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FATHOM (Version 3) - Commercial Software Validation and Configuration Control

F J Heard

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Richland, WA 99352

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Abstract FATHOM (Version 3), an incompressible flow piping network modeling and analysis computer program from Applied Flow Technology, was installed for use at the U S Department of Energy Hanford Site near Richland, Washington. A series of sample problems were executed to validate the software and confirm proper installation.

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FATHOM (Version 3) – Commercial Software Validation and Configuration Control

Prepared by

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December 1999

ABSTRACT

FATHOM (Version 3), an incompressible flow piping network analysis computer code from Applied Flow Technology, was installed for use at the Department of Energy (DOE) Hanford site near Richland, Washington. A series of tests were performed to validate the software and confirm proper installation.

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1 0 INTRODUCTION AND PURPOSE

The purpose of this report is to document the validation of AFT FATHOM (Version 3) computer code consistent with the requirements of HNF-PRO-309 (Revision 0) "Computer Software Quality Assurance Requirements" for commercial-off-the-shelf (COTS) software

AFT FATHOM, hereafter referred to as FATHOM, was supplied by Applied Flow Technology Corporation in Woodlawn Park, Colorado for use at the Department of Energy's Hanford site near Richland, Washington "Applied Flow Technology", "AFT", and "AFT Fathom" are registered trademarks of the Applied Flow Technology Corporation

Software validation is the process of evaluating a system or component during or at the end of the development process to determine whether it satisfies specified requirements Validation involves running test cases to ensure that the computed output meets specified expectations and requirements, including numerical correctness of the results based on comparisons with alternate calculations (e g , hand calculations, analytical solutions, or acceptance testing)

2 0 DESCRIPTION AND APPLICATION

FATHOM is an incompressible flow piping network analysis tool. FATHOM is intended as an aide for network analyses and not as a replacement for other design and analysis methods, including sound judgement, hand calculations or independent checks. FATHOM is supplied by Applied Flow Technology Corporation in Woodlawn Park, Colorado. "Applied Flow Technology", "AFT", and "AFT Fathom" are registered trademarks of the Applied Flow Technology Corporation.

2 1 Overview

FATHOM uses a graphical interface that is based on drag-and-drop operations inherent to most Windows based applications. This allows the user to build a piping network using selections from a palette of components. Data is entered or edited for each of the components by double-clicking the component of interest. Additional global editing features are available from the menu or tool bars that simplify making large-scale changes to the model.

FATHOM has five integrated subordinate windows. The five windows can be viewed as an integrated environment for entering, processing, analyzing, and documenting the results of a piping network simulation. The user will work from one of the five windows at all times. Of the five windows, two are input windows and three are output windows.

2 1 1 Input Windows

The two input windows are the Workspace window and the Model Data windows. These two windows, one graphical and the other text-based, process the input data for the model.

2 1 2 Output Windows

The three output windows are the Output, the Graph Results, and the Visual Report. The Output window is text-based. The Graph Results and Visual Report windows are graphical. These three windows are essential for reviewing the results of the analysis, spotting analysis errors and preparing the results for documentation.

2 2 Modeling Capabilities

FATHOM is an incompressible steady-state one-dimensional Newtonian fluid network flow analysis program and can be used to model a variety of engineering systems including

- Open and closed (recirculating) systems
- Network systems that branch or loop with no limit on the number of loops
- Pressure and/or gravity feed systems
- Pumped systems, including multiple pumps in parallel and/or in series
- Pumps with variable speed, controlled discharge pressure, and viscosity corrections
- Systems with pressure and/or flow control valves
- Systems with valves closed or pumps turned off

- Systems with heat exchangers
- Systems heat transfer from external surfaces
- Systems with variable density and viscosity

FATHOM also provides hundreds of standard loss models based on well known references such as, Crane (1988), Idelchik (1994), and Miller (1990), but also allows the user to enter there own loss data. Variable or dynamic loss coefficients are supported. Variable loss coefficients may depend on flow, area ratios, and/or flow splits (such as tee's and wye's), and the angle of the connecting piping. FATHOM also provides automatic calculation of friction factors using the well-known Colebrook-White correlation. Also provided is an extensive database of thermophysical properties for numerous fluids and gases.

FATHOM uses a Newton-Raphson method to solve the fundamental equations of pipe flow that govern conservation of mass, momentum, and energy. Solutions are obtained by iterative matrix methods that have been optimized for speed and convergence.

2.3 Engineering Assumptions

FATHOM is based on the following fundamental fluid mechanics assumptions:

- Incompressible flow
- Steady-state conditions
- One-dimensional flow
- Newtonian fluid model (fluid viscosity is independent of the fluid dynamics)

3 0 CONFIGURATION CONTROL

FATHOM was purchased from Applied Flow Technology located in Woodlawn, Colorado. FATHOM is currently licensed for a single user on a single personal computer within a Windows 9x or NT environment. FATHOM is considered commercial-off-the-shelf (COTS) software.

3 1 Hardware

FATHOM has been installed on an AST Bravo with a 200 MHz Pentium processor and 128 MB of main memory. The property tag is WC65744. The operating system is Windows 95 Version 4 00 950B. FATHOM was installed by running the automated SETUP program located on the installation disk.

The FATHOM installation program is very simple and standard for most Windows based applications. SETUP asks you where to unzip the program and where (i.e., pathname) to install the program. The executable files supplied with FATHOM are compiled code. No source code is supplied. SETUP handles all the file manipulations, short cuts, desktop icons, and registry entries required by Windows. FATHOM was installed using the following default pathname: C\FATHOM.

To install and run AFT FATHOM, the computer must meet the following minimum requirements:

Table 3-1 Hardware and System Requirements

Feature	Required	Recommended
IBM – Compatible Processor	80286	80386 or higher
Hard Disk Space	5 Mb	
Floppy Drive	3 ½ -inch	
Monitor Resolution	VGA	VGA or higher
Random Access Memory (RAM)	4Mb	8Mb
Mouse	Yes	
Math Co-processor	No	Yes
MS-DOS	Version 3.1	Version 5.0 or higher
MS-Windows	Version 3.11	Windows 95, 98 or NT

3 2 License Key

A license key is required to activate the AFT FATHOM program for use. The license key is supplied by the vendor on a separate floppy disk. The user must supply the license key when requested during setup. The license key is copied from the floppy and stored within a hidden and encrypted file somewhere on the system. FATHOM will check for the existence and content of the license file each time the program is activated.

The license key contains information pertaining to the registered purchaser of the program, authorized number of users, and time remaining for the annual software upgrade maintenance (SUM) and help agreement if purchased with FATHOM

3 3 Problem Reporting

AFT FATHOM provides an extensive context searchable online help manual and access to additional help, frequently asked questions (FAQ's), and modeling tips via the internet (www.aft.com)

Modeling problems, bug reports, and general pleas for assistance can be supplied to AFT via support (support@aft.com). A bug report is first verified and then acknowledged usually within two to three business days. The response may or may not solve the problem, but may provide a workaround until the problem is fixed. If requested, a special version of FATHOM containing the bug fix (when available) can be supplied to the customer. If the error(s) persist, a special version of FATHOM containing an extensive set of debugging tools can be supplied for use by the customers in an attempt to resolve the problem.

Users are notified via email when an update to FATHOM is available. Minor updates are received several times a year. Major updates are received approximately once a year. Most of the minor revisions address bugs that have been found and corrected. The major once-a-year revisions usually deal with major enhancements and new capabilities that have been added. Whether or not to update depends on the time remaining in the annual SUM agreement, current workscope, and the nature of the bug fixes or enhancements.

3 4 User Manual

The user manual for AFT FATHOM is a soft cover booklet running about 250 pages. The user manual is also available via online help. A single copy of the user manual was included with the software and is currently located at 2440 Stevens Center Room 1704. Additional copies can be purchased from Applied Flow Technology.

4 0 VALIDATION

The FATHOM user's manual contains a detailed discussion of the fundamental concepts and conventions used in processing piping systems and how to interpret the database information imbedded within FATHOM (see Section 2.1). FATHOM assumes that the user has a good general understanding of engineering hydraulics. FATHOM is designed for use by persons who possess a level of knowledge consistent with that obtained from an undergraduate engineering course in the analysis of piping systems and fluid networks.

4.1 Internal Databases

Most engineering analyses involve processing very large amounts of information, some of which is critical, but most of which is of lesser importance. The key to accurate and efficient analysis is the proper identification of critical information. Two databases embedded within FATHOM manage critical information associated with the fluid properties and pressure loss factors.

4.1.1 Fluids

Density and dynamic viscosity are two fluid properties required for all analyses. Fluid vapor pressure is optional. FATHOM provides a fluid database for numerous common fluids. If the working fluid is not in the database, the user can enter fluid properties into a custom database for later recall.

Spot checks of the properties for air, helium, hydrogen, oxygen, nitrogen, and water against the values summarized in HOLMAN (1990) showed very good agreement.

4.1.2 Losses

FATHOM provides hundreds of standard loss models based on well known references such as, Crane (1988), Idelchik (1994), and Miller (1990), but also allows the user to enter their own loss data. Variable or dynamic loss coefficients are supported. Variable loss coefficients may depend on flow, area ratios, and/or flow splits (such as tee's and wye's) and the angle of the connecting piping. FATHOM also provides automatic calculation of friction factors using the well-known Colebrook-White correlation.

Spot checks of representative loss coefficients for valves and fittings against values summarized within Crane (1988) showed very good agreement.

4.2 Test Problems

Twenty-two sample problems (input files) are supplied with FATHOM. All twenty-two input files are installed in the SAMPLE sub-directory below the C:\FATHOM directory. The sample problems model systems that range in size from one pipe to seventy pipes. Twenty of the twenty-two sample problems are for systems with solutions available in published literature. Sample problems 3 and 4 do not have published solutions, but were run and documented within Appendix A for completeness.

Table 4-1 lists the sample problems and provides a brief description of each model. Appendix A summarizes the model, the reference, and the output test results.

Table 4-1 Listing of Sample Problems Supplied with FATHOM

Number	Description	File Name
1	2 pipes, 3 junctions Model of a water tower fire protection system	Sample1.fth
2	6 pipes, 7 junctions Model of a pumping system between two reservoirs Problem is to find the required pump horsepower Water is the working fluid	Sample2.fth
3	3 pipes, 4 junctions Model of a three reservoir branching system. Water is the working fluid No published solution available for comparison	Sample3.fth
4	7 pipes, 7 junctions Model of a circulation system with an orifice connected in a single loop and driven by a pump Water is the working fluid No published solution available for comparison	Sample4.fth
5	10 pipes, 10 junctions Model of a system with three pumps supplied by three reservoirs that connect together. One loop exists. Water is the working fluid.	Sample5.fth
6	9 pipes, 8 junctions Model of a branching system with a pump, a PRV and two loops. Water is the working fluid.	Sample6.fth
7	17 pipes, 12 junctions Model of a branching system fed by two reservoirs. One reservoir has a pump. Numerous loops are involved. Water is the working fluid.	Sample7.fth
8	48 pipes, 32 junctions Model of a large branching network. Water is the working fluid.	Sample8.fth
9	3 pipes, 4 junctions Model of a series flow pressure drop. Water is the working fluid.	Sample9.fth
10	3 pipes, 2 junctions Model of a parallel flow pressure drop. Water is the working fluid.	Sample10.fth
11	2 pipes, 3 junctions Model of a series flow pressure drop with component losses included. Water is the working fluid.	Sample11.fth

Number	Description	File Name
12	2 pipes, 2 junctions Model of a series flow pressure drop with benzene as the working fluid	Sample12 fth
13	3 pipes, 4 junctions Model of a branching system with component losses included Ethyl alcohol is the working fluid	Sample13 fth
14	2 pipes, 3 junctions Model of a siphoning system The problem is to determine how high a junction can be raised and continue flowing Water is the working fluid	Sample14 fth
15	1 pipes 2 junctions Model of the pressure drop through a cylindrical annulus Water is the working fluid	Sample15 fth
16	8 pipes, 9 junctions Model of a branching system fed by three reservoirs, one of which has a pump One loop is included Water is the working fluid	Sample16 fth
17	10 pipes, 9 junctions Model of a branching system with a pump and a PRV Two loops are included Water is the working fluid	Sample17 fth
18	12 pipes, 10 junctions Model of a branching system fed by two reservoirs and containing two PRV's Several loops are included Water is the working fluid	Sample18 fth
19	16 pipes, 14 junctions Model of a branching network fed by two reservoirs One reservoir has a pump One PRV is included Water is the working fluid	Sample19 fth
20	31 pipes, 21 junctions Model of a complicated branching network fed by two reservoirs Each reservoir has a pump One other booster pump also is modeled Multiple loops exist Water is the working fluid	Sample20 fth
21	68 pipes, 44 junctions Model of a complicated branching network fed by six reservoirs Four of the reservoirs have pumps One other booster pump is modeled Multiple loops exist Water is the working fluid	Sample21 fth
22	70 pipes, 40 junctions Model of a complicated branching network fed by six reservoirs Four of the reservoirs have pumps One other booster pump is modeled Multiple loops exist Water is the working fluid	Sample22 fth

5 0 RESULTS

Twenty-two sample problems were successfully executed and inspected. The input and output files are attached in Appendix A.

5 1 Acceptance Criteria

The following acceptance criteria were used to evaluate the results of the sample runs:

- 1) Each of the sample problems must execute and converge using the default or input supplied convergence criteria.
- 2) Each of the sample problems, with the exception of sample problems #3 and #4, were compared to the published solutions.

5 2 Test Results

The pertinent results from each of the sample problems are summarized within the following tables and discussed within the following paragraphs. It must be noted that significant differences between FATHOM and the published results were found, most notably for a few pipes in sample problems 21 and 22. Most of the differences in flow rates and head losses were due to a combination of items: tighter tolerances (both global and individual pipes/junctions), friction factor models, and the rigorous treatment of pump heads (fitted polynomial versus linear interpolation). This is acceptable given that most of the piping lengths in sample problems 21 and 22 are in thousands of feet. Even minor differences in the treatment of friction factors and pump heads will have a noticeable effect on the results. These differences were judged to reflect the improvements associated with the general state of knowledge now available for use within FATHOM. These differences should not reflect adversely given the relatively simple hand calculations and techniques that were used to derive the published solutions.

5 2 1 Sample Problem #1

Sample problem # 1 is a model of a water tower fire protection system consisting of two pipes and three junctions from FOX (1985).

A fire protection system is supplied from a water tower and standpipe 80 ft tall. The longest pipe in the system is 600 ft long and is made of cast iron. The pipe contains one gate valve. Other losses may be neglected. The pipe diameter is four inches. The goal of the analysis is to determine the maximum rate of flow through this pipe, in gallons per minute.

The results for sample problem #1 are presented in Table 5-1. A simple hand calculation after two iterations gives a volumetric flow rate of 350 gpm. The corresponding FATHOM results are 351.755 gpm after three iterations. Appendix A contains a listing of the input and output results for sample problem #1.

Table 5-1 Comparison of Results for Sample Problem #1

	f	Volumetric Flowrate (gpm)	Convergence Criteria (gpm)	# of Iterations
Fox	0.031	350.0	± 0.1	2
FATHOM	0.0306798	351.755	± 0.001	3

5.2.2 Sample Problem #2

Sample problem #2 is a model of a pumping system between two reservoirs consisting of six pipes and seven junctions from WHITE (1979). The goal is to determine the required pump horsepower. Water is the working fluid.

The results for sample problem #2 are presented in Table 5-2. A simple hand calculation after gives the pump horsepower at 4.2 Hp. The corresponding FATHOM results are 4.1892 Hp. Appendix A contains a listing of the input and output results for sample problems #2.

Table 5-2 Comparison of Results for Sample Problem #2

	White	FATHOM
Flow Velocity (ft/s)	9.17	9.19714
Reynolds Number	139000	139349
Pump Head (ft)	184.0	184.0
Pump Power (Hp)	4.2	4.1892

5.2.3 Sample Problems #3 and #3a

Sample problem #3 is a classical model of a three reservoir branching system consisting of three pipes and four junctions. This particular problem was obtained from LINDEBURG (1984), but variations can be found in most engineering textbooks about fluid mechanics. Water is the working fluid. However, since there are no published results for this problem, no comparisons are made.

Sample problem #3a is also a classical model of a three reservoir branching system consisting of three pipes and four junctions. This particular problem was obtained from WHITE (1994). Three reservoirs (J1, J2, and J3) are interconnected with a common junction (J4) at an elevation 34.53 meters above some arbitrary reference point. The water surface levels for reservoirs J1, J2, and J3 are at elevations of 20, 100, and 40 meters, respectively. The pipe from reservoir J1 to the junction is 100 meters of 8-cm pipe. The pipe from reservoir J2 to the junction is 150 meters of 6-cm pipe. The pipe from reservoir J3 to the junction is 80 meters of 4-cm pipe. The goal is to determine the flow velocity and direction in each pipe.

The results for sample problem #3a are presented in Table 5-3. Comparison is made to the published results from WHITE (1994). Appendix A contains a listing of the input and output results for sample problems #3 and #3a.

Table 5-3 Comparison of Results for Sample Problem #3

Description		White	FATHOM*
Friction Factor			
	Pipe 1	0.0268	0.0267
	Pipe 2	0.0241	0.0241
	Pipe 3	0.0321	0.0321
Flow Velocity (m/s)			
	Pipe 1	2.90	2.9214
	Pipe 2	4.63	4.6198
	Pipe 3	1.32	1.2911
Volumetric Flowrate			
	Pipe 1	52.8	52.864
	Pipe 2	47.0	47.024
	Pipe 3	5.8	5.841

* Common junction elevation of 34.53 meters

5.2.4 Sample Problem #4

Sample problem #4 is a model of a circulation system connected in a single loop and driven by a pump. The model contains an orifice, seven pipes, and seven junctions. Water is the working fluid. Given the system as shown, determine the mass and volumetric flow rate in the system, the pressure added by the pump and the total pressure at each junction.

Table 5-4 was purposely left blank. There are no published results for this problem. Appendix A contains a listing of the input and output results for sample problem #4.

Table 5-4 Comparison of Results for Sample Problem #4

This table was purposely left blank. There are no published results for comparison.

5.2.5 Sample Problem #5

Sample Problem 5 is a model of a system containing 10 pipes, 10 junctions, and three pumps supplied by three reservoirs. Water is the working fluid.

The supply head for each is given by the equation $h_p = -10.328Q^2 + 2.823Q + 22.289$. There is a defined system outflow of 2.0 cfs at junction 2. Assume all pipes have roughness of 0.012 inch. Find the flow and head loss in each pipe, the pump head added for each pump and the pressure at each junction.

The results for sample problem #5 are presented in Table 5-5. Comparison is made to the published results from JEPPSON (1976). FATHOM requires that each pump junction have two connecting pipes: an inflow and outflow. This differs from the problem statement in JEPPSON showing a single pipe for each pump. The corresponding FATHOM head losses for Pipes 1, 5, and 7 as shown in Table 5-5 are the total head losses for two pipes at each of the three pump junctions. Very good agreement between the published and FATHOM results for values of volumetric flow and pump head gain. Some small differences are noted between the published and FATHOM values for head loss. In general, very good agreement was found. Appendix A contains a listing of the input and output results for sample problem #5.

Table 5-5 Comparison of Results for Sample Problem #5

	Jeppson	FATHOM
Volumetric Flowrate (ft³/s)		
Pipe 1	0.841	0.8411
Pipe 2	0.666	0.6664
Pipe 3	1.334	1.3336
Pipe 4	0.573	0.5726
Pipe 5	0.761	0.7610
Pipe 6	0.175	0.1747
Pipe 7	0.398	0.3979
Head Loss (ft)		
Pipe 1	3.15	3.1246*
Pipe 2	17.63	17.5309
Pipe 3	15.46	15.3840
Pipe 4	1.50	1.4836
Pipe 5	11.42	11.3715**
Pipe 6	0.674	0.6633
Pipe 7	3.24	3.2088***
Head Gain (ft)		
Pipe 1	17.36	17.356
Pipe 2	18.46	18.456
Pipe 3	21.78	21.777

* P1 + P8. See output (Appendix A)

** P5 + P9, See output (Appendix A)

*** P7 + P10, See output (Appendix A)

5.2.6 Sample Problem #6

Sample problem #6 is a model of a branching system containing nine pipes, eight junctions, one pump, one pressure relief valve (PRV), and two loops. Water is the working fluid.

Consider the nine-pipe network shown in Appendix A for Sample Problem #5. A PRV exists 500 feet downstream of junction 1. The pump characteristics are the following: $Q_1 = 1.0$ cfs @ $H_{p1} = 50$ ft, $Q_2 = 1.5$ cfs @ $H_{p2} = 55$ ft, $Q_3 = 2.0$ cfs @ $H_{p3} = 48$ ft. There are defined system

outflows of 1.0 cfs at junction 2 and 4. Assume all pipes have roughness of 0.02 inches. Find the flow and head loss in each pipe, the pump head added for each pump and the pressure at each junction.

The results for sample problem #6 are presented in Table 5-6. Comparison is made to the published results from JEPPSON (1976). As discussed with Sample Problem #5, FATHOM requires that each pump junction have two connecting pipes: an inflow and outflow. This is also true for pressure relief valves (PRV). This differs from the problem statement in JEPPSON showing a single pipe, the pump and PRV. The corresponding FATHOM head losses for pipes 1 and 6, as shown in Table 5-6, are the total head loss for two pipes each at the pump and PRV. Very good agreement between the published and FATHOM results for values of volumetric flow. Small differences are noted between the published and FATHOM values for head loss. In general, very good agreement was found. Appendix A contains listing of the input and output results for sample problem #6.

Table 5-6 Comparison of Results for Sample Problem #6

	Jeppson	FATHOM
Volumetric Flowrate (ft³/s)		
Pipe 1	1.03	1.02686
Pipe 2	0.98	0.98435
Pipe 3	0.017	0.01565
Pipe 4	0.97	0.97314
Pipe 5	0.96	0.96007
Pipe 6	0.041	0.03993
Pipe 7	0.003	0.00258
Head Loss (ft)		
Pipe 1	23.35	23.32407*
Pipe 2	21.43	21.44967
Pipe 3	0.009	0.00632
Pipe 4	4.21	4.19376
Pipe 5	40.92	40.82923
Pipe 6	0.05	0.04598**
Pipe 7	23.68	21.44336

* P1 + P9, See output (Appendix A)

** P6 + P8 See output (Appendix A)

5 2 7 Sample Problem #7

Sample problem #7 is a model of a branching system with 17 pipes and 12 junctions fed by two reservoirs. One reservoir has a pump. Numerous loops are involved. Water is the working fluid.

Solve for the flow rate in each pipe and the head at each junction of the network shown below. The pump characteristic curve is given by $h_p = -2.505Q^2 + 16.707Q + 155.29$ (h_p is in feet and Q in cfs). There are defined system outflows of 0.5 cfs at junctions 2, 3, and 7. There are additional defined system outflows of 2.0, 1.0, and 2.0 cfs at junctions 2, 3, and 4, respectively. Finally, there is a defined system inflow of 1.5 cfs at junction 4. Assume all pipes have a Hazen-Williams friction factor of 130.

The results for sample problem #7 are presented in Table 5-7. Comparison is made to the published results from JEPPSON (1976). As discussed with Sample Problem #5, FATHOM requires that each pump junction have two connecting pipes: an inflow and outflow. This differs from the problem statement in JEPPSON showing a single pipe for the pump. The corresponding FATHOM head loss for Pipe 1, as shown in Table 5-7, is actually the total head loss for two pipes (P1 and P17) adjacent to the pump junction. Very good agreement between the published and FATHOM results for values of volumetric flow. Small differences are noted between the published and FATHOM values for head loss. In general, very good agreement was found. Appendix A contains a listing of the input and output results for sample problem #7.

Table 5-7 Comparison of Results for Sample Problem #7

Pipe	Volumetric Flowrate (ft ³ /s)		Head Loss (ft)	
	Jeppson	FATHOM	Jeppson	FATHOM
1	4.975	4.9767	11.32	11.3356*
2	1.653	1.6557	10.60	10.5746
3	0.114	0.1145	0.03	0.0307
4	2.777	2.7764	8.41	8.3911
5	1.277	1.2764	2.22	2.2142
6	2.045	2.0446	13.25	13.2338
7	-1.039	-1.0412	4.48	4.4829
8	-0.960	-0.9582	1.83	1.8237
9	1.415	1.4126	2.21	2.2062
10	0.889	0.8907	4.04	4.0230
11	0.609	0.6101	2.17	2.1681
12	0.109	0.1101	0.04	0.0381
13	0.413	0.4133	0.27	0.2750

Pipe	Volumetric Flowrate (ft ³ /s)		Head Loss (ft)	
	Jeppson	FATHOM	Jeppson	FATHOM
14	1 587	1 5867	4 31	4 3049
15	2 391	2 3910	2 62	2 6285
16	0 025	0 0233	0 00	0 0003

*P1 + P17, see Sample #7 output (Appendix A)

5 2 8 Sample Problem #8

Sample problem #8 is model of a large branching network containing 48 pipes and 32 junctions. Water is the working fluid. Solve for the flow rate in each pipe and the head at each junction of the network shown below. Note that there are outflows at each junction as described in the problem, except at junction 15 which has an inflow of 20 428 cfs. Assume all pipes have a roughness of 0 012 inches.

The results are presented in Table 5-8. Comparison is made to the published results from JEPPSON (1976). Very good agreement between the published and FATHOM results for values of volumetric flow. Small differences are noted between the published and FATHOM values for head loss. In general, very good agreement was found. Appendix A contains a listing of the input and output results for sample problem #8.

Table 5-8 Comparison of Results for Sample Problem #8

Pipe	Volumetric Flowrate (ft ³ /s)		Head Loss (ft)	
	Jeppson	FATHOM	Jeppson	FATHOM
1	19 80	19 7980	10 59	10 5618
2	10 37	10 3747	2 97	2 9608
3	4 89	4 8909	0 69	0 6862
4	4 00	4 0033	24 57	24 5118
5	2 66	2 6558	0 22	0 2134
6	4 13	4 1308	17 43	17 3836
7	4 44	4 4392	10 04	10 0182
8	4 60	4 6011	16 17	16 1278
9	13 67	13 6671	11 30	11 2740
10	2 40	2 4019	3 01	2 9964
11	4 07	4 0661	16 90	16 8501
12	6 07	6 0661	2 29	2 2741

Pipe	Volumetric Flowrate (ft ³ /s)		Head Loss (ft)	
	Jeppson	FATHOM	Jeppson	FATHOM
13	1 64	1 6384	2 86	2 8444
14	1 11	1 1084	1 01	1 0030
15	5 47	5 4680	0 86	0 8510
16	1 60	1 5980	4 10	4 0648
17	0 40	0 4020	0 10	0 0982
18	1 33	1 3363	1 45	1 4380
19	2 83	2 8363	0 52	0 5183
20	4 83	4 8363	1 02	1 0072
21	4 07	4 0679	12 69	12 6492
22	2 59	2 5911	10 46	10 4272
23	1 41	1 4089	1 07	1 0618
24	3 07	3 0657	7 29	7 2504
25	3 11	3 1123	15 00	14 9371
26	3 07	3 0675	7 28	7 2587
27	2 57	2 5732	5 16	5 1433
28	6 98	6 9746	61 39	61 2163
29	2 48	2 4828	0 95	0 8022
30	8 02	8 0190	7 89	7 8688
31	10 26	10 2618	1 46	1 4491
32	12 26	12 2618	5 16	5 1367
33	2 94	2 9442	6 73	6 6972
34	1 06	1 0558	0 92	0 9137
35	17 21	17 2061	8 03	8 0059
36	0 63	0 6352	0 05	0 0461
37	8 06	8 0638	5 99	5 9668
38	11 69	11 6990	2 82	2 8104
39	4 50	4 4943	1 53	1 5185
40	12 03	12 0332	13 17	13 1446
41	12 55	12 5478	9 54	9 5199
42	8 16	8 1601	4 90	4 8862

Pipe	Volumetric Flowrate (ft ³ /s)		Head Loss (ft)	
	Jeppson	FATHOM	Jeppson	FATHOM
43	29 73	29 7310	17 75	17 7189
44	26 58	26 5810	9 48	9 4606
45	19 58	19 5709	7 77	7 7428
46	2 48	2 4804	6 41	6 3821
47	4 96	4 9642	25 04	24 9846
48	9 74	9 7446	2 63	2 6191

5 2 9 Sample Problem #9

Sample problem #9 is a model of a simple network with three pipes in series each with a different diameter. Water is the working fluid.

The results are presented in Table 5-9. Comparison is made to the published results from WHITE (1979). Very good agreement was found between the published and FATHOM results for friction factor, Reynolds numbers, flow velocities, and volumetric flows. Appendix A contains a listing of the input and output results for sample problem #9.

Table 5-9 Comparison of Results for Sample Problem #9

	White	FATHOM
Friction Factor		
Pipe 1	0 0288	0 02887
Pipe 2	0 0260	0 02608
Pipe 3	0 0314	0 03139
Reynolds Number		
Pipe 1	45,400	44 340
Pipe 2	60 500	59,119
Pipe 3	90 800	88,679
Flow Velocity (m/s)		
Pipe 1	0 565	0 5653
Pipe 2	1 004	1 0050
Pipe 3	2 260	2 2613
Volumetric Flowrate (m³/s)	10 22	10 2299

5 2 10 Sample Problem #10

Sample problem #10 is a model of a simple network with three pipes in parallel with component losses included. Water is the working fluid.

The results are presented in Table 5-10. Comparison is made to the published results from WHITE (1979). Very good agreement was found between the published and FATHON results for volumetric flows. Appendix A contains a listing of the input and output results for sample problem #10.

Table 5-10 Comparison of Results for Sample Problem #10

Pipe #	Volumetric Flowrate (m ³ /hr)	
	White	FATHOM
1	62.5	62.5578
2	25.9	25.9119
3	11.4	11.4099

5.2.11 Sample Problem #11

Sample problem #11 is a model of a simple series network containing two pipes and three junctions with component losses. Water is the working fluid.

Water at 68 °F leaves an open tank whose surface elevation is 180 ft and enters a 2-inch schedule 40 steel pipe (Pipe 1) via a sharp-edged entrance. Pipe 1 is 50 feet in length. Pipe 1 contains a 2-inch globe valve. Pipe 1 enlarges suddenly to an 8-inch Schedule 40 steel pipe (Pipe 2). Pipe 2 is 100 feet in length and contains two standard 90° elbows and an 8-inch angle valve. Pipe 2 discharges below the surface of another open tank whose surface elevation is 100 feet. Determine the volumetric flow rate.

The results are presented in Table 5-11. Comparison is made to the published results from BAUMEISTER (1978). Very good agreement was found between the published and FATHON results for volumetric flows. Appendix A contains a listing of the input and output results for sample problem #11.

Table 5-11 Comparison of Results for Sample Problem #11

Description	Baumeister	FATHOM
Flow Velocity (ft/s) – Pipe 1	17.77	17.7830
Volumetric Flowrate (ft ³ /s – System)	0.4143	0.4144

5.2.12 Sample Problem #12

Sample problem #12 is a model of a simple parallel network containing two pipes and two junctions. Benzene is the working fluid.

Benzene at 68 °F flows at a total rate of 0.5 ft³/s through two parallel straight, horizontal pipes connecting two pressurized tanks. One pipe is 1-inch Schedule 40. The other pipe is 2-inch Schedule 40. Both pipes are 100 feet long and have connections that project inwardly in the supply tank.

If the pressure in the supply tank is maintained at 100 lbf/in², what is the pressure in the receiving tank?

The results are presented in Table 5-12. Comparison is made to the published results from BAUMEISTER (1978). Very good agreement was found between the published and FATHON results for volumetric flows. Appendix A contains a listing of the input and output results for sample problem #12.

Table 5-12 Comparison of Results for Sample Problem #12

	Baumeister	FATHOM
Friction Factor		
Pipe 1	0.02389	0.02392
Pipe 2	0.01981	0.01980
Flow Velocity (ft/s)		
Pipe 1	12.50	12.1112
Pipe 2	18.23	18.3373
Reynolds Number		
Pipe 1	136800	132534
Pipe 2	393200	395406
Pressure (lbf/in²)		
Receiving Tank	73.40	73.5748

5.2.13 Sample Problem #13

Sample problem #13 is a model of a small branching system with three pipes and four junctions. Component losses are included. Ethyl alcohol is the working fluid.

Ethyl alcohol at 68 °F flows from tank A (Junction 1), which is maintained at a constant pressure of 100 psi, through 200 feet of 2-inch Schedule 40 cast-iron pipe (Pipe 1) to a Y branch connection (Junction 2). The flow branches into 100 feet of 2-inch pipe (Pipe 2) to tank B (Junction 3) and 50 feet of 2-inch pipe (Pipe 3) to tank C (Junction 4). Tanks B and C are maintained at 80 psi. All tank connections are flush and sharp-edged and are at the same elevation. Estimate the flow rate to each tank.

The results are presented in Table 5-13. Comparison is made to the published results from BAUMEISTER (1978). Very good agreement was found between the published and FATHON results for volumetric flows. Appendix A contains a listing of the input and output results for sample problem #13.

Table 5-13 Comparison of Results for Sample Problem #13

Tank	Pipe	Volumetric Flowrate (ft ³ /s)	
		Baumeister	FATHOM
A	1	0 22531	0 22520
B	2	0 09491	0 09484
C	3	0 13040	0 13036

5 2 14 Sample Problem #14

Sample problem #14 is simple model of a siphoning system containing two pipes and three junctions. Each pipe contains a gradual bend. The problem is to determine how high junction 3 can be raised and still siphon. Water is the working fluid.

The model contains 2000 feet of 6-inch schedule 40 cast-iron pipe. Reservoir A (Junction 1) is at elevation 800 feet and reservoir C (Junction 2) at 600 feet. Estimate the maximum height of point B (Junction 3) if the water temperature may reach 104 °F. The amount of straight pipe (Pipe 2) from A (Junction 1) to B (Junction 3) is 100 feet. The amount of straight pipe (Pipe 3) from B (Junction 3) to C (Junction 2) is 1900 feet. Assume a L/D ratio of 25 for the first bend and a L/D ratio of 50 for the second. Assume an atmospheric pressure equal to 14.7-psia.

The problem is solved by successively increasing the elevation of point B (Junction 3) until a maximum elevation is obtained that does not decrease the pressure at point B below the vapor pressure of water (1.07-psia).

The results are presented in Table 5-14. Comparison is made to the published results from BAUMEISTER (1978). Very good agreement was found between the published and FATHON results for the elevation of point B. Appendix A contains a listing of the input and output results for sample problem #14.

Table 5-14 Comparison of Results for Sample Problem #14

	Baumeister	FATHOM
Elevation (ft) of Point B (Junction 3) Above Source	16.58	16.69*

* $16.69 - 800.00 = 16.69$. See input to Sample Problem #14 (Appendix A).

5 2 15 Sample Problem #15

Sample problem #15 is a model of the pressure drop through a cylindrical annulus. Water is the working fluid. The goal is to determine the minimum reservoir level necessary to maintain a flow of 0.01 m³/s. The problem reduces to finding the total head loss associated with the cylindrical annulus. The height in feet of the reservoir must be equal to or greater than the head losses for flow to occur.

The results are presented in Table 5-15. Comparison is made to the published results from WHITE (1979). Very good agreement was found between the published and FATHON results for the minimum reservoir level. Appendix A contains a listing of the input and output results for sample problem #15.

Table 5-15 Comparison of Results for Sample Problem #15

	White	FATHOMS
Reservoir Level (m)	3.71	3.71238

5.2.16 Sample Problem #16

Sample problem #16 is a model of a branching system containing seven pipes and nine junctions. The system is fed by three reservoirs, one of which has a pump. One loop is included. Water is the working fluid.

The elevation of all junctions is 80 feet. The pump curve is given by $h_p = -10.33Q^2 + 2.823Q + 22.29$. There is a defined system outflow of 2.0-cfs junction 2. All pipes have a roughness of 0.012 inches. Find the flow and head loss in each pipe, and the head and pressures at each junction.

As discussed with Sample Problem #5, FATHOM requires that each pump junction have two connecting pipes: an inflow and outflow. This differs from the problem statement in JEPPSON showing a single pipe (P7) to the pump. The corresponding FATHOM head losses for pipe 7, as shown in Table 5-16, are actually the total head loss for pipes 7 and 8.

The results are presented in Table 5-16. Comparison is made to the published results from JEPPSON (1976). Very good agreement was found between the published and FATHON results for volumetric flow and head loss. Appendix A contains a listing of the input and output results for sample problem #16.

Table 5-16 Comparison of Results for Sample Problem #16

Pipe	Volumetric Flowrate (ft³/s)		Head Loss (ft)	
	Jeppson	FATHOM	Jeppson	FATHOM
1	0.533	0.5351	1.306	1.3023
2	0.662	0.6636	17.384	17.3877
3	1.338	1.3416	15.563	15.5675
4	0.699	0.7007	2.201	2.1919
5	0.639	0.6409	8.127	8.1225
6	-0.129	-0.1284	0.380	0.3718
7	0.828	0.8292	13.474	13.4593*

*P7 + P8. See Output for Sample Problem #16 (Appendix A).

5 2 17 Sample Problem #17

Sample problem #17 is a model of a branching system containing 10 pipes, 9 junctions, a pump and a PRV. Two loops are included. Water is the working fluid.

The ten-pipe network is supplied by two reservoirs with water surfaces at 180 and 200 feet, respectively. The PRV is located 450 feet downstream from the upstream junction [J2] and has a pressure setting, which maintains the elevation of the HGL at 50 ft downstream from the valve. The pump characteristics are the following: $Q_1 = 1.0 \text{ cfs @ } h_{p1} = 40 \text{ ft}$, $Q_2 = 1.5 \text{ cfs @ } h_{p2} = 35 \text{ ft}$, $Q_3 = 2.0 \text{ cfs @ } h_{p3} = 26 \text{ ft}$. There are defined system outflows of 1.0, 2.0, and 2.0 cfs at junctions 6, 8 and 9, respectively. Assume that pipes 1, 3 and 10 have a CHW = 110. Pipes 2, 4, 5, 6 and 9 have CHW = 120, and pipes 7 and 8 have CHW = 130. Find the flow and head loss in each pipe.

As discussed with Sample Problem #5, FATHOM requires that each pump junction have two connecting pipes: an inflow and outflow. This is also true for pressure relief valves (PRV). This differs from the problem statement in JEPPSON (1976) showing a single pipe the pump and PRV. The corresponding FATHOM head losses for pipes 1 and 5, as shown in Table 5-6, are the total head loss for two pipes each at the pump and PRV.

The results are presented in Table 5-17. Comparison is made to the published results from JEPPSON (1976). Very good agreement was found between the published and FATHOM results for volumetric flow and head loss. Appendix A contains a listing of the input and output results for sample problem #17.

Table 5-17 Comparison of Results for Sample Problem #17

Pipe	Volumetric Flowrate (ft ³ /s)		Head Loss (ft)	
	Jeppson	FATHOM	Jeppson	FATHOM
1	2.56	2.5329	130.61	127.6450*
2	-0.32	-0.3758	1.89	2.5478
3	2.44	2.4671	119.67	121.5822
4	0.73	0.7203	8.75	8.4898
5	0.88	0.9087	18.42	19.5720**
6	1.12	1.0913	24.12	22.8889
7	1.83	1.8126	6.33	6.2512
8	3.17	3.1874	17.88	17.7615

* P1 + P10 See output (Appendix A)

** P5 + P9 See output (Appendix A)

5 2 18 Sample Problem #18

Sample problem #18 is a model of a branching system containing 12 pipes, 10 junctions, two PRVs and fed by two reservoirs. Several loops are included. The PRVs will act as check valves preventing flow if downstream pressure control is lost.

Obtain the volumetric flow rates and head losses in each pipe. Water is the working fluid (dynamic viscosity = 0.00113 Kg/m-s and the density = 1000 Kg/m³). Reservoirs A and B are elevations of 300 m and 250 m, respectively.

The results are presented in Table 5-18. Comparison is made to the published results from JEPPSON (1976). Downstream pressure control was determined to be lost for both PRVs. The corresponding pipe flow (Pipes 7 and 8) was correctly calculated to be zero. Very good agreement was found between the published and FATHON results for volumetric flow. Some minor differences were noted for head loss, but overall the general agreement was very good. Appendix A contains a listing of the input and output results for sample problem #18.

Table 5-18 Comparison of Results for Sample Problem #18

Pipe	Volumetric Flowrate (ft ³ /s)		Head Loss (ft)	
	Jeppson	FATHOM	Jeppson	FATHOM
1	0.6402	0.65141	6.00	6.12723
2	0.2857	0.28252	16.21	15.65500
3	0.1857	0.18252	12.32	11.79865
4	-0.0857	-0.08252	1.79	1.66547
5	0.2344	0.24889	30.32	29.11912
6	-0.2402	-0.25141	11.77	12.64710
7	0.0	0.00000	0.00	0.00000
8	0.0	0.00000	0.00	0.00000
9	0.12	0.12000	56.47	55.66505
10	-0.1902	-0.20141	1.91	2.10655

5.2.19 Sample Problem #19

Sample problem #19 is a model of a branching network containing six pipe, 14 junctions and fed by two reservoirs. One reservoir has a pump. One PRV is included. Water is the working fluid.

In this network the PRV is placed in pipe P5 and has a pressure setting to maintain the HGL downstream from the valve at 350 feet. The pump is placed in pipe 1. Solve for the flow rate and the head loss in each pipe. The pump characteristics are the following: $Q_1 = 2.0$ cfs @ $h_{p1} = 80$ ft, $Q_2 = 3.0$ cfs @ $h_{p2} = 75$ ft, $Q_3 = 4.0$ cfs @ $h_{p3} = 68$ ft (h_p is in feet and Q in cfs). There are defined system outflows.

As discussed with Sample Problem #5, FATHOM requires that each pump junction have two connecting pipes: an inflow and outflow. This is also true for pressure relief valves (PRV). This differs from the problem statement in JEPPSON (1976) showing a single pipe for the pump and PRV. The corresponding FATHOM head loss for pipes 4 and 5, as shown in Table 5-6, are actually the total head loss for two pipes each at the pump and PRV. Very good agreement is noted between the published and FATHON results for values of volumetric flow. Small differences are noted between the published and FATHOM values for head loss. Pressure control for the PRV was lost and the flow through pipe 5 is zero. In general, very good agreement was found. Appendix A contains listing of the input and output results for sample problem #19.

