HELIX TECHNOLOGIES

Helix delta-Q for Windows™

Pipe Network Analysis Program
for Liquids, Slurries and Gasses
Version 2.0

Standard Version

OPERATING INSTRUCTION MANUAL

HELIX TECHNOLOGIES

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Version 2.

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HELIX DELTA-Q version 2 and DELTA-Q DEMO PROGRAM

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1.1. Introduction

Welcome to the *Helix delta-Q* version 2 Pump & Pipe Flow Analysis Program - an essential tool for engineers to quickly and easily optimise pipe networks for **compressible** and **incompressible** fluids.

You can calculate friction losses and pressure drops in pipes and fittings for **Liquids**, **Slurries** and **Gasses**. Model complex process flow pipe networks and solve for unknown flow rates and node pressures at the press of a button. Retrieve data from user accessible databases for Liquids, Slurries, Gasses, Pumps, Pipes and Fittings.
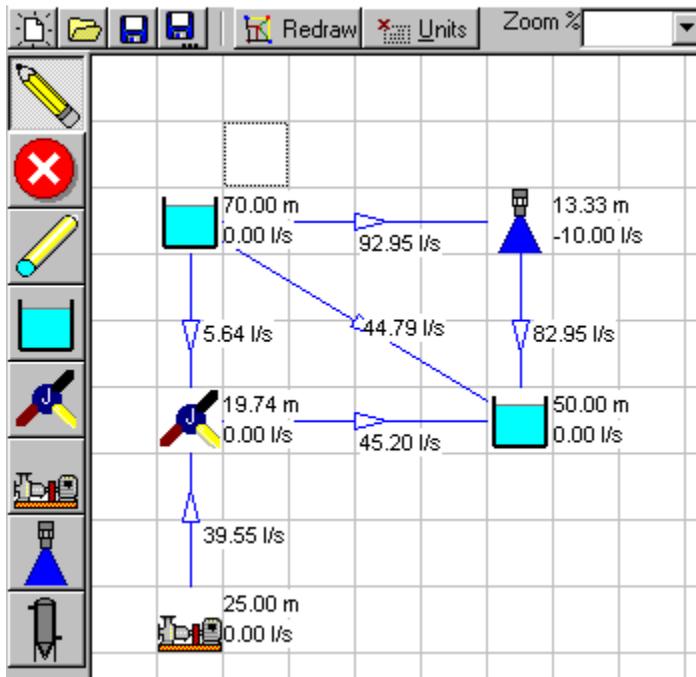
delta-Q version 2 is the fourth generation of Pump and Pipe Flow analysis software produced by Helix Technologies and is founded on many years of practical fluid flow system and software design experience by the company.

Sketch your pipe and pump network by dragging and dropping icons onto the screen. Setup your pipe, pump and sprinkler details, press Solve, and the program will calculate flow rates and pressure drops in each branch of the network.

You can have different fluids flowing in different pipes in the network to cater for process changes in the system - for example, you may have a concentrated slurry in one pipe flowing into a junction with a water pipe (or pipes) and dilute slurry flowing through the network from there onwards. Or a heat-exchanger in the system may raise the temperature and change the fluid properties - you only need to enter the altered properties in the downstream section and the network will be re-modeled.

Answer What if? questions such as what if this pipe in the system has a closed valve in it, or becomes isolated from the system? What size orifice plate is required?

You can incorporate as much or as little detail as you require - if you are doing a quick feasibility calculation you can merely enter a total pipe length and an estimated total K value for fittings. Alternatively, if you are doing detailed design work you can model the system to include every single bend, valve and fitting with individual head losses calculated using the K and Kf methods.

You can choose the method of calculation - the default is **Darcy-Weisbach** but you can set the program to calculate the network using **Hazen Williams** (to comply with NFPA standards, for example). For **Slurries**, the program handles both **Heterogeneous** settling type slurries as well as **non-Newtonian** fluids such as **Bingham** slurries. And you can have a combination of these in the same network!

For **Gas** networks, the program lets you choose whether to use classic **Isothermal** gas flow theory or the **Modified Darcy** method where an expansion factor compensates for choked flow conditions. The program solves complex gas flow pipe networks at the touch of a button. This means that you can model almost any fluid flow situation

which may be encountered in a large process environment, from water to solutions, slurries, steam, compressed air and process gas lines.

A pipe **capital** versus **operating cost** model will help you make the correct decisions on pipe size versus pressure drop operating costs and result in a more cost effective plant design.

Helix delta-Q is designed to assist engineers and process pipe system designers to produce technically and commercially sound designs in a very short time.

The network diagram and system head curves can be printed and Design Reports are produced simply in a compact table format which can be printed or pasted into MS Excel™, Lotus 1-2-3™ or any other Windows compatible spreadsheet or word processor. Network results can be viewed in graph form too for easy interpretation.
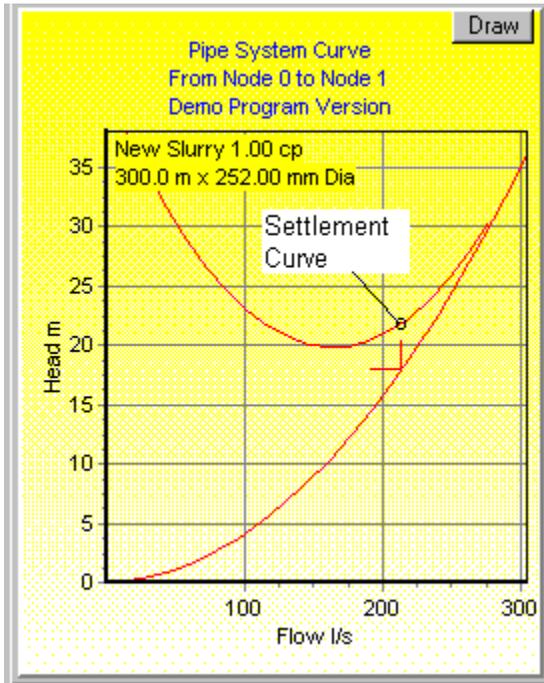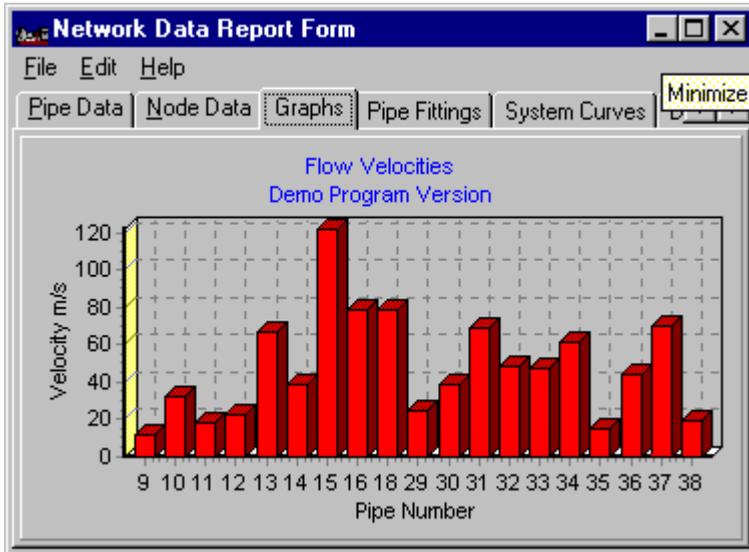
delta-Q will save you time and reduce your plant capital, maintenance and operating costs.

1.2. System Requirements

To run the *Helix delta-Q* version 2 program you need:
- Personal computer with 486 or higher microprocessor.
- 16 MB of RAM.
- 4 Mb of Hard Disk space.
- 3.5" 1.44 MB or CD ROM disk drive.
- Microsoft Windows 95™, 98 or NT 3.51 or later version.
- 800 x 600 or better resolution VGA monitor.
- Printers, plotters and networks supported by Windows 95 or later.
- Microsoft mouse or compatible is recommended.

1.3. Program Installation

The program is supplied in one of the following file formats:

A) 3 x 1.44 Mb 3.5" disks
B) CD ROM disk.

1.3.1 Floppy Disk Installation

Insert Disk 1 in your **A:** drive.

From the Microsoft Windows Desktop, Select the Start button and the Run menu option and type:

a:\setup

or use the Browse button to locate the Setup.exe file.

Press OK and the Setup program will start. Follow the on-screen prompts of the Setup Program which will guide you through the installation process.

1.3.2 CD ROM Disk Installation

Insert the CD ROM in your CD-ROM drive, usually designated **D:** drive. From the Microsoft Windows Desktop, Select the **Start** button and the **Run** menu option and select the browse button. Change to your CD-ROM drive, then select the Delta_Q sub-directory and then select the Setup.EXE program. The Run window should look something like this :

d:\delta_Q\setup

Press OK and the Setup program will start. Follow the on-screen prompts of the Setup Program which will guide you through the installation process.

1.3.3 Security Key (Dongle) Device Driver.

(Full Version Only)

Before you can run the Helix delta-Q program, you need to install a device driver for the Dongle. The dongle is a match box sized device which activates the Helix delta-Q software, and this device requires a Device Driver program to control it.

After running Setup.exe, you must run the **Hdd32.exe** program to install this device driver. It is located on Disk 3. Run it by inserting the Disk marked number 3 in your A:\ drive. Then Select Start, Run from the Windows task bar and Run the **Hdd32.exe** program by following the on screen instructions.

This program will install the Device Driver for the Dongle hardware lock device. You only need to run this program once to install the device driver. Refer to the **Hdd.hlp** file for more details. It is not necessary to copy the **Hdd32.exe** file to your computer Hard disk.

Installing the Dongle:

After installing the files described above, you need to install the Dongle on the parallel (LPT) port on your computer. This port is usually the one connected to your printer. Switch off your computer, remove the printer cable (if fitted) from the port, insert the dongle, tighten the screws and re-insert the printer cable (if fitted). Re-start the computer and run the Delta-Q program by selecting the Start, Programs, Helix delta-Q menu option. The Dongle will not affect the operation of the printer in any way. It is not necessary to have a printer coupled to the computer to use the software. The Dongle may be installed on any parallel port on the computer.

1.4. Un-Installing delta-Q

Select **Start**, **Settings**, **Control Panel**. Click on the **Add / Remove** Programs icon. A list of programs installed on your computer will be displayed. Select the Helix delta-Q program from the list and click the Add / Remove button. Confirm the removal and follow the instructions of the removal program.

The *Helix delta-Q* program does not install any files except those listed in the **Program Files, Helix, delta-Q** sub-directory and these can be deleted after un-installing the program.

1.5. Using Help

The program is provided with context sensitive on-line help for all functions and procedures. Simply press **F1** and the help topic relating to the current subject will be displayed. Alternatively, use the **Help** main menu to access the **Help Contents** list and select the subject you require from the contents list, or use the **Search for Help on...** menu to search for a topic using keywords. A section on how to use the Help files is also provided under the Help menu.

1.6. Files and Data

The Helix delta-Q program only installs files to the application subdirectory. The default location of the application subdirectory is :

c:\Program Files\Helix\delta_Q2

In addition to the files in this directory, the setup program also creates the following subdirectories:

c:\Program Files\Helix\delta_Q2\Data\Liquids   Liquid data files
c:\Program Files\Helix\delta_Q2\Data\Gasses   Gas data files
c:\Program Files\Helix\delta_Q2\Data\Slurries   Slurry data files
c:\Program Files\Helix\delta_Q2\Data\Pipes   Pipe data files
c:\Program Files\Helix\delta_Q2\Data\Pumps   Pump data files

These are data files and should be backed up when doing disk maintenance.

The setup program also creates a data directory for storing Project design files:

c:\Program Files\Helix\delta_Q2\ProjectsNetwork data files

Each network requires two files, the first being a file with an extension of .NWK which contains the node and pipe details and the second with an extension .NWI which contains the project details and design comments. If you are transferring network design files from one directory to the next, you must transfer both of these files.

<p align="center">***************</p>

2.1 Getting Started - Creating and Solving a Pipe Network

Using delta-Q is easy - follow these steps to create and solve your first network. You can get context sensitive help by pressing F1 at any time. You can also Print this topic by pressing the Print Button.

1. Install the program.

2. Run delta-Q and Select the Pipe Networks option on the main form.

3. The Network Analysis form will be displayed. Select **File**, **New** and type in a file name for your network. Press OK.

4. The Project Details form will be displayed. Enter the project details and set up the Default Liquid, Slurry, Gas and Pipe by entering data in the relevant tabbed pages.

5. Click on the Units of Measure tab and select the units you want to use. The important ones are Flow, Head, Pressure, Length and Diameter units.

6. Click on the Calculation Method tab and Select **Liquid** and **Darcy-Weisbach.** The first network will be a simple liquid network.

7. Close the Project Settings form by clicking the OK button at the bottom of the form. You will be returned to the Network Diagram form, and it will now be open for editing, although still blank.

