27
12/3/79
240 NTIS

MASTER

ARGONNE NATIONAL LABORATORY

ENERGY AND ENVIRONMENTAL SYSTEMS DIVISION

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

The facilities of Argonne National Laboratory are owned by the United States Government. Under the terms of a contract (W-31-109-Eng-38) between the U. S. Department of Energy, Argonne Universities Association and The University of Chicago, the University employs the staff and operates the Laboratory in accordance with policies and programs formulated, approved and reviewed by the Association.

MEMBERS OF ARGONNE UNIVERSITIES ASSOCIATION

The University of Arizona
Carnegie-Mellon University
Case Western Reserve University
The University of Chicago
University of Cincinnati
Illinois Institute of Technology
University of Illinois
Indiana University
Iowa State University
The University of Iowa

Kansas State University
The University of Kansas
Loyola University
Marquette University
Michigan State University
The University of Michigan
University of Minnesota
University of Missouri
Northwestern University
University of Notre Dame

The Ohio State University
Ohio University
The Pennsylvania State University
Purdue University
Saint Louis University
Southern Illinois University
The University of Texas at Austin
Washington University
Wayne State University
The University of Wisconsin

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately-owned rights. Mention of commercial products, their manufacturers, or their suppliers in this publication does not imply or connote approval or disapproval of the product by Argonne National Laboratory or the U. S. Department of Energy.

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue
Argonne, Illinois 60439

A SURVEY OF AVAILABLE COMPUTER PROGRAMS FOR
DISTRICT HEATING/COOLING DISTRIBUTION SYSTEMS

prepared by

Stone & Webster Management Consultants, Inc.
90 Broad Street
New York, New York 10004

for

Energy and Environmental Systems Division
Argonne National Laboratory

under Contract No. 31-109-38-4598

September 1979

DISCLAIMER

This book was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Work sponsored by
U.S. Department of Energy
Assistant Secretary for Conservation and Solar Applications
Office of Buildings and Community Systems

fig

This informal report presents preliminary results of ongoing work or work that is more limited in scope and depth than that described in formal reports issued by the Energy and Environmental Systems Division.

Available from

National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161

TABLE OF CONTENTS

I—Introduction

II—Summary Table

Feature Summary of Computer Programs for District Heating/Cooling Distribution Systems

III—Abstracts

Stoner Associates GASSS

Stoner Associates LIQSS

James F. MacLaren Limited

Consultants Computation Bureau CCBDIST

Massachusetts Institute of Technology TDIST2-MIT

University of Illinois Simulation of Central Chilled Water Systems

Oklahoma Natural Gas ISAP-2

Boston Edison Engsteam

Consumers' Gas Company Gas Distribution Network Design and Analysis Programs

Consumers' Gas Company Hydraulic Distribution Network Design and Analysis Programs

Public Service Electric & Gas

Battelle Northwest Laboratory GEOCITY

SYNTHA Corporation SYNTHA III

Building Research Establishment District Heating Network Optimization Package

EKONO KAKUST

University of Kentucky

I-INTRODUCTION

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

I-INTRODUCTION

This report includes a summary of the steps taken, contacts made, and results obtained from a survey conducted by Stone & Webster Management Consultants, Inc. (SWMCI) for Argonne National Laboratory (ANL) as part of the involvement in the Integrated Community Energy System Program. The goal of this survey was to locate computer programs which would be useful in the design and evaluation of district heating and cooling systems (DHCS) and to determine the level of computerization in this area. Documentation, which was available for each program, was reviewed to determine the general approach and area of application. Of interest in this study were existing distribution network computer programs for hot water, steam, chilled water, and natural gas.

The procedures followed in conducting the survey involved the following steps:

- Preparation of a list of potential program sources.
- Mailing questionnaires to organizations with computer programs of potential interest.
- Follow-up phone calls to complete the questionnaires (North America only).

The list of organizations to be surveyed was compiled by making a search of current literature to determine where and by what organizations work had been done on computerization of DHCS analyses. There were 82 organizations chosen, both domestic and overseas, which included engineering and consulting firms, government agencies, universities, trade associations, equipment manufacturers, and utilities.

Having determined which organizations would be contacted, a survey form was prepared and mailed to each. Within two weeks of the mailing date, SWMCI contacted, by telephone, those organizations located in the continental United States and Canada and completed the questionnaires. Replies from organizations outside the continental United States and Canada were received by mail.

Responses were received from 95% of the domestic (United States and Canadian) organizations and 13% from other parts of the world. The incomplete domestic results were the consequence of the following:

- Some organizations chose not to respond.
- Some firms could not be located.
- Key individuals were not available.

Of those firms responding, 65% had or used computer programs for energy demand, transmission, or distribution system analysis. In some cases, respondents were using programs developed by other organizations included in this survey.

Documentation, to the extent available, was obtained for those computer programs which were available according to survey forms and telephone contact replies. This material was then reviewed in order to make a preliminary assessment of the applicability of the program, its capabilities, and approaches used.

The results of this survey indicate a fair amount of work continues within both the public and private sectors to develop computer programs for the analysis of district heating and cooling systems. As stated previously, 65% of the domestic organizations responding to the survey have developed or have access to programs which meet their particular needs. This result was predictable, considering the criteria used in selecting the organizations to be included in the survey and the role of computer applications in United States industry.

Of the organizations responding, the following 14 have distribution system analysis programs available.

- Stoner Associates, Inc.
- James F. MacLaren, Ltd.
- Consultants Computation Bureau
- Massachusetts Institute of Technology
- University of Illinois
- Oklahoma Natural Gas Company
- Boston Edison
- Consumers' Gas Company
- Public Service Electric & Gas
- Battelle Northwest Laboratory
- Syntha Corporation
- Building Research Establishment
- EKONO Consulting Engineers
- University of Kentucky

Subsequent contacts were made to obtain more comprehensive data for programs available to district heating systems. The abstracts and lists of features of these programs were compiled and are included as Section III in this report.

The abstracts give a brief description of the functions performed by the program and highlight any unique characteristics and capabilities of the program. Program features listed include the following:

- Program objectives.
- Program capabilities.
- System configurations analyzed.
- System components.
- Equations used.
- Type of flow analyzed.
- Type of media carried.
- Thermal transfer.
- Economic analysis.
- Computer configuration and language.
- Input/output mode.
- Input/output data.

These features will be used as a basis for future evaluation and selection of programs offering broad applications in technical and/or economic scope, and detailed representation of important parameters.

Also included in Section III are the authors and owners of the programs, program availability, cost for purchasing and/or testing the program, test turnaround time, availability of program documentation (users' manual), name and address of person contacted, and list of users of the program. Efforts have been made to compile the preceding information to the fullest extent possible for each program based on the materials provided by the program owners.

Section II summarizes the features of each program in a tabular form for easy comparison.

Each of these programs has unique features and capabilities. Most of the programs indicate a broad range of application with sufficient scope of technical and/or economic aspects, and provide a detailed representation of important parameters. However, no one program can perform all the functions. Additional criteria should be established to further evaluate and compare these programs.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

