

CHAPTER IV

PROGRAMME DEVELOPMENT

4.1 Overview Information

The programme is written in C++ language and can be run on IBM personal computer or IBM compatibles with colour monitors under Microsoft Windows 95 or later. The 486 DX2 with 8MB RAM is recommended for running this programme. The application programme is stored in its compiled form as "CRYOSIM.EXE", which is not a stand-alone executable module because it can link to the other software such as GASPAK, ALLPROPS and CAL95. Figure 4.1 presents the main window of developed programme.

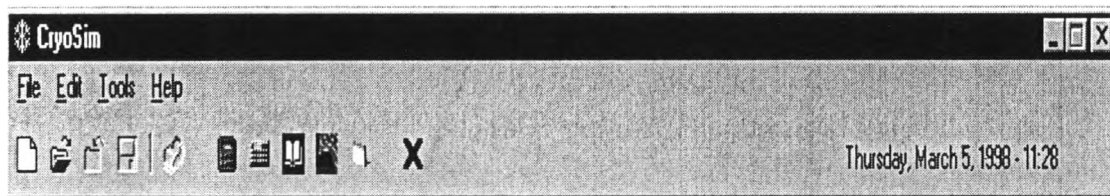


Figure 4.1 The main window of CryoSim

The cryogenic piping simulation programme displayed in this work is a Windows application consisting of four parts as follows,

4.1.1 Unit conversion and calculator

The developed programme provides quick conversion of some engineering units. By selecting the initial and final units from list and entering the initial numerical value, the conversion calculation can be made. Some of conversions are available under the categories of pressure, temperature, density, viscosity, and flow rate. Whenever a specific conversion is required, select the unit conversion in tools menu or CAL95 button to load the conversion calculator. In addition, this programme provides the best link to calculator of Windows. Whenever a calculator is required, select the button of CAL95 or Windows' calculator to load the specific calculator.

4.1.2 Selection of thermodynamic and transport properties prediction software

User can select the thermodynamic and transport properties prediction programmes in the cryodata menu. The estimated results from gas encyclopaedia can compare with the predicted results of selected software. ALLPROPS is the thermodynamic properties package software developed by the Center for Applied Thermodynamic Studies, University of Idaho. The other programme is GASPAK, which is an integrated package of the thermodynamic equations for properties of fluids. The equations are valid from the triple point and melting point through the compressed liquid and the liquid-vapor mixture region to well above room temperature. In pressure, they are valid up to the melting line or several hundred atmospheres. The developers are R.D. McCarty, V. Arp, and J.R. Fox.

4.1.3 Gas encyclopaedia database managerial part

This part collects data of selected cryogenic fluids properties, which is used to support the operation of main developed programme. There are four windows in this part as shown in figure 4.2.

Two windows show the database in tabular form which one of them use as a main window for opening, closing, adding and removing of required fluid and another window is used for collecting monograph of fluid properties.

They have one window that shows the information of selected fluid in text form, which can be used as a word pad to describe fluid characteristic and properties in term of safety concern as written in chapter III.

The another window is used to estimate the selected property of fluid that shown in the window of Gas Encyclopedia-Table. This window can be loaded by selecting calculation in view menu.

In the Gas Encyclopedia-Table window, user can add and remove the property table or value in the table from the display by using the button under menu system.

The screenshot displays four windows from the Gas Encyclopedia software:

- Gas Encyclopedia:** A list of fluid properties for Oxygen, including Atomic number (8), Molecular weight (31.9988), and various phase transition points.
- Gas Encyclopedia - Table:** A table showing properties for Oxygen at different temperatures. The table is as follows:

Table	Tsat (K)	Psat (kPa)	Beta(kK^-1)
Liquid-gas equilibrium	90.18	101.3	4.26
Density(kg/m^3)	97	196	4.71
Viscosity(cP)	104	352	5.39
Surface tension(dyne/cm)	111	583	6.30
Compressibility factor(Z)	118	908	7.38
Volume expansion coeff (K^-1)	125	1348	9.65
	132	1924	11.9
	140	2782	17.6
	146	3591	29.0
	154	3939	54.5
- Gas Encyclopedia - Calculation:** A window for inputting pressure, temperature, and phase to calculate density. The current input is Pressure (empty), Temperature (empty), Phase (Gas), and Output property (Density (kg/m^3)).
- Gas Encyclopedia - Description:** A text window providing a monograph for Oxygen, stating it is a gas at normal atmospheric conditions, essential for life, and colorless and odorless.