Table 5-19 Comparison of Results for Sample Problem #19

Pipe	Volumetric Flowrate (ft ³ /s)		Head Loss (ft)	
	Jeppson	FATHOM	Jeppson	FATHOM
1	0 50	0 5000	2 44*	4 8165
2	0 37	0 3736	0 63	0 6361
3	2 16	2 1679	19 27	19 2163
4	3 16	3 1678	6 40	6 3752**
5	0 0	0 0000	0 0	0 0000***
6	1 00	1 0000	6 40	6 3288
7	0 25	0 2464	1 01	0 9885
8	0 25	0 2536	1 06	1 0448
9	0 05	0 0464	0 06	0 0564
10	1 00	1 0000	2 56	2 5315
11	0 79	0 7943	2 73	2 6986
12	0 71	0 7057	2 22	2 1473
13	0 13	0 1264	0 09	0 0848
14	1 84	1 8322	2 21	2 1780

* P4 + P16, See output (Appendix A)

** Reported head loss is velocity (ft/s) Comparable velocity from FATHOM is 2 5465 ft/s

*** P5 + P15, See output (Appendix A)

5 2 20 Sample Problem #20

Sample problem #20 is a model of a very large and complicated branching network containing 28 pipes 21 junctions, and 2 reservoirs The pipe diameters range from 6- to 20-inches The piping runs range from 250- to 2800-feet Each reservoir has a pump One booster pump also is modeled Multiple loops exist Water is the working fluid

The results for sample problem #20 are presented in Table 5-20 Comparison is made to the published results from JEPPSON (1976) FATHOM requires that each pump junction have two connecting pipes an inflow and outflow This differs from the problem statement in JEPPSON showing a single pipe for each pump The corresponding FATHOM head losses for Pipes 25 26, and 27, as shown in Table 5-20, are the total head losses for two pipes at each of the three pump junctions Very good agreement between the published and FATHOM results for values of volumetric flow Small differences are noted between the published and FATHOM values for head loss In general, very good agreement was found Appendix A contains a listing of the input and output results for sample problem #20

Table 5-20 Comparison of Results for Sample Problem #20

Pipe	Volumetric Flowrate (ft ³ /s)		Head Loss (ft)	
	Jeppson	FATHOM	Jeppson	FATHOM
1	2 94	2 9439	6 41	6 4373
2	-1 74	-1 7564	11 85	11 7952
3	-0 54	-0 5344	0 62	0 6154

Pipe	Volumetric Flowrate (ft ³ /s)		Head Loss (ft)	
	Jeppson	FATHOM	Jeppson	FATHOM
4	1 74	1 7348	9 10	9 0593
5	0 88	0 8799	10 76	10 6609
6	-2 55	-2 5531	30 20	30 0546
7	-3 35	-3 3532	45 50	45 2429
8	2 17	2 1759	51 10	50 8208
9	3 07	3 0710	43 90	43 6955
10	-0 44	-0 4417	7 92	7 8225
11	-0 58	-0 5750	9 90	9 8010
12	0 64	0 6439	8 20	8 1816
13	0 73	0 7280	9 38	9 3325
14	1 32	1 3208	59 00	58 6433
15	1 18	1 1875	29 60	29 4356
16	0 80	0 8001	23 40	23 2014
17	-2 29	-2 2908	7 86	7 8394
18	-0 17	-0 1705	1 37	1 3284
19	0 09	0 0865	0 28	0 2732
20	3 27	3 2789	37 60	37 4324
21	2 45	2 4570	30 70	30 5407
22	-0 04	-0 0366	0 01	0 0117
23	1 15	1 1506	6 90	6 8800
24	-0 41	-0 4151	6 91	6 8917
25	6 84	6 8499	30 60	30 7051*
26	6 01	6 0150	0 91	0 9202**
27	3 35	3 3427	0 31	0 3104***
28	-2 39	-2 3939	8 43	8 4859

* P25 + P29

** P26 + P31

*** P27 + P30

5 2 21 Sample Problem #21

Sample problem #21 is an example of a very large and complicated branching network containing 63 pipes, 44 junctions, and fed by six reservoirs. Four of the reservoirs have pumps. One other booster pump is modeled. Multiple loops exist. The pipe diameters range from 8- to 16-centimeters. The piping runs range from 500- to 4300-meters. Water is the working fluid.

All pipes have a roughness of 0.026 cm. The network is supplied by two reservoirs without pumps and four reservoirs with pumps. One booster pump exists between pipe P43 and P68. The water surface elevations are 500, 540, 530, 480, 600 and 600 m for reservoirs J46, J47, J48, J49, J50 and J51 respectively.

The results for sample problem #21 are presented in Table 5-21. Comparison is made to the published results from JEPPSON (1976). FATHOM requires that each pump junction have two

connecting pipes an inflow and outflow. This differs from the problem statement in JEPSON showing a single pipe for each pump. The corresponding FATHOM head losses for Pipes 1, 20, 27, 43 and 52, as shown in Table 5-21, are the total head losses for two pipes at each of the three pump junctions. A comparison of the volumetric flow rates shows very good agreement. However, significant differences are noted between the published and FATHOM values for head loss for some of the longer pipes. This is acceptable given that most of the piping lengths are in thousands of meters. Even minor differences in the treatment of friction factors and pump heads will have a noticeable affect on the results. These differences were judged to reflect the improvements associated with the general state of knowledge now available for use within FATHOM. These differences should not reflect adversely given the relatively simple hand calculations and techniques that were used to derive the published solutions.

In general, very good agreement was found. Appendix A contains a listing of the input and output results for sample problem #21.

Table 5-21 Comparison of Results for Sample Problem #21

Pipe	Volumetric Flowrate (m ³ /s)		Head Loss (m)	
	Jeppson	FATHOM	Jeppson	FATHOM
1	0.0869	0.08722	201.1	201.947*
2	0.0208	0.02089	53.6	53.585
3	0.0132	0.01334	19.1	19.228
4	0.0153	0.01537	27.4	27.333
5	0.0092	0.00911	7.16	7.024
6	0.0274	0.02746	27.5	27.416
7	0.0254	0.02552	27.3	27.309
8	0.0148	0.01468	8.3	8.081
9	-0.0027	-0.00185	0.22	0.107
10	0.0299	0.03069	68.4	71.741
11	0.0212	0.02197	63.1	67.037
12	0.0081	0.00769	5.11	4.597
13	0.0089	0.00734	10.1	6.937
14	0.0164	0.01886	38.1	22.288
15	0.0273	0.02598	91.0	82.387
16	0.0107	0.01095	78.9	83.017
17	0.0118	0.01155	165.5	156.685
18	0.0078	0.00725	86.5	73.668
19	0.0243	0.02512	48.4	51.380
20	0.0791	0.07866	166.9	164.517**
21	0.0351	0.03475	150.0	146.499
22	-0.0035	-0.00335	16.3	14.687
23	0.0106	0.01028	117.7	109.806
24	0.0166	0.01640	45.8	44.362
25	0.0119	0.01192	29.7	29.675
26	0.0277	0.02830	25.3	26.171
27	0.0805	0.08081	287.6	289.252***

Pipe	Volumetric Flowrate (m ³ /s)		Head Loss (m)	
	Jeppson	FATHOM	Jeppson	FATHOM
28	-0 0043	-0 00417	1 37	1 248
29	0 0061	0 00609	12 52	12 241
30	-0 0065	-0 00622	3 74	3 350
31	0 0148	0 01474	11 16	10 993
32	0 0071	0 00728	6 62	6 822
33	0 0046	0 00468	0 80	0 821
34	0 0274	0 02741	27 6	27 308
35	0 0094	0 00947	3 5	3 466
36	0 0219	0 02189	31 8	31 595
37	0 1306	0 13040	297 8	299 642
38	-0 0214	-0 02122	12 7	12 404
39	-0 0299	-0 02989	24 4	24 285
40	-0 0238	-0 02374	15 7	15 453
41	0 0239	0 02385	37 8	37 410
42	0 0287	0 02865	45 2	44 721
43	0 0450	0 04500	54 6	54 405****
44	0 0139	0 01396	11 1	10 980
45	-0 0002	-0 00010	0 11	0 013
46	0 0056	0 00562	55 0	55 846
47	0 0051	0 00521	54 9	55 833
48	0 0167	0 01665	267 5	266 148
49	0 0137	0 01368	322 4	321 981
50	-0 0078	-0 00782	14 3	14 116
51	0 0222	0 02218	336 7	336 097
52	0 0547	0 05492	240 7	242 343*****
53	0 0210	0 02103	94 2	93 810
54	0 0165	0 01647	58 1	57 832
55	0 0135	0 01347	39 1	38 898
56	-0 0020	-0 00196	2 97	2 920
57	0 0116	0 01157	93 0	92 565
58	0 0109	0 01093	82 9	82 641
59	0 0031	0 00309	7 07	7 004
60	0 0072	0 00717	36 2	35 994
61	0 0078	0 00783	43 2	42 886
62	0 0003	0 00033	0 12	0 112
63	0 1276	0 12750	284 5	286 517

- * P1 + P64 See output (Appendix A)
- ** P20 + P65 See output (Appendix A)
- *** P27 + P66, See output (Appendix A)
- **** P43 + P68 See output (Appendix A)
- ***** P52 + P27, See output (Appendix A)

5 2 22 Sample Problem #22

Sample problem #22 is another example of a very large and complicated branching network containing 64 pipes, 40 junctions, and fed by six reservoirs. Four of the reservoirs have pumps. One other booster pump is modeled. Multiple loops exist. The pipe diameters range from 8- to 14-inches. The piping runs range from 500- to 4500-feet. Water is the working fluid.

All pipes have a roughness of 0.0102-inches. The network is supplied by two reservoirs without pumps and four reservoirs with pumps. One booster pump exists in pipe P55. The water surface elevations are 300, 350, 280, 400, 150, and 300 feet for reservoirs J41, J42, J43, J44, J46, and J47, respectively.

The results for sample problem #22 are presented in Table 5-22. Comparison is made to the published results from JEPPSON (1976). FATHOM requires that each pump junction have two connecting pipes, an inflow and outflow. This differs from the problem statement in JEPPSON showing a single pipe for each pump. The corresponding FATHOM head losses for Pipes 1, 13, 52, 55, and 62, as shown in Table 5-22, are the total head losses for two pipes at each of the three pump junctions. A comparison of the volumetric flowrates shows very good agreement. However, significant differences are noted between the published and FATHOM values for head loss for some of the longer pipes. This is acceptable given that most of the piping lengths are in thousands of meters. Even minor differences in the treatment of friction factors and pump heads will have a noticeable effect on the results. These differences were judged to reflect the improvements associated with the general state of knowledge now available for use within FATHOM. These differences should not reflect adversely given the relatively simple hand calculations and techniques that were used to derive the published solutions.

In general, very good agreement was found. Appendix A contains a listing of the input and output results for sample problem #22.

Table 5-22 Comparison of Results for Sample Problem #22

Pipe	Volumetric Flowrate (ft ³ /s)		Head Loss (ft)	
	Jeppson	FATHOM	Jeppson	FATHOM
1	11.61	11.506	82.15	80.425*
2	3.18	3.174	14.20	14.138
3	2.18	2.174	9.23	9.166
4	1.50	1.497	23.43	23.304
5	2.22	2.201	26.31	25.851
6	-1.19	-1.126	2.87	2.547
7	0.30	0.376	0.18	0.264
8	-0.68	-0.669	3.60	3.499
9	0.49	0.565	0.73	0.953
10	-1.43	-1.400	3.42	3.235
11	2.63	2.523	7.68	7.032
12	2.06	1.989	11.10	10.267
13	10.00	9.936	25.67	26.733**
14	0.93	1.071	1.89	2.468

Pipe	Volumetric Flowrate (ft ³ /s)		Head Loss (ft)	
	Jeppson	FATHOM	Jeppson	FATHOM
15	1 49	1 531	5 33	5 545
16	1 89	1 822	11 07	10 277
17	1 54	1 324	3 78	2 778
18	1 47	1 393	3 44	3 077
19	2 75	2 476	7 22	5 855
20	2 71	2 456	7 04	5 762
21	-0 26	-0 194	0 18	0 093
22	-1 45	-1 262	4 21	3 176
23	-1 77	-1 545	4 03	3 082
24	-1 71	-1 550	5 74	4 732
25	0 58	0 568	1 71	1 649
26	2 09	1 985	19 84	17 905
27	-2 10	-1 987	18 13	16 256
28	0 07	-0 048	0 02	0 010
29	1 18	1 072	3 26	2 704
30	2 73	2 574	21 37	18 970
31	1 14	1 093	20 22	18 640
32	-0 92	-0 762	1 88	1 282
33	4 72	4 634	28 18	27 133
34	3 51	3 022	28 34	25 015
35	0 71	0 637	8 01	6 375
36	-1 95	-1 744	22 30	17 866
37	-2 72	-2 440	14 28	11 491
38	0 88	0 859	0 85	0 801
39	-0 43	-0 313	0 13	0 073
40	-3 72	-3 324	21 31	16 992
41	1 05	0 954	2 40	1 973
42	-1 00	-0 922	4 25	3 578
43	-0 86	-0 784	1 63	1 354
44	-0 50	-0 478	1 72	1 532
45	-0 40	-0 354	0 90	0 692
46	1 45	1 330	4 75	3 984
47	1 43	1 289	4 87	3 973
48	0 35	0 329	0 79	0 703
49	2 55	2 445	17 59	16 156
50	1 45	1 378	4 21	3 768
51	4 25	4 096	13 38	12 389
52	9 03	8 946	26 61	26 033****
53	1 24	1 562	3 32	5 128
54	-3 02	-2 869	24 63	22 120
55	3 27	3 431	18 65	20 412*****
56	-1 21	-1 121	1 55	1 332
57	-0 22	-0 110	0 08	0 022
58	-1 22	-1 080	3 78	2 978

Pipe	Volumetric Flowrate (ft³/s)		Head Loss (ft)	
	Jeppson	FATHOM	Jeppson	FATHOM
59	0 92	0 863	1 17	1 017
60	-0 80	-0 718	1 15	0 929
61	1 80	1 718	4 23	3 855
62	6 25	6 054	12 87	12 043*****
63	-5 14	-3 945	19 47	29 610
64	2 80	2 659	16 80	15 453
65	7 00	6 254	23 88	22 977

- * P1 + P71 See output (Appendix A)
- ** P13 + P72, See output (Appendix A)
- *** P52 + P73, See output (Appendix A)
- **** P55 + P75, See output (Appendix A)
- ***** P52 + P74 See output (Appendix A)

6 0 SUMMARY AND CONCLUSIONS

The FATHOM (Version 3) piping network fluid flow analysis program has been installed and successfully validated for use. The FATHOM computer program is judged acceptable for use. This is based on the use of a license key to assure proper installation and configuration control and comparison of twenty of twenty-two sample problems to published results.

The pertinent results from each of the sample problems are summarized within the preceding tables. It must be noted that in most cases very good agreement was found. However, a few cases of significant differences between FATHOM and the published results were found, most notably for a few pipes in sample problems 21 and 22. Most of the differences in flow rates and head losses were due to a combination of items: tighter tolerances (both global and individual pipes/junctions), friction factor models, and the rigorous treatment of pump heads (fitted polynomial versus linear interpolation). This is acceptable given that most of the piping lengths in sample problems 21 and 22 are in thousands of feet. Even minor differences in the treatment of friction factors and pump heads will have a noticeable effect on the results.

These differences were judged to reflect the improvements associated with the general state of knowledge now automated and available for use within FATHOM. These differences should not reflect adversely given the relatively simple hand calculations and techniques that were used to derive the published solutions.

7 0 REFERENCES

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APPENDIX A – SAMPLE PROBLEMS INPUT AND OUTPUT

Sample #1

2 pipes 3 junctions

Model of a water tower fire protection system

Reference Fox R W and A T McDonald *Introduction to Fluid Mechanics* 3rd Ed 1985 p 376

A fire protection system is supplied from a water tower and standpipe 80 ft tall. The longest pipe in the system is 600 ft long and is made of cast iron about 20 year old. The pipe contains one gate valve. Other minor losses may be neglected. The pipe diameter is 4 in. Determine the maximum rate of flow through this pipe in gallons per minute.

AFT Fathom 3.0 Input
NUMATEC HANFORD CORPORATION

(1)

11/30/1999 02 20 PM

Sample 1 Introduction to Fluid Mechanics p 376 Fox and McDonald 3rd Ed 1985

Title Sample 1 Introduction to Fluid Mechanics p 376 Fox and McDonald 3rd Ed 1985

Number Of Pipes= 2
Number Of Junctions= 3

Head/Pressure Convergence= 001 psia
Flow Rate Convergence= 001 ft3/sec
Relaxation= AFT Fathom Automatic
Maximum Iterations= 500

Constant Fluid Property Model

Fluid Water at 1 atm
Temperature 68 deg F
Density= 62.3229 lbm/ft3
Viscosity= 2.42744 lbm/hr ft
Vapor Pressure= 33656 psia
Gravitational Acceleration= 1 g
Atmospheric Pressure= 1 atm

Pipe	Name	Object Defined	Length	Length Units	Hydraulic Diameter	Hydraulic Diam Units	Roughness	Roughness Units	Losses (K)	Junctions (Up Down)
1	Pipe	Yes	80	feet	4	inches	005	Eps/D	0	1 2
2	Pipe	Yes	600	feet	4	inches	005	Eps/D	0	2 3

Pipe	Geometry	Material	Thermal Boundary	Overall U	Include Internal h	Special Condition
1	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
2	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None

Bend	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units	Connected Pipes (+ = in = out)
2	90 Deg Bend	Yes	N/A	0	feet			1 2
Reservoir	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units	Connected Pipes (+ = in = out)
1	Reservoir	Yes	N/A	80	feet	80	feet	1
Valve	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units	Connected Pipes (+ = in = out)
3	Valve	Yes	None	0	feet			2

Bend	Type	Angle (Degrees)	r/d	Loss Factor	
2	Custom	90		0	
Reservoir	Surface Pressure	Surface Pressure Units	Depth	Depth Units	Balance Energy
1	1	atm	0	feet	No
Valve	Loss Model	Loss Value	Exit Valve	Restricted Area	
3	K Constant	1.24	Yes		

AFT Fathom 3.0 Output
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(1)

12/01/1999

Sample 1 Introduction to Fluid Mechanics p 376 Fox and McDonald 3rd Ed 1985

Title Sample 1 Introduction to Fluid Mechanics p 376 Fox and McDonald 3rd Ed 1985

Analysis run on 12/01/1999 2 36 35 PM

Input File C:\FATHOM\SAMPLES\SAMPLE1.FTH

Execution Time= 0 11 seconds

Total Number Of Head/Pressure Iterations= 0

Total Number Of Temperature Iterations= 0

Total Number Of Flow Iterations= 2

Number Of Pipes= 2

Number Of Junctions= 3

Pressure Tolerance= 0.01 psia

Volumetric Flow Rate Tolerance= 0.01 gal/min

Relaxation= 1 (None)

Constant Fluid Property Model

Fluid Water at 1 atm

Temperature 68 deg F

Density= 62.3229 lbm/ft³

Viscosity= 2.42744 lbm/hr ft

Vapor Pressure= 33656 psia

Gravitational Acceleration= 1 g

Atmospheric Pressure= 1 atm

Overall Delta Pressure = 0.00000 psi

Overall Frictional Pressure Loss = 34.6238 psi

Total Inflow= 0.783715 ft³/sec

Total Outflow= 0.783715 ft³/sec

Maximum Pressure is 44.7831 psi at Junction 2 Inlet

Minimum Pressure is 14.1535 psi at Junction 3 Outlet

=====VALVE SUMMARY=====

Jct	Type	Flow (gal/min)	DP (psid)	DH (feet)	P Inlet (psia)	Cv	K	State
3	REGULAR	351.76	0.67266	1.5542	15.369	428.71	1.2400	Open

Pipe	Vol Flow (gal/min)	Mass Flow (lbm/sec)	Velocity (feet/sec)	dP Total (psid)	dP Friction (psid)	dP Gravity (psid)	dH (feet)	Max Pres (psia)	Min Pres (psia)	Dyn Pres (psia)
1	351.755	48.8434	8.98071	30.6296	3.99426	34.6238	9.22892	44.7831	14.1535	0.542465
2	351.755	48.8434	8.98071	29.9569	29.95692	0.0000	69.21688	44.7831	14.8262	0.542465

Pipe	dPf/dx (psi/100 ft)	Resistance (sec ² /ft ⁵)	f	Reynolds No	fL/D	K	fL/D + K
1	4.99282	15.0257	0.0306798	2.76688E+05	7.36316	0	7.36316
2	4.99282	112.6928	0.0306798	2.76688E+05	55.22372	0	55.22372

Jct	dP (psid)	dH (feet)	Vol Flow Into System (gal/min)	Loss Factor (K)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)	P Stag In (psia)
1	0.000000	0.00000	351.755	0.00000	80.00000	80.0000	80.000000	80.00000	14.6960
2	0.000000	0.00000	0.000	0.00000	70.77108	70.7711	69.517691	69.51769	45.3256
3	0.672656	1.55420	351.755	1.24000	1.55420	0.0000	0.300813	1.25339	15.3686

Jct	P Stag Out (psia)	P Inlet (psia)	P Outlet (psia)
1	14.6960	14.6960	14.6960
2	45.3256	44.7831	44.7831
3	14.6960	14.8262	14.1535

Sample #2

6 pipes 7 junctions

Model of a pumping system between two reservoirs Problem is to find the required pump horsepower
Water is the working fluid

Reference White F *Fluid Mechanics* 1979 p 359

AFT Fathom 3.0 Input
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(1)

11/30/1999 02:20 PM

Sample 2 Frank White Fluid Mechanics 1979 pg 359

Title Sample 2 Frank White Fluid Mechanics 1979 pg 359

Number Of Pipes= 6

Number Of Junctions= 7

Head/Pressure Convergence= .001 psia

Flow Rate Convergence= .001 ft³/sec

Relaxation= 1

Maximum Iterations= 500

Constant Fluid Property Model

Fluid Unspecified

Density= 1.94 slug/ft³

Viscosity= .0006866 lbm/s ft

Vapor Pressure=

Gravitational Acceleration= 1 g

Atmospheric Pressure= 1 atm

Pipe	Name	Object Defined	Length	Length Units	Hydraulic Diameter	Hydraulic Diam Units	Roughness	Roughness Units	Losses (K)	Junctions (Up Down)
1	Pipe	Yes	50	feet	2	inches	.001	Eps/D	0	1 2
2	Pipe	Yes	50	feet	2	inches	.001	Eps/D	0	2 3
3	Pipe	Yes	50	feet	2	inches	.001	Eps/D	0	3 4
4	Pipe	Yes	150	feet	2	inches	.001	Eps/D	0	4 5
5	Pipe	Yes	50	feet	2	inches	.001	Eps/D	0	5 6
6	Pipe	Yes	50	feet	2	inches	.001	Eps/D	0	6 7

Pipe	Geometry	Material	Thermal Boundary	Overall U	Include Internal h	Special Condition
1	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
2	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
3	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
4	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
5	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
6	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None

Bend	Name	Object Defined	Special Condition	Elevation	Elevation Units	Connected Pipes (+ = in, = out)	Type	Angle (Degrees)
4	12 in bend	Yes	N/A	20	feet	3 4	Custom	90
5	Regular Bend	Yes	N/A	120	feet	4, 5	Custom	90
Pump	Name	Object Defined	Special Condition	Elevation	Elevation Units	Connected Pipes (+ = in, = out)	Independent Variable	Ind Variable Units
3	Pump	Yes	None	20	feet	2, 3	Vol Flow	ft ³ /sec
Reservoir	Name	Object Defined	Special Condition	Elevation	Elevation Units	Connected Pipes (+ = in, = out)	Surface Pressure	Surface Pressure Units
1	Reservoir	Yes	N/A	20	feet	1	1	atm
7	Reservoir	Yes	N/A	120	feet	6	1	atm
Valve	Name	Object Defined	Special Condition	Elevation	Elevation Units	Connected Pipes (+ = in, = out)	Loss Model	Loss Value
2	Globe Valve	Yes	None	20	feet	1 2	K Constant	6.9
6	Gate Valve 1/2 open	Yes	None	120	feet	5, 6	K Constant	2.7

Bend	r/d	Loss Factor

AFT Fathom 3.0 Input
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(2)

11/30/1999 02 20 PM

4		15								
5		95								
Pump	Dependent Variable	Dep Variable	Units	Loss Constant a	Loss Constant b	Loss Constant c	Loss Constant d	Loss Constant e	Speed %	Viscosity Correction
3	Head	feet		184	0	0	0	0	100	No
Reservoir	Depth	Depth	Units	Density	Density	Temperature	Temperature	Balance Energy		
1	0	feet						No		
7	0	feet						No		
Valve	Exit Valve	Restricted Area	Restricted Area	Units						
2	No									
6	No									

AFT Fathom 3.0 Output
NUMATEC HANFORD CORPORATION

(1)

11/30/1999

Sample 2 Frank White Fluid Mechanics 1979 pg 359

Title Sample 2 Frank White Fluid Mechanics 1979 pg 359

Analysis run on 11/30/1999 1 30 52 PM

Input File C:\FATHOM\SAMPLES\SAMPLE2.FTH

Execution Time= 0.17 seconds

Total Number Of Head/Pressure Iterations= 0

Total Number Of Temperature Iterations= 0

Total Number Of Flow Iterations= 3

Number Of Pipes= 6

Number Of Junctions= 7

Pressure Tolerance= .001 psia

Volumetric Flow Rate Tolerance= .001 ft³/sec

Relaxation= 1 (None)

Constant Fluid Property Model

Fluid Unspecified

Density= 1.94 slug/ft³

Viscosity= .0006866 lbm/s ft

Vapor Pressure=

Gravitational Acceleration= 1 g

Atmospheric Pressure= 1 atm

Overall Delta Pressure = 79.7559 psi

Overall Frictional Pressure Loss = 36.4103 psi

Total Inflow= 0.200650 ft³/secTotal Outflow= 0.200650 ft³/sec

Maximum Pressure is 82.3004 psi at Junction 3 Outlet

Minimum Pressure is 2.54457 psi at Junction 3 Inlet

=====PUMP SUMMARY=====

Jct	Flow (gal/min)	DP (psid)	DH (feet)	Speed (%)	ideal hp (hp)	NPSHA (feet)	NPSHR (feet)
3	90.058	79.756	184.00	100.00	4.1892	N/A	N/A

=====VALVE SUMMARY=====

Jct	Type	Flow (gal/min)	DP (psid)	DH (feet)	P Inlet (psia)	Cv	K	State
2	REGULAR	90.058	3.9316	9.0703	10.729	45.435	6.9000	Open
6	REGULAR	90.058	1.5384	3.5492	20.485	72.633	2.7000	Open

Pipe	Vol Flow (gal/min)	Mass Flow (lbm/sec)	Velocity (feet/sec)	dP Total (psid)	dP Friction (psid)	dP Gravity (psid)	dH (feet)	Max Pres (psia)	Min Pres (psia)	Dyn Pres (psia)
1	90.0582	12.5241	9.19714	3.68258	3.68258	0.0000	8.49586	13.84129	10.15871	0.569791
2	90.0582	12.5241	9.19714	3.68258	3.68258	0.0000	8.49586	6.22716	2.54457	0.569791
3	90.0582	12.5241	9.19714	3.68258	3.68258	0.0000	8.49586	82.30045	78.61787	0.569791
4	90.0582	12.5241	9.19714	54.39333	11.04774	43.3456	25.48759	78.53239	24.13907	0.569791
5	90.0582	12.5241	9.19714	3.68258	3.68258	0.0000	8.49586	23.59777	19.91519	0.569791
6	90.0582	12.5241	9.19714	3.68078	3.68078	0.0000	8.49170	18.37676	14.69598	0.569791

Pipe	dPf/dx (psi/100 ft)	Resistance (sec ² /ft ⁵)	f	Reynolds No	fL/D	K	fL/D + K
1	7.36516	211.022	0.0215435	1.39349E+05	6.46304	0	6.46304
2	7.36516	211.022	0.0215435	1.39349E+05	6.46304	0	6.46304
3	7.36516	211.022	0.0215435	1.39349E+05	6.46304	0	6.46304
4	7.36516	633.065	0.0215435	1.39349E+05	19.38912	0	19.38912
5	7.36516	211.022	0.0215435	1.39349E+05	6.46304	0	6.46304
6	7.36156	210.918	0.0215435	1.39349E+05	6.46304	0	6.46304

AFT Fathom 3.0 Output
NUMATEC HANFORD CORPORATION

(2)

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Jct	dP (psid)	dH (feet)	Vol Flow Into System (ft3/sec)	Loss Factor (K)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)
1	0.2848954	0.657265	0.200650	0.500000	20.00000	20.00000	20.00000	20.000000
2	3.9315572	9.070260	0.000000	6.90000	10.84687	1.77661	9.53234	0.462082
3	79.7558746	184.000007	0.000000	0.00000	6.71925	177.28075	8.03378	175.966224
4	0.0854686	0.197180	0.000000	0.150000	168.78490	168.58771	167.47037	167.273179
5	0.5413014	1.248804	0.000000	0.950000	143.10013	141.85133	141.78560	140.536795
6	1.5384355	3.549232	0.000000	2.70000	133.35546	129.80623	132.04093	128.491702
7	0.5697909	1.314530	0.200650	1.00000	120.00000	120.00000	120.00000	120.000000

Jct	P Stag In (psia)	P Stag Out (psia)	P Inlet (psia)	P Outlet (psia)
1	14.69598	14.69598	14.69598	14.69598
2	10.72850	6.79695	10.15871	6.22716
3	3.11437	82.87024	2.54457	82.30045
4	79.18766	79.10219	78.61787	78.53239
5	24.70887	24.16756	24.13907	23.59777
6	20.48498	18.94655	19.91519	18.37676
7	14.69598	14.69598	14.69598	14.69598

Sample #3

3 pipes 4 junctions

Model of a three reservoir branching system Water is the working fluid

Reference Lindeburg M R *Mechanical Engineering Review Manual for the P E Exam* 7th Ed
1984 p 3-47 timed problem #1

Three reservoirs (A B C) are interconnected with a common junction at elevation 25 ft above some arbitrary reference point The water surface levels for reservoirs A B and C are at elevations of 50 40 and 22 feet respectively The pipe from reservoir A to the junction is 800 feet of 3 pipe The pipe from reservoir B to the junction is 500 feet of 10 pipe The pipe from reservoir C to the junction 1000 feet of 4 pipe Determine the flow velocity and direction in each pipe Assume $f = 0.02$ and disregard minor losses and velocity heads

AFT Fathom 3.0 Input
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(1)

11/30/1999 01:58 PM

Sample 3 Mechanical Engineering Review Manual for PE exam 7th Ed page 3-47 timed problem #1

Title Sample 3 Mechanical Engineering Review Manual for PE exam 7th Ed page 3 47 timed problem #1

Number Of Pipes= 3
Number Of Junctions= 4

Head/Pressure Convergence= 0.01 psia
Flow Rate Convergence= 0.01 ft³/sec
Relaxation= AFT Fathom Automatic
Maximum Iterations= 500

Constant Fluid Property Model
Fluid Water at 1 atm
Temperature 60 deg F
Density= 62.37217 lbm/ft³
Viscosity= 2.72848 lbm/hr ft
Vapor Pressure= 25024 psia
Gravitational Acceleration= 1 g
Atmospheric Pressure= 0 atm

Pipe	Name	Object Defined	Length	Length Units	Hydraulic Diameter	Hydraulic Diam Units	Roughness	Roughness Units	Losses (K)	Initial Flow
1	Res Connector A	Yes	800	feet	2557	feet	02	Explicit f	0	1649
2	Res Connector B	Yes	500	feet	835	feet	02	Explicit f	0	2244
3	Res Connector C	Yes	1000	feet	3355	feet	02	Explicit f	0	3893

Pipe	Initial Flow Units	Junctions (Up,Down)	Geometry	Material	Thermal Boundary	Overall U	Include Internal h	Special Condition
1	ft ³ /sec	1, 4	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
2	ft ³ /sec	2, 4	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
3	ft ³ /sec	4, 3	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None

Branch	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units	Connected Pipes (+ = in, = out)
4	Branch D	Yes	None	25	feet	39.9687	feet	1, 2, 3

Reservoir	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units	Connected Pipes (+ = in, = out)
1	Reservoir A	Yes	N/A	50	feet	50	feet	1
2	Reservoir B	Yes	N/A	40	feet	40	feet	2
3	Reservoir C	Yes	N/A	22	feet	22	feet	3

Branch	Boundary Flow (+ = in, = out)	Boundary Flow Units			
4	0	ft ³ /sec			

Reservoir	Surface Pressure	Surface Pressure Units	Depth	Depth Units	Balance Energy
1	0	atm	10	feet	No
2	0	atm	10	feet	No
3	0	atm	10	feet	No

AFT Fathom 3.0 Output
NUMATEC HANFORD CORPORATION

(1)

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Sample 3 Mechanical Engineering Review Manual for PE exam 7th Ed page 3 47 timed problem #1

Title Sample 3 Mechanical Engineering Review Manual for PE exam 7th Ed page 3-47 timed problem #1

Analysis run on 11/30/1999 1 44 40 PM

Input File C:\FATHOM\SAMPLES\SAMPLE3.FTH

Execution Time= 0 22 seconds

Total Number Of Head/Pressure Iterations= 2

Total Number Of Temperature Iterations= 0

Total Number Of Flow Iterations= 2

Number Of Pipes= 3

Number Of Junctions= 4

Pressure Tolerance= .001 psia

Volumetric Flow Rate Tolerance= .001 ft³/sec

Relaxation= 1 (None)

Constant Fluid Property Model

Fluid Water at 1 atm

Temperature 60 deg F

Density= 62.37217 lbm/ft³

Viscosity= 2.72848 lbm/hr ft

Vapor Pressure= 25024 psia

Gravitational Acceleration= 1 g

Atmospheric Pressure= 0 atm

Total Inflow= 0.389343 ft³/sec

Total Outflow= 0.389343 ft³/sec

Maximum Pressure is 6.43539 psi at Junction 4 Inlet

Minimum Pressure is 4.33140 psi at Junction 1 Outlet

Pipe	Vol Flow (gal/min)	Mass Flow (lbm/sec)	Velocity (feet/sec)	dP Total (psid)	dP Friction (psid)	dP Gravity (psid)	dH (feet)	Max Pres (psia)	Min Pres (psia)	Dyn Pres (psia)
1	74.0261	10.2871	3.211815	2.15216	4.3449392	6.49710	10.0312574	6.41412	4.26196	0.06943756
2	100.7232	13.9971	0.409811	2.15216	0.0135388	2.16570	0.0312573	6.48243	4.33027	0.00113048
3	174.7493	24.2842	4.404105	2.15216	7.7829819	5.63082	17.9687426	6.35300	4.20084	0.13055952

Pipe	dPf/dx (psi/100 ft)	Resistance (sec ² /ft ⁵)	f	Reynolds No	fL/D	K	fL/D + K
1	0.54311740	368.766594	0.0200000	6.75855E+04	62.5733	0	62.5733
2	0.00270776	0.620666	0.0200000	2.81607E+04	11.9760	0	11.9760
3	0.77829819	118.536607	0.0200000	1.21597E+05	59.6125	0	59.6125

Jct	dP (psid)	dH (feet)	Vol Flow Into System (gal/min)	Loss Factor (K)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)	P Stag In (psia)
1	0	0	74.0261	0.00000	50.0000	50.0000	50.0000	50.0000	0.00000
2	0	0	100.7232	0.00000	40.0000	40.0000	40.0000	40.0000	0.00000
3	0	0	174.7493	0.00000	22.0000	22.0000	22.0000	22.0000	0.00000
4	0	0	0.0000	0.00000	39.9687	39.9687	39.8575	39.8575	6.48356

Jct	P Stag Out (psia)	P Inlet (psia)	P Outlet (psia)
1	4.33140	0.00000	4.33140
2	4.33140	0.00000	4.33140
3	4.33140	0.00000	4.33140
4	6.48356	6.43539	6.43539

Sample #3a

3 pipes, 4 junctions

Model of a three reservoir branching system Water is the working fluid

Reference White, F M , "Fluid Mechanics", 3rd Ed , 1994, pp 346-347

Three reservoirs (1, 2, and 3) are interconnected with a common junction at elevation 34.53m above some arbitrary reference point. The water surface levels for reservoirs 1, 2, and 3 are at elevations of 20, 100, and 40 meters, respectively. The pipe from reservoir 1 to the common junction is 100 meters of 8-cm pipe ($E=0.24\text{mm}$). The pipe from reservoir 2 to the common junction is 150 meters of 6-cm pipe ($E=0.12\text{mm}$). The pipe from reservoir 3 to the common junction is 80 meters of 4-cm pipe ($E=0.20\text{mm}$). Determine the flow velocity and direction in each pipe. Assume the fluid is water with a density of 1000 kg/m^3 and a dynamic viscosity of $1.02 \times 10^{-6}\text{ m}^2/\text{s}$. Disregard minor losses and velocity heads.

AFT Fathom 3.0 Input
NUMATEC HANFORD CORPORATION

(1)

12/07/1999 04:17 PM

Sample 3a Three-reservoir junction problem White (1994) Example 6.19 page 346-347

Title Sample 3a Three-reservoir junction problem White (1994) Example 6.19 page 346-347

Number Of Pipes= 3

Number Of Junctions= 4

Head/Pressure Convergence= 0.01 psia

Flow Rate Convergence= 0.01 ft³/sec

Relaxation= AFT Fathom Automatic

Maximum Iterations= 500

Constant Fluid Property Model

Fluid Unspecified

Density= 1000 kg/m³

Viscosity= 0.0102 kg/sec m

Vapor Pressure=

Gravitational Acceleration= 1 g

Atmospheric Pressure= 0 atm

Pipe	Name	Object Defined	Length	Length Units	Hydraulic Diameter	Hydraulic Diam Units	Roughness	Roughness Units	Losses (K)	Initial Flow
1	Res Connector A	Yes	100	meters	8	cm	24	mm	0	1649
2	Res Connector B	Yes	150	meters	6	cm	12	mm	0	2244
3	Res Connector C	Yes	80	meters	4	cm	2	mm	0	3893

Pipe	Initial Flow Units	Junctions (Up,Down)	Geometry	Material	Thermal Boundary	Overall U	Include Internal h	Special Condition
1	ft ³ /sec	4, 1	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
2	ft ³ /sec	2, 4	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
3	ft ³ /sec	3, 4	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None

Branch	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units	Connected Pipes (+ = in, = out)
4	Branch D	Yes	None	34.53	meters	39.9687	feet	1,2,3
Reservoir	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units	Connected Pipes (+ = in, = out)
1	Reservoir A	Yes	N/A	20	meters			1
2	Reservoir B	Yes	N/A	100	meters			2
3	Reservoir C	Yes	N/A	40	meters			-3

Branch	Boundary Flow (+ = in, = out)	Boundary Flow Units			
4	0	ft ³ /sec			
Reservoir	Surface Pressure	Surface Pressure Units	Depth	Depth Units	Balance Energy
1	0	atm	10	feet	No
2	0	atm	10	feet	No
3	0	atm	10	feet	No

AFT Fathom 3.0 Output
NUMATEC HANFORD CORPORATION

(1)

12/07/1999

Sample 3a Three-reservoir junction problem White (1994) Example 6 19 page 346-347

Title Sample 3a Three-reservoir junction problem White (1994) Example 6 19 page 346-347

Analysis run on 12/07/1999 4 17 20 PM

Input File C:\FATHOM\SAMPLES\SAMPLE3A.FTH

Execution Time= 0 16 seconds

Total Number Of Head/Pressure Iterations= 8

Total Number Of Temperature Iterations= 0

Total Number Of Flow Iterations= 3

Number Of Pipes= 3

Number Of Junctions= 4

Pressure Tolerance= 001 psia

Volumetric Flow Rate Tolerance= 001 ft3/sec

Relaxation= 1 (None)

Constant Fluid Property Model

Fluid Unspecified

Density= 1000 kg/m3

Viscosity= 00102 kg/sec-m

Vapor Pressure=

Gravitational Acceleration= 1 g

Atmospheric Pressure= 0 atm

Total Inflow= 0 518580 ft3/sec

Total Outflow= 0 518580 ft3/sec

Maximum Pressure is 4 33528 psi at Junction 1 Outlet

Minimum Pressure is 0 614585 psi at Junction 4 Inlet

Pipe	Vol Flow (m3/hr)	Mass Flow (kg/sec)	Velocity (meters/sec)	dP Total (psid)	dP Friction (psid)	dP Gravity (psid)	dH (feet)	Max Pres (psia)	Min Pres (psia)	Dyn Pres (psia)
1	52 86440	14 68455	2 92140	4 32129	20 68050	25 00179	47 7029	3 71636	0 604936	0 618919
2	47 02378	13 06216	4 61979	4 32130	93 10625	88 78495	214 7643	2 78754	1 533753	1 547736
3	5 84062	1 62239	1 29106	4 32129	7 76619	3 44490	17 9139	4 21440	-0 106894	0 120877

Pipe	dPf/dx (psi/100 ft)	Resistance (sec2/ft5)	f	Reynolds No	fL/D	K	fL/D + K
1	6 30342	177.383	0 0267311	2 29129E+05	33 4138	0	33 4138
2	18 91919	1009 304	0 0240624	2 71753E+05	60 1561	0	60 1561
3	2 95892	5457 174	0 0321244	5 06298E+04	64 2488	0	64 2488

Jct	dP (psid)	dH (feet)	Vol Flow Into System (m3/hr)	Loss Factor (K)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)	P Stag In (psia)
1	0	0	52 86440	0 00000	65 6168	65 6168	65 6168	65 6168	0 0000000
2	0	0	47 02378	0 00000	328 0840	328 0840	328 0840	328 0840	0 0000000
3	0	0	5 84062	0 00000	131 2336	131 2336	131 2336	131 2336	0 0000000
4	0	0	0 00000	0 00000	113 3197	113 3197	111 8698	111 8698	0 0139829

Jct	P Stag Out (psia)	P Inlet (psia)	P Outlet (psia)
1	4 3352752	0 000000	4 335275
2	4 3352752	0 000000	4 335275
3	4 3352752	0 000000	4 335275
4	0 0139829	0 614585	-0 614585

Sample #4

7 pipes 7 junctions

Model of an orificed circulation system connected in a single loop and driven by a pump. Water is the working fluid.

Reference: Circulation Loop (No reference)

Given the system as shown, determine the mass and volumetric flow rate in the system, the pressure added by the pump, and the total pressure at each junction.

