CHAPTER V

RESULTS AND DISCUSSION

Table 5.1 Comparison of the results of GAS code with TGNET code for flow distribution of gas transmission system

I - J	Q1(I , J)	Q2(I , J)	Diff. (%)
1 - 2	268.780	268.800	0.00
2 - 3	64.297	62.560	2.70
2 - 10	204.483	206.240	0.86
3 - 4	63.618	61.880	2.73
4 - 5	25.000	25.000	0.00
4 - 6	3.619	1.880	48.05
6 - 7	23.187	21.880	5.63
9 - 6	29.112	29.010	0.35
6 - 17	9.542	9.000	0.59
7 - 8	14.187	12.880	9.21
9 - 8	32.268	30.120	6.65
16 - 8	23.544	27.000	14.68
10 - 9	61.378	59.130	3.66
10 - 11	143.099	147.110	2.80
11 - 12	20.000	20.000	0.00
11 - 13	123.103	127.110	3.25
13 - 14	40.000	40.000	0.00
13 - 15	79.601	83.610	5.03
15 - 16	74.601	78.590	5.34
16 - 18	47.057	47.600	1.15
17 - 18	2.943	2.400	18.45
18 - 19	20.000	20.000	0.00
18 - 20	20.000	20.000	0.00
20 - 21	20.000	20.000	0.00

Q1(I , J) = The flow rates results from GAS code (MMscfd)

Q2(I , J) = The flow rates results from TGNET code (MMscfd)

