost Assignments. Select the option to "Include in Cost Report and Sizing" for both pumps so that the ANS module will size the pumps along with the pipes as shown in Figure 3.6.

Similar to the Common Size Groups for pipes, Pumps can be placed into Maximum Cost Groups based on monetary cost. If pump costs are added to a Maximum Cost Group, the ANS module will determine the pump in the group with the maximum costs and set all pumps in the group to the same costs as that pump. In this case we do not want to group the pumps, so nothing else needs to be added for the pumps.

We also want to include the Bend junctions in the sizing for this model.

➢ **Click the General Junctions button** and change each of the Bends (J5, J7, J16, J19) to "Include in Cost Report and Sizing" (Figure 3.7). We are now finished with the Size/Cost Assignments.

Note: Pipes in the Size/Cost Assignments table can be sorted by Common Size Group instead of sorting by number by clicking on the "Pipe Grouping" header. Clicking on the header for a particular group will sort the pipes in that specific group to the top of the window.

Now go to the Workspace window. It is possible to inspect the Common Size Groups in the model by coloring the pipes. From the View menu, select All under Color Common Size Groups. The model should appear as shown in Figure 3.8. It is also possible to color a specific Common Size Group from the Size/Cost Assignments panel by right-clicking on the header of the desired group.

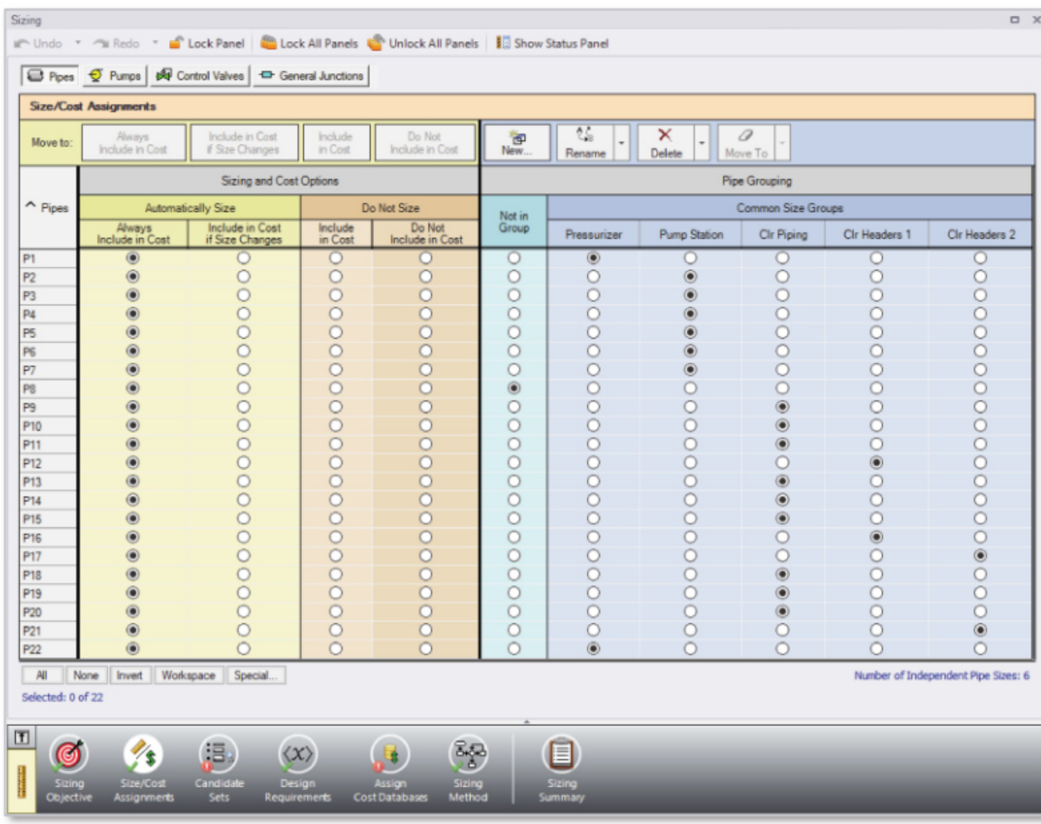


Figure 3.5 Pipe settings in the Size/Cost Assignments panel

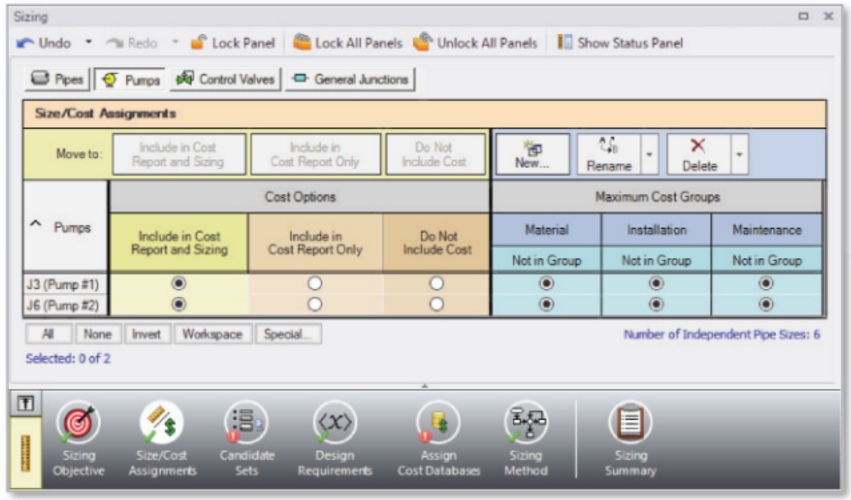


Figure 3.6 Pump settings in the Size/Cost Assignments panel

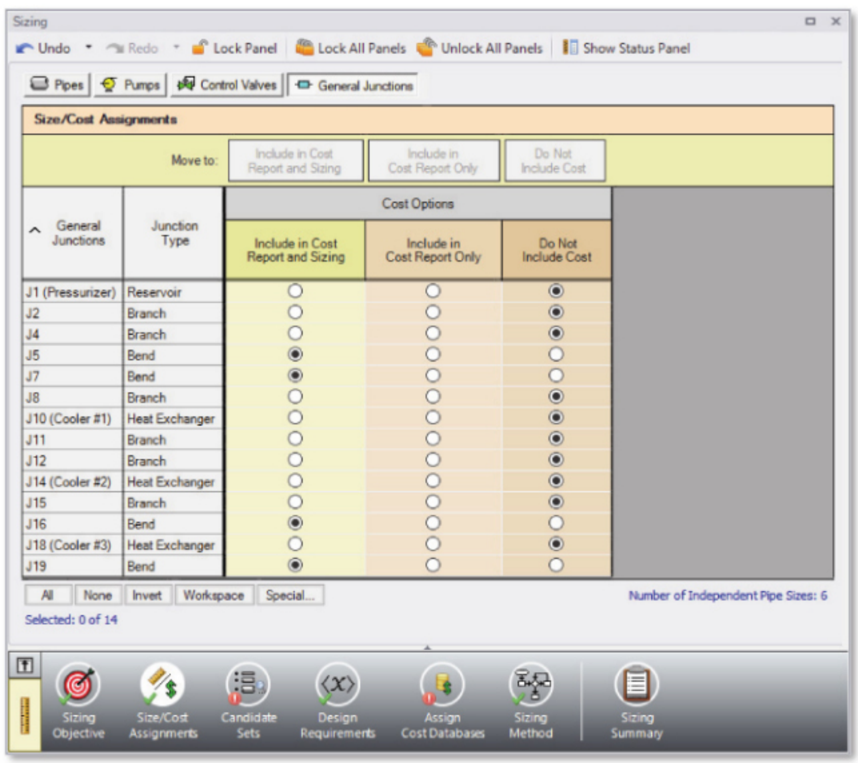


Figure 3.7 Junctions tab in the Size/Cost Assignments panel

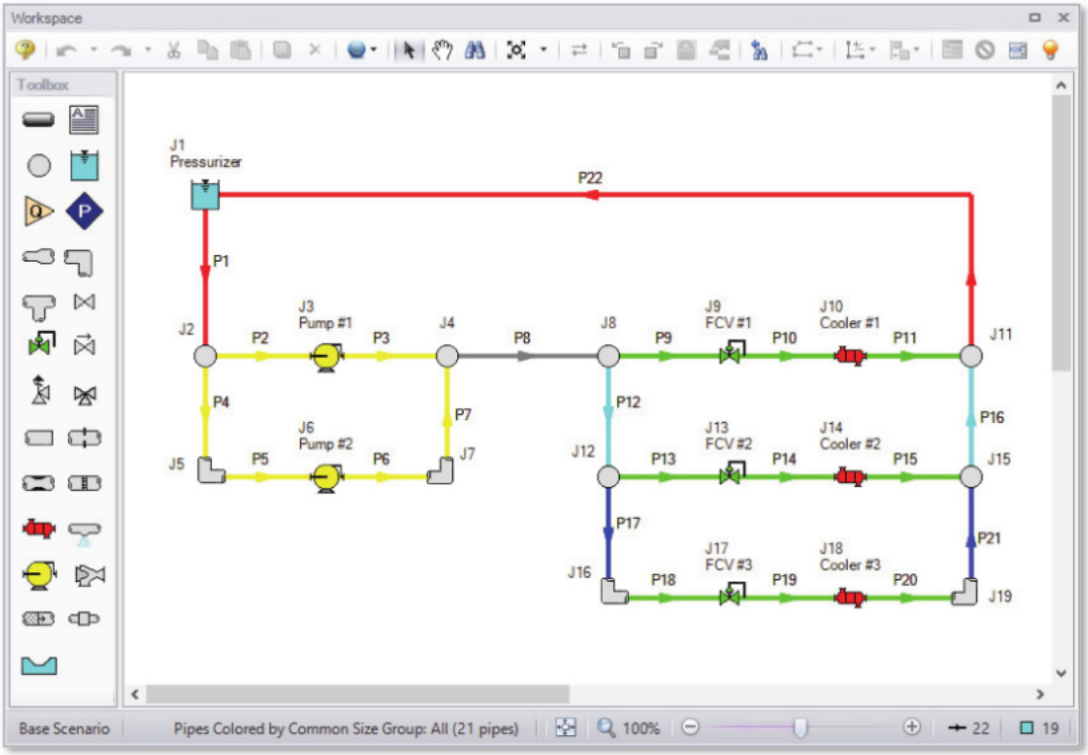


Figure 3.8 Common Size Groups shown by color in the Workspace

C. Candidate sets

Click on the Candidate Sets button to open the Candidate Sets panel.

You should see that the STD Steel 1”-36" Candidate Set has already been created for the model. Expand the set by clicking the “+” sign next to its name to see that the pipe sizes from 1" to 36" have been added for STD Steel - ANSI pipe.

In the bottom section of the window, check that each of the Common Size Groups and pipe P8 have been assigned to use the existing Candidate Set. The window should appear as shown in Figure 3.9.

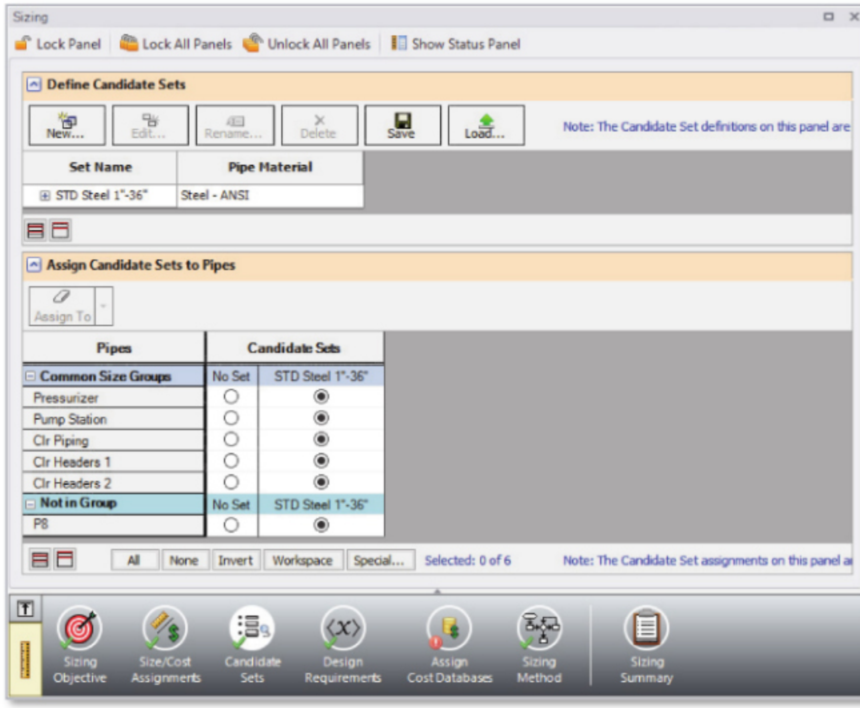


Figure 3.9 Candidate Sets panel fully defined for the model

D. Design requirements

Select the Design Requirements button.

Design Requirements can be applied to both sized and unsized pipes and junctions. Design Requirements are design limitations on certain parameters. For example, there may be a Design Requirement that the velocity cannot exceed 5 meters/sec. As the ANS module evaluates different pipe sizes, if a particular size results in a velocity greater than 5 meters/sec, that pipe size is rejected because it causes a Design Requirement violation.

When a pipe that is not sized has a Design Requirement, it means that the sized pipe sizes cannot be such that it violates the Design Requirement for the unsized pipe. There can be multiple Design Requirements defined and applied to a pipe, junction or group. For instance, in addition to a maximum velocity limit, a maximum pressure limit may exist. Individual pipes/junctions in a Common Size Group can have different Design Requirements applied.

For this model we have multiple requirements for the system:

1. All pipes have a maximum velocity of 3.7 meters/sec
2. All pipes have a minimum static pressure requirement of 100 kPa
3. All heat exchangers must receive a minimum flow of 430 m3/hr
4. All pumps must have an NPSHA at least 3 meters above the NPSHR (for this system the nominal NPSHR is 15 meters)
5. All control valves must have a minimum pressure drop of 35 kPa

Define and assign the first two requirements listed above as Pipe Design Requirements as shown in Figure 3.10, and item 4 as a Pump Design Requirement as shown in Figure 3.11. Notice that we have accounted for the minimum flow requirement in this system by using flow control valves at each of the heat exchangers. By using assigned flow pumps and flow control valves at the heat exchangers we have incorporated the necessary flow rate as a boundary condition, so we do not need to apply a Design Requirement to account for this item.