8. Click on the Fixed Head Node (Tank) Toolbutton on the left of the screen. Drop a fixed or known head node in the network by clicking in drawing area as shown below:
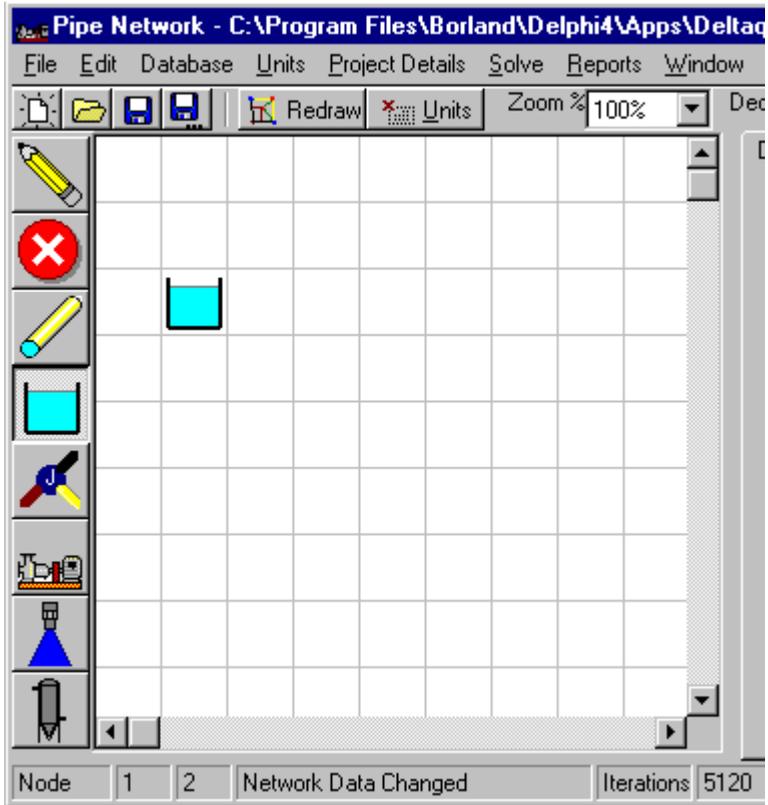
9.

10. Add another tank by clicking in another square to the right and below the first tank.

11. Click on the [icon] Pipe Toolbutton and then click with the mouse on the first Tank, hold the left mouse button down and move the mouse to the second tank. Release the left mouse button whilst it is over the second tank. A line will be drawn joining the two tanks. Press the Redraw button above the drawing area and the pipe will be redrawn with a direction arrow. You have now drawn two tanks connected by a pipe and to complete the network we need to set the tank levels and the pipe details. Your sketch should look like this:

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12.

13. Every network should have known head or pressure nodes at the terminal points of the network. The known head nodes may be tanks or pumps (or pressure vessels and compressors for gas networks). Junction, sprinkler and vessel nodes are generally unknown head nodes and the heads will be calculated by the program.

14. Click on the Pointer Toolbutton. This is the network selection tool. Click on the **Details** tab to right of the drawing area.

15.
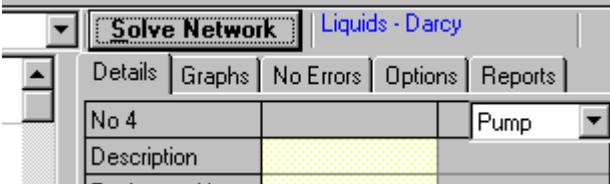
16. Click on the first tank in the diagram. The tank details will appear in the Details data grid on the right hand side of the diagram. The pale yellow area of the grid is where you can enter data such as the description of the tank, Equipment number and other node data. The default Liquid details you setup in the Project settings form will be displayed. The value entered in the altitude box in the Project Details form will be displayed in the Datumn Level cell, in this case 50m. Click in this cell (Datumn Level) and change the

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value to 70m. We will leave the second tank's level at 50m so that there is a differential of 20m.

17. Move the mouse over the pipe in the diagram. The cursor will change to display a Hand when it is over the pipe. Left Click and the Pipe Details will be displayed in the Data grid. The Default liquid details will be displayed followed by pipe and fitting details. The pipe details will be the default values set up under Project Settings. Click in the Pipe Length Cell and enter a value of 50m. The network is now complete and we can solve for the flow rate by pressing the **Solve Network** button. The Flow rate and the node heads will be shown in the diagram as below:

18.
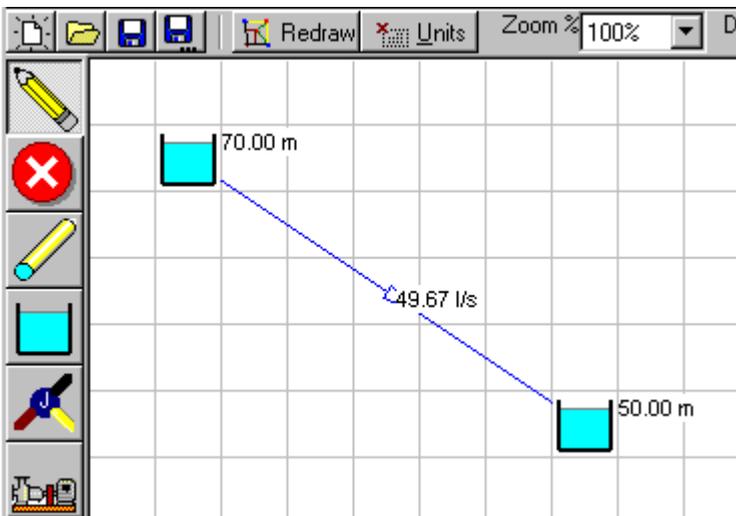
19. You can add fittings to the pipe by entering a fitting K value in the K value cell or you can go to a list of fittings. Click on the pipe to give it the focus. Now move the mouse over the Fitting K value cell. The cursor will change to a Hand, indicating that that cell has a drill down function. Double click the left mouse button in the Fitting K value cell. A new form with two lists will be displayed. The top list shows a list of fittings in the Fittings database file. Scroll down this list and select the fittings you require by double clicking on it. It will be transferred to the bottom list - a list of fittings in the current pipe. See the Pipe Fittings help topic for more details. You can build up a list of fittings for the pipe using

this method. Click the **OK** button to close the Pipe Fittings form. The Total K and Kf values will be transferred to the Pipe data grid. If you press the **Solve Button** the new flow rate, which takes into account the fitting losses, will be displayed.

20. Now let us add an unknown head junction and a pump to the network. Click on the Junction Toolbutton and drop a Junction in the diagram somewhere below the first tank. Click on the Pump Toolbutton and add a Pump Node below the Junction node. Click on the Pipe Toolbutton and then click on the Pump Node in the diagram and holding the left mouse button down, drag the mouse until it is over the Junction node. Release the mouse button and the pipe will be drawn. Now connect the first Tank to the junction and then the junction to the second tank. Your network should look like the diagram below. Click on the Pump Node. In the Details data grid enter a value of 25 m (say) in the Pump Head cell. Now click on each of the three pipes you have just added and enter a pipe length for each (say 23, 48 and 72.5 m). Now press the **Solve Network** button. The result will look something like this

21.
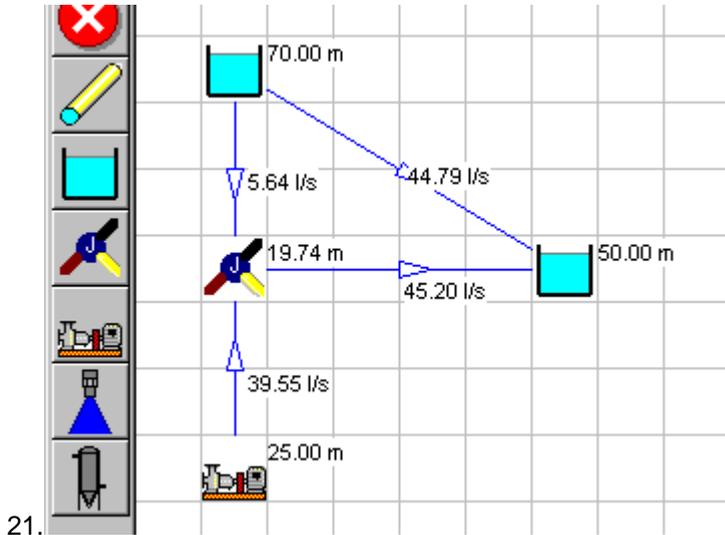
22. You can continue to add nodes and pipes in this way.

23. You can view a **System** curve of any of the pipes. Click on the **Graphs** tab. Select the Selection (Pointer) Toolbutton and click on any pipe in the network. The System graph will drawn.

24.
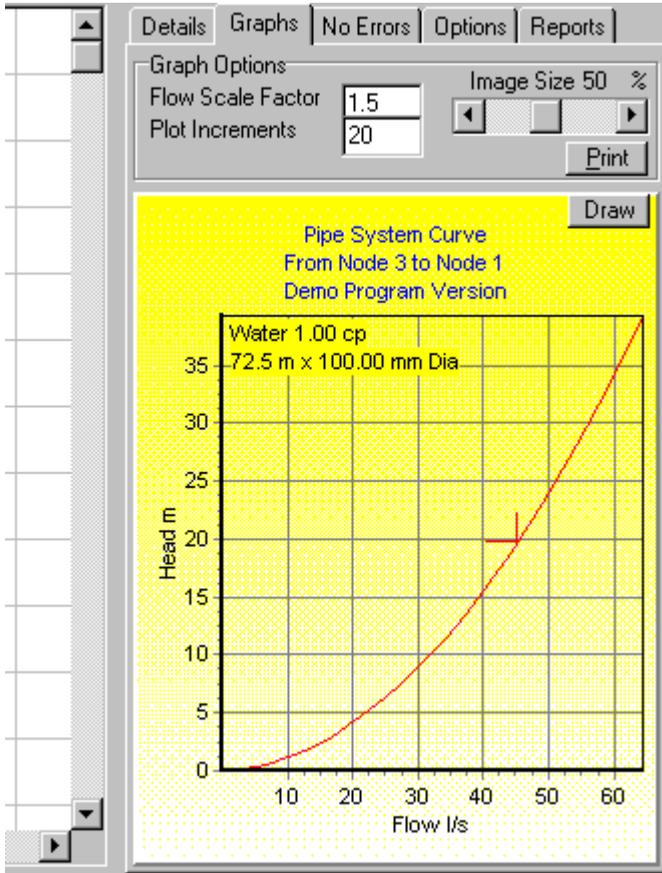
25. If you make changes to the network whilst the system graph is visible, you can refresh the graph by pressing the **Draw** button. You can print this graph by pressing the **Print** button. The Flow and Head scales can be changed by changing the Flow scale and the Plot Increment value changes the number of points calculated and drawn on the graph. (A high value plots more points).

26. We can also add a sprinkler nozzle to this network. Select the

Nozzle Toolbutton [icon] and drop a nozzle to right of the first tank. Now draw a pipe from the first tank to the nozzle and

another pipe from the nozzle to the second tank. Now click on the Selection Toolbutton and click on the new pipe to give it the focus and enter a relevant length (say 6 m and 15 m for the other pipe). Click on the Nozzle and enter a value of -10 in the Flow In (+) / Out (-) cell. This cell is where you enter sources or supply flows into and sinks or demand flows out of the network. A minus indicates flow out of the network at that point. You can also specify external flows at Junction nodes. See the Nozzles and Spays help topic for more details. Click on the **Solve Network** button. You will see that the flow out from the nozzle junction will be equal to the flow into the nozzle minus the external flow value you entered, as shown below. Now click on the **Reports** tab and click on **Display External Flow Rates** check box. The external flow rates will be drawn on the network.

27.

Right Click with mouse to copy diagram to Windows Clipboard - you can then paste it into other applications.
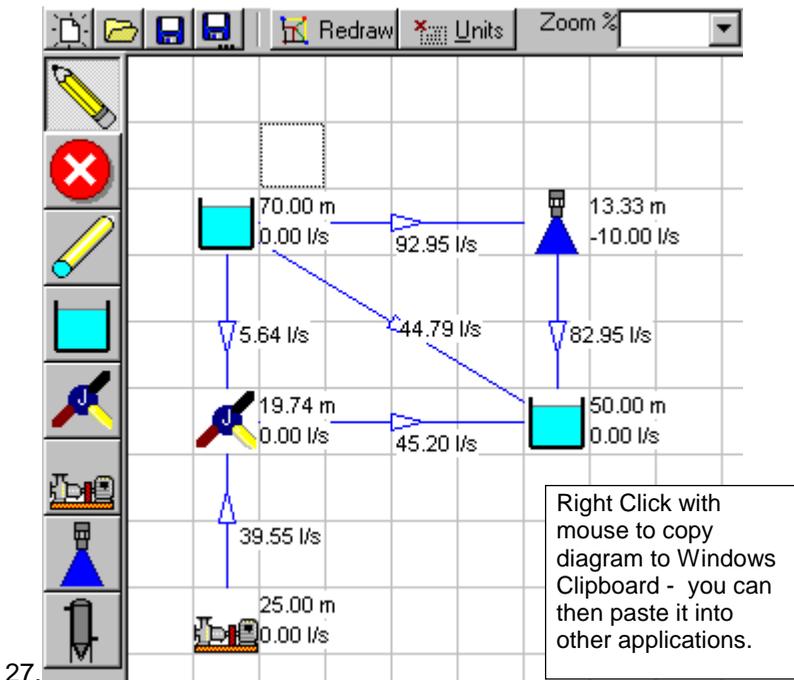
28. Experiment with the other **Display ...** checkboxes. You will usually find that you can display two or three values comfortably at a time on a network. We suggest that you can display a few, print

the network, change the display and then print it again. This prevents the diagram from becoming too crowded.

