

GPIPE

Gas Pipeline Hydraulics Simulation



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1

INTRODUCTION

GPIPE is a hydraulic simulation software for gas pipelines considering heat transfer between the pipe and the surrounding medium. Multiple compressor stations along the pipeline may be specified. Calculations are performed for a given input flow rate and gas properties. Gas may be injected or delivered at various locations along the pipeline. The pipeline may be bare or insulated. Pressure drop for each segment is calculated using one of the various equations (such as AGA, Colebrook-White, Panhandle, etc.). The gas compressibility factor is calculated using CNGA, Standing-Katz or AGA NX19 methods. Pipeline elevations are taken into account in determining the pressures and station horsepower required at each compressor station. The pipeline pressures, temperatures, compressor station suction pressures and discharge pressures and compressor horsepower required are calculated and output on the screen. Results are also saved to a disk file.

Multiple cases may be easily modeled quickly and accurately. GPIPE is ideal for the design of a new pipeline or checking capabilities of existing pipelines. Data is entered using pull down menus and dialog boxes under the Microsoft Windows operating environment. Default data is provided in most cases. Pipeline profile data is entered using a spreadsheet style input screen. Help is available on each data entry screen and on the status bar at the bottom of each data entry screen.

A toolbar consisting of icons for commonly used menu items such as *File Open, Save, Print, Run etc.* is available below the menu bar. These menu items or commands can be accessed by clicking on the icons. As the mouse is moved over an icon, a tool tip HELP appears explaining the function of each icon on the toolbar.

The calculated results are displayed on the screen in a scrollable window, as well as saved in a disk file for later viewing or printing. A printed hard copy of the calculated results can be created simultaneously with screen output.

This software can be run on Pentium and Athlon based computers and compatibles with a minimum of 512 MB RAM running Microsoft Windows XP, Windows Vista and Windows 7. A minimum hard disk space of 20 MB is required for installing the program.

2

GETTING STARTED

The software program is supplied on a CD-ROM that must be installed on your computer's hard disk as described below. If you purchased a USB dongle version (hardware key) follow the installation steps under section 2.1 below. If you have licensed an internet authenticated version of the program that does not use a dongle follow the steps under section 2.2.

This single user license entitles you to use the software only on one computer at a time. If you purchased a multi-user or network license, you are entitled to use the software on more than one computer as described in other documentation that accompanied the software.

2.1 Installation – USB dongle version

The software is protected by a USB dongle that plugs into your computer's USB port. This dongle is plugged into the USB port *after* the installation of the software. This dongle, shown in the figure below, *must* be in place for the software to operate properly. **Do not attach the dongle until after the dongle installation step is completed.**



Since the *dongle* is critical to the operation of the software, it must be stored safely when not in use. It is recommended that Laptop computer users remove the *dongle* from the USB port before packing the laptop in its carrying case.

The software will work **only** with the specific USB dongle included with the program CD. If this is an upgrade to the program, you will continue to use the original USB dongle when you first purchased the software. The USB dongles cannot be interchanged. Each dongle is specific to the software.

With one licensed copy, the program may be concurrently installed on more than one computer. However, the software will only run on the computer that has the USB dongle attached.

A lost or damaged dongle is equivalent to losing the software. A replacement dongle can only be obtained at the full retail price of the software. In other words, the dongle costs as much as the software itself.

Getting Started

Before starting the installation process, close all running applications and turn off any virus checking software, if currently present on the hard disk. If you want to ensure that the program disk is free of any virus you may run the virus scanning software and check the program CD prior to starting installation.

This program requires Microsoft .NET Framework 4.0 or higher. If it is missing on your computer the installation program will request permission to install the Microsoft .NET Framework. After installing the .NET Framework and restarting the computer, start the setup program again and follow the screen instructions.

Step-1:

Insert the software CD into the CD-ROM drive. If *Autostart* is enabled on the CD-ROM drive, setup will start automatically. If not, from the **Start** button choose **Run**.

Type the following in the resulting screen: `G:\setup` and press Enter
Where G represents the drive letter for your CD-ROM drive.

Note that Windows Vista and Windows 7 require installing software with administrative privileges. Therefore, disable the automatic setup and run the "setup.exe" program from the CD-ROM as an Administrator.

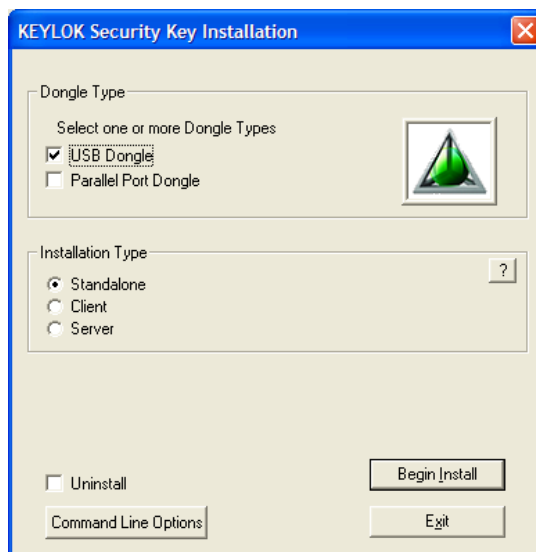
Follow the subsequent screen instructions to continue with the installation process.

Step-2:

After the software is installed, the Dongle Installation will automatically start.

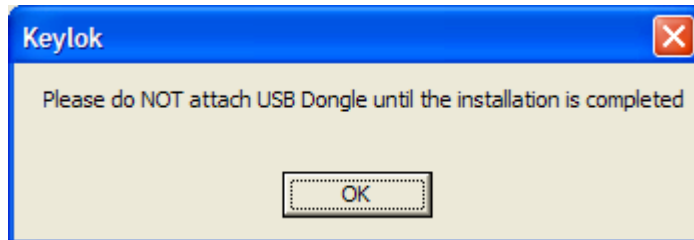
Do not attach the dongle until after the dongle installation step is completed.

Initially, the screen below is displayed:

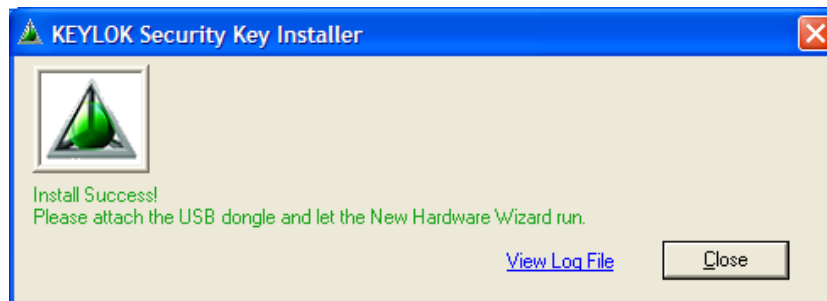


Choose the **USB Dongle** type and **Standalone** installation type as shown and click **Begin Install**.

Next, the following screen is displayed. Click OK to confirm.



When the dongle installation is completed (may take a few minutes), and a message is displayed to this effect, you should attach the dongle to one of the USB ports as directed in screen below.



The computer will recognize the dongle and the software driver will be installed automatically.

After the setup is completed and you start GPIPE software from the Windows Start button, the User Registration screen will prompt you to enter your name, company and the software serial number.

The serial number found on the software CD container must be entered exactly. Otherwise the installation will be incomplete.

The Licensed User is eligible to receive **free** technical support for one year from the date of purchase. After this period, the User may sign up for an annual Software Maintenance Program.

Put your original software CD-ROM away safely.

After the setup is completed, the **User Registration screen** will prompt you to enter your name, company name and the program serial number. ***The serial number found on the program CD container must be entered exactly.*** Otherwise the installation will be incomplete.

Once installation is completed, a program icon and program folder will be automatically created. You may launch the program from the Windows **Start** button. You may also create a shortcut to the program on your desktop.

2.2 Installation – Internet Authenticated Version

Before starting the installation process, close all currently running programs and turn off any virus checking software, if present on the hard disk. If you want to ensure that the program disk is free of any virus you may run the virus scanning software and check the program CD prior to starting installation.

This program requires Microsoft .NET Framework 4.0 or higher. If it is missing on your computer the installation program will request permission to install the Microsoft .NET Framework. After installing the .NET Framework and restarting the computer, start the setup program again and follow the screen instructions.

Insert the software CD into the CD-ROM drive. If *Autostart* is enabled on the CD-ROM drive, setup will start automatically. If not, from the Windows **Start** button choose **Run**.

Type the following in the resulting screen:

G:\setup and press Enter

Where G represents the drive letter for your CD-ROM drive.

Note that Windows Vista and Windows 7 require installing software with administrative privileges. Therefore, disable the automatic setup and run the "setup.exe" program from the CD-ROM as an Administrator.

Follow the subsequent screen instructions to continue with the installation process.

After the setup is completed, the **User Registration screen** will prompt you to enter your name, company name and the program serial number. ***The serial number found on the program CD container must be entered exactly.*** Otherwise the installation will be incomplete.

You must be connected to the Internet to register the program and obtain a license. Otherwise you will not be able to run the software after installation.

Once installation is completed, a program icon and program folder will be automatically created. You may launch the program from the Windows **Start** button. You may also create a shortcut to the program on your desktop.

2.3 Retaining/Releasing - Internet Authenticated Version

To launch the program, you will either use the Windows **Start** button or click the program icon from the Program menu. If the program is properly registered and the license obtained, you will be able to start the program.

When you quit the program, you will be prompted to either retain control or release control of the program in the event you want to use the current license on another computer. *This enables you to quit the program on your work computer, release control and restart the program on your home computer or on a laptop while traveling. However each time you quit the program you must release control if you want to run the program on another computer. Also, internet access is required to do this.*

Remember that once a program is registered and control is retained on the computer, the license can only be released from *that* computer. If you have multiple SYSTEK programs installed on your computer and you are using a CV version of the program, you can use the utility program called **SYSTEK Control Panel** to release or retain control of selected SYSTEK programs. This program `ControlPanel.exe` is located in the GPIPE folder. This does not apply to the new SV version of the program.

2.4 Installation on a Network

If you are licensed to use the program in a network environment, the software may be installed on multiple workstations on your network. The software can then be run from any workstation on the network, subject to the maximum user limit programmed during the installation process and in accordance with your license. **PLEASE REVIEW SEPARATE DOCUMENTATION ON LAN/WAN INSTALLATION SUPPLIED WITH PROGRAM.**

2.5 Uninstallation

To **uninstall** the software from the hard disk, go to the Windows **Start button** and choose **Settings**. Next select the **Control Panel** and click on **Add/Remove Programs**. Follow subsequent instruction to uninstall **GPIPE**. All pipeline models and gas properties database are located in `My Documents\GPIPE\` folder and maybe backed up for future use.

Put your original program disk away safely.

3

FEATURES

GPIPE is a powerful steady-state, single phase thermal hydraulic simulation program for gas pipelines with multiple compressor stations. Despite the complexity of the program it is very user-friendly. Online HELP is available for most data entry screens and the program has extensive error checking features.

GPIPE has the following significant features:

- Beginning with GPIPE Version 6.0 the pipeline model may be created graphically using a drag and drop approach. In this method, objects such as pipe segments, valves, compressor stations and other devices may be selected from a toolbox and dropped on a drawing canvas. These objects can be connected with pipe segments to form the pipeline system. The properties of each object may be defined by double-clicking on them and entering data in the screen that is displayed. See the section titled *Building pipeline model graphically* for details.
- Simulates hydraulics of a pipeline transporting gas, considering heat transfer between the gas and the surrounding medium. Gas may be injected or delivered at various points along the pipeline.
- The pipe diameter, wall thickness, absolute roughness and the surrounding soil temperatures can all be varied throughout the length of the pipeline. The maximum number of pipe nodes is limited to 200.
- The available pressure drop formulas include the General flow equation, AGA Turbulent, Colebrook-White, Panhandle A & B, Weymouth and IGT equations.
- The gas compressibility factor may be calculated using one of the three options: CNGA, Standing-Katz or AGA NX19 method.
- Several compressor stations (up to a maximum of 10) may be located along the pipeline. The maximum discharge pressure, minimum suction pressure and the adiabatic and mechanical compressor efficiency may be specified. The final delivery pressure at the end of the pipeline may be fixed and the corresponding discharge pressure at the last compressor station computed. Alternatively, the discharge pressure at the last compressor station may be fixed and the resulting pipeline delivery pressure calculated. Fuel

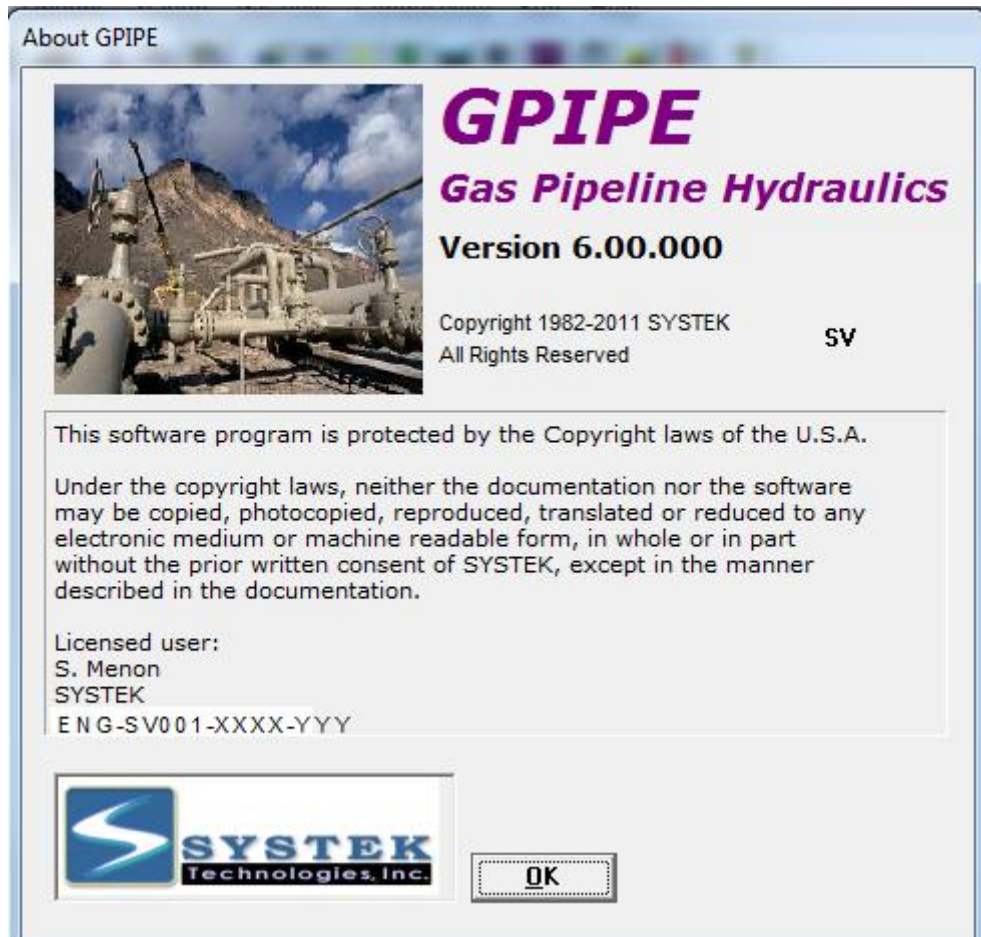
consumption at the compressor stations may be calculated, based on the power required.