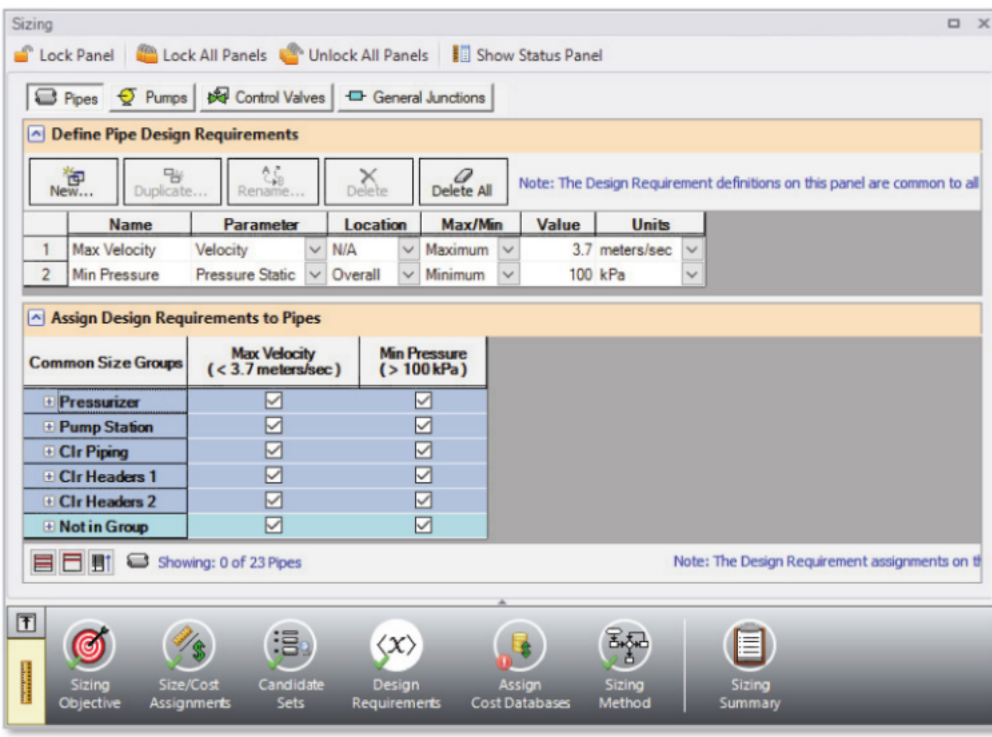


Figure 3.10 Design Requirements panel for pipes

For flow control valves J9 and J13 define and apply the minimum pressure drop requirement in the Control Valves section as shown in Figure 3.12. Note that for pump sizing purposes as discussed earlier control valve J17 has been defined as a Constant Pressure Drop valve, so the pressure drop Design Requirement does not need to be applied to this valve.

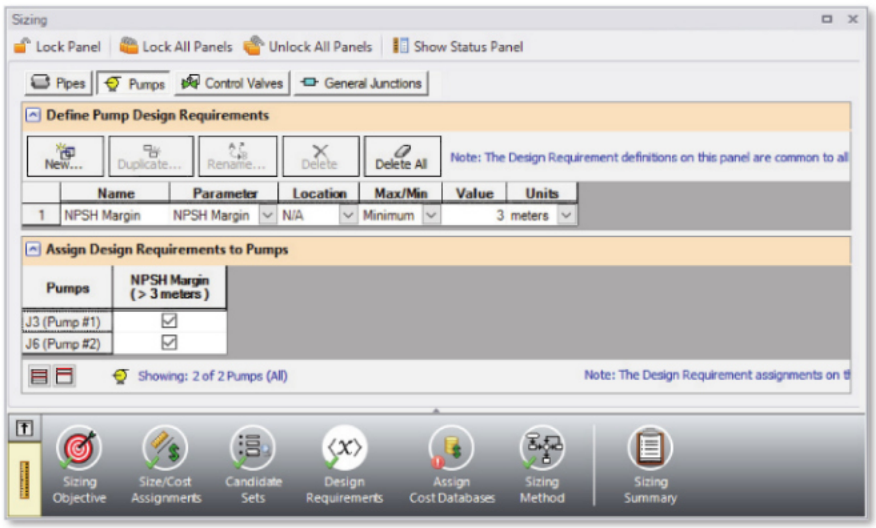


Figure 3.11 Design Requirements panel for pumps

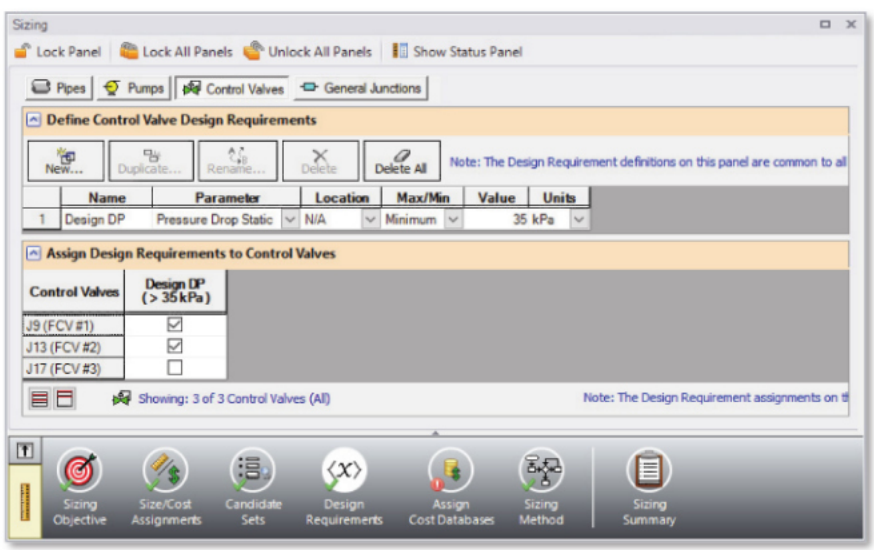


Figure 3.12 Design Requirements panel for control valves

E. Assign cost databases

Select the Assign Cost Databases button. The material and installation costs for all pipes and junctions being sized must be entered into cost databases, which are then assigned to the appropriate components here. The cost databases needed for this cooling water example have been pre-built, and just need to be accessed.

The Database Manager (opened from the Database Manager button or the Database menu) shows all of the available and connected databases. Databases can either be engineering databases or cost databases. Cost databases are always associated with an engineering database and are thus displayed subordinate to an engineering database in the database lists.

Here we will summarize some key aspects of databases:

- Cost information for a pipe system component is accessed from a cost database. Cost database items are based on corresponding items in an engineering database. (The engineering databases also include engineering information such as pipe diameters, hydraulic loss factors, etc.)
- To access a cost for a particular pipe or junction in a model, that pipe or junction must be based on items in an engineering database. Moreover, that database must be *connected* to the model, and to the specific item in the model.
- There can be multiple cost databases associated with and connected to an engineering database. This makes it easier to manage costs of items. If multiple cost databases are assigned to a Candidate Set, then the costs will be stacked to find a cumulative cost.

➢ **Open the Database Manager** by clicking the Database Manager button. The AFT DEFAULT INTERNAL DATABASE, AFT FATHOM LOCAL USER DATABASE, and PIPE MATERIAL DATABASES should be available and connected by default. In the top section of the window, Available Databases will be shown based on databases that AFT Fathom has identified on your machine. The default connected databases will be visible here, and additional databases may be visible from other example files, or from databases previously built and used on your machine.

This example uses one user-defined engineering database, “Cooling System ANS.dat”, which contains the data for the pumps and bends. There are also two cost databases, “Cooling System ANS.cst” and “STD

Steel Pipe 1in-36in.cst", which contain the cost data for the junctions and the pipe materials, respectively. "Cooling System ANS.cst" was built off of the engineering database "Cooling System ANS.dat", and "STD Steel Pipe 1in-36in.cst" was built off of the default PIPE MATERIAL DATABASE. To connect these databases, do the following:

1. Click the button to "Edit Available List" and select "Add Engineering Database".
2. Browse to the AFT Fathom 11 Examples folder (located by default in C:\AFT Products\AFT Fathom 11\Examples\), and open the file titled "Cooling System ANS.dat".
3. Repeat the above steps, but choose "Add Cost Database" to browse for "Cooling System ANS.cst", then "STD Steel Pipe 1in-36in.cst".

Note that it may be possible that the model file already has the cooling system databases connected, in which case you will be notified that the database you are trying to add is already available. If the databases are available, you will simply need to connect them by selecting them from the Available Databases list at the top, then clicking the button to "Add to Connections" for each of the three databases.

Once these steps have been completed, you should now see that the new databases have been added to the Available Databases list, and have been automatically connected to the model so that they can also be seen in the Connected Databases list, as shown in Figure 3.13 for the junction databases. The junction databases appear in the Connected Databases section under the names "Cooling System ANS Junctions" and "Cooling System ANS Costs", with the cost database indented beneath the engineering database to denote that they are linked. The cost database for the pipes appears with the name "STD Steel Pipe 1"-36", and is similarly indented under the Steel-ANSI database within the standard pipe material databases.

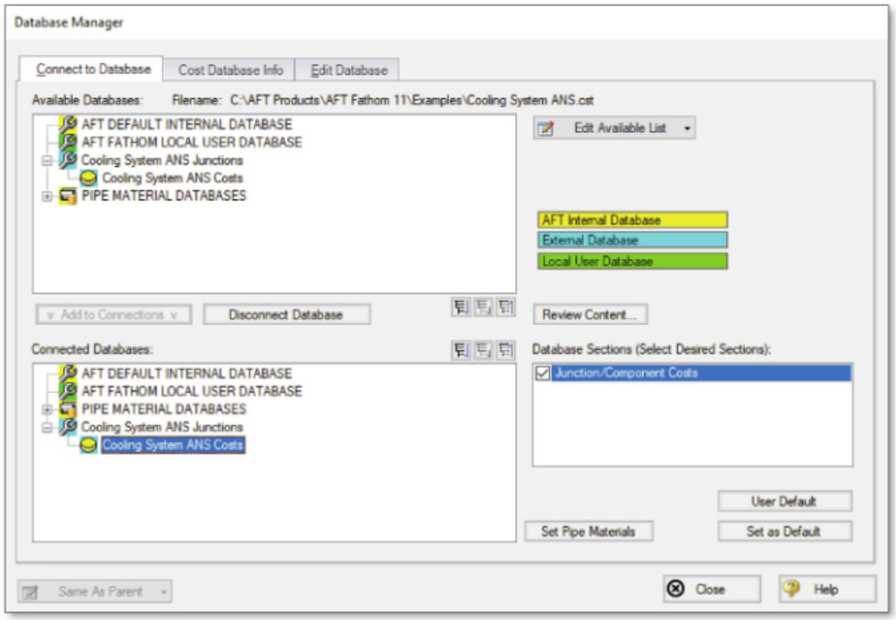


Figure 3.13 Database Manager showing the Junctions for Cooling System databases connected and available

Once you have confirmed that the necessary databases are connected as shown, click Close to exit the Database Manager.

Since we are connecting a pre-built database, we will need to take an additional step to make sure that the junctions in the Workspace are linked to the Cooling System engineering database that we added.

1. Go to the Workspace, and open Pump#1 (junction J3)
2. From the Database List, select “Pump 680 m3/hr”. None of the input should change, as this database item is identical to the existing pump. However, AFT Fathom will now recognize that this junction is connected to the engineering and cost database for this pump.
3. Repeat step 2 for Pump #2 (junction J6). Similarly, open each of the Bends (J5, J7, J16, J19), and select "Std Elbow" for each from the Database List.

We have now re-connected the junctions that will be considered for the Cost Report and sizing calculations to the engineering database. This is important, since a junction must be connected to an engineering database before cost information can be assigned to it. Let's now return to the Sizing window.

Back in the Assign Cost Databases panel for the Pipes, the "STD Steel Pipe 1"-36" cost database should be the only visible cost database, since it is the only connected database for the pipe sizes in the Candidate Set. Make sure that the database is checked to be applied for the model as shown in Figure 3.14.

- **Click on the Pumps button,** to view the cost database assignments for the Pumps. The only visible database should be the "Cooling System ANS Costs" database, as this was the only cost database connected for the associated engineering database. Make sure that the checkboxes are selected under the database name so that the cost data will be applied for each of the pumps (Figure 3.15). To review the cost data for the Bends click the General Junctions button to verify that the "Cooling System ANS Costs" is being applied to each of the bends (Figure 3.16).

F. Sizing method

Select the Sizing Method button to go to the corresponding panel.

- **Select Discrete Sizing** to complete the sizing for a set of commercial pipe sizes.