29. You can copy data from the Pipe, Liquid and Slurry Databases to the current node or pipe. Simply select the item in the diagram, then **Right click** in the **Data Grid**. A pop-up menu allows you to retrieve data from the databases or to print the Pipe or Node Data currently shown in the Data Grid.

30. You have now completed a network design. You can print the Network Diagram by pressing the **Print Network Diagram** button on the **Reports** tab. You can view the **Data Reports** by clicking on the button on the same tab.

31. The Data Reports form allows you to view and print the network data. Click on each tab sheet to view the different reports, print some of them if you wish. You can also view the network solution in **Graph** form. This is a useful tool for you to check for minimum or maximum values at a glance. For example, you can check the Node pressures or the velocities and view the results in a graph.

32. You can Export Data from the Data Reports. For example, click on the **Pipe Data** tab and click anywhere in the data grid to give it the focus. Now select the **Edit, Copy** menu. The data grid has been copied to the Windows clipboard and you can paste it into another application such as a spreadsheet program. For example, if you have MS Excel installed, start it up and when it is open at a blank spreadsheet, click in the top left cell, press the **Edit**, **Paste** menu option, and the data will be pasted in that column. Now, to spread the data into multiple columns, select the column where the data was pasted, select the **Data, Text To Columns...**menu option, select the **Delimited Option** in the wizard, Press the **Next** button, set the **Comma** Delimiter option to on (because it is a comma separated value file which is pasted from Helix delta-Q) and press the **Finish** button. The Pipe data should now be in separate columns in the spread sheet and you can add, modify, customize and print the data. Refer to your spreadsheet application help file for details on how to parse comma separated values if you have any difficulty.

33. You have now created a simple network, solved it and viewed and printed the data.

34. You can delete nodes by using the Delete Toolbutton . Click on the Toolbutton then click on the node you want to delete. Confirm your deletion and the program will remove the node and all pipes connected to that node.

35. You can change the size of the diagram by selecting a **Zoom** percentage and you can alter the number of **Decimals** displayed on the diagram and in the Data Grid and the Data Reports form by selecting values from the Decimals drop down box above the diagram.

36. You can move nodes. Click the Selection Toolbutton, click on a node and hold the left mouse button down whilst you drag the node to a new un-occupied cell. When you release the mouse button the node and pipes will be re-drawn in the new position.

37.
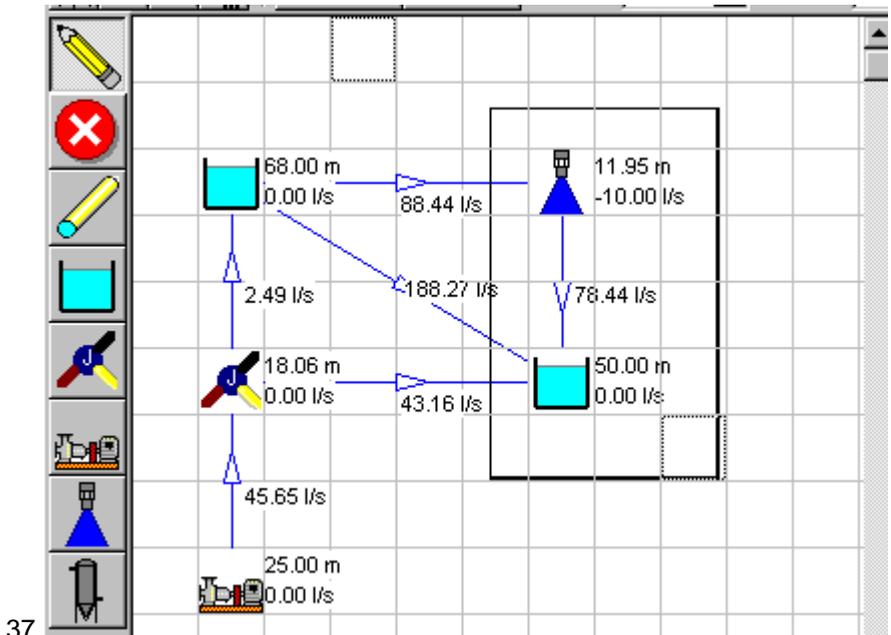
38. You can move more than one node at a time. Click in an empty cell and hold the mouse down to drag a rectangular window

around the cells you want to move. When you release the mouse, move it to inside the rectangular window and a cross with four pointers will appear. Left click and hold down to drag the window a few cells and then release the mouse. The cells will be re-drawn in the new position.

39. You can change the liquid details in any pipe by selecting the pipe and altering the values in the Data Grid. In addition to manually changing the values you can select a liquid from the database. If you move the mouse over the Liquid Description cell, a Hand cursor will be displayed. Double click and the Liquid Database will be displayed. Click on the liquid you want to use, Right click with the mouse and select the **Copy Record to Network** option. The liquid details will be copied to the network data grid.

40. Orifice Plates. You can an add an orifice plate to any pipe in the network. Select the pipe and in the Data Grid, enter an Orifice Plate Diameter. This diameter should be less than the pipe Inside Diameter (preferably less than 70% of the pipe ID for good accuracy). Press the Solve Button and the program will calculate the new flow rate in the system. The Orifice Head losses are shown separately in the data grid. To remove the orifice enter a zero for the Orifice Plate Diameter. A pipe with an orifice plate present is drawn with a small perpendicular line crossing it just upstream of the direction arrow head, as shown below:

41.
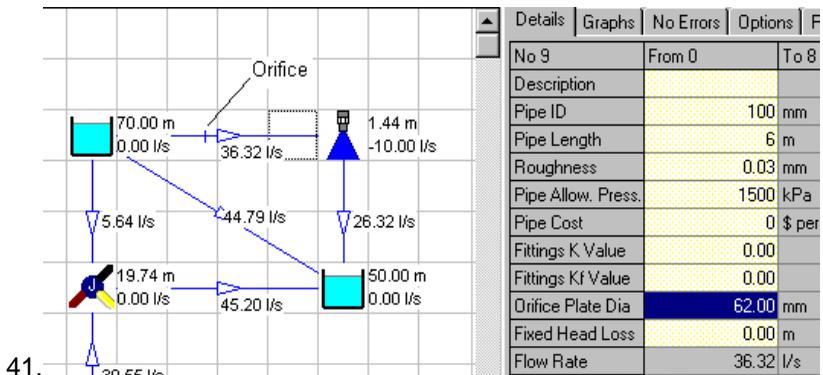
42. For **Slurry Networks,** click on a pipe and in the **Details** tab, click the **Slurry** check box to on. The Liquid label will change to Slurry. Double click in the cell next to Slurry and the Slurry input form will

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be displayed. Enter the Slurry details and press OK to return. The network will now be analysed with slurry flowing in the pipe selected when you press Solve. You should check the settling velocity of the slurry against the actual velocity. It is also useful to use the System graph to view where your duty point falls if you have a slurry in the network. For Settling slurries, you should select a pipe size which will give you a velocity close to or above the settling velocity. For example, the following flow rate is too low (or pipe size too large, or pipe too long) as the duty point falls well below the slurry settling velocity.
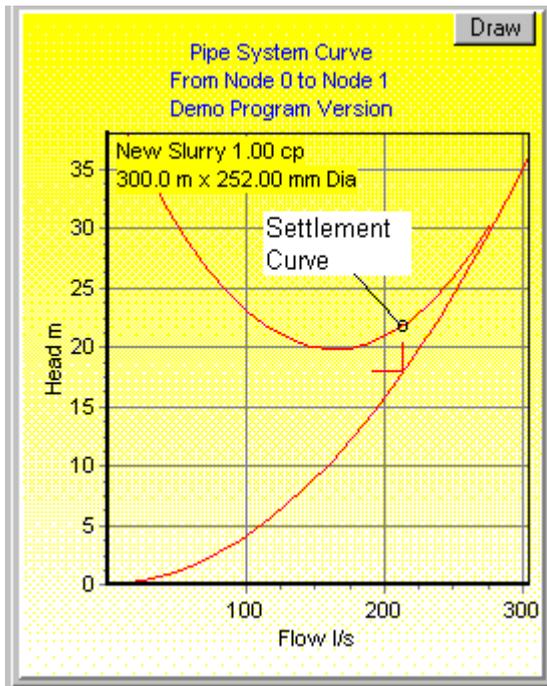
Right Click with mouse to copy graph to Windows Clipboard - you can then paste it into other applications.

43.

44. You should increase the velocity in the pipe by increasing the available head or reducing the pipe diameter so that the duty point falls closer to the point of intersection between the settlement curve and the main curve. Refer to Slurry Settling Calculations.

45. For Bingham slurries, it is possible that the head available across a pipe is insufficient to overcome the initial yield stress. In this

case, the flow would be zero, as there is insufficient head to overcome the initial resistance to flow. The flow in the pipe will be set to zero when the network is analysed. You should increase the available head to avoid this situation. If the flow becomes turbulent, the slurry behaves like a normal Newtonian fluid and the system curve shows a pronounced increase in slope beyond this point. Operating too far into the turbulent region wastes energy in the form of high friction losses for a small increase in flow rate. Operating in the laminar zone, you can get a large increase in flow rate with a small increase in head, so the best operating point is close to the 'knee' of the curve.

Pipe System Curve
From Node 0 to Node 1
Demo Program Version

Bingham Slurry 1.00 cp
400.0 m x 252.00 mm Dia
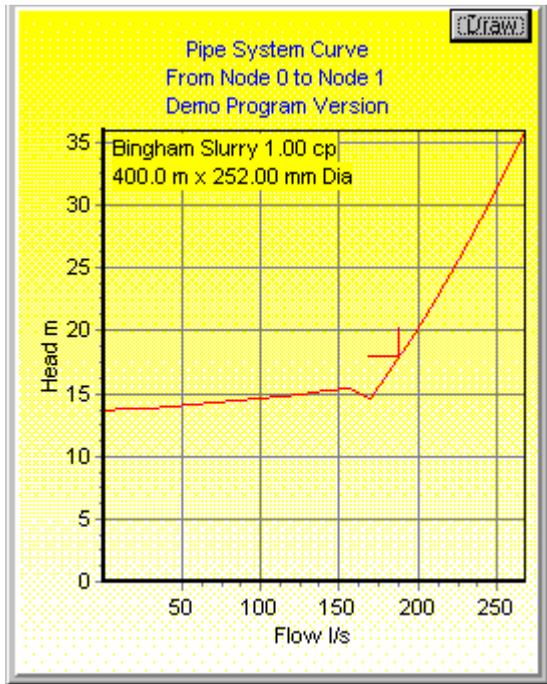
46.

47. Note: Irregularities near the 'knee' of the curve are due to the flow being in the Transition zone between laminar and turbulent flow. These irregularities may not always appear, and they depend on the plot increments used.

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48. The Vessel [icon] Toolbutton is treated in the same way as an unknown pressure Junction node - it is intended only for visual differentiation from other nodes.

49. **Gas Networks**. For gas networks, the method of operation is basically the same as described above except for the following:

- When you set-up the Project Details in step number 4 above, you must select the **Gas** option on the **Calculation Method** tab. The default gas details must also be added.

- After you have you have opened a new file (step 7) , click on the **Options** tab and select the **Use Gas Picture Icons** button. This will replace the Tank button with a Gas Cylinder [icon] icon in the network diagram. (This is optional - you can analyse the network using any of the picture options).

- Instead of entering liquid details you must enter gas details. You can double click in the Gas Description value cell to open the Gas Database file.

- You should work in Absolute pressure units for all known pressure nodes such as vessels and pumps / compressors.

- Refer to Choked Flow conditions for details on sonic flow conditions.

- You can calculate any type of gas flow system such as long gas pipe lines, steam lines, compressed air lines, air conditioning and ventilation ducts, dust extraction systems - basically any compressible fluid. You must have at least the following data about the gas:

  - The molecular weight of the gas

  - The ratio of the specific heat capacities Cp/Cv

  - The viscosity of the gas

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- the inlet temperature of the gas.

- Refer to the Gas database for typical values for Air and some common gasses.

50. Booster Pumps. You can add a booster pump to any pipe by entering a Negative Fixed Head loss. For example, if you want to boost the pressure in a section of a pipe network, click on the Details tab, click on the pipe, and then in the Fixed Head Loss cell enter a value of -20m (say). Now Solve the network and you will see that the pressures have been increased by 20m fluid head.

51. Finally, you should **Save** your network design file regularly. Each Network design is stored in two files in the Data\Projects sub-directory. The first file has an extension of .NWK which contains the node and pipe data and the second an extension of NWK which contains the Project Setup data. You should always back-up and keep these files together, as both are required to open a network.