- A compressor station must be specified at the beginning of the pipeline. If there is no compressor at the beginning of the pipeline, a hypothetical compressor station must be specified by entering identical values for suction pressure and discharge pressure at this compressor station. Also the suction and discharge piping losses must also be entered as zero so that the calculated results will show zero power requirements at the hypothetical compressor station. An example of such a situation may be where Pipeline-1 is connected to Pipeline-2 at some connection point A. The pressure at A will be the common suction and discharge pressures to be used for the hypothetical compressor station at the beginning of Pipeline-1.
- Pressure drop devices such as valves, fittings and regulators may be modeled. Either a fixed pressure drop may be specified or calculated using a head loss coefficient K. Standard values of K are included for commonly used valves and fittings.
- Heat transfer calculations may be based on a fixed value of the overall heat transfer coefficient or calculated from individual thermal conductivities of pipe, soil and insulation.
- The line pack volume in the various pipe segments can be calculated.
- The pressure drop in a given pipe segment may be quickly calculated using the Quick Pressure Drop Option. If the pipe size, length and gas properties are given, the inlet or outlet pressure in a pipe segment can be calculated for a specified flow rate. Alternatively, given the inlet and outlet pressures for a pipe segment, the flow rate possible may be calculated. This quick pressure drop calculation for a pipe segment is based on isothermal flow.
- Units of calculation may be English (U.S. Customary) units or SI - Metric units. Options are available for different sets of units for pipeline distance, flow rates, temperature and pressure. In English units, pipeline distances have to be in either *miles* or *feet*. Pipeline flow rates for English units may be in Billion SCFD (BSCFD), Million SCFD(MMSCFD), ft^3/hr etc. For SI-Metric units, distance options are *kilometers* or *meters* and flow rates may be in Million m^3/day (Mm^3/day), *Thousand m^3/hr (km^3/hour), etc.* All pressures are specified as gauge pressures. Thus in English units, pressures are entered in psig. In SI-Metric units, pressures may be specified as KiloPascal (kPa), MegaPascal (MPa), Bar or kg/cm^2

Running the Program

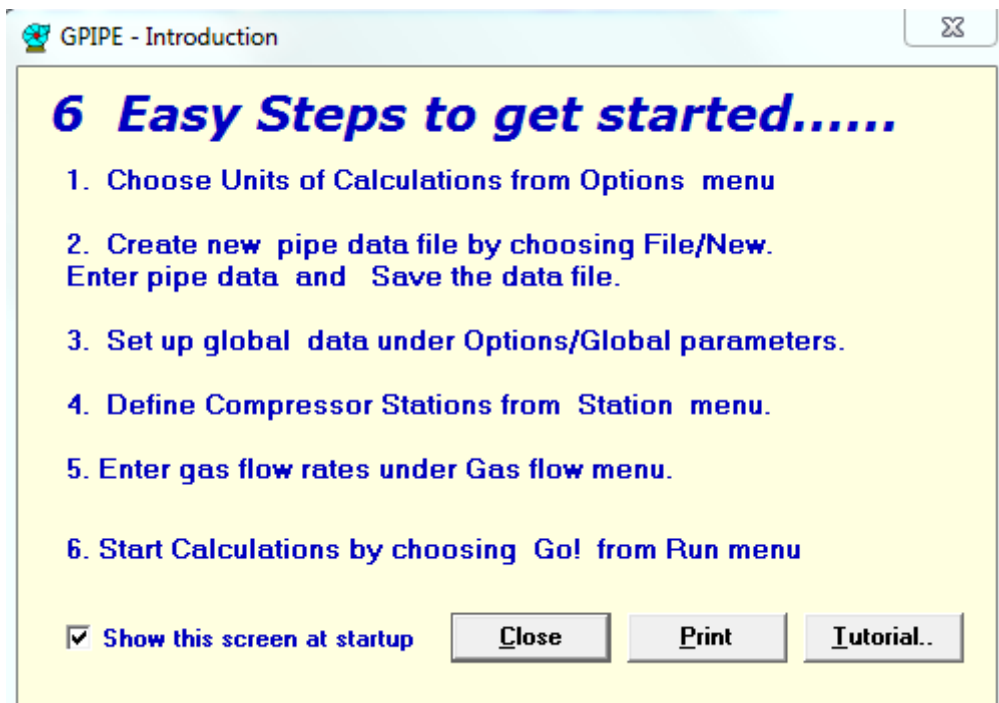
To run the program, click on the GPIPE icon or from the Windows Start button, click on the GPIPE program group.

The initial screen will be displayed as follows:



This screen shows the copyright screen, containing program version number and the licensed user information.

After the copyright screen, the Intro screen will be displayed. This shows the six easy steps to get started.



The menu bar along the top has several pull down options under each menu item, such as *File*, *Edit* etc. as explained below:

The pull down menu under **File** has the following :

- New** - To create a new pipeline data file.
- Open** - To open and edit an existing data file.
- Import.** - To import a previous (DAT) version of pipe data file.
- View** - To view the results of the last calculation.
- Save** - To save the current data file onto the disk drive under the current file name.
- Save As-** To save a data file under a new name.
- Close** - To close a data file.
- Print setup-** To setup the printer, such as orientation, etc.
- Print** - To print the spreadsheet data file or the last output file.
- Send email** - To send an email with attachment.
- Exit** - To quit the program

The pull down menu under **Edit** has the following :

- Cut** - To remove selected (highlighted) data from the spreadsheet to the Windows clipboard.
- Copy** - To copy selected (highlighted) data from the spreadsheet to the Windows clipboard.
- Paste** - To paste the data from Windows clipboard to the current cursor location in the spreadsheet.
- Insert row** - To insert a new line in the spreadsheet
- Delete row** - To delete a line in the spreadsheet.
- Format Spreadsheet** - To format individual cells in the spreadsheet.

The pull down menu under **Options** has the following :

Units - For selecting English or SI-Metric units of calculation. Also to specify the unit of measurement for the distance along the pipeline and the pipeline flow rate.

Global Parameters - For specifying the ratio of specific heats of gas (C_p/C_v), the maximum gas velocity in the pipeline, the pipeline efficiency, the base temperature and base pressure. Also you can choose the desired pressure drop formula such as AGA, Colebrook-White, etc. and Compressibility factor method. Available options for the compressibility factor are: CNGA, Standing-Katz or AGA NX19 method. In addition, you select Joule-Thompson cooling effect in the calculations, if desired. If Joule-Thompson cooling effect is considered, less conservative results (lower pressure drop for given flow rate due to cooler gas temperatures) will be obtained. Neglecting this cooling effect will cause higher pressure drops for a given flow rate.

Interpolate Elevation - To interpolate the elevation of pipeline at an intermediate mile post.

The pull down menu under **Station** has the following:

Compressor Station - This lets you specify the compressor station locations along the pipeline. The name, mile post location, compressor efficiencies and mechanical efficiencies. In addition discharge and suction pressures, maximum discharge temperature, and the suction and discharge piping losses are input in this screen. Only the suction pressure at the first compressor station is used by the program. The suction pressures at all other compressor stations are calculated for the specified discharge pressures and flow rates. At the end of the pipeline, if a particular delivery pressure is required, the discharge pressure of the last compressor station will be adjusted to provide the desired pipeline delivery pressure. To turn on this option, a check box is provided in the main pipeline spreadsheet. In addition to specifying the compressor station data, the fuel gas consumption for gas turbine driven compressors can also be calculated as an option by checking the box on the bottom left of this screen.

Valve and Regulator Station - This is used for specifying minor pressure drop devices. These include valves, fittings and other custom components such as meters and filters along the pipeline. The K-values needed for calculating the minor losses through valves and fittings are built into the program. You may also specify the actual pressure drop through a valve, fitting or custom device. In the latter case, the K-value is not used. To model a pressure regulator, you may indicate the pressure drop required at a specific milepost location where the regulator will be installed.

The menu item **Gas flow** is used for entering the gas flow rates (injection or delivery) along the pipeline, together with the gas gravity, viscosity and the gas inlet temperature. Incoming flows are entered as positive numbers and outflows or deliveries are entered as negative numbers. For each incoming flow (injection), you must enter data in all columns, such as specific gravity (relative to air = 1.00), viscosity and the inlet temperature. Outlet flows require only the flow rate column to be filled in. Also, there is no need to enter a negative flow at the last mile post, since GPIPE will automatically perform the algebraic addition and subtractions of all flows.

The menu item **Conductivity** is used for specifying the thermal conductivity and pipe insulation data for heat transfer calculations. The pipeline distance (from the beginning), cover (pipe burial depth), soil thermal conductivity, pipe thermal conductivity, insulation thermal conductivity, thickness of insulation, if any, and the temperature of the surrounding soil are input. If these values are constant along the pipeline, you may simply input two rows of data signifying the starting point and the end point of the pipeline.

Alternatively, an overall heat transfer coefficient can be specified for the entire pipeline. In this event all thermal conductivity data are ignored.

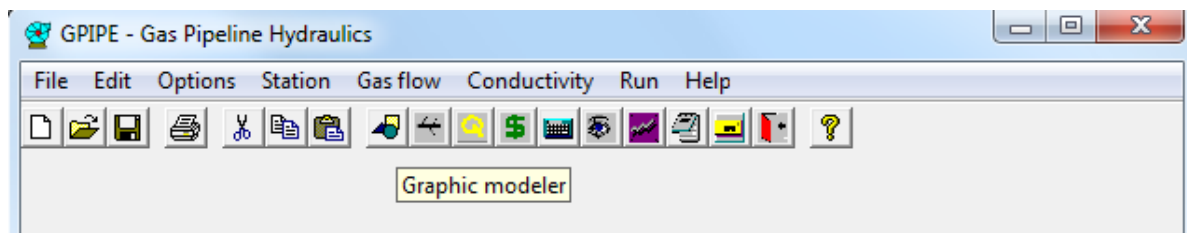
Running the Program

The pull down menu under **Run** has the following :

- Output Format** - For entering date, project title, case number, output file name and whether printer output is required.
- Go!** - This initiates calculation after confirming the basis of Calculations.

The menu item on the extreme right titled **HELP** provides information about the program, such as version number, user registration information and general help on the program.

A toolbar consisting of icons for commonly used menu items is available below the menu bar. These menu items or commands can be accessed by clicking on the icons. As the mouse is moved over an icon, a tool tip help appears explaining the function of each icon, as shown below:



Some toolbar icons are not active for GPIPE. These are features available in the larger commercial model GASMODO. Examples of these features include – Branches and Loops, Cost Calculations and Hydraulic Gradient.

The **Graphic modeler** icon shown above next to the **Paste** icon, is a new feature introduced in GPIPE Version 6.0. This is explained under the GPIPE Features section of the User Manual.

Running the Program

The toolbar icon designated as **Q** is used for quickly calculating the pressure drop in a pipe segment for *isothermal flow*.

Quick Pressure Drop

Project:

Pipe Data

Diameter: (in)
Wall thickness: (in)
Length: (mi)
Efficiency:
Roughness: (in)

Gas Properties

Gravity:
Viscosity: (lb/ft-sec)

Base Values

Base pressure: (psig)
Base temp.: (degF)

Flow rate: (MMSCFD)
Flow temp.: (degF)
Pressure in: (psig)
Pressure out: (psig)

Formula:
Line pack: (MMSCF)

Start calculations.

This is for quick calculation of isothermal pressure drop in a pipe segment. For a given flow rate, pipe diameter, pipe length, elevations, specific gravity and viscosity, the Quick Pressure Drop Option calculates the inlet or outlet pressure, given one of the two pressures. If the outlet pressure is specified, the inlet pressure is calculated and vice versa. Alternatively, given the inlet and outlet pressures for a pipe segment, the flow rate possible may be calculated. You may also choose the pressure drop formula (such as AGA turbulent, Colebrook-White etc.) to be used. To choose a particular method for compressibility factor, select Global Parameters under Options menu. Units of calculations may be changed by clicking the **Units...** button in screen above. Clicking the **More...** button displays additional results of calculation such as Velocities, Reynolds number, etc.

4

TUTORIAL

This section leads you through the program, using an illustrative example. See the **Reference** section for an explanation of the symbols and formulas used.

