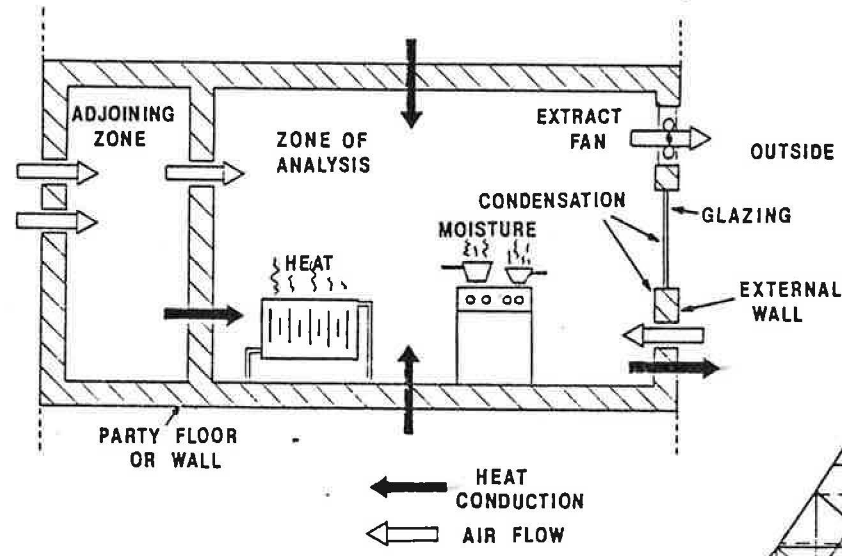
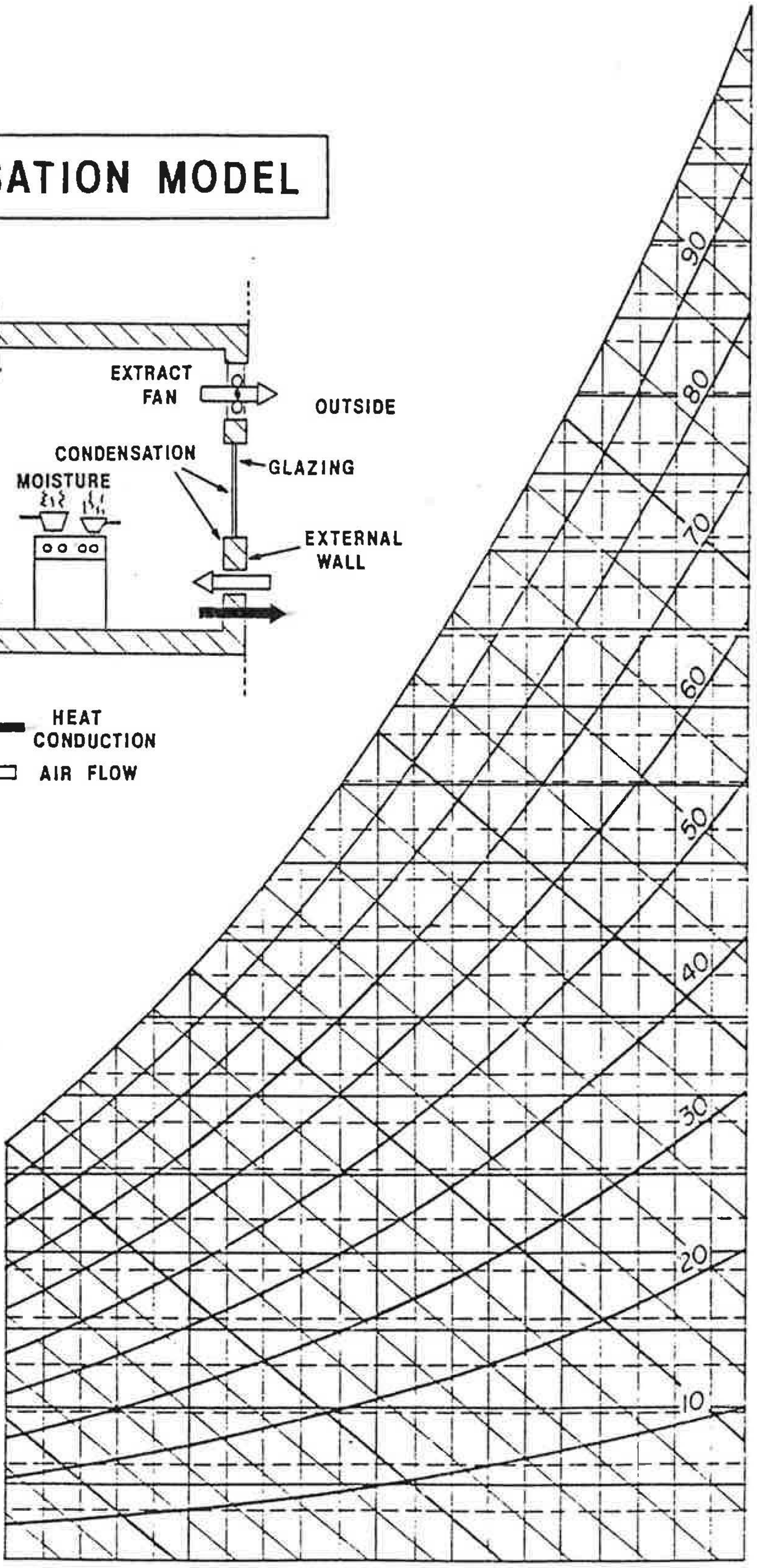
RESEARCH IN CONDENSATION & VENTILATION

BERG CONDENSATION MODEL





BERG
Built Environment Research Group

Polytechnic of Central London
PCL

THE BERG CONDENSATION MODEL

by

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THE BERG CONDENSATION MODEL

1. INTRODUCTION

BERG has considerable experience in the modelling of the thermal performance of buildings. Recent work has involved programming of a comprehensive computer model which simulates the behaviour of an occupied building to determine the incidence of surface condensation. The model will be used primarily as a research tool which will ultimately lead to the development of appropriate design tools for architects and engineers. In the immediate future it will be utilized in a variety of situations, including:

a) as a means of assessing the effects of various anti-condensation remedial measures applied to local authority dwellings (e.g. improved heating systems, insulation of external walls, double glazing, extract fans, etc.).

b) to investigate the effects of ventilation modes on condensation risk (e.g. to study the implications of draught-stripping).

c) to study the effect of various types of cold bridge on condensation risk in different types of building.

d) to investigate the influence of the type of occupancy on dwelling condensation risk, particularly with regard to low income group occupants.

The use of a model such this has certain advantages over other types research in the field of condensation (particularly environmental monitoring of occupied dwellings) for a variety of reasons:

i) gathering of data from occupied dwellings is extremely resource intensive (BERG has considerable first hand experience of this). It is also extremely difficult to ensure that: the data gathered is meaningful (e.g. in addition to monitored environmental conditions there is often insufficient information about the activities of occupants).

ii) processing of the data is fraught with difficulties and may take as long as the collection task itself.

iii) it is necessary to monitor a large number of dwellings (over fairly long periods) for results to be statistically significant, due to the wide number of parameters involved in any single study.

Nevertheless, a computer model can never be a complete substitute for experimental work which is necessary for the purposes of model validation. Experimental work also provides appropriate input data to the model and validates the theoretical assumptions made therein.