2.2 Project Settings - overview

Each time you use *Helix delta-Q* to analyse a pipe network, you need to open a new network file. In order to save time the program allows you to set up certain default values which are used when you add new items to the network. For example, you can set up a default liquid, slurry, gas and pipe. Each time you add a new node or pipe, the defaults settings and values are entered for you. You can then edit the items which differ from the default before solving the network.

The default settings can be changed after you have created the network too, but as a first step in the network creation process, you need to set up these defaults.

The Project Settings form also includes the Project Details, Designers Comments, Units of measure and it gives you an option of choosing the calculation method you want to use.

Project Details

Set up your company name, client details, designers name, project details.

<u>Default Liquid</u>

Set up the default liquid. Each component added to the network will have this liquid entered as the default.

<u>Default Slurry</u>

Set up the default slurry.

<u>Default Gas</u>

Set up the default gas.

<u>Default Pipe</u>

Set up the default pipe. Each pipe added to the network will have this pipe entered as the default. You can set a default, then add pipes of one type, then change the default and add the next pipes and so on - this will save you time when building a large network.

<u>Units of Measure</u>

Set up the project units. Units apply to all nodes and pipes in the network.

<u>Calculation Method</u>

Select the default calculation method to use and whether it is a liquid or gas network. This can be changed at any time.

<u>Designers Comments</u>

Enter designers comments about the network.

<u>Operating Costs</u>

Set up the project cost details for operating cost calculations.

2.3 Project Details

Enter the project details in the text boxes provided. They are intended for record and checking purposes and appear on the printouts.

The Altitude box is linked to the Atmospheric pressure available calculation. Enter the altitude of the project and site and press calculate to obtain an estimate of the Atmospheric pressure at site.

2.4 Default Liquid

Enter the default liquid details here. You can click on the **Database** button to open the Liquid Database. Then open the relevant data file, scroll down, click on the item required and Right Click with your mouse. Select the Copy to Network menu and the liquid details will be transferred to this form.

The settings on this form will be added as the Liquid values for each node and pipe you add in the network diagram. You can then change individual values at different places in the network, if required, to cater for changing process conditions.

If you have already drawn the network, you can change the Liquid values at **all** nodes and pipes in the network by Selecting the **Apply Liquid To All Pipes** button. This action will alter all existing nodes

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and pipes to reflect the default settings. Use this function with caution as there is no Undo facility!

2.5 Default Slurry

Enter the default liquid details here. You can click on the **Database** button to open the Slurry Database. Then open the relevant data file, scroll down, click on the item required and Right Click with your mouse. Select the Copy to Network menu and the Slurry details will be transferred to this form.

The settings on this form will be added as the Slurry values for each node and pipe you add in the network diagram. You can then change individual values at different places in the network, if required, to cater for changing process conditions.

If you have already drawn the network, you can change the Slurry values at **all** nodes and pipes in the network by Selecting the **Apply Slurry To All Pipes** button. This action will alter all existing nodes and pipes to reflect the default settings. Use this function with caution as there is no Undo facility!

Definitions and Terminology
For more details about the data required look up the topics listed below:

Description and Slurry number are for your record purposes only.
Carrier Liquid Viscosity
SG of Dry Solids
Concentration by Mass (Weight)
d50 and d80 Particle Size
Closely Graded - enter a Y or a N
Bingham Slurry - enter a Y or a N
Yield Stress - applies to Bingham slurry only
Co-efficient of Rigidity - applies to Bingham slurry only
Pump Wear Factor - default value is 1 (0.9 would indicate a 10% deration of the pump - this value is for future use.)

The above topics can be found in the Slurries section under Definitions and Formulae.

2.6 Default Gas

Enter the default liquid details here. You can click on the **Database** button to open the Gas Database. Then open the relevant data file, scroll down, click on the item required and Right Click with your mouse. Select the Copy to Network menu and the Gas details will be transferred to this form.

The settings on this form will be added as the Gas values for each node and pipe you add in the network diagram. You can then change individual values at different places in the network, if required, to cater for changing process conditions.

If you have already drawn the network, you can change the Gas values at **all** nodes and pipes in the network by Selecting the **Apply Gas To All Pipes** button. This action will alter all existing nodes and pipes to reflect the default settings. Use this function with caution as there is no Undo facility!

Essential data required by this version of the program is:
- Description
- Molecular mass

- Ratio of Specific Heat capacities
- Gas Viscosity
- Gas Temperature

The Chemical Formula field is for information only and the Critical Temperature and Pressure are intended as calculation stop limits for future versions of the software.

2.7 Default Pipe

Enter the default liquid details here. You can click on the **Database** button to open the Pipe Database. Then open the relevant data file, scroll down, click on the item required and Right Click with your mouse. Select the Copy to Network menu and the Pipe details will be transferred to this form.

The settings on this form will be added as the Pipe values for each node and pipe you add in the network diagram. You can then change individual values at different places in the network, if required, to cater for changing process conditions.

If you have already drawn the network, you can change the Pipe values at **all** nodes and pipes in the network by Selecting the **Apply Pipe To All Pipes** button. This action will alter all existing nodes and pipes to reflect the default settings. Use this function with caution as there is no Undo facility!

Default Project Settings ☒

Project Details | Liquid | Slurry | Gas | Pipe | Units of Measure | Calculation Method | Comments | Costing

Description	Steel Pipes AS1836 (ANSI B36.1
Pipe Class	Sch 40
Nominal Dia	100 mm
Inside Dia	102.3 mm
Outside Dia	114.3 mm
Temperature	20 C
Pressure Rating	10200 bar
Roughness	0.15 mm
Price / Cost	0

Apply To All Pipes

Pipe Database

OK | Cancel | Help

2.8 Units of Measure

You can select the units of measure for data entry and reporting purposes. The program is supplied with a comprehensive set of units to choose from. Click on the drop down arrow next to the current units and select the units you which to use.

If you change the units, the changes will be reflected in all nodes and pipes in the network. if you have already entered data, changing the units does not convert the input data to the new values. The user must maintain the input values. For example, if you entered 12 bar as a node pressure then you change the units to kPa, the input value will remain as 12.
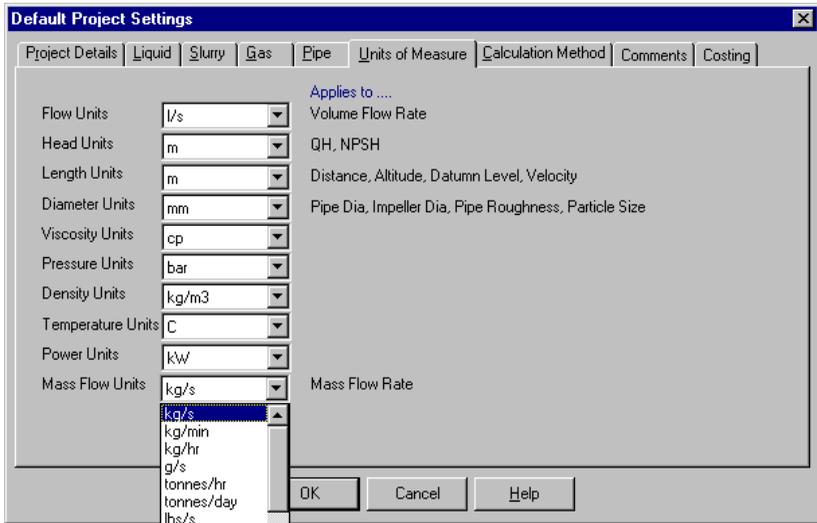
For **Gas Networks** you should work in **absolute pressure** units of measure when specifying node pressures. The Modified Darcy and Isothermal formulae require Absolute pressures.

Adding Units of Measure not Listed

You can add your own units of measure. The units are stored in text files in the program sub-directory and can be edited using a text editor such as Notepad. Each unit has to entries in the file - the first is a description of the unit and the second is a conversion factor to the base units used by the program. These base units are the first item listed in the file and this first item should not be deleted or altered in any way. Example file VolFlowUnits.txt is listed below:

```
l/s=1
l/min=0.0166666667
l/hr=0.0002777778
m3/hr=0.27777778
m3/s=1000
m3/min=16.666667
m3/day=0.011574074
cfs=28.316850
I Gal/hr=0.001262803
I Gal/min=0.075768200
US Gal/hr=0.001051503
US Gal/min=0.0630902
US barrels/day=0.001840133
```

l/s=1   <---------- the master value - do not alter
l/min=0.0166666667   <---------- your values - enter as many as you like
l/hr=0.0002777778 <---------- your values - units followed by conversion to master units
m3/hr=0.27777778 <---------- your values ....
m3/s=1000
m3/min=16.666667
m3/day=0.011574074

2.9 Calculation Method

The program allows the user to choose from a number of methods for solving the network.

The first choice which must be made is whether it is a Liquid (incompressible fluid) or a Gas (compressible fluid) network. You cannot analyse a network containing both gasses and liquids in the same file. Separate the network into a Gas network and a separate Liquid network.

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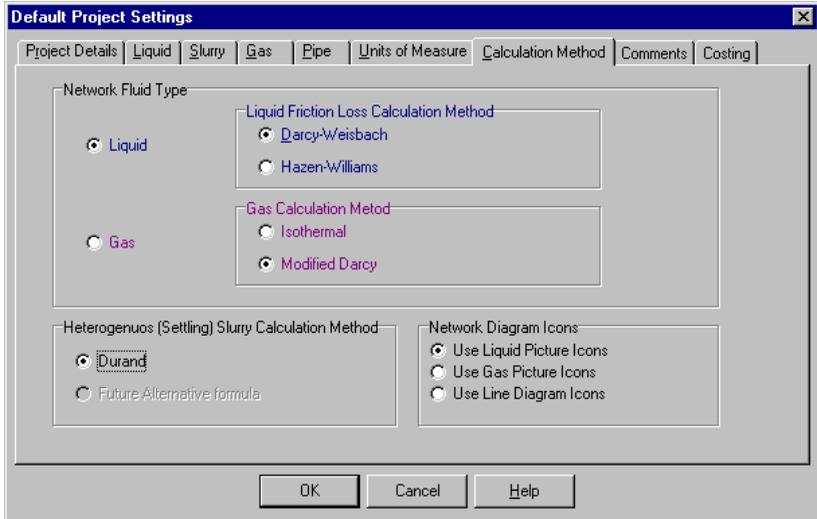
If you select **Liquid** you can then choose to use the Darcy-Weisbach method or the Hazen-Williams method.

If you select Gas you can choose to use the Isothermal or the Modified Darcy methods.

For **Slurry** networks choose Liquid and use the **Darcy - Weisbach** method.

2.10 Designers Comments

This form allows the designer to record comments about the design. These comments may be used to explain why certain options were used in the network or any other comments, record or description the user would like to record. They can also be used to describe the network in words.

You are allowed to enter up to fifteen lines of comments, each containing up to 80 characters per line.
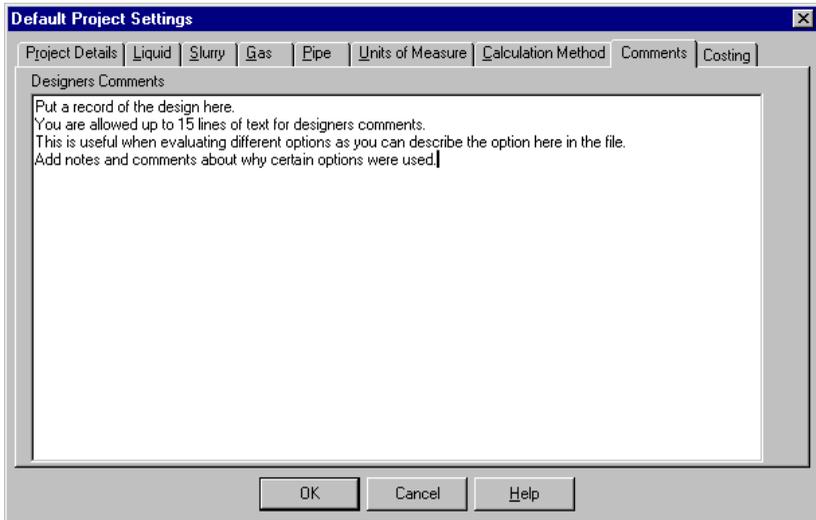
2.11 Project Operating Costs

The program uses the Operating Cost parameters to compare individual pipe capital costs versus the energy cost of operating the pipe. i.e. the cost of the head losses in the pipe. The designer can then decide whether a larger pipe diameter with higher capital cost but a lower head loss, and therefor a lower operating cost, will be more economical than a smaller pipe diameter with a higher head loss.

The total energy cost is calculated is follows:

absorbed power $kW = \dfrac{QHg}{100}$

Efficiency is taken as unity as the calculation is intended for comparison purposes.

Operating cost
$C = EnergyCostPerUnit * AbsorbedPower * OperatingHours$

2.12 Entering Slurry Data

The Slurry data entry form is shown below.

You should enter data for all item in the left hand column. If it is a settling slurry, you do not need to enter the Yield Shear Stress or the Co-efficient of Rigidity, as these apply to Bingham type slurries only.

Once you have entered the data, press the **Calc Slurry Values** button and the values marked in blue will be calculated for you. You can also obtain an explanation of the parameters required by clicking on the item and pressing F1 for context sensitive help.

