NBSIR 82-2512

A Computer Program for Analysis of Smoke Control Systems

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Center for Fire Research
Washington, DC 20234

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Final Report

Sponsored in part by:

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U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, *Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

PREFACE

This report is an interim product of a joint effort of the Department of Health and Human Services and the National Bureau of Standards (NBS), Center for Fire Research. The program is a multi-year activity initiated in 1975. It consists of projects in the areas of: decision analysis, fire and smoke detection, smoke movement and control, automatic extinguishment, and behavior of institutional populations in fire situations.

This report describes a computer program which analyzes pressurized stairwells and pressurized elevators. The program was initially intended as a research tool to investigate the feasibility of specific systems. However, this program may be of interest to design engineers responsible for pressurized stairwells or pressurized elevators.

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A COMPUTER PROGRAM FOR ANALYSIS OF SMOKE CONTROL SYSTEMS

John H. Klote

Abstract

This paper describes a computer program developed to analyze systems intended to control smoke in building fires. These systems include pressurized stairwells, pressurized elevator shafts, zone smoke control systems, and pressurized corridors. This program calculates air flows and differential pressures throughout a building in which a smoke control system is operating. The basic assumptions and limitations of the program are also discussed. The appendices contain a program listing and examples.

Key words: Air movement; computer programs; egress; elevator shafts; escape means; modeling; pressurization; simulation; smoke control; stairwells.

1. INTRODUCTION

The majority of fire fatalities result from smoke inhalation. As a result of this, a number of systems have been designed and built to control smoke movement in building fires. The most common smoke control systems are pressurized stairwells and zone smoke control systems[1]. These systems are intended to control smoke movement in a building by use of air flows and by differential pressures. The computer program described in this paper provides a means to calculate the air flows and differential pressures throughout a building (either real or conceptual) in which a smoke control system is operating.

A number of computer programs have been developed which are applicable to smoke control. Some of these programs calculate steady state air flow and pressures throughout a building [1,2][2]. Other programs go beyond this to calculate smoke concentrations throughout a building that would be produced in the event of a fire [3-73. In general, most of these programs are capable of analyzing smoke control

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[1] The concept of extending the use of smoke control to protect elevators is currently being investigated at NBS.

[2] Numbers in brackets refer to the literature references listed at the end of this paper.

systems. However, the program described in this paper has been specifically written for analysis of smoke control systems, and is an extension of a program specifically written for analysis of pressurized stairwells and elevators [8]. While the basic theory of this program is the same as that of the stairwell program it has been extended to include analysis of (1) stairwells with vestibules, (2) elevators with elevator lobbies, (3) zone smoke control systems, and (4) pressurized corridors. The data input has been designed to minimize the quantity of required data and still maintain a high level of generality in the model. The output consists of the pressure differences across all of the building shafts, as well as the flows and pressures throughout the building.

This program was originally intended primarily as a research tool to investigate the feasibility of specific smoke control systems and to determine the interaction between these systems and the rest of the building. The predecessor *[8]* of this program has already been used to analyze pressurized stairwells without vestibules and to evaluate factors which affect the performance of these systems [9]. And, this program has been used to generate data for an National Bureau of Standards (NBS) Handbook on Smoke Control Design which is being developed. This paper is not intended to be a design guide for smoke control systems. The state-of-the-art of these systems is still under development and designers of these systems should seek the most current data available.

2. PROGRAM CONCEPT

In this computer program a building is represented by a network of spaces or nodes each at a specific pressure and temperature. The stairwells and other shafts are modeled by a vertical series of spaces, one for each floor. Air flows through leakage paths from regions of high pressure to regions of low pressure. These leakage paths are doors and windows which may be opened or closed. Leakage can also occur through partitions, floors, exterior walls and roofs. The air flow through a leakage path is a function of the pressure difference across the leakage path.

In this computer model air from outside the building can be introduced by a pressurization system into any level of a shaft or even into other building spaces. This allows simulation of stairwell pressurization, elevator shaft pressurization, stairwell vestibule pressurization, and pressurization of any other building space. In addition, any building space can be exhausted. This allows analysis of zone smoke control systems where the fire zone is exhausted and other zones are pressurized. The pressures throughout the building and flow rates through all the flow paths are obtained by solving the air flow network including the driving forces such as the wind, the pressurization system or an inside to outside temperature difference.

3. ASSUMPTIONS AND LIMITATIONS

1. Each space is considered to be at one specific pressure and one specific temperature.

2. The flows and leakage paths are assumed to occur at mid-height of each level.

3. The net air supplied by the air handling system or by the pressurization system is assumed to be constant and independent of building pressure.

4. The outside air temperature is assumed to be constant.

5. The barometer pressure at ground level is assumed to be standard atmospheric pressure (101325 P_a)[3].

4. EQUATIONS

A. Flow equation

$$F = CA\sqrt{2\rho\Delta P} \qquad (3.1)$$

where:

F = mass flow rate
C = flow coefficient
A = flow area
ρ = density of air in flow path
ΔP = pressure difference across flow path

The flow coefficient is dimensionless and for smoke control analysis it is generally taken to be in the range of 0.6 to 0.7. Because of the large number of flow calculations performed during the computer analysis the flow equation is rewritten in the program as $F = C'\sqrt{\Delta P}$. Using the ideal gas law, the adjusted flow coefficient, C', can be expressed as

$$C' = CA\sqrt{\frac{2\,P_{atm}}{RT}} \qquad (3.2)$$

where:

P_{atm} = absolute barometric pressure at ground level
R = gas constant of air
T = absolute temperature of air in flow path

[3]The results of the program are not very sensitive to changes in atmospheric pressure. For altitudes considerably different from sea level the more accurate value can be substituted by changing an assign statement in the subroutine INPUT and one in the subroutine CORR.

B. Mass Balance Equations

For building compartment[4] i

$$\sum_{j=1}^{N_c} F_{(i,j)} + \sum_{k=1}^{N_o} F_{o(i,k)} + F_{f(i)} = 0 \quad (3.3)$$

and for shafts

$$\sum_{i=N_1}^{N_2} \left| \sum_{j-1}^{N_c} F_{(i,j)} + \sum_{k=1}^{N_o} F_{o(i,k)} + F_{f(i)} \right| = 0 \quad (3.4)$$

where:

$F_{(i,j)}$ = mass flow rate from space j to space i. For building compartments this flow can be either horizontal or vertical, however for shafts this flow can only be horizontal.

$F_{o(i,k)}$ = mass flow rate from direction k outside of the building to space i.

$F_{f(i)}$ = net mass flow rate of air due to the air handling system or due to a pressurization system.

N_c = number of building spaces connected to space i.

N_o = number of connections to the outside from space i.

N_1 is the space number at the bottom level of the shaft and the spaces in the shaft are numbered consecutively up to N_2 which is the space number at the top of the shaft.

C. Shaft Pressures

The following relationship is used to calculate the gage pressure, $P_{(i)}$, at floor i of a shaft in terms of $P_{(i-1)}$ at floor i - 1.

$$P_{(i)} = P_{(i-1)} - P_z - P_f \quad (3.5)$$

where:

P_z = hydrostatic pressure difference

P_f = pressure loss due to friction

The following equation is used to calculate the hydrostatic pressure difference.

---

[4]In this paper the term building compartment refers to a space in a building other than in a shaft.

$$P_z = \frac{g\bar{P}}{R\bar{T}} \quad h_{(i)} - h_{(i-1)} \tag{3.6}$$

where :

$h_{(i)}$ = height of point i

$h_{(i-1)}$ = height of point i-1

g = gravitational acceleration

R = gas constant

$\bar{T} = \frac{T_{(i)} + T_{(i-1)}}{2}$

$\bar{P} = \frac{P_{(i)} + P_{(i-1)}}{2} + P_b$

P_b is a constant used to convert an average gage pressure to the average absolute pressure, $\bar{P}$.

The following equation is used to calculate the pressure **loss** due to friction.

$$P_f = S\left(\frac{\dot{m}_u}{C_s}\right)^2 \tag{3.7}$$

where:

$\dot{m}_u$ = upward flow from i-1 to i in shaft

C_s = shaft flow coefficient

S = sign of $\dot{m}_u$

D. Outside Pressures

Outside pressures can either be entered by the user or can be **calculated** by **the** following method.

$$P_{o(i)} = P_{h(i)} + C_w P_{v(i)} \tag{3.8}$$

where :

$P_{o(i)}$ = outside gage pressure at height h(i) above absolute pressure at ground level

$P_{h(i)}$ = hydrostatic pressure difference between h(i) and ground level

$P_{v(i)}$ = velocity pressure due to the wind at height h(i)

C_w = pressure coefficient

Because the outside temperature is constant

$$P_{h(i)} = P_{atm} \exp\left(-\frac{gh(i)}{RT_{out}}\right) - P_b \tag{3.9}$$

where:

P_{atm} = absolute barometric pressure at ground level

T_{out} = outside absolute temperature

When the outside pressures are calculated by the computer the wind velocities are assumed to be described by the power law.

$$V = V_o \left(\frac{h}{h_o}\right)^n$$

where:

V_o = wind velocity at height h_o

n = wind exponent

This relationship has been extensively used to describe the boundary-layer velocity profile of the wind near the surface of the earth. It assumes that the terrain surrounding the building is homogeneous. That is, that there are no large obstructions near the building which could produce local wind effects. A value of 0.16 for the wind exponent is appropriate for flat terrain. The wind exponent increases with rougher terrain. For very rough terrain such as urban areas a value of **0.40** would be appropriate.

The equation for the velocity pressure at height $h(i)$ is obtained by substituting the velocity from the power law into the usual relation for velocity pressure ($P_v = \frac{1}{2} \rho V^2$).

$$P_v = \frac{\rho V_o^2}{2} \left(\frac{h_{(i)}}{h_o}\right)^{2n} \qquad (3.10)$$

where ρ is the outside air density.

The pressure coefficients are in the range of -0.8 to 0.8 where positive values are for windward walls and negative values are for leeward walls. The z pressure coefficient depends upon building geometry and varies locally over the wall surface. Numerical values for C_w and n as well as practical engineering information are available from a number of sources [lo-131.

5. PROGRAM DESCRIPTION

This program is written in ANSI FORTRAN on the UNIVAC 1100/82 and a program listing is provided in appendix D. The following is a detailed description of the main program and the major subroutines.

5.1 Main Program

The main program calls the subroutines which read the data, calculate the adjusted flow coefficients, calculates the initial values of pressures and inter-atively solves for the pressures according to the logic illustrated in the flow chart of figure 1.

5.2 INPUT Subroutine

This routine reads the data that are necessary for a flow analysis of the stairwell or elevator, including an analysis of the rest of the building. These data consist of the following:

1. Outside temperature.
2. Temperature throughout the building,
3. Outside pressures. These can be entered or calculated as described earlier,
4. Description of the flow network including flow coefficients and flow areas for all connections and the net air flows to each space due to the air conditioning system or due to a pressurization system.

The data above can be entered in either SI units or in engineering units. Appendix A contains a detailed description of the data input method.

In addition to reading data, this subroutine provides temperature and pressure data as well as a complete description of the flow network. This routine also calculates initial estimates of the hydrostatic pressure differences. When data is entered in engineering units the subroutine UNITS is called which converts all units to the SI system.

5.3 CORR Subroutine

This routine calculates adjusted flow coefficients for all flow paths using eq. (3.2). Two sets of these coefficients are calculated for each flow path to allow for flow in either direction.

5.4 INIT Subroutine

This routine calculates initial estimates of the building pressures by a technique used by Sander [1]. In this technique, mass flows are considered linear functions of differential pressure and therefore the flow equations can be expressed and solved in matrix form. In this estimate, shaft pressures are considered hydrostatic. The resulting pressures form a starting point for the iterative solution which follows.

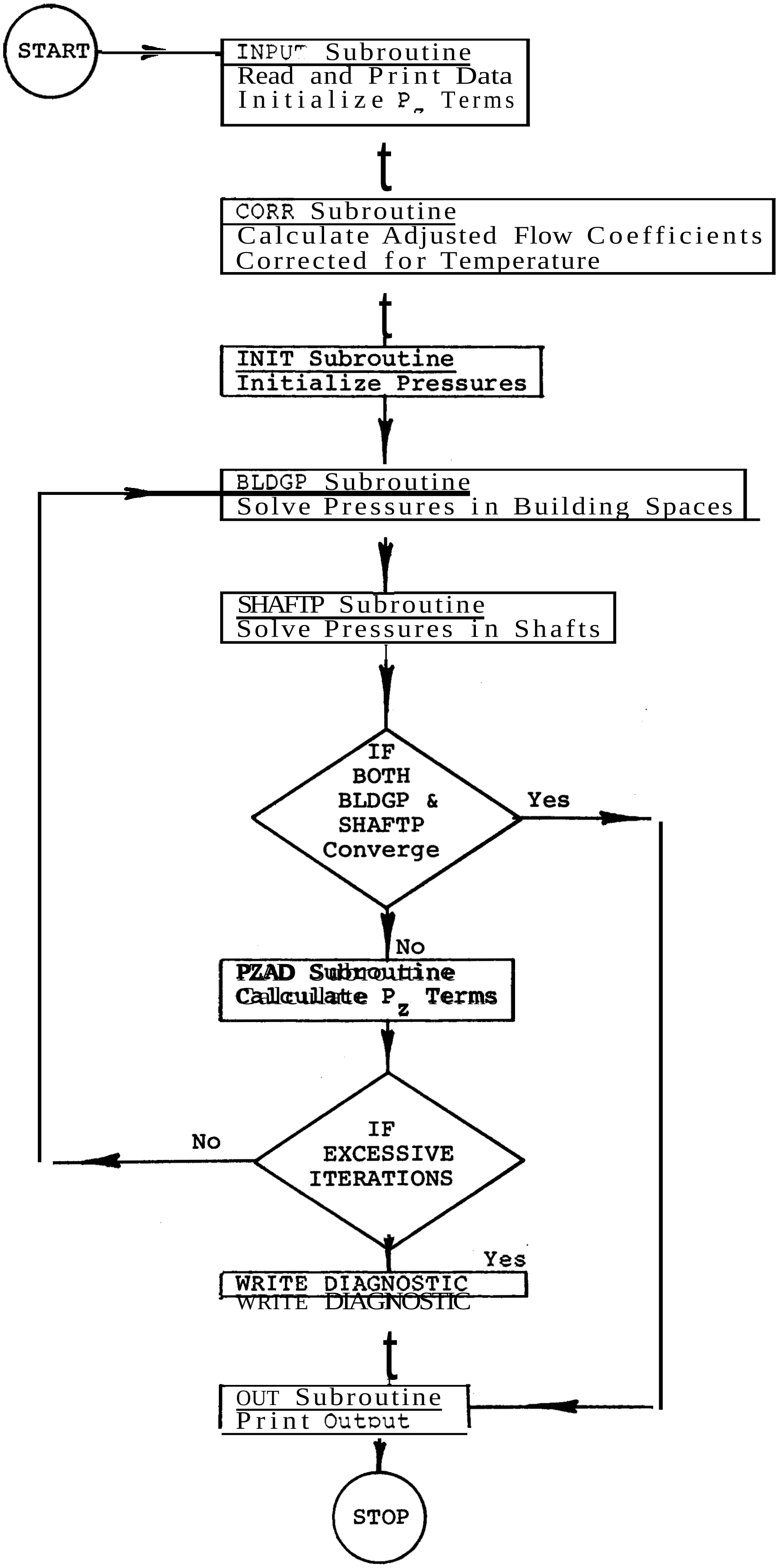

Figure 1. Flow chart for main program

5.5 BLDGP Subroutine

The iterative solution for the building pressures and flows consists of the three subroutines BLDGP, SHAFTP and PZAD. The subroutine BLDGP operates on the building compartments sequentially. The sum of all the mass flows into compartment i is calculated. If the absolute value of this sum is less than a convergence limit then eq. (3.3) is considered satisfied and the computer proceeds to the next compartment or returns to the main program. However, if the absolute value of the sum is greater than the convergence limit, then an improved estimate of the pressure at compartment i is obtained by the regula falsi method [14]. When none of the pressures need to be modified this routine passes a convergence signal to the main program.