The computer implementation of the BERG model has the facility for choice between a number of simulation methods, particularly with regard to the variation of internal and external conditions:

A) **steady-state.** External conditions (e.g external temperature and relative humidity (RH), wind speed and direction) and conditions in the adjoining parts of the building are held constant; the program then calculates other variables over a sufficiently long period for steady-state to be reached.

B) **transient.** External conditions of air temperature, RH, wind speed and direction are determined from hourly weather data (Cardington UK, 1st April 1979 to 31st March 1980). Hourly values of other parameters such as heat and moisture input to the main zone are set by means of individual 24 hour profiles. The flow coefficients of openings between zones and to the outside are specified; orientation of the building is given, therefore, air flow through openings and extract fan may be calculated using a simple air-flow network model.

C) **Constant air change rate.** The use of external wind speed and direction may be suppressed and ventilation determined by setting the wind pressure driving air from outside or from the adjoining occupied zone to a constant (IWPCON is set to 1).

The program requires the compilation, linking and execution of two FORTRAN files held on the "MOLE" mainframe computer (VAX 8600, VMS operating system) under user no. COOPERP:

HUMID.FOR	main program
SETDATHUM.FOR	main data input

In addition, the following data files are required:-

HUMIN.DAT	short data file containing various parameters
weather data files:-	
T7980	temperature (°C)
RH7980	relative humidity
WS7980	wind speed (knots)
WD7980	wind direction (degrees E of N)

2. THE COMPUTER PROGRAM

The HUMID.FOR file contains a number of subprograms:-

HUMID	main program
SETWAL	intializes the finite difference wall model
ROOM	calculates conditions in the zone
VENT	calculates air flow rates in dwelling
VAPRES	calculates saturated vapour pressure at a given dry bulb temperature
GAUSS	solution of a set of simultaneous equations by Gaussian elimination
WINDP	finds pressure across building due to wind

2.1 Main program HUMID

Fig. 2 shows a greatly simplified flow chart of program operation when using full transient analysis.

After input of required data and initilization of the wall model, thermal and moisture conditions in the main zone are calculated at periods of STEP seconds. Values of external conditions at each time step are interpolated from the immediately preceding and following hourly variable magnitudes (taken from the weather data files listed above).

In the case of full transient calculations, variable magnitudes are printed to the output file, HOUT.DAT, at the end of each hour. In addition, there is a facility for printing results at every time step at the beginning of a moisture production period (e.g. during cooking) for greater detail under highly transient conditions. This printing is enabled by setting IHRON to 1 in the data file HUMIN.DAT (the number of time steps covered at the time of writing is 30)

For steady-state program runs, data is only printed out once for each air change rate at the end of each respective calculation period of a given number (KAC) of days. The program automatically performs a number of these calculations for increasing air change rates, the magnitudes of which are held in the twelve element array ACCH.

2.2 Calculation of air flow rates

In regard of air flow modelling the building is treated in two stages: a) to find the pressure coefficients on the building, i.e. to calculate the pressure driving air through the main zone; b) to solve the air-flow resistance network model.

a) Wind pressure across the building is calculated in subroutine **WINDP** from the interpolated hourly values of wind speed and direction. A very simple empirical approach is adopted where the pressure on the two opposite faces of building is calculated from data in the Air Infiltration Centre (AIC) Guide [1]. Essentially the wind direction angle normal to the left hand face of the building shown in Fig. 1 is considered as falling in one of eight sectors, see Fig. 3. The pressure coefficient is then set from the data in section 6.2 of the AIC Guide.

b) Ventilation rates are then found using the subroutine **VENT.** This treats the building as a simple air-flow network as shown in Fig. 4. Air flows through crackage in the two outside building faces as shown in Fig. 1 and through the adjoining zone to/from the main zone. A positive wind pressure is taken as when the wind blows from left to right in Fig. 1. The extract fan is modelled as a constant pressure source in series with a standard opening flow coefficient. The fan pressure is equivalent to the static pressure head quoted in manufacturer's data. The flow coefficient may then be determined from the extract capacity, i.e.:

$$\text{flow coefficient, XKAV} = \frac{\text{extract capacity}}{\text{(fan pressure)}}$$

Using techniques outlined in the AIC Guide, air flow rates are calculated using flow coefficients XKAV above and XKA1, XKA3 for crackage/openings in the building. These are input from the data file HUMIN.DAT. Data on these coefficients for a variety of building openings are given in section 6.3 of the AIC Guide. Air-flow directions (i.e. of Q1, Q3 and VEN) are as shown in Fig.s 1 and 4. The network solution is then found assuming that flow rate through all openings is proportional to the square root of pressure difference across the opening (a commonly used approximation). [Note: the network model solved in VENT differs slightly from that shown in Fig.s 1 and 3 in that Q3 is taken as positive for flow from inside to outside, thus the sign of Q3 is reversed upon return to the main program to preserve the notation given in this paper].

2.3 Room conditions

The core of the model lies in the subroutine **ROOM** which determines the air temperature and vapour pressure in the main zone at each time step. Several separate functions are performed:

- i) **finite difference analysis of external wall temperature**
- ii) **determination of glass surface temperature**
- iii) **condensation rates on wall and glass**
- iv) **heat balance calculation to find air temperature**
- v) **vapour pressure in main zone**

Fig. 5 summarizes the network model of heat production and flow as used in the analysis below.

i) Wall temperature.

To take account of transient conditions, the temperature distribution through the external wall is modelled by a one-dimensional transient finite difference technique. The wall is divided into NELEM-1 slabs and NELEM nodes, two nodes being positioned on the inside and outside surfaces. An "implicit" (Crank Nicholson) formulation of the problem is employed, i.e. all the available results for node temperatures of the latest time step are used to calculate the temperatures of remaining nodes. A very helpful treatment of numerical methods for temperature distribution problems may be found in Bayley et al [2]; chapter 4 is particularly relevant to the present case.

Node temperatures are held in the array TLY(NELEM,2) where the second column of the array is designed to hold the temperatures of a different wall type (not yet implemented). Element TLY(1,1) corresponds to the inside wall surface and TLY(NELEM,1) to the outside surface node. At any given time step the new temperature distribution is required and the node temperatures are calculated progressing from node 1 to node NELEM. The temperatures of nodes in the interior of the wall are related by the following expression:

$$2.(TLY(I)_n - TLY(I)_o)/F = TLY(I-1)_n - 2.TLY(I)_n + TLY(I+1)_n + TLY(I-1)_o - 2.TLY(I)_o + TLY(I+1)_o \qquad (1)$$

where I is the node in question and the subscripts $_n$ and $_o$ refer to latest and previously calculated values of node temperature (only one wall type is considered for simplicity, thus, the array TLY is treated as a column vector). F is the Fourier Number given by:

$$F = STEPxK1/(ROCPxD1^2)$$

where the variables on the left hand side of the equation may be found in the variable list in section 3 below. The treatment of nodes on the external surfaces of the wall is slightly different in that the boundary conditions (i.e a surface heat transfer coefficient) must be taken into account (as detailed in [2]). Thus, the outer slabs of material are taken to have half the thickness of those in the interior of the wall. In addition, condensation or evaporation may occur on the interior surface of the wall leading to the requirement that the latent heat of vaporization or condensation be included in the thermodynamic model of the wall surface. Hence, the relationship between nodes adjacent to the internal wall surface temperature is written as:

$$- 2.F.B.TA_n + (1+F.(1+B)).TLY(1)_n - F.TLY(2)_n$$

$$= F.B.TA_o + (1-F.(1+B)).TLY(1)_o + F.TLY(2)_o \quad (2)$$

$$+ 2.QLATW/(D1.ROCP)$$

where QLATW is the latent heat input to the wall, TA is the internal bulk air temperature and B is the Biot Number given by:

B = (surface heat transfer coefficient).D1/K1

A similar expression is used for the external wall surface temperature. The solution to the whole wall temperature distribution is then a matter of solving the set of simultaneous equations relating the old and new node temperatures. This is formulated by the matrix equation:

$$[A].\{TLY\} = \{B\} \quad (3)$$

where: {TLY} is the column vector holding the new node temperatures; {B} is that holding the old values; the NELEMxNELEM matrix [A] contains the coefficients linking the two as determined by equations (1) and (2). Equation (3) is then solved by Gaussian elimination using the subroutine **GAUSS**. Note: in the calculation of wall surface temperature the rate of condensation (and hence QLATW) used relates to the previous time step. An improvement to the code would involve an iterative calculation method to find the condensation rate and wall temperatures simultaneously.

The implicit Crank Nicholson technique is rather more mathematically complex than "explicit" formulations where only "old" (i.e. explicitly known) node temperatures are used to calculate new values. However, it has the advantage that significantly longer time steps may be used between calculations without causing stability problems in the solution. Nevertheless, there remains a (higher) upper limit to the time step, and a number of checks are made in the subroutine **ROOM** to ensure that this limit is not exceeded.

ii) Glazing heat loss and condensation

The heat loss and condensation rate on the external glazing is calculated on a steady-state basis using standard internal and external heat transfer coefficients. There is an option as to whether windows are singly or double glazed.

iii) Condensation and evaporation.

Condensation/evaporation rates on the wall are calculated using the "Lewis" relationship which quantifies the relation between heat and mass convection coefficients. This is quoted in the ASHRAE Handbook as [3]:

$$h = h_d.\rho c_p$$

where h is the heat transfer coefficient, h_d is the mass transfer coefficient, ρ is the density of the air and c_p is its specific heat capacity.
To compute the rate of condensation on a surface one therefore requires the driving vapour pressure difference between the bulk air in the room and that at the surface itself. If condensation or evaporation is taking place water will be present on the wall and the air immediately adjacent to that surface will be saturated. The vapour pressure at this point will then be the saturated vapour pressure (VPS) for the current wall surface temperature. The rate of condensation or evaporation on the total wall surface, MVAPW, is then:

$$MVAPW = h_D.AW(VP-VPS)M/(R.T_m)$$

where AW is the wall area, VP bulk air vapour pressure (in Pa), M is the molecular weight of air, R the universal gas constant and T_m the mean absolute temperature of the bulk air and air at the surface. It is then a simple matter to calculate the latent heat input/loss per unit area to the wall, QLATW, from the latent heat of water.

The condensation rate on glazing is calculated in the same way as for the wall.

iv) Zone heat balance

The network used for solving for the zone air temperature at the new time is shown in Fig. 5. It should be noted that no thermal capacity is included in the system other than that implicitly present in the finite difference model of the external wall (this should be addressed at the earliest opportunity). The resultant air temperature is then found by one single calculation. Only the adjoining zone (with air temperature of TA2) has a ventilation connection with the main zone. The other zones have thermal transmission through walls or floors. The temperatures in the surrounding zones and the vapour pressure in the adjoining zone are assigned 24 hour profiles by means of the four 24 element arrays TA2X, TA3X, TA4X and VP2X, respectively. A similar approach is used to determine hourly heat and moisture inputs to the main zone.

v) Vapour pressure

The vapour pressure in the main zone at each time step is determined by a simple moisture balance calculation. Moisture is convected in and out of the zone through crackage and the extract fan; it is produced by the occupants and their activities; and it condenses and evaporates to/from the external wall and window surfaces.

3. VARIABLE LIST FOR PROGRAM HUMID

A(11,11)	used for finite difference analysis
A2	area of wall between main zone and zone 2
A3	 3
A4	 3
ACH	air change rate under steady-state conditions

ACR	air change rate in main zone
AG	area of glazed surface
AW	area of outside wall
B(11)	used in finite difference analysis
BI, BO	Biot Numbers (on inside and outside of wall) - for finite difference model
CHJJ, CHKK	check that time step is small enough for f.d. calc
CONG	amount of condensate on glass (kg)
CONW	amount of condensate on external wall surface (kg)
D1, D2	distances between nodes in materials 1 and 2 in finite difference model of wall (m)
DGH	thermal conductance of glass and air-gap in double glazing (W/m^2K)
EXVP	excess vapour pressure; inside-to-outside (mbar)
F	Fourier Number - for finite difference model
FP	fan pressure (Pa)
FP1	0 - fan is off; 1- fan is on
HCW	internal heat transfer coefficient on wall (W/m^2K)
HCO	external heat transfer coefficient on wall (W/m^2K)
HRG	radiative HTC from glass (W/m^2K)
HRW	radiative HTC on inside of wall (W/m^2K)
HRO	radiative HTC on outside of wall (W/m^2K)
IACH	when =1 program calculates steady-state conditions for a series of air change rates (see ACCH)
ICODE	title of run to be output to header of HOUT.DAT
IDAY	present day number (from start of run)
IDG	0 for single glazed zone; 1 for double glazing.
IHRON	0 normally set to 1 for detailed printout at start of moisture input periods
IITT	time of previous hour
IJK	number of present time step in present hour
IRHO(24)	array for input of 24hrs external RH data
ITAAO(24)	array for input of 24hrs external temperature data
IWD(24)	array for input of 24hrs wind pressure data
IWS(24)	array for input of 24hrs wind direction data
ISTART	start day (from 1st April) of run (0-365)
ITTT	present time in hours
IWPCON	set to 1 for constant wind pressure on building
J	counter; hour of the day
JAC	counter; sets air change rate see ACCH(12)
K	counter; day number
K1	thermal conductivity of wall material 1 (W/mK)

