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DIVISION OF BUILDING RESEARCH

FORTRAN IV PROGRAM TO CALCULATE AIR INFILTRATION IN BUILDINGS

by

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Air leakage through the exterior envelope of a building is an important factor in calculating heating and cooling loads and in considering moisture problems. The purpose of this program is to calculate the air flows and pressure differentials that will occur in a building as a result of a combination of wind effect, stack action and operation of air handling systems.

MATHEMATICAL MODEL OF BUILDING

The building model has previously been described by Tamura (1). It is represented by a set of compartments stacked one on top of another and by a set of shafts that pass through all the compartments. Leakage openings are present in each outside wall of each compartment and in all the floors and shaft walls so that air can pass from every compartment to adjacent compartments and to each of the vertical shafts. Each compartment may represent a number of building storeys in order to save computation time. Each shaft may have two vents to outside. Vent openings are designated "top" and "bottom," but they may be located at any level. The effects of the air handling systems are accounted for by specifying the net quantity of air supplied to each vertical shaft and to each compartment. Stack effect is calculated for the given outdoor temperature.

The flow equation used is

$$F = EA\,(\Delta P)^{x} \tag{1}$$

where F = flow rate through a leakage opening (cfm)

EA = flow coefficient (cfm/in.^{x}) *

ΔP = pressure differential (in.)

x = flow exponent ($0.5 \le x \le 1.0$)

In order to account for the effects of wind, the pressures due to wind on each face of the building at each level must be determined. This may be done by specifying a matrix of wind pressure

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* inch = 5.2 lb/ft^2, which is the pressure of one inch head of water

coefficients that relate the wind pressures at each level to the ambient wind velocity pressure, based on the wind speed at a height of 30 ft as measured by a meteorological station. These wind pressure coefficients account for wind velocity profile, ground effect, and shading effect by other buildings. (They would generally be obtained from wind tunnel tests on a model of the building.) Wind pressure coefficients for each level and for sixteen directions must be specified along with the other data.

ASSUMPTIONS AND LIMITATIONS

1) Frictional resistance of vertical shafts is neglected.

2) Net air supplied by the air handling system is assumed to be constant and independent of building pressures.

3) The building has an open floor plan with no provision for separate rooms or vestibules.

4) Pressures, flows, and leakage openings are assumed to occur at mid-height of each level.

5) Temperature inside compartments and shafts is assumed to be 75°F.

DESCRIPTION OF PROGRAM

Flow balance equations for each compartment and for each shaft are:

for the ith compartment,

$$\sum_{k=1}^{4} F_{o(i,k)} + F_{b(i)} - F_{a(i)} - \sum_{j=1}^{JJ} F_{s(i,j)} + F_{ac(i)} = 0 \qquad (2)$$

and for the jth shaft,

$$\sum_{i=1}^{NN} F_{s(i,j)} + F_{bv(j)} + F_{tv(j)} + F_{sh(j)} = 0 \qquad (3)$$

where $F_{o(i,k)}$ = flow from outside through side (k) to compartment (i)

$F_{b(i)}$ = flow from compartment below to compartment (i)

$F_{a(i)}$ = flow from compartment (i) to compartment above

$F_{s(i,j)}$ = flow from compartment (i) to shaft (j)

$F_{ac(i)}$ = net flow of air supplied to compartment (i) by air handling system

$F_{bv(j)}$ = flow into shaft (j) through bottom vent

$F_{tv(j)}$ = flow into shaft (j) through top vent

$F_{sh(j)}$ = net flow of outside air supplied into shaft (j) by air handling system

NN = number of compartments

JJ = number of shafts

The flows appearing in equations (2) and (3) are indicated in Figure 1. Combination of mass balance equations (2 and 3) with flow equation (1) results in a set of simultaneous non-linear equations. The outside pressures and the pressure differences due to column weight may be calculated from the input data.

These simultaneous non-linear equations are solved by a method of successive linear approximations. The non-linear function described by equation (1) is shown in Figure 2. In the region near point (ΔP_t, F_t) this function may be approximated by a straight line which is tangent to the curve at this point. The equation of this linear function is

$$F = K' \left[\Delta P - \Delta P_i \right] \qquad (4a)$$

where

$$K' = K \times \Delta P_t^{\,x-1} \qquad (4b)$$

and

$$\Delta P_i = \Delta P_t - \frac{F_t}{K'} \qquad (4c)$$

Each leakage flow in equations (2 and 3) may be expressed by this type of linear approximation. The resulting set of NN + JJ linear equations for the pressures can then be solved by standard methods.

The iteration procedure is as follows: an initial linear approximation is made for each flow and the resulting equations are solved for space and shaft pressures. The flows corresponding to these pressures are then calculated, and the flow through each element is compared with the flow used for linearization of that element. If the difference is greater than the convergence criterion,* that element is re-linearized about the most recently determined flow and the linear simultaneous equations are solved again. This procedure is repeated until the flow through every element satisfies the convergence criterion. A block diagram of the program is given in Figure 3.

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* The convergence criterion is specified by variable "error" in subroutine INFILT. The value used is 0.1 cfm.

In order to facilitate use in a load calculation package, this infiltration program has been divided into subroutines. Subroutine INPUT reads building leakage characteristics from fortran device number IIN into common block INPX. Before calling calculations subroutine INFILT the main program must specify outdoor temperature, wind pressures and, if desired, change air-conditioning pressurization flows. These values are in common block INARG. Subroutine INFILT will return with air flow arrays in common block BKARG.

This program was written for IBM 360 model 67. Execution time is approximately 0.9 sec for a building with 10 compartments and two shafts. The program is dimensioned for a maximum of 25 compartments and eight shafts.

INPUT/(See Figure 3)

Input is from punched cards as follows:

CARD 1	NN - number of compartments (maximum 25) JJ - number of shafts (maximum eight, minimum one) (format 2I4)
CARDS 2 to NN+1	one card per compartment beginning with compartment No. 1 - height (thickness) of compartment, ft, [H(i)] - net quantity of air supplied to compartment, cfm, [ACPF(I)] (format 2F8.1)
CARD NN+2	- values of flow exponent (sides 1, 2, 3, 4, between levels, and from compartments to shafts ONE to JJ) [X(k)] (format 13F6.5)
CARDS NN+3 to 2NN+3	one card per level beginning with level No. 1 - values of leakage coefficient (sides 1, 2, 3, and 4, from compartment to compartment above, and from compartment to shafts ONE to JJ, [EA(i, j)] units: $\frac{\text{thousand of cfm}}{\text{in.}^{x}}$ (format 13F6.2)
CARDS 2NN+4 to 2NN+JJ+4	one card per shaft beginning with shaft No. 1 - net air supplied to shaft, cfm (FANSH(j)] - leakage coefficient of bottom vent, $\frac{\text{thousands cfm}}{\text{in.}^{x}}$

[BV(j)]
- level at which bottom vent located [IBV(j)]
- side of building on which bottom vent located (1, 2, 3 or 4) [JBV(j)]
- leakage coefficient of top vent, $\frac{\text{thousands cfm}}{\text{in.}^x}$

[TV(j)]
- level at which top vent located [ITV(j)]
- side of building on which top vent located (1, 2, 3 or 4) [JTV(j)] (format F12.2, 2(F8.4, 2I4))

CARDS 2NN+JJ+5 to 18NN+JJ+5	wind pressure coefficients for four sides of building - 16 sets of cards; one set for each wind direction each set is NN cards with one card per compartment beginning at compartment No. 1 (format 4F6.3)
CARDS 18NN+JJ+6 to END OF DATA	- Outdoor temperature, °F, wind speed, mph, wind direction (1 to 16) (format 2F8.1, I8)

EXAMPLE

Calculate infiltration and exfiltration rates for a 19-storey building, 120 by 120 by 250 ft high (schematically shown in Figure 4). This building has five elevators and two stairwells. The elevator machine room is in a penthouse and the mechanical equipment room is the top storey. The air supplied to the first storey exceeds the return air by 2000 cfm to produce some positive pressurization of the building. The air supplied to each remaining storey exceeds the return by 200 cfm. The four sides of the building face the cardinal directions.

It is assumed that representation of the building by nine compartments each representing two storeys is adequate for reasonably accurate results without excessive requirement of computer time. Level 10 is the mechanical floor; level 11 is the elevator room penthouse. The stairwells and service shafts are represented by one vertical shaft (shaft 1) and all elevators are represented by one other vertical shaft (shaft 2).

Building Leakage Input Data

The building leakage input data used in this example are based on the information of leakage characteristics of buildings given in References 1 and 2.

The following are the assumed leakage data:

- flow exponents for the outside walls are 0.66
- all other flow exponents are 0.5
- outside wall = 0.7 $cfm/ft^2\ in.^{0.66}$
  = 2100 $cfm/in.^{0.66}$/side of compartment

- mechanical room (i.e., compartment No. 10)	= 10,000 $cfm/in.^{0.66}$/side
- elevator penthouse	= 10,000 $cfm/in.^{0.66}$/side
- stairwell door	= 600 $cfm/in.^{0.66}$/door
- service shafts at each level	= 2400 $cfm/in.^{0.5}$
- stairwell and service shafts - total	= 4800 $cfm/in.^{0.5}$/compartment
- stairway to elevator penthouse	= 600 $cfm/in.^{0.5}$
- one elevator door	= 2400 $cfm/in.^{0.5}$
- total elevator door leakage per compartment for compartments 1 to 9	= 24,000 $cfm/in.^{0.5}$
- compartment No. 10, one elevator door	= 2400 $cfm/in.^{0.5}$
- elevator shaft to elevator penthouse, per elevator	= 7200 $cfm/in.^{0.5}$
- elevator shaft to elevator penthouse, total	= 5 x 7200 = 36,000 $cfm/in.^{0.5}$
- net air supplied by air handling system to compartments 2 to 9	= 400 cfm/compartment
- net air supplied by air handling system to compartment 1	= 2200 cfm

Wind Pressure Coefficients

The wind pressure coefficients for the 10 levels, four outside building surface orientations, and 16 wind directions are listed on the sample input data sheets. The values of the coefficients are based on the information given in References 3 and 4.

REFERENCES

1. Tamura, G. T. Computer Analysis of Smoke Movement in Buildings. ASHRAE Transactions, Vol. 75, Part II, 1969 (NRCC 11542).
2. C. Y. Shaw, D. M. Sander and G. T. Tamura. Air Leakage Measurements of the Exterior Walls of Tall Buildings. ASHRAE, Paper No. 2280, Presented at Spring Conference in Minneapolis, U. S. A., May 1973.
3. M. Jensen and N. Frauck. Model-Scale Tests in Turbulent Wind. Part II. The Danish Technical Press, Copenhagen 1965.
4. Canadian Structural Design Manual 1970. Supplement No. 4 to the National Building Code of Canada. Associate Committee on the National Building Code, National Research Council of Canada, Ottawa.