II-SUMMARY TABLE

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

ARGONNE NATIONAL LABORATORY
FEATURE SUMMARY OF COMPUTER PROGRAMS
FOR
DISTRICT HEATING/COOLING DISTRIBUTION SYSTEMS

9

	Stoner Associates GASSS	Stoner Associates. LIQSS	James F. MacLaren, Ltd.	Consultants Computation Bureau	Massachusetts Institute of Technology	University of Illinois
<u>Engineering Analysis</u>						
Preliminary Feasibility	X	X	X	X	X	
Detailed Feasibility	X	X		X	X	
Preliminary Design	X	X			X	X
Final Design	X	X			X	X
System Simulation	X	X				
Optimization						
Function						
Basis						
<u>Economic Analysis</u>						
Simulation				X	X	
Optimization	X		X			
Function	Least New Facility Cost.		Minimum Cost.			
Basis	Minimizing Square of Source Flow from Various Sources.		Selecting Plant Size to Meet Demand.			
<u>Economic Parameters</u>						
Hard Coded			X			
User Input	X		X	X	X	
<u>Program Size</u>						
Number of Mains and Nodes	10,000 Nodes and Mains Including Devices.	1,600 Nodes and 2,000 Mains Including Devices.	7 Building Sizes and 8 Land Uses.	2,000 Nodes and 2,000 Mains.	No Limit.	999 Nodes.
Units of Input and Output	English and Metric.	English and Metric.		English and Metric.	English.	English.
Significant Digits	6.	6.		No Limit.	12.	4 or 5.
<u>Configuration Analyzed</u>						
Branches and Trees				X		
Branches, Trees, and Loops	X	X			X	X
<u>Components Included</u>						
Elbows, Tees, and Valves	X	X			X	X
Expansion Loops	X	X				X
Pumps and Pressure Regulators	X	X			X	X
Returns						X
Others	• Fourth-degree Polynomial Horsepower per Million Curve.	• Forced Flow.			• Heat Exchangers. • Absorptive Air Conditioners.	• Coils. • Chillers.
<u>Flow Equations</u>						
Darcy-Weisbach		X			X	X
Hazen-Williams		X				
Manning		X				
Panhandle A	X					
New Panhandle	X					
IGT Distribution						
Weymouth	X					
Spitzglass Low	X					
Spitzglass High	X					
Others	• Fundamental. • Theoretical Horsepower. • Centrifugal Compressor. • Storage Field.					
<u>Type of Flow Analyzed</u>						
Pressurized in Closed Conduits	X	X		X	X	X
Nonpressurized in Closed Conduits				X		
Open Channel						
<u>Type of Media Carried</u>						
Steam	X					
Natural Gas	X					
Hot Water		X			X	
Chilled Water		X			X	X
Others	• Isothermal Gas.	• Any Single or Multiple Liquid System.		• No Limitation.		
<u>Thermal Transfer</u>						
No Heat Loss	X	X		X		X
Heat Loss Input					X	
Heat Loss Calculated						
Conduction						
Convection						
Radiant						
Ground Moisture Handled						
<u>Cost and Heat Loss for Distribution Pipe</u>						
Above Ground					X	
Buried						
<u>Computer Configuration</u>						
Manufacturer and Model	IBM and IBM Compatible.	IBM and IBM Compatible.	IBM 370.	CDC 6,000 and 7,000 Series.	IBM 370/168.	IBM 360/175.
Core Requirement (in bytes)	Variable. For 1,000 Nodes, 400K + 72K Supervisor.	Variable. For 1,000 Nodes, 400K + 72K Supervisor.		Less than 100K.	350K for Compil- ation, 740K for Execution.	200K.
Language	FORTAN (IBM) and ASSEMBLER.	FORTAN (IBM) and ASSEMBLER.	COBOL.	FORTAN IV and ASSEMBLER.	FORTAN IV, Level C.	FORTAN.
<u>Data Input Mode</u>						
Card	X	X	X	X	X	X
CRT	X	X				
<u>Data Output Mode</u>						
Hard Copy	X	X	X	X	X	X

ARGONNE NATIONAL LABORATORY
FEATURE SUMMARY OF COMPUTER PROGRAMS
FOR
DISTRICT HEATING/COOLING DISTRIBUTION SYSTEMS

	Oklahoma Natural Gas Company	Boston Edison	Consumers' Gas Gas Distribution	Consumers' Gas Hydraulic Distribution	PSE&C	Battelle Pacific Northwest Laboratories
<u>Engineering Analysis</u>						
Preliminary Feasibility	X				X	X
Detailed Feasibility		X				
Preliminary Design	X		X	X	X	X
Final Design			X	X		
System Simulation	X	X	X	X	X	
Optimization			X	X		X
Function			Smallest Pipe Size.	Smallest Pipe Size.		Pipe Size and Insulation Thickness.
Basis			Satisfying Specified Requirements and Restrictions	Satisfying Specified Requirements and Restrictions.		Capital Costs, Pressure Drops, Pumping Requirements, and Heat Loss.
<u>Economic Analysis</u>						
Simulation			X	X		X
Optimization						
Function						
Basis						
Economic Parameters						
Hard Coded						
User Input						X
<u>Program Size</u>						
NUMBER OF MAINS and Nodes	600 Mains and 600 Nodes.	500 Nodes.	6,500 Nodes and 6,500 Mains for Analysis Program, 1,600 Nodes and 1,600 Mains for Design Program.	4,000 Nodes and 4,000 Mains for Analysis Program, 2,000 Nodes and 2,000 Mains for Design Programs.	2,000 Nodes.	20 Demand Areas and 8 District Types.
Units of Input and Output	English.	English.	English and Metric.	English.	English	English for Input; English and Metric for Output.
Significant Digits	Double Precision.	2.				
<u>Configuration Analyzed</u>						
Branches and Trees						X
Branches, Trees, and Loops	X	X	X	X	X	
<u>Components Included</u>						
Elbows, Tees, and Valves			X	X		X
Expansion Loops						X
Pumps and Pressure Regulators	X		X	X		X
Returns						
Others	• Compressor.	• Equivalent Length for All Components Except Pipes.			• Equivalent Pipe- line Length for Components.	
<u>Flow Equations</u>						
Darcy-Weisbach		X				
Hazen-Williams				X		
Manning						
Panhandle A	X		X			
New Panhandle			X			
10T Distribution			X			
Weymouth			X			
Spitzglass Low			X		X	
Spitzglass High			X		X	
Others			• Pole.			• Single-phase Flow.
<u>Type of Flow Analyzed</u>						
Pressurized in Closed Conduits	X	X	X	X	X	X
Nonpressurized in Closed Conduits						
Open Channel						
<u>Type of Media Carried</u>						
Steam		X				
Natural Gas	X				X	
Hot Water						X
Chilled Water						
Others			• Any Gas.	• Any Liquid.		
<u>Thermal Transfer</u>						
No Heat Loss	X	X	X	X	X	
Heat Loss Input						
Heat Loss Calculated						
Conduction						X
Convection						
Radiant						
Ground Moisture Handled						X
<u>Cost and Heat Loss for Distribution Pipe</u>						
Above Ground						
Buried						X
<u>Computer Configuration</u>						
Manufacturer and Model	IBM.	IBM 360.	• Several IBM Configurations. • Honeywell 56/10.	Several IBM Configurations.	UNIVAC 1106	CDC.
Core Requirement	96K (Overlaid).	50K.	196K for 1,600 Branch Design Program and 264K for 6,500 Branch Analysis Program.	196K for 1,000 Branch Design Program and 216K for 4,000 Branch Analysis Program.		160K.
Language	FORTRAN.	FORTRAN.	FORTRAN.	FORTRAN.	FORTRAN.	FORTRAN IV.
<u>Data Input Mode</u>						
Card	X	X	X	X	X	X
CRT		Possible.	X	X	X	
<u>Data Output Mode</u>						
Hard Copy	X	X	X	X	X	X
CRT		Possible.	X	X	X	