K2	thermal conductivity of wall material 2 (W/mK)
KAC	number of days duration of program run
MVAP0, MVAP2	moisture migration during one time step
MVAP01	notation as for TMV0, TMV2 and TMVEN
MVCK	rate of moisture production
MVAPCK	ditto
MVAPG	mass rate of condensation on glass (kg/s)
MVAPW	mass rate of condensation on external wall (kg/s)
NUM	number of time steps per hour (3600/step)
NELEM	no of nodes in finite difference wall model
Q1	air flow rate from adjoining zone to main zone (m^3/s)
Q3	air flow rate from outside to main zone (m^3/s)
QFI(24)	array holding profile of heat input to main zone (W)
QFIREN	heat input to main zone (W)
QLATG	latent heat input/unit area to glass surface (W/m^2)
QLATW	latent heat input/unit area to wall surface (W/m^2)
RH	relative humidity in main room (%)
RHSET	set point of humidity controlled extract fan
RHSURF	RH at wall surface (%)
ROCP	density X specific heat of material of wall (J/m^3K)
STEP	no. of seconds between calculation steps
TA	air temp in main zone (used in subroutine ROOM)
TAO	outside air temp. (°C)
TA1	air temp. of main zone - only in subroutine ROOM (°C)
TA2	temp. in zone 2 (°C)
TA2X(24)	temperature profile in zone 2
TA3X(24)	temperature profile in zone 3
TA4X(24)	temperature profile in zone 4
TAO1	old hourly value of outside air temp. (°C)
TAO2	latest hourly value of outside air temp. (°C)
TG	internal surface temperature of glazing (°C)
TLY(2,11)	array holding temp.s of nodes in the finite difference wall model, there can be two wall types i.e. plane and cold bridge walls
TMV0, TMV2, TMVEN	hourly totals of moisture flowing through openings; adjoining zone to main zone; main zone to outside; and through extract fan, respectively (kg).
TS	inside wall surface temperature (°C)
TSLOP	variable for interpolation of external temp.
TW	internal surface temperature of wall (°C)
U2	U-value of wall between main zone and zone 2 (W/m^2K)
U3	U-value of wall between main zone and zone 2 (W/m^2K)
U4	U-value of wall between main zone and zone 2 (W/m^2K)
VEN	air flow through extract fan (m^3/s)

VOL	volume of main zone (m^3)
VP	vapour pressure in main zone (mbar)
VPO	external vapour press (mbar)
VPO1	old outside hourly vapour pressure (mbar)
VPO2	latest outside hourly vapour pressure (mbar)
VPS	saturated vapour pressure
VPW	saturated vp at wall surface (mbar)
VSLOP	variable for interpolation of external vapour press.
WP	wind pressure (constant value) (Pa)
WPMIN	min. wind pressure to ensure ventilation rate greater than min. when wind speed is low, i.e. to account for bouyancy.
WD	wind direction (degrees E of N)
WD1	old hourly wind direction (degrees)
WD2	latest hourly wind direction (degrees)
WDSLOP	variable for interpolation of wind direction
WS1	old hourly wind speed (m/s)
WS2	latest hourly wind speed (m/s)
WSSLOP	variable for interpolation of wind speed
XKA1	effective flow coefficient for openings from main zone to adjoining zone in series with those from adjoining zone to outside
XKA3	flow coefficient from main zone to outside
XKAV	flow coefficient for the extract fan
XMCO(12)	array holding required air change rates for steady-state calculations (per hour)s
XORIEN	orientation of building (degrees E of N)
XRHO	constant external RH (%)
XTO	constant external temperature (°C)
XWD	constant wind direction (see IWPCON) (degrees)
XWS	constant wind speed (see IWPCON) (m/s)

4. LIMITATIONS OF THE BERG CONDENSATION MODEL

The following is a brief list of factors that are not dealt with by the model but which will be in effect in real buildings. Some of these could be dealt with and, given sufficient resources (i.e. people and time), could easily be incorporated in the program. Other factors are very much more difficult to handle (e.g. how moisture is distributed in the air within a room, local effects of draughts etc.). Indeed, a great deal more experimental and theoretical research is required to determine their effects and their importance on condensation risk and occurrence.

4.1 Air movement

At present the model does not deal with:

- buoyancy effects, air movement is purely by forced convection.
- in reality, there is often a two-way air flow through large openings within the building and through its external envelope.
- air flows down cold vertical surfaces; often very rapidly. This has implications for both heat transfer and condensation or evaporation. As the warm air both cools and accelerates, the convective heat transfer coefficient will change; particularly with a transition from laminar to turbulent flow regimes. Similarly, air will absorb or lose moisture in a

condensation or evaporation situation - as it passes down a window pane, say. There is therefore a question against the accuracy of the heat and mass convection coefficients that apply in practice.

- at present air flows through the extract fan unit when the fan is not operating due to wind pressure (this simple because the programmer has not yet implemented spring loaded flaps in the code!).

4.2 Condensation processes

- as condensation occurs on a vertical surface condensate forms in a dropwise fashion until it is forced by gravity to run down and off that surface. Thus, the surface area of the condensate is drastically reduced as it forms a pool at the bottom of the condensing area. Moreover, the liquid will be at a completely different temperature to the surface on which it condensed. The model takes no account of this.

- water is absorbed on many surfaces in a dwelling (e.g. walls). The exact processes by which absorbtion and desorbtion take place are not well known. More research is required in this area.

- no account is taken of changes that may take place in the rate of condensation during a given time step.

4.4 Thermal modelling

- as stated above the model does not include a comprehensive treatment of the thermal capacity of the building and its elements. There are several ways by which such a treatment could be implemented. A simple method would involve linking a capacitance to the air node of the main zone in the network of Fig. 5. A more rigorous approach would involve a finite difference analysis of the building as a whole, e.g. with nodes and capacitance at/within all the major building elements and air spaces.

- cold bridges have yet to treated. This would be relatively simple to implement and should be carried out as a priority since cold bridges are the sites of highest condensation risk.

- radiative heat transfer between surfaces (e.g. walls and heating elements) within the building are not considered. This could be a major and erroneous simplification. A quick sensitivity analysis is called for.

5. GRAPHICAL PRESENTATION OF RESULTS

A number of graphics programs have been developed to assist with the presentation of the hour-by-hour results from the transient runs of **HUMID**. **PLOTHUM** plots out the various parameters of greatest interest (e.g. air temperature and RH) against time over a few days. It also produces a plot of air humidity and temperature (in the room bulk and on the various surfaces) on a psychrometric chart. It is also possible to calculate cumulative frequency data for various parameters, though this facility is relatively underdeveloped at the time of writing.

Two examples of the graphical output from program **PLOTHUM** are shown in Fig.s 6 and 7.

REFERENCES

[1] Liddament, M. W., Air Infiltration Calculation Techniques - An Applications Guide, Air Infiltration and Ventilation Centre, Bracknell, UK, 1986.

[2] Bayley, F. J., Owen, J. M. and Turner, A. B., Heat Transfer, Nelson, 1972.

[3] ASHRAE Handbook, p3.9.