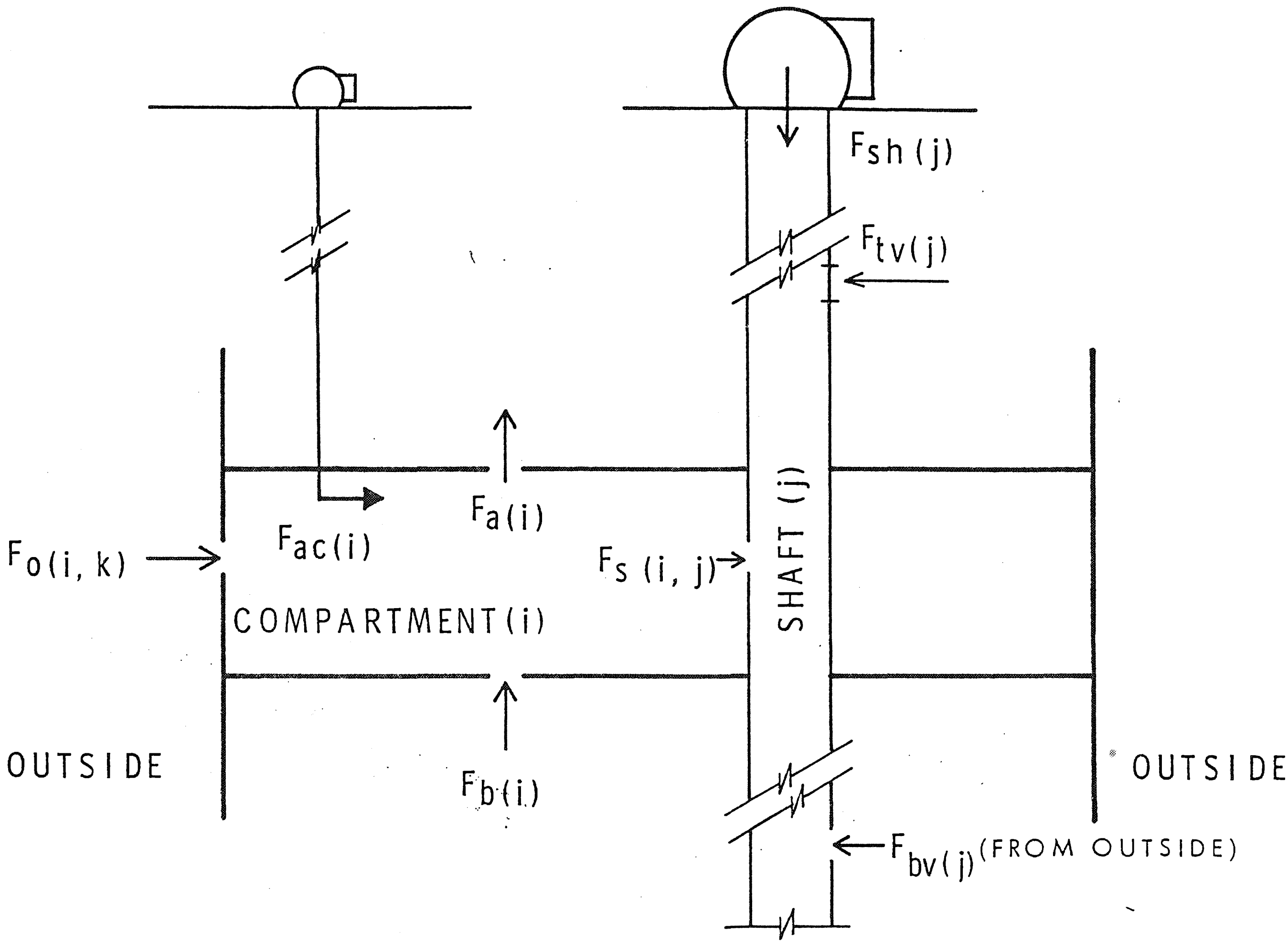

FIGURE 1

AIR FLOWS FOR A TYPICAL COMPARTMENT AND TYPICAL SHAFT

BR 5056-1

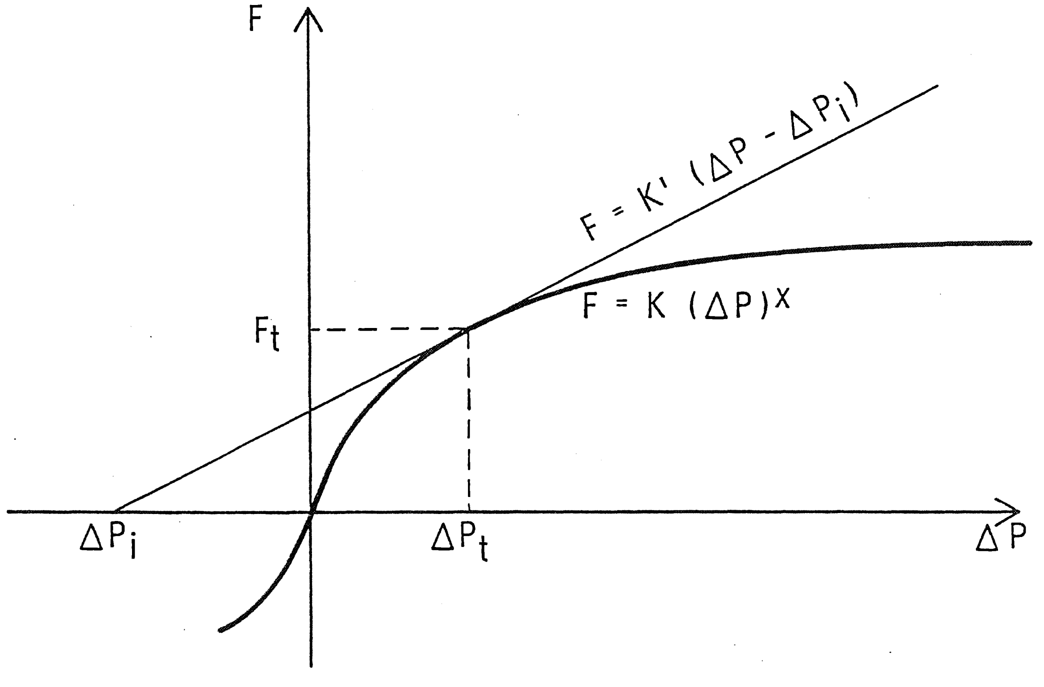

FIGURE 2

LINEAR APPROXIMATION OF FLOW EQUATION

BR 5056-2

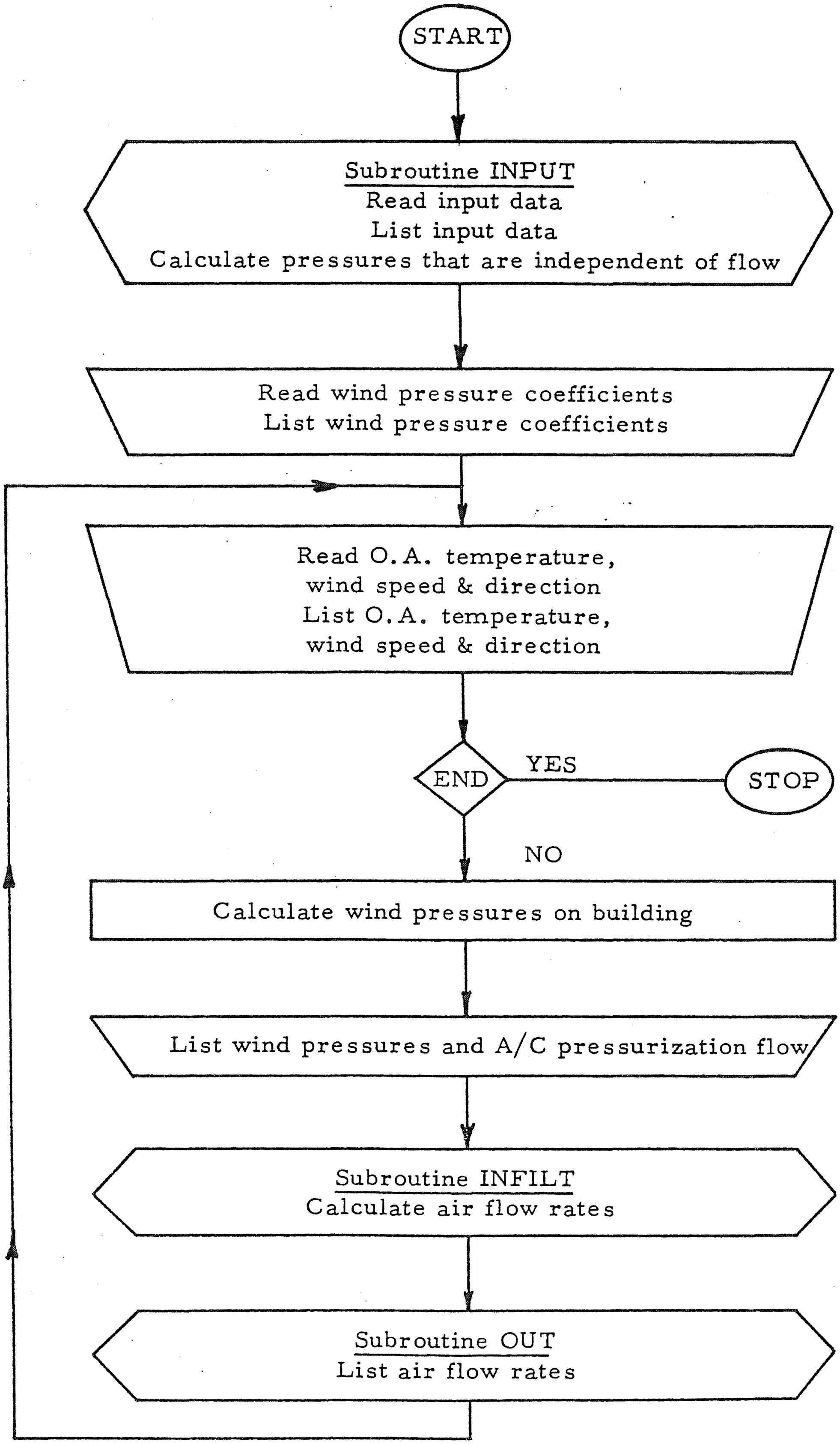

FIG 3a BLOCK DIAGRAM OF MAIN PROGRAM

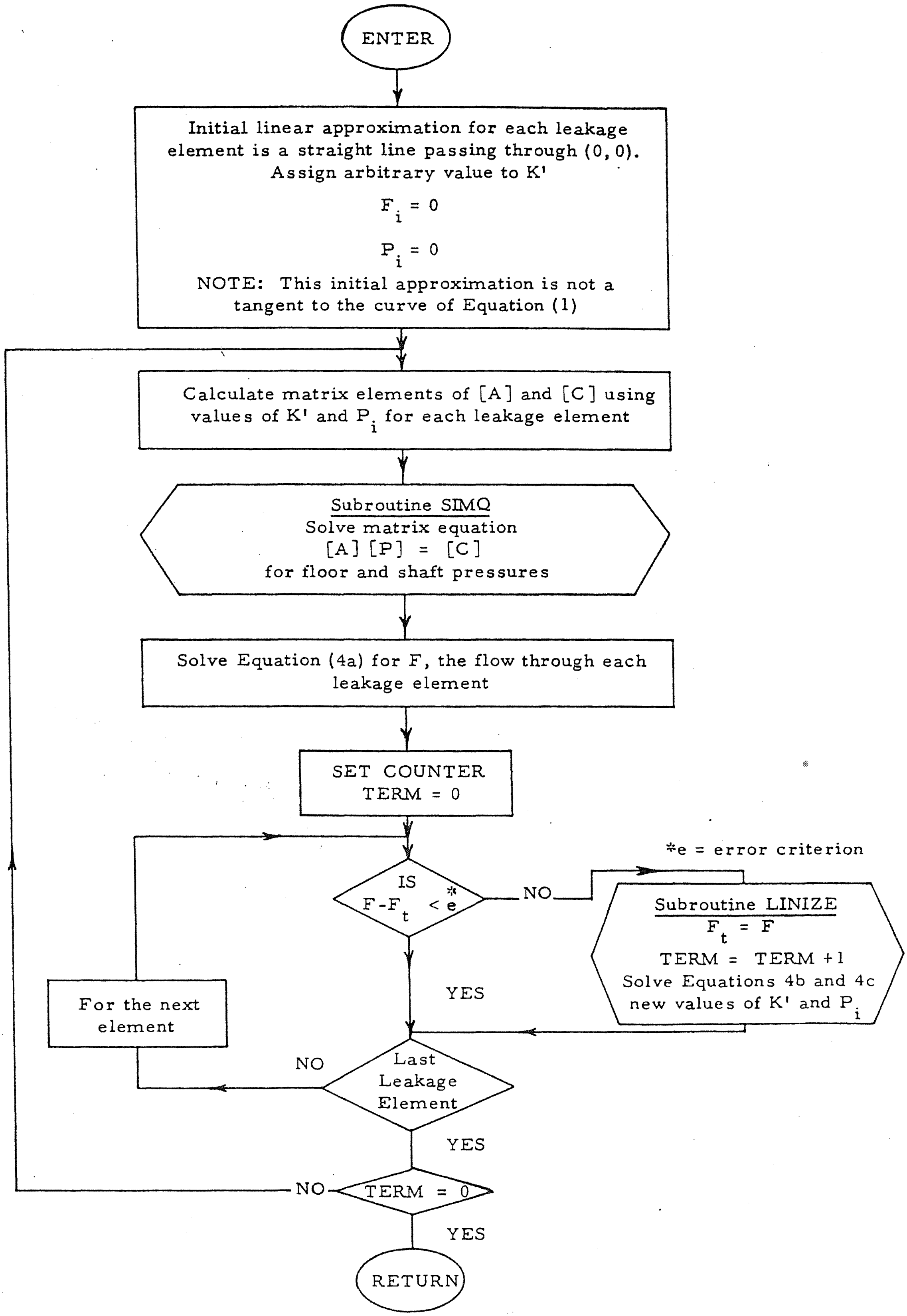

FIG 3b BLOCK DIAGRAM OF SUBROUTINE INFILT

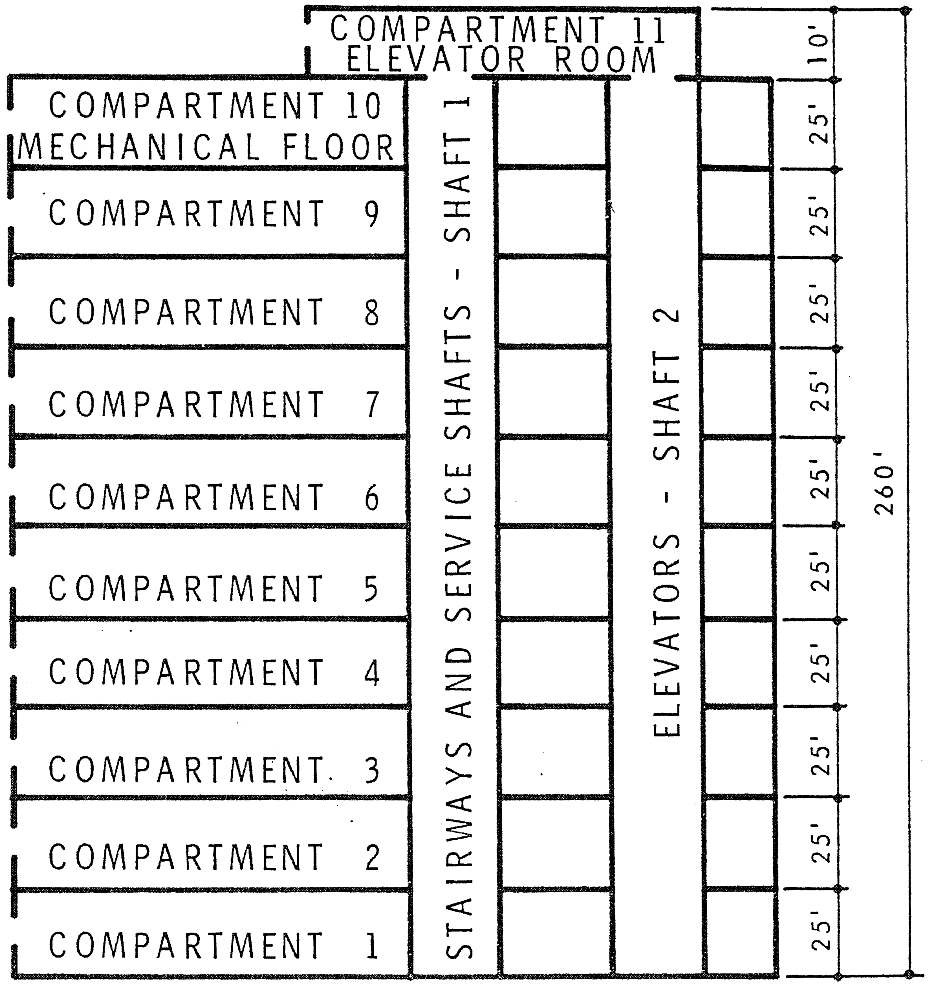

FIGURE 4

SCHEMATIC DIAGRAM OF THE BUILDING USED IN SAMPLE CALCULATIONS

BR 5224

APPENDIX A

EXAMPLE INPUT DATA

EXAMPLE INPUT DATA

```
 11     2
 25.0   2200.
 25.0    400.
 25.0    400.
 25.0    400.
 25.0    400.
 25.0    400.
 25.0    400.
 25.0    400.
 25.0    400.
 25.0      0.
 10.0      0.
 .66    .66    .66    .66    .50    .50    .50
 7.1    2.1    7.1    2.1    3.0    4.8   24.0
 2.1    2.1    2.1    2.1    3.0    4.8   24.0
 2.1    2.1    2.1    2.1    3.0    4.8   24.0
 2.1    2.1    2.1    2.1    3.0    4.8   24.0
 2.1    2.1    2.1    2.1    3.0    4.8   24.0
 2.1    2.1    2.1    2.1    3.0    4.8   24.0
 2.1    2.1    2.1    2.1    3.0    4.8   24.0
 2.1    2.1    2.1    2.1    3.0    4.8   24.0
 2.1    2.1    2.1    2.1    3.0    4.8   24.0
10.0   10.0   10.0   10.0    0.0    4.8    2.4
10.0   10.0   10.0   10.0    0.0    0.6   36.0
        0.0          0.0      1     1     0.0    11     1
        0.0          0.0      1     1     0.0    11     1
+.39   -.39   -.13   -.39
+.39   -.39   -.13   -.39
+.39   -.39   -.13   -.39
+.45   -.52   -.13   -.52
+.52   -.52   -.13   -.52
+.58   -.52   -.26   -.52                  DIRECTION 1
+.65   -.65   -.26   -.65
+.71   -.65   -.26   -.65
+.78   -.65   -.26   -.65
+.58   -.65   -.26   -.65
 0.0    0.0    0.0    0.0
+.36    0.0   -.13   -.13
+.36    0.0   -.13   -.13
+.36    0.0   -.13   -.13
+.43    0.0   -.13   -.13
+.50    0.0   -.13   -.13                  DIRECTION 2
+.55    0.0   -.26   -.26
+.60    0.0   -.26   -.26
+.66    0.0   -.26   -.26
+.60    0.0   -.26   -.26
+.55    0.0   -.26   -.26
 0.0    0.0    0.0    0.0
```

+.13	+.13	-.13	-.13	
+.13	+.13	-.13	-.13	
+.26	+.26	-.13	-.13	
+.26	+.26	-.13	-.13	
+.26	+.26	-.13	-.13	