Figure 4.2 Gas encyclopedia database managerial part

4.1.4 Developed programme

When user select new or open button in main window, the developed programme is loaded automatically and ready for making new .CSM file with particular input conditions or changing the input data in the existing .CSM file. It is most important for designer to spend sufficient time for sketching the proposed installation to check all relevant details of configuration, pipe properties and fittings. Therefore, this programme provides graphical user interface for sketching the proposed piping system in window of Draw Pipe. In addition, user can use the pipe properties window to enter number of fitting and valve, pipe length and to select material and size of pipe and insulation type before running programme.

In PDROP window, user has to specify the calculation mode, name and state of fluid, upstream pressure and temperature, ambient temperature and volume flow rate. This programme separates into two states one for gas piping system and the another one for two-phase flow of cryogen. There are three calculation modes in single-phase flow those are pressure drop, diameter and length, which are calculated by using equation (3-74). For two-phase flow, there are only two calculation modes. The first mode is calculation of pressure drop by considering the effect of pipe configuration and heat inleak through insulation from ambient air. The heat transfer rate of two-phase flow is determined from equation (3-23), (3-26) and (3-27) for uninsulated, porous-insulated and vacuum-insulated pipe, respectively. The another calculation mode is calculation of diameter via considering commercial pipe size that covers required pressure drop. Figure 4.3 displays PDROP windows of developed programme. Windows of Draw Pipe and Pipe Properties are shown in Figure 4.4 and 4.5.

Before running this programme, it is recommended to check the input data from window of Pipe Summary presented by clicking the calculate button as shown figure 4.6. However, the input data can be changed by selecting the cancel button and entering new data in the dialog of the data which user wants to change. The calculation reports of developed programme are illustrated in figure 4.7 and 4.8 for two-phase flow and gas piping system, respectively.

Reference title	Case 1.1A	
Calculation mode	Pressure drop	
Fluid	Nitrogen	Open
State	Two phase	
Inlet pressure	1.515000	bara
Pressure drop	0	mbar
Temperature	0	t(K)
Ambient Temp.	308.150000	t(K)
Volume flow rate	2058.056612	Nm ³ /Hr

Horizontal Calculation Calculate Cancel

Figure 4.3 Display of PDROP window

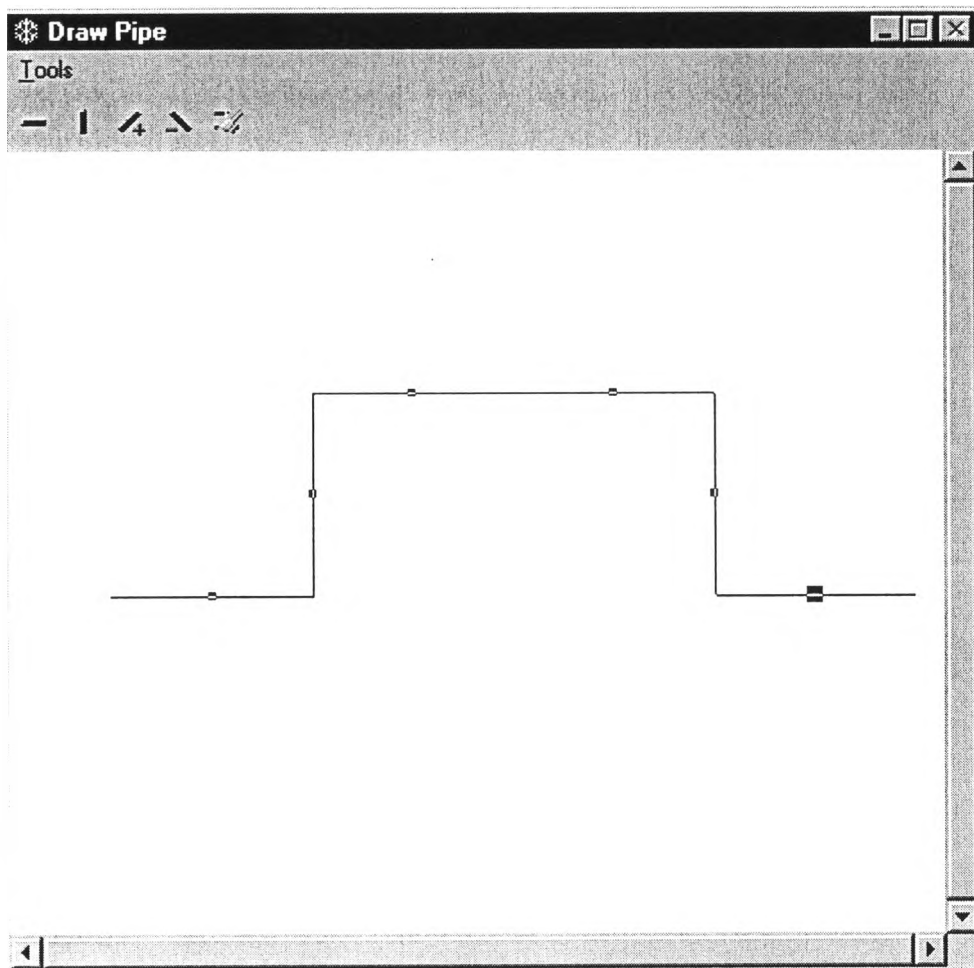
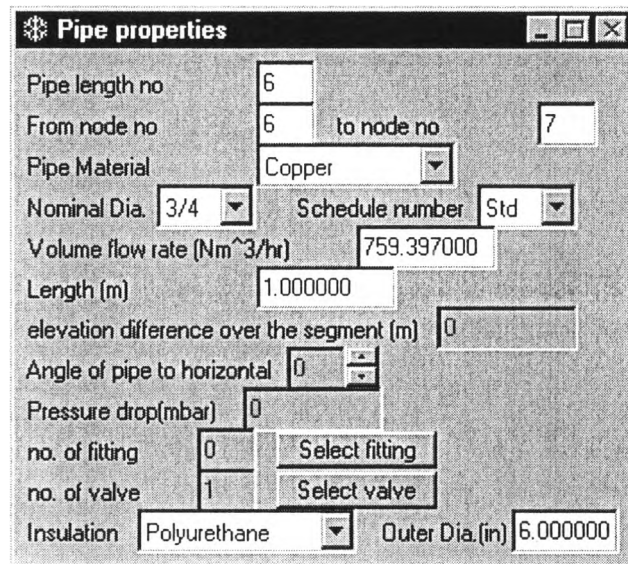