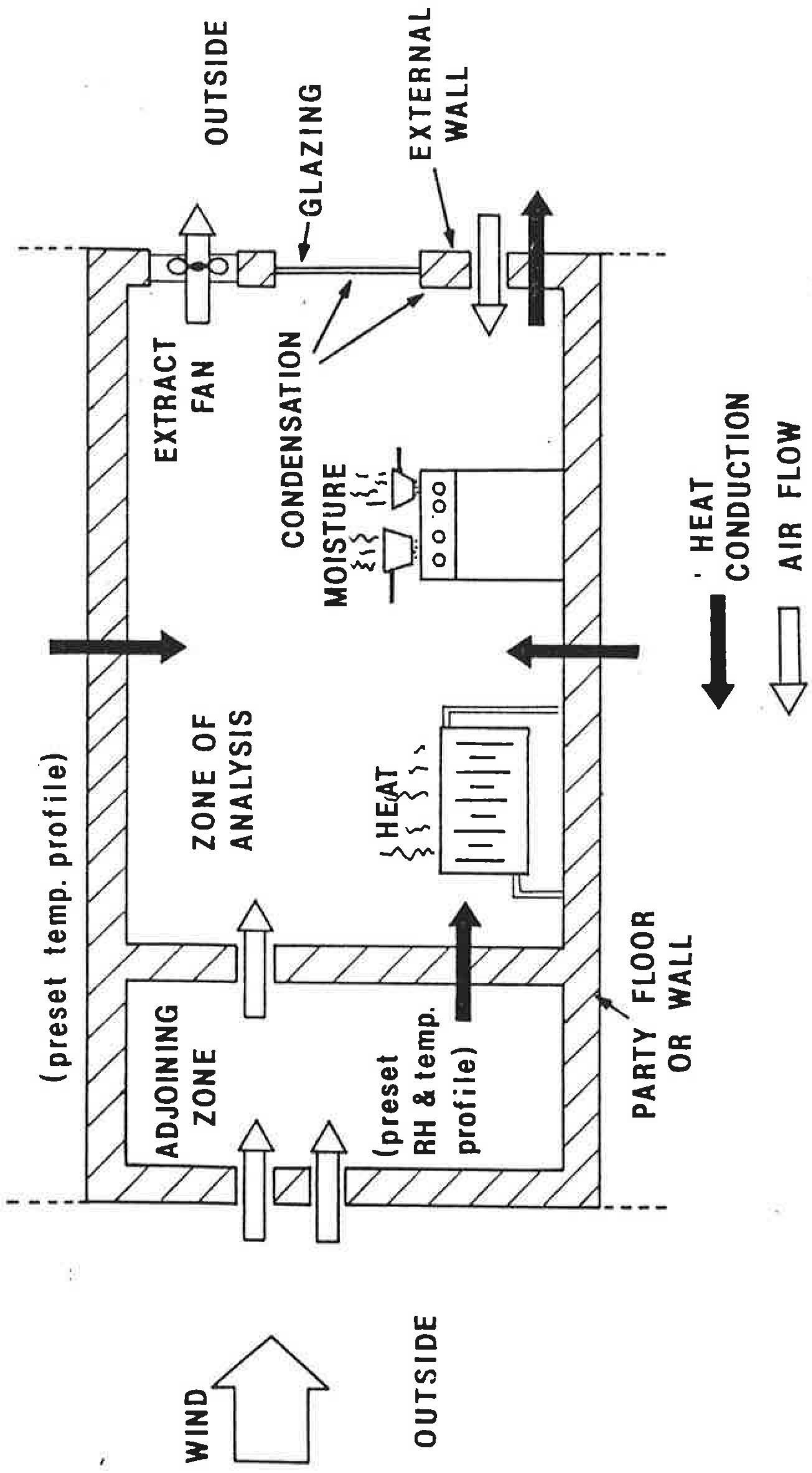


Figure 1. Schematic diagram of the BERG condensation model

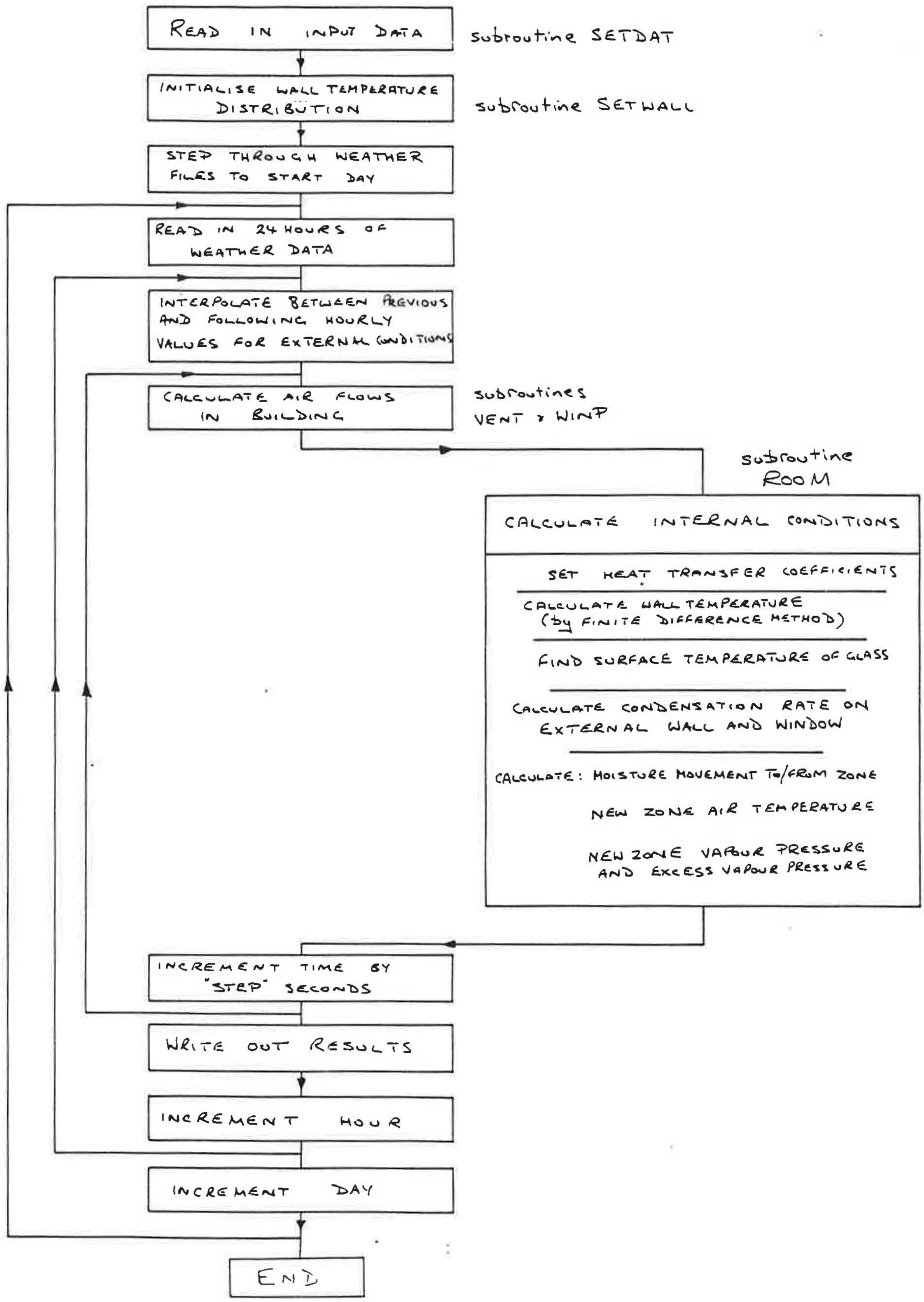
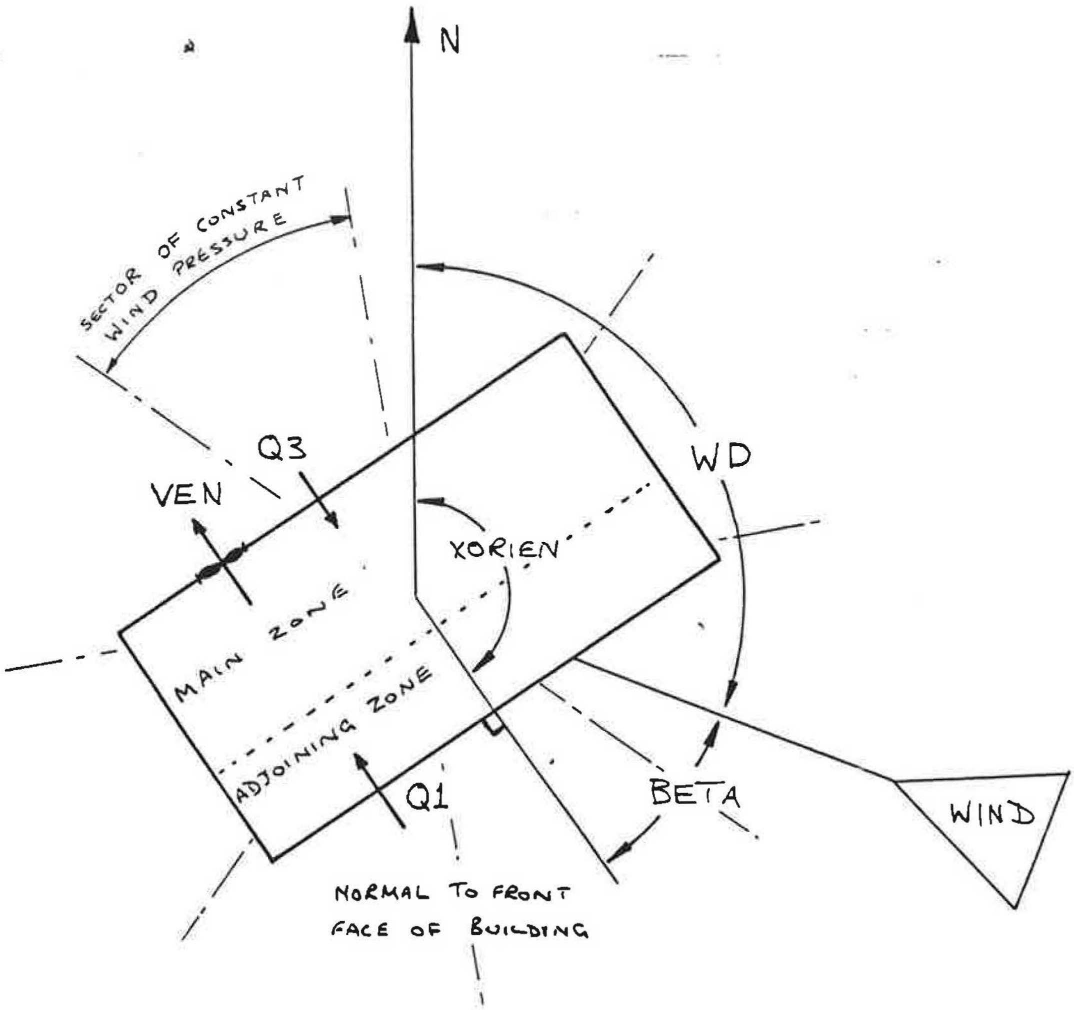