+.26	+.26	-.26	-.26	DIRECTION 3
+.39	+.39	-.26	-.26	
+.39	+.39	-.26	-.26	
+.39	+.39	-.26	-.26	
+.26	+.26	-.26	-.26	
0.0	0.0	0.0	0.0	
0.0	+.36	-.13	-.13	
0.0	+.36	-.13	-.13	
0.0	+.36	-.13	-.13	
0.0	+.43	-.13	-.13	
0.0	+.50	-.13	-.13	
0.0	+.55	-.26	-.26	DIRECTION 4
0.0	+.60	-.26	-.26	
0.0	+.66	-.26	-.26	
0.0	+.60	-.26	-.26	
0.0	+.55	-.26	-.26	
0.0	0.0	0.0	0.0	
-.39	+.39	-.39	-.13	
-.39	+.39	-.39	-.13	
-.39	+.39	-.39	-.13	
-.52	+.45	-.52	-.13	
-.52	+.52	-.52	-.13	
-.52	+.58	-.52	-.26	DIRECTION 5
-.65	+.65	-.65	-.26	
-.65	+.71	-.65	-.26	
-.65	+.78	-.65	-.26	
-.65	+.58	-.65	-.26	
0.0	0.0	0.0	0.0	
-.13	+.36	0.0	-.13	
-.13	+.36	0.0	-.13	
-.13	+.43	0.0	-.13	
-.13	+.50	0.0	-.13	
-.13	+.50	0.0	-.13	
-.26	+.55	0.0	-.26	DIRECTION 6
-.26	+.60	0.0	-.26	
-.26	+.66	0.0	-.26	
-.26	+.60	0.0	-.26	
-.26	+.55	0.0	-.26	
0.0	0.0	0.0	0.0	
-.13	+.13	+.13	-.13	
-.13	+.13	+.13	-.13	
-.13	+.26	+.26	-.13	
-.13	+.26	+.26	-.13	
-.13	+.26	+.26	-.13	
-.26	+.26	+.26	-.26	DIRECTION 7
-.26	+.39	+.39	-.26	
-.26	+.39	+.39	-.26	

-.26	+.39	+.39	-.26	
-.26	+.26	+.26	-.26	
0.0	0.0	0.0	0.0	
-.13	0.0	+.36	-.13	
-.13	0.0	+.36	-.13	
-.13	0.0	+.36	-.13	
-.13	0.0	+.43	-.13	
-.13	0.0	+.50	-.13	
-.26	0.0	+.55	-.26	DIRECTION 8
-.26	0.0	+.60	-.26	
-.26	0.0	+.66	-.26	
-.26	0.0	+.60	-.26	
-.26	0.0	+.55	-.26	
0.0	0.0	0.0	0.0	
-.13	-.39	+.39	-.39	
-.13	-.39	+.39	-.39	
-.13	-.39	+.39	-.39	
-.13	-.52	+.45	-.52	
-.13	-.52	+.52	-.52	
-.26	-.52	+.58	-.52	DIRECTION 9
-.26	-.65	+.65	-.65	
-.26	-.65	+.71	-.65	
-.26	-.65	+.78	-.65	
-.26	-.65	+.58	-.65	
0.0	0.0	0.0	0.0	
-.13	-.13	+.36	0.0	
-.13	-.13	+.36	0.0	
-.13	-.13	+.36	0.0	
-.13	-.13	+.43	0.0	
-.13	-.13	+.50	0.0	
-.26	-.26	+.55	0.0	DIRECTION 10
-.26	-.26	+.60	0.0	
-.26	-.26	+.66	0.0	
-.26	-.26	+.60	0.0	
-.26	-.26	+.55	0.0	
0.0	0.0	0.0	0.0	
-.13	-.13	+.13	+.13	
-.13	-.13	+.13	+.13	
-.13	-.13	+.26	+.26	
-.13	-.13	+.26	+.26	
-.13	-.13	+.26	+.26	
-.26	-.26	+.26	+.26	DIRECTION 11
-.26	-.26	+.39	+.39	
-.26	-.26	+.39	+.39	
-.26	-.26	+.39	+.39	
-.26	-.26	+.26	+.26	
0.0	0.0	0.0	0.0	
-.13	-.13	0.0	+.36	
-.13	-.13	0.0	+.36	
-.13	-.13	0.0	+.36	
-.13	-.13	0.0	+.43	
-.13	-.13	0.0	+.50	DIRECTION 12
-.26	-.26	0.0	+.55	