AFT Fathom 3.0 Input
NUMATEC HANFORD CORPORATION

(1)

11/30/1999 02:04 PM

Sample 4 Circulation Loop (No reference)

Title Sample 4 Circulation Loop (No reference)

Number Of Pipes= 7

Number Of Junctions= 7

Head/Pressure Convergence= 00001 (Relative change)

Flow Rate Convergence= 00001 (Relative change)

Relaxation= 1

Maximum Iterations= 500

Constant Fluid Property Model

Fluid Unspecified

Density= 62.06239 lbm/ft³

Viscosity= 1.72622 lbm/hr ft

Vapor Pressure= 82151 psia

Gravitational Acceleration= 1 g

Atmospheric Pressure= 1 atm

Pipe	Name	Object Defined	Length	Length Units	Hydraulic Diameter	Hydraulic Diam Units	Roughness	Roughness Units	Losses (K)	Junctions (Up,Down)
1	Pipe 1/Upper Leg	Yes	200	feet	3.068	inches	00015	feet	0	1, 2
2	Pipe 2/Upper Leg	Yes	200	feet	3.068	inches	00015	feet	0	2, 3
3	Downflow Leg	Yes	15	feet	3.068	inches	00015	feet	0	3, 4
4	Pipe 1/Lower Leg	Yes	100	feet	3.068	inches	00015	feet	0	4, 5
5	Pipe 2/Lower Leg	Yes	100	feet	3.068	inches	00015	feet	0	5, 6
6	Pipe 3/Lower Leg	Yes	200	feet	3.068	inches	00015	feet	0	6, 7
7	Upflow Leg	Yes	15	feet	3.068	inches	00015	feet	0	7, 1

Pipe	Geometry	Material	Size	Type	Thermal Boundary	Overall U	Include Internal h	Special Condition
1	Cylindrical Pipe	Steel	3 inch	schedule 40	Adiabatic	0	No	None
2	Cylindrical Pipe	Steel	3 inch	schedule 40	Adiabatic	0	No	None
3	Cylindrical Pipe	Steel	3 inch	schedule 40	Adiabatic	0	No	None
4	Cylindrical Pipe	Steel	3 inch	schedule 40	Adiabatic	0	No	None
5	Cylindrical Pipe	Steel	3 inch	schedule 40	Adiabatic	0	No	None
6	Cylindrical Pipe	Steel	3 inch	schedule 40	Adiabatic	0	No	None
7	Cylindrical Pipe	Steel	3 inch	schedule 40	Adiabatic	0	No	None

Assigned Pressure	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units
5	Pressure Msmt	Yes	N/A	0	feet	100	psia
Bend	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units
1	Second Elbow	Yes	N/A	15	feet		
3	Third Elbow	Yes	N/A	15	feet		
4	Fourth Elbow	Yes	N/A	0	feet		
7	First Elbow	Yes	N/A	0	feet		
Orifice	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units
2	Metering Orifice	Yes	N/A	15	feet		
Pump	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units
6	ACME Pump 10345 A	Yes	None	0	feet		

AFT Fathom 3.0 Input
NUMATEC HANFORD CORPORATION

(2)

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Assigned Pressure	Connected Pipes (+ = in, = out)	Pressure	Pressure Units	Temperature	Temperature Units	Balance Energy		
5	4, 5	100	psia			No		
Bend	Connected Pipes (+ = in, = out)	Type	Angle (Degrees)	r/d	Loss Factor			
1	7, 1	Standard Elbow	90		538			
3	2, 3	Standard Elbow	90		538			
4	3, 4	Mitre Bend	90		1 076			
7	6, 7	Standard Elbow	90		538			
Orifice	Connected Pipes (+ = in, = out)	Orifice Type	Loss Value K Constant		Flow Area Type Area	Dimension	Dimension Units	r/D
2	1, 2	Sharp-Edged	8 3952			3	inches ²	
Pump	Connected Pipes (+ = in, = out)	Independent Variable	Ind Variable Units	Dependent Variable Pressure	Dep Variable Units	Loss Constant a	Loss Constant b	Loss Constant c
6	5, 6	Vol Flow	ft ³ /sec		psia	20	4	60

Assigned Pressure				
5				
Bend				
1				
3				
4				
7				
Orifice	Restricted Area	Restricted Area Units		
2				
Pump	Loss Constant d	Loss Constant e	Speed %	Viscosity Correction
6	0	0	100	No

AFT Fathom 3.0 Output
NUMATEC HANFORD CORPORATION

(1)

11/30/1999

Sample 4 Circulation Loop (No reference)

Title Sample 4 Circulation Loop (No reference)
Analysis run on 11/30/1999 1 47 25 PM
Input File C:\FATHOM\SAMPLES\SAMPLE4.FTH

Execution Time= 0.16 seconds
Total Number Of Head/Pressure Iterations= 0
Total Number Of Temperature Iterations= 0
Total Number Of Flow Iterations= 8
Number Of Pipes= 7
Number Of Junctions= 7
Pressure Tolerance= 0.0001 relative change
Volumetric Flow Rate Tolerance= 0.0001 relative change
Relaxation= 1 (None)

Constant Fluid Property Model

Fluid Unspecified
Density= 62.06239 lbm/ft³
Viscosity= 1.72622 lbm/hr ft
Vapor Pressure= 82151 psia
Gravitational Acceleration= 1 g
Atmospheric Pressure= 1 atm

Total Inflow= 3.26559E-08 ft³/sec
Total Outflow= 3.26559E-08 ft³/sec
Maximum Pressure is 114.182 psi at Junction 6 Outlet
Minimum Pressure is 95.4408 psi at Junction 3 Outlet

=====PUMP SUMMARY=====

Jct	Flow (gal/min)	DP (psid)	DH (feet)	Speed (%)	Ideal hp (hp)	NPSHA (feet)	NPSHR (feet)
6	131.20	16.042	37.222	100.00	1.2276	226.31	23.202

Pipe	Vol Flow (gal/min)	Mass Flow (lbm/sec)	Velocity (feet/sec)	dP Total (psid)	dP Friction (psid)	dP Gravity (psid)	dH (feet)	Max Pres (psia)	Min Pres (psia)	Dyn Pres (psia)
1	131.203	18.1422	5.69408	3.28553	3.285526	0.00000	7.623228	103.9518	100.6663	0.217159
2	131.203	18.1422	5.69408	3.28553	3.285526	0.00000	7.623228	98.8432	95.5577	0.217159
3	131.203	18.1422	5.69408	6.21842	0.246414	6.46483	0.571742	101.6592	95.4408	0.217159
4	131.203	18.1422	5.69408	1.64274	1.642737	0.00000	3.811555	101.4256	99.7828	0.217159
5	131.203	18.1422	5.69408	1.64276	1.642763	0.00000	3.811614	99.7828	98.1401	0.217159
6	131.203	18.1422	5.69408	3.28553	3.285526	0.00000	7.623228	114.1822	110.8967	0.217159
7	131.203	18.1422	5.69408	6.71125	0.246414	6.46483	0.571742	110.7799	104.0686	0.217159

Pipe	dPf/dx (psi/100 ft)	Resistance (sec ² /ft ⁵)	f	Reynolds No	fL/D	K	fL/D + K
1	1.64276	89.21048	0.0193406	1.88422E+05	15.12958	0	15.12958
2	1.64276	89.21048	0.0193406	1.88422E+05	15.12958	0	15.12958
3	1.64276	6.69079	0.0193406	1.88422E+05	1.13472	0	1.13472
4	1.64274	44.60455	0.0193406	1.88422E+05	7.56479	0	7.56479
5	1.64276	44.60524	0.0193406	1.88422E+05	7.56479	0	7.56479
6	1.64276	89.21048	0.0193406	1.88422E+05	15.12958	0	15.12958
7	1.64276	6.69079	0.0193406	1.88422E+05	1.13472	0	1.13472

Jct	dP (psid)	dH (feet)	Vol Flow Into System (gal/min)	Loss Factor (K)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)	P Stag In (psia)
1	0.116832	0.271078	0	0.538000	222.870	222.599	222.367	222.095	104.2858
2	1.823094	4.230025	0	8.39520	214.976	210.746	214.472	210.242	100.8834
3	0.116832	0.271078	0	0.538000	203.123	202.852	202.619	202.348	95.7748
4	0.233663	0.542156	0	1.07600	202.280	201.738	201.776	201.234	101.8764

AFT Fathom 3.0 Output
NUMATEC HANFORD CORPORATION

(2)

11/30/1999

Jct	dP (psid)	dH (feet)	Vol Flow Into System (gal/min)	Loss Factor (K)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)	P Stag In (psia)
5	0.000000	0.000000	0	0.000000	197.926	197.926	197.422	197.422	100.0000
6	16.042158	37.221753	0	0.000000	194.115	231.336	193.611	230.833	98.3572
7	0.116832	0.271078	0	0.538000	223.713	223.442	223.209	222.938	111.1139

Jct	P Stag Out (psia)	P Inlet (psia)	P Outlet (psia)
1	104.1690	104.0686	103.9518
2	99.0603	100.6663	98.8432
3	95.6580	95.5577	95.4408
4	101.6427	101.6592	101.4256
5	100.0000	99.7828	99.7828
6	114.3994	98.1401	114.1822
7	110.9970	110.8967	110.7799

Sample #5

10 pipes 10 junctions

Model of a system with three pumps supplied by three reservoirs that connect together One loop exists Water is the working fluid

Reference Jeppson R W *Analysis of Flow in Pipe Networks* 1976 p 84

Consider the ten-pipe one loop network supplied by three identical pumps as shown below Each pump supply head according to the equation $h_p = 10.328Q^2 + 2.823Q + 22.289$ There is an outflow of 2.0 cfs leaving the system at junction 2 Assume all pipes have $e = 0.012$ inch Find the flow and head loss in each pipe the pump head added for each pump and the pressure at each junction

AFT Fathom 3.0 Input
NUMATEC HANFORD CORPORATION

(1)

11/30/1999 02:15 PM

Sample 5 Roland Jeppson Analysis of Flow in Pipe Networks 1976 p 84

Title Sample 5 Roland Jeppson Analysis of Flow in Pipe Networks 1976 p 84

Number Of Pipes= 10
Number Of Junctions= 10

Head/Pressure Convergence= 0001 (Relative change)
Flow Rate Convergence= 0001 (Relative change)
Relaxation= AFT Fathom Automatic
Maximum Iterations= 1000

Constant Fluid Property Model

Fluid Unspecified

Density= 62.4 lbm/ft³Viscosity= 5.65E-09 lbf hr/ft²

Vapor Pressure= 3 psia

Gravitational Acceleration= 1 g

Atmospheric Pressure= 1 atm

Pipe	Name	Object Defined	Length	Length Units	Hydraulic Diameter	Hydraulic Diam Units	Roughness	Roughness Units	Losses (K)	Initial Flow
1	Pipe	Yes	500	feet	8	inches	0.12	inches	0	84114334955497
2	Pipe	Yes	2000	feet	6	inches	0.12	inches	0	66639596823311
3	Pipe	Yes	2000	feet	8	inches	0.12	inches	0	133357022166288
4	Pipe	Yes	1000	feet	8	inches	0.12	inches	0	572645634254048
5	Pipe	Yes	500	feet	6	inches	0.12	inches	0	760992752885893
6	Pipe	Yes	1000	feet	6	inches	0.12	inches	0	174815547788017
7	Pipe	Yes	500	feet	6	inches	0.12	inches	0	397898251379419
8	Pipe	Yes	500	feet	8	inches	0.12	inches	0	84114334955497
9	Pipe	Yes	500	feet	6	inches	0.12	inches	0	760992752885893
10	Pipe	Yes	500	feet	6	inches	0.12	inches	0	397898251379419

Pipe	Initial Flow Units	Junctions (Up,Down)	Geometry	Material	Thermal Boundary	Overall U	Include Internal h	Special Condition
1	ft ³ /sec	5, 1	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
2	ft ³ /sec	1, 2	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
3	ft ³ /sec	3, 2	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
4	ft ³ /sec	4, 3	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
5	ft ³ /sec	6, 3	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
6	ft ³ /sec	1, 4	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
7	ft ³ /sec	7, 4	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
8	ft ³ /sec	8, 5	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
9	ft ³ /sec	10, 6	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
10	ft ³ /sec	9, 7	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None

Branch	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units	Connected Pipes (+ = in, = out)
1	Branch	Yes	None	100	feet	114.231627547982	feet	1, 2, -6
2	Branch	Yes	None	100	feet	96.7006888750291	feet	2, 3
3	Branch	Yes	None	100	feet	112.084714204485	feet	3, 4, 5
4	Branch	Yes	None	100	feet	113.568290626129	feet	-4, 6, 7
Pump	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units	Connected Pipes (+ = in, = out)
5	Pump	Yes	None	100	feet	98.4376689086968	feet	8, 1
6	Pump	Yes	None	100	feet	99.3141452735089	feet	9, 5
7	Pump	Yes	None	100	feet	93.3954509453878	feet	10, 7

AFT Fathom 3.0 Input
NUMATEC HANFORD CORPORATION

(2)

11/30/1999 02:15 PM

Reservoir	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units	Connected Pipes (+ = in, = out)
8	Reservoir	Yes	N/A	100	feet	100	feet	-8
9	Reservoir	Yes	N/A	95	feet	95	feet	10
10	Reservoir	Yes	N/A	105	feet	105	feet	9

Branch	Boundary Flow (+ = in/ = out)	Boundary Flow Units						
1	0	ft3/sec						
2	2	ft3/sec						
3	0	ft3/sec						
4								
Pump	Independent Variable	Ind Variable Units	Dependent Variable	Dep Variable Units	Loss Constant a	Loss Constant b	Loss Constant c	Loss Constant d
5	Vol Flow	ft3/sec	Head	feet	22 289	2 823	10 328	0
6	Vol Flow	ft3/sec	Head	feet	22 289	2 823	10 328	0
7	Vol Flow	ft3/sec	Head	feet	22 289	2 823	10 328	0
Reservoir	Surface Pressure	Surface Pressure Units	Depth	Depth Units	Density	Density Units	Temperature	Temperature Units
8	1	atm	0	feet				
9	1	atm	0	feet				
10	1	atm	0	feet				

Branch			
1			
2			
3			
4			
Pump	Loss Constant e	Speed %	Viscosity Correction
5	0	100	No
6	0	100	No
7	0	100	No
Reservoir	Balance Energy		
8	No		
9	No		
10	No		

AFT Fathom 3.0 Output
NUMATEC HANFORD CORPORATION

(1)

12/01/1999

Sample 5 Roland Jeppson Analysis of Flow in Pipe Networks 1976 p 84

Title Sample 5 Roland Jeppson Analysis of Flow in Pipe Networks 1976 p 84

Analysis run on 12/01/1999 3 12 31 PM

Input File C:\FATHOM\SAMPLES\SAMPLE5.FTH

Execution Time= 0 17 seconds

Total Number Of Head/Pressure Iterations= 2

Total Number Of Temperature Iterations= 0

Total Number Of Flow Iterations= 2

Number Of Pipes= 10

Number Of Junctions= 10

Head Tolerance= 0001 relative change

Volumetric Flow Rate Tolerance= 0001 relative change

Relaxation= 2

Constant Fluid Property Model

Fluid Unspecified

Density= 62.4 lbm/ft³Viscosity= 5.65E-09 lbf hr/ft²

Vapor Pressure= 3 psia

Gravitational Acceleration= 1 g

Atmospheric Pressure= 1 atm

Total Inflow= 2.00007 ft³/secTotal Outflow= 2.00007 ft³/sec

Maximum Pressure is 22.2954 psia at Junction 6 Outlet

Minimum Pressure is 11.8064 psia at Junction 7 Inlet

=====PUMP SUMMARY=====

Jct	Flow (ft ³ /sec)	DP (psid)	DH (feet)	Speed (%)	ideal hp (hp)	NPSHA (feet)	NPSHR (feet)
5	0.84114	7.5211	17.356	100.00	1.6561	31.659	N/A
6	0.76099	7.9977	18.456	100.00	1.5932	32.536	N/A
7	0.39789	9.4368	21.777	100.00	0.98292	26.617	N/A

Pipe	Vol Flow (ft ³ /sec)	Mass Flow (lbm/sec)	Velocity (feet/sec)	dP Total (psid)	dP Friction (psid)	dP Gravity (psid)	dH (feet)	Max Pres (psia)	Min Pres (psia)	Dyn Pres (psia)
1	0.841140	52.4872	2.409690	0.676997	0.676997	0.00000	1.562300	21.5009	20.8239	0.03910293
2	0.666391	41.5828	3.393902	7.596742	7.596742	0.00000	17.530943	20.7855	13.1887	0.07756855
3	1.333587	83.2158	3.820447	6.666407	6.666407	0.00000	15.384017	19.8344	13.1680	0.09829134
4	0.572641	35.7328	1.640495	0.642884	0.642884	0.00000	1.483578	20.5575	19.9148	0.01812328
5	0.760990	47.4858	3.875692	2.463801	2.463801	0.00000	5.685695	22.2954	19.8316	0.10115457
6	0.174793	10.9071	0.890213	0.287451	0.287451	0.00000	0.663349	20.8577	20.5703	0.00533673
7	0.397891	24.8284	2.026445	0.695203	0.695203	0.00000	1.604314	21.2431	20.5479	0.02765391
8	0.841140	52.4872	2.409690	0.677005	0.677005	0.00000	1.562320	14.6569	13.9799	0.03910293
9	0.760990	47.4858	3.875692	0.297188	2.463854	2.16667	5.685817	14.5948	14.2976	0.10115457
10	0.397891	24.8284	2.026445	2.861948	0.695281	2.16667	1.604496	14.6683	11.8064	0.02765391

Pipe	dP/dx (psi/100 ft)	Resistance (sec ² /ft ⁵)	f	Reynolds No	fL/D	K	fL/D + K
1	0.1353993	2.20814	0.0230846	1.53179E+05	17.3134	0	17.3134
2	0.3798371	39.47725	0.0244846	1.61807E+05	97.9384	0	97.9384
3	0.3333204	8.65021	0.0226066	2.42857E+05	67.8198	0	67.8198
4	0.0642884	4.52424	0.0236493	1.04283E+05	35.4739	0	35.4739
5	0.4927602	9.81805	0.0243573	1.84777E+05	24.3573	0	24.3573
6	0.0287451	21.71172	0.0269440	4.24417E+04	53.8879	0	53.8879
7	0.1390406	10.13352	0.0251422	9.66125E+04	25.1423	0	25.1423
8	0.1354011	2.20817	0.0230846	1.53179E+05	17.3134	0	17.3134
9	0.4927708	9.81827	0.0243573	1.84777E+05	24.3573	0	24.3573
10	0.1390563	10.13467	0.0251422	9.66125E+04	25.1423	0	25.1423

AFT Fathom 3.0 Output
NUMATEC HANFORD CORPORATION

(2)

12/01/1999

Jct	dP (psid)	dH (feet)	Vol Flow Into System (gal/min)	Loss Factor (K)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)	P Stag In (psia)
1	0 00000	0 0000	0 000	0 00000	114 2317	114 2317	114 1543	114 1543	20 8630
2	0 00000	0 0000	-897 652	0 00000	96 7007	96 7007	96 4739	96 7007	13 2663
3	0 00000	0 0000	0 000	0 00000	112 0848	112 0848	111 9342	111 9342	19 9327
4	0 00000	0 0000	0 000	0 00000	113 5683	113 5683	113 5325	113 5325	20 5756
5	7 52106	17 3563	0 000	0 00000	98 4377	115 7940	98 3474	115 7037	14 0190
6	7 99771	18 4563	0 000	0 00000	99 3142	117 7704	99 0807	117 5370	14 3988
7	9 43676	21 7771	0 000	0 00000	93 3955	115 1726	93 3317	115 1088	11 8340
8	0 00000	0 0000	377 530	0 00000	100 0000	100 0000	100 0000	100 0000	14 6960
9	0 00000	0 0000	178 586	0 00000	95 0000	95 0000	95 0000	95 0000	14 6960
10	0 00000	0 0000	341 556	0 00000	105 0000	105 0000	105 0000	105 0000	14 6960

Jct	P Stag Out (psia)	P Inlet (psia)	P Outlet (psia)
1	20 8630	20 8295	20 8295
2	13 2663	13 1680	13 2663
3	19 9327	19 8675	19 8675
4	20 5756	20 5601	20 5601
5	21 5400	13 9799	21 5009
6	22 3965	14 2976	22 2954
7	21 2708	11 8064	21 2431
8	14 6960	14 6960	14 6960
9	14 6960	14 6960	14 6960
10	14 6960	14 6960	14 6960

Sample #6

9 pipes 8 junctions

Model of a branching system with a pump a PRV and two loops Water is the working fluid

Reference Jeppson R W *Analysis of Flow in Pipe Networks* 1976 p 86

Consider the nine-pipe network shown below A pressure reducing valve exists 500 feet downstream of junction 1 The pump characteristics are the following $Q_1 = 1.0 \text{ cfs @ } H_{p1} = 50 \text{ ft}$ $Q_2 = 1.5 \text{ cfs @ } H_{p2} = 55 \text{ ft}$ $Q_3 = 2.0 \text{ cfs @ } H_{p3} = 48 \text{ ft}$ There are outflows of 1.0 cfs leaving the system at both junction 2 and 4 Assume all pipes have $e = 0.02 \text{ inch}$ Find the flow and head loss in each pipe the pump head added for each pump and the pressure at each junction

AFT Fathom 3.0 Input
NUMATEC HANFORD CORPORATION

(1)

11/30/1999 02:23 PM

Sample 6 Roland Jeppson Analysis of Flow in Pipe Networks 1976 p 86

Title Sample 6 Roland Jeppson Analysis of Flow in Pipe Networks 1976 p 86

Number Of Pipes= 9

Number Of Junctions= 8

Head/Pressure Convergence= 0001 (Relative change)

Flow Rate Convergence= 0001 (Relative change)

Relaxation= AFT Fathom Automatic

Maximum Iterations= 1000

Constant Fluid Property Model

Fluid Unspecified

Density= 62.4 lbm/ft³

Viscosity= 0.006558 lbm/s ft

Vapor Pressure= 3 psia

Gravitational Acceleration= 1 g

Atmospheric Pressure= 1 atm

Pipe	Name	Object Defined	Length	Length Units	Hydraulic Diameter	Hydraulic Diam Units	Roughness	Roughness Units	Losses (K)	Junctions (Up,Down)
1	Pipe	Yes	500	feet	6	inches	02	inches	0	5, 1
2	Pipe	Yes	1000	feet	6	inches	02	inches	0	1, 2
3	Pipe	Yes	800	feet	6	inches	02	inches	0	3, 2
4	Pipe	Yes	200	feet	6	inches	02	inches	0	8, 3
5	Pipe	Yes	2000	feet	6	inches	02	inches	0	3, 4
6	Pipe	Yes	500	feet	6	inches	02	inches	0	1, 6
7	Pipe	Yes	10000	feet	1	inches	02	inches	0	1, 3
8	Pipe	Yes	500	feet	6	inches	02	inches	0	6, 4
9	Pipe	Yes	500	feet	6	inches	02	inches	0	7, 5

Pipe	Geometry	Material	Thermal Boundary	Overall U	Include Internal h	Special Condition
1	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
2	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
3	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
4	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
5	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
6	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
7	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
8	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
9	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None

Branch	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units	Connected Pipes (+ = in, = out)
1	Branch	Yes	None	50	feet			1, 2, 6, 7
2	Branch	Yes	None	50	feet			2, 3
3	Branch	Yes	None	50	feet			3, 4, 5, 7
4	Branch	Yes	None	20	feet			5, 8
Control Valve	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units	Connected Pipes (+ = in, = out)
6	1 Way Valve	Yes	None	55	feet			6, 8
Pump	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units	Connected Pipes (+ = in, = out)
5	Pump	Yes	None	90	feet			9, 1

AFT Fathom 3.0 Input
NUMATEC HANFORD CORPORATION

(2)

11/30/1999 02:23 PM

Reservoir	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units	Connected Pipes (+ = in, = out)
7	Reservoir	Yes	N/A	90	feet	90	feet	9
8	Reservoir	Yes	N/A	100	feet	100	feet	-4

Branch	Boundary Flow (+ = in/ = out)	Boundary Flow Units						
1								
2	1	ft3/sec						
3								
4	1	ft3/sec						
Control Valve	Valve Type	Control	Control Units	Action on Failure	Failed Loss Model	Failed Loss Value		
6	PRV	55	feet	Fail Close	None			
Pump	Independent Variable	Ind Variable Units	Dependent Variable	Dep Variable Units	Loss Constant a	Loss Constant b	Loss Constant c	Loss Constant d
5	Vol Flow	ft3/sec	Head	feet	4	70	24	0
Reservoir	Surface Pressure	Surface Pressure Units	Depth	Depth Units	Density	Density Units	Temperature	Temperature Units
7	1	atm	0	feet				
8	1	atm	0	feet				

Branch			
1			
2			
3			
4			
Control Valve			
6			
Pump	Loss Constant e	Speed %	Viscosity Correction
5	0	100	No
Reservoir	Balance Energy		
7	No		
8	No		

AFT Fathom 3.0 Output
NUMATEC HANFORD CORPORATION

(1)

11/30/1999

Sample 6 Roland Jeppson Analysis of Flow in Pipe Networks 1976 p 86

Title Sample 6 Roland Jeppson Analysis of Flow in Pipe Networks 1976 p 86
Analysis run on 11/30/1999 2 26 14 PM
Input File C:\FATHOM\SAMPLES\SAMPLE6.FTH

Execution Time= 0.83 seconds
Total Number Of Head/Pressure Iterations= 117
Total Number Of Temperature Iterations= 0
Total Number Of Flow Iterations= 70
Number Of Pipes= 9
Number Of Junctions= 8
Head Tolerance= 0.001 relative change
Volumetric Flow Rate Tolerance= 0.001 relative change
Relaxation= 2

Constant Fluid Property Model

Fluid Unspecified
Density= 62.4 lbm/ft³
Viscosity= 0.006558 lbm/s ft
Vapor Pressure= 3 psia
Gravitational Acceleration= 1 g
Atmospheric Pressure= 1 atm

Total Inflow= 2.00000 ft³/sec
Total Outflow= 2.00000 ft³/sec
Maximum Pressure is 43.7873 psia at Junction 1 Inlet
Minimum Pressure is 2.88782 psia at Junction 4 Outlet

=====PUMP SUMMARY=====

Jct	Flow (ft ³ /sec)	DP (psid)	DH (feet)	Speed (%)	ideal hp (hp)	NPSHA (feet)	NPSHR (feet)
5	1.0269	21.915	50.574	100.00	5.8910	21.559	N/A

=====VALVE SUMMARY=====

Jct	Type	Flow (ft ³ /sec)	DP (psid)	DH (feet)	P Inlet (psia)	Cv	K	State
6	PRV	0.039927	26.965	62.227	41.661	3.4517	96.836	Open

Pipe	Vol Flow (ft ³ /sec)	Mass Flow (lbm/sec)	Velocity (feet/sec)	dP Total (psid)	dP Friction (psid)	dP Gravity (psid)	dH (feet)	Max Pres (psia)	Min Pres (psia)
1	1.02686301	64.076253	5.2297710	12.27985477	5.05347729	17.33333	11.66187136	43.6533	31.37343
2	0.98435121	61.423517	5.0132602	9.29485798	9.29485798	0.00000	21.44967354	43.6682	34.37336
3	0.01564889	0.976490	0.0796991	0.00273658	0.00273658	0.00000	0.00631519	34.5453	34.54257
4	0.97313773	60.723798	4.9561504	19.84937096	1.81729567	21.66667	4.19375949	34.3799	14.53056
5	0.96007315	59.908566	4.8896130	4.69266605	17.69266510	13.00000	40.82922959	34.3843	29.69168
6	0.03992695	2.491442	0.2033463	2.17662859	0.00996214	2.16667	0.02298955	43.8372	41.66056
7	0.00258430	0.161260	0.4738229	9.29212093	9.29212093	0.00000	21.44335728	43.8360	34.54384
8	0.03992695	2.491442	0.2033463	15.15670395	0.00996238	15.16667	0.02299011	29.8524	14.69570
9	1.02686301	64.076253	5.2297710	5.05361938	5.05361938	0.00000	11.66219928	14.5118	9.45818

Pipe	Dyn Pres (psia)	dP/dx (psi/100 ft)	Resistance (sec ² /ft ⁵)	f	Reynolds No	fL/D	K	fL/D + K
1	0.1841841936	1.010695457	11.05970	0.0274379	2.48809E+05	27.4379	0	27.4379
2	0.1692495495	0.929485798	22.13709	0.0274594	2.38508E+05	54.9187	0	54.9187
3	0.0000427754	0.000342073	25.78813	0.0399607	3.79172E+03	63.9371	0	63.9371
4	0.1654154062	0.908647835	4.42848	0.0274653	2.35791E+05	10.9861	0	10.9861
5	0.1610037535	0.884633255	44.29580	0.0274725	2.32626E+05	109.8899	0	109.8899

AFT Fathom 3.0 Output
NUMATEC HANFORD CORPORATION

(2)

11/30/1999

Pipe	Dyn Pres (psia)	dP/dx (psi/100 ft)	Resistance (sec ² /ft ⁵)	f	Reynolds No	fL/D	K	fL/D + K
6	0 0002784580	0 001992427	14 42109	0 0357761	9 67430E+03	35 7761	0	35 7761
7	0 0015118860	0 092921209	3,210,746 79410	0 0512172	3 75706E+03	6146 0615	0	6146 0615
8	0 0002784580	0 001992476	14 42144	0 0357761	9 67430E+03	35 7761	0	35 7761
9	0 1841841936	1 010723877	11 06001	0 0274379	2 48809E+05	27 4379	0	27 4379

Jct	dP (psid)	dH (feet)	Vol Flow Into System (gal/min)	Loss Factor (K)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)	P Stag In (psia)
1	0 0000	0 0000	0 000	0 00000	117 2496	117 24960	117 1338	117 13377	43 83747
2	0 0000	0 0000	-448 831	0 00000	95 7999	95 79993	95 7998	95 79993	34 54261
3	0 0000	0 0000	0 000	0 00000	95 8062	95 80624	95 7012	95 70120	34 54535
4	0 0000	0 0000	-448 831	0 00000	54 9770	7 24960	54 9764	7 24960	29 85268
5	21 9153	50 5737	0 000	0 00000	78 3378	128 91147	77 9128	128 48643	9 64236
6	26 9649	62 2266	0 000	96,836 4	117 2266	55 00000	117 2260	54 99936	41 66084
7	0 0000	0 0000	460 888	0 00000	90 0000	90 00000	90 0000	90 00000	14 69598
8	0 0000	0 0000	436 774	0 00000	100 0000	100 00000	100 0000	100 00000	14 69598

Jct	P Stag Out (psia)	P Inlet (psia)	P Outlet (psia)
1	43 83747	43 78728	43 78728
2	34 54261	34 54257	34 54261
3	34 54535	34 49983	34 49983
4	2 88782	29 85241	2 88782
5	31 55762	9 45818	31 37343
6	14 69598	41 66056	14 69570
7	14 69598	14 69598	14 69598
8	14 69598	14 69598	14 69598

Sample #7

17 pipes 12 junctions

Model of a branching system fed by two reservoirs. One reservoir has a pump. Numerous loops are involved. Water is the working fluid.

Reference: Jeppson, R. W. *Analysis of Flow in Pipe Networks*, 1976, p. 135

Solve for the flow rate in each pipe and the head at each junction of the network shown below. The pump characteristic curve is given by $h_p = -2.505Q^2 + 16.707Q + 155.29$ (h_p is in feet and Q_p in cfs). There are outflows of 0.5 cfs leaving the system at junctions 2, 3, and 7. There are additional outflows of 2.0, 1.0, and 2.0 cfs at junctions 2, 3, and 4 respectively. Finally, there is an inflow of 1.5 cfs entering the system at junction 4. Assume all pipes Hazen-Williams factor of 130.

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Sample 7 Roland Jeppson Analysis of Flow in Pipe Networks 1976 p 135

Title Sample 7 Roland Jeppson Analysis of Flow in Pipe Networks 1976 p 135

Number Of Pipes= 17

Number Of Junctions= 12

Head/Pressure Convergence= 0001 (Relative change)

Flow Rate Convergence= 0001 (Relative change)

Relaxation= AFT Fathom Automatic

Maximum Iterations= 500

Constant Fluid Property Model

Fluid Unspecified

Density= 62.29329 lbm/ft³

Viscosity= 2.47554 lbm/hr ft

Vapor Pressure=

Gravitational Acceleration= 1 g

Atmospheric Pressure= 1 atm

Pipe	Name	Object Defined	Length	Length Units	Hydraulic Diameter	Hydraulic Diam Units	Roughness	Roughness Units	Losses (K)	Junctions (Up,Down)
1	Pipe	Yes	500	feet	12	inches	130	C Hazen Williams	0	10, 12
2	Pipe	Yes	1000	feet	8	inches	130	C Hazen Williams	0	1, 2
3	Pipe	Yes	1200	feet	10	inches	130	C Hazen Williams	0	2, 3
4	Pipe	Yes	900	feet	10	inches	130	C Hazen Williams	0	4, 3
5	Pipe	Yes	1000	feet	10	inches	130	C Hazen Williams	0	1, 4
6	Pipe	Yes	2500	feet	10	inches	130	C Hazen Williams	0	1, 6
7	Pipe	Yes	1000	feet	8	inches	130	C Hazen Williams	0	5, 2
8	Pipe	Yes	1400	feet	10	inches	130	C Hazen Williams	0	5, 6
9	Pipe	Yes	2000	feet	12	inches	130	C Hazen Williams	0	5, 8
10	Pipe	Yes	1200	feet	8	inches	130	C Hazen Williams	0	6, 8
11	Pipe	Yes	1300	feet	8	inches	130	C Hazen Williams	0	5, 7
12	Pipe	Yes	1600	feet	10	inches	130	C Hazen Williams	0	7, 8
13	Pipe	Yes	1000	feet	10	inches	130	C Hazen Williams	0	8, 9
14	Pipe	Yes	1300	feet	10	inches	130	C Hazen Williams	0	6, 9
15	Pipe	Yes	900	feet	12	inches	130	C Hazen Williams	0	3, 6
16	Pipe	Yes	500	feet	12	inches	130	C Hazen Williams	0	11, 5
17	Pipe	Yes	500	feet	12	inches	130	C Hazen Williams	0	12, 1

Pipe	Geometry	Material	Thermal Boundary	Overall U	Include Internal h	Special Condition
1	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
2	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
3	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
4	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
5	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
6	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
7	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
8	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
9	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
10	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
11	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
12	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
13	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
14	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
15	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
16	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
17	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None

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Branch	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units	Connected Pipes (+ = in, = out)
1	Branch	Yes	None	0	feet			2, 5, 6, 17
2	Branch	Yes	None	0	feet			2, 3, 7
3	Branch	Yes	None	0	feet			3, 4, 15
4	Branch	Yes	None	0	feet			4, 5
5	Branch	Yes	None	0	feet			7, 8, 9, 11, 16
6	Branch	Yes	None	0	feet			6, 8, 10, 14, 15
7	Branch	Yes	None	0	feet			11, 12
8	Branch	Yes	None	0	feet			9, 10, 12, 13
9	Branch	Yes	None	0	feet			14, 13
Pump	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units	Connected Pipes (+ = in, = out)
12	Pump	Yes	None	0	feet			1, 17
Reservoir	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units	Connected Pipes (+ = in, = out)
10	Reservoir	Yes	N/A	0	feet	0	feet	1
11	Reservoir	Yes	N/A	150	feet	150	feet	16

Branch	Boundary Flow (+ = in, = out)	Boundary Flow Units							
1	0	ft3/sec							
2	5	ft3/sec							
3	5	ft3/sec							
4	15	ft3/sec							
5	0	ft3/sec							
6	1	ft3/sec							
7	5	ft3/sec							
8	2	ft3/sec							
9	2	ft3/sec							
Pump	Independent Variable	Ind Variable Units	Dependent Variable	Dep Variable Units	Loss Constant a	Loss Constant b	Loss Constant c	Loss Constant d	
12	Vol Flow	ft3/sec	Head	feet	155.29	16.707	2.505	0	
Reservoir	Surface Pressure	Surface Pressure Units	Depth	Depth Units	Density	Density Units	Temperature	Temperature Units	
10	1	atm	0	feet					
11	1	atm	0	feet					

Branch			
1			
2			
3			
4			
5			
6			
7			
8			
9			

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Pump	Loss Constant e	Speed %	Viscosity Correction
12	0	100	No
Reservoir	Balance Energy		
10	No		
11	No		

AFT Fathom 3.0 Output
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Sample 7 Roland Jeppson Analysis of Flow in Pipe Networks 1976 p 135

Title Sample 7 Roland Jeppson Analysis of Flow in Pipe Networks 1976 p 135

Analysis run on 11/30/1999 2 35 30 PM

Input File C:\FATHOM\SAMPLES\SAMPLE7.FTH

Execution Time= 0.99 seconds

Total Number Of Head/Pressure Iterations= 129

Total Number Of Temperature Iterations= 0

Total Number Of Flow Iterations= 58

Number Of Pipes= 17

Number Of Junctions= 12

Head Tolerance= 0.001 relative change

Volumetric Flow Rate Tolerance= 0.001 relative change

Relaxation= 2

Constant Fluid Property Model

Fluid Unspecified

Density= 62.29329 lbm/ft³

Viscosity= 2.47554 lbm/hr ft

Vapor Pressure=

Gravitational Acceleration= 1 g

Atmospheric Pressure= 1 atm

Total Inflow= 6.50000 ft³/sec

Total Outflow= 6.50000 ft³/sec

Maximum Pressure is 88.2804 psia at Junction 12 Outlet

Minimum Pressure is 11.9742 psia at Junction 12 Inlet

=====PUMP SUMMARY=====

Jct	Flow (ft ³ /sec)	DP (psid)	DH (feet)	Speed (%)	ideal hp (hp)	NPSHA (feet)	NPSHR (feet)
12	4.9767	76.306	176.39	100.00	99.411	N/A	N/A

Pipe	Vol Flow (ft ³ /sec)	Mass Flow (lbm/sec)	Velocity (feet/sec)	dP Total (psid)	dP Friction (psid)	dP Gravity (psid)	dH (feet)	Max Pres (psia)	Min Pres (psia)
1	4.9767170	310.01607	6.3365537	2.4518454	2.451845407	0.0000	5.667797903	14.4261	11.9742
2	1.6557157	103.13998	4.7432766	4.5745068	4.574506760	0.0000	10.574638899	85.9472	81.3727
3	0.1145445	7.13535	0.2100133	0.0132878	0.013287811	0.0000	0.030716710	81.5237	81.5104
4	2.7764240	172.95258	5.0904770	3.6299405	3.629940510	0.0000	8.391136385	84.9664	81.3365
5	1.2764275	79.51287	2.3402856	0.9578540	0.957853973	0.0000	2.214219022	86.0617	85.1038
6	2.0445776	127.36346	3.7486621	5.7248497	5.724849701	0.0000	13.233824217	86.0040	80.2792
7	1.0411705	-64.85793	2.9827340	1.9392785	1.939278483	0.0000	-4.482924775	81.4642	79.5249
8	-0.9582140	59.69030	1.7568521	-0.7889354	0.788935363	0.0000	1.823739043	80.3529	79.5639
9	1.4125584	87.99291	1.7985254	0.9543895	0.954389513	0.0000	2.206210417	79.5630	78.6086
10	0.8906736	55.48299	2.5515923	1.7433249	1.743324876	0.0000	4.029949460	80.3299	78.5865
11	0.6101066	38.00555	1.7478269	0.9379200	0.937919974	0.0000	2.168138679	79.5642	78.6262
12	0.1101078	6.85898	0.2018788	0.0164696	0.016469564	0.0000	0.038071798	78.6465	78.6300
13	0.4133408	25.74836	0.7578460	0.1189548	0.118954785	0.0000	0.274981318	78.6264	78.5075
14	1.5866583	98.83816	2.9090829	1.8622797	1.862279654	0.0000	4.304930761	80.3167	78.4545
15	2.3909677	148.94124	3.0442751	1.1370553	1.137055278	0.0000	2.628468948	81.4484	80.3113
16	0.0232739	1.44981	0.0296333	-64.8887253	0.000118093	-64.8888	0.000272988	79.5847	14.6960
17	4.9767170	310.01607	6.3365537	2.4518452	2.451845169	0.0000	5.667797352	88.2804	85.8286

Pipe	Dyn Pres (psia)	dP/dx (psi/100 ft)	Resistance (sec ² /ft ⁵)	f	Reynolds No	fL/D	K	fL/D + K
1	0.26992923021	0.4903690815	0.228838	0.0181666	5.74020E+05	9.08329	0	9.08329
2	0.15125180781	0.4574506760	3.857394	0.0201629	2.86458E+05	30.24435	0	30.24435
3	0.00029650869	0.0011073176	2.341135	0.0311237	1.58540E+04	44.81814	0	44.81814
4	0.17420500517	0.4033267233	1.088552	0.0192937	3.84283E+05	20.83715	0	20.83715
5	0.03681980073	0.0957853973	1.359027	0.0216789	1.76669E+05	26.01473	0	26.01473

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Pipe	Dyn Pres (psia)	dP/dx (psi/100 ft)	Resistance (sec ² /ft ⁵)	f	Reynolds No	fL/D	K	fL/D + K
6	0 09447051585	0 2289939880	3 165761	0 0201998	2 82989E+05	60 59937	0	60 59937
7	0 05980985239	-0 1939278483	4 135402	0 0216159	1 80135E+05	32 42380	0	32 42380
8	0 02074980922	-0 0563525259	1 986267	0 0226317	1 32626E+05	38 02133	0	38 02133
9	0 02174587362	0 0477194756	1 105692	0 0219439	1 62926E+05	43 88778	0	43 88778
10	0 04376896098	0 1452770730	5 079985	0 0221280	1 54097E+05	39 83049	0	39 83049
11	0 02053716592	0 0721476903	5 824727	0 0234202	1 05556E+05	45 66933	0	45 66933
12	0 00027398401	0 0010293478	3 140272	0 0313087	1 52399E+04	60 11266	0	60 11266
13	0 00386105152	0 0118954785	1 609484	0 0256739	5 72102E+04	30 80863	0	30 80863
14	0 05889261109	0 1432522810	1 710013	0 0209829	2 19608E+05	32 73328	0	32 73328
15	0 06230336055	0 1263394753	0 459786	0 0202782	2 75777E+05	18 25034	0	18 25034
16	0 00000590341	0 0000236185	0 503971	0 0406241	2 68444E+03	20 31207	0	20 31207
17	0 26992923021	0 4903690338	0 228838	0 0181666	5 74020E+05	9 08329	0	9 08329

Jct	dP (psid)	dH (feet)	Vol Flow Into System (gal/min)	Loss Factor (K)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)	P Stag In (psia)
1	0 0000	0 000	0 0000	0 00000	165 05728	165 057	164 77098	164 771	86 0985
2	0 0000	0 000	224 4158	0 00000	154 48266	154 483	154 37391	154 374	81 5240
3	0 0000	0 000	224 4158	0 00000	154 45193	154 452	154 33169	154 332	81 5107
4	0 0000	0 000	673 2449	0 00000	162 84308	162 843	162 75796	162 440	85 1406
5	0 0000	0 000	0 0000	0 00000	149 99973	150 000	149 95675	149 957	79 5847
6	0 0000	0 000	-448 8308	0 00000	151 82347	151 823	151 70145	151 701	80 3736
7	0 0000	0 000	224 4150	0 00000	147 83160	147 832	147 78412	147 831	78 6468
8	0 0000	0 000	897 6616	0 00000	147 79352	147 794	147 76613	147 766	78 6303
9	0 0000	0 000	897 6616	0 00000	147 51853	147 519	147 50961	147 519	78 5114
10	0 0000	0 000	2233 7050	0 00000	0 00000	0 000	0 00000	0 000	14 6960
11	0 0000	0 000	10 4461	0 00000	150 00000	150 000	150 00000	150 000	14 6960
12	76 3062	176 393	0 0000	0 00000	5 66780	170 725	6 29178	170 101	12 2441

Jct	P Stag Out (psia)	P Inlet (psia)	P Outlet (psia)
1	86 0985	85 9746	85 9746
2	81 5240	81 4769	81 4769
3	81 5107	81 4587	81 4587
4	85 1406	85 1038	84 9664
5	79 5847	79 5661	79 5661
6	80 3736	80 3208	80 3208
7	78 6468	78 6262	78 6465
8	78 6303	78 6185	78 6185
9	78 5114	78 5075	78 5114
10	14 6960	14 6960	14 6960
11	14 6960	14 6960	14 6960
12	88 5503	11 9742	88 2804

Sample #8

48 pipes 32 junctions

Model of a large branching network Water is the working fluid

Reference Jeppson R W *Analysis of Flow in Pipe Networks* 1976 p 138

Solve for the flow rate in each pipe and the head at each junction of the network shown below Note that there are outflows at each junction as described in the problem except at junction 15 which has an inflow of 20 428 cfs Assume all pipes have $e = 0.012$ inch

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Sample 8 Roland Jeppson Analysis of Flow in Pipe Networks 1976 p 138

Title Sample 8 Roland Jeppson Analysis of Flow in Pipe Networks 1976 p 138

Number Of Pipes= 48

Number Of Junctions= 32

Head/Pressure Convergence= 0001 feet

Flow Rate Convergence= 0001 ft3/sec

Relaxation= AFT Fathom Automatic

Maximum Iterations= 5000

Constant Fluid Property Model

Fluid Unspecified

Density= 62.4 lbm/ft3

Viscosity= 0.006558 lbm/s ft

Vapor Pressure=

Gravitational Acceleration= 1 g

Atmospheric Pressure= 1 atm

Pipe	Name	Object Defined	Length	Length Units	Hydraulic Diameter	Hydraulic Diam Units	Roughness	Roughness Units	Losses (K)	Initial Flow	Initial Flow Units
1	Pipe	Yes	2000	feet	24	inches	012	inches	0	19 79796	ft3/sec
2	Pipe	Yes	2000	feet	24	inches	012	inches	0	10 37466	ft3/sec
3	Pipe	Yes	2000	feet	24	inches	012	inches	0	4 890931	ft3/sec
4	Pipe	Yes	3000	feet	12	inches	012	inches	0	4 003279	ft3/sec
5	Pipe	Yes	2000	feet	24	inches	012	inches	0	2 655788	ft3/sec
6	Pipe	Yes	2000	feet	12	inches	012	inches	0	4 130847	ft3/sec
7	Pipe	Yes	1000	feet	12	inches	012	inches	0	4 439231	ft3/sec
8	Pipe	Yes	1500	feet	12	inches	012	inches	0	-4 601061	ft3/sec
9	Pipe	Yes	1000	feet	18	inches	012	inches	0	13 66711	ft3/sec
10	Pipe	Yes	1000	feet	12	inches	012	inches	0	2 4019	ft3/sec
11	Pipe	Yes	2000	feet	12	inches	012	inches	0	-4 066052	ft3/sec
12	Pipe	Yes	1000	feet	18	inches	012	inches	0	6 066052	ft3/sec
13	Pipe	Yes	2000	feet	12	inches	012	inches	0	1 638393	ft3/sec
14	Pipe	Yes	1500	feet	12	inches	012	inches	0	1 108378	ft3/sec
15	Pipe	Yes	2000	feet	24	inches	012	inches	0	5 467951	ft3/sec
16	Pipe	Yes	3000	feet	12	inches	012	inches	0	1 597958	ft3/sec
17	Pipe	Yes	1000	feet	12	inches	012	inches	0	4020416	ft3/sec
18	Pipe	Yes	1500	feet	12	inches	012	inches	0	1 336329	ft3/sec
19	Pipe	Yes	1000	feet	18	inches	012	inches	0	2 836329	ft3/sec
20	Pipe	Yes	3000	feet	24	inches	012	inches	0	-4 836329	ft3/sec
21	Pipe	Yes	1500	feet	12	inches	012	inches	0	4 067944	ft3/sec
22	Pipe	Yes	3000	feet	12	inches	012	inches	0	2 591123	ft3/sec
23	Pipe	Yes	1000	feet	12	inches	012	inches	0	1 408877	ft3/sec
24	Pipe	Yes	1500	feet	12	inches	012	inches	0	3 065712	ft3/sec
25	Pipe	Yes	3000	feet	12	inches	012	inches	0	3 112348	ft3/sec
26	Pipe	Yes	1500	feet	12	inches	012	inches	0	3 067491	ft3/sec
27	Pipe	Yes	1500	feet	12	inches	012	inches	0	2 573217	ft3/sec
28	Pipe	Yes	2500	feet	12	inches	012	inches	0	6 974588	ft3/sec
29	Pipe	Yes	2000	feet	18	inches	012	inches	0	2 482776	ft3/sec
30	Pipe	Yes	2000	feet	18	inches	012	inches	0	8 018992	ft3/sec
31	Pipe	Yes	1000	feet	24	inches	012	inches	0	10 26185	ft3/sec
32	Pipe	Yes	2500	feet	24	inches	012	inches	0	12 26185	ft3/sec
33	Pipe	Yes	1500	feet	12	inches	012	inches	0	2 944224	ft3/sec
34	Pipe	Yes	1500	feet	12	inches	012	inches	0	1 055776	ft3/sec
35	Pipe	Yes	2000	feet	24	inches	012	inches	0	17 20607	ft3/sec
36	Pipe	Yes	1500	feet	18	inches	012	inches	0	6351839	ft3/sec
37	Pipe	Yes	1500	feet	18	inches	012	inches	0	8 063849	ft3/sec
38	Pipe	Yes	1500	feet	24	inches	012	inches	0	11 69903	ft3/sec