Figure 4.4 Display of Draw Pipe window



Pipe properties

Pipe length no: 6

From node no: 6 to node no: 7

Pipe Material: Copper

Nominal Dia.: 3/4 Schedule number: Std

Volume flow rate (Nm³/hr): 759.397000

Length (m): 1.000000

elevation difference over the segment (m): 0

Angle of pipe to horizontal: 0

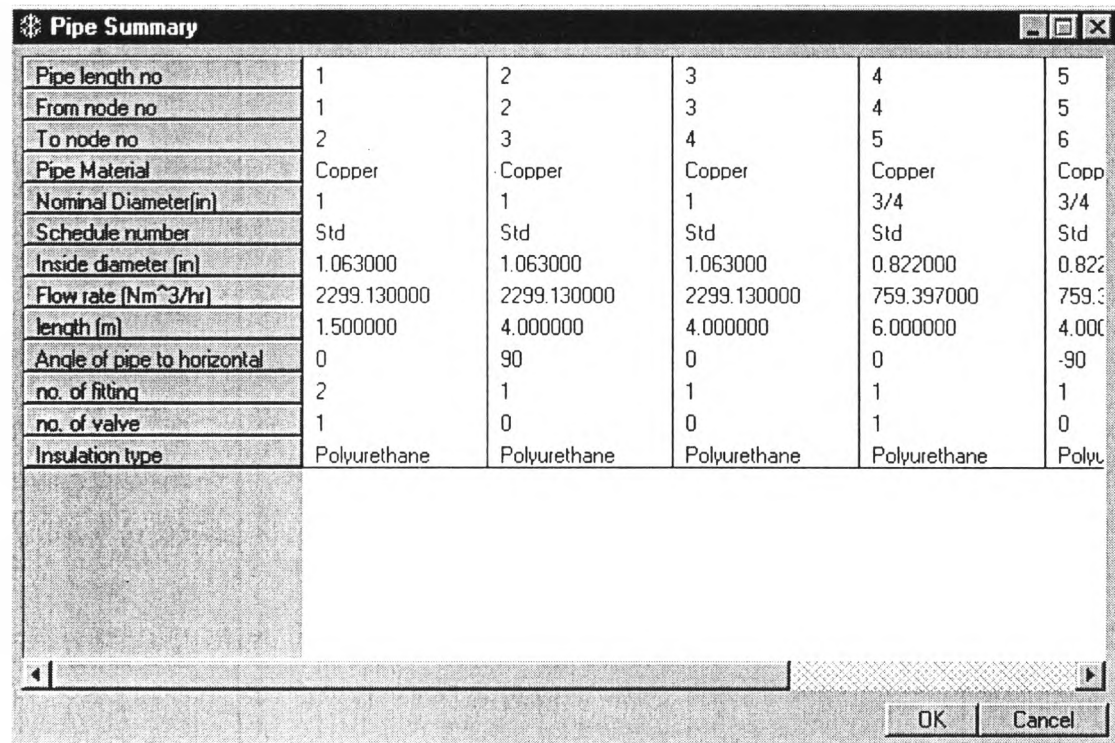
Pressure drop (mbar): 0

no. of fitting: 0

no. of valve: 1

Insulation: Polyurethane Outer Dia. (in): 6.000000

Figure 4.5 Display of Pipe Properties window



	1	2	3	4	5
Pipe length no	1	2	3	4	5
From node no	1	2	3	4	5
To node no	2	3	4	5	6
Pipe Material	Copper	Copper	Copper	Copper	Copp
Nominal Diameter (in)	1	1	1	3/4	3/4
Schedule number	Std	Std	Std	Std	Std
Inside diameter (in)	1.063000	1.063000	1.063000	0.822000	0.822
Flow rate (Nm ³ /hr)	2299.130000	2299.130000	2299.130000	759.397000	759.3
length (m)	1.500000	4.000000	4.000000	6.000000	4.000
Angle of pipe to horizontal	0	90	0	0	-90
no. of fitting	2	1	1	1	1
no. of valve	1	0	0	1	0
Insulation type	Polyurethane	Polyurethane	Polyurethane	Polyurethane	Polyu

OK Cancel

Figure 4.6 Display of Pipe Summary window

Calculation Report

Reference Title: Case 1.1A Fluid: Nitrogen
 Calculation mode: Pressure drop State: Two phase

Upstream pressure(bar)	1.515000	Gas density(kg/m ³)	6.688855
Upstream temperature(K)	80.889638	liquid density(kg/m ³)	7.91991E+2
Ambient temperature(K)	308.150000	Gas viscosity(N.S/m ²)	5.67339E-6
Gas enthalpy(Kcal/kg)	1.90594E+1	liquid viscosity(N.S/m ²)	1.30613E-4
liquid enthalpy(Kcal/kg)	-2.72554E+1	Surface tension(N/m)	8.07872E-3
liquid thermal conductivity(W/m.k)	1.30203E-1		
liquid heat capacity at constant pressure(KJ/kg.K)	2.078806		
Fluid coefficient of thermal expansion(1/K)	6.02478E-3		

Pipe length	1	2	3
From node	1	2	3
to node	2	3	4
Volume flow rate(Nm ³ /m)	2299.130000	2299.130000	2299.130000
Internal pipe diameter(m)	0.027000	0.027000	0.027000
length(m)	1.500000	4.000000	4.000000
Pressure drop due to friction(mbar)	1.04214E+1	2.94657E+1	3.10779E+1

