LIQTHERM

Liquid Pipeline Thermal Hydraulics

User Manual

Version 7.0

SYSTEK Technologies, Inc.

www.systek.us

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CONTENTS

1. Introduction

LIQTHERM™ simulates the steady state thermal and isothermal hydraulics of a liquid pipeline with several pump stations. Thermal hydraulics with heater stations may be simulated considering heat transfer with the surrounding medium. The pipeline may be buried or portions may be above-ground. Various liquid products may be injected or stripped at locations along the pipeline. The resultant blended liquid properties (specific gravity and viscosity) are calculated for each pipe segment at the flowing liquid temperature. Pressure drop for each pipe segment is calculated using one of the various equations, such as Colebrook-White, Miller, MIT, Moody or Hazen-Williams.

Multiple pump stations along the pipeline may be modeled, considering pump performance curve data. Pump curve data (flow rate, head and efficiency) may be specified for each pump station along with the pump configuration (series or parallel). Calculations are performed such that maximum allowable operating pressure (MAOP) of each pipe segment is not exceeded. Optionally, the MAOP check may be turned off to determine the maximum pumping capability for a given pipeline and pump station configuration. Snap-shot batching of different liquids can also be simulated by specifying the batch size, specific gravity and viscosity of each liquid batch. AutoBatching is also available for dynamic modeling of batched liquids.

For design of a new pipeline, the approximate number and locations of pump stations required can be calculated for hydraulic balance for a specified flow rate and MAOP. Branch piping and pipe loops (parallel piping) off the main pipeline can also be modeled. The effect of drag reduction agent (DRA) can also be simulated, for de-bottlenecking a pipeline system.

The liquid temperature, specific gravity, viscosity and the pressure profile along the pipeline at the flow rates are calculated considering heat transfer with the surroundings. The heat generated due to friction can be included in the temperature calculations. The heater duty at each heater station site and horsepower required at each pump station are calculated. An isothermal analysis can also be performed for situations where liquid temperatures do not vary along the pipeline.

The input data consists of pipeline profile (distance, elevation, pipe diameter and wall thickness, pipe roughness), depth of burial, liquid flow rates, specific gravity and viscosity of each liquid at two distinct temperatures, liquid inlet temperature, heater outlet temperature, soil temperature, soil and pipe insulation conductivities and delivery pressure.

All the above properties may be considered variable along the length of the pipeline. Accordingly, the pipe roughness may be varied at specific points along the pipeline to simulate different internal conditions of pipe such as internally coated pipe versus un-coated pipe. Similarly, the pipeline may be buried for a portion of its length and the rest may be above ground. Pipe may be insulated with a certain thickness and type of insulation for a specified length, while the remaining pipe may be bare or un-insulated.

The properties of the liquid, such as specific gravity, viscosity are specified at two known temperatures for determining the property versus temperature correlation. In addition, the locations of pumps and heater stations are input along with the minimum suction pressure at each pump station. If pump curves are not available, an average value of pump efficiency for each pump station is input. If pump curve data is available, efficiencies will be automatically calculated by the program.

If the input pipeline flow rate is too high for the pumps or requires pipeline pressure exceeding MAOP, the program iteratively calculates the maximum flow possible. This feature can be turned off, if desired. The hydraulic gradient showing the pipeline pressures superimposed on the pipeline elevation profile along the pipeline can be plotted. If desired for thermal hydraulics, a temperature profile may also be plotted.

The output from the program consists of the temperature, specific gravity, viscosity, and the pressures along the pipeline, along with the heater duty and horsepower required at each pump station. LIQTHERM can be used for the design of a new pipeline or checking capabilities of existing pipelines.

Most data are entered in Microsoft Excel compatible spreadsheets that results in easy editing and cut and paste operations via the Windows clipboard. For the sample problem, pipeline profile data (distance, elevation, pipe diameter and wall thickness, pipe roughness, MAOP) is saved in a file named `MyPipe001.TOT`. In addition, all other data such as thermal conductivity, pump and heater station, liquid flow rate etc. are also saved in the same text file named `MyPipe001.TOT`. Auxiliary data files such as pump curves, liquid data that may be used with other pipelines will be saved separately from the specific pipeline data. For example in the `MyPipe001.TOT` file there may be references to pump curves such as `PUMP1.PMP`, `PUMP2.PMP` etc. All liquid properties are stored in a common Liquid Properties Database files. Help is available on each data entry screen and on the status bar at the bottom of each data entry screen. Answers to specific queries such as "How to create a pipe data file or pump curve file" can be found under **How Do I?**

Calculations may be performed in English or SI/Metric units.

The results of the hydraulic calculations are displayed on the screen in a scrollable window, as well as saved in a file for later viewing or printing. A printed copy of the calculated results can be generated after reviewing the screen output.

Last minute changes to the program are documented in a file named README.TXT, if present on the program disk.

This software can be run on Pentium and Athlon based computers and compatibles with a minimum of 8 GB RAM running Microsoft Windows XP/7/8/10 operating systems. A minimum hard disk space of 25 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.

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 – 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.

1. Insert the software CD into the CD-ROM drive.

2. Run as administrator "Setup.exe"

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.

Note that Windows 7/8/10 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 pin a shortcut to the Taskbar.

2.2 Retaining/Releasing - Internet Authenticated Version

To launch the program, you will 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.

In order to use the program on another computer, you may release control of the license of this program. This is done by Clicking **HELP** followed by **Release Control**. *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.

2.3 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.**

2.4 Un-installation

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 (Uninstall)** Programs. Follow subsequent instruction to uninstall ***LIQTHERM***. All pipeline models and gas properties database are located in My Documents\LIQTHERM\ folder and maybe backed up for future use.

Put your original program disk away safely.

3. Features

LIQTHERM for windows is a steady state Hydraulic Simulation software. It will make all your pipeline thermal or isothermal hydraulic simulation easy. Use it to calculate the pipeline hydraulics, temperature and pressure profile, pump station HP required, heater duty and pump performance. Despite the complexity of the program it is very user friendly. Online HELP is available for all data entry screens and the program has extensive error checking features. In addition, answers to specific queries such as "How to create a pipe data file or pump curve file" can be found under **How Do I?**

Here are the salient features:

- The pipeline model may be created graphically (PipeGraph model) using a drag and drop approach. In this method, objects such as pipe segments, valves, tanks, pump 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. A video tutorial is available that explains how the pipeline model can be created graphically. Visit www.systek.us/LiqthermVideoTutorial.htm for details.

- Pipe diameter, wall thickness, roughness, burial depth, insulation thickness, insulation conductivity and the ambient soil temperature can all be varied along the pipeline. An Excel compatible spreadsheet for data entry makes it easy to create and save pipe data files.

- All model input data combined into one compact XML style data file for each pipeline.

- Import data files from Microsoft Excel files or previous versions of LIQTHERM.

- Simulate isothermal flow when modeling water and refined petroleum products.

- Heaters may be installed along the pipeline, and the Heater duty may be calculated or thermal flow for crude oils or other liquids.

- Liquid may be injected or delivered at various points along the pipeline.

- Several batches of different liquids transported in series in the pipeline can be modeled.

- Pipe may be modeled above ground or below ground or a combination of both.

- Simulate drag reduction agent (DRA) in mainline and branch piping.

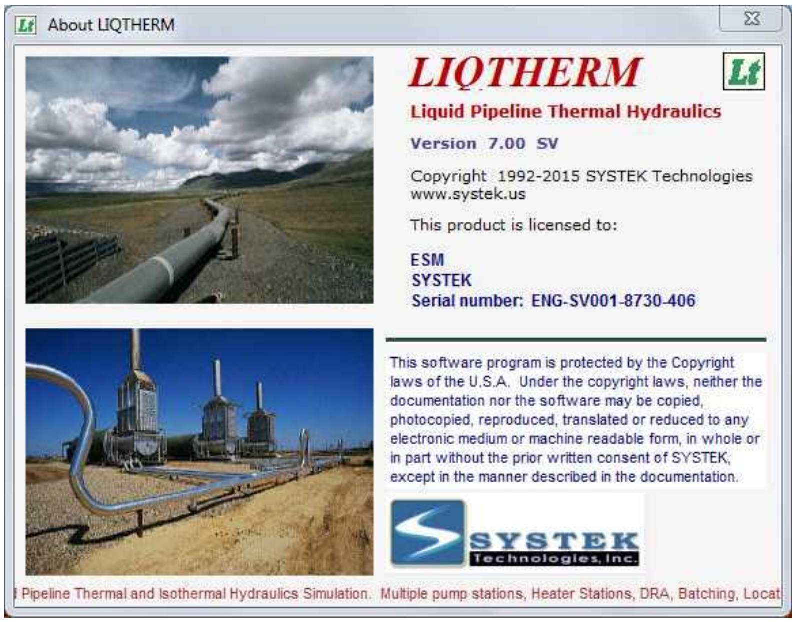
- Pressure drop calculations may be based on Colebrook-White, Hazen- Williams, MIT, Moody, Miller equations.

- The pipeline may have several pump stations (maximum 50) with pumps in series or parallel at each pump station. Calculations can be performed *with* or *without* considering pump curve data. There may be a maximum of 10 pumps at each station. Pumps can be in series or parallel configuration or a combination of series and parallel.

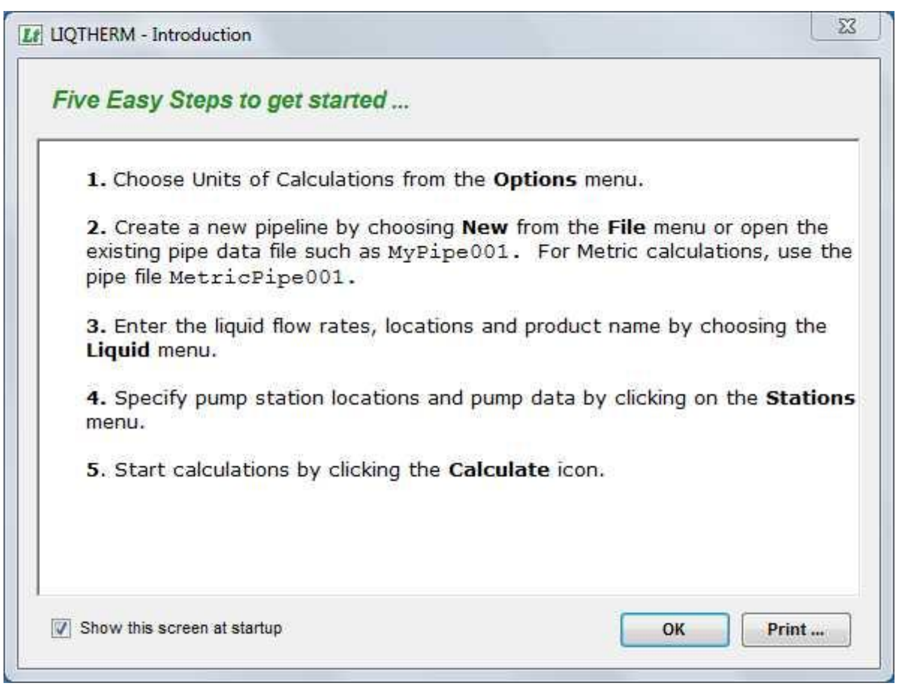
- Turn pump stations ON/OFF to simulate station shut-down conditions.
- Turn individual pumps ON/OFF at each pump station.
- Determine the approximate number and locations of pump stations needed for given flow rate and pipe MAOP, for hydraulic balance.
- The amount of pump impeller trims required to minimize throttling can be calculated.
- Mix variable speed (VSD/VFD) pumps with constant speed, electric motor driven pumps.
- Individual pump curve data can be viewed, edited and plotted on the screen or the printer.
- The maximum pipeline throughput for a given MAOP can be calculated for a specified pump station configuration.
- The pipeline may have branches and parallel loops. Maximum number of branches and loops is limited to 50. Each branch pipe may have up to 500 data points compared to a maximum of 1000 sets of data points for the main pipeline. Currently the branch piping may not have any pump stations. Flow injection and stripping are allowed on the branches. Each pipeline segment between any two pump stations can have only one pipe loop. Branches may not be present on branches or loops. Loops may not be present on loops or branches.
- Pressure reducing valves, fittings, custom devices etc. may be specified at any location along the pipeline.
- For quick economic analyses, the Capital cost and Operating cost for a pipeline system can be calculated. The annual cost of service and transportation tariff can also be determined for various project financing scenarios (see Reference section for details).
- New improved temperature based batching
- Plot hydraulic pressure gradient with MAOP plot.
- Plot pipeline liquid temperature profile.
- Export output report to Microsoft Notepad or Excel for inclusion in project reports.
- The Quick Pressure Drop Option calculates the inlet or outlet pressure of a pipe segment, given one of the two pressures and the flow rate for isothermal flow or the flow rate for a given inlet and outlet pressure.

3.1 Running the Program

To run the program, click on the **LIQTHERM** program icon. The initial program screen will be momentarily displayed as follows:

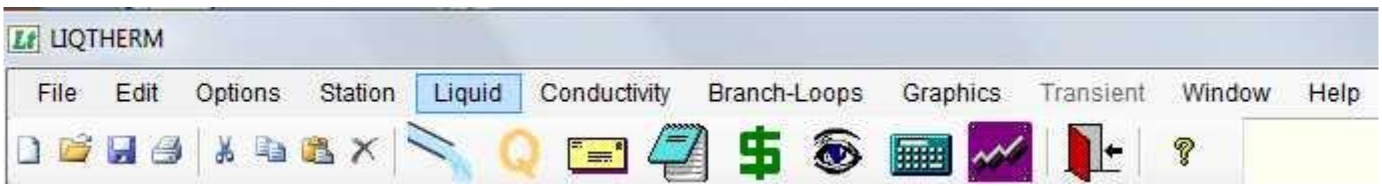


An introductory screen shown below describes the 5 steps necessary to model a typical pipeline using LIQTHERM.



By clicking the **How Do I?** icon on the left panel, additional help is available to perform specific tasks such as "Create a pipe data file, Determine pump requirements, etc.

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:



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 pipe data file.
Open - To open and edit an existing data file.
View - To view the results of the last calculation or the pipeline TOT file
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 - To print the spreadsheet data file or the last output file.
Send Email - To send email of a spreadsheet data file or an output file to an associate or to SYSTEK for technical support.
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 row in the spreadsheet
Delete row - To delete a row of data in the spreadsheet.
Add rows - To add rows of data in the spreadsheet
Format cells - To format the cells in the spreadsheet.

Accelerator keys, such as **Ctrl-X** for ***Cut*** and **Ctrl-I** for ***Insert row*** are available for several menu items.

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

Units - This screen is used to choose English or SI units of calculation. Options are available for different sets of units for pipeline distance, pipeline flow rates, pressures and temperatures. For pump curve data you may choose the units for flow rate and head. *Note that the pipeline flow rate units need not necessarily be the same as the pump curve flow rate units.*

Pump curves - For selecting pump curve data that can be viewed, edited, printed and plotted on the screen or printer.

Formula - For selecting the pressure drop formula to be used. Options include Colebrook-White, Miller, Hazen-Williams, Moody friction factor and the MIT equations.

Batching - For specifying different liquid batches and properties for snapshot hydraulics.

AutoBatching - To simulate batching of different products dynamically as the batches move through the pipeline.

Drag Reduction - For using drag reducer in the pipeline (simple and batched)

Isothermal flow - For modeling constant temperature flow (no heat transfer effects)

Customize Report - For customizing the output report, such as a short or a long output. Also used for including branch, loop, DRA and other options desired.

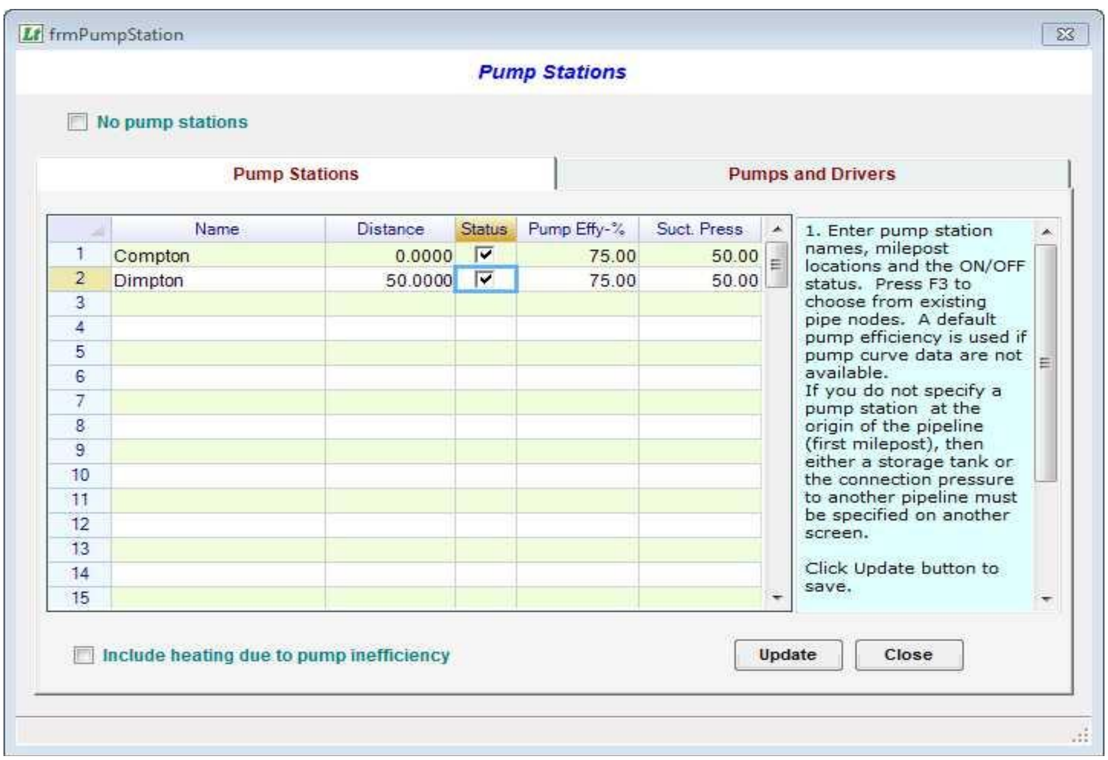
Interpolate - For interpolating pipeline elevations.

Quick Start - To quickly build a pipeline model by specifying some basic pipe, pump stations, liquid flow rate and properties data.

The pull down menu under **Stations** has options for specifying pump station data, heater station data and valve and fitting data and for locating pump stations.

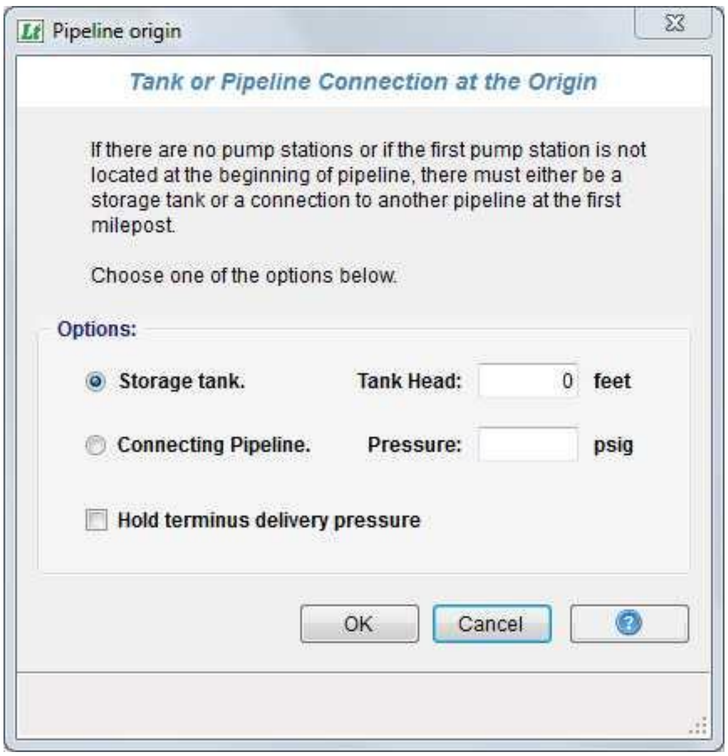
On clicking the **Pump stations** option, a tabbed screen is displayed. The **Pump Stations** tab is used to enter the name of each pump station, its distance from the beginning of the pipeline (mile post), ON/OFF status, pump efficiency and the minimum station suction pressure. The default efficiency value of 75% is used to calculate the pump HP required at each pump station, if pump curve data is not specified. You may change this default efficiency, if desired. If the temperature rise of the pumped liquid, due to the pump inefficiency is to be included, check the option box. Click **Update** button to save all data.

With the cursor in the station name or distance column, press **F3** and a screen showing all the available pipeline nodes is displayed. You may specify pump station location, by choosing the pipe nodes as desired. If a desired pump station location is not present in the list of pipe nodes, close the pipe node screen and enter the desired location in the **Pump Stations** tab below. This additional pipe node will be automatically added to the pipe data file.



There may be instances where there are no pump stations at all, such as in a short pipeline with a tank at the origin or a connection to another pipeline. In such a case, check the box titled **No pump stations** in the screen above, and Click the **Update** button.

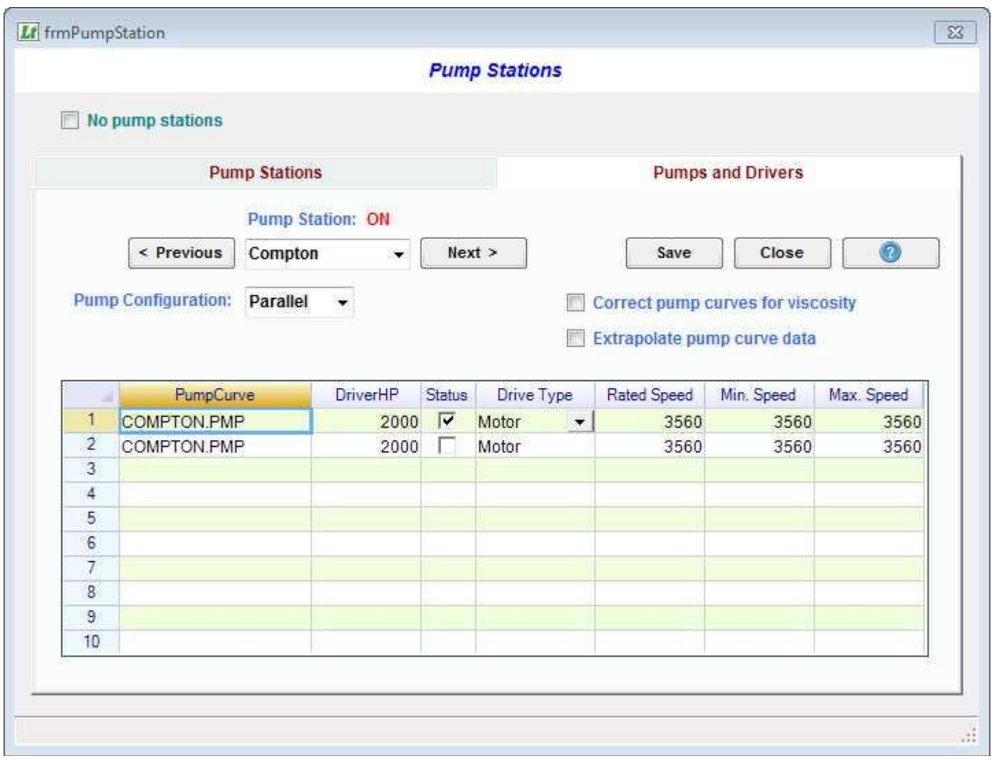
If there are no pump stations at all or the first pump station is not located at the origin (first milepost) of the pipeline, the program assumes that there is either a storage tank at the beginning of the pipeline or a connection to another pipeline that provides the pressure at the pipeline origin. In this case, upon clicking the **Update** button above, a screen is displayed for choosing a **Storage tank** or a **Connecting pipeline** at the first pipe node, as shown below.



For a storage tank, you must specify the tank head that will provide the starting pressure. For the connecting pipeline, the pipeline pressure must be specified. Refer to the **Sample Problem–7** for an example of a pipeline with a storage tank at the origin.

In the **Pumps and Drivers** tab, enter the details of each pump station, pump configuration (series or parallel), pump curve data, driver HP and pump ON/OFF status. Press **F3** for available pump curve files, when in the cell containing pump curve data. Additional data, such as drive type (Motor, Engine, Gas turbine, and Variable Speed Drive Motor), the rated speed, minimum speed and maximum speed, if available, can be specified as well. If you choose Motor, all speeds (rated, minimum and maximum) will be the same, indicating constant speed electric motor. For Variable speed electric motor, choose VSD motor and enter the rated, minimum and maximum speeds. For automatically correcting pump performance for high viscosity liquids, check the box titled **Correct pump curves for viscosity** shown in screen below.

For the liquid viscosity higher than 10cSt the pump performance must be corrected using the Hydraulic Institute charts. This is automatically taken care of by Liqtherm. The User simply inputs the water performance data and LIQTHERM will use the Hydraulic Institute charts method in the calculations.



Remember that for variable speed pumps, the pump curve data specified is assumed to be at the rated speed. LIQTHERM will calculate the pump performance at different speeds as needed, using the Affinity Laws for centrifugal pumps. You may cycle through each pump station data using the **Previous** and **Next** buttons.

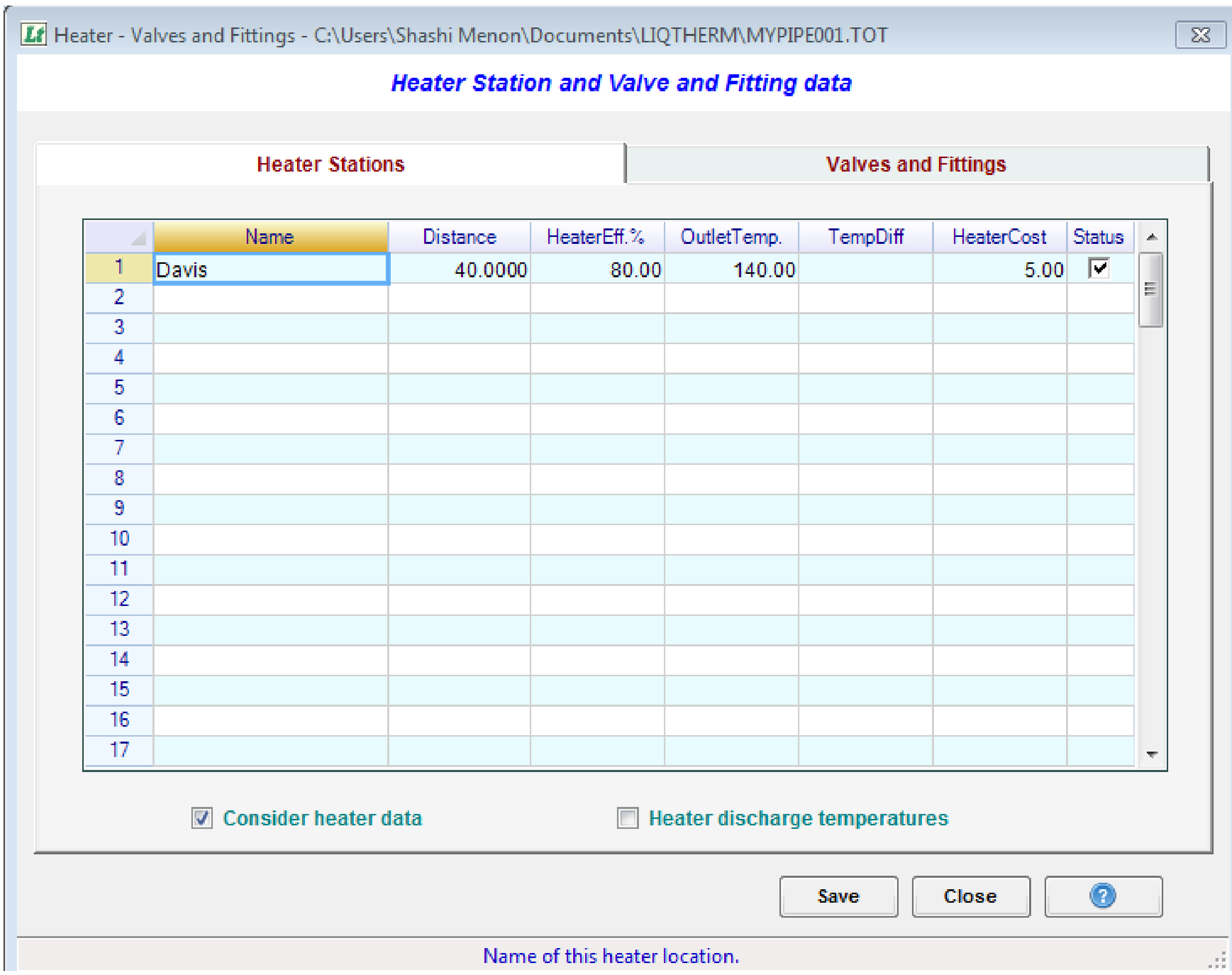
If you have not decided on the pump curves for a specific pump station, enter TBD under pump curve and specify a value for the driver HP. Make sure the Unit is ON. ***Do not enter any more TBD entries under pump curve data.***

When you run a case with no pump curves at all or TBD pumps at certain pump stations, LIQTHERM will create pump files suitable at the TBD pump stations. For example, if you have specified actual pump curves for Compton pump station but a TBD pump at Dimpton pump station, the simulation for a particular flow rate will create a new pump curve named D**impton_TBD.PMP**. This pump curve may then be inserted at Dimpton pump station and the simulation repeated. Note however, that each time a case is run for a particular flow rate with TBD pumps at some stations, corresponding new pump curves will be created automatically with the same name.

To view or edit a pump curve file, double click on the pump curve file name. A File open screen will be displayed, with the default pump curve name. Click **Open** and a screen containing the pump curve data will be displayed. From this screen, the pump performance at different speeds or impeller size and viscosity corrected performance can be calculated.
Finally, click the **Save** button to save all pump station data and exit this screen.

Note that the pump curve data must be corrected for viscosity of the liquid, if appropriate. In the Pump Station screen, a check box is provided for *automatic* corrections for high viscosity. This means that the pump data files must contain head, flow rate and efficiency values for water and LIQTHERM will correct the performance for high viscosity liquids. You may also choose to input pump curve data that have already been corrected for viscosity using either the Hydraulic Institute Charts or SYSTEK's program **PUMPCALC.** Alternatively**,** use LIQTHERM's **Viscosity Correction** Option provided under **Pump Curves.** After opening a pump curve file, use the menu options for viscosity correction, described later.