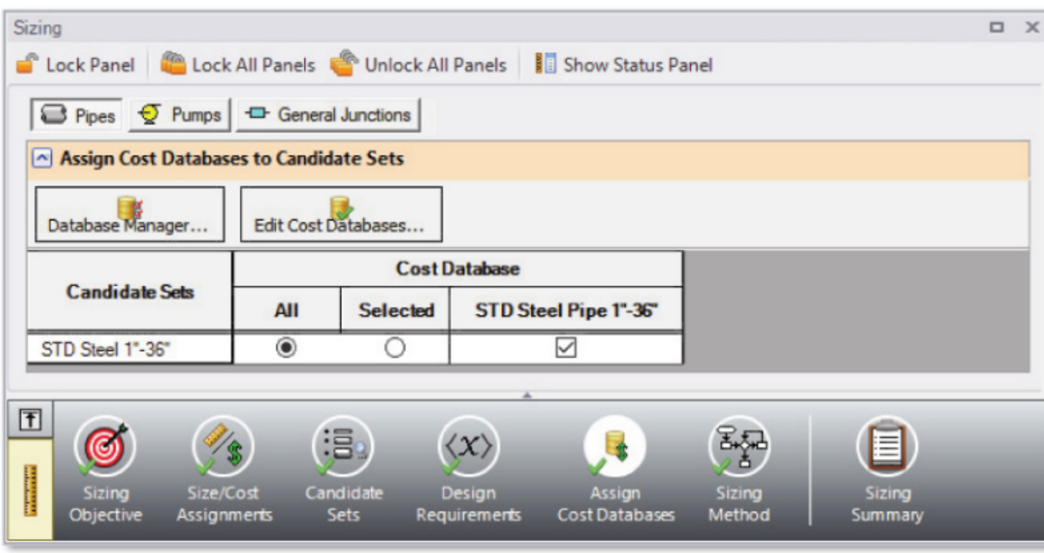


Figure 3.14 Assign Cost Databases panel for pipes

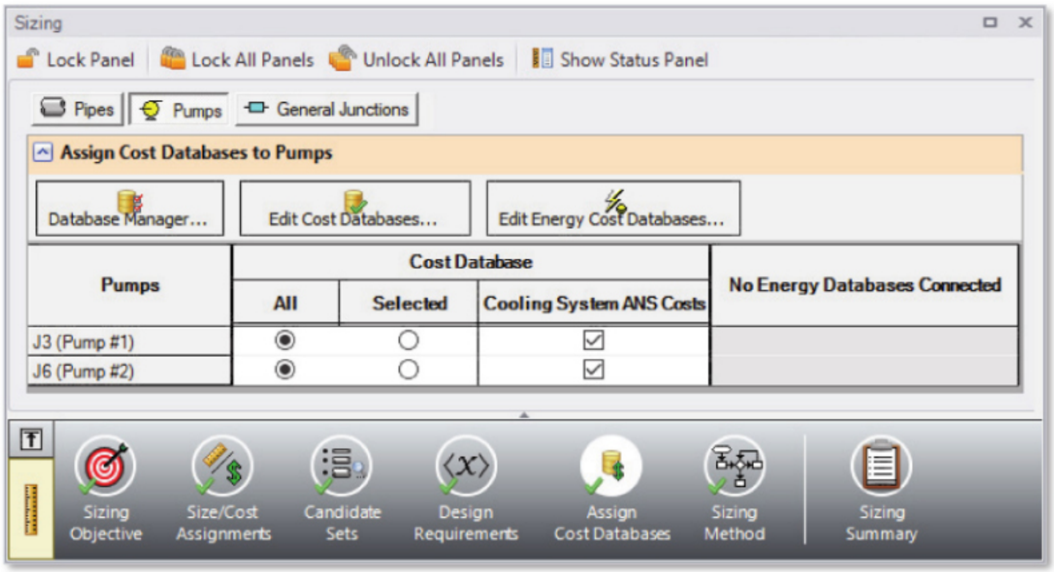


Figure 3.15 Assign Cost Databases panel for pumps

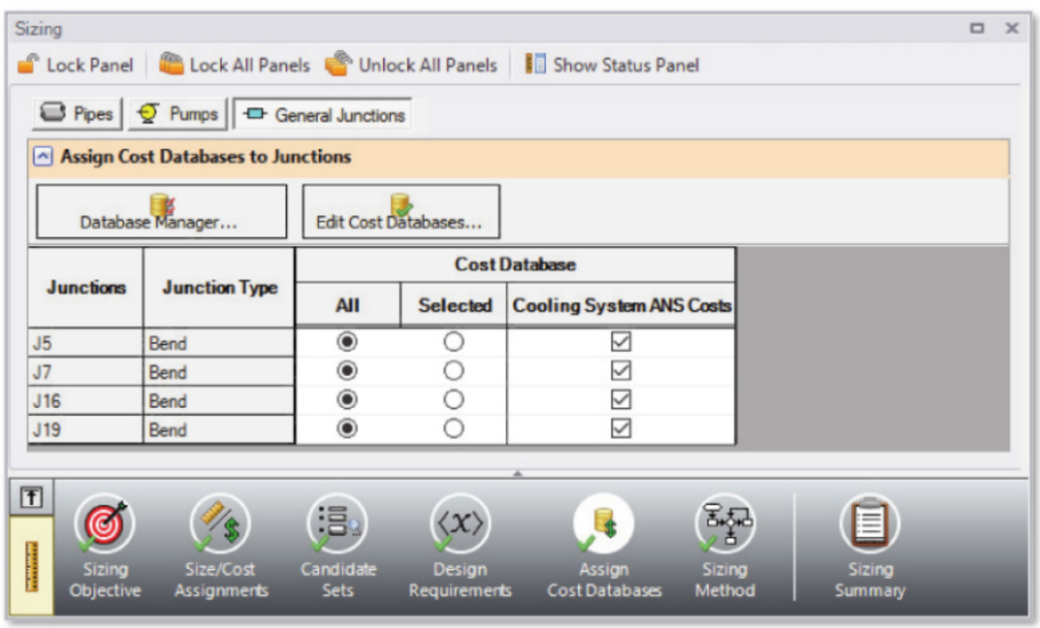


Figure 3.16 Assign Cost Databases panel for junctions

For this model we have 6 independent pipe sizes as noted on the Size/Cost Assignments panel (5 groups and pipe P8), and 55 design requirements (2 pipe design requirements applied to all of the pipes, a minimum flow rate on the 9 Cooler group pipes, and the pump NPSH requirement). Due to the small number of independent sizes, it would be recommended to try the MMFD or SQP search method. Though it is not shown here, if both methods are run for this scenario the same solution will be obtained, though the Modified Method of Feasible Directions (MMFD) Method is slightly faster. Select this method from the list as shown in Figure 3.17.

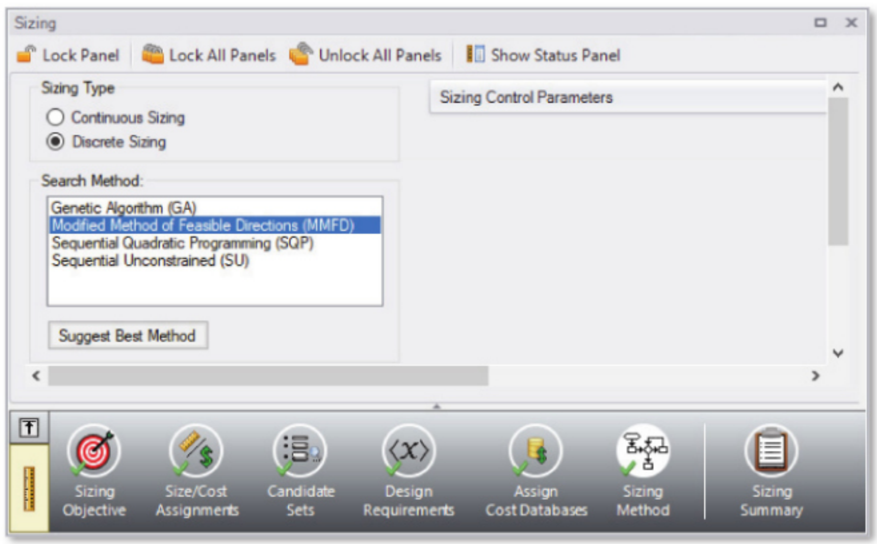


Figure 3.17 Sizing Method panel defined for Discrete sizing with the Modified Method of Feasible Directions method

G. Sizing Summary

From the Sizing Navigation Panel select the Sizing Summary button.

The Sizing Summary panel allows the user to view all of the sizing input for the model in a tree view layout, which is shown in Figure 3.18. Items can be organized by sizing parameters (Design Requirements, Candidate Sets, etc.), or information can be viewed for an individual pipe. For clarity these categories can be shown/hidden using the check boxes at the top of the panel.

Each tree node can be expanded/collapsed individually by using the '+' and '-' buttons on the node. Alternatively, the buttons on the bottom of the panel can be used to collapse/expand all items. Right-clicking on the nodes provides additional options to collapse/expand items, view related nodes, or to copy information to the clipboard. The Sizing Summary panel can be printed from the printer button at the bottom of the panel.

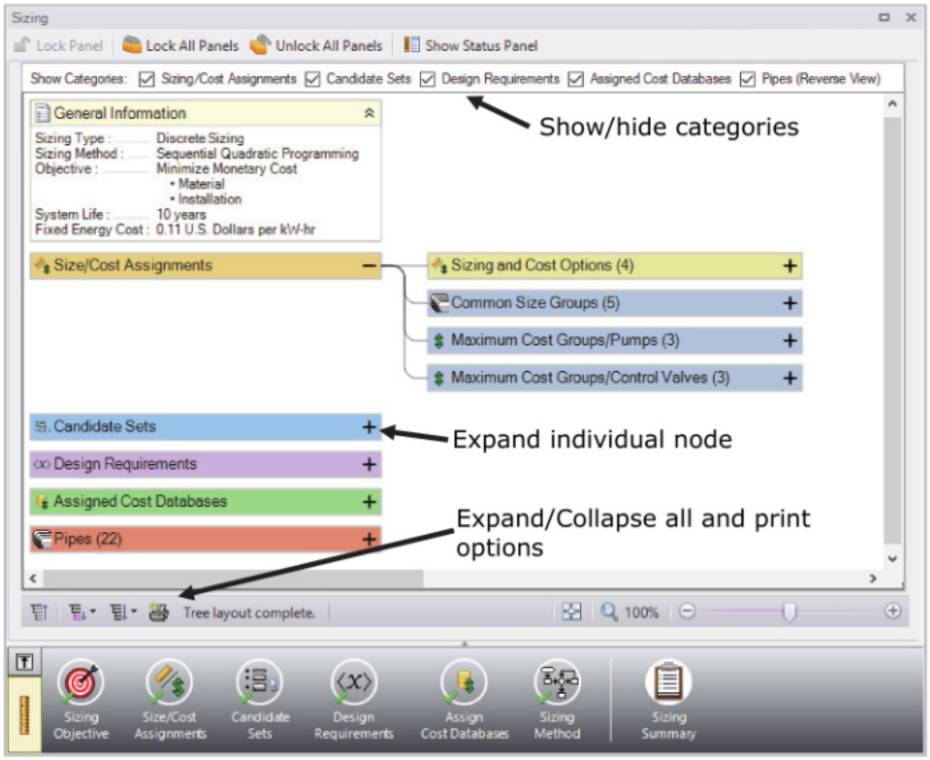


Figure 3.18 Sizing Summary panel layout with the Size/Cost Assignments expanded. The number of children nodes for each item can be seen in parentheses.

Step 4. Run the model

Select Run Model in the Analysis menu. This will open the Solution Progress window. This window allows you to watch as the AFT Fathom Solver and the ANS module converge on a solution.

After the run has been completed, the results can be reviewed clicking the Output button at the bottom of the solution control window.

Step 5. Review the output

The Cost Report is shown in the General Section of the Output window as shown in Figure 3.19. (The Output Control has been set up to show costs in thousands of U.S. Dollars, and to show one decimal.)

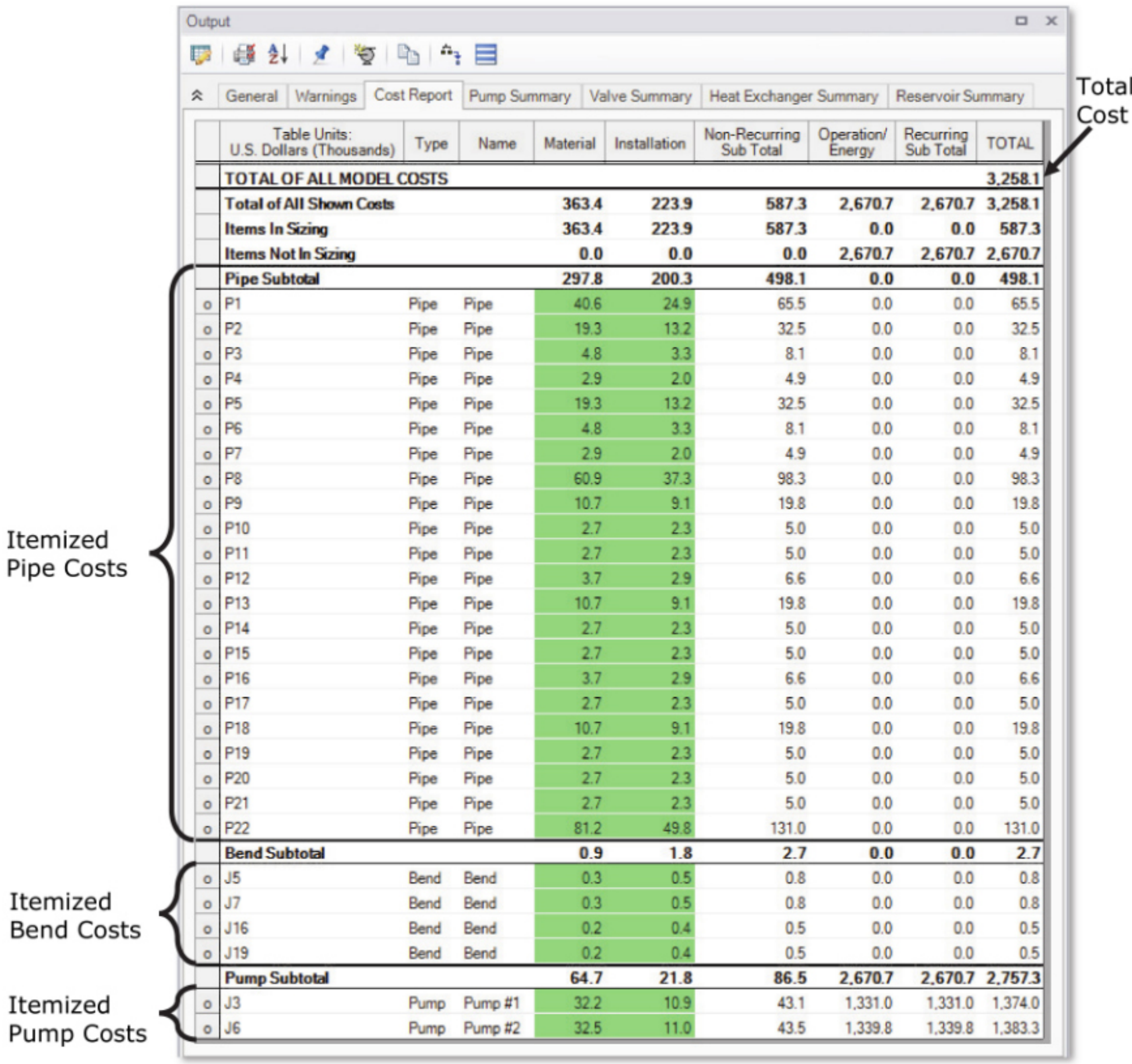


Table Units: U.S. Dollars (Thousands)	Type	Name	Material	Installation	Non-Recurring Sub Total	Operation/ Energy	Recurring Sub Total	TOTAL
TOTAL OF ALL MODEL COSTS								**3,258.1**
Total of All Shown Costs			**363.4**	**223.9**	**587.3**	**2,670.7**	**2,670.7**	**3,258.1**
Items In Sizing			**363.4**	**223.9**	**587.3**	**0.0**	**0.0**	**587.3**
Items Not In Sizing			**0.0**	**0.0**	**0.0**	**2,670.7**	**2,670.7**	**2,670.7**
Pipe Subtotal			**297.8**	**200.3**	**498.1**	**0.0**	**0.0**	**498.1**
P1	Pipe	Pipe	40.6	24.9	65.5	0.0	0.0	65.5
P2	Pipe	Pipe	19.3	13.2	32.5	0.0	0.0	32.5
P3	Pipe	Pipe	4.8	3.3	8.1	0.0	0.0	8.1
P4	Pipe	Pipe	2.9	2.0	4.9	0.0	0.0	4.9
P5	Pipe	Pipe	19.3	13.2	32.5	0.0	0.0	32.5
P6	Pipe	Pipe	4.8	3.3	8.1	0.0	0.0	8.1
P7	Pipe	Pipe	2.9	2.0	4.9	0.0	0.0	4.9
P8	Pipe	Pipe	60.9	37.3	98.3	0.0	0.0	98.3
P9	Pipe	Pipe	10.7	9.1	19.8	0.0	0.0	19.8
P10	Pipe	Pipe	2.7	2.3	5.0	0.0	0.0	5.0
P11	Pipe	Pipe	2.7	2.3	5.0	0.0	0.0	5.0
P12	Pipe	Pipe	3.7	2.9	6.6	0.0	0.0	6.6
P13	Pipe	Pipe	10.7	9.1	19.8	0.0	0.0	19.8
P14	Pipe	Pipe	2.7	2.3	5.0	0.0	0.0	5.0
P15	Pipe	Pipe	2.7	2.3	5.0	0.0	0.0	5.0
P16	Pipe	Pipe	3.7	2.9	6.6	0.0	0.0	6.6
P17	Pipe	Pipe	2.7	2.3	5.0	0.0	0.0	5.0
P18	Pipe	Pipe	10.7	9.1	19.8	0.0	0.0	19.8
P19	Pipe	Pipe	2.7	2.3	5.0	0.0	0.0	5.0
P20	Pipe	Pipe	2.7	2.3	5.0	0.0	0.0	5.0
P21	Pipe	Pipe	2.7	2.3	5.0	0.0	0.0	5.0
P22	Pipe	Pipe	81.2	49.8	131.0	0.0	0.0	131.0
Bend Subtotal			**0.9**	**1.8**	**2.7**	**0.0**	**0.0**	**2.7**
J5	Bend	Bend	0.3	0.5	0.8	0.0	0.0	0.8
J7	Bend	Bend	0.3	0.5	0.8	0.0	0.0	0.8
J16	Bend	Bend	0.2	0.4	0.5	0.0	0.0	0.5
J19	Bend	Bend	0.2	0.4	0.5	0.0	0.0	0.5
Pump Subtotal			**64.7**	**21.8**	**86.5**	**2,670.7**	**2,670.7**	**2,757.3**
J3	Pump	Pump #1	32.2	10.9	43.1	1,331.0	1,331.0	1,374.0
J6	Pump	Pump #2	32.5	11.0	43.5	1,339.8	1,339.8	1,383.3