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NUMATEC HANFORD CORPORATION

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Pipe	Name	Object Defined	Length	Length Units	Hydraulic Diameter	Hydraulic Diam Units	Roughness	Roughness Units	Losses (K)	Initial Flow	Initial Flow Units
39	Pipe	Yes	1200	feet	18	inches	012	inches	0	4 494274	ft3/sec
40	Pipe	Yes	1500	feet	18	inches	012	inches	0	12 03318	ft3/sec
41	Pipe	Yes	1000	feet	18	inches	012	inches	0	12 5478	ft3/sec
42	Pipe	Yes	1200	feet	18	inches	012	inches	0	8 160127	ft3/sec
43	Pipe	Yes	1500	feet	24	inches	012	inches	0	29 73101	ft3/sec
44	Pipe	Yes	1000	feet	24	inches	012	inches	0	26 58098	ft3/sec
45	Pipe	Yes	1500	feet	24	inches	012	inches	0	19 57089	ft3/sec
46	Pipe	Yes	2000	feet	12	inches	012	inches	0	2 480441	ft3/sec
47	Pipe	Yes	2000	feet	12	inches	012	inches	0	4 964172	ft3/sec
48	Pipe	Yes	2000	feet	24	inches	012	inches	0	9 744624	ft3/sec

Pipe	Junctions (Up,Down)	Geometry	Material	Thermal Boundary	Overall U	Include Internal h	Special Condition
1	15, 19	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
2	15, 16	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
3	16, 17	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
4	17, 21	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
5	20, 21	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
6	19, 20	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
7	20, 26	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
8	26, 27	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
9	19, 27	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
10	26, 28	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
11	28, 29	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
12	27, 29	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
13	26, 24	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
14	24, 25	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
15	28, 25	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
16	30, 24	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
17	22, 30	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
18	22, 23	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
19	23, 31	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
20	31, 25	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
21	21, 24	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
22	21, 32	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
23	32, 18	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
24	18, 22	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
25	9, 17	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
26	9, 7	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
27	7, 5	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
28	5, 18	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
29	13, 14	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
30	13, 9	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
31	11, 14	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
32	10, 11	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
33	10, 12	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
34	13, 12	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
35	10, 2	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
36	8, 2	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
37	9, 8	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
38	6, 8	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
39	6, 7	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
40	4, 6	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
41	5, 4	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None

AFT Fathom 3.0 Input
NUMATEC HANFORD CORPORATION

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Pipe	Junctions (Up,Down)	Geometry	Material	Thermal Boundary	Overall U	Include Internal h	Special Condition
42	3, 6	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
43	3, 1	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
44	1, 4	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
45	2, 3	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
46	13, 16	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
47	16, 20	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
48	14, 15	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None

Branch	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units	Connected Pipes (+ = in, = out)
2	Branch	Yes	None	100	feet	74 53826	feet	35,36,-45
3	Branch	Yes	None	100	feet	82 28107	feet	-42,-43,45
4	Branch	Yes	None	100	feet	90 53942	feet	-40,41,44
5	Branch	Yes	None	100	feet	81 01955	feet	27, 28,-41
6	Branch	Yes	None	100	feet	77 39483	feet	38, 39,40,42
7	Branch	Yes	None	100	feet	75 87629	feet	26, 27,39
8	Branch	Yes	None	100	feet	74 5844	feet	36,37,38
9	Branch	Yes	None	100	feet	68 61764	feet	25, 26,30, 37
10	Branch	Yes	None	100	feet	66 53236	feet	32, 33, 35
11	Branch	Yes	None	100	feet	61 39567	feet	31,32
12	Branch	Yes	None	100	feet	59 83518	feet	33,34
13	Branch	Yes	None	100	feet	60 74883	feet	29, 30, 34,-46
14	Branch	Yes	None	100	feet	59 94662	feet	29,31,-48
15	Branch	Yes	None	100	feet	57 32753	feet	1, 2,48
16	Branch	Yes	None	100	feet	54 3667	feet	2, 3,46,-47
17	Branch	Yes	None	100	feet	53 68051	feet	3,-4,25
18	Branch	Yes	None	100	feet	19 80331	feet	23, 24,28
19	Branch	Yes	None	100	feet	46 76577	feet	1,-6, 9
20	Branch	Yes	None	100	feet	29 38215	feet	5,6, 7,47
21	Branch	Yes	None	100	feet	29 16871	feet	4,5, 21, 22
22	Branch	Yes	None	100	feet	12 55292	feet	17, 18,24
23	Branch	Yes	None	100	feet	13 99092	feet	18, 19
24	Branch	Yes	None	100	feet	16 51952	feet	13, 14,16,21
25	Branch	Yes	None	100	feet	15 51648	feet	14,15,20
26	Branch	Yes	None	100	feet	19 36394	feet	7, 8, 10, 13
27	Branch	Yes	None	100	feet	35 49176	feet	8,9, 12
28	Branch	Yes	None	100	feet	16 36752	feet	10, 11, 15
29	Branch	Yes	None	100	feet	33 21765	feet	11,12
30	Branch	Yes	None	100	feet	12 45476	feet	16,17
31	Branch	Yes	None	100	feet	14 50923	feet	19, 20
32	Branch	Yes	None	100	feet	18 74156	feet	22, 23
Reservoir	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units	Connected Pipes (+ = in, = out)
1	Reservoir	Yes	N/A	100	feet	100	feet	43,-44

Branch	Boundary Flow (+ = in/ = out)	Boundary Flow Units			
2	3	ft3/sec			
3	2	ft3/sec			
4	2	ft3/sec			
5	3	ft3/sec			

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NUMATEC HANFORD CORPORATION

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6	-4	ft3/sec			
7	-4	ft3/sec			
8	3	ft3/sec			
9					
10	2	ft3/sec			
11	2	ft3/sec			
12	-4	ft3/sec			
13	2	ft3/sec			
14	3	ft3/sec			
15	20 428	ft3/sec			
16	3	ft3/sec			
17	-4	ft3/sec			
18	2 5	ft3/sec			
19	2	ft3/sec			
20	2	ft3/sec			
21					
22	-4	ft3/sec			
23	1 5	ft3/sec			
24	3	ft3/sec			
25	1 74	ft3/sec			
26	5	ft3/sec			
27	3	ft3/sec			
28	1	ft3/sec			
29	2	ft3/sec			
30	2	ft3/sec			
31	2	ft3/sec			
32	-4	ft3/sec			
Reservoir	Surface Pressure	Surface Pressure Units	Depth	Depth Units	Balance Energy
1	1	atm	0	feet	No

AFT Fathom 3.0 Output
NUMATEC HANFORD CORPORATION

(1)

12/02/1999

Sample 8 Roland Jeppson Analysis of Flow in Pipe Networks 1976 p 138

Title Sample 8 Roland Jeppson Analysis of Flow in Pipe Networks 1976 p 138

Analysis run on 12/02/1999 10 57 30 AM

Input File C:\FATHOM\SAMPLES\SAMPLE8.FTH

Execution Time= 0.44 seconds

(Iteration History was ON)

Total Number Of Head/Pressure Iterations= 3

Total Number Of Temperature Iterations= 0

Total Number Of Flow Iterations= 2

Number Of Pipes= 48

Number Of Junctions= 32

Head Tolerance= .0001 feet

Volumetric Flow Rate Tolerance= .0001 ft³/sec

Relaxation= 1 (None)

Constant Fluid Property Model

Fluid Unspecified

Density= 62.4 lbm/ft³

Viscosity= .0006558 lbm/s ft

Vapor Pressure=

Gravitational Acceleration= 1 g

Atmospheric Pressure= 1 atm

Total Inflow= 76.74 ft³/sec

Total Outflow= 76.74 ft³/sec

Maximum Pressure is 14.70 psia at Junction 1 Outlet

Minimum Pressure is 23.27 psia at Junction 30 Outlet

Pipe	Vol Flow (ft ³ /sec)	Mass Flow (lbm/sec)	Velocity (feet/sec)	dP Total (psid)	dP Friction (psid)	dP Gravity (psid)	dH (feet)	Max Pres (psia)	Min Pres (psia)	Dyn Pres (psia)
1	19.7980	1235.39	6.3019	4.57677	4.57677	0	10.56177	-4.06286	8.639625	0.2674412
2	10.3747	647.38	3.3024	1.28303	1.28303	0	2.96083	3.86886	5.151888	0.0734405
3	4.8909	305.19	1.5568	0.29735	0.29735	0	0.68619	5.09477	5.392118	0.0163219
4	4.0033	249.80	5.0971	10.62178	10.62178	0	24.51180	5.55076	16.172537	0.1749601
5	2.6558	165.72	0.8454	0.09249	0.09249	0	0.21344	15.90990	16.002390	0.0048125
6	4.1308	257.76	5.2596	7.53290	7.53290	0	17.38362	-8.55847	16.091372	0.1862884
7	4.4392	277.01	5.6522	4.34123	4.34123	0	10.01822	16.12022	20.461452	0.2151409
8	-4.6011	287.11	5.8583	-6.98872	-6.98872	0	16.12782	13.48870	20.477423	0.2311125
9	13.6671	852.83	7.7340	4.88541	4.88541	0	11.27401	8.77499	13.660396	0.4028060
10	2.4019	149.88	3.0582	1.29845	1.29845	0	2.99642	20.30929	21.607742	0.0629821
11	-4.0661	253.72	5.1771	7.30172	7.30172	0	16.85013	14.42353	21.725250	0.1804900
12	6.0661	378.52	3.4327	0.98545	0.98545	0	2.27411	13.33694	14.322389	0.0793514
13	1.6384	102.24	2.0861	1.23258	1.23258	0	2.84442	20.27562	21.508196	0.0293051
14	1.1084	69.16	1.4112	0.43465	0.43465	0	1.00305	21.49230	21.926956	0.0134117
15	5.4680	341.20	1.7405	0.36879	0.36879	0	0.85104	21.56516	21.933945	0.0204003
16	1.5980	99.71	2.0346	1.76140	1.76140	0	-4.06476	21.50677	23.268164	0.0278765
17	0.4020	25.09	0.5119	0.04254	0.04254	0	0.09816	23.19952	23.242052	0.0017646
18	1.3363	83.39	1.7015	0.62313	-0.62313	0	1.43800	22.59411	23.217247	0.0194955
19	2.8363	176.99	1.6050	-0.22460	-0.22460	0	0.51831	22.36736	22.591967	0.0173483
20	-4.8363	301.79	1.5395	0.43647	-0.43647	0	1.00725	21.92950	22.365976	0.0159595
21	4.0679	253.84	5.1795	5.48131	5.48131	0	12.64919	16.17823	21.659550	0.1806580
22	2.5911	161.69	3.2991	4.51843	4.51843	0	10.42715	16.07087	20.589306	0.0732966
23	1.4089	87.91	1.7938	0.46009	0.46009	0	1.06175	20.07759	20.537678	0.0216697
24	3.0657	191.30	3.9034	3.14184	3.14184	0	7.25039	20.15852	23.300358	0.1026054
25	3.1123	194.21	3.9628	6.47275	6.47275	0	14.93713	0.99121	5.481546	0.1057508
26	3.0675	191.41	3.9057	3.14542	3.14542	0	7.25865	4.13965	0.994233	0.1027245
27	2.5732	160.57	3.2763	2.22875	2.22875	0	5.14327	6.39883	4.170086	0.0722870
28	6.9746	435.21	8.8803	26.52704	26.52704	0	61.21625	5.94006	20.586977	0.5310612
29	2.4828	154.93	1.4050	0.34762	0.34762	0	0.80221	2.32615	2.673777	0.0132928
30	-8.0190	500.39	-4.5378	3.40982	3.40982	0	7.86881	0.95829	2.451530	0.1386698
31	10.2618	640.34	3.2664	0.62792	0.62792	0	1.44905	2.10441	2.732336	0.0718519

AFT Fathom 3.0 Output
NUMATEC HANFORD CORPORATION

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Pipe	Vol Flow (ft ³ /sec)	Mass Flow (lbm/sec)	Velocity (feet/sec)	dP Total (psid)	dP Friction (psid)	dP Gravity (psid)	dH (feet)	Max Pres (psia)	Min Pres (psia)	Dyn Pres (psia)
32	12 2618	765 14	3 9031	2 22590	2 22590	0	5 13669	0 09075	2 135150	0 1025886
33	2 9442	183 72	3 7487	2 90211	2 90211	0	6 69718	0 09870	2 803409	0 0946344
34	1 0558	65 88	1 3443	0 39591	0 39591	0	0 91365	2 32503	2 720943	0 0121689
35	17 2061	1073 66	5 4769	3 46922	3 46922	0	-8 00590	3 46056	0 008661	0 2019998
36	0 6352	39 64	0 3594	0 01999	0 01999	0	0 04614	3 68168	3 661690	0 0008700
37	8 0638	503 18	-4 5632	2 58560	2 58560	0	5 96676	3 54233	0 956732	0 1402255
38	11 6990	730 02	3 7239	1 21785	1 21785	0	2 81043	4 80702	3 589166	0 0933872
39	4 4943	280 44	2 5432	0 65803	0 65803	0	1 51854	4 85685	4 198816	0 0435573
40	12 0332	750 87	6 8094	5 69599	5 69599	0	13 14459	10 28415	4 588156	0 3122505
41	12 5478	782 98	7 1006	-4 12528	-4 12528	0	9 51987	10 25687	6 131592	0 3395298
42	8 1601	509 19	4 6177	2 11737	2 11737	0	4 88624	6 87418	4 756813	0 1435940
43	29 7310	1855 22	9 4637	7 67820	7 67820	0	17 71893	14 09286	6 414651	0 6031244
44	26 5810	1658 65	8 4610	4 09958	4 09958	0	9 46058	14 21389	10 114305	0 4820916
45	19 5709	1221 22	-6 2296	3 35522	3 35522	0	7 74281	6 75643	3 401218	0 2613416
46	2 4804	154 78	3 1582	2 76559	2 76559	0	6 38212	2 38003	5 145616	0 0671684
47	4 9642	309 76	6 3206	10 82664	10 82664	0	24 98455	5 34748	16 174114	0 2690302
48	9 7446	608 06	3 1018	1 13494	1 13494	0	2 61908	2 72528	3 860211	0 0647914

Pipe	dP/dx (psi/100 ft)	Resistance (sec ² /ft ⁵)	f	Reynolds No	fL/D	K	fL/D + K
1	0 228838	0 02695	0 01711	1 199E+06	17 113	0	17 113
2	0 064151	0 02751	0 01747	6 284E+05	17 470	0	17 470
3	0 014867	0 02869	0 01822	2 963E+05	18 218	0	18 218
4	0 354059	1 52948	0 02024	4 850E+05	60 710	0	60 710
5	0 004625	0 03026	0 01922	1 609E+05	19 219	0	19 219
6	0 376645	1 01874	0 02022	5 005E+05	40 437	0	40 437
7	0 434123	0 50836	0 02018	5 378E+05	20 179	0	20 179
8	-0 465915	0 76183	0 02016	5 574E+05	30 239	0	30 239
9	0 488541	0 06036	0 01819	1 104E+06	12 128	0	12 128
10	0 129845	0 51939	0 02062	2 910E+05	20 616	0	20 616
11	-0 365086	1 01920	0 02023	4 926E+05	40 455	0	40 455
12	0 098545	0 06180	0 01863	4 899E+05	12 419	0	12 419
13	0 061629	1 05964	0 02103	1 985E+05	42 060	0	42 060
14	0 028977	0 81648	0 02161	1 343E+05	32 409	0	32 409
15	0 018439	0 02846	0 01808	3 312E+05	18 077	0	18 077
16	0 058713	1 59186	0 02106	1 936E+05	63 186	0	63 186
17	0 004254	0 60729	0 02411	4 871E+04	24 105	0	24 105
18	0 041542	0 80525	0 02131	1 619E+05	31 963	0	31 963
19	-0 022460	0 06443	0 01942	2 291E+05	12 947	0	12 947
20	0 014549	0 04306	0 01823	2 930E+05	27 349	0	27 349
21	0 365421	0 76439	0 02023	4 928E+05	30 341	0	30 341
22	0 150614	1 55306	0 02055	3 139E+05	61 646	0	61 646
23	-0 046009	0 53491	0 02123	1 707E+05	21 232	0	21 232
24	0 209456	0 77143	0 02041	3 714E+05	30 621	0	30 621
25	0 215758	1 54202	0 02040	3 771E+05	61 208	0	61 208
26	-0 209694	0 77142	0 02041	3 716E+05	30 620	0	30 620
27	0 148583	0 77676	0 02055	3 117E+05	30 832	0	30 832
28	1 061082	1 25843	0 01998	8 450E+05	49 951	0	49 951
29	0 017381	0 13014	0 01961	2 005E+05	26 151	0	26 151
30	0 170491	0 12237	0 01844	6 477E+05	24 589	0	24 589
31	0 062792	0 01376	0 01748	6 216E+05	8 739	0	8 739
32	0 089036	0 03416	0 01736	7 428E+05	21 697	0	21 697
33	0 193474	0 77259	0 02044	3 567E+05	30 667	0	30 667
34	0 026394	0 81966	0 02169	1 279E+05	32 535	0	32 535
35	-0 173461	0 02704	0 01717	1 042E+06	17 174	0	17 174

AFT Fathom 3.0 Output
NUMATEC HANFORD CORPORATION

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Pipe	dP/dx (psi/100 ft)	Resistance (sec ² /ft ⁵)	f	Reynolds No	fL/D	K	fL/D + K
36	0 001333	0 11436	0 02298	5 130E+04	22 979	0	22 979
37	0 172373	0 09176	0 01844	6 513E+05	18 439	0	18 439
38	0 081190	0 02053	0 01739	7 087E+05	13 041	0	13 041
39	0 054836	0 07518	0 01888	3 630E+05	15 107	0	15 107
40	0 379733	0 09078	0 01824	9 719E+05	18 242	0	18 242
41	-0 412528	0 06046	0 01822	1 013E+06	12 150	0	12 150
42	0 176447	0 07338	0 01843	6 591E+05	14 746	0	14 746
43	-0 511880	0 02005	0 01697	1 801E+06	12 731	0	12 731
44	0 409958	0 01339	0 01701	1 610E+06	8 504	0	8 504
45	0 223681	0 02022	0 01712	1 186E+06	12 838	0	12 838
46	0 138279	1 03731	0 02059	3 005E+05	41 174	0	41 174
47	0 541332	1 01386	0 02012	6 014E+05	40 243	0	40 243
48	0 056747	0 02758	0 01752	5 903E+05	17 517	0	17 517

Jct	dP (psid)	dH (feet)	Vol Flow Into System (gal/min)	Loss Factor (K)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)	P Stag In (psia)
1	0	0	25,274 6	0 000	100 00	100 00	100 00	100 00	14 6960
2	0	0	1,346 5	0 000	74 54	74 54	74 29	74 29	3 6626
3	0	0	-897 7	0 000	82 28	82 28	81 57	81 57	7 0178
4	0	0	897 7	0 000	90 54	90 54	89 68	89 68	10 5964
5	0	0	1,346 5	0 000	81 02	81 02	80 38	80 38	6 4711
6	0	0	1,795 3	0 000	77 39	77 39	77 09	77 09	4 9004
7	0	0	1,795 3	0 000	75 88	75 88	75 71	75 71	4 2424
8	0	0	1,346 5	0 000	74 58	74 58	74 46	74 46	3 6826
9	0	0	0 0	0 000	68 62	68 62	68 34	68 34	1 0970
10	0	0	897 7	0 000	66 53	66 53	66 23	66 23	0 1933
11	0	0	897 7	0 000	61 40	61 40	61 16	61 23	2 0326
12	0	0	1,795 3	0 000	59 84	59 84	59 81	59 84	2 7088
13	0	0	897 7	0 000	60 75	60 75	60 64	60 64	2 3129
14	0	0	1,346 5	0 000	59 95	59 95	59 84	59 84	2 6605
15	0	0	9,168 7	0 000	57 33	57 33	57 05	57 05	3 7954
16	0	0	1,346 5	0 000	54 37	54 37	54 17	54 17	5 0784
17	0	0	1,795 3	0 000	53 68	53 68	53 49	53 49	5 3758
18	0	0	1,122 1	0 000	19 80	19 80	19 44	19 44	20 0559
19	0	0	-897 7	0 000	46 77	46 77	46 12	46 12	8 3722
20	0	0	897 7	0 000	29 38	29 38	29 06	29 06	15 9051
21	0	0	0 0	0 000	29 17	29 17	28 97	28 97	15 9976
22	0	0	1,795 3	0 000	12 55	12 55	12 49	12 49	23 1978
23	0	0	-673 2	0 000	13 99	13 99	13 95	13 95	22 5746
24	0	0	1,346 5	0 000	16 52	16 52	16 41	16 41	21 4789
25	0	0	781 0	0 000	15 52	15 52	15 48	15 48	21 9135
26	0	0	2,244 2	0 000	19 36	19 36	19 09	19 09	20 2463
27	0	0	1,346 5	0 000	35 49	35 49	34 99	34 99	13 2576
28	0	0	-448 8	0 000	16 37	16 37	16 20	16 20	21 5448
29	0	0	-897 7	0 000	33 22	33 22	33 03	33 22	14 2430
30	0	0	897 7	0 000	12 45	12 45	12 45	12 39	23 2403
31	0	0	897 7	0 000	14 51	14 51	14 47	14 47	22 3500
32	0	0	1,795 3	0 000	18 74	18 74	18 57	18 69	20 5160

Jct	P Stag Out (psia)	P Inlet (psia)	P Outlet (psia)
1	14 6960	14 69598	14 69598
2	3 6626	3 55363	3 55363
3	7 0178	6 70910	6 70910
4	10 5964	10 22193	10 22193

AFT Fathom 3.0 Output
NUMATEC HANFORD CORPORATION

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Jct	P Stag Out (psia)	P Inlet (psia)	P Outlet (psia)
5	6 4711	6 19364	6 19364
6	4 9004	4 76863	4 76863
7	4 2424	4 17160	4 17160
8	3 6826	3 62661	3 62661
9	1 0970	0 97576	0 97576
10	0 1933	0 06437	0 06437
11	2 0326	2 13515	2 10441
12	2 7088	2 72094	2 70877
13	2 3129	2 35878	2 35878
14	2 6605	2 70570	2 70570
15	3 7954	3 91622	3 91622
16	5 0784	5 16497	5 16497
17	5 3758	-5 46013	5 46013
18	20 0559	20 21492	20 21492
19	8 3722	8 65077	-8 65077
20	15 9051	16 04263	16 04263
21	15 9976	16 08511	16 08511
22	23 1978	23 22575	23 22575
23	22 5746	22 59411	22 59197
24	21 4789	21 52718	21 52718
25	21 9135	21 93001	21 93001
26	20 2463	20 36306	20 36306
27	13 2576	13 47447	13 47447
28	21 5448	21 61922	21 61922
29	14 2430	14 32239	14 24304
30	23 2403	23 24205	23 26816
31	22 3500	22 36736	22 36598
32	20 5160	20 58931	20 53768

Sample #9

3 pipes 4 junctions

Model of a simple series flow pressure drop Water is the working fluid

Reference White F *Fluid Mechanics* 1979 p 362

AFT Fathom 3.0 Input
NUMATEC HANFORD CORPORATION

(1)

11/30/1999 02:49 PM

Sample 9 Fluid Mechanics Frank White 1979 p 362

Title Sample 9 Fluid Mechanics Frank White 1979 p 362

Number Of Pipes= 3

Number Of Junctions= 4

Head/Pressure Convergence= 0.01 meters

Flow Rate Convergence= 0.001 m3/sec

Relaxation= AFT Fathom Automatic

Maximum Iterations= 500

Constant Fluid Property Model

Fluid Unspecified

Density= 1000 kg/m3

Viscosity= 0.0102 kg/sec-m

Vapor Pressure=

Gravitational Acceleration= 1 g

Atmospheric Pressure= 1 atm

Pipe	Name	Object Defined	Length	Length Units	Hydraulic Diameter	Hydraulic Diam Units	Roughness	Roughness Units	Losses (K)	Junctions (Up,Down)
1	Pipe	Yes	100	meters	8	cm	0.03	Eps/D	0	1, 2
2	Pipe	Yes	150	meters	6	cm	0.02	Eps/D	0	2, 3
3	Pipe	Yes	80	meters	4	cm	0.05	Eps/D	0	3, 4

Pipe	Geometry	Material	Thermal Boundary	Overall U	Include Internal h	Special Condition
1	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
2	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
3	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None

Assigned Pressure	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units
1	Assigned Pressure	Yes	N/A	5	meters	200000	Pascals
4	Assigned Pressure	Yes	N/A	0	meters	50000	Pascals
Branch	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units
2	Branch	Yes	None	5	meters		
3	Branch	Yes	None	5	meters		

Assigned Pressure	Connected Pipes (+ = in, = out)	Pressure	Pressure Units	Balance Energy
1	1	200000	Pascals	No
4	3	50000	Pascals	No
Branch	Connected Pipes (+ = in, = out)	Boundary Flow (+ = in/ = out)	Boundary Flow Units	
2	1, 2	0	ft3/sec	
3	2, 3	0	ft3/sec	

AFT Fathom 3.0 Output
NUMATEC HANFORD CORPORATION

(1)

11/30/1999

Sample 9 Fluid Mechanics Frank White 1979 p 362

Title Sample 9 Fluid Mechanics Frank White 1979 p 362
Analysis run on 11/30/1999 2 48 12 PM
Input File C:\FATHOM\SAMPLES\SAMPLE9.FTH

Execution Time= 0.11 seconds
Total Number Of Head/Pressure Iterations= 0
Total Number Of Temperature Iterations= 0
Total Number Of Flow Iterations= 2
Number Of Pipes= 3
Number Of Junctions= 4
Head Tolerance= 0.001 meters
Volumetric Flow Rate Tolerance= 0.001 m3/sec
Relaxation= 1 (None)

Constant Fluid Property Model

Fluid Unspecified
Density= 1000 kg/m3
Viscosity= 0.0102 kg/sec-m
Vapor Pressure=
Gravitational Acceleration= 1 g
Atmospheric Pressure= 1 atm

Overall Delta Head = 20.2957 meters
Total Inflow= 2.84165E-03 m3/sec
Total Outflow= 2.84165E-03 m3/sec
Maximum Pressure is 0.199840 MPa at Junction 1 Inlet
Minimum Pressure is 0.0474432 MPa at Junction 4 Inlet

Pipe	Vol Flow (m3/hr)	Mass Flow (lbm/sec)	Velocity (feet/sec)	dP Total (psid)	dP Friction (psid)	dP Gravity (psid)	dH (feet)	Max Pres (psia)	Min Pres (psia)	Dyn Pres (psia)
1	10.2299	6.26477	1.85475	0.836469	0.836469	0.00000	1.92945	28.9844	28.14789	0.0231768
2	10.2299	6.26477	3.29734	4.776439	4.776439	0.00000	11.01761	28.0978	23.32138	0.0732502
3	10.2299	6.26477	7.41901	16.142748	23.254419	7.11167	53.64001	23.0238	6.88106	0.3708290

Pipe	dPf/dx (psi/100 ft)	Resistance (sec2/ft5)	f	Reynolds No	fL/D	K	fL/D + K
1	0.254956	191.594	0.0288726	4.43395E+04	36.0908	0	36.0908
2	0.970572	1094.046	0.0260829	5.91193E+04	65.2072	0	65.2072
3	8.859934	5326.437	0.0313882	8.86790E+04	62.7764	0	62.7764

Jct	dP (psid)	dH (feet)	Vol Flow Into System (gal/min)	Loss Factor (K)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)	P Stag In (psia)
1	0	0	45.0411	0.00000	49.4161	49.4161	49.3626	49.3626	29.00754
2	0	0	0.0000	0.00000	47.4866	47.4866	47.4332	47.3177	28.17107
3	0	0	0.0000	0.00000	36.4690	36.4690	36.3001	35.6136	23.39463
4	0	0	-45.0411	0.00000	17.1710	17.1710	18.0264	18.0264	7.25188

Jct	P Stag Out (psia)	P Inlet (psia)	P Outlet (psia)
1	29.00754	28.98436	28.98436
2	28.17107	28.14789	28.09782
3	23.39463	23.32138	23.02380
4	7.25188	6.88106	6.88106

Sample #10

3 pipes 2 junctions

Model of a simple parallel flow pressure drop Water is the working fluid

Reference White F *Fluid Mechanics* 1979 p 363

AFT Fathom 3.0 Input
NUMATEC HANFORD CORPORATION

(1)

11/30/1999 02:54 PM

Sample 10 Fluid Mechanics Frank White 1979 p 363

Title Sample 10 Fluid Mechanics Frank White 1979 p 363

Number Of Pipes= 3
Number Of Junctions= 2

Head/Pressure Convergence= 0.01 meters
Flow Rate Convergence= 0.01 m3/hr
Relaxation= AFT Fathom Automatic
Maximum Iterations= 500

Constant Fluid Property Model
Fluid Unspecified
Density= 1000 kg/m3
Viscosity= 0.0102 kg/sec-m
Vapor Pressure=
Gravitational Acceleration= 1 g
Atmospheric Pressure= 1 atm

Pipe	Name	Object Defined	Length	Length Units	Hydraulic Diameter	Hydraulic Diam Units	Roughness	Roughness Units	Losses (K)	Junctions (Up,Down)
1	Pipe	Yes	100	meters	8	cm	003	Eps/D	0	1, 2
2	Pipe	Yes	150	meters	6	cm	002	Eps/D	0	1, 2
3	Pipe	Yes	80	meters	4	cm	005	Eps/D	0	1, 2

Pipe	Geometry	Material	Thermal Boundary	Overall U	Include Internal h	Special Condition
1	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
2	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
3	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None

Assigned Pressure	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units
1	Assigned Pressure	Yes	N/A	0	meters	249000	Pascals
2	Assigned Pressure	Yes	N/A	0	meters	50000	Pascals

Assigned Pressure	Connected Pipes (+ = in, = out)	Pressure	Pressure Units	Balance Energy
1	1, 2, 3	249000	Pascals	No
2	1,2,3	50000	Pascals	No

AFT Fathom 3.0 Output
NUMATEC HANFORD CORPORATION

(1)

11/30/1999

Sample 10 Fluid Mechanics Frank White 1979 p 363

Title Sample 10 Fluid Mechanics Frank White 1979 p 363

Analysis run on 11/30/1999 2 53 21 PM

Input File C:\FATHOM\SAMPLES\SAMPLE10.FTH

Execution Time= 0.11 seconds

(Iteration History was ON)

Total Number Of Head/Pressure Iterations= 0

Total Number Of Temperature Iterations= 0

Total Number Of Flow Iterations= 4

Number Of Pipes= 3

Number Of Junctions= 2

Head Tolerance= 0.01 meters

Volumetric Flow Rate Tolerance= 0.01 m3/hr

Relaxation= 1 (None)

Constant Fluid Property Model

Fluid Unspecified

Density= 1000 kg/m3

Viscosity= 0.0102 kg/sec-m

Vapor Pressure=

Gravitational Acceleration= 1 g

Atmospheric Pressure= 1 atm

Total Inflow= 99.8796 m3/hr

Total Outflow= 99.8796 m3/hr

Maximum Pressure is 35.5288 psia at Junction 1 Inlet

Minimum Pressure is 6.66630 psia at Junction 2 Inlet

Pipe	Vol Flow (m3/hr)	Mass Flow (lbm/sec)	Velocity (feet/sec)	dP Total (psid)	dP Friction (psid)	dP Gravity (psid)	dH (feet)	Max Pres (psia)	Min Pres (psia)	Dyn Pres (psia)
1	62.5578	38.31010	11.34212	28.8625	28.8625	0	66.5759	35.2477	6.38518	0.866702
2	25.9119	15.86832	8.35197	28.8625	28.8625	0	66.5759	35.6444	6.78193	0.469959
3	11.4099	6.98739	8.27476	28.8625	28.8625	0	66.5759	35.6531	6.79058	0.461310

Pipe	dPf/dx (psi/100 ft)	Resistance (sec2/ft5)	f	Reynolds No	fL/D	K	fL/D + K
1	8.79729	176.787	0.0266412	2.71143E+05	33.3015	0	33.3015
2	5.86486	1030.419	0.0245660	1.49746E+05	61.4150	0	61.4150
3	10.99661	5314.301	0.0312832	9.89078E+04	62.5664	0	62.5664

Jct	dP (psid)	dH (feet)	Vol Flow Into System (gal/min)	Loss Factor (K)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)	P Stag In (psia)
1	0	0	439.757	0.00000	49.4050	49.4050	48.0542	48.0542	36.11439
2	0	0	-439.757	0.00000	17.1710	17.1710	18.5217	18.5217	7.25188

Jct	P Stag Out (psia)	P Inlet (psia)	P Outlet (psia)
1	36.11439	35.52880	35.52880
2	7.25188	6.66630	6.66630

Sample #11

2 pipes 3 junctions

Model of a simple series flow pressure drop with component losses included Water is the working fluid

Reference *Marks Standard Handbook for Mechanical Engineers* 8th ed 1978 T Baumeister editor p 3 58

Water at 68°F leaves an open tank whose surface elevation is 180 ft and enters a 2-in schedule 40 steel pipe via a sharp edged entrance After 50 ft of straight 2 in pipe that contains a 2-in globe valve the line enlarges suddenly to an 8 in schedule 40 steel pipe which consists of 100 ft of straight 8 in pipe two standard 90° elbows and one 8 in angle valve The 8 in line discharges below the surface of another open tank whose surface elevation is 100 ft Determine the volumetric flow rate

AFT Fathom 3.0 Input
NUMATEC HANFORD CORPORATION

(1)

11/30/1999 02:58 PM

Sample 11 Marks Standard Handbook for Mechanical Engineers 8th ed 1978 p 3 58

Title Sample 11 Marks Standard Handbook for Mechanical Engineers 8th ed 1978 p 3 58

Number Of Pipes= 2
Number Of Junctions= 3

Head/Pressure Convergence= 0.01 feet
Flow Rate Convergence= 0.01 ft³/sec
Relaxation= AFT Fathom Automatic
Maximum Iterations= 500

Constant Fluid Property Model

Fluid Unspecified

Density= 62.4 lbm/ft³

Viscosity= 2.092E-05 lbf s/ft²

Vapor Pressure=

Gravitational Acceleration= 1 g

Atmospheric Pressure= 1 atm

Pipe	Name	Object Defined	Length	Length Units	Hydraulic Diameter	Hydraulic Diam Units	Roughness	Roughness Units	Losses (K)	Junctions (Up,Down)
1	Pipe	Yes	50	feet	2.067	inches	0.0015	feet	9.04	1, 2
2	Pipe	Yes	100	feet	7.981	inches	0.0015	feet	4.016	2, 3

Pipe	Geometry	Material	Size	Type	Thermal Boundary	Overall U	Include Internal h	Special Condition
1	Cylindrical Pipe	Steel	2 inch	schedule 40	Adiabatic	0	No	None
2	Cylindrical Pipe	Steel	8 inch	schedule 40	Adiabatic	0	No	None

Area Change	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units	Connected Pipes (+ = in, = out)
2	Area Change	Yes	N/A	180	feet			1, 2
Reservoir	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units	Connected Pipes (+ = in, = out)
1	Reservoir	Yes	N/A	180	feet	180	feet	1
3	Reservoir	Yes	N/A	100	feet	100	feet	2

Area Change	Type	Geometry	Angle	Loss Factor	
2	Abrupt	Unspecified		87	
Reservoir	Surface Pressure	Surface Pressure Units	Depth	Depth Units	Balance Energy
1	1	atm	100	feet	No
3	1	atm	100	feet	No

AFT Fathom 3.0 Output
NUMATEC HANFORD CORPORATION

(1)

12/01/1999

Sample 11 Marks Standard Handbook for Mechanical Engineers 8th ed 1978 p 3 58

Title Sample 11 Marks Standard Handbook for Mechanical Engineers 8th ed 1978 p 3 58

Analysis run on 12/01/1999 2 26 00 PM

Input File C:\FATHOM\SAMPLES\SAMPLE11.FTH

Execution Time= 0 11 seconds

Total Number Of Head/Pressure Iterations= 0

Total Number Of Temperature Iterations= 0

Total Number Of Flow Iterations= 3

Number Of Pipes= 2

Number Of Junctions= 3

Head Tolerance= 0.01 feet

Volumetric Flow Rate Tolerance= 0.01 ft3/sec

Relaxation= 1 (None)

Constant Fluid Property Model

Fluid Unspecified

Density= 62.4 lbm/ft3

Viscosity= 2.092E-05 lbf s/ft2

Vapor Pressure=

Gravitational Acceleration= 1 g

Atmospheric Pressure= 1 atm

Overall Delta Head = 80.0000 feet

Total Inflow= 0.414394 ft3/sec

Total Outflow= 0.414394 ft3/sec

Maximum Pressure is 58.0293 psia at Junction 1 Outlet

Minimum Pressure is 20.1704 psia at Junction 2 Inlet

Pipe	Vol Flow (ft3/sec)	Mass Flow (lbm/sec)	Velocity (feet/sec)	dP Total (psid)	dP Friction (psid)	dP Gravity (psid)	dH (feet)	Max Pres (psia)	Min Pres (psia)	Dyn Pres (psia)
1	0.414394	25.8582	17.78298	75.0054	31.6720295	43.3333	73.089303	54.8349	20.1704	2.12959146
2	0.414394	25.8582	1.19281	77.9325	0.0675128	78.0000	0.155799	58.0293	19.9032	0.00958140

Pipe	dP/dx (psi/100 ft)	Resistance (sec2/ft5)	f	Reynolds No	fL/D	K	fL/D + K
1	63.3440590	425.625779	0.0200924	2.83976E+05	5.83235	9.04000	14.87235
2	0.0675128	0.907273	0.0201711	7.35470E+04	3.03287	4.01600	7.04887

Jct	dP (psid)	dH (feet)	Vol Flow Into System (gal/min)	Loss Factor (K)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)
1	1.06479573	2.4572211	185.993	0.500000	180.000	180.000	180.0000	180.000
2	1.85274470	4.2755649	0.000	0.870000	104.453	100.178	99.5390	100.156
3	0.00958140	0.0221109	185.993	1.00000	100.000	100.000	100.0000	100.000

Jct	P Stag In (psia)	P Stag Out (psia)	P Inlet (psia)	P Outlet (psia)
1	14.6960	58.0293	14.6960	58.0293
2	18.0408	19.8936	20.1704	19.9032
3	14.6960	58.0293	14.6960	58.0293

Sample #12

2 pipes 2 junctions

Model of a simple series flow pressure drop with benzene as the working fluid

Reference *Marks Standard Handbook for Mechanical Engineers* 8th ed 1978 T Baumeister editor p 3 58

Benzene at 68°F flows at a rate of 0.5 ft³/s through two parallel straight horizontal pipes connecting two pressurized tanks. The pipes are both schedule 40 steel, one being 1 in. the other 2 in. They both are 100 ft long and have connections that project inwardly in the supply tank. If the pressure in the supply tank is maintained at 100 lbf/in², what pressure should be maintained on the receiving tank?