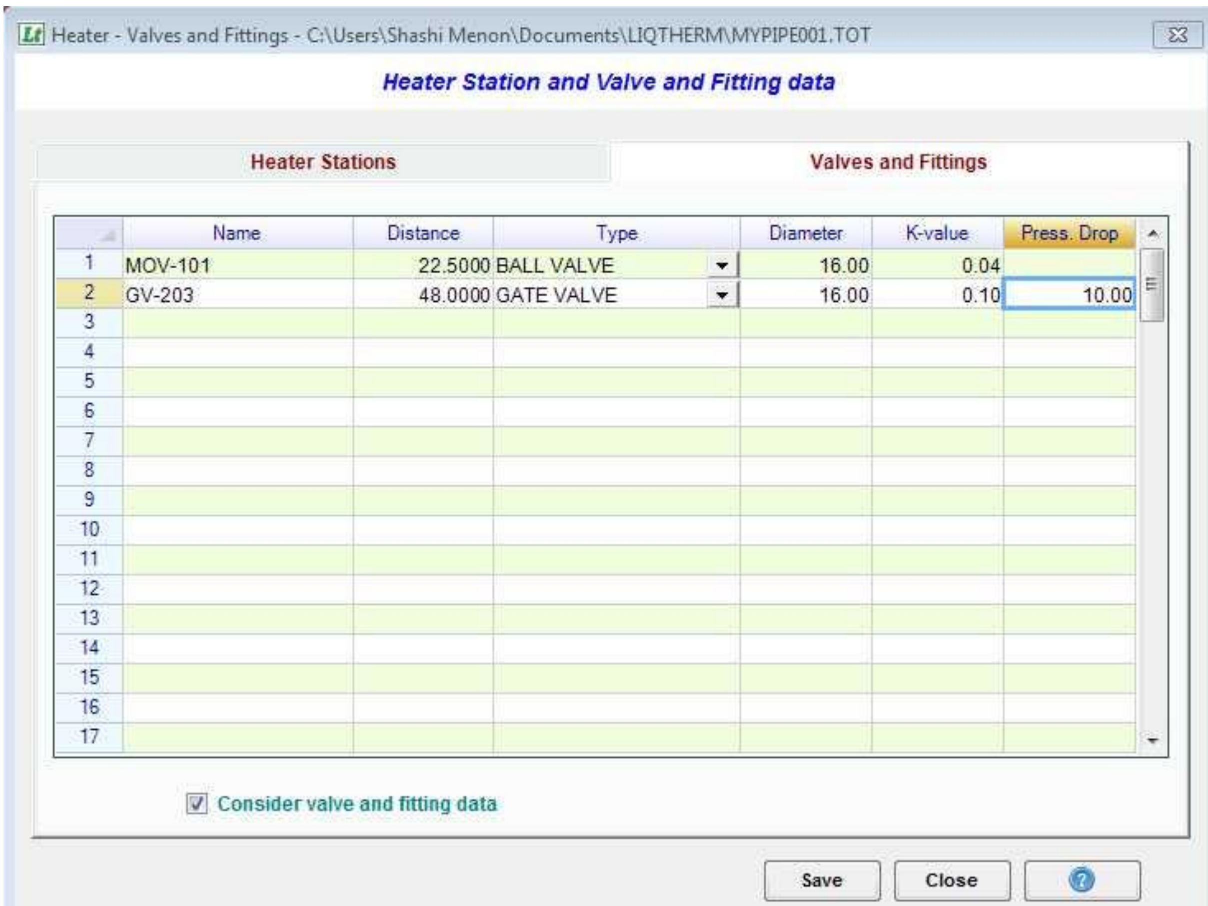
The menu item **Heater stations** is used for entering heater station data along the pipeline. The heater data consists of the heater name, its location along the pipeline (mile post), the heater efficiency (%) and the heater outlet temperature. You may also enter a value for the heating costs in $/MMBtu or $/MMWhr.



The liquid entering the heater will be heated to the **outlet temperature** specified. The heater duty will be calculated based on the mass flow of the liquid and the temperature rise of the liquid through the heater. If a value is entered in the **Temperature Difference** column, the heater **outlet temperature** is ignored.

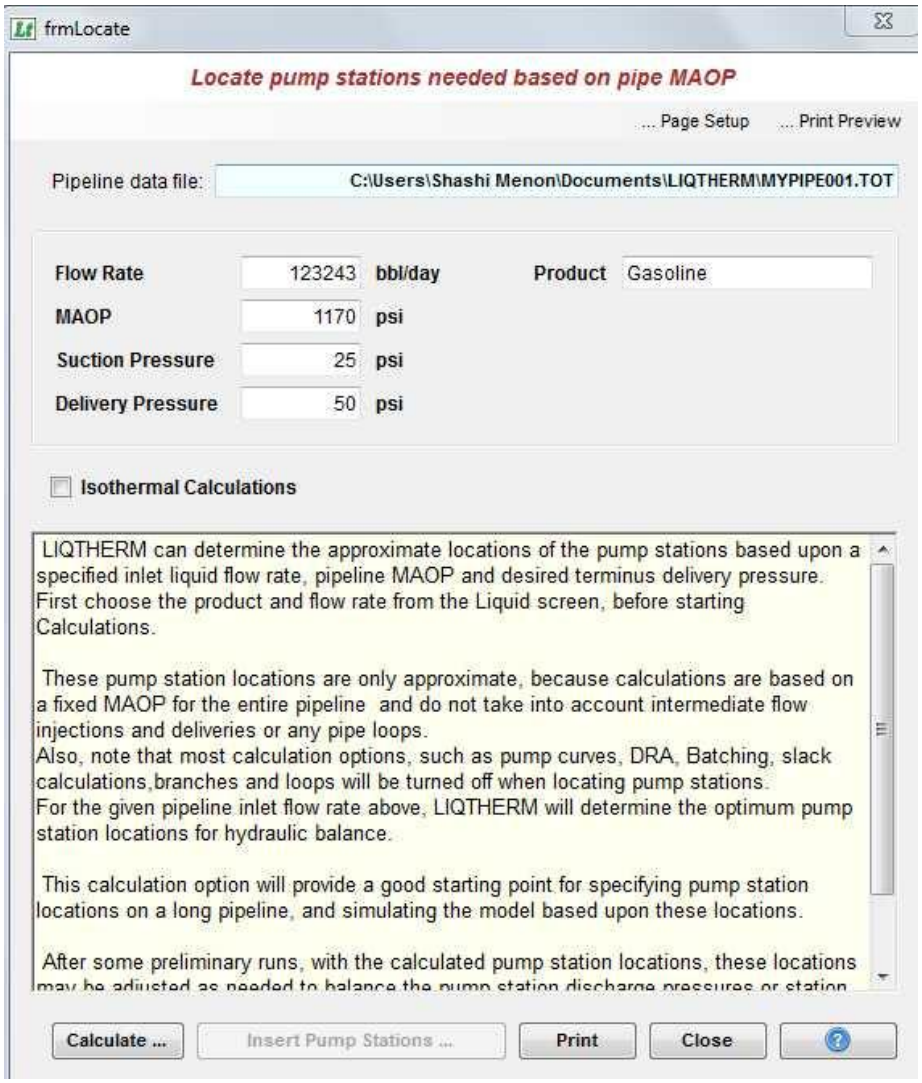
Note that you must specify distinct pipe nodes (mileposts) for each heater station. These locations *cannot be the same* as other nodes such as the pipe origin, pipe terminus, a pump station, pipeline flow entry or exit point, devices, DRA locations, branches or loops.

The menu item **Valve and Fittings** is used for modeling pressure drops through valves and fittings along the pipeline. 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. Note that you must specify distinct pipe nodes (mileposts) for each valve or fitting. These locations *cannot be the same* as other nodes such as the pipe origin, pipe terminus, a pump station, pipeline flow entry or exit point, or location of heaters, devices, DRA locations, branches or loops.



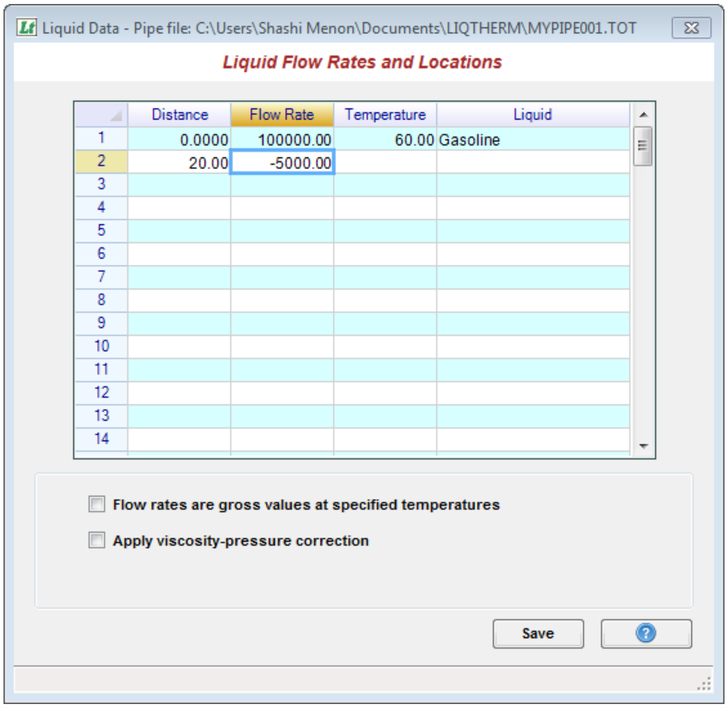
In the **Heater Stations** tab and the **Valves and Fittings** tab of the above screen, with the cursor in the second column (distance), press **F3** and a screen showing all the available pipeline nodes is displayed. You may specify the heater station or valve location, by choosing the pipe nodes as desired. If a desired pipe location (milepost) is not present in the list of pipe nodes, close the pipe node screen and enter the desired location in the screen above. This additional pipe node will be automatically added to the pipe data file, upon saving the data and closing the above screen

The menu item **Locate Pump Stations** may be used for determining the approximate number and locations of pump stations when modeling a grass roots pipeline. This option allows you to enter a flow rate, MAOP, pump station suction pressure and terminus delivery pressure along with a specific product pumped. LIQTHERM will calculate the approximate number of pump stations required and their locations (milepost) for hydraulic balance. An isothermal calculation option is also available as shown below.



Once the pump station locations are defined these may be inserted into the pipeline data file by clicking the **Insert pump stations** button. The simulation can then be continued and finalized with the newly defined pump station sites.

The pull down menu under **Liquid** is used for entering the flow rates and their locations and also for reviewing and editing a database of liquid properties.



At the beginning of the pipeline, where the product enters the pipeline, a flow rate must be entered as a positive number such as 100,000 bbl/day shown above. If there is a *delivery* at a particular point on the pipeline, the flow rate in this column will have a *negative* value, as indicated above at location 20.0. At such locations where flow is *out* of the pipeline (negative), *do not* enter any temperature or product name.

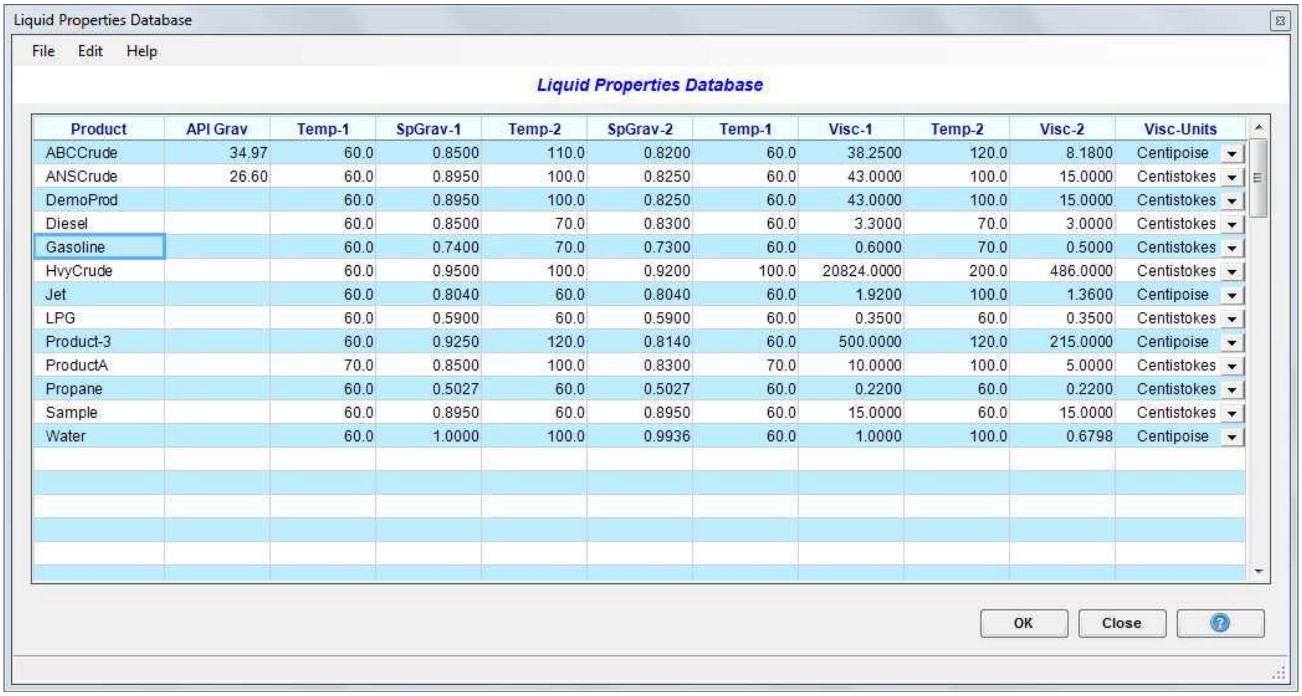
Pressing the **F3** key with the cursor in the first column, titled **Distance** will display a screen showing all the available pipeline nodes. You may specify flow rate location, by choosing the pipe nodes as desired. If a desired flow location is not present in the list of pipe nodes, close the pipe node screen and enter the desired location in the Liquid screen. This additional pipe node will be automatically added to the pipe data file, after clicking the **Save** button above.

The third column is for the inlet temperature of the liquid. All injection points (positive flow rates) should have inlet *temperature and product name specified*. For delivery locations (negative flow rates) no temperature or product name entries are needed.

Pressing the **F3** key with the cursor in the last column, titled **Liquid** will display the Liquid Properties Database screen. Choose the product from the given list. You may also add a new product to the database.

Check "Flow rates are gross values at specified temperatures" if you want the program to adjust flow rates based on actual pipeline temperatures in pipeline flow.
"Viscosity pressure correction" is used for heavy crude simulation.

The **Liquid Properties Database** screen shown below can also be accessed by choosing **Database** under the **Liquid** menu from the main LIQTHERM screen.



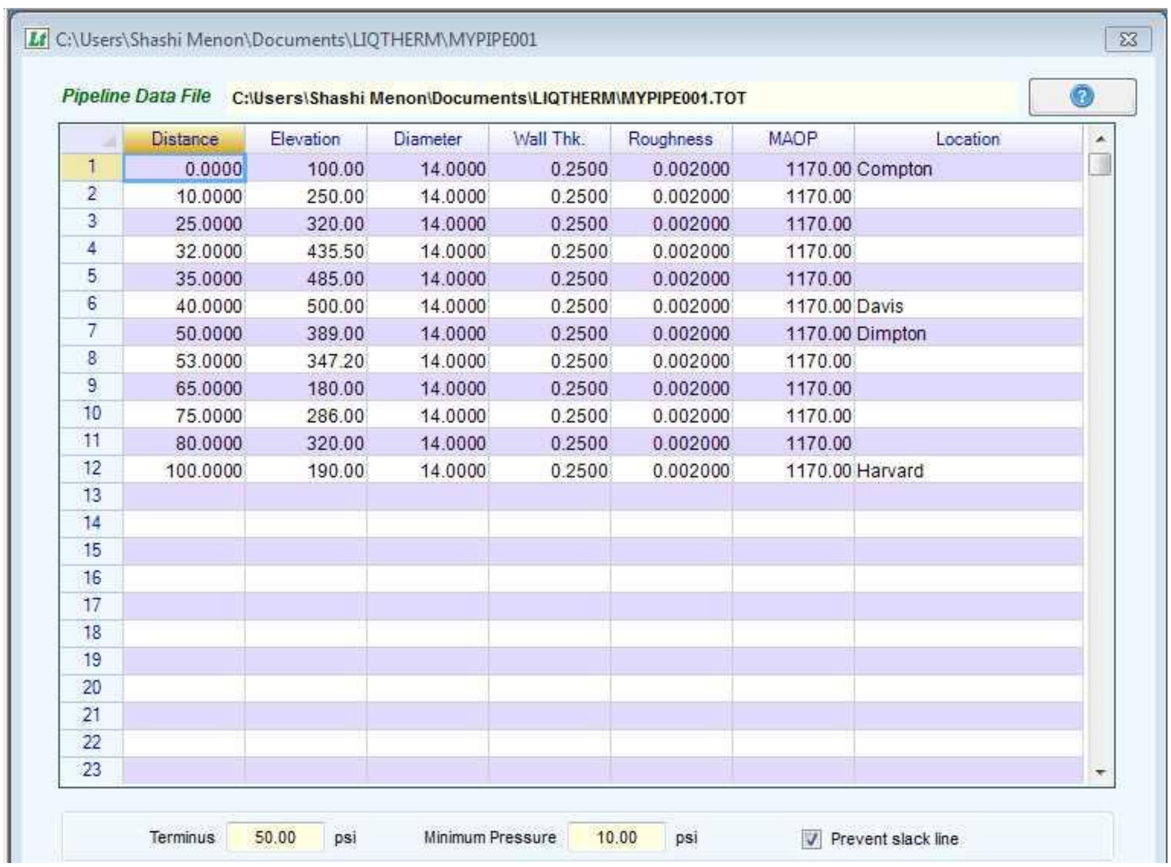
Product	API Grav	Temp-1	SpGrav-1	Temp-2	SpGrav-2	Temp-1	Visc-1	Temp-2	Visc-2	Visc-Units
ABCCrude	34.97	60.0	0.8500	110.0	0.8200	60.0	38.2500	120.0	8.1800	Centipoise
ANSCrude	26.60	60.0	0.8950	100.0	0.8250	60.0	43.0000	100.0	15.0000	Centistokes
DemoProd		60.0	0.8950	100.0	0.8250	60.0	43.0000	100.0	15.0000	Centistokes
Diesel		60.0	0.8500	70.0	0.8300	60.0	3.3000	70.0	3.0000	Centistokes
Gasoline		60.0	0.7400	70.0	0.7300	60.0	0.6000	70.0	0.5000	Centistokes
HvyCrude		60.0	0.9500	100.0	0.9200	100.0	20824.0000	200.0	486.0000	Centistokes
Jet		60.0	0.8040	60.0	0.8040	60.0	1.9200	100.0	1.3600	Centipoise
LPG		60.0	0.5900	60.0	0.5900	60.0	0.3500	60.0	0.3500	Centistokes
Product-3		60.0	0.9250	120.0	0.8140	60.0	500.0000	120.0	215.0000	Centipoise
ProductA		70.0	0.8500	100.0	0.8300	70.0	10.0000	100.0	5.0000	Centistokes
Propane		60.0	0.5027	60.0	0.5027	60.0	0.2200	60.0	0.2200	Centistokes
Sample		60.0	0.8950	60.0	0.8950	60.0	15.0000	60.0	15.0000	Centistokes
Water		60.0	1.0000	100.0	0.9936	60.0	1.0000	100.0	0.6798	Centipoise

The screen above shows the liquid properties (specific gravity and viscosity) for several common liquids used. For thermal hydraulics, the specific gravity and viscosities at two distinct temperatures must be input. Otherwise, LIQTHERM will not be able to interpolate the liquid properties at any other temperature. For isothermal hydraulics, properties at a single temperature will suffice. However, if the liquid temperature in the above Database screen is 60 F, whereas the liquid inlet temperature in the **Liquid Flow rate** screen is a different value, LIQTHERM will use the temperature in the above screen as the inlet temperature.

The liquid properties database can be saved under different file names such as *CrudeOilDatabase* containing all the crude oil properties or *RefinedProductDatabase* containing all the refined product properties. Create the database and save it, using File/SaveAs option to rename your file. Remember however, that you can use only one Database file at a time for picking the products. For example, while running Mypipe.TOT file, you have incoming and outgoing flows. All the products incoming and outgoing have to be from one database. In other words you CANNOT choose one product, say **Gasoline** from *RefinedProductDatabase* and another product **Diesel** from another file named *XYZProductDatabase*. Both products **Gasoline** and **Diesel** should be chosen from the same database. You are allowed to change the database association each time you make a run.

The lower portion of the main pipeline spreadsheet is used for entering **Pressure** information, such as the delivery pressure at the end of the pipeline and the minimum pipeline pressure (important in hilly terrain). If the pipeline must run packed and slack line conditions are to be avoided, check the option titled **Prevent Slack Line.**

In calculating the pressures along the pipeline, LIQTHERM makes allowance for peaks in the pipeline elevation profile. Hence the final pressure at the end of the pipeline may be higher than the minimum delivery pressure specified. This is true only if **Prevent slack line** option is chosen in the main pipe data screen. Obviously, a back pressure valve will be needed at the pipeline terminus to pack the line. However, if slack line conditions can be tolerated, this option may be unchecked and the desired delivery pressure would be forced. In the latter case, the last pump station segments will indicate slack line locations showing zero pressures. Please note that if a **Minimum pressure** is specified, the line must run packed to prevent slack line conditions. An example of a pipeline through a hilly terrain is also included in the Sample Problems.

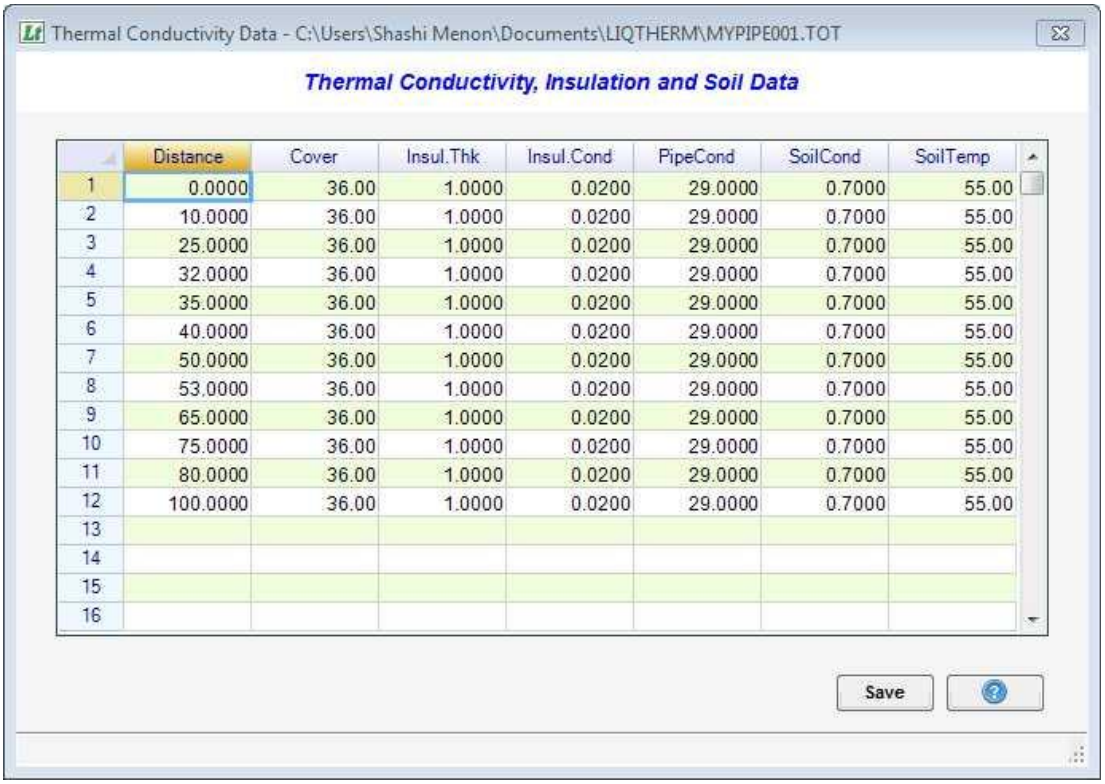

C:\Users\Shashi Menon\Documents\LIQTHERM\MYPIPE001

Pipeline Data File C:\Users\Shashi Menon\Documents\LIQTHERM\MYPIPE001.TOT

	Distance	Elevation	Diameter	Wall Thk.	Roughness	MAOP	Location
1	0.0000	100.00	14.0000	0.2500	0.002000	1170.00	Compton
2	10.0000	250.00	14.0000	0.2500	0.002000	1170.00	
3	25.0000	320.00	14.0000	0.2500	0.002000	1170.00	
4	32.0000	435.50	14.0000	0.2500	0.002000	1170.00	
5	35.0000	485.00	14.0000	0.2500	0.002000	1170.00	
6	40.0000	500.00	14.0000	0.2500	0.002000	1170.00	Davis
7	50.0000	389.00	14.0000	0.2500	0.002000	1170.00	Dimpton
8	53.0000	347.20	14.0000	0.2500	0.002000	1170.00	
9	65.0000	180.00	14.0000	0.2500	0.002000	1170.00	
10	75.0000	286.00	14.0000	0.2500	0.002000	1170.00	
11	80.0000	320.00	14.0000	0.2500	0.002000	1170.00	
12	100.0000	190.00	14.0000	0.2500	0.002000	1170.00	Harvard
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							

Terminus 50.00 psi Minimum Pressure 10.00 psi Prevent slack line

The pull down menu under **Conductivity** is used for entering the thermal conductivity of pipe, soil and insulation, if any, the insulation thickness, pipe burial depth (Cover) and the surrounding soil temperature at various points along the pipeline for thermal hydraulics only. *For isothermal hydraulics, this information is not used.*



	Distance	Cover	Insul.Thk	Insul.Cond	PipeCond	SoilCond	SoilTemp
1	0.0000	36.00	1.0000	0.0200	29.0000	0.7000	55.00
2	10.0000	36.00	1.0000	0.0200	29.0000	0.7000	55.00
3	25.0000	36.00	1.0000	0.0200	29.0000	0.7000	55.00
4	32.0000	36.00	1.0000	0.0200	29.0000	0.7000	55.00
5	35.0000	36.00	1.0000	0.0200	29.0000	0.7000	55.00
6	40.0000	36.00	1.0000	0.0200	29.0000	0.7000	55.00
7	50.0000	36.00	1.0000	0.0200	29.0000	0.7000	55.00
8	53.0000	36.00	1.0000	0.0200	29.0000	0.7000	55.00
9	65.0000	36.00	1.0000	0.0200	29.0000	0.7000	55.00
10	75.0000	36.00	1.0000	0.0200	29.0000	0.7000	55.00
11	80.0000	36.00	1.0000	0.0200	29.0000	0.7000	55.00
12	100.0000	36.00	1.0000	0.0200	29.0000	0.7000	55.00
13							
14							
15							
16							

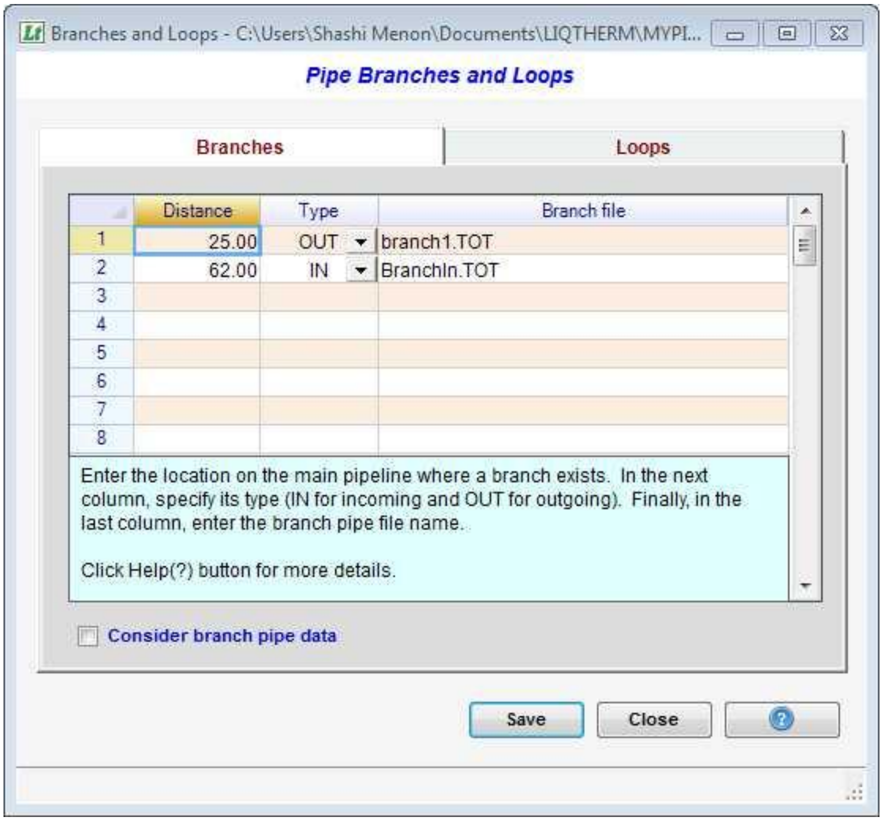
Data for thermal conductivity need not be entered at all milepost locations. The values at the beginning mile post must be supplied along with changes at any additional locations along the pipeline. *Thus, if the properties do not change at all, simply input the values for the first mile post only.*

For buried pipe, **Cover** represents the burial depth of the pipe at that location, measured from the ground surface to the top of pipe. If a certain portion of the pipeline is above ground, in the column titled cover, simply enter a negative number such as –999. If the pipe is not insulated, enter *zero* values for the insulation thickness and conductivity.

Note that when LIQTHERM is used as an isothermal model, all heat transfer effects are ignored. This means that the liquid inlet temperature specified at the beginning of the pipeline is used as the ambient soil temperature in the screen above. Isothermal analysis is generally performed for water pipelines and refined petroleum products pipelines such as gasoline and diesel.

Running the Program

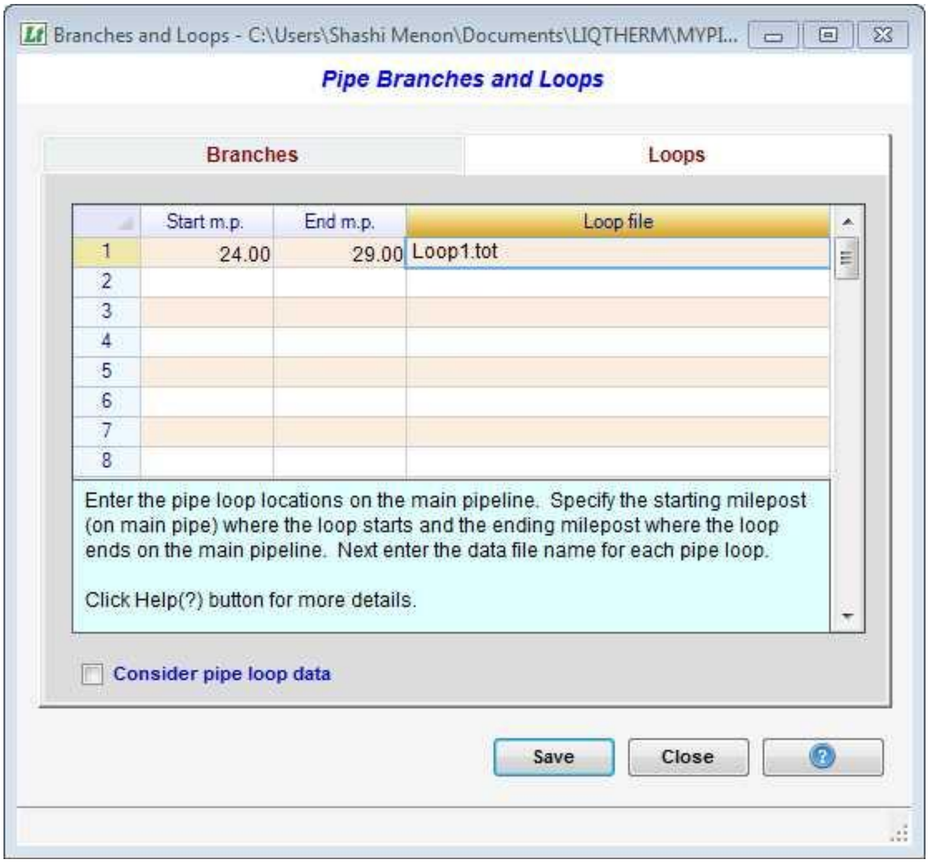
The pull down menu under **Branch/Loop** is used for entering branch pipe and pipe loop information, as shown below:



In the screen above, the first column for distance represents the location (milepost) along the main pipeline where a branch pipe is connected. An *outgoing* branch off the main pipeline must be designated by entering OUT under the column **Type**. A pipe branch that delivers product *into* the main pipeline is called an *incoming* branch and therefore must be designated as IN under the **Type** column. In the third column enter name of the branch pipe file name. The branch pipe data file has a format similar to the main pipe data file and needs to be created separately. Pressing F3 shows all available branch data files. For outgoing branch pipe you must specify the delivery pressure required at the end of the branch. If the mainline pressure where the outgoing branch connects is inadequate to produce the desired delivery pressure at the end of the branch pipe, a warning message will be displayed. In such an instance, the pressure and temperature profile for the branch pipe will not be calculated. For an *incoming* branch pipe, you must indicate the starting temperature at the beginning of the branch in the screen above.