Figure 3.19 The Cost Report in the Output window shows the total and individual costs (in thousands of U.S. Dollars) for the sized system

The ANS module shows all costs in the Cost Report, including those that were calculated but not used in the automated sizing. The total cost for this system is $3,258,100. This includes all costs over 10 years. The initial cost, which was the basis for the automated sizing, was the total of the material and installation costs ($587,300). This total is listed as the total for the "Items in Sizing" line, since it was specified to only include the initial costs (material and installation) in the Sizing Objective section. Individual items that were included in the automated sizing have their costs highlighted in green, which can be turned on/off in the Format & Action tab of the Output Control window.

Other costs that are displayed in the Cost Report are "Items Not in Sizing". These are items that were set to have their costs calculated but were not included in the automated sizing. Note that the Items Not in Sizing total to $2,670,700. Looking across at the subtotal, one can see that all of this cost is in energy (i.e., pump power costs). This cost will be included in the automated sizing later for comparison.

In the Pipes section of the Output window the final pipe sizes from the automated sizing can be seen, along with the Design Requirements status. The maximum velocity requirement for the pipes near the coolers and the minimum NPSH margin for pump J6 were active, as is indicated by the highlighting (Figure 3.20).

For this model, the final system used pipe sizes varying from 10 to 16 inches, as seen in Figure 3.21. Data on the Common Size Groups and pipe costs can also be viewed from here. The information for the pumps can be seen in the Pump Summary tab in the General Section, which is also shown in Figure 3.21.

When a monetary cost objective is selected, additional tabs are available that display the Database Sources used for the Cost Report for each of the pipes/junctions. In this case both the Pipe Material and Pipe Installation costs for all of the pipes came from the STD Steel Pipe 1"-36" database which was connected earlier. Information for the Pumps and Bends came from the “Cooling System ANS Costs” database. If multiple cost databases are used for the same cost type they will all be listed separated by commas. This is useful for model verification.

On the General tab of the Output window at the bottom of the report, the initial cost of the items included in the sizing can be seen, which was $649,200 for this design, showing that the initial costs were reduced by about 10% from the initial design. We can also see that the initial design was feasible, meaning all of the design requirements were met (Figure 3.22).

Though not shown here, if the model is run using the objective to "Calculate Costs, Do Not Size", it can be seen that the total cost for the system before sizing was $3,209,900, which is actually less than the system that has been sized for initial costs. This is due to the fact that the larger pipe sizes in the initial system allowed for lower energy costs over the ten year system life. This system is heavily weighted towards energy costs, so any change in the energy costs will have a much larger impact on the overall life cycle cost than the material and installation costs.

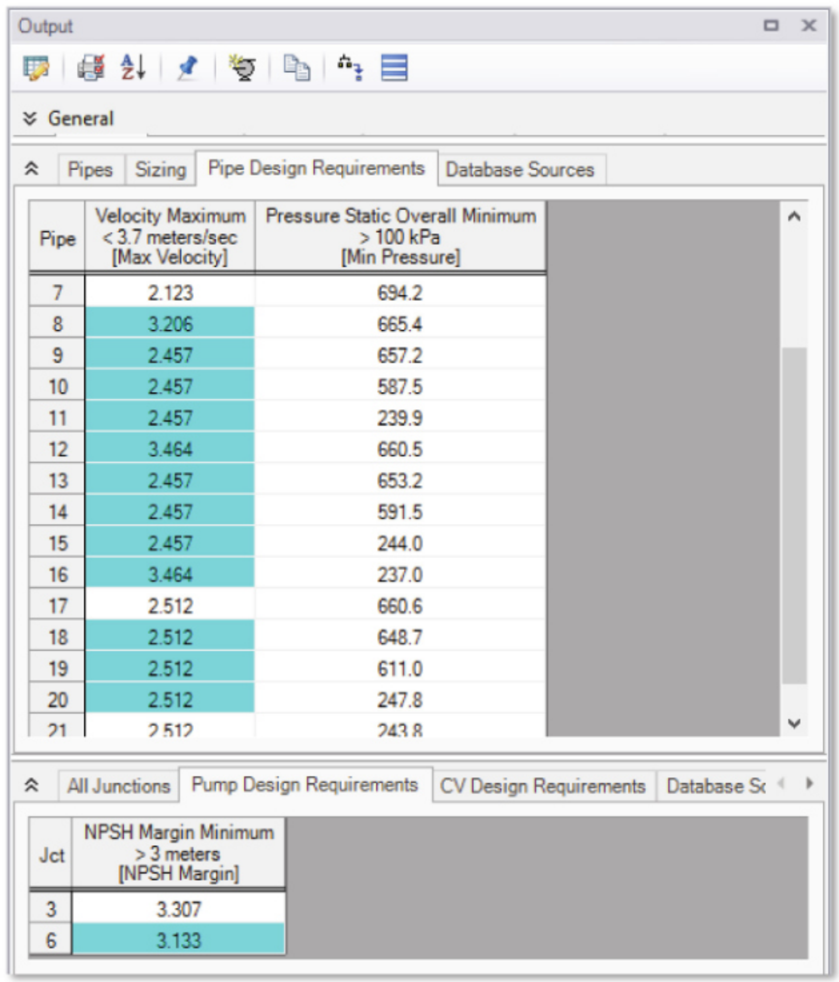
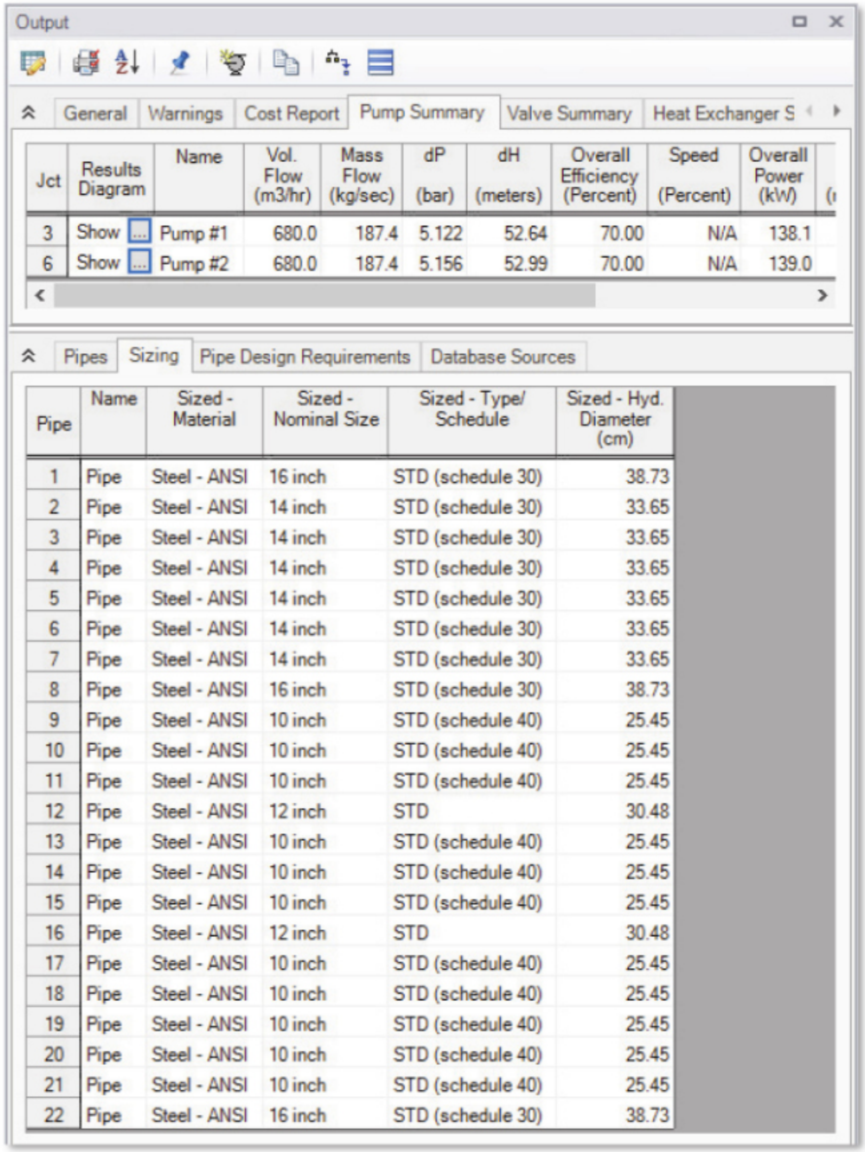


Figure 3.20 Active Design Requirements shown in the Output window for the pipes and pumps



Jct	Results Diagram	Name	Vol. Flow (m3/hr)	Mass Flow (kg/sec)	dP (bar)	dH (meters)	Overall Efficiency (Percent)	Speed (Percent)	Overall Power (kW)
3	Show	Pump #1	680.0	187.4	5.122	52.64	70.00	N/A	138.1
6	Show	Pump #2	680.0	187.4	5.156	52.99	70.00	N/A	139.0

Pipe	Name	Sized - Material	Sized - Nominal Size	Sized - Type/ Schedule	Sized - Hyd. Diameter (cm)
1	Pipe	Steel - ANSI	16 inch	STD (schedule 30)	38.73
2	Pipe	Steel - ANSI	14 inch	STD (schedule 30)	33.65
3	Pipe	Steel - ANSI	14 inch	STD (schedule 30)	33.65
4	Pipe	Steel - ANSI	14 inch	STD (schedule 30)	33.65
5	Pipe	Steel - ANSI	14 inch	STD (schedule 30)	33.65
6	Pipe	Steel - ANSI	14 inch	STD (schedule 30)	33.65
7	Pipe	Steel - ANSI	14 inch	STD (schedule 30)	33.65
8	Pipe	Steel - ANSI	16 inch	STD (schedule 30)	38.73
9	Pipe	Steel - ANSI	10 inch	STD (schedule 40)	25.45
10	Pipe	Steel - ANSI	10 inch	STD (schedule 40)	25.45
11	Pipe	Steel - ANSI	10 inch	STD (schedule 40)	25.45
12	Pipe	Steel - ANSI	12 inch	STD	30.48
13	Pipe	Steel - ANSI	10 inch	STD (schedule 40)	25.45
14	Pipe	Steel - ANSI	10 inch	STD (schedule 40)	25.45
15	Pipe	Steel - ANSI	10 inch	STD (schedule 40)	25.45
16	Pipe	Steel - ANSI	12 inch	STD	30.48
17	Pipe	Steel - ANSI	10 inch	STD (schedule 40)	25.45
18	Pipe	Steel - ANSI	10 inch	STD (schedule 40)	25.45
19	Pipe	Steel - ANSI	10 inch	STD (schedule 40)	25.45
20	Pipe	Steel - ANSI	10 inch	STD (schedule 40)	25.45
21	Pipe	Steel - ANSI	10 inch	STD (schedule 40)	25.45
22	Pipe	Steel - ANSI	16 inch	STD (schedule 30)	38.73

Figure 3.21 Pump and pipe sizes after initial cost sizing is performed

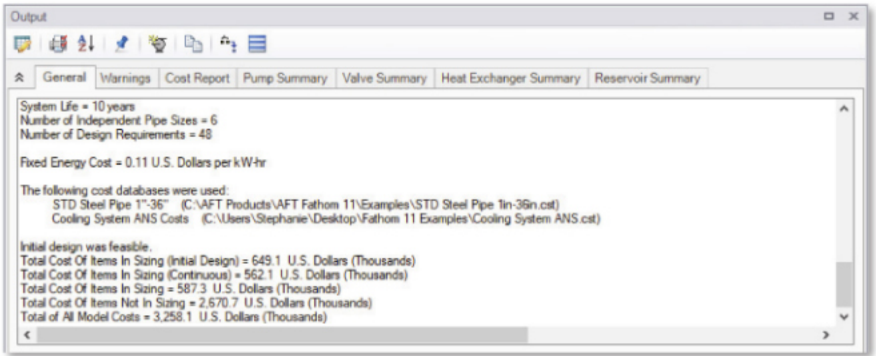


Figure 3.22 General section of Output window showing initial status of Items in Sizing

Step 6. Size system for life cycle cost over 10 years

Now we want to size the system based on life cycle costs, rather than just minimizing the initial costs of the system. As previously discussed, the energy costs can often be weighted much more heavily than the initial cost of the system components. This means that sizing based on recurring costs will often result in larger pipes with higher material/installation costs being chosen so that smaller pumps with lower energy costs can be used.

From the Scenario Manager in the Quick Access Panel, we will create two child scenarios. From the Base Scenario, right click and choose “Create Child”. Name the new scenario “Initial Cost”. This scenario will store the initial cost sizing results we just obtained. Repeat this process to create a second child scenario and name it "Life Cycle Cost". The “Life Cycle Cost” scenario should now be active, as indicated by the green check mark symbol. For this scenario the only change that will need to be made is to update the Sizing Objective.

- **Go to the Sizing window**, and make sure that the Sizing Objective panel is selected. Under “Options to Minimize Monetary Cost”, choose “Size for Initial and Recurring Costs”. This will move the Energy costs selection to “Include in Sizing Objective” as shown in Figure 3.23. The scenario is now complete.