You can retrieve data from the Slurry Database by clicking the **Slurry Database** button and selecting a slurry from the data list then Right clicking and pressing the Copy Data menu option. The selected slurry will be transferred to the current pipe in the network. Press the **Calc Slurry Values** button to ensure that the current values are transferred to the pipe for calculation purposes.

Press OK to return to the Network Diagram.

2.13 Pipe Fittings

Pipe Fittings can be added as individual items to any pipe or they can be represented by a global K value without having to enter each fitting.

To enter a global value, simply select the pipe in the network diagram, then enter the K value and / or the Kf value in the Data Grid.

Details	Graphs	No Errors	Options	Reports

No 2	From 0	To 1
Description		
Slurry	Water	☑ Slurry
Viscosity	1	cp
Temp	20	C
Density	1000	kg/m3
Vapour Press	1	kPa
Pipe Desc	Steel	☐ Closed
Pipe Class	Sch 40	
Pipe NB	100	mm
Pipe OD	114.3	mm
Pipe ID	100	mm
Pipe Length	50	m
Roughness	0.03	mm
Pipe Allow. Press.	1500	kPa
Pipe Cost	0	$ per m
Fittings K Value	2.30	
Fittings Kf Value	105.00	
Orifice Plate Dia	0.00	mm
Fixed Head Loss	0.00	m
Flow Rate	44.79	l/s

To enter individual fittings, select the pipe in the diagram, move the mouse over the K Value cell. The cursor will change to a Hand. Double click with the left mouse button and the Pipe Fittings form will be displayed.

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Reference List of Typical Fittings K Values	*Kf*	*K*	Save to File

$$Hf = K_{fn} f \frac{V^2}{2g} \qquad Hf = K \frac{V^2}{2g}$$

Fitting Description	K ft	K	▲
Angle Valve - 90 degree seat pattern	340	7	
Angle Valve - 45 degree seat pattern	55	1.1	
Angle Valve combined 90 deg bend	150	3	
Ball Valve, full bore	3	0.06	
Bend - 90 degree elbow r/d = 1	20	0.4	
Bend - 90 degree elbow r/d = 1.5	14	0.28	▼

OK

List of Fittings in Current Pipe					Clear List
Description of Fitting	Quantity	Kft	Total Kf	K	Total K
Bend - Standard 90 degree elbow	1	30	30.00	0.6	0.60
Globe Valve - 45 degree seat pattern	1	55	55.00	1.1	1.10
Tee - Line to Line	1	20	20.00	0.4	0.40
Entrance - flush	1	0	0.00	0.2	0.20

Total Fittings Kf and K value for pipe	105.00	2.30

The top grid is a list of fittings from the file called **KFittings.dat**. You can open and edit this file using a text editor. The bottom grid is a list of fittings present in the pipe.

Scroll down the top grid and Double click on an item in the list. It will be added to the list below, and the total K values re-calculated.

You can delete an item from the pipe list by double clicking on it. You can also delete all the items by pressing the **Clear List** button.

There are two methods used for calculating fitting losses in this program. The first is the standard shock loss or velocity head method in which a K factor, which depends on the fitting, is multiplied by the velocity head i.e. $Hf = K \frac{V^2}{2g}$. This method is the one which should be used for all fittings if the Hazen-Williams method is used. It does not allow for changes in the fluid viscosity.

The other fitting loss calculation method uses a Kf factor and the velocity head. The Kf factor is multiplied by the Darcy friction factor to arrive at the K value, making the fitting loss vary as the friction factor changes (due to changes in fluid viscosity or turbulence). i.e.

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$$Hf = f \bullet Kf \frac{V^2}{2g}$$ This method is not suitable for use when the

Hazen-Williams calculation method is used.

NOTE: In some cases, the K value data file contains values for both the K Value and the Kf value. **YOU SHOULD USE ONE OR THE OTHER, NOT BOTH**. After you have copied the fitting from the top grid into the bottom grid, you should enter the number of fittings of that type and also delete the K value you do not want to use, leaving the value do want to use. You can mix and match K values and Kf values in the same pipe in combination you wish. In fact, some fitting losses, such entry and exit losses, are pure shock losses and should be specified as K values.

You can add your own descriptions and K and Kf values - you don't have to select them from the database.

If you would rather use the L/d equivalent length method to allow for fittings, you can do so by doing a manual calculation of the total equivalent pipe length for the fittings and then adding this length to the actual pipe length. In this case you can leave the K values as zero.

When you have entered the Fittings, press the OK button and the total K value and Kf values will be transferred to the Network Pipe Data grid. Press the Solve Button to see the new flow and head losses.

You can print a list of fittings in each pipe in the Data Reports form.

2.14 Data Reports

The Data Reports form allows you to view and print the network data. Click on each tab sheet to view the different reports, print some of them if you wish. The **Pipe Data** tab sheet shows the network pipe details in tabular form. The **Node Data** tab shows details about each network node. The **Pipe Fittings** tab shows the pipe fittings in each pipe in the network. If you did not enter individual pipe details, and

you only used the total K or Kf value for fitting losses, the Fittings data sheet will be blank.

Right click on any of the tables - a pop-up menu will allow you to **print** any of the tables.

You can alter the number of Decimals displayed in the Data Reports form by selecting values from the **Decimals** drop down box above the Network diagram.

You can also view the network solution in **Graph** form. This is a useful tool for you to check for minimum or maximum values at a glance. For example, you can check the Node pressures or the velocities and view the results in a graph. To use this facility, Click on the Graph tab sheet. A Graph of the Flow Rates in each pipe in the network will be shown. **Right Click** on the graph and click on a menu option. A graph showing that particular variable will be drawn. Some of the graphs apply to the pipes in a network and some graphs apply

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to the Nodes in a network. A commonly used graph is one showing the velocities in each pipe, such as the one below.
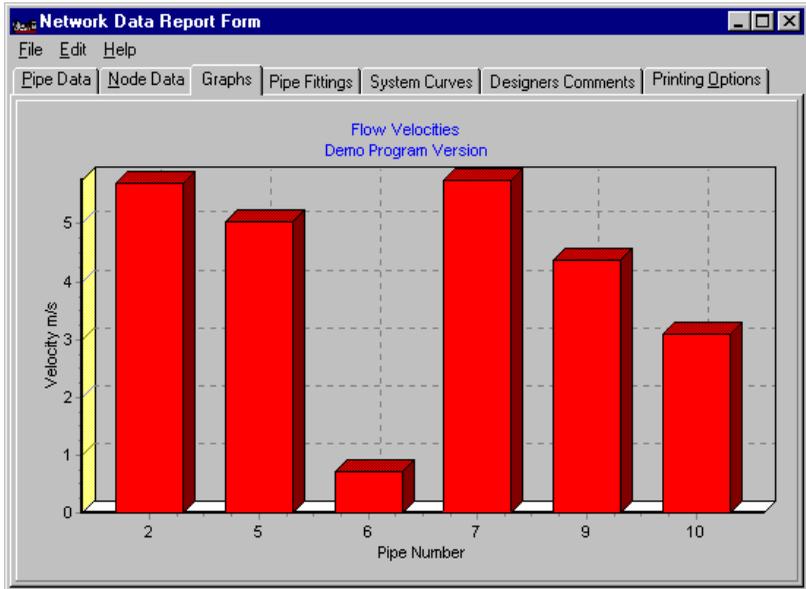
You can print this graph. Right click on the graph and select the **Print Graph** menu option. The graph will be printed at the same size as shown on the **Image Size** scroll bar on the **Reports** tab on the Network form. (The default size is 50% of the printer paper size)

The Data Reports form also has a **System Graph** tab sheet where for Liquid Networks a system graph for each pipe in the network can be displayed. Click on the **System Curves** tab and then click on the **Draw System** button. The program will loop through each pipe in the network and construct a system graph by performing 20 friction loss calculations at different flow rates for each pipe. This procedure may take some time on large networks - it also depends on your PC hardware speed. On some systems it may be necessary to press the System Curves button twice to get all the curves to display simultaneously. You can adjust width (aspect ratio) that the curves are drawn at by moving the column dividing line between curves with your mouse.

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The Designers comments tab sheet allows you enter any comments or notes about the Design for record or information purposes. These comments are the same comments as those displayed on the Project Settings form which is accessed from the Units button in the Network Design form.

The Print tab allows you to print various tables and network data.

You can also Export Data to other applications such as spreadsheet programs, where you can customise the layout and add your own data before printing.

2.15 Exporting Data

You can **Export Data** from the Data Reports. For example, click on the **Pipe Data** tab and click anywhere in the data grid to give it the focus. Now select the **Edit, Copy** menu. The data grid has been copied to the Windows clipboard and you can paste it into another application such as a spreadsheet program.

For example, if you have **Microsoft Excel**ä installed, start it up and when it is open at a blank spreadsheet, click in the top left cell, press the **Edit**, **Paste** menu option, and the data will be pasted in that column. Now, to spread the data into multiple columns   (if necessary), select the column where the data was pasted, select the **Data, Text To Columns...**menu option, select the **Delimited Option** in the wizard, Press the **Next** button, set the **Comma** Delimiter option to on (because it is a comma separated value file which is pasted from Helix delta-Q) and press the **Finish** button. The Pipe data should now be in separate columns in the spread sheet and you can add, modify, customize and print the data. Refer to your spreadsheet application help file for details on how to parse comma separated values if you have any difficulty.

2.16 Network Calculation Method and Accuracy

Helix delta-Q uses a combination of the Linear Theory and Newton-Raphson methods coupled to a matrix algebra calculator to solve for pipe network flow rates and pressure drops. The program algorithm

has been built from the ground up by Helix Technologies and it utilises the 32 bit power of modern computers to arrive at a solution without the user having to enter flow or head loss estimates.

The program sets up random pressure values for the unknown pressure nodes, calculates the flow rates and pressure drops in each pipe in the network, using the user selected method of calculation, and then adjusts the node pressures and repeats the process until the sum of the square roots of the change in node pressures of all nodes is less than the network error factor value specified. The number of iterations used to arrive at the solution is shown on the status bar at the bottom of the network diagram. You can alter the accuracy by selecting the **Options** tab and selecting values from the drop-down boxes provided. The smaller the error factor, the more accurate the solution. The Maximum number of iterations allowed prevents the program from running on indefinitely with the results oscillating or 'hunting' about the solution i.e. the process stops when the maximum number of iterations has been reached, even if the network has not fully converged.

The **current status of the network** is shown in the status panel below the network diagram. You should always check to ensure that the Network has converged to a solution. There are three possible conditions:

- **Network Data Changed** - occurs when you edit the network.

- **Network Solved** - displayed when a solution has been found.

- **Network Calc did Not Converge** - no solution was possible. Try pressing the Solve Button again a few times. The program sets up random values for the unknown node pressures and these random initial values may be outside feasible limits, resulting in non-convergence to a solution. By pressing the Solve button a few times, new random numbers are generated and a solution may be found. If the solution still does not converge, try relaxing the error factor (make it bigger) and increase the number of allowable calculations (use the Options tab to do this).

Do not use calculation results where the network status is not shown as Network Solved.

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A warning message is shown on the pipe Data Report if the network did not converge.

When solving **Bingham** slurry networks, it is possible that the initial head chosen by the random number generator is insufficient to overcome the Yield Stress in the pipe. This may cause non-convergence. Try pressing the Solve button a few times to set up different random initial pressures. If this still does not work, increase the available head (at the pump, say). You may have to simplify your network to a single pipe for some Bingham slurry systems. Try changing the liquid to water by switching off the Slurry option under the details tab. The network should now converge. This shows that the error is being caused by insufficient head to overcome the Yield Shear stress.

You can increase the accuracy of a calculation by selecting a smaller error factor and by increasing the maximum number of iterations allowed.

You can terminate a calculation run at any time by pressing the SEC key or by pressing the **Cancel Calculation Run** button.

For some networks, especially gas networks where you have choked flow conditions present, you may find that you need to decrease the network accuracy to some value below the default setting (which is set to very accurate), in order to obtain a solution. This usually occurs where there is insufficient pipe length to give a solid basis for friction loss changes due to flow rate changes. When the program has correctly arrived at a solution of the network, it will display a message **Network Solved** in the status bar below the network diagram. You should not use the results of any network calculation which has not converged to a solution.

If you have a network which will not converge, try changing the pipe length or diameter to increase the friction loss, or alter a known pressure node head or pressure.

In some very rare cases, the algorithm my result in an ill-conditioned or a singular matrix. A message to this effect will be displayed. Do not use the network results if this happens.

2.17 Orifice Diameter

The Orifice Calculations are based on differential pressure calculations.