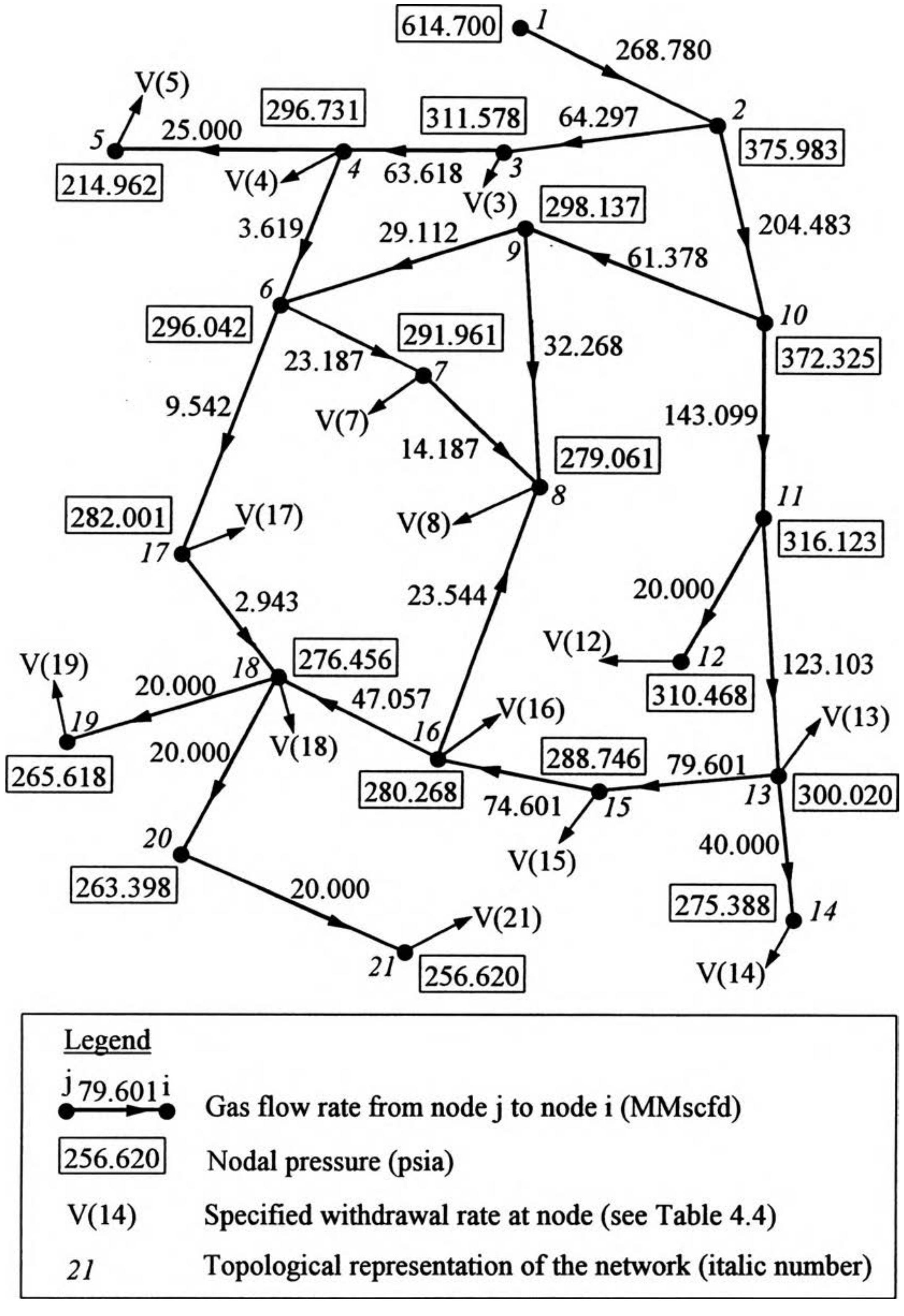


Fig. 5.1 Topological representation of gas transmission network with flow rates and nodal pressures distribution.

Table 5.2 Comparison of the results of LIQUID code with PICCOLO code for flow distribution of water transmission tunnel system

I - J	Q3(I , J)	Q4(I , J)	Diff. (%)
1 - 2	43844.70	43814.00	0.00
2 - 3	43842.49	43814.00	0.00
3 - 4	2677.73	2649.00	1.07
3 - 5	41164.28	4116 5.00	0.00
4 - 17	2677.64	2649.00	1.06
5 - 6	38740.03	38742.00	0.00
6 - 7	25825.85	25825.00	0.00
6 - 8	12916.30	12917.00	0.00
7 - 9	14583.72	14583.00	0.00
7 - 11	11041.73	11042.00	0.00
8 - 15	12916.43	12917.00	0.00
9 - 10	14583.78	14583.00	0.00
11 - 12	11041.73	11042.00	0.00
12 - 13	11041.75	11042.00	0.00
13 - 14	11042.01	11042.00	0.00
15 - 16	12916.25	12917.00	0.00
17 - 18	8332.79	8333.00	0.00
19 - 17	5656.31	5684.00	0.48
20 - 19	5656.57	5684.00	0.48
21 - 20	58152.87	58184.00	0.05
20 - 24	52503.21	52500.00	0.00
22 - 21	58153.02	58184.00	0.05
23 - 22	58158.40	58184.00	0.05
24 - 25	17500.07	17500.00	0.00
24 - 26	35002.49	35000.00	0.00
26 - 27	35002.59	35000.00	0.00
27 - 28	4999.80	5000.00	0.00
27 - 32	30002.08	30000.00	0.00
28 - 29	4999.83	5000.00	0.00
29 - 30	4999.82	5000.00	0.00
30 - 31	4999.83	5000.00	0.00
32 - 33	30001.70	30000.00	0.00
33 - 34	14582.77	14583.00	0.00
33 - 35	15413.43	15417.00	0.00

Table 5.2 (Continued)

I - J	Q3(I , J)	Q4(I , J)	Diff. (%)
35 - 36	15418.07	15417.00	0.00
36 - 37	15417.19	15417.00	0.00

Q3(I , J) = The flow rates results from LIQUID code (m^3/hr)

Q4(I , J) = The flow rates results from PICCOLO code (m^3/hr)