Figure 2. Simplified flow chart of program "HUMID"



WD - WIND DIRECTION

BETA - ANGLE OF INCIDENCE OF WIND TO BUILDING

XORIEN - ORIENTATION (AZIM TH) OF BUILDING

Figure 3. Method for determination of wind pressure coefficient as used in subroutine "WINDP"

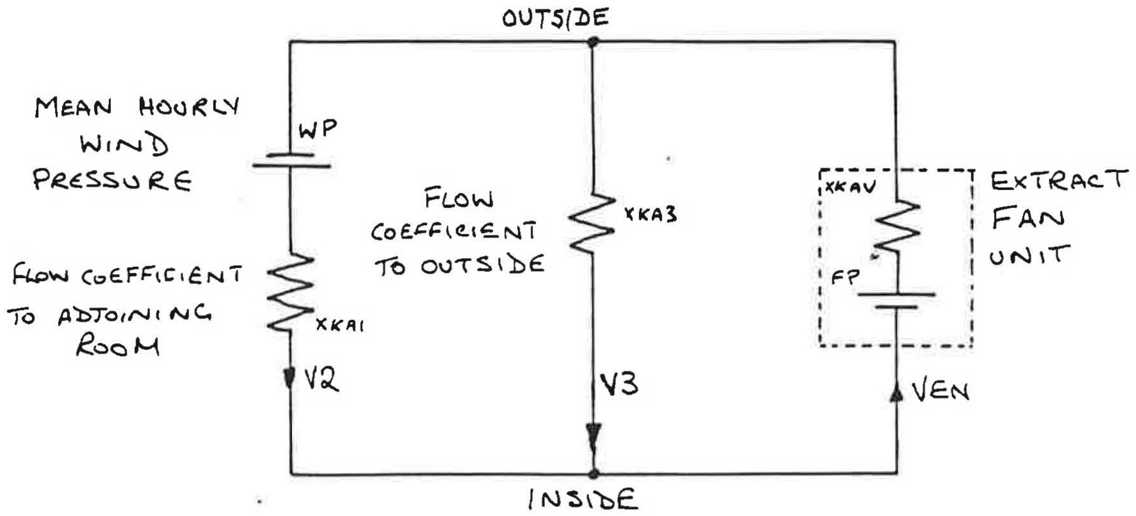
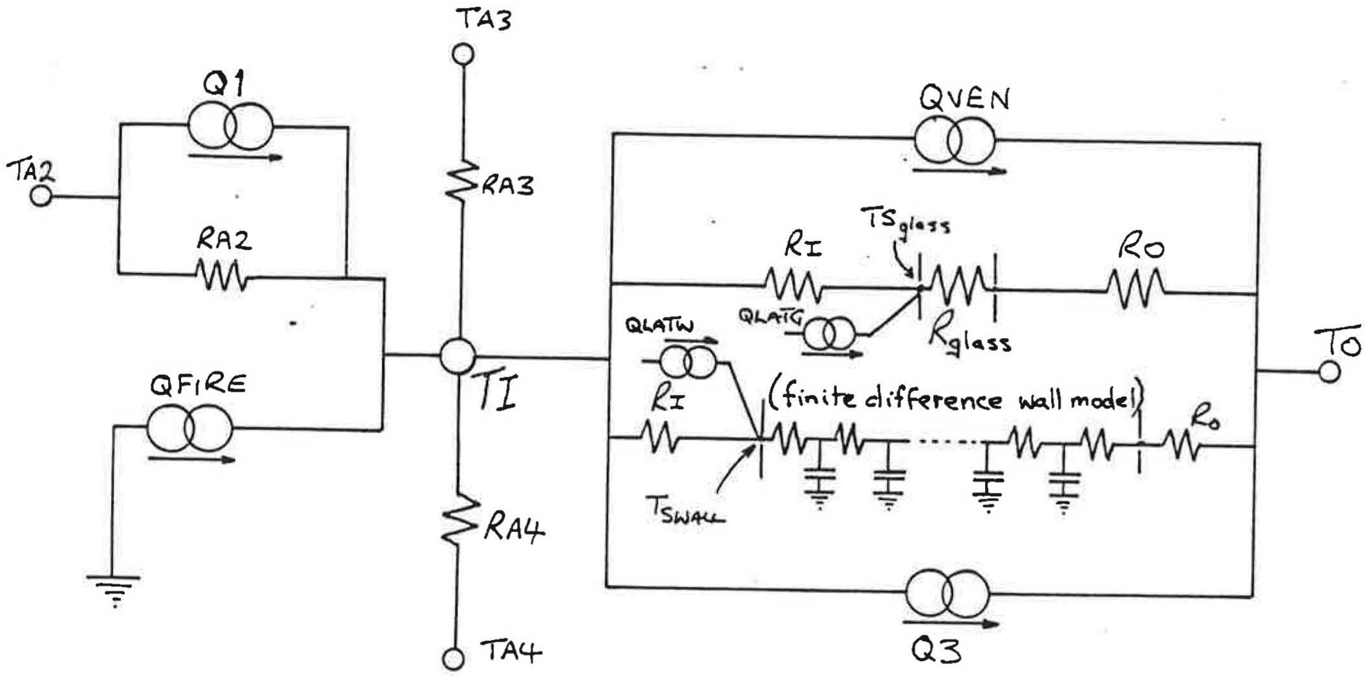