ARGONNE NATIONAL LABORATORY
FEATURE SUMMARY OF COMPUTER PROGRAMS
FOR
DISTRICT HEATING/COOLING DISTRIBUTION SYSTEMS

11

	<u>SYNTHA Corporation</u>	<u>Building Research Establishment</u>	<u>EKONO Consulting Engineers</u>	<u>University of Kentucky</u>
<u>Engineering Analysis</u>				
Preliminary Feasibility	X		X	X
Detailed Feasibility	X		X	
Preliminary Design	X	X	X	X
Final Design	X	X	X	X
System Simulation	X			
Optimization		X		
Function		Optimum Layout and Pipe Sizes.		
Basis		Dynamic Programming and Fast Pipe Sizing Approach.		
<u>Economic Analysis</u>				
Simulation				
Optimization	X	X	X	
Function	Overall Cost.	Total Costs-in-use of the Network.	Optimal Financial Condition.	
Basis	Varying Heat Exchanger Sizes.	Optimum Layout and Pipe Size.	Changing Input Parameters and Repeated Reruns.	
<u>Economic Parameters</u>				
Hard Coded				
User Input	X	X	X	
<u>Program Size</u>				
Number of Mains and Nodes	350 Streams.	400 Nodes and 400 Mains.		400 Nodes and 400 Mains.
Units of Input and Output Metric.	English.	Metric.	Metric.	English and
Significant Digits	7.			
<u>Configuration Analyzed</u>				
Branches and Trees		X		
Branches, Trees, and Loops	X			X
<u>Components Included</u>				
Elbows, Tees, and Valves				
Expansion Loops				
Pumps and Pressure Regulators		X		X
Returns	X	X		X
Others	• Any Combination of Elements.			• Storage Tanks. • Fittings.
<u>Flow Equations</u>				
Darcy-Weisbach				X
Hazen-Williams				X
Manning				
Panhandle A				
New Panhandle				
IGT Distribution				
Weymouth				
Spitzglass Low				
Spitzglass High				
Others	• No Restriction.	• Colebrook-White.		
<u>Type of Flow Analyzed</u>				
Pressurized in Closed Conduits	X	X		X
Nonpressurized in Closed Conduits				
Open Channel				
<u>Type of Media Carried</u>				
Steam	X			
Natural Gas	X			
Hot Water	X	X		X
Chilled Water	X			X
<u>Thermal Transfer</u>				
No Heat Loss				X
Heat Loss Input	X	X		
Heat Loss Calculated				
Conduction				
Convection				
Radiant				
Ground Moisture Handled				
<u>Cost and Heat Loss for Distribution Pipe</u>				
Above Ground				
Buried				
<u>Computer Configuration</u>				
Manufacturer and Model	• CDC 6400, 6600, 7600. • IBM 360, 370.	ICL, Model 1904S.	DEC, VAX-11/780.	IBM 370 or Compatible.
Core Requirement	• 250K for CDC 6600. • 500K for IBM.	38K.		160K.
Language	FORTRAN.	FORTRAN IV.	FORTRAN.	FORTRAN IV, Level G.
<u>Data Input Mode</u>				
Card	X		X	X
CRT		X	X	
<u>Data Output Mode</u>				
Hard Copy	X	X	X	X
CRT		X	X	

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

III-ABSTRACTS

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

STONER ASSOCIATES GASSS

Abstract

The Gas Steady-state System (GASSS) Service determines the balanced steady-state pressure-flow relationship for an isothermal gas system (natural gas, steam, and so on) composed of pipelines, compressors, and regulators. The program uses modern equation solving techniques to provide fast convergence of the model equations.

Both high-pressure and low-pressure distribution systems can be modeled by the program. The program also supports a new concept of network analysis for natural gas systems having variable specific gravity and Btu content, allowing the user to balance gas network based on the therm rate loading as opposed to the standard or historical volumetric rate loading.

The GASSS Service also provides the ability to solve dry saturated steam flow models. A fundamental steam flow equation has been developed that is intended primarily for district heating system analysis.

The GASSS Service has the capability of performing sensitivity analyses on the balanced model, which provide approximate answers as to how much the unknown would vary for a given change in one of the fixed value parameters.

The GASSS Service may also be used in conjunction with the Facility Optimization Program (FOP) for the calculation of the least cost of new facilities.

The Service is designed to serve the modeling interests of natural gas production, transmission and distribution companies, municipal steam systems, and other gas systems.

Program Features

A. Objectives

The program is designed for use in an engineering planning as well as operating environment with the following objectives:

- Preliminary and detailed feasibility.
- Preliminary and final design.
- System simulation.

B. Program Capacity

- Up to 10,000 nodes and mains (including devices) can be accommodated. It is expected that ultimately 30,000 elements can be accommodated by the program.

- Both English and metric units can be used.
- Six significant digits are obtained for input and output data.

C. Configurations Analyzed

Systems with branches, trees, and loops can be analyzed.

D. Components of Distribution System

- Pipelines.
- Compressors.
- Fisher, Grove, Reliance regulators.
- Fourth-degree polynomial horsepower per million curve.

E. Flow Equations

- Panhandle A.
- Panhandle B.
- Weymouth.
- Spitzglass.
- Fundamental equations.
- Theoretical horsepower equation.
- Centrifugal compressor equation.
- Storage field equation.

F. Type of Flow Analyzed

- Pressurized flow in closed conduits.

G. Type of Media Carried

- Isothermal gas (natural gas, steam, air, and other gases).

H. Thermal Transfer

Heat loss is not considered in this program.

I. Economic Analysis

This program may be used in conjunction with the FOP to calculate the least cost of new facilities. FOP is essentially a gradient optimization procedure which calculates the least costs by minimizing the square of source flows from various sources.

The economic parameters used by FOP are inputted by the users.

J. Computer Configuration

- IBM or IBM compatible system.
- Core requirement varies with the size of the case analyzed. For example, a case with 1,000 nodes requires 400K bytes plus 72K bytes supervisor.

K. Language

The program is written mostly in FORTRAN (IBM) with a small amount in ASSEMBLER.

L. Data Input Mode

- Card or CRT.

M. Output Mode

- Hard copy or CRT.

N. Input Data

The input data for GASSS is of the following three major categories.

- System variables and execution controls.
- Node connecting element data.
- Node data.

O. Output Data

The following is available for output:

- Value of unknown node flows.
- The sum of system loads.
- The nth largest node residuals.
- The nth highest node pressures.
- The nth lowest node pressures.
- The n NCES (node connecting elements) with highest squared loss per mile.
- The volume of linepack for all pipes in the system.
- Zero flow nodes (nodes having more than one attached NCE, which are sinks of the system).

Sensitivity analysis computations for a balanced system can be initiated by the user.

Author(s) - Stoner Associates.

Owner(s) - Stoner Associates.

Availability - Readily available on National CSS, Inc. time-sharing systems.

Cost

- Purchase: Use is available on a surcharge basis.

Person Contacted and Address

Dr. Michael A. Stoner, President
Stoner Associates, Inc.
P. O. Box 86
Carlisle, Pennsylvania 17013
(717) 243-9212

List of Users

- Baltimore Gas & Electric Company.
- Bay State Gas Company.
- Brooklyn Union Gas Company.
- Columbia Gas System.
- Commonwealth Gas Company.
- The Consolidated Edison Company of New York.
- Consumers Power Company.
- Delmarva Power & Light Company.
- Pacific Gas & Electric Company.
- Southern California Gas Company.
- Union Gas Limited.
- Washington Gas Light Company.

STONER ASSOCIATES LIQSS

Abstract

The Liquid Steady-state System (LIQSS) Service determines the balanced steady-state head-flow relationship for a liquid network composed of pipelines, pumps, and valves. The program utilizes modern techniques to provide fast convergence of model equations, and is capable of modeling networks having different liquids in different parts of the system. A high degree of flexibility is provided for formulating and solving unknowns. Given a specific pressure response, for example, pipe diameters, pump horsepowers, and valve settings can be determined.

The LIQSS Service has the capability of performing sensitivity analyses on the balanced model, which provide approximate answers to how much the unknowns would vary for a given change in one of the fixed value parameters.

The Service is designed to serve the modeling interests of water distribution companies, petroleum pipeline companies, petrochemical and industrial piping systems complexes, and other liquid piping systems.

Program Features

A. Objectives

The Service is designed for use in an engineering planning as well as operating environment for the following objectives:

- Preliminary and detailed feasibility.
- Preliminary and final design.
- System simulation.

B. Program Capacity

- Up to 1,600 nodes and 2,000 mains (including devices) can be accommodated.
- Units of input and output are in both English and metric systems.
- Six significant digits are obtained for input and output data.

C. Configurations Analyzed

Systems with branches, trees, and loops can be analyzed.

D. Components of Distribution System

- Pump horsepower.
- Pump curve tabular data.
- Valve regulator.
- Check valve.
- Forced flow.
- Velocity head loss, representing elbows and tees, for example.

E. Flow Equations

- Darcy-Weisbach Pipeline.
- Hazen-Williams.
- Mannings equation.

F. Type of Flow Analyzed

- Pressurized flow in closed conduits.

G. Type of Media Carried

- Any single liquid (water, oil, and so on).
- Multiple liquid system.

H. Thermal Transfer

Heat loss is not considered in the program.