Sample Problem:

A 14-inch diameter, 100 mile long natural gas pipeline defined below is used to transport 150 MMSCFD of natural gas from Yale to the delivery terminus at Sheridan. There are two compressor stations located at Yale and Harvard, with electric motor driven centrifugal compressors. The pipeline is not insulated and the maximum pipeline temperature is limited to 140 degF. Determine the pipeline temperature and pressure profile and horsepower required at each compressor station.

The pipeline profile is defined below:

Distance (miles)	Elevation (ft)	Diameter (in)	Thickness (in)	Roughness (in)	MAOP (psig)	Location
0.0	100	14.00	.250	0.000700	1400	Yale
10.0	250	14.00	.250	0.000700	1400	
20.0	150	14.00	.250	0.000700	1400	Peoria
30.0	300	14.00	.250	0.000700	1400	
40.0	375	14.00	.250	0.000700	1400	
50.0	450	14.00	.250	0.000700	1400	Harvard
60.0	350	14.00	.250	0.000700	1400	
70.0	280	14.00	.250	0.000700	1400	Lewis
80.0	560	14.00	.250	0.000700	1400	
95.0	365	14.00	.250	0.000700	1400	
100.0	300	14.00	.250	0.000700	1400	Sheridan

A flow rate of 150 MMSCFD enters the pipeline at Yale (mile post: 0.0) and at an intermediate location named Peoria (mile post: 20.0), a delivery of 20 MMSCFD is made. The resulting flow then continues to the end of the pipeline.

Sample Problem

The compressor stations are as follows:

Location	Distance miles	Suct Press psig	Disch Press psig	Disch Temp degF	Compr Effy %	Mech Effy %	Suct Loss psig	Disch Loss psig	Fuel Factor MCFD/HP
Yale	0.00	800	1200	140	80	98	5.0	10.0	0.200
Harvard	50.00	800	1200	140	80	98	5.0	10.0	0.200

Pipeline delivery pressure : 600 psig
 Minimum pressure : 200 psig

Gas specific heat ratio : 1.30
 Maximum Gas velocity : 60.0 ft/sec
 Pipeline efficiency : 1.00
 Base temperature : 60.0 degF
 Base pressure : 14.70 psia.
 Pressure drop formula : Colebrook-White
 Compressibility factor : CNGA

Gas specific gravity(air = 1.00) : 0.600
 Viscosity : 0.0000080 lb/ft-sec
 Inlet temperature : 80.0 degF

Pipe burial depth (cover) : 36.00 inches
 Soil thermal conductivity : 0.800 Btu/hr/ft/degF
 Pipe thermal conductivity : 29.0 Btu/hr/ft/degF
 Insulation thermal conductivity : 0.200 Btu/hr/ft/degF
 Pipe is un-insulated
 Soil temperature : 80 degF

Some of the default data may not be the same as the above example. Check all input data to match the sample problem above before running the case.

Solution

After setting up the software as described in the **Getting Started** section, start **GPIPE** by double clicking on its icon.

In the main program window, choose **File/Open** to open an existing file. From the resulting screen, choose the name of the pipe data file. As a convention, pipe data files are designated with a file name extension of `.TOT`. Thus a pipeline data file may be `MYPIPE.TOT`. In previous versions of GPIPE, pipeline data files were designated with a `.DAT` file extension.

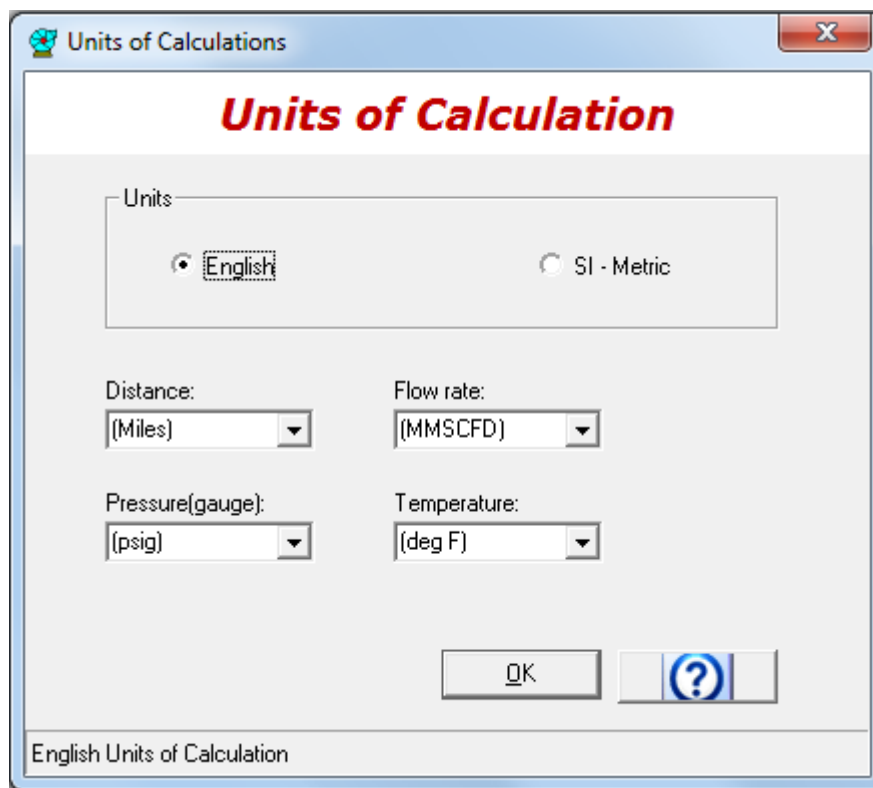
Choose `MyPipe001` from the list of pipe files. The sample pipeline data file opens up in a spreadsheet. This screen displays the pipeline information (distance, elevation, etc.) required for the sample problem. Also displayed below the spreadsheet are Pipe delivery pressure, Minimum pressure and a check box for choosing “Holding delivery pressure” option.

To save changes, Select **File /Save** from the menu bar or click on the Toolbar icon.

For further explanation on creating data files, see the section, **Creating a Data File**, later on in this manual.

To create a new data file, choose **File/New**. A blank spreadsheet will be presented for inputting the data. Enter the pipeline data similar to the sample problem.

To proceed with the sample problem, choose the pull down menu item **Options** followed by **Units** and the following screen is displayed:

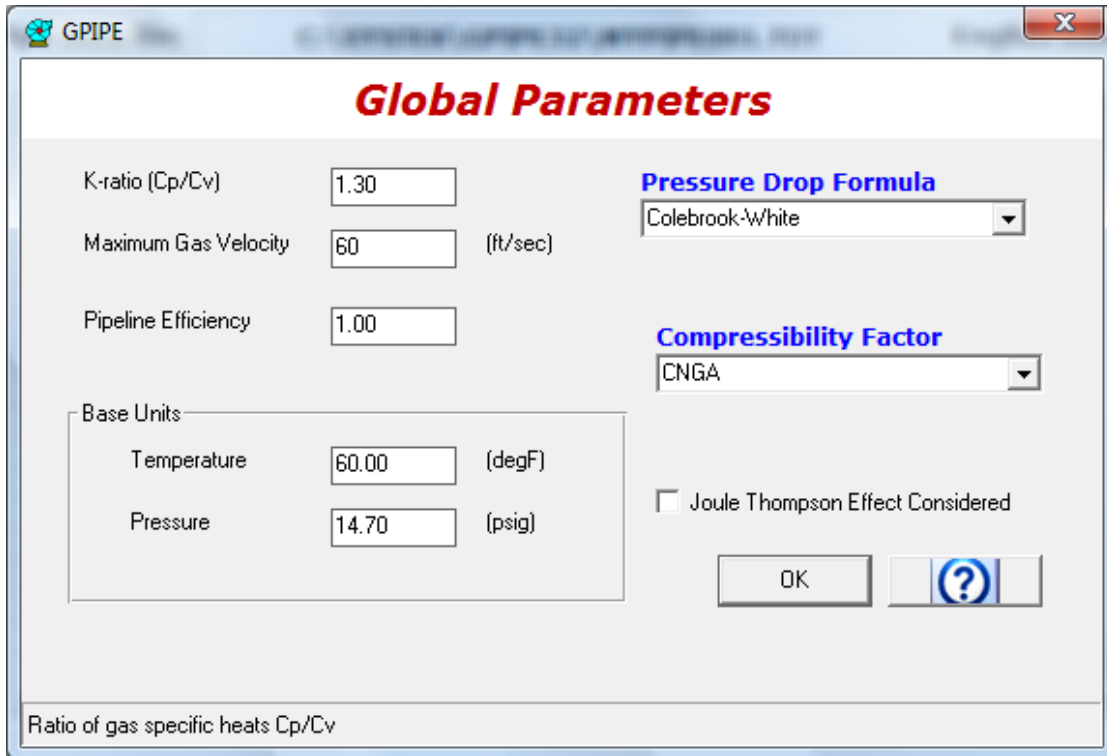


This screen is used to choose English or SI-Metric units of calculation. Options are available for different sets of units for pipeline distance, flow rates, temperature and pressure.

In English units, pipeline distances have to be in either *miles* or *feet*. Pipeline flow rates for English units can be in Billion SCFD (BSCFD), Million SCFD(MMSCFD), ft^3/hr etc. For SI-Metric units, distance options are *kilometers* or *meters* and flow rates may be in Million m^3/day (Mm^3/day), *Thousand m^3/hr* (km^3/hour), etc.

Choose English units of calculations for the sample problem. Also choose *miles* for units of distance, MMSCFD for the flow rate units, psig for pressure and the degF for temperature.

Next, choose **Options** followed by **Global Parameters** on the menu bar and the following screen is displayed

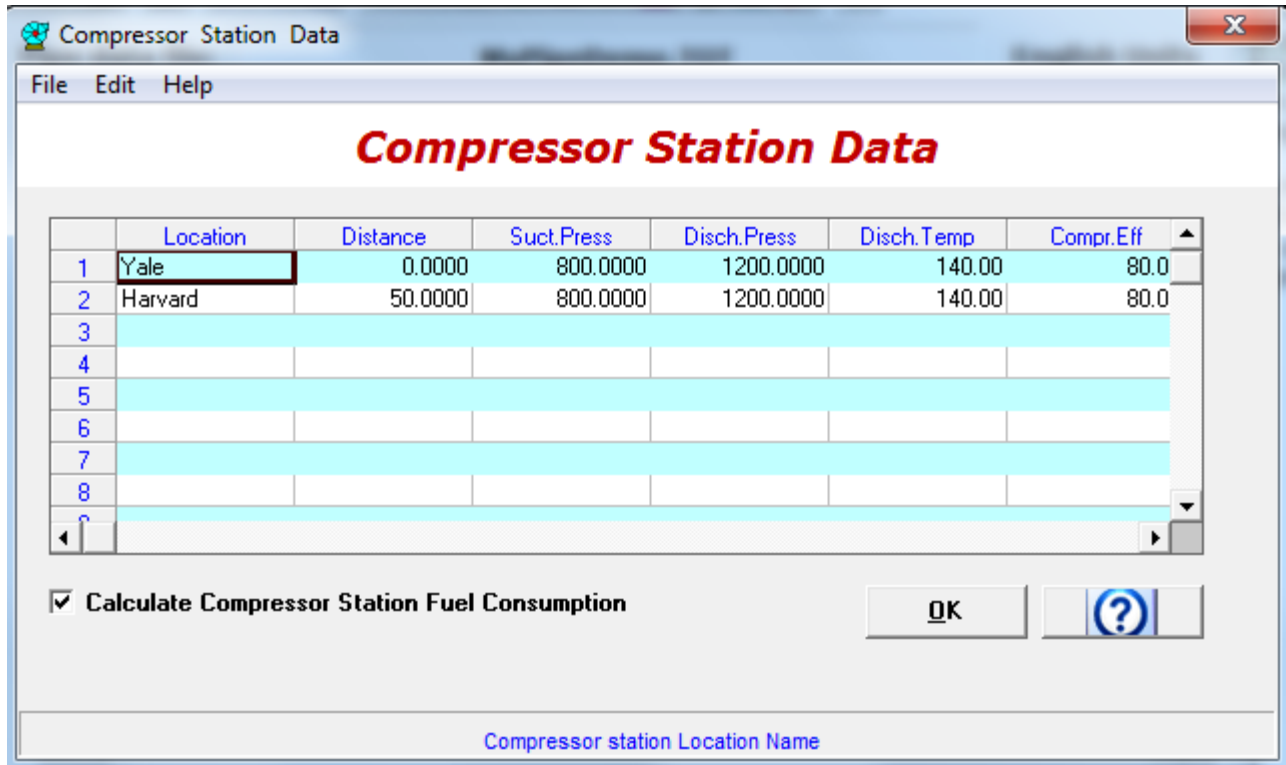


Choose Colebrook-White equation for pressure drop formula.

Complete the remaining data entry for the sample problem - **K-ratio**, **Gas velocity**, **Pipeline Efficiency** etc.

Default values are provided for most data entry fields. Correct these as required to match the sample problem.

The pull down menu under **Stations** is used for entering compressor station and valve and regulator data. Click on the **Compressor station** and the following screen is displayed..