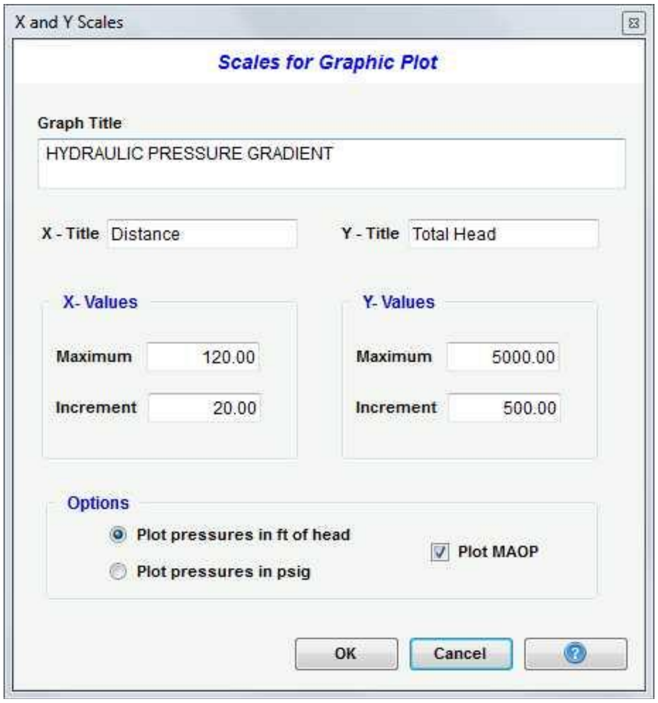
To edit the branch or loop files, first close the mainline file using File/Close. Then Open the branch or loop data file and edit the pipe data just as it is done in the mainline file. The flow rate in the incoming or outgoing branch file should match the main line flow rate of injection (incoming branch) and delivery (outgoing branch).

For a pipe loop, under the tab designated as **Loops**, the beginning milepost and ending milepost where the pipe loop begins and ends on the main pipeline must be entered, along with the data file name for the pipe loop, as shown in the screen below. Press F3 for available pipe loop data files.



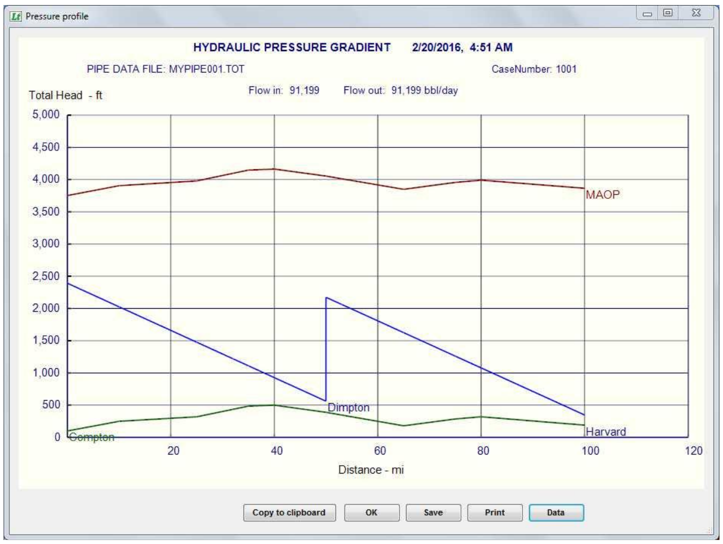
You may view the loop pipe data file by double-clicking on the file name above. The loop pipe has a format similar to the main pipeline.

The **Graph** icon is used for selecting the different graph types for Hydraulic Pressure Gradient along the pipeline. Choosing this option displays the following screen for selecting the labels and scales for the plot of the Hydraulic Pressure Gradient.

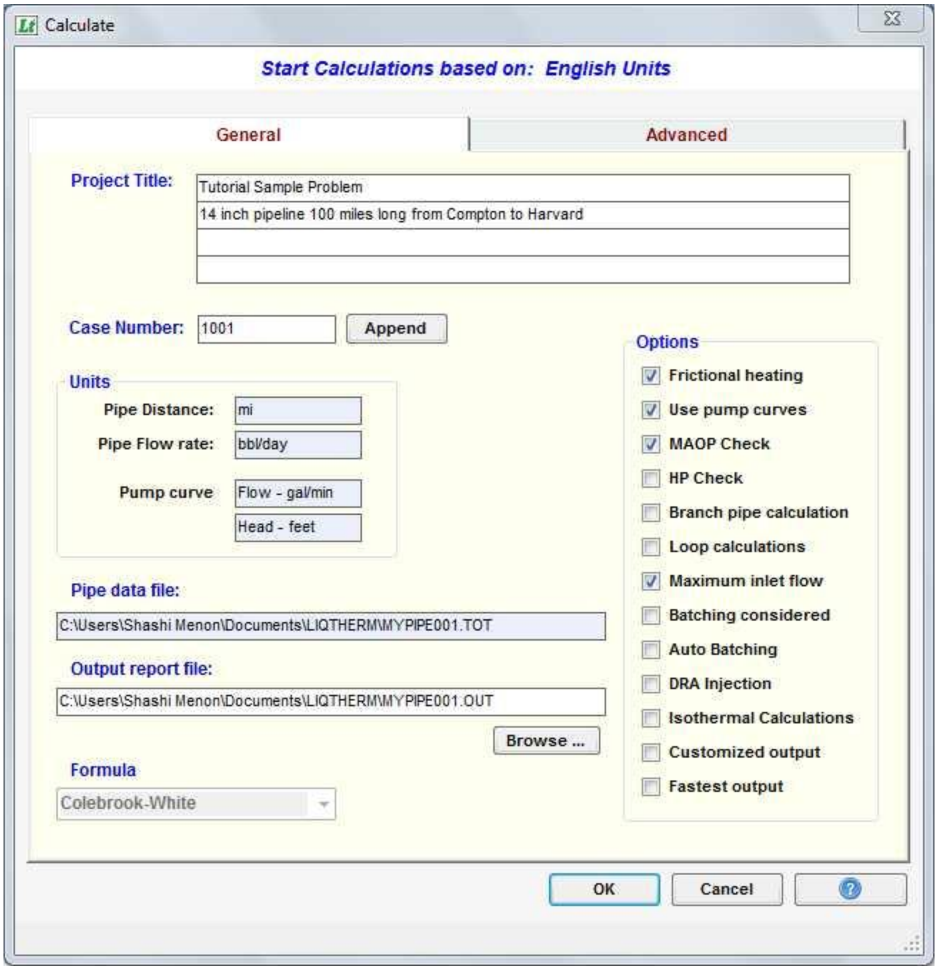


In the **Options** above you can choose radio button for plotting the pressures in ft of head of liquid or psig (in SI/Metric meters of liquid head or kPa). Additionally the check box "**Plot MAOP**" when checked displays the MAOP values superimposed on the pipeline elevation and pressures.

On entering data and clicking the OK button, the hydraulic gradient will be plotted, as shown below:



The **Calculate** icon will display the following screen for specifying the format of the calculated results.



The project title may be a maximum of four lines. The calculated results are stored in an output file as shown above. You may rename this file when making multiple runs for the same pipeline system. For example, if the pipeline data file is named `MyPipe001` as in the sample above, the output file may be named `MyPipe001.001`, `MyPipe001.002`, etc.

When the **Isothermal Calculations** option is checked in above screen, the **Frictional heating** is automatically unchecked. Isothermal calculations are generally performed for water pipelines and refined petroleum products pipelines such as gasoline and diesel.

Under the **Advanced** tab, the calculated accuracy may be selected. Generally medium accuracy will suffice. Clicking the **OK** button initiates calculation. The results of calculation are displayed in a scrollable window.

For customizing the output report, such as a short or a long output, click **Option/Customize Report...** and choose the options desired.

The menu bar item **Window** lets you customize your screen.

The menu bar item on the extreme right titled **HELP** provides information about the program, such as version number, user registration information and General Help information on the program, in case the User Manual is not handy.

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.

*If you are using the DEMO version of LIQTHERM, the sample pipeline data file included with the DEMO is named `MyPipe001-Demo.TOT`. The following explanation **does not** apply to the DEMO version.*

Sample Problem:

Determine the temperature and pressure profile for a 100 mile pipeline transporting Alaskan North Slope (ANS) crude oil from Compton pump Station to Harvard terminus with the following data:

Distance (miles)	**Elevation** (ft)	**Pipe dia.** (in)	**Wall Thk** (in)	**Roughness** (in)	**MAOP** (psig)
0	100	14	0.25	0.0018	1170
10	250	14	0.25	0.0018	1170
25	320	14	0.25	0.0018	1170
35	485	14	0.25	0.0018	1170
40	500	14	0.25	0.0018	1170
50	389	14	0.25	0.0018	1170
65	180	14	0.25	0.0018	1170
75	286	14	0.25	0.0018	1170
80	320	14	0.25	0.0018	1170
100	190	14	0.25	0.0018	1170

The above pipeline data file is included with program disk as `MyPipe001.TOT`.

The two pump stations, pump curve data and the pump configuration are as follows:

Pump station	**Distance** (mi)	**Suction Pressure** (psi)	**Drive Type**	**Installed HP**
Compton	0.0	25.0	Motor	2 - 2000
Dimpton	50.0	50.0	VSD	1 - 2000

The VSD motor speeds in RPM are as follows:

Rated	Minimum	Maximum
3500	2000	4000

The pump stations, pump curve data and the pump configuration are as follows:

Pump station	**No. of pumps**	**Configuration**	**Pump curves** (data file)
Compton	2	Parallel	`Compton.pmp`
Dimpton	1	Parallel	`Dimpton.pmp`

Pump curve: `Compton.pmp`

Flow (gpm)	Head (ft)	Efficiency (%)
0	3185	0.0
400	3150	34.5
600	3135	46.4
800	3100	55.7
1200	3035	64.3
1600	2900	78.0
2000	2690	81.2
2400	2350	79.3
2700	2100	76.0
3000	1800	72.0

Pump curve: `Dimpton.pmp`

Flow (gpm)	Head (ft)	Efficiency (%)
0.0	3170	0.0
400	3160	34.3
800	3140	57.5
1200	3130	72.0
1600	2820	79.0
1900	2560	80.0
2000	2460	79.8
2400	2060	76.0
3000	1680	65.7

There is one heater station located at Davis (milepost 40) as follows:

Location	Heater Discharge Temp (deg.F)	Efficiency (%)
Davis	140	80.0

The liquid properties and other pipeline data are as follows:

Product Name	ANSCrude
Specific gravity at 60 deg F	0.890
Specific gravity at 100 deg F	0.825
Viscosity at 60 deg F	43.00 centistokes
Viscosity at 100 deg F	15.00 centistokes
Delivery pressure at Terminus	50 psi
Flow rate at inlet temperature	85,000 bbl/day
Pipe Depth of cover	36 in
Insulation thickness	1.0 in
Insulation Conductivity	0.02 Btu/hr/ft/deg F
Pipe Conductivity	29.0 Btu/hr/ft/deg F
Thermal conductivity of soil	0.7 Btu/hr/ft/deg F
Soil temperature	55 deg F
Liquid temperature at pipe inlet	140 deg F

The pump curve data files for this sample problem are included with LIQTHERM and should be available in the document (C:\Documents\Liqtherm) folder.

4.2 Solution

In the main program window, choose **File** from the pull down menu by using the mouse**.** Choose **Open** to open an existing file. You are presented with the **File/Open** screen to choose the name of the pipe data file. All pipe data files are contained in an XML style file with a filename extension of `.TOT`. Similarly, pump curve data files are designated with a file extension of **`.PMP.`** For example, a pipeline data file may be **`MYPIPE.TOT`** whereas a pump curve data file may be shown as **`DIMPTON.PMP.`**

You may also click on the **Open file** icon on the toolbar to open a data file.

Type **`MyPipe001.TOT`** for the filename. The sample pipeline data file opens up in an Excel style spreadsheet. This data file contains the pipeline information for the sample problem. Verify that this data matches this problem.

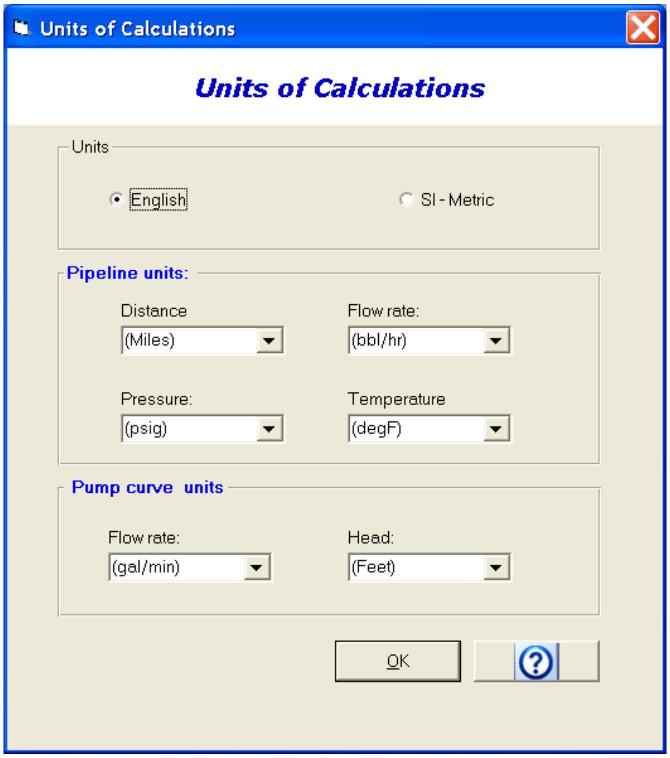
Alternatively, to create a new data file, choose **File** followed by **New.** A blank editing window (spreadsheet style) will be presented for inputting the data. Input the pipeline data similar to the sample problem.

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

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

The pipe delivery pressure at the end of the pipeline and the minimum pipe pressure required for clearing any high elevation points are entered on the lower portion of the spreadsheet.

To proceed with the sample problem, choose the pull down menu item **Options** *followed by* **Units.** The following window opens up:



This screen is used to choose English or SI-Metric units of calculation. Options are available for different sets of units for pipeline distance, pipeline flow rates, pressures and temperatures. For pump curve data you may choose the units for flow rate and head. Note that the pipeline flow rate units need not necessarily be the same as the pump curve flow rate units.

In English units, pipeline distances have to be in either miles or feet. Pipeline flow rates for English units can be in gallons/minute, barrels/hour or barrels/day. Pressures are input in psig and temperatures in deg F. For pump curve data - flow rates are input in gal/min or bbl/hr and head is input in either ft or psig.

For SI units, distance options are kilometers or meters and flow rates may be in m^3/hr, liters/minute, tons/hr or Megatons/hr. Pressures can be input in kilopascal, Megapascal, Bar or kg/cm^2 Temperatures are input in deg C only. For pump curve data - flow rates are input in m^3/hr or liters/minute and head is input in meters only.

In both cases selections are made from the appropriate drop-down lists.

Choose English units of calculations for the sample problem. Also choose *miles* for units of distance, *bbl/day* for pipeline flow rate units, *psig* for pressures and *deg F* for temperature. For pump curves, choose the units of pump flow rate in *gal/min* and head in *feet*.

Click the **OK** button, after making your choice.

Next, choose **Options** *followed by* **Formula** and choose the default formula (Colebrook-White) for the sample problem.

If you choose **Hazen-Williams** formula, the Hazen-Williams C-value may either be specified or automatically calculated by the program. The two choices **Colebrook-White** and the **Moody friction factor** method are very similar. The original Moody method was modified based on US Bureau of Mines experiments and referred to as the **Modified Colebrook-White equation**. This latter equation for pressure drop is more conservative and results in a higher pressure drop per unit length of pipeline. Read the explanation of the pressure drop formulas in the **Reference** section of this manual.

Other input data are entered using the pull down menus such as **Stations, Liquid** and **Conductivity.** Default values are provided for the above input data fields, which in most cases will match the sample problem.

To input the pump, heater, valve and fittings data, click on the pull down menu titled **Stations** followed by the appropriate option, such as **Pump Stations**.

Begin by inputting the pump station name, distance from the beginning of the pipeline (such as mile post location), the ON or OFF status of pump, default pump efficiency and suction pressure. If pump curve data is not available, LIQTHERM calculates the horsepower required at each pump station by using this default efficiency for each pump stations.
Note: A maximum of 100 pump stations can be specified.

After clicking Update in the station screen, choose the **Pumps and Drivers** tab; enter the details of each pump station, pump configuration (series or parallel), pump curve data, driver HP and pump ON/OFF status. Press **F3** for available pump curve files, when in the cell containing pump curve data. Additional data, such as drive type (Motor, Engine, Gas turbine, and Variable Speed Drive Motor), the rated speed, minimum speed and maximum speed, if available, can be specified as well. If you choose Motor, all speeds (rated, minimum and maximum) will be the same, indicating constant speed electric motor. For Variable speed electric motor, choose VSD motor and enter the rated, minimum and maximum speeds.

Remember that for variable speed pumps, the pump curve data specified is assumed to be at the rated speed. LIQTHERM will calculate the pump performance at different speeds as needed, using the Affinity Laws for centrifugal pumps.

You may cycle through each pump station data using the **Previous** and **Next** buttons.
If you have not decided on the pump curves for a specific pump station, enter TBD under pump curve and specify a value for the driver HP. Make sure the Unit is ON. ***Do not enter any more TBD entries under pump curve data.***

To view or edit a pump curve file, double click on the pump curve file name. A File open screen will be displayed, with the default pump curve name. Click **Open** and a screen containing the pump curve data will be displayed. From this screen, the pump performance at different speeds or impeller size and viscosity corrected performance can be calculated.

Finally, click the **Save** button to save all pump station data and exit this screen.

Note that the pump curve data must be corrected for viscosity of the liquid when pumping viscous liquids. In the screen above, a check box is provided for *automatic* corrections for high viscosity. This means that the pump data files must contain head, flow rate and efficiency values for water and LIQTHERM will correct the performance for high viscosity liquids. You may also choose to input pump curve data that have already been corrected for viscosity using either the Hydraulic Institute Charts or SYSTEK's program **PUMPCALC.** Alternatively**,** use LIQTHERM's **Viscosity Correction** Option provided under **Pump Curves.** After opening a pump curve file, use the menu options for viscosity correction.

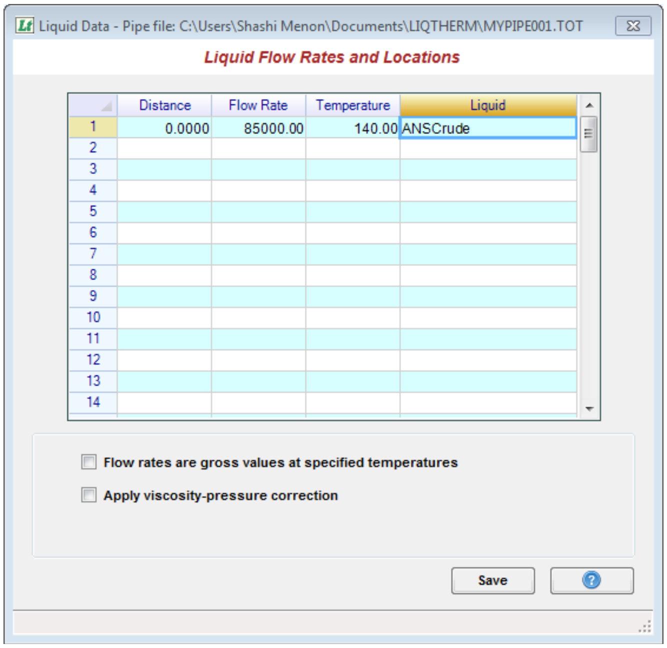
Double-clicking on the pump data file name opens up a spreadsheet for editing the pump curve data file. You may review the pump data, make changes, save the changes or plot the pump curve data from this spreadsheet. A maximum of 5 pump data files can be specified for each pump station. Each pump data file may have up to 15 sets of data points (flow rate, head and efficiency values).

When entering pump curve data, make sure that the first column containing flow rates are in increasing order, with each subsequent value larger than the previous value.

Refer to the **Pump Curve Data File** for further details on How to Create, Edit and Save Pump Data file.

After the sample problem data is input, save data and close the screen.

Next, click on the beaker icon or choose the pull down menu item **Liquid** followed by **Flow Rates**. This screen is used to enter the location, the liquid flow rate, the temperature and product name such as gasoline, diesel etc.



At the beginning of the pipeline, where the product enters the pipeline, *a flow rate must be entered as a positive number* such as 85,000 bbl/day for the sample problem. If there is a *delivery* at a particular point on the pipeline, the flow rate in this column will have a *negative* value.

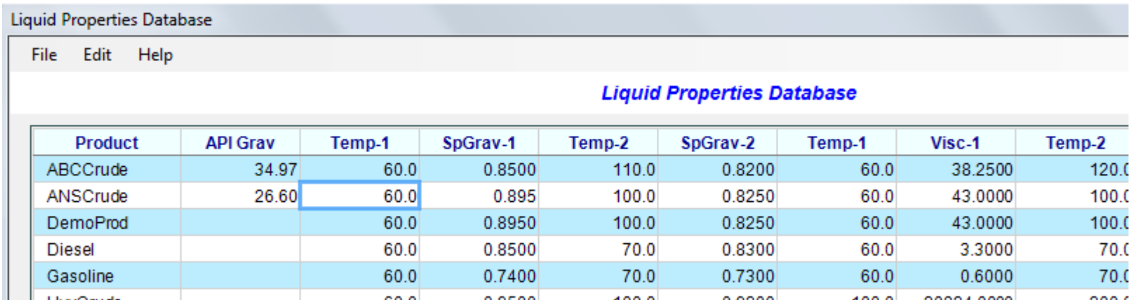
The third column is for the inlet temperature of the liquid. All injection points should have inlet *temperature and product name specified*. For delivery or outgoing locations no temperature or product name entries are needed. No flow rate need to be entered at the last milepost.

The last column is for selecting the product transported. Choose from available product names (PRODUCT-A, XYZCRUDE etc.) from the default database by pressing **F3**. At locations where flow is *out* of the pipeline (negative), *do not* enter any product name.

Note: *No entry is needed at the last milepost location, for delivery out of the pipeline at the pipeline terminus.*

The status bar at the bottom of the spreadsheet window briefly describes the expected data in each cell. In English units, the pipeline flow rate may be *gal/min, bbl/day or bbl/hr*. If a different unit such as bbl/hr is desired, enter the data in the spreadsheet as above, go to the pull down menu for **Units** under **Options** and select the appropriate units, *before initiating calculations.*

To add new liquid property data to the Liquid property database screen, open the database from **Liquid** on the menu bar and click on **Database**. The following screen opens up.


Liquid Properties Database

File Edit Help

Liquid Properties Database

Product	API Grav	Temp-1	SpGrav-1	Temp-2	SpGrav-2	Temp-1	Visc-1	Temp-2
ABCCrude	34.97	60.0	0.8500	110.0	0.8200	60.0	38.2500	120.0
ANSCrude	26.60	60.0	0.895	100.0	0.8250	60.0	43.0000	100.0
DemoProd		60.0	0.8950	100.0	0.8250	60.0	43.0000	100.0
Diesel		60.0	0.8500	70.0	0.8300	60.0	3.3000	70.0
Gasoline		60.0	0.7400	70.0	0.7300	60.0	0.6000	70.0

This is a simple database of liquid properties such as API gravity, Specific gravity and viscosities at different temperatures and units such as centistokes, centipoise, SSU and SSF. You may add new products, edit the data above and save changes as needed.

Double clicking on a cell containing Specific gravity, API gravity or Viscosity will open up conversion screens to convert from one set of units to another.

You must enter two distinct sets of values for temperature and specific gravities for each product for thermal hydraulics. For example, enter specific gravities at 60 F and 100 F. Similarly, two sets of viscosity versus temperature values must be input. However, for isothermal flow, such as for water and refined products (gasoline, diesel, etc) the specific gravity and viscosity values may be input at a single temperature, as long as the pipeline inlet temperature is also the same.

The liquid properties database can be saved under different file names such as *CrudeOilDatabase* containing all the crude oil properties or *RefinedProductDatabase* containing all the refined product properties. Create the database and save it, using File/SaveAs option to rename your file. Remember however, that you can use only one Database file at a time for selecting the products. For example, while running Mypipe.TOT file, you have incoming and outgoing flows. All the products incoming and outgoing have to be from one database. In other words you CANNOT choose one product, say **Gasoline** from *RefinedProductDatabase* and another product **Diesel** from another file named *XYZProductDatabase*. Both products **Gasoline** and **Diesel** should be chosen from the same database. You are allowed to change the database association each time you make a run.

Next, click on the **Calculator** icon on the toolbar to start calculations. In the resulting screen, enter the project title, case number and name of the output file name.

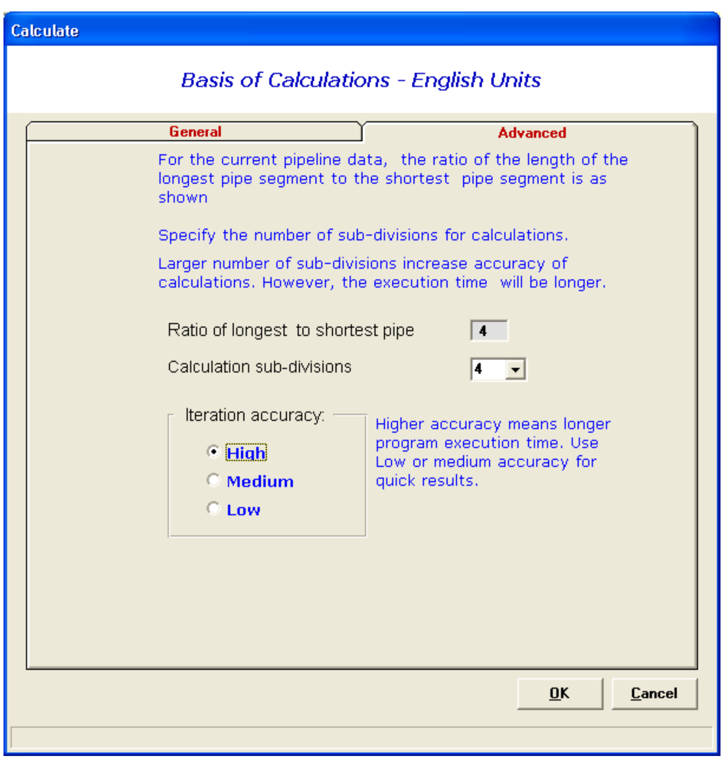
The project title may be a maximum of four lines. Press the **Tab** key to move from each line to the next to enter the additional lines for the project title. The calculated results are stored in an output file as shown above. You may rename this file when making multiple runs for the same pipeline system. For example, if the pipeline data file is named `MyPipe001.TOT` as in the sample above, the output file may be named **`MyPipe001.001`, `MyPipe001.002`**, etc. Clicking the **OK** button initiates calculation.

Notice that the pipe data file name and the corresponding output file names are shown as **`MyPipe001`** and **`MyPipe001.OUT`** respectively. If the input pipe data file were `ANewPipeline`, the corresponding results of calculation will be stored in a file named `ANewPipeline`**`.OUT`**. Change the output file name as desired.

For customizing the output report, such as a short or a long output, click **Option/Customize Report…** and choose the options desired.

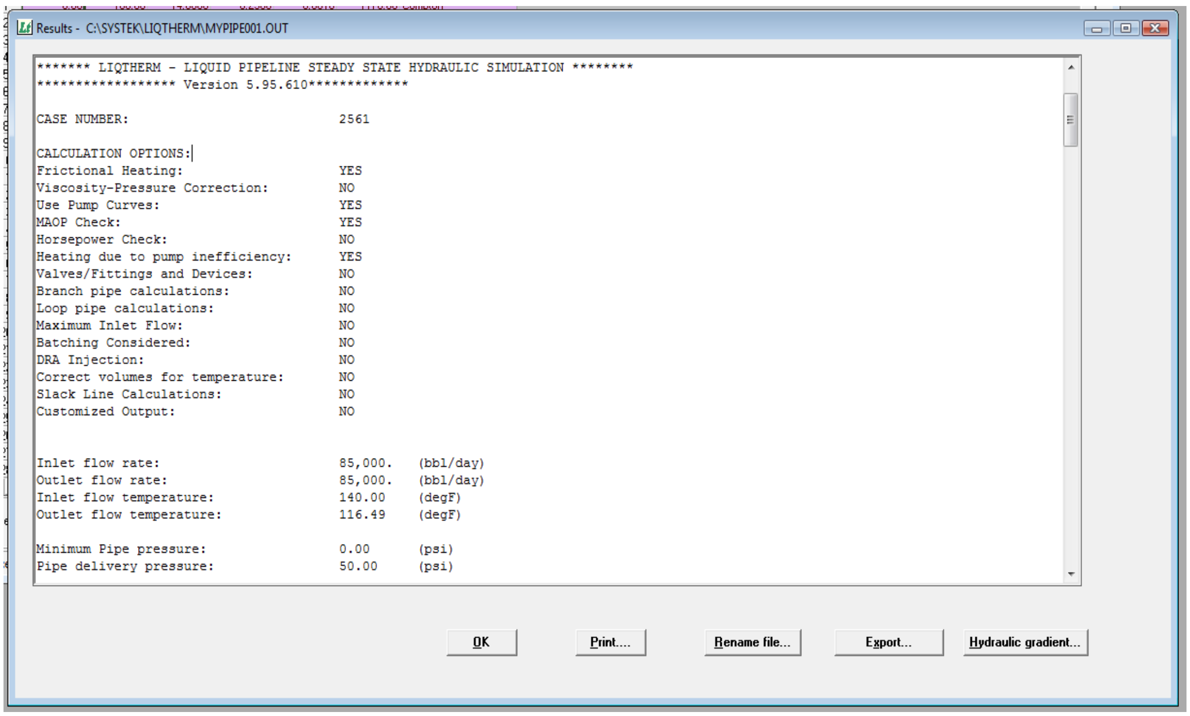
Please pay special attention to the check boxes on the right side of the screen. Ensure that the **Pump curves and MAOP check** categories are checked for the sample problem, indicating that pump curves are to be used and calculated pressures have to be checked against Maximum Allowable Operating Pressure (MAOP) values. If all information above is correct, press **OK** to start calculations.

The calculation accuracy can be improved by increasing the sub-divisions in the **Advanced** tab. However, this may sometimes result in extraordinarily long program execution time.



After a pause, varying from a few seconds to several minutes depending on the length of the pipeline and computer speed, the results of the calculation are displayed in a scrollable text window as shown next.

The calculated results are automatically saved on disk. If the input pipe data file is `MyPipe001.TOT` the corresponding output file will be saved under the name `MyPipe001.OUT`. After viewing the results of the calculations on screen, click the **Print** button to print the results on the printer. The button titled **Hydraulic Gradient** is for plotting the hydraulic pressure gradient. **Rename File...** can be used to rename the output file.