-.26	-.26	0.0	+.60	
-.26	-.26	0.0	+.66	
-.26	-.26	0.0	+.60	
-.26	-.26	0.0	+.55	
0.0	0.0	0.0	0.0	
-.39	-.13	-.39	+.39	
-.39	-.13	-.39	+.39	
-.39	-.13	-.39	+.39	
-.52	-.13	-.52	+.45	
-.52	-.13	-.52	+.52	
-.52	-.26	-.52	+.58	DIRECTION 13
-.65	-.26	-.65	+.65	
-.65	-.26	-.65	+.71	
-.65	-.26	-.65	+.78	
-.65	-.26	-.65	+.58	
0.0	0.0	0.0	0.0	
0.0	-.13	-.13	+.36	
0.0	-.13	-.13	+.36	
0.0	-.13	-.13	+.36	
0.0	-.13	-.13	+.43	
0.0	-.13	-.13	+.50	
0.0	-.26	-.26	+.55	DIRECTION 14
0.0	-.26	-.26	+.60	
0.0	-.26	-.26	+.66	
0.0	-.26	-.26	+.60	
0.0	-.26	-.26	+.55	
0.0	0.0	0.0	0.0	
+.13	-.13	-.13	+.13	
+.13	-.13	-.13	+.13	
+.26	-.13	-.13	+.26	
+.26	-.13	-.13	+.26	
+.26	-.13	-.13	+.26	
+.26	-.26	-.26	+.26	DIRECTION 15
+.39	-.26	-.26	+.39	
+.39	-.26	-.26	+.39	
+.39	-.26	-.26	+.39	
+.26	-.26	-.26	+.26	
0.0	0.0	0.0	0.0	
+.36	-.13	-.13	0.0	
+.36	-.13	-.13	0.0	
+.36	-.13	-.13	0.0	
+.43	-.13	-.13	0.0	
+.50	-.13	-.13	0.0	
+.55	-.26	-.26	0.0	DIRECTION 16
+.60	-.26	-.26	0.0	
+.66	-.26	-.26	0.0	
+.60	-.26	-.26	0.0	
+.55	-.26	-.26	0.0	
0.0	0.0	0.0	0.0	
20.	20.		5	

APPENDIX B

EXAMPLE PROGRAM OUTPUT

EXAMPLE OUTPUT

SOLUTION FOR 11 LEVELS, 2 SHAFTS

********INPUT PARAMETERS********

FLOW EQUATION IS...F=COEF*(DELTA P)**X

WHERE:
F =FLOW RATE (CFM)
COEF =LEAKAGE COEFICIENT (1000 CFM/INCH
DELTA P =PRESSURE DIFFERENTIAL (INCHES OF WATER)
X =FLOW EXPONENT

***** VALUES OF X *****

OUTSIDE SIDE 1	OUTSIDE SIDE 2	OUTSIDE SIDE 3	OUTSIDE SIDE 4	LEVEL ABOVE	SHAFT 1	SHAFT 2	SHAFT 3	SHAFT 4	SHAFT 5
0.660	0.660	0.660	0.660	0.500	0.500	0.500			

VALUE OF X FOR SHAFT VENTS IS 0.5

****LEAKAGE COEFICIENTS=(1000 SCFM/INCH)****

LEVEL	OUTSIDE SIDE 1	OUTSIDE SIDE 2	OUTSIDE SIDE 3	OUTSIDE SIDE 4	LEVEL ABOVE	SHAFT 1	SHAFT 2	SHAFT 3	SHAFT 4	SHAFT 5
1	7.100	2.100	7.100	2.100	3.000	4.800	24.000			
2	2.100	2.100	2.100	2.100	3.000	4.800	24.000			
3	2.100	2.100	2.100	2.100	3.000	4.800	24.000			
4	2.100	2.100	2.100	2.100	3.000	4.800	24.000			
5	2.100	2.100	2.100	2.100	3.000	4.800	24.000			
6	2.100	2.100	2.100	2.100	3.000	4.800	24.000			
7	2.100	2.100	2.100	2.100	3.000	4.800	24.000			
8	2.100	2.100	2.100	2.100	3.000	4.800	24.000			
9	2.100	2.100	2.100	2.100	3.000	4.800	24.000			
10	10.000	10.000	10.000	10.000	0.000	4.800	2.400			
11	10.000	10.000	10.000	10.000	0.000	0.600	36.000			

*****SHAFT VENTS AND PRESSURIZATION*****

SHAFT	PRESS FLOW (CFM)	****BOTTOM VENT**** COEF	LEVEL	SIDE	****TOP VENT**** COEF	LEVEL	SIDE
1	0.00	0.00	1	1	0.00	11	1
2	0.00	0.00	1	1	0.00	11	1

WIND PRESSURE COEFICIENTS

LEVEL	SIDE 1	SIDE 2	SIDE 3	SIDE 4
		WIND DIRECTION= 1		
1	0.3900	-0.3900	-0.1300	-0.3900
2	0.3900	-0.3900	-0.1300	-0.3900
3	0.3900	-0.3900	-0.1300	-0.3900
4	0.4500	-0.5200	-0.1300	-0.5200
5	0.5200	-0.5200	-0.1300	-0.5200
6	0.5800	-0.5200	-0.2600	-0.5200
7	0.6500	-0.6500	-0.2600	-0.6500
8	0.7100	-0.6500	-0.2600	-0.6500
9	0.7800	-0.6500	-0.2600	-0.6500
10	0.5800	-0.6500	-0.2600	-0.6500
11	0.0000	0.0000	0.0000	0.0000
LEVEL		WIND DIRECTION= 2		
1	0.3600	0.0000	-0.1300	-0.1300
2	0.3600	0.0000	-0.1300	-0.1300
3	0.3600	0.0000	-0.1300	-0.1300
4	0.4300	0.0000	-0.1300	-0.1300
5	0.5000	0.0000	-0.1300	-0.1300
6	0.5500	0.0000	-0.2600	-0.2600
7	0.6000	0.0000	-0.2600	-0.2600
8	0.6600	0.0000	-0.2600	-0.2600
9	0.6000	0.0000	-0.2600	-0.2600
10	0.5500	0.0000	-0.2600	-0.2600
11	0.0000	0.0000	0.0000	0.0000
LEVEL		WIND DIRECTION= 3		
1	0.1300	0.1300	-0.1300	-0.1300
2	0.1300	0.1300	-0.1300	-0.1300
3	0.2600	0.2600	-0.1300	-0.1300
4	0.2600	0.2600	-0.1300	-0.1300
5	0.2600	0.2600	-0.1300	-0.1300
6	0.2600	0.2600	-0.2600	-0.2600
7	0.3900	0.3900	-0.2600	-0.2600
8	0.3900	0.3900	-0.2600	-0.2600
9	0.3900	0.3900	-0.2600	-0.2600

10	0.2600	0.2600	-0.2600	-0.2600
11	0.0000	0.0000	0.0000	0.0000
LEVEL		WIND DIRECTION= 4		
1	0.0000	0.3600	-0.1300	-0.1300
2	0.0000	0.3600	-0.1300	-0.1300
3	0.0000	0.3600	-0.1300	-0.1300
4	0.0000	0.4300	-0.1300	-0.1300
5	0.0000	0.5000	-0.1300	-0.1300
6	0.0000	0.5500	-0.2600	-0.2600
7	0.0000	0.6000	-0.2600	-0.2600
8	0.0000	0.6600	-0.2600	-0.2600
9	0.0000	0.6000	-0.2600	-0.2600
10	0.0000	0.5500	-0.2600	-0.2600
11	0.0000	0.0000	0.0000	0.0000
LEVEL		WIND DIRECTION= 5		
1	-0.3900	0.3900	-0.3900	-0.1300
2	-0.3900	0.3900	-0.3900	-0.1300
3	-0.3900	0.3900	-0.3900	-0.1300
4	-0.5200	0.4500	-0.5200	-0.1300
5	-0.5200	0.5200	-0.5200	-0.1300
6	-0.5200	0.5800	-0.5200	-0.2600
7	-0.6500	0.6500	-0.6500	-0.2600
8	-0.6500	0.7100	-0.6500	-0.2600
9	-0.6500	0.7800	-0.6500	-0.2600
10	-0.6500	0.5800	-0.6500	-0.2600
11	0.0000	0.0000	0.0000	0.0000
LEVEL		WIND DIRECTION= 6		
1	-0.1300	0.3600	0.0000	-0.1300
2	-0.1300	0.3600	0.0000	-0.1300
3	-0.1300	0.4300	0.0000	-0.1300
4	-0.1300	0.5000	0.0000	-0.1300
5	-0.1300	0.5000	0.0000	-0.1300
6	-0.2600	0.5500	0.0000	-0.2600
7	-0.2600	0.6000	0.0000	-0.2600
8	-0.2600	0.6600	0.0000	-0.2600
9	-0.2600	0.6000	0.0000	-0.2600
10	-0.2600	0.5500	0.0000	-0.2600
11	0.0000	0.0000	0.0000	0.0000

LEVEL		WIND DIRECTION= 7		
1	-0.1300	0.1300	0.1300	-0.1300
2	-0.1300	0.1300	0.1300	-0.1300
3	-0.1300	0.2600	0.2600	-0.1300
4	-0.1300	0.2600	0.2600	-0.1300
5	-0.1300	0.2600	0.2600	-0.1300
6	-0.2600	0.2600	0.2600	-0.2600
7	-0.2600	0.3900	0.3900	-0.2600
8	-0.2600	0.3900	0.3900	-0.2600
9	-0.2600	0.3900	0.3900	-0.2600
10	-0.2600	0.2600	0.2600	-0.2600
11	0.0000	0.0000	0.0000	0.0000

LEVEL		WIND DIRECTION= 8		
1	-0.1300	0.0000	0.3600	-0.1300
2	-0.1300	0.0000	0.3600	-0.1300
3	-0.1300	0.0000	0.3600	-0.1300
4	-0.1300	0.0000	0.4300	-0.1300
5	-0.1300	0.0000	0.5000	-0.1300
6	-0.2600	0.0000	0.5500	-0.2600
7	-0.2600	0.0000	0.6000	-0.2600
8	-0.2600	0.0000	0.6600	-0.2600
9	-0.2600	0.0000	0.6000	-0.2600
10	-0.2600	0.0000	0.5500	-0.2600
11	0.0000	0.0000	0.0000	0.0000

LEVEL		WIND DIRECTION= 9		
1	-0.1300	-0.3900	0.3900	-0.3900
2	-0.1300	-0.3900	0.3900	-0.3900
3	-0.1300	-0.3900	0.3900	-0.3900
4	-0.1300	-0.5200	0.4500	-0.5200
5	-0.1300	-0.5200	0.5200	-0.5200
6	-0.2600	-0.5200	0.5800	-0.5200
7	-0.2600	-0.6500	0.6500	-0.6500
8	-0.2600	-0.6500	0.7100	-0.6500
9	-0.2600	-0.6500	0.7800	-0.6500
10	-0.2600	-0.6500	0.5800	-0.6500
11	0.0000	0.0000	0.0000	0.0000

LEVEL		WIND DIRECTION= 10		
1	-0.1300	-0.1300	0.3600	0.0000

2	-0.1300	-0.1300	0.3600	0.0000
3	-0.1300	-0.1300	0.3600	0.0000
4	-0.1300	-0.1300	0.4300	0.0000
5	-0.1300	-0.1300	0.5000	0.0000
6	-0.2600	-0.2600	0.5500	0.0000
7	-0.2600	-0.2600	0.6000	0.0000
8	-0.2600	-0.2600	0.6600	0.0000
9	-0.2600	-0.2600	0.6000	0.0000
10	-0.2600	-0.2600	0.5500	0.0000
11	0.0000	0.0000	0.0000	0.0000
LEVEL		WIND DIRECTION= 11		
1	-0.1300	-0.1300	0.1300	0.1300
2	-0.1300	-0.1300	0.1300	0.1300
3	-0.1300	-0.1300	0.2600	0.2600
4	-0.1300	-0.1300	0.2600	0.2600
5	-0.1300	-0.1300	0.2600	0.2600
6	-0.2600	-0.2600	0.2600	0.2600
7	-0.2600	-0.2600	0.3900	0.3900
8	-0.2600	-0.2600	0.3900	0.3900
9	-0.2600	-0.2600	0.3900	0.3900
10	-0.2600	-0.2600	0.2600	0.2600
11	0.0000	0.0000	0.0000	0.0000
LEVEL		WIND DIRECTION= 12		
1	-0.1300	-0.1300	0.0000	0.3600
2	-0.1300	-0.1300	0.0000	0.3600
3	-0.1300	-0.1300	0.0000	0.3600
4	-0.1300	-0.1300	0.0000	0.4300
5	-0.1300	-0.1300	0.0000	0.5000
6	-0.2600	-0.2600	0.0000	0.5500
7	-0.2600	-0.2600	0.0000	0.6000
8	-0.2600	-0.2600	0.0000	0.6600
9	-0.2600	-0.2600	0.0000	0.6000
10	-0.2600	-0.2600	0.0000	0.5500
11	0.0000	0.0000	0.0000	0.0000
LEVEL		WIND DIRECTION= 13		
1	-0.3900	-0.1300	-0.3900	0.3900
2	-0.3900	-0.1300	-0.3900	0.3900
3	-0.3900	-0.1300	-0.3900	0.3900