Figure 4. Air-flow network of dwelling



TI	room air temperature
TO	outside air temp.
TA2,TA3,TA4	temp.s in adjoining spaces
QFIRE	heat inputs from heating and cooking
QVEN	heat loss through extract fan unit
QLATG,QLATW	latent heat input to glass and wall surfaces
Q ,Q3	ventilation heat flows
RI,RO	internal and external surface heat transfer coefficients
RA2,RA3,RA4	thermal resistances to adjacent spaces

Figure 5. Thermal network model of dwelling

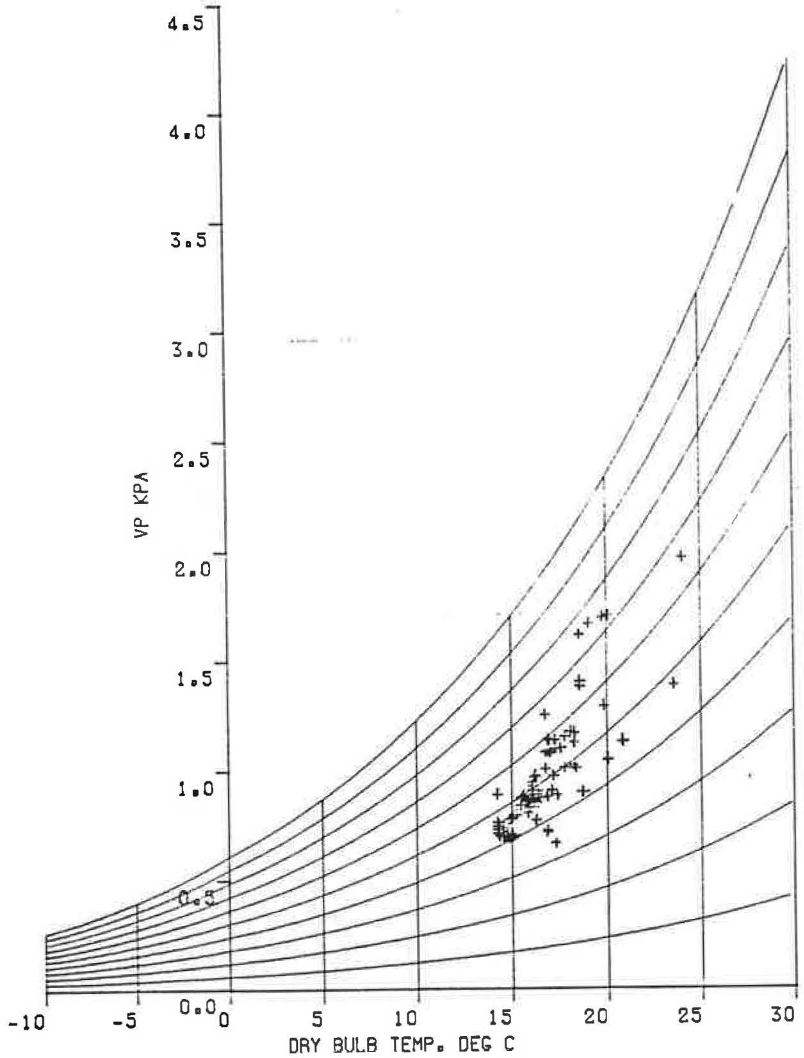


Figure 6. Results from HUMID plotted on psychrometric chart

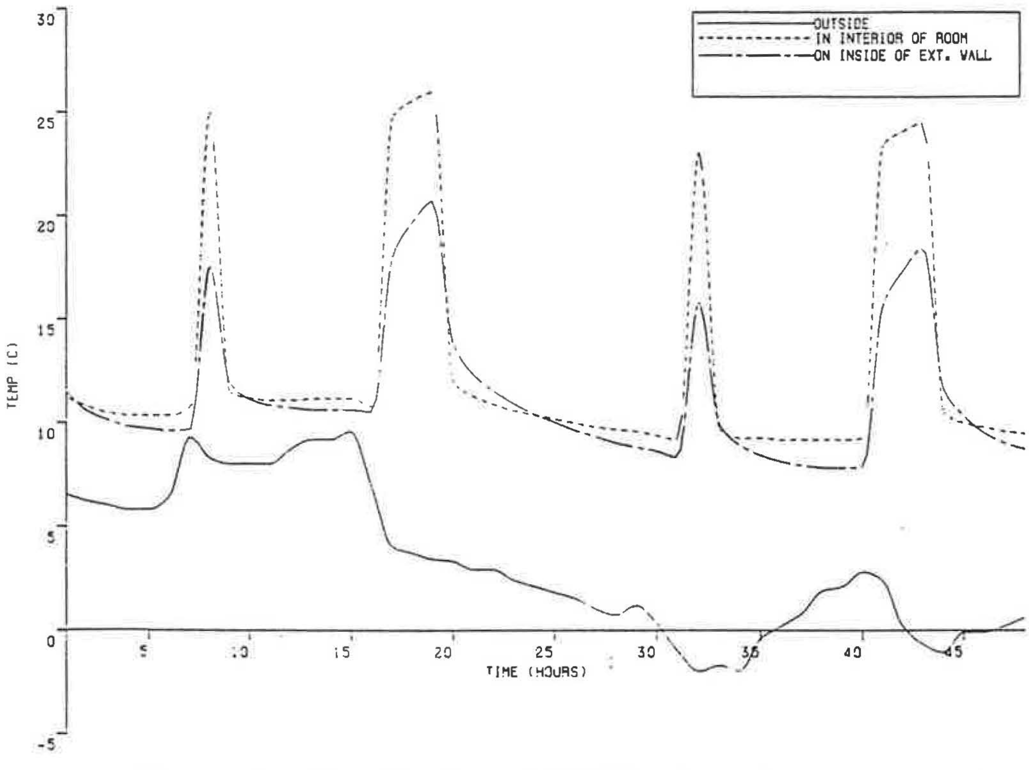


Figure 7. Results from HUMID plotted against time

```
      PROGRAM HUMID
C*************************************************************************
C     PROGRAM TO MODEL THE INTERNAL HUMIDITY AND TEMPERATURES
C       IN AN OCCUPIED DWELLING (P.C. AND D.B. april 1987)
C*************************************************************************
C
      COMMON/STOR/ELEC,TCORE,RK,DN,RMN,CPN,AN,TSN,TCMAX
      COMMON/SWITCH/SW1,SW2,SW3,SW4
      COMMON/SWALL/TLY(2,11),K1,K2,D1,D2,RML,CL,AW,ROCP
      COMMON/OUT/CONW,CONG,Q1,Q3,MVAP0,MVAP2
      COMMON/VENTL/WP,WPMIN,FP,XKA1,XKA3,XKAV,ACH,ACCH(12)
      COMMON/OTHER/TA2X(24),VP2X(24),TA3X(24),TA4X(24),
     1     U2,U3,U4,A2,A3,A4,AG,PI,VOL,TA2,TA3,TA4,VP2
     2     ,XMCO(24),QFI(24)
      DIMENSION ITAAO(24),IRHO(24),IWS(24),IWD(24)
      REAL MVAPCK,MVCK,K1,K2,MVAP0,MVAP2
      CHARACTER*24 ICODE
C
      OPEN(UNIT=28,FILE='WD7980.DAT',STATUS='OLD')
      OPEN(UNIT=29,FILE='WS7980.DAT',STATUS='OLD')
      OPEN(UNIT=30,FILE='T7980.DAT',STATUS='OLD')
      OPEN(UNIT=31,FILE='RH7980.DAT',STATUS='OLD')
      OPEN (UNIT=32,FILE='HOUT.DAT',STATUS='NEW')
C     OPEN (UNIT=33,FILE='WALLTEM.DAT',STATUS='NEW')
      OPEN (UNIT=34,FILE='HUMIN.DAT',STATUS='OLD')
      DATA (ACCH(K),K=1,12)/.1,.2,.3,.5,.75,1.,
     1     1.5,2.,3.,4.,5.,6./
C
C     TYPE 3
C 3   FORMAT(1X,' Input values for:',/,
C     3        ' FAN PRESSURE',/,
C     4        ' STEP = NO OF SEC BETWEEN ITERATIONS',/,
C     5        ' ISTART = NO. OF DAYS TO SKIP FROM 1ST APRIL',/,
C     6   ' ICODE - 24 CHARACTER DESCRIPTOR FOR THIS RUN',/
C     7   ' XORIEN = ORIENTATION FROM NORTH (DEGS)'/,
C     8   ' IHRON  = 1 IF WE WANT RESULTS AT EACH TIME STEP OF COOKING PERIOD',/
C     9   ' IWPCON - 1 IF THE WIND PRESS. IS CONSTANT WITH TIME')
C     10  ' XWS,XWD,XTO,XRHO CONST.VALUES OF EX. WIND SPEED, PRESS, TEM. AND RH',
C     11  ' ACH IS AIR CHNAGE RATE UNDER STEADY STATE'
C     12  ' WPMIN - MIN. WIND PRESS.'