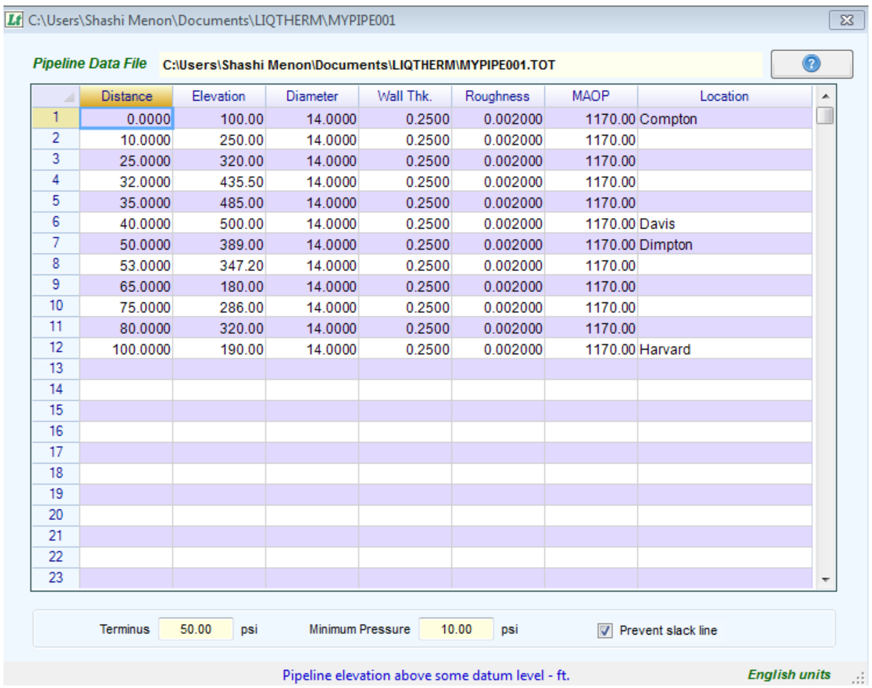
The calculated results are included at the end of this User Manual under the heading **Sample Output.**

4.3 File Format for Pipe Data File

The screen below shows a sample pipe data file used with LIQTHERM. It is displayed in a spreadsheet when you use the pull down menu **File|Open.** *The status bar located at the bottom of the spreadsheet window briefly describes the expected data in each cell.*

4.4 Creating a pipe data file

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



	Distance	Elevation	Diameter	Wall Thk.	Roughness	MAOP	Location
1	0.0000	100.00	14.0000	0.2500	0.002000	1170.00	Compton
2	10.0000	250.00	14.0000	0.2500	0.002000	1170.00	
3	25.0000	320.00	14.0000	0.2500	0.002000	1170.00	
4	32.0000	435.50	14.0000	0.2500	0.002000	1170.00	
5	35.0000	485.00	14.0000	0.2500	0.002000	1170.00	
6	40.0000	500.00	14.0000	0.2500	0.002000	1170.00	Davis
7	50.0000	389.00	14.0000	0.2500	0.002000	1170.00	Dimpton
8	53.0000	347.20	14.0000	0.2500	0.002000	1170.00	
9	65.0000	180.00	14.0000	0.2500	0.002000	1170.00	
10	75.0000	286.00	14.0000	0.2500	0.002000	1170.00	
11	80.0000	320.00	14.0000	0.2500	0.002000	1170.00	
12	100.0000	190.00	14.0000	0.2500	0.002000	1170.00	Harvard
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							

Most data are entered in Microsoft Excel compatible spreadsheet that results in easy editing and cut and paste operations via the Windows clipboard. The spreadsheets are saved in a proprietary file format compared to the familiar .XLS file extension for Microsoft Excel. For the sample problem, pipeline profile data (distance, elevation, pipe diameter, wall thickness, pipe roughness, MAOP) is saved in a file designated as MyPipe001.TOT. *Do not edit this file using a text editor or Word Processor.* To edit the input data file, use only the LIQTHERM spreadsheet editor described here. You may export files to or import files from an Excel Spreadsheet, via the Windows Clipboard.

The pipeline data file name can be a long filename (max 255 characters) with a 3-letter extension, such as ACME 16-INCH PIPELINE.TOT. *The file name extension must be TOT and if not specified, is automatically appended by the program.* The calculated results are automatically saved under the same name, with file extension of OUT. Thus, if the input pipe data file is named **`MyPipeline.TOT`**, the results of the calculations are stored in the output file **`MyPipeline.OUT`** in the same sub-directory or folder. *After each successful run, a backup file (with a .BAK extension such as* **`MyPipeline.BAK`**) *of the TOT file is automatically created within the same folder.*

Note: All pipeline and pump data files are always saved in C:\Documents\Liqtherm folder. By backing up the My Documents\Liqtherm folder you have the assurance of saving all files created during the Liqtherm session.

The screen shot on the previous page shows the spreadsheet editor with a sample file already typed in. Initially, when creating a New pipe data file, the title above the spreadsheet will be blank, but once data is entered and the file saved, the name of the sub-directory and data file are shown on the title panel just above the spreadsheet as seen on the previous page.

Each column in the spreadsheet is for a specific data for the pipeline. Each row represents a specific location along the pipeline. The first column is for the distance *measured from the origin* of the pipeline, such as *mile post or Km 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.).

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, fourth and fifth columns represent the pipe *outside* diameter, pipe wall thickness and pipe absolute roughness at this location. The pipe diameter, wall thickness and roughness entered at a specific location represent those for the pipe segment *downstream* of that milepost location. Thus, if the first two milepost locations are 0.0 and 10.0, the diameter, wall thickness and roughness entered at 0.0 milepost are for the pipe segment from 0.0 to the 10.0 location. The diameter, wall thickness and roughness entered at milepost 10.0 are for the *next* pipe segment starting at milepost 10.0. Finally, for the very last milepost location (the last data row of the spreadsheet) the diameter, wall thickness and roughness entered should be a duplicate of the *immediately previous location*, since there is no pipe segment downstream of the last milepost.

The next column entry is the Maximum Allowable Operating Pressure (MAOP) for the pipe at that milepost location. If you double-click with the cursor in the cell containing the MAOP, a new screen opens up. This screen can be used to verify or calculate the MAOP of the pipe. From this screen, you may also calculate the hydrostatic test pressures for pipe hoop stresses of 80%, 90% and 100% of the specified minimum yield strength (SMYS) of pipe material.

Note: A maximum of 1,000 points (nodes) are allowed in the pipe data file and a maximum of 100 pump stations can be specified.

Location of pipeline and pump data files:

Note that all pipeline data files (including branch and loop files) *must be created and saved* under the `C:\Documents\Liqtherm` folder. These files *should not be saved* on an external disk drive or a server. LIQTHERM expects all working pipeline models and pump curve files to be always available in the Documents\Liqtherm folder. To organize pipeline models for different projects, you may save the files in sub-folders within this main folder. For example, all pipeline and pump data files for Project-A may be created and saved under: `C:\MyDocuments\Liqtherm\Project-A\ folder.`

Similarly for the project ApexPipeline, the pipeline model named ApexPipeline20-inch.TOT will be saved as follows: `C:\MyDocuments\Liqtherm\ApexPipeline\ApexPipeline20-inch.TOT`
The corresponding pump curve files **(*.**PMP), such as Station-1.PMP, Station-2.PMP, etc will also be created and saved in the same folder as follows:
`C:\MyDocuments\Liqtherm\ApexPipeline\Station-1.PMP, etc`

Also note that the pipeline or pump curve files *must not be saved* in the LIQTHERM program folder (usually `C:\ProgramFiles (x86)\SYSTEK\LIQTHERM`\).

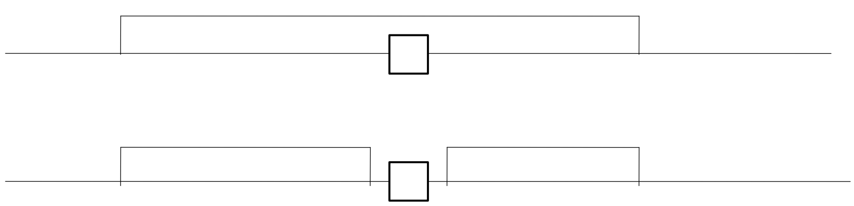
4.5 Pipe Loops

1. An important consideration with looped pipelines is that the loops must be contained entirely within a segment of the main pipeline *between* two pump stations. Also, only one pipe loop can exist between any two pump stations. No branch piping or injection/delivery may be present in this pipe segment.

2. The start and end of loops should *not* be at a location where flow delivery or injection occurs.

3. Loops cannot start at the beginning milepost or end at the last milepost of the pipeline. Ensure that a small length (such as 0.01 miles) of main pipe *precedes* the start of the loop and similarly a small section of pipe *follows* the end of the looped pipe segment.

If there is a pipe loop upstream and downstream of a pump station as shown in the sketch below, the loops have to be split so that the entire loop is contained between the pump stations, resulting in two loops as shown below. Otherwise calculations will be incorrect, and sometimes the program may hang up.



Loops may not be stacked. In other words, you cannot model a loop within a loop.
No pump stations are allowed on the pipe loops at this time..

4.6 Pipe Branches

Branches off the main pipeline can be modeled easily. Branches may be *incoming or outgoing*. Assuming that the branch pipe data file already exists on disk, double clicking on the branch file name will open up the contents of the branch data file in a spreadsheet on top of the existing window. If the branch file does not exist, a message will appear, asking if the data file is to be created.

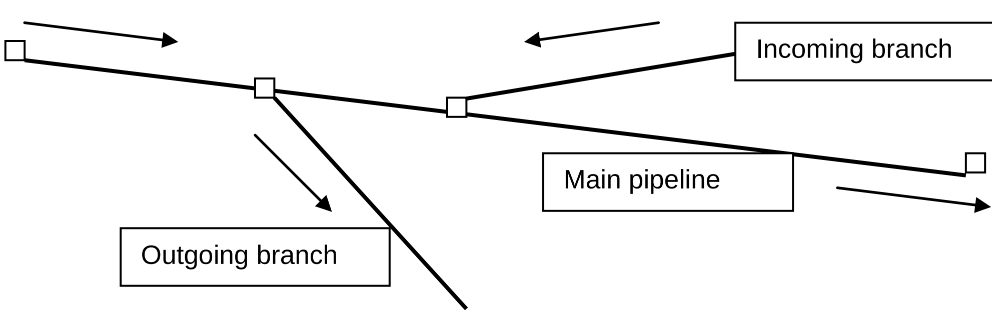
If you click on **Yes** a blank spreadsheet opens up for creating the branch pipe data file. This branch data file spreadsheet is created describing the pipe distance, elevation, flow rates etc., similar to the main pipeline as described in **Creating a data file** above. An important aspect of branch pipe format needs to be kept in mind. An outgoing branch pipe will have distances increasing in the direction of flow (outward) and the starting elevation should be the same as that of the main pipeline at the connection point. Similarly, for an incoming pipe branch, the distances are measured from the start of the pipe branch in the direction of flow, towards the main pipeline. The elevation of the pipe branch at the connecting point must match that of the main pipeline at the junction.

No pump stations are allowed on the branch piping at this time. Also, branches may not be stacked. In other words, you cannot model a branch within a branch.

Enter all data and click on **Save** when done. To abandon edit, click on **Done.** To get help, press the **Help** button

Note: *The maximum number of data points (nodes) allowed on a branch pipe is 500 points. There can be a maximum of 50 branches off the mainline.*

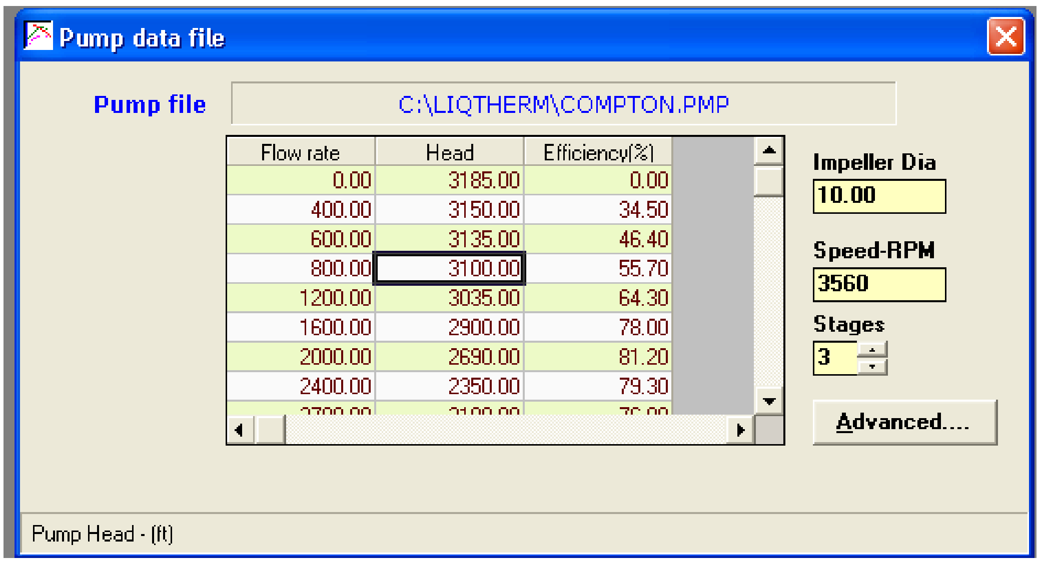
Hydraulic calculations are first performed along the main pipeline. The pressure at the main pipeline take off point is used to calculate the downstream pressures along each branch pipe. The delivery pressure at the end of each branch pipe can be specified individually (under Branch menu) or a default value for the main pipeline is used. If the main pipeline pressure at the take off point is inadequate to produce the desired delivery pressure at the end of the branch, a message indicating that the main pipeline pressure at the branch is inadequate, is displayed in the output. If the main pipeline flow rate at the branch takeoff point does not match the flow rate specified in the branch pipe data file, a warning message is displayed prior to calculations. No calculations will then be performed for that branch pipe.



Similarly, for an *incoming* branch pipe, the flow rate into the main pipeline should match the combined flow rate in the last segment of the branch pipe connecting to the main line. The program calculates the pressure at the beginning of the branch pipe needed to match the junction pressure at the main pipeline connection.

4.7 Creating a pump curve file

A pump curve file is created by entering the flow rates, heads and efficiencies of the pump at several points from the pump manufacturer's performance curve. From the **Stations** menu, under **Pump stations**, double clicking on the cell containing the pump curve name opens up a spreadsheet that will help edit or create a pump file. Choosing **Open** will show the pump curve data in a spreadsheet. To create a new pump curve, open an existing pump data file, make changes to the data and use the **Save As** option from the **File** menu to save under the new file name.



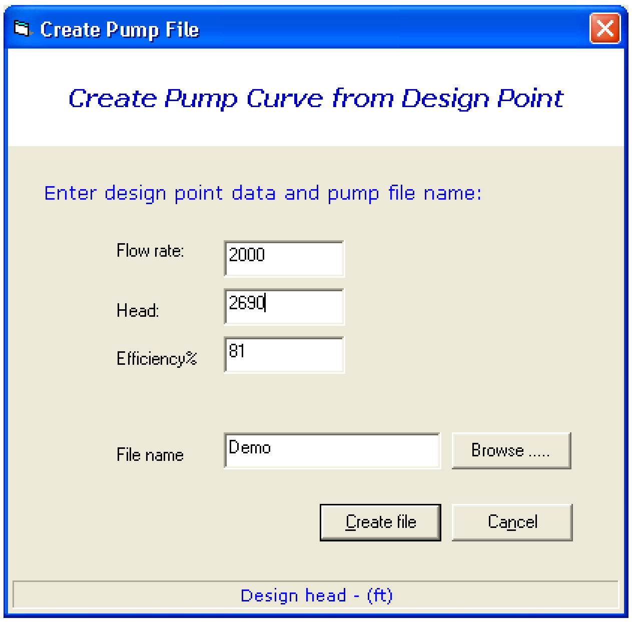
Pump curve data are ASCII text files that can be edited easily. As a rule, all pump curve data files are designated with the .PMP extension, such as COMPTON.PMP. The maximum set of data points allowed on a pump curve is 15 sets. The minimum sets of data points are three. For each pump station, a maximum of 5 pumps either in series *or* parallel configuration can be specified. Therefore 5 pump curve data files can be specified per pump station on the spreadsheet describing the pump station data.

Note that all pipeline and pump curve data files *must be created and saved* under the *C:\MyDocuments\Liqtherm* folder. These files *should not be saved* on an external disk drive or a server. LIQTHERM expects all working pipeline models and pump curve files to be always available in the MyDocuments\Liqtherm folder. To organize pipeline models for different projects, you may save the files in sub-folders within this main folder. For example, all pipeline and pump data files for Project-A may be created and saved under:
`C:\MyDocuments\Liqtherm\Project-A\` folder.
Similarly for the project ApexPipeline, the corresponding pump curve files **(*.**PMP), such as Station-1.PMP, Station-2.PMP, etc will also be created and saved in the same folder as follows:
`C:\MyDocuments\Liqtherm\ApexPipeline\Station-1.PMP`, etc

Also note that the pump curve files *must not be saved* in the LIQTHERM program folder (such as `C:\ProgramFiles (x86)\SYSTEK\LIQTHERM\`)

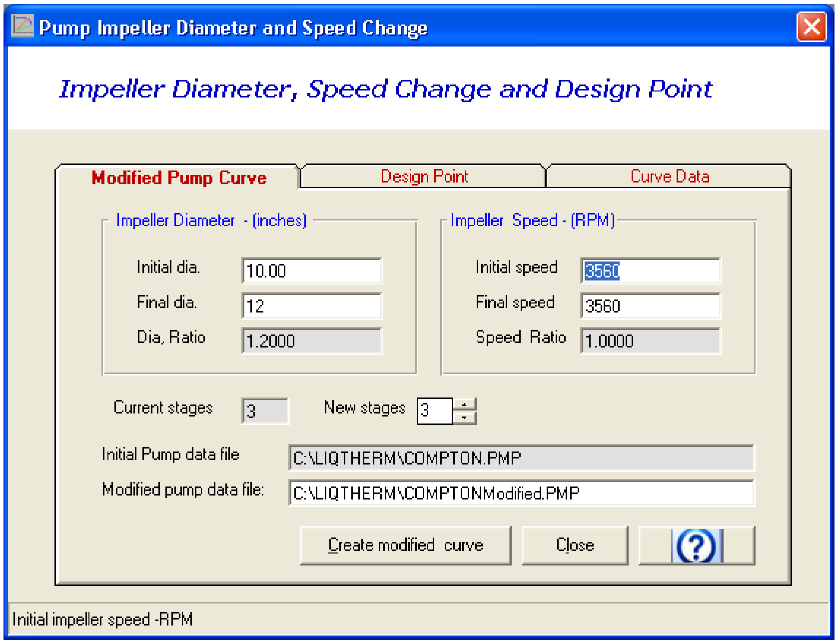
A new pump curve may also be created from a single design point (flow, head and efficiency at the best efficiency point).

Click the **Advanced…** button and the following screen is displayed

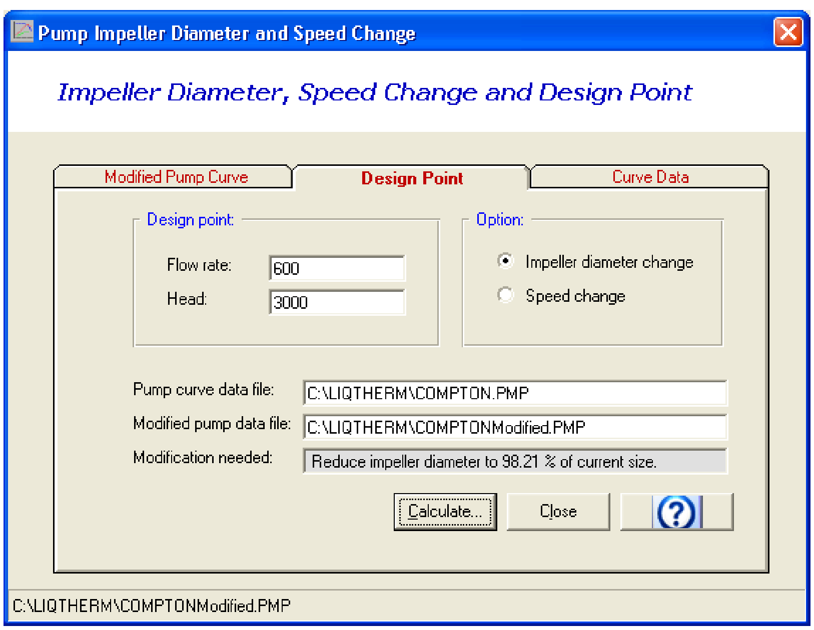


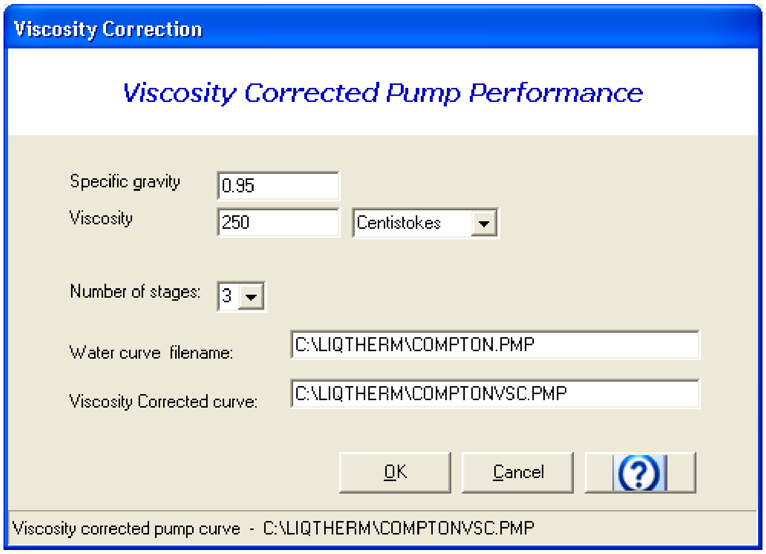
Input the flow rate, head and efficiency required at the design point, provide a new file name and click the **Create file** button. A pump curve will be generated with the specified design point as the best efficiency point (BEP).

Several other options are available with pump curves. You may plot the pump curve data, develop new pump head curves for different impeller diameter and speed and perform viscosity correction as seen from the screen below.

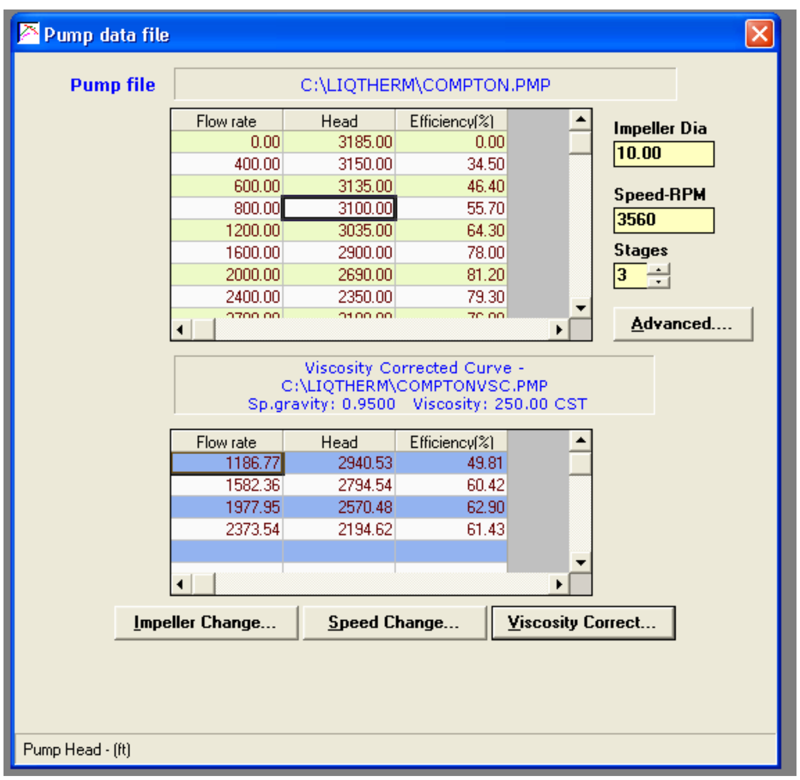


In order to determine the impeller diameter or speed change required for a specific design point (flow and head) choose the **Design Point** tab and enter information required.





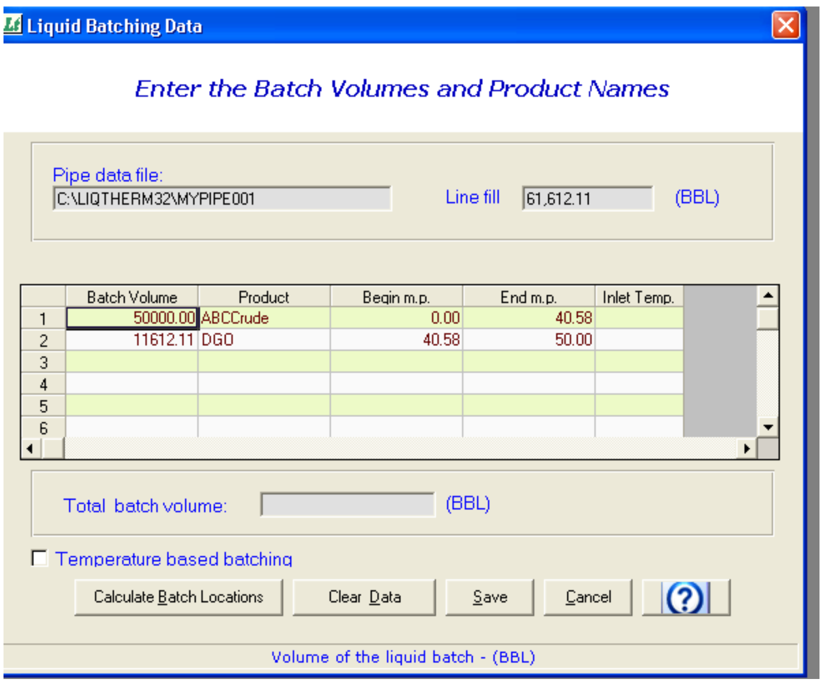
Enter the specific gravity and viscosity of the viscous liquid and click OK to create the viscosity corrected pump curve displayed along with the water performance curve as shown below.



4.8 Batching

A batched pipeline is one in which liquids of different viscosities and gravities are pumped with the least amount of co-mingling. In a typical batched pipeline, a specific crude oil or petroleum product such as gasoline may be pumped followed by another batch of a different liquid such as diesel. In order to simulate the hydraulics of such a pipeline with different batches *at any moment*, use the **Batching** option under the pull down menu **Option.**

Clicking the **Batching** menu item from the pull down menu opens up the **Liquid Batching Information** screen as follows:



The Batching screen above shows some typical information for a hypothetical pipeline system. The program automatically displays the current pipeline *line fill volume.* For each liquid batch, enter the batch size (in barrels in English units) followed by the corresponding product name. Press the F3 key to select the product from the Liquid Database Screen. Also enter the inlet temperature of each batch in the last column. Leave the column 3 & 4 blank.

Click the **Calculate Batch Locations** button and the program adjusts the last batch size to fill the pipeline volume and the beginning and ending mile post locations for each liquid batch are calculated and displayed. If the batch sizes are too large for the pipe line fill volume, a warning message is displayed and you are given an opportunity to correct the input data. Since the program automatically calculates the beginning and ending mile post location of each batch (and the corresponding *interpolated* pipeline elevation), this information can optionally be inserted in the main pipeline spreadsheet. The pipe data file is thus updated automatically. When the pipeline data file is loaded the next time, the newly created mile post locations will show up on the spreadsheet.

Once the above batch configuration is specified, hydraulic calculations can be performed by clicking on the **Calculate** icon. You can then simulate movement of the batches along the pipeline by altering the batch sequence, sizes and locations and re-running the calculations.

For a batched pipeline system, all liquid input should originate at the beginning of the pipeline. No intermediate injection or delivery points are allowed in a batched pipeline system in the current version of LIQTHERM.

4.9 AutoBatching

A batched pipeline is one in which liquids of different viscosities and gravities are pumped simultaneously with the least amount of co-mingling. In a typical batched pipeline, a crude oil or petroleum product such as gasoline may be pumped followed by batches of jet fuel and diesel as shown below.

17 Mbbl	60 Mbbl	50 Mbbl
Diesel	Jet Fuel	Gasoline

Batched Pipeline

In order to simulate the hydraulics of such a pipeline with different batches *at any moment*, use the **Batching** option under the pull down menu **Option.** This will calculate the hydraulics for a snapshot batch configuration.

With the new **AutoBatching** feature, you can simulate batching of different products dynamically as the batches move through the pipeline. Whereas the **Batching** option calculates hydraulics in a snapshot configuration, **AutoBatching** simulates hydraulics dynamically over a period of time.

For setting up dynamic batching simulation for a certain period such as 24 hours or more and simulating hydraulics in time steps of 1 hour, 2 hours or more, use the **AutoBatching** option under the pull down menu **Option.**

Here is how **AutoBatching** works:

1. Input a monthly or weekly batching schedule of different products and their volumes.

2. Specify a total simulation time, such as 24 hours or more.

3. Specify a time interval for advancing the batches, such as 1, 2, 4 or more hours.

4. If drag reduction is used, indicate the drag reduction segments and input % Drag reduction (or DRA ppm), including individual %DR (or ppm) for each product batched. For example you may specify that in the pipe segment from milepost 10 to milepost 50, the %Drag reduction is 20% for Gasoline, 30% for diesel or zero for Jet fuel.

5. You may also specify minimum pressures for each product batch, such as 250 psig for propane or 50 psig for gasoline. LIQTHERM will automatically adjust the pipeline pressures to ensure the appropriate minimum pressure is maintained to prevent vaporization of a volatile product.

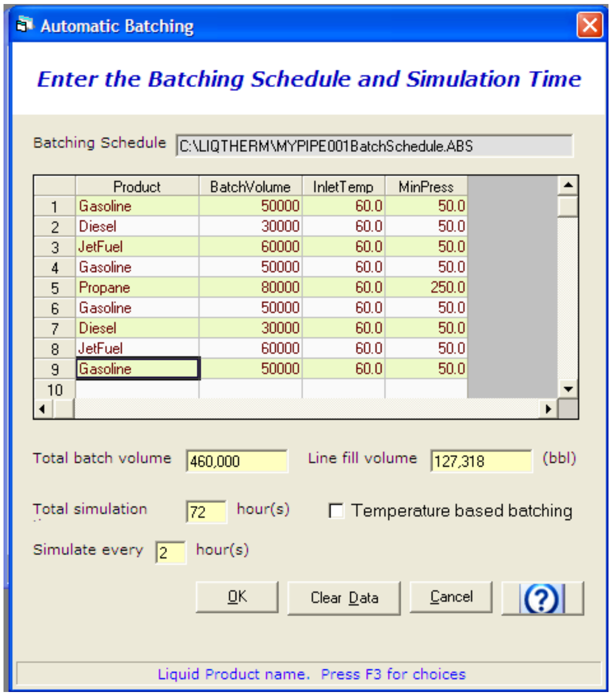
6. After the **AutoBatching** simulation, the report will show a hydraulic summary for each time step and finally an average pipeline flow rate for the simulation period. For example, in a 50 hour simulation, the flow rate for each 2 hour time step may vary from 3,000 bbl/hr to 5,000 bbl/hr, with an average flow rate of 4,200 bbl/hr.

AutoBatching data entry is explained further below:

1. First, using the **File/Open** menu, choose a pipeline data file such as MyPipe001.

2. Review global parameters such as **Units** and **Formula** for pressure drop from the **Option** menu.

3. Choose **AutoBatching** from the **Option** menu and the following screen is displayed. For illustration purposes, data has been filled in.