I. Computer Configuration

- IBM or IBM compatible system.
- Core requirement varies with the size of the case analyzed. As an example, a case with 1,000 nodes requires 400K bytes plus 72K bytes supervisor.

J. Language

The program is written mostly in FORTRAN (IBM) with a small amount in ASSEMBLER.

K. Data Input Mode

- Card or CRT.

L. Output Mode

- Hard copy or CRT.

M. Input Data

The input data for LIQSS is of the following three major categories:

- System variables and execution controls.
- Node connecting element data.
- Node data.

N. Output Data

A summary of the following is available:

- Value of unknown node flows.
- The sum of system loads.
- The nth largest node residuals.
- The nth highest node pressures and hydraulic grade lines.
- The nth lowest node pressure and hydraulic grade lines.
- The n NCES (node connecting elements) with highest head loss per foot.
- Zero flow nodes (nodes having more than one attached NCE which are sinks of the system).

Also available is the capacity to perform a sensitivity analysis on the model equations which have just been balanced.

Author(s) - Stoner Associates.

Owner(s) - Stoner Associates.

Availability - Readily available on National CSS, Inc. time-sharing systems.

Cost

- Purchase: Use is available on a surcharge basis.

Person to Contact and Address

Dr. Michael A. Stoner, President
Stoner Associates, Inc.
P. O. Box 86
Carlisle, Pennsylvania 17013

(717) 243-9212

List of Users

- Transco.
- LOVACA.
- Brown and Root, Inc.
- Duke Power Company.
- Fluor Ocean Services.
- Greeley and Hansen.
- Miller Engineering.
- Penfield & Smith Engineers, Inc.

JAMES F. MACLAREN LIMITED**Abstract**

The program, primarily designed for economic analysis, calculates the minimum overall cost for a district steam heating system by selecting the proper plant size to meet the heat demand.

The seven size ranges for the buildings to be heated are as follows:

0 to 2 000-Square Foot Gross Floor Area

2 001 to 10 000

10 001 to 50 000

50 001 to 100 000

100 001 to 500 000

500 001 and Over

The eight land use classifications are as follows:

1. Apartments (six dwelling units and over).
2. Residential (one to five dwelling units).
3. Offices.
4. Institutions.
5. Industry.
6. Warehousing.
7. Commercial.
8. Miscellaneous.

Heating plant data for both steam and HTW plants are stored in the model data base for plant sizes in equivalent thousands of pounds of steam per hour installed capacity.

The model calculates the cost of the steam (with or without condensate return) or HTW distribution system, adds the distribution heat losses and selects the proper size of heating plant(s) to serve the connected load. It then compares the cost of district heating for each building size and land use class with the cost of heating individually, using natural gas, oil, coal, or electricity.

Program Features**A. Objectives**

This program is developed to aid in preliminary feasibility study.

B. Economic Analysis

The program minimizes the overall cost for a district steam heating system by selecting the proper plant size to meet the heat demand.

The economic parameters can be either hard coded or user inputted. The parameters include the capital, interest rates and terms, plant labor, administrative overhead, maintenance, fuel, taxes, insurance premiums, supplies (e.g., chemicals), water, and electric power costs.

C. Computer Configurations

- IBM 370.
- Core requirement can be obtained from City of Toronto, Finance Department.

D. Language

- COBOL.

E. Data Input Mode

- Card.

F. Output Mode

- Hard copy.

G. Input Data

- Published in Volume 3 of the Technical Report of the Steering Committee on the City of Toronto District Heating Study, December 1973 - available from the City of Toronto.

Author(s) - James F. MacLaren, Limited.

Owner(s) - City of Toronto.

Availability - Available only through City of Toronto.

Cost

- Purchase: Check with City of Toronto.

Person Contacted and Address

Allen Turton, P.E.
James F. MacLaren, Ltd.
435 McNicoll Avenue
Willowdale, Ontario, Canada
(416) 499-0880

List of Users

- City of Toronto.

CONSULTANTS COMPUTATION BUREAU CCBDIST

Abstract

This program provides a way to lay out distribution trees, to size them, and to calculate their cost. Given main branches and user points (sinks), the program generates a tree connecting main branches and generates branches to the user points. The criteria used for connecting a given node (user point) to a branch is the "smallest rectangular distance at time of connection." The costing routines assume linear cost functions. Sizing the branches is done by calculating the flow at each node, using ASHRAE Handbook of Fundamentals. This program is versatile in the sense that all costing routines may be altered by the user. The program also has a simulation mode which generates random user points of given flow and characteristics, this serves as an aid for testing and simulation.

Program Features

A. Objectives

This program is designed for use with the following objectives.

- Preliminary and detailed feasibility.
- Preliminary design.

B. Program Capacity

- Up to 2,000 nodes and 2,000 branches can be accommodated, however, the capacity can be extended by changing dimension statements.
- Units of input and output data are in English and metric.
- No limitations of significant digits are imposed.

C. Configurations Analyzed

Branches and trees, but no loops can be analyzed.

D. Type of Flow Analyzed

- Pressurized in closed conduits.
- Nonpressurized in closed conduits.

E. Type of Media Carried

There is no limitation.

F. Thermal Transfer

Heat loss is not considered.

G. Economic Analysis

This program does a straight calculation of the costs of nodes and branches generated by the program.

The economic parameters are user provided.

H. Computer Configuration

- CDC 6,000's and 7,000's series.
- Core requirement for 2,000 nodes is less than 100K bytes.

I. Language

Most of the major routines are written in FORTRAN IV. The packing, unpacking, and searching routines, however, are written in CDC 7600 Assembly for faster execution.

J. Data Input Mode

- Card.

K. Output Mode

- Hard copy (on printer/plotter).

L. Input Data

The input data required includes coordinates, consumptions, cross-sections at nodes; and costing types and cross-sections of branches.

M. Output Data

Information available for output includes: echoes of input data, node flow and size, branch flow and size, graphical printout of designed system.

Author(s) - CCB.

Owner(s) - CCB.

Availability - The program is available to the public.

Cost

- Purchase: Negotiable.

Person Contacted and Address

Mr. Zulfikar Cumali, President
Consultants Computating Bureau
2930 Lakeshore Avenue
Oakland, California 94610
(415) 465-0511

List of Users

- Argonne National Laboratory.

**MASSACHUSETTS INSTITUTE OF TECHNOLOGY
TDIST2-MIT**

Abstract

TDIST2 is a computer program developed at Massachusetts Institute of Technology to aid in the design and dynamic performance analysis of a large integrated community Total Energy System (TES) supplying thermal and electrical energy to a multiconsumer metropolitan area. The program models the time-dependent energy requirements of building unit consumers, distributes these demands within a Thermal Utility System (TUS), simulates the TUS performance, and determines the required behavior of the power station and thermal energy storage reservoir.

Subroutine TUS calculates the water mass flow rates and temperature distribution in the TUS such that consumer demand will be satisfied. TUS also calculates required pipe size and heat exchanger transfer area, the pressure drop in each pipe segment, and the total pumping power required by the TUS.

Subroutine COST computes the installed capital costs of the pipes in the thermal utility system, based on length, cost file, service, and cross-sectional area. In addition, COST computes the capital costs of the end use electrical space conditioning equipment, as desired.

Program Features**A. Objectives**

This program is developed to aid in the following:

- Energy demand analysis.
- Preliminary and detailed feasibility.
- Preliminary and final design.
- System simulation.

B. Program Capacity

- Unlimited nodes and branches are allowed, with the restriction that only one source is allowed and that no load center can be more than four pipes away from the source.
- English system is used.
- Twelve-digit figure is obtained.

C. Configurations Analyzed

Systems with branches, trees, and loops can be analyzed.

D. Components of Distribution System

- Pipes.
- Pumps.
- Heat exchangers.
- Absorptive air conditioners.
- Tees and valves.

E. Flow Equations

- Darcy-Weisbach.

F. Type of Flow Analyzed

- Pressurized flow in closed conduits.

G. Type of Media Carried

- Hot water.
- Chilled water.

H. Thermal Transfer

Heat loss coefficients are input by user. Heat loss is considered for underground pipe design.

I. Economic Analysis

The program calculates the required pipe design and thus gives the capital cost associated.

Economic parameters are user input.