➢ **Click Run from the Analysis menu** to run the automated sizing. When the calculations have finished, click Output to view the results. The new Cost Report can be seen in Figure 3.24.

After viewing the Cost Report, it can be seen that the overall cost is now $3,004,000. The "Items Not in Sizing" line now has a value of zero, and the Energy column is highlighted green, reflecting the changes made to include these costs in the Objective.

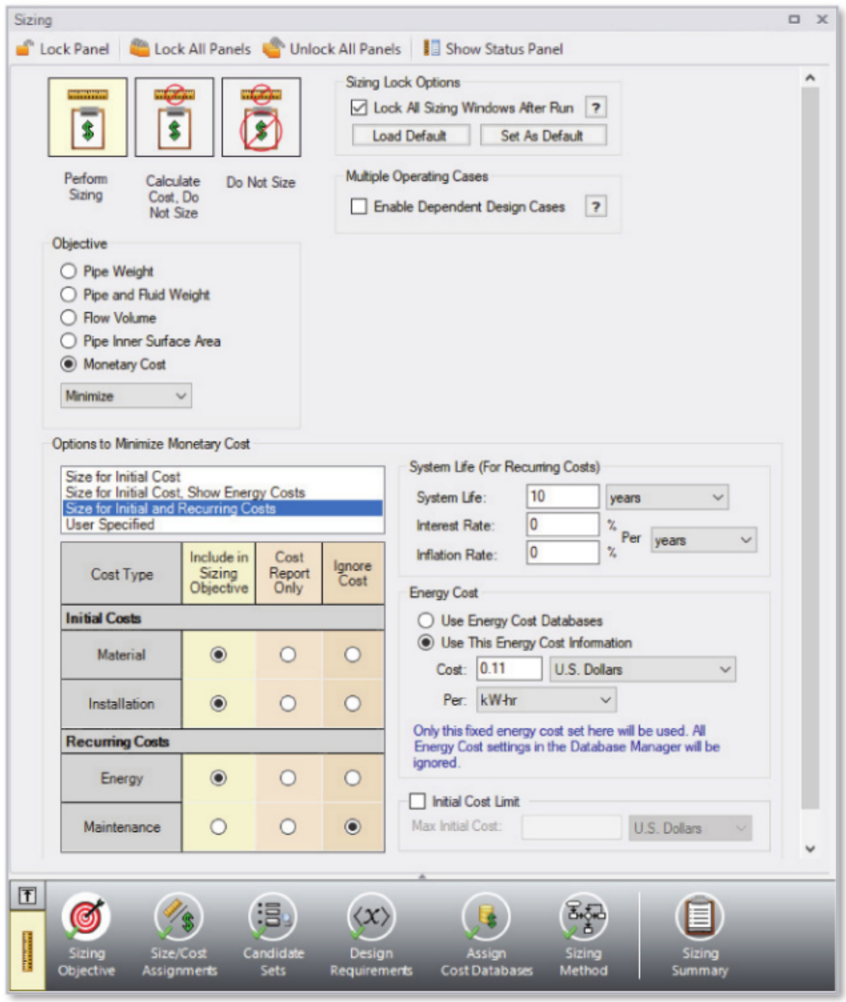


Figure 3.23 Sizing Objective defined for life cycle cost sizing – Energy cost in table was moved from the "Cost Report Only" column to the left column "Include in Sizing Objective"

Output

General | Warnings | Cost Report | Pump Summary | Valve Summary | Heat Exchanger Summary | Reservoir Summary

	Table Units: U.S. Dollars (Thousands)	Type	Name	Material	Installation	Non-Recurring Sub Total	Operation/ Energy	Recurring Sub Total	TOTAL
	TOTAL OF ALL MODEL COSTS								**3,004.0**
	Total of All Shown Costs			**487.6**	**266.9**	**754.5**	**2,249.5**	**2,249.5**	**3,004.0**
	Items In Sizing			**487.6**	**266.9**	**754.5**	**2,249.5**	**2,249.5**	**3,004.0**
	Items Not In Sizing			**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
	Pipe Subtotal			**435.1**	**247.6**	**682.7**	**0.0**	**0.0**	**682.7**
o	P1	Pipe	Pipe	60.6	30.5	91.1	0.0	0.0	91.1
o	P2	Pipe	Pipe	24.4	14.9	39.3	0.0	0.0	39.3
o	P3	Pipe	Pipe	6.1	3.7	9.8	0.0	0.0	9.8
o	P4	Pipe	Pipe	3.7	2.2	5.9	0.0	0.0	5.9
o	P5	Pipe	Pipe	24.4	14.9	39.3	0.0	0.0	39.3
o	P6	Pipe	Pipe	6.1	3.7	9.8	0.0	0.0	9.8
o	P7	Pipe	Pipe	3.7	2.2	5.9	0.0	0.0	5.9
o	P8	Pipe	Pipe	90.9	45.8	136.7	0.0	0.0	136.7
o	P9	Pipe	Pipe	14.9	11.7	26.6	0.0	0.0	26.6
o	P10	Pipe	Pipe	3.7	2.9	6.6	0.0	0.0	6.6
o	P11	Pipe	Pipe	3.7	2.9	6.6	0.0	0.0	6.6
o	P12	Pipe	Pipe	7.5	4.2	11.7	0.0	0.0	11.7
o	P13	Pipe	Pipe	14.9	11.7	26.6	0.0	0.0	26.6
o	P14	Pipe	Pipe	3.7	2.9	6.6	0.0	0.0	6.6
o	P15	Pipe	Pipe	3.7	2.9	6.6	0.0	0.0	6.6
o	P16	Pipe	Pipe	7.5	4.2	11.7	0.0	0.0	11.7
o	P17	Pipe	Pipe	6.1	3.7	9.8	0.0	0.0	9.8
o	P18	Pipe	Pipe	14.9	11.7	26.6	0.0	0.0	26.6
o	P19	Pipe	Pipe	3.7	2.9	6.6	0.0	0.0	6.6
o	P20	Pipe	Pipe	3.7	2.9	6.6	0.0	0.0	6.6
o	P21	Pipe	Pipe	6.1	3.7	9.8	0.0	0.0	9.8
o	P22	Pipe	Pipe	121.2	61.1	182.3	0.0	0.0	182.3
	Bend Subtotal			**1.8**	**2.5**	**4.3**	**0.0**	**0.0**	**4.3**
o	J5	Bend	Bend	0.5	0.7	1.2	0.0	0.0	1.2
o	J7	Bend	Bend	0.5	0.7	1.2	0.0	0.0	1.2
o	J16	Bend	Bend	0.5	0.7	1.2	0.0	0.0	1.2
o	J19	Bend	Bend	0.2	0.4	0.6	0.0	0.0	0.6
	Pump Subtotal			**50.7**	**16.7**	**67.4**	**2,249.5**	**2,249.5**	**2,316.9**
o	J3	Pump	Pump #1	25.3	8.3	33.6	1,122.4	1,122.4	1,156.0
o	J6	Pump	Pump #2	25.4	8.4	33.8	1,127.1	1,127.1	1,160.9

Figure 3.24 Cost Report for life cycle cost sizing scenario

Taken on its own, this new cost represents a savings of about $254,000 over the Initial cost scenario which was sized based on Initial Cost only. This represents an 8% cost reduction. In the initial cost scenario, the non-recurring cost was $587,300, while the overall cost was $3,258,100. Now the non-recurring cost is $754,500 while the overall cost is $3,004,000. The initial cost thus increased by about $170,000 in order to reduce the operating cost from $2,670,700 to $2,249,500 (a reduction of about $420,000). The source of the operating cost is the cost of power for the pumps. To reduce pump power usage, it makes sense to increase the pipe size and thus reduce frictional losses. The larger pipe sizes can be reviewed by looking at the Sizing tab in the Pipe Output section. From the Pump Summary tab it can be seen that the pump power usage decreased from 138 kW to 117 kW at each of the pumps, which is approximately a 15% power requirement decrease at each pump.

Step 7. Apply initial cost limit

While the energy cost savings from life cycle cost sizing are desirable, the budget for the project may not support the higher initial cost that is required. In that case, we can apply an initial cost limit to the life cycle cost sizing.

- **Return to the Sizing Objective panel** and select the option for Initial Cost Limit. We will set the limit as $649,200, which was the initial cost before sizing the system. Run the model and go to the Output tab. The Cost Report can be seen in Figure 3.25.

A summary of the difference between each of the initial and life cycle cost sizing scenarios for a 10 year life cycle can be seen in Table 3.1. Notice that while the material and installation costs were limited to the cost of the original design, the energy costs over a 10 year lifetime are decreased by about $140,000 compared to the original design. These energy costs were achieved by increasing the pressurizer pipes, pipe P8, and several of the header pipes at the coolers while decreasing the pipe sizes at the coolers. Figure 3.26 shows a comparison of the pipe and pump sizes throughout the system for the initial design, the system sized for initial cost only, and the system sized for life cycle cost with an initial cost limit.

Table 3.1 Cost summary of automated sizing runs for Cooling System

Sized for:	Material	Installation	Total non-recurring	Energy	Overall Total	Reduction
Not sized (original design)	404,900	244,300	649,200	2,560,800	3,209,900	
Sized for initial cost	363,400	223,900	587,300	2,670,700	3,258,100	**-49,000**
Sized for life cycle cost	487,600	266,900	754,500	2,249,500	3,004,000	**205,900**
Sized for life cycle cost with initial cost limit	409,900	238,400	648,300	2,421,800	3,070,100	**139,900**

Output

General | Warnings | Cost Report | Pump Summary | Valve Summary | Heat Exchanger Summary | Reservoir Summary

	Table Units: U.S. Dollars (Thousands)	Type	Name	Material	Installation	Non-Recurring Sub Total	Operation/ Energy	Recurring Sub Total	TOTAL
	TOTAL OF ALL MODEL COSTS								**3,070.1**
	Total of All Shown Costs			**409.9**	**238.4**	**648.3**	**2,421.8**	**2,421.8**	**3,070.1**
	Items In Sizing			**409.9**	**238.4**	**648.3**	**2,421.8**	**2,421.8**	**3,070.1**
	Items Not In Sizing			**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
	Pipe Subtotal			**352.4**	**217.6**	**570.1**	**0.0**	**0.0**	**570.1**
o	P1	Pipe	Pipe	50.1	27.7	77.9	0.0	0.0	77.9
o	P2	Pipe	Pipe	19.3	13.2	32.5	0.0	0.0	32.5
o	P3	Pipe	Pipe	4.8	3.3	8.1	0.0	0.0	8.1
o	P4	Pipe	Pipe	2.9	2.0	4.9	0.0	0.0	4.9
o	P5	Pipe	Pipe	19.3	13.2	32.5	0.0	0.0	32.5
o	P6	Pipe	Pipe	4.8	3.3	8.1	0.0	0.0	8.1
o	P7	Pipe	Pipe	2.9	2.0	4.9	0.0	0.0	4.9
o	P8	Pipe	Pipe	75.2	41.6	116.8	0.0	0.0	116.8
o	P9	Pipe	Pipe	10.7	9.1	19.8	0.0	0.0	19.8
o	P10	Pipe	Pipe	2.7	2.3	5.0	0.0	0.0	5.0
o	P11	Pipe	Pipe	2.7	2.3	5.0	0.0	0.0	5.0
o	P12	Pipe	Pipe	7.5	4.2	11.7	0.0	0.0	11.7
o	P13	Pipe	Pipe	10.7	9.1	19.8	0.0	0.0	19.8
o	P14	Pipe	Pipe	2.7	2.3	5.0	0.0	0.0	5.0
o	P15	Pipe	Pipe	2.7	2.3	5.0	0.0	0.0	5.0
o	P16	Pipe	Pipe	7.5	4.2	11.7	0.0	0.0	11.7
o	P17	Pipe	Pipe	4.8	3.3	8.1	0.0	0.0	8.1
o	P18	Pipe	Pipe	10.7	9.1	19.8	0.0	0.0	19.8
o	P19	Pipe	Pipe	2.7	2.3	5.0	0.0	0.0	5.0
o	P20	Pipe	Pipe	2.7	2.3	5.0	0.0	0.0	5.0
o	P21	Pipe	Pipe	4.8	3.3	8.1	0.0	0.0	8.1
o	P22	Pipe	Pipe	100.2	55.5	155.7	0.0	0.0	155.7
	Bend Subtotal			**1.0**	**2.0**	**3.0**	**0.0**	**0.0**	**3.0**
o	J5	Bend	Bend	0.3	0.5	0.8	0.0	0.0	0.8
o	J7	Bend	Bend	0.3	0.5	0.8	0.0	0.0	0.8
o	J16	Bend	Bend	0.3	0.5	0.8	0.0	0.0	0.8
o	J19	Bend	Bend	0.2	0.4	0.5	0.0	0.0	0.5
	Pump Subtotal			**56.4**	**18.8**	**75.2**	**2,421.8**	**2,421.8**	**2,497.0**
o	J3	Pump	Pump #1	28.1	9.4	37.4	1,206.5	1,206.5	1,243.9
o	J6	Pump	Pump #2	28.4	9.5	37.8	1,215.3	1,215.3	1,253.1

Figure 3.25 Cost Report for life cycle cost sizing scenario with initial cost limit

Discussion on sizing with pump curve data

One can consider the previous discussion in this chapter as Phase 1 of the pump and pipe sizing process. Phase 2 involves using the Phase 1 results in order to select actual pumps which have pump curve data. The actual pump should closely match the sizing results in the generated head at the design flow, efficiency at the design flow, and cost. If it does not, then it may be advisable to repeat the Phase 1 sizing with updated information from actual pumps (e.g., monetary costs, nominal efficiency, nominal NPSHr, etc.). A complete Phase 2 analysis will run the automated sizing again for each actual pump considered. The pipe sizing may change slightly for each pump considered.

By reviewing the Pump Summary for the life cycle cost sizing with an initial cost limit, one can see that the ideal system calls for a pump of about 126 kW that generates about 48 meters of head at 680 m3/hr. The nominal efficiency used in the sizing part of the analysis was 70%. The material cost for such a pump was about $28,400, and the installation cost was about $9,500. Note that if no actual pumps can be found that reflect these requirements, then the Phase 1 process should be repeated with better performance and/or cost data for the pump.

Conclusions

Using cost databases in the automated sizing process involves increased complexity from simple non-monetary automated sizing as discussed in Chapter 2. However, it allows more powerful automated sizing options including the ability to size costs over a system life cycle.