4. Enter the product name in the first column followed by batch volume in the second column. Then enter the inlet temperature of the batch in the third column followed by the minimum pressure in the last column. This last entry represents the minimum pressure in the pipeline for that specific product to prevent vaporization. For example, when batching propane and gasoline, a minimum pressure of 250 psig may be used for propane and 50 psig for gasoline. In isothermal flow the inlet temperature column should be the same for all products. Remember that the product name in the first column may be chosen by pressing the F3 key and selecting the product from the liquid properties database. The check box titled **Temperature based batching** is used for thermal hydraulics only.

5. It must be noted that the **Total batch volume**, which is the sum of all batches, must equal or exceed the pipeline **Line fill volume** shown. The first batch specified on this screen (row 1) enters the pipeline first followed by the batch from row 2 and so on until the very last batch (row 9) listed enters the pipeline.

The above screen shows the various batches of products to be batched in the proper order. The product that enters the pipeline first is the one shown in the first row of the spreadsheet (Gasoline). In the screen above, since the line fill is 127,318 bbl, the batches filling the pipeline will be as follows starting with 47,318 bbl of Jet fuel from row 3 above and ending with the 50,000 bbl Gasoline from row 1 as shown in the configuration below.

47.3 Mbbl	30 Mbbl	50 Mbbl
Jet Fuel	Diesel	Gasoline

Batched Pipeline

6. The **Total simulation** time is the desired time for simulating batch movements along the pipeline. The time step, designated as **Simulate every** … hours is the interval of time between each successive hydraulic simulations. Note that the total simulation must be an exact multiple of the simulation step. Therefore a time step of the 4 hours and a total simulation time of 72 hours are acceptable. However, changing the total simulation time to 75 hours will not work since it is not an exact multiple of time step of 4 hours. Clicking Cancel button cancels the **AutoBatching** simulation and closes the data entry screen.

7. After entering the batch volumes and product names and specifying the total simulation time and time step for hydraulics simulation, click **OK** to proceed with the remaining data entry such as drag reduction, pump stations data etc.

8. If DRA is used, first enter data in the **AutoBatching** screen and then proceed to enter DRA data. For DRA injection, two data entry screens are provided – **Simple** and **Batched**. Use the **Drag reduction/Batched** screen for **AutoBatching.**

Drag reduction/Simple option is for specifying DRA injection for pipe segments without regards to product pumped. Therefore, this option is used for drag reduction when batching is not used. For product specific DRA injection such as for **Batching** or **AutoBatching,** choose the **Drag reduction/Batched** option.

For more details, refer to the **Drag Reduction** section of this manual.

9. Finally in the **Calculate** screen specify the necessary options such as **Use pump curves**, **MAOP check**, **Maximum inlet flow** etc.

Note that unless the **Maximum inlet flow** option is checked, the starting flow rate will be what is specified in the **Liquid/Flow rates** screen. For example, if the inlet flow rate in the **Flow rates** screen is 5,000 bbl/hr the hydraulics simulation will be based on this flow rate and it will be reduced if necessary to limit pressures to MAOP if that option is checked. Therefore, it is recommended that in an AutoBatching case, the **Maximum inlet flow** option be checked to ensure that the highest flow rate consistent with pipeline and pump capacity is obtained.

Since **AutoBatching** performs several hydraulics simulations as the batches move, it takes longer to create a report compared to a simple simulation such as a snapshot batching hydraulics. For example if a simple snapshot batching case takes 30 seconds and you want to simulate Autobatching for a total of 100 hours every 2 hour time step, the 50 simulations will take 50 x 30 = 1500 seconds or 25 minutes. In some cases, especially with VFD pumps and many pump stations, Autobatching could take 2 to 3 hrs to complete depending upon the total simulation time desired. Therefore, for quick results, choose the **Low** or **Medium Iteration accuracy** option under the **Advanced** tab of the **Calculate** screen. Once a preliminary run is made, and an average flow rate obtained, you may want to rerun the case with a higher accuracy.

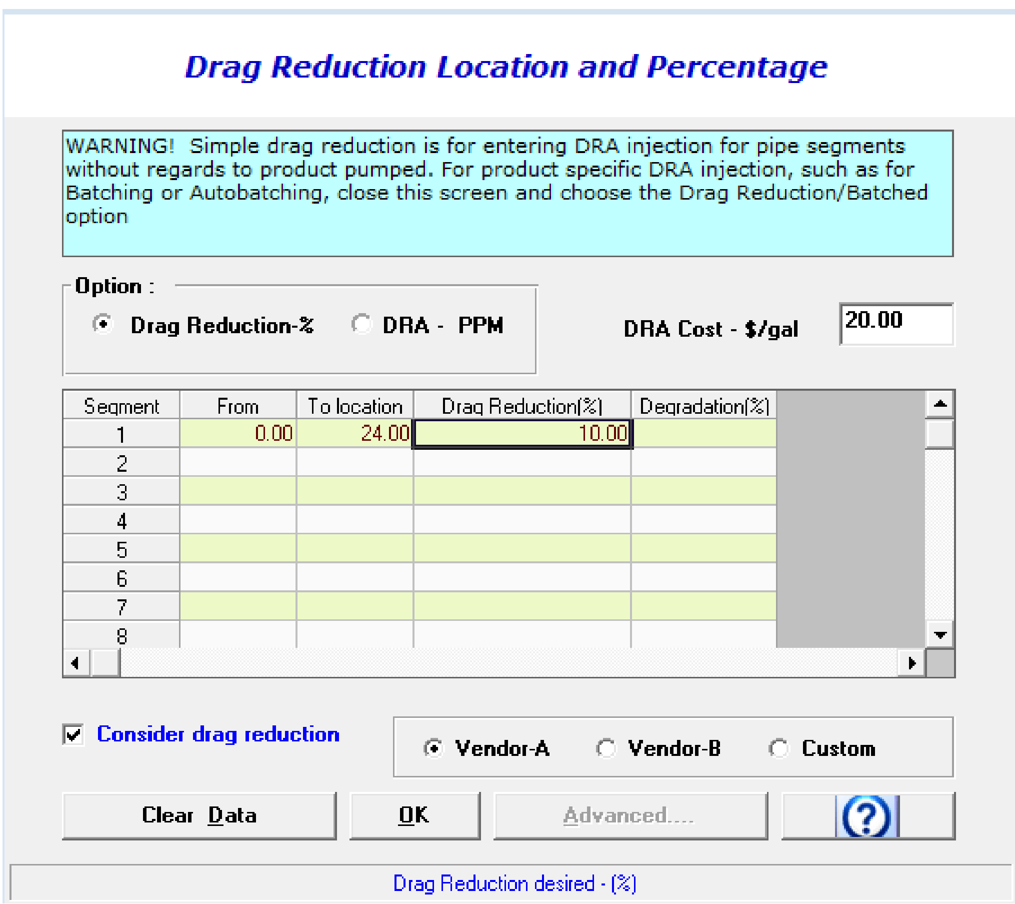
4.10 Drag Reduction

A Drag Reduction Additive or Agent (DRA) is sometimes used for de-bottlenecking pipelines to improve flow rate, when the pipeline throughput is limited by MAOP. LIQTHERM includes an option to simulate DRA injection by specifying pipe segments where DRA injection is used.

Input may be in percent Drag reduction (% DR) or parts per million (PPM) of DRA. Two generic algorithms (Vendor A and Vendor B) are built-in to LIQTHERM for calculating the PPM from the percent drag reduction. A DRA degradation rate may also be specified. This number represents the linear reduction in percent DR for the pipe segment. You must contact the DRA vendor to verify the actual DRA PPM required for the assumed percent Drag reduction. In addition to the two generic algorithms, a Custom DRA option is provided for users that may have their own algorithm based upon field test data.

Note that PPM of DRA is based on volumes not weight. See the **Reference** section for details.

From the main LIQTHERM screen, under the **Option** menu, choose **Drag reduction....Simple** and the following screen is displayed.



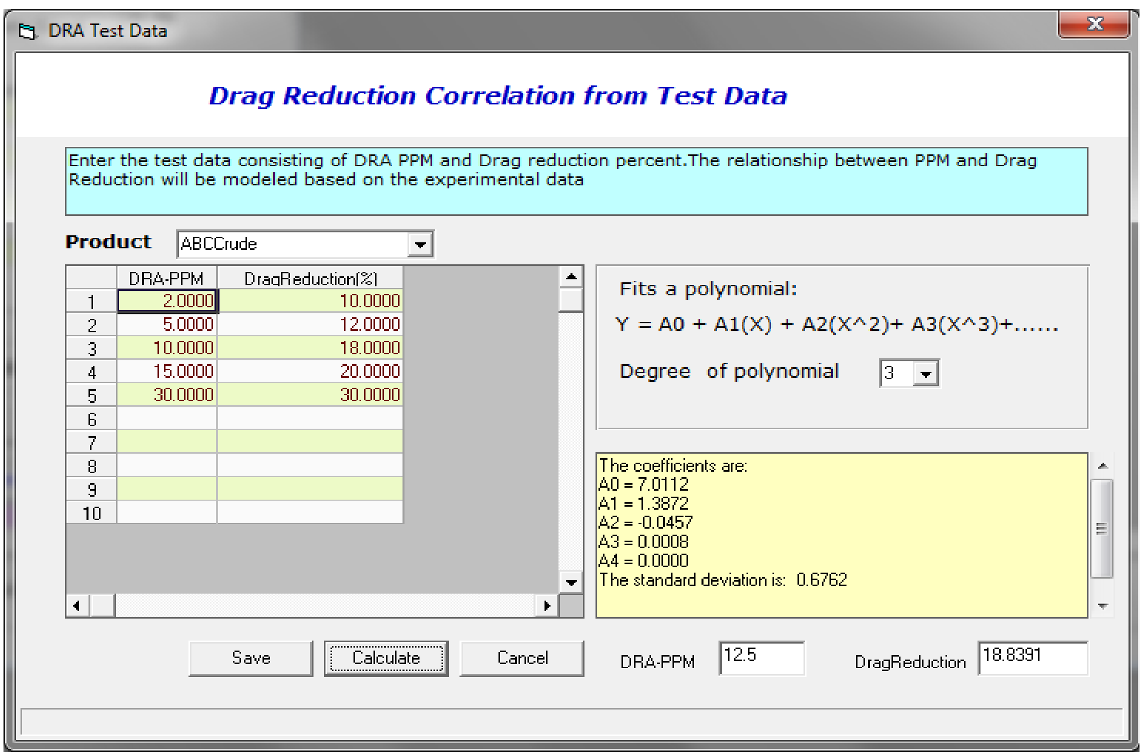
Drag reduction/Simple option is for specifying DRA injection for pipe segments without regards to product pumped. Therefore, this option is used for drag reduction when batching is not used. You have a choice of Vendor A, Vendor B or Custom algorithm. Choosing Vendor A or Vendor B gives you built-in formulas for calculating PPM of DRA from %drag reduction and vice versa. See the following page for more information on **Custom DRA algorithm.**

Enter the locations (mileposts) where the DRA is injected and the percentage of drag reduction expected or ppm of DRA for that pipe segment. Since the effectiveness of each DRA may be different, you must specify a start and end of each DRA segment. A percentage degradation may also be input.

Note that you must specify distinct pipe nodes (mileposts) for the DRA injection points. These start and end points *cannot be the same* as the pipe origin, pipe terminus, a pump station, pipeline flow entry or exit point, or location of heaters, devices, branches or loops.

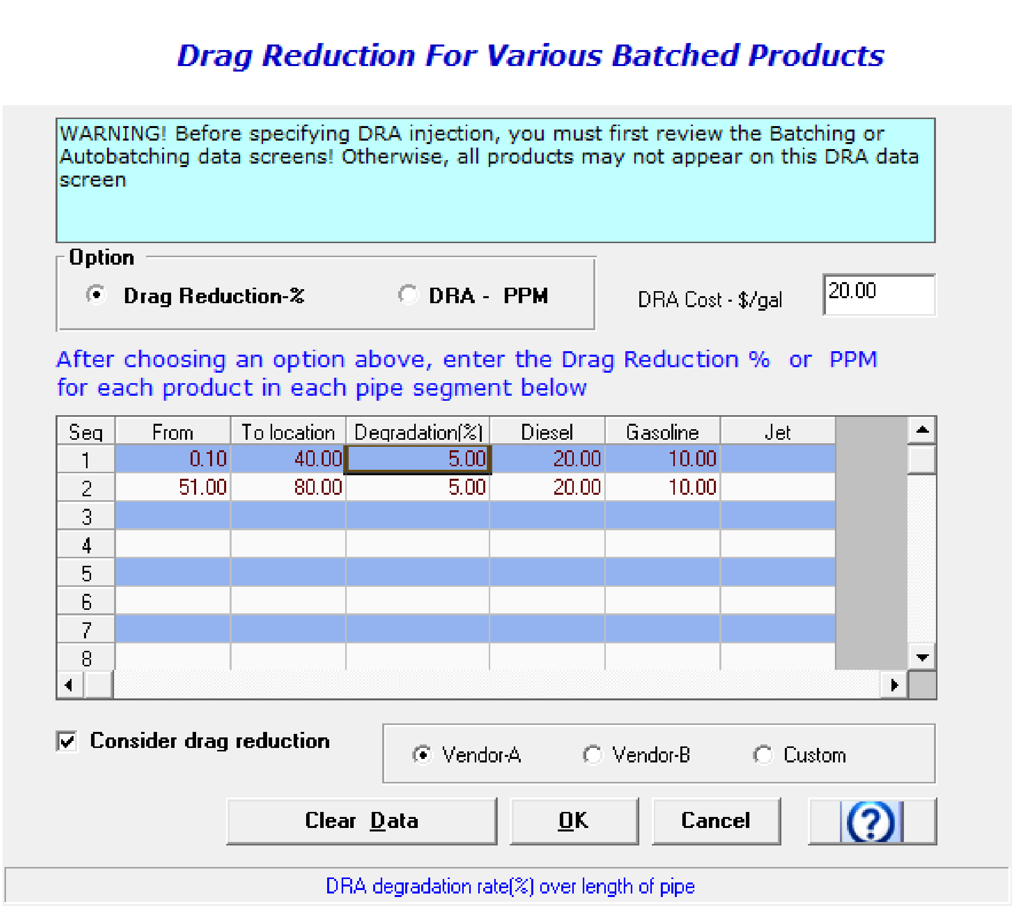
For example, if the pump stations are located at milepost 0 and milepost 50 on a 100 mile pipeline, DRA injection can start at milepost 0.1 and end at milepost 49.9. It may also start at milepost 50.1 and end at milepost 99.9.

If you choose **Custom** DRA algorithm and click **OK**, the following screen is displayed:



Available experimental data for the pipeline, such as DRA ppm versus percent Drag reduction may be entered in the screen above. A suitable polynomial correlation can be developed for the data. This relationship will then be used in the hydraulic simulation.

If **Batching** or **AutoBatching** is used**,** choose the **Drag reduction/Batched** screen from the Option menu. This will display the following screen.

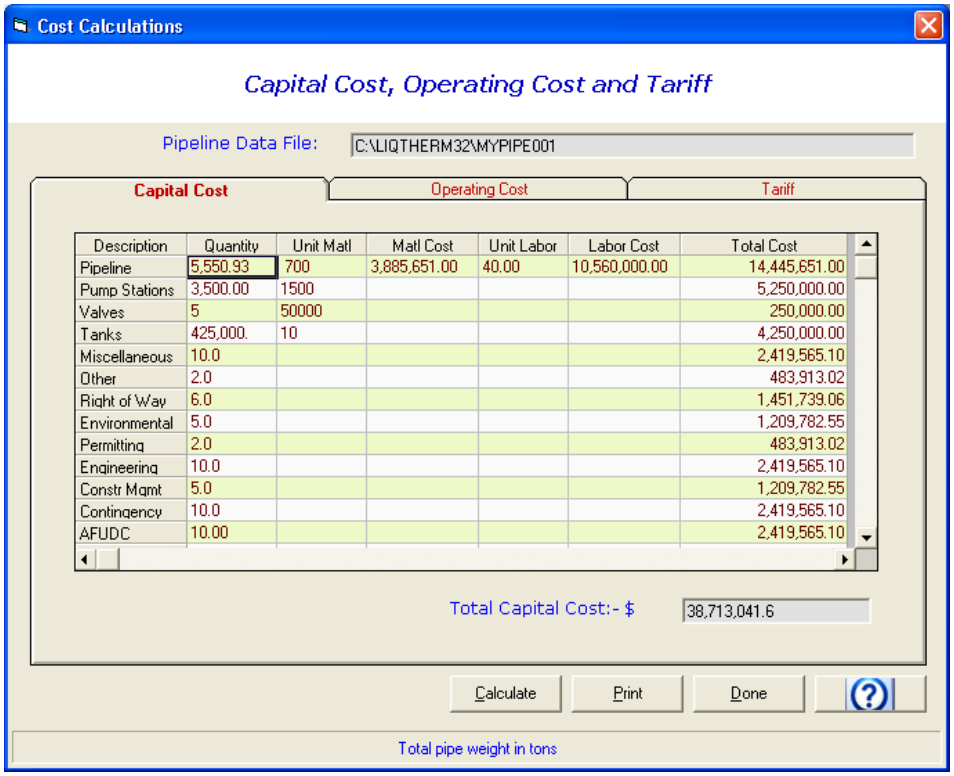


When batching various products, you may specify different DRA injection rate or % drag reduction for each pipe segment depending upon the product batch that traverses the segment. Thus in the screen above, for the pipe segment between milepost 0.01 and milepost 40.0, the DRA injection rate is 20% for the Diesel batch and it is 20% for Gasoline.

As before, you may choose between Vendor A, Vendor B or Custom DRA algorithm. Choosing Vendor A or Vendor B gives you built-in formulas for calculating PPM of DRA from %drag reduction and vice versa.

4.11 Cost Calculations

The toolbar icon with a **$** sign is used for quick estimation of pipeline capital costs, annual operating costs, the annual cost of service and transportation tariff. On clicking this icon the following screen is displayed:



Description	Quantity	Unit Matl	Matl Cost	Unit Labor	Labor Cost	Total Cost
Pipeline	5,550.93	700	3,885,651.00	40.00	10,560,000.00	14,445,651.00
Pump Stations	3,500.00	1500				5,250,000.00
Valves	5	50000				250,000.00
Tanks	425,000.	10				4,250,000.00
Miscellaneous	10.0					2,419,565.10
Other	2.0					483,913.02
Right of Way	6.0					1,451,739.06
Environmental	5.0					1,209,782.55
Permitting	2.0					483,913.02
Engineering	10.0					2,419,565.10
Constr Mgmt	5.0					1,209,782.55
Contingency	10.0					2,419,565.10
AFUDC	10.00					2,419,565.10

The above screen displays the three tabs for *Capital cost*, *Operating cost and Tariff*. Most of the data in the various fields have already been filled in as a result of the hydraulic calculations. Make changes as needed and click the **Calculate** button to recalculate the costs.

In the Capital Cost screen, for the current pipeline system, the pipe tonnage, number of pump stations, estimated main line valve installations, tankage in bbl and miscellaneous costs are shown.

In English units, Pipe material cost is based on a default value of $1500 per ton and pump station cost is based on $1500 per HP installed. Tankage cost is calculated based on $10/bbl. These numbers can be changed as required.

In SI units, pipe material cost is based on $1500 per ton and pump station cost is based on $800 per HP installed. Tankage cost is calculated at $60 /cu.meter,

These default values may be changed as needed.

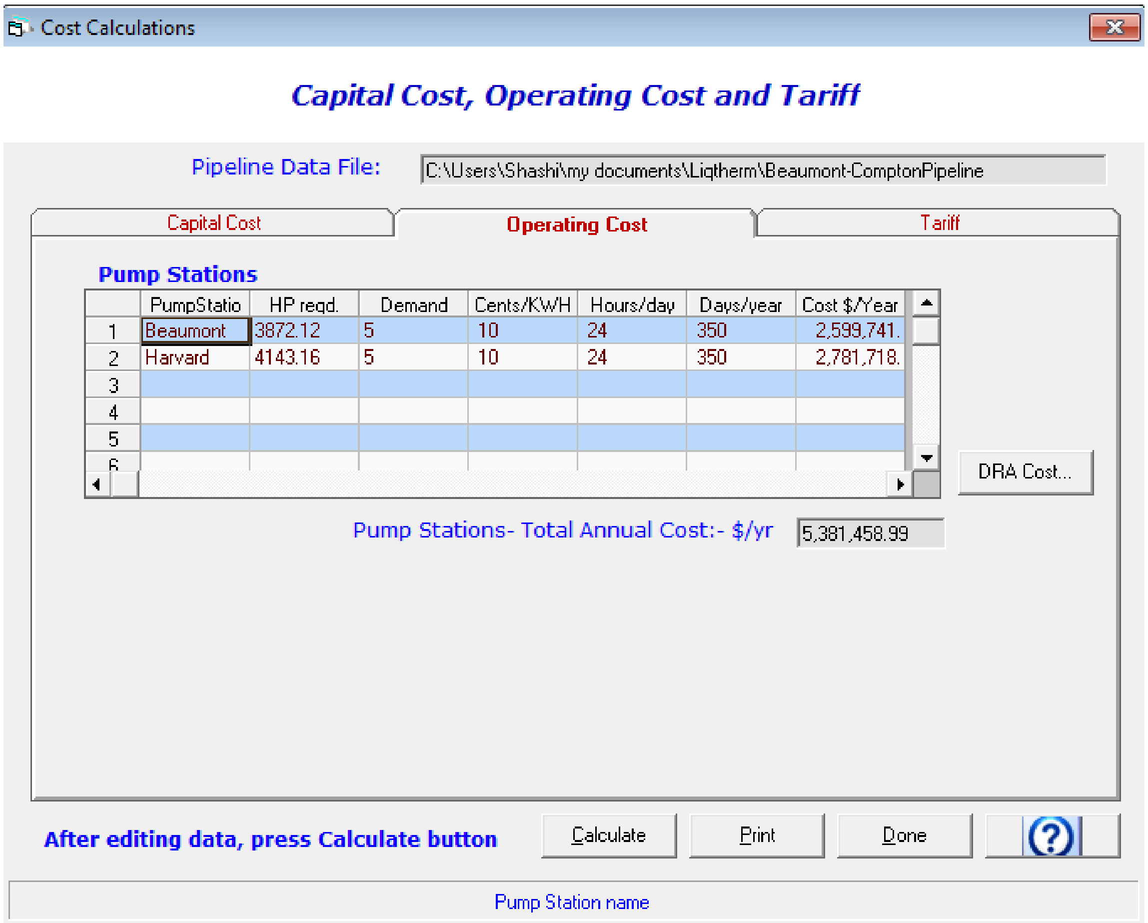
Other costs such as ROW, engineering etc are percentage estimates based on the sub-total of the first 4 items. Default values used for typical pipeline are:

Miscellaneous - 10%
Right of Way (ROW) - 6%
Environmental - 5%
Permitting - 2%
Engineering - 10%
Construction management - 5%
Contingency - 10%

To use a different value for any of the above indirect cost categories, make changes in the last column, titled Total cost.

Press **Calculate**, to re-compute the new capital cost.

Similar to the Capital cost tab, the tab designated as Operating costs will display a spreadsheet showing the pump stations, HP, electric energy cost in cents/KWH, etc for calculating the annual operating costs for the pump stations.



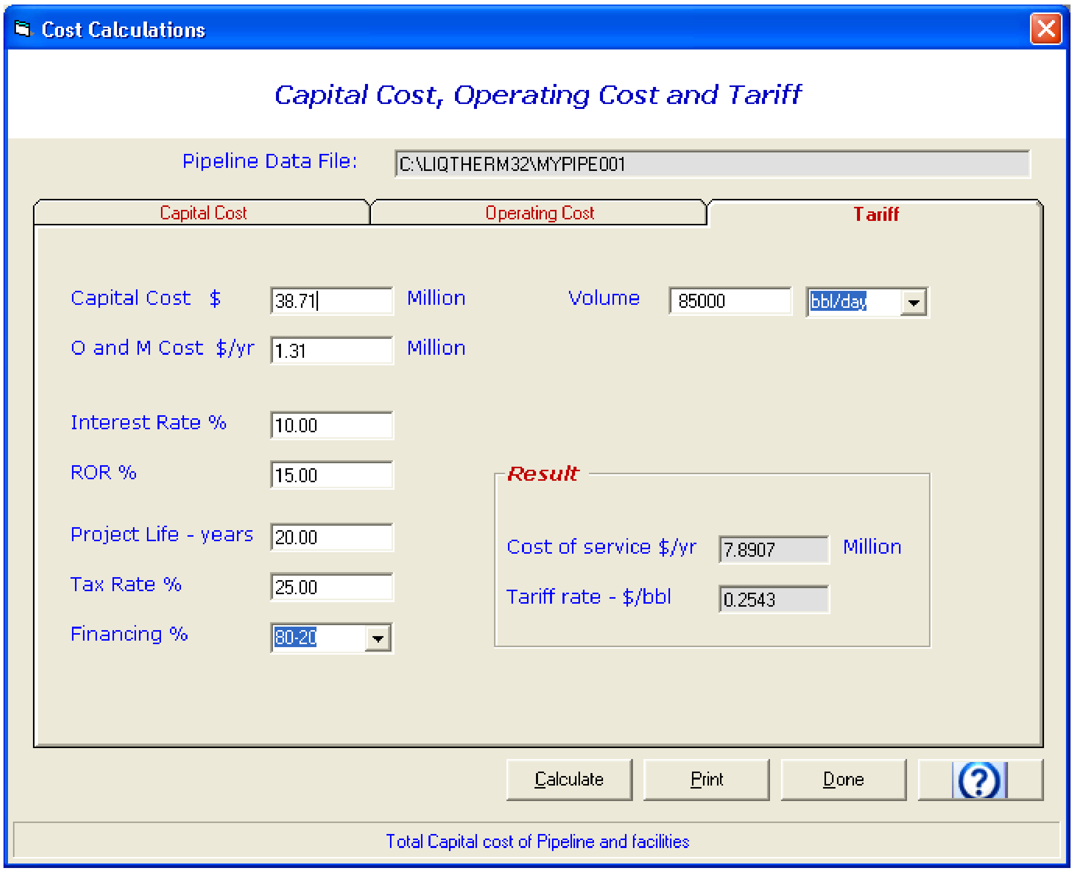
For the current pipeline system, the calculated horsepower for each pump station is shown. For each station, the energy cost in cents/KWh, the electric demand charge in $/KW per month, the number of hours per day and the number of days per year that each pump station operates are also shown. Based on this information, the energy cost is calculated and displayed.

Make changes needed and press **Calculate**, to re-compute the new operating cost.

Note that the calculated HP does not include allowance for electric motor efficiency. For example, to use a motor efficiency of 98% divide the HP required column by 0.98 and re-compute the cost.

Click the **Tariff Tab** to go to the Annual cost of Service or Tariff screen discussed next.

The *Annual cost of service* and the *Transportation tariff* can be calculated from the results of the previous cost screens as shown below:

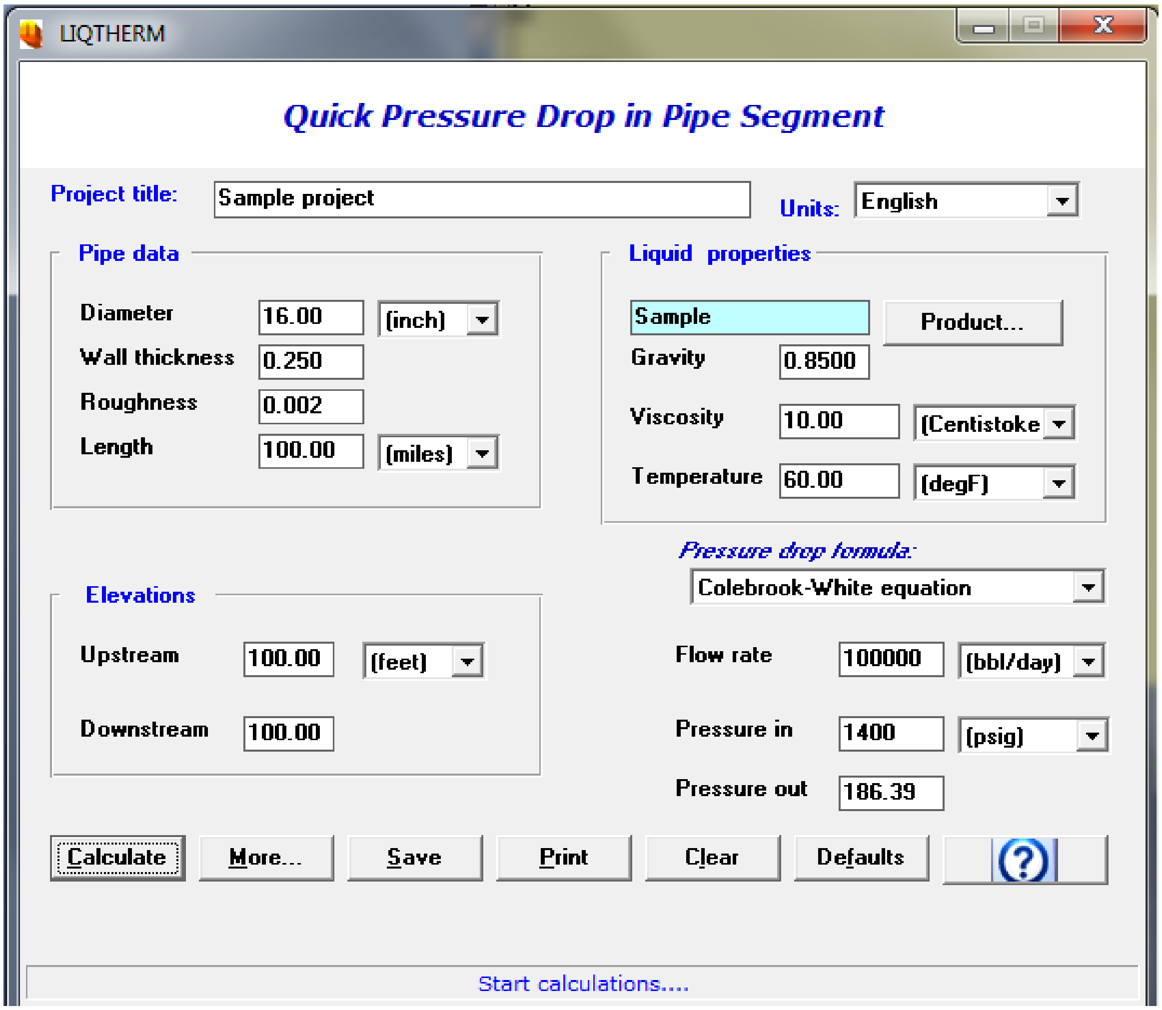


In the above display, the Capital cost and Annual operating costs from the previous screens have been transferred to this screen. The pipeline input flow rate has also been filled in. You may change any or all the financial parameters such as interest rate, rate of return (ROR), tax rate, financing option (debt/equity ratio), etc. and perform " what if " analyses.

Clicking the **Calculate** button will calculate *Annual cost of service* and the *transportation tariff*, such as $/bbl or $/m^3. Pressing the **Print** button will produce a hard copy of the results of these calculations. Click **Done** button or the Escape key to close this screen. See the **Reference** section for the basis of these financial calculations.

4.12 Quick Pressure Drop

Upon clicking the icon with the letter **Q**, the **Quick Pressure Drop** option screen shown below opens up.



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. You may also choose the pressure drop formula (such as Colebrook-White, Hazen-Williams etc.) to be used. Liquid viscosity may be specified in centistokes, centipoise, SSU etc. The pipe roughness is specified in the pull down menu as in the main program. Of the three parameters – Pressure in, Pressure out and Flow rate, input 2 items and the third will be calculated. The product may be specified by clicking the **Product...** button and choosing the product from the Liquid Properties Database.

5. Reference

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

5.1 Hydraulic Formulas

The following symbols are used in the equations below:

Q - Pipeline flow rate, gal/min (liters/sec or liters/min).