AFT Fathom 3.0 Input
NUMATEC HANFORD CORPORATION

(1)

11/30/1999 03:51 PM

Sample 12 Mark's Standard Handbook for Mechanical Engineers 8th ed 1978 p 3 58

Title Sample 12 Mark's Standard Handbook for Mechanical Engineers 8th ed 1978 p 3 58

Number Of Pipes= 2
Number Of Junctions= 2

Head/Pressure Convergence= 0.01 (Relative change)
Flow Rate Convergence= 0.01 (Relative change)
Relaxation= AFT Fathom Automatic
Maximum Iterations= 500

Constant Fluid Property Model
Fluid Unspecified
Density= 1.705 slug/ft³
Viscosity= 1.362E-05 lbf s/ft²
Vapor Pressure=
Gravitational Acceleration= 1 g
Atmospheric Pressure= 1 atm

Pipe	Name	Object Defined	Length	Length Units	Hydraulic Diameter	Hydraulic Diam Units	Roughness	Roughness Units	Losses (K)	Junctions (Up,Down)
1	Pipe	Yes	100	feet	1.049	inches	0.0015	feet	0	1, 2
2	Pipe	Yes	100	feet	2.067	inches	0.0015	feet	0	1, 2

Pipe	Geometry	Material	Size	Type	Thermal Boundary	Overall U	Include Internal h	Special Condition
1	Cylindrical Pipe	Steel	1 inch	schedule 40	Adiabatic	0	No	None
2	Cylindrical Pipe	Steel	2 inch	schedule 40	Adiabatic	0	No	None

Assigned Pressure	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units
1	Assigned Pressure	Yes	N/A	0	feet	100	psia
Branch	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units
2	Branch	Yes	None	0	feet		

Assigned Pressure	Connected Pipes (+ = in, = out)	Pressure	Pressure Units	Balance Energy
1	1, 2	100	psia	No
Branch	Connected Pipes (+ = in, = out)	Boundary Flow (+ = in/ = out)	Boundary Flow Units	
2	1,2	5	ft ³ /sec	

AFT Fathom 3.0 Output
NUMATEC HANFORD CORPORATION

(1)

11/30/1999

Sample 12 Marks Standard Handbook for Mechanical Engineers 8th ed 1978 p 3 58

Title Sample 12 Marks Standard Handbook for Mechanical Engineers 8th ed 1978 p 3 58

Analysis run on 11/30/1999 3 51 03 PM

Input File C:\FATHOM\SAMPLES\SAMPLE12.FTH

Execution Time= 0 11 seconds

Total Number Of Head/Pressure Iterations= 8

Total Number Of Temperature Iterations= 0

Total Number Of Flow Iterations= 3

Number Of Pipes= 2

Number Of Junctions= 2

Head Tolerance= 0.01 relative change

Volumetric Flow Rate Tolerance= 0.01 relative change

Relaxation= 1 (None)

Constant Fluid Property Model

Fluid Unspecified

Density= 1.705 slug/ft³

Viscosity= 1.362E-05 lbf s/ft²

Vapor Pressure=

Gravitational Acceleration= 1 g

Atmospheric Pressure= 1 atm

Total Inflow= 0.500000 ft³/sec

Total Outflow= 0.500000 ft³/sec

Maximum Pressure is 100.000 psia at Junction 1 Inlet

Minimum Pressure is 73.5748 psia at Junction 2 Inlet

Junction 1 Loss Results

Pipe 1 1.77800 feet 0.677329 psid K= 0.780000

Pipe 2 4.07598 feet 1.55274 psid K= 0.780000

Pipe	Vol Flow (ft ³ /sec)	Mass Flow (lbm/sec)	Velocity (feet/sec)	dP Total (psid)	dP Friction (psid)	dP Gravity (psid)	dH (feet)	Max Pres (psia)	Min Pres (psia)	Dyn Pres (psia)
1	0.0726883	3.98745	12.1112	23.7572	23.7572	0	62.3631	98.4543	74.6971	0.868371
2	0.4273117	23.44093	18.3373	22.8818	22.8818	0	60.0651	96.4566	73.5748	1.990698

Pipe	dP/dx (psi/100 ft)	Resistance (sec ² /ft ⁵)	f	Reynolds No	fL/D	K	fL/D + K
1	23.7572	11,803.151	0.0239163	1.32534E+05	27.3589	0	27.3589
2	22.8818	328.952	0.0197990	3.95406E+05	11.4943	0	11.4943

Jct	dP (psid)	dH (feet)	Vol Flow Into System (ft ³ /sec)	Loss Factor (K)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)
1	See General	See General	0.500000	See General	223.925	223.925	223.925	218.699
2	0	0	0.500000	0.00000	159.784	155.708	154.558	155.708

Jct	P Stag In (psia)	P Stag Out (psia)	P Inlet (psia)	P Outlet (psia)
1	100.0000	100.0000	100.0000	98.0093
2	75.5655	74.0127	73.5748	74.0127

Sample #13

3 pipes 4 junctions

Model of a branching system with component losses included Ethyl alcohol is the working fluid

Reference *Marks Standard Handbook for Mechanical Engineers* 8th ed 1978 T Baumeister editor p 3 59

Ethyl alcohol at 68°F flows from tank A which is maintained at a constant pressure of 100 psi through 200 ft of 2 in cast iron schedule 40 pipe to a Y branch connection ($K = 0.5$) where 100 ft of 2-in pipe goes to tank B which is maintained at 80 psi and 50 ft of 2 in pipe to tank C which is also maintained at 80 psi All tank connections are flush and sharp edged and are at the same elevation Estimate the flow rate to each tank

AFT Fathom 3.0 Input
NUMATEC HANFORD CORPORATION

(1)

11/30/1999 04 07 PM

Sample 13 "Mark's Standard Handbook for Mechanical Engineers 8th ed 1978 p 3 59

Title Sample 13 "Mark's Standard Handbook for Mechanical Engineers 8th ed 1978 p 3 59

Number Of Pipes= 3
Number Of Junctions= 4

Head/Pressure Convergence= 0.01 psia
Flow Rate Convergence= 0.01 ft³/sec
Relaxation= AFT Fathom Automatic
Maximum Iterations= 500

Constant Fluid Property Model

Fluid Unspecified

Density= 1.532 slug/ft³

Viscosity= 2.506E-05 lbf s/ft²

Vapor Pressure=

Gravitational Acceleration= 1 g

Atmospheric Pressure= 1 atm

Pipe	Name	Object Defined	Length Units	Length	Hydraulic Diameter	Hydraulic Diam Units	Roughness	Roughness Units	Losses (K)	Junctions (Up,Down)
1	Pipe	Yes	feet	200	2.067	inches	0.0085	feet	5	1, 2
2	Pipe	Yes	feet	100	2.067	inches	0.0085	feet	1	2, 3
3	Pipe	Yes	feet	50	2.067	inches	0.0085	feet	1	2, 4

Pipe	Geometry	Material	Thermal Boundary	Overall U	Include Internal h	Special Condition
1	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
2	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
3	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None

Assigned Pressure	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units
1	Assigned Pressure	Yes	N/A	0	feet	100	psia
3	Assigned Pressure	Yes	N/A	0	feet	80	psia
4	Assigned Pressure	Yes	N/A	0	feet	80	psia
Branch	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units
2	Branch	Yes	None	0	feet		

Assigned Pressure	Connected Pipes (+ = in, = out)	Pressure	Pressure Units	Balance Energy
1	1	100	psia	No
3	2	80	psia	No
4	3	80	psia	No
Branch	Connected Pipes (+ = in, = out)	Boundary Flow (+ = in/ = out)	Boundary Flow Units	
2	1, 2, 3	0	ft ³ /sec	

Pipe Losses	K Total	Entrances	Exits
1	0.5	1 (0.5)	
2	1.0		1 (1.0)
3	1.0		1 (1.0)

AFT Fathom 3.0 Output
NUMATEC HANFORD CORPORATION

(1)

11/30/1999

Sample 13 Marks Standard Handbook for Mechanical Engineers 8th ed 1978 p 3 59

Title Sample 13 Marks Standard Handbook for Mechanical Engineers 8th ed 1978 p 3 59

Analysis run on 11/30/1999 4 06 22 PM

Input File C:\FATHOM\SAMPLES\SAMPLE13.FTH

Execution Time= 0 11 seconds

Total Number Of Head/Pressure Iterations= 8

Total Number Of Temperature Iterations= 0

Total Number Of Flow Iterations= 3

Number Of Pipes= 3

Number Of Junctions= 4

Pressure Tolerance= 001 psia

Volumetric Flow Rate Tolerance= 001 ft3/sec

Relaxation= 1 (None)

Constant Fluid Property Model

Fluid Unspecified

Density= 1 532 slug/ft3

Viscosity= 2 506E-05 lbf s/ft2

Vapor Pressure=

Gravitational Acceleration= 1 g

Atmospheric Pressure= 1 atm

Total Inflow= 0 225202 ft3/sec

Total Outflow= 0 225202 ft3/sec

Maximum Pressure is 99 5032 psi at Junction 1 Inlet

Minimum Pressure is 79 8335 psi at Junction 4 Inlet

Junction 2 Loss Results

Pipe 2 0 128713 feet 0 0440579 psid K= 0 500000

Pipe 3 0 243169 feet 0 0832356 psid K= 0 500000

Pipe	Vol Flow (ft3/sec)	Mass Flow (lbm/sec)	Velocity (feet/sec)	dP Total (psid)	dP Friction (psid)	dP Gravity (psid)	dH (feet)	Max Pres (psia)	Min Pres (psia)	Dyn Pres (psia)
1	0 2252023	11 10036	9 86417	18 21457	18 21457	0	53 21291	99 5032	81 2886	0 4968164
2	0 0948423	4 67483	4 06999	1 74137	1 74137	0	5 08733	81 6533	79 9119	0 0881158
3	0 1303601	6 42553	5 59418	1 70220	1 70220	0	4 97288	81 5357	79 8335	0 1664713

Pipe	dPf/dx (psi/100 ft)	Resistance (sec2/ft5)	f	Reynolds No	fL/D	K	fL/D + K
1	9 10728	1049 231	0 0311452	1 01766E+05	36 16275	0 500000	36 6628
2	1 74137	565 570	0 0323188	4 28579E+04	18 78272	1 000000	19 7627
3	3 40439	292 630	0 0317808	5 89079E+04	9 22519	1 000000	10 2252

Jct	dP (psid)	dH (feet)	Vol Flow Into System (gal/min)	Loss Factor (K)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)
1	0	0	101 0778	0 00000	249 211	249 211	247 760	247 760
2	See General	See General	0 0000	See General	195 998	195 998	195 353	195 353
3	0	0	-42 5681	0 00000	190 782	190 782	190 525	190 525
4	0	0	58 5096	0 00000	190 782	190 782	190 296	190 296

Jct	P Stag In (psia)	P Stag Out (psia)	P Inlet (psia)	P Outlet (psia)
1	100 0000	100 0000	99 5032	99 5032
2	81 7854	81 7854	81 5646	81 5646
3	80 0000	80 0000	79 9119	79 9119
4	80 0000	80 0000	79 8335	79 8335

Pipe	K Total	Entrances	Exits
1	0 5	1 (0 5)	
2	1 0		1 (1 0)
3	1 0		1 (1 0)

Sample #14

2 pipes 3 junctions

Model of a siphoning system The problem is to determine how high a junction can be raised and still continue flowing Water is the working fluid

Reference *Marks Standard Handbook for Mechanical Engineers* 8th ed 1978 T Baumeister editor p 3-60

The siphon shown in [sample problem] is composed of 2000 ft of 6-in schedule 40 cast iron pipe Reservoir J1 is at elevation 800 ft and J2 at 600 ft Estimate the maximum height of junction J3 if the water temperature may reach 104oF The amount of straight pipe from A to B is 100 ft For the first bend $L/D = 25$ and the second $L/D = 50$ Atmospheric pressure is 14.7 psia

AFT Fathom 3.0 Input
NUMATEC HANFORD CORPORATION

(1)

12/01/1999 09:30 AM

Sample 14 Marks Standard Handbook for Mechanical Engineers 8th ed 1978 p 3-60

Title Sample 14 Marks Standard Handbook for Mechanical Engineers 8th ed 1978 p 3-60

Number Of Pipes= 2

Number Of Junctions= 3

Head/Pressure Convergence= 0.01 feet

Flow Rate Convergence= 0.01 ft³/sec

Relaxation= AFT Fathom Automatic

Maximum Iterations= 500

Constant Fluid Property Model

Fluid Unspecified

Density= 1.925 slug/ft³

Viscosity= 1.361E-05 lbf s/ft²

Vapor Pressure= 1.07 psia

Gravitational Acceleration= 1 g

Atmospheric Pressure= 1 atm

Pipe	Name	Object Defined	Length	Length Units	Hydraulic Diameter	Hydraulic Diam Units	Roughness	Roughness Units	Losses (K)	Junctions (Up,Down)
1	Pipe	Yes	1900	feet	6.065	inches	0.0085	feet	2.1	3, 2
2	Pipe	Yes	100	feet	6.065	inches	0.0085	feet	1.5	1, 3

Pipe	Geometry	Material	Thermal Boundary	Overall U	Include Internal h	Special Condition
1	Cylindrical Pipe	Cast Iron	Adiabatic	0	No	None
2	Cylindrical Pipe	Cast Iron	Adiabatic	0	No	None

Branch	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units	Connected Pipes (+ = in, = out)
3	Branch	Yes	None	816.69	feet			1, 2

Reservoir	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units	Connected Pipes (+ = in, = out)
1	Reservoir	Yes	N/A	800	feet	800	feet	2
2	Reservoir	Yes	N/A	600	feet	600	feet	1

Branch	Boundary Flow (+ = in, = out)	Boundary Flow Units			
3	0	ft ³ /sec			

Reservoir	Surface Pressure	Surface Pressure Units	Depth	Depth Units	Balance Energy
1	1	atm	0	feet	No
2	1	atm	0	feet	No

AFT Fathom 3.0 Output
NUMATEC HANFORD CORPORATION

(1)

12/01/1999

Sample 14 Mark's Standard Handbook for Mechanical Engineers 8th ed 1978 p 3-60

Title Sample 14 Mark's Standard Handbook for Mechanical Engineers 8th ed 1978 p 3-60

Analysis run on 12/01/1999 9 28 06 AM

Input File C:\FATHOM\SAMPLES\SAMPLE14.FTH

Execution Time= 0.11 seconds

Total Number Of Head/Pressure Iterations= 0

Total Number Of Temperature Iterations= 0

Total Number Of Flow Iterations= 3

Number Of Pipes= 2

Number Of Junctions= 3

Head Tolerance= 0.01 feet

Volumetric Flow Rate Tolerance= 0.01 ft³/sec

Relaxation= 1 (None)

Constant Fluid Property Model

Fluid Unspecified

Density= 1.925 slug/ft³

Viscosity= 1.361E-05 lbf s/ft²

Vapor Pressure= 1.07 psia

Gravitational Acceleration= 1 g

Atmospheric Pressure= 1 atm

Overall Delta Head = 200.000 feet

Total Inflow= 2.35942 ft³/sec

Total Outflow= 2.35942 ft³/sec

Maximum Pressure is 14.6960 psia at Junction 1 Outlet

Minimum Pressure is 1.07183 psia at Junction 3 Inlet

Pipe	Vol Flow (gal/min)	Mass Flow (lbm/sec)	Velocity (feet/sec)	dP Total (psid)	dP Friction (psid)	dP Gravity (psid)	dH (feet)	Max Pres (psia)	Min Pres (psia)	Dyn Pres (psia)
1	1058.98	146.131	11.7602	12.6997	80.49958	93.19930	187.1629	13.7716	1.07183	0.924424
2	1058.98	146.131	11.7602	12.6997	5.52128	7.17844	12.8371	13.7716	1.07183	0.924424

Pipe	dP/dx (psi/100 ft)	Resistance (sec ² /ft ⁵)	f	Reynolds No	fL/D	K	fL/D + K
1	4.23682	33.62091	0.0226056	8.40696E+05	84.98075	2.10000	87.08075
2	5.52128	2.30598	0.0226056	8.40696E+05	4.47267	1.50000	5.97267

Jct	dP (psid)	dH (feet)	Vol Flow Into System (gal/min)	Loss Factor (K)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)	P Stag In (psia)
1	0	0	1058.98	0.00000	800.000	800.000	800.000	800.000	14.69598
2	0	0	1058.98	0.00000	600.000	600.000	600.000	600.000	14.69598
3	0	0	0.00	0.00000	787.163	787.163	785.014	785.014	1.99626

Jct	P Stag Out (psia)	P Inlet (psia)	P Outlet (psia)
1	14.69598	14.69598	14.69598
2	14.69598	14.69598	14.69598
3	1.99626	1.07183	1.07183

Sample #15

1 pipes 2 junctions

Model of the pressure drop through an cylindrical annulus Water is the working fluid

Reference White F *Fluid Mechanics* 1979 p 349

AFT Fathom 3.0 Input
NUMATEC HANFORD CORPORATION

(1)

12/01/1999 10 20 AM

Sample 15 Fluid Mechanics Frank White 1979 p 349

Title Sample 15 Fluid Mechanics Frank White 1979 p 349

Number Of Pipes= 1

Number Of Junctions= 2

Head/Pressure Convergence= 001 meters

Flow Rate Convergence= 0001 m3/sec

Relaxation= AFT Fathom Automatic

Maximum Iterations= 500

Constant Fluid Property Model

Fluid Unspecified

Density= 1000 kg/m3

Viscosity= 00102 kg/sec-m

Vapor Pressure=

Gravitational Acceleration= 1 g

Atmospheric Pressure= 1 atm

Pipe	Name	Object Defined	Length	Length Units	Hydraulic Diameter	Hydraulic Diam Units	Roughness	Roughness Units	Losses (K)	Junctions (Up,Down)
1	Pipe	Yes	30	meters	4	cm	046	mm	1	1, 3

Pipe	Geometry	Material	Thermal Boundary	Overall U	Include Internal h	Outer Pipe ID	Outer Pipe ID Units	Inner Pipe OD
1	Cylindrical Annulus	Unspecified	Adiabatic	0	No	10	cm	6

Pipe	Inner Pipe OD Units	Special Condition
1	cm	None

Assigned Flow	Name	Object Defined	Special Condition	Elevation	Elevation Units	Connected Pipes (+ = in, = out)	Type	Flow	Flow Units
1	Assigned Flow	Yes	None	0	meters	1	Inflow	01	m3/sec
Reservoir	Name	Object Defined	Special Condition	Elevation	Elevation Units	Connected Pipes (+ = in, = out)	Surface Pressure	Surface Pressure Units	Depth
3	Reservoir	Yes	N/A	0	meters	1	1	atm	0

Assigned Flow	Loss Factor	
1	0	
Reservoir	Depth Units	Balance Energy
3	meters	No

Pipe Losses	K Total	Entrances
1	1.0	2 (1.0)

AFT Fathom 3.0 Output
NUMATEC HANFORD CORPORATION

(1)

12/01/1999

Sample 15 Fluid Mechanics Frank White 1979 p 349

Title Sample 15 Fluid Mechanics Frank White 1979 p 349
Analysis run on 12/01/1999 10 05 30 AM
Input File C:\FATHOM\SAMPLES\SAMPLE15.FTH

Execution Time= 0.11 seconds
Total Number Of Head/Pressure Iterations= 0
Total Number Of Temperature Iterations= 0
Total Number Of Flow Iterations= 2
Number Of Pipes= 1
Number Of Junctions= 2
Head Tolerance= 0.01 meters
Volumetric Flow Rate Tolerance= 0.001 m3/sec
Relaxation= 1 (None)

Constant Fluid Property Model
Fluid Unspecified
Density= 1000 kg/m3
Viscosity= 0.0102 kg/sec-m
Vapor Pressure=
Gravitational Acceleration= 1 g
Atmospheric Pressure= 1 atm

Overall Delta Head = 12.1797 feet
Total Inflow= 0.353147 ft3/sec
Total Outflow= 0.353147 ft3/sec
Maximum Pressure is 0.135752 MPa at Junction 1 Inlet
Minimum Pressure is 0.101325 MPa at Junction 3 Outlet

Pipe	Vol Flow (m3/sec)	Mass Flow (lbm/sec)	Velocity (feet/sec)	dP Total (psid)	dP Friction (psid)	dP Gravity (psid)	dH (meters)	Max Pres (psia)	Min Pres (psia)	Dyn Pres (psia)
1	0.0100000	22.0462	6.52702	5.28024	5.28024	0	3.71238	19.6892	14.4090	0.287020

Pipe	dPf/dx (psi/100 ft)	Resistance (sec2/ft5)	f	Reynolds No	fL/D	K	fL/D + K
1	5.36472	97.6623	0.0231957	7.80171E+04	17.3968	1.00000	18.3968

Jct	dP (psid)	dH (feet)	Vol Flow Into System (gal/min)	Loss Factor (K)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)	P Stag In (psia)
1	0	0	158.503	0.00000	12.1797	12.1797	11.5177	11.5177	19.9762
3	0	0	158.503	0.00000	0.0000	0.0000	0.0000	0.0000	14.6960

Jct	P Stag Out (psia)	P Inlet (psia)	P Outlet (psia)
1	19.9762	19.6892	19.6892
3	14.6960	14.6960	14.6960

Pipe	K Total	Entrances
1	1.0	2 (1.0)

Sample #16

8 pipes 9 junctions

Model of a branching system fed by three reservoirs one of which has a pump One loop is included
Water is the working fluid

Reference Jeppson R W *Analysis of Flow in Pipe Networks* 1976 p 94

Water supply comes from one pump and two reservoirs as shown below The elevation of all junctions is 80 feet The pump characteristic curve is given by $h_p = -10.33Q^2 + 2.823Q + 22.29$ There is an outflow of 2.0 cfs leaving the system at junction 2 Assume all pipes have $e = 0.012$ inch Find the flow and head loss in each pipe and the head and pressures at each junction

AFT Fathom 3.0 Input
NUMATEC HANFORD CORPORATION

(1)

12/01/1999 10:40 AM

Sample 16 Analysis of Flow in Pipe Networks Roland Jeppson 1976 p 94

Title Sample 16 Analysis of Flow in Pipe Networks Roland Jeppson 1976 p 94

Number Of Pipes= 8

Number Of Junctions= 8

Head/Pressure Convergence= 0001 feet

Flow Rate Convergence= 0001 ft³/sec

Relaxation= 1

Maximum Iterations= 500

Constant Fluid Property Model

Fluid Unspecified

Density= 62.4 lbm/ft³

Viscosity= 0.006558 lbm/s ft

Vapor Pressure=

Gravitational Acceleration= 1 g

Atmospheric Pressure= 1 atm

Pipe	Name	Object Defined	Length	Length Units	Hydraulic Diameter	Hydraulic Diam Units	Roughness	Roughness Units	Losses (K)	Junctions (Up,Down)
1	Pipe	Yes	1000	feet	8	inches	0.12	inches	0	5, 1
2	Pipe	Yes	2000	feet	6	inches	0.12	inches	0	1, 2
3	Pipe	Yes	2000	feet	8	inches	0.12	inches	0	3, 2
4	Pipe	Yes	1000	feet	8	inches	0.12	inches	0	4, 3
5	Pipe	Yes	1000	feet	6	inches	0.12	inches	0	6, 3
6	Pipe	Yes	1000	feet	6	inches	0.12	inches	0	1, 4
7	Pipe	Yes	500	feet	6	inches	0.12	inches	0	8, 4
8	Pipe	Yes	500	feet	6	inches	0.12	inches	0	7, 8

Pipe	Geometry	Material	Thermal Boundary	Overall U	Include Internal h	Special Condition
1	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
2	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
3	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
4	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
5	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
6	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
7	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
8	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None

Branch	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units	Connected Pipes (+ = in, = out)
1	Branch	Yes	None	80	feet			1, 2, -6
2	Branch	Yes	None	80	feet			2, 3
3	Branch	Yes	None	80	feet			3, 4, 5
4	Branch	Yes	None	80	feet			-4, 6, 7
Pump	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units	Connected Pipes (+ = in, = out)
8	Pump	Yes	None	80	feet			8, 7
Reservoir	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units	Connected Pipes (+ = in, = out)
5	Reservoir	Yes	N/A	100	feet	100	feet	1
6	Reservoir	Yes	N/A	105	feet	105	feet	5
7	Reservoir	Yes	N/A	95	feet	95	feet	8

AFT Fathom 3.0 Input
NUMATEC HANFORD CORPORATION

(2)

12/01/1999 10 40 AM

Branch	Boundary Flow (+ = in/ = out)	Boundary Flow Units						
1								
2	900	gal/min						
3								
4								
Pump	Independent Variable	Ind Variable Units	Dependent Variable	Dep Variable Units	Loss Constant a	Loss Constant b	Loss Constant c	Loss Constant d
8	Vol Flow	ft3/sec	Head	feet	22.29	2.823	10.33	0
Reservoir	Surface Pressure	Surface Pressure Units	Depth	Depth Units	Density	Density Units	Temperature	Temperature Units
5	1	atm	0	feet				
6	1	atm	0	feet				
7	1	atm	0	feet				

Branch			
1			
2			
3			
4			
Pump	Loss Constant e	Speed %	Viscosity Correction
8	0	100	No
Reservoir	Balance Energy		
5	No		
6	No		
7	No		

Pipe 1 Detailed Input Data

Name Pipe
Geometry Cylindrical Pipe
Material Unspecified
Inner Diameter= 8 inches
Length= 1000 feet
Absolute Roughness= 0.12 inches
Additional Losses= 0

Pipe 2 Detailed Input Data

Name Pipe
Geometry Cylindrical Pipe
Material Unspecified
Inner Diameter= 6 inches
Length= 2000 feet
Absolute Roughness= 0.12 inches
Additional Losses= 0

Pipe 3 Detailed Input Data

Name Pipe
Geometry Cylindrical Pipe
Material Unspecified
Inner Diameter= 8 inches

AFT Fathom 3.0 Input
NUMATEC HANFORD CORPORATION

(3)

12/01/1999 10:40 AM

Sample 16 Analysis of Flow in Pipe Networks Roland Jeppson 1976 p 94

Pipe 3 Detailed Input Data (cont.)

Length= 2000 feet
Absolute Roughness= 0.12 inches
Additional Losses= 0

Pipe 4 Detailed Input Data

Name Pipe
Geometry Cylindrical Pipe
Material Unspecified
Inner Diameter= 8 inches
Length= 1000 feet
Absolute Roughness= 0.12 inches
Additional Losses= 0

Pipe 5 Detailed Input Data

Name Pipe
Geometry Cylindrical Pipe
Material Unspecified
Inner Diameter= 6 inches
Length= 1000 feet
Absolute Roughness= 0.12 inches
Additional Losses= 0

Pipe 6 Detailed Input Data

Name Pipe
Geometry Cylindrical Pipe
Material Unspecified
Inner Diameter= 6 inches
Length= 1000 feet
Absolute Roughness= 0.12 inches
Additional Losses= 0

Pipe 7 Detailed Input Data

Name Pipe
Geometry Cylindrical Pipe
Material Unspecified
Inner Diameter= 6 inches
Length= 500 feet
Absolute Roughness= 0.12 inches
Additional Losses= 0

Pipe 8 Detailed Input Data

Name Pipe
Geometry Cylindrical Pipe
Material Unspecified
Inner Diameter= 6 inches
Length= 500 feet
Absolute Roughness= 0.12 inches
Additional Losses= 0

AFT Fathom 3.0 Output
NUMATEC HANFORD CORPORATION

(1)

12/01/1999

Sample 16 Analysis of Flow in Pipe Networks Roland Jeppson 1976 p 94

Title Sample 16 Analysis of Flow in Pipe Networks Roland Jeppson 1976 p 94
Analysis run on 12/01/1999 10 39 23 AM
Input File C:\FATHOM\SAMPLES\SAMPLE16.FTH

Execution Time= 0 27 seconds
Total Number Of Head/Pressure Iterations= 21
Total Number Of Temperature Iterations= 0
Total Number Of Flow Iterations= 7
Number Of Pipes= 8
Number Of Junctions= 8
Head Tolerance= 0001 feet
Volumetric Flow Rate Tolerance= 0001 ft3/sec
Relaxation= 1 (None)

Constant Fluid Property Model
Fluid Unspecified
Density= 62.4 lbm/ft3
Viscosity= 0.006558 lbm/s ft
Vapor Pressure=
Gravitational Acceleration= 1 g
Atmospheric Pressure= 1 atm

Total Inflow= 2.00521 ft3/sec
Total Outflow= 2.00521 ft3/sec
Maximum Pressure is 25.7554 psia at Junction 8 Outlet
Minimum Pressure is 14.6960 psia at Junction 5 Outlet

=====PUMP SUMMARY=====

Jct	Flow (ft3/sec)	DP (psid)	DH (feet)	Speed (%)	ideal hp (hp)	NPSHA (feet)	NPSHR (feet)
8	0.82916	7.5958	17.529	100.00	1.6487	N/A	N/A

Pipe	Vol Flow (ft3/sec)	Mass Flow (lbm/sec)	Velocity (feet/sec)	dP Total (psid)	dP Friction (psid)	dP Gravity (psid)	dH (feet)	Max Pres (psia)	Min Pres (psia)	Dyn Pres (psia)
1	0.535126	33.39189	1.533025	8.102343	0.564323	8.66667	1.302285	22.7825	14.6802	0.01582651
2	0.663565	41.40648	3.379511	7.534648	7.534648	0.00000	17.387650	22.7214	15.1868	0.07691213
3	1.341644	83.71856	3.843526	6.745902	6.745902	0.00000	15.567466	21.9101	15.1642	0.09948251
4	0.700724	43.72517	2.007426	0.949843	0.949843	0.00000	2.191947	22.9323	21.9824	0.02713728
5	0.640920	39.99339	3.264178	7.313597	3.519736	10.83333	8.122469	21.9378	14.6242	0.07175209
6	-0.128439	-8.01459	-0.654134	0.161097	0.161097	0.00000	0.371763	22.9565	22.7954	0.00288151
7	0.829163	51.73976	4.222892	2.916030	2.916030	0.00000	6.729301	25.7554	22.8393	0.12009005
8	0.829163	51.73976	4.222892	3.583684	2.916316	-6.50000	6.729959	18.1596	14.5759	0.12009005

Pipe	dP/dx (psi/100 ft)	Resistance (sec2/ft5)	f	Reynolds No	fL/D	K	fL/D + K
1	0.0564323	4.54771	0.0237716	9.72458E+04	35.6574	0	35.6574
2	0.3767324	39.48875	0.0244911	1.60782E+05	97.9643	0	97.9643
3	0.3372951	8.64856	0.0226033	2.43810E+05	67.8099	0	67.8099
4	0.0949843	4.46412	0.0233343	1.27339E+05	35.0014	0	35.0014
5	0.3519736	19.77338	0.0245271	1.55295E+05	49.0542	0	49.0542
6	-0.0161097	22.53578	0.0279536	3.11207E+04	55.9071	0	55.9071
7	0.5832060	9.78792	0.0242844	2.00906E+05	24.2844	0	24.2844
8	0.5832631	9.78887	0.0242844	2.00906E+05	24.2844	0	24.2844

Jct	dP (psid)	dH (feet)	Vol Flow Into System (gal/min)	Loss Factor (K)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)	P Stag In (psia)
1	0.00000	0.0000	0.000	0.00000	98.6977	98.6977	98.6442	98.6442	22.7983
2	0.00000	0.0000	900.000	0.00000	81.3101	81.3101	81.0805	81.3101	15.2637
3	0.00000	0.0000	0.000	0.00000	96.8775	96.8775	96.7341	96.7341	22.0096

AFT Fathom 3.0 Output
NUMATEC HANFORD CORPORATION

(2)

12/01/1999

Jct	dP (psid)	dH (feet)	Vol Flow Into System (gal/min)	Loss Factor (K)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)	P Stag In (psia)
4	0.00000	0.0000	0.000	0.00000	99.0695	99.0695	98.9876	98.9876	22.9594
5	0.00000	0.0000	240.181	0.00000	100.0000	100.0000	100.0000	100.0000	14.6960
6	0.00000	0.0000	287.665	0.00000	105.0000	105.0000	105.0000	105.0000	14.6960
7	0.00000	0.0000	372.154	0.00000	95.0000	95.0000	95.0000	95.0000	14.6960
8	7.59579	17.5287	0.000	0.00000	88.2700	105.7988	87.9929	105.5216	18.2797

Jct	P Stag Out (psia)	P Inlet (psia)	P Outlet (psia)
1	22.7983	22.7751	22.7751
2	15.2637	15.1642	15.2637
3	22.0096	21.9474	21.9474
4	22.9594	22.9240	22.9240
5	14.6960	14.6960	14.6960
6	14.6960	14.6960	14.6960
7	14.6960	14.6960	14.6960
8	25.8755	18.1596	25.7554

Pipe 1 Detailed Input Data

Name Pipe
Geometry Cylindrical Pipe
Material Unspecified
Inner Diameter= 8 inches
Length= 1000 feet
Absolute Roughness= 0.12 inches
Additional Losses= 0

Pipe 2 Detailed Input Data

Name Pipe
Geometry Cylindrical Pipe
Material Unspecified
Inner Diameter= 6 inches
Length= 2000 feet
Absolute Roughness= 0.12 inches
Additional Losses= 0

Pipe 3 Detailed Input Data

Name Pipe
Geometry Cylindrical Pipe
Material Unspecified
Inner Diameter= 8 inches
Length= 2000 feet
Absolute Roughness= 0.12 inches
Additional Losses= 0

Pipe 4 Detailed Input Data

Name Pipe
Geometry Cylindrical Pipe
Material Unspecified
Inner Diameter= 8 inches
Length= 1000 feet
Absolute Roughness= 0.12 inches
Additional Losses= 0

Pipe 5 Detailed Input Data

Name Pipe
Geometry Cylindrical Pipe
Material Unspecified

Sample 16 Analysis of Flow in Pipe Networks Roland Jeppson 1976 p 94

Pipe 5 Detailed Input Data (cont.)

Inner Diameter= 6 inches
Length= 1000 feet
Absolute Roughness= 0.12 inches
Additional Losses= 0

Pipe 6 Detailed Input Data

Name Pipe
Geometry Cylindrical Pipe
Material Unspecified
Inner Diameter= 6 inches
Length= 1000 feet
Absolute Roughness= 0.12 inches
Additional Losses= 0

Pipe 7 Detailed Input Data

Name Pipe
Geometry Cylindrical Pipe
Material Unspecified
Inner Diameter= 6 inches
Length= 500 feet
Absolute Roughness= 0.12 inches
Additional Losses= 0

Pipe 8 Detailed Input Data

Name Pipe
Geometry Cylindrical Pipe
Material Unspecified
Inner Diameter= 6 inches
Length= 500 feet
Absolute Roughness= 0.12 inches
Additional Losses= 0

Sample #17

10 pipes 9 junctions

Model of a branching system with a pump and a PRV Two loops are included Water is the working fluid

Reference Jeppson R W *Analysis of Flow in Pipe Networks* 1976 p 110

Solve the ten pipe network shown in the accompanying sketch which is supplied by two reservoirs with water surfaces at 180 and 200 feet respectively The PRV is located 450 feet downstream from the upstream junction [J2] and has a pressure setting which maintains the elevation of the HGL at 50 ft downstream from the valve The pump characteristics are the following $Q_1 = 1.0$ cfs @ $H_{p1} = 40$ ft $Q_2 = 1.5$ cfs @ $H_{p2} = 35$ ft $Q_3 = 2.0$ cfs @ $H_{p3} = 26$ ft There are outflows of 1.0 2.0 and 2.0 cfs at junctions 6 8 and 9 respectively Assume pipes 1 3 and 10 have CHW = 110 pipes 2 4 5 6 and 9 have CHW = 120 and pipes 7 and 8 have CHW = 130 Find the flow and head loss in each pipe the pump head added for each pump and the pressure at each junction

AFT Fathom 3.0 Input
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12/01/1999 10:56 AM

Sample 17 Analysis of Flow in Pipe Networks Roland Jeppson 1976 p 110

Title Sample 17 Analysis of Flow in Pipe Networks Roland Jeppson 1976 p 110

Number Of Pipes= 10
Number Of Junctions= 9

Head/Pressure Convergence= 0.001 (Relative change)
Flow Rate Convergence= 0.001 (Relative change)
Relaxation= 1
Maximum Iterations= 500

Constant Fluid Property Model

Fluid Water at 1 atm

Temperature 70 deg F

Density= 62.30842 lbm/ft³

Viscosity= 2.36004 lbm/hr ft

Vapor Pressure= 36157 psia

Gravitational Acceleration= 1 g

Atmospheric Pressure= 1 atm

Pipe	Name	Object Defined	Length	Length Units	Hydraulic Diameter	Hydraulic Diam Units	Roughness	Roughness Units	Losses (K)	Junctions (Up,Down)
1	Pipe	Yes	500	feet	6	inches	110	C Hazen Williams	0	1, 9
2	Pipe	Yes	800	feet	6	inches	120	C Hazen Williams	0	2, 3
3	Pipe	Yes	1000	feet	6	inches	110	C Hazen Williams	0	4, 3
4	Pipe	Yes	800	feet	6	inches	120	C Hazen Williams	0	4, 1
5	Pipe	Yes	450	feet	6	inches	120	C Hazen Williams	0	2, 6
6	Pipe	Yes	1000	feet	6	inches	120	C Hazen Williams	0	3, 5
7	Pipe	Yes	500	feet	8	inches	130	C Hazen Williams	0	7, 1
8	Pipe	Yes	500	feet	8	inches	130	C Hazen Williams	0	8, 4
9	Pipe	Yes	750	feet	6	inches	120	C Hazen Williams	0	6, 5
10	Pipe	Yes	500	feet	6	inches	110	C Hazen Williams	0	9, 2

Pipe	Geometry	Material	Thermal Boundary	Overall U	Include Internal h	Special Condition
1	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
2	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
3	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
4	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
5	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
6	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
7	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
8	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
9	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
10	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None

Branch	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units
1	Branch	Yes	None	0	feet		
2	Branch	Yes	None	0	feet		
3	Branch	Yes	None	0	feet		
4	Branch	Yes	None	0	feet		
5	Branch	Yes	None	0	feet		
Control Valve	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units
6	One Way Valve	Yes	None	0	feet		
Pump	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units

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9	Pump	Yes	None	100	feet		
Reservoir	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units
7	Reservoir	Yes	N/A	180	feet	180	feet
8	Reservoir	Yes	N/A	200	feet	200	feet

Branch	Connected Pipes (+ = in, = out)	Boundary Flow (+ = in/ = out)	Boundary Flow Units				
1	1,4,7	0	ft3/sec				
2	2, 5,10	2	ft3/sec				
3	2,3,-6	1	ft3/sec				
4	3,-4,8	0	ft3/sec				
5	6,9	2	ft3/sec				
Control Valve	Connected Pipes (+ = in, = out)	Valve Type	Control Units	Control	Action on Failure	Failed Loss Model	Failed Loss Value
6	5, 9	PRV	50	feet	Fail Open	None	
Pump	Connected Pipes (+ = in, = out)	Independent Variable	Ind Variable Units	Dependent Variable	Dep Variable Units	Loss Constant a	Loss Constant b
9	1, 10	Vol Flow	ft3/sec	Head	feet	38	10
Reservoir	Connected Pipes (+ = in, = out)	Surface Pressure	Surface Pressure Units	Depth	Depth Units	Density	Density Units
7	7	1	atm	0	feet		
8	8	1	atm	0	feet		

Branch					
1					
2					
3					
4					
5					
Control Valve					
6					
Pump	Loss Constant c	Loss Constant d	Loss Constant e	Speed %	Viscosity Correction
9	8	0	0	100	No
Reservoir	Temperature	Temperature Units	Balance Energy		
7			No		
8			No		

AFT Fathom 3.0 Output
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(1)

12/01/1999

Sample 17 Analysis of Flow in Pipe Networks Roland Jeppson 1976 p 110

Title Sample 17 Analysis of Flow in Pipe Networks Roland Jeppson 1976 p 110
Analysis run on 12/01/1999 10 48 16 AM
Input File C:\FATHOM\SAMPLES\SAMPLE17.FTH

Execution Time= 0.28 seconds
Total Number Of Head/Pressure Iterations= 31
Total Number Of Temperature Iterations= 0
Total Number Of Flow Iterations= 12
Number Of Pipes= 10
Number Of Junctions= 9
Head Tolerance= 0.001 relative change
Volumetric Flow Rate Tolerance= 0.001 relative change
Relaxation= 1 (None)

Constant Fluid Property Model
Fluid Water at 1 atm
Temperature 70 deg F
Density= 62.30842 lbm/ft³
Viscosity= 2.36004 lbm/hr ft
Vapor Pressure= 36157 psia
Gravitational Acceleration= 1 g
Atmospheric Pressure= 1 atm

Total Inflow= 5.00002 ft³/sec
Total Outflow= 5.00002 ft³/sec
Maximum Pressure is 93.0694 psia at Junction 4 Inlet
Minimum Pressure is 14.6960 psia at Junction 7 Outlet

=====PUMP SUMMARY=====

Jct	Flow (ft ³ /sec)	DP (psid)	DH (feet)	Speed (%)	ideal hp (hp)	NPSHA (feet)	NPSHR (feet)
9	2.5329	5.1944	12.005	100.00	3.4442	43.054	N/A

=====VALVE SUMMARY=====

Jct	Type	Flow (ft ³ /sec)	DP (psid)	DH (feet)	P Inlet (psia)	Cv	K	State
6	PRV	0.90867	0.33276	0.76904	36.664	706.63	2.3106	Open

Pipe	Vol Flow (ft ³ /sec)	Mass Flow (lbm/sec)	Velocity (feet/sec)	dP Total (psid)	dP Friction (psid)	dP Gravity (psid)	dH (feet)	Max Pres (psia)	Min Pres (psia)	Dyn Pres (psia)
1	2.532886	157.8201	12.89988	70.88551	27.61578	43.2697	63.82239	88.7576	17.8721	1.1189760
2	-0.375803	23.4157	1.91395	1.10244	1.10244	0.0000	2.54783	40.9172	39.8148	0.0246326
3	2.467133	153.7231	12.56501	52.60828	52.60828	0.0000	121.58218	92.4885	39.8802	1.0616332
4	0.720300	44.8808	3.66846	3.67350	3.67350	0.0000	8.48977	93.4596	89.7861	0.0904934
5	0.908670	56.8178	4.62782	3.17578	3.17578	0.0000	7.33949	39.6954	36.5196	0.1440131
6	1.091330	67.9990	5.55810	9.90397	9.90397	0.0000	22.88891	40.7341	30.8301	0.2077311
7	1.812586	112.9393	5.19268	75.18063	2.70489	77.8855	6.25122	89.6953	14.5147	0.1813141
8	3.187433	198.6039	9.13132	78.85413	7.68533	86.5395	17.76145	92.9894	14.1353	0.5606821
9	0.908670	56.8178	4.62782	5.29299	5.29299	0.0000	12.23254	36.1868	30.8938	0.1440131
10	2.532886	157.8201	12.89988	15.65365	27.61588	-43.2697	63.82263	38.7204	23.0666	1.1189760

Pipe	dPf/dx (psi/100 ft)	Resistance (sec ² /ft ⁵)	f	Reynolds No	fL/D	K	fL/D + K
1	5.523156	9.94814	0.0246795	6.13036E+05	24.6795	0	24.6795
2	-0.137805	18.04061	0.0279722	9.09557E+04	44.7555	0	44.7555
3	5.260828	19.97491	0.0247771	5.97121E+05	49.5541	0	49.5541
4	0.459187	16.36320	0.0253713	1.74335E+05	40.5941	0	40.5941

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(2)

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Pipe	dP/dx (psi/100 ft)	Resistance (sec ² /ft ⁵)	f	Reynolds No	fL/D	K	fL/D + K
5	0.705729	8.88902	0.0245024	2.19926E+05	22.0522	0	22.0522
6	0.990397	19.21821	0.0238384	2.64135E+05	47.6767	0	47.6767
7	0.540977	1.90269	0.0198910	3.29026E+05	14.9182	0	14.9182
8	1.537067	1.74822	0.0182762	5.78592E+05	13.7071	0	13.7071
9	0.705732	14.81508	0.0245024	2.19926E+05	36.7536	0	36.7536
10	5.523176	9.94817	0.0246795	6.13036E+05	24.6795	0	24.6795

Jct	dP (psid)	dH (feet)	Vol Flow Into System (gal/min)	Loss Factor (K)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)	P Stag In (psia)
1	0.000000	0.000000	0.000	0.00000	173.7488	173.7488	172.9311	172.9311	89.8766
2	0.000000	0.000000	-897.671	0.00000	58.1085	58.1085	57.4559	57.4559	39.8394
3	0.000000	0.000000	-448.831	0.00000	60.6564	60.6564	59.9631	59.9631	40.9418
4	0.000000	0.000000	0.000	0.00000	182.2385	182.2385	181.1276	181.1276	93.5501
5	0.000000	0.000000	897.662	0.00000	37.7675	36.9984	37.4346	36.9984	31.0379
6	0.332762	0.769041	0.000	2.31064	50.7690	50.0000	50.4362	49.6672	36.6636
7	0.000000	0.000000	813.545	0.00000	180.0000	180.0000	180.0000	180.0000	14.6960
8	0.000000	0.000000	1430.619	0.00000	200.0000	200.0000	200.0000	200.0000	14.6960
9	5.194432	12.004770	0.000	0.00000	109.9264	121.9312	107.3403	119.3451	18.9911

Jct	P Stag Out (psia)	P Inlet (psia)	P Outlet (psia)
1	89.8766	89.5228	89.5228
2	39.8394	39.5570	39.5570
3	40.9418	40.6419	40.6419
4	93.5501	93.0694	93.0694
5	30.7051	30.8938	30.7051
6	36.3308	36.5196	36.1868
7	14.6960	14.6960	14.6960
8	14.6960	14.6960	14.6960
9	24.1855	17.8721	23.0666

Sample #18

12 pipes 10 junctions

Model of a branching system fed by two reservoirs and containing two PRV's Several loops are included Water is the working fluid

Reference Jeppson R W *Analysis of Flow in Pipe Networks* 1976 p 111

Obtain the flow rates in each pipe and the pressure at each junction of the network in the accompanying sketch Water is flowing (in SI units the kinematic viscosity $\nu = 1.13 \times 10^{-6} \text{ m}^2/\text{s} = 0.0133 \text{ Stokes}$ and the specific weight $\gamma = 9800 \text{ N/m}^3$) Reservoir A and B are elevations of 300 m and 250 m respectively

AFT Fathom 3.0 Input
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(1)

12/01/1999 11 07 AM

Sample 18 Analysis of Flow in Pipe Networks Roland Jeppson 1976 p 111

Title Sample 18 Analysis of Flow in Pipe Networks Roland Jeppson 1976 p 111

Number Of Pipes= 12
Number Of Junctions= 10

Head/Pressure Convergence= 0.01 meters
Flow Rate Convergence= 0.0001 m3/sec
Relaxation= AFT Fathom Automatic
Maximum Iterations= 500