5.6 SHAFTP Subroutine

The structure of this routine is very similar to that of BLDGP except that it operates on shafts sequentially. The sum of all the mass flows into shaft i is calculated. If the absolute value of this sum is less than the convergence limit then eq. (3.4) is also considered satisfied and the computer proceeds to the next shaft or returns to the main program. However, if the absolute value of the sum is greater than the convergence limit, then improved estimates of the shaft pressure are calculated. This is done by changing the pressures at the bottom of the shaft and then recalculating the shaft pressure by eq. (3.5). Again the regula falsi method is used, and if none of the shaft pressures require modification a convergence signal is passed to the main program. It can be seen from figure 1 that if convergence is achieved in both BLDGP and SHAFTP, then the subroutine OUT will print the solution. Otherwise, the hydrostatic pressure differences are adjusted in the subroutine PZAD.

5.7 PZAD Subroutine

This routine calculates hydrostatic pressure differences by eq. (3.6) using the most recent pressure estimates.

5.8 OUT Subroutine

This routine outputs mass flows and pressures for the flow network as well as the differential pressures across each shaft. If the data input was in engineering units then appropriate variables are converted to the engineering system before output.

6. FUTURE DIRECTION

It is planned to use this computer program in a project at NBS to study the feasibility of protected elevators as a means of fire escape for handicapped individuals. Consideration is being given to further development of the program for use as a design tool. Also, a program may be developed for microcomputers which can be used interactively.

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APPENDIX A. DATA INPUT DESCRIPTION FOR COMPUTER PROGRAM

Data input consists of the following elements:

1. Initial data
2. Building heights
3. Temperature profiles
4. Outside pressure profiles
5. Building data
6. Shaft data

Each of these input elements is described in detail in the following sections. Elements 1 through 6 are always required. In the following sections the input required for each of the six data elements is described in detail. Each **block** or group of blocks below represent an input card. Unless otherwise stated these cards are unformatted; that is, the numbers do not have to be placed in specific columns and integers can be written with or without decimal points. However, separate pieces of numerical data must be separated by one or more **spaces.** Examples of input data are provided in Appendix B.

1. <u>Initial data</u>

project title, (col. 1-72)

outside temperature (°C, °F)	unit indication (1 for SI, 2 for Eng)	summary output (0 for none, or file number)[1]

[1]The user must assign this file before program execution.

2. Building heights

N_h, no. of building levels — input parameter (either 0 or 1)

If input parameter = 0, then heights for each building level are to be individually entered as follows:

$h_{(1)}$ $h_{(2)}$ $h_{(3)}$ . . . $h_{(i)}$ . . . $h_{(N_h)}$

where $h_{(i)}$ is the height of the center of level i above the ground (m, ft).

If input parameter = 1, then the following card must be entered.

$h_{(1)}$ — distance between floors (m, ft)

3. Temperature profiles

no. of temperature profiles

For each temperature profile the following data must be supplied.

no. of temp. points	level no.	temperature (°C,°F)	level no.	temperature (°C,°F)		level no.	temperature (°C,°F)
					. .		

4. Outside pressure profiles

N_{po}
no. of outside pressure profiles

input parameter (either 0 or 1)

If the input parameter = 0, each outside pressure profile is entered as follows:

$P_{o(1)}$ $P_{o(2)}$ $P_{o(3)}$ . . . $P_{o(i)}$ . . . $P_{o(N_h)}$

where $P_{o(i)}$ is the outside pressure at the center of level i.

If the input parameter = 1, the outside pressures are calculated and the following data are required.

V_o
wind velocity (mph)

h_o
height at which velocity is measured

n
wind exponent

pressure coefficients for each pressure profile

$C_{W(1)}$ $C_{W(2)}$ . . . . $C_{W(Npo)}$

5. Building data

N_f
no. of levels (or floors)

All of the following data in this input element are supplied for each level, or consecutive groups of similar levels.

I_1 Starting floor	I_2 Ending floor	N_{com} No. of compartments per floor

(Floor data is entered in ascending order of levels or floors. When data is for only one level then $I_1 = I_2$, and the same number is supplied for both.)

For each compartment on a level the following data are supplied:

N_{CS} No. of connections to other compartments on the same level	N_{CA} No. of connections to compartments on the level above	N_{CO} No. of connections to the outside	F_f Net flow[2] (l/s, cfm)	Temperature profile number

For each connection between this compartment and another on the same floor the following data are required.

Other compartment number on the same level	C flow coefficient	A flow area (m^2, ft^2)

For each connection between this compartment and one on the level above the following data are required.

[2] All net flows are at standard conditions of 21°C (70°F) and one atmosphere.

Other compartment number on floor above	C flow coefficient	A flow area (m^2, ft^2)

For each connection to the outside the following data are required.

outside pressure profile number	C flow coefficient	A flow area (m^2, ft^2)

6. <u>Shaft data</u>

no. of shafts

All of the following data in this input element are required for each shaft.

shaft title (col 1-20)

C_s shaft flow coefficient	bottom level of shaft	top level of shaft	temperature profile number

Enter the following typical data which applies to each level of the shaft.

Exceptions can be entered later.

no. of connections between typical level of shaft and outside	F_f net flow into typical level of shaft (l/s, cfm)

The connection data to the building for a typical level are required.

compartment no. to which shaft is connected	C flow coefficient	A flow area (m^2, ft^2)

For each connection to the outside, the connection data for **a** typical floor are required.

outside pressure profile	C flow coefficient	A flow area (m^2, ft^2)

The number of exceptions to the typical data is required.

no. of exceptions

All of the following data in this input element are required for each exception.

exception type (1, 2 or 3)	level of shaft

The next card depends on the exception type. For exception type = 1, to the net flow into the floor of the shaft is defined.

F_f
net flow
(l/s, cfm)

For exception type = 2, an exception to an outside connection for this shaft is defined.

outside pressure profile number	C flow coefficient	A flow area (m^2, ft^2)

For exception type = 3, an exception to the connection between the shaft and the building is defined.

compartment no. to which shaft is connected	C flow coefficient	A flow area (m^2, ft^2)

APPENDIX B. INPUT EXAMPLES

1. Example 1

A ten story building with a pressurized stairwell and no vertical leakage within the building is heated to 70°F when the outside temperature is -20°F. The stairwell temperature is 60°F at the tenth floor and 50°F at the bottom floor. The stairwell is pressurized by a net 550 cfm[1] per floor. The wind is 30 mph at a height of 30 ft and the wind exponent is 0.14. This building has connections to the outside in two directions. The wind pressure coefficients are 0.7 for the windward wall and -0.7 for the leaward wall. The flow areas are the same vertically and are listed in Table B1. The flow coefficient is taken to be 0.65 for all connections.

Table B1. Flow areas for example 1

Connection location	Area (ft^2)
Between stairwell & building	0.42
Between building & outside into the wind	0.75
Between building & outside away from the wind	0.75

1.1 Data for Computer Input

initial data	TEN STORY BUILDING WITHOUT VERTICAL LEAKAGE				
	-20	20			
building *heights*	10	1			
	5	10			
temperature profiles	2				
	1	1	70		
	2	1	50	10	60
outside pressure profiles	2	1			
	30	30	.15		
	0.7	-0.7			

[1]At standard conditions of 21°C (70°F) and one atmosphere.

building data	10				
	1	10	1		
	0	0	2	0	1
	1	.65	0.75		
	2	.65	0.75		

shaft data	1			
	STAIRWELL			
	80000	1	10	2
	0	550		
	1	.65	.42	
	0			

2. Example 2

This is a 10 story building which is 70°F inside. Outside the air temperature is -5°F and there is no wind. This building has a stairwell and an elevator. The flow areas which are generally the same vertically are listed in table B2 and the flow exponents are taken to be 0.5. The stairwell is pressurized by a net 550 cfm per floor. The elevator shaft has a 4 ft^2 vent to the outside at the top. On floors 2 through 10 the elevator lobby separated from the building by doors that automatically close in the event of a fire. The flow coefficient is taken as 0.65 in all connections.

Table B2. Flow areas for example 2

Connection location	Area (ft^2)
Between stairwell & building	0.42
Between building & outside	1.5
Between elevator & elevator lobby	0.65
Between elevator lobby & building	0.55

2.1 Data for Computer Input

initial data	TEN STORY BUILDING WITH ELEVATOR		
	-5	2	0
building heights	10	1	
	5	10	
temperature profile	1		
	1	1	70
outside pressure data			

```
building      { 10
data

    1st       { 1     1     1
    floor     { 0     0     1     0     1
              { 1  0.65  0.75

              { 2    10     2
    2nd       { 1     0     1     0     1
    through   { 2  0.65  0.55
    10th floors { 1  0.65  0.75
              { 0     0     0     0     1

shaft         { 2
data

              |  STAIRWELL
              |80000    1    10     1
    shaft 1   |    0  550
              |    1  .65   .42
              |    0

              (  ELEVATOR
              ( 2.7E6   1    10     1
              (    0    0
              (    2  .65   .65
    shaft 2   (    2
              (    2   10
              (    1  .65   4.0
              (    3    1
              (    1  .65   .65
```

2.2 Example 2 Output

The output for example 2 case 1 (the data above not including modifications for Cases 2 and 3) is given in appendix C.

APPENDIX C. EXAMPLE OUTPUT

EXAMPL OUTPUT DATE 100281

TEN STORY BUILDING WITH ELEVATOR

OUTSIDE TEMPERATURE -50 F

HEIGHT FT	TEMPERATURE PROFILES (DEG F) 1
5.00	70.0
15.00	70.0
25.00	70.0
35.00	70.0
45.00	70.0
55.00	70.0
65.00	70.0
75.00	70.0
85.00	70.0
95.00	70.0

HEIGHT FT	OUTSIDE PRESSURE PROFILES (IN H2O) 1
5.00	1.909
15.00	1.741
25.00	1.574
35.00	1.406
45.00	1.239
55.00	1.071
65.00	.904
75.00	.736
85.00	.569
95.00	.402

[illegible] ITERATIONS

THE FOLLOWING UNITS ARE USED FOR OUTPUT

FLOW IN CFM AT 70 DEG F AND 1 ATM
PRESSURE IN INCHS H2O
AREA IN FEET SQUARED

EXAMPLE OUTPUT

DATE 100281

TEN STORY BUILDING WITH ELEVATOR

FLOOR	COMPARTMENT	PRESSURE	TEMP PROFILE	FIXED FLOW	CONNECTIONS		DIFFERENTIAL PRESSURE	ADJUSTED FLOW COEFFICIENT	FLOW AREA	FLOW
1	1	1.903	1	0.	STAIRWELL		.182	1095.	.039	467.5
					ELEVATOR		-.136	1694.	.650	-624.7
					OUTSIDE DIRECTION	1	.006	2110.	.750	157.2
										-.1 NET
2	1	1.744	1	0.	FLOOR 2 COMPARTMENT	2	-.070	1434.	.051	-380.3
					STAIRWELL		.197	1095.	.420	486.3
					OUTSIDE DIRECTION	1	-.003	1955.	.750	-106.4
										-.4 NET
2	2	1.674	1	0	FLOOR 2 COMPARTMENT	1	.070	1434.	.051	30.3
					ELEVATOR		-.050	1694.	.650	-30.5
										-.1 NET
3	1	1.581	1	0.	FLOOR 3 COMPARTMENT	2	-.059	1434.	.051	-348.0
					STAIRWELL		.217	1095.	.420	509.9
					OUTSIDE DIRECTION	1	-.007	1955.	.750	-162.2
										-.3 NET
3	2	1 522	1	0	FLOOR 3 COMPARTMENT	1	.059	1434.	.051	38.0
					ELEVATOR		-.042	1694.	.650	-38.0
										.0 NET
4	1	1 418	1	0	FLOOR 4 COMPARTMENT	2	-.048	1434.	[illegible]51	-314.9
					STAIRWELL		[illegible]35	1095.	[illegible]20	530.8
					OUTSIDE DIRECTION	1	-.012	1955.	[illegible]50	-216.2
										-.3 NET
4	2	1 370	1	0	FLOOR 4 COMPARTMENT	1	.048	1434.	.051	314.9
					ELEVATOR		-.035	1694.	.650	-315.0
										-.1 NET
5	1	1 257	1	0.	FLOOR 5 COMPARTMENT	2	-.038	1434.	.051	-280.9
					STAIRWELL		.252	1095.	.420	549.5
					OUTSIDE DIRECTION	1	-.019	1955.	.750	-268.8
										-.3 NET
5	2	1.219	1	0	FLOOR 5 COMPARTMENT	1	.0[illegible]8	1434.	.051	[illegible]0.9
					ELEVATOR		-.0[illegible]	1694.	.650	-[illegible]1.1
										-.2 NET
6	1	1.098	1	0.	FLOOR 6 COMPARTMENT	2	-.029	1434.	.051	-245.4
					STAIRWELL		.267	1095.	.420	566.1
					OUTSIDE DIRECTION	1	-.027	1955.	.750	-320.7
										-.0 NET
6	2	1.069	1	0	FLOOR 6 COMPARTMENT	1	.029	[illegible]434.	.051	[illegible]5.[illegible]
					ELEVATOR		-.021	[illegible]694.	.650	-[illegible]5.[illegible]
										-.[illegible] NET

[illegible] OUTPUT

DATE 100281

TEN STORY BUILDING WITH ELEVATOR

FLOOR	COMPARTMENT	PRESSURE	TEMP PROFILE	FIXED FLOW	CONNECTION		DIFFERENTIAL PRESSURE	ADJUSTED FLOW COEFFICIENT	FLOW AREA	FLOW
7	1	.940	1	0.	FLOOR 7 COMPARTMENT	2	-.021	1434.	.051	-208.2
					STAIRWELL		.281	1095.	.420	580.7
					OUTSIDE DIRECTION	1	-.036	1955.	.750	-372.7
										-.2 NET
7	2	.919	1	0	FLOOR 7 COMPARTMENT	1	.021	1434.	.051	208.2
					ELEVATOR		-.015	1694.	.650	-208.4
										-.2 NET
8	1	7[illegible]	1	0.	FLOOR 8 COMPARTMENT	2	-.014	1434.	.051	-168.3
					STAIRWELL		.294	1095.	.420	593.4
					OUTSIDE DIRECTION	1	-.047	1955.	.750	-425.3
										-.2 NET
8	2	770	1	0	FLOOR 8 COMPARTMENT	1	.014	1434.	.051	168.3
					ELEVATOR		-.010	1694.	.650	-168.4
										-.2 NET
9	1	.629	1	0.	FLOOR 9 COMPARTMENT	2	-.008	1434.	.051	-124.6
					STAIRWELL		.304	1095.	.420	604.0
					OUTSIDE DIRECTION	1	-.060	1955.	.750	-479.6
										-.2 NET
9	2	.622	1	0	FLOOR 9 COMPARTMENT	1	.008	1434.	.051	124.6
					ELEVATOR		-.005	1694.	.650	-124.8
										-.2 NET
10	1	.477	1	0	FLOOR 10 COMPARTMENT	2	-.003	1434.	.051	-75.3
					STAIRWEL		.013	1095.	.420	612.0
					OUTSIDE DIRECTION	1	-.075	1955.	.750	-537.0
										-.4 NET
10	2	.475	1	0	FLOOR 10 COMPARTMENT	1	.003	1434.	.051	75.3
					ELEVATOR		-.002	1694.	.650	-75.5
										-.2 NET

STAIRWELL

TEMPERATURE PROFILE 1
SHAFT FLOW COEFFICIENT 80000.