Typical Orifice Plate Arrangements

Flange Tappings
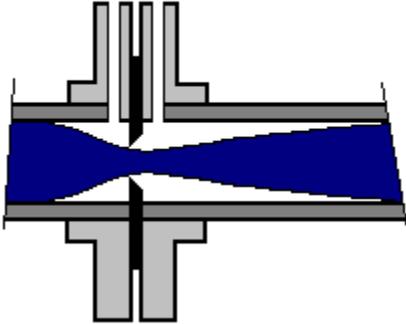
Vena Contracta Tappings
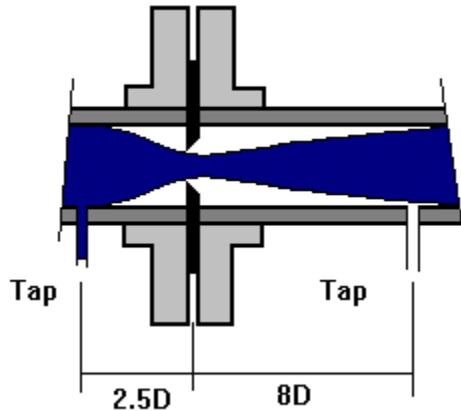
The orifice plate flow measurement principle is commonly known as the ΔP principle. This program uses the following formula to calculate the three options offered.

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$$Q = \frac{Sm \times Nvg \times Fa \times D^2 \times \sqrt{h}}{\sqrt{sg}}$$

$$Sm = \sqrt{\frac{-0.36}{1 - \left(\dfrac{1}{B}\right)^4}}$$

$$B = \left[1 + \left(\frac{0.6}{Sm} + 0.06\right)^2\right]^{-0.25} \quad \text{where } 10000 < R < 200000$$

$$B = \left[1 + \left(\frac{0.6}{Sm}\right)^2\right]^{-0.25} \quad \text{where } R > 200000$$

where :

Sm. is the sizing factor
Q is the flow rate in US gal/in
B is the Beta ratio *d/D*
d is the orifice diameter in inches
D is the pipe diameter in inches
Nvg is a unit correction factor = 5.666
R is Reynolds number
h is the differential pressure in inches H2O
Fa thermal expansion factor - varies with temperature

Note : For Reynolds numbers of less than 10000 the accuracy of the calculation diminishes as the flow becomes less turbulent.

2.18 Nozzles and Sprays

Helix delta-Q uses either a fixed discharge flow rate from nozzles or a Nozzle K factor method.

The **fixed flow rate** method allows the user to specify the draw-off flow rate from the network by entering a flow at the Flow in(+) / out(-) cell. If the flow is out of the Network use a minus sign, if the flow is into the network use a plus sign. This method always uses this flow rate no matter what the pressure at the node is.

Details	Graphs	No Errors	Options	Reports	
No 1			Nozzle	▼	
Description					
Equipment No.					
Liquid	Sea Water				
Viscosity	1.01	cp			
Temp	20	C			
Density	1025	kg/m3			
Vapour Press	1.6	psi			
Datumn Level	10	m			
Pressure	0	psi			
Nozzle K value	-10				
Nozzle Max Flow	-120	US Gal/min			
Nozzle Min Flow	-10	US Gal/min			
Flow in(+) / out(-)	-39.26	US Gal/min			
Total Node Head	20.57	m			
Gauge Head	10.57	m			

The **K factor method** uses the following formula to determine the discharge from the nozzle:

$$Q = K\sqrt{P}$$

where **Q** is the discharge flow rate in US Gallons per minute
K is the Nozzle factor
P is the pressure at the nozzle in psi

Nominal NFPA discharge capacities for a Standard half inch Nozzle:

Pressure at Sprinkler in psi	Discharge in US Gal/min
10	18
15	22
20	25
25	28
35	34
50	41
75	50
100	58

Nominal Orifice Size in Inches	Orifice Type	K Factor	% of Nominal 1/2 In Discharge
1/4	Small	1.3-1.5	25
5/16	Small	1.8-2.0	33.3
3/8	Small	2.6-2.9	50
7/16	Small	4.0-4.4	75
1/2	Standard	5.3-5.8	100
17/32	Large	7.4-8.2	140

(Refer to NFPA 13 for more details)

If you enter a K value other than zero, the program will try to resolve the network by using the discharge flow rate calculated in the above formula. If you enter a K factor of zero, the program will use the flow specified in the Flow in(+) / out(-) cell.

You must use the correct sign - i.e. for Flow out of the network use a minus K factor

The Max Flow and the Min Flow cells are the boundary flow values which the program will use when trying to solve the network if the node pressure yields a very high flow rate. This is to try to ensure that a converging solution results during the network solving process.

Note: If you find that the network is not converging, you may want to try to set the K factor to zero and enter a fixed Flow in / out. This will prevent 'hunting' during the solution process.

****

3.1. Liquids

Using delta-Q is easy - follow these steps to create and solve your first network. You can get context sensitive help by pressing F1 at any time. You can also Print this topic by pressing the Print Button.

3.1.1 Viscosity

The viscosity of a fluid is a measure of its resistance to flow due to the existence of internal friction. The co-efficient of dynamic viscosity is the force required to move a unit area of fluid a unit distance.

Newton's law of viscosity : $R = -m\dfrac{dv}{dz}$

The shear stress R is proportional to the velocity gradient *-dv/dz* in the fluid.

The constant of proportionality is known as the co-efficient of dynamic viscosity μ .

Dynamic or Absolute Viscosity = Shear Stress / Shear Rate   and

$$v = \frac{Force \times time}{Area} = \frac{Ns}{m^2} = Pas = 1x10^3 cP$$

Kinematic Viscosity = Dynamic Viscosity * Density

$$v = \frac{Pas}{r} = \frac{m^2}{S} = 1x10^3 cSt(Centistokes)$$

3.1.2   Reynolds Number Calculation

Reynolds Number gives an indication of whether the motion of a fluid is laminar or turbulent. The distinction was made by Professor Osbourne Reynolds in a paper published in 1883. It is a dimensionless value, given by :

$$R = \frac{VD}{v}$$

where :
   R is Reynolds Number
   V is the average velocity in m/s (ft/sec)
   D is the pipe diameter in m (ft)
   v is the kinematic viscosity in m2/sec (ft2/sec)

Comment [PB1]:

Note : A Reynolds number of less than 2000 generally indicates that flow is laminar. From 2000 to 4000 there is a transition zone and then above 4000 flow is considered to be turbulent.

See Darcy Formula

3.1.3   Liquid Classifications

Liquids may be classified into a number of categories depending on their behavior.

The most common type is known as a Newtonian Liquid, in which the dynamic viscosity remains a constant at varying rates of shear.

SHEAR STRESS T vs SHEAR RATE (dv/dz): Bingham Plastic, Pseudo-plastic, Thixotropic, Newtonian, Rheoptic, Dilatant
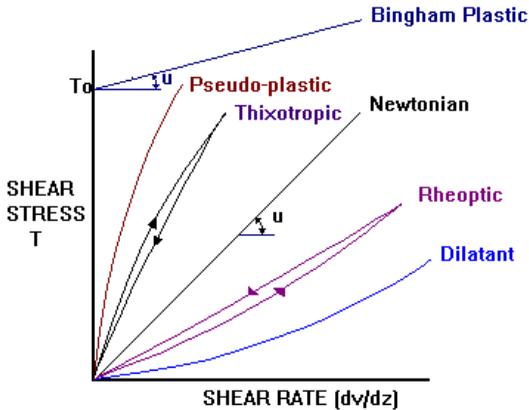
Note: The Bingham plastic requires a shear stress of some finite value before flow starts. This results in a relatively high friction loss even at very low flow rates.

3.1.4   Darcy-Weisbach Friction Loss Theory

INTRODUCTION

Many empirical formulae for the calculation of friction losses and estimation of flow have been developed over the years, beginning with Chezy in 1775, and including well known formulae by Manning, Bazin, Kutter and Hazen-Williams .

However, as these are empirical formulae, they are based on limited test data and do not have a scientific physical basis, although they are readily calculated. It was only after Professor Osbourne Reynolds discovered in 1883 that there are two definite states of flow, one being Streamline or Laminar flow and the other Turbulent flow, that the physical basis of fluid friction became evident. Reynolds determined the non dimensional ratio $R = VD/v$ now called Reynolds Number. A value of R below 2000 is deemed to indicate a

Streamline flow condition, and above R > 4000 is considered a Turbulent flow condition.

In the 1930's, Karman and Prandtl published theories and formulae which estimated a friction factor for smooth turbulence and for rough turbulence. Nikuradse performed experiments on determining roughness factors by using pipes roughened by uniform particle size sand grains stuck to the internal surfaces, and this led Colebrooke and White to study friction losses in commercial pipes. The equation derived by Colebrooke and White for determining the friction factor is now regarded as the most accurate method of determining friction losses in pipes, and is the one used in this program, in conjunction with the Darcy-Weisbach formula.

Darcy formula

$$H_f = f \, \frac{L}{D} \frac{V^2}{2g}$$

and

$$f = \frac{64}{R} \qquad \text{for } 0 \,<\, R \,<\, 2000$$

$$\frac{1}{\sqrt{f}} = -2\log_{10}\left(\frac{\epsilon}{3.7D} + \frac{2.51}{R\sqrt{f}}\right) \qquad \text{for } 2000 \,\leq\, R \,\leq\, \infty$$

where :
　　　Hf is the friction loss in m (ft)
　　　f is the friction factor
　　　R is Reynolds Number
　　　Î is the <u>Absolute Roughness</u> in m (ft)
　　　D is the pipe diameter in m (ft)

See Also Fitting 'k' Value Calculation

Refer to the <u>Hazen-Williams</u> method for an alternative for water friction loss calculations.

3.1.5 Hazen Williams Friction Loss Calculation

The Hazen-Williams friction loss equation is one of the most widely
used of a number of Empirical equations for friction loss calculations.
It is only suitable for use on Water.
in English units it is :

$$H_f = \frac{4.73L}{C_{HW}^{1.852} D^{4.87}} Q^{1.852}$$

where   Hf   =   head loss in ft
        L   =   pipe length in ft
        CHW   =   Hazen-Williams C factor
        D   =   Pipe diameter in feet
        Q   =   Flow rate in cubic feet per second

The Hazen-Williams C factor depends on the smoothness of the pipe
with values ranging from about 100 for rough pipes up about 150 for
very smooth bore pipes. Typical values are 120 for new steel pipes
and 140 for uPVC pipes.

Note : There are two methods used for calculating fitting losses in
this program. The first is the standard shock loss or velocity head
method in which a K factor, which depends on the fitting, is multiplied

by the velocity head i.e. $Hf = K\dfrac{V^2}{2g}$. This method is the one which

should be used for all fittings if the Hazen-Williams method is used.
The other fitting loss calculation method uses a Kf factor and the
velocity head. The Kf factor is multiplied by the <u>Darcy</u> friction factor to
arrive at the K value, making the fitting loss vary as the friction factor
changes (due to changes in fluid viscosity or turbulence). i.e.

$Hf = f \bullet Kf \dfrac{V^2}{2g}$ This method is not suitable for use when the

Hazen-Williams calculation method is used.

3.1.6   Pipe Roughness

The Absolute roughness of the inside of a pipe is used in the calculation of the friction factor in the <u>Darcy-Weisbach Friction Loss Formula.</u>

When the Hazen-Williams method of friction loss is used, the program does not use the f factor but rather a C factor which usually ranges from about 100 for rough fouled cast iron pipes to about 150 for very smooth pipes with little flow disruption at the pipe joints. Refer to the <u>Hazen-Williams</u> section for more details.

Search for Roughness Tables in the Help files for recommended values.

3.2.   SLURRIES

3.2.1   Viscosity of Slurry

In the slurry context the viscosity of liquid refers to the viscosity of the carrier liquid. This is usually water.

For non Newtonian slurries such as <u>Bingham</u> slurries flowing in a pipe at velocities less than the Critical Velocity Vc, the slurry has an apparent viscosity which varies as the shear rate varies, so it is not possible to say what the viscosity of the slurry is without also specifying an accompanying shear rate. The Bingham friction loss formulae compensate for this behaviour so it is not a requirement that you enter a viscosity for the mixture, only enter the viscosity of the carrier liquid. When the flow becomes turbulent, the liquid no longer behaves like a plastic but reverts to a normal liquid characteristic and so the conventional Darcy friction loss formula is applied where the liquid viscosity affects the friction factor and thus the friction loss. Some slurries may have additives or constituents which modify the apparent viscosity. Consult your metallurgical laboratory for viscosity values to use which will most closely represent the actual slurry characteristics in the laminar and the turbulent flow regimes.

Note : For both Heterogeneous and non-Heterogeneous slurries you may choose to use a carrier liquid viscosity higher than that of water. This will result in higher friction losses (in the turbulent flow regime for Bingham slurries and in all flow regimes for Heterogeneous slurries) than if you used a viscosity of 1 cp (say).

3.2.2   SG of Dry Solids

In the slurry context this refers to the specific gravity of the solids material of the slurry.