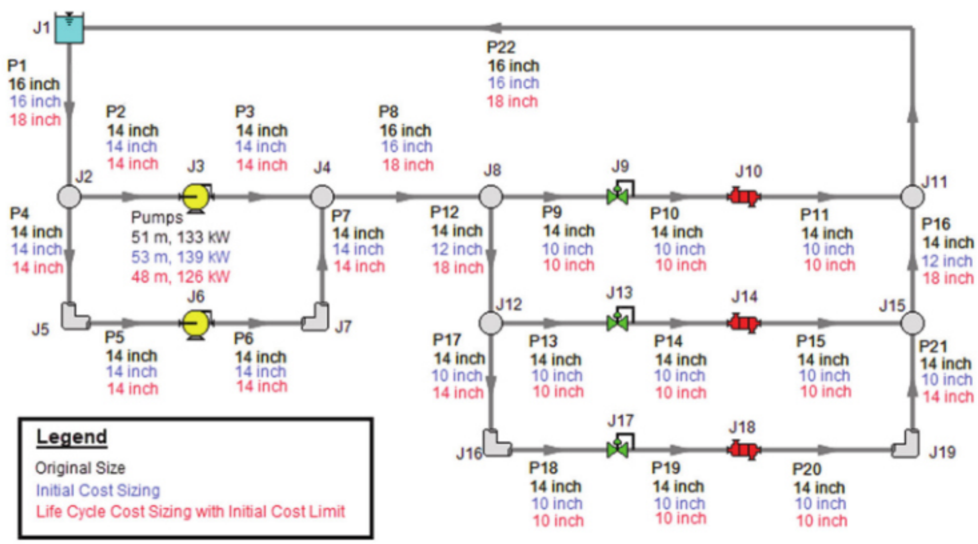


Figure 3.26 Pipe and pump sizes selected by the ANS module for initial cost and life cycle cost sizing with initial cost limit

CHAPTER 4

Multiple Design Case Example

This example will size the pipes for a water supply system to a housing development where there are two design cases. This example uses monetary cost automated sizing.

Topics covered

This example will cover the following topics:

- How dependent design cases are used to satisfy two different operating modes for a system
- Common Size Groups and their effect on how well the ANS module can size a system

Required knowledge

This example assumes that the user has some familiarity with AFT Fathom ANS module such as placing junctions, connecting pipes, entering pipe and junction properties, and creating and using Candidate Sets and Design Requirements. Refer to the Weight Sizing Example in Chapter 2 for more information on these topics.

Model files

Metric - Housing Water Supply - ANS.fth - AFT Fathom model file

Pipe-PVC-sch40.cst - Pipe cost database for PVC pipe

Problem statement

This example uses an existing model to investigate a single system with two operating cases. The cases are as follows:

1. Normal flow to houses and North Hydrant closed. Supply to each house must be at least 2.2 m3/hr with a minimum static pressure of 410 kPa (g).
2. North Hydrant open with at least 23.5 m3/hr and at least 620 kPa (g) minimum static pressure. During fires the supply to each house must be at least 0.5 m3/hr with no minimum pressure requirement.

For this example, we will evaluate both operating cases assuming the pipes can be at most three different sizes.

Step 1. Start AFT Fathom

From the Start Menu, choose AFT Products and AFT Fathom.

Enable the ANS module from the Startup Menu by checking the box next to the ANS module. Alternatively, the ANS module can be activated from the Add-on Modules button at the bottom of the Quick Access Panel, or from the Activate Modules option in the Tools menu.

Step 2. Open model file

For this example we will be starting from a pre-built model file that is fully defined for a normal AFT Fathom run. We will add automated sizing settings to find a more cost effective design. From either the startup screen or the File menu, browse to the model file name shown above and copy it to a new location. Open the “One Hydrant” scenario from the Scenario Manager in the Quick Access Panel.

This example consists of a reservoir (i.e., West Lake) at an elevation of 72 meters that supplies water to 10 houses and one fire hydrant. All of the pipes in the system are Schedule 40 PVC pipe. The supply line to each house is set to 1 inch PVC. T The automated sizing of this system will only be used to size the supply line from the reservoir, the neighborhood mains, and the hydrant line. The model should appear as shown in Figure 4.1.

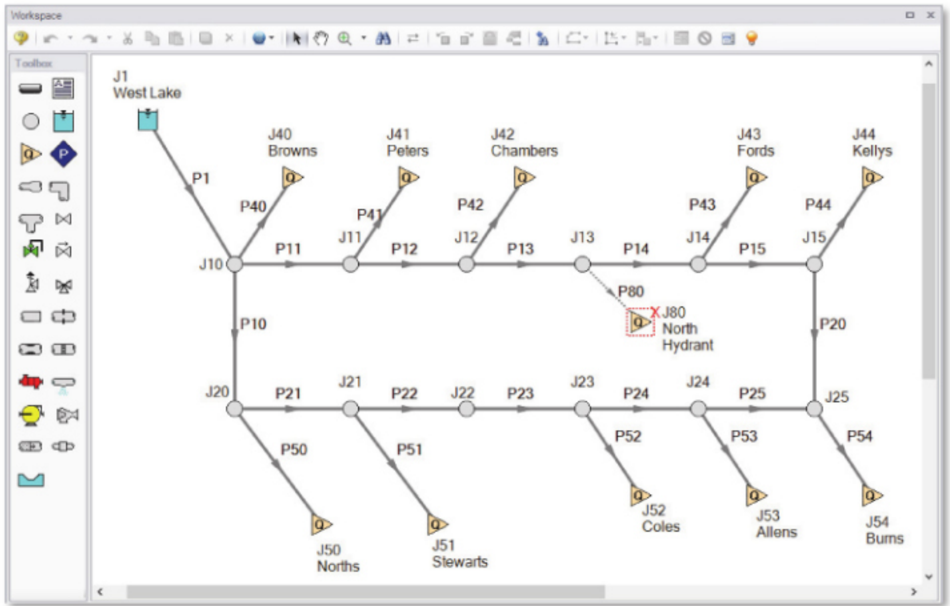


Figure 4.1 Single Hydrant scenario for Housing Project example

Step 3. Review model settings

A. Sizing objective

Go to the Sizing window by selecting the tab. The Sizing Objective panel should be selected by default from the buttons along the bottom.

For this analysis, we are interested in sizing the system considering the monetary cost for the initial costs only.

1. Set the calculation to Perform Sizing.
2. For the Objective, choose "Monetary Cost", and select the Minimize option from the drop-down list.
3. Under Options to Minimize Monetary Cost, choose "Size for Initial Cost", which will automatically configure the table to include all non-recurring costs in the sizing while ignoring the recurring costs.

B. Size/Cost assignments

On the Sizing Navigation Panel select the Size/Cost Assignments button.

For the supply lines to each house (pipes 40-54), the pipe size is fixed to one inch and will not be sized. We will ignore the costs of these pipes for the purpose of this example, though they could be considered using the "Do Not Size, Include in Cost" option.

We want to find the three pipe sizes that will serve for the supply from the reservoir, the "neighborhood mains", and the hydrant (pipe 1, pipes 10-25, and pipe 80 respectively). To do this, we have to establish one Common Size Group for the neighborhood mains, while leaving pipes P1 and P80 to be sized separately.

In the Size/Cost Assignments panel select the rows for pipes P1, P10-P25, and P80 (multiple rows can be selected using the shift or ctrl key). We will first need to set the pipes to be included in the sizing calculation.

- **Move the selected pipes** by clicking the "Always Include in Cost" button above the Sizing and Cost Options table. Now we will need to create a Common Size Group for the neighborhood mains.
- **Click New above the Pipe Grouping table** and name the group "Mains". Select pipes P10-P25 and use the "Move To" button above the Pipe Grouping table to add them to the Common Size Group. The Size/Cost Assignments panel should now appear as shown in Figure 4.2.

C. Candidate sets

Click on the Candidate Sets button to display the Candidate Sets panel.

In this case we will be considering schedule 40 PVC pipe within the range of 1" - 10".

1. Select New, and name the Candidate set "PVC sch 40".
2. Choose PVC - ASTM from the material list.
3. Expand the schedule 40 type, then double click each of the sizes from 1 inch to 10 inch to add them to the Candidate Set.
4. Click OK to accept the defined set.

In the bottom section of the window make sure that the Common Size Group and pipes P1 and P80 are assigned to use the new PVC sch 40 Candidate Set as shown in Figure 4.3.

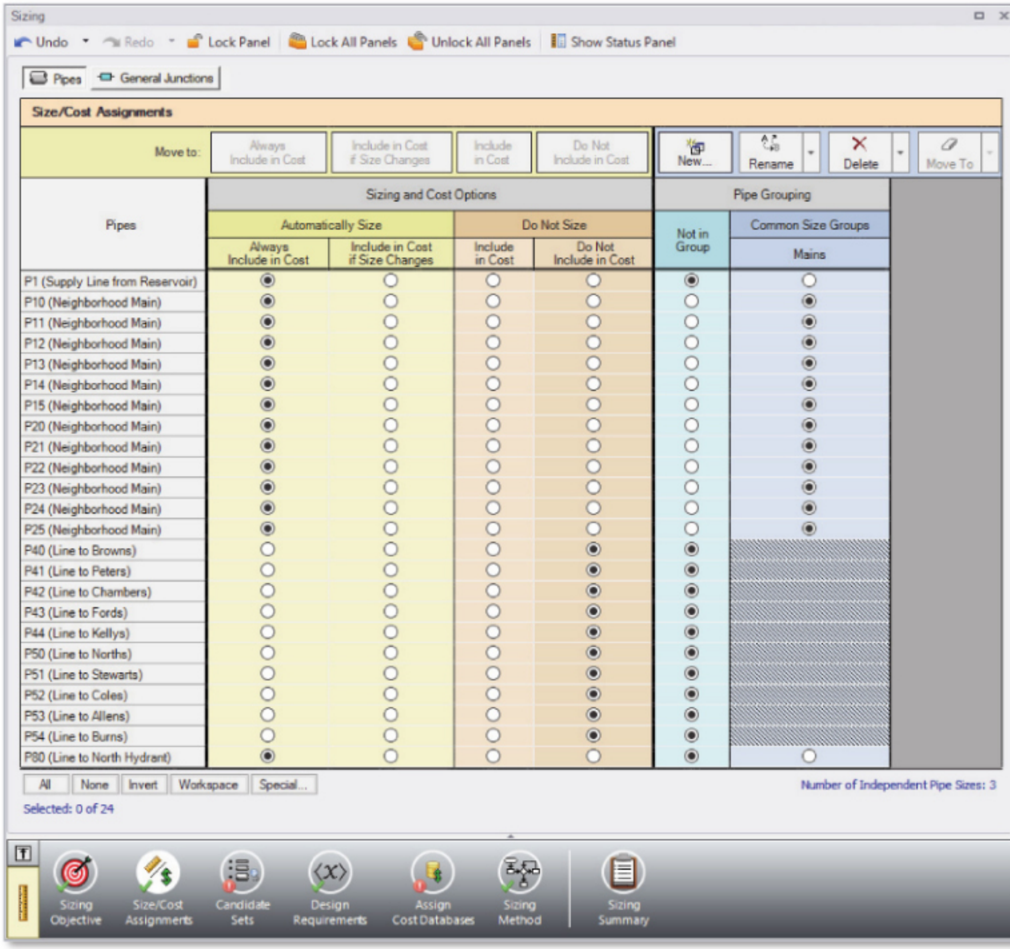


Figure 4.2 Size/Cost Assignments panel for the primary design case

D. Design requirements

Select the Design Requirements button.

For the primary design case the only design requirement is for the minimum supply pressure of 410 kPa(g) to each of the houses. With the Pipes button selected click new to add a “House Supply” Design Requirement specifying the static pressure at the outlet of the pipe to a minimum value of 410 kPa(g).

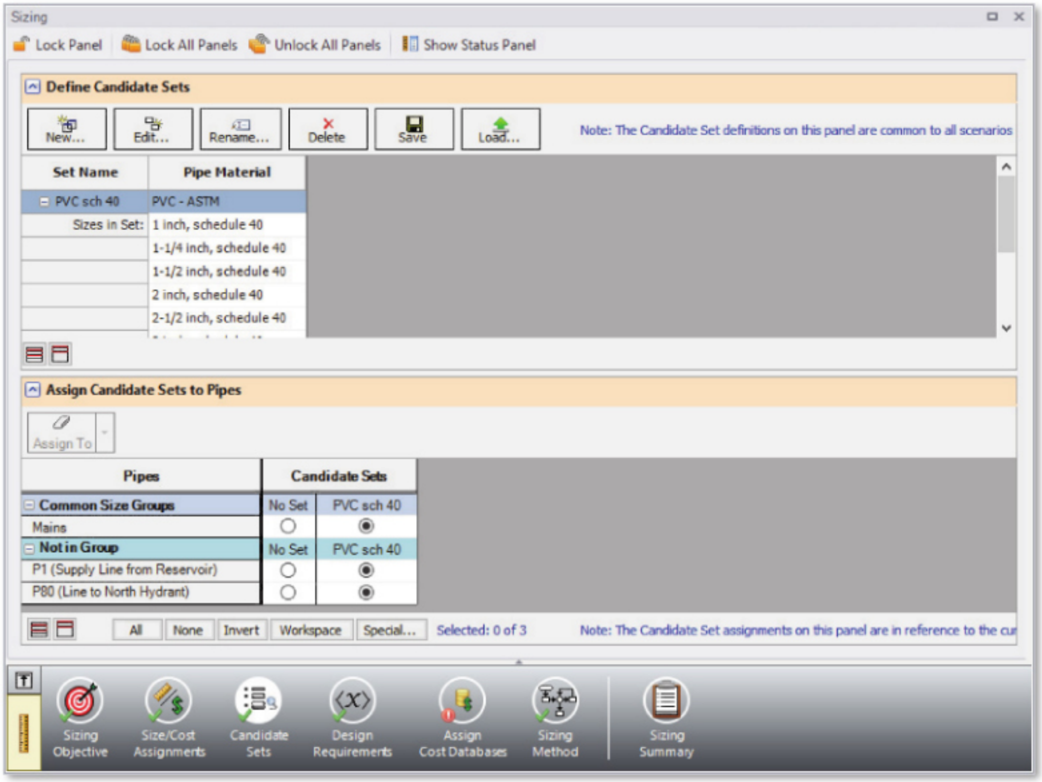


Figure 4.3 Candidate Sets panel for the primary design case

In the bottom section of the window, make sure that the 410 kPa(g) design requirement is applied to each of the supply lines to the houses, as shown in Figure 4.4.

Create a second Design Requirement named "Fire Supply" specifying the static pressure at the outlet of the pipe to a minimum value of 620 kPa(g). We will apply this requirement later when the dependent design case is created.

E. Assign cost databases

Select the Assign Cost Databases button. The actual material and installation costs are contained in cost databases.

➢ **Open the Database Manager** by clicking the Database Manager button to see which databases are connected.