FLOOR	PRESSURE	FIXED FLOW	CONNECTION	TO	DIFFERENTIAL PRESSURE	ADJUSTED FLOW COEFFICIENT	FLOW AREA	FLOW
1	2.086	550.	FLOOR 1	COMPARTMENT 1	-.182	1095.	.039	-467.5
2	1.942	550.	FLOOR 2	COMPARTMENT 1	-.197	1095.	.039	-486.3
3	1.798	550.	FLOOR 3	COMPARTMENT 1	-.217	1095.	.039	-509.9
4	1.653	550.	FLOOR 4	COMPARTMENT 1	-.235	1095.	.039	-530.8
5	1.509	550.	FLOOR 5	COMPARTMENT 1	-.252	1095.	.039	-549.5
6	1.365	550.	FLOOR 6	COMPARTMENT 1	-.267	1095.	.039	-566.1
7	1.221	550.	FLOOR 7	COMPARTMENT 1	-.281	1095.	.039	-580.7
8	1.078	550.	FLOOR 8	COMPARTMENT 1	-.294	1095.	.039	-593.4
9	.934	550.	FLOOR 9	COMPARTMENT 1	-.304	1095.	.039	-604.0
10	.790	550.	FLOOR 10	COMPARTMENT 1	-.313	1095.	.039	-612.0
								-.1 NET

ELEVATOR

TEMPERATURE PROFILE 1
SHAFT FLOW COEFFICIENT 2700000.

FLOOR	PRESSURE	FIXED FLOW	CONNECTION	TO	DIFFERENTIAL PRESSURE	ADJUSTED FLOW COEFFICIENT	FLOW AREA	FLOW
1	1.767	0.	FLOOR 1	COMPARTMENT 1	.136	1694.	.060	624.7
2	1.623	0.	FLOOR 2	COMPARTMENT 2	.050	1694.	.060	380.5
3	1.479	0.	FLOOR 3	COMPARTMENT 2	.042	1694.	.060	348.0
4	1.335	0.	FLOOR 4	COMPARTMENT 2	.035	1694.	.060	315.0
5	1.191	0.	FLOOR 5	COMPARTMENT 2	.028	1694.	.060	281.1
6	1.048	0.	FLOOR 6	COMPARTMENT 2	.021	1694.	.060	245.7
7	.904	0.	FLOOR 7	COMPARTMENT 2	.015	1694.	.060	208.4
8	.760	0.	FLOOR 8	COMPARTMENT 2	.010	1694.	.060	168.4
9	.616	0.	FLOOR 9	COMPARTMENT 2	.005	1694.	.060	124.8
10	.473	0.	FLOOR 10	COMPARTMENT 2	.002	1694.	.060	75.5
			OUTSIDE	DIRECTION 1	-.071	10426.	4.000	-2772.5
								-.4 NET

APPENDIX D. PROGRAM LISTING

MAIN PROGRAM

```
@NBS*PLIBS.SHOW A.MAIN
C
C      COMPUTER PROGRAM FOR AIR FLOW ANALYSIS IN BUILDINGS
C       SPECIFICALLY FOR ANALYSIS OF SMOKE CGNTROL SYSTEMS
C
C
C      PROGRAM VARIABLES
C      AI      LEAKAGE AREA OF INTERNAL CONNECTION
C      AO      LEAKAGE AERA OF CCNNECTICN TO OUTSIDE
C      C       FLOW COEFFICIENT BETWEEN BUILDING POINTS
C      CO      FLOW COEFFICIENT TO OUTSIOE
C      CS      FLOW COEFFICIENT OF SHAFT
C      E       LIMIT WITHIN WHICH CCNVERGENCE IS ACCEPTABLE
C      F       NET FLOW INTO POINT I
C      FC      FLOW BETWEEN INTERNAL FOINTS
C      FF      FIXED FLOW INTO PCINT I
C      FO      FLOW TO OUTSIDE
C      FSS     NET FLOW INTO SHAFT IS
C      H       HEIGHT FROM GROUND TO MIDPOINT OF FLOOR
C      IBUG    OUTPUT VARIABLE
C      ICONV   INTEGER USED IN SUBROUTINES BLDGP AND SHAFTP
C              IF ICONV = 0 THEN THE PRESSURES WERE UNCHANGED
C      IFLCCR  FLOOR LEVEL WHERE POINT IS LOCATED
C      IT      POINTER TO TEMP PROFILE FOR POINT I
C      ITS     POINTER TO TEMPERATURE PROFILE OF SHAFT
C      JC      POINT NO. CCNNECTED TO POINT I
C      JOC     DIRECTION OF OUTSIOE CONNECTION
C      N       NC. OF BUILOING CCMPARTMENTS
C      NC      NO. OF INTERNAL POINTS CCNNECTED TO POINT I
C      NCO     NO. OF OUTSIDE CONNECTICNS
C      NFSI    BOTTOM FLOOR OF SHAFT
C      NFS2    TOP FLOOR OF SHAFT
C      NH      NO. OF FLOORS
C      NPO     NO. OF OUTSIDE FRESSURE PROFILES
C      NS      NO0 OF SHAFTS
C      NS1      I VALUE FOR START OF SHAFT
C      NS2      I VALUE FOR END OF SHAFT
C      NT      TOTAL NO. OF POINTS (BLDG AND SHAFT)
C      NTP     NO. OF TEMPERATURE PROFILES
C      P       PRESSURE AT POINT I
C      FFO     OUTSIDE FRESSURE PROFILES
C      FO      OUTSIDE PRESSURE
C      PS      PRESSURE PROFILE OF SHAFT - WORKSPACE
C      PZ      PRESSURE DUE TO ELEVATION DIFFERENCE
C      T       TEMPERATURE PROFILE ARRAY
C      TITLE   PROJECT TITLE
C      TITSH   SHAFT TITLE
C
C
C      PROGRAM PARAMETERS
C      MB      MAX NO0 OF BUILDING COMPARTMENTS
C      MM      MAX NO. OF POINTS
C      MS      MAX NO. CF SHAFTS
C      MC      MAX NO. OF CONNECTIONS FOR ANY POINT
C      MPO     MAX NO. OF OUTSIDE PRESSURE PRCFILES
C      MTP     MAX NO. CF TEMPERATURE PROFILES
C      MFL     MAX NO. OF FLOORS
```

MAIN PROGRAM

```
C
C
      PARAMETER  (MM=140,MS=8,MC=9,MPO=2,MTP=2,MFL=25,MB=50)
      COMMON NT,    P(MM),C(MM,MC),NC(MM),JC(MM,MC),ITS(MS),
     1 FC(MM,MC),PZ(MM,MC),PO(MM,MPO),CO(MM,MPO),F(MM),PFO(MFL,MPO),
     2 FF(MM),FO(MM,MPO),CS(MS),PS(MFL),NS1(MS),NS2(MS),
     3 FSS(MS),N,NS,NPO,ICONV,E,IBUG,AI(MM,MC),AO(MM,MPO),TITSH(MS,5),
     4 NH,H(MFL),IFLOOR(MM),T(MTP,MFL),NFS1(MS),NFS2(MS),IT(MB),NTP
     5 ,NCC(MM),JOC(MM,MPO),TOUT
      DOUBLE PRECISION P,PO,PS
      COMMON /RUN/IRUN
      DIMENSION B1(MM,MC),B2(MM,MPO)
      NITER=5000
      IRUN=1
C
C       CALL INPUT TO READ CATA
C
      CALL INPUT
C
      E=0.2
20    ICS=1
C
C         SPVE AI(I,J) IN B1(I,J) AND FINO
C           MAX VALUE OF AI(I,J)
C
      AZZ=C
      AMAX=0
      GO 10 I=1,NT
      CO 8 J=1,MC
      61(I,J)=AI(I,J)
      IF(AI(I,J) .GT. AMAX)AMAX=AI(I,J)
e     CONTINLE
      DO 9 J=1,MPO
      E2(I,J)=AO(I,J)
      IF(AC(I,J) .GT. AMAX)AMAX=AO(I,J)
S     CONTINUE
10    COFTINUE
C
C        ACJUST FOR LARGE VALUES OF FLOW AREA
C
      IF(AMAX .LT. 0.3)GO TO 25
      AZZ=1
      AM=0.2/(AMAX-0.1)
      BB=0.1*(1.0-AM)
      GO 15 I=1,NT
      CO 15 J=1,MC
      IF(AI(I,J) .LT. 0.1)GO TO 12
      AI(I,J)=AM*AI(I,J)+BB
12    COhTINUE
      DO 14 J=1,MPO
      IF(AC(I,J) .LT. 0.1)GO TO 14
      AO(I,J)=AM*AO(I,J)+BB
14    CONTINUE
15    CONTINUE
C
C       TEMPERATURE CORRECTICN
C
25    CALL CCRR
```

MAIN PROGRAM

```
C
C         CALL INIT TO INITIALIZE PRESSURE ARRAY , P
C
22      CALL INIT
C
C
C         DO LCOP TO 30 IS ITERATIVE SOLUTION TO PRESSURE ARRAY
C
24      CO 3C ITER=1,NITER
C
C         CALL BLDGP TO SOLVE FOR BUILDING PRESSURES
C
        CALL BLDGP
        ICE= ICONV
        IF(ICB .EQ. 0 .AND. ICS .EQ. 0)GO TO 40
C
C         CALL SHAFTP TO SCLVE FOR SHAFT PRESSURES
C
        CALL SHAFTP
        ICS=ICONV
        IF(ICB .EQ. 0 .AND. ICS .EQ. 0)GO TO 40
C
C         CALL PZAD TO CALCULATE PZ TERMS
C
        CALL FZAD
30      CONTINUE
C
C         IF ROUTINE FAILS TO CONVERGE IN NITER
C         ITERATIONS PRINT ERROR MESSAGE
C
        WRITE(6,800)
40      CONTINUE
        WRITE(6 9801)ITER
        IF(AZZ .EQ. 0.)GO TO 42
        AZZ = 0.
        CO 6C I=1,NT
        DO 5C J=1,MC
SO      AI(I,J)=B1(I,J)
        DO 5S J=1,MPO
55      AO(I,J)=B2(I,J)
€0      CONTINUE
        CALL CCRR
        GO TC 24
C
C
C
C         CALL OUT TO OUTPUT SOLUTION
C
42      CALL OUT
C
        WRITE(6,805)
         STOP
C
C
C        FORMAT STATEMENTS
C
800     FORMAT(/////5X,35(1H1)//5X,
      +35HFAILURE OF MAIN PROGRAM TO CCNVERGE //5X,35(1H1)//)
```

```
801    FORMAT(    10X,I5,5X,11HITERATIONS    )
805    FORMAT(1H1)
       END
```

&HDG,P SUBROUTINE INPUT.L,1

SUBROUTINE INPUT

```
@NBS*PLIB$.SHOW  A.INPUT
      SUBRCUTINE INPUT
C
C       ThIS ROUTINE HEADS AND PRINTS OATA
C        ANC INITIALIZES PZ ARRPY
C
      FARAMETER  (MM=140,MS=8,MC=9,MPO=2,MTP=2,MFL=25,MB=50)
      COMMCN /PZZ/ PGZ
      COMMCN  /IO/TITLE(18),IOUT,IUNIT,NCOMP(MFL),SNCOMP(MFL)
      COMMCN NT,   P(MM),C(MM,MC),NC(MM),JC(MM,MC),ITS(MS),
     1 FC(MM,MC),PZ(MM,MC),PO(MM,MPC),CO(MM,MPO),F(MM),PFO(MFL,MPO),
     2 FF(MM),FO(MM,MPO),CS(MS),PS(MFL),NS1(MS),NS2(MS),
     3 FSS(MS),N,NS,NPO,ICONVIE,IBUG,AI(MM,MC),AO(MM,MPO),TITSH(MS,5),
     4 NH,H(MFL)IIFLOOR(MM),T(MTP,MFL),NFS1(MS),NFS2(MS),IT(MB),NTP
     5 ,NCC(MM),JOC(MM,MPO),TOUT
      DOUBLE PRECISICN P,PO,PS
      CHARPCTER PAR86
      DIMENSION IK(MFL),TT(MFL),PAR(7),CW(MPO),PH(MFL),NZZ(MM)
      CATA  FAR/' MM',' MS',' MC','MPO','MTP','MFL',' MB'/
      IBUG=0
C
C        RECO AND WRITE PROJECT TITLE
C
      REAC(5,600)(TITLE(I),I=1,18)
      WRITE(6,601)(TITLE(I),I=1,18)
C
C
C        REAC GENERAL OATA
C
C
C        TOUT = OUTSIDE TEMPERATURE
C        IUNIT = 1 FOR S I UNITS
C              = 2 FOR ENG UNITS
C        IOUT = 0 FOR NO SUMMARY OUTPUT
C        OTHERWISE IOUT IS FILE NO. TO
C        WHICH SUMMARY OUTPUT IS WRITTEN
C
      REAC(5,700)TOUT,IUNIT,IOUT
      WRITE(6,411)TOUT,IUNIT,IOUT
      IF(IUNIT .GT. 2 .OR. IUNIT .LT. 1)GO TO 105
C
C        READ HEIGHTS
C        NN=0 FOR INPUT OF ALL HEIGHTS
C        NN=1 FOR CALCULATICN OF HEIGHTS
C
      READ(5,700)NH,NN
      WRITE(6,412)NH,NN
      IF(NH .LE. MFL)GO TO 89
      IPAR=6
      GO TC 110
€9    IF(NN .EG. 1)GO TO S7
      READ(5,700)(H(I),I=1,NH)
      WRITE(6,413)(H(I),I=1,NH)
      GC TC 99
S7    REAC(5,700)H(1),DH
      WRITE(6,414)H(1),DH
      CO SE I=2,NH
```

SUBROUTINE INPUT

```
      IM=I-1
58    H(I)=H(IM)+DH
C
C       READ TEMPERATURE PROFILES
C
59    READ(5,700)NTP
      WRITE(6,415)NTP
      IF(NTP .LE. MTP)GO TO 50
      IPAR=5
      GO TC 110
50    DO 3 IP=1,NTP
      READ(5,700)NNN,(II(J),TT(J),J=1,NNN)
      WRITE(6,416)NNN,(II(J),TT(J),J=1,NNN)
      IF(NNN .GT. 1)GO TC 2
      DO 1 IFF=1,NH
1     T(IP,IFF)=TT(1)
      GO TC 3
2     J=1
      JP1=2
      DO 4 IFF=1,NH
      T(IP,IFF)=TT(J)+(TT(JP1)-TT(J))*(IFF-II(J))/(II(JP1)-II(J))
      IF(IFF .NE. II(JP1))GO TC 4
      IF(JP1 .EQ. NNN)GO TO 4
      J=JP1
      JP1=J+1
4     CONTINUE
3     CONTINUE
C
C
C       READ OUTSIDE PRESSURE PROFILES
C       NN=0 FOR INPUT OF ALL PRESSURES
C       NN=1 FOR CALCULATION BY POWER LAW
C
      READ(5,700)NPO,NN
      WRITE(6,417)NPO,NN
      IF(NPO .LE. MPO)GO TO 51
      IPAR=4
      GO TC 110
51    IF(NN .EQ. 1)GO TO 81
C
C       READ ALL OUTSIDE PRESSURES
C
      DO 6 I=1,NPO
6     READ(5,700) PGZ,(PFO(J,I),J=1,NH)
      WRITE(6,418)PGZ,(PFO(J,I),J=1,NH)
      GO TC 85
C
C       CALCULATE OUTSIDE PRESSURES
C       PATMOS IS ATMOSPHERIC PRESSURE (PA)
C
81    READ(5,700)VW,HW,XW,(CW(I),I=1,NPO)
      WRITE(6,419)VW,HW,XW,(CW(I),I=1,NPO)
      IF(IUNIT .EQ. 1)VW=VW*0.2778
      IF(IUNIT .EQ. 2)VW=VW*0.4470
      PATMOS=101325O
      TOO=TOUT+273.
      IF(IUNIT .EQ. 2)TOO=(TOUT+460.)/1.8
      PVA=176.4*VW*VW/TOO
```