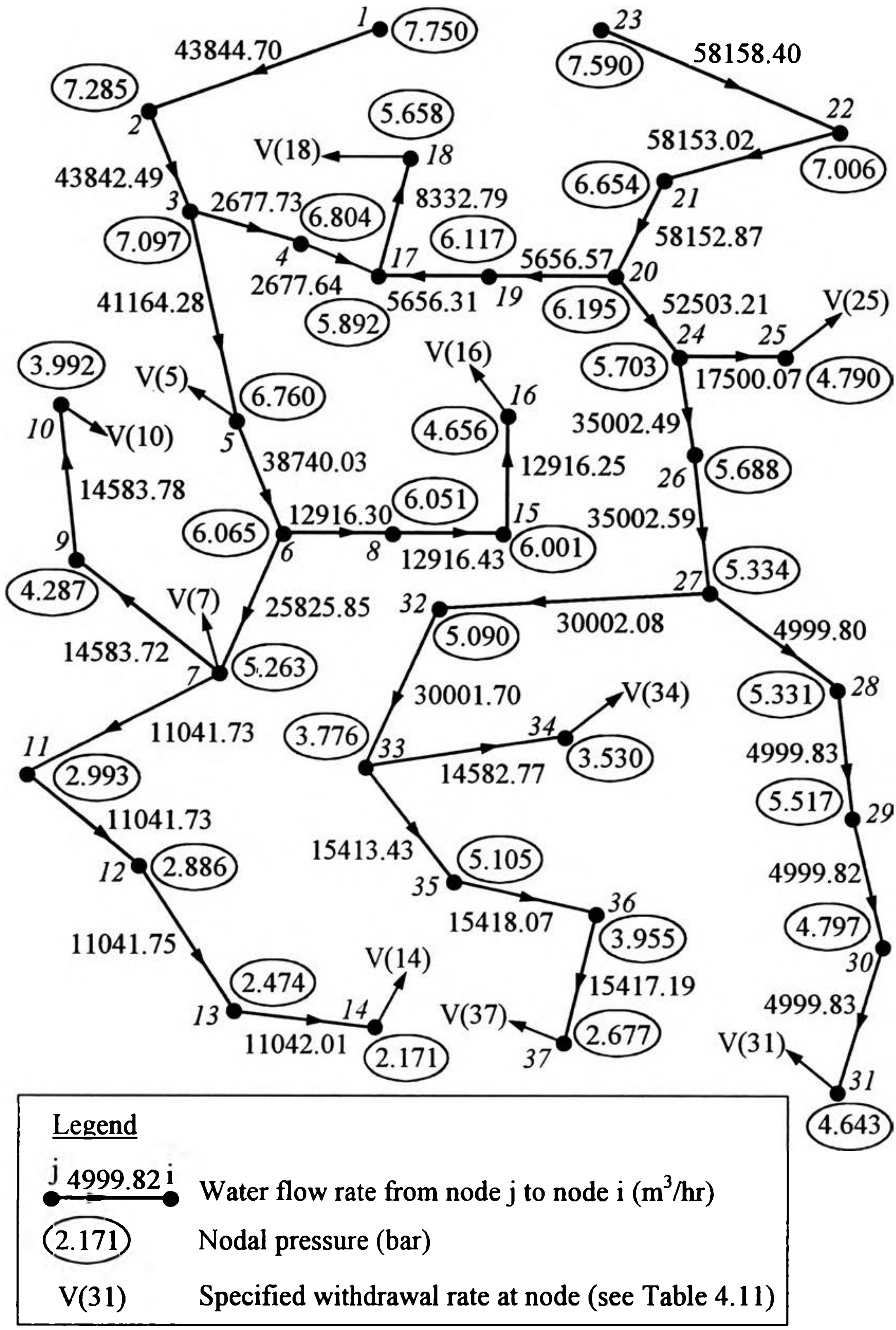


Fig. 5.2 Topological representation of water transmission tunnel network with flow rates and nodal pressures distribution.

5.1 Effects of Assumptions

1. *No mechanical work*: from Fig. 4.2 and Fig. 4.6, it is considered that no work is done on the gas or water beginning at node (1) and node (23) respectively by putting pressure recorders measured. Thereby no mechanical energy is added by compressors or pumps starting these two nodes as individual source. This condition can be satisfied the assumption.