4	-0.5200	-0.1300	-0.5200	0.4500
5	-0.5200	-0.1300	-0.5200	0.5200
6	-0.5200	-0.2600	-0.5200	0.5800
7	-0.6500	-0.2600	-0.6500	0.6500
8	-0.6500	-0.2600	-0.6500	0.7100
9	-0.6500	-0.2600	-0.6500	0.7800
10	-0.6500	-0.2600	-0.6500	0.5800
11	0.0000	0.0000	0.0000	0.0000

LEVEL		WIND DIRECTION= 14		
1	0.0000	-0.1300	-0.1300	0.3600
2	0.0000	-0.1300	-0.1300	0.3600
3	0.0000	-0.1300	-0.1300	0.3600
4	0.0000	-0.1300	-0.1300	0.4300
5	0.0000	-0.1300	-0.1300	0.5000
6	0.0000	-0.2600	-0.2600	0.5500
7	0.0000	-0.2600	-0.2600	0.6000
8	0.0000	-0.2600	-0.2600	0.6600
9	0.0000	-0.2600	-0.2600	0.6000
10	0.0000	-0.2600	-0.2600	0.5500
11	0.0000	0.0000	0.0000	0.0000

LEVEL		WIND DIRECTION= 15		
1	0.1300	-0.1300	-0.1300	0.1300
2	0.1300	-0.1300	-0.1300	0.1300
3	0.2600	-0.1300	-0.1300	0.2600
4	0.2600	-0.1300	-0.1300	0.2600
5	0.2600	-0.1300	-0.1300	0.2600
6	0.2600	-0.2600	-0.2600	0.2600
7	0.3900	-0.2600	-0.2600	0.3900
8	0.3900	-0.2600	-0.2600	0.3900
9	0.3900	-0.2600	-0.2600	0.3900
10	0.2600	-0.2600	-0.2600	0.2600
11	0.0000	0.0000	0.0000	0.0000

LEVEL		WIND DIRECTION= 16		
1	0.3600	-0.1300	-0.1300	0.0000
2	0.3600	-0.1300	-0.1300	0.0000
3	0.3600	-0.1300	-0.1300	0.0000
4	0.4300	-0.1300	-0.1300	0.0000
5	0.5000	-0.1300	-0.1300	0.0000

*****PRESSURE DIFFERENCES (INCHES OF WATER, REFERENCED TO FLOOR PRESSURE)*****

LEVEL	OUTSIDE SIDE 1	OUTSIDE SIDE 2	OUTSIDE SIDE 3	OUTSIDE SIDE 4	LEVEL ABOVE	SHAFT 1	SHAFT 2	SHAFT 3	SHAFT 4	SHAFT 5
1	0.1127	0.2631	0.1127	0.1628	-0.0380	-0.0506	-0.0506			
2	0.1097	0.2601	0.1097	0.1599	-0.0051	-0.0126	-0.0126			
3	0.0739	0.2243	0.0739	0.1241	-0.0037	-0.0075	-0.0075			
4	0.0116	0.1986	0.0116	0.0868	-0.0026	-0.0039	-0.0039			
5	-0.0267	0.1738	-0.0267	0.0485	-0.0012	-0.0012	-0.0012			
6	-0.0664	0.1456	-0.0664	-0.0163	-0.0004	-0.0001	-0.0000			
7	-0.1320	0.1186	-0.1320	-0.0568	-0.0010	0.0003	0.0004			
8	-0.1720	0.0902	-0.1720	-0.0968	-0.0044	0.0013	0.0013			
9	-0.2085	0.0672	-0.2085	-0.1333	-0.1304	0.0057	0.0057			
10	-0.1191	0.1181	-0.1191	-0.0439	0.0784	0.1361	0.1361			
11	-0.1008	-0.1008	-0.1008	-0.1008	0.0000	0.0577	0.0577			

......TOP VENT......	0.16	0.16
......BOTTOM VENT.....	-0.16	-0.16

....VENT PRESSURE DIFFERENCES ARE RELATIVE TO OUTSIDE AT THAT LEVEL....

****VOLUME FLOW RATE (SCFM)****

LEVEL	OUTSIDE SIDE 1 (1)	OUTSIDE SIDE 2 (1)	OUTSIDE SIDE 3 (1)	OUTSIDE SIDE 4 (1)	LEVEL ABOVE (2)	SHAFT 1 (3)	SHAFT 2 (3)	SHAFT 3 (3)	SHAFT 4 (3)	SHAFT 5 (3)
1	1681.0	870.5	1681.0	633.8	584.8	1079.8	5400.0			
2	488.6	863.1	488.6	626.9	214.5	539.2	2697.3			
3	376.5	782.5	376.5	529.7	181.6	416.5	2080.9			
4	110.8	722.5	110.8	418.3	153.8	299.5	1491.7			
5	-192.3	661.0	-192.3	285.0	103.9	169.6	843.1			
6	-350.8	588.1	-350.8	-138.9	60.3	35.1	157.4			
7	-552.0	513.4	-552.0	-316.5	93.1	-88.8	-450.8			
8	-658.1	428.4	-658.1	-449.8	200.2	-173.1	-868.9			
9	-747.1	353.3	-747.1	-555.5	1083.6	-362.8	-1815.4			
10	-2455.1	2441.1	-2455.1	-1270.7	0.0	-1770.8	-885.4			
11	-2198.9	-2198.9	-2198.9	-2198.9	0.0	-144.2	-8651.3			
......TOP VENT..(4).						0.0	0.0			
.....BOTTOM VENT..(4).						0.0	0.0			
....SUM OF FLOWS....										
+VE	2657.	8224.	2657.	2494.		2540.	12670.			
-VE	-7154.	-2199.	-7154.	-4930.		-2540.	-12672.			

*****SIGN CONVENTIONS*****

(1) + INDICATES FLOW FROM OUTSIDE TO FLOOR AREA
(2) + INDICATES FLOW FROM FLOOR SPACE TO FLOOR ABOVE
(3) + INDICATES FLOW FROM FLOOR SPACE TO SHAFT
(4) + INDICATES FLOW FROM OUTSIDE TO SHAFT(THROUGH VENT OPENING)

LEVEL	INFILTRATION THROUGH WALLS
1	4866.
2	2467.
3	2065.
4	1362.
5	946.
6	588.
7	513.
8	428.
9	353.
10	2441.
11	0.

TOTAL= 16031.

....NUMBER OF ITERATIONS = 6.....