Cfact - Hazen Williams C Factor

D - Inside diameter of pipe, inches (millimeter).

S - Specific gravity of liquid at flowing temperature, dimensionless.

V - Viscosity of liquid at flowing temperature, centistokes (cSt)

R - Reynolds number, dimensionless.

K - Absolute roughness of pipe, inches.
(use 0.0018 inch for new steel pipe).

F - Transmission factor, dimensionless.

Pm - Pressure drop due to friction, psi/mile.

L(I) - Pipeline mile post, I = 1,2,3...........1000 (max).

H(I) - Pipeline elevation, ft.

P(I) - Pipeline pressure, psi (kPa).

P9 - Pipe delivery pressure, psi (kPa).

PD(J) - Pump station discharge pressure, psi.
J = 1,2,3.............................50 (max).

E - Pump efficiency, percent.

DeltaH - Pump differential head, ft (meter).

1. Velocity Vel = $\frac{0.408Q}{D^2}$ ft/sec (m/sec)

2. Reynold's number R = $\frac{3162.5Q}{VD}$ dimensionless

3. Pressure drop Pm = $\frac{284.6(Q/F)^2 S}{D^5}$ psi/mi (kPa/km) (Darcy-Weisbach equation)

4. Discharge Pressure PD(J) = PM(L(I)-L(I-1)) + (H(I)-H(I-1))S/2.31+P9 psi (kPa)

5. Horsepower HP = $\frac{DeltaH \times Q \times S}{39.60 \times E}$ HP (kW)

The pressure drop equation 3 above uses the *Transmission factor* F instead of a *friction factor.* These two parameters have a reciprocal relationship as follows:

Transmission factor $F = \frac{2}{\sqrt{f}}$ dimensionless

Darcy or Moody friction factor $f = \frac{4}{F^2}$ dimensionless

Where F is the transmission factor and f is referred to as the *Darcy or Moody friction factor.* There is another friction factor called the *Fanning friction factor* which is related to the Moody friction factor as follows:

Fanning friction factor = $\frac{f}{4}$

The Transmission factor F used in the pressure drop equation 3 on this page is calculated as follows:

Colebrook-White Equation:

$F = \frac{\sqrt{R}}{4}$ for laminar flow (R <= 2100)

$F = \frac{1}{\sqrt{(R-2100)/1277500+0.008}}$ for transition flow (R >= 2100) or (R < 4555)

$F = -4Log_{10}\left(\frac{K}{3.7D} + \frac{1.4125F}{R}\right)$ for turbulent flow (R > 4555)

Moody friction factor method:

$$F = \frac{\sqrt{R}}{4}$$ for laminar flow (R <= 2100)

$$F = \frac{1}{\sqrt{(R - 2{,}100)/1{,}277{,}500 + 0.008}}$$ for transition flow (R <= 4555)

$$F = -4Log_{10}\left(\frac{K}{3.7D} + \frac{1.25F}{R}\right)$$ for turbulent flow (R > 4555)

MIT Equation:

F = $\frac{\sqrt{R}}{4}$ for laminar flow (R <= 2100)

F = $\frac{1}{\sqrt{0.0018 + 0.159/R^{0.355}}}$ for turbulent flow (R > 2100)

Several other pressure drop formulas are discussed below. These do not use a friction factor or transmission factor. They either use an experience factor or some modified form of calculating pressure drop from the flow rate.

Miller Equation:

BConst1 = 0.1692

BConst2 = 4.35

BConst3 = $\frac{(Q/24)^2 S}{BConst1^2 \times D^5}$

BConst4 = $\frac{D^3 S}{(V \times S)^2}$

$$Pm = \frac{BConst3}{\left(Log_{10}(BConst4 \times Pm) + BConst2\right)^2}$$

Hazen-William Equation:
This pressure drop equation is widely used in the water industry as well to calculate pressure drop in pipelines transporting products such as gasoline and diesel. This equation uses a C factor to calculate the flow rate in bbl/day from a given pressure drop Pm in psi/mi as follows:

$$Q = 0.1482 Cfact D^{2.63} \left(\frac{Pm}{S} \right)^{0.54}$$ bbl/day (m^3/hr).

The C factor is usually a number between 100 and 200, based on experience with different products. Typical values in the range 120 to 160 are used for petroleum products.

In the absence of data, the C factor may be approximated by the following viscosity related equation:

$$Cfact = \frac{146.59}{V^{0.08}}$$

Drag Reduction:
Drag Reduction (DR) in a pipeline using a Drag Reduction Agent (DRA), results in reduction in frictional pressure drop. The mechanism of DR is quite complex and the amount of drag reduction achieved varies from one vendor's product to the next.

The parts per million (PPM) of DRA required for a particular product depends on various factors, such as the specific gravity and viscosity of the product pumped in the pipeline, the Reynolds number of flow, pipe diameter and length. DRA vendors provide approximate curves of PPM versus drag reduction for various liquids pumped, such as gasoline, diesel and light crude oils. The PPM of DRA is related to the volume injection rate of DRA and the pipeline flow rate as follows:

DRA injection rate in gal/day = (PPM/10^6) (Q) (24)(42)

Where the pipeline flow rate Q is in bbl/hr

For 4,000 bbl/hr flow rate and 20 PPM, DRA, the injection rate is

DRA injection rate in gal/day = (PPM/10^6) (4000) (24)(42) = 80.64 gal/day (liters/day)

5.2 Cost Formulas

The following symbols are used in the equations below:

Capital	- Total capital employed, $
Debt	- Percentage of capital that is borrowed, %
Cap1	- Portion of total capital that is borrowed (debt capital), $
Cap2	- Portion of total capital that is equity (equity capital), $
Tax	- Annual corporate tax rate, %
ROR	- Annual Rate of Return desired, %
IntRate	- Interest rate per year on borrowed capital, %
CostSvc	- Cost of Service per year, $/year
IntCost	- Interest cost per year, $/year
EqtyCost	- Equity cost per year, $/year
OMCost	- Annual Operating and Maintenance cost, $/yr
OtherCost	- Other annual costs (G&A, etc.), $/yr
Life	- Project life in years
Depr	- Annual depreciation cost (linear with zero salvage value), $/yr
Vol	- Daily throughput volume, MMSCFD
Tariff	- Transportation tariff, $/MCF

Capital split between debt and equity:

Debt capital $$Cap1 = \frac{Capital \times Debt}{100}$$

Equity capital $$Cap2 = Capital - Cap1$$

Calculate interest payment on debt:

Interest cost per year $$IntCost = \frac{Cap1 \times IntRate}{100}$$

Calculate earnings on equity required at ROR:

Equity cost per year $$EqtyCost = \frac{Cap2 \times (ROR/100)}{1 - Tax/100}$$

Calculate Depreciation:

Straight line depreciation per year

$$Depr = \frac{Capital}{Life}$$

Total cost of service:

CostSvc = IntCost + EqtyCost + Depr + OMCost + OtherCost

$$Tariff = \frac{CostSvc \times 1000 \times 1000}{365 \times Vol}$$

6. Troubleshooting

LIQTHERM is a powerful hydraulic simulation program for liquid pipelines under steady state, thermal (variable temperature) 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 **TaskBar** and using end task close the program.

If you cannot get **LIQTHERM** to run properly even after following the steps outlined in the *Getting Started* section of this manual, please check the following *before* you call Technical Support. Have your program disk serial number and program version number handy to facilitate quick response.

Error Messages:

The following are some errors that you may encounter while running **LIQTHERM**:

Divide by zero error
This is generally due to some data input value that is zero. Check all input data for zero values. The pump efficiencies, specific gravity, 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 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 pump curves, make sure the file is present in the sub-directory or folder containing LIQTHERM data (C:\documents\Liqtherm\ ). Otherwise, ensure that the file name is typed in correctly, including the full path.

Input past end of file
This happens when the program reads a data file and looks for *more* information than present in the file. For example, it tries to read 10 sets of pump curve data (flow, head and efficiency values) from a data file where only 9 sets of data exist. In such a case, first load the pump data file in an ASCII or text editor, such as the Windows Notepad. Review the data file to ensure that the number of data sets specified in the first line matches the data below. If there are less number of rows of data as compared to the sets specified, correct the data file and save the information. If any of the rows of data shows a string of zero values, make corrections and save the data file.

If the above problems persist or you cannot successfully install the software on your hard disk, contact Technical Support.

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. *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 program CD serial number and program version available when you call us.

7.1 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

7.2 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 LIQTHERM 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.

7.3 Training workshops and Online webinar:

SYSTEK also conducts hands-on training in pipeline hydraulics. These two-day workshops are held in major cities in the USA. In addition, customized training programs are also conducted at client company sites. Also several 4-8 hrs online webinars are conducted throughout the year. Check our web site for details or call us for special scheduling.

Sample Problems

Several sample problems and their solutions are included on the LIQTHERM CD-ROM as part of the LIQTHERM User Manual. These may be printed as needed.

Sample Problem –1

This is similar to the sample problem MyPipe001.TOT discussed in the **Tutorial** section of this manual.

Determine the temperature and pressure profile for a 14" pipeline transporting crude oil with the following data:

Specific gravity at 60 deg. F	0.890
Specific gravity at 100 deg. F	0.825
Viscosity at 60 deg. F	43 centistokes
Viscosity at 100 deg. F	15 centistokes
Pipe delivery pressure	50 psi
Flow rate at inlet temperature	85,000 bbl/day
Pipe Depth of cover	36 in.
Insulation thickness	1.00 in.
Insulation Conductivity	0.02 Btu/hr/ft/degF
Pipe Conductivity	29.0 Btu/hr/ft/degF
Thermal conductivity of soil	0.7 Btu/hr/ft/degF
Soil temperature	55 deg F
Pipe Inlet temperature	140 deg F

The pipeline data file is provided on the program disk as MyPipe001.TOT**.**

The pump stations, pump curve data and the pump configuration are as follows:

Pump station	**Distance** (mi)	**Suction Pressure** (psi)	**Drive Type**	**Installed HP**
Compton	0.0	25.0	Motor	2 - 2000
Dimpton	50.0	50.0	VSD	1 - 2000

The VSD motor speeds in RPM are as follows:

Rated	Minimum	Maximum
3500	2000	4000

Pump station	**No. of pumps**	**Configuration**	**Pump curves**
Compton	2	Parallel	`Compton.pmp`
Dimpton	1	Series	`Dimpton.pmp`

A heater station is located at Davis (milepost 40.0) as follows:

Location	**Heater Temp** (deg.F)	**Efficiency** (%)
Davis	140	80

```
******* LIQTHERM  STEADY STATE PIPELINE HYDRAULIC SIMULATION REPORT *********

DATE: 3/5/2016            TIME:  7:58 AM

PROJECT:                  Problem 1
                          Compton to Harvard Pipeline

Pipeline data file:       C:\Users\Shashi Menon\Documents\LIQTHERM\Problems\Problem1.TOT

******* LIQTHERM - LIQUID PIPELINE STEADY STATE HYDRAULIC SIMULATION ********
****************** 7.00*************

CASE NUMBER:                             1004

CALCULATION OPTIONS:
Thermal Calculations:                    NO
Frictional Heating:                      YES
Use Pump Curves:                         YES
Pump Curves Corrected for Viscosity:     NO
MAOP Check:                              YES
Horsepower Check:                        NO
Heating due to pump inefficiency:        NO
Valves/Fittings and Devices:             NO
Branch pipe calculations:                NO
Loop pipe calculations:                  NO
Maximum Inlet Flow:                      NO
Batching Considered:                     NO
DRA Injection:                           NO
Correct volumes for temperature:         NO
Slack Line Calculations:                 NO
Customized Output:                       NO


Inlet flow rate:                         85,000 bbl/day
Outlet flow rate:                        85,000 bbl/day
Inlet flow temperature:                  140.00 degF
Outlet flow temperature:                 115.14 degF

Minimum Pipe pressure:                   0.00 psi
Pipe delivery pressure:                  50.00 psi


Pressure drop formula used:              Colebrook-White equation

Calculation sub-divisions:               2
Iteration Accuracy:                      MEDIUM



********** LIQUID PROPERTIES **********

Liquid properties file: C:\Users\Shashi Menon\Documents\LIQTHERM\Liquid Properties
Database

PRODUCT:                  ANSCrude
Specific gravity:         0.8950 at 60.0 degF
                          0.8250 at 100.0 degF
```

```
Viscosity:               43.00 CST at 60.0 degF
                         15.00 CST at 100.0 degF
```

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

Location mi	Flow rate bbl/day	Inlet Temp. degF	Product
0.00	85,000	140.0	ANSCrude

********** PUMP STATIONS **********

Pump station	Distance mi	Pump suct pressure psi	Pump disch pressure psi	Sta. disch pressure psi	Throttled pressure psi	BHP Reqd by pump	TotHPinst. (Active)	KW
Compton	0.00	25.00	1013.82	1013.82	0.00	2185	4000	1630
Dimpton	50.00	164.56	768.06	768.06	0.00	1185	2000	884

Total active pump stations: 2   TOTAL Power: 3,370   6,000   2514

********** PUMP AND DRIVER DATA **********

PumpSta.	Config.	Pump Curves	Status	Driver	RPM	Pump BHP	HPInstalled
Compton	Parallel	COMPTON.PMP	ON	Motor	3,500	1,093	2000
Compton	Parallel	COMPTON.PMP	ON	Motor	3,500	1,093	2000
Dimpton	Series	DIMPTON.PMP	ON	VSDMotor	3,500	1,185	2000

```
Pump Station:       Compton
Pump curve file: COMPTON.PMP
Constant Speed Pump(s): 3,500 RPM
Pump curve: COMPTON.PMP         Pump Status:ON
Pump impeller: 12.000 in.   Number of stages: 2
Operating point:  1239.58 gal/min  3025.40 ft  65.44%
```

Flow rate gal/min	Head ft	Efficiency %	WaterHP HP
0.00	3185.0	0.01	0.00
400.00	3150.0	34.50	922.27
600.00	3135.0	46.40	1023.71
800.00	3100.0	55.70	1124.35
1200.00	3035.0	64.30	1430.32
1600.00	2900.0	78.00	1502.20

2000.00	2690.0	81.20	1673.14
2400.00	2350.0	79.30	1796.02
2700.00	2100.0	76.00	1883.97
3000.00	1800.0	72.00	1893.94

Resultant Pump Curve: Compton Pump station
Constant Speed Pump(s): 3,500 RPM
Operating point: 2479.17 gal/min 3025.40 ft 65.44%

Flow rate gal/min	Head ft	Efficiency %	WaterHP HP
0.01	3185.00	0.01	80.43
800.00	3150.00	34.50	1844.53
1200.00	3135.00	46.40	2047.41
1600.00	3100.00	55.70	2248.70
2400.00	3035.00	64.30	2860.64
3200.00	2900.00	78.00	3004.40
4000.00	2690.00	81.20	3346.27
4800.00	2350.00	79.30	3592.04
5400.00	2100.00	76.00	3767.94
6000.00	1800.00	72.00	3787.88

Pump Station: Dimpton
Rated Pump speed:3500 RPM
Minimum speed: 2000 RPM
Maximum speed: 4000 RPM
Pump curve: DIMPTON.PMP Pump Status:ON
Pump impeller: 12.000 in. Number of stages: 2

Flow rate gal/min	Head ft	Efficiency %	WaterHP HP
0.00	3170.0	0.01	0.00
400.00	3160.0	34.30	930.59
800.00	3140.0	57.50	1103.21
1200.00	3130.0	72.00	1317.34
1600.00	2820.0	79.00	1442.27
1900.00	2560.0	80.00	1535.35
2000.00	2460.0	79.80	1556.92
2400.00	2060.0	76.00	1642.74
3000.00	1680.0	65.70	1937.18

Resultant Pump Curve: Dimpton Pump station
Pump speed required: 3,500.00 RPM
Percentage of rated speed: 97.04%
Percentage of Maximum speed: 87.50%
Operating point: 2479.17 gal/min 1825.37 ft 73.65%

Flow rate gal/min	Head ft	Efficiency %	WaterHP HP

0.01	2984.94	0.01	75.38
388.15	2975.53	34.30	850.30
776.30	2956.69	57.50	1008.03
1164.45	2947.28	72.00	1203.69
1552.60	2655.37	79.00	1317.84
1843.71	2410.55	80.00	1402.89
1940.74	2316.39	79.80	1422.59
2328.89	1939.74	76.00	1501.01
2911.12	1581.93	65.70	1770.06

********** HEATER STATIONS **********

Heater Station	Distance mi	Heater Inlet Temp.	Heater Outlet Temp.	HeaterEffy %	HeaterDuty MMBtu/hr	HeatingCost $/MMBtu
Davis	40.00	121.95	140.00	80.00	9.87	5.00

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

Distance mi	Elevation ft	Diameter in	Wall Thk. in	Roughness in	MAOP psi	Location
0.0000	100.00	14.000	0.250	0.00180	1170	Compton
10.0000	250.00	14.000	0.250	0.00180	1170	
25.0000	320.00	14.000	0.250	0.00180	1170	
35.0000	485.00	14.000	0.250	0.00180	1170	
40.0000	500.00	14.000	0.250	0.00180	1170	Davis
50.0000	389.00	14.000	0.250	0.00180	1170	Dimpton
65.0000	180.00	14.000	0.250	0.00180	1170	
75.0000	286.00	14.000	0.250	0.00180	1170	
80.0000	320.00	14.000	0.250	0.00180	1170	
100.0000	190.00	14.000	0.250	0.00180	1170	Harvard

********** THERMAL CONDUCTIVITY PROFILE DATA **********

Distance	Burial depth (Cover)	Insul.Thk	Thermal Conductivity Insulation	Pipe	Soil	Soil Temp
mi	in	in	Btu/hr/ft/degF			degF
0.0000	36.00	1.000	0.02	29.00	0.70	55.0
10.0000	36.00	1.000	0.02	29.00	0.70	55.0
25.0000	36.00	1.000	0.02	29.00	0.70	55.0
35.0000	36.00	1.000	0.02	29.00	0.70	55.0
40.0000	36.00	1.000	0.02	29.00	0.70	55.0
50.0000	36.00	1.000	0.02	29.00	0.70	55.0
65.0000	36.00	1.000	0.02	29.00	0.70	55.0
75.0000	36.00	1.000	0.02	29.00	0.70	55.0
80.0000	36.00	1.000	0.02	29.00	0.70	55.0
100.0000	36.00	1.000	0.02	29.00	0.70	55.0

********** VELOCITY, REYNOLD'S NUMBER AND PRESSURE DROP **********

Distance mi	Diameter in	FlowRate bbl/day	Velocity ft/sec	Reynolds number	Press.drop psi/mi	Location

```
    0.0000      14.00      85,000.00      5.55         82,015      14.59    Compton
   10.0000      14.00      85,000.00      5.55         75,403      15.01
   25.0000      14.00      85,000.00      5.55         67,050      15.60
   35.0000      14.00      85,000.00      5.55         62,303      15.98
   40.0000      14.00      85,000.00      5.55         82,015      14.59    Davis
   50.0000      14.00      85,000.00      5.55         75,403      15.01    Dimpton
   65.0000      14.00      85,000.00      5.55         67,050      15.60
   75.0000      14.00      85,000.00      5.55         62,303      15.98
   80.0000      14.00      85,000.00      5.55         60,166      16.16
  100.0000      14.00      85,000.00      5.55         60,166      16.16    Harvard


********** TEMPERATURE AND PRESSURE PROFILE **********
 Distance   Elevation    FlowRate    Temp.   SpGrav   Viscosity Pressure   MAOP
Location
      mi         ft       bbl/day    degF               CST         psi      psi
Name

    0.0000     100.00    85,000.00  140.00    0.7550      7.08     25.00  1170.00
Compton

    0.0000     100.00    85,000.00  140.00    0.7550      7.08   1013.82  1170.00
Compton
   10.0000     250.00    85,000.00  134.85    0.7640      7.70    818.89  1170.00
   25.0000     320.00    85,000.00  127.98    0.7760      8.66    570.62  1170.00
   35.0000     485.00    85,000.00  123.86    0.7832      9.32    359.18  1170.00
   40.0000     500.00    85,000.00  121.95    0.7866      9.65    274.18  1170.00  Davis

   40.0000     500.00    85,000.00  140.00    0.7550      7.08    274.18  1170.00  Davis
   50.0000     389.00    85,000.00  134.85    0.7640      7.70    164.56  1170.00
Dimpton

   50.0000     389.00    85,000.00  134.85    0.7640      7.70    768.06  1170.00
Dimpton
   65.0000     180.00    85,000.00  127.98    0.7760      8.66    612.07  1170.00
   75.0000     286.00    85,000.00  123.86    0.7832      9.32    420.44  1170.00
   80.0000     320.00    85,000.00  121.95    0.7866      9.65    329.01  1170.00
  100.0000     190.00    85,000.00  115.14    0.7985     10.98     50.00  1170.00
Harvard


Simulation Date:  5-March-2016
Output file: C:\Users\Shashi Menon\Documents\LIQTHERM\Problems\Problem1.OUT
```

Sample Problem –2

A 14-inch, 0.250-inch wall thickness pipeline is used for shipping heavy crude oil from Joplin to a delivery terminal at Beaumont. A pump station and a heater station are located at Joplin with the following data:

Joplin heater:		**Joplin pump station:**	
Inlet temperature:	100 degF	Suction pressure:	25 psig.
Outlet temperature:	150 degF	Total Motor HP installed:	1800 HP
Heater efficiency:	82%		

Three identical pumps (600 HP each) are installed in series at Joplin pump station. Each pump curve is defined by JOPLIN.PMP as given below:

Flow rate gpm	**Head ft**	**Efficiency %**
0.0	2020	0.0
400	2070	54.2
600	2060	68.2
800	2000	76.9
1100	1820	82.0
1200	1725	81.1
1400	1500	76.1

The crude oil properties are as follows:

Temp. degF	**Sp.Gravity**	**Viscosity (cp)**
60	.925	500
120	.814	215

Pipe delivery pressure	75 psig
Pipe Depth of cover	36 in.
Insulation thickness	0.0 in. (uninsulated)
Insulation Conductivity	0.02 Btu/hr/ft/degF
Pipe Conductivity	29.0 Btu/hr/ft/degF
Thermal conductivity of soil	0.54 Btu/hr/ft/degF
Soil temperature	60 deg F

The pipeline elevation profile is as below:

Distance (mi)	**Elevation (ft)**
0.00	50.00
10.00	75.00
25.00	125.00
35.00	89.00
40.00	67.00
50.00	112.00
65.00	152.00
75.00	423.00
80.00	300.00
100.00	240.00

Determine the pressure and temperature profile and the HP required to transport the crude oil at 1,500 bbl/hr considering the pump curve data. Use a pipe absolute roughness of 0.002 inches and constant MAOP for pipe equal to 1800 psig.

******* LIQTHERM STEADY STATE PIPELINE HYDRAULIC SIMULATION REPORT *********

DATE: 3/5/2016   TIME: 8:11 AM

PROJECT: Problem 2
                          Joplin to Beaumont Pipeline

Pipeline data file: C:\Users\Shashi Menon\Documents\LIQTHERM\Problems\Problem2.TOT

******* LIQTHERM - LIQUID PIPELINE STEADY STATE HYDRAULIC SIMULATION ********
****************** 7.00*************

CASE NUMBER: 1006

CALCULATION OPTIONS:

Thermal Calculations:	NO
Frictional Heating:	YES
Use Pump Curves:	YES
Pump Curves Corrected for Viscosity:	NO
MAOP Check:	NO
Horsepower Check:	NO
Heating due to pump inefficiency:	NO
Valves/Fittings and Devices:	NO
Branch pipe calculations:	NO
Loop pipe calculations:	NO
Maximum Inlet Flow:	NO
Batching Considered:	NO
DRA Injection:	NO
Correct volumes for temperature:	NO
Slack Line Calculations:	NO
Customized Output:	NO

Inlet flow rate:	1,500 bbl/hr
Outlet flow rate:	1,500 bbl/hr
Inlet flow temperature:	100.00 degF
Outlet flow temperature:	65.42 degF
Minimum Pipe pressure:	0.00 psi
Pipe delivery pressure:	75.00 psi
Pressure drop formula used:	Colebrook-White equation
Calculation sub-divisions:	2
Iteration Accuracy:	MEDIUM

********** LIQUID PROPERTIES **********

Liquid properties file: C:\Users\Shashi Menon\Documents\LIQTHERM\Liquid Properties Database

PRODUCT:	ABCCrude
Specific gravity:	0.9250 at 60.0 degF
	0.8140 at 120.0 degF

Viscosity: 500.00 CP at 60.0 degF
215.00 CP at 120.0 degF

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

Location	Flow rate	Inlet Temp.	Product
mi	bbl/hr	degF	
0.00	1,500	100.0	ABCCrude

********** PUMP STATIONS **********

Pump station	Distance mi	Pump suct pressure psi	Pump disch pressure psi	Sta. disch pressure psi	Throttled pressure psi	BHP Reqd by pump	TotHPinst. (Active)	KW
Joplin	0.00	25.00	1857.44	1724.50	132.94	1370	1800	1022
Total active pump stations: 1			TOTAL Power:			1,370	1,800	1022

********** PUMP AND DRIVER DATA **********

PumpSta.	Config.	Pump Curves	Status	Driver	RPM	Pump BHP	HPInstalled
Joplin	Series	JOPLIN.PMP	ON	Motor	3,500	457	600
Joplin	Series	JOPLIN.PMP	ON	Motor	3,500	457	600
Joplin	Series	JOPLIN.PMP	ON	Motor	3,500	457	600

Pump Station: Joplin
Pump curve file: JOPLIN.PMP
Constant Speed Pump(s): 3,500 RPM
Pump curve: JOPLIN.PMP Pump Status:ON
Pump impeller: 12.000 in. Number of stages: 2
Operating point: 1050.00 gal/min 1860.22 ft 81.93%

Flow rate	Head	Efficiency	WaterHP
gal/min	ft	%	HP
0.00	2020.0	0.01	0.00
400.00	2070.0	54.20	385.78
600.00	2060.0	68.20	457.66
800.00	2000.0	76.90	525.41
1100.00	1820.0	82.00	616.53
1200.00	1725.0	81.10	644.55
1400.00	1500.0	76.10	696.85

Resultant Pump Curve: Joplin Pump station

Constant Speed Pump(s): 3,500 RPM
Operating point: 1050.00 gal/min 5580.66 ft 81.93%

Flow rate gal/min	Head ft	Efficiency %	WaterHP HP
0.01	6060.00	0.01	153.03
400.00	6210.00	54.20	1157.33
600.00	6180.00	68.20	1372.97
800.00	6000.00	76.90	1576.23
1100.00	5460.00	82.00	1849.59
1200.00	5175.00	81.10	1933.64
1400.00	4500.00	76.10	2090.55

********** HEATER STATIONS **********

Heater Station	Distance mi	Heater Inlet Temp.	Heater Outlet Temp.	HeaterEffy %	HeaterDuty MMBtu/hr	HeatingCost $/MMBtu
Joplin	0.00	100.00	150.00	82.00	11.87	5.00

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

Distance mi	Elevation ft	Diameter in	Wall Thk. in	Roughness in	MAOP psi	Location
0.0000	50.00	14.000	0.250	0.00200	1800	Joplin
10.0000	75.00	14.000	0.250	0.00200	1800	
25.0000	125.00	14.000	0.250	0.00200	1800	
35.0000	89.00	14.000	0.250	0.00200	1800	
40.0000	67.00	14.000	0.250	0.00200	1800	
50.0000	112.00	14.000	0.250	0.00200	1800	
65.0000	152.00	14.000	0.250	0.00200	1800	
75.0000	423.00	14.000	0.250	0.00200	1800	
80.0000	300.00	14.000	0.250	0.00200	1800	
100.0000	240.00	14.000	0.250	0.00200	1800	Beaumont

********** THERMAL CONDUCTIVITY PROFILE DATA **********

Distance	Burial depth (Cover)	Insul.Thk	Thermal Conductivity Insulation	Pipe	Soil	Soil Temp
mi	in	in	Btu/hr/ft/degF			degF
0.0000	36.00	0.000	0.02	29.00	0.54	60.0
10.0000	36.00	0.000	0.02	29.00	0.54	60.0
25.0000	36.00	0.000	0.02	29.00	0.54	60.0
35.0000	36.00	0.000	0.02	29.00	0.54	60.0
40.0000	36.00	0.000	0.02	29.00	0.54	60.0
50.0000	36.00	0.000	0.02	29.00	0.54	60.0
65.0000	36.00	0.000	0.02	29.00	0.54	60.0
75.0000	36.00	0.000	0.02	29.00	0.54	60.0
80.0000	36.00	0.000	0.02	29.00	0.54	60.0
100.0000	36.00	0.000	0.02	29.00	0.54	60.0

********** VELOCITY, REYNOLD'S NUMBER AND PRESSURE DROP **********

Distance mi	Diameter in	FlowRate bbl/hr	Velocity ft/sec	Reynolds number	Press.drop psi/mi	Location
0.0000	14.00	1,500.00	2.35	747	12.76	Joplin
10.0000	14.00	1,500.00	2.35	929	9.81	
25.0000	14.00	1,500.00	2.35	697	13.85	
35.0000	14.00	1,500.00	2.35	619	15.94	
40.0000	14.00	1,500.00	2.35	591	16.80	
50.0000	14.00	1,500.00	2.35	552	18.21	
65.0000	14.00	1,500.00	2.35	518	19.61	
75.0000	14.00	1,500.00	2.35	505	20.18	
80.0000	14.00	1,500.00	2.35	501	20.38	
100.0000	14.00	1,500.00	2.35	501	20.38	Beaumont

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

Distance mi	Elevation ft	FlowRate bbl/hr	Temp. degF	SpGrav	Viscosity CP	Pressure psi	MAOP psi	Location Name
0.0000	50.00	1,500.00	100.00	0.8510	280.37	25.00	1800.00	Joplin
0.0000	50.00	1,500.00	150.00	0.7585	147.98	25.00	1800.00	Joplin
0.0000	50.00	1,500.00	150.00	0.7585	147.98	1724.50	1800.00	Joplin
10.0000	75.00	1,500.00	119.80	0.8144	215.58	1648.93	1800.00	
25.0000	125.00	1,500.00	94.05	0.8620	304.28	1484.12	1800.00	
35.0000	89.00	1,500.00	84.07	0.8805	350.12	1359.06	1800.00	
40.0000	67.00	1,500.00	80.37	0.8873	369.19	1287.76	1800.00	
50.0000	112.00	1,500.00	74.87	0.8975	399.98	1102.44	1800.00	
65.0000	152.00	1,500.00	69.86	0.9068	430.73	813.81	1800.00	
75.0000	423.00	1,500.00	67.94	0.9103	443.27	511.38	1800.00	
80.0000	300.00	1,500.00	67.26	0.9116	447.82	458.98	1800.00	
100.0000	240.00	1,500.00	65.42	0.9150	460.39	75.00	1800.00	Beaumont

Simulation Date: 5-March-2016
Output file: C:\Users\Shashi Menon\Documents\LIQTHERM\Problems\Problem2.OUT

Sample Problem – 3

A 20 inch pipeline (0.375 inch wall thickness and 0.002 inch pipe roughness), 285 miles long is used to transport approximately 7,000 bbl/hr of SJVH crude from an originating station at Corona to a tank farm at Kingman. There are 5 pump stations located at Corona (mp 0.0), Banning (mp 54.0), Morongo (mp 120.0), Sheephole (mp 175.0) and Oatman (mp 232.0). The pipeline is buried with 36 inch cover and is insulated with 0.2 inch thickness insulation. The thermal conductivity of insulation, pipe and soil may be assumed as 0.02, 29 and 0.45 Btu/hr/ft/degF respectively. Assume constant soil temperature of 65 degF.