C     13  ' IDG  DOUBLE GLAZING SWITCH 1= DOUBLE GLAZING, 0=SINGLE'
C     14  ' IACH = 0 IF USING WEATHER DATA OR CONST. WP.
C     15  '       = 1 DOES A NUMBER OF ACH RATE CALCULATIONS
C
      READ(34,*)FP,STEP,ISTART,ICODE,XORIEN,
     1 IHRON,IWPCON,XWS,XWD,XTO,XRHO,ACH,WPMIN,IDG,IACH
C
      CALL SETDAT(1)
C
C     WRITE OUT INPUT DATA
C
      WRITE(32,5)ICODE,A2,A3,A4,AG,AW,U2,U3,U4,VOL,K1,
     1  K2,D1,D2,ROCP,CL,IDG,XKA1,XKA3,
     2  XKAV,WP,FP,WPMIN
 5    format('1',1X,128('*'),/,10X,'HUMID....A PROGRAM MODELLING THE HEAT',
     1   ' AND MOISTURE BALANCE IN A DWELLING.  JAN 1987',/,
     1   1X,128('*'),/,
     1   1X,1A24,//,1X,'   AREAS(M2):  A2=',E11.5,'    A3=',
     1   E11.5,'     A4=',E11.5,'     GLASS=',E11.5,
     1   '     EX WALL=',E11.5,/,1X'"U" VALUES(W/M2K): U2=',E11.5,'    U3='
```

```
     2   ,E11.5
     2   '   U4=',E11.5,'   ROOM VOLUME (M3)=',F7.2,
     2   /,'   CONDUCTIVITY OF EX WALL (W/MK)',
     2   ' K1=',E11.5,'  K2=',E11.5,'   THICKNESS OF F.D. WALL ELEMENTS(M)',
     2   '   D1=',E11.5,'   D2=',E11.5,/,1X,
     3   'ROCP=',E10.4,'   CL=',E11.5,'   IDG (DOUBLE GLAZING IF=1)=',I1,
     4    //,1X,'VENT PARAMS: XKA1=',E10.4,
     4   'XKA3=',E10.4,'XKAV=',E10.4,/,' WIND PRESS.(PA)=',E10.4,
     5   '   FAN PRESS. (PA)=',E10.4,'   WPMIN (PA)',E10.4)
C
      WRITE(32,515)(TA2X(JK),JK=1,24),(VP2X(JK),JK=1,24),
     2   (TA3X(JK),JK=1,24),(TA4X(JK),JK=1,24),
     2   (XMCO(JK),JK=1,24),(QFI(JK),JK=1,24),
     3   STEP,ISTART,XORIEN
 515  FORMAT(/,1X,'TEMPERATURE AND VAPOUR PRESS. PROFILES'
```

```
     1  '(TA2,VP2,TA3,TA4 RESPECTIVELY)',4(/,1X,24(1X,F4.1)),
     1  /,'  MOISTURE PRODUCTION RATE AND HEAT INPUT PROFILES'
     2  ,2(/,1X,12(1X,E10.2)),2(/,1X,12(1X,E10.2)),
     2  //,' ITERATION TIME STEP (SECS)=',F5.1,
     3  '    NO. OF DAYS SKIPPED AFTER 1ST APRIL=',I3,' ORIEN (DEG)=',F5.0,
     4  /,' CONW/Q ARE CONDENSATE MASS (KG) ON TOT. WALL AND WINDOW AREAS',
     5  '  WP = WIND PRESS.   ACR = AIR CHANGE RATE',//)
C    5  /,' TMV2/0 ARE THE MASSES OF WATER CONVECTED FROM DWELLING TO TEST',
C    6  ' ROOM AND FROM TEST ROOM TO OUTSIDE',/,1X,128('='),//)
C
C       STEP THROUGH WEATHER FILES TO REQUIRED DAY
C
C       TAKE OUT FILE HEADERS
        READ(28,145)
        READ(29,145)
        READ(30,145)
        READ(31,145)
 145    FORMAT(////)
        DO 345 KKL=1,ISTART
        READ(28,1000)(IWD(I),I=1,24)
        READ(29,1000)((WS(I),I=1,24)
        READ(30,1000)(ITAAO(I),I=1,24)
        READ(31,1000)((RHO(I),I=1,24)
 345    CONTINUE
        NUM=INT(3600./STEP