3.2.3   SG of Mixture - Sm

In the slurry context this refers to the **combined** specific gravity of the solids material of the slurry and the carrier liquid.

$$Sm = Sl + \left(\frac{Cv(S - Sl)}{100} \right)$$

or

$$Sm = \frac{Sl}{1 - \frac{Cw}{100}\left(\frac{S - Sl}{S} \right)}$$

where :
> Sm is the SG of Slurry Mixture
> Sl is the SG of the Slurry Carrier Liquid
> Cv is the concentration of solids in the slurry by true volume
> S is the SG of the Dry Solids

3.2.4   Convert Tonnes / hr of Solids to Flow Rate

Used to convert metric Tonnes per hour of Solid Material to a flow rate of the slurry mixture.
The formula used is :

$$Q = \frac{1000}{3600} * \text{Tonnes} / \text{hr} * \left(\frac{\%\ \text{Water}}{\%\ \text{Solids}} + \frac{1}{\text{SG Solids}} \right)$$

where:

Q is the calculated flow rate of slurry mixture in litres per second
% Water is the percentage of water by mass in the mixture
% Solids is the percentage of Solids by mass in the mixture
Tonnes / hr is the number of metric tonnes per hour of solids to be transported
SG Solids is the specific gravity of the Solids material.

3.2.5 Concentration by Mass (Weight) - Cw

In the slurry context this refers to the concentration of solids in the slurry expressed as a percentage by mass.

$$Cw = \frac{100 \times S}{\left(\frac{100 \times Sl}{Cv}\right) + (S - Sl)}$$

where :

Cw is the concentration by mass in %
S is the SG of Slurry of the Dry Solids
Sl is the SG of the Slurry Carrier Liquid
Cv is the concentration of solids in the slurry by true volume

3.2.6 Concentration by Volume - Cv

In the slurry context this refers to the concentration of solids in the slurry expressed as a percentage of the true volume occupied by the solids.

$$Cv = \frac{(Sm - Sl) \times 100}{(S - Sl)}$$

where :

Cv is the concentration by volume in %
S is the SG of Slurry of the Dry Solids
Sl is the SG of the Slurry Carrier Liquid
Sm is the SG of the Mixture

3.2.7 Average Solids Size - d50

In the slurry context this refers to the average size of the solids in mm. i.e. 50% of the solids would pass a screen of that size and 50% would be retained.

HELIX   3-8

3.2.8 Yield Shear Stress - Bingham Slurry

This is a Bingham Slurry Property which defines the Yield Shear Stress at which the slurry begins to flow.

3.2.9 Co-efficient of Rigidity (n) - Bingham Slurry

This is a Bingham Slurry Property which is similar to the Viscosity property of a Newtonian Fluid. It denotes the slope of the Shear Stress vs Shear Rate diagram for the fluid.

$$T = T_o + n\frac{dv}{dz}$$

where :

T is the shear stress
T_o is the <u>Yield Shear Stress</u>
n is the Co-efficient of Rigidity

3.2.10 Pump Wear Factor Pw

This is a pump performance correction factor which the user can enter to derate performance for future wear of the pump. It affects the Head that the pump produces at a given flow rate. For example if you enter 0.9 then the pump performance (head) is de-rated by the original database curve performance x 0.9 at any given flow rate. The pump efficiency is also de-rated accordingly.

### 3.2.11 Slurry Pump Performance Head Ratio - HR

This is a pump performance correction factor which the program automatically calculates from de-ration charts built into the program. It depends on the slurry characteristics and is applied to the head and to the efficiency of the pump performance. The value of HR depends

on the concentration of solids Cv, the SG of Dry Solids S, the SG of the mixture Sm and the average solid size d50.

3.2.12 Bingham Slurry

A Bingham slurry is a **homogenous slurry** and usually consists of very fine particles. These are usually smaller than 0.1 mm. It is has unique properties in that it does not begin to flow until some finite Shear Stress is applied to it (called the Yield Shear Stress) and when it does begin to flow it moves a slug of liquid and this slug moving in pipe has a large surface area of contact with the pipe thus causing a relative large friction loss even at very small flow rates.

The **apparent viscosity** of a Bingham Slurry varies with the Shear Rate :
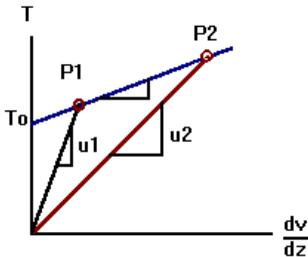
The apparent viscosity's at P1 and at P2, u1 and u2 are not equal.

A Bingham slurry does not settle out its particles when it is at rest. It remains as a sort of gel.
If the slurry you are dealing with displays the above characteristics, it is probably a Bingham type slurry. Click the Bingham Slurry Option Box to on and do not forget to enter the Yield Shear Stress and Co-efficient of Rigidity in order to calculate the system head losses Above Reynolds Numbers of about 2000 - 4000, the flow becomes turbulent and the normal Darcy-Weisbach friction loss formulae apply as there is no longer a slug of liquid moving in the pipe.

HELIX

Bingham Slurry Formulae:

$$R = \frac{DVr}{n + \dfrac{T_o D}{6V}}$$

where :

  R is the Reynolds Number
  D is the pipe ID
  V is the velocity of flow
  To is the Yield Shear Stress
  n is the Co-efficient of Rigidity of the Slurry

When flow is laminar (i.e. R < 2000) then the friction factor is given by $f = \dfrac{64}{R}$

but from <u>Darcy</u>

$$f = \frac{H_f \, D2g}{LV^2}$$

The critical velocity Vc is the velocity at which flow becomes turbulent i.e. R > 4000 and is given by

$$V_c = \frac{2000n}{Dr}\left(1 + \sqrt{1 + \frac{T_o \, r D^2}{6000n^2}}\right)$$

The Friction Loss can thus be expressed as :

$$H_f = \left(\frac{16LT_o}{3gr\,D}\right) + \left(\frac{32nLV}{gr\,D^2}\right)$$

See <u>Liquid Classification</u>

3.2.13 Widely Graded / Closely Graded Slurry

A Widely Graded Slurry is classed as one where the ratio of the particle sizes exceeds a ratio of 2:1 for at least 90% by mass of the total mass of solids. If the above condition is not true then a slurry is considered to be Closely Graded. This characteristic affects the so called Froude shape factor and in turn has an effect on the limiting settling velocity of the slurry.

See Durand's Formula for the settling velocity calculation.

3.2.14 Slurry Settling Velocity - Vl

Heterogeneous slurries are classed as slurries in which the solid particles settle out of suspension when the slurry is at rest. They may Widely or Closely Graded and are called heterogeneous (or sand) slurries because they separate into the carrier liquid and solid particles.

The velocity of flow below which a sand slurry begins to deposit its solid particles whilst moving in a pipe is known as the **Limiting Settling Velocity, Vl.**
Durand's Formula is used in this program to predict this limiting settling velocity, and is given below:

$$V_l = F_l \sqrt{2gD\frac{(S - Sl)}{Sl}}$$

where :

Vl is the Limiting Settling Velocity
Fl is the Froude Factor obtained from experimental charts
g is the gravitational acceleration constant
D is the pipe internal diameter
Sl is the SG of Carrier Liquid
S is the SG of Dry Solids

At velocities below the Limiting Velocity, the settlement of solid particles reduces the cross-sectional area available for the liquid to flow and this in turn increases the friction losses.

HELIX

SAND SLURRY SYSTEM CURVE

Pipe gradualy blocks up as more solids settle
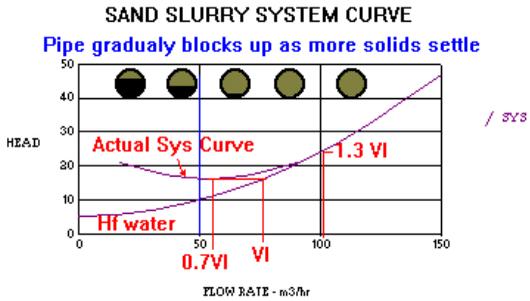
Note : The minimum head on the slurry system curve is reached at a velocity of approximately 0.7 x *VI,* and at a flow rate equating to 1.3 x *VI,* the system head generally follows that of the carrier liquid which is usually water.

3.3. Gasses

3.3.1 Ideal Gas Laws

Boyle's Law

The volume of a gas, at constant temperature, varies inversely with pressure

$$P_1V_1 = P_2V_2 = \text{Constant}$$

Charles' Law

At constant pressure the volume of a gas varies directly with the absolute temperature

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} = \text{Constant}$$

Amonton's Law

The pressure of a gas, at constant volume, varies directly with the absolute temperature

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} = \text{Constant}$$

Avogadro's Law

All gasses subjected to the same conditions of pressure, volume and temperature, contain the same number of molecules. For example, one gram mole of oxygen, mass 32 grams, contains 6.02×10^{23} molecules and has a volume of 22.4 litres at standard temperature and pressure.

General Gas Law

By combining the above laws

$$PV = mRT \qquad \text{and} \qquad R = \frac{R_u}{M_w}$$

where   P is the absolute pressure in Pa
V is the volume in m3
m is the mass of the gas in kg
R is the individual gas constant in J/kg-K
Ru is the universal gas constant = 8314
Mw is the molecular weight of the gas

For air, Mw = 28.96 and

R = 8314/28.96 = 287.1

3.3.2   Isothermal Gas Flow

Isothermal gas flow occurs in relatively long gas pipelines where the heat transfer to the surroundings is sufficient to maintain constant temperature.

The pressure drop equation is given as :

$$p_1^2 - p_2^2 = G^2 \frac{RT}{M_w} \left[\frac{fL}{D} + 2\ln\left(\frac{p_1}{p_2}\right) \right]$$

where

G	= mass flow rate in kg/m2 = w/A
P	= the beginning and end pressures
R	= gas constant
T	= absolute temperature in deg Kelvin
Mw	= molecular weight
f	= <u>Darcy</u> friction factor
L	= pipe length in m
D	= pipe diameter in m

HELIX

Isothermal conditions can only be maintained when flow velocity and pressure drop are kept below certain levels. If pressure drop is high then velocity may increase until it reaches the local speed of sound, at which point flow becomes **choked** and sonic velocities occur. At this point flow conditions can no longer be regarded as isothermal and the <u>Modified Darcy</u> method of calculation should be used.

This program indicates a choked flow condition graphically in the network sketch by drawing a filled circle on the pipe just downstream of the arrow head if the flow is choked.

Choked Flow

Free Flow

Refer to Perry's Chemical Engineers Handbook for more details.

3.3.3   Modified Darcy Method

The rate of flow of a gas from a high pressure area to a low pressure area reaches a maximum at a certain pressure differential and will not increase above this flow rate even if the upstream pressure is increased. This condition is known as a choked flow condition - the velocity of flow has reached the speed of sound in the fluid, also known as a sonic flow condition.

The Modified Darcy method of calculation checks for this choked flow condition and if necessary reduces the flow rate by a factor also called the net expansion factor. This factor depends on the gas characteristics and in this program the ratio of the specific heat capacities and the pressure drop ratio are used to calculate the expansion factor, and reduce the flow rate where required.

HELIX

A typical formula used is:

sonic velocity $\quad V s = \sqrt{g R T}$

where g is the ratio of the specific heat capacities of the gas
           = Cp/Cv
     R   is the gas constant
     T   is the absolute temperature in deg K

also $\qquad w = Xd^2 \sqrt{\dfrac{\Delta p}{KV_1}}$

where X   is the net expansion factor multiplied by a unit constant
     w   is the mass flow rate in kg/s
     d   is the pipe diameter in mm
     P   is the pressure drop
     K   is the total pipe and fitting shock loss co-efficient
     V   is the specific volume of the gas in m3/kg

Choked Flow

12.00 bar		1.01 bar
	712.95 l/s	
	10.99 bar	

Free Flow

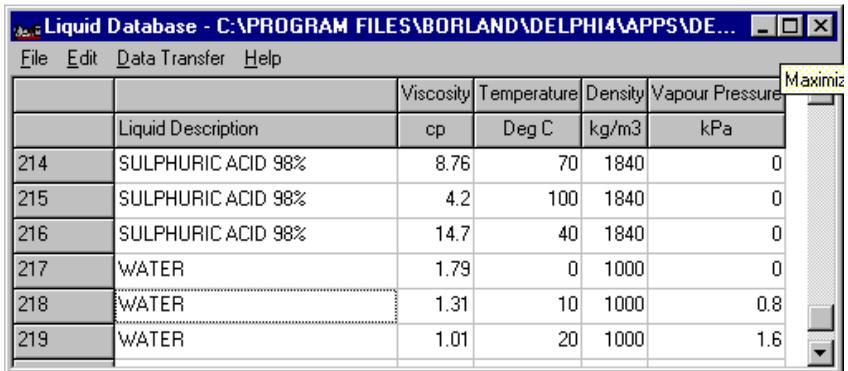| 4.00 bar		1.01 bar
	438.01 l/s	
	2.99 bar	

Note : All Gas Network Node Pressures should be entered in Absolute Pressure values, not in Gauge Pressures, even if you select kPa g or psi g as the units of pressure.

4.1. Liquid Database Files

Helix delta-Q is provided with a number of data files for you to use to store reference data.

Liquid data may be stored in the Liquid Database files. These files are located in the Data\Liquids sub-directory and have a .DAT file extension.