The crude oil has the following properties:

```
PRODUCT:                     SJVH
Specific gravity:            0.9854 at  60.0(degF)
                             0.7918 at  100.0(degF)

Viscosity:                   2100.00 CST at 65.0(degF)
                             985.00 CST at 110.0(degF)
```

Oil enters the Corona pump station at 140 degF and is pumped towards Banning. At Sunnymead, located 37.5 miles away from Corona, 1,200 bbl/hr is delivered and the remainder continues on to Banning, Morongo and finally to the Kingman terminal. Heaters are located at Banning, Morongo, Sheephole and Oatman at a distance of 0.01 miles upstream of each pump station. Each heater station operates at a maximum outlet temperature of 140 degF.

There are three identical 2,000 HP pumps in series at Corona. At Banning, Morongo and Sheephole there are two identical 2,000 HP pumps each in series. At Oatman a single 4,000 HP pump is used. The pump characteristics are as follows:

Corona			**Banning**			**Morongo**		
Flow gpm	Head ft	Effy %	Flow gpm	Head ft	Effy %	Flow gpm	Head ft	Effy %
0	2378	0	0	2773	0	0	2864	0
804	2393	34.3	868	2791	34	882	2882	34
1608	2363	57.5	1736	2756	58	1765	2846	58
2412	2302	72.0	2604	2685	72	2647	2773	72
3215	2135	79.0	3473	2491	79	3529	2572	79
3818	1938	80.0	4124	2261	80	4191	2335	80
4019	1863	79.8	4341	2173	80	4411	2244	80
4823	1560	76.0	5209	1819	76	5294	1879	76
5627	1272	65.7	6077	1484	66	6176	1532	66

Sheephole			**Oatman**		
Flow gpm	Head ft	Effy %	Flow gpm	Head ft	Effy %
0	2501	0	0	5577	0
824	2517	34.3	1125	5684	37.8
1649	2485	57.5	1687	5737	51.7
2473	2422	72.0	2249	5715	62.5
3298	2246	79.0	3374	5577	76.0
3916	2039	80.0	4498	4887	84.4
4122	1960	79.8	5623	4493	84.0
4947	1641	76.0	6748	3612	78.8
5771	1338	65.7			

(a). Determine the pressure and temperature profile for the pipeline, without considering pump curve data. Use the MIT pressure drop equation and consider 1440 psig MAOP throughout. Assume fixed pump efficiency of 85%.

```
******* LIQTHERM  STEADY STATE PIPELINE HYDRAULIC SIMULATION REPORT *********

DATE: 3/5/2016          TIME:  8:22 AM

PROJECT:                Problem 3a
                        Corona to Kingman Pipeline
                        5 Pump stations and 4 heater stations

Pipeline data file:     C:\Users\Shashi Menon\Documents\LIQTHERM\Problems\Problem3a.TOT

******* LIQTHERM - LIQUID PIPELINE STEADY STATE HYDRAULIC SIMULATION ********
****************** 7.00*************

CASE NUMBER:                            1007

CALCULATION OPTIONS:
Thermal Calculations:                   NO
Frictional Heating:                     YES
Use Pump Curves:                        NO
MAOP Check:                             YES
Horsepower Check:                       NO
Heating due to pump inefficiency:       NO
Valves/Fittings and Devices:            NO
Branch pipe calculations:               NO
Loop pipe calculations:                 NO
Maximum Inlet Flow:                     NO
Batching Considered:                    NO
DRA Injection:                          NO
Correct volumes for temperature:        NO
Slack Line Calculations:                NO
Customized Output:                      NO


Inlet flow rate:                        6,547 bbl/hr
Outlet flow rate:                       5,347 bbl/hr
Inlet flow temperature:                 140.00 degF
Outlet flow temperature:                114.38 degF

Minimum Pipe pressure:                  0.00 psi
Pipe delivery pressure:                 50.00 psi


Pressure drop formula used:             Colebrook-White equation

Calculation sub-divisions:              2
Iteration Accuracy:                     MEDIUM
```

********** LIQUID PROPERTIES **********

Liquid properties file: C:\Users\Shashi Menon\Documents\LIQTHERM\Problems\Liquid Properties Database

PRODUCT:	SJVH
Specific gravity:	0.9854 at 60.0 degF
	0.7918 at 100.0 degF
Viscosity:	2100.00 CST at 65.0 degF
	985.00 CST at 110.0 degF

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

Location mi	Flow rate bbl/hr	Inlet Temp. degF	Product
0.00	6,547	140.0	SJVH
37.50	-1,200	124.4	

****** INLET FLOW RATE REDUCED DUE TO PIPE MAOP OR INSTALLED HP LIMITS ****

************ Pump Curve Data Not Considered ***********

Pump Sta.	Pump Efficiency (%)
Corona	75.00
Banning	75.00
Morongo	75.00
Sheephole	75.00
Oatman	75.00

NOTE: When not using pump curve data, an average pump efficiency is used to calculate HP at each pump station.

********** PUMP STATIONS **********

Pump station	Distance mi	Pump suct pressure psi	Pump disch pressure psi	Sta. disch pressure psi	Throttled pressure psi	BHP Reqd by pump	TotHPinst. (Active)	KW
Corona	0.00	50.00	1326.72	1326.72	0.00	4551	5000	3395
Banning	54.00	50.00	1286.36	1286.36	0.00	3599	5000	2685
Morongo	120.00	50.00	1338.20	1338.20	0.00	3750	5000	2798
Sheephole	175.00	50.00	1135.41	1135.41	0.00	3160	5000	2357
Oatman	232.00	50.00	1438.83	1438.83	0.00	4043	5000	3016

Total active pump stations: 5 TOTAL Power: 19,103 25,000 14251

NOTE: Throttle pressures are zero because pump curve data is not used.

Pump Station: Corona
Requires pump with following condition: Head : 4930.18 ft at Flow : 4582.92 gal/min

Pump Station: Banning
Requires pump with following condition: Head : 4774.02 ft at Flow : 3742.92 gal/min

Pump Station: Morongo
Requires pump with following condition: Head : 4974.16 ft at Flow : 3742.92 gal/min

Pump Station: Sheephole
Requires pump with following condition: Head : 4191.15 ft at Flow : 3742.92 gal/min

Pump Station: Oatman
Requires pump with following condition: Head : 5362.75 ft at Flow : 3742.92 gal/min

********** HEATER STATIONS **********

Heater Station	Distance mi	Heater Inlet Temp.	Heater Outlet Temp.	HeaterEffy %	HeaterDuty MMBtu/hr	HeatingCost $/MMBtu
Banning	53.99	117.77	140.00	85.00	14.72	5.00
Morongo	119.99	110.87	140.00	85.00	20.13	5.00
Sheephole	174.99	113.78	140.00	85.00	17.81	5.00
Oatman	231.99	113.32	140.00	85.00	18.17	5.00

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

Distance mi	Elevation ft	Diameter in	Wall Thk. in	Roughness in	MAOP psi	Location
0.0000	610.00	20.000	0.375	0.00200	1440	Corona
12.0000	851.00	20.000	0.375	0.00200	1440	
24.0000	920.00	20.000	0.375	0.00200	1440	
37.5000	1245.00	20.000	0.375	0.00200	1440	
53.9900	1140.00	20.000	0.375	0.00200	1440	BannHtr
54.0000	1140.00	20.000	0.375	0.00200	1440	Banning
98.0000	1265.00	20.000	0.375	0.00200	1440	
112.0000	987.00	20.000	0.375	0.00200	1440	
119.9900	1199.73	20.000	0.375	0.00200	1440	MorongoHtr
120.0000	1200.00	20.000	0.375	0.00200	1440	Morongo
134.0000	1540.00	20.000	0.375	0.00200	1440	
156.0000	1875.00	20.000	0.375	0.00200	1440	
168.0000	2120.00	20.000	0.375	0.00200	1440	
174.9900	2000.17	20.000	0.375	0.00200	1440	SHHtr
175.0000	2000.00	20.000	0.375	0.00200	1440	Sheephole
189.0000	1742.00	20.000	0.375	0.00200	1440	
212.0000	1485.00	20.000	0.375	0.00200	1440	
231.9900	1894.80	20.000	0.375	0.00200	1440	OatmanHtr
232.0000	1895.00	20.000	0.375	0.00200	1440	Oatman
233.9900	1911.92	20.000	0.375	0.00200	1440	
234.0000	1912.00	20.000	0.375	0.00200	1440	
248.0000	2369.00	20.000	0.375	0.00200	1440	
269.0000	2842.00	20.000	0.375	0.00200	1440	
285.0000	3220.00	20.000	0.375	0.00200	1440	Kingman

********** THERMAL CONDUCTIVITY PROFILE DATA **********

Distance	Burial depth (Cover)	Insul.Thk	Thermal Conductivity Insulation	Pipe	Soil	Soil Temp

mi	in	in	Btu/hr/ft/degF			degF
0.0000	36.00	0.200	0.02	29.00	0.45	65.0
12.0000	36.00	0.200	0.02	29.00	0.45	65.0
24.0000	36.00	0.200	0.02	29.00	0.45	65.0
37.5000	36.00	0.200	0.02	29.00	0.45	65.0
53.9900	36.00	0.200	0.02	29.00	0.45	65.0
54.0000	36.00	0.200	0.02	29.00	0.45	65.0
98.0000	36.00	0.200	0.02	29.00	0.45	65.0
112.0000	36.00	0.200	0.02	29.00	0.45	65.0
119.9900	36.00	0.200	0.02	29.00	0.45	65.0
120.0000	36.00	0.200	0.02	29.00	0.45	65.0
134.0000	36.00	0.200	0.02	29.00	0.45	65.0
156.0000	36.00	0.200	0.02	29.00	0.45	65.0
168.0000	36.00	0.200	0.02	29.00	0.45	65.0
174.9900	36.00	0.200	0.02	29.00	0.45	65.0
175.0000	36.00	0.200	0.02	29.00	0.45	65.0
189.0000	36.00	0.200	0.02	29.00	0.45	65.0
212.0000	36.00	0.200	0.02	29.00	0.45	65.0
231.9900	36.00	0.200	0.02	29.00	0.45	65.0
232.0000	36.00	0.200	0.02	29.00	0.45	65.0
233.9900	36.00	0.200	0.02	29.00	0.45	65.0
234.0000	36.00	0.200	0.02	29.00	0.45	65.0
248.0000	36.00	0.200	0.02	29.00	0.45	65.0
269.0000	36.00	0.200	0.02	29.00	0.45	65.0
285.0000	36.00	0.200	0.02	29.00	0.45	65.0

********** VELOCITY, REYNOLD'S NUMBER AND PRESSURE DROP **********

Distance mi	Diameter in	FlowRate bbl/hr	Velocity ft/sec	Reynolds number	Press.drop psi/mi	Location
0.0000	20.00	6,547.03	5.05	1,179	18.35	Corona
12.0000	20.00	6,547.03	5.05	1,083	20.99	
24.0000	20.00	6,547.03	5.05	1,010	23.37	
37.5000	20.00	5,347.03	4.12	773	21.02	
53.9900	20.00	5,347.03	4.12	963	14.99	BannHtr
54.0000	20.00	5,347.03	4.12	963	14.99	Banning
98.0000	20.00	5,347.03	4.12	692	24.76	
112.0000	20.00	5,347.03	4.12	652	27.03	
119.9900	20.00	5,347.03	4.12	963	14.99	MorongoHtr
120.0000	20.00	5,347.03	4.12	963	14.99	Morongo
134.0000	20.00	5,347.03	4.12	843	18.44	
156.0000	20.00	5,347.03	4.12	725	23.13	
168.0000	20.00	5,347.03	4.12	682	25.30	
174.9900	20.00	5,347.03	4.12	963	14.99	SHHtr
175.0000	20.00	5,347.03	4.12	963	14.99	Sheephole
189.0000	20.00	5,347.03	4.12	843	18.44	
212.0000	20.00	5,347.03	4.12	721	23.32	
231.9900	20.00	5,347.03	4.12	963	14.99	OatmanHtr
232.0000	20.00	5,347.03	4.12	963	14.99	Oatman
233.9900	20.00	5,347.03	4.12	943	15.50	
234.0000	20.00	5,347.03	4.12	943	15.51	
248.0000	20.00	5,347.03	4.12	830	18.91	
269.0000	20.00	5,347.03	4.12	721	23.33	
285.0000	20.00	5,347.03	4.12	721	23.33	Kingman

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

Distance mi	Elevation ft	FlowRate bbl/hr	Temp. degF	SpGrav	Viscosity CST	Pressure psi	MAOP psi	Location Name
0.0000	610.00	6,547.03	140.00	0.5982	638.34	50.00	1440.00	Corona
0.0000	610.00	6,547.03	140.00	0.5982	638.34	1326.72	1440.00	Corona
12.0000	851.00	6,547.03	133.81	0.6282	695.31	1044.12	1440.00	
24.0000	920.00	6,547.03	128.85	0.6522	745.75	773.50	1440.00	
37.5000	1245.00	5,347.03	124.39	0.6738	795.09	366.22	1440.00	
53.9900	1140.00	5,347.03	117.77	0.7058	876.10	50.15	1440.00	BannHtr
53.9900	1140.00	5,347.03	140.00	0.5982	638.34	50.15	1440.00	BannHtr
54.0000	1140.00	5,347.03	139.99	0.5982	638.41	50.00	1440.00	Banning
54.0000	1140.00	5,347.03	139.99	0.5982	638.41	1286.36	1440.00	Banning
98.0000	1265.00	5,347.03	116.85	0.7102	888.18	594.48	1440.00	
112.0000	987.00	5,347.03	112.82	0.7297	943.66	333.35	1440.00	
119.9900	1199.73	5,347.03	110.87	0.7392	972.10	50.22	1440.00	MorongoHtr
119.9900	1199.73	5,347.03	140.00	0.5982	638.34	50.22	1440.00	MorongoHtr
120.0000	1200.00	5,347.03	139.99	0.5982	638.41	50.00	1440.00	Morongo
120.0000	1200.00	5,347.03	139.99	0.5982	638.41	1338.20	1440.00	Morongo
134.0000	1540.00	5,347.03	130.44	0.6445	729.08	1040.30	1440.00	
156.0000	1875.00	5,347.03	119.99	0.6951	847.88	541.14	1440.00	
168.0000	2120.00	5,347.03	115.85	0.7151	901.57	189.87	1440.00	
174.9900	2000.17	5,347.03	113.78	0.7251	930.16	50.11	1440.00	SHHtr
174.9900	2000.17	5,347.03	140.00	0.5982	638.34	50.11	1440.00	SHHtr
175.0000	2000.00	5,347.03	139.99	0.5982	638.41	50.00	1440.00	Sheephole
175.0000	2000.00	5,347.03	139.99	0.5982	638.41	1135.41	1440.00	Sheephole
189.0000	1742.00	5,347.03	130.44	0.6445	729.08	992.39	1440.00	
212.0000	1485.00	5,347.03	119.61	0.6969	852.57	639.95	1440.00	
231.9900	1894.80	5,347.03	113.32	0.7273	936.59	50.20	1440.00	OatmanHtr
231.9900	1894.80	5,347.03	140.00	0.5982	638.34	50.20	1440.00	OatmanHtr
232.0000	1895.00	5,347.03	139.99	0.5982	638.41	50.00	1440.00	Oatman
232.0000	1895.00	5,347.03	139.99	0.5982	638.41	1438.83	1440.00	Oatman
233.9900	1911.92	5,347.03	138.44	0.6058	652.13	1404.62	1440.00	
234.0000	1912.00	5,347.03	138.43	0.6058	652.20	1404.45	1440.00	
248.0000	2369.00	5,347.03	129.28	0.6501	741.18	1067.51	1440.00	
269.0000	2842.00	5,347.03	119.59	0.6970	852.80	537.28	1440.00	
285.0000	3220.00	5,347.03	114.38	0.7222	921.75	50.00	1440.00	Kingman

(b). Repeat the above calculations, considering pump curve data given above. Assume that all pump stations are constant speed electric motor driven pumps.

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******* LIQTHERM  STEADY STATE PIPELINE HYDRAULIC SIMULATION REPORT *********

DATE: 3/5/2016           TIME:  8:33 AM

PROJECT:                 Problem 3b
                         Corona to Kingman Pipeline
                         5 Pump stations and 4 heater stations

Pipeline data file:      C:\Users\Shashi Menon\Documents\LIQTHERM\Problems\Problem3b.TOT

******* LIQTHERM - LIQUID PIPELINE STEADY STATE HYDRAULIC SIMULATION ********
****************** 7.00*************

CASE NUMBER:                            1008

CALCULATION OPTIONS:
Thermal Calculations:                   NO
Frictional Heating:                     YES
Use Pump Curves:                        YES
Pump Curves Corrected for Viscosity:    NO
MAOP Check:                             YES
Horsepower Check:                       NO
Heating due to pump inefficiency:       NO
Valves/Fittings and Devices:            NO
Branch pipe calculations:               NO
Loop pipe calculations:                 NO
Maximum Inlet Flow:                     NO
Batching Considered:                    NO
DRA Injection:                          NO
Correct volumes for temperature:        NO
Slack Line Calculations:                NO
Customized Output:                      NO


Inlet flow rate:                        6,547 bbl/hr
Outlet flow rate:                       5,347 bbl/hr
Inlet flow temperature:                 140.00 degF
Outlet flow temperature:                114.38 degF

Minimum Pipe pressure:                  0.00 psi
Pipe delivery pressure:                 50.00 psi


Pressure drop formula used:             Colebrook-White equation

Calculation sub-divisions:              2
Iteration Accuracy:                     MEDIUM


********** LIQUID PROPERTIES **********

Liquid properties file: C:\Users\Shashi Menon\Documents\LIQTHERM\Liquid Properties
Database
```

PRODUCT: SJVH
Specific gravity: 0.9854 at 60.0 degF
0.7918 at 100.0 degF

Viscosity: 2100.00 CST at 65.0 degF
985.00 CST at 110.0 degF

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

Location mi	Flow rate bbl/hr	Inlet Temp. degF	Product
0.00	6,547	140.0	SJVH
37.50	-1,200	124.4	

********** PUMP STATIONS **********

Pump station (Active)	Distance mi	Pump suct pressure psi	Pump disch pressure psi	Sta. disch pressure psi	Throttled pressure psi	BHP Reqd by pump	TotHPinst.	KW
Corona	0.00	50.00	1331.44	1331.44	0.00	4402	6000	3284
Banning	54.00	54.72	1299.44	1299.44	0.00	3410	4000	2544
Morongo	120.00	63.08	1359.30	1359.30	0.00	3555	4000	2652
Sheephole	175.00	71.11	1159.97	1159.97	0.00	2972	4000	2217
Oatman	232.00	74.56	1466.10	1438.83	27.27	3833	4000	2860

Total active pump stations: 5 TOTAL Power: 18,172
22,000 13557

********** PUMP AND DRIVER DATA **********

PumpSta.	Config.	Pump Curves	Status	Driver	RPM	Pump BHP	HPInstalled
Corona	Series	CORONA.PMP	ON	Motor	3,500	1,467	2000
Corona	Series	CORONA.PMP	ON	Motor	3,500	1,467	2000
Corona	Series	CORONA.PMP	ON	Motor	3,500	1,467	2000
Banning	Series	BANNING.PMP	ON	Motor	3,500	1,705	2000
Banning	Series	BANNING.PMP	ON	Motor	3,500	1,705	2000
Morongo	Series	MORONGO.PMP	ON	Motor	3,500	1,778	2000
Morongo	Series	MORONGO.PMP	ON	Motor	3,500	1,778	2000
Sheephole	Series	SHEEPHOLE.PMP	ON	Motor	3,500	1,486	2000

Sheephole	Series	SHEEPHOLE.PMP	ON	Motor	3,500	1,486	2000
Oatman	Series	OATMAN.PMP	ON	Motor	3,500	3,833	4000

Pump Station: Corona
Pump curve file: CORONA.PMP
Constant Speed Pump(s): 3,500 RPM
Pump curve: CORONA.PMP Pump Status:ON
Pump impeller: 12.000 in. Number of stages: 2
Operating point: 4582.90 gal/min 1649.46 ft 77.81%

Flow rate gal/min	Head ft	Efficiency %	WaterHP HP
0.00	2378.0	0.01	0.00
804.00	2393.0	34.30	1416.48
1608.00	2363.0	57.50	1668.73
2412.00	2302.0	72.00	1947.40
3215.00	2135.0	79.00	2194.10
3818.00	1938.0	80.00	2335.63
4019.00	1863.0	79.80	2369.37
4823.00	1560.0	76.00	2499.96
5627.00	1272.0	65.70	2751.08

Resultant Pump Curve: Corona Pump station
Constant Speed Pump(s): 3,500 RPM
Operating point: 4582.90 gal/min 4948.39 ft 77.81%

Flow rate gal/min	Head ft	Efficiency %	WaterHP HP
0.01	7134.00	0.01	180.15
804.00	7179.00	34.30	4249.43
1608.00	7089.00	57.50	5006.20
2412.00	6906.00	72.00	5842.20
3215.00	6405.00	79.00	6582.30
3818.00	5814.00	80.00	7006.90
4019.00	5589.00	79.80	7108.11
4823.00	4680.00	76.00	7499.88
5627.00	3816.00	65.70	8253.24

Pump Station: Banning
Pump curve file: BANNING.PMP
Constant Speed Pump(s): 3,500 RPM
Pump curve: BANNING.PMP Pump Status:ON
Pump impeller: 12.000 in. Number of stages: 2
Operating point: 3742.90 gal/min 2403.14 ft 79.71%

Flow rate gal/min	Head ft	Efficiency %	WaterHP HP
0.00	2773.0	0.01	0.00
868.00	2791.0	34.00	1799.31

1736.00	2756.0	58.00	2083.08
2604.00	2685.0	72.00	2452.21
3473.00	2491.0	79.00	2765.39
4124.00	2261.0	80.00	2943.30
4341.00	2173.0	80.00	2977.59
5209.00	1819.0	76.00	3148.32
6077.00	1484.0	66.00	3450.52

Resultant Pump Curve: Banning Pump station
Constant Speed Pump(s): 3,500 RPM
Operating point: 3742.90 gal/min 4806.29 ft 79.71%

Flow rate gal/min	Head ft	Efficiency %	WaterHP HP
0.01	5546.00	0.01	140.05
868.00	5582.00	34.00	3598.62
1736.00	5512.00	58.00	4166.16
2604.00	5370.00	72.00	4904.42
3473.00	4982.00	79.00	5530.78
4124.00	4522.00	80.00	5886.59
4341.00	4346.00	80.00	5955.17
5209.00	3638.00	76.00	6296.63
6077.00	2968.00	66.00	6901.03

Pump Station: Morongo
Pump curve file: MORONGO.PMP
Constant Speed Pump(s): 3,500 RPM
Pump curve: MORONGO.PMP Pump Status:ON
Pump impeller: 12.000 in. Number of stages: 2
Operating point: 3742.90 gal/min 2502.56 ft 79.60%

Flow rate gal/min	Head ft	Efficiency %	WaterHP HP
0.00	2864.0	0.01	0.00
882.00	2882.0	34.00	1887.94
1765.00	2846.0	58.00	2187.04
2647.00	2773.0	72.00	2574.40
3529.00	2572.0	79.00	2901.35
4191.00	2335.0	80.00	3089.01
4411.00	2244.0	80.00	3124.46
5294.00	1879.0	76.00	3305.23
6176.00	1532.0	66.00	3620.15

Resultant Pump Curve: Morongo Pump station
Constant Speed Pump(s): 3,500 RPM
Operating point: 3742.90 gal/min 5005.12 ft 79.60%

Flow rate gal/min	Head ft	Efficiency %	WaterHP HP

0.01	5728.00	0.01	144.65
882.00	5764.00	34.00	3775.88
1765.00	5692.00	58.00	4374.08
2647.00	5546.00	72.00	5148.80
3529.00	5144.00	79.00	5802.70
4191.00	4670.00	80.00	6178.02
4411.00	4488.00	80.00	6248.92
5294.00	3758.00	76.00	6610.46
6176.00	3064.00	66.00	7240.31

Pump Station: Sheephole
Pump curve file: SHEEPHOLE.PMP
Constant Speed Pump(s): 3,500 RPM
Pump curve: SHEEPHOLE.PMP Pump Status:ON
Pump impeller: 12.000 in. Number of stages: 2
Operating point: 3742.90 gal/min 2102.22 ft 80.00%

Flow rate gal/min	Head ft	Efficiency %	WaterHP HP
0.00	2501.0	0.01	0.00
824.00	2517.0	34.30	1526.94
1649.00	2485.0	57.50	1799.63
2473.00	2422.0	72.00	2100.73
3298.00	2246.0	79.00	2367.76
3916.00	2039.0	80.00	2520.43
4122.00	1960.0	79.80	2556.62
4947.00	1641.0	76.00	2697.38
5771.00	1338.0	65.70	2967.88

Resultant Pump Curve: Sheephole Pump station
Constant Speed Pump(s): 3,500 RPM
Operating point: 3742.90 gal/min 4204.45 ft 80.00%

Flow rate gal/min	Head ft	Efficiency %	WaterHP HP
0.01	5002.00	0.01	126.31
824.00	5034.00	34.30	3053.87
1649.00	4970.00	57.50	3599.27
2473.00	4844.00	72.00	4201.46
3298.00	4492.00	79.00	4735.52
3916.00	4078.00	80.00	5040.86
4122.00	3920.00	79.80	5113.24
4947.00	3282.00	76.00	5394.75
5771.00	2676.00	65.70	5935.76

Pump Station: Oatman
Constant Speed Pump(s): 3,500 RPM
Pump curve: OATMAN.PMP Pump Status:ON
Pump impeller: 12.000 in. Number of stages: 2
Operating point: 3742.90 gal/min 5373.20 ft 79.26%

Flow rate gal/min	Head ft	Efficiency %	WaterHP HP

0.00	5577.0	0.01	0.00
1125.00	5684.0	37.80	4271.89
1687.00	5737.0	51.70	4727.31
2249.00	5715.0	62.50	5193.15
3374.00	5577.0	76.00	6252.26
4498.00	4887.0	84.00	6608.26
5623.00	4493.0	84.00	7595.04
6748.00	3612.0	78.80	7810.91

********** HEATER STATIONS **********

Heater Station	Distance mi	Heater Inlet Temp.	Heater Outlet Temp.	HeaterEffy %	HeaterDuty MMBtu/hr	HeatingCost $/MMBtu
Banning	53.99	117.77	140.00	85.00	14.72	5.00
Morongo	119.99	110.87	140.00	85.00	20.13	5.00
Sheephole	174.99	113.78	140.00	85.00	17.81	5.00
Oatman	231.99	113.32	140.00	85.00	18.17	5.00

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

Distance mi	Elevation ft	Diameter in	Wall Thk. in	Roughness in	MAOP psi	Location
0.0000	610.00	20.000	0.375	0.00200	1440	Corona
12.0000	851.00	20.000	0.375	0.00200	1440	
24.0000	920.00	20.000	0.375	0.00200	1440	
37.5000	1245.00	20.000	0.375	0.00200	1440	
53.9900	1140.00	20.000	0.375	0.00200	1440	BannHtr
54.0000	1140.00	20.000	0.375	0.00200	1440	Banning
98.0000	1265.00	20.000	0.375	0.00200	1440	
112.0000	987.00	20.000	0.375	0.00200	1440	
119.9900	1199.73	20.000	0.375	0.00200	1440	MorongoHtr
120.0000	1200.00	20.000	0.375	0.00200	1440	Morongo
134.0000	1540.00	20.000	0.375	0.00200	1440	
156.0000	1875.00	20.000	0.375	0.00200	1440	
168.0000	2120.00	20.000	0.375	0.00200	1440	
174.9900	2000.17	20.000	0.375	0.00200	1440	SHHtr
175.0000	2000.00	20.000	0.375	0.00200	1440	Sheephole
189.0000	1742.00	20.000	0.375	0.00200	1440	
212.0000	1485.00	20.000	0.375	0.00200	1440	
231.9900	1894.80	20.000	0.375	0.00200	1440	OatmanHtr
232.0000	1895.00	20.000	0.375	0.00200	1440	Oatman
233.9900	1911.92	20.000	0.375	0.00200	1440	
234.0000	1912.00	20.000	0.375	0.00200	1440	
248.0000	2369.00	20.000	0.375	0.00200	1440	
269.0000	2842.00	20.000	0.375	0.00200	1440	
285.0000	3220.00	20.000	0.375	0.00200	1440	Kingman

********** THERMAL CONDUCTIVITY PROFILE DATA **********

Distance	Burial depth (Cover)	Insul.Thk	Thermal Conductivity Insulation	Pipe	Soil	Soil Temp
mi	in	in	Btu/hr/ft/degF			degF

0.0000	36.00	0.200	0.02	29.00	0.45	65.0
12.0000	36.00	0.200	0.02	29.00	0.45	65.0
24.0000	36.00	0.200	0.02	29.00	0.45	65.0
37.5000	36.00	0.200	0.02	29.00	0.45	65.0
53.9900	36.00	0.200	0.02	29.00	0.45	65.0
54.0000	36.00	0.200	0.02	29.00	0.45	65.0
98.0000	36.00	0.200	0.02	29.00	0.45	65.0
112.0000	36.00	0.200	0.02	29.00	0.45	65.0
119.9900	36.00	0.200	0.02	29.00	0.45	65.0
120.0000	36.00	0.200	0.02	29.00	0.45	65.0
134.0000	36.00	0.200	0.02	29.00	0.45	65.0
156.0000	36.00	0.200	0.02	29.00	0.45	65.0
168.0000	36.00	0.200	0.02	29.00	0.45	65.0
174.9900	36.00	0.200	0.02	29.00	0.45	65.0
175.0000	36.00	0.200	0.02	29.00	0.45	65.0
189.0000	36.00	0.200	0.02	29.00	0.45	65.0
212.0000	36.00	0.200	0.02	29.00	0.45	65.0
231.9900	36.00	0.200	0.02	29.00	0.45	65.0
232.0000	36.00	0.200	0.02	29.00	0.45	65.0
233.9900	36.00	0.200	0.02	29.00	0.45	65.0
234.0000	36.00	0.200	0.02	29.00	0.45	65.0
248.0000	36.00	0.200	0.02	29.00	0.45	65.0
269.0000	36.00	0.200	0.02	29.00	0.45	65.0
285.0000	36.00	0.200	0.02	29.00	0.45	65.0

********** VELOCITY, REYNOLD'S NUMBER AND PRESSURE DROP **********

Distance mi	Diameter in	FlowRate bbl/hr	Velocity ft/sec	Reynolds number	Press.drop psi/mi	Location
0.0000	20.00	6,547.00	5.05	1,179	18.35	Corona
12.0000	20.00	6,547.00	5.05	1,083	20.99	
24.0000	20.00	6,547.00	5.05	1,010	23.37	
37.5000	20.00	5,347.00	4.12	773	21.02	
53.9900	20.00	5,347.00	4.12	963	14.99	BannHtr
54.0000	20.00	5,347.00	4.12	963	14.99	Banning
98.0000	20.00	5,347.00	4.12	692	24.76	
112.0000	20.00	5,347.00	4.12	652	27.03	
119.9900	20.00	5,347.00	4.12	963	14.99	MorongoHtr
120.0000	20.00	5,347.00	4.12	963	14.99	Morongo
134.0000	20.00	5,347.00	4.12	843	18.44	
156.0000	20.00	5,347.00	4.12	725	23.13	
168.0000	20.00	5,347.00	4.12	682	25.30	
174.9900	20.00	5,347.00	4.12	963	14.99	SHHtr
175.0000	20.00	5,347.00	4.12	963	14.99	Sheephole
189.0000	20.00	5,347.00	4.12	843	18.44	
212.0000	20.00	5,347.00	4.12	721	23.32	
231.9900	20.00	5,347.00	4.12	963	14.99	OatmanHtr
232.0000	20.00	5,347.00	4.12	963	14.99	Oatman
233.9900	20.00	5,347.00	4.12	943	15.50	
234.0000	20.00	5,347.00	4.12	943	15.51	
248.0000	20.00	5,347.00	4.12	830	18.91	
269.0000	20.00	5,347.00	4.12	721	23.33	
285.0000	20.00	5,347.00	4.12	721	23.33	Kingman

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

Distance mi	Elevation ft	FlowRate bbl/hr	Temp. degF	SpGrav	Viscosity CST	Pressure psi	MAOP psi	Location Name
0.0000	610.00	6,547.00	140.00	0.5982	638.34	50.00	1440.00	Corona
0.0000	610.00	6,547.00	140.00	0.5982	638.34	1331.44	1440.00	Corona
12.0000	851.00	6,547.00	133.81	0.6282	695.31	1048.84	1440.00	
24.0000	920.00	6,547.00	128.85	0.6522	745.75	778.22	1440.00	
37.5000	1245.00	5,347.00	124.39	0.6738	795.10	370.94	1440.00	
53.9900	1140.00	5,347.00	117.77	0.7058	876.10	54.87	1440.00	BannHtr
53.9900	1140.00	5,347.00	140.00	0.5982	638.34	54.87	1440.00	BannHtr
54.0000	1140.00	5,347.00	139.99	0.5982	638.41	54.72	1440.00	Banning
54.0000	1140.00	5,347.00	139.99	0.5982	638.41	1299.44	1440.00	Banning
98.0000	1265.00	5,347.00	116.85	0.7102	888.19	607.56	1440.00	
112.0000	987.00	5,347.00	112.82	0.7297	943.66	346.44	1440.00	
119.9900	1199.73	5,347.00	110.87	0.7392	972.10	63.30	1440.00	MorongoHtr
119.9900	1199.73	5,347.00	140.00	0.5982	638.34	63.30	1440.00	MorongoHtr
120.0000	1200.00	5,347.00	139.99	0.5982	638.41	63.08	1440.00	Morongo
120.0000	1200.00	5,347.00	139.99	0.5982	638.41	1359.30	1440.00	Morongo
134.0000	1540.00	5,347.00	130.44	0.6445	729.08	1061.40	1440.00	
156.0000	1875.00	5,347.00	119.99	0.6951	847.88	562.24	1440.00	
168.0000	2120.00	5,347.00	115.85	0.7151	901.57	210.98	1440.00	
174.9900	2000.17	5,347.00	113.78	0.7251	930.17	71.21	1440.00	SHHtr
174.9900	2000.17	5,347.00	140.00	0.5982	638.34	71.21	1440.00	SHHtr
175.0000	2000.00	5,347.00	139.99	0.5982	638.41	71.11	1440.00	Sheephole
175.0000	2000.00	5,347.00	139.99	0.5982	638.41	1159.97	1440.00	Sheephole
189.0000	1742.00	5,347.00	130.44	0.6445	729.08	1016.94	1440.00	
212.0000	1485.00	5,347.00	119.61	0.6969	852.57	664.50	1440.00	
231.9900	1894.80	5,347.00	113.32	0.7273	936.59	74.76	1440.00	OatmanHtr
231.9900	1894.80	5,347.00	140.00	0.5982	638.34	74.76	1440.00	OatmanHtr
232.0000	1895.00	5,347.00	139.99	0.5982	638.41	74.56	1440.00	Oatman
232.0000	1895.00	5,347.00	139.99	0.5982	638.41	1438.83	1440.00	Oatman
233.9900	1911.92	5,347.00	138.44	0.6058	652.13	1404.62	1440.00	
234.0000	1912.00	5,347.00	138.43	0.6058	652.20	1404.44	1440.00	
248.0000	2369.00	5,347.00	129.28	0.6501	741.18	1067.51	1440.00	
269.0000	2842.00	5,347.00	119.59	0.6970	852.80	537.28	1440.00	
285.0000	3220.00	5,347.00	114.38	0.7222	921.75	50.00	1440.00	Kingman

Simulation Date: 5-March-2016
Output file: C:\Users\Shashi Menon\Documents\LIQTHERM\Problems\Problem3b.OUT

Sample Problem – 4 (SI/Metric)

A 400 mm diameter pipeline 100 km long transports 1,000 m3/hr of a liquid product ANSMetric from an originating station at San Jose to a delivery terminal at Cuiaba. There are 2 pump stations located at San Jose and Rio Grande (50.0 km). The product enters San Jose at 40 degC. At an intermediate location, Santa Clara (20.0 km) liquid is delivered at 200 m^3/hr. The remainder of the product continues on to Cuiaba. Delivery pressure at Cuiaba: 350 kPa.

The pipeline elevation profile is as follows:

Distance km	**Elevation m**	**Location**
0.0	100	San Jose
5.0	150	
10.0	200	
12.5	180	
20.0	300	Santa Clara
22.6	120	
24.0	200	
30.0	350	
40.0	400	
50.0	120	Rio Grande
60.0	200	
70.0	340	
80.0	460	
85.0	620	
90.0	400	
100.0	350	Cuiaba

The pump curve data for San Jose and Rio Grande are on the output report.

San Jose Pump Curves:

Flow rate (m3/hr)	Head (meters)	Efficiency (%)	WaterPower (KW)
0	1655	0.01	0.00
550.5	1572.3	63.8	3692.00
1101	1324	85	4667.09
1376.3	1137.8	79.7	5347.01
1651.5	910.3	63.8	6412.57

Rio Grande Pump Curves:

Flow rate (m3/hr)	Head (meters)	Efficiency (%)	WaterPower (KW)
0	1400	0.01	0.00
562	1330	63.8	3188.29
1124	1120	85	4030.47
1405	962.5	79.7	4617.52
1686	770	63.8	5537.55

There is one pump in parallel in San Jose driven by a 2000 HP constant speed motor, the rated speed is 3560 RPM. At Rio Grande there are 2 identical pumps in parallel, each driven by a 2500 HP constant speed electric motor of 3560 RPM.

4a. Determine the pressure and temperature profile for the pipeline considering pump curve data. Use the Colebrook-White pressure drop equation and consider 9800 kPa MAOP for the entire pipeline.