....NUMBER OF UNCONVERGED TERMS= 0

APPENDIX C

PROGRAM LISTING

```
C                MAIN PROGRAM (INFILTRATION)
C
C                TO CALCULATE INFILTRATION FLOW RATES FOR
C                GIVEN OUTDOOR TEMPERATURES AND WIND SPEEDS AND
C                DIRECTIONS
C
      IMPLICIT REAL*8(A-H,O-Z),INTEGER*4(I-N)
      COMMON/INARG/TEMP,WP(25,4),ACPF(25),FANSH(8)
      COMMON/BKARG/NN,JJ,ITERM,KOUNT,F(25,13),FTV(8),FBV(8),C(33)
      COMMON/INPX/H(25),EA(25,13),X(13),TV(8),BV(8),PRESX(25,13),ITV(8)
     1          ,JTV(8),IBV(8),JBV(8)
      DIMENSION WPCOEF(16,25,4)
C     .....ASSIGN INPUT/OUTPUT DEVICE NUMBERS.....
      IIN=1
      IOUT=3
      CALL INPUT(IIN,IOUT)
C          READ WIND PRESSURE COEFFICIENTS
      DO 5 K=1,16
      DO 4 I=1,NN
      READ (IIN,100)(WPCOEF(K,I,J),J=1,4)
    4 CONTINUE
    5 CONTINUE
C          WRITE WIND PRESSURE COEFICIENTS
      WRITE (IOUT,199)
      WRITE (IOUT,200)
      DO 7 K=1,16
      WRITE (IOUT,201) K
      DO 6 I=1,NN
      WRITE (IOUT,202) I,(WPCOEF(K,I,J),J=1,4)
    6 CONTINUE
    7 CONTINUE
C          READ TEMPERATURE AND WIND
    9 READ (IIN,101,END=99) TEMP,WV,IDIR
C          CALCULATE WIND VELOCITY PRESSURE
      VP=.000482*WV*WV
C          CALCULATE WIND PRESSURES ON BUILDING
      DO 12 J=1,4
```

```
      DO 11 I=1,NN
      WP(I,J)=VP*WPCOEF(IDIR,I,J)
   11  CONTINUE
   12  CONTINUE
C          WRITE TEMPERATURE, WIND, AND PRESSURES
      WRITE (IOUT,207) TEMP
      WRITE (IOUT,208) WV,IDIR
      WRITE (IOUT,204)
      WRITE(IOUT,205)
      DO 20 I=1,NN
      WRITE (IOUT,206)  I,H(I),WP(I,1),WP(I,2),WP(I,3),WP(I,4),ACPF(I)
   20   CONTINUE
C          CALCULATE INFILTRATION
      CALL INFILT (IOUT)
C          OUTPUT INFILTRATION
      CALL OUT1 (IOUT)
      CALL OUT2 (IOUT)
C          TOTAL INFILTRATION THROUGH WALLS
      TFLT=0.
      WRITE (IOUT,209)
      DO 50 I=1,NN
      FLT=0.
      DO 40 J=1,4
      IF (F(I,J)) 40,40,30
   30 FLT=FLT+F(I,J)
   40 CONTINUE
      WRITE (IOUT,210) I,FLT
      TFLT=TFLT+FLT
   50 CONTINUE
      WRITE (IOUT,211) TFLT
      WRITE (IOUT,3001)  KOUNT
      WRITE(IOUT,3002)  ITERM
      GO TO 9
   99  STOP
  100  FORMAT (4F6.3)
  101  FORMAT (2F8.1,I8)
  199 FORMAT ('1',20X,'WIND PRESSURE COEFICIENTS')
  200 FORMAT ('0',15X,'SIDE 1',6X,'SIDE 2', 6X,'SIDE 3',6X,'SIDE 4'/)
```

```
 201     FORMAT (1X,'LEVEL',22X,'WIND DIRECTION=',I3)
 202     FORMAT (1X,I3,6X,4F12.4)
 204    FORMAT (///,1X,'FLOOR',8X,'FLOOR HEIGHT',8X,'WIND SIDE 1',
     1          5X,'WIND SIDE 2',7X,'WIND SIDE 3',7X,'WIND SIDE 4'
     2           ,7X,'A/C/PRESS. FLOW')
 205    FORMAT (17X,'(FT)',1X,4(10X,'(INCHES)'),15X,'(SCFM)')
 206    FORMAT (3X,I2,11X,F6.1,4(11X,F8.5),11X,F8.0)
 207    FORMAT ('1',40X,'O.A. TEMPERATURE=',F5.0,'    (DEGREES F.)')
 208    FORMAT (/////,25X,'WIND SPEED=',F4.0,5X,'DIRECTION=',I3)
 209   FORMAT('1','LEVEL',15X,'INFILTRATION'/24X,'THROUGH'/25X,' WALLS'/)
 210   FORMAT (2X,I2,14X,F12.0)
 211   FORMAT ('0','TOTAL=',F12.0)
3001    FORMAT ('0',20X,'....NUMBER OF ITERATIONS =',I4,'.....')
3002    FORMAT (////20X,'....NUMBER OF UNCONVERGED TERMS=',I4)
        END
```

```
      SUBROUTINE INPUT(IIN,IOUT)
C
C     INPUT ROUTINE FOR AIR INFILTRATION PROGRAM
C
C             INPUTS FROM FORTRAN DEVICE NUMBER IIN INTO COMMON
C             LISTS INPUT INFORMATION ON FORTRAN DEVICE NUMBER IOUT
C
C
C
C     INPUTS ARE AS FOLLOWS...
C                  NN -NUMBER OF LEVELS
C                  JJ -NUMBER OF VERTICAL SHAFTS
C                  H -LEVEL HEIGHTS (FT)
C                  ACPF -NET AIR SUPPLIED BY A/C SYSTEM (SUPPLY-RETURN)
C                        FOR PRESSURIZATION (SCFM)
C                  EA -LEAKAGE COEFICIENTS (1000 SCFM/INCH)
C                  X -FLOW EXPONENT
C                  BV -LEAKAGE COEFICIENT OF BOTTOM VENT OPENING
C                  TV -LEAKAGE COEFICIENT OF TOP VENT OPENING
C                  ITV -LEVEL AT WHICH TOP VENT OPENING OCCURS
C                  IBV -LEVEL AT WHICH BOTTOM VENT OPENING OCCURS
C                  JBV -SIDE OF BUILDING AT WHICH BOTTOM VENT OCCURS
C                  JTV -SIDE OF BUILDING AT WHICH TOP VENT OCCURS
C                  FANSH -NET AIR SUPPLIED TO SHAFT FOR PRESSURIZATION
C
C
C
C  ***DIMENSIONS ARE FOR MAXIMUM OF 25 LEVELS AND 8 SHAFTS***
C
      IMPLICIT REAL*8(A-H,O-Z),INTEGER*4(I-N)
      COMMON/INARG/TEMP,WP(25,4),ACPF(25),FANSH(8)
      COMMON/BKARG/NN,JJ,ITERM,KOUNT,F(25,13),FTV(8),FBV(8),C(33)
      COMMON/INPX/H(25),EA(25,13),X(13),TV(8),BV(8),PRESX(25,13),ITV(8)
     1            ,JTV(8),IBV(8),JBV(8)
C
C
      READ (IIN,100) NN,JJ
```

```
C
      NNJ=NN+J
      JJ5=JJ+5
C
      READ(IIN,101) (H(I),ACPF(I),I=1,NN)
C
      READ(IIN,105)  (X(J),J=1,JJ5)
C
      DØ 12 I=1,NN
      READ(IIN,103) (EA(I,J),J=1,JJ5)
   12 CØNTINUE
C
      READ (IIN,104)(FANSH(J),BV(J),IBV(J),JBV(J),TV(J),ITV(J),
     1               JTV(J),J=1,JJ)
C
C
C
C     WRITE INPUT INFØRMATIØN
C
      WRITE (IØUT,200) NN,JJ
C
C
      WRITE (IØUT,201)
      WRITE (IØUT,190)
      WRITE (IØUT,191)
      WRITE (IØUT,192)
      WRITE (IØUT,193)
      WRITE (IØUT,195)
      WRITE (IØUT,196)
      WRITE (IØUT,230)
      WRITE (IØUT,222)
      WRITE (IØUT,213)
      WRITE (IØUT,223) (X(J) ,J=1,JJ5)
      WRITE (IØUT,224)
C
      WRITE (IØUT,211)
      WRITE (IØUT,212)
      WRITE (IØUT,213)
```

```
      DO 18 I=1,NN
      WRITE (IOUT,214) I,(EA(I,J),J=1,JJ5)
 18   CONTINUE
C
      WRITE (IOUT,215)
      WRITE (IOUT,216)
      WRITE (IOUT,217)
      DO 20 J=1,JJ
      WRITE(IOUT,219) J,FANSH(J),BV(J),IBV(J),JBV(J),TV(J),ITV(J)
     1 ,JTV(J)
 20   CONTINUE
C
      AVKS= .1920*.074367/2.
      AVKJ=-.1920*.074367
      NN1=NN-1
C           CALCULATE RHO*H BETWEEN LEVELS
      DO 31 I=1,NN1
      PRESX(I,5)=(H(I)+H(I+1))*AVKS
 31   CONTINUE
C           CALCULATE MID-LEVEL HEIGHT ABOVE GROUND
      HX=H(1)/2.
      H(1)=HX
      DO 32 I=2,NN
      HT=H(I-1)+HX
      HX=H(I)/2.
      H(I)=HT+HX
 32   CONTINUE
C           CALCULATE RHO*H IN SHAFTS
      DO 34 J=1,JJ
      J5=J+5
      DO 33 I=1,NN
      PRESX(I,J5)=H(I)*AVKJ
 33   CONTINUE
 34   CONTINUE
C
      RETURN
C
 100  FORMAT (2I4)
```

```
  101     FORMAT (F8.4,F40.1)
  103     FORMAT (13F6.2)
  104     FORMAT (F12.2,F8.4,2I4,F8.4,2I4)
  105     FORMAT (13F6.5)
C
  190     FORMAT ('0',35X,'FLOW EQUATION IS...F=COEF*(DELTA P)**X')
  191     FORMAT ('0',30X,'WHERE:')
  192     FORMAT (35X,'F =FLOW RATE (CFM)')
  193     FORMAT (35X,'COEF =LEAKAGE COEFICIENT (1000 CFM/INCH')
  195     FORMAT (35X,'DELTA P =PRESSURE DIFFERENTIAL (INCHES OF WATER)')
  196     FORMAT (35X,'X =FLOW EXPONENT')
  200     FORMAT('1',40X,'SOLUTION FOR ',I4,' LEVELS, ',I4,' SHAFTS')
  201     FORMAT ('1',40X,'********INPUT PARAMETERS********')
  211     FORMAT ('1',40X,'****LEAKAGE COEFICIENTS=(1000 SCFM/INCH)****')
  212     FORMAT ('0','LEVEL',2X,4('OUTSIDE',3X),
      1          'LEVEL',8(5X,'SHAFT'))
  213     FORMAT (8X,'SIDE 1',4X,'SIDE 2',4X,'SIDE 3',4X,'SIDE 4',4X,
      1          'ABOVE',7X,'1',9X,'2',9X,'3',9X,'4',9X,'5',9X,'6',9X,'7',
      1          9X,'8')
  214     FORMAT (1X,I2,13(2X,F8.3))
  215     FORMAT ('1',40X,'*****SHAFT VENTS AND PRESSURIZATION*****')
  216     FORMAT (1H0,1X,'SHAFT',10X,'PRESS FLOW',16X,'****BOTTOM VENT****'
      1          22X,'****TOP VENT*****')
  217     FORMAT (19X,'(SCFM)',11X,2(6X,'COEF',9X,'LEVEL',8X,'SIDE'))
  219     FORMAT (1X,I4,7X,F12.2,10X,F12.2,2(8X,I4),F12.2,2(8X,I4))
  222     FORMAT ('0',7X,4('OUTSIDE',3X),
      1          'LEVEL',8(5X,'SHAFT'))
  223     FORMAT (3X,13(2X,F8.3))
  224     FORMAT (/////40X,'VALUE OF X FOR SHAFT VENTS IS 0.5 ')
  230     FORMAT (/////50X,'***** VALUES OF X *****')
          END
```

```
      SUBROUTINE INFILT (IDIAG)
C
C******************************PURPOSE*****************************
C
C       PROGRAM TO COMPUTE AIR FLOWS AND PRESSURES FOR A BUILDING
C
C       FLOWS AND PRESSURES MAY BE DUE TO ANY COMBINATION OF
C                   STACK EFFECT
C                   WIND EFFECT
C                   NET AIR SUPPLIED BY A/C SYSTEM FOR PRESSURIZATION
C
C
C*****************************************************************
C
C             CALLING SEQUENCE:
C                    ENTER WITH INPUT VALUES IN COMMON BLOCKS /INPX/ AND
C                    IDIAG = FORTRAN DEVICE NUMBER FOR ERROR MESSAGE OUT
C
C
C********************ASSUMPTIONS AND LIMITATIONS*********************
C
C       AIR FLOW EQUATION USED IS      F=K*(DELTA P)**X
C                   WHERE    F= VOLUME FLOW RATE