Constant Fluid Property Model

Fluid Unspecified

Density= 1000 kg/m3

Viscosity= 0.0113 kg/sec-m

Vapor Pressure=

Gravitational Acceleration= 1 g

Atmospheric Pressure= 1 atm

Pipe	Name	Object Defined	Length	Length Units	Hydraulic Diameter	Hydraulic Diam Units	Roughness Units	Losses (K)	Junctions (Up,Down)	Geometry
1	Pipe	Yes	500	meters	50	cm	Smooth	0	8, 1	Cylindrical Pipe
2	Pipe	Yes	500	meters	30	cm	Smooth	0	1, 2	Cylindrical Pipe
3	Pipe	Yes	600	meters	28	cm	Smooth	0	2, 3	Cylindrical Pipe
4	Pipe	Yes	500	meters	30	cm	Smooth	0	4, 3	Cylindrical Pipe
5	Pipe	Yes	600	meters	28	cm	Smooth	10	1, 4	Cylindrical Pipe
6	Pipe	Yes	500	meters	30	cm	Smooth	0	5, 4	Cylindrical Pipe
7	Pipe	Yes	250	meters	28	cm	Smooth	0	5, 7	Cylindrical Pipe
8	Pipe	Yes	200	meters	30	cm	Smooth	0	3, 10	Cylindrical Pipe
9	Pipe	Yes	1200	meters	20	cm	Smooth	0	1, 6	Cylindrical Pipe
10	Pipe	Yes	500	meters	40	cm	Smooth	0	9, 5	Cylindrical Pipe
11	Pipe	Yes	600	meters	28	cm	Smooth	0	7, 6	Cylindrical Pipe
12	Pipe	Yes	500	meters	30	cm	Smooth	0	10, 6	Cylindrical Pipe

Pipe	Material	Thermal Boundary	Overall U	Include Internal h	Special Condition
1	Unspecified	Adiabatic	0	No	None
2	Unspecified	Adiabatic	0	No	None
3	Unspecified	Adiabatic	0	No	None
4	Unspecified	Adiabatic	0	No	None
5	Unspecified	Adiabatic	0	No	None
6	Unspecified	Adiabatic	0	No	None
7	Unspecified	Adiabatic	0	No	None
8	Unspecified	Adiabatic	0	No	None
9	Unspecified	Adiabatic	0	No	None
10	Unspecified	Adiabatic	0	No	None
11	Unspecified	Adiabatic	0	No	None
12	Unspecified	Adiabatic	0	No	None

Branch	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units
1	Branch	Yes	None	200	meters		
2	Branch	Yes	None	200	meters		
3	Branch	Yes	None	180	meters		
4	Branch	Yes	None	180	meters		
5	Branch	Yes	None	200	meters		
6	Branch	Yes	None	140	meters		
Control Valve	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units

AFT Fathom 3.0 Input
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7	One-Way Valve	Yes	None	150	meters		
10	One Way Valve	Yes	None	145	meters		
Reservoir	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units
8	Reservoir	Yes	N/A	300	meters	300	meters
9	Reservoir	Yes	N/A	250	meters	250	meters

Branch	Connected Pipes (+ = in, = out)	Boundary Flow (+ = in/ = out)	Boundary Flow Units				
1	1, 2, 5, 9	0	m3/sec				
2	2, 3	1	m3/sec				
3	3, 4, 8	1	m3/sec				
4	-4, 5, 6	08	m3/sec				
5	-6, 7, 10	05	m3/sec				
6	9, 11, 12	12	m3/sec				
Control Valve	Connected Pipes (+ = in, = out)	Valve Type	Control	Control Units	Action on Failure	Failed Loss Model	
7	7, 11	PRV	150	meters	Fail Close	None	
10	8, 12	PRV	145	meters	Fail Close	None	
Reservoir	Connected Pipes (+ = in, = out)	Surface Pressure	Surface Pressure Units	Depth	Depth Units	Density	Balance Energy
8	1	1	atm	0	meters		No
9	10	1	atm	0	meters		No

AFT Fathom 3.0 Output
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(1)

12/01/1999

Sample 18 Analysis of Flow in Pipe Networks Roland Jeppson 1976 p 111

Title Sample 18 Analysis of Flow in Pipe Networks Roland Jeppson 1976 p 111

Analysis run on 12/01/1999 11 09 08 AM

Input File C:\FATHOM\SAMPLES\SAMPLE18.FTH

Execution Time= 0.71 seconds

Total Number Of Head/Pressure Iterations= 111

Total Number Of Temperature Iterations= 0

Total Number Of Flow Iterations= 16

Number Of Pipes= 12

Number Of Junctions= 10

Head Tolerance= .001 meters

Volumetric Flow Rate Tolerance= .00001 m3/sec

Relaxation= 1 (None)

Constant Fluid Property Model

Fluid Unspecified

Density= 1000 kg/m3

Viscosity= .00113 kg/sec-m

Vapor Pressure=

Gravitational Acceleration= 1 g

Atmospheric Pressure= 1 atm

Total Inflow= 0.651407 m3/sec

Total Outflow= 0.651407 m3/sec

Maximum Pressure is 1.29204 MPa at Junction 10 Inlet

Minimum Pressure is 0.101325 MPa at Junction 8 Outlet

=====VALVE SUMMARY=====

Jct	Type	Flow (m3/sec)	DP (psid)	DH (feet)	P Inlet (psia)	Cv	K	State
7	PRV	0.0000	19.769	45.600	159.93	N/A	0.0000	Failed Closed
10	PRV	0.0000	40.126	92.557	187.39	N/A	0.0000	Failed Closed

Pipe	Vol Flow (m3/sec)	Mass Flow (lbm/sec)	Velocity (feet/sec)	dP Total (psid)	dP Friction (psid)	dP Gravity (psid)	dH (meters)	Max Pres (psia)	Min Pres (psia)
1	0.6514074	1436.108	10.88448	133.51846	8.71497	142.23343	6.12723	147.4163	13.8978
2	0.2825215	622.853	13.11306	22.26664	22.26664	0.00000	15.65500	147.0560	124.7893
3	0.1825214	402.391	9.72507	11.66504	16.78163	28.44667	11.79865	136.9756	125.3106
4	-0.0825214	181.929	3.83018	2.36885	2.36885	0.00000	1.66547	137.5140	135.1452
5	0.2488859	548.700	13.26109	12.97045	41.41712	28.44667	29.11912	147.0296	134.0592
6	-0.2514074	554.258	11.66892	-46.43508	17.98841	28.44667	12.64710	134.3266	87.8915
7	0.0000000	0.000	0.00000	71.11671	0.00000	71.11671	0.00000	159.9256	88.8089
8	0.0000000	0.000	0.00000	-49.78170	0.00000	-49.78170	0.00000	187.3945	137.6128
9	0.1200000	264.555	12.53189	-6.16573	79.17432	85.34005	55.66505	153.3221	147.1564
10	0.2014074	-444.027	5.25836	74.11293	2.99621	71.11671	2.10655	88.6226	14.5097
11	0.0000000	0.000	0.00000	14.22334	0.00000	14.22334	0.00000	154.3802	140.1568
12	0.0000000	0.000	0.00000	7.11167	0.00000	7.11167	0.00000	154.3802	147.2685

Pipe	Dyn Pres (psia)	dP/dx (psi/100 ft)	Resistance (sec2/ft5)	f	Reynolds No	fL/D	K	fL/D + K
1	0.7981732	0.531265	0.0379869	0.0109186	1.48798E+06	10.9186	0.0000	10.9186
2	1.1584830	1.357374	0.5159705	0.0115323	1.06111E+06	19.2205	0.0000	19.2205
3	0.6371878	0.852507	0.9317071	0.0122906	7.34493E+05	26.3370	0.0000	26.3370
4	0.0988372	0.144405	0.6433945	0.0143803	3.09940E+05	23.9672	0.0000	23.9672
5	1.1847872	2.103990	1.2366657	0.0116468	1.00155E+06	24.9574	10.0000	34.9574
6	0.9173664	1.096573	0.5263926	0.0117653	9.44253E+05	19.6087	0.0000	19.6087
7	0.0000000	0.000000	0.0000000	0.0000000	0.00000E+00	0.0000	0.0000	0.0000
8	0.0000000	0.000000	0.0000000	0.0000000	0.00000E+00	0.0000	0.0000	0.0000

AFT Fathom 3.0 Output
NUMATEC HANFORD CORPORATION

(2)

12/01/1999

Pipe	Dyn Pres (psia)	dP/dx (psi/100 ft)	Resistance (sec ² /ft ⁵)	f	Reynolds No	fL/D	K	fL/D + K
9	1 0580702	2 011028	10 1693895	0 0124715	6 76056E+05	74 8290	0 0000	74 8290
10	0 1862871	-0 182649	0 1366140	0 0128670	5 67345E+05	16 0837	0 0000	16 0837
11	0 0000000	0 000000	0 0000000	0 0000000	0 00000E+00	0 0000	0 0000	0 0000
12	0 0000000	0 000000	0 0000000	0 0000000	0 00000E+00	0 0000	0 0000	0 0000

Jct	dP (psid)	dH (feet)	Vol Flow Into System (gal/min)	Loss Factor (K)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (meters)	HGL Outlet (meters)	P Stag In (psia)
1	0 0000	0 0000	0 000	0 00000	964 149	964 149	293 139	293 139	148 2144
2	0 0000	0 0000	1,585 032	0 00000	912 788	912 788	277 403	277 770	125 9478
3	0 0000	0 0000	1,585 032	0 00000	874 078	874 078	266 322	266 322	137 6128
4	0 0000	0 0000	1,268 026	0 00000	868 614	868 614	264 318	264 318	135 2440
5	0 0000	0 0000	792 516	0 00000	827 121	827 121	251 956	251 956	88 8089
6	0 0000	0 0000	1,902 038	0 00000	781 521	781 521	238 125	238 125	154 3802
7	19 7688	45 5998	0 000	0 00000	827 121	781 521	252 107	238 208	159 9256
8	0 0000	0 0000	10,325 015	0 00000	984 252	984 252	300 000	300 000	14 6960
9	0 0000	0 0000	3,192 371	0 00000	820 210	820 210	250 000	250 000	14 6960
10	40 1260	92 5571	0 000	0 00000	874 078	781 521	266 419	238 208	187 3945

Jct	P Stag Out (psia)	P Inlet (psia)	P Outlet (psia)
1	148 2144	147 1705	147 1705
2	125 9478	124 7893	125 3106
3	137 6128	137 4753	137 4753
4	135 2440	134 6248	134 6248
5	88 8089	88 5944	88 5944
6	154 3802	154 2626	154 2626
7	140 1568	159 9256	140 1568
8	14 6960	14 6960	14 6960
9	14 6960	14 6960	14 6960
10	147 2685	187 3945	147 2685

Sample #19

16 pipes 14 junctions

Model of a branching network fed by two reservoirs One reservoir has a pump One PRV is included
Water is the working fluid

Reference Jeppson R W *Analysis of Flow in Pipe Networks* 1976 p 88

As an example of a network in which a PRV acts as a check valve consider the 16 pipe network in the sketch below In this network the PRV is placed between pipes P5 and P15 and has a pressure setting which results in the elevation of the HGL downstream from the valve being 350 ft Solve for the flow rate in each pipe and the head at each junction The pump characteristics are the following $Q_1 = 2.0$ cfs @ $H_{p1} = 80$ ft $Q_2 = 3.0$ cfs @ $H_{p2} = 75$ ft $Q_3 = 4.0$ cfs @ $H_{p3} = 68$ ft (hp is in feet and Qp in cfs) There are outflow leaving the system as defined

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Sample 19 Analysis of Flow in Pipe Networks Roland Jeppson 1977 p 88

Title Sample 19 Analysis of Flow in Pipe Networks Roland Jeppson 1977 p 88

Number Of Pipes= 16
Number Of Junctions= 14

Head/Pressure Convergence= 00001 feet
Flow Rate Convergence= 00001 ft3/sec
Relaxation= AFT Fathom Automatic
Maximum Iterations= 500

Constant Fluid Property Model

Fluid Unspecified

Density= 62.4 lbm/ft3

Viscosity= 0.006558 lbm/s-ft

Vapor Pressure=

Gravitational Acceleration= 1 g

Atmospheric Pressure= 1 atm

Pipe	Name	Object Defined	Length	Length Units	Hydraulic Diameter	Hydraulic Diam Units	Roughness	Roughness Units	Losses (K)
1	Pipe	Yes	1000	feet	6	inches	01	inches	0
2	Pipe	Yes	1000	feet	8	inches	01	inches	0
3	Pipe	Yes	1000	feet	8	inches	01	inches	0
4	Pipe	Yes	250	feet	10	inches	01	inches	0
5	Pipe	Yes	500	feet	8	inches	01	inches	0
6	Pipe	Yes	1500	feet	8	inches	01	inches	0
7	Pipe	Yes	800	feet	6	inches	01	inches	0
8	Pipe	Yes	800	feet	6	inches	01	inches	0
9	Pipe	Yes	1000	feet	6	inches	01	inches	0
10	Pipe	Yes	600	feet	8	inches	01	inches	0
11	Pipe	Yes	1000	feet	8	inches	01	inches	0
12	Pipe	Yes	1000	feet	8	inches	01	inches	0
13	Pipe	Yes	1000	feet	8	inches	01	inches	0
14	Pipe	Yes	500	feet	10	inches	01	inches	0
15	Pipe	Yes	500	feet	8	inches	01	inches	0
16	Pipe	Yes	250	feet	10	inches	01	inches	0

Pipe	Initial Flow	Initial Flow Units	Junctions (Up, Down)	Geometry	Material	Thermal Boundary	Overall U	Include Internal h
1	5	ft3/sec	2, 1	Cylindrical Pipe	Unspecified	Adiabatic	0	No
2	37369948305699	ft3/sec	3, 2	Cylindrical Pipe	Unspecified	Adiabatic	0	No
3	2 16825299864968	ft3/sec	4, 3	Cylindrical Pipe	Unspecified	Adiabatic	0	No
4	3 16783112983741	ft3/sec	14, 4	Cylindrical Pipe	Unspecified	Adiabatic	0	No
5	0	ft3/sec	4, 13	Cylindrical Pipe	Unspecified	Adiabatic	0	No
6	1 00000004586222	ft3/sec	4, 5	Cylindrical Pipe	Unspecified	Adiabatic	0	No
7	246357792187553	ft3/sec	5, 6	Cylindrical Pipe	Unspecified	Adiabatic	0	No
8	253642223095689	ft3/sec	5, 7	Cylindrical Pipe	Unspecified	Adiabatic	0	No
9	4 63577891309046E-02	ft3/sec	6, 7	Cylindrical Pipe	Unspecified	Adiabatic	0	No
10	1	ft3/sec	9, 8	Cylindrical Pipe	Unspecified	Adiabatic	0	No
11	794553454453055	ft3/sec	3, 9	Cylindrical Pipe	Unspecified	Adiabatic	0	No
12	705868630339062	ft3/sec	10, 9	Cylindrical Pipe	Unspecified	Adiabatic	0	No
13	126300516943676	ft3/sec	10, 2	Cylindrical Pipe	Unspecified	Adiabatic	0	No
14	1 83216920841504	ft3/sec	11, 10	Cylindrical Pipe	Unspecified	Adiabatic	0	No
15	0	ft3/sec	13, 8	Cylindrical Pipe	Unspecified	Adiabatic	0	No
16	3 16783112983741	ft3/sec	12, 14	Cylindrical Pipe	Unspecified	Adiabatic	0	No

Pipe	Special Condition
1	None
2	None

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Pipe	Special Condition
3	None
4	None
5	None
6	None
7	None
8	None
9	None
10	None
11	None
12	None
13	None
14	None
15	None
16	None

Assigned Flow	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units
1	Assigned Flow	Yes	None	300	feet	392 920617876157	feet
Branch	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units
2	Branch	Yes	None	300	feet	397 737148463747	feet
3	Branch	Yes	None	300	feet	398 373235905226	feet
4	Branch	Yes	None	300	feet	417 589628774364	feet
5	Branch	Yes	None	250	feet	411 26078479926	feet
6	Branch	Yes	None	250	feet	410 272319964602	feet
7	Branch	Yes	None	250	feet	410 21594757185	feet
8	Branch	Yes	None	250	feet	393 143162561562	feet
9	Branch	Yes	None	280	feet	395 674699945281	feet
10	Branch	Yes	None	300	feet	397 82197805416	feet
Control Valve	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units
13	1 Way Valve	Yes	None	350	feet	417 589628774364	feet
Pump	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units
14	Pump	Yes	None	350	feet	346 812424494175	feet
Reservoir	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units
11	Reservoir	Yes	N/A	400	feet	400	feet
12	Reservoir	Yes	N/A	350	feet	350	feet

Assigned Flow	Connected Pipes (+ = in, = out)	Type	Flow	Flow Units	Loss Factor		
1	1	Outflow	5	ft3/sec	0		
Branch	Connected Pipes (+ = in, = out)	Boundary Flow (+ = in/ = out)	Boundary Flow Units				
2	1,2,13						
3	2,3, 11	1	ft3/sec				

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4	3,4, 5,-6	0	ft3/sec				
5	6, 7, 8	5	ft3/sec				
6	7, 9	2	ft3/sec				
7	8,9	3	ft3/sec				
8	10,15	1	ft3/sec				
9	10,11,12	5	ft3/sec				
10	12, 13,14	1	ft3/sec				
Control Valve	Connected Pipes (+ = in, = out)	Valve Type	Control	Control Units	Action on Failure	Failed Loss Model	Failed Loss Value
13	5, 15	PRV	350	feet	Fail Close	None	
Pump	Connected Pipes (+ = in, = out)	Independent Variable	Ind Variable Units	Dependent Variable	Dep Variable Units	Loss Constant a	Loss Constant b
14	16,-4	Vol Flow	ft3/sec	Head	feet	84	0
Reservoir	Connected Pipes (+ = in, = out)	Surface Pressure	Surface Pressure Units	Depth	Depth Units	Density	Density Units
11	14	1	atm	50	feet		
12	16	1	atm	50	feet		

Assigned Flow					
1					
Branch					
2					
3					
4					
5					
6					
7					
8					
9					
10					
Control Valve					
13					
Pump	Loss Constant c	Loss Constant d	Loss Constant e	Speed %	Viscosity Correction
14	1	0	0	100	No
Reservoir	Temperature	Temperature Units	Balance Energy		
11			No		
12			No		

AFT Fathom 3.0 Output
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Sample 19 Analysis of Flow in Pipe Networks Roland Jeppson 1977 p 88

Title Sample 19 Analysis of Flow in Pipe Networks Roland Jeppson 1977 p 88
Analysis run on 12/01/1999 12 00 15 PM
Input File C:\FATHOM\SAMPLES\SAMPLE19.FTH

Execution Time= 2.20 seconds
Total Number Of Head/Pressure Iterations= 399
Total Number Of Temperature Iterations= 0
Total Number Of Flow Iterations= 111
Number Of Pipes= 16
Number Of Junctions= 14
Head Tolerance= 0.0001 feet
Volumetric Flow Rate Tolerance= 0.0001 ft³/sec
Relaxation= 2

Constant Fluid Property Model
Fluid Unspecified
Density= 62.4 lbm/ft³
Viscosity= 0.006558 lbm/s ft
Vapor Pressure=
Gravitational Acceleration= 1 g
Atmospheric Pressure= 1 atm

Total Inflow= 5.00004 ft³/sec
Total Outflow= 5.00004 ft³/sec
Maximum Pressure is 84.5537 psia at Junction 5 Inlet
Minimum Pressure is 13.0875 psia at Junction 14 Inlet

=====PUMP SUMMARY=====

Jct	Flow (ft ³ /sec)	DP (psid)	DH (feet)	Speed (%)	ideal hp (hp)	NPSHA (feet)	NPSHR (feet)
14	3.1678	32.051	73.965	100.00	26.579	N/A	N/A

=====VALVE SUMMARY=====

Jct	Type	Flow (ft ³ /sec)	DP (psid)	DH (feet)	P Inlet (psia)	Cv	K	State
13	PRV	0.0000	10.593	24.446	43.985	N/A	0.0000	Failed Closed

Pipe	Vol Flow (ft ³ /sec)	Mass Flow (lbm/sec)	Velocity (feet/sec)	dP Total (psid)	dP Friction (psid)	dP Gravity (psid)	dH (feet)	Max Pres (psia)	Min Pres (psia)
1	0.5000000	31.20000	2.546479	2.0871632	2.0871632	0.00000	4.8165308	57.0051	54.9179
2	0.3735694	23.31073	1.070198	0.2756374	0.2756374	0.00000	0.6360862	57.3167	57.0410
3	2.1678820	135.27584	6.210525	8.3270731	8.3270731	0.00000	19.2163237	65.3917	57.0646
4	3.1678458	197.67358	5.808135	20.2853699	1.3812969	21.66667	3.1876084	65.4243	45.1389
5	0.0000000	0.00000	0.000000	21.6666660	0.0000000	21.66667	0.0000000	65.6514	43.9848
6	1.0000000	62.40000	2.864789	18.9241676	2.7424989	21.66667	6.3288439	84.5203	65.5962
7	0.2463578	15.37273	1.254690	0.4283347	0.4283347	0.00000	0.9884648	84.5650	84.1367
8	0.2536422	15.82728	1.291789	0.4527628	0.4527628	0.00000	1.0448373	84.5644	84.1116
9	0.0463578	2.89273	0.236098	0.0244280	0.0244280	0.00000	0.0563724	84.1469	84.1225
10	1.0000000	62.40000	2.864789	11.9029999	1.0969995	13.00000	2.5315375	76.6694	64.7664
11	0.7943126	49.56511	2.275538	7.4972768	1.1693892	8.66667	2.6985907	64.7868	57.2895
12	0.7057237	44.03716	2.021750	7.7361574	0.9305084	8.66667	2.1473271	64.7941	57.0580
13	0.1264306	7.88927	0.362197	0.0367565	0.0367565	0.00000	0.0848226	57.0846	57.0478
14	1.8321544	114.32644	3.359191	20.7228451	0.9438208	21.66667	2.1780481	57.0095	36.2867
15	0.0000000	0.00000	0.000000	-43.3333321	0.0000000	-43.33333	0.0000000	76.7246	33.3913
16	3.1678458	197.67358	5.808135	23.0479622	1.3812953	21.66667	3.1876048	36.1355	13.0875

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Pipe	Dyn Pres (psia)	dP/dx (psi/100 ft)	Resistance (sec ² /ft ⁵)	f	Reynolds No	fL/D	K	fL/D + K
1	0 043668408	0 20871632	19 266123	0 0238979	1 21150E+05	47 79572	0	47 79572
2	0 007712852	0 02756374	4 557991	0 0238267	6 78869E+04	35 73998	0	35 73998
3	0 259742916	0 83270731	4 088830	0 0213733	3 93958E+05	32 05998	0	32 05998
4	0 227174982	0 55251875	0 317641	0 0202677	4 60541E+05	6 08032	0	6 08032
5	0 000000000	0 00000000	0 000000	0 0000000	0 00000E+00	0 00000	0	0 00000
6	0 055267833	0 18283326	6 328843	0 0220542	1 81725E+05	49 62197	0	49 62197
7	0 010601320	0 05354184	16 286532	0 0252524	5 96925E+04	40 40390	0	40 40390
8	0 011237519	0 05659535	16 240730	0 0251814	6 14575E+04	40 29028	0	40 29028
9	0 000375381	0 00244280	26 231375	0 0325376	1 12325E+04	65 07524	0	65 07524
10	0 055267826	0 18283325	2 531538	0 0220542	1 81725E+05	19 84879	0	19 84879
11	0 034870267	0 11693892	4 277147	0 0223582	1 44346E+05	33 53736	0	33 53736
12	0 027525917	0 09305084	4 311504	0 0225374	1 28248E+05	33 80611	0	33 80611
13	0 000883440	0 00367565	5 306490	0 0277315	2 29756E+04	41 59719	0	41 59719
14	0 075990014	0 18876415	0 648849	0 0207005	2 66359E+05	12 42033	0	12 42033
15	0 000000000	0 00000000	0 000000	0 0000000	0 00000E+00	0 00000	0	0 00000
16	0 227174982	0 55251813	0 317641	0 0202677	4 60541E+05	6 08032	0	6 08032

Jct	dP (psid)	dH (feet)	Vol Flow Into System (gal/min)	Loss Factor (K)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)	P Stag In (psia)
1	0 0000	0 0000	224 4155	0 00000	392 921	392 921	392 820	392 820	54 9616
2	0 0000	0 0000	0 0000	0 00000	397 737	397 737	397 710	397 710	57 0487
3	0 0000	0 0000	-448 8310	0 00000	398 373	398 373	398 216	398 216	57 3244
4	0 0000	0 0000	0 0000	0 00000	417 590	417 590	417 374	417 374	65 6514
5	0 0000	0 0000	224 4155	0 00000	411 261	411 261	411 210	411 210	84 5756
6	0 0000	0 0000	89 7662	0 00000	410 272	410 272	410 248	410 271	84 1473
7	0 0000	0 0000	134 6493	0 00000	410 216	410 216	410 215	410 216	84 1228
8	0 0000	0 0000	-448 8310	0 00000	393 143	368 697	393 143	368 697	76 7246
9	0 0000	0 0000	224 4318	0 00000	395 675	395 675	395 586	395 586	64 8216
10	0 0000	0 0000	-448 8310	0 00000	397 822	397 822	397 765	397 765	57 0855
11	0 0000	0 0000	822 3277	0 00000	400 000	400 000	400 000	400 000	14 6960
12	0 0000	0 0000	1421 8274	0 00000	350 000	350 000	350 000	350 000	14 6960
13	10 5935	24 4465	0 0000	0 00000	417 590	393 143	417 590	393 143	43 9848
14	32 0514	73 9648	0 0000	0 00000	346 812	420 777	346 288	420 253	13 3147

Jct	P Stag Out (psia)	P Inlet (psia)	P Outlet (psia)
1	54 9616	54 9179	54 9179
2	57 0487	57 0369	57 0369
3	57 3244	57 2560	57 2560
4	65 6514	65 5582	65 5582
5	84 5756	84 5537	84 5537
6	84 1473	84 1367	84 1469
7	84 1228	84 1225	84 1228
8	66 1312	76 7246	66 1312
9	64 8216	64 7833	64 7833
10	57 0855	57 0608	57 0608
11	36 3626	14 6960	36 3626
12	36 3626	14 6960	36 3626
13	33 3913	43 9848	33 3913
14	45 3661	13 0875	45 1389

Sample #20

31 pipes 21 junctions

Model of a complicated branching network fed by two reservoirs. Each reservoir has a pump. One other booster pump also is modeled. Multiple loops exist. Water is the working fluid.

Reference: Jeppson, R. W. *Analysis of Flow in Pipe Networks*, 1976, p. 96

Determine the flow and head loss in each pipe, the pump head added for each pump, and the pressure at each junction for the network described below.

Pipe	Dia (in)	Length (ft)	CHW	Pipe	Dia (in)	Length (ft)	CHW
1	12	1500	130	16	6	1800	120
2	8	1000	130	17	10	1200	130
3	10	1200	120	18	6	1800	120
4	10	2000	120	19	6	1300	120
5	8	2800	120	20	8	1000	130
6	8	1100	120	21	8	1200	120
7	8	1000	120	22	8	1100	120
8	8	2500	120	23	8	1100	120
9	8	811	100	24	6	1800	120
10	6	1300	100	25	12	750	130
11	6	1000	100	26	20	250	110
12	6	1100	130	27	20	250	110
13	6	1000	130	28	12	2500	120
14	6	1800	120	29	12	750	130
15	6	1100	120	30	20	250	110
				31	20	250	110

Pump J17 $h_p = -0.417Q^2 + 5.17Q + 440.3$

Pump J18 $h_p = 0.378Q^2 - 5.09Q + 298.2$

Pump J19 $h_p = -2.51Q^2 + 16.7Q + 155.3$

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Sample 20 Analysis of Flow in Pipe Networks Roland Jeppson 1976 p 96

Title Sample 20 Analysis of Flow in Pipe Networks Roland Jeppson 1976 p 96

Number Of Pipes= 31

Number Of Junctions= 21

Head/Pressure Convergence= 0001 (Relative change)

Flow Rate Convergence= 00001 (Relative change)

Relaxation= 1

Maximum Iterations= 1000

Constant Fluid Property Model

Fluid Unspecified

Density= 62.4 lbm/ft³

Viscosity= 2.7 lbm/hr ft

Vapor Pressure=

Gravitational Acceleration= 1 g

Atmospheric Pressure= 1 atm

Pipe	Name	Object Defined	Length	Length Units	Hydraulic Diameter	Hydraulic Diam Units	Roughness	Roughness Units	Losses (K)	Junctions (Up,Down)
1	Pipe	Yes	1500	feet	12	inches	130	C Hazen Williams	0	1, 2
2	Pipe	Yes	1000	feet	8	inches	130	C Hazen Williams	0	3, 2
3	Pipe	Yes	1200	feet	10	inches	120	C Hazen Williams	0	3, 4
4	Pipe	Yes	2000	feet	10	inches	120	C Hazen Williams	0	5, 4
5	Pipe	Yes	2800	feet	8	inches	120	C Hazen Williams	0	5, 6
6	Pipe	Yes	1100	feet	8	inches	120	C Hazen Williams	0	7, 6
7	Pipe	Yes	1000	feet	8	inches	120	C Hazen Williams	0	8, 7
8	Pipe	Yes	2500	feet	8	inches	120	C Hazen Williams	0	9, 8
9	Pipe	Yes	811	feet	8	inches	100	C Hazen Williams	0	1, 9
10	Pipe	Yes	1300	feet	6	inches	100	C Hazen Williams	0	9, 10
11	Pipe	Yes	1000	feet	6	inches	100	C Hazen Williams	0	10, 11
12	Pipe	Yes	1100	feet	6	inches	130	C Hazen Williams	0	12, 11
13	Pipe	Yes	1000	feet	6	inches	130	C Hazen Williams	0	5, 12
14	Pipe	Yes	1800	feet	6	inches	120	C Hazen Williams	0	10, 8
15	Pipe	Yes	1100	feet	6	inches	120	C Hazen Williams	0	10, 2
16	Pipe	Yes	1800	feet	6	inches	120	C Hazen Williams	0	11, 7
17	Pipe	Yes	1200	feet	10	inches	130	C Hazen Williams	0	11, 3
18	Pipe	Yes	1800	feet	6	inches	120	C Hazen Williams	0	6, 12
19	Pipe	Yes	1300	feet	6	inches	120	C Hazen Williams	0	4, 12
20	Pipe	Yes	1000	feet	8	inches	130	C Hazen Williams	0	13, 14
21	Pipe	Yes	1200	feet	8	inches	120	C Hazen Williams	0	13, 15
22	Pipe	Yes	1100	feet	8	inches	120	C Hazen Williams	0	14, 16
23	Pipe	Yes	1100	feet	8	inches	120	C Hazen Williams	0	15, 16
24	Pipe	Yes	1800	feet	6	inches	120	C Hazen Williams	0	14, 15
25	Pipe	Yes	750	feet	12	inches	130	C Hazen Williams	0	8, 19
26	Pipe	Yes	250	feet	20	inches	110	C Hazen Williams	0	17, 1
27	Pipe	Yes	250	feet	20	inches	110	C Hazen Williams	0	18, 5
28	Pipe	Yes	2500	feet	12	inches	120	C Hazen Williams	0	6, 14
29	Pipe	Yes	750	feet	12	inches	130	C Hazen Williams	0	19, 13
30	Pipe	Yes	250	feet	20	inches	110	C Hazen Williams	0	21, 18
31	Pipe	Yes	250	feet	20	inches	110	C Hazen Williams	0	20, 17

Pipe	Geometry	Material	Thermal Boundary	Overall U	Include Internal h	Special Condition
1	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
2	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
3	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
4	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
5	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
6	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None

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Pipe	Geometry	Material	Thermal Boundary	Overall U	Include Internal h	Special Condition
7	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
8	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
9	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
10	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
11	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
12	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
13	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
14	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
15	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
16	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
17	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
18	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
19	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
20	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
21	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
22	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
23	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
24	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
25	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
26	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
27	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
28	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
29	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
30	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
31	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None

Branch	Name	Object Defined	Special Condition	Elevation	Elevation Units	Connected Pipes (+ = in, = out)	Boundary Flow (+ = in/ = out)	Boundary Flow Units
1	Branch	Yes	None	990	feet	26, 1, 9	0	gal/min
2	Branch	Yes	None	1022	feet	1,2,15	0	gal/min
3	Branch	Yes	None	1038	feet	2, 3,17	0	gal/min
4	Branch	Yes	None	1057	feet	3,4, 19	500	gal/min
5	Branch	Yes	None	1080	feet	-4, 5, 13,27	0	gal/min
6	Branch	Yes	None	1047	feet	5,6, 18, 28	-400	gal/min
7	Branch	Yes	None	1025	feet	-6,7,16	0	gal/min
8	Branch	Yes	None	1011	feet	7,8,14, 25	0	gal/min
9	Branch	Yes	None	987	feet	8,9, 10	-600	gal/min
10	Branch	Yes	None	1015	feet	10, 11, 14, 15	0	gal/min
11	Branch	Yes	None	1030	feet	11,12, 16, 17	700	gal/min
12	Branch	Yes	None	1051	feet	12,13,18,19	0	gal/min
13	Branch	Yes	None	1100	feet	20, 21,29	500	gal/min
14	Branch	Yes	None	1085	feet	20, 22, 24,28	-600	gal/min
15	Branch	Yes	None	1075	feet	21, 23,24	-400	gal/min
16	Branch	Yes	None	1110	feet	22,23	500	gal/min
Pump	Name	Object Defined	Special Condition	Elevation	Elevation Units	Connected Pipes (+ = in, = out)	Independent Variable	Ind Variable Units
17	Pump	Yes	None	910	feet	31, 26	Vol Flow	ft3/sec
18	Pump	Yes	None	1080	feet	30, 27	Vol Flow	ft3/sec
19	Pump	Yes	None	1011	feet	25, 29	Vol Flow	ft3/sec
Reservoir	Name	Object Defined	Special Condition	Elevation	Elevation Units	Connected Pipes (+ = in, = out)	Surface Pressure	Surface Pressure Units

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20	Reservoir	Yes	N/A	910	feet	31	1	atm
21	Reservoir	Yes	N/A	1080	feet	30	1	atm

Branch									
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
Pump	Dependent Variable	Dep Variable Units	Loss Constant a	Loss Constant b	Loss Constant c	Loss Constant d	Loss Constant e	Speed %	Viscosity Correction
17	Head	feet	440.3	5.14	417	0	0	100	No
18	Head	feet	298.2	5.09	378	0	0	100	No
19	Head	feet	155.3	16.7	2.51	0	0	100	No
Reservoir	Depth	Depth Units	Density	Density Units	Temperature	Temperature Units	Balance Energy		
20	0	feet					No		
21	0	feet					No		

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Sample 20 Analysis of Flow in Pipe Networks Roland Jeppson 1976 p 96

Title Sample 20 Analysis of Flow in Pipe Networks Roland Jeppson 1976 p 96

Analysis run on 12/01/1999 12 10 58 PM

Input File C:\FATHOM\SAMPLES\SAMPLE20.FTH

Execution Time= 3 57 seconds

Total Number Of Head/Pressure Iterations= 606

Total Number Of Temperature Iterations= 0

Total Number Of Flow Iterations= 16

Number Of Pipes= 31

Number Of Junctions= 21

Head Tolerance= 0001 relative change

Volumetric Flow Rate Tolerance= 00001 relative change

Relaxation= 1 (None)

Constant Fluid Property Model

Fluid Unspecified

Density= 62.4 lbm/ft³

Viscosity= 2.7 lbm/hr ft

Vapor Pressure=

Gravitational Acceleration= 1 g

Atmospheric Pressure= 1 atm

Total Inflow= 9 35764 ft³/secTotal Outflow= 9 35764 ft³/sec

Maximum Pressure is 212 102 psia at Junction 17 Outlet

Minimum Pressure is 14 4454 psia at Junction 17 Inlet

=====PUMP SUMMARY=====

Jct	Flow (ft ³ /sec)	DP (psid)	DH (feet)	Speed (%)	ideal hp (hp)	NPSHA (feet)	NPSHR (feet)
17	6 0150	197 66	456 13	100 00	311 22	N/A	N/A
18	3 3427	120 02	276 96	100 00	105 02	N/A	N/A
19	6 8499	65 832	151 92	100 00	118 05	N/A	N/A

Pipe	Vol Flow (ft ³ /sec)	Mass Flow (lbm/sec)	Velocity (feet/sec)	dP Total (psid)	dP Friction (psid)	dP Gravity (psid)	dH (feet)	Max Pres (psia)	Min Pres (psia)
1	2 9439258	183 70097	3 748323	16 6561756	2 78950977	13 86667	6 4373306	177 1922	160 5360
2	1 7564210	109 60068	5 031776	12 0445871	5 11125422	-6 93333	11 7952027	160 4602	148 4156
3	0 5343721	33 34482	-0 979753	7 9666753	-0 26665717	8 23333	0 6153627	148 5796	140 6129
4	1 7348345	108 25368	3 180759	-6 0409546	3 92571187	9 96667	9 0593356	140 5513	134 5103
5	0 8798799	54 90451	2 520671	9 6802769	4 61972237	14 30000	10 6608984	144 2159	134 5356
6	2 5530714	159 31166	7 314012	3 4903440	13 02367687	9 53333	30 0546407	143 8985	140 4081
7	3 3531911	209 23913	9 606186	13 5385818	19 60524750	6 06667	-45 2428815	140 1469	126 6084
8	2 1759463	135 77905	6 233628	32 4223480	22 02234650	10 40000	50 8208026	159 3905	126 9681
9	3 0710364	191 63280	8 797878	17 6346951	18 93469429	1 30000	43 6954510	176 7656	159 1309
10	-0 4417140	27 56295	2 249631	8 7435865	3 38974547	12 13333	7 8224900	159 6180	150 8745
11	-0 5749961	35 87976	2 928431	2 2528973	-4 24710226	6 50000	9 8010058	150 8508	148 5979
12	0 6439297	40 18121	3 279507	5 5546322	3 54536724	9 10000	8 1816172	148 5832	143 0286
13	0 7279635	45 42493	3 707488	8 5225801	4 04408550	12 56667	9 3325056	143 0085	134 4859
14	1 3207869	82 41710	6 726713	23 6787586	25 41209221	1 73333	58 6432932	150 6038	126 9251
15	1 1875048	74 10030	-6 047913	9 7221069	12 75543976	3 03333	29 4356320	160 3843	150 6622
16	0 8001197	49 92747	4 074977	7 8872800	10 05394850	2 16667	23 2014164	148 5438	140 6565
17	2 2907932	142 94550	-4 200090	0 0695829	-3 39708352	3 46667	7 8394240	148 5369	148 4673
18	-0 1704912	10 63865	-0 868305	1 1576960	-0 57563716	1 73333	1 3283935	144 2536	143 0959
19	0 0864573	5 39494	0 440324	2 4816265	0 11837340	2 60000	0 2731694	143 0997	140 6181
20	3 2789327	204 60540	9 393451	9 7207031	16 22070313	-6 50000	37 4323941	140 5958	130 8751
21	2 4569866	153 31597	7 038749	2 4009638	13 23429680	10 83333	30 5406867	140 8563	138 4554
22	0 0366432	2 28653	0 104975	10 8282623	-0 00507058	10 83333	-0 0117013	131 4692	120 6409
23	1 1506482	71 80045	3 296365	18 1480026	2 98133564	15 16667	6 8800057	138 7158	120 5678

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Pipe	Vol Flow (ft ³ /sec)	Mass Flow (lbm/sec)	Velocity (feet/sec)	dP Total (psid)	dP Friction (psid)	dP Gravity (psid)	dH (feet)	Max Pres (psia)	Min Pres (psia)
24	0 4151344	25 90438	2 114262	7 3197393	2 98640633	-4 33333	-6 8917073	138 7589	131 4392
25	6 8499243	427 43529	8 721596	6 6527605	6 65276051	0 00000	15 3525252	126 7175	120 0648
26	6 0149642	375 33378	2 757057	34 8660507	0 19938616	34 66666	0 4601219	212 1017	177 2356
27	3 3426780	208 58311	1 532171	0 0672432	0 06724323	0 00000	0 1551767	134 6299	134 5626
28	2 3939042	149 37963	3 048014	12 7894468	3 67721844	16 46667	8 4858892	144 1962	131 4067
29	6 8499243	427 43529	8 721596	45 2194328	6 65276575	38 56667	15 3525373	185 8971	140 6777
30	3 3426780	208 58311	1 532171	0 0672495	0 06724953	0 00000	0 1551912	14 6802	14 6129
31	6 0149642	375 33378	2 757057	0 1993864	0 19938639	0 00000	0 4601225	14 6448	14 4454

Pipe	Dyn Pres (psia)	dPf/dx (psi/100 ft)	Resistance (sec ² /ft ⁵)	f	Reynolds No	fL/D	K	fL/D + K
1	0 0946152359	0 185967318	0 7427661	0 0196551	3 11860E+05	29 48267	0	29 48267
2	0 1705020666	-0 511125422	3 8233860	0 0199851	2 79096E+05	29 97767	0	29 97767
3	0 0064642779	0 022221431	2 1549818	0 0286464	6 79295E+04	41 25088	0	41 25088
4	0 0681315884	0 196285594	3 0100953	0 0240081	2 20533E+05	57 61955	0	57 61955
5	0 0427877270	0 164990085	13 7704134	0 0257068	1 39813E+05	107 96838	0	107 96838
6	0 3602452874	1 183970625	4 6108991	0 0219105	4 05684E+05	36 15225	0	36 15225
7	0 6214253902	1 960524750	4 0237745	0 0210326	5 32823E+05	31 54883	0	31 54883
8	0 2616789341	0 880893860	10 7335940	0 0224421	3 45759E+05	84 15790	0	84 15790
9	0 5212461948	2 334734191	4 6330365	0 0298609	4 87989E+05	36 32582	0	36 32582
10	0 0340807885	-0 260749652	40 0924634	0 0382546	9 35846E+04	99 46206	0	99 46206
11	0 0577506796	-0 424710226	29 6442786	0 0367710	1 21823E+05	73 54203	0	73 54203
12	0 0724276230	0 322306113	19 7315990	0 0222502	1 36428E+05	48 95049	0	48 95049
13	0 0925649554	0 404408550	17 6107966	0 0218446	1 54232E+05	43 68916	0	43 68916
14	0 3047142923	1 411782900	33 6165292	0 0231657	2 79831E+05	83 39645	0	83 39645
15	0 2463190854	1 159585433	20 8738543	0 0235383	2 51593E+05	51 78421	0	51 78421
16	0 1118245870	0 558552583	36 2413637	0 0249745	1 69519E+05	89 90819	0	89 90819
17	0 1187966466	0 283090293	1 4938686	0 0198582	2 91206E+05	28 59579	0	28 59579
18	0 0050772829	0 031979842	45 7006863	0 0314930	3 61215E+04	113 37497	0	113 37497
19	0 0013056633	0 009105646	36 5450219	0 0348698	1 83175E+04	90 66154	0	90 66154
20	0 5942065120	1 622070313	3 4816299	0 0181987	5 21023E+05	27 29809	0	27 29809
21	0 3336398900	1 102858067	5 0590995	0 0220369	3 90416E+05	39 66641	0	39 66641
22	0 0000742094	-0 000460962	8 7146316	0 0414106	5 82261E+03	68 32754	0	68 32754
23	0 0731741264	0 271030513	5 1964130	0 0246927	1 82838E+05	40 74303	0	40 74303
24	0 0301026478	0 165911463	39 9898219	0 0275576	8 79533E+04	99 20743	0	99 20743
25	0 5122463703	0 887034734	0 3271962	0 0173166	7 25637E+05	12 98742	0	12 98742
26	0 0511892214	0 079754466	0 0127176	0 0259672	3 82312E+05	3 89509	0	3 89509
27	0 0158088952	0 026897290	0 0138879	0 0283594	2 12461E+05	4 25390	0	4 25390
28	0 0625634789	-0 147088737	1 4807571	0 0235103	2 53595E+05	58 77579	0	58 77579
29	0 5122463703	0 887035433	0 3271965	0 0173166	7 25637E+05	12 98742	0	12 98742
30	0 0158088952	0 026899812	0 0138892	0 0283594	2 12461E+05	4 25390	0	4 25390
31	0 0511892214	0 079754555	0 0127177	0 0259672	3 82312E+05	3 89509	0	3 89509

Jct	dP (psid)	dH (feet)	Vol Flow Into System (gal/min)	Loss Factor (K)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)	P Stag In (psia)
1	0 0000	0 000	0 000	0 00000	1365 210	1365 210	1364 805	1364 805	177 2868
2	0 0000	0 000	0 000	0 00000	1358 772	1358 772	1358 393	1358 393	160 6307
3	0 0000	0 000	0 000	0 00000	1346 977	1346 977	1346 797	1346 797	148 5861
4	0 0000	0 000	500 000	0 00000	1347 592	1347 592	1347 556	1347 556	140 6194
5	0 0000	0 000	0 000	0 00000	1356 652	1356 652	1356 536	1356 536	134 5784
6	0 0000	0 000	-400 000	0 00000	1345 991	1345 991	1345 807	1345 807	144 2587
7	0 0000	0 000	0 000	0 00000	1315 936	1315 936	1315 175	1315 175	140 7684
8	0 0000	0 000	0 000	0 00000	1270 693	1270 693	1269 743	1269 743	127 2298
9	0 0000	0 000	-600 000	0 00000	1321 514	1321 514	1320 999	1320 999	159 6521
10	0 0000	0 000	0 000	0 00000	1329 337	1329 337	1329 024	1329 024	150 9086

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Jct	dP (psid)	dH (feet)	Vol Flow Into System (gal/min)	Loss Factor (K)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)	P Stag In (psia)
11	0 0000	0 000	700 000	0 00000	1339 138	1339 138	1338 934	1338 934	148 6557
12	0 0000	0 000	0 000	0 00000	1347 319	1347 319	1347 252	1347 252	143 1010
13	0 0000	0 000	500 000	0 00000	1391 909	1391 909	1390 817	1390 817	141 1900
14	0 0000	0 000	600 000	0 00000	1354 477	1354 477	1354 268	1354 268	131 4693
15	0 0000	0 000	-400 000	0 00000	1361 369	1361 369	1361 101	1361 101	138 7890
16	0 0000	0 000	500 000	0 00000	1354 489	1354 489	1354 320	1354 489	120 6410
17	197 6563	-456 130	0 000	0 00000	909 540	1365 670	909 422	1365 552	14 4966
18	120 0170	276 962	0 000	0 00000	1079 845	1356 807	1079 808	1356 771	14 6287
19	-65 8324	151 921	0 000	0 00000	1255 341	1407 262	1254 159	1406 080	120 5770
20	0 0000	0 000	2699 702	0 00000	910 000	910 000	910 000	910 000	14 6960
21	0 0000	0 000	1500 298	0 00000	1080 000	1080 000	1080 000	1080 000	14 6960

Jct	P Stag Out (psia)	P Inlet (psia)	P Outlet (psia)
1	177 2868	177 1116	177 1116
2	160 6307	160 4661	160 4661
3	148 5861	148 5080	148 5080
4	140 6194	140 6035	140 6035
5	134 5784	134 5280	134 5280
6	144 2567	144 1791	144 1791
7	140 7684	140 4386	140 4386
8	127 2298	126 8178	126 8178
9	159 6521	159 4287	159 4287
10	150 9086	150 7729	150 7729
11	148 6557	148 5674	148 5674
12	143 1010	143 0721	143 0721
13	141 1900	140 7166	140 7166
14	131 4693	131 3788	131 3788
15	138 7890	138 6730	138 6730
16	120 6410	120 5678	120 6410
17	212 1529	14 4454	212 1017
18	134 6457	14 6129	134 6299
19	186 4094	120 0648	185 8971
20	14 6960	14 6960	14 6960
21	14 6960	14 6960	14 6960

Sample #21

68 pipes 44 junctions

Model of a complicated branching network fed by six reservoirs. Four of the reservoirs have pumps. One other booster pump is modeled. Multiple loops exist. Water is the working fluid.