SUBROUTINE INPUT

```
      Z=-0.03417/TOO
      IF(IUNIT .EQ. 2)Z=0.3048*Z
      CWM=CW(1)
      IF(NPO .EQ. 1)GO TO 212
      DO 211 I=1,NPO
      IF(CW(I) .LT. CWM)CWM=CW(I)
211   CONTINUE
212   PGZ=PATMOS*EXP(H(NH)*Z)+CWM*PVA*((H(NH)/HW)**(2.*XW))-100.
      DO 210 I=1,NH
      PH(I)=PATMOS*EXP(H(I)*Z)
210   CONTINUE
      DO 82 I=1,NPO
      DO 82 J=1,NH
      PFO(J,I)=PH(J)+CW(I)*PVA*((H(J)/HW)**(2.*XW))-PGZ
82    CONTINUE
C
C
C         BUILDING DATA INPUT
C        NFLS = NO. OF FLOORS IN BUILDING
C        IF1 = LOWER FLOOR IN SERIES OF SIMILAR FLOORS
C        IF2 = UPPER FLOOR IN SERIES OF SIMILAR FLOORS
C        NCC = NO. OF COMPARTMENTS PER FLOOR
C        NZ = NO. OF CONNECTIONS TO COMPARTMENTS ON SAME FLOOR
C        NA = NO. OF CONNECTIONS TO COMPARTMENTS ON FLOOR ABOVE
C
e5    I=0
      SNCOMP(1)=0.
      READ(5,700)NFLS
      WRITE(6,420)NFLS
      IF(NFLS .GT. NH)GO TO 106
7     READ(5,700)IF1,IF2,NOC
      WRITE(6,400)IF1,IF2,NOC
      IF(IF1 .GT. IF2)GO TO 107
      NCOMP(IF1)=NOC
      IFP=IF1+1
      SNCOMP(IFP)=SNCOMP(IF1)+NOC
      DO 10 IZ=1,NOC
      I=I+1
      READ(5,700)NZ,NA,NNO,FF(I),IT(I)
      WRITE(6,401)NZ,NA,NNO,FF(I),IT(I)
      NZZ(I)=NZ
      NN=NZ+NA
      IFLOOR(I)=IF1
      IF(NN .LE. MC)GO TO 111
      IPAR=3
      GO TO 110
111   IF(NNO .LE. MPO)GO TO 112
      IPAR=4
      GO TO 110
112   IF(IT(I) .GT. NTP .OR. IT(I) .LT. 1)GO TO 102
      NC(I)=NN
      IF(NZ .EQ. 0)GO TO 63
C
C         INPUT CONNECTIONS TO COMPARTMENTS ON SAME FLOOR
C
      READ(5,700)(JC(I,J),C(I,J),AI(I,J),J=1,NZ)
      WRITE(6,402)
      WRITE(6,403)(JC(I,J),C(I,J),AI(I,J),J=1,NZ)
```

SUBROUTINE INPUT

```
      CO €2 J=1,NZ
€2    JC( I,J)=JC(I, J)+SNCCMF( IF1)
e3    IF(NA .EG. 0)GO TO 8
C
C       INFUT CONNECTIUNS TO CCMPARTMENTS GN FLOOR ABOVE
C
      NP=NZ+1
      REAC(5,700)(JC(I,J),C(I,J),AI(I,J),J=NP,NN)
      WRITE(6,404)
      WRITE(6,403)(JC(I,J),C(I,J),AI(I,J),J=NP,NN)
      DC 6€ J=NP,NN
€6    JC(I,J)=JC(I,J)+NCCMP(IF1)+SNCOMP(IF1)
e     NCC(I)=NNO
      IF(NNO .EQ. 0)GO TO 10
C
C       INFUT CONNECTION TO OLTSIOE
C
      REAC(5,700)(JOC(I,JJ),CO(I,JJ),AO( I,JJ),JJ=1,NNO)
      WRITE(6,405)
      WRITE(€,403)(JCC(I,JJ),CO(I,JJ),AO( I,JJ),JJ=1,NNO)
      CO 9 JJ=1,NNO
      J=JOC(I,JJ)
S     PO(I,JJ)=PFO(IF1,J)
10    CONTINUE
      IF(IF1 .NE. IF2)GO TO 11
      IF(IF1 .EQ. NFLS)GO TO 20
      GO TC 19
C
C       ASIGN CATA FOR FLOORS SIMILAR TO FLOOR IF1
C
11    IFP=IF1+1
      OO 17 IFF=IFP,IF2
      NCOMF(IFF)=NOC
      IFFP=IFF+1
      SNCOMP(IFFP)=SNCOMP(IFF)+NOC
      CO 1€ IZ=1,NOC
      I= I-1I-
      I1=I2+ONCOMP( IF1)
      IFLOCR( I)=IFF
      FF(I)=FF(I1)
      IT(I)=IT(I1)
      NN=NC(I1)
      NNO=NCO(I1)
      NC( I)=NN
      NCC(I)=NNO
      IF(IFF .NE. NFLS)GO TO 23
      NN=NZZ(I1)
      NC(I)=NN
23    IF(NN .EG. 0)GC TO 14
      DO 12 J=1,NN
      C(I,J)=C(I1,J)
      AI(I,J)=AI(I1,J)
      JC( I,J)=JC(I1,J)+SNCOMP(IFF)-SNCOMP( IF1)
12    COhTINUE
14    IF(NNO .EQ. 0)GO TO 16
      DO 1S JJ=1,NNO
      JOC(I,JJ)=JOC(I1,JJ)
      J=JOC(I,JJ)
```

```
      CO(I,JJ)=CO(I1,JJ)
      AO(I,JJ)=AO(I1,JJ)
15    FO(I,JJ)=PFO(IFF,J)
16    CONTINLE
17    CONTINUE
18    IF(IF2 .EQ. NFLS)GC TO 20
19    CONTINUE
      GO TC 7
20    N=I
      N2=N
      IF(N .LE. MB)GO TO 114
      IPAR=7
      GO TC 110
C
C       SHAFT CATA INPUT
C
114   REAC(5,700)NS
      IF(NS .LE. MS)GC TC 113
      IPAR=2
      GO TC 110
113   DO 1C0 IS=1,NS
      REAC(5,603)(TITSH(IS,I),I=1,5)
      WRITE(6,406)(TITSH(IS,I),I=1,5)
      READ(5,700)CS(Id),NFS1(IS),NFS2(IS),ITS(IS)
      WRITE(6,407)CS(IS),NFS1(IS),NFS2(IS),ITS(IS)
      N1=N2+1
      N2=N1+NFS2(IS)-NFS1(IS)
      NS1(IS)=N1
      NS2(IS)=N2
      IFF=NFS1(IS)-1
      REAC(5,700)NNO,FFF,JCP,CC,AA
      WRITE(6,408)NNC,FFF,JCP,CC,AA
      IF(NNO .EQ. 0)GC TO 21
      REAC(5,7C0)(JOC(N1,J),CO(N1,J),AO(N1,J),J=1,NNO)
      WRITE(6,403)(JOC(N1,J),CO(N1,J),AO(N1,3),J=1,NNO)
21    DO 24 I=N1,N2
      NC(I)=1
      NCO(I)=NNO
      IFF=IFF+1
      IFLOCR(I)=IFF
      IF(IFF .GT. NFLS)GO TO 25
      FF(I)=FFF
      IF(JCP .GT. NCOMP(IFF))GO TO 25
      JC(I,1)=JCP+SNCOMP(IFF)
      C(I,1)=CC
      AI(I,1)=AA
26    IF(NNO .EQ. 0)GO TC 24
      CO 22 J=1,NNO
      JJ=JCC(N1,J)
      FO(I,J)=PFO(IFF,JJ)
      JOC(I,J)=JJ
      CO(I,J)=CO(N1,J)
22    AO(I,J)=AO(N1,J)
      GO TC 24
25    NC(I)=0
      GO TC 26
24    CONTINUE
C
```

SUBROUTINE INPUT

```
C          EXCEPTIONS TO GENERAL SHAFT  INPUT
C          NAN = NO. OF EXCEPTIONS
C          KE = 1 FOR FF EXCEPTICN
C          KE = 2 FOR OUTSIDE CONNECTION
C          KE = 3 FOR INTERNAL CCNNJECTIGN
C
      READ(5,700)NNN
      IF(NNN .EQ. 0)GO TO 100
      OO 69 IK=1,NNN
      READ(5,700)KE,IFF
      WRITE(6,409)KE,IFF
      I=NS1(IS)+IFF-NFS1(IS)
      IF(KE .EQ. 1)GO TO 41
      IF(KE .EQ. 2)GO TO 42
      IF(KE .EQ. 3)GO TO 51
      GO TC 104
41    READ(5,700)FF(I)
      WRITE(6,410)FF(I)
      GO TC 69
42    REAC(5,700)J,CCO,AAO
      WRITE(6,405)
      WRITE(6,403)J,CCO,AAO
      NNC=NCO(I)
      IF(NNC .EQ. 0)GO TO 44
      DO 43 K=1,NNC
      IF(JCC(I,K) .EQ. J)GO TO 46
43    CONTINUE
44    NJC=NNC+1
      NCO(I)=NJO
47    PO(I,NJO)=PFO(IFF,J)
      JOC(I,NJO)=J
      CO(I,NJO)=CCO
      AO(I,NJO)=AAO
      GO TC 69
46    NJO =K
      KK=K+1
      IF(CCO .NE. 0)GO TO 47
      NJO=NNC-1
      NCO(I)=NJO
      IF(NJO .EQ. 0)GO TO 69
      DO 49 K=KK,NNC
      KM=K-1
      PO(I,KM)=PO(I,K)
      JOC(I,KM)=JOC(I,K)
      CO(I,KM)=CO(I,K)
49    AO(I,KM)=AO(I,K)
      GO TC 69
21    READ(5,700)JCP,CC,AA
      WRITE(6,402)
      WRITE(6,403)JCP,CC,AA
      J=JCP+SNCOMP(IFF)
      NN=NC(I)
      IF(NN .EQ. 0)GO TO 53
      DO 52 K=1,NN
      IF(JC(I,K) .EQ. J)GO TO 55
52    CONTINUE
      IF(CC .NE. 0.)GC TO 53
      WRITE(6,520)IS,KE,IFF
```

```
      GO TC €S
53    ᴺJ=NN+1
      NC(I)=NJ
54    JC(I,NJ)=J
      C(I,NJ)=CC
      AI( I,NJ)=AA
      GO TC 69
55    NJ=K
      KK=K+1
      IF(AA .NE. 0.)GO TO 54
      NJ=NN-1
      NC( I)=NJ
      IF(NJ .EQ. 0)GO TO 65
      CO 61 K=KK,NN
      KM=K-1
      JC(I,KM)=JC(I,K)
      C( I,KM)=C(I,K)
61    AI(I,KM)=AI( I,K)
69    CONTINUE
100   CONTINUE
      NT=N2
      IF(NT .LE. MM)GO TO 160
      IPAR=1
      GO TC 110
C
C       PRINT OUTSIDE TEMPERATURE
C
160   WRITE(6,601)(TITLE( I),I=1,12)
      IF(IUNIT .EQ. 1)WRITE(6,800)TOUT
      IF(IUNIT .EQ. 2)WRITE(6,500)TOUT
      IF(IUNIT .EQ. 2)TOUT=(TOUT-32.)/1.8
      TOUT=TOUT+273.
C
C       PRINT HEIGHT AND TEMPERATURE PROFILES
C
      IF(IUNIT .EQ. 1)WRITE(6,811)(IP,IP=1,NTP)
      IF(IUNIT .EQ. 2)WRITE(6,511)(IP,IP=1,NTP)
      WRITE(6,813)
      CO 3C IFF=1,NH
20    WRITE(6,812)H(IFF),(T(IP,IFF),IP=1,NTP)
C
C       CONVERT TEMPERATURES TO DEG K
C
      DO 33 IFF=1,NH
      CO 33 IP=1,NTP
      IF(IUNIT .EQ. 2)T(IP,IFF)=(T(IP,IFF)-32.)/1.8
33    T(IP,IFF)=T(IP,IFF)+273.
C
C       PRINT OUTSIDE PRESSURE PROFILES
C
      IF(IUNIT .EQ. 1)GO TO 79
      WRITE(6,514)(IP,IP=1,NPO)
      WRITE(6,813)
      CO 76 IFF=1,NH
      DO 77 J=1,NPO
77    PFO(IFF,J)=PFO(IFF,J)/248.8
      WRITE(6,515)H(IFF),(PFO(IFF,J),J=1,NPO)
      CO 76 J=1,NPO
```

```
70      PFC(IFF,J)=PFO(IFF,J)*248.8
76      CONT INUE
        GO TC e3
79      WRITE(6,814)(IP,IP=1,NPO)
        WRITE(6,813)
        OO 31 IFF=1,NH
        WRITE(6,815)H(IFF),(PFO(IFF,J),J=1,NPO)
21      CONTINLE
C
C         CCRRECT FOR CONNECTICNS ONLY INPUTED ONCE
C
E3      OO 6C I=1,NT
        NN=NC(I)
        IF(NN .EC. 0)GO TO 60
        CO 58 JJ=1,NN
        J=JC(I,JJ)
        IF(J .EQ. 0)GO TO 58
        NNJ=NC(J)
        IF(NNJ .EQ. 0)GO TO 57
        DO 56 IA=1,NNJ
        IF(JC(J,IA) .EQ. I)GO TO 58
56      CON7INLE
E7      NNJ=NNJ+1
        IF(NNJ .LE. MC)GO TO 59
        IPAR=3
        GO TC 110
59      NC(J)=NNJ
        JC(J,NNJ)=I
        C(J,NNJ)=C(I,JJ)
        AI(J,NNJ)=AI(I,JJ)
        IF(J .GT. N .OR. I .GT. N)GO TO 58
        PZ(J,NNJ)=-PZ(I,JJ)
58      CONT INUE
€0      CONTINLE
C
C         CCRRECT UNITS
C
        IF(IUNIT .EQ. 2)CALL UNITS
C
C         INITIALIZE PZ FOR BUILD COMPARTMENTS
C
€7      DO 4C I=1,N
        NN=NC(I)
        IF(NN .EC. 0)GO TO 40
        IA=IT(I)
        IFI=IFLOOR(I)
        CO 3E JJ=1,NN
        J=JC(I,JJ)
        IFJ=IFLOOR(J)
        IF(IFI .EQ. IFJ)GO TO 3e
        IB=IT(J)
        TEMPA=0.5*(T(IA,IFI)+T(IB,IFJ))
        PZ(I,JJ)=3462.*(H(IFJ)-H(IFI))/TEMPA
38      CONTINUE
40      CGNT INLE
C
C         INITIALIZE PZ FOR SHAFTS
C
```

```
      DO 50 IS=1,NS
      N1=NS1(IS)
      N2=NS2(IS)-1
      ITT=ITS(IS)
      DO 45 I=N1,N2
      IFI=IFLOOR(I)
      IFJ=IFI+1
      TEMPA=0.5*(T(ITT,IFI)+T(ITT,IFJ))
      PZ(I,1)=3462.*(H(IFJ)-H(IFI))/TEMPA
45    CONTINUE
50    CONTINUE
C
C        CHECK SHAFT CONNECTIONS
C
      DO 240 IS=1,NS
      N1=NS1(IS)
      N2=NS2(IS)
      DO 239 I=N1,N2
      NN=NC(I)
      IF(NN .EQ. 0)GO TO 239
      DO 236 J=1,NN
      JJ=JC(I,J)
      IF(IFLOOR(I) .NE. IFLOOR(JJ))GO TO 103
236   CONTINUE
239   CONTINUE
240   CONTINUE
      RETURN
C
C
C        DIAGNOSTIC OUTPUT
C
102   WRITE(6,902)I,IT(I)
      GO TO 109
103   WRITE(6,903)
      GO TO 109
104   WRITE(6,904)
      GO TO 109
105   WRITE(6,905)
      GO TO 109
106   WRITE(6,906)
      GO TO 109
107   WRITE(6,907)
      GO TO 109
110   WRITE(6,910)PAR(IPAR)
C
C        PRINT CORRECTED BUILDING DATA
C
109   WRITE(6,940)
      DO 70 I=1,N
      NN=NC(I)
      IF(NN .GT. 0)GO TO 180
      WRITE(6,941)I,IFLOOR(I),IT(I),FF(I)
      GO TO 182
180   WRITE(6,942)I,IFLOOR(I),IT(I),FF(I),JC(I,1),C(I,1),AI(I,1)
      IF(NN .EQ. 1)GO TO 182
      WRITE(6,943)(JC(I,J),C(I,J),AI(I,J),J=2,NN)
182   NNC=NCC(I)
      IF(NNC .EQ. 0)GO TO 70
```