	Liquid Description	Viscosity cp	Temperature Deg C	Density kg/m3	Vapour Pressure kPa
214	SULPHURIC ACID 98%	8.76	70	1840	0
215	SULPHURIC ACID 98%	4.2	100	1840	0
216	SULPHURIC ACID 98%	14.7	40	1840	0
217	WATER	1.79	0	1000	0
218	WATER	1.31	10	1000	0.8
219	WATER	1.01	20	1000	1.6

Liquid Database - C:\PROGRAM FILES\BORLAND\DELPHI4\APPS\DE...
File Edit Data Transfer Help

To open an existing Liquid data file, select the **Database**, **Liquid Database** menu option. The current file will be opened. When you are in the Database file you can select the **File** menu and open existing files or add new files.

You can add new records to the data file by clicking in the empty row at the bottom of the datagrid. Fill in the required parameters and press **File, Save**. You can use the **Edit** menu options and hot keys to **copy** records for quick data capture routines.

You can **Sort** data in the grid by double clicking on the column heading or clicking in the column you want to sort by and pressing the Sort menu.

If you right click on an item in the data grid, you can select that item for transfer to the Pipe Network Diagram. For this option to function, the Data file should be called from the Pipe Network diagram form.

Importing Data

You can import data from other sources. The data should be in a Comma Separated Value (CSV) text file format, with the values in the same order as the columns in the datafile. To import data, open the file you want to add to, and add a new record by clicking in the last row in the description column. Now select the **Data Transfer, Import CSV Text File** menu option and open the CSV file. The program will attempt to copy the data into the file, starting at the cursor position. A CSV file is an ordinary text where the individual values in one row of data are separated by commas. for example 'Water,1.31,10,1000,0.8' would be a record for water at viscosity = 1.31, temperature at 10 deg, density at 1000 kg/m3 and Vapour pressure at 0.8. Each record should be on a new line in the CSV file.

Don't forget to save your data after importing it. The program will automatically enter a value of 1 if you leave a numeric value blank.

You can print the data file by selecting the **File**, **Print** menu option.

4.2. Gas Database

Helix delta-Q is provided with a number of data files for you to use to store reference data.

Gas data may be stored in the Gas Database files. These files are located in the Data\Gasses sub-directory and have a .DAT file extension.

Gas Database - C:\PROGRAM FILES\BORLAND\DELPHI4\APPS\DELTAQ2\Data\Gasses\Gasse...

File Edit Data Transfer Help
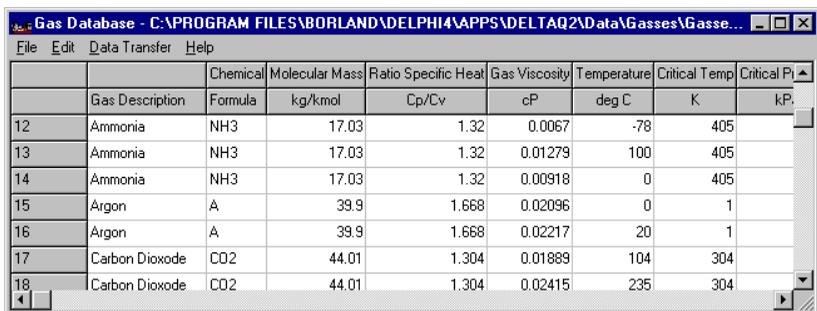
	Gas Description	Chemical Formula	Molecular Mass kg/kmol	Ratio Specific Heat Cp/Cv	Gas Viscosity cP	Temperature deg C	Critical Temp K	Critical Pr kP.
12	Ammonia	NH3	17.03	1.32	0.0067	-78	405	
13	Ammonia	NH3	17.03	1.32	0.01279	100	405	
14	Ammonia	NH3	17.03	1.32	0.00918	0	405	
15	Argon	A	39.9	1.668	0.02096	0	1	
16	Argon	A	39.9	1.668	0.02217	20	1	
17	Carbon Dioxode	CO2	44.01	1.304	0.01889	104	304	
18	Carbon Dioxode	CO2	44.01	1.304	0.02415	235	304	

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To open an existing Gas data file, select the **Database**, **Gas Database** menu option. The current file will be opened. When you are in the Database file you can select the **File** menu and open existing files or add new files.

Essential data required by this version of the program is:
- Description
- Molecular mass
- Ratio of Specific Heat capacities
- Gas Viscosity
- Gas Temperature

The Chemical Formula field is for information only and the Critical Temperature and Pressure are intended as calculation stop limits for future versions of the software.

You can add new records to the data file by clicking in the empty row at the bottom of the datagrid. Fill in the required parameters and press **File, Save**. You can use the **Edit** menu options and hot keys to **copy** records for quick data capture routines.

You can **Sort** data in the grid by double clicking on the column heading or clicking in the column you want to sort by and pressing the Sort menu.

If you right click on an item in the data grid, you can select that item for transfer to the Pipe Network Diagram. For this option to function, the Data file should be called from the Pipe Network diagram form.

Importing Data
You can import data from other sources. The data should be in a Comma Separated Value (CSV) text file format, with the values in the same order as the columns in the datafile. To import data, open the file you want to add to, and add a new record by clicking in the last row in the description column. Now select the **Data Transfer, Import CSV Text File** menu option and open the CSV file. The program will attempt to copy the data into the file, starting at the cursor position. A CSV file is an ordinary text where the individual values in one row of data are separated by commas. For example

'Water,1.31,10,1000,0.8' would be a record for water at viscosity = 1.31, temperature at 10 deg, density at 1000 kg/m3 and Vapour pressure at 0.8. Each record should be on a new line in the CSV file.

Don't forget to save your data after importing it. The program will automatically enter a value of 1 if you leave a required numeric value blank.

You can print the data file by selecting the **File**, **Print** menu option.

4.3. Slurry Database

Helix delta-Q is provided with a number of data files for you to use to store reference data.

Slurry data may be stored in the Slurry Database files. These files are located in the Data\Slurries sub-directory and have a .DAT file extension.

To open an existing Slurry data file, select the **Database**, **Slurry Database** menu option. The current file will be opened. When you are in the Database file you can select the **File** menu and open existing files or add new files.

You can add new records to the data file by clicking in the empty row at the bottom of the datagrid. Fill in the required parameters and press **File, Save**. You can use the **Edit** menu options and hot keys to **copy** records for quick data capture routines.

Definitions and Terminology

For more details about the data required look up the help topics listed below:

Description and Slurry number are for your record purposes only.
Carrier Liquid Viscosity
SG of Dry Solids
Concentration by Mass (Weight)
d50 and d80 Particle Size
Closely Graded - enter a Y or a N
Bingham Slurry - enter a Y or a N
Yield Stress - applies to Bingham slurry only
Co-efficient of Rigidity - applies to Bingham slurry only
Pump Wear Factor - default value is 1 (0.9 would indicate a 10% deration of the pump - this value is for future use)

You can **Sort** data in the grid by double clicking on the column heading or clicking in the column you want to sort by and pressing the Sort menu.

If you right click on an item in the data grid, you can select that item for transfer to the Pipe Network Diagram. For this option to function, the Data file should be called from the Pipe Network diagram form.

Importing Data
You can import data from other sources. The data should be in a Comma Separated Value (CSV) text file format, with the values in the same order as the columns in the datafile. To import data, open the file you want to add to, and add a new record by clicking in the last row in the description column. Now select the **Data Transfer, Import CSV Text File** menu option and open the CSV file. The program will attempt to copy the data into the file, starting at the cursor position. A CSV file is an ordinary text where the individual values in one row of data are separated by commas. for example 'Water,1.31,10,1000,0.8' would be a record for water at viscosity = 1.31, temperature at 10 deg, density at 1000 kg/m3 and Vapour pressure at 0.8. Each record should be on a new line in the CSV file.

Don't forget to save your data after importing it. The program will automatically enter a value of 1 if you leave a numeric value blank.

HELIX

You can print the data file by selecting the **File**, **Print** menu option.

4.4. Pipe Database

Helix delta-Q is provided with a number of data files for you to use to store reference data.

Pipe data may be stored in the Pipe Database files. These files are located in the Data\Pipes sub-directory and have a .DAT file extension.
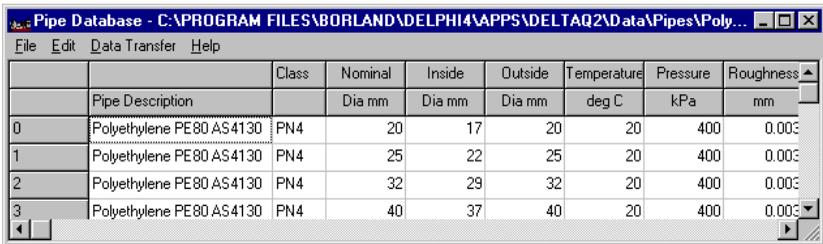
	Pipe Description	Class	Nominal Dia mm	Inside Dia mm	Outside Dia mm	Temperature deg C	Pressure kPa	Roughness mm
0	Polyethylene PE80 AS4130	PN4	20	17	20	20	400	0.003
1	Polyethylene PE80 AS4130	PN4	25	22	25	20	400	0.003
2	Polyethylene PE80 AS4130	PN4	32	29	32	20	400	0.003
3	Polyethylene PE80 AS4130	PN4	40	37	40	20	400	0.003

To open an existing Pipe data file, select the **Database**, **Pipe Database** menu option. The current file will be opened. When you are in the Database file you can select the **File** menu and open existing files or add new files. There are many different pipe data files supplied with delta-Q. Browse through the names and view any which may be of interest to you. Most of this data has also been combined into a single data file called **All Pipes Combined.dat.** You can also create a new file and add your own data.

You can add new records to the data file by clicking in the empty row at the bottom of the datagrid. Fill in the required parameters and press **File, Save**. You can use the **Edit** menu options and hot keys to **copy** records for quick data capture routines.

You can **Sort** data in the grid by double clicking on the column heading or clicking in the column you want to sort by and pressing the Sort menu.

If you right click on an item in the data grid, you can select that item for transfer to the Pipe Network Diagram. For this option to function, the Data file should be called from the Pipe Network diagram form.

Importing Data
You can import data from other sources. The data should be in a Comma Separated Value (CSV) text file format, with the values in the same order as the columns in the datafile. To import data, open the file you want to add to, and add a new record by clicking in the last row in the description column. Now select the **Data Transfer, Import CSV Text File** menu option and open the CSV file. The program will attempt to copy the data into the file, starting at the cursor position. A CSV file is an ordinary text where the individual values in one row of data are separated by commas. for example 'Poly,Class 16,110,99,110,65,1600,0.003, 15.65' would be a record for a Poly pipe, Class 16, NB 110, ID 99, OD 110 Temperature 65, roughness 0.003 mm and pipe cost $15.65. Each record should be on a new line in the CSV file.

Don't forget to save your data after importing it. The program will automatically enter a value of 1 if you leave a numeric value blank.

You can print the data file by selecting the **File**, **Print** menu option.

4.5. Pump Database

Helix delta-Q is provided with a number of data files for you to use to store reference data.

Pump data may be stored in the Pump Database files. These files are located in the Data\Pumps sub-directory and have a .DAT file extension.
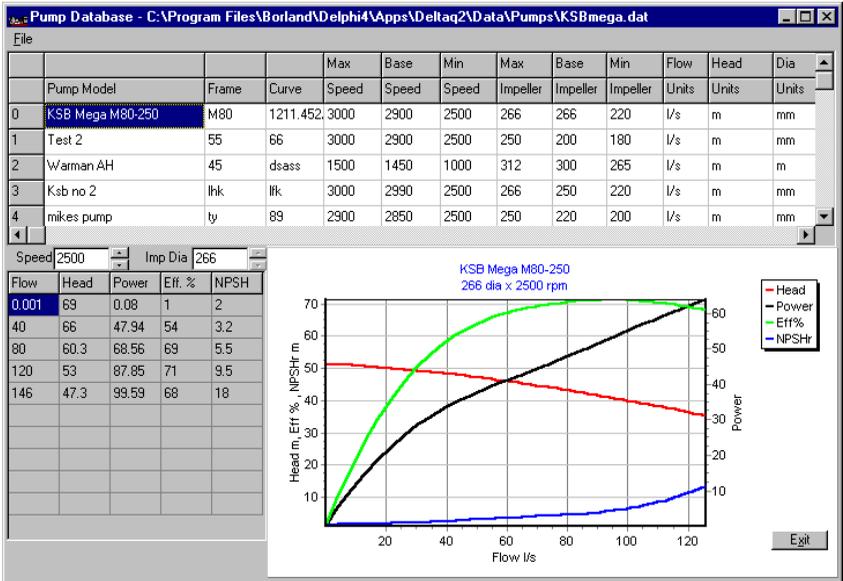
To open an existing Pump data file, select the **Database**, **Pump Database** menu option. The current file will be opened. When you are in the Database file you can select the **File** menu and open existing files or add new files.

You can add new records to the data file by clicking in the empty row at the bottom of the datagrid. Fill in the required parameters and press **File, Save**. You can use the **Edit** menu options and hot keys to **copy** records for quick data capture routines.

The linking of Pumps into the delta-Q version 2 program is still under development. Use the delta-Q version 1 for performing pump selections, pumps in series, system curves etc.

Importing Data
Not implemented yet.
Don't forget to save your data after importing it. The program will automatically enter a value of 1 if you leave a numeric value blank.

You can print the data file by selecting the **File**, **Print** menu option.