Total pressure drop(mbar): 2.22928E+2

Print OK

Figure 4.7 Calculation report for two-phase flow calculation

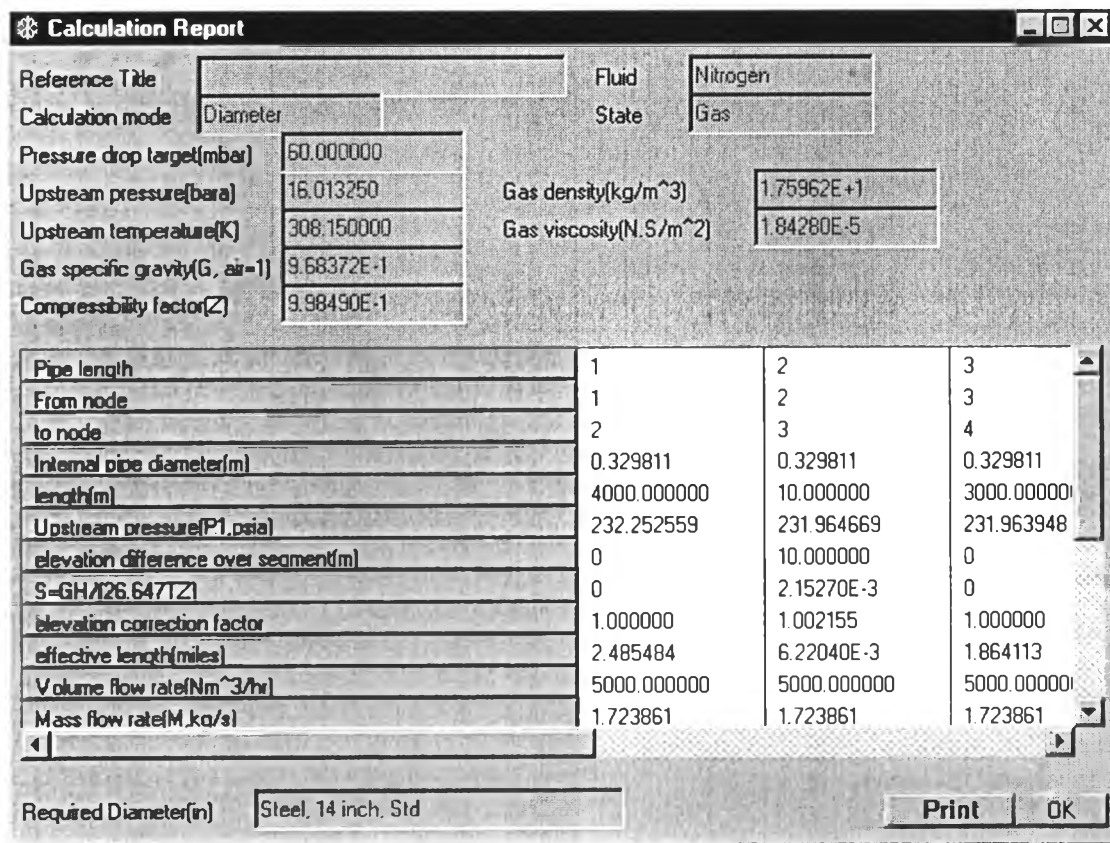


Figure 4.8 Calculation report for gas piping system calculation

4.2 Calculation Procedure

All variables have been defined as zero when piping system configuration is specified by user. The calculation procedure of pressure drop estimation is based on equation (3-30) and (3-74) for two-phase flow and gas piping system, respectively.

For two phase flow, the entered inlet pressure is used as saturated pressure to determine saturated temperature and concerned properties from liquid-gas equilibrium monograph in database of selected fluid. These properties are used for finding the heat inleak from given flow rate and specified insulation type.

The estimated heat inleak is used to determine exit gas quality for each pipe length by using equation (3-29) plus inlet gas quality of that pipe length. The exit gas quality of previous pipe length is the inlet gas quality of next pipe length. The inlet gas quality of first pipe length is zero.

The next step is identification of pipe direction to determine the angle of pipe to horizontal for use to obtaining the pressure change due to gravity of equation (3-32). The gravitational components of pressure drop for horizontal pipe is zero. The other pressure drop such as frictional pressure drop is considered in term of two-phase multiplier that does not explicitly consider the flow pattern by using equation (3-57). The pressure change due to change in momentum flux is pondered on the lockhart-Martinelli parameter by implement of inlet and exit gas quality as defined in equation (3-62).

The pressure drop due to the fittings and valve are calculated by using equation (3-71) with predicted head loss from the two K method.

The summation of all pressure losses in equation (3-30) is the total pressure drop of that pipe length. When the calculation mode is change to be diameter, the pressure drop summation of that piping system is used to compare with target pressure drop to determine the suitable diameter that covers required pressure drop. The different of target pressure drop and calculated pressure drop should be less than 1% of target pressure drop by varying diameter from the first size in table of that selected schedule to the proper diameter.

For gas piping system, the entered inlet pressure and temperature are used to find density, viscosity and compressibility factor from monograph of those properties. The calculated pressure drop from equation (3-74) is total pressure drop of pipeline only. This pressure drop including with the pressure drop due to fitting and valve is total pressure drop of that pipe length. Downstream pressure of each pipe length is the different of upstream pressure and total pressure drop of system. The upstream pressure of next pipe length is downstream pressure of previous length. The pressure drop due to fitting and valve are presented by the same module that used in two-phase flow calculation.

When the calculation mode is changed to be diameter, the proper diameter that should be the answer is determined by the same categories as above. For the calculation mode of length, pipe diameter and required pressure drop of each pipe length are given by user. Therefore, equation (3-74) can use to predict the suitable length of that pipe. The flow charts of this programme are summarized in appendix E.