SUBROUTINE INPUT

```
      WRITE(6,944)(JOC(I,J),CO(I,J),AO(I,J),J=1,NNO)
70    CONTINUE
C
C       PRINT CORRECTED SHAFT INPUT OATA
C
      CO 80 IS=1,NS
      WRITE(6,816)(TITSH(IS,I),I=1,5)
      CRITE(6,806)IS,CS(IS),ITS(IS)
      N1=NS1(IS)
      N2=NS2(IS)
      WRITE(6,807)
      CO 75 I=N1,N2
      NN=NC( I)
      IF(NN .GT. 0)GO TO 72
      WRITE(6,801)IFLCOR(I),FF(I)
      GO TC 74
72    WRITE(6,808)IFLOOR(I),FF(I),JC(Is1),C( 1),AI(I,1)
      IF(NN .EQ. 1)GO TO 74
      WRITE(6,809)(JC(I,J),C( J),A ( 3),J=2,NN)
74    NNC=NCO(I)
      IF(NNO .EQ. 0)GO TO 75
      WRITE(6,810)(JOC( J),CO(I,J),AO(I,J),J=1,NNO)
75    CONTINUE
€0    CONTINLE
      STOP
C
C       FORMAT STATEMENTS
C
400   FORMAT(5X,5HIF1 =,I3,7H, IF2 =,I3,7H, NOC =,I3)
401   FORMAT(5X,4HNZ =,I3,6H NA = ,I3,7H, NNO = ,I3,6H, FF =,F8.1,
     + 7kr  IT =,I3)
402   FORMAT(5X,25HCONNECTION ON SAME FLOOR   )
403   FORMAT(5X,3HJ =,I3,5H, C =,F10.3,5H, A =,F9.4)
404   FORMAT(5X,26HCONNECTION TO FLOOR ABOVE   )
405   FORMCT(5X,22HCONNECTION TO OUTSIOE   )
406   FORMAT(5X,5A4)
407   FORMAT(5X,4HCS =,F9.1,8H, NFSI =,I3,8H, NFS2 =,I3,7H, ITS =,I3)
408   FORMAT(5X,5HNNO =,I3,7H, FFF =,F8.1,5H, 3 =,I3,5H, C =, F10.3,
     + 5H, A = ,F9.4)
409   FORMAT(5X,4HKE =,I3, 7H, IFF =,I3)
410   FORMAT(5X,4HFF =,F8.1)
411   FORMLT(5X,6HTOUT =,F6.0,9H, IUNIT =,I3,8H, IOUT =,I3)
412   FORMAT(5X,4HNH =,I3,6H, NN =,I3)
413   FORMAT(5X,7HHEIGHTS /(10F8.2))
414   FORMIT(5X,6HH(1) =,F8.2,6H, OH =,F8.2)
415   FORMAT(6X,5HNTP =,I3)
416   FORMAT(5X,20HTEMPERATURE PROFILE /I5,(10(I4,F7.1)))
417   FORMAT(5X,5HNPO =,I3,6H, NN =,I3)
410   FORMAT(5X,5HPGZ =,F12.1/17HPRESSURE PROFILE /(10F12.1))
419   FORMAT(5X,4HVW =,F6.1,6H, HW =,F6.1,6H, XW =,F4.2,6H, CW =,
     + (10F4.2))
420   FORMAT(/5X,6HNFLS =,I3)
Z00   FORMAT(//10X,20HOUTSIDE TEMPERATURE   ,F6.1,2H F)
511   FORMAT(  ///5X,6HHEIGHT,5X,29HTEMPERATURE PROFILES (DEG F)   /
     + 7X,2HFT,3X,19I6)
514   FORMAT(////5X,6HHEIGHT ,5X,26HOUTSIDE PRESSURE PROFILES
     1 11H (IN H2O)    /7X,2HFT.3X,8I10)
515   FORMAT(F11.2,3X,8F1003)
```

SUBROUTINE INPUT

```
t20    FORMAT(///5X,15HERROR IN SHAFT  ,I2,15HEXCEPTION KE =  ,I2,
      + 2X,SHFLOOR ,I3//)
€00    FORMAT(18A4)
€01    FORMAT(1H1///10X,18A4///)
e03    FORMAT(5A4)
700    FORMAT( )
€00    FORMAT(//10X,20HOUTSIDE TEMPERATURE   ,F6.1,2H C)
801    FORMAT(I13,F11.1)
€06    FORMAT(   10X,12HSHAFT NUMBER ,I4/10X,17HSHAFT COEFFICIENT ,F10.1/
      1 10X,20HTEMPERATURE PROFILE  ,14)
807    FORMAT(/21X,5HFIXED,25X,4HFLOW,12X,4HFLOW/10X,5HFLOOR,6X,
      1 4HFLOW,5X,12HCONNECTED TO  ,6X,11HCOEFFICIENT ,6X,8H  AREA
      2  /)
808    FORMAT(I13,F11.1,6X,5HPOINT,I5,F16.1,F15.4)
8C9    FORMAT(30X,5HPOINT,I5,F16.1,F15.4)
E10    FORMPT(30X,7HOUTSIDE ,I3,F16.1,F15.4)
811    FORMAT(   ///5X,6HHEIGHT,5X,29HTEMPERATURE PROFILES (DEG C)    /
      + 7X,2HM ,3X,19I6)
E12    FORMAT(F11.2,3X,19F6.1)
€13    FORMAT(/)
e14    FORMAT(////5X,6HHEIGHT ,5X,26HOUTSIDE PRESSURE PROFILES
      1 11H (PASCALS)   /7X,2HM ,3X,8I10)
E15    FORMAT(F11.2,3X,8F10.1)
816    FORMAT(///10X,SA4)
e17    FORMAT(10X,45HFLOW COEFFICIENTS CORRECTED FOR TEMPREATURE    )
S02    FORMAT(10(/),10X,11HCOMPARTMENT  ,I4/
      1 10X,20HTEMPERATURE PROFILE  ,I4,17H  DOES NOT EXIST  /
      + 10X,16HPROGRAM STOPPED  ,10(/))
S03    FORMAT(10(/),5X,23HSHAFT CONNECTION ERROR    ,
      1 /10X,16HPROGRAM STOPPED  ,10(/))
S04    FORMAT(10(/),10X,40HINPUT ERROR IN EXCEPTIONS TO SHAFT DATA
      1 /10X,16HPROGRAM STOPPED  ,10(/))
405    FORMAT(10(/),10X,37HINPUT ERROR IN UNIT TYPE DESIGNATION     /
      1  10X,16HPROGRAM STOPPED   ,10(/))
CC6    FORMIT(10(/),10X,37HINPUT ERROR NO. OF FLOORS EXCEEDS NH    /
      1 10X,16HPROGRAM STCPPED  ,10(/))
S07     FORMAT(10(/),10X,25HINPUT ERROR IF1 .GT. IF2    /
      1 10X,16HPROGRAM STOPPED  ,10(/))
S10    FORMAT(10(/),10X,36HINPUT EXCEEDS DIMENSION PARAMETER  ,A3/
      + 10X,16HPROGRAM STOPPEO  ,10(/))
S30    FORMAT(10X,3A6)
C35    FORMAT(// 10X,26HFLOW COEFFICIENTS AS READ  )
S40    FORMAT(10X,15HBUILOING  DATA  //34X,11HTEMPERATURE  ,4X,5HFIXED,
      1 12X,2(11X,4HFLOW)/10X,11HCOMPARTMENT ,4X,5HFLOOR,6X,7HPROFILE,
      2 6X,4HFLOW,5X,13HCONNECTION TO ,4X,11HCOEFFICIENT ,4X,
      3 8H  AREA   )
S41    FORMAT(/4X,3I12,F14.1)
S42    FORMIT(/4X,3I12,F14.1,4X,5HPOINT,I7,F1102,F15.4)
C43    FORMAT(58X,5HPOINT,I7,F11.2,F15.4)
S44    FORMAT(58X,9HOUTSIDE   ,I3,F11.2,F1504)
       ENC
```

@HDG,P   SUEROUTINE CORR.L,1

SUBROUTINE CORR

```
@NBS*PLIBS.SHOW  A CORR
      SUBROUTINE CORR
C
C        THIS ROUTINE CALCULATES ADJUSTED FLOW COEFFICIENTS
C                        (C1,C2,CO1,CO2)
C
      PARAMETER  (MM=140,MS=8,MC=9,MPO=2,MTP=2,MFL=25,MB=50)
      COMMON /CORR/C1(MM,MC),C2(MM,MC),CO1(MM,MPO),CO2(MM,MPO)
      COMMON NT,    P(MM),C(MM,MC),NC(MM),JC(MM,MC),ITS(MS),
     1 FC(MM,MC),PZ(MM,MC),PO(MM,MPO),CO(MM,MPO),F(MM),PFO(MFL,MPO),
     2 FF(MM),FO(MM,MPO),CS(MS),PS(MFL),NS1(MS),NS2(MS),
     3 FSS(MS),N,NS,NPO,ICONV,E,IBUG,AI(MM,MC),AO(MM,MPO),TITSH(MS,5),
     4 NH,H(MFL),IFLOOR(MM),T(MTP,MFL),NFS1(MS),NFS2(MS),IT(MB),NTP
     5 ,NCC(MM),JOC(MM,MFC),TOUT
      DOUBLE PRECISION P,PO,PS
      DO 12 I=1,NT
C
C        CORRECT C
C
      PATMOS=101325.
      BB=1000.*SQRT(2.*PATMOS/287.)/1.2
      NN=NC(I)
      IF(I .GT. N)GO TO 1
      IP=IT(I)
      GO TO 4
1     DO 2 IS=1,NS
      IF(I .LE. NS2(IS) .AND. I .GE. NS1(IS))GO TO 3
2     CONTINUE
      WRITE(6,700)
      STOP
3     IP=ITS(IS)
4     IFF=IFLOOR(I)
      T1=T(IP,IFF)
      IF(NN .EQ. 0)GO TO 10
      DO 9 J=1,NN
      JJ=JC(I,J)
      C1(I,J)=BB*C(I,J)*AI(I,J)/SQRT(T1)
      IF(JJ .GT. N)GO TO 5
      IP=IT(JJ)
      GO TO 8
5     DO 6 IS=1,NS
      IF(JJ .LE. NS2(IS) .AND. JJ .GE. NS1(IS))GO TO 7
6     CONTINUE
      WRITE(6,700)
      STOP
7     IP=ITS(IS)
8     IFF=IFLOOR(JJ)
      T2=T(IP,IFF)
      C2(I,J)=BB*C(I,J)*AI(I,J)/SQRT(T2)
9     CONTINUE
C
C        CORRECT CO
C
10    NNC=NCO(I)
      IF(NNC .EQ. 0)GO TO 12
      DO 11 J=1,NNC
      CO1(I,J)=BB*CO(I,J)*AO(I,J)/SQRT(T1)
```

```
      CO2( 1, J)=BB*CO(I, J)*AC (I,J)/SQRT(TOUT)
11    CON1INLE
12    CONT INUE
      RETURN
700   FORMAT(///10X,36HPROGRAM STOPPED IN SUBROUTINE COR8    //)
      END
```

```
@FDG,P                        SUBROUTINE INIT.L,1
```

SUERCUTINE INIT

```
ENBS*PLIE$.SHCW  A.INIT
      SUEFCUTINE  INIT
C
C
C      THIS ROUTINE INITIALIZES THE PRESSURE ARRAY
C
      PARANETER  (MM=140,MS=8,MC=9,MFO=2,MTP=2,MFL=25,MB=50)
      PARANETER  (MBP=MB+1)
      COMMCN /CORR/C1(MM,MC),C2(MM,MC),CO1(MM,MPO),CO2(MM,MPO)
      COMMCN NT,    P(MM),C(MM,MC),NC(MM),JC(MM,MC),ITS(MS),
     1 FC(MM,MC),PZ(MM,MC),PC(MM,MPC),CO(MM,MPO),F(MM),PFO(MFL,MPO),
     2 FF(MM),FO(MM,MPO),CS(MS),PS(MFL),NS1(MS),NS2(MS),
     3 FSS(MS),N,NS,NPO,ICONV,E,IBUG,AI(MM,MC),AO(MM,MPO),TITSH(MS,5),
     4 NH,H(MFL),IFLOOR(MM),T(MTP,MFL),NFS1(MS),NFS2(MS),IT(MB),NTP
     5 ,NCC(MM),JOC(MM,MFC),TOUT
      COUBLE PRECISICN F,FO,FS
      CIMENSION SC(MS),SCO(MS)
      COMMCN /MAT/A(MB,MBP),XX(MB),NNN
      COUBLE PRECISION A,XX
      NNN=N
C
C        CALCULATE AVERAGE OUTSIDE PRESSURE
C
      SUM=C.
      CO 1C J=1,NPO
      CO 1C I=1,NH
10    SUM=SUM+PFO(I,J)
      PA=SUM/(NPO*NH)
C
C
C
C        THE CO LOOP TO STATEMENT 30 ESTIMATES
C          SHAFT PRESSURES
C
      DO 30 IS=1,NS
C
C        CALCULATE SHAFT PRESSURE CIFFERENCE , DP
C
      SUM=C.
      SUMN=0.
      N1=NS1(IS)
      N2=NS2(IS)
      CO 18 I=N1,N2
      SUM=SUM+FF(I)
      NN=NC(I)
      IF(NN .EC. 0.)GO TO 16
      DO 15 J=1,NN
      SUMN=SUMN+C1(I,J)
15    CONTINLE
      SC(IS)=SUMN
16    NNC=NCC(I)
      IF(NNO .EQ. 0)GO TO 18
      DO 17 J=1,NNO
      SUMN=SUMN+CO1(I,J)
17    CONTINLE
      SCO(IS)=SUMN-SC(IS)
18    CONTINLE
```

```
      DP2=SUM/SUMN
      SIGN=1.
      IF(DP2 .LT. 0.)SIGN=-1.
      DP=SIGN*(SIGN*DP2)**2
C
C       CALCULATE AVERAGE TEMP OF SHAFT
C
      SUM=0.
      IP=ITS(IS)
      DO 20 I=N1,N2
      IFF=IFLOOR(I)
20    SUM=SUM+T(IP,IFF)
      TA=SUM/(N2-N1+1)
C
C       ESTIMATE PRESSURE AT BOTTOM OF SHAFT , PBOT
C
      HH=0.5*(H(NH)-H(1))+H(1)
      NF1=NFS1(IS)
      PBOT=PA+DP+3462.*(HH-H(NF1))/TA
C
C       ESTIMATE OTHER SHAFT PRESSURES
C
      P(N1)=PBOT
      NM=N2-1
      DO 24 I=N1,NM
      IP1=I+1
24    P(IP1)=P(I)-PZ(I,1)
20    CONTINUE
C
C       END OF SHAFT PRESSURE ESTIMATES
C
C       SET UP MATRIX FOR BUILDING COMPARTMENTS
C
      NP1=N+1
      DO 50 I=1,N
      NN=NC(I)
      SUMII=0.
      SUMNP=0.
      IF(NN .EQ. 0.)GO TO 42
      DO 40 JJ=1,NN
      J=JC(I,JJ)
      IF(J .GT. N)GO TO 34
      A(I,J)=C1(I,JJ)
      SUMII=SUMII-C1(I,JJ)
      SUMNP=SUMNP-C1(I,JJ)*PZ(I,JJ)
      GO TO 40
34    SUMII=SUMII-C1(I,JJ)
      SUMNP=SUMNP-C1(I,JJ)*P(J)
40    CONTINUE
42    NNO=NCO(I)
      IF(NNO .EQ. 0)GO TO 46
      DO 45 K=1,NNO
      SUMII=SUMII-CO1(I,K)
45    SUMNP=SUMNP-CO1(I,K)*PO(I,K)
46    A(I,I)=SUMII
      A(I,NP1)=SUMNP-FF(I)
50    CONTINUE
C
```