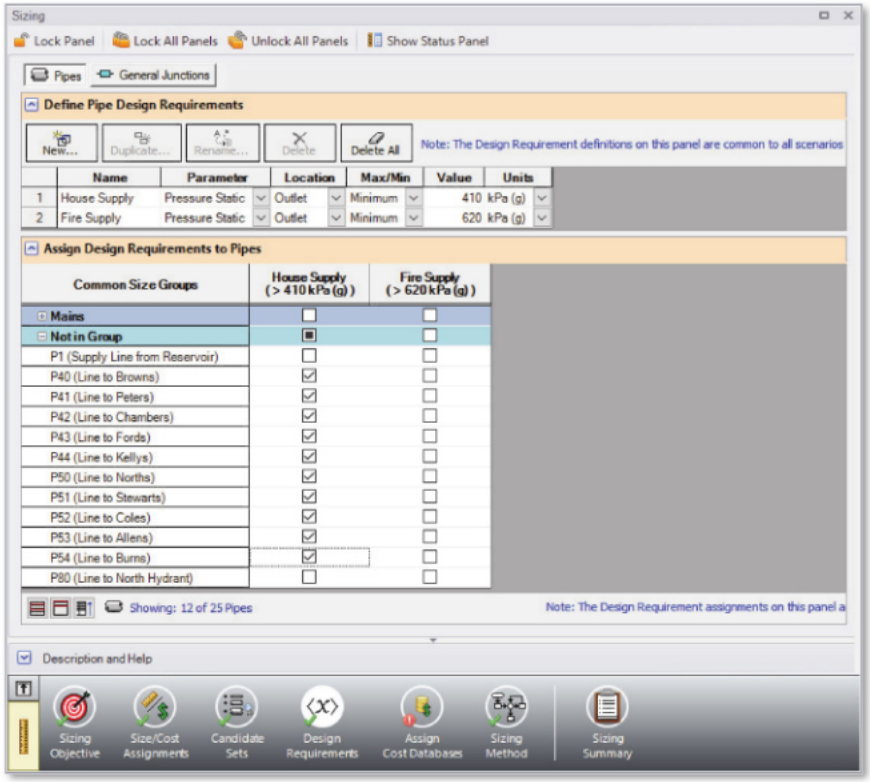


Figure 4.4 House Supply pressure Design Requirement defined for the primary case

This example uses a pre-built cost database for the pipes containing the PVC material costs. To connect the database do the following:

1. Click the button to "Edit Available List" and select Add Cost Database.
2. Browse to the Fathom 11 Examples folder (located by default in C:\AFT Products\AFT Fathom 11\Examples\), and open the file titled "pipe-pvc-sch40.cst".

The new database should now be visible in the Available Databases list and be automatically connected to the model, as shown in Figure 4.5.

Once you have confirmed that the database is connected, click Close to exit the Database Manager.

Back in the Assign Cost Databases panel for the Pipes the pipe-pvc-sch40.cst database should be the only available cost database, and should be selected to show that it is being applied to the Candidate Set and each of the supply lines to the houses.

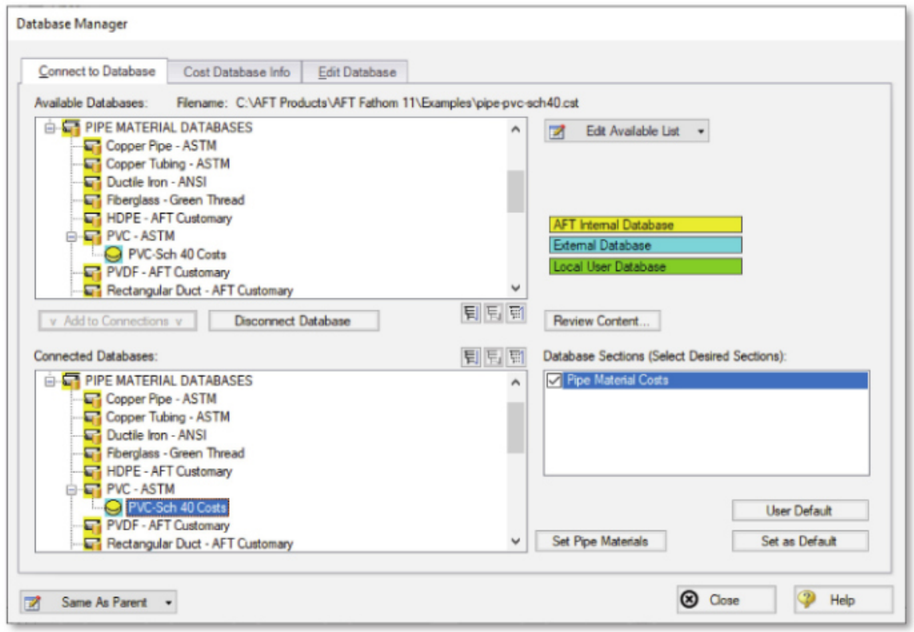


Figure 4.5 Database Manager showing the PVC schedule 40 cost database connected and available in the model

F. Sizing method

Select the Sizing Method button to go to the Sizing Method panel.

Ensure that Discrete Sizing is selected with the Modified Method of Feasible Directions (MMFD) chosen for the Search Method.

G. Dependent design cases

Now that we have defined the primary design case model shown in Figure 4.1, we will create one *dependent design case*. A dependent design case (or DDC) in the ANS module is a system that models the same physical pipes and junctions as the primary design but with different operating requirements. The dependent design case for this model is when the North Fire Hydrant is opened. When the hydrant is opened, the flow out of the hydrant is 23.5 m3/hr and the homes are allowed to drop to 0.5 m3/hr each.

Here are the steps to create this Dependent Design Case:

1. Go to the Sizing Objective panel and select the "Enable Dependent Design Cases" option. A new button will now be available for the Dependent Design Cases panel in the Sizing Navigation Panel as shown in Figure 4.6.

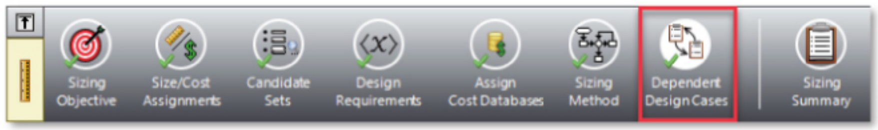


Figure 4.6 Sizing Navigation Panel with Dependent Design Cases enabled

2. Select the Dependent Design Cases button. You should now see instructions displayed to create the Dependent Design Case, along with a summary table of dependent design settings. We will need to use the Duplicate Special tool to create the dependent design case.
3. Go to the Workspace and choose Select All from the Edit menu.
4. Open Duplicate Special from the Edit menu, enter an increment of 100 and select "Make Dependent Design Case", and "Clear Design Requirements" (Figure 4.7). Click OK.
5. Move the duplicated pipes and junctions to distinguish them from the original ones from the Primary Design Case (Figure 4.8).

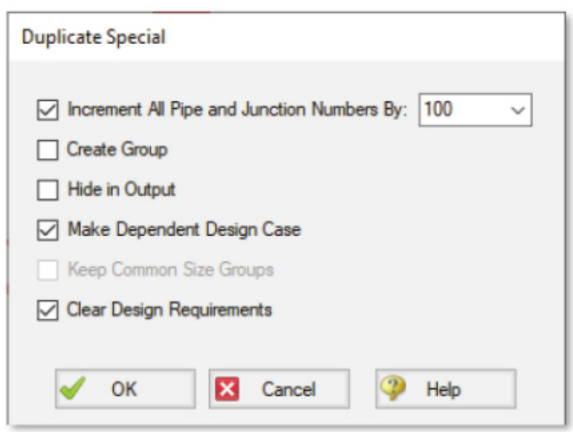


Figure 4.7 Duplicate Special is the easiet way to create a dependent design case

6. Open the J180 hydrant to flow in the DDC by selecting it and toggling off the Special Condition setting on the toolbar.
7. Use Global Junction Edit (from the Edit menu) to change all of the assigned flow junctions at the DDC homes (junctions 140-154) from 2.2 m3/hr to 0.5 m3/hr (see Figure 4.9).
8. In the Sizing window navigate to the Design Requirements panel. Assign the "Fire Supply" Design Requirement created earlier to pipe P180 by checking the adjacent box.

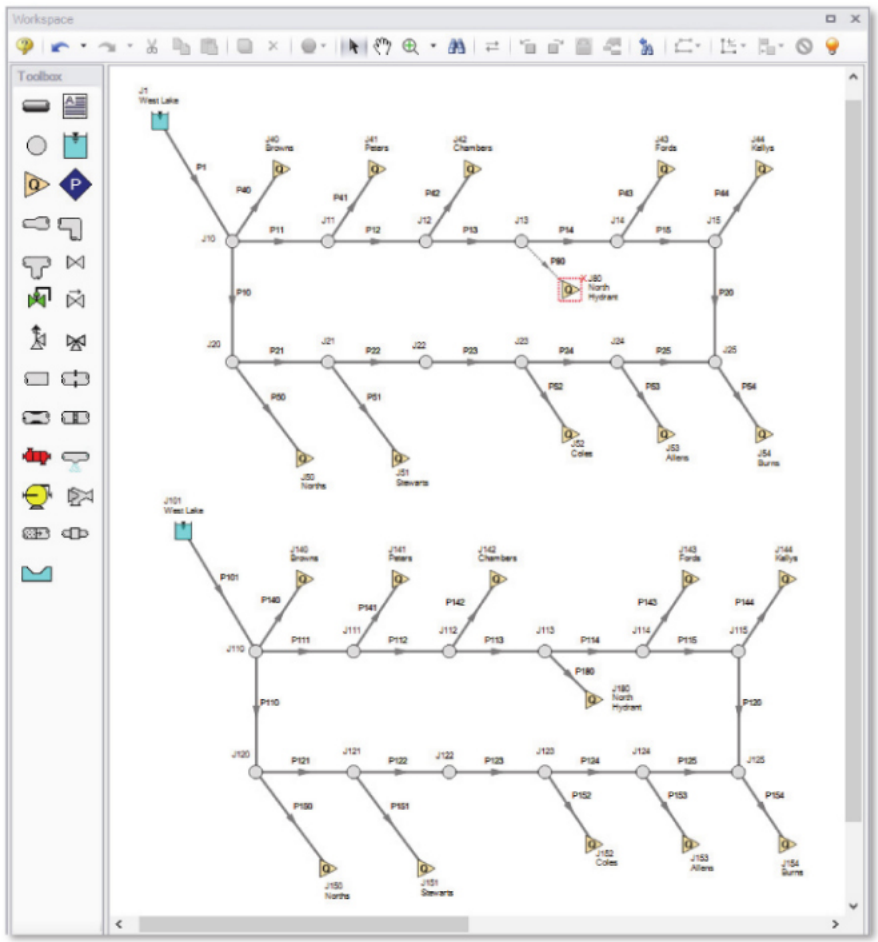


Figure 4.8 Workspace with Primary Design Case (at top) and one Dependent Design Case (at bottom)

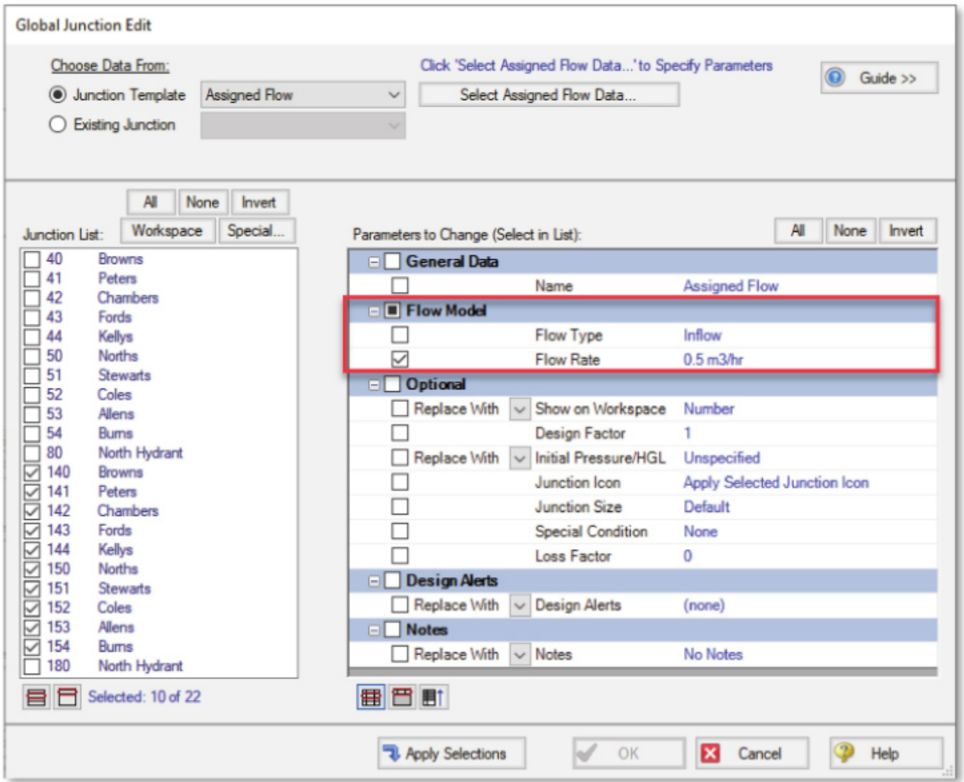


Figure 4.9 Global Junction Edit is used to change the flows to 0.5 m3/hr in the homes for the fire flow DDC

Return to the Dependent Design Cases panel.

When Duplicate Special was performed with Dependent Design Case selected, each of the duplicated pipes was created with a special type of grouping. For example, pipe 101 is grouped with pipe 1 as a DDC pipe (see Figure 4.10). This type of assignment allows the dependent design pipes to be sized, but to not be counted in the cost so that the cost will not be duplicated.

It should also be noted that the dependent design grouping causes each of the dependent pipes to inherit their Common Size Groups, Candidate Sets, and Cost Database settings from the pipes in the primary case. The dependent design case pipes are therefore hidden on all sizing panels except for the Design Requirements and Dependent Design Cases panels.