J. Computer Configuration

- IBM 370/168.
- Core requirements are 350K bytes for program compilation, and 240K bytes for execution of the compiled load module.

K. Language

- FORTRAN IV, Level G.

L. Data Input Mode

- Card.

M. Output Mode

- Hard copy.

N. Data Input

- Node, pipe identification (physical parameters), heat sources, and sinks.

O. Data Output

In addition to water mass flow rates and system temperature distributions, the program also calculates required pipe sizes, heat exchanger heat transfer areas, pressure drop in each pipe segment, and total required pumping power.

Author(s) - S. B. Goldman, F. R. Best, and Michael W. Golay.

Owner(s) - Massachusetts Institute of Technology, Department of Defense.

Availability - Available from NTIS. ANL has this program.

Cost - No cost.

Person Contacted and Address

Professor M. W. Golay
Department of Nuclear Engineering
MIT
Cambridge, Massachusetts 02139
(617) 253-5824

List of Users

- Department of Defense.
- Black & Veatch.

UNIVERSITY OF ILLINOIS
SIMULATION OF CENTRAL CHILLED WATER SYSTEMS

Abstract

For a central chilled water system, this program calculates water pressures, temperatures, and flow rates throughout the piping system as well as the outlet air temperatures of the cooling coils at various combinations of thermal loads. Since this program is designed for simulation, not for equipment selection, it requires, as necessary input information, the assumption of the network and specification of the location of all components. In addition, the performance characteristics of all components must be specified which for the pipe includes the diameter and length; for pumps, several pairs of headflow points; and for coils, the heat transfer characteristics. Although simulation is its main objective, this program can be used as a design tool by repeated application of the program for various thermal load combinations on the system being explored.

Program Features

A. Objectives

The program is designed to aid in the following.

- Final design.
- System simulation.

B. Program Capacity

- Limited by 999 nodes.
- English system is used.
- Four or five significant figures are obtained.

C. Configurations Analyzed

Any arbitrary flow network can be analyzed.

D. Components of Distribution System

- Elbows and tees.
- Coils.
- Two-way and three-way valves.
- Chillers.
- Constant-speed and variable-speed pumps.
- Coil control valves.
- Pressure relief valves.

- Return water temperature control valves.
- Return.

E. Flow Equations

- Darcy—Weisbach.

F. Type of Flow Analyzed

- Pressurized flow in closed conduits.

G. Type of Media Carried

- Chilled water.

H. Thermal Transfer

Heat loss is not considered.

I. Computer Configuration

- IBM 360/175.
- Core requirement is approximately 200K.

J. Language

- FORTRAN.

K. Data Input Mode

- Card.

L. Output Mode

- Hard copy.

M. Input Data

- Number of points, connectors, coils, valves, chillers, pumps, and associated physical and performance characteristics.

N. Output Data

- System point pressure, temperature, flow rate, coil outlet air and water temperature, rate of heat transfer, flow coefficients of valves, chiller loads (tons).

Author(s) - W. F. Stoeker
University of Illinois at Urbana—Champaign.

Owner(s) - University of Illinois.

Availability - On request.

Cost - Cards or on tape for \$80.

Person Contacted and Address

Professor W. F. Stoecker
Department of Mechanical and Industrial
Engineering
University of Illinois
Urbana, Illinois 61801
(217) 333-0916

List of Users

OKLAHOMA NATURAL GAS ISAP-2

Abstract

ISAP-2 is a program for steady state modeling of a gas system using a solution technique developed by M. A. Stonner while working for Consumer Power Company of Jackson, Michigan. This program uses the Panhandle B equation for calculating gas flow in pipelines. It also has the capabilities of modeling a compressor, a regulator, and a storage field deliverability curve.

Program Features

A. Objectives

This program will aid in the following:

- Preliminary feasibility (long range).
- Preliminary design (short range).
- System simulation.

B. Program Capacity

- English system is used for input and output.
- 600 mains and 600 nodes can be accommodated.
- Double precision numbers are used in calculations.

C. Configurations Analyzed

Systems with branches, trees, and loops can be analyzed.

D. Components of Transmission System

- Pipeline.
- Compressor.
- Regulator.

E. Flow Equations

- Panhandle.

F. Type of Flow Analyzed

- Pressurized flow in closed conduits.

G. Type of Media Carried

- Natural gas.

H. Thermal Transfer

No heat loss is considered.

I. Computer Configuration

- IBM.
- Core requirement is 96K (overlaid).

J. Language

- FORTRAN.

K. Data Input Mode

- Card.

L. Output Mode

- Hard copy.

M. Input Data

Three major types of inputs are required. They are the following:

- System variables including flowing temperatures, specific gravity, system efficient factor, and pressure base.
- Node data including pressure, load, and supply.
- Connecting element data such as types, lengths, diameters, horsepower, and compressibility factors.

N. Output Data

The solution is printed in double entry format—each node number is listed with the connecting node number, which results in a double entry of the node connecting elements (NCE) data. The input data is listed with each NCE solution output so that all information is available for analysis.

Author(s) - Oklahoma Natural Gas Co.

Owner(s) - ONG.

Availability - This program is readily available upon request.

Cost - There is no cost for purchase.

Person Contacted and Address

Mr. J. H. Glamser
Vice President—Technical Service
Oklahoma Natural Gas Co.
P. O. Box 871
Tulsa, Oklahoma 74102
(918) 583-6161 - Ext. 2918

List of Users

- ONG.

BOSTON EDISON ENGSTEAM

Abstract

The program calculates the flow and pressures drops within a distribution system especially designed for steam. Detailed information and features of this program are not available based on the documentation provided by Boston Edison.

Program Features

A. Objectives

The program is developed for the following:

- Detailed feasibility.
- System simulation.

B. Program Capacity

- Up to 500 nodes can be accommodated.
- English system is used for units.
- Two significant digits are obtained.

C. Configurations Analyzed

Systems with branches, trees, and loops can be analyzed.

D. Components of Distribution Systems

- All components besides pipes are represented by equivalent length in the program.
- No return.

E. Flow Equations

- Darcy-Weisbach with friction factors.

F. Type of Flow Analyzed

- Pressurized flow in close conduits.

G. Type of Media Carried

- Steam.

H. Thermal Transfer

No heat loss is considered.

I. Computer Configuration

- IBM 360.
- Core requirement is 50K bytes.

J. Language

- FORTRAN.

K. Data Input Mode

Input is presently on cards. CRT input may be made available.

L. Output Mode

Output is presently on hard copy. CRT output may be made available.

M. Input Data

The input data required are source or load and estimated pressure at each node; and length and diameter of each connecting line. In addition, the number of iterations and accuracy criteria can be specified.

N. Output Data

Echo of input data; source and/or load pressure at each connecting point, and flow and pressure drop of mains are available from this program output.

Author(s) - Boston Edison.

Owner(s) - Boston Edison.

Availability - This program is readily available to other utilities.

Costs - Costs for purchasing and testing are negotiable.

Person Contacted and Address

Mr. Robert F. Bucelwicz
Engineer
Boston Edison Company
800 Boylston Street
Boston, Massachusetts 02199
(617) 424-3382

List of Users

- Boston Edison

CONSUMER'S GAS COMPANY GAS DISTRIBUTION NETWORK DESIGN AND ANALYSIS PROGRAMS

Abstract

This package, used for choosing pipe sizes and calculating pressures and flows in gas distribution networks, consists of two programs: the network design program and the network analysis program. The design program calculates, for a given network, the smallest pipe sizes which satisfy the specified requirements and restraints. The analysis program calculates the flows and pressures in a network of known pipe sizes for any specified loading conditions.

The programs are available in versions of different capacity, the programs handling larger networks requiring more computer storage. In addition, there is an analysis program which solves networks with gases of different gravities.

Program Features

A. Objectives

These programs are intended to aid in the following:

- Detailed design.
- Preliminary design.
- System simulation.

B. Program Capacity

- Up to 6,500 nodes, 6,500 branches, 50 sources, and 2,000 loops can be handled by the largest analysis program. Up to 1,600 nodes, 1,600 branches, 16 sources, and 300 loops can be accommodated by the design program.
- Program versions exist for Imperial and for Metric units.