Reference: Jeppson, R. W. *Analysis of Flow in Pipe Networks*, 1976, p. 107.

Determine the flow rates and head losses of each of the 68 pipes of the network shown below. The diameter of each pipe is given in centimeters and the length in meters. All pipes have a roughness of 0.026 cm. The network is supplied by two reservoirs without pumps and 4 pumps obtaining their water from the reservoirs as shown in the sketch. A booster pump exists between pipe P43 and P68. The water surface elevations are 500, 540, 530, 480, 600, and 600 m for reservoirs J46, J47, J48, J49, J50, and J51, respectively.

The pump characteristics are the following (hp is in meters and Qp in m³/s):

Pump J41: $Q_1 = 0.03$ @ $H_{p1} = 84$; $Q_2 = 0.045$ @ $H_{p2} = 70$; $Q_3 = 0.06$ @ $H_{p3} = 52$

Pump J42: $Q_1 = 0.06$ @ $H_{p1} = 45$; $Q_2 = 0.105$ @ $H_{p2} = 39$; $Q_3 = 0.15$ @ $H_{p3} = 31$

Pump J43: $Q_1 = 0.06$ @ $H_{p1} = 45$; $Q_2 = 0.105$ @ $H_{p2} = 39$; $Q_3 = 0.15$ @ $H_{p3} = 31$

Pump J44: $Q_1 = 0.06$ @ $H_{p1} = 45$; $Q_2 = 0.105$ @ $H_{p2} = 39$; $Q_3 = 0.15$ @ $H_{p3} = 31$

Pump J45: $Q_1 = 0.03$ @ $H_{p1} = 9.0$; $Q_2 = 0.045$ @ $H_{p2} = 7.5$; $Q_3 = 0.06$ @ $H_{p3} = 5.5$

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Sample 21 Analysis of Flow in Pipe Networks Roland Jeppson 1976 p 107

Title Sample 21 Analysis of Flow in Pipe Networks Roland Jeppson 1976 p 107

Number Of Pipes= 68

Number Of Junctions= 44

Head/Pressure Convergence= 0001 (Relative change)

Flow Rate Convergence= 0001 (Relative change)

Relaxation= 1

Maximum Iterations= 1000

Constant Fluid Property Model

Fluid Water at 1 atm

Temperature 22 deg C

Density= 62.29624 lbm/ft³

Viscosity= 2.30822 lbm/hr ft

Vapor Pressure= 38264 psia

Gravitational Acceleration= 1 g

Atmospheric Pressure= 1 atm

Pipe	Name	Object Defined	Length	Length Units	Hydraulic Diameter	Hydraulic Diam Units	Roughness	Roughness Units	Losses (K)	Junctions (Up,Down)
1	Pipe	Yes	750	meters	16	cm	026	cm	0	41, 1
2	Pipe	Yes	1500	meters	12	cm	026	cm	0	1, 2
3	Pipe	Yes	1300	meters	12	cm	026	cm	0	1, 4
4	Pipe	Yes	1400	meters	12	cm	026	cm	0	4, 3
5	Pipe	Yes	1000	meters	12	cm	026	cm	0	3, 2
6	Pipe	Yes	2000	meters	16	cm	026	cm	0	1, 5
7	Pipe	Yes	2300	meters	16	cm	026	cm	0	1, 6
8	Pipe	Yes	2000	meters	16	cm	026	cm	0	4, 6
9	Pipe	Yes	1300	meters	16	cm	026	cm	0	5, 6
10	Pipe	Yes	2100	meters	14	cm	026	cm	0	7, 5
11	Pipe	Yes	1700	meters	12	cm	026	cm	0	7, 8
12	Pipe	Yes	2000	meters	14	cm	026	cm	0	8, 6
13	Pipe	Yes	1500	meters	12	cm	026	cm	0	7, 9
14	Pipe	Yes	1700	meters	14	cm	026	cm	0	10, 9
15	Pipe	Yes	1500	meters	12	cm	026	cm	0	8, 10
16	Pipe	Yes	1000	meters	8	cm	026	cm	0	9, 11
17	Pipe	Yes	1700	meters	8	cm	026	cm	0	12, 11
18	Pipe	Yes	2000	meters	8	cm	026	cm	0	12, 9
19	Pipe	Yes	1000	meters	12	cm	026	cm	0	12, 10
20	Pipe	Yes	750	meters	16	cm	026	cm	0	42, 12
21	Pipe	Yes	1500	meters	12	cm	026	cm	0	12, 13
22	Pipe	Yes	1800	meters	8	cm	026	cm	0	14, 13
23	Pipe	Yes	1500	meters	8	cm	026	cm	0	14, 10
24	Pipe	Yes	2000	meters	12	cm	026	cm	0	13, 31
25	Pipe	Yes	2500	meters	12	cm	026	cm	0	14, 31
26	Pipe	Yes	1800	meters	16	cm	026	cm	0	15, 14
27	Pipe	Yes	1250	meters	16	cm	026	cm	0	43, 15
28	Pipe	Yes	3400	meters	16	cm	026	cm	0	15, 8
29	Pipe	Yes	3800	meters	12	cm	026	cm	0	8, 16
30	Pipe	Yes	4300	meters	16	cm	026	cm	0	6, 15
31	Pipe	Yes	2700	meters	16	cm	026	cm	0	15, 16
32	Pipe	Yes	1500	meters	12	cm	026	cm	0	6, 17
33	Pipe	Yes	1800	meters	16	cm	026	cm	0	17, 16
34	Pipe	Yes	2000	meters	16	cm	026	cm	0	18, 17
35	Pipe	Yes	2000	meters	16	cm	026	cm	0	16, 21
36	Pipe	Yes	1800	meters	14	cm	026	cm	0	18, 21
37	Pipe	Yes	1000	meters	16	cm	026	cm	0	50, 18
38	Pipe	Yes	1500	meters	16	cm	026	cm	0	4, 18
39	Pipe	Yes	1500	meters	16	cm	026	cm	0	19, 18

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Pipe	Name	Object Defined	Length	Length Units	Hydraulic Diameter	Hydraulic Diam Units	Roughness	Roughness Units	Losses (K)	Junctions (Up,Down)
40	Pipe	Yes	1500	meters	16	cm	026	cm	0	3, 19
41	Pipe	Yes	1800	meters	14	cm	026	cm	0	20, 19
42	Pipe	Yes	1500	meters	14	cm	026	cm	0	20, 21
43	Pipe	Yes	750	meters	16	cm	026	cm	0	20, 45
44	Pipe	Yes	3000	meters	16	cm	026	cm	0	30, 16
45	Pipe	Yes	1400	meters	8	cm	026	cm	0	30, 15
46	Pipe	Yes	2500	meters	8	cm	026	cm	0	15, 31
47	Pipe	Yes	2900	meters	8	cm	026	cm	0	30, 31
48	Pipe	Yes	1400	meters	8	cm	026	cm	0	31, 32
49	Pipe	Yes	2500	meters	8	cm	026	cm	0	30, 32
50	Pipe	Yes	2700	meters	12	cm	026	cm	0	33, 32
51	Pipe	Yes	1000	meters	8	cm	026	cm	0	30, 33
52	Pipe	Yes	500	meters	12	cm	026	cm	0	44, 30
53	Pipe	Yes	1000	meters	10	cm	026	cm	0	22, 24
54	Pipe	Yes	1000	meters	10	cm	026	cm	0	22, 23
55	Pipe	Yes	1000	meters	10	cm	026	cm	0	23, 25
56	Pipe	Yes	1000	meters	8	cm	026	cm	0	25, 24
57	Pipe	Yes	1000	meters	8	cm	026	cm	0	24, 27
58	Pipe	Yes	1000	meters	8	cm	026	cm	0	25, 26
59	Pipe	Yes	1000	meters	8	cm	026	cm	0	26, 27
60	Pipe	Yes	1000	meters	8	cm	026	cm	0	27, 28
61	Pipe	Yes	1000	meters	8	cm	026	cm	0	26, 29
62	Pipe	Yes	1000	meters	8	cm	026	cm	0	29, 28
63	Pipe	Yes	1000	meters	16	cm	026	cm	0	51, 20
64	Pipe	Yes	750	meters	16	cm	026	cm	0	46, 41
65	Pipe	Yes	750	meters	16	cm	026	cm	0	47, 42
66	Pipe	Yes	1250	meters	16	cm	026	cm	0	48, 43
67	Pipe	Yes	500	meters	12	cm	026	cm	0	49, 44
68	Pipe	Yes	750	meters	16	cm	026	cm	0	45, 22

Pipe	Geometry	Material	Thermal Boundary	Overall U	Include Internal h	Special Condition
1	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
2	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
3	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
4	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
5	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
6	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
7	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
8	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
9	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
10	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
11	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
12	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
13	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
14	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
15	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
16	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
17	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
18	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
19	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
20	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
21	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
22	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
23	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None

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Pipe	Geometry	Material	Thermal Boundary	Overall U	Include Internal h	Special Condition
24	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
25	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
26	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
27	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
28	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
29	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
30	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
31	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
32	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
33	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
34	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
35	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
36	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
37	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
38	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
39	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
40	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
41	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
42	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
43	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
44	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
45	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
46	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
47	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
48	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
49	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
50	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
51	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
52	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
53	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
54	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
55	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
56	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
57	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
58	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
59	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
60	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
61	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
62	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
63	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
64	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
65	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
66	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
67	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None
68	Cylindrical Pipe	Unspecified	Adiabatic	0	No	None

Branch	Name	Object Defined	Special Condition	Elevation	Elevation Units	Connected Pipes (+ = in, = out)	Boundary Flow (+ = in/ = out)	Boundary Flow Units
1	Branch	Yes	None	300	meters	1, 2, 3-6, 7	0	m3/sec
2	Branch	Yes	None	250	meters	2, 5	03	m3/sec
3	Branch	Yes	None	255	meters	4, 5-40	03	m3/sec
4	Branch	Yes	None	260	meters	3-4, 8, 38	0045	m3/sec
5	Branch	Yes	None	280	meters	6, 9, 10	06	m3/sec

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6	Branch	Yes	None	200	meters	7,8,9,12, 30, 32	045	m3/sec
7	Branch	Yes	None	340	meters	10, 11, 13	06	m3/sec
8	Branch	Yes	None	270	meters	11, 12, 15,28, 29	03	m3/sec
9	Branch	Yes	None	330	meters	13,14, 16,18	0225	m3/sec
10	Branch	Yes	None	360	meters	14,15,19,23	03	m3/sec
11	Branch	Yes	None	260	meters	16,17	0225	m3/sec
12	Branch	Yes	None	420	meters	17, 18, 19,20, 21	0	m3/sec
13	Branch	Yes	None	270	meters	21,22, 24	015	m3/sec
14	Branch	Yes	None	240	meters	22, 23, 25,26	03	m3/sec
15	Branch	Yes	None	260	meters	26,27, 28,30, 31,45,-46	03	m3/sec
16	Branch	Yes	None	260	meters	29,31,33, 35,44	03	m3/sec
17	Branch	Yes	None	260	meters	32, 33,34	03	m3/sec
18	Branch	Yes	None	280	meters	34, 36,37,38,39	03	m3/sec
19	Branch	Yes	None	270	meters	39,40,41	03	m3/sec
20	Branch	Yes	None	300	meters	-41,-42,-43,63	03	m3/sec
21	Branch	Yes	None	250	meters	35,36,42	06	m3/sec
22	Branch	Yes	None	260	meters	53, 54,68	0075	m3/sec
23	Branch	Yes	None	200	meters	54, 55	003	m3/sec
24	Branch	Yes	None	160	meters	53,56, 57	0075	m3/sec
25	Branch	Yes	None	160	meters	55, 56, 58	0045	m3/sec
26	Branch	Yes	None	70	meters	58, 59,-61	0	m3/sec
27	Branch	Yes	None	70	meters	57,59, 60	0075	m3/sec
28	Branch	Yes	None	40	meters	60,62	0075	m3/sec
29	Branch	Yes	None	20	meters	61,-62	0075	m3/sec
30	Branch	Yes	None	260	meters	-44,-45,-47,-49, 51,52	0	m3/sec
31	Branch	Yes	None	200	meters	24,25,46,47,-48	0225	m3/sec
32	Branch	Yes	None	50	meters	48,49,50	0225	m3/sec
33	Branch	Yes	None	-60	meters	50,51	03	m3/sec
Pump	Name	Object Defined	Special Condition	Elevation	Elevation Units	Connected Pipes (+ = in, = out)	Independent Variable	Ind Variable Units
41	Pump 1	Yes	None	300	meters	64, 1	Vol Flow	m3/sec
42	Pump 2	Yes	None	420	meters	65, 20	Vol Flow	m3/sec
43	Pump 3	Yes	None	260	meters	66, 27	Vol Flow	m3/sec
44	Pump 4	Yes	None	260	meters	67, 52	Vol Flow	m3/sec
45	Pump 5	Yes	None	260	meters	43, 68	Vol Flow	m3/sec
Reservoir	Name	Object Defined	Special Condition	Elevation	Elevation Units	Connected Pipes (+ = in, = out)	Surface Pressure	Surface Pressure Units
46	Reservoir 1	Yes	N/A	500	meters	-64	1	atm
47	Reservoir 2	Yes	N/A	540	meters	65	1	atm
48	Reservoir 3	Yes	N/A	530	meters	-66	1	atm
49	Reservoir 4	Yes	N/A	480	meters	-67	1	atm
50	Reservoir 5	Yes	N/A	600	meters	37	1	atm
51	Reservoir 6	Yes	N/A	600	meters	-63	1	atm

Branch								
1								
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AFT Fathom 3.0 Input
NUMATEC HANFORD CORPORATION

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Pump	Dependent Variable	Dep Variable Units	Loss Constant a	Loss Constant b	Loss Constant c	Loss Constant d	Loss Constant e	Speed %	Viscosity Correction
41	Head	meters	100	266.67	8888.9	0	0	100	No
42	Head	meters	49.889	51.852	-493.83	0	0	100	No
43	Head	meters	49.889	51.852	-493.83	0	0	100	No
44	Head	meters	49.889	51.852	-493.83	0	0	100	No
45	Head	meters	10.5	16.667	1111.1	0	0	100	No
Reservoir	Depth	Depth Units	Density	Density Units	Temperature	Temperature Units	Balance Energy		
46	500	meters					No		
47	540	meters					No		
48	530	meters					No		
49	480	meters					No		
50	600	meters					No		
51	600	meters					No		

AFT Fathom 3.0 Output
NUMATEC HANFORD CORPORATION

(1)

12/02/1999

Sample 21 Analysis of Flow in Pipe Networks Roland Jeppson 1976 p 107

Title Sample 21 Analysis of Flow in Pipe Networks Roland Jeppson 1976 p 107
Analysis run on 12/02/1999 3 29 51 PM
Input File C:\FATHOM\SAMPLES\SAMPLE21.FTH

Execution Time= 1.43 seconds
Total Number Of Head/Pressure Iterations= 62
Total Number Of Temperature Iterations= 0
Total Number Of Flow Iterations= 11
Number Of Pipes= 68
Number Of Junctions= 44
Head Tolerance= 0.001 relative change
Volumetric Flow Rate Tolerance= 0.001 relative change
Relaxation= 1 (None)

Constant Fluid Property Model
Fluid Water at 1 atm
Temperature 22 deg C
Density= 62.29624 lbm/ft³
Viscosity= 2.30822 lbm/hr ft
Vapor Pressure= 38264 psia
Gravitational Acceleration= 1 g
Atmospheric Pressure= 1 atm

Total Inflow= 22.9369 ft³/sec
Total Outflow= 22.9369 ft³/sec
Maximum Pressure is 866.296 psia at Junction 50 Outlet
Minimum Pressure is 11.7080 psia at Junction 12 Inlet

=====PUMP SUMMARY=====

Jct	Flow (m3/sec)	DP (psid)	DH (feet)	Speed (%)	ideal hp (hp)	NPSHA (feet)	NPSHR (feet)
41	0.087215	12.957	29.950	100.00	10.447	357.98	N/A
42	0.078664	60.683	140.27	100.00	44.129	156.91	N/A
43	0.080810	60.285	139.35	100.00	45.036	444.42	N/A
44	0.054920	64.653	149.45	100.00	32.825	357.33	N/A
45	0.045000	10.645	24.606	100.00	4.4284	119.31	N/A

Pipe	Vol Flow (m3/sec)	Mass Flow (lbm/sec)	Velocity (feet/sec)	dP Total (psid)	dP Friction (psid)	dP Gravity (psid)	dH (meters)	Max Pres (psia)
1	0.0872153609	191.871282	14.2314171	143.3150787	143.3150787	0.00000	100.9735308	166.8424
2	0.0208933286	45.964721	6.0609441	5.0885162	76.0551758	70.96666	53.5851475	24.6420
3	0.0133393284	29.346138	3.8696048	29.4823704	27.2909489	56.77332	19.2280079	54.2707
4	0.0153686018	33.810481	4.4582765	31.6983776	38.7950325	7.09665	27.3332816	54.2377
5	0.0091066723	20.034417	2.6417539	2.8725147	9.9691963	7.09668	7.0238593	22.6261
6	0.0274607760	60.412916	4.4809280	10.5259933	38.9126396	28.38665	27.4161425	24.7540
7	0.0255219280	56.147506	4.1645554	103.1720886	38.7612305	141.93332	27.3094662	127.9445
8	0.0146868776	32.310708	2.3965398	73.6897125	11.4702816	85.16000	8.0814583	128.0225
9	-0.0018467025	-4.062692	0.3013368	113.6980743	0.1514088	113.54667	0.1066760	128.0605
10	0.0306925233	67.522667	6.5414139	16.6642761	101.8242722	85.16000	71.7409248	30.7396
11	0.0219668163	48.326363	6.3723521	-4.2054901	95.1478424	99.35333	67.0370046	34.9598
12	0.0076925306	16.923346	1.6394881	92.8283157	6.5250177	99.35333	4.5972419	128.0430
13	0.0073406622	16.149245	2.1294522	-4.3467827	9.8465805	14.19336	6.9374696	35.3436
14	0.0188611521	41.493991	4.0198260	10.9462852	31.6337509	-42.58004	22.2877561	35.2654
15	0.0259801164	57.155508	7.5365700	10.8049927	116.9350128	127.74001	82.3872912	34.8509
16	0.0109524056	24.094977	7.1486605	18.4761658	117.8294678	99.35330	83.0174850	35.0305
17	0.0115475960	25.404379	7.5371427	-4.7048340	222.3884735	227.09331	156.6851833	16.5160
18	0.0072505929	15.951095	4.7324788	23.1810074	104.5589981	127.74001	73.6676930	35.2235
19	0.0251176379	55.258080	7.2863737	12.2347183	72.9252472	85.15997	51.3799368	24.0708
20	0.0786637581	173.058002	12.8360043	116.7527924	116.7527924	0.00000	82.2589066	127.8381

AFT Fathom 3.0 Output
NUMATEC HANFORD CORPORATION

(2)

12/02/1999

Pipe	Vol Flow (m3/sec)	Mass Flow (lbm/sec)	Velocity (feet/sec)	dP Total (psid)	dP Friction (psid)	dP Gravity (psid)	dH (meters)	Max Pres (psia)
21	0 0347479314	76 444448	10 0800248	-4 9695282	207 9304352	212 89996	146 4986824	16 4795
22	0 0033475388	7 364489	2 1849463	21 7341557	20 8458271	42 57998	14 6870572	38 8647
23	-0 0102763703	22 607719	6 7074107	14 4689789	155 8510132	170 31999	109 8058015	38 5943
24	0 0164003921	36 080390	4 7575885	36 3886070	62 9647255	99 35333	44 3621893	53 3990
25	0 0119204789	26 224710	3 4580108	14 6544456	42 1189003	56 77335	29 6751334	53 4708
26	0 0282965706	62 251640	4 6173093	8 7584763	37 1451225	28 38665	26 1708273	47 5119
27	0 0808099868	177 779644	13 1862164	205 2727509	205 2727509	0 00000	144 6261944	251 7590
28	0 0041691812	9 172079	0 6803086	12 4224634	1 7708730	14 19334	1 2476796	47 6521
29	0 0060852200	13 387309	1 7652610	3 1804295	17 3737659	14 19334	12 2407949	35 2118
30	-0 0062228649	13 690123	1 0154196	80 4058533	-4 7541447	85 16000	3 3495622	128 0542
31	0 0147444864	32 437445	2 4059401	15 6028929	15 6028929	0 00000	10 9931153	47 6163
32	0 0072774990	16 010288	2 1111291	94 8434677	9 6834707	85 16000	6 8225496	128 0311
33	0 0046832789	10 303079	0 7641967	1 1652765	1 1652765	0 00000	0 8210028	33 2137
34	0 0274057808	60 291928	4 4719542	10 3731270	38 7598000	28 38667	27 3084583	43 4563
35	0 0094686889	20 830843	1 5450588	9 2739086	4 9194283	14 19334	3 4660139	41 3102
36	0 0218858464	48 148232	4 6644708	2 2644958	44 8445053	-42 58001	31 5954754	43 4445
37	0 1303959869	286 867415	21 2774407	822 7051392	425 2918396	397 41330	299 6420129	863 2522
38	-0 0212161508	-46 674921	3 4619577	10 7806282	17 6060448	28 38667	12 4044484	54 2908
39	0 0298882081	-65 753197	-4 8770257	20 2749023	34 4682388	14 19334	24 2848122	43 4308
40	0 0237380715	52 223073	3 8734736	0 6428490	21 9328403	21 28999	15 4529192	23 2150
41	0 0238498642	52 469014	5 0830566	10 5170975	53 0970802	-42 57998	37 4098784	33 6592
42	0 0286454666	63 019201	6 1051303	7 4933128	63 4733467	70 96666	44 7205415	41 0757
43	0 0450000013	98 998707	7 3429013	18 1641083	38 6092110	56 77332	27 2023599	51 6346
44	0 0139557046	30 702148	2 2772302	15 5841322	15 5841322	0 00000	10 9798973	47 6016
45	-0 0000973423	0 214150	0 0635356	0 0187602	0 0187602	0 00000	0 0132176	47 6552
46	0 0056179064	12 359232	3 6668206	5 8959732	79 2640228	85 16000	55 8459607	53 4608
47	0 0052064486	11 454037	3 3982611	5 9147339	79 2452621	-85 16000	55 8327427	53 4736
48	0 0166452245	36 619015	10 8643766	22 9198303	377 7531128	354 83328	266 1483070	52 7577
49	0 0136756900	30 086124	8 9261546	17 0050964	456 9983826	-439 99329	321 9810551	47 1008
50	0 0078209113	17 205780	2 2687676	5 8423424	20 0356789	14 19334	14 1162623	30 5968
51	0 0221790896	48 793358	14 4763432	22 8474426	477 0340576	-454 18661	336 0973147	46 2276
52	0 0549195905	120 821517	15 9316199	171 9830170	171 9830170	0 00000	121 1717052	217 9131
53	0 0210323735	46 270616	8 7858437	8 7854919	133 1478271	141 93332	93 8101304	32 2994
54	0 0164676276	36 228307	6 8790146	3 0771790	82 0828171	85 16000	57 8319597	26 7919
55	0 0134676276	29 628393	5 6258259	1 5639038	55 2094154	56 77332	38 8981373	28 4611
56	-0 0019596016	-4 311067	1 2790365	-4 1444082	-4 1444082	0 00000	2 9199686	32 8073
57	0 0115727716	25 459764	7 5535749	3 6410599	131 3810425	127 73998	92 5653313	32 4347
58	0 0109272291	24 039589	7 1322277	10 4449234	117 2950592	127 73998	82 6409641	38 7769
59	0 0030931780	6 804903	2 0189245	9 9415693	9 9415693	0 00000	7 0043946	39 0914
60	0 0071659494	15 764882	4 6772318	8 5074501	51 0874481	-42 58000	35 9939796	29 0302
61	0 0078340510	17 234687	5 1133033	10 0970726	60 8695869	70 96666	42 8860464	49 0401
62	0 0003340508	0 734902	0 2180357	28 5460930	0 1594305	28 38666	0 1123278	49 2156
63	0 1274953330	280 486060	20 8041249	832 4628906	406 6629944	425 79993	286 5169441	863 3861
64	0 0872153609	191 871282	14 2314171	569 1151123	143 3151855	425 79993	100 9736081	723 0009
65	0 0786637581	173 058002	12 8360043	712 8726807	116 7527313	596 11993	82 2588636	780 0281
66	0 0808099868	177 779644	13 1862164	574 2993774	205 2727509	369 02661	144 6261944	765 7736
67	0 0549195905	120 821517	15 9316199	541 0096436	171 9830475	369 02661	121 1717267	694 2695
68	0 0450000013	98 998707	7 3429013	38 6092110	38 6092110	0 00000	27 2023599	62 2796

Pipe	Min Pres (psia)	Dyn Pres (psia)	dP/dx (psi/100 ft)	Resistance (sec ² /ft ⁵)	f	Reynolds No	fL/D	K	fL/D + K
1	23 5274	1 3616344929	5 824324891	34 9218	0 0224538	7 25839E+05	105 252	0	105 252
2	19 5535	0 2469703555	1 545441196	322 9267	0 0246362	2 31843E+05	307 953	0	307 953
3	24 7883	0 1006693989	0 639867796	284 2766	0 0250241	1 48020E+05	271 095	0	271 095
4	22 5394	0 1336282492	0 844623292	304 4373	0 0248846	1 70538E+05	290 321	0	290 321

AFT Fathom 3.0 Output
NUMATEC HANFORD CORPORATION

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Pipe	Min Pres (psia)	Dyn Pres (psia)	dP/dx (psi/100 ft)	Resistance (sec2/ft5)	f	Reynolds No	L/D	K	L/D + K
5	19 7536	0 0469190255	0 303861109	222 8082	0 0254972	1 01052E+05	212 477	0	212 477
6	14 2280	0 1349895746	0 593028637	95 6435	0 0230611	2 28539E+05	288 264	0	288 264
7	24 7724	0 1166008040	0 513670575	110 2963	0 0231253	2 12403E+05	332 427	0	332 427
8	54 3328	0 0386129990	0 174807094	98 5611	0 0237646	1 22230E+05	297 058	0	297 058
9	14 3624	0 0006104758	0 003549954	82 2901	0 0305255	1 53690E+04	248 020	0	248 020
10	14 0753	0 2876785696	1 477906602	200 3441	0 0235968	2 91925E+05	353 952	0	353 952
11	30 7543	0 2730007172	1 705944872	365 4728	0 0246018	2 43755E+05	348 526	0	348 526
12	35 2147	0 0180709418	0 099441272	204 3778	0 0252755	7 31659E+04	361 078	0	361 078
13	30 9968	0 0304859709	0 200082519	338 6923	0 0258390	8 14557E+04	322 987	0	322 987
14	24 3191	0 1086372510	0 567174555	164 8180	0 0239801	1 79394E+05	291 187	0	291 187
15	24 0459	0 3818666637	2 376119498	321 1092	0 0244976	2 88288E+05	306 219	0	306 219
16	16 5543	0 3435687125	3 591442234	1820 6450	0 0274366	1 82300E+05	342 958	0	342 958
17	11 8111	0 3819246888	3 987294576	3091 1459	0 0274016	1 92207E+05	582 284	0	582 284
18	12 0425	0 1505710930	1 593479156	3686 4196	0 0277766	1 20684E+05	694 416	0	694 416
19	11 8361	0 3569333553	2 222761569	214 2450	0 0245173	2 78718E+05	204 311	0	204 311
20	11 0854	1 1077046394	4 744833556	34 9710	0 0224855	6 54669E+05	105 401	0	105 401
21	11 5100	0 6831049919	4 225146509	319 1909	0 0243512	3 85581E+05	304 390	0	304 390
22	17 1305	0 0320956223	0 352989344	3447 9288	0 0288663	5 57190E+04	649 491	0	649 491
23	24 1253	0 3024642766	3 166892637	2735 3980	0 0274811	1 71048E+05	515 271	0	515 271
24	17 0104	0 1521731466	0 959582432	433 8896	0 0248262	1 81987E+05	413 770	0	413 770
25	38 8164	0 0803927630	0 513513640	549 3891	0 0251479	1 32276E+05	523 914	0	523 914
26	38 7534	0 1433316916	0 628990751	85 9854	0 0230360	2 35495E+05	259 155	0	259 155
27	46 4863	1 1689734459	5 005370835	58 2628	0 0224769	6 72531E+05	175 601	0	175 601
28	35 2297	0 0031115455	-0 015875355	188 8323	0 0267826	3 46975E+04	569 130	0	569 130
29	32 0314	0 0209499076	0 139355893	869 6246	0 0261884	6 75247E+04	829 300	0	829 300
30	47 6483	0 0069319485	0 033699147	227 5527	0 0255193	5 17890E+04	685 831	0	685 831
31	32 0134	0 0389165096	0 176139327	133 0259	0 0237590	1 22709E+05	400 932	0	400 932
32	33 1876	0 0299635921	0 196768128	338 8887	0 0258540	8 07548E+04	323 175	0	323 175
33	32 0484	0 0039262199	0 019732016	98 4735	0 0263816	3 89760E+04	296 793	0	296 793
34	33 0832	0 1344494224	0 590699361	95 6506	0 0230628	2 28081E+05	288 285	0	288 285
35	32 0363	0 0160492323	0 074972089	101 7010	0 0245217	7 88020E+04	306 521	0	306 521
36	41 1800	0 1462746412	0 759366968	173 5293	0 0238449	2 08163E+05	306 577	0	306 577
37	40 5470	3 0437083244	12 962895474	46 3606	0 0223565	1 08520E+06	139 728	0	139 728
38	43 5102	0 0805763826	0 357754835	72 4968	0 0233068	1 76569E+05	218 501	0	218 501
39	23 1559	0 1599095315	0 700394624	71 5171	0 0229918	2 48741E+05	215 548	0	215 548
40	22 5721	0 1008707955	0 445675323	72 1430	0 0231931	1 97557E+05	217 435	0	217 435
41	23 1421	0 1737057418	0 899110573	173 0172	0 0237745	2 26843E+05	305 673	0	305 673
42	33 5824	0 2505844533	1 289778425	143 3739	0 0236414	2 72455E+05	253 301	0	253 301
43	33 4704	0 3624930084	1 569078358	35 3392	0 0227222	3 74507E+05	106 510	0	106 510
44	32 0175	0 0348640718	0 158334786	148 3097	0 0238398	1 16145E+05	446 997	0	446 997
45	47 6364	0 0000271393	0 000408436	3669 6430	0 0395003	1 62024E+03	691 256	0	691 256
46	47 5648	0 0903948247	0 966386981	4654 9766	0 0280597	9 35087E+04	876 865	0	876 865
47	47 5588	0 0776386112	0 832895044	5418 5181	0 0281571	8 66600E+04	1020 694	0	1020 694
48	29 8378	0 7935492396	8 224225041	2527 0808	0 0272017	2 77056E+05	476 030	0	476 030
49	30 0957	0 5356647372	5 571724367	4529 0442	0 0273006	2 27628E+05	853 143	0	853 143
50	24 7544	0 0346054323	0 226180556	607 1273	0 0257322	8 67848E+04	578 975	0	578 975
51	23 3801	1 4089059830	14 539998303	1797 4315	0 0270868	3 69165E+05	338 585	0	338 585
52	45 9301	1 7064129114	10 484084878	105 6870	0 0241887	6 09415E+05	100 786	0	100 786
53	23 5139	0 5189568400	4 058345835	557 8891	0 0256568	2 80063E+05	256 568	0	256 568
54	23 7147	0 3181388676	2 501884304	561 0229	0 0258009	2 19280E+05	258 009	0	258 009
55	26 8972	0 2127829641	1 682783009	564 1847	0 0259464	1 79332E+05	259 464	0	259 464
56	28 6629	0 0109984167	0 126321565	2000 4022	0 0301455	3 26171E+04	376 819	0	376 819
57	28 7937	0 3835918307	4 004494237	1818 2280	0 0274002	1 92626E+05	342 502	0	342 502
58	28 3319	0 3419910073	3 575153460	1820 7487	0 0274382	1 81881E+05	342 977	0	342 977

AFT Fathom 3.0 Output
NUMATEC HANFORD CORPORATION

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Pipe	Min Pres (psia)	Dyn Pres (psia)	dP/dx (psi/100 ft)	Resistance (sec ² /ft ⁵)	f	Reynolds No	fL/D	K	fL/D + K
59	29 1499	0 0274033975	0 303019038	1925 9078	0 0290229	5 14852E+04	362 786	0	362 786
60	20 5228	0 1470760852	1 557145443	1843 9839	0 0277883	1 19275E+05	347 354	0	347 354
61	38 9431	0 1757791489	1 855305039	1838 3066	0 0277028	1 30396E+05	346 284	0	346 284
62	20 6695	0 0003196095	0 004859442	2648 1144	0 0399062	5 56019E+03	498 828	0	498 828
63	30 9231	2 9098002911	12 395088263	46 3699	0 0223610	1 06106E+06	139 756	0	139 756
64	153 8858	1 3616344929	5 824329232	34 9218	0 0224538	7 25839E+05	105 252	0	105 252
65	67 1555	1 1077046394	4 744831075	34 9710	0 0224855	6 54669E+05	105 401	0	105 401
66	191 4742	1 1689734459	5 005370835	58 2628	0 0224769	6 72531E+05	175 601	0	175 601
67	153 2598	1 7064129114	10 484086739	105 6870	0 0241887	6 09415E+05	100 786	0	100 786
68	23 6704	0 3624930084	1 569078358	35 3392	0 0227222	3 74507E+05	106 510	0	106 510

Jct	dP (psid)	dH (feet)	Vol Flow Into System (gal/min)	Loss Factor (K)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)	P Stag In (psia)
1	0 0000	0 0000	0 0000	0 00000	1007 813	1007 813	1007 144	1007 144	24 8890
2	0 0000	0 0000	-475 5096	0 00000	832 009	832 009	831 901	832 009	19 8005
3	0 0000	0 0000	-475 5096	0 00000	855 053	855 053	854 845	854 845	22 6730
4	0 0000	0 0000	71 3264	0 00000	944 729	944 729	944 534	944 534	54 3714
5	0 0000	0 0000	951 0192	0 00000	917 866	917 866	917 644	917 644	14 3630
6	0 0000	0 0000	713 2643	0 00000	918 215	918 215	918 157	918 157	128 0611
7	0 0000	0 0000	951 0192	0 00000	1153 236	1153 236	1152 845	1152 845	31 0273
8	0 0000	0 0000	-475 5096	0 00000	933 298	933 298	933 097	933 097	35 2328
9	0 0000	0 0000	356 6322	0 00000	1130 475	1130 475	1130 159	1130 159	35 3741
10	0 0000	0 0000	475 5096	0 00000	1203 598	1203 598	1202 964	1202 964	24 4278
11	0 0000	0 0000	356 6322	0 00000	858 108	858 108	857 225	858 108	16 8979
12	0 0000	0 0000	0 0000	0 00000	1372 167	1372 167	1371 046	1371 046	12 1931
13	0 0000	0 0000	237 7548	0 00000	891 528	891 528	891 028	891 028	17 1626
14	0 0000	0 0000	-475 5096	0 00000	843 343	843 343	843 063	843 063	38 8968
15	0 0000	0 0000	-475 5096	0 00000	929 205	929 205	928 996	928 996	47 6552
16	0 0000	0 0000	-475 5096	0 00000	893 138	893 138	893 091	893 091	32 0523
17	0 0000	0 0000	-475 5096	0 00000	895 832	895 832	895 739	895 739	33 2176
18	0 0000	0 0000	-475 5096	0 00000	985 426	985 426	984 493	984 493	43 5907
19	0 0000	0 0000	-475 5096	0 00000	905 752	905 752	905 421	905 421	23 3158
20	0 0000	0 0000	-475 5097	0 00000	1028 488	1028 488	1026 985	1026 985	33 8329
21	0 0000	0 0000	951 0192	0 00000	881 767	881 767	881 505	881 505	41 3262
22	0 0000	0 0000	118 8774	0 00000	874 601	874 601	873 687	873 687	24 0328
23	0 0000	0 0000	-47 5509	0 00000	684 863	684 863	684 128	684 372	27 1100
24	0 0000	0 0000	118 8774	0 00000	566 825	566 825	566 289	566 289	32 8183
25	0 0000	0 0000	71 3264	0 00000	557 245	557 245	556 905	556 905	28 6739
26	0 0000	0 0000	0 0000	0 00000	286 113	286 113	285 762	285 762	39 1188
27	0 0000	0 0000	118 8774	0 00000	263 133	263 133	262 782	262 782	29 1773
28	0 0000	0 0000	118 8774	0 00000	145 042	145 042	145 042	145 042	20 6698
29	0 0000	0 0000	118 8774	0 00000	145 411	145 411	145 005	145 410	49 2159
30	0 0000	0 0000	0 0000	0 00000	929 162	929 162	928 285	928 285	47 6365
31	0 0000	0 0000	356 6322	0 00000	745 983	745 983	745 558	745 558	53 5512
32	0 0000	0 0000	356 6323	0 00000	127 207	127 207	128 047	128 047	30 6314
33	0 0000	0 0000	-475 5096	0 00000	173 520	173 520	176 777	173 600	24 7890
41	12 9567	29 9498	0 0000	0 00000	1309 142	1339 091	1305 994	1335 944	155 2474
42	-60 6826	140 2701	0 0000	0 00000	1501 775	1642 045	1499 215	1639 485	68 2632
43	60 2848	139 3504	0 0000	0 00000	1264 350	1403 700	1261 648	1400 998	192 6432
44	-64 6532	149 4483	0 0000	0 00000	1177 258	1326 706	1173 314	1322 762	154 9662
45	10 6450	24 6063	0 0000	0 00000	939 241	963 847	938 403	963 010	51 9970
46	0 0000	0 0000	1382 3913	0 00000	1640 420	1640 420	1640 420	1640 420	14 6960
47	0 0000	0 0000	1246 8457	0 00000	1771 654	1771 654	1771 654	1771 654	14 6960
48	0 0000	0 0000	1280 8641	0 00000	1738 845	1738 845	1738 845	1738 845	14 6960

AFT Fathom 3.0 Output
NUMATEC HANFORD CORPORATION

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Jct	dP (psid)	dH (feet)	Vol Flow Into System (gal/min)	Loss Factor (K)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)	P Stag In (psia)
49	0 0000	0 0000	870 4930	0 00000	1574 803	1574 803	1574 803	1574 803	14 6960
50	0 0000	0 0000	2066 8181	0 00000	1968 504	1968 504	1968 504	1968 504	14 6960
51	0 0000	0 0000	2020 8418	0 00000	1968 504	1968 504	1968 504	1968 504	14 6960

Jct	P Stag Out (psia)	P Inlet (psia)	P Outlet (psia)
1	24 8890	24 5995	24 5995
2	19 8005	19 7536	19 8005
3	22 6730	22 5830	22 5830
4	54 3714	54 2868	54 2868
5	14 3630	14 2672	14 2672
6	128 0611	128 0358	128 0358
7	31 0273	30 8582	30 8582
8	35 2328	35 1457	35 1457
9	35 3741	35 2375	35 2375
10	24 4278	24 1535	24 1535
11	16 8979	16 5160	16 8979
12	12 1931	11 7080	11 7080
13	17 1626	16 9461	16 9461
14	38 8968	38 7758	38 7758
15	47 6552	47 5651	47 5651
16	32 0523	32 0317	32 0317
17	33 2176	33 1773	33 1773
18	43 5907	43 1869	43 1869
19	23 3158	23 1729	23 1729
20	33 8329	33 1828	33 1828
21	41 3262	41 2130	41 2130
22	24 0328	23 6374	23 6374
23	27 1100	26 7919	26 8972
24	32 8183	32 5865	32 5865
25	28 6739	28 5267	28 5267
26	39 1188	38 9669	38 9669
27	29 1773	29 0256	29 0256
28	20 6698	20 6695	20 6698
29	49 2159	49 0401	49 2156
30	47 6365	47 2571	47 2571
31	53 5512	53 3674	53 3674
32	30 6314	30 2679	30 2679
33	24 7890	23 3801	24 7544
41	168 2041	153 8858	166 8424
42	128 9458	67 1555	127 8381
43	252 9280	191 4742	251 7590
44	219 6195	153 2598	217 9131
45	62 6421	51 6346	62 2796
46	724 3625	14 6960	724 3625
47	781 1359	14 6960	781 1359
48	766 9426	14 6960	766 9426
49	695 9759	14 6960	695 9759
50	866 2959	14 6960	866 2959
51	866 2959	14 6960	866 2959

Sample #22

70 pipes 40 junctions

Model of a complicated branching network fed by six reservoirs Four of the reservoirs have pumps

One other booster pump is modeled Multiple loops exist Water is the working fluid

Reference Jeppson R W *Analysis of Flow in Pipe Networks* 1976 p 103

Solve the 70-pipe network below for the flow rates in all pipes the head losses in all pipes the elevation of the HGL at all junctions and the pressure at all junctions All pipes have $e = 0.0102$ inch