2. *Steady-state flow*: Table 5.1 displays the results of flow rates distribution for gas transmission pipeline system compared with TGNET model. This network has been taken in the analysis and design as steady-flow in case of Gas Separation Plant shut down and thereby the Operating and Control Pipeline System have to control the block valve station to pressurize in the system with operating pressure at node (1) as shown in Fig. 4.2. The GAS code has proven erroneous where the operational conditions to be validated by comparison with TGNET code based on the transient analyzed. This assumption is the major cause of discrepancies for gas flow in pipeline calculations, since steady flow in pipeline operation seldom exists in actual practice because of flow rate pulsations, variations in withdrawal or injection rates, and variations in operating conditions.

3. *Isothermal flow*: in the topological representation of internodal distances for gas transmission network discussed herein concerns the buried pipelines used as shown in Fig. 4.3. This assumption can be considered as isothermal at average effective temperature. Because they are not affected much by atmospheric variations, heat of compression from an offshore compressor station is usually dissipated rapidly within a short distance.

4. *Average gas compressibility factor and density*: the verification and validation of the GAS code was initially based on a steady state single phase and single component. However, the application of gas transmission distribution network is a multi-component system. Although this assumption introduces inaccurate but it is a reasonable approximation in the case of isothermal. And the properties is generally computed at average pressure given by equation as follows:

$$p_{avg} = \frac{2}{3}\left(\frac{p_j^3 - p_i^3}{p_i^2 - p_i^2}\right)$$

In which:

p_{avg} = average pressure, psia

p_j = upstream pressure, psia

p_i = downstream pressure, psia

5. *Negligible kinetic energy change*: the results of the flow rate network analysis are shown in Table 5.1. This assumption for neglecting kinetic change is justified compared with the changes in pressures, especially for very long pipelines. For example the node (1) to node (2), the length of the pipeline between these two nodes are 8200 ft and the nodal pressures at node (1) and node (2) are 614.700 and 375.893 psia respectively. However, it can be verified by equation in CHAPTER II as follows:

A complete integration in Eqn. 2.30 will lead the term in the denominator:

$$\phi_{ij} = \exp\left(\frac{\frac{4f_F L}{D}\frac{Mg(z_j - z_i)}{ZRT} + \ln\left(\frac{p_j}{p_i}\right)^2 \frac{Mg(z_j - z_i)}{ZRT}}{\frac{2f_F L}{D} + \frac{Mg(z_i - z_j)}{ZRT}}\right) \qquad (5.1)$$

From the above Eqn. (5.1) the two terms are sufficed for explaining regarding to the omit of the kinetic change:

$$\frac{4f_F L}{D} \quad \text{and} \quad \ln\left(\frac{p_j}{p_i}\right)^2$$

Consider $f_F = 0.005$, $L = 50{,}000$ ft, $D = 1$ ft with inlet pressure of $p_i = 100$ psia and exit pressure of $p_j = 10$ psia

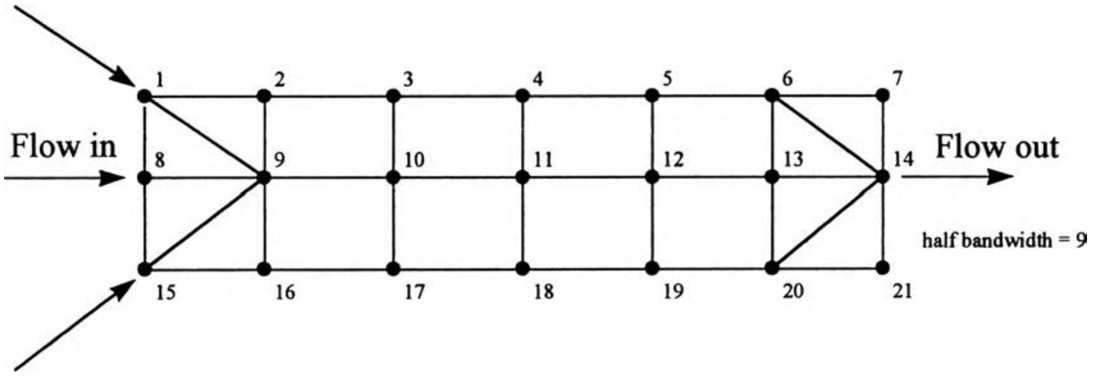
The two terms are:

$$\frac{4f_F L}{D} = 1000, \qquad \ln\left(\frac{p_j}{p_i}\right)^2 = 4.61$$

thereby proving this assumption.