C. Configurations Analyzed

Networks with branches, trees, and loops can be analyzed.

D. Components of Distribution System

- Pressure regulators are represented as sources (pressure constant within specified flow limits, variable outside this range).
- Branches (defined by length, diameter, efficiency, material).
- Loads (specified at input).

E. Flow Equations

- Weymouth.
- IGT Distribution.
- Spitzglass high pressure.
- Panhandle A.
- Spitzglass low pressure.
- Pole.
- Other equations can be made available.

F. Type of Flow Analyzed

- Pressurized flow in closed conduits.

G. Type of Media Carried

- Any gas.

H. Thermal Transfer

- Heat loss is not considered.

I. Optimization

The design program calculates the smallest pipe size which will satisfy the specified requirements and restraints.

J. Economic Analysis

The cost estimate of the designed network is calculated on the basis of lengths, diameters, and unit costs.

K. Computer Configurations

- Several IBM configurations, Honeywell 66/10, potentially any machine with a Fortran compiler.
- Core requirements for the design and analysis programs are approximately as follows: 1,000 branch analysis program, 132K bytes; 4,000 branch analysis program, 264K; 6,500 branch analysis program, 376K; 1,600 branch design program, 196K.

L. Language

- FORTRAN.

M. Data Input Mode

- Card, tape, or CRT.

N. Output Mode

- Hard copy or CRT.

O. Input Data

Input to the program includes: network identification, design minimum pressure (for network design), convergence criteria, physical properties of the gas, flow equation to be used, pipe sizes available, node loads, lengths (and diameters if known) of connecting branches, source pressures and flow limits, modifications to the basic problem specified.

P. Output Data

The program output consists of several reports, as follows:

- Input listings with diagnostic messages.
- Processing log indicating the completion of various stages of the program.
- Program results showing pressure tabulation, flow tabulation and cost tabulation.
- Modification data.

Author(s) - Consumer's Gas Company.

Owner(s) - Consumer's Gas Company.

Availability - The programs are available in versions of different capacity and different units, as noted above.

Cost

- Purchase: Negotiable.

Person Contacted and Address

Mr. Ralph Jones
Vice-President of Strategic Planning
Consumer's Gas Company
1 First Canadian Place
Suite 4200, P.O. Box 90
Toronto, Ontario M5X 1C5
(416) 492-5000

List of Users

- Consumers' Gas Company, Toronto.
- South Australia Gas Company.
- Illinois Power Company.
- Michigan Consolidated Gas Company.
- Philadelphia Electric Company.
- Consolidated Natural Gas Service Company.
- Companhia Estadual De Gas, Rio de Janeiro.
- Many users through McDonnell Douglas Automation Co.

CONSUMERS' GAS COMPANY

HYDRAULIC DISTRIBUTION NETWORK DESIGN AND ANALYSIS PROGRAMS

Abstract

This package, used for choosing pipe sizes and calculating pressures and flows in hydraulic distribution networks, consists basically of two programs: the Network Design Program and the Network Analysis Program. The design program calculates, for a given network, the smallest pipe sizes which satisfy the specified requirements and restraints. The analysis program calculates the flows and pressures in a network of known pipe sizes for any specified loading conditions. The programs are available in versions of different capacity, the programs handling larger networks requiring more computer storage.

Program Features

A. Objectives

These programs are intended to aid in the following:

- Detailed design.
- Preliminary design.
- System simulation.

B. Program Capacity

- Up to 4,000 nodes, 4,000 branches, 50 sources, and 1,600 loops can be handled by the largest analysis program. Up to 2,000 nodes, 2,000 branches, ten sources, and 300 loops can be accommodated by the design program.
- The programs use Imperial units.

C. Configurations Analyzed

- Networks with branches, trees, and loops can be analyzed.

D. Components of Distribution System

- Pressure regulators and reservoirs are represented as sources (pressure constant within specified flow limits, variable outside this range).
- Branches (defined by length, diameter, efficiency, material).
- Loads (specified at input).
- Pumps (specified by points on the Head/Flow curve).

E. Flow Equations

- Hazen-Williams.
- Other equations can be made available.

F. Type of Flow Analyzed

- Pressurized flow in closed conduits.

G. Type of Media Carried

- Any liquid.

H. Thermal Transfer

- Heat loss is not considered.

I. Optimization

The design program calculates the smallest pipe size which will satisfy the specified requirements and restraints.

J. Economic Analysis

The cost estimate of the designed network is calculated on the basis of lengths, diameters, and unit costs.

K. Computer Configurations

- Several IBM configurations, potentially any machine with a Fortran compiler.
- Core requirements for the design and analysis programs are approximately as follows: 1,000 branch analysis program, 118K bytes; 4,000 branch analysis program, 216K; 1,000 branch design program, 196K.

L. Language

- FORTRAN.

M. Data Input Mode

- Card, tape, or CRT.

N. Output Mode

- Hard copy or CRT.

O. Input Data

Input to the program includes: network identification, design minimum pressure (for network design), convergence criterion, physical properties of the gas, flow equation to be used, pipe sizes available, node loads and elevations, lengths (and diameters if known) of connecting branches, source pressures and flow limits, pump performance curves, modifications to the basic problem specified.

P. Output Data

The program output consists of several reports, as follows:

- Input listings with diagnostic messages.
- Processing log indicating the completion of various stages of the program.
- Program results showing pressure tabulation, flow tabulation and cost tabulation.
- Pump lead/flow graphs.
- Modification data.

Author(s) - Consumers' Gas Company.

Owner(s) - Consumers' Gas Company.

Availability - The programs are available in versions of different capacity and different units, as noted previously.

Cost

- Purchase: Negotiable.

Person Contacted and Address

Mr. Ralph Jones
Vice-President of Strategic Planning
Consumers' Gas Company
1 First Canadian Place
Suite 4200, P.O. Box 90
Toronto, Ontario M5X 1C5
(416) 492-5000

List of Users

- Many users through McDonnell Douglas Automation Co.

PUBLIC SERVICE ELECTRIC & GAS

Abstract

The program calculates the node pressures and main flows within a distribution network system carrying natural gas. The Hardy-Cross Method was utilized for solution calculation.

Program Features

A. Objectives

The program is intended to aid in the following:

- Preliminary feasibility and design.
- System simulation.

B. Program Capacity

- Up to 2,000 nodes can be accommodated.
- English system is used.
- Limitations of significant digits were not available. However, accuracy to one tenth of a pound or Mcf can be obtained.

C. Configurations of Distribution System

Systems with branches, trees, and loops can be analyzed.

D. Components of Distribution System

Corrections for elements such as valves and fittings are built in using the Spitzglass pipeline equation for equivalent pipeline lengths.

E. Flow Equations

- Spitzglass low for 15-pound system.
- Spitzglass high for 60-pound system.

F. Type of Flow Analyzed

- Pressurized flow in closed conduits.

G. Type of Media Carried

- Natural gas.

H. Thermal Transfer

No heat loss is considered. System is assumed to stay at 60°F.

I. Computer Configurations

- UNIVAC 1106.
- Core requirement is not available.

J. Language

- FORTRAN.

K. Data Input Mode

- Interactive via terminals or remote batch via cards.

L. Output Mode

- CRT and hard copy printout.

M. Input Data

The input data required are supply source and loads firm and interruptible, if any, at each node and distribution main lengths and diameters.

N. Output Data

The data available for output are: node pressure and main flow values, gas source flows and pressures.

Author(s) - PSE&G and Brooklyn Union Gas.

Owner(s) - PSE&G.

Availability - Questionable.

Cost - Not available.

Person Contacted and Address

Mr. W. G. Harding
Principal Staff Engineer
Public Service Electric & Gas Company
80 Park Place, Room 5102
Newark, New Jersey 07101
(201) 430-7820

List of Users

- PSE&G.

