Get Started

PIPESYS

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Since software is always a work in progress, any version, while representing a milestone, is nevertheless but a point in a continuum. Those individuals whose contributions created the foundation upon which this work is built have not been forgotten. The current authors would like to thank the previous contributors. A special thanks is also extended by the authors to everyone who contributed through countless hours of proof-reading and testing.

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Table of Contents

Welcome to PIPESYS

Introduction

A pipeline must transport fluids over diverse topography and under varied conditions. Ideally this would be done efficiently with a correctly sized pipeline that adequately accounts for pressure drop, heat losses and includes the properly specified and sized inline facilities, such as compressors, heaters or fittings. Due to the complexity of pipeline network calculations, this often proves a difficult task. It is not uncommon that during the design phase an over-sized pipe is chosen to compensate for inaccuracies in the pressure loss calculations. With multi-phase flow, this can lead to greater pressure and temperature losses, increased requirements for liquid handling and increased pipe corrosion. Accurate fluid modeling helps to avoid these and other complications and results in a more economic pipeline system. To accomplish this requires single and multi-phase flow technology that is capable of accurately and efficiently simulating the pipeline flow.

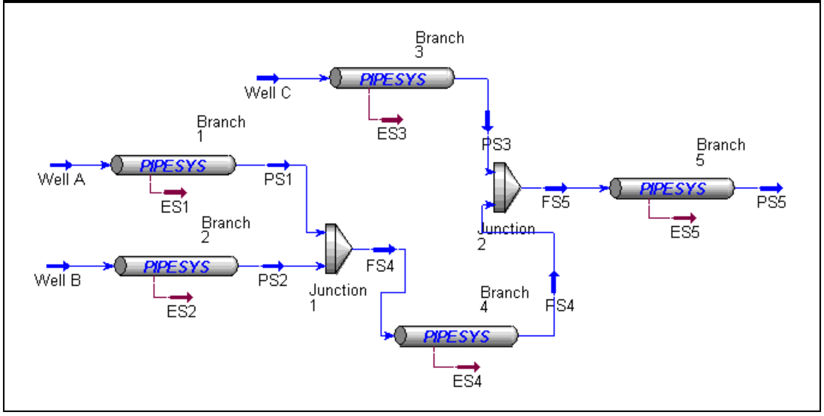
PIPESYS has far-reaching capabilities to accurately and powerfully model pipeline hydraulics. It uses the most reliable single and multi-phase flow technology available to simulate pipeline flow. Functioning as a seamless extension to HYSYS, PIPESYS has access to HYSYS features such as the component database and fluid properties. PIPESYS includes many inline equipment and facility options relevant to pipeline construction and testing. The extension models pipelines that stretch over varied elevations and environments. PIPESYS enables you to:

- rigorously model single phase and multi-phase flows.
- compute detailed pressure and temperature profiles for pipelines that traverse irregular terrain, both on shore and off.
- perform forward and reverse pressure calculations.
- model the effects of inline equipment such as compressors, pumps, heaters, coolers, regulators and fittings including valves and elbows.
- perform special analyses including:
  - pigging slug prediction.
  - erosion velocity prediction.
  - severe slugging checks.
- model single pipelines or networks of pipelines in isolation or as part of a HYSYS process simulation.
- perform sensitivity calculations to determine the dependency of system behaviour on any parameter.

- quickly and efficiently perform calculations with the internal calculation optimizer, which significantly increases calculation speed without loss of accuracy.
- determine the possibility of increasing capacity in existing pipelines based on compositional effects, pipeline effects and environmental effects.

A PIPESYS network is shown below:

Figure 1



A wide variety of correlations and mechanistic models are used in computing the PIPESYS extension. Horizontal, inclined and vertical flows may all be modeled. Flow regimes, liquid holdup and friction losses can also be determined. There is considerable flexibility in the way calculations are performed. You can:

- compute the pressure profile using an arbitrarily defined temperature profile, or compute the pressure and temperature profiles simultaneously.
- given the conditions at one end, perform pressure profile calculations either with or against the direction of flow to determine either upstream or downstream conditions.
- perform iterative calculations to determine the required upstream pressure and the downstream temperature for a specified downstream pressure and upstream temperature.
- compute the flow rate corresponding to specified upstream and downstream conditions.

It is recommended that all users read the PIPESYS User Guide in order to fully understand the functioning and principles involved when constructing a PIPESYS simulation.

Users familiar with HYSYS will recognize a similar logical worksheet and data entry format in the PIPESYS extension. Those not familiar with HYSYS will quickly acquire the skills to run HYSYS and PIPESYS using the tools available such as the user manuals, online help and status bar indicators.

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1 Installation

1.1 PIPESYS Features

The PIPESYS extension is functionally equivalent to a HYSYS flowsheet operation. It is installed in a flowsheet and connected to material and energy streams. All PIPESYS extension properties are accessed and changed through a set of property views that are simple and convenient to use. Chief among these—and the starting point for the definition of a PIPESYS operation—is the Main PIPESYS View:

- Main PIPESYS View - Used to define the elevation profile, add pipeline units, specify material and energy streams, choose calculation methods and check results.

The PIPESYS extension includes these pipeline units, each of which is accessible through a property view:

- Pipe - The basic pipeline component used to model a straight section of pipe and its physical characteristics.
- Compressor - Boosts the gas pressure in a pipeline.
- Pump - Boosts the liquid pressure in a pipeline.
- Heater - Adds heat to the flowing fluid(s).
- Cooler - Removes heat from the flowing fluid(s).
- Unit X - A “black box” component that allows you to impose arbitrary changes in pressure and temperature on the flowing fluid(s).
- Regulator - Reduces the flowing pressure to an arbitrary value.
- Fittings - Used to account for the effect of fittings such as tees, valves and elbows on the flowing system.
- Pigging Slug Size Check - An approximate procedure for estimating the size of pigging slugs.
- Severe Slugging Check - A tool for estimating whether or not severe slugging should be expected.
- Erosion Velocity Check - Checks fluid velocities to estimate whether or not erosion effects are likely to be significant.

1.2 System Requirements

PIPESYS has the following fundamental system requirements.

System Component	Requirement
Operating System	Microsoft Windows 2000/NT 4.0/98/95
Disk Space	Approximately 6 MB of free disk space is required.
Serial Port	The green security key is used with the standalone version of HYSYS and can only be attached to a serial communications port of the computer running the application (do not plug in a serial mouse behind the security key).
Parallel Port	SLM keys are white Sentinel SuperPro keys, manufactured by Rainbow Technologies. The Computer ID key is installed on the parallel port (printer port) of your computer. An arrow indicates which end should be plugged into the computer. This is the new key that is used for both Standalone and Network versions of HYSYS.
Monitor/Video	Minimum usable: SVGA (800x600). Recommended: SVGA (1024x768).
Mouse	Required.

The mouse cannot be plugged into the back of the green serial port key used with the “standalone” version of HYSYS.

1.3 Software Requirements

The PIPESYS Extension runs as a plug-in to HYSYS. That is, it is uses the HYSYS interface and property packages to build a simulation and is accessed in the same manner as a HYSYS unit operation. Therefore, to run PIPESYS you are required to have **HYSYS v2.0** or higher.

You will not be able to use PIPESYS without the proper HYSYS and PIPESYS licenses. You can refer to Chapter 2 - Software Licensing of the HYSYS Get Started manual for information on licenses.

1.4 Installing PIPESYS

The following instructions relate to installing PIPESYS as an extension to HYSYS. HYSYS must be installed prior to installing the PIPESYS Extension.

1. Shut down all other operating Windows programs on the computer before starting the installation process.
2. Insert the HYSYS software CD into the CD drive of the computer.

For instructions on installing HYSYS refer to **Chapter 1 - Installing HYSYS** of the HYSYS Get Started manual.

For computers which have the CD-ROM Autorun feature enabled, steps #3 and #4 will be automatically performed.

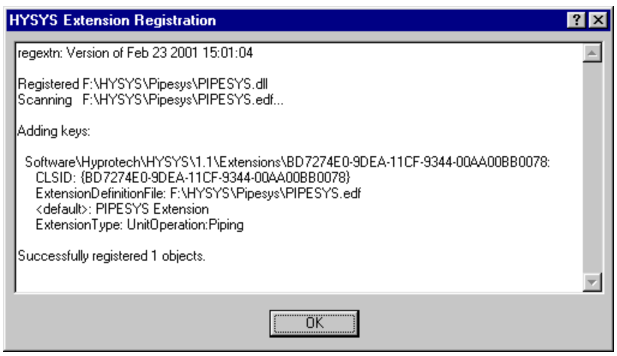
3. From the **Start** menu, select **Run**.
4. In the Run view, type: **d:\setup.exe** and click on the **OK** button (where d: is your CD drive). The Installation browser appears

Figure 1.1

5. Click the **Install Products** link.
6. Click the **HYSYS Extensions** link.

7. Select **PIPESYS** to start the installation. It may take a few moments for the installer to load.
8. The first view that appears welcomes you to the installation program and displays the name of the application you are trying to install. If all of the information is correct click the **Next** button.
9. The Information view provides information regarding licenses. Please read the information presented on this screen as it is important. Click the **Next** button to continue.
10. Specify a destination folder where the setup will install the PIPESYS files. If you do not want to install the application in the default directory use the **Browse** button to specify the new path. When the information is correct click the **Next** button.
11. The installation program will then allow you to review the information that you have provided. If all of the information is correct click the **Next** button. HYSYS will then begin installing files to your computer.
12. Once the files have been transferred to their proper locations, the installation program will register the PIPESYS extension with HYSYS. Once the extension is successfully registered click **OK** to continue.

Figure 1.2



13. Click the **Finish** button to complete the installation.
14. Click the **Return to Products** link, then the **Main Menu** link, then the **Exit** link to close the Installation browser.

1.5 Starting PIPESYS

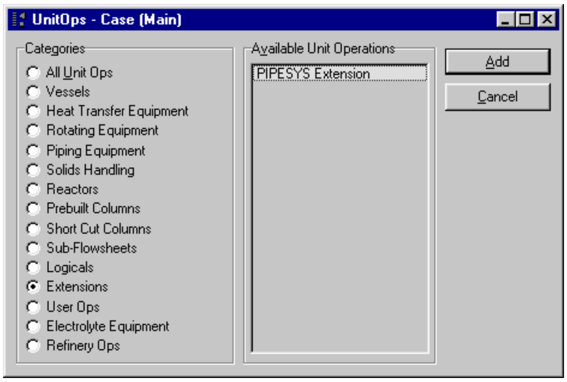
For additional information on the properties of HYSYS unit operations, refer to the HYSYS **Operations Guide**.

To access a HYSYS case, refer to **Chapter 3 - Get Started** from the HYSYS Get Started manual.

You can work with PIPESYS only as it exists as part of a HYSYS case. Extensions that are part of an existing case may be accessed upon entering HYSYS' Main Simulation Environment. Here you can view and manipulate them as you would any HYSYS unit operation.

Before creating a new PIPESYS Extension you are required to be working within a HYSYS case that has as a minimum a fluid package, consisting of a property package and components. New PIPESYS Extensions are added within the Main Simulation Environment from the UnitOps view (press F12), which lists all the available Unit Operations.

Figure 1.3

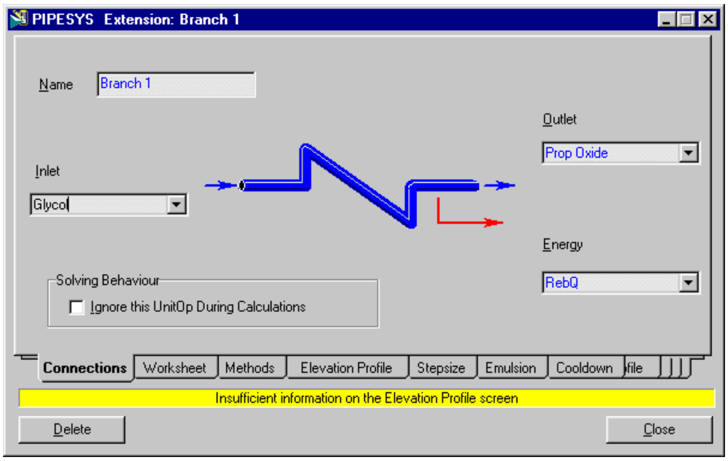


To create a new PIPESYS Extension:

1. Open the UnitOps view by selecting **Flowsheet-Add Operation** in the menu bar.
2. Select the **Extensions** radio button in the Categories group.
3. Select the **PIPESYS Extension** in the list of Available Unit Operations as shown above.
4. Click the **Add** button and a new PIPESYS Extension view will appear on the screen.

The initial PIPESYS view is the Connections tab and it is shown below.

Figure 1.4



To view any other tabs of the PIPESYS view, simply click on the tab.

For more information, see **Chapter 2 - PIPESYS View** from the PIPESYS User Guide.

2 Elevation Profile Example

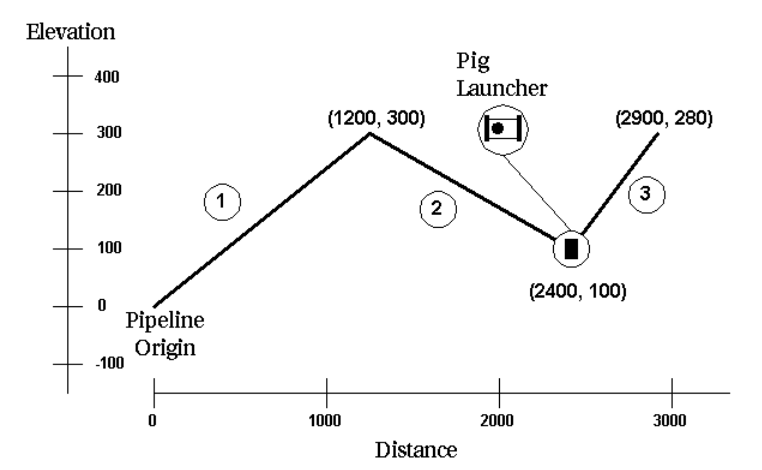
2.1 Introduction

If you would like to follow a more detailed step-by-step procedure for creating a PIPESYS case, see **Chapter 1 - Gas Condensate Tutorial** from the PIPESYS **Tutorial** manual.

One of the first and most important steps in adding a PIPESYS operation to a HYSYS flowsheet is the construction of the elevation profile. The purpose of this procedure is to create a representation of the pipeline as a connected series of components with the corresponding position data. In this example, you will go through the steps to enter an elevation profile components and data. All units of measurement in this example are SI, but you can change these to whatever unit system you prefer.

For this case, a simple pipeline consisting of three pipe units and a pig launcher will be built to demonstrate the PIPESYS procedures. The figure below shows a schematic of these four components with coordinate axes.

Figure 2.1



2.2 Setting Up the Flowsheet

Before working with the PIPESYS extension, you must first create a HYSYS case. In the Simulation Basis Manager, create a fluid package. Add a property package and these components:

Property Package	Components
Peng Robinson	C1, C2, C3, i-C4, n-C4, i-C5, n-C5, C6, Nitrogen, CO2, H2S

Create a stream called Inlet in the Main Simulation Environment and define it as follows:

Name	Inlet
Vapour Fraction	1.00
Temperature [^{o}C]	45**
Pressure [kPa]	8000**
Molar Flow [kgmole/h]	300**
Mass Flow [kg/h]	6595
LiqVol Flow [m3/h]	17.88
Heat Flow [kJ/h]	-2.783e+07
Comp Mass Frac [methane]	0.7822**
Comp Mass Frac [ethane]	0.0803**
Comp Mass Frac [propane]	0.0290**
Comp Mass Frac [i-Butane]	0.0077**
Comp Mass Frac [n-Butane]	0.0246**
Comp Mass Frac [i-Pentane]	0.0074**
Comp Mass Frac [n-Pentane]	0.0072**
Comp Mass Frac [n-Hexane]	0.0012**
Comp Mass Frac [Nitrogen]	0.0098**
Comp Mass Frac [CO2]	0.0409**
Comp Mass Frac [H2S]	0.0097**

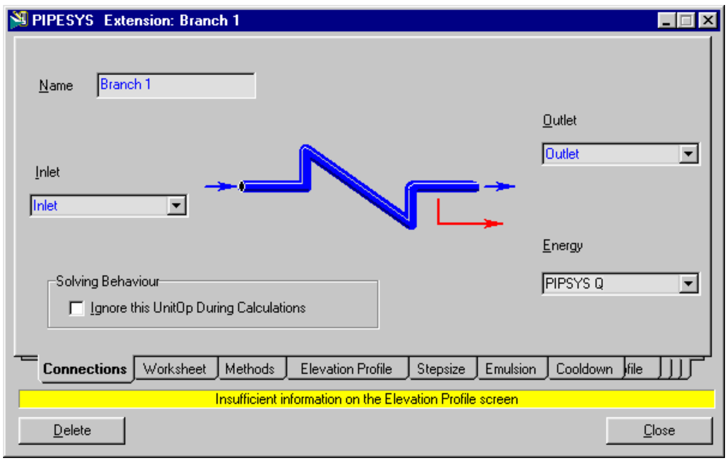
** signifies required input

2.3 Adding a PIPESYS Extension

Once the case is created, the PIPESYS extension can be added:

1. Go to the **UnitOps** tab in the workbook and click the **Add UnitOp** button.
2. From the available list, select **PIPESYS Extension** and click **Add**.
3. On the **Connections** tab, complete the form as shown below.

Figure 2.2



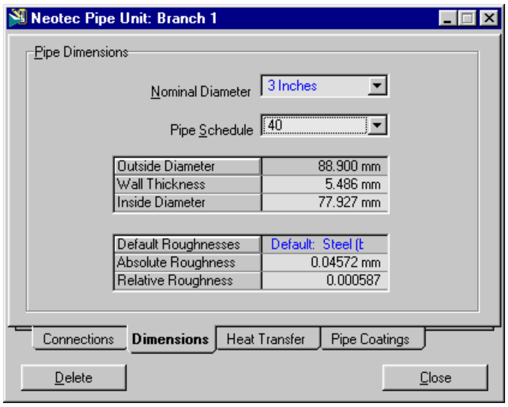
2.4 Defining the Elevation Profile

1. Go to the **Elevation Profile** tab. As you can see from **Figure 2.1**, the coordinates of the Pipeline Origin have the value 0.0.
2. Enter **0.0** into both the **Distance** and the **Elevation** cells in the Pipeline Origin group.

Add a Pipe Unit to the matrix as follows:

3. Select the **<empty>** cell in the Pipeline Unit column.
4. Select **Pipe** from the drop-down list. The Pipe Unit Property View appears.
5. On the Pipe Unit view, go to the **Dimensions** tab.
6. Specify a Nominal Diameter of **3 Inches** and a Pipe Schedule of **40**. The completed tab is shown below.

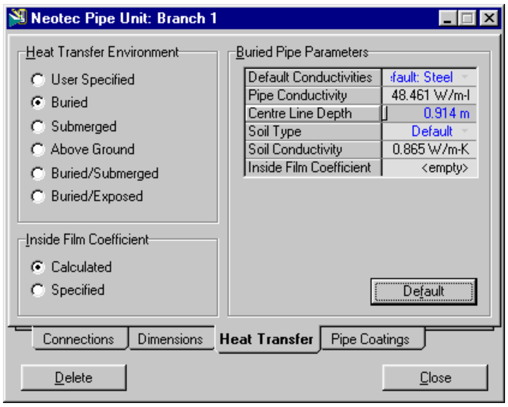
Figure 2.3



7. Go to the **Heat Transfer** tab.

8. Select the cell **<empty>** for the Centre Line Depth and the click the **Default** button. The completed tab is shown below.

Figure 2.4

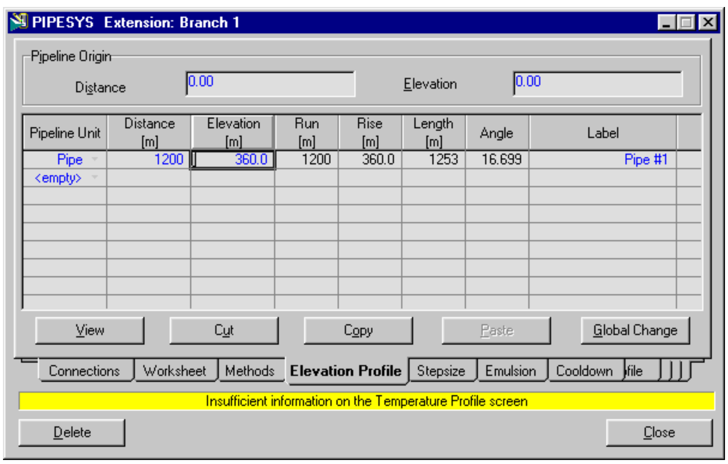


9. Click the **Close** button to close the complete Pipe Unit view.

The pipe unit will now appear as an entry in the matrix, with **<empty>** in all parameter cells. Pipe #1 has endpoint coordinates of (1200, 360).

10. To complete the profile data entry, enter **1200** into the Distance cell and **360** into the Elevation cell. PIPESYS automatically calculates all the other parameters, as shown in the figure below.

Figure 2.5

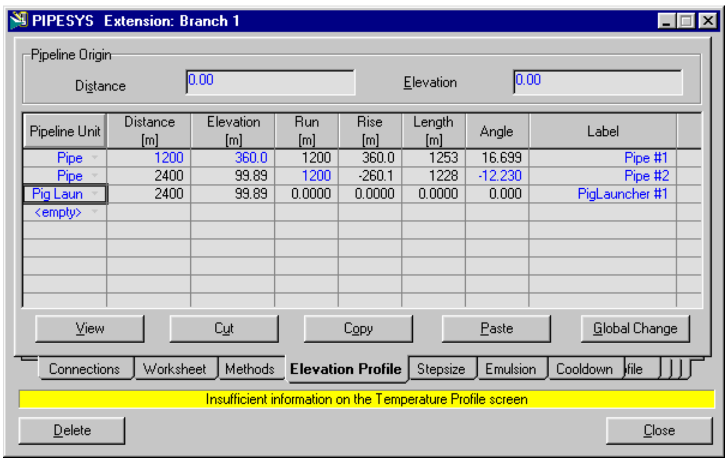


11. Add the second pipe unit to the matrix. Fill in the pipe unit view with the same specifications as were used for Pipe Unit #1. You may either re-enter all this information, or use the **Copy** and **Paste** buttons on the Elevation Profile tab.
12. This time specify the second pipe unit endpoint using the **Run** and **Length** parameters instead of Elevation and Distance. Figure 2.1 shows that the second pipe unit has a Run of **1200** and a Length of **1227.84**. Enter these values on the Elevation Profile tab.

You may have noticed that the data on the Elevation Profile tab does not correctly represent the actual geometry of the pipeline. This is because PIPESYS always assumes a positive angle for the pipe unit when the Run and Length parameters are used to specify the coordinates of the endpoint.

13. To correct the matrix data, make a note of the Angle value, which is 12.23, and then delete the value in the Length cell.
14. Enter **-12.23** into the Angle cell. Or alternately, you could enter the value for the Rise as **-260** m.
15. To add the Pig Launcher, select the **<empty>** cell and choose **Pig Launcher** from the drop-down list.

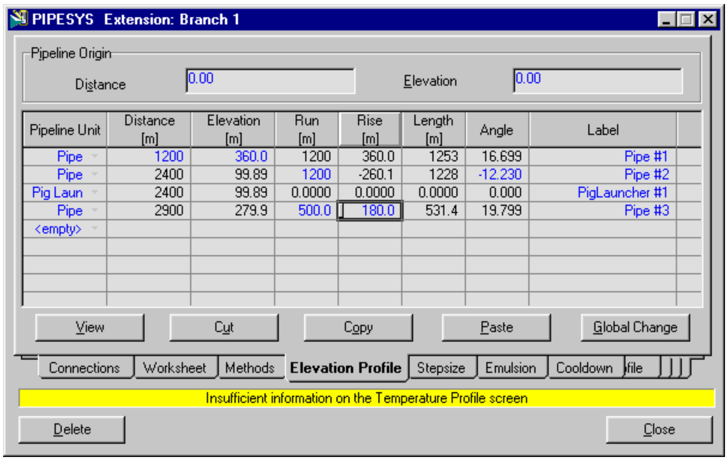
Figure 2.6



You are not required to specify any additional data to incorporate the Pig Launcher into the matrix. The above figure shows the Elevation Profile tab after the Pig Launcher has been added. Position data for the launcher or any other inline facility does not have to be specified because this information is obtained automatically from the preceding component.

16. Add a third pipe unit with the same parameters as the previous two. Using the Run and Rise parameters, specify the endpoint coordinates. The Run value is **500** (2900-2400) and the **Rise** is **180** (280-100). The completed Elevation Profile tab is shown below.

Figure 2.7



The status bar at the bottom of the PIPESYS view indicates that there is “Insufficient information on the Temperature Profile screen”.

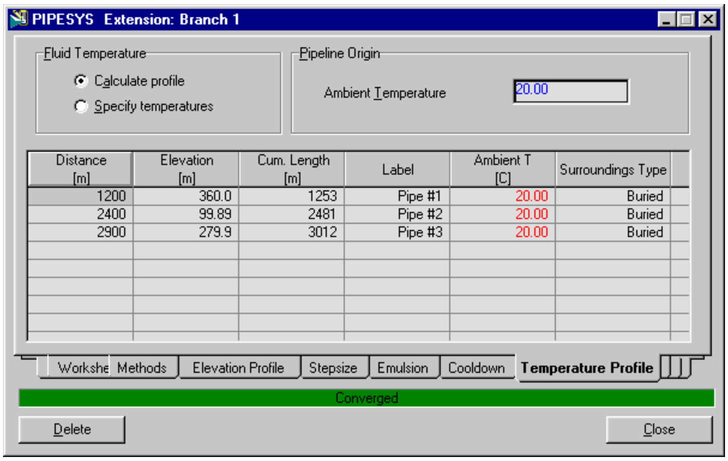
17. Open the **Temperature Profile** tab. Enter **20** into the Ambient Temperature field of the Pipeline Origin group.

Notice that the Ambient Temperature value is automatically copied in the Ambient T cell for each individual pipe unit, unless otherwise specified.

Once the Ambient Temperature information is provided, PIPESYS begins calculating. When completed, the status bar reads “Converged”.

The Temperature Profile tab of the converged extension is shown below.

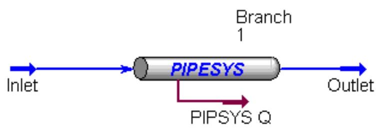
Figure 2.8



To add a table to a PFD, right-click on the PFD and choose **Add Workbook Table** from the drop-down list.

18. Save your completed case as **Pipesys1.hsc**. The PFD generated for the completed case, plus a material stream table is shown below:

Figure 2.9



Material Streams			
		Inlet	Outlet
Vapour Fraction		1.0000	1.0000
Temperature	C	45.00	27.06
Pressure	kPa	8000	7183
Molar Flow	kgmole/h	300.0	300.0
Mass Flow	kg/h	6504	6504
Liquid Volume Flow	m3/h	17.78	17.78
Heat Flow	kJ/h	-2.775e+007	-2.799e+007

A References

[1] American Petroleum Institute, “Subsurface Controlled Subsurface Safety Valve Sizing Computer Program”, API Manual 14BM, Second Ed., p. 38, API, January (1978)

[2] American Petroleum Institute, Technical Data Book - Petroleum Refining, API, New York (1982)

[3] Aziz, K., Govier, G.W., and Fogarasi, M.,“Pressure Drop in Wells Producing Oil and Gas”, Journal of Canadian Petroleum Technologists., Vol. 11, p. 38, July (1972)

[4] Baker, O. “Simultaneous Flow of Oil and Gas”, Oil & Gas Journal, Vol. 54, No. 12, p. 185, July (1954)

[5] Baker, O. “Experience with Two-Phase Pipelines”, Canadian Oil & Gas Industry, Vol. 14, No. 3, p. 43, March (1961)

[6] Beggs, H.D., and Brill, J.P. “A Study of Two-Phase Flow in Inclined Pipes”, Journal of Petroleum Technologists, p. 607, May (1973)

[7] Bendiksen, K.H., Maines, D., Moe, R., and Nuland, S., “The Dynamic Two Fluid Model OLGA: Theory and Application”, SPE Paper No. 19451, SPE Production Engineering, May (1991)

[8] Burke, N.E., and Kashou, S.F., “History Matching of a North Sea Flowline Startup Using OLGA Transient Multi-phase Flow Simulator”, SPE Paper No. 24789, Presented at the 67th Annual SPE Technical Conference and Exhibition, Washington, DC, October (1992)

[9] Chen, N.H., “An Explicit Equation for Friction Factor in Pipe”, Ind. Eng. Chem. Fund., Vol. 18, No. 3, p. 296 (1979)

[10] Dukler, A.E., Wicks, M., and Cleveland, R., “Frictional Pressure Drop in Two-Phase Flow: B. An Approach Through Similarity Analysis”, AIChE Journal, Vol. 10, No. 1, p. 44, January (1964)

[11] Dukler, A.E., “Gas-Liquid Flow in Pipelines”, Monograph, Project NX-28, AGA/API, May (1969)

[12] Duns, H., Jr., and Ros, N., “Vertical Flow of Gas and Liquid Mixtures in Wells”, Paper No. 22, Section II, World Petroleum Conference, Frankfurt, Germany (1963)

[13] Eaton, B.A., Andrews, D.E., Knowles, C.R., Silberberg, I.H., and Brown, K.E., “The Prediction of Flow Patterns, Liquid Holdup and Pressure Losses Occurring During Continuous Two-Phase Flow in Horizontal Pipelines”, Journal of Petroleum Technologists, p. 815, June (1967)

[14] Flanking, O., “Effect of Uphill Flow on Pressure Drop in Design of Two-Phase Gathering Systems”, Oil & Gas Journal, p. 132, March (1958)