5.2 Computational Aspects

1. The bandwidth depends on the topological representation of the network. Such as the network shown in Fig. 5.3, two different topological descriptions are given which present different bandwidths in the coefficient matrix. Hence, the lower the bandwidth, the faster the procedure is computing.



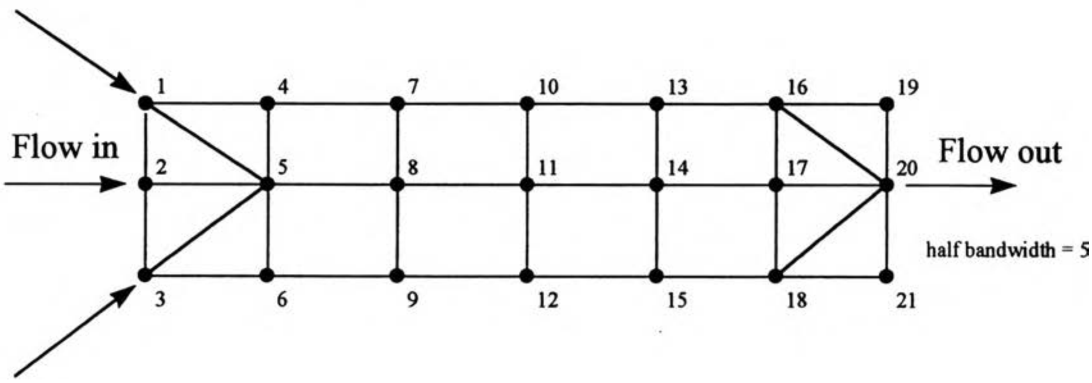


Fig 5.3 Two topological descriptions of the same network resulting in different bandwidths.

2. The topological representation as i_th node for gas transmission system as shown in Fig. 4.1 or water transmission tunnel systems as shown in Fig. 4.5 should be fixed in accordance with increasing numeration such as $i = 1, 2, 3, 4, \ldots, n$ (n = number of nodes). Otherwise the Gaussian elimination method will encounter a zero pivot and the result cannot be obtained.

3. The length of the pipeline in the inclined flow equations as shown in Fig. 2.3 is based on the profile of the line between nodes as a uniform slope. For a non-uniform slope (where the elevation change cannot be simplified to a single section of constant gradient), an approach is to subdivide the pipelines into several short sections of nearly uniform slope.

5.3 Simulation Approach

1. The results of flow rate distribution for gas transmission network as shown in Table 5.1 were examined by TGNET code obtained by a model of an operational use. This network is described by 21 nodes and 24 nodal connections. This network is supplied from an offshore compressor station.

The results from both programs seem to be consistent, except the pipeline connection from node (4) to node (6). Its discrepancy is quite large. The reason is that the TGNET code takes the fluid property variations into account. In addition, these differences may be mainly attributed to the different algorithms for the computation of the pipeline pressure drop between nodes.

2. The results of flow rates distribution for water transmission tunnel network shown in Table 5.2 were verified by the PICCOLO code calibrated by comparing computed pressures and flows in the field tests. This particular network is a part of the treated water transmission and distribution systems in Metropolitan Waterworks Authority supplying water to the customers at about 4,400 million liters per day. This network consist of 37 nodes and 36 nodal connections. Both results has proven to be consistent. Since this network model has been designed and constructed for the water supply and distribution system during the steady state operation. Besides the methods for the computation of the pressure drop are not deviated much by the assumption.

3. Generally, good initial guesses are required to achieve satisfactory convergence for the LIQUID code and especially for GAS code. If the compressors are considered in the network, it is recommended to initialize the outlet pressure be 1.5 times the inlet pressure (suggested by TGNET code).

4. The special case of a terminal node with no flow, the program can be solved without the instability for the convergence by estimating pressure for adjacent nodal connection identically.