BATTELLE NORTHWEST LABORATORY GEOCITY

Abstract

This program designs the reservoir well field layout, the transmission system, and the district heating systems for a geothermal energy system. The capital and operating costs of the entire system are also calculated. The program consists of two major submodels, a geothermal reservoir model, and a distribution system model. The distribution system model calculates the cost of heat by simulating the design and the operation of the district heating system. The reservoir model calculates the cost of energy by simulating the discovery, development, and operation of a hydrothermal geothermal resource and the transmission of this energy to a distribution center. The submodels can be used independently. Among the many designs for hot water heating systems that can be simulated are various configurations of heat pumps and/or heat exchangers, different piping system design practices, and the use of different materials for pipe, insulation, and casing. GEOCITY can simulate nearly any financial and tax structure by varying the rates of return on equity and debt, the debt-equity ratios, and tax rates. Both private enterprise and municipal utility systems can be simulated.

Program Features

A. Objectives

This program is intended to aid in the following:

- Preliminary economic feasibility.
- Preliminary design.
- Systematic analysis of design options.
- Sensitivity studies of economic and technical parameters.

B. Program Capacity

- Up to 20 separate demand areas (districts) can be accommodated.
- Up to eight different district types can be accommodated. The five default types are: suburban, high density single-family, garden apartments, townhouses or rowhouses, and high rise apartments. The user can also define his own district types.
- English system for input, both English and metric for output.

C. Configurations Analyzed

Systems with branches, trees and loops can be analyzed.

D. Components of Distribution System

- Pipe, insulation, and casing.
- Elbows, tees, and valves.
- Expansion loops.
- Heat pumps, booster pumps, and exchangers.
- Either single-pipe system for supply only or two-pipe system to accommodate supply and return.

E. Flow Equations

- Single-phase flow equations for calculating pressure drops of pressurized water flow in pipes.

F. Type of Flow Analyzed

- Pressurized flow in closed conduits.

G. Type of Media Carried

- Hot water.

H. Thermal Transfer

- Heat loss is calculated by the program for conduction.
- Ground conductivity can be inputted for heat loss consideration.

I. Optimization

The program optimizes the pipe size and insulation thickness by considering the capital costs, pressure drops, pumping requirements, and heat losses.

J. Cost and Heat Loss

They are both considered for buried distribution pipe.

K. Economic Analysis

- Nearly any financial and tax structure can be simulated by the program.
The capital and operating costs of the entire system are calculated.
- Economic parameters are user input.

L. Computer Configurations

- Cyber (CDC).
- Core requirement is 160K.

M. Language

- FORTRAN IV.

N. Data Input Mode

- Card.

O. Output Mode

- Hard copy.

P. Input Data

- Reservoir characteristics and well properties, including resource temperature.
- Well drilling costs.
- Transmission and disposal (reinjection) system parameters.
- Reservoir financial and tax data, including its rates of return on debt and equity, debt-equity ratio, and tax rates.
- Reservoir exploration, development, and operation costs and dates.
- City characteristics, including minimum and design temperatures, heating degree-days, number of districts, and distance from reservoir.
- District characteristics.
 - Residential district type of each district, area, length, and width of each district.
 - Density of buildings in each district type.
 - Peak heat demand per building in each district type at the design temperature.
 - Daily sanitary hot water demand per building in each district type.
 - Temperature of the return water at the outlet of the building heating system in each district type.
- Distribution piping, insulation, and casing design parameters.
- Parameters for branching mains, point demand, heat exchanger, adjustment factors, and output options.
- Distribution system financial and tax data, including its rates of return on debt and equity, debt-equity ratio, and tax rates.

Q. Output Data

The model designs the reservoir well field layout, the transmission system, and district heating systems. This includes lengths and diameters of pipe sections, the number of valves, fittings, and expansion loops in each section, the insulation, casing and trenching, the meters, pumps, and heat exchanger, and the flow rate, heat loss, head loss, and supply temperature at each house. From this design, GEOCITY calculates the capital and operating costs for the entire system, including the production and disposal of the geothermal water. Using discounted cash flow analysis, GEOCITY calculates the unit cost of energy from the reservoir and the unit cost of heat for the district heating system over the economic life of the district heating system.

Author(s) - Batelle Pacific Northwest Laboratories.

Owner(s) - DOE.

Availability - Readily available from Argonne Code Center.

Cost - The code and documentation are both available at a minimal cost.

Person Contacted and Address

Clarence H. Bloomster
Linda L. Fassbender
Harlan D. Huber
Batelle Pacific Northwest Laboratory
P.O. Box 999
Batelle Boulevard
Richland, Washington 99352
(509) 942-4359

List of Users

- DOE.
- WESTEC (San Diego, CA).
- The Futures Group (Connecticut).
- Sandia Laboratories.

SYNTHA CORPORATION SYNTHA III

Abstract

SYNTHA III Program is developed to aid in the design and performance analysis of cogeneration power plants and process utility systems in the chemical process industry. This program has been used to design and evaluate oil refineries, paper mills, and so on.

Program Features

A. Objectives

The program is intended to aid in the following:

- Preliminary and detailed feasibility.
- Preliminary and final design.
- System simulation.

B. Program Capacity

- Up to 350 streams can be accommodated.
- English units are used.
- Seven digits, not including the decimal point, are obtained.

C. Configurations Analyzed

Systems with branches, trees, and loops can be analyzed.

D. Components of Distribution System

Capability has been provided to represent any combination of elements, with or without return.

E. Flow Equations

There is no restriction on the use of mathematical modeling. Calculations are performed extensively on table basis.

F. Type of Flow Analyzed

- Pressurized flow in closed conduits.

G. Type of Media Carried

- Steam and water (with ASME properties).
- Natural gas.
- Others including air, H₂S, H₂O, N₂, O₂, H₂, CO₂, CO, SO₂, and ash.

H. Thermal Transfer

Heat loss associated with radiant efficiency can be inputted by user.

I. Economic Analysis

The optimization subroutine minimizes the overall cost of the system by varying the heat exchanger sizes. The economic parameters are inputted by the user.

J. Computer Configurations

- CDC 6400, 6600, 7600 or IBM 360, 370.
- Core requirement is 500K for IBM or 250K for CDC 6600.

K. Language

- FORTRAN.

L. Data Input Mode

- Card.

M. Output Mode

- Hard copy.

N. Input Data

- The process flow or piping diagram (in numerical form).
- Individual steam, heat, and power requirements for each user.
- Engineering component performance data such as: pump, boiler, and fan efficiencies; turbine extraction flow limits; generator fixed and variable losses; gas and fuel constituents for use in calculating heating value and products of combustion. Radiation efficiency of all heat transfer components, plus desired approach or exit temperature differences.
- Optional flow limitations for the selected primary, secondary, and tertiary steam sources for each header (such as turbine extraction and letdown flows) for use by Syntha III in balancing the header entrance flows with the header steam requirements.

O. Output Data

- The flow, pressure, temperature, enthalpy, and entropy of all water, steam, and gas streams. The composition and liquid/vapor ratio are shown for each gas stream.
- The individual engineering performance data for each component such as: RPM, efficiency, horsepower, kw, heat transfer, heating value, fuel requirements, pressure ratio.
- The Overall System Performance Summary provides:
 - Total Fuel Flow, thousands of pounds per hour; Equivalent Fuel Heat, Other Heat Added, and Total Heat Requirements in millions of Btu's per hour.
 - Total Generator Output, Total Motor Requirements, Total Electric Loads, Net Plant Generation in Mw.
 - Horsepower Provided, Horsepower Required, and Net Plant Horsepower.

Author(s) - David W. Hutchinson.

Owner(s) - SYNTHA Corporation.

Availability - Readily available on Cybernet time-sharing system.

Cost

- Purchase: Negotiable.

Person Contacted and Address

David W. Hutchinson, President
 SYNTHA Corporation
 51 W. Putnam
 Greenwich, Connecticut 06830
 (203) 869-2703

List of Users

- Pullman-Kellogg.
- Georgia Pacific.
- Rust Engineering Company.
- DuPont.
- ALCOA.

BUILDING RESEARCH ESTABLISHMENT DISTRICT HEATING NETWORK OPTIMIZATION PACKAGE

Abstract

The package is intended primarily for the design of district heating networks of a tree-like structure. The objective is to minimize the costs-in-use of a network with respect to the layout of the pipes and the size of pipe used for each connection.

The three major programs in the package are the following.