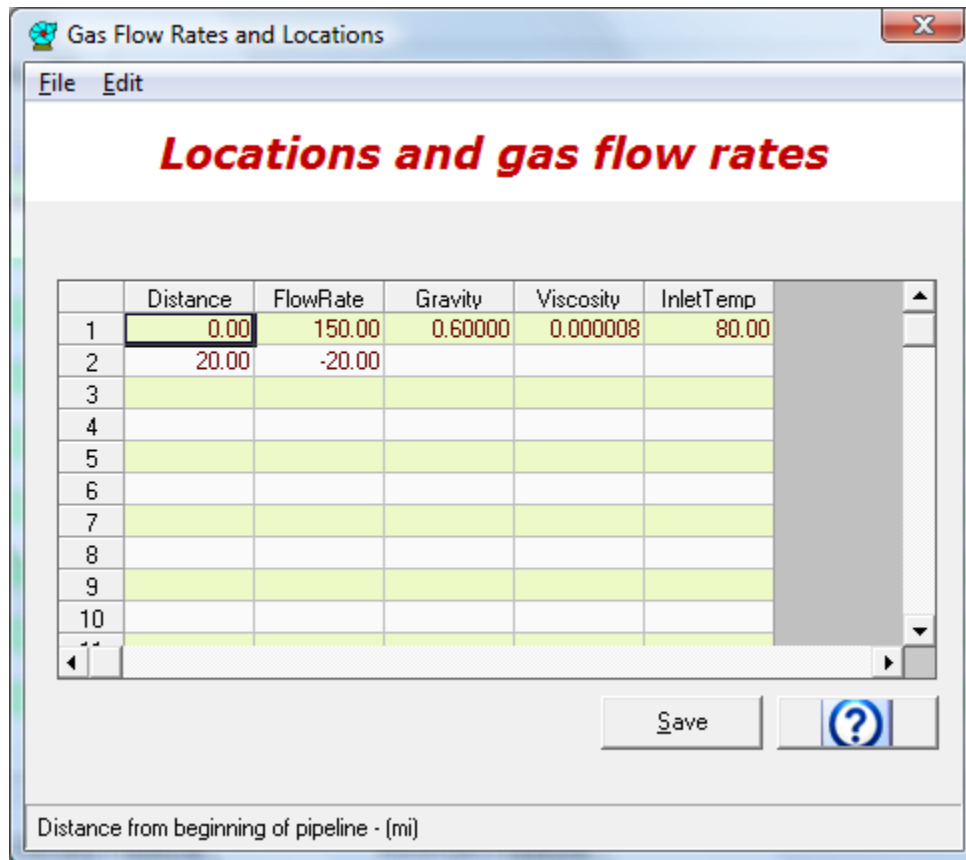
The name, distance, suction pressure, discharge pressure, compressor efficiency, mechanical efficiency and suction and discharge piping losses are input in this screen. The suction pressure and discharge pressure in this screen are actually the pipeline suction pressure and discharge pressure at the specified compressor station. The actual compressor station suction pressure will be calculated by deducting the suction piping loss specified above. Similarly, compressor station discharge pressure will be calculated by adding the discharge piping loss to the station discharge pressure.

Thus in the above screen, the compressor station suction pressure will be $800 - 5$ or 795 psig and the compressor station discharge pressure will be $1200 + 10 = 1210$ psig considering a suction piping loss of 5 psi and discharge piping loss of 10 psi.

Also, if fuel consumption is to be included, enter the fuel factor. The latter is a number representing the gas consumption per compressor power. In English Units, this is approximately 0.200 MCFD/HP (thousand standard ft³/HP). In SI-Metric units, the fuel factor is approximately 7.59 m³/day per KW. You may input zero for the fuel factor if you want to ignore fuel consumption at a particular compressor station, such as the hypothetical compressor station at the beginning of the pipeline.

Note: The *overall* compressor efficiency is the product of the compressor adiabatic efficiency and the mechanical efficiency. Thus, for an adiabatic efficiency of 85% and a mechanical efficiency of 98%, the overall efficiency is $0.85 \times 0.98 = 83.3\%$. This overall efficiency is used in the compressor HP calculations.

The menu item **Gas flow** is used for entering flow rates, gas properties and their locations.

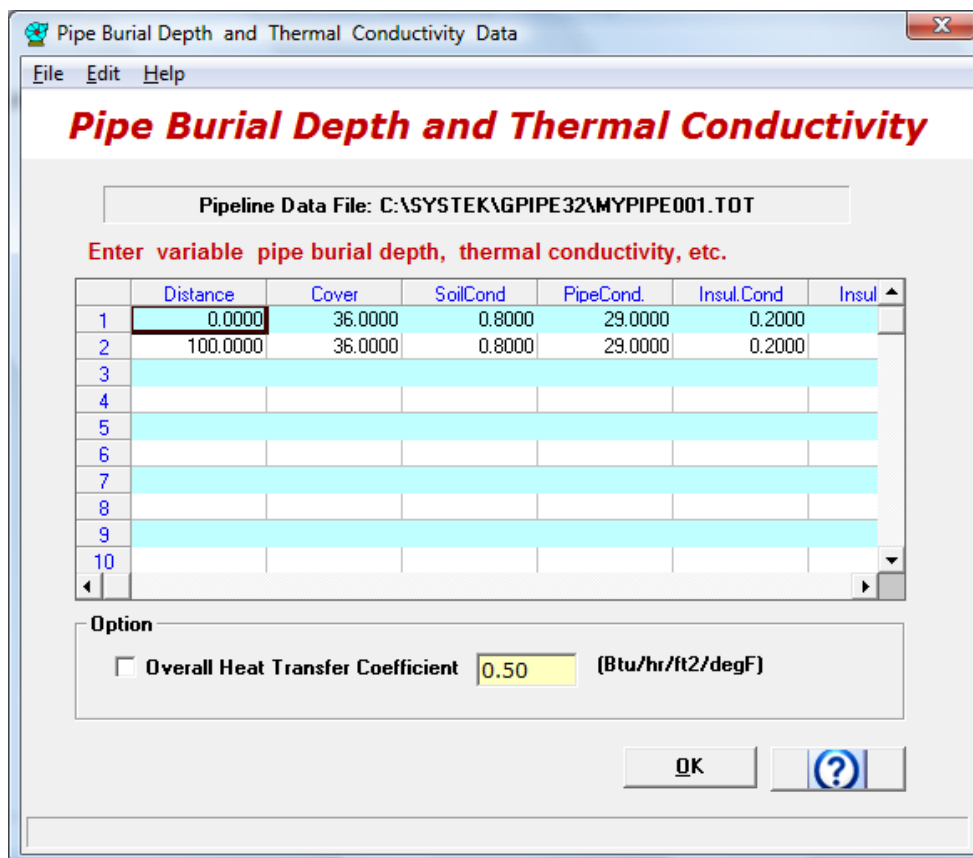


At the beginning of the pipeline, where the gas enters the pipeline, the value input for flow rate is a positive number, such as 150 MMSCFD for the sample problem. If there is a delivery at a particular point on the pipeline (such as at Peoria, mile post 20.0 in the sample problem), the flow rate in this column will have a *negative* value (e.g. -20 MMSCFD), indicating *outflow* or *delivery*.

Gas specific gravity (Air = 1.00) and viscosity (lb/ft-sec in English units) are entered in the next columns. As explained above, flow out of the pipeline (delivery) is indicated with a *negative* value, while flow into the pipeline (injection), as in the beginning of the pipeline, is entered as a *positive* number. At locations where flow is out of the pipeline (negative), do not enter the specific gravity and viscosity. For flow into the pipeline (injection), gravity and viscosity *must be input*. If not specified, the program will warn you that the specific gravity and viscosity are invalid values (zeros). In the last column, input the gas inlet flow temperature for all incoming flows.

The menu item **Conductivity** is used for specifying the thermal conductivity and pipe insulation data for heat transfer calculations. The pipeline distance (from the beginning), cover (pipe burial depth), soil thermal conductivity, pipe thermal conductivity, insulation thermal conductivity, thickness of insulation, if any, and the temperature of the surrounding soil are input. If these values are constant along the pipeline, you may simply input two rows of data signifying the starting point and the end point of the pipeline.

Alternatively, an overall heat transfer coefficient can be specified for the entire pipeline. In this event all thermal conductivity data are ignored.



Next, from the pull-down menu **Run**, choose **Output format**. In the resulting dialog box shown below, enter the date, project title and case number.

Output Report Format

Date: 13-November-2007

Project : 14-inch Pipeline from Yale to Sheridan
100 miles long
with two compressor stations at Yale and Harvard
150 MMSCFD inlet flow rate

Case number: 1001 English Units

Pipe input data file: C:\SYSTEMK\GPIPE32\MYPIPE001.TOT

Output file: C:\SYSTEMK\GPIPE32\MYPIPE001.OUT

OK ?

Project title

The project title may be a maximum of 4 lines. Press the **Tab** key to move from each line to the next to enter the additional lines for the project title. Notice that the pipe data file name and the corresponding output file names are shown as MyPipe001.TOT and MyPipe001.OUT respectively. If the input pipe data file were XYZPipeline.tot, the corresponding results of calculation will be stored in a file named XYZPipeline.out.

Click the **OK** button after entering all data.

Finally, choose **Go!** from the **Run** menu or click on the **Run** icon. You are presented with a screen containing the basis of calculations for a final review as shown:

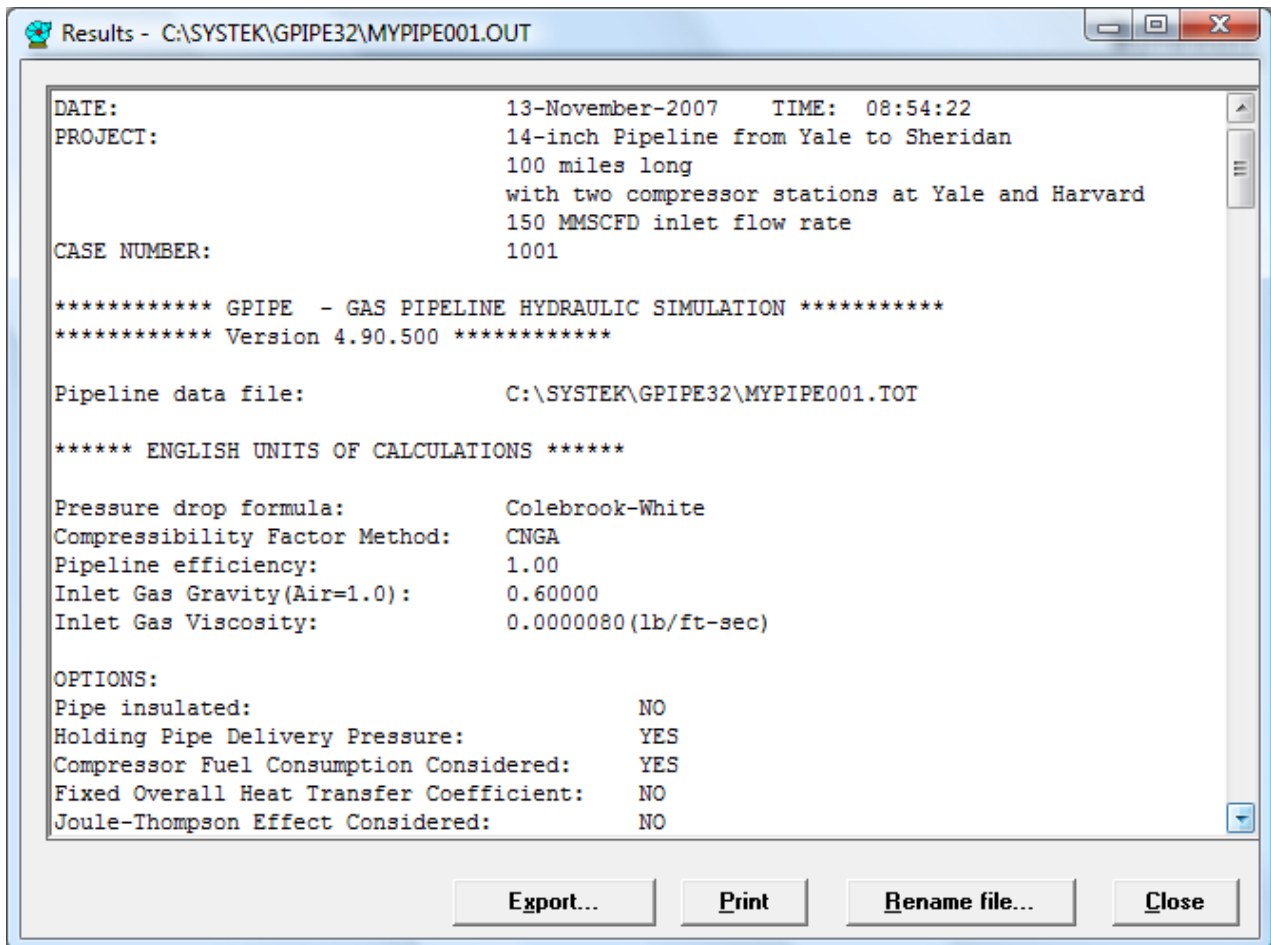
The screenshot shows a window titled "CALCULATE" with a sub-header "Basis of Calculation". The window contains the following fields and options:

- Project Title:**
 - 14-inch Pipeline from Yale to Sheridan
 - 100 miles long
 - with two compressor stations at Yale and Harvard
 - 150 MMSCFD inlet flow rate
- Units:**
 - Distance: (mi)
 - Flow rate: (MMSCFD)
 - Pressure: (psig)
 - Temperature: (degF)
- Start Calculations based on: English Units**
- Input File name:** C:\SYSTEK\GPIPE32\MYPIPE001.TOT
- Output File name:** C:\SYSTEK\GPIPE32\MYPIPE001.OUT
- Pressure Drop Formula:** Colebrook-White
- Compressibility Factor method:** CNGA
- Joule Thompson Effect ignored**
- Holding pipe delivery pressure**
- Buttons:** OK, Cancel, and a help icon (?)

At the bottom of the window, there is a status bar that reads "Project title - first line".

If any of the above information is incorrect, press **Cancel** and proceed to the appropriate menu item to correct the input data before re-starting calculations. If all information above is correct, press **OK** to initiate calculations.