The pump characteristics are the following (hp is in feet and Q_p in cfs)

Pump J31 $Q_1 = 8.0 @ H_{p1} = 200$ $Q_2 = 11.0 @ H_{p2} = 180$ $Q_3 = 16.0 @ H_{p3} = 80$

Pump J32 $Q_1 = 5.0 @ H_{p1} = 180$ $Q_2 = 7.5 @ H_{p2} = 150$ $Q_3 = 10.0 @ H_{p3} = 50$

Pump J33 $Q_1 = 4.0 @ H_{p1} = 200$ $Q_2 = 6.0 @ H_{p2} = 180$ $Q_3 = 10.0 @ H_{p3} = 80$

Pump J34 $Q_1 = 4.0 @ H_{p1} = 250$ $Q_2 = 6.0 @ H_{p2} = 210$ $Q_3 = 8.0 @ H_{p3} = 150$

Pump J35 $Q_1 = 2.0 @ H_{p1} = 50$ $Q_2 = 4.0 @ H_{p2} = 40$ $Q_3 = 6.0 @ H_{p3} = 20$

AFT Fathom 3.0 Input
NUMATEC HANFORD CORPORATION
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Sample 22 Analysis of Flow in Pipe Networks Roland Jeppson 1976 p 103

Title Sample 22 Analysis of Flow in Pipe Networks Roland Jeppson 1976 p 103

Number Of Pipes= 70
Number Of Junctions= 40

Head/Pressure Convergence= 0001 (Relative change)
Flow Rate Convergence= 0001 (Relative change)
Relaxation= AFT Fathom Automatic
Maximum Iterations= 500

Constant Fluid Property Model
Fluid Water at 1 atm
Temperature 70 deg F
Density= 62.30842 lbm/ft³
Viscosity= 2.36004 lbm/hr-ft
Vapor Pressure= 36157 psia
Gravitational Acceleration= 1 g
Atmospheric Pressure= 1 atm

Pipe	Name	Object Defined	Length	Length Units	Hydraulic Diameter	Hydraulic Diam Units	Roughness	Roughness Units	Losses (K)	Junctions (Up,Down)	Geometry
1	Pipe	Yes	500	feet	12	inches	0102	inches	5	31, 1	Cylindrical Pipe
2	Pipe	Yes	1100	feet	10	inches	0102	inches	0	1, 2	Cylindrical Pipe
3	Pipe	Yes	1500	feet	10	inches	0102	inches	0	2, 3	Cylindrical Pipe
4	Pipe	Yes	2500	feet	8	inches	0102	inches	0	1, 3	Cylindrical Pipe
5	Pipe	Yes	1300	feet	8	inches	0102	inches	0	1, 4	Cylindrical Pipe
6	Pipe	Yes	1500	feet	10	inches	0102	inches	0	4, 3	Cylindrical Pipe
7	Pipe	Yes	1250	feet	10	inches	0102	inches	0	3, 5	Cylindrical Pipe
8	Pipe	Yes	1800	feet	8	inches	0102	inches	0	6, 3	Cylindrical Pipe
9	Pipe	Yes	2100	feet	10	inches	0102	inches	0	4, 6	Cylindrical Pipe
10	Pipe	Yes	1250	feet	10	inches	0102	inches	0	6, 5	Cylindrical Pipe
11	Pipe	Yes	2200	feet	12	inches	0102	inches	0	7, 5	Cylindrical Pipe
12	Pipe	Yes	2000	feet	10	inches	0102	inches	0	7, 6	Cylindrical Pipe
13	Pipe	Yes	500	feet	14	inches	0102	inches	4	32, 7	Cylindrical Pipe
14	Pipe	Yes	1600	feet	10	inches	0102	inches	0	7, 8	Cylindrical Pipe

15	Pipe	Yes	1800	feet	10	inches	0102	inches	0	7, 11	Cylindrical Pipe
16	Pipe	Yes	750	feet	8	inches	0102	inches	0	7, 12	Cylindrical Pipe
Pipe	Name	Object Defined	Length	Length Units	Hydraulic Diameter	Hydraulic Diam Units	Roughness	Roughness Units	Losses (K)	Junctions (Up Down)	Geometry
17	Pipe	Yes	1200	feet	10	inches	0102	inches	0	9, 8	Cylindrical Pipe
18	Pipe	Yes	1200	feet	10	inches	0102	inches	0	8, 11	Cylindrical Pipe
19	Pipe	Yes	1900	feet	12	inches	0102	inches	0	9, 11	Cylindrical Pipe
20	Pipe	Yes	1900	feet	12	inches	0102	inches	0	9, 10	Cylindrical Pipe
21	Pipe	Yes	1500	feet	10	inches	0102	inches	0	11, 10	Cylindrical Pipe
22	Pipe	Yes	1500	feet	10	inches	0102	inches	0	20, 10	Cylindrical Pipe
23	Pipe	Yes	2500	feet	12	inches	0102	inches	0	20, 11	Cylindrical Pipe
24	Pipe	Yes	1500	feet	10	inches	0102	inches	0	12, 11	Cylindrical Pipe
25	Pipe	Yes	3600	feet	10	inches	0102	inches	0	20, 12	Cylindrical Pipe
26	Pipe	Yes	3500	feet	10	inches	0102	inches	0	20, 13	Cylindrical Pipe
27	Pipe	Yes	1000	feet	8	inches	0102	inches	0	12, 13	Cylindrical Pipe
28	Pipe	Yes	2000	feet	10	inches	0102	inches	0	12, 6	Cylindrical Pipe
29	Pipe	Yes	1750	feet	10	inches	0102	inches	0	13, 14	Cylindrical Pipe
30	Pipe	Yes	700	feet	8	inches	0102	inches	0	6, 14	Cylindrical Pipe
31	Pipe	Yes	3700	feet	8	inches	0102	inches	0	15, 14	Cylindrical Pipe
32	Pipe	Yes	1600	feet	10	inches	0102	inches	0	15, 4	Cylindrical Pipe
33	Pipe	Yes	1000	feet	10	inches	0102	inches	0	1, 15	Cylindrical Pipe
34	Pipe	Yes	1800	feet	10	inches	0102	inches	0	15, 16	Cylindrical Pipe
35	Pipe	Yes	3600	feet	8	inches	0102	inches	0	14, 16	Cylindrical Pipe
36	Pipe	Yes	4500	feet	10	inches	0102	inches	0	25, 14	Cylindrical Pipe
37	Pipe	Yes	1500	feet	10	inches	0102	inches	0	25, 16	Cylindrical Pipe
38	Pipe	Yes	2000	feet	12	inches	0102	inches	0	14, 17	Cylindrical Pipe
39	Pipe	Yes	1200	feet	12	inches	0102	inches	0	24, 17	Cylindrical Pipe
40	Pipe	Yes	3100	feet	12	inches	0102	inches	0	25, 24	Cylindrical Pipe
41	Pipe	Yes	1600	feet	10	inches	0102	inches	0	18, 17	Cylindrical Pipe
42	Pipe	Yes	3100	feet	10	inches	0102	inches	0	24, 13	Cylindrical Pipe
43	Pipe	Yes	1600	feet	10	inches	0102	inches	0	24, 23	Cylindrical Pipe
44	Pipe	Yes	1500	feet	8	inches	0102	inches	0	13, 18	Cylindrical Pipe
45	Pipe	Yes	1200	feet	8	inches	0102	inches	0	23, 18	Cylindrical Pipe
46	Pipe	Yes	1700	feet	10	inches	0102	inches	0	19, 18	Cylindrical Pipe
47	Pipe	Yes	1800	feet	10	inches	0102	inches	0	22, 23	Cylindrical Pipe
48	Pipe	Yes	1400	feet	8	inches	0102	inches	0	19, 22	Cylindrical Pipe

49	Pipe	Yes	2100	feet	10	inches	0102	inches	0	20, 22	Cylindrical Pipe
50	Pipe	Yes	1500	feet	10	inches	0102	inches	0	21, 22	Cylindrical Pipe
51	Pipe	Yes	1500	feet	12	inches	0102	inches	0	20, 21	Cylindrical Pipe
52	Pipe	Yes	750	feet	14	inches	0102	inches	0	33, 20	Cylindrical Pipe

Pipe	Name	Object Defined	Length	Length Units	Hydraulic Diameter	Hydraulic Diam Units	Roughness	Roughness Units	Losses (K)	Junctions (Up Down)	Geometry
53	Pipe	Yes	1600	feet	10	inches	0102	inches	0	25, 26	Cylindrical Pipe
54	Pipe	Yes	2100	feet	10	inches	0102	inches	0	26, 24	Cylindrical Pipe
55	Pipe	Yes	1750	feet	12	inches	0102	inches	0	26, 35	Cylindrical Pipe
56	Pipe	Yes	2000	feet	12	inches	0102	inches	0	24, 27	Cylindrical Pipe
57	Pipe	Yes	1000	feet	10	inches	0102	inches	0	27, 23	Cylindrical Pipe
58	Pipe	Yes	1900	feet	10	inches	0102	inches	0	27, 28	Cylindrical Pipe
59	Pipe	Yes	1000	feet	10	inches	0102	inches	0	22, 28	Cylindrical Pipe
60	Pipe	Yes	1300	feet	10	inches	0102	inches	0	28, 29	Cylindrical Pipe
61	Pipe	Yes	1000	feet	10	inches	0102	inches	0	21, 29	Cylindrical Pipe
62	Pipe	Yes	750	feet	14	inches	0102	inches	0	34, 24	Cylindrical Pipe
63	Pipe	Yes	1500	feet	10	inches	0102	inches	0	46, 25	Cylindrical Pipe
64	Pipe	Yes	1500	feet	10	inches	0102	inches	5	20, 19	Cylindrical Pipe
65	Pipe	Yes	1000	feet	12	inches	0102	inches	4	47, 9	Cylindrical Pipe
71	Pipe	Yes	500	feet	12	inches	0102	inches	0	41, 31	Cylindrical Pipe
72	Pipe	Yes	500	feet	14	inches	0102	inches	0	42, 32	Cylindrical Pipe
73	Pipe	Yes	750	feet	14	inches	0102	inches	0	43, 33	Cylindrical Pipe
74	Pipe	Yes	750	feet	14	inches	0102	inches	0	44, 34	Cylindrical Pipe
75	Pipe	Yes	1750	feet	12	inches	0102	inches	0	35, 27	Cylindrical Pipe

Pipe	Material	Thermal Boundary	Overall U	Include Internal h	Special Condition
1	Unspecified	Adiabatic	0	No	None
2	Unspecified	Adiabatic	0	No	None
3	Unspecified	Adiabatic	0	No	None
4	Unspecified	Adiabatic	0	No	None
5	Unspecified	Adiabatic	0	No	None
6	Unspecified	Adiabatic	0	No	None
7	Unspecified	Adiabatic	0	No	None
8	Unspecified	Adiabatic	0	No	None
9	Unspecified	Adiabatic	0	No	None
10	Unspecified	Adiabatic	0	No	None

11	Unspecified	Adiabatic	0	No	None
Pipe	Material	Thermal Boundary	Overall U	Include Internal h	Special Condition
12	Unspecified	Adiabatic	0	No	None
13	Unspecified	Adiabatic	0	No	None
14	Unspecified	Adiabatic	0	No	None
15	Unspecified	Adiabatic	0	No	None
16	Unspecified	Adiabatic	0	No	None
17	Unspecified	Adiabatic	0	No	None
18	Unspecified	Adiabatic	0	No	None
19	Unspecified	Adiabatic	0	No	None
20	Unspecified	Adiabatic	0	No	None
21	Unspecified	Adiabatic	0	No	None
22	Unspecified	Adiabatic	0	No	None
23	Unspecified	Adiabatic	0	No	None
24	Unspecified	Adiabatic	0	No	None
25	Unspecified	Adiabatic	0	No	None
26	Unspecified	Adiabatic	0	No	None
27	Unspecified	Adiabatic	0	No	None
28	Unspecified	Adiabatic	0	No	None
29	Unspecified	Adiabatic	0	No	None
30	Unspecified	Adiabatic	0	No	None
31	Unspecified	Adiabatic	0	No	None
32	Unspecified	Adiabatic	0	No	None
33	Unspecified	Adiabatic	0	No	None
34	Unspecified	Adiabatic	0	No	None
35	Unspecified	Adiabatic	0	No	None
36	Unspecified	Adiabatic	0	No	None
37	Unspecified	Adiabatic	0	No	None
38	Unspecified	Adiabatic	0	No	None
39	Unspecified	Adiabatic	0	No	None
40	Unspecified	Adiabatic	0	No	None
41	Unspecified	Adiabatic	0	No	None
42	Unspecified	Adiabatic	0	No	None
43	Unspecified	Adiabatic	0	No	None
44	Unspecified	Adiabatic	0	No	None

45	Unspecified	Adiabatic	0	No	None
46	Unspecified	Adiabatic	0	No	None
47	Unspecified	Adiabatic	0	No	None
48	Unspecified	Adiabatic	0	No	None
Pipe	Material	Thermal Boundary	Overall U	Include Internal h	Special Condition
49	Unspecified	Adiabatic	0	No	None
50	Unspecified	Adiabatic	0	No	None
51	Unspecified	Adiabatic	0	No	None
52	Unspecified	Adiabatic	0	No	None
53	Unspecified	Adiabatic	0	No	None
54	Unspecified	Adiabatic	0	No	None
55	Unspecified	Adiabatic	0	No	None
56	Unspecified	Adiabatic	0	No	None
57	Unspecified	Adiabatic	0	No	None
58	Unspecified	Adiabatic	0	No	None
59	Unspecified	Adiabatic	0	No	None
60	Unspecified	Adiabatic	0	No	None
61	Unspecified	Adiabatic	0	No	None
62	Unspecified	Adiabatic	0	No	None
63	Unspecified	Adiabatic	0	No	None
64	Unspecified	Adiabatic	0	No	None
65	Unspecified	Adiabatic	0	No	None
71	Unspecified	Adiabatic	0	No	None
72	Unspecified	Adiabatic	0	No	None
73	Unspecified	Adiabatic	0	No	None
74	Unspecified	Adiabatic	0	No	None
75	Unspecified	Adiabatic	0	No	None

Branch	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Initial HGL/Pressure Units	Connected Pipes (+ = in, = out)
1	Branch	Yes	None	150	feet			1, 2, 4, 5, 33
2	Branch	Yes	None	150	feet			2, 3
3	Branch	Yes	None	160	feet			3, 4, 6, 7, 8
4	Branch	Yes	None	150	feet			5, 6, 9, 32

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5	Branch	Yes	None	165	feet		7,10,11
6	Branch	Yes	None	160	feet		-8,9,-10,12,28,-30
7	Branch	Yes	None	180	feet		-11,-12,13,-14,-15,16
8	Branch	Yes	None	190	feet		14,17,18
9	Branch	Yes	None	200	feet		-17,-19,-20,65
10	Branch	Yes	None	180	feet		20,21,22
11	Branch	Yes	None	190	feet		15,18,19,-21,23,24
12	Branch	Yes	None	190	feet		16,-24,25,-27,-28
13	Branch	Yes	None	180	feet		26,27,-29,42,-44
14	Branch	Yes	None	160	feet		29,30,31,-35,36,-38
15	Branch	Yes	None	150	feet		-31,-32,33,-34
16	Branch	Yes	None	150	feet		34,35,37
17	Branch	Yes	None	140	feet		38,39,41
18	Branch	Yes	None	150	feet		-41,44,45,46
19	Branch	Yes	None	170	feet		-46,-48,64
20	Branch	Yes	None	180	feet		-22,-23,25,26,-49,-51,52,-64
21	Branch	Yes	None	170	feet		50,51,-61
22	Branch	Yes	None	160	feet		-47,48,49,50,-59
23	Branch	Yes	None	150	feet		43,-45,47,57
24	Branch	Yes	None	150	feet		-39,40,-42,-43,54,56,62
25	Branch	Yes	None	140	feet		-36,-37,-40,-53,63
26	Branch	Yes	None	130	feet		53,-54,-55
27	Branch	Yes	None	130	feet		56,-57,-58,75
28	Branch	Yes	None	130	feet		58,59,60
29	Branch	Yes	None	125	feet		60,61

Pump	Name	Object Defined	Special Condition	Elevation	Elevation	Initial HGL/Pressure	Initial HGL/Pressure	Connected Pipes (+ = in, - = out)
31	Pump 1	Yes	None	150	feet			71,-1
32	Pump 2	Yes	None	180	feet			72,-13
33	Pump 3	Yes	None	180	feet			73,-52
34	Pump 4	Yes	None	150	feet			74,-62

35	Pump 5	Yes	None	130	feet		55,-75
Reservoir	Name	Object Defined	Special Condition	Elevation	Elevation Units	Initial HGL/Pressure	Connected Pipes (+ = in, - = out)
41	Reservoir 1	Yes	N/A	300	feet	300	71
42	Reservoir 2	Yes	N/A	350	feet	350	72
43	Reservoir 3	Yes	N/A	280	feet	280	-73
44	Reservoir 4	Yes	N/A	150	feet	150	-74
46	Reservoir 6	Yes	N/A	300	feet	300	-63
47	Reservoir 7	Yes	N/A	400	feet	400	-65

[illegible]

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(9)

AFT Fathom 3.0 Input
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Pump	Speed %	Viscosity Correction	
31	100	No	
32	100	No	
33	100	No	
34	100	No	
35	100	No	

AFT Fathom 3.0 Input
NUMATEC HANFORD CORPORATION

(10)

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Reservoir		
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AFT Fathom 3.0 Output
NUMATEC HANFORD CORPORATION

(1)

12/03/1999

Sample 22 Analysis of Flow in Pipe Networks Roland Jeppson 1976 p 103

Title Sample 22 Analysis of Flow in Pipe Networks Roland Jeppson 1976 p 103
Analysis run on 12/03/1999 11 16 40 AM
Input File C:\FATHOM\SAMPLES\SAMPLE22.FTH

Execution Time= 3 30 seconds
Total Number Of Head/Pressure Iterations= 143
Total Number Of Temperature Iterations= 0
Total Number Of Flow Iterations= 57
Number Of Pipes= 70
Number Of Junctions= 40
Head Tolerance= 0001 relative change
Volumetric Flow Rate Tolerance= 0001 relative change
Relaxation= 2

Constant Fluid Property Model
Fluid Water at 1 atm
Temperature 70 deg F
Density= 62 30842 lbm/ft3
Viscosity= 2 36004 lbm/hr-ft
Vapor Pressure= 36157 psia
Gravitational Acceleration= 1 g
Atmospheric Pressure= 1 atm

Total Inflow= 42 6950 ft3/sec
Total Outflow= 42 6950 ft3/sec
Maximum Pressure is 139 514 psia at Junction 31 Outlet
Minimum Pressure is 11 8748 psia at Junction 34 Inlet

=====PUMP SUMMARY=====

Jct	Flow (ft3/sec)	DP (psid)	DH (feet)	Speed (%)	Ideal hp (hp)	NPSHA (feet)	NPSHR (feet)
31	11 506	75 148	173 67	100 00	226 34	151 25	N/A
32	9 9358	23 126	53 446	100 00	60 150	192 45	N/A
33	8 9458	49 379	114 12	100 00	115 64	120 11	N/A
34	6 0539	90 280	208 65	100 00	143 07	27 106	N/A
35	3 4309	18 980	43 863	100 00	17 046	217 40	N/A

AFT Fathom 3.0 Output
NUMATEC HANFORD CORPORATION

(2)

12/03/1999

Sample 22 Analysis of Flow in Pipe Networks Roland Jeppson 1976 p 103

Pipe	Vol Flow (ft ³ /sec)	Mass Flow (lbm/sec)	Velocity (feet/sec)	dP Total (psid)	dP Friction (psid)	dP Gravity (psid)	dH (feet)	Max Pres (psia)	Min Pres (psia)	Dyn Pres (psia)
1	11.5055912	716.89519	14.6493756	21.007530	21.00753021	0.00000	48.55017342	139.5137	118.5062	1.4430699348
2	3.1738682	197.75871	5.8191773	6.117567	6.11756659	0.00000	14.13821214	119.7216	113.6040	0.2277048677
3	2.1738712	135.45048	3.9857175	8.293011	3.96603727	4.32697	9.16584651	113.7249	105.4319	0.1068223640
4	1.4972624	93.29205	4.2893413	14.410578	10.08360386	4.32697	23.30405864	119.8256	105.4150	0.1237172782
5	2.2008398	137.13085	6.3049423	11.185513	11.18551254	0.00000	25.85066251	119.6820	108.4965	0.2673076391
6	-1.1257671	-70.14477	-2.0640550	3.225065	-1.10190880	4.32697	2.54660414	108.7351	105.5101	0.0286478270
7	0.3763869	23.45207	0.6900923	2.277747	0.11426017	2.16349	0.26406488	105.5355	103.2578	0.0032023110
8	-0.6689768	-41.68289	-1.9164777	-1.514155	1.51415479	0.00000	-3.49933938	105.5140	103.9999	0.0246977098
9	0.5649479	35.20101	1.0358123	4.739220	0.41224608	4.32697	0.95273544	108.7566	104.0173	0.0072145835
10	-1.3995495	-87.20371	-2.5660254	0.763592	-1.39989471	2.16349	-3.23527471	103.9803	103.2167	0.0442762747
11	2.5231654	157.21444	3.2125943	3.447754	3.04270554	-6.49046	7.03194902	103.1916	99.7438	0.0694002286
12	1.9887487	123.91579	3.6463017	-4.211347	4.44260025	-8.65395	10.26722372	103.9352	99.7238	0.0894034654
13	9.9357539	619.08111	9.2943154	6.945422	6.94542217	0.00000	16.05145619	106.1777	99.2323	0.5808767080
14	1.0713452	66.75382	1.9642742	5.395069	1.06809545	4.32697	2.46845862	99.7873	94.3922	0.0259449817
15	1.5307675	95.37970	2.8066092	6.726415	2.39944172	4.32697	5.54531210	99.7602	93.0338	0.0529679358
16	1.8217398	113.50973	5.2189007	8.773886	4.44691277	4.32697	10.27719031	99.6301	90.8562	0.1831501275
17	1.3214518	82.33757	2.4228359	-3.124740	1.20223320	-4.32697	2.77846227	94.3787	91.2539	0.0394727290
18	1.3927975	86.78301	2.5536458	1.331346	1.33134639	0.00000	3.07685376	94.3743	93.0429	0.0438500866
19	2.4763655	154.29841	3.1530068	1.793394	2.53357959	-4.32697	5.85531603	93.0199	91.2265	0.0668496266
20	2.4560630	153.03340	3.1271570	-6.160719	2.49322796	-8.65395	5.76206001	97.3884	91.2276	0.0657579899
21	-0.1942166	-12.10133	-0.3560894	-4.367325	-0.04035158	-4.32697	-0.09325591	97.4533	93.0859	0.0008526430
22	-1.2618410	-78.62332	-2.3135417	-1.374106	1.37410605	0.00000	3.17567493	97.4181	96.0440	0.0359918177
23	1.5446395	-96.24404	-1.9666963	2.993219	-1.33375454	4.32697	-3.08241919	96.0540	93.0608	0.0260090064
24	1.5495067	96.54731	-2.8409668	2.047471	-2.04747081	0.00000	-4.73187766	93.0325	90.9850	0.0542727038
25	0.5678895	35.38430	1.0412057	5.040690	0.71371639	4.32697	1.64945874	96.0727	91.0320	0.0072899102
26	1.9851892	123.69400	3.6397755	7.747440	7.74743986	0.00000	17.90498669	95.9909	88.2435	0.0890837237
27	1.9868835	123.79957	5.6920025	2.706750	7.03372335	-4.32697	16.25552767	90.8215	88.1147	0.2178609073
28	-0.0477391	-2.97455	-0.0875279	-12.985232	-0.00431243	-12.98092	-0.00996640	104.0245	91.0393	0.0000515160

29	1 0721936	66 80669	1 9658298	7 483893	1 17005360	-8 65395	2 70409252	95 7905	88 3066	0 0259860940
30	2 5744900	160 41240	7 3753713	8 208090	8 2080983	0 00000	18 96958760	103 6588	95 4507	0 3657774329
31	1 0930816	68 10818	3 1314484	12 392658	8 06568432	4 32697	18 64047646	108 1432	95 7505	0 0659385920
Pipe	Vol Flow (ft ³ /sec)	Mass Flow (lbm/sec)	Velocity (feet/sec)	dP Total (psid)	dP Friction (psid)	dP Gravity (psid)	dH (feet)	Max Pres (psia)	Min Pres (psia)	Dyn Pres (psia)
32	0 7616650	-47 45814	-1 3964864	-0 554651	-0 55465144	0 00000	-1 28184624	108 7507	108 1960	0 0131136198
33	4 6336280	288 71403	8 4955962	11 740164	11 74016380	0 00000	27 13250834	119 4640	107 7238	0 4853296876
34	3 3022192	205 75606	6 0545044	10 824026	10 82402611	0 00000	25 01523688	107 9626	97 1386	0 2464939952
35	0 6373324	39 71117	1 8258231	-1 568632	2 75834179	-4 32697	6 37476042	97 3627	95 7940	0 0224164352
36	-1 7435872	-108 64016	3 1968066	0 923456	7 73049068	8 65395	-17 86581571	96 6712	95 7477	0 0687197968
37	-2 4395489	-152 00443	-4 4728283	-0 645176	-4 97214937	4 32697	-11 49105639	97 2506	96 6054	0 1345282793
38	0 8588453	53 51329	1 0935160	8 307167	0 34678006	8 65395	0 80143796	104 1156	95 8084	0 0080408026
39	-0 3126611	19 48142	-0 3980925	-4 358459	-0 03148544	-4 32697	-0 07276551	104 1226	99 7641	0 0010856563
40	-3 3240809	-207 11822	-4 2323518	-3 025252	7 35222530	4 32697	-16 99161253	99 6447	96 6195	0 1204516292
41	0 9538183	59 43091	1 7487928	-3 473101	0 85387236	-4 32697	1 97337101	104 1031	100 6300	0 0205648653
42	-0 9215089	-57 41776	-1 6895546	11 432601	1 54831910	12 98092	-3 57829598	99 7460	88 3134	0 0191952437
43	-0 7837122	-48 83187	-1 4369091	-0 585762	-0 58576161	0 00000	-1 35374446	100 3370	99 7513	0 0138837807
44	0 4783721	29 80661	1 3704353	12 317959	0 66296130	-12 98092	1 53215947	100 6379	88 3199	0 0126289204
45	-0 3542340	22 07176	-1 0148057	-0 299596	-0 29959619	0 00000	0 69239205	100 6436	100 3440	0 0069249235
46	1 3296835	82 85048	2 4379286	-6 930206	1 72374058	8 65395	3 98370980	100 6106	93 6804	0 0399660394
47	1 2893209	80 33555	2 3639252	-2 607747	1 71922624	-4 32697	3 97327679	100 3134	97 7056	0 0375765264
48	0 3290826	20 50461	0 9427522	-4 022863	0 30411056	-4 32697	0 70282514	97 7372	93 7143	0 0059764641
49	2 4448335	152 33371	4 4825174	1 663176	6 99077129	-8 65395	16 15626184	97 6081	95 9449	0 1351117492
50	1 3780923	85 86675	2 5266844	2 696740	1 63023353	-4 32697	3 76760712	97 7003	95 0035	0 0429290347
51	4 0956179	255 19147	5 2147033	1 033564	5 36053753	-4 32697	12 38865416	95 8972	94 8636	0 1828556359
52	8 9457959	557 39840	8 3682877	5 632269	5 63226891	0 00000	13 01664828	101 2414	95 6091	0 4708908796
53	1 5622082	97 33872	2 8642546	-2 108056	2 21891761	-4 32697	5 12810566	98 7928	96 6847	0 0551661141
54	-2 8686853	-178 74324	-5 2596349	-0 917196	-9 57114315	8 65395	-22 11971874	99 5791	98 6620	0 1860202998
55	3 4308988	213 77388	4 3683566	4 416104	4 41610432	0 00000	10 20598939	98 7197	94 3036	0 1283173263
56	1 1209685	-69 84577	-1 4272615	-9 230133	0 57618570	-8 65395	-1 33161374	108 9816	99 7515	0 0136979716
57	-0 1098400	-6 84396	-0 2013878	8 644371	-0 00957591	8 65395	-0 02213073	108 9950	100 3507	0 0002727190
58	-1 0802192	67 30675	-1 9805444	1 288767	-1 28876734	0 00000	-2 97844997	110 2577	108 9689	0 0263765696
59	0 8626910	53 75291	1 5817140	12 540885	0 44003484	-12 98092	1 01695761	110 2672	97 7264	0 0168230645
60	0 7175291	-44 70810	-1 3155647	-2 565579	0 40209222	-2 16349	0 92926902	112 8380	110 2724	0 0116378721
61	1 7175309	107 01663	3 1490333	-17 803204	1 66817617	-19 47138	3 85529578	112 7830	94 9798	0 0666812360
62	6 0539041	377 20919	5 6630724	2 605489	2 60548878	0 00000	6 02150423	102 1550	99 5495	0 2156519443

63	-3.9450219	-245.80808	-7.2330609	-77.716965	-12.81236553	-64.90460	-29.61045693	96.3881	18.6712	0.3517980278
64	2.6587608	165.66318	4.8747456	2.359687	6.68666077	-4.32697	15.45343677	95.9202	93.5605	0.1597912759
65	6.2538755	389.66909	7.9626825	72.270447	9.94204903	-82.21249	22.97691349	90.8670	18.5966	0.4263516366
71	11.5055912	716.89519	14.6493756	-46.785442	13.79218197	-60.57763	31.87489532	64.3653	17.5799	1.4430699348

Pipe	Vol Flow (ft ³ /sec)	Mass Flow (lbm/sec)	Velocity (feet/sec)	dP Total (psid)	dP Friction (psid)	dP Gravity (psid)	dH (feet)	Max Pres (psia)	Min Pres (psia)	Dyn Pres (psia)
72	9.9357539	619.08111	9.2943154	-64.609665	4.62191296	-69.23158	10.68163050	83.0517	18.4421	0.5808767080
73	8.9457959	557.39840	8.3682677	33.310436	5.63232517	-38.94276	13.01677832	51.8625	18.5521	0.4708908796
74	6.0539041	377.20919	5.6630724	6.932485	2.60551119	4.32697	6.02155602	18.8073	11.8748	0.2156519443
75	3.4308988	213.77388	4.3683566	4.416149	4.41614914	0.00000	10.20609298	113.2831	108.8670	0.1283173263

Pipe	dP/dx (psi/100 ft)	Resistance (sec ² /ft ⁵)	f	Reynolds No	fL/D	K	fL/D + K
1	4.201506042	0.366752	0.0191151	1.39235E+06	9.55753	5.00000	14.55753
2	0.556142417	1.403514	0.0203532	4.60904E+05	26.86622	0.00000	26.86622
3	0.264402485	1.939568	0.0206264	3.15686E+05	37.12754	0.00000	37.12754
4	0.403344154	10.395269	0.0217348	2.71787E+05	81.50551	0.00000	81.50551
5	0.860424042	5.336971	0.0214591	3.99503E+05	41.84523	0.00000	41.84523
6	-0.073460587	2.009390	0.0213689	1.63482E+05	38.46396	0.00000	38.46396
7	0.009140813	1.863982	0.0237886	5.46583E+04	35.68292	0.00000	35.68292
8	-0.084119711	7.819228	0.0227064	1.21435E+05	61.30716	0.00000	61.30716
9	0.019630766	2.985077	0.0226752	8.20408E+04	57.14160	0.00000	57.14160
10	-0.111991577	1.651713	0.0210782	2.03240E+05	31.61727	0.00000	31.61727
11	0.138304797	1.104547	0.0199284	3.05341E+05	43.84251	0.00000	43.84251
12	0.222130013	2.595931	0.0207048	2.88803E+05	49.69150	0.00000	49.69150
13	1.389084435	0.162597	0.0185658	1.03061E+06	7.95679	4.00000	11.95679
14	0.066755965	2.150637	0.0214422	1.55579E+05	41.16910	0.00000	41.16910
15	0.133302318	2.366505	0.0209724	2.22295E+05	45.30047	0.00000	45.30047
16	0.592921702	3.096718	0.0215827	3.30687E+05	24.28048	0.00000	24.28048
17	0.100186100	1.591116	0.0211500	1.91899E+05	30.45607	0.00000	30.45607
18	0.110945533	1.586101	0.0210841	2.02260E+05	30.36111	0.00000	30.36111
19	0.133346294	0.954819	0.0199467	2.99678E+05	37.89873	0.00000	37.89873
20	0.131222524	0.955210	0.0199548	2.97221E+05	37.91418	0.00000	37.91418
21	-0.002690105	2.472314	0.0262918	2.82038E+04	47.32530	0.00000	47.32530
22	0.091607070	1.994467	0.0212103	1.83242E+05	38.17848	0.00000	38.17848
23	-0.053350182	1.291925	0.0205122	1.86925E+05	51.28049	0.00000	51.28049
24	-0.136498054	1.970818	0.0209587	2.25017E+05	37.72561	0.00000	37.72561

25	0 019825455	5 114625	0 0226628	8 24679E+04	97 90347	0 00000	97 90347
26	0 0221355425	4 543287	0 0207064	2 88286E+05	86 96701	0 00000	86 96701
Pipe	dP/idx (psi/100 ft)	Resistance (sec2/ft5)	f	Reynolds No	fL/D	K	fL/D + K
27	0 703372335	4 117715	0 0215233	3 60665E+05	32 28499	0 00000	32 28499
28	-0 000215622	4 373109	0 0354170	6 93258E+03	85 00085	0 00000	85 00085
29	0 066860206	2 352205	0 0214410	1 55702E+05	45 02620	0 00000	45 02620
30	1 172584261	2 862039	0 0213715	4 67329E+05	22 44005	0 00000	22 44005
31	0 217991468	15 600979	0 0220398	1 98419E+05	122 32095	0 00000	122 32095
32	-0 034665715	2 209571	0 0220291	1 10608E+05	42 29583	0 00000	42 29583
33	1 174016380	1 263711	0 0201585	6 72887E+05	24 19016	0 00000	24 19016
34	0 601334784	2 293997	0 0203295	4 79543E+05	43 91177	0 00000	43 91177
35	0 076620605	15 693935	0 0227872	1 15690E+05	123 05113	0 00000	123 05113
36	-0 171788682	5 876727	0 0208320	2 53201E+05	112 49299	0 00000	112 49299
37	-0 331476625	1 930816	0 0205334	3 54267E+05	36 96010	0 00000	36 96010
38	0 017339003	1 086526	0 0215637	1 03933E+05	43 12730	0 00000	43 12730
39	-0 002623787	0 744351	0 0246385	3 78368E+04	29 56621	0 00000	29 56621
40	0 237168558	1 537770	0 0196899	4 02264E+05	61 03882	0 00000	61 03882
41	0 053367022	2 169089	0 0216256	1 38512E+05	41 52118	0 00000	41 52118
42	-0 049945777	4 213832	0 0216832	1 33820E+05	80 66136	0 00000	80 66136
43	-0 036610100	2 204060	0 0219742	1 13809E+05	42 19039	0 00000	42 19039
44	0 044197420	6 695334	0 0233314	8 68355E+04	52 49574	0 00000	52 49574
45	-0 024966349	5 517872	0 0240353	6 43016E+04	43 26347	0 00000	43 26347
46	0 101396505	2 253155	0 0211421	1 93094E+05	43 12992	0 00000	43 12992
47	0 095512569	2 390159	0 0211819	1 87233E+05	45 75288	0 00000	45 75288
48	0 021722183	6 489893	0 0242311	5 97360E+04	50 88525	0 00000	50 88525
49	0 332893871	2 702977	0 0205317	3 55035E+05	51 73996	0 00000	51 73996
50	0 108682235	1 983851	0 0210972	2 00124E+05	37 97495	0 00000	37 97495
51	0 357369169	0 738559	0 0195435	4 95632E+05	29 31519	0 00000	29 31519
52	0 750969187	0 162653	0 0186060	9 27924E+05	11 96100	0 00000	11 96100
53	0 138682351	2 101257	0 0209495	2 26861E+05	40 22306	0 00000	40 22306
54	-0 455768721	2 687904	0 0204175	4 16586E+05	51 45214	0 00000	51 45214
55	0 252348818	0 867040	0 0196660	4 15191E+05	34 41549	0 00000	34 41549
56	-0 028809285	1 059721	0 0210316	1 35654E+05	42 06311	0 00000	42 06311
57	0 000957591	1 834319	0 0292801	1 59508E+04	35 13616	0 00000	35 13616
58	-0 067829860	2 552505	0 0214298	1 56868E+05	48 86001	0 00000	48 86001

59	0.044003484	1.366445	0.0217975	1.25278E+05	26.15700	0.00000	26.15700
60	-0.030930171	1.804939	0.0221476	1.04198E+05	34.55032	0.00000	34.55032
61	0.166817617	1.306919	0.0208475	2.49417E+05	25.01702	0.00000	25.01702
62	0.347398504	0.164299	0.0187943	6.27955E+05	12.08202	0.00000	12.08202

Pipe	dP/dx (psi/100 ft)	Resistance (sec ² /ft ⁵)	f	Reynolds No	fl/D	K	fl/D + K
63	-0.854157702	1.902595	0.0202331	5.72889E+05	36.41966	0.00000	36.41966
64	0.445777384	2.186083	0.0204698	3.86101E+05	36.84565	5.00000	41.84565
65	0.994204903	0.587480	0.0193182	7.56814E+05	19.31815	4.00000	23.31815
71	2.758436394	0.240786	0.0191151	1.39235E+06	9.55753	0.00000	9.55753
72	0.924382591	0.108202	0.0185658	1.03061E+06	7.95679	0.00000	7.95679
73	0.750976690	0.162654	0.0186060	9.27924E+05	11.96100	0.00000	11.96100
74	0.347401492	0.164300	0.0187943	6.27955E+05	12.08202	0.00000	12.08202
75	0.252351379	0.867049	0.0196660	4.15191E+05	34.41549	0.00000	34.41549

Jct	dP (psid)	dH (feet)	Vol Flow Into System (gal/min)	Loss Factor (K)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)	P Stag In (psia)	P Stag Out (psia)
1	0.0000	0.0000	0.000	0.00000	393.249	393.249	392.276	392.276	119.9493	119.9493
2	0.0000	0.0000	-448.830	0.00000	379.111	379.111	378.585	378.864	113.8317	113.8317
3	0.0000	0.0000	-673.248	0.00000	369.945	369.945	369.841	369.841	105.5387	105.5387
4	0.0000	0.0000	-897.659	0.00000	367.399	367.399	367.285	367.285	108.7638	108.7638
5	0.0000	0.0000	-673.248	0.00000	369.681	369.681	369.609	369.609	103.2610	103.2610
6	0.0000	0.0000	897.659	0.00000	366.446	366.446	366.327	366.327	104.0246	104.0246
7	0.0000	0.0000	-448.825	0.00000	376.713	376.713	376.418	376.418	99.8132	99.8132
8	0.0000	0.0000	-448.831	0.00000	374.245	374.245	374.161	374.161	94.4181	94.4181
9	0.0000	0.0000	0.000	0.00000	377.023	377.023	376.753	376.753	91.2934	91.2934
10	0.0000	0.0000	-448.834	0.00000	371.261	371.261	371.203	371.203	97.4541	97.4541
11	0.0000	0.0000	1122.078	0.00000	371.168	371.168	371.087	371.087	93.0868	93.0868
12	0.0000	0.0000	897.658	0.00000	366.436	366.436	366.298	366.298	91.0393	91.0393
13	0.0000	0.0000	-673.246	0.00000	350.180	350.180	350.052	350.052	88.3326	88.3326
14	0.0000	0.0000	-673.247	0.00000	347.476	347.476	347.327	347.327	95.8165	95.8165
15	0.0000	0.0000	-448.827	0.00000	366.117	366.117	365.763	365.763	108.2091	108.2091
16	0.0000	0.0000	-673.248	0.00000	341.102	341.102	340.838	340.838	97.3851	97.3851
17	0.0000	0.0000	673.248	0.00000	346.675	346.675	346.657	346.657	104.1236	104.1236
18	0.0000	0.0000	-224.417	0.00000	348.648	348.648	348.606	348.606	100.6505	100.6505
19	0.0000	0.0000	-448.829	0.00000	352.632	352.632	352.514	352.514	93.7203	93.7203

20	0.0000	0.0000	0.0000	0.0000	0.0000	368.085	367.838	367.838	96.0800	96.0800
21	0.0000	0.0000	-448.829	0.0000	0.0000	355.697	355.492	355.492	95.0464	95.0464
Jct	dP (psid)	dH (feet)	Vol Flow Into System (gal/min)	Loss Factor (K)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)	P Stag In (psia)	P Stag Out (psia)
22	0.0000	0.0000	-897.660	0.0000	351.929	351.929	351.841	351.841	97.7432	97.7432
23	0.0000	0.0000	-336.624	0.0000	347.956	347.956	347.931	347.931	100.3509	100.3509
24	0.0000	0.0000	-1346.488	0.0000	346.602	346.602	346.474	346.474	99.7652	99.7652
25	0.0000	0.0000	-897.656	0.0000	329.610	329.610	329.310	329.310	96.7399	96.7399
26	0.0000	0.0000	-448.829	0.0000	324.482	324.482	324.213	324.213	98.8480	98.8480
27	0.0000	0.0000	-1570.904	0.0000	347.934	347.934	347.872	347.872	108.9953	108.9953
28	0.0000	0.0000	-224.416	0.0000	350.912	350.912	350.871	350.871	110.2841	110.2841
29	0.0000	0.0000	-448.832	0.0000	351.841	351.841	351.687	351.687	112.8496	112.8496
31	-75.1484	-173.6743	0.000	0.0000	268.125	441.799	264.790	438.464	65.8084	140.9568
32	-23.1260	-53.4462	0.000	0.0000	339.318	392.765	337.976	391.422	83.6326	106.7586
33	-49.3789	114.1188	0.000	0.0000	266.983	381.102	265.895	380.014	52.3334	101.7123
34	90.2802	-208.6451	0.000	0.0000	143.978	352.624	143.480	352.125	12.0905	102.3707
35	-18.9796	-43.8634	0.000	0.0000	314.276	358.140	313.980	357.843	94.4319	113.4115
41	0.0000	0.0000	5164.066	0.0000	300.000	300.000	300.000	300.000	14.6960	19.0230
42	0.0000	0.0000	4459.475	0.0000	350.000	350.000	350.000	350.000	14.6960	19.0230
43	0.0000	0.0000	4015.151	0.0000	280.000	280.000	280.000	280.000	14.6960	19.0230
44	0.0000	0.0000	2717.180	0.0000	150.000	150.000	150.000	150.000	14.6960	19.0230
46	0.0000	0.0000	-1770.648	0.0000	300.000	300.000	300.000	300.000	14.6960	19.0230
47	0.0000	0.0000	2806.933	0.0000	400.000	400.000	400.000	400.000	14.6960	19.0230

Jct	P Inlet (psia)	P Outlet (psia)
1	119.5284	119.5284
2	113.6040	113.7249
3	105.4936	105.4936
4	108.7147	108.7147
5	103.2297	103.2297
6	103.9729	103.9729
7	99.6855	99.6855
8	94.3821	94.3821
9	91.1767	91.1767
10	97.4290	97.4290
11	93.0518	93.0518

12	90 9798	90 9798	90 9798
Jct	P Inlet (psia)	P Outlet (psia)	
13	88 2771	88 2771	
14	95 7519	95 7519	
15	108 0562	108 0562	
16	97 2711	97 2711	
17	104 1158	104 1158	
18	100 6324	100 6324	
19	93 6694	93 6694	
20	95 9731	95 9731	
21	94 9578	94 9578	
22	97 7051	97 7051	
23	100 3403	100 3403	
24	99 7097	99 7097	
25	96 6097	96 6097	
26	98 7314	98 7314	
27	108 9686	108 9686	
28	110 2663	110 2663	
29	112 7830	112 8496	
31	64 3653	139 5137	
32	83 0517	106 1777	
33	51 8625	101 2414	
34	11 8748	102 1550	
35	94 3036	113 2831	
41	14 6960	19 0230	
42	14 6960	19 0230	
43	14 6960	19 0230	
44	14 6960	19 0230	
46	14 6960	19 0230	
47	14 6960	19 0230	