- The Geometry Program generates an initial tree for use as a starting point by the Layout Optimization Program and a list of connections which might be used in the optimized network.
- The Layout Optimization Program gradually improves the layout of the network by making changes to its structure in such a way as to reduce the total cost. A fast approximate method of pipe sizing is employed.
- The Pipe Sizing Program uses dynamic programming to derive pipe sizes which minimize the total costs-in-use of the network.

Program Features

A. Objectives

This package is intended to aid in the following.

- Preliminary design.
- Final design.

B. Program Capacity

- 400 nodes and up to 400 mains can be accommodated. The capacity can be extended by modification.
- Metric unit is used.
- Significant digits are limited only by hardware.

C. Configurations Analyzed

System with branches and trees but no loops can be analyzed.

D. Components of Distribution System

- Pumps and pressure regulators.
- Return.

E. Flow Equations

- Colebrook-White.

F. Type of Flow Analyzed

- Pressurized in closed conduits.

G. Type of Media Carried

- Hot water.

H. Thermal Transfer

Heat loss is input by user.

I. Optimization

The optimum layout structure of the network as well as the pipe sizes are derived by dynamic programming and fast pipe sizing approach so that the total costs-in-use of the network is minimized.

J. Economic Analysis

- The total costs-in-use of the network is minimized with respect to the layout of the pipes and the size of pipe for each connection.
- Economic parameters are user input.

K. Computer Configurations

- ICL, Model 1904S.
- Core requirement for the package is 38K.

L. Language

- FORTRAN IV.

M. Data Input Mode

- Via CRT.

N. Data Output Mode

- Hard copy and CRT.

O. Input Data

Two data files should be prepared by the user as follows.

- The Site Description File, which should include details of the layout of the site, including the position of the Boiler House, and the positions and design loads associated with each of the demand points.
- The Component Specification and Program Control File, which should give details of the various pipes which could be used, and the installed cost per meter of each, the cost of the energy used to pump the hot water around the system, the temperature in the flow and return pipes, the expected period for which the system will operate each year and the ratio between the average and the design loads, the marginal cost of heat lost from the pipes, and the discount rate and expected lifetime of the system.

Other variables which may be specified if appropriate include the diversity factor of the scheme as a whole and the allowance to be made for head losses at fittings in the network.

P. Output Data

The following data are made available for output.

1. The X coordinate of the node.
2. The Y coordinate of the node.
3. The design load.
4. The node identification number (N).
5. The node identification number of the node immediately upstream (SUPL).
6. The status of the pipe joining N and SUPL as defined in the input connection list is as follows.
 - 0 prohibited pipe.
 - 1 normal pipe.
 - 2 compulsory pipe.
7. The rate of heat flow through the pipe joining N and SUPL under design conditions. This heat flow rate includes components to account for heat losses downstream of node N.
8. The length of the pipe joining N and SUPL.
9. The recommended internal diameter for the previously mentioned pipe.

10. The installed cost of the pipe.
11. The pressure drop (along both flow and return pipes) between N and the boiler under design conditions.
12. The pressure drop (along both flow and return pipes) between N and SUPL under design conditions.
13. The temperature in the pipe joining N and SUPL under design conditions.
14. The flow velocity in the pipe joining N and SUPL under design conditions.

In addition, a breakdown of the estimated cost of the network is included in the form of comments at the end of the document. Graphical output is also available showing the plots of the sites and pipe layouts.

Author(s) - J. R. Appleyard
Building Research Station

Owner(s) - Building Research Establishment.

Availability - Availability for use for commercial purposes is yet to be determined.

Cost(s) - Not available for either purchase or test.

Person Contacted and Address

Mr. D. J. Fisk
Head of Mechanical and Electrical
Engineering Division
Building Research Establishment
Building Research Station
Garston, Watford, WD2 7JR
United Kingdom

List of Users

EKONO KAKUST

Abstract

The KAKUST system has been developed for investigations of the economics of district heating development programs. It will, for instance, provide answers to the following questions:

- Is district heating feasible for the area in question?
- What are the annual investments?
- What is the income from the connection fees, and how much outside capital is needed?
- What will the annual energy consumption be, and how high are the peak loads?

In practice, the KAKUST system provides possibilities for much more detailed investigations of district heating development programs than what would be possible by manual calculation. By changing the input parameters and by repeated reruns, the optimum conditions can be found for each alternative construction program and heat load forecast. Thus, the program can be used to find the following:

- Proper tariffs to guarantee the economic feasibility of a district heating development program.
- The optimum construction program of heat supply units.

Program Features

A. Objectives

The program is designed to aid in the following:

- Preliminary feasibility.
- Detailed feasibility.
- Preliminary design.
- Final design.

B. Unit System

The metric system is used for input and output.

C. Economic Analysis.

The program finds the optimum financial condition for each alternative construction program and heat load forecast, by changing the input parameters and by repeated reruns.

Economic parameters are user input.

D. Computer Configurations

DEC, VAX-11/780 system is used.

E. Language

- FORTRAN.

F. Data Input Mode

- Cards or CRT.

G. Data Output Mode

- Hard copy or CRT.

H. Input Data

- Consumer designation and type.
- Building age.
- Volume of building.
- Consumer connection pipe length.
- Cost factors including the following.
 - Pipe work and metering installations.
 - Heating plants.
 - Fuels.
 - Rate of interest and period of loan.
 - Charge tariff in district heating.

I. Output Data

- Consumer's contracted water flow.
- Consumer's heat load in Mw.
- Consumer's heat demand in Gwh.
- Connection charge.
- Demand charge.

- Consumption charge.
- Consumer connection pipe nominal size.
- Consumer connection pipe investment.
- Investment in consumer metering unit.
- Project cash flow and financing calculation.

Author(s) - EKONO.

Owner(s) - EKONO.

Availability - Internal use per company policy.

Cost - Not available.

Person to Contact and Address

Mr. Kalevi Leppa
Manager, Energy Services
EKONO Inc.
410 Bellevue Way S.E.
Bellevue, WA 98004
(206) 455-5969

List of Users

UNIVERSITY OF KENTUCKY

Abstract

This program handles virtually any type of problem dealing with the steady flow of liquids in pipe systems with no restrictions. It is based on a method of analysis which offers advantages over the commonly used techniques such as the Hardy-Cross Method. The program can handle systems containing storage tanks, pumps, valves, fittings, or various single pressure regulating valves distributed throughout the system. Pressure or flow requirements can be specified and readily changed for different situations. For output, the program provides pressures and grade lines at all junctions, head losses at all valves, pump heads, flow rates, and flow velocities in all pipes.

Program FeaturesA. Objectives

This program is intended to aid in the following:

- Preliminary feasibility.
- Preliminary and final design.

B. Program Capacity

- Up to 400 mains and less than 400 nodes can be accommodated.
- The capacity can be extended by redimensioning.
- Both English and metric systems can be used.

C. Configurations Analyzed

Systems with branches, trees, and loops can be analyzed.

D. Components of Distribution System

- Storage tanks.
- Pumps and pressure regulating valves.
- Valves, check valves.
- Fittings.
- Return.

E. Flow Equations

- Darcy-Weisbach.
- Hazen-Williams.

F. Type of Flow Analyzed

- Pressurized in closed conduits.

G. Type of Media Carried

- Liquids, primarily water.

H. Thermal Transfer

Heat loss is not considered.

I. Computer Configuration

- IBM 370 or compatible.
- Core requirement is 160K.

J. Language

- FORTRAN IV, level G.

K. Data Input Mode

- Card.

L. Output Mode

- Hard copy.

M. Input Data

Data input requirements are minimum and the computer will determine and identify the majority of user errors.

N. Output Data

Complete output is provided including pressures at all junctions, head losses at all valves, pump head, flow rates, and flow velocities in all pipes.

Author(s) - University of Kentucky.

Owner(s) - University of Kentucky.

Availability - Readily available through purchase.

Cost

- Purchase: \$30 per FORTRAN user manual and \$40 per FORTRAN source deck.

Person Contacted and Address

Professor Don Wood
College of Engineering
University of Kentucky
Lexington, Kentucky 40506
(606) 257-2936

List of Users