C                            K= LEAKAGE COEFFICIENT
C                            X= LEAKAGE EXPONENT
C                            DELTA P= PRESSURE DIFFERENTIAL
C
C       FRICTIONAL RESISTANCE OF VERTICAL SHAFTS IS NEGLECTED
C
C       NET AIR FLOW SUPPLIED BY A/C SYSTEM FOR PRESSURIZATION IS ASSUMED
C       CONSTANT  (INDEPENDANT OF THE LEVEL PRESSURES)
C
C       PRESSURES ARE ASSUMED UNIFORM THROUGHOUT THE LEVEL AREA (NO
C       PROVISION IS MADE FOR VESTIBULES OR COMPARTMENTIZATION OF LEVELS)
C
C       PROGRAM IS DIMENSIONED FOR A MAXIMUM OF 25 LEVELS AND 8 SHAFTS
C
```

```
C*******************************************************************
C
C
C
C*******************USE WITH THE FOLLOWING SUBROUTINES***************
C
C                    -LINIZE
C
C                    -SIMG
C
C*******************************************************************
C
C
C
C************************* NOTATION *******************************
C
C       PRESSURES:   REFERENCED TO OUTSIDE LEFT AT GROUND LEVEL
C           PRESX(I,1)    -PRESSURE OUTSIDE WALL #1 AT ITH LEVEL
C           PRESX(I,2)    -PRESSURE OUTSIDE WALL #2 AT ITH LEVEL
C           PRESX(I,3)    -PRESSURE OUTSIDE WALL #3 AT ITH LEVEL
C           PRESX(I,4)    -PRESSURE OUTSIDE WALL #4 AT ITH LEVEL
C           PRESX(I,5)    -PRESSURE DIFFERENCE DUE TO COLUMN HEIGHT
C                          BETWEEN LEVEL I AND I+1
C           PRESX(I,J+3)  -PRESSURE DIFFERENCE BETWEEN SHAFT J AT ITH
C                          LEVEL AND BOTTOM OF SHAFT J
C           P(I)          -PRESSURE AT ITH LEVEL
C           P(NN+J)       -PRESSURE AT BOTTOM OF SHAFT J
C
C       FLOWS:
C           F(I,1)        -FLOW FROM OUTSIDE WALL #1 TO LEVEL I
C           F(I,2)        -FLOW FROM OUTSIDE WALL #2 TO LEVEL I
C           F(I,3)        -FLOW FROM OUTSIDE WALL #3 TO LEVEL I
C           F(I,4)        -FLOW FROM OUTSIDE WALL #4 TO LEVEL I
C           F(I,5)        -FLOW FROM LEVEL I TO LEVEL I+1
C           F(I,J+5)      -FLOW FROM LEVEL I TO SHAFT J
C           FBV(J)        -FLOW INTO SHAFT J THROUGH BOTTOM VENT
C
C           FTV(J)        -FLOW INTO SHAFT J THROUGH TOP VENT
```

```
C          ACPF(I)        =FLOW SUPPLIED BY A/C SYSTEM TO LEVEL I
C          FANSH          =FLOW SUPPLIED TO SHAFT J BY A/C SYSTEM
C
C      LEAKAGE CONSTANTS:
C          EA(I,1)        =COEFICIENT WALL #1 AT ITH LEVEL
C          EA(I,2)        =COEFICIENT WALL #2 AT ITH LEVEL
C          EA(I,3)        =COEFICIENT WALL  3 AT ITH LEVEL
C          EA(I,4)        =COEFICIENT WALL  4 AT ITH LEVEL
C          EA(I,5)        =COEFICIENT FROM LEVEL I TO LEVEL I+1
C          EA(I,J+5)      =COEFICIENT FROM LEVEL I TO SHAFT J
C          TV(J)          =COEFICIENT TOP VENT SHAFT J
C          BV(J)          =COEFICIENT BOTTOM VENT SHAFT J
C          X(J)           =EXPONENT
C
C      INTEGERS:
C
C          NN             =NUMBER OF LEVELS
C          JJ             =NUMBER OF SHAFTS
C          IBV            =LOCATION OF BOTTOM VENT (LEVEL)
C          ITV            =LOCATION OF TOP VENT (LEVEL)
C          JBV            =SIDE AT WHICH BOTTOM VENT OCCURS (1,2,3 OR 4)
C          JTV            =SIDE AT WHICH TOP VENT OCCURS (1,2,3 OR 4)
C
C
C
C************************************************************************
C
      IMPLICIT REAL*8(A-H,O-Z),INTEGER*4(I-N)
      COMMON/INARG/TEMP,WP(25,4),ACPF(25),FANSH(8)
      COMMON/BKARG/NN,JJ,ITERM,KOUNT,F(25,13),FTV(8),FBV(8),C(33)
      COMMON/INPX/H(25),EA(25,13),X(13),TV(8),BV(8),PRESX(25,13),ITV(8)
     1         ,JTV(8),IBV(8),JBV(8)
      DIMENSION  G(25,13),PL(25,13),GTV(8),PTVL(8),GBV(8),PBVL(8)
      DIMENSION A(33,33),AA(1089),PLL(325),P(33)
      EQUIVALENCE (PL(1,1), PLL(1))
      EQUIVALENCE (A(1,1),AA(1))
      EQUIVALENCE (P(1),C(1))
C
```

```
      DATA PO,IEND/.500,0/
C
      ERROR=.0001
C      ....ZERO MATRIX A
      DO 1 K=1,1089
      AA(K)=0.00
    1 CONTINUE
C
    3 CONTINUE
C           CALCULATE OUTSIDE PRESSURES
      RHO=39.76578000/(TEMP+459.7200)
      AVKR=-.1920*RHO
      DO 5 J=1,4
      DO 4 I=1,NN
      PRESX(I,J)=AVKR*H(I)+WP(I,J)
    4 CONTINUE
    5 CONTINUE
C
C     ....INITIAL LINEAR APPROXIMATION....
C     ....STRAIGHT LINE THRU ZERO AND POINT CORRESPONDING TO PINIT....
      NNJJ=NN+JJ
      NNJJ2=NNJJ*NNJJ
      JJ5=JJ+5
      PPI=PO**(-0.500)
      DO 20 J=1,JJ5
      DO 10 I=1,NN
      G(I,J)= (EA(I,J))*PPI
   10 CONTINUE
   20 CONTINUE
      DO 30 J=1,JJ
      GTV(J)=(TV(J))*PPI
      GBV(J)=(BV(J))*PPI
   30 CONTINUE
C    .....SET PL EQUAL TO ZERO.....
      DO 40 K=1,325
      PLL(K)=0.00
   40 CONTINUE
      DO 50 K=1,8
```

```
      PTVL(K)=0.00
      PBVL(K)=0.00
 50   CONTINUE
C
 60   CONTINUE
      KOUNT=0
C
C
 70   CONTINUE
C
C     ....CALCULATION OF ELEMENTS OF MATRIX A AND VECTOR C.....
C
      JJ5=JJ+5
      NNJJ=NN+JJ
C
C     ....ELEMENTS OF MATRIX A.....
C
C     ....1ST ROW....
      A(1,1)=0.0
      DO 11 J=1,JJ5
      A(1,1) = A(1,1) - G(1,J)
 11   CONTINUE
      A(1,2) = G(1,5)
      DO 21 J=1,JJ
      NNJ=NN+J
      J5=J+5
      A(1,NNJ) =G(1,J5)
 21   CONTINUE
C
C     ....ROWS 2 TO NN-1......
      NN1=NN-1
      DO 51 I=2,NN1
      A(I,I-1) = G(I-1,5)
      A(I,I+1) = G(I,5)
      A(I,I) = -G(I-1,5)
      DO 31 J=1,JJ5
      A(I,I) = A(I,I) - G(I,J)
 31   CONTINUE
```

```
      DØ 41  J=1,JJ
      NNJ=NN+J
      J5=J+5
      A(I,NNJ)=G(I,J5)
 41   CØNTINUE
 51   CØNTINUE
C
C     ....RØW NN.....
      A(NN,NN-1) = G(NN-1,5)
      A(NN,NN) = -G(NN-1,5)
      DØ 61 J=1,4
      A(NN,NN) = A(NN,NN) - G(NN,J)
 61   CØNTINUE
      DØ 71 J=6,JJ5
      A(NN,NN) = A (NN,NN) - G(NN,J)
 71   CØNTINUE
      DØ 81  J=1,JJ
      NNJ=NN+J
      J5=J+5
      A(NN,NNJ)=G(NN,J5)
 81   CØNTINUE
C
C     ....RØW NN+J....
      DØ 101 J=1,JJ
      NNJ=NN+J
      J5=J+5
      A(NNJ,NNJ)=0.0
      DØ 91 I=1,NN
      A(NNJ,I)=G(I,J5)
      A(NNJ,NNJ)=A(NNJ,NNJ)-G(I,J5)
 91   CØNTINUE
      A(NNJ,NNJ)=A(NNJ,NNJ) -GBV(J) -GTV(J)
101   CØNTINUE
C
C     ....ELEMENTS ØF VECTØR C....
C
      DØ 111 K=1,NN
      C(K)=-.001*ACPF(K)
```

```
111    CONTINUE
C
C      ....1ST ROW....
       DO 121 J=1,4
       C(1) = C(1) - G(1,J)*(PRESX(1,J) + PL(1,J))
121    CONTINUE
       DO 131 J=5,JJ5
       C(1) = C(1) - G(1,J) * (PRESX(1,J) - PL(1,J))
131    CONTINUE
C
C      ....ROWS 2 TO NN-1....
       DO 161 I=2,NN1
       DO 141  J=1,4
       C(I)= C(I) - G(I,J) *(PRESX(I,J) + PL(I,J))
141    CONTINUE
       DO 151 J=5,JJ5
       C(I) = C(I) -G(I,J)*(PRESX(I,J) - PL(I,J))
151    CONTINUE
       C(I)=C(I)+G(I-1,5)*(PRESX(I-1,5)-PL(I-1,5))
161    CONTINUE
C
C      .....ROW NN....
       DO 171  J=1,4
       C(NN) =C(NN) - G(NN,J)*(PRESX(NN,J) +PL(NN,J))
171    CONTINUE
       DO 181 J=6,JJ5
       C(NN) = C(NN) - G(NN,J)*(PRESX(NN,J) - PL(NN,J))
181    CONTINUE
       C(NN) = C(NN) +G(NN-1,5) * (PRESX(NN-1,5) - PL(NN-1,5))
C
C      ....ROW NN+J....
       DO 201 J=1,JJ
       NNJ=NN+J
       IB=IBV(J)
       JB=JBV(J)
       J5=J+5
       C(NNJ)=GBV(J)*(PRESX(IB,J5)-PRESX(IB,JB)-PBVL(J))-.001*FANSH(J)
       IT=ITV(J)
```

```
      JT=JTV(J)
      C(NNJ)=C(NNJ)+GTV(J)*(PRESX(IT,J5)-PRESX(IT,JT)-PTVL(J))
      DO 191 I=1,NN
      C(NNJ)=C(NNJ)+G(I,J5)*(PRESX(I,J5)-PL(I,J5))
191   CONTINUE
201   CONTINUE
C
C
C     ...COMPRESS MATRIX A INTO AA STORED BY COLUMNS....
      DO 211 J=1,NNJJ
      JAA=J-1
      IAA=JAA*NNJJ
      DO 211 I=1,NNJJ
      IIAA=I+IAA
      AA(IIAA)=A(I,J)
211  CONTINUE
C
      CALL SIMQ (AA,C,NNJJ,KS)
C     ..PRESSURES P(I) ARE RETURNED IN C...
      IF (KS) 1000,221,1100
221   CONTINUE
C
C
C    .....CALCULATE FLOW FUNCTIONS FOR LINEAR MODEL....
C
      ITERM = 0
C
      DO 22 J=1,4
      DO 12 I=1,NN
      FX = G(I,J) * (PRESX(I,J)-P(I) + PL(I,J))
      IF (DABS(FX-F(I,J))-ERROR) 12,12,2
  2   F(I,J) =FX
      CALL LINIZF (FX,EA(I,J),G(I,J),PL(I,J),X(J))
      ITERM =ITERM +1
 12   CONTINUE
 22   CONTINUE
C
      NN1=NN-1
```

```
C
      DO 42 I=1,NN1
      FX= G(I,5)*(P(I)-P(I+1) +PL(I,5) -PRESX(I,5))
      IF (DABS(FX-F(I,5))-ERROR) 42,42,32
 32   F(I,5) =FX
      CALL LINIZE (FX,EA(I,5),G(I,5),PL(I,5),X(5))
      ITERM =ITERM +1
 42   CONTINUE
C
      DO 72 J=1,JJ
      NNJ=NN+J
      J5=J+5
      DO 62 I=1,NN
      FX= G(I,J5)*(P(I)-PRESX(I,J5)-P(NNJ) +PL(I,J5))
      IF (DABS(FX-F(I,J5))-ERROR) 62,62,52
 52   F(I,J5) = FX
      CALL LINIZE (FX,EA(I,J5),G(I,J5),PL(I,J5),X(J5))
      ITERM =ITERM +1
 62   CONTINUE
 72   CONTINUE
C
      XVENT=0.500
C
      DO 122 J=1,JJ