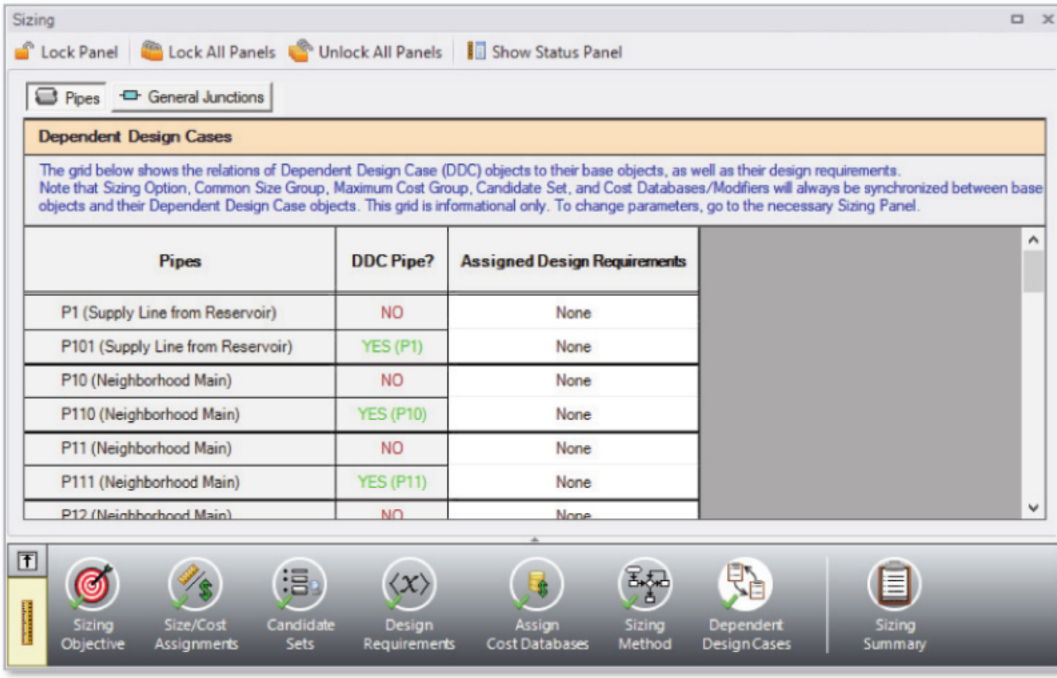


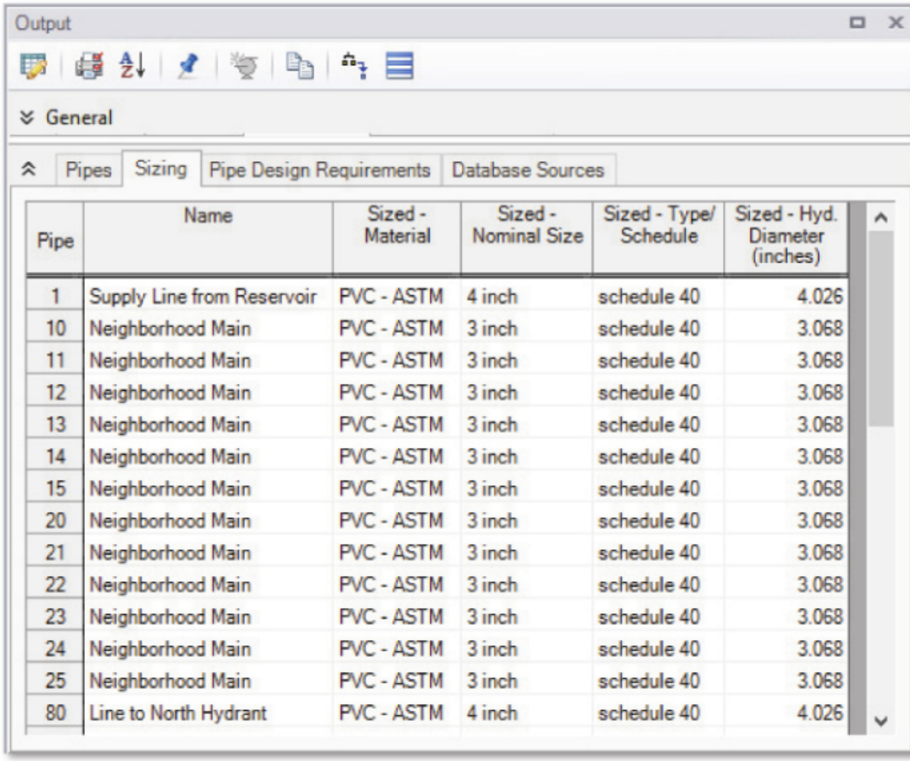
Figure 4.10 Pipes in Dependent Design Cases have a special grouping relationship with pipes in the primary case

Run the automated sizing

Select Run from the Analysis menu to perform the automated sizing.

After the run finishes, examine the final pipe sizes calculated by the ANS module. One can see that the resultant size is 3-inch PVC for the neighborhood mains, with larger 4-inch PVC-ASTM pipe for the reservoir and hydrant lines, as shown in Figure 4.11.

The cost for all sized pipes is $55,890 (see Cost Report in Figure 4.12). This is the cost for "Items in Objective". Since we did not size the pipes to the homes (because these were fixed at 1- inch), they were set to not be included in the cost report using Output Control.



Pipe	Name	Sized - Material	Sized - Nominal Size	Sized - Type/ Schedule	Sized - Hyd. Diameter (inches)
1	Supply Line from Reservoir	PVC - ASTM	4 inch	schedule 40	4.026
10	Neighborhood Main	PVC - ASTM	3 inch	schedule 40	3.068
11	Neighborhood Main	PVC - ASTM	3 inch	schedule 40	3.068
12	Neighborhood Main	PVC - ASTM	3 inch	schedule 40	3.068
13	Neighborhood Main	PVC - ASTM	3 inch	schedule 40	3.068
14	Neighborhood Main	PVC - ASTM	3 inch	schedule 40	3.068
15	Neighborhood Main	PVC - ASTM	3 inch	schedule 40	3.068
20	Neighborhood Main	PVC - ASTM	3 inch	schedule 40	3.068
21	Neighborhood Main	PVC - ASTM	3 inch	schedule 40	3.068
22	Neighborhood Main	PVC - ASTM	3 inch	schedule 40	3.068
23	Neighborhood Main	PVC - ASTM	3 inch	schedule 40	3.068
24	Neighborhood Main	PVC - ASTM	3 inch	schedule 40	3.068
25	Neighborhood Main	PVC - ASTM	3 inch	schedule 40	3.068
80	Line to North Hydrant	PVC - ASTM	4 inch	schedule 40	4.026

Figure 4.11 Results for sized pipes for the case with three Independent Pipe Sizes

Review the results

The automated sizing we just ran had two operating cases. One was for normal water supply, and the second was for hydrant supply for a fire. The normal flow case is modeled by the network shown in the upper part of Figure 4.8. The second model shown at the bottom of Figure 4.8 models the fire flow case.

The pipes and junctions in the fire flow case are separate entities for modeling purposes, but represent the same pipes and junctions as the normal flow case. Thus when performing automated sizing, we only count the cost of the pipes and junctions once. This occurs in the primary design case, which in our model is the normal flow case. This is why pipes P100-P180 are not shown in the Cost Report.

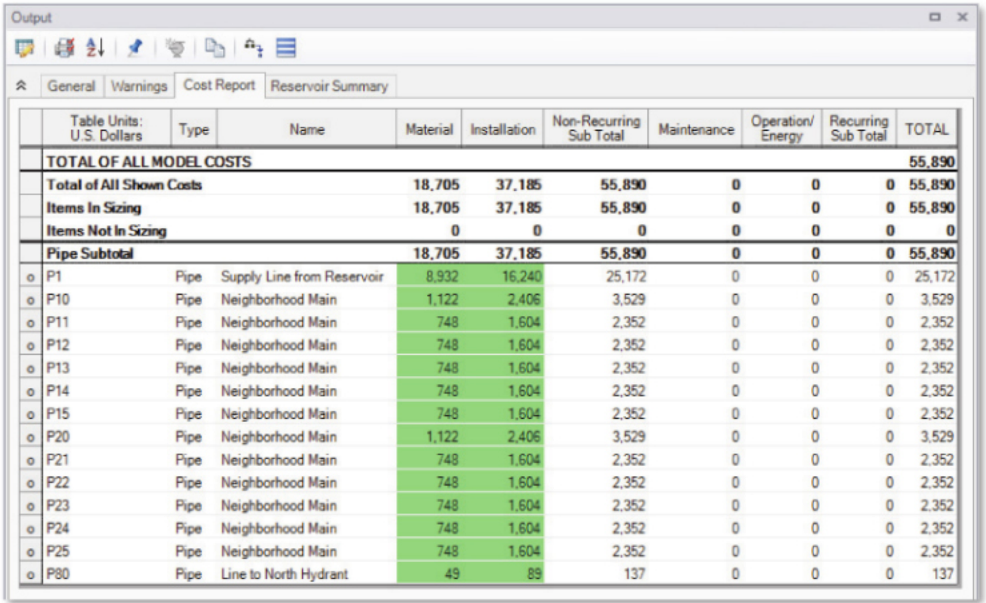


	Table Units: U.S. Dollars	Type	Name	Material	Installation	Non-Recurring Sub Total	Maintenance	Operation/ Energy	Recurring Sub Total	TOTAL
	TOTAL OF ALL MODEL COSTS									**55,890**
	Total of All Shown Costs			**18,705**	**37,185**	**55,890**	**0**	**0**	**0**	**55,890**
	Items In Sizing			**18,705**	**37,185**	**55,890**	**0**	**0**	**0**	**55,890**
	Items Not In Sizing			**0**	**0**	**0**	**0**	**0**	**0**	**0**
	Pipe Subtotal			**18,705**	**37,185**	**55,890**	**0**	**0**	**0**	**55,890**
o	P1	Pipe	Supply Line from Reservoir	8,932	16,240	25,172	0	0	0	25,172
o	P10	Pipe	Neighborhood Main	1,122	2,406	3,529	0	0	0	3,529
o	P11	Pipe	Neighborhood Main	748	1,604	2,352	0	0	0	2,352
o	P12	Pipe	Neighborhood Main	748	1,604	2,352	0	0	0	2,352
o	P13	Pipe	Neighborhood Main	748	1,604	2,352	0	0	0	2,352
o	P14	Pipe	Neighborhood Main	748	1,604	2,352	0	0	0	2,352
o	P15	Pipe	Neighborhood Main	748	1,604	2,352	0	0	0	2,352
o	P20	Pipe	Neighborhood Main	1,122	2,406	3,529	0	0	0	3,529
o	P21	Pipe	Neighborhood Main	748	1,604	2,352	0	0	0	2,352
o	P22	Pipe	Neighborhood Main	748	1,604	2,352	0	0	0	2,352
o	P23	Pipe	Neighborhood Main	748	1,604	2,352	0	0	0	2,352
o	P24	Pipe	Neighborhood Main	748	1,604	2,352	0	0	0	2,352
o	P25	Pipe	Neighborhood Main	748	1,604	2,352	0	0	0	2,352
o	P80	Pipe	Line to North Hydrant	49	89	137	0	0	0	137

Figure 4.12 Cost Report is shown in Output window

By applying different pressure and flow requirements between the normal and fire flow cases, we performed an automated sizing that selected the best pipe size which simultaneously met the requirements of both cases.

Finally, since the previous case only selected three pipe sizes to be used for all sized pipes, there were only three design variables. By creating more Common Size Groups, a better solution is possible.

Other possibilities

To obtain the best possible design for the system, one can allow each pipe to be sized independently by removing all pipes from the common size group. While not shown here, it is possible to reduce the overall cost for this system to $49,000.

This final automated sizing takes much longer to run (a few minutes vs. a few seconds previously). Since all the pipes are sized independently, the practical result is that ordering and installing the pipe is more complicated because there are so many more sizes involved.

Alternatively, this sizing could be performed by using weight as the objective instead of monetary cost to simplify the setup. Using a non-monetary objective can produce less accurate sizing results in cases where the energy costs or costs of equipment such as pumps need to be accounted for. However, since this is a gravity-fed system only the pipe sizes need to be considered for the sizing calculations. Though not shown here, changing the objective to pipe weight produces nearly identical results, with only the line to the hydrant having a slightly larger size.

CHAPTER 5

Other AFT Fathom ANS Module Capabilities

This Quick Start Guide necessarily omitted coverage of a number of ANS module capabilities. This chapter briefly describes some of the important capabilities not covered.

Size with operating costs spread over multiple cases

For systems with multiple design cases, the system may operate a significant portion of the time in each design case mode. The ANS module allows one to assign a percentage of the operating cost to each relevant design.

For example, assume you are designing a two-pump cooling system which uses both pumps in the summer but only one in the winter (because of reduced demand for cooling water). The winter operating cost is thus much less than in the summer. You can account for this by assigning the percentage of the time the pump operates in each design case. This allows a proper accounting of annual operating costs, and a proper life cycle automated sizing to be performed.

Vary recurring costs over time

Through "scale tables" the ANS module allows you to input recurring data for pipes or junctions that vary over time. For instance, perhaps the maintenance cost of a piece of equipment is low at first but requires increased maintenance over some time period. The cost for maintenance can be varied over time to match the anticipated maintenance schedule.

Time value of money

An important consideration in evaluating recurring cost items is the cost of money for future expenses. The ANS module allows you to enter an interest rate and inflation rate to account for actual value of future expenses based on today's currency value. This data is entered on the Assign Cost Databases panel of the Sizing window.

Determine cost effectiveness of replacing existing pipe

The ANS module can determine the cost effectiveness of leaving existing pipe in place or replacing it with new pipe. This can be defined on the Size/Cost Assignments panel.

Working with different currencies

Cost data can be entered in any currency you wish. Different currencies can be defined in the Parameter and Unit Preferences window, and then used as a basis for cost databases.

Costs vs. size

Scale tables can be used to model how equipment costs vary with pipe diameter. For instance, a 4-inch valve will cost more than a comparable 2-inch valve. This can be accounted for in the cost database by use of scale tables.

Generic pump costs can be modeled as a function of power, and generic control valve costs can be modeled as a function of maximum Cv.

Sizing rectangular duct systems

The ANS module can size systems with only rectangular ducts or a combination of rectangular and cylindrical ducts. Rectangular ducts have two space dimensions, and thus two design variables are required for each independent duct size.

Compare VFD vs. FCV sized systems

Variable Frequency Drive (VFD) control methods are frequently compared to Flow Control Valve (FCV) methods. However, this is typically only evaluated in the context of a given pipe system. The ANS module allows one to size the system for each of these methods. This allows a more meaningful comparison.

Maximum cost groups

When evaluating multiple operating cases, one of the pump operating modes will drive the pump selection for all cases. This is by virtue of the fact that the cost will be based on the mode requiring the most power and/or largest head. This can be modeled in the ANS module with Maximum Cost Groups. A Maximum Cost Group allows one to couple costs together for all pumps that will eventually be of the same design (and thus cost the same). This allows the proper cost information to be used for each design case.

Maximum cost groups can also be used for control valves.

Discrete costs

For sizing items such as pump motors, a discrete cost table can be created. This allows costs to be reported based on the discrete motor sizes available for the pump, rather than interpolating the cost assuming that motors are available for purchase at any capacity.

Network databases

Engineering and cost databases can be located on local PC's or deployed across local or wide area networks. The Database Manager allows users to connect to relevant databases for their specific pipe system design.

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Additional AFT Fathom Modules

GSC
Goal Seek & Control
Identifies input parameters that yield desired output values and simulates control functions

XTS
Extended Time Simulation
Models dynamic system behavior and how critical system parameters vary over time

SSL
Settling Slurries
Models the effects of pumping fluids containing settling solids using the Wilson/GIW method

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