```
******* LIQTHERM  STEADY STATE PIPELINE HYDRAULIC SIMULATION REPORT *********

DATE: 3/8/2016            TIME:  9:59 AM

PROJECT:                  Problem 4a
                          San Jose to Cuiaba Pipeline using pump curves

Pipeline data file:       C:\Users\Shashi Menon\Documents\LIQTHERM\Problems\Problem4a.TOT

******* LIQTHERM - LIQUID PIPELINE STEADY STATE HYDRAULIC SIMULATION ********
****************** 7.00*************

CASE NUMBER:                           1010

CALCULATION OPTIONS:
Thermal Calculations:                  NO
Frictional Heating:                    YES
Use Pump Curves:                       YES
Pump Curves Corrected for Viscosity:   NO
MAOP Check:                            YES
Horsepower Check:                      NO
Heating due to pump inefficiency:      NO
Valves/Fittings and Devices:           NO
Branch pipe calculations:              NO
Loop pipe calculations:                NO
Maximum Inlet Flow:                    NO
Batching Considered:                   NO
DRA Injection:                         NO
Correct volumes for temperature:       NO
Slack Line Calculations:               NO
Customized Output:                     NO

Inlet flow rate:                       1,000 m³/hr
Outlet flow rate:                      800 m³/hr
Inlet flow temperature:                40.00 degC
Outlet flow temperature:               28.27 degC

Minimum Pipe pressure:                 0.00 kPa
Pipe delivery pressure:                812.22 kPa

Pressure drop formula used:            Colebrook-White equation

Calculation sub-divisions:             2
Iteration Accuracy:                    MEDIUM
```

********** LIQUID PROPERTIES **********

```
Liquid properties file: C:\Users\Shashi Menon\Documents\LIQTHERM\Liquid Properties DatabaseMetric
PRODUCT:                 ANSMetric
Specific gravity:        0.8950 at 20.0 degC
                         0.8500 at 30.0 degC

Viscosity:               50.00 CST at 20.0 degC
                         15.00 CST at 30.0 degC
```

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

Location km	Flow rate m^3/hr	Inlet Temp. degC	Product
0.00	1,000	40.0	ANSMetric
20.00	-200	37.6	

********** PUMP STATIONS **********

Pump station	Distance km	Pump suct pressure kPa	Pump disch pressure kPa	Sta. disch pressure kPa	Throttled pressure kPa	KW Reqd by pump	TotKWinst. (Active)
SanJose	0.00	350.00	35576.66	9800.00	25776.66	3329	2000
RioGrande	50.00	4920.54	42377.03	7302.10	35074.93	5096	5000

Total active pump stations: 2   TOTAL Power: 8,425   7,000

WARNING!!!.....Installed KW exceeded at SanJose Pump Station.
WARNING!!!.....Installed KW exceeded at RioGrande Pump Station.

********** PUMP AND DRIVER DATA **********

PumpSta.	Config.	Pump Curves	Status	Driver	RPM	Pump KW	KW Installed
SanJose	Parallel	SANJOSE.PMP	ON	Motor	3,560	3,329	2000
RioGrande	Parallel	RIOGRANDE.PMP	ON	Motor	3,560	2,548	2500
RioGrande	Parallel	RIOGRANDE.PMP	ON	Motor	3,560	2,548	2500

WARNING!.......Required KW exceeds available Installed KW at pump station SanJose
WARNING!.......Required KW exceeds available Installed KW at pump station RioGrande
WARNING!.......Required KW exceeds available Installed KW at pump station RioGrande

Pump Station: SanJose
Constant Speed Pump(s): 3,560 RPM
Pump curve: SANJOSE.PMP   Pump Status:ON
Pump impeller: 12.000 mm.   Number of stages: 2
Operating point: 1000.00 m^3/hr 1220.40 meters 80.30%

Flow rate m³/hr	Head meters	Efficiency %	WaterPower KW
0.00	1376.3	0.01	0.00
662.00	1307.4	63.80	3691.78
1324.00	1101.0	85.00	4667.09
1655.00	946.2	79.70	5347.03
1986.00	756.9	63.80	6411.90

Pump Station: RioGrande
Pump curve file: RIOGRANDE.PMP
Constant Speed Pump(s): 3,560 RPM
Pump curve: RIOGRANDE.PMP Pump Status:ON
Pump impeller: 300.000 mm. Number of stages: 2
Operating point: 400.00 m³/hr 1360.71 meters 48.62%

Flow rate m³/hr	Head meters	Efficiency %	WaterPower KW
0.00	1400.0	0.01	0.00
562.00	1330.0	63.80	3188.29
1124.00	1120.0	85.00	4030.47
1405.00	962.5	79.70	4617.52
1686.00	770.0	63.80	5537.55

Resultant Pump Curve: RioGrande Pump station
Constant Speed Pump(s): 3,560 RPM
Operating point: 800.00 m³/hr 1360.71 meters 48.62%

Flow rate m³/hr	Head meters	Efficiency %	WaterPower KW
0.01	1400.00	0.01	380.99
1124.00	1330.00	63.80	6376.57
2248.00	1120.00	85.00	8060.93
2810.00	962.50	79.70	9235.04
3372.00	770.00	63.80	11075.10

********* Heater Stations not Active *************

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

Distance km	Elevation m	Diameter mm	Wall Thk. mm	Roughness mm	MAOP kPa	Location
0.0000	100.00	400.000	10.000	0.05000	9800.0	SanJose
5.0000	150.00	400.000	10.000	0.05000	9800.0	
10.0000	200.00	400.000	10.000	0.05000	9800.0	
12.5000	180.00	400.000	10.000	0.05000	9800.0	
20.0000	300.00	400.000	10.000	0.05000	9800.0	SantaClara

22.6000	120.00	400.000	10.000	0.05000	9800.0	
24.0000	200.00	400.000	10.000	0.05000	9800.0	
30.0000	350.00	400.000	10.000	0.05000	9800.0	
40.0000	400.00	400.000	10.000	0.05000	9800.0	
50.0000	120.00	400.000	10.000	0.05000	9800.0	RioGrande
60.0000	200.00	400.000	10.000	0.05000	9800.0	
70.0000	340.00	400.000	10.000	0.05000	9800.0	
80.0000	460.00	400.000	10.000	0.05000	9800.0	
85.0000	620.00	400.000	10.000	0.05000	9800.0	
90.0000	400.00	400.000	10.000	0.05000	9800.0	
100.0000	350.00	400.000	10.000	0.05000	9800.0	Cuiaba

********** THERMAL CONDUCTIVITY PROFILE DATA **********

Distance km	Burial depth (Cover) mm	Insul.Thk mm	Thermal Conductivity Insulation Watts/m/degC	Pipe	Soil	Soil Temp degC
0.0000	915.00	0.000	0.00	50.00	1.20	15.0
5.0000	915.00	0.000	0.00	50.00	1.20	15.0
10.0000	915.00	0.000	0.00	50.00	1.20	15.0
12.5000	915.00	0.000	0.00	50.00	1.20	15.0
20.0000	915.00	0.000	0.00	50.00	1.20	15.0
22.6000	915.00	0.000	0.00	50.00	1.20	15.0
24.0000	915.00	0.000	0.00	50.00	1.20	15.0
30.0000	915.00	0.000	0.00	50.00	1.20	15.0
40.0000	915.00	0.000	0.00	50.00	1.20	15.0
50.0000	915.00	0.000	0.00	50.00	1.20	15.0
60.0000	915.00	0.000	0.00	50.00	1.20	15.0
70.0000	915.00	0.000	0.00	50.00	1.20	15.0
80.0000	915.00	0.000	0.00	50.00	1.20	15.0
85.0000	915.00	0.000	0.00	50.00	1.20	15.0
90.0000	915.00	0.000	0.00	50.00	1.20	15.0
100.0000	915.00	0.000	0.00	50.00	1.20	15.0

********** VELOCITY, REYNOLD'S NUMBER AND PRESSURE DROP **********

Distance km	Diameter mm	FlowRate m^3/hr	Velocity m/sec	Reynolds number	Press.drop kPa/km	Location
0.0000	400.00	1,000.00	2.45	146,442	113.18	SanJose
5.0000	400.00	1,000.00	2.45	139,594	114.51	
10.0000	400.00	1,000.00	2.45	133,272	115.84	
12.5000	400.00	1,000.00	2.45	130,305	116.48	
20.0000	400.00	800.00	1.96	97,610	78.94	SantaClara
22.6000	400.00	800.00	1.96	94,092	79.67	
24.0000	400.00	800.00	1.96	92,278	80.05	
30.0000	400.00	800.00	1.96	85,030	81.77	
40.0000	400.00	800.00	1.96	74,709	84.55	
50.0000	400.00	800.00	1.96	66,265	87.21	RioGrande
60.0000	400.00	800.00	1.96	59,319	89.74	
70.0000	400.00	800.00	1.96	53,575	92.18	
80.0000	400.00	800.00	1.96	48,802	94.45	

85.0000	400.00	800.00	1.96	46,737	95.57	
90.0000	400.00	800.00	1.96	44,847	96.60	
100.0000	400.00	800.00	1.96	44,847	96.60	Cuiaba

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

Distance km	Elevation m	FlowRate m^3/hr	Temp. degC	SpGrav	Viscosity CST	Pressure kPa	MAOP kPa	Location Name
0.0000	100.00	1,000.00	40.00	0.8050	6.36	350.00	9800.00	SanJose
0.0000	100.00	1,000.00	40.00	0.8050	6.36	9800.00	9800.00	SanJose
5.0000	150.00	1,000.00	39.35	0.8079	6.67	8839.82	9800.00	
10.0000	200.00	1,000.00	38.74	0.8107	6.98	7871.48	9800.00	
12.5000	180.00	1,000.00	38.44	0.8120	7.14	7740.69	9800.00	
20.0000	300.00	800.00	37.60	0.8158	7.63	5912.51	9800.00	SantaClara
22.6000	120.00	800.00	37.13	0.8179	7.91	7145.75	9800.00	
24.0000	200.00	800.00	36.89	0.8190	8.07	6393.28	9800.00	
30.0000	350.00	800.00	35.89	0.8235	8.76	4709.53	9800.00	
40.0000	400.00	800.00	34.37	0.8303	9.97	3488.54	9800.00	
50.0000	120.00	800.00	33.02	0.8364	11.24	4920.54	9800.00	RioGrande
50.0000	120.00	800.00	33.02	0.8364	11.24	7302.10	9800.00	RioGrande
60.0000	200.00	800.00	31.83	0.8418	12.55	5774.58	9800.00	
70.0000	340.00	800.00	30.77	0.8465	13.90	3722.60	9800.00	
80.0000	460.00	800.00	29.83	0.8508	15.26	1805.72	9800.00	
85.0000	620.00	800.00	29.41	0.8527	15.93	0.00	9800.00	
90.0000	400.00	800.00	29.01	0.8545	16.60	1359.74	9800.00	
100.0000	350.00	800.00	28.27	0.8578	17.94	812.22	9800.00	Cuiaba

Simulation Date: 8-March-2016

Output file: C:\Users\Shashi Menon\Documents\LIQTHERM\Problems\Problem4a.OUT

4b. Determine the maximum inlet flow rate possible without exceeding MAOP.

```
******* LIQTHERM  STEADY STATE PIPELINE HYDRAULIC SIMULATION REPORT *********

DATE: 3/8/2016            TIME:  10:22 AM
PROJECT:                  Problem 4b
                          San Jose to Cuiaba Pipeline using pump curves

Pipeline data file:       C:\Users\Shashi Menon\Documents\LIQTHERM\Problems\Problem4a.TOT

******* LIQTHERM - LIQUID PIPELINE STEADY STATE HYDRAULIC SIMULATION ********
****************** 7.00*************

CASE NUMBER:                            1012

CALCULATION OPTIONS:
Thermal Calculations:                   NO
Frictional Heating:                     YES
Use Pump Curves:                        YES
Pump Curves Corrected for Viscosity:    NO
MAOP Check:                             YES
Horsepower Check:                       NO
Heating due to pump inefficiency:       NO
Valves/Fittings and Devices:            NO
Branch pipe calculations:               NO
Loop pipe calculations:                 NO
Maximum Inlet Flow:                     YES
Batching Considered:                    NO
DRA Injection:                          NO
Correct volumes for temperature:        NO
Slack Line Calculations:                NO
Customized Output:                      NO


Inlet flow rate:                        1,330 m³/hr
Outlet flow rate:                       1,130 m³/hr
Inlet flow temperature:                 40.00 degC
Outlet flow temperature:                34.71 degC

Minimum Pipe pressure:                  0.00 kPa
Pipe delivery pressure:                 350.00 kPa


Pressure drop formula used:             Colebrook-White equation

********** MAXIMUM PIPELINE CAPACITY RUN **********
Calculation sub-divisions:              2
Iteration Accuracy:                     MEDIUM



********** LIQUID PROPERTIES **********

Liquid properties file: C:\Users\Shashi Menon\Documents\LIQTHERM\Liquid Properties DatabaseMetric

PRODUCT:                  ANSMetric
Specific gravity:         0.8950 at 20.0 degC
                          0.8500 at 30.0 degC

Viscosity:                50.00 CST at 20.0 degC
                          15.00 CST at 30.0 degC
```

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

Location km	Flow rate m^3/hr	Inlet Temp. degC	Product
0.00	1,330	40.0	ANSMetric
20.00	-200	39.5	

****** INLET FLOW RATE REDUCED DUE TO PUMP LIMITS AND/OR PIPE MAOP LIMITS ****

********** PUMP STATIONS **********

Pump station	Distance km	Pump suct pressure kPa	Pump disch pressure kPa	Sta. disch pressure kPa	Throttled pressure kPa	KW Reqd by pump	TotKWinst. (Active)
SanJose	0.00	350.00	35419.54	9800.00	25619.54	3765	2000
RioGrande	50.00	1470.42	37997.01	9808.55	28188.46	5217	5000
Total active pump stations: 2			TOTAL Power:			8,983	7,000

WARNING!!!.....Installed KW exceeded at SanJose Pump Station.
WARNING!!!.....Installed KW exceeded at RioGrande Pump Station.

********** PUMP AND DRIVER DATA **********

PumpSta.	Config.	Pump Curves	Status	Driver	RPM	Pump KW	KW Installed
SanJose	Parallel	SANJOSE.PMP	ON	Motor	3,560	3,765	2000
RioGrande	Parallel	RIOGRANDE.PMP	ON	Motor	3,560	2,609	2500
RioGrande	Parallel	RIOGRANDE.PMP	ON	Motor	3,560	2,609	2500

WARNING!.......Required KW exceeds available Installed KW at pump station SanJose
WARNING!.......Required KW exceeds available Installed KW at pump station RioGrande
WARNING!.......Required KW exceeds available Installed KW at pump station RioGrande

Pump Station: SanJose
Constant Speed Pump(s): 3,560 RPM
Pump curve: SANJOSE.PMP Pump Status:ON
Pump impeller: 12.000 mm. Number of stages: 2
Operating point: 1329.92 m^3/hr 1098.53 meters 85.00%

Flow rate m^3/hr	Head meters	Efficiency %	WaterPower KW
0.00	1376.3	0.01	0.00
662.00	1307.4	63.80	3691.78
1324.00	1101.0	85.00	4667.09
1655.00	946.2	79.70	5347.03
1986.00	756.9	63.80	6411.90

Pump Station: RioGrande
Pump curve file: RIOGRANDE.PMP
Constant Speed Pump(s): 3,560 RPM
Pump curve: RIOGRANDE.PMP Pump Status:ON
Pump impeller: 300.000 mm. Number of stages: 2

Operating point: 564.96 m³/hr 1329.31 meters 64.04%

Flow rate m³/hr	Head meters	Efficiency %	WaterPower KW
0.00	1400.0	0.01	0.00
562.00	1330.0	63.80	3188.29
1124.00	1120.0	85.00	4030.47
1405.00	962.5	79.70	4617.52
1686.00	770.0	63.80	5537.55

Resultant Pump Curve: RioGrande Pump station
Constant Speed Pump(s): 3,560 RPM
Operating point: 1129.92 m³/hr 1329.31 meters 64.04%

Flow rate m³/hr	Head meters	Efficiency %	WaterPower KW
0.01	1400.00	0.01	380.99
1124.00	1330.00	63.80	6376.57
2248.00	1120.00	85.00	8060.93
2810.00	962.50	79.70	9235.04
3372.00	770.00	63.80	11075.10

********* Heater Stations not Active *************

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

Distance km	Elevation m	Diameter mm	Wall Thk. mm	Roughness mm	MAOP kPa	Location
0.0000	100.00	400.000	10.000	0.05000	9800.0	SanJose
5.0000	150.00	400.000	10.000	0.05000	9800.0	
10.0000	200.00	400.000	10.000	0.05000	9800.0	
12.5000	180.00	400.000	10.000	0.05000	9800.0	
20.0000	300.00	400.000	10.000	0.05000	9800.0	SantaClara
22.6000	120.00	400.000	10.000	0.05000	9800.0	
24.0000	200.00	400.000	10.000	0.05000	9800.0	
30.0000	350.00	400.000	10.000	0.05000	9800.0	
40.0000	400.00	400.000	10.000	0.05000	9800.0	
50.0000	120.00	400.000	10.000	0.05000	9800.0	RioGrande
60.0000	200.00	400.000	10.000	0.05000	9800.0	
70.0000	340.00	400.000	10.000	0.05000	9800.0	
80.0000	460.00	400.000	10.000	0.05000	9800.0	
85.0000	620.00	400.000	10.000	0.05000	9800.0	
90.0000	400.00	400.000	10.000	0.05000	9800.0	
100.0000	350.00	400.000	10.000	0.05000	9800.0	Cuiaba

********** THERMAL CONDUCTIVITY PROFILE DATA **********

Distance	Burial depth (Cover)	Insul.Thk	Thermal Conductivity Insulation	Pipe	Soil	Soil Temp
km	mm	mm	Watts/m/degC			degC
0.0000	915.00	0.000	0.00	50.00	1.20	15.0
5.0000	915.00	0.000	0.00	50.00	1.20	15.0
10.0000	915.00	0.000	0.00	50.00	1.20	15.0
12.5000	915.00	0.000	0.00	50.00	1.20	15.0
20.0000	915.00	0.000	0.00	50.00	1.20	15.0
22.6000	915.00	0.000	0.00	50.00	1.20	15.0
24.0000	915.00	0.000	0.00	50.00	1.20	15.0
30.0000	915.00	0.000	0.00	50.00	1.20	15.0

40.0000	915.00	0.000	0.00	50.00	1.20	15.0
50.0000	915.00	0.000	0.00	50.00	1.20	15.0
60.0000	915.00	0.000	0.00	50.00	1.20	15.0
70.0000	915.00	0.000	0.00	50.00	1.20	15.0
80.0000	915.00	0.000	0.00	50.00	1.20	15.0
85.0000	915.00	0.000	0.00	50.00	1.20	15.0
90.0000	915.00	0.000	0.00	50.00	1.20	15.0
100.0000	915.00	0.000	0.00	50.00	1.20	15.0

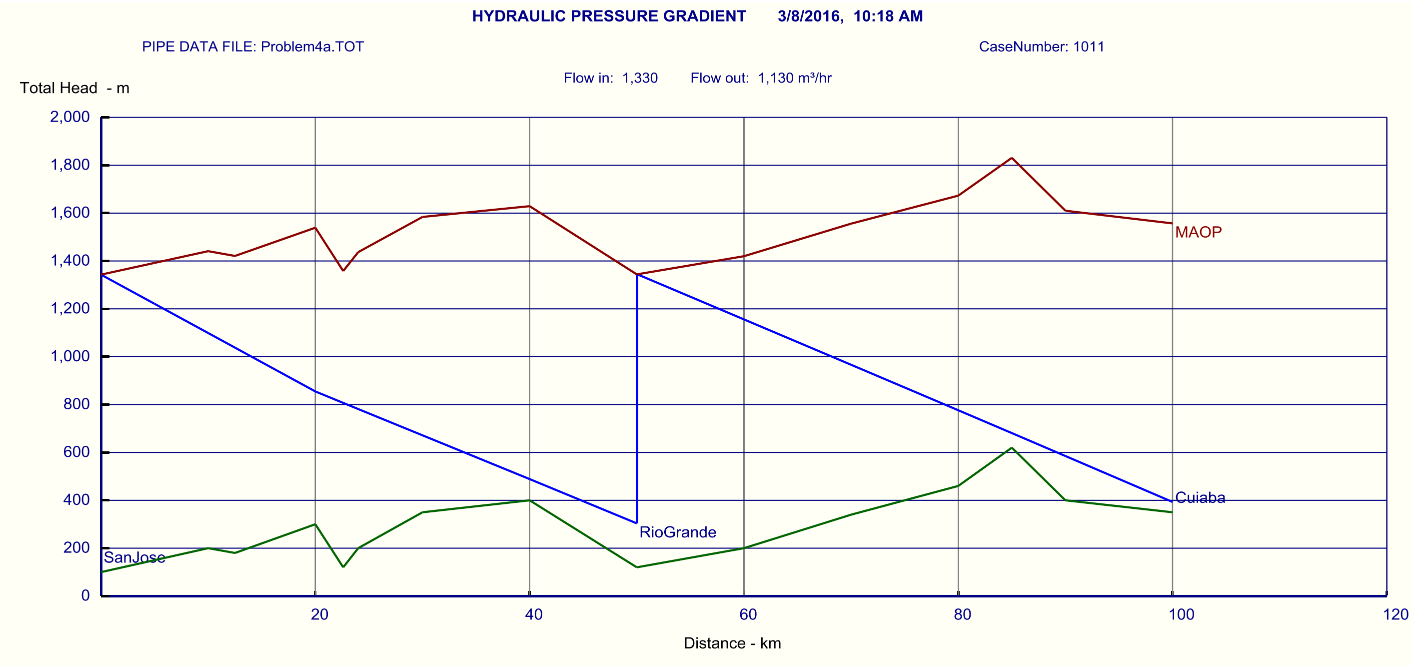
********** VELOCITY, REYNOLD'S NUMBER AND PRESSURE DROP **********

Distance km	Diameter mm	FlowRate m^3/hr	Velocity m/sec	Reynolds number	Press.drop kPa/km	Location
0.0000	400.00	1,329.92	3.25	194,757	191.05	SanJose
5.0000	400.00	1,329.92	3.25	192,791	191.48	
10.0000	400.00	1,329.92	3.25	190,920	191.91	
12.5000	400.00	1,329.92	3.25	190,030	192.12	
20.0000	400.00	1,129.92	2.76	159,233	142.88	SantaClara
22.6000	400.00	1,129.92	2.76	156,682	143.44	
24.0000	400.00	1,129.92	2.76	155,348	143.74	
30.0000	400.00	1,129.92	2.76	149,851	145.02	
40.0000	400.00	1,129.92	2.76	141,529	147.04	
50.0000	400.00	1,129.92	2.76	134,215	148.92	RioGrande
60.0000	400.00	1,129.92	2.76	127,773	150.72	
70.0000	400.00	1,129.92	2.76	122,088	152.39	
80.0000	400.00	1,129.92	2.76	117,060	153.98	
85.0000	400.00	1,129.92	2.76	114,798	154.71	
90.0000	400.00	1,129.92	2.76	112,667	155.44	
100.0000	400.00	1,129.92	2.76	112,667	155.44	Cuiaba

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

Distance km	Elevation m	FlowRate m^3/hr	Temp. degC	SpGrav	Viscosity CST	Pressure kPa	MAOP kPa	Location Name
0.0000	100.00	1,329.92	40.00	0.8050	6.36	350.00	9800.00	SanJose
0.0000	100.00	1,329.92	40.00	0.8050	6.36	9800.00	9800.00	SanJose
5.0000	150.00	1,329.92	39.86	0.8056	6.42	8450.59	9800.00	
10.0000	200.00	1,329.92	39.73	0.8062	6.48	7098.61	9800.00	
12.5000	180.00	1,329.92	39.67	0.8065	6.51	6776.75	9800.00	
20.0000	300.00	1,129.92	39.48	0.8073	6.60	4387.75	9800.00	SantaClara
22.6000	120.00	1,129.92	39.26	0.8083	6.71	5439.73	9800.00	
24.0000	200.00	1,129.92	39.15	0.8088	6.77	4605.47	9800.00	
30.0000	350.00	1,129.92	38.67	0.8110	7.02	2554.54	9800.00	
40.0000	400.00	1,129.92	37.93	0.8143	7.43	707.27	9800.00	
50.0000	120.00	1,129.92	37.26	0.8173	7.84	1470.42	9800.00	RioGrande
50.0000	120.00	1,129.92	37.26	0.8173	7.84	9808.55	9800.00	RioGrande
60.0000	200.00	1,129.92	36.65	0.8201	8.23	7678.70	9800.00	
70.0000	340.00	1,129.92	36.09	0.8226	8.61	5046.77	9800.00	
80.0000	460.00	1,129.92	35.58	0.8249	8.98	2555.74	9800.00	
85.0000	620.00	1,129.92	35.35	0.8259	9.16	493.02	9800.00	
90.0000	400.00	1,129.92	35.13	0.8269	9.33	1499.29	9800.00	
100.0000	350.00	1,129.92	34.71	0.8288	9.67	350.00	9800.00	Cuiaba

Simulation Date: 8-March-2016
Output file: C:\Users\Shashi Menon\Documents\LIQTHERM\Problems\Problem4a.OUT


HYDRAULIC PRESSURE GRADIENT 3/8/2016, 10:18 AM
PIPE DATA FILE: Problem4a.TOT
CaseNumber: 1011
Flow in: 1,330 Flow out: 1,130 m³/hr
Total Head - m
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
20
40
60
80
100
120
Distance - km
MAOP
Cuiaba
RioGrande
SanJose