CHAPTER I
INTRODUCTION

Although chemical engineers have long been acquainted with a pipeline system for liquid and gas flow, relatively little has appeared in chemical engineering literature on the systems and computational aspects of pipeline network design and analysis. Therefore, the pipeline designer is confronted with an array of relatively untested or obscure predictions of pressures and flow rates, which are two of the most important items of information needed for design. In an effort to provide a more rational basis, a study is undertaken in this project to produce an overall design strategy that utilizes correlations and models that are most relevant to the design problem.

Pipeline networks are designed using sophisticated computer programs. These programs are built on simple basic equations that govern the flow in a single pipeline, but the program is constructed so that it can accommodate an arbitrarily large network of such pipelines.

Most of the following fluid properties and other variables are involved in the design of liquid and gas pipelines.

1. Pipeline diameter
2. Pipeline length
3. Density
4. Compressibility factor
5. Temperature
6. Viscosity
7. Reynolds number
8. Fanning friction factor

Other properties of the fluid may be used in specific calculations, but these are the basic variables used to determine pressure drop and flow rate.

Some variables in the pipeline system are interdependent. For example, operating pressure depends, in part, on pressure drops in the line. Pressure drop and the Reynolds number, in turn, depend on flow rates. The Fanning friction factor is a function of the Reynolds number and roughness ratio.

There are many reasons why relatively few general purpose simulators are available, from both mathematical and programming viewpoints. For the mathematical side, the systems are modeled by both differential and algebraic equations. In most cases, the equations may comprise a stiff system so that they have to be solved by using some special kind of algorithms to obtain the desired accuracy. For the programming side, more work has to be done to make a simulator a general-purpose one. Furthermore, many techniques and algorithms must be incorporated into the program.

This study considers the building of a general-purpose simulator for networks of a single phase fluid at steady state. Some codes are developed and some testings are given. The code has been created in FORTRAN Power Station Version. 1.0. It has the ability to use the minimum computer memory in analyzing large scale networks even though double precision calculations are performed throughout.

1.1 Formulation of Design Strategy

Studies of flow in pipelines have led to a mathematical model of complex equations. The equations that serve as the basic building blocks for most of this model and the associated computer simulator are:

1. The continuity equation

$$\left(\text{Net rate of mass flow flow entering volume element}\right) = 0$$

2. The momentum balance equation

$$(\text{Mass})(\text{acceleration}) = \begin{pmatrix}\text{body forces}\\ \text{acting in}\end{pmatrix} + \begin{pmatrix}\text{surface forces}\\ \text{acting in}\end{pmatrix}$$

3. The energy balance equation

$$\begin{pmatrix}\text{Rate of increase}\\ \text{of energy in element}\end{pmatrix} = \begin{pmatrix}\text{rate of energy input}\\ \text{by surface stress}\end{pmatrix} + \begin{pmatrix}\text{rate of energy input}\\ \text{by body forces}\end{pmatrix}$$

1.2 Process Simulator

The process simulator solves algebraic equation set of steady state models which principally arise from continuity and energy or momentum balance equations.

There are four main computational aspects presented for network analysis regarding the items of the previous section:

1. Generate nodal material balance equations at every node in the whole network and combine them to form a set of simultaneous nonlinear equations.
2. An assumption of the initial values of the unknowns variables is required.

3. Use the Newton-Raphson method, which converts the problem of solving simultaneous nonlinear equations into an iterative solution of successive sets of simultaneous linear equations.

4. The coefficient matrices for the simultaneous linear equations are banded. A Gaussian elimination method is implemented with normalization and reduction steps with partial pivot strategy to solve the simultaneous equations at each new iteration of the Newton-Raphson method.

The flow network analysis code consists of five principal modules as follows:

1. The input process module handles the main initial data and information given for the case under analysis. Included here are the standard code, the selection of the network to be considered, the fluid property and the pressure and temperature at standard conditions, the selection of the pressure formula, the network geometry and topology, the connection data, the injection or withdrawal requirements and tolerances for convergence.

2. The bandwidth process module manages the matrix which depends on the topological representation of the network.

3. The computational process module generates simultaneous linear equations of coefficient matrices that are based on the Newton-Raphson algorithm to find the solution of the system.

4. The solution process module uses the Gaussian elimination method for banded systems that is implemented by normalization and reduction scheme with column pivoting strategy to solve it at each iteration.

5. Finally, the output process module presents all detailed information about the pipeline network system and results. The output can be divided into elemental output such as the Fanning friction factor, volumetric flow rates, length, diameter, roughness and nodal output such as pressure, elevation, and injection or withdrawal rates.