      NNJ=NN+J
      IB=IBV(J)
      JB=JBV(J)
      IT=ITV(J)
      JT=JTV(J)
      J5=J+5
      FX= GBV(J)*(PRESX(IB,JB) -P(NNJ)-PRESX(IB,J5)+PBVL(J))
      IF (DABS(FX-FBV(J))-ERROR)  92,92,82
 82   FBV(J) = FX
      CALL LINIZE (FX,BV(J),GBV(J),PBVL(J),XVENT)
      ITERM =ITERM +1
 92   CONTINUE
      FX = GTV(J)*(PRESX(IT,JT)-P(NNJ)-PRESX(IT,J5)+PTVL(J))
      IF (DABS(FX-FTV(J))-ERROR) 112,112,102
```

```
102    FTV(J) = FX
       CALL LINIZE (FX,TV(J),GTV(J),PTVL(J),XVENT)
       ITERM = ITERM + 1
112    CØNTINUE
122    CØNTINUE
C
       KØUNT =KØUNT +1
       IF (KØUNT-50) 800,800,1000
800    IF(ITERM) 900,1000,900
900    DØ 950 K=1,NNJJ2
       AA(K)=0.00
950    CØNTINUE
       GØ TØ 70
C
1000   CØNTINUE
C          ....FLØWS IN CFM....
       DØ 1010 J=1,JJ5
       DØ 1010 I=1,NN
       F(I,J)=F(I,J)*1000.
1010   CØNTINUE
       DØ 1020 J=1,JJ5
       FTV(J)=FTV(J)*1000.
       FBV(J)=FBV(J)*1000.
1020   CØNTINUE
       RETURN
C
1100   WRITE (IDIAG,3000)
1999   STØP
3000   FØRMAT(1X,'SINGULAR MATRIX-NØ SØLUTIØN GIVEN BY SIMQ')
       END
```

```
      SUBROUTINE SIMQ( A,B,N,KS)
C
C
C     THIS SUBROUTINE IS FOR USE WITH THE AIR FLOW BUILDING MODEL PROGR
C     THIS SUBROUTINE SOLVES THE LINEAR SIMULTANEOUS EQUATIONS
C
      IMPLICIT REAL*8(A-H,O-Z),INTEGER*4(I-N)
      DIMENSION A(1),B(1)
C     FORWARD SOLUTION
      KS=0
      JJ=-N
      DO 65 J=1,N
      JY=J+1
      JJ=JJ+N+1
      BIGA=0.00
      IT=JJ-J
      DO 30 I=J,N
C     SEARCH FOR MAXIMUM COEFFICIENT IN COLUMN
      IJ=IT+I
      IF(A(IJ)) 2,30,4
    2 ABSA=-A(IJ)
      GO TO 5
    4 ABSA=A(IJ)
    5 IF(BIGA) 6,20,8
    6 BIGA=-BIGA
    8 DIF=BIGA-ABSA
      IF(DIF) 20,30,30
   20 IMAX=I
   25 BIGA=ABSA
   30 CONTINUE
      ITIM=IT+IMAX
      BIGA=A(ITIM)
C          TEST FOR SINGULAR MATRIX
      IF(BIGA) 40,35,40
   35 KS=1
      RETURN
C     INTERCHANGE ROWS IF NECESSARY
```

```
   40   I1=J+N*(J-2)
        IT=IMAX-J
        DØ 50 K=J,N
        I1=I1+N
        I2=I1+IT
        SAVE =A(I1)
        A(I1)=A(I2)
        A(I2)=SAVE
C       DIVIDE EQUATIØN BY LEADING CØEFFICIENT
   50   A(I1)=A(I1)/BIGA
        SAVE=B(IMAX)
        B(IMAX)=B(J)
        B(J)=SAVE/BIGA
C       ELIMINATE NEXT VARIABLE
        IF(J-N) 55,70,55
   55   IQS=N*(J-1)
        DØ 65 IX=JY,N
        IXJ=IQS+IX
        IT=J-IX
        DØ 60 JX=JY,N
        IXJX=N*(JX-1)+IX
        JJX=IXJX+IT
   60   A(IXJX)=A(IXJX)-(A(IXJ)*A(JJX))
   65   B(IX)=B(IX)-(B(J)*A(IXJ))
C       BACK SØLUTIØN
   70   NY=N-1
        IT=N*N
        DØ 80 J=1,NY
        IA=IT-J
        IB=N-J
        IC=N
        DØ 80 K=1,J
        B(IB)=B(IB)-A(IA)*B(IC)
        IA=IA-N
   80   IC=IC-1
        RETURN
        END
```

```
      SUBROUTINE LINIZE(FINIT,CONS,SLOPE,PX,XX)
C
      IMPLICIT REAL*8(A-H,O-Z),INTEGER*4(I-N)
      FMIN=.00005
      IF(XX-.050) 20,2,1
    1 IF(XX-1.00) 2,9,20
    2 IF (CONS) 20,8,3
    3 IF (FINIT-FMIN) 5,7,4
    4 PINIT=(FINIT/CONS)**(1.00/XX)
      SLOPE=XX*CONS*PINIT**(XX-1.00)
      PX=FINIT/SLOPE-PINIT
      GO TO 11
    5 IF (FINIT+FMIN) 6,7,7
    6 PINIT=-(-FINIT/CONS)**(1.00/XX)
      SLOPE=XX*CONS*(-PINIT)**(XX-1.00)
      PX=FINIT/SLOPE-PINIT
      GO TO 11
    7 PMIN=(FMIN/CONS)**(1.00/XX)
      SLOPE=FMIN/PMIN
      GO TO 10
    8 SLOPE=0.00
      GO TO 10
    9 SLOPE=CONS
   10 PX=0.00
   11 RETURN
   20 STOP
      END
```

```
      SUBROUTINE OUT1(IOUT)
C
C     THIS SUBROUTINE CALCULATES AND OUTPUTS PRESSURE DIFFERENCES
C     ON FORTRAN DEVICE NUMBER IOUT
C
C
C  ***DIMENSIONS ARE FOR MAXIMUM OF 25 FLOORS AND 8 SHAFTS***
C
      IMPLICIT REAL*8(A-H,O-Z),INTEGER*4(I-N)
      COMMON/BKARG/NN,JJ,ITERM,KOUNT,F(25,13),FTV(8),FBV(8),C(33)
      COMMON/INPX/H(25),EA(25,13),X(13),TV(8),BV(8),PRESX(25,13),ITV(8)
     1            ,JTV(8),IBV(8),JBV(8)
      DIMENSION PPX(8),DELP(25,13),DELPTV(8),DELPBV(8),P(33)
      EQUIVALENCE (P(1),C(1))
C
      JJ5=JJ+5
      NN1=NN-1
C
C
C     ...CALCULATE PRESSURE DIFFERENCES...
C
      DO 30 J=1,4
      DO 31 I=1,NN
      DELP(I,J)=PRESX(I,J)-P(I)
   31 CONTINUE
   30 CONTINUE
C
      DO 40 I=1,NN1
      DELP(I,5)=P(I+1)-P(I)+PRESX(I,5)
   40 CONTINUE
C
C     ....NO FLOOR ABOVE, SO SET DELP EQUAL TO ZERO....
      DELP(NN,5)=0.
C
      DO 50 J=1,JJ
      J5=J+5
      NNJ=NN+J
```

```
      DO 51 I=1,NN
      DELP(I,J5)=P(NNJ)+PRESX(I,J5)-P(I)
   51 CONTINUE
      ITVJ=ITV(J)
      JTVJ=JTV(J)
      IBVJ=IBV(J)
      JBVJ=JBV(J)
      DELPTV(J)=P(NNJ)+PRESX(ITVJ,J5)-PRESX(ITVJ,JTVJ)
      DELPBV(J)=P(NNJ)+PRESX(IBVJ,J5)-PRESX(IBVJ,JBVJ)
   50 CONTINUE
C
C     ...WRITE PRESSURE DIFFERENCES...
C
      WRITE (IOUT,2000)
      WRITE (IOUT,2001)
      WRITE (IOUT,2002)
      DO 60 I=1,NN
      WRITE (IOUT,101) I,(DELP(I,J),J=1,JJ5)
   60 CONTINUE
      WRITE (IOUT,2004) (DELPTV(J),J=1,JJ)
      WRITE (IOUT,2005) (DELPBV(J),J=1,JJ)
      WRITE (IOUT,2006)
      RETURN
C
  101 FORMAT (1X, I2 ,13(2X,F8.4))
 2000 FORMAT ('1',25X,'*****PRESSURE DIFFERENCES (INCHES OF WATER'
     1           ,',REFERENCED TO FLOOR PRESSURE)*****')
 2001 FORMAT ('0','LEVEL',2X,4('OUTSIDE',3X),
     1           'LEVEL',8(5X,'SHAFT'))
 2002 FORMAT (8X,'SIDE 1',4X,'SIDE 2',4X,'SIDE 3',4X,'SIDE 4',4X,
     1  'ABOVE',7X,'1',9X,'2',9X,'3',9X,'4',9X,'5',9X,'6',9X,'7',9X,'8')
 2004 FORMAT ( / 13X,'......TOP VENT......',10F10.2)
 2005 FORMAT (    11X,'......BOTTOM VENT.....',10F10.2)
 2006 FORMAT (/////20X,'....VENT PRESSURE DIFFERENCES ARE',
     1           ' RELATIVE TO OUTSIDE AT THAT LEVEL....')
      END
```

```
      SUBROUTINE OUT2(IOUT)
C
C     THIS SUBROUTINE IS FOR USE WITH THE AIR INFILTRATION PROGRAM
C
C     THIS SUBROUTINE OUTPUTS VOLUME FLOW RATES
C     ON FORTRAN DEVICE NUMBER IOUT
C
C  ***DIMENSIONS ARE FOR MAXIMUM OF 25 LEVELS AND 8 SHAFTS***
C
      IMPLICIT REAL*8(A-H,O-Z),INTEGER*4(I-N)
      COMMON/BKARG/NN,JJ,ITERM,KOUNT,F(25,13),FTV(8),FBV(8),C(33)
      COMMON/INPX/H(25),EA(25,13),X(13),TV(8),BV(8),PRESX(25,13),ITV(8)
     1            ,JTV(8),IBV(8),JBV(8)
      DIMENSION SUMPOS(13), SUMNEG(13)
C
      JJ5=JJ+5
C
      DO 30 J=1,JJ5
      SUMPOS(J)=0.00
      SUMNEG(J)=0.00
      DO 20 I=1,NN
      IF (F(I,J)) 10,15,15
   10 SUMNEG(J)=SUMNEG(J)+F(I,J)
      GO TO 20
   15 SUMPOS(J)=SUMPOS(J)+F(I,J)
   20 CONTINUE
   30 CONTINUE
      DO 90 J=1,JJ
      J5=J+5
      IF (FTV(J)) 40,50,50
   40 SUMNEG(J5)=SUMNEG(J5)+FTV(J)
      GO TO 60
   50 SUMPOS(J5)=SUMPOS(J5)+FTV(J)
   60 IF (FBV(J)) 70,80,80
   70 SUMNEG(J5)=SUMNEG(J5)+FBV(J)
      GO TO 90
   80 SUMPOS(J5)=SUMPOS(J5)+FBV(J)
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   90   CONTINUE
C
C      ...OUTPUT VOLUME FLOW....
        WRITE (IOUT,1200)
        WRITE (IOUT,1101)
        WRITE (IOUT,1102)
        WRITE (IOUT,1106)
        DO 100 I=1,NN
        WRITE (IOUT,1203) I,(F(I,J),J=1,JJ5)
  100   CONTINUE
        WRITE (IOUT,1204) (FTV(J),J=1,JJ)
        WRITE (IOUT,1205) (FBV(J),J=1,JJ)
C
C       ...WRITE SUM OF +VE AND -VE FLOWS FOR EACH COLUMN...
        WRITE (IOUT,1107)
        WRITE (IOUT,1105) (SUMPOS(J),J=1,4),(SUMPOS(J),J=6,JJ5)
        WRITE (IOUT,1108) (SUMNEG(J),J=1,4),(SUMNEG(J),J=6,JJ5)
C
        WRITE (IOUT,1109)
        WRITE (IOUT,1110)
        WRITE (IOUT,1111)
        WRITE (IOUT,1112)
        WRITE (IOUT,1113)
C
        RETURN
 1101   FORMAT ('0','LEVEL',2X,4('OUTSIDE',3X),
      1           'LEVEL',8(5X,'SHAFT'))
 1102   FORMAT (8X,'SIDE 1',5X,'SIDE 2',3X,'SIDE 3',4X,'SIDE 4',4X,
      1          'ABOVE',7X,'1',9X,'2',9X,'3',9X,'4',9X,'5',9X,'6',9X,'7',
      1          9X,'8')
 1105   FORMAT (1X,'+VE',F9.0,3F10.0,10X,8F10.0)
 1106   FORMAT (10X,'(1)',3(7X,'(1)'),6X,'(2)',8(7X,'(3)'))
 1107   FORMAT (/ 1X,'....SUM OF FLOWS....')
 1108   FORMAT ('0','-VE',F9.0,3F10.0,10X,8F10.0)
 1109   FORMAT (///10X,'*****SIGN CONVENTIONS*****')
 1110   FORMAT (10X,'(1)    + INDICATES FLOW FROM OUTSIDE TO LEVEL AREA')
 1111   FORMAT (10X,'(2)    + INDICATES FLOW FROM LEVEL SPACE TO LEVEL'
      1           ,' ABOVE')
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1112   FØRMAT (10X,'(3)    + INDICATES FLØW FRØM LEVEL SPACE TØ SHAFT')
1113   FØRMAT (10X,'(4)    + INDICATES FLØW FRØM ØUTSIDE TØ SHAFT',
     1             '(THRØUGH VENT ØPENING)')
1200   FØRMAT ('1',45X,'****VØLUME FLØW RATE (SCFM)****')
1203   FØRMAT (1X,I2,13(2X,F8.1))
1204   FØRMAT ( / 13X,'......TØP VENT..(4).',20X,8F10.1)
1205   FØRMAT (    11X,'.....BØTTØM VENT..(4).',20X,8F10.1)
       END
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