SUBROUTINE INIT

```
C         WRITE MATRIX
C
          IF(IEUG .EQ. 0)GO TO 84
          WRITE(6,802)
          DO 82 I=1,N
e2        WRITE(6,803)(A(I,J),J=1,NP1)
<
C
C         CALL ROUTINE TO SOLVE FOR INITIAL BUILDING PRESSURES
C
e4        CALL SIMEQ
C
C         OUTPUT INITIAL PRESSURES
C
          IF(IEUG .EQ. 0)GO TO 89
          WRITE(6,800)
          WRITE(6,801)(I,XX(I),I=1,N)
          NN=NS1(1)
          WRITE(6,801)(I,P(I),I=NN,NT)
C
C
C         ASSIGN BUILDING PRESSURES
C
€9        DO 90 I=1,N
90        P(I)=XX(I)
          RETURN
800       FORMAT(///8(6X,1HI,4X,3HP   )/)
€01       FORMAT(8(I7,F7.1))
€02       FORMAT(///10X,20HMATRIX COEFFICIENTS    /)
803       FORMAT(10X,11F11.1)
          END
```

@HDG,P SUBROUTINE BLDGP.L,1

SUBROUTINE BLDGP

```
&NBS*PLIES.SHOW  A.BLDGP
      SUBROUTINE  BLDGP
C
C
C       THIE ROUTINE CALCULATES STEAOY STATE PRESSURES
C            FOR BUILDING COMPARTMENTS
C
C
C
      PARAMETER  (MM=140,MS=8,MC=9,MPO=2,MTP=2,MFL=25,MB=50)
      COMMON NT,    P(MM),C(MM,MC),NC(MM),JC(MM,MC),ITS(MS),
     1 FC(MM,MC),PZ(MM,MC),PO(MM,MPO),CO(MM,MPO),F(MM),PFO(MFL,MPO),
     2 FF(MM),FO(MM,MPO),CS(MS),PS(MFL),NS1(MS),NS2(MS),
     3 FSS(MS),N,NS,NPO,ICONV,E,IBUG,AI(MM,MC),AO(MM,MPO),TITSH(MS,5),
     4 NH,H(MFL),IFLOOR(MM),T(MTP,MFL),NFS1(MS),NFS2(MS),IT(MB),NTP
     5 ,NCC(MM),JOC(MM,MFC),TOUT
      DOUBLE PRECISION P,FO,PS,PI
      IF(IEUG .GT. 0)WRITE(6,806)
      ITM=100
      ICONV=0
      DO 15 I=1,N
C
C     CALCLLATE NET FLOW ,FI, INTO POINT I
      FI=PFLOW(I,P(I))
C
C     CHECK YAGNITUDE OF FI
      IF(AES(FI) .LT. E)GO TO 15
      ICCNV=ICONV+1
C
C     SET UP PARAMETERS FOR ITERATION
      DP=1.0
      IPHASE=1
      DPI=C.
      EE=0.2*ABS(FI)
      IF(EE .LT. E)EE=E
      SIGN=1
      IF(FI .LT. 0.)SIGN=-1
      IK=0
      IF(IEUG .GT. 0)WRITE(6,802)
C
C     ITERATION TO RECUICE MAGNITUDE OF FN
2     IK=IK+1
C
C     NEW ESTIMATE OF PRESSURE ,PI, AT POINT I
      PI=P(I)+SIGN*DP
C
C     CALCLLATE NET FLOW ,FN, INTO POINT I USING PI
      FN=PFLOW(I,PI)
      IF(IEUG.GT.0)WRITE(6,804) I,IK,FI,FN,FP,DPI,DP,DPP,PI,IPHASE
C
C     CHECK YAGNITUDE OF FN
      IF(AES(FN) .LT. EE)GO TO 10
C
C     CHECK NUMBER OF ITERATIONS
      IF(IK .GT. ITM)GO TO 25
C
C     CHECK PHASE
```

```
      IF(IFHASE .EQ. 2)GO TO 6
C
C     CHECK FOR TRANSITION FROM PHASE 1 TO PHASE 2
      IF(FI*FN .LT. 0.)GO TO 4
C
C     PHASE 1
      DPI=DP
      DP=5.0*DP
      FI=FN
      GO TC 2
C
C     PHASE 2
4     IPHASE=2
      GO TC 9
6     IF(FI*FN .GT. 0.)GO TO 8
C
C     NEW DP BETWEEN DPI AND DP
9     DPP=DP
      FP=FN
      DP=DP I+(CPP-OPI)*FI/(FI-FN)
      GO TC 2
C
C     NEW DP BETWEEN CP AND CFF
8     FI=FN
      DPI=DP
      DP=DPI+(DPP-DP I)*FN/(FN-FP)
      GO TC 2
10    P(I)=PI
15    CONTINUE
C
      RETURN
25    WRITE(6,800)
      STOP
C
C      FORMAT STATEMENTS
C
800   FORMAT(///10X,20(1H*)///10X,22HEXCESSIVE ITERATIONS    /
     + 10X,8HIN BLDGP ///10X,20(1H*)//////)
802   FORMAT(//11X,1HI,2X,2H1T,12X,2HFI,13X,2HFN,13X,2HFP,12X,3HDPIs
     +13X,2HCP,12X,3HDPP,13X,2HPI,3X,5HPHASE /)
804   FORMAT(8X,2I4,3E15.4,4F15.6,I5)
806   FORMAT(    ///10X,6HBLDGP   )
      END
```

SUBROUTINE **SHAFTP**

```
@NBS*PLIES.SHOW   A.SHAFTP
      SUBRCUTINE  SHAFTP
C
C
C       THIS RCUTINE CALCULATES STEADY STATE PRESSURES
C            FCR SHAFTS
C
C
      PARAMETER  (MM=140,MS=8,MC=9,MPO=2,MTP=2,MFL=25,MB=50)
      COMMCN NT,    P(MM),C(MM,MC),NC(MM),JC(MM,MC),ITS(MS),
     1 FC(MM,MC),PZ(MM,MC),PO(MM,MPO),CO(MM,MPO),F(MM),PFO(MFL,MPO),
     2 FF(MM),FO(MM,MPO),CS(MS),PS(MFL),NS1(MS),NS2(MS),
     3 FSS(MS),N,NS,NPO,ICONV,E,IBUG,AI(MM,MC),AO(MM,MPO),TITSH(MS,5),
     4 NH,H(MFL),IFLCCR(MM),T(MTP,MFL),NFS1(MS),NFS2(MS),IT(MB),NTP
     5 ,NCC(MM),JOC(MM,MPO),TOUT
      DOUBLE PRECISION P,PO,PS,PI
      IF(IBUG .GT. 0)WRITE(6,806)
      ITM=100
      ICONV=0
      DO 15 I=1,NS
C
C     CALCLLATE NET FLOW ,FI, INTC PCINT I
      N1=NS1(I)
      FI=SFLCW(I,P(N1))
C
C     CHECK MAGNITUDE OF FI
      IF(ABS(FI) .LT. E)GO TO 15
      ICONV=ICCNV+1
C
C     SET UP PARAMETERS FOR ITERATICN
      DP=1.0
      IPHASE=1
      DPI=C.
      EE=0.2*ABS(FI)
      IF(EE .LT. E)EE=E
      SIGN=1
      IF(FI .LT. 00)SIGN=-1
      IK=0
      IF(IBUG .GT. 0)WRITE(6,802)
C
C     ITERATICN TO RECUICE MAGNITUDE OF FN
2     IK=IK+1
C
C     NEW ESTIMATE OF PRESSURE ,PI, AT BOTTOM OF SHAFT I
      PI=P(N1)+SIGN*DP
C
C       CALCULATE NET FLOW ,FN, INTO SHAFT I USING PI
      FN=SFLOW(I,PI)
      IF(IBUG.GT.0)WRITE(6,804)I,IK,FI,FN,FP,DPI,DP,DPP,PI,IPHASE
C
C     CHECK YAGNITUDE OF FN
      IF(ABS(FN) .LT. EE)GO TO 10
C
C     CHECK NUMBER OF ITERATIONS
      IF(IK .GT. ITM)GO TO 25
C
C     CHECK FHASE
```

SUBROUTINE SHAFTP

```
      IF(IPHASE .EQ. 2)GO TO 6
C
C     CHECK FOR TRANSITICN FROM PHASE 1 TO PHASE 2
      IF(FI*FN .LT. 0.)GO TO 4
C
C     PHASE 1
      DPI=DP
      DP=5.0*DP
      FI=FN
      GO TC 2
C
C     PHASE 2
4     IPHASE=2
      GO TC 5
e     IF(FI*FN .GT. 0.)GO TO 8
C
C     NEW OP BETWEEN CPI AND OP
5     DPP=DP
      FP=FN
      DP=DFI+(DPP-DPI)*FI/(FI-FN)
      CO TC 2
C
C     NEW DP BETWEEN DP AND DPP
E     FI=FN
      DPI=DP
      DP=DFI+(OPP-DPI)*FN/(FN-FP)
      GO TC 2
10    N2=NS2(I)
      CO 11 IF=N1,N2
      II=IF+1-N1
11    F(IF)=PS(II)
15    CONTINUE
C
      RETURN
25    WRITE(6,800)
      STOP
C
C      FORYAT STATEMENTS
C
800   FORMAT(///10X,20(1H*)///10X,22HEXCESSIVE ITERATIONS   /
     + 10X,9HIN SHAFTP  ///10X,20(1H*)//////)
E02   FORMAT(//11X,1HI,2X,2HIT,12X,2HFI,13X,2HFN,13X,2HFP,12X,3HDPI,
     +13X,2HDP,12X,3HDPP,13X,2HPI,3X,5HPHASE /)
€04   FORMAT(8X,2I4,3E15.4,4F15.6,I5)
€06   FORMAT(    ///10X,6HSHAFTP)
      END
```

EHDG,P SUBROUTINE PZAO .L,1

SUBROUTINE PZAO

```
@NBS*PLIES.SHOW  A.PZAO
      SUBROUTINE  PZAD
C
C        THIS ROUTINE CORRECTS PZ TERMS FOR PRESSURE
C
      PARAMETER  (MM=140,MS=8,MC=9,MPO=2,MTP=2,MFL=25,MB=50)
      COMMON NT,    P(MM),C(MM,MC),NC(MM),JC(MM,MC), ITS(MS),
     1 FC(MM,MC),PZ(MM,MC),PO(MM,MPO),CO(MM,MPO),F(MM),PFO(MFL,MPO),
     2 FF(MM),FO(MM,MPO),CS(MS),PS(MFL),NS1(MS),NS2(MS),
     3 FSS(MS),N,NS,NPO,ICONV,E,IBUG,AI(MM,MC),AO(MM,MPO),TITSH(MS,5),
     4 NH,H(MFL),IFLOOR(MM),T(MTP,MFL),NFS1(MS),NFS2(MS),IT(MB),NTP
     5 ,NCC(MM),JOC(MM,MPO),TOUT
      COMMON /PZZ/ PGZ
      DOUBLE PRECISION P,PO,PS
      IF(IBUG .GT. -2)GO TO 1
      WRITE(6,800)
      DO 2 I=1,N
      NN=NC(I)
      IF(NN .EQ. 0)GO TO 2
      WRITE(6,801)(I,J,PZ(I,J),J=1,NN)
2     CONTINUE
      NP1=N+1
      WRITE(6,802)(IL,PZ(IL,1),IL=NP1,NT)
1     DO 10 I=1,N
      NN=NC(I)
      IF(NN .EQ. 0)GO TO 10
      IA=IT(I)
      IFI=IFLOOR(I)
      DO 8 JJ=1,NN
      J=JC(I,JJ)
      IFJ= IFLOOR(J)
      IF(IFI .EQ. IFJ)GO TO 8
      IB=IT(J)
      TEMPA=0.5*(T(IA,IFI)+T(IB,IFJ))
      PAVE=0.5*(P(I)+P(J))+PGZ
      PZ(I,JJ)=(0.03416*PAVE/TEMPA)*(H(IFJ)-H(IFI))
8     CONTINUE
10    CONTINUE
      DO 20 IS=1,NS
      N1=NS1(IS)
      N2=NS2(IS)-1
      ITT=ITS(IS)
      DO 15 I=N1,N2
      IFI=IFLOOR(I)
      IFJ= IFI+1
      TEMPA=0.5*(T(ITT,IFI)+T(ITT,IFJ))
      J= I+1
      PA=0.5*(P(I)+P(J))+PGZ
15    PZ(I,1)=(0.03416*PA/TEMPA)*(H(IFJ)-H(IFI))
20    CONTINUE
      RETURN
800   FORMAT(/10X,10HINITIAL PZ /)
801   FORMAT(10X,3HPZ(,I2,1H,I2,4H) =  ,F12.4)
802   FORMAT(10X,3HPZ(,I2,6H,1) '  ,F12.4)
803   FORMAT(/10X,11HADJUSTED PZ  /)
      END
```

SUBROUTINE OUT

```
@NES*PLIES.SHOW  A.OUT
      SUBROUTINE OUT
C
C
C        THIS ROUTINE OUTPUTS FLOWS AND DIFFERENTIAL PRESSURES
C        FOR ALL SHAFTS AND BUILDING  COMPARTMENTS
C
C
      PARAMETER  (MM=140,MS=8,MC=9,MPO=2,MTP=2,MFL=25,MB=50)
      COMMON /CORR/C1(MM,MC),C2(MM,MC),CO1(MM,MPO),CO2(MM,MPO)
      COMMON  /IO/TITLE(18),IOUT,IUNIT,NCOMP(MFL),SNCOMP(MFL)
      COMMON NT,    P(MM),C(MM,MC),NC(MM),JC(MM,MC),ITS(MS),
     1 FC(MM,MC),PZ(MM,MC),PO(MM,MPO),CO(MM,MPO),F(MM),PFO(MFL,MPO),
     2 FF(MM),FO(MM,MPO),CS(MS),FS(MFL),NS1(MS),NS2(MS),
     3 FSS(MS),N,NS,NPO,ICONV,E,IBUG,AI(MM,MC),AO(MM,MPO),TITSH(MS,5),
     4 NF,H(MFL),IFLOOR(MM),T(MTP,MFL),NFS1(MS),NFS2(MS),IT(MB),NTP
     5 ,NCC(MM),JOC(MM,MPO),TOUT
      DOUBLE PRECISION P,FO,PS
      INTEGER  COM
C
C        IUNIT = 1 FOR S I UNITS
C        IUNIT = 2 FOR ENG UNITS
C        WHEN IUNIT = 2 GO TO 100
      IF(IUNIT .EQ. 2)GO TO 100
C
C        BUILDING COMPARTMENT OUTPUT
C
1     I=0
      IL=0
      WRITE(6,800)(TITLE(I),I=1,18)
      DO 30 IFF=1,NH
      NNN=NCOMP(IFF)
      IF(NNN .EQ. 0)GO TO 30
      DO 29 IC=1,NNN
      I=I+1
      NN=NC(I)
      NNO=NCO(I)
      IL=IL+NN+NNO+2
      IF(IL .LT. 51)GO TO 2
      WRITE(6,800)(TITLE(I),I=1,18)
      IL=NN+NNO+2
2     IF(NN .GT. 0)GO TO 3
      WRITE(6,801)IFF,IC,P(I),IT(I),FF(I)
      GO TO 21
3     DO 20 J=1,NN
      JJ=JC(I,J)
      DP=P(JJ)-P(I)+PZ(I,J)
      CC=C2(I,J)
      IF(DP .LT. 0.)CC=C1(I,J)
      IF(JJ .LE. N)GO TO 10
      DO 5 IS=1,NS
      IF(JJ .GE. NS1(IS) .AND. JJ .LE. NS2(IS))GO TO 6
5     CONTINUE
6     IF(J .GT. 1)GO TO 7
      WRITE(6,802)IFF,IC,P(I),IT(I),FF(I),(TITSH(IS,K),K=1,5)
     + ,DP,CC,AI(I,1),FC(I,1)
      GO TO 20
```

SUBROUTINE OUT

```
7       WRITE(6,803)(TITSH(IS,K),K=1,5),DP,CC,AI(I,J),FC(I,J)
        GO TO 20
10      IFJ=IFLOOR(JJ)
        COM=JJ-SNCOMP(IFJ)
        IF(J .GT. 1)GO TO 12
        WRITE(6,804)IFF,IC,P(I),IT(I),FF(I),IFJ,COM,DP,CC,AI(I,1),FC(I,1)
        GO TO 20
12      WRITE(6,805)IFJ,COM,DP,CC,AI(I,J),FC(I,J)
20      CONTINUE
21      IF(NNO .EQ. 0)GO TO 29
        DO 23 J=1,NNO
        JJ=JCC(I,J)
        DP=PC(I,J)-P(I)
        CC=CC2(I,J)
        IF(DP .LT. 0.)CC=CO1(I,J)
23      WRITE(6,806)JJ,DP,CC,AO(I,J),FO(I,J)
29      WRITE(6,807)F(I)
30      CONTINUE
        WRITE(6,900)
C
C         SHAFT OUTPUT
C
        DO 60 IS=1,NS
        N1=NS1(IS)
        N2=NS2(IS)
22      WRITE(6,814)(TITLE(I),I=1,18)
        WRITE(6,808)(TITSH(IS,K),K=1,5),ITS(IS),CS(IS)
        DO 50 I=N1,N2
        NN=NC(I)
        IF(NN .GT. 0)GO TO 35
        WRITE(6,809)IFLOOR(I),P(I),FF(I)
        GO TO 41
35      DO 40 J=1,NN
        JJ=JC(I,J)
        DP=P(JJ)-P(I)
        CC=C2(I,J)
        IF(DP .LT. 0.)CC=C1(I,J)
        IFJ=IFLOOR(JJ)
        COM=JJ-SNCOMP(IFJ)
        IF(J .GT. 1)GO TO 36
        WRITE(6,810)IFLOOR(I),P(I),FF(I),IFJ,COM,DP,CC,AI(I,1),FC(I,1)
        GO TO 40
36      WRITE(6,811)IFJ,COM,DP,CC,AI(I,J),FC(I,J)
40      CONTINUE
41      NNO=NCC(I)
        IF(NNO .EQ. 0)GO TO 50
        DO 46 J=1,NNO
        JJ=JCC(I,J)
        DP=PC(I,J)-P(I)
        CC=CC2(I,J)
        IF(DP .LT. 0.)CC=CO1(I,J)
46      WRITE(6,812)JJ,DP,CC,AO(I,J),FO(I,J)
50      CONTINUE
        WRITE(6,813)FSS(IS)
        WRITE(6,900)
60      CONTINUE
        GO TO 165
C
```

```
                        SUEROUTINE OUT
C         EUILCING CATA OUTPLT  FOR IUNIT = 2
C
100     I=0
        IL=0
        WRITE(6,800)(TITLE(I),I=1,18)
        CO 120 IFF=1,NH
        NNN=NCOMP(IFF)
        IF(NNN .EQ. 0)GO TO 130
        CO 129 IC=1,NNN
        I=I+1
        FFI=F(I)/0.4719
        PIII=P(I)/248.8
        FFF=FF(I)/0.4719
        NN=NC(I)
        NNO=NCO(I)
        IL=IL+NN+NNO+2
        IF(IL .LT. 51)GO TO 102
        WRITE(6,800)(TITLE(I),I=1,18)
        IL=NN+NNO+2
102     IF(NN .GT. 0)GO TO 103
        WRITE(6,601)IFF.IC,PIII,IT(I),FFF
        GC TC 121
103     CO 120 J=1,NN
        FCCC=FC(I,J)/0.4719
        JJ=JC(I,J)
        DP=(F(JJ)-P(I)+PZ(I,J))/248.8
        AAI=AK(I,J)/0.0929
        CC=C2(I,J)
        IF(DF .LT. 0.)CC=C1(I,J)
        CC=CC*33.43
        IF(JJ .LE. N)GO TO 110
        CO 105 IS=1,NS
        IF(JJ .GE. NS1(IS) .AND. JJ .LE. NS2(IS))GO TO 106
105     CONTINUE
106     IF(J .GT. 1)GO TO 107
        WRITE(6,602)IFF,IC,PIII,IT(I),FFF  ,(TITSH(IS,K),K=1,5)
       + ,CP,CC,AAI,FCCC
        GO TC 120
1C7     WRITE(6,603)(TITSH(IS,K),K=1,5),DP,CC,AAI,FCCC
        GO TC 120
110     IFJ=IFLOOR(JJ)
        COM=JJ-SNCOMP(IFJ)
        IF(J .GT. 1)GO TO 112
        WRITE(6,604)IFF,IC,PIII,IT(I),FFF  ,IFJ,COM,DP,CC,AAI,FCCC
        CO TC 120
112     WRITE(6,605)IFJ,COM,DP,CC,AAI,FCCC
120     CONTINUE
121     IF(NNO .EQ. 0)GO TO 129
        CO 123 J=1,NNO
        FOC=FO(I,J)/0.4719
        JJ=JCC(I,J)
        DP=(FO(I,J)-P(I))/248.8
        AAO=AC(I,J)/0.0929
        CC=CC2(I,J)
        IF(DF .LT. 0.)CC=CO1(I,J)
        CC=CC*33.43
123     WRITE(6,606)JJ,CP,CC,AAC,FOO
129     WRITE(6,807)FFI
```

SUBROUTINE OUT

```
130     CONTINUE
        WRITE(6,901)
C
C         SHAFT OUTPUT FOR IUNIT = 2
C
        DO 160 IS=1,NS
        CSS=CS(IS)/0.02992
        FFI=FSS(IS)/0.4719
        N1=NS1(IS)
        N2=NS2(IS)
132     WRITE(6,814)(TITLE(I),I=1,18)
        WRITE(6,808)(TITSH(IS,K),K=1,5),ITS(IS),CSS
        DO 150 I=N1,N2
        FFF=FF(I)/0.4719
        PIII=P(I)/248.8
        NN=NC(I)
        IF(NN .GT. 0)GO TO 135
        WRITE(6,609)IFLOOR(I),PIII,FFF
        GO TO 141
135     DO 140 J=1,NN
        FCCC=FC(I,J)/0.4719
        JJ=JC(I,J)
        DP=(P(JJ)-P(I))/248.8
        AAI=AI(I,J)/0.0929
        CC=C2(I,J)
        IF(DP .LT. 0.)CC=C1(I,J)
        CC=CC*33.43
        IFJ=IFLOOR(JJ)
        COM=JJ-SNCOMP(IFJ)
        IF(J .GT. 1)GO TO 136
        WRITE(6,610)IFLOOR(I),PIII,FFF   ,IFJ,COM,DP,CC, AAI,FCCC
        GO TO 140
136     WRITE(6,611)IFJ,COM,DP,CC, AAI,FCCC
140     CONTINUE
141     NNO=NCO(I)
        IF(NNO .EQ. 0)GO TO 150
        DO 146 J=1,NNO
        FOO=FO(I,J)/0.4719
        JJ=JCC(I,J)
        DP=(PO(I,J)-P(I))/248.8
        AAO=AO(I,J)/0.0929
        CC=CC2(I,J)
        IF(DP .LT. 0.)CC=CO1(I,J)
        CC=CC*33.43
146     WRITE(6,612)JJ,DP,CC,AAO,FOO
150     CONTINUE
        WRITE(6,813)FFI
        WRITE(6,901)
160     CONTINUE
C
C         SUMMARY OUTPUT
C         USER INSERTS WRITE STATEMENTS TO FILE IOUT
C
165     CONTINUE
        RETURN
C
C
C         FORMAT STATEMENTS
```

SUBROUTINE OUT

```
C
€01    FORMAT(/4X,I3,I10,F13.3,I8,F12.0)
€02    FORMAT(/4X,I3,I10,F13.3,18,F1500,3X,SA4,F14.3,F15.0,F10.3,F11o1)
€03    FORMAT(53X,5A4,F14.3,F15.0,F10o2,F11o1)
e04    FORMAT(/4X,I3,I10,F13.3,I8,F12.0,3X,5HFLOOR,I3,12H COMPARTMENT,I3,
      1 F1103,F15.0,F10.3,F11o1)
C05    FORMAT(53X,SHFLOOR,I3,12H COMPARTMENT, 13,F11.3,F15.0,F10.3,F11.1)
106    FORMAT(53X,17HCUTSIDE DIRECTION,I3,F14.3,F15.0,F10.3,F11.1)
€09    FORMAT(4X,I3,F1003,F11.0)
€10    FORMAT(4X,I3,FA0.3,F11.0,3X,SHFLOOR,I3,12H COMPARTMENT,I3,F11.3,
      1 F15.0,F10.3,F11.1)
€11    FORMAT(31X,5HFLOOR,13,12H COMPARTMENT,I3,F11.3,F15.0,F10.3,F11.1)
€12    FORMAT(31X,17HOUTSIDE DIRECTION ,I3,F14.3,F15.0,F10o3,F1101)
800    FORMAT(1H1,20X,18A4,/94X,8HADJUSTED/35X,4HTEMP,7X,5HFIXED,28X,
      1 12HDIFFERENTIAL,5X,4HFLOW,8X,4HFLOW/4X,5HFLOOR,2X,11HCOMPARTMENT
      2 ,2X,8HPRESSURE,2X,7HPROFILE,5X,4HFLOW,3X,16HCONNECTION    TO ,
      312X,8HPRESSURE,4X,11HCOEFFICIENT,2X,8H   AREA   ,5X,4HFLOW /)
€01    FORMAT(/4X,I3,I10,F13.1,I8,F12.0)
802    FORMAT(/4X,13,I10,F13.1,I8,F12.0,3X,5A4,F14.1,F15.1 ,F10.4,F1101)
803    FORMAT(53X,SA4,F14.1,F15o1,F10.4,F11o1)
€04    FORMAT(/4X,I3,I10,F13.1,I8,F12.0,3X,5HFLOOR,I3,12H COMPARTMENT, I3,
      1 F11.1,F15.1,F10.4,F11.1)
€05    FORMAT(53X,5HFLOOR,I3,12H COMPARTMENT, I3,F11.1,F15.1,F10.4,F11.1)
€06    FORMAT(53X,17HOUTSIDE DIRECTION,13,F14.1,F15.1,F1004,F11.1)
€07    FORMAT(115X,F8.1,4H NET)
EC8    FORMAT(////20X,SA4//20X,20HTEMPERATURE PROFILE  ,I3/ 20X,
      1 23HSHAFT FLOW COEFFICIENT   ,F10.0//72X,8HADJUSTED/24X,5HFIXED,
      2 28X,12HDIFFERENTIAL,5X,4HFLOW,8X,4HFLOW/4X,5HFLOOR,2X,8HPRESSURE,
      3 5X,4HFLOW,3X,16HCONNECTION    TO,12X,8HPRESSURE,4X,11HCOEFFICIENT
      4,2X,8H   AREA   ,5X,4HFLOW /)
€09    FORMAT(4X,I3,F10.1,F11.0)
810    FORMAT(4X,I3,F10.1,F11.0,3X,5HFLOOR,I3,12H COMPARTMENT,I3,F11.1,
      1 F15.1,F10.4,F11.1)
811    FORMAT(31X,SHFLOOR,I3,12H COMPARTMENT,I3,F11.1,F15.1,F10.4,F11.1)
e12    FORMAT(31X,17HOUTSIDE DIRECTION ,I3,F14.1,F15.1,F10.4,F11.1)
€13    FORMAT(93X,F8.1,4H NET)
e14    FORMAT(1H1,20X,18A4)
S00    FORMAT(//15X,'THE FOLLOWING UNITS ARE USED FOR OUTPUT'
      1//5X,'FLOW IN  LITERS PER SECCNO AT 21 DEG C AND 1 ATM'
      2/5X,'PRESSURE IN  PASCALS'/5X,'AREA IN  METERS SQUARED')
SO1    FORMAT(///,5X,'THE FOLLOWING UNITS ARE USED FOR OUTPUT'
      1 //5X,'FLOW IN  CFM AT 70 DEG F AND 1 ATM'
      2 /5X,'PRESSURE IN  INCHS H2O'/5X,'AREA IN  FEET SQUARED')
       END
```

&HDG,P   SUBROUTINE UNITS.L,1

SUBROUTINE UNITS

```
aNBS*PLIE$.SHOW  A.UNITS
      SUERCUTINE UNITS
C
C        ThIS RCUTINE CONVERTS VARIABLES H,FF,AI,AO,CS TO SI UNITS
C
C
      PARAMETER  (MM=140,MS=8,MC=9,MPO=2,MTP=2,MFL=25,MB=50)
      COMMCN NT,    P(MM),C(MM,MC),NC(MM),JC(MM,MC),ITS(MS),
     1 FC(MM,MC),PZ(MM,MC),PO(MM,MPO),CO(MM,MPO),F(MM),PFO(MFL,MPO),
     2 FF(MM),FO(MM,MPO),CS(MS),PS(MFL),NS1(MS),NS2(MS),
     3 FSS(MS),N,NS,NFO,ICONV,E,IBUG,AI(MM,MC),AO(MM,MPO),TITSH(MS,5),
     4 NH,H(MFL),IFLOCR(MM),T(MTP,MFL),NFS1(MS),NFS2(MS),IT(MB),NTP
     5 ,NCC(MM),JOC(MM,MPO),TOUT
      DOUBLE PRECISION P,PO,PS
      DIMENSION B(5)
      DATA B/0.3048,248.8,0.4719,0.02992,0.0929/
      DO 10 I=1,NH
10    H(I)=H(I)*B(1)
      DO 20 I=1,NT
      FF(I)=FF(I)*B(3)
      DO 16 J=1,MC
      AI(I,J)=AI(I,J)*B(5)
16    CONTINUE
      DO 18 J=1,MPO
      AO(I,J)=AO(I,J)*B(5)
18    CONTINUE
SO    CONTINUE
      DO 22 IS=1,NS
22    CS(IS)=CS(IS)*B(4)
      RETURN
      END

aHDG,P                          SUEROUTINE SIMEQ.L,1
```

SUBROUTINE SIMEQ

```
€NBS*PLIB$.SHOW  A.SIMEQ
      SUBRCUTINE SIMEC
C
C        CHCLESKY'S METHOD CF SOLUTICN OF
C      SIMULTANEOUS LINEAR ALGEBRIC EQUATIONS
C
      PARAMETER  (MM=140,MS=8,MC=9,MFO=2,MTP=2,MFL=25,MB=50)
      PARAMETER  (MBP=MB+1)
      DOUBLE PRECISICN A,X
      COMMCN /MAT/ A(MB,MBP),X(MB),N
      NP1=N+1
      ZERO=1.0E-35
      K=0
C
C
C        SEE IF A(1,1) IS ZERO
C      IF SC ADC ANOTHER RCW TO ROW 1
      IF(AES(A(1,1)) .GT. ZERO)GO TO 40
      DO 31 I=1,N
      IF(A(I,1) .NE. 0.)GO TO 32
   31 CONTINUE
   12 WRITE(6,804)K
      STOP
   32 DO 33 J=1,NP1
   33 A(1,J)=A(1,J)+A(I,J)
C
C      CALCULATE UPPER AND COWER
C      TRIANGULAR MATRICES OVER ORIG
C      MATRIX A
   40 AA=A(1,1)
      DO 2 J=2,NP1
    2 A(1,J)=A(1,J)/AA
      DO 1C I=2,N
      K=0
C
C      STORE A(I,1) ... A(I,I) IN X ARRAY
C      N CCSE NEW A(I,I) IS ZERO
C      ROW I CAN BE RECALCULATED
    4 CO 5 J=1,I
    5 X(J)=A(I,J)
      K=K+1
      CO 10 J=2,NP1
      IF(J .GT. I)GO TO 8
      JM1=J-1
      AA=0.
      GO 3 IR=1,JM1
    3 AA=AA+A(I,IR)*A(IR,J)
      A(I,J)=A(I,J)-AA
C
C      CHECU IF A(I,I) IS ZERO
C      IF SC MULTIPLY OLD ROW I BY 2.
C
      IF(I .NE. J)GO TO 10
      IF(AES(A(I,I)) .GT. ZERO)GO TO 10
      CO 6 JJ=1,I
    6 A(I,JJ)=X(JJ)
      DO 7 JJ=1,NP1
```

```
    7 A(I,J)=2.*A(I,J)
      IF(K .GT. 3)GO TO 12
      GO TC 4
    8 IM1=I-1
      AA=0.
      DO 9 IR=1,IM1
    9 AA=AA+A(I,IR)*A(IR,J)
      A( [redacted],J)=(A(I,J)-AA)/A (IsI)
   10 CONTINUE
C     ENC CF CALCULATION OF TRIANGULAR MATRICES
C
C
C     EACKWARD SUBSTITUTIGN
C
      X(N)=A(N,NP1)
      DO 2C II=2,N
      AA=0.
      I=NP1- [redacted]
      IP1=I+1
      DO 1E J=IP1,N
   15 AA=AA+A(I,J)*X(J)
   20 X(I)=A(I,NP1)-AA
C
  804 FORMAT(//////10X,16HPROGRAM FAILURE  ,I3/////)
      END
```

@HDG,P   FUNCTION FLOW.L,1

FUNCTIGN FLOW

```
@NBS*PLIB$.SHOW   A.FLCW
      FUNCTION FLOW(PI,PJ,PZ,C)
      COUELE PRECISICN PI,PJ
C
C     ThIS FLNCTXON CALCULATES FLOWS EETWEEN TWO POINTS
C
      IF(C .LT. 0.001)GO TO 10
      DP=PJ-PI+PZ
      SIGN=1.0
      IF(DP .LT. .0)SIGN=-1.
      FLOW=SIGN*C*SQRT(SIGN*DP)
      RETURN
 10   FLOW=0 00
      RETURN
      END
@HDG,P                          FUNCTION PFLOW.L.1
```

FUNCTION **PFLOW**

```
@NBS*PLIES.SHOW   A.PFLOW
      FUNCTICN PFLOW(I,PI)
C
C
C     THIS FUNCTION CALCULATES NET FLOWS INTO POINT I
C
      PARAMETER  (MM=140,MS=8,MC=9,MPO=2,MTP=2,MFL=25,MB=50)
      COMMCN /CORR/C1(MM,MC),C2(MM,MC),CO1(MM,MPO),CO2(MM,MPO)
      COMMCN NT,    P(MM),C(MM,MC),NC(MM),JC(MM,MC),ITS(MS),
     1 FC(MM,MC),PZ(MM,MC),PO(MM,MPO),CO(MM,MPO),F(MM),PFO(MFL,MPO),
     2 FF(MM),FO(MM,MPO),CS(MS),PS(MFL),NS1(MS),NS2(MS),
     3 FSS(MS),N,NS,NPO,ICONV,E,IBUG,AI(MM,MC),AO(MM,MPO),TITSH(MS,5),
     4 NH,H(MFL),IFLOOR(MM),T(MTP,MFL),NFS1(MS),NFS2(MS),IT(MB),NTP
     5 ,NCC(MM),JOC(MM,MPO),TOUT
      COUELE PRECISION P,PO,PS,PI
      NN=NC(I)
      SUM=0.
      IF(NN .EQ. 0)GO TO 3
      DO 1 JJ=1,NN
      J=JC(I,JJ)
      CC=C1(I,JJ)
      IF(PI .LT. P(J))CC=C2(I,JJ)
      PZZ=PZ(I,JJ)
      IF(I .GT. N)PZZ=0.
      FC(I,JJ)=FLOW(PI,P(J),PZZ,CC)
1     SUM=SUM+FC(I,JJ)
3     NNO=NCC(I)
      IF(NNO .EQ. 0)GO TO 4
      DO 2 K=1,NNO
      CC=CO1(I,K)
      IF(PI .LT. PO(I,K))CC=CO2(I,K)
      FO(I,K)=FLOW(PI,PO(I,K),0,CC)
2     SUM=SUM+FO(I,K)
4     PFLOW=SUM+FF(I)
      IF(I .LE. N)F(I)=SUM+FF(I)
      RETURN
      END

@HDG,P                           FUNCTION SFLOW.L,1
```

FUNCTION SFLOW

```
@NBS*PLIES.SFOW  A.SFLOW
      FUNCTION SFLOW(IS,PI)
C
C
C      THIS ROUTINE CALCULATES NET FLOW INTO A SHAFT AND
C         SHAFT PRESSURE PROFILE
C
C
      PARAMETER  (MM=140,MS=8,MC=9,MPO=2,MTP=2,MFL=25,MB=50)
      COMMON NT,    P(MM),C(MM,MC),NC(MM),JC(MM,MC),ITS(MS),
     1 FC(MM,MC),PZ(MM,MC),PO(MM,MPO),CO(MM,MPO),F(MM),PFO(MFL,MPO),
     2 FF(MM),FO(MM,MPO),CS(MS),PS(MFL),NS1(MS),NS2(MS),
     3 FSS(MS),N,NS,NPO,ICONV,E,IBUG,AI(MM,MC),AO(MM,MPO),TITSH(MS,5),
     4 NF,F(MFL),IFLOOR(MM),T(MTP,MFL),NFS1(MS),NFS2(MS),IT(MB),NTP
     5 ,NCC(MM),JOC(MM,MFC),TOUT
      DOUBLE PRECISION P,PO,PS,PI
      IF(IBUG .GT.1)WRITE(6,800)IS
      SUM=0.
      N1=NS1(IS)
      N2=NS2(IS)
      PS(1)=PI
      FUP=0.
      CSS=CS(IS)
      DO 10 I=N1,N2
      II=I+1-N1
      FLO=FFLOW(I,PS(II))
      FUP=FLO+FUP
      SUM=SUM+FLO
      IF(I .EQ. N2)GO TO 5
      IIP1=II+1
      SIGN=1
      IF(FLP .GT. 0.)SIGN=-1.
      PS(IIP1)=PS(II)-PZ(I,1)+SIGN*FUP*FUP/(CSS*CSS)
5     IF(IBUG .GT. 1)WRITE(6,801)I,II,PS(II),FLO,FUP,SUM
10    CONTINUE
      FSS(IS)=SUM
      SFLOW=SUM
      RETURN
C
C      FORMAT STATEMENTS
C
800   FORMAT(///5X,17HFLOW - SHAFT NO  ,I5/)
801   FORMAT(5X,3HI =,I3,5X,4HII =,I3,5X,4HPS =,
     + E15.7,5X,5HFLO =,E10.4,5X,5HFUP =,E10.4,5X,5HSUM =,E10.4/)
      END

@BRKPT PRINTS
```

FEDERAL INFORMATION PROCESSING STANDARD SOFTWARE SUMMARY

01. Summary date (Yr. / Mo. / Day)

02. Summary prepared by (Name and Phone)
John Klote 921-3387

03. Summary action: New [X] Replacement [ ] Deletion [ ]
Previous Internal Software ID

04. Software date (Yr. / Mo. / Day): 82 05 28

05. Software title
A Computer Program for Analysis of Smoke Control Systems

07. Internal Software ID

08. Software type
- [ ] Automated Data System
- [X] Computer Program
- [ ] Subroutine/Module

09. Processing mode
- [ ] Interactive
- [ ] Batch
- [ ] Combination

10. Application area

General
- [ ] Computer Systems Support/Utility
- [ ] Scientific/Engineering
- [ ] Bibliographic/Textual
- [ ] Management/Business
- [ ] Process Control
- [ ] Other

Specific
Smoke control in buildings

11. Submitting organization and address
Suppression & Extinguishment Group
Center for Fire Research
National Bureau of Standards
Washington, D.C. 20234

12. Technical contact(s) and phone
John Klote
921-3387

13. Narrative

Pressurized stairwells and pressurized elevators can be used as a means of providing a smoke free exit route during fire situations. This computer program analyzes systems intended to pressurize stairwells and elevator shafts.

14. Keywords
Air movement; computer programs; egress; elevator shafts; escape means; modeling; pressurization; simulating; smoke control; stairwells

15. Computer manuf'r and model	16. Computer operating system	17. Programing language(s)	18. Number of source program statements
Univac 1100/82		ANSI FORTRAN	1756

19. Computer memory requirements	20. Tape drives	21. Disk/Drum units	22. Terminals

24. Software availability: Available [X] Limited [ ] In-house only [ ]

25. Documentation availability: Available [ ] Inadequate [ ] In-house only [ ]

26. FOR SUBMITTING ORGANIZATION USE

INSTRUCTIONS

01. Summary Date. Enter date summary prepared. Use Year, Month, Day format: YYMMDD.

02. Summary Prepared By. Enter name and phone number (including area code) of individual who prepared this summary.

03. Summary Action. Mark the appropriate box for new summary, replacement summary or deletion of summary. If this software summary is a replacement, enter under "Previous Internal Software ID" the internal software identification as reported in item 07 of the original summary, and enter the new internal software identification in item 07 of this form; complete all other items as for a new summary. If a software summary is to be deleted, enter under "Previous Internal Software ID" the internal software identification as reported in item 07 of the original summary; complete only items **01, 02, 03** and **11** on this form.

04. Software Date. Enter date software was completed or last updated. Use Year, Month, Day format: WMMDD.

05. Software Title. Make title as descriptive as possible.

06. Short Title. (Optional) Enter commonly used abbreviation or acronym which identifies the software.

07. Internal Software ID. Enter a unique identification number or code.

08. Software Type. Mark the appropriate box for an Automated Data System (set of computer programs), Computer Program, or **Subroutine/Module,** whichever best describes the software.

09. Processing Mode. Mark the appropriate box for an Interactive, Batch, or Combination mode, whichever best describes the software.

10. Application Area.
General: Mark the appropriate box which best describes the general area of application from among:

Computer Systems **Support/Utility**	Process Control
Management/Business	**Bibliographic/Textual**
Scientific/Engineering	Other

Specific: Specify the sub-area of application; e.g.: "COBOL optimizer" if the general area is "Computer Systems Support/Utility"; "Payroll" if the general area is "Management/Business"; etc. Elaborate here if the general area is "Other."

11. Submitting Organization and Address. Identify the organization responsible for the software as completely as possible, to the Branch or Division level, but including Agency, Department (Bureau/Administration), Service, Corporation, Commission, or Council. Fill in complete mailing address, including mail code, street address, city, state, and ZIP code.

12. Technical Contact(s) and Phone: Enter person(s) or office(s) to be contacted for technical information on subject matter and/or operational aspects of software. Include telephone area code. Provide organization name and mailing address, if different from that in item **11.**

13. Narrative. Describe concisely the problem addressed and methods of solution. Include significant factors such as special operating system modifications, security concerns, relationships to other software, input and output media, virtual memory requirements, and unique hardware features. Cite references, if appropriate.

14. Keywords. List significant words or phrases which reflect the functions, applications and features of the software. Separate entries with semicolons.

15. Computer Manufacturer and Model. Identify mainframe computer(s) on which software is operational.

16. Computer Operating System. Enter name, number, and release under which software is operating. Identify enhancements in the Narrative (item **13).**

17. Programing Language(s). Identify the language(s) in which the software is written, including version; e.g., ANSI COBOL, FORTRAN V, SIMSCRIPT 115, SLEUTH II.

18. Number of Source Program Statements. Include statements in this software, separate macros, called subroutines, etc.

19. Computer Memory Requirements. Enter minimum internal memory necessary to execute software, exclusive of memory required for the operating system. Specify words, bytes, characters, etc., and number of bits per unit. Identify virtual memory requirements in the Narrative (item **13).**

20. Tape Drives. Identify number needed to operate software. Specify, if critical, manufacturer, model, tracks, recording density, etc.

21. Disk/Drum Units. Identify number and size (in same units as "Memory"—item **19)** needed to operate software. Specify, if critical, manufacturer, model, etc.

22. Terminals. Identify number of terminals required. Specify, if critical, type, speed, character set, screen/line size, etc.

23 Other Operational Requirements. Identify peripheral devices, support software, ot related equipment not indicated above, e.g., optical character devices, facsimile, computer-output microfilm, graphic plotters.

24. Software Availability. Mark the appropriate box which best describes the software availability from among: Available to the Public, Limited Availability (e.g.: for government use only), and For-In-house Use Only. If the software is "Available", include a mail or phone contact point, as well as the price and form in which the software is available, if possible.

25. Documentation Availability. Mark the appropriate box which best describes the documentation availability from among: Available to the Public, Inadequate for Distribution, and For In-house Use Only. If documentation is "Available", include a mail or phone contact point, as well as the price and form in which the documentation is available, if possible. If docurnentation is presently "Inadequate", show the expected availability date.

26. For Submitting Organization Use. This area is provided for the use of the organization submitting this summary. It may contain any information deemed useful for internal operation.

GPO : 1974 O - 554-655

NBS-114A (REV. 2-80)

U.S. DEPT. OF COMM.

BIBLIOGRAPHIC DATA SHEET *(See instructions)*

1. PUBLICATION OR REPORT NO.
NBSIR 82-2512

2. Performing Organ. Report No.

3. Publication Date
June 1982

4. TITLE AND SUBTITLE

A COMPUTER PROGRAM FOR ANALYSIS OF SMOKE CONTROL SYSTEMS

5. AUTHOR(S)

John H. Klote

6. PERFORMING ORGANIZATION *(If joint or other than NBS, see instructions)*

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20234

7. Contract/Grant No.

8. Type of Report & Period Covered
Final Report

9. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS *(Street, City, State, ZIP)*
Department of Health and Human Services
Washington, D.C. 20201

10. SUPPLEMENTARY NOTES

[ ] Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A *200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)*

This paper describes a computer program developed to analyze systems intended to control smoke in building fires. These systems include pressurized stairwells, pressurized elevator shafts, zone smoke control systems, and pressurized corridors. This program calculates air flows and differential pressures throughout a building in which a smoke control system is operating. The basic assumptions and limitations of the program are also discussed. The appendices contain a program listing and examples.

12. KEY WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

Air movement; computer programs; egress; elevator shafts; escape means; modeling; pressurization; simulation; smoke control; stairwells

13. AVAILABILITY

[xx] Unlimited

[ ] For Official Distribution. Do Not Release to NTIS

[ ] Order From Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

[X] Order From National Technical Information Service (NTIS), Springfield, VA. 22161

14. NO. OF PRINTED PAGES
69

15. Price