[15] Fuchs, P., “The Pressure Limit for Terrain Slugging”, Paper B.4, Proc. of the 3rd International Conference on Multi-phase Flow, BHRA, The Hague, Netherlands (1987)

[16] Govier, G.W., and Aziz, K., The Flow of Complex Mixtures in Pipes, Van Nostrand-Reinhold, (1972), reprinted by Robert E. Krieger Publishing Co., Huntingdon, New York (1977)

[17] Govier, G.W., and Fogarasi, M., “Pressure Drop in Wells Producing Gas and Condensate”, Journal of Canadian Petroleum Technologists, October (1975)

[18] Gregory, G.A., “Estimation of the Overall Heat Transfer Coefficient for Calculating Heat Loss/Gain in Flowing Wells”, Technical Note No. 4, Neotechnology Consultants Ltd., Calgary, Canada, March (1991)

[19] Gregory, G.A., Mandhane, J., and Aziz, K. “Some Design Considerations for Two-Phase Flow in Pipes”, Journal of Canadian Petroleum Technologists, January-March (1975)

[20] Gregory, G.A., “Comments on the Prediction of Minimum Unloading Velocities for Wet Gas Wells”, Technical Note No. 14, Neotechnology Consultants Ltd., Calgary, Canada, December (1989)

[21] Gregory, G.A., “Estimation of the Overall Heat Transfer Coefficient for the Calculation of Pipeline Heat Loss/Gain”, Technical Note No.3, Neotechnology Consultants Ltd., Calgary, Canada, October (1984), 1st Revision September (1990), 2nd Revision March (1991)

[22] Hooper, W.B., “The Two-K Method Predicts Heat Losses in Pipe Fittings”, Chemical Engineering, p. 96, August (1981)

[23] Hughmark, G.A., “Holdup and Heat Transfer in Horizontal Slug Gas-Liquid Flow”, Chem. Eng. Sci., Vol 20, p. 1007 (1965)

[24] Hughmark, G.A. “Holdup in Gas-Liquid Flow”, Chem. Eng. Prog., Vol. 58, No. 4, p. 62, April (1962)

[25] Lockhart, R.W., and Martinelli, R.C. “Proposed Correlation of Data for Isothermal Two-Phase, Two-Component Flow in Pipes”, Chem. Eng. Prog., Vol. 45, No. 1, p. 39, January (1949)

[26] Mandhane, J., Gregory, G., and Aziz, K., “A Flow Pattern Map for Gas-Liquid Flow in Horizontal Pipes”, International Journal of Multi-phase Flow, Vol. 1, p. 537 (1974)

[27] Mandhane, J.M., Gregory, G.A., and Aziz, K., “Critical Evaluation of Friction Pressure-Drop Prediction Methods for Gas-Liquid Flow in Horizontal Pipes”, Journal of Petroleum Technologists, p. 1348, October (1977)

[28] Mukherjee, H., and Brill, J.P., “Liquid Holdup Correlations for Inclined Two-Phase Flow”, Journal of Petroleum Technologists, p. 1003, May (1983)

[29]Oliemans, R.V.A., “Two-Phase Flow in Gas-Transmission Pipelines”, Paper No. 76-Pet-25, Joint Petroleum Mechanical Engineering & Pressure Vessels and Piping Conference, Mexico City, Mexico, September (1976)

[30]Oliemans, R.V.A., “Modeling of Gas Condensate Flow in Horizontal and Inclined Pipes”, Proc., ASME Pipeline Eng. Symp., ETCE, p. 73, Dallas, Texas, February (1987)

[31]Pots, B.F.M., Bromilow, I.G., and Konijn, M.J.W.F., “Severe Slug Flow in Offshore Flowline/Riser Systems”, SPE Prod. Eng., p. 319, November (1987)

[32]Salama, M.M and Venkatesh, E.S., “Evaluation of API RP 14E Erosional Velocity Limitations for Offshore Gas Wells”, Paper No. OTC 4485, presented at the 15th Annual Offshore Technology Conference, Houston, May (1983)

[33]Singh, B., and Gregory, G.A., unpublished work (1983)

[34]Taitel, Y., and Dukler, A. “A Model for Predicting Flow Regime Transitions in Horizontal and Near Horizontal Gas-Liquid Flow”, AIChE J., Vol. 22, No. 1, p. 47, January (1976)

[35]Tennessee Gas Pipeline Co., private communication (1979)