After a pause, varying from 20 seconds to five minutes depending on the computer, the results of the calculation are displayed on the screen in a scrollable window as shown below:



```
Results - C:\SYSTEK\GPIPE32\MYPIPE001.OUT
DATE:                13-November-2007    TIME: 08:54:22
PROJECT:             14-inch Pipeline from Yale to Sheridan
                   100 miles long
                   with two compressor stations at Yale and Harvard
                   150 MMSCFD inlet flow rate
CASE NUMBER:        1001

***** GPIPE - GAS PIPELINE HYDRAULIC SIMULATION *****
***** Version 4.90.500 *****

Pipeline data file:  C:\SYSTEK\GPIPE32\MYPIPE001.TOT

***** ENGLISH UNITS OF CALCULATIONS *****

Pressure drop formula:      Colebrook-White
Compressibility Factor Method:  CNGA
Pipeline efficiency:       1.00
Inlet Gas Gravity(Air=1.0):  0.60000
Inlet Gas Viscosity:       0.0000080 (lb/ft-sec)

OPTIONS:
Pipe insulated:           NO
Holding Pipe Delivery Pressure:  YES
Compressor Fuel Consumption Considered:  YES
Fixed Overall Heat Transfer Coefficient:  NO
Joule-Thompson Effect Considered:  NO

Export...  Print  Rename file...  Close
```

The calculated results are also saved on disk with the default file name of **MyPipe001.out**. After viewing the results of the calculations on the screen, click the **Print** button to print the results. You may also export the results to the Windows Notepad or rename the output file.

The calculated results are included at the end of this manual under the heading **Sample Output**.

File Format for Pipe Data File

The sample data file used with GPIPE is named `MyPipe001.TOT` and is pulled up in a spreadsheet format when you use the pull down menu **File/Open** to open the specified data file. The format of the file as it shows up on the spreadsheet is self-explanatory. The pipe filename extension is TOT and is automatically appended by the program.

Creating a pipe data file:

Since the pipeline data file is the most important data that is needed for running GPIPE, it is appropriate to describe the creation and editing of the data file.

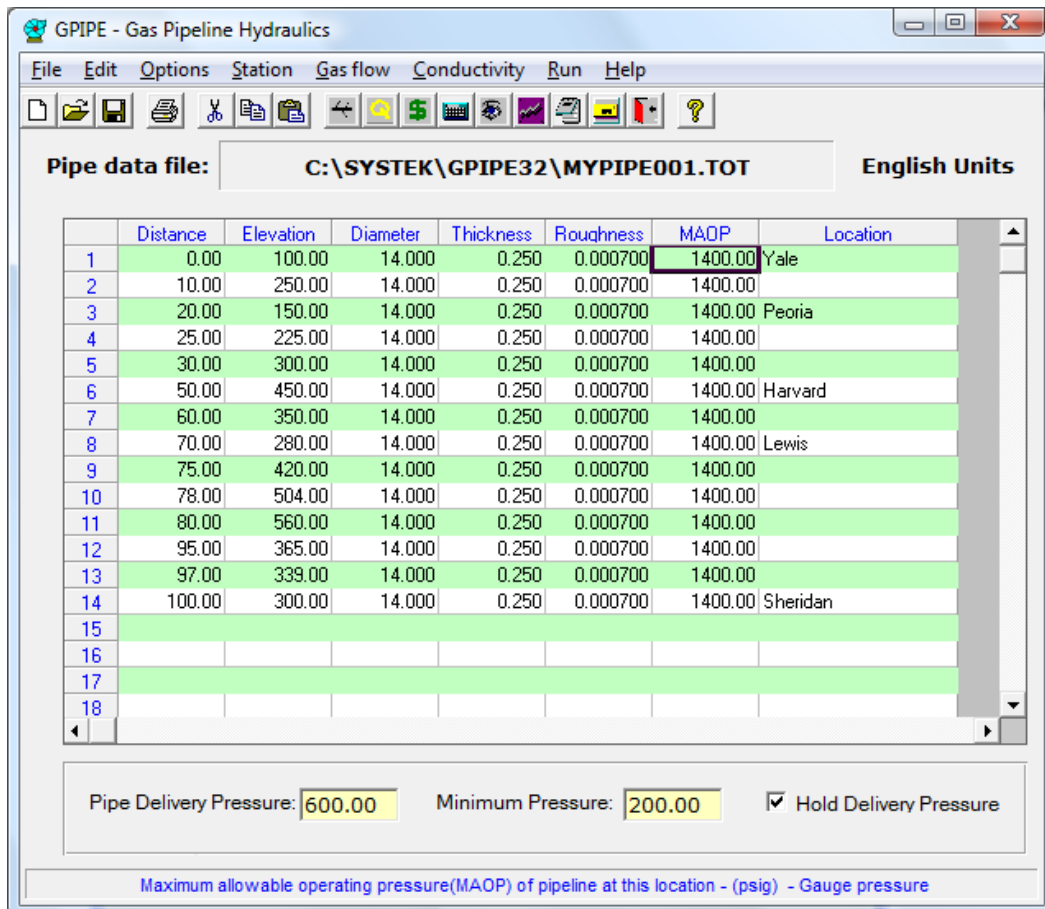
The pipeline information is created in a spreadsheet format and stored in a data file for future use.

The pipeline data file can be given any valid 255 character filename such as `MyGasPipeline.TOT`. The calculated results are automatically saved under the same name, except the file extension is OUT. Thus, if the input pipe data file is named `MyGasPipeline.TOT` then the results of the calculations are stored in the file `MyGasPipeline.OUT` in the same sub-directory. The data file is created in a spreadsheet style editor. When saved to disk, the format is a special ASCII text format.

DO NOT edit this file using a text editor or Word Processor. To edit the input data file, use only the GPIPE spreadsheet editor described here.

Note: A maximum of 200 points are allowed in the pipe data file.

The screen shot below shows the spreadsheet editor with the MyPipe001.TOT information already typed in. Initially the title above the spreadsheet will be Untitled.TOT, but once data is entered and the file saved, the name of the subdirectory and data file are shown on the title panel just above the spreadsheet.



Each column in the spreadsheet is for a specific data for the pipeline. Each row represents a specific location along the pipeline. As the cursor (arrow) keys are moved around in the spreadsheet cells, the status bar at the bottom of the screen briefly describes the information to be entered in each cell. After each numeric entry, move to the next cell by using the arrow keys. The first column is for the distance measured from the origin of the pipeline, such as *mile post*. Each subsequent location of the pipeline is measured from the beginning of the pipeline and hence the first column is the cumulative length of each point on the pipeline measured from the beginning, also designated as mile post location (m.p.).

Note that unlike other hydraulic simulation models, the distances are cumulative and not pipe segment lengths.

The second column is for the elevation of the pipe at that mile post location, measured above some datum, such as sea level.

The third and fourth columns represent the pipe *outside* diameter and pipe wall thickness at this location. The pipe diameter and wall thickness entered at a specific milepost location represent those for the pipe segment *downstream* of that milepost location. Thus, if the first two milepost locations are 0.0 and 48.0, the diameter and wall thickness entered at 0.0 milepost are for the pipe segment from 0.0 to the 48.0 location. The diameter and wall thickness entered at milepost 48.0 are for the *next* pipe segment starting at milepost 48.0. Accordingly, for the very last milepost location (the last data row of the spreadsheet), the diameter and wall thickness entered should be a duplicate of the immediately previous location, since there is no pipe segment downstream of the last milepost.

The fifth column is for the absolute roughness of the pipe interior. For new steel pipe, a roughness value of 0.0007 inches (700 micro-inches) is used. If the pipe is internally coated, a lower value such as 200-300 micro-inches is used.

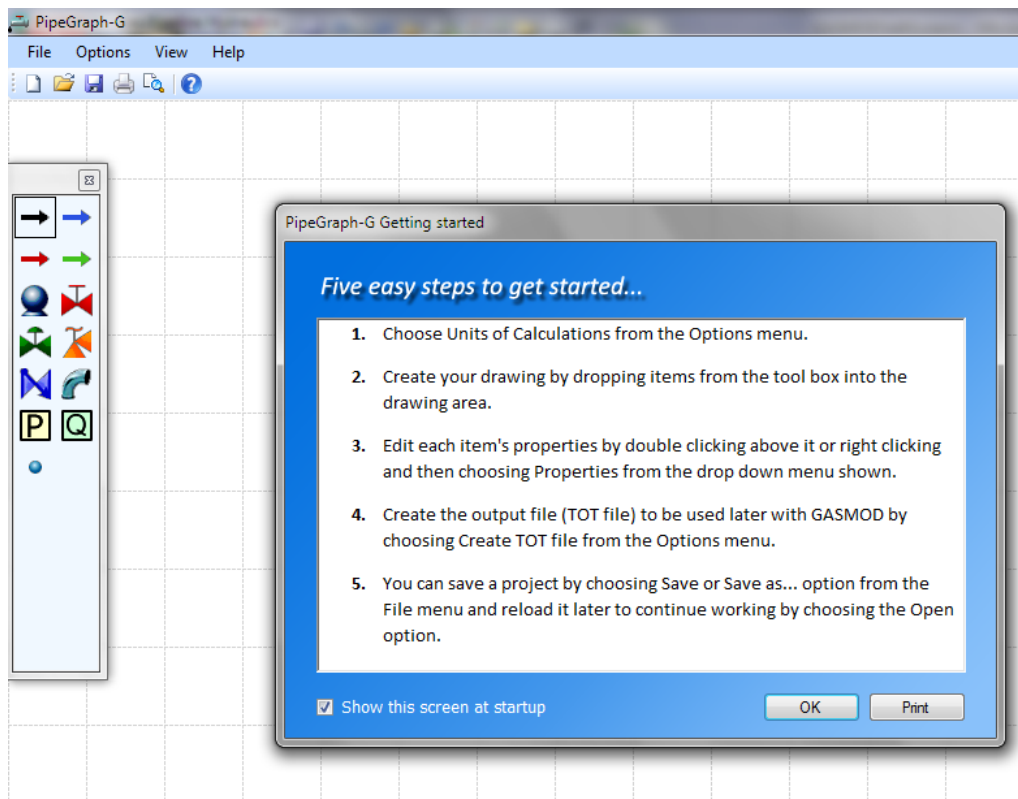
The next column entry is the Maximum Allowable Operating Pressure (MAOP) for the pipe at that milepost location and the final column is for the name of the location.

Also displayed below the spreadsheet are Pipe delivery pressure, Minimum pressure and a check box for choosing "Hold Delivery Pressure" option. If the latter option is selected, calculations will be performed to ensure that the specified pipe delivery pressure at the end of the pipeline is attained. Otherwise, the delivery pressure will be calculated by holding the compressor station discharge pressure at the last compressor station.

Building pipeline model graphically

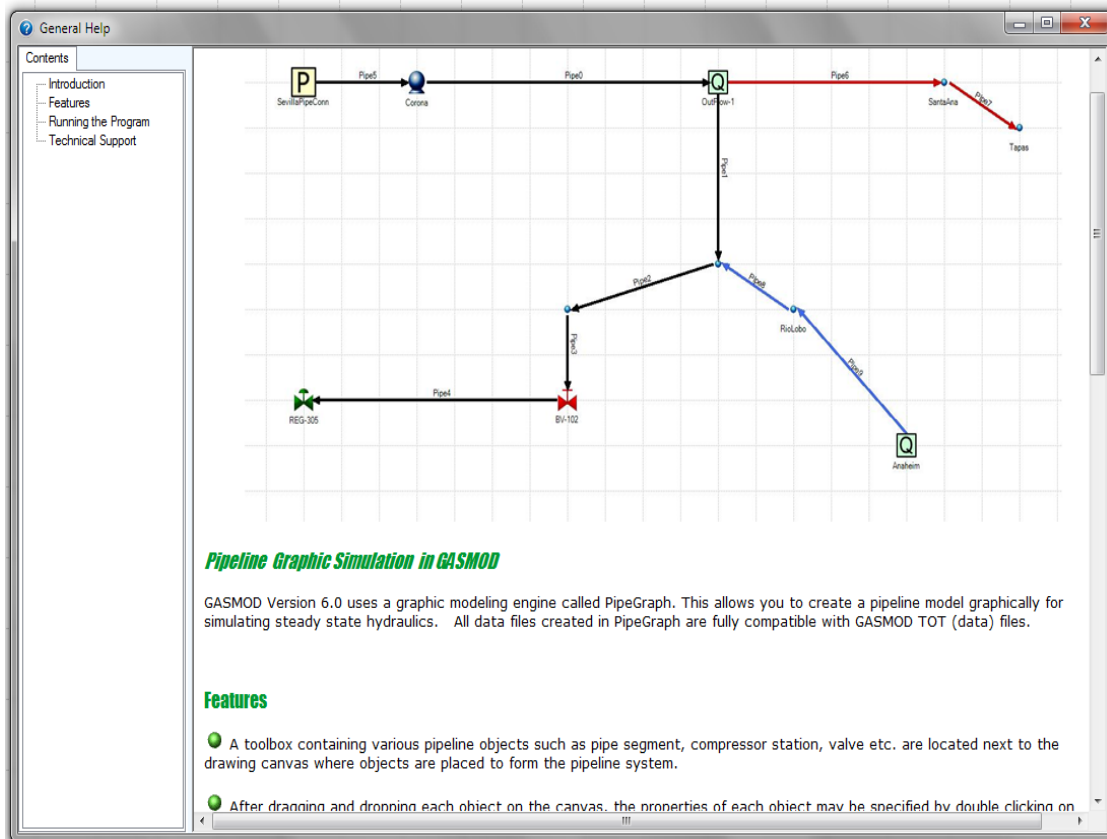
The pipeline model may be created graphically using a drag and drop approach, via a Graphic model builder known as **PipeGraph-G**. In this method, objects such as pipe segments, valves, compressor stations and other devices may be selected from a toolbox and dropped on a drawing area. These objects can be connected with pipe segments to form the pipeline system. The properties of each object may be defined by double-clicking on them and entering data in the screen that is displayed. A video tutorial is available at SYSTEK's website that explains how the pipeline model can be created graphically. Once the graphic model is created, the GPIPE input file is automatically created.

Upon choosing the **Graphic modeler** option, from the icon menu, the **PipeGraph-G** screen is displayed as below:



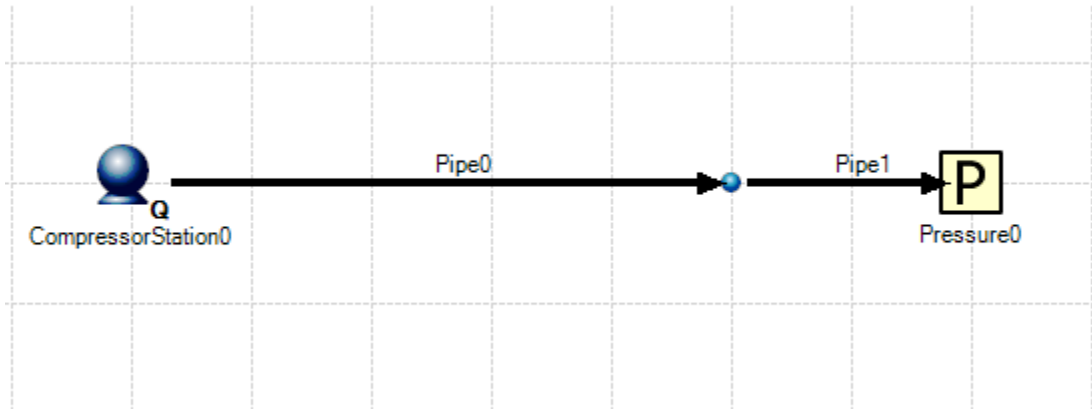
*Note that the **PipeGraph-G** was mainly designed to work in conjunction with the **GASMOD** program. Hence many of the features of **PipeGraph-G** will not work with **GPIPE**. These include branch pipes, loops and origin pressure and a few other features.*

The Help menu displays a General Help screen explaining the features of **PipeGraph-G** as shown below:



Create the pipeline by choosing objects from the toolbox on the left and dropping them on the canvas or drawing area as shown.

In the example shown, a pipeline consists of two pipe segments (Pipe0 and Pipe1), a compressor station object (CompressorStation0) at the origin and a terminus pressure object Pressure0. Since there must be a gas flow at the inlet of the pipeline, a flow object (Q) is dropped on the compressor object. This results in the Compressor icon having a small Q object at its bottom right hand corner.



Compressor station data:

Double-clicking the compressor object displays the properties screen for entering data on the compressor station as well as the gas flow rate as shown.

Compressor Station Properties

Name: CompressorStation0 Driver: 5000.00 Status: ON

Compr Effy (%)	Mech Effy (%)	SuctPress (psig)	DischPress (psig)	SuctLoss (psig)	DischLoss (psig)	MaxTemp (degF)	FuelFactor (MCF/day/HP)
80	98	800	1200	5	10	140	0.2

Flow Rate Properties

Flow Rate (MMSCFD)	Temperature (degF)	Product Name
100	60	GULFCOAST

Calculate Compressor Fuel Consumption Save

Pipe segment data:

Similarly, double-clicking the pipe object Pipe0 displays the properties for entering data on the pipe segment as shown.

The screenshot shows the PipeGraph-G interface with a pipeline diagram and a properties dialog. The pipeline consists of a compressor station (CompressorStation0) connected to two pipe segments (Pipe0 and Pipe1) which terminate at a pressure object (Pressure0). The properties dialog for Pipe0 is open, showing the following data:

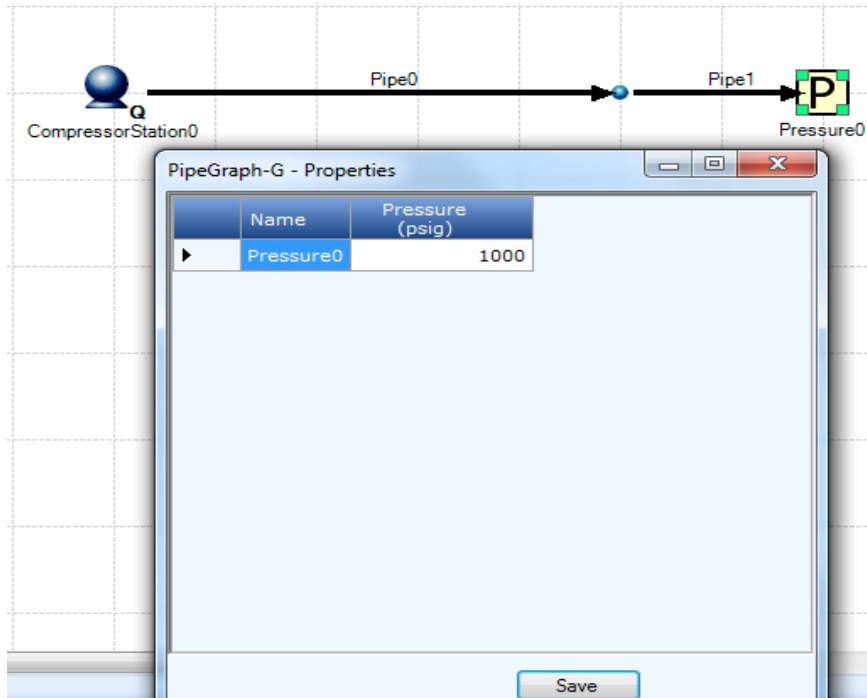
Name	Length (mi)	Diameter (in)	Wall Thk (in)	Roughness (in)	MAOP (psig)	ElevUp (ft)	ElevDown (ft)
Pipe0	2	16	0.25	0.0007	1400	100	100

Similarly, the properties of the remaining pipe segment, and the pressure object Pressure0 at the end of the pipeline are specified by double-clicking each object and entering the properties as indicated in the subsequent screens.

The screenshot shows the PipeGraph-G interface with the pipeline diagram and the properties dialog for Pipe1. The properties dialog for Pipe1 is open, showing the following data:

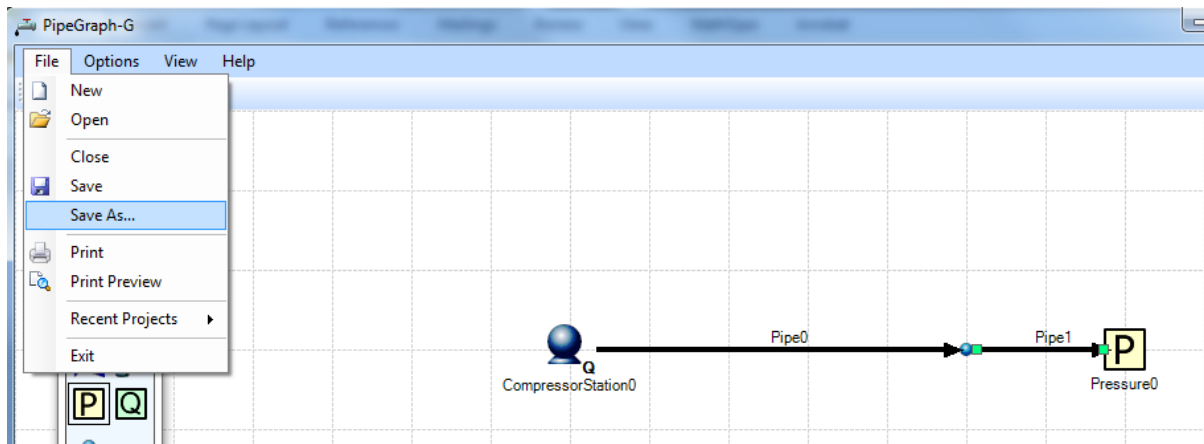
Name	Length (mi)	Diameter (in)	Wall Thk (in)	Roughness (in)	MAOP (psig)	ElevUp (ft)	ElevDown (ft)
Pipe1	2	16	0.25	0.0007	1400	100	125

Terminus Pressure data:

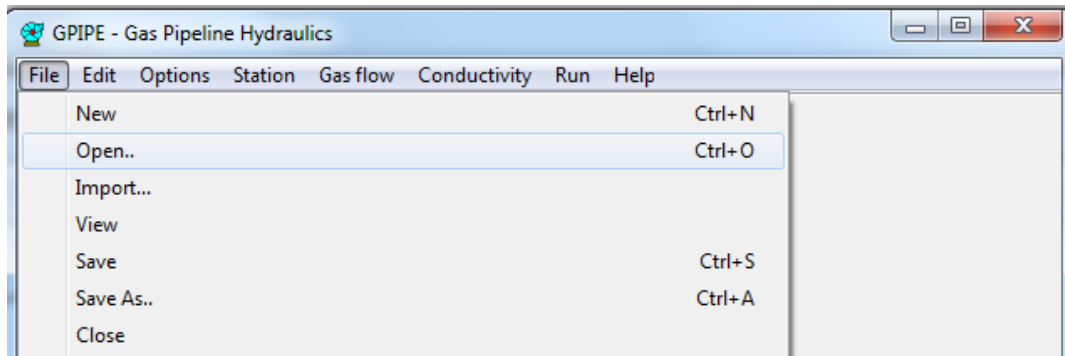


After entering all properties, the project file may be saved by choosing **File| Save As** option. Project files created have a file extension of .plproj. A TOT file for use with GPIPE is automatically created in the right format.

*Note that the default folder for saving the graphic pipeline file (.plproj) and the TOT file is automatically set to \My Documents\GASMOD folder since **PipeGraph-G** was designed to work in conjunction with GASMOD program. When running GPIPE you must change the save folder to \My Documents\GPIPE since all GPIPE models should be located in this folder.*



Quitting **PipeGraph-G** will revert to the GPIPE screen. You may then open the TOT file that **PipeGraph-G** created using the **File| Open** dialog box for choosing the TOT file as shown below



5

REFERENCE

This section provides an explanation of formulas and variable names used.

Formulas

Reynold's number of flow:

$$R = C5 (P_b / T_b) (GQ / (\mu D))$$

Laminar Flow:

Friction factor

$$f = 64/R \quad \text{for} \quad R \leq 2000$$

Average Pressure:

$$P_{avg} = (2/3) (P_1 + P_2 - P_1 P_2 / (P_1 + P_2))$$

Elevation Adjustment:

$$s = C6 G(E_1 - E_2) / (T_f Z)$$

$$\Delta P_{sq} = (P_1^2 - P_2^2 - s P_{avg}^2)$$

Pressure Drop Equations

General Flow Equation:

$$Q = C1 (F)(T_b / P_b) (\Delta P_{sq} / (G T_f L Z))^{0.5} D^{2.5}$$

AGA Equation for Transmission Factor:

Fully Turbulent

$$F = 4 \text{ Log}(3.7D/e)$$

Partially Turbulent

$$F = 4 D_f \text{ Log}[R/(1.4125 F_t)]$$

$$F_t = 4 \text{ Log}(R/ F_t) - 0.6$$

Colebrook-White Equation for Friction Factor:

Friction factor

$$1/f^{1/2} = -2 \text{ Log} [(e/3.7D) + 2.51/(R f^{1/2})]$$

for Turbulent flow $R > 2000$

Darcy friction factor and Transmission factor:

$$f = 4/F^2$$

$$F = 2/f^{1/2}$$

Panhandle-A:

$$Q = C7 (E)(T_b / P_b)^{1.0788} (\Delta P_{sq} / (G^{0.8539} T_f L Z))^{0.5392} D^{2.6182}$$

Panhandle B:

$$Q = C8 (E)(T_b / P_b)^{1.02} (\Delta P_{sq} / (G^{0.961} T_f L Z))^{0.51} D^{2.53}$$

Weymouth:

$$Q = C9 (E)(T_b / P_b) ((P_1^2 - P_2^2) / (G T_f L Z))^{0.5} D^{2.667}$$

Compressibility Factor

The compressibility factor varies with the Gas composition of temperature and pressure. GPIPE calculates the compressibility factor using one of the following three methods:

1. Standing-Katz Method
2. CNGA Method
3. AGA NX19 Method

1. The Standing-Katz Method is based on charts published in the Transactions of AIME, 146, 144 in January 1941.

2. CNGA Method is based on the following equation:

$$Z = 1 / [1 + (P_{avg} C_2 (10)^{C_4 G}) / T_f^{C_3}]^2$$

for $P_{avg} > 100$

$$Z = 1.00 \quad \text{for } P_{avg} \leq 100$$

3. AGA NX19 method uses the approach outlined in AGA-IGT, Report No. 10. This correlation is valid for temperatures between 30 degF and 120 degF and for pressures up to 1,380 psig. It produces an error of less than 0.03 percent in this range of temperatures and pressures. Beyond this range the discrepancy can be up to 0.07 percent.

For details of other methods of compressibility calculations refer to American Gas Association publication Report No. 8, Second Edition, November 1992.

E_T	$= E_a * E_m$
γ	$= C_p/C_v$
Head	$= C_{11} * T_{s1} * Z_{avg} * (M^{s_{ratio}} - 1) / (s_{ratio} * G)$
Hpow	$= W_{flow} * Head / (C_{10} * E_T)$
M	$= P_{dischc} / P_{suctc}$
Pdischc	$= P_{disch} + DischLoss$
Psuctc	$= P_{suct} - SuctLoss$
Qact	$= C_{12} * Q * Z_{avg} * T_{s1} / P_{stmp}$
sratio	$= (\gamma - 1) / \gamma$
Ts1	$= T_{suct} + 460$
Tfinal	$= T_{s1} * (1 + (M^{s_{ratio}} - 1) * 100.0 / E_a)$
Vel	$= 0.75 * Q / (24 * D^2 P)$
Wflow	$= G * P_b * Q / (10 * C_{11} * T_b * Z_b)$

Symbols used

The following symbols are used in the equations below:

C1 through C12 - Constants as follows:

C1 = 38.774	C2 = 344,400	C3 = 3.825
C4 = 1.785	C5 = 0.0004778	C6 = 0.0375
C7 = 435.87	C8 = 737.0	C9 = 433.5
C10 = 330.0	C11 = 53.35	C12 = 19.631

D - Pipe inside diameter, inches

D_f - Pipe drag factor, dimensionless

DischLoss - Discharge piping loss, psi

E_a - Compressor adiabatic efficiency, %

E_T - Overall compressor efficiency, %

E_m - Compressor mechanical efficiency, %

E - Pipeline efficiency, decimal value less than 1.00

E_1, E_2 - Upstream & Downstream pipe elevations, ft

e - Absolute pipe roughness, inches

F - Transmission factor, dimensionless

F_t - Intermediate transmission factor, dimensionless

f - Darcy friction factor, dimensionless

G - Gas gravity (Air = 1.00)

μ - Gas viscosity, lb/ft-sec

γ - Specific heat ratio of gas

Head - Compressor adiabatic head, ft

H_{pow} - Compressor horsepower

L	- Pipe segment length, miles
Log	- Logarithm to base 10
M	- Compression ratio, dimensionless
P	- Pressure at any location, psia
P _{avg}	- Average pressure of segment, psia
P _{base}	- Base pressure, psia.
Press1, Press2	- Pressure at two locations, psia.
P _{suct} , P _{disch}	- Pipeline suction and discharge pressures, psia.
P _{suctc} , P _{dischc}	- Compressor suction and discharge pressures, psia.
P ₁	- Upstream Pressure, psia.
P ₂	- Downstream Pressure, psia.
P _b	- Base pressure, psia.
P _{avg}	- Average pipe pressure, psia.
ΔP _{sq}	- Pressure drop, psia squared
Q	- Gas flow rate - std ft ³ /day (SCFD)
R	- Reynold's number, dimensionless.
s	- Elevation adjustment factor
s _{ratio}	- Factor that depends on ratio of specific heats, γ
SuctLoss	- Suction piping loss, psi
T	- Temperature, degR
T _b	- Base temperature, degR
T _f	- Average gas flow temperature, degR
T _{final}	- Compressor discharge temperature, degR
T _{s1}	- Suction temperature, degR
T _{suct}	- Suction temperature, degF
Vel	- Flow velocity, ft/sec
W _{flow}	- Mass flow rate of gas, lb/min
Z, Z _{avg} , Z _b	- Gas compressibility factor, dimensionless

6

Troubleshooting

GPIPE is a powerful hydraulic simulation program for gas pipelines under thermal flow. Despite the complexity of the program it is very user friendly. Online HELP is available for most data entry screens and the program has extensive error checking features. However, there is always a possibility that some extraneous or invalid data was entered and the program may hang up. In such cases, try quitting the program by using the **File/Exit** menu item or click on the **Exit** icon on the toolbar. If this does not work, you have no choice but to shut down GPIPE by going to the Windows Task Manager using CTRL-ALT-DEL keys.

Error Messages:

The following are some errors that you may encounter while running GPIPE

Divide by zero error

This is generally due to some data input value that is zero. Check all input data for zero values. The compressor efficiencies, gas gravity and viscosity are usually suspect.

Illegal Function call

This is generally due to some illegal mathematical operation such as trying to extract the square root of a negative value. Ensure that there are no inadmissible negative values, such as a negative value for viscosity or gas specific gravity.

File not found

A common error when a file specified cannot be located on the hard disk or does not exist. When specifying pipe data files, make sure the file is present in the sub-directory or folder containing GPIPE. Otherwise, ensure that the file name is typed in correctly, including the full path.

7

Technical Support:

Please read the Troubleshooting section of this manual before you call us for technical support.

Free Technical Support is provided for registered users of this software for a period of one year from the initial purchase date. If the software is leased, free technical support is provided for sixty (60) days from the start of lease period. *After that period, Technical Support can be provided only if an annual software maintenance and support plan has been purchased. Contact SYSTEK for details*

In order to facilitate quick response, please have your disk serial number and program version available when you call us.

How to contact us:

You may contact SYSTEK in any of the following ways:

Phone/Fax: (928) 453-9587

E-mail: support@systek.us

Web site: www.systek.us

Consulting Services:

If you would like SYSTEK to perform consulting work, such as pipeline feasibility studies, hydraulic analysis, surge or transient studies, please contact us at the above address.

We can also put together the first pipeline model using your pipeline data in GPIPE at a very reasonable fee. This will save you considerable time, if you find yourself short of time or do not have the staff to perform the work.

Sample Output

1. Sample Problem

A 14-inch diameter, 100 mile long natural gas pipeline defined below is used to transport 150 MMSCFD of natural gas from Yale to the delivery terminus at Sheridan. There are two compressor stations located at Yale and Harvard, with electric motor driven centrifugal compressors. The pipeline is not insulated and the maximum pipeline temperature is limited to 140 degF. Determine the pipeline temperature and pressure profile and horsepower required at each compressor station.

A flow rate of 150 MMSCFD enters the pipeline at Yale (mile post: 0.0) and at an intermediate location named Peoria (mile post: 20.0), a delivery of 20 MMSCFD is made. The resulting flow then continues to the end of the pipeline.

The compressor stations are as follows:

Location	Distance miles	Suct Press psig	Disch Press psig	Disch Temp degF	Compr Effy %	Mech Effy %	Suct Loss psig	Disch Loss psig	Fuel Factor MSCFD/HP
Yale	0.00	800	1200	140	80	98	5.0	10.0	0.200
Harvard	50.00	800	1200	140	80	98	5.0	10.0	0.200

Pipeline delivery pressure : 600 psig.
Minimum pressure : 200 psig.

Gas specific heat ratio : 1.30
Maximum Gas velocity : 60.0 ft/sec
Pipeline efficiency : 1.00
Base temperature : 60.0 degF
Base pressure : 14.70 psia.
Pressure drop formula : Colebrook-White
Compressibility Factor Method : CNGA
Gas specific gravity(air = 1.00) : 0.600
Viscosity : 0.0000080 lb/ft-sec
Inlet temperature : 80.0 degF

Pipe burial depth (cover) : 36.00 inches
Soil thermal conductivity : 0.800 Btu/hr/ft/degF
Pipe thermal conductivity : 29.0 Btu/hr/ft/degF
Insulation thermal conductivity : 0.200 Btu/hr/ft/degF
Pipe is uninsulated
Soil temperature : 80 degF

The pipeline profile is as described in the Tutorial section.

DATE: 5-June-2011 TIME: 13:08:36

PROJECT: 14-inch Pipeline from Yale to Sheridan
100 miles long
with two compressor stations at Yale and Harvard
150 MMSCFD inlet flow rate

CASE NUMBER: 1001

***** GPIPE - GAS PIPELINE HYDRAULIC SIMULATION *****
***** Version 6.00.100 *****

Pipeline data file: \My Documents\GPipe\MyPipe001.TOT

***** ENGLISH UNITS OF CALCULATIONS *****

Pressure drop formula: Colebrook-White
Compressibility Factor Method: CNGA
Pipeline efficiency: 1.00
Inlet Gas Gravity(Air=1.0): 0.60000
Inlet Gas Viscosity: 0.0000080 (lb/ft-sec)

OPTIONS:

Pipe insulated: NO
Holding Pipe Delivery Pressure: YES
Compressor Fuel Consumption Considered: YES
Fixed Overall Heat Transfer Coefficient: NO
Joule-Thompson Effect Considered: NO
Valves and Fittings Considered: NO
Custom Pressure Drop Devices Considered: NO

Origin suction temperature: 80.00 (degF)
Base temperature: 60.00 (degF)
Base pressure: 14.700 (psig)
Origin suction pressure: 800.00 (psig)
Delivery pressure: 600.38 (psig)
Minimum pressure: 200.00 (psig)
Gas specific heat ratio: 1.3
Maximum gas velocity: 60.00 (ft/sec)

Inlet Flow rate: 150.0000 (MMSCFD)
Outlet Flow rate: 128.7174 (MMSCFD)

***** PIPELINE PROFILE DATA *****

Distance (mi)	Elevation (ft)	Diameter (in)	Thickness (in)	Roughness (in)
0.00	100.00	14.000	0.250	0.000700
10.00	250.00	14.000	0.250	0.000700
20.00	150.00	14.000	0.250	0.000700
30.00	300.00	14.000	0.250	0.000700
40.00	375.00	14.000	0.250	0.000700
50.00	450.00	14.000	0.250	0.000700
60.00	350.00	14.000	0.250	0.000700
70.00	280.00	14.000	0.250	0.000700
80.00	560.00	14.000	0.250	0.000700
95.00	365.00	14.000	0.250	0.000700
100.00	300.00	14.000	0.250	0.000700

***** THERMAL CONDUCTIVITY AND INSULATION DATA *****

Distance (mi)	Cover (in)	Thermal Conductivity (Btu/hr/ft/degF)			Insul.Thk (in)	Soil Temp (degF)
		Pipe	Soil	Insulation		
0.000	36.00	29.000	0.800	0.200	0.000	80.0
100.000	36.00	29.000	0.800	0.200	0.000	80.0

***** COMPRESSOR STATION DATA *****

FLOW RATES, PRESSURES AND TEMPERATURES:

Name	Flow Rate (MMSCFD)	Suct. Press. (psig)	Disch. Press. (psig)	Compr. Ratio	Suct. Loss. (psig)	Disch. Loss. (psig)	Suct. Temp. (degF)	Disch. Temp (degF)	MaxPipe Temp (degF)
Yale	149.31	795.00	1210.00	1.5125	5.00	10.00	80.00	147.63	140.00
Harvard	128.72	713.39	1084.63	1.5099	5.00	10.00	80.31	147.68	140.00

NOTE: The Suction and Discharge pressures shown above are at the compressor suction and discharge. The Pipeline Suction and Discharge pressures will be adjusted by compressor station suction and discharge piping losses.

***** COMPRESSOR EFFICIENCY, HP AND FUEL USED *****

Name	Distance (mi)	Compr Effy. (%)	Mech. Effy. (%)	Overall Effy. (%)	Horse Power	Fuel Factor (MCFD/HP)	Fuel Used (MMSCFD)
Yale	0.00	80.00	98.00	78.40	3,433.58	0.2000	0.6867
Harvard	50.00	80.00	98.00	78.40	2,979.67	0.2000	0.5959

Total Compressor Station Horsepower: 6,413.25

Total Fuel consumption: 1.2826(MMSCFD)

***** LOCATIONS AND FLOW RATES *****

Location	Distance (mi)	Flow in/out (MMSCFD)	Gravity	Pressure (psig)	Gas Temp. (degF)
Yale	0.00	150.0000	0.6000	1200.00	140.00
Peoria	20.00	-20.0000	0.0000	1000.09	89.33
Sheridan	100.00	-128.7174	0.6000	600.38	80.22

***** REYNOLD'S NUMBER HEAT TRANSFER COEFFICIENT AND COMPRESSIBILITY FACTOR *****

Distance (mi)	Reynold's Num.	FrictFactor (Darcy)	Transmission Factor	HeatTransferCoeff (Btu/hr/ft2/degF)	CompressibilityFactor(Z) (CNGA)
0.000	11,204,097.	0.0111	18.98	0.5457	0.8881
10.000	11,204,097.	0.0111	18.98	0.5457	0.8810
20.000	9,703,315.	0.0111	18.94	0.5454	0.8833
30.000	9,703,315.	0.0111	18.94	0.5454	0.8904
40.000	9,703,315.	0.0111	18.94	0.5454	0.9007

50.000	9,656,293.	0.0111	18.94	0.5454	0.8967
60.000	9,656,293.	0.0111	18.94	0.5454	0.8885
70.000	9,656,293.	0.0111	18.94	0.5454	0.8922
80.000	9,656,293.	0.0111	18.94	0.5454	0.9043
95.000	9,656,293.	0.0111	18.94	0.5454	0.9171
100.000	9,656,293.	0.0111	18.94	0.5454	0.9171

***** PIPELINE TEMPERATURE AND PRESSURE PROFILE *****

Distance (mi)	Diameter (in)	Flow (MMSCFD)	Velocity (ft/sec)	Press. (psig)	Gas Temp. (degF)	Soil Temp. (degF)	MAOP (psig)	Location
0.00	14.000	149.3133	21.08	1200.00	140.00	80.00	1400.00	Yale
10.00	14.000	149.3133	22.99	1098.88	104.27	80.00	1400.00	
20.00	14.000	129.3133	21.85	1000.09	89.33	80.00	1400.00	Peoria
30.00	14.000	129.3133	23.86	914.53	83.02	80.00	1400.00	
40.00	14.000	129.3133	26.48	822.49	80.97	80.00	1400.00	
50.00	14.000	129.3133	30.11	718.39	80.31	80.00	1400.00	Harvard
50.00	14.000	128.7174	20.26	1074.63	140.00	80.00	1400.00	Harvard
60.00	14.000	128.7174	21.84	996.05	100.92	80.00	1400.00	
70.00	14.000	128.7174	23.75	914.54	86.86	80.00	1400.00	Lewis
80.00	14.000	128.7174	26.49	818.41	82.20	80.00	1400.00	
95.00	14.000	128.7174	32.60	662.34	80.39	80.00	1400.00	
100.00	14.000	128.7174	35.88	600.38	80.22	80.00	1400.00	Sheridan

***** LINE PACK VOLUMES AND PRESSURES *****

Distance (mi)	Pressure (psig)	Line Pack (million std.cu.ft)
0.00	1200.00	0.0000
10.00	1098.88	4.3696
20.00	1000.09	4.1093
30.00	914.53	3.7749
40.00	822.49	3.4115
50.00	718.39	3.0018
60.00	996.05	3.2242
70.00	914.54	3.7276
80.00	818.41	3.3922
95.00	662.34	4.3225
100.00	600.38	1.2122

Total line pack in main pipeline = 34.5459(million std.cu.ft)

2. Sample Problem in SI Units

A 600 mm outside diameter, 10 mm wall thickness pipeline is 205 km long and runs from Canterbury to Kent. Natural gas (0.6 specific gravity and 0.000119 poise viscosity) at 20 Million m³/day enters the pipeline at Canterbury with an intermediate delivery of 5 Mm³/day at Bath (km 100) followed by an injection of 10 Mm³/day (0.58 specific gravity and 0.000119 poise viscosity) at Leeds (km 172). There are four compressor stations located as follows: Canterbury (km 0.0), Salisbury (km 50.0), Cornwall (km 105.0) and York (km 160.0). All stations have gas turbine driven centrifugal compressors. The pipeline inlet pressure at Canterbury is 6,000 kPa and the pipeline discharge pressure is limited to 9,000 kPa at all stations. The suction and discharge piping losses are assumed to be 30 kPa and 60 kPa respectively. The pipeline is not insulated and the maximum pipeline temperature is limited to 60 deg C. Determine the pipeline temperature and pressure profile and kW required at each compressor station for a pipeline delivery pressure of 5,000 kPa at Kent. Consider compressor fuel consumption of 7.59 m³/day/kW at each station. Pipe MAOP is 10 MPa.

Minimum pressure	: 3000 kPa
Gas specific heat ratio	: 1.29
Maximum Gas velocity	: 15.00(m/sec)
Pipeline efficiency	: 0.95
Base temperature	: 15.56 degC
Base pressure	: 100.0 kPa
Pressure drop formula	: Colebrook-White
Compressibility Factor Method	: Standing-Katz
Inlet temperature	: 25.0 degC
Pipe burial depth (cover)	: 915.0 mm
Soil thermal conductivity	: 1.04 Watts/m/degC
Pipe thermal conductivity	: 50.0 Watts/m/degC
Pipe is uninsulated	
Soil temperature	: 20 degC

DATE: 5-June-2011 TIME: 13:34:24
 PROJECT: Pipeline from Canterbury to Kent
 600 mm dia. 205 km long
 Inlet flow 20 Mm3/day
 CASE NUMBER: 1001

***** GPIPE - GAS PIPELINE HYDRAULIC SIMULATION *****
 ***** Version 6.00.100 *****

Pipeline data file: \My Documents\GPipe\AnSIPipeline2.TOT

***** SI UNITS OF CALCULATIONS *****

Pressure drop formula: Colebrook-White
 Compressibility Factor Method: Standing-Katz
 Pipeline efficiency: 0.95
 Inlet Gas Gravity(Air=1.0): 0.60000
 Inlet Gas Viscosity: 0.0001190 (poise)

OPTIONS:
 Pipe insulated: NO
 Holding Pipe Delivery Pressure: YES
 Compressor Fuel Consumption Considered: YES
 Fixed Overall Heat Transfer Coefficient: NO
 Joule-Thompson Effect Considered: NO
 Valves and Fittings Considered: NO
 Custom Pressure Drop Devices Considered: NO

Origin suction temperature: 25.00 (degC)
 Base temperature: 15.56 (degC)
 Base pressure: 100.000 (kPa)
 Origin suction pressure: 6000.00 (kPa)
 Delivery pressure: 4997.73 (kPa)
 Minimum pressure: 3000.00 (kPa)
 Gas specific heat ratio: 1.29
 Maximum gas velocity: 15.00 (m/sec)

Inlet Flow rate: 20.0000 (Mm3/day)
 Outlet Flow rate: 24.6484 (Mm3/day)

***** PIPELINE PROFILE DATA *****

Distance (km)	Elevation (meters)	Diameter (mm)	Thickness (mm)	Roughness (mm)
0.00	250.00	600.000	10.000	0.017800
5.00	250.00	600.000	10.000	0.017800
10.00	250.00	600.000	10.000	0.017800
15.00	250.00	600.000	10.000	0.017800
25.00	250.00	600.000	10.000	0.017800
30.00	250.00	600.000	10.000	0.017800
50.00	250.00	600.000	10.000	0.017800
60.00	250.00	600.000	10.000	0.017800
75.00	250.00	600.000	10.000	0.017800
80.00	250.00	600.000	10.000	0.017800
90.00	250.00	600.000	10.000	0.017800
95.00	250.00	600.000	10.000	0.017800
100.00	250.00	600.000	10.000	0.017800
105.00	250.00	600.000	10.000	0.017800
120.00	250.00	600.000	10.000	0.017800
130.00	250.00	600.000	10.000	0.017800
140.00	250.00	600.000	10.000	0.017800

156.00	250.00	600.000	10.000	0.017800
160.00	250.00	600.000	10.000	0.017800
168.00	250.00	600.000	10.000	0.017800
172.00	250.00	600.000	10.000	0.017800
180.00	250.00	600.000	10.000	0.017800
184.00	250.00	600.000	10.000	0.017800
190.00	250.00	600.000	10.000	0.017800
196.00	250.00	600.000	10.000	0.017800
200.00	250.00	600.000	10.000	0.017800
205.00	250.00	600.000	10.000	0.017800

***** THERMAL CONDUCTIVITY AND INSULATION DATA *****

Distance (km)	Cover (mm)	Thermal Conductivity (Watts/m/degC)			Insul.Thk (mm)	Soil Temp (degC)
		Pipe	Soil	Insulation		
0.000	915.00	50.000	1.040	0.280	0.000	20.0
205.000	915.00	50.000	1.040	0.280	0.000	20.0

***** COMPRESSOR STATION DATA *****

FLOW RATES, PRESSURES AND TEMPERATURES:

Name	Flow Rate (Mm3/day)	Suct. Press. (kPa)	Disch. Press. (kPa)	Compr. Ratio	Suct. Loss. (kPa)	Disch. Loss. (kPa)	Suct. Temp. (degC)	Disch. Temp (degC)	MaxPipe Temp (degC)
Canterbury	19.91	5970.00	9060.00	1.5091	30.00	60.00	25.00	61.14	60.00
Salisbury	19.79	5319.72	9060.00	1.6901	30.00	60.00	43.31	92.87	60.00
Cornwall	14.69	5112.13	9060.00	1.7574	30.00	60.00	41.54	94.73	60.00
York	14.65	7062.93	9214.09	1.3003	30.00	60.00	37.68	62.36	60.00

NOTE: The Suction and Discharge pressures shown above are at the compressor suction and discharge. The Pipeline Suction and Discharge pressures will be adjusted by compressor station suction and discharge piping losses.

***** COMPRESSOR EFFICIENCY, POWER AND FUEL USED *****

Name	Distance (km)	Compr Effy. (%)	Mech. Effy. (%)	Overall Effy. (%)	Power KWatts	Fuel Factor (m3/day/KW)	Fuel Used (Mm3/day)
Canterbury	0.00	80.00	98.00	78.40	11,507.94	7.5900	0.0873
Salisbury	50.00	80.00	98.00	78.40	16,286.46	7.5900	0.1236
Cornwall	105.00	80.00	98.00	78.40	12,987.63	7.5900	0.0986
York	160.00	80.00	98.00	78.40	5,536.57	7.5900	0.0420

Total Compressor Station Power: 46,318.60 KWatts

Total Fuel consumption: 0.3516 (Mm3/day)

***** LOCATIONS AND FLOW RATES *****

Location	Distance (km)	Flow in/out (Mm3/day)	Gravity	Pressure (kPa)	Gas Temp. (degC)
Canterbury	0.00	20.0000	0.6000	9000.00	60.00
Bath	100.00	-5.0000	0.0000	5413.54	43.22
Leeds	172.00	10.0000	0.5800	8769.90	53.66
Kent	205.00	-24.6484	0.5920	4997.73	45.08

***** REYNOLD'S NUMBER HEAT TRANSFER COEFFICIENT AND COMPRESSIBILITY FACTOR *****

Distance (km)	Reynold's Num.	FrictFactor (Darcy)	Transmission Factor	HeatTransferCoeff (Watts/m2/degC)	CompressibilityFactor (Z) (Standing-Katz)
0.000	30,782,591.	0.0100	19.96	1.6663	0.8904
5.000	30,782,591.	0.0100	19.96	1.6663	0.8902
10.000	30,782,591.	0.0100	19.96	1.6663	0.8905
15.000	30,782,591.	0.0100	19.96	1.6663	0.8920
25.000	30,782,591.	0.0100	19.96	1.6663	0.8947
30.000	30,782,591.	0.0100	19.96	1.6663	0.9030
50.000	30,585,976.	0.0100	19.96	1.6663	0.8902
60.000	30,585,976.	0.0100	19.96	1.6663	0.8911
75.000	30,585,976.	0.0100	19.96	1.6663	0.8943
80.000	30,585,976.	0.0100	19.96	1.6663	0.8985
90.000	30,585,976.	0.0100	19.96	1.6663	0.9041
95.000	30,585,976.	0.0100	19.96	1.6663	0.9090
100.000	22,856,423.	0.0101	19.91	1.6655	0.9130
105.000	22,693,167.	0.0101	19.91	1.6655	0.8866
120.000	22,693,167.	0.0101	19.91	1.6655	0.8818
130.000	22,693,167.	0.0101	19.91	1.6655	0.8796
140.000	22,693,167.	0.0101	19.91	1.6655	0.8789
156.000	22,693,167.	0.0101	19.91	1.6655	0.8793
160.000	22,619,792.	0.0101	19.91	1.6655	0.8870
168.000	22,619,792.	0.0101	19.91	1.6655	0.8838
172.000	37,571,180.	0.0100	19.99	1.6667	0.8883
180.000	37,571,180.	0.0100	19.99	1.6667	0.8920
184.000	37,571,180.	0.0100	19.99	1.6667	0.8962
190.000	37,571,180.	0.0100	19.99	1.6667	0.9026
196.000	37,571,180.	0.0100	19.99	1.6667	0.9093
200.000	37,571,180.	0.0100	19.99	1.6667	0.9169
205.000	37,571,180.	0.0100	19.99	1.6667	0.9169

***** PIPELINE TEMPERATURE AND PRESSURE PROFILE *****

Distance (km)	Diameter (mm)	Flow (Mm3/day)	Velocity (m/sec)	Press. (kPa)	Gas Temp. (degC)	Soil Temp. (degC)	MAOP (kPa)	Location
0.00	600.000	19.9127	9.73	9000.00	60.00	20.00	10000.00	Canterbury
5.00	600.000	19.9127	10.07	8697.87	57.96	20.00	10000.00	
10.00	600.000	19.9127	10.44	8387.00	56.00	20.00	10000.00	
15.00	600.000	19.9127	10.85	8066.09	54.14	20.00	10000.00	
25.00	600.000	19.9127	11.83	7387.78	50.66	20.00	10000.00	
30.00	600.000	19.9127	12.43	7026.19	49.04	20.00	10000.00	
50.00	600.000	19.9127	16.15	5349.72	43.31	20.00	10000.00	Salisbury
50.00	600.000	19.7890	9.67	9000.00	60.00	20.00	10000.00	Salisbury
60.00	600.000	19.7890	10.36	8395.12	55.98	20.00	10000.00	
75.00	600.000	19.7890	11.72	7410.95	50.61	20.00	10000.00	
80.00	600.000	19.7890	12.30	7055.42	48.98	20.00	10000.00	
90.00	600.000	19.7890	13.78	6287.44	45.96	20.00	10000.00	
95.00	600.000	19.7890	14.75	5866.74	44.56	20.00	10000.00	
100.00	600.000	14.7890	11.93	5413.54	43.22	20.00	10000.00	Bath
105.00	600.000	14.7890	12.46	5142.13	41.54	20.00	10000.00	Cornwall

105.00	600.000	14.6905	7.18	9000.00	60.00	20.00	10000.00	Cornwall
120.00	600.000	14.6905	7.59	8506.01	52.24	20.00	10000.00	
130.00	600.000	14.6905	7.90	8168.62	47.84	20.00	10000.00	
140.00	600.000	14.6905	8.25	7822.29	43.98	20.00	10000.00	
156.00	600.000	14.6905	8.90	7243.48	38.80	20.00	10000.00	
160.00	600.000	14.6905	9.06	7092.93	37.68	20.00	10000.00	York
160.00	600.000	14.6484	7.04	9154.09	60.00	20.00	10000.00	York
168.00	600.000	14.6484	7.24	8898.66	55.67	20.00	10000.00	
172.00	600.000	24.6484	12.36	8769.90	53.66	20.00	10000.00	Leeds
180.00	600.000	24.6484	13.50	8019.86	51.37	20.00	10000.00	
184.00	600.000	24.6484	14.20	7617.98	50.28	20.00	10000.00	
190.00	600.000	24.6484	15.50	6972.13	48.70	20.00	10000.00	
196.00	600.000	24.6484	17.24	6259.29	47.20	20.00	10000.00	
200.00	600.000	24.6484	18.79	5733.90	46.24	20.00	10000.00	
205.00	600.000	24.6484	21.50	4997.73	45.08	20.00	10000.00	Kent

***** LINE PACK VOLUMES AND PRESSURES *****

Distance (km)	Pressure (kPa)	Line Pack (million std.cu.m)
0.00	9000.00	0.0000
5.00	8697.87	0.1161
10.00	8387.00	0.1128
15.00	8066.09	0.1092
25.00	7387.78	0.2075
30.00	7026.19	0.0969
50.00	5349.72	0.3391
60.00	8395.12	0.1815
75.00	7410.95	0.3193
80.00	7055.42	0.0973
90.00	6287.44	0.1808
95.00	5866.74	0.0822
100.00	5413.54	0.0763
105.00	5142.13	0.0715
120.00	8506.01	0.2758
130.00	8168.62	0.2284
140.00	7822.29	0.2222
156.00	7243.48	0.3416
160.00	7092.93	0.0813
168.00	8898.66	0.1690
172.00	8769.90	0.0946
180.00	8019.86	0.1811
184.00	7617.98	0.0842
190.00	6972.13	0.1180
196.00	6259.29	0.1069
200.00	5733.90	0.0643
205.00	4997.73	0.0718

Total line pack in main pipeline = 4.0297(million std.cu.m)

WARNING !...Maximum gas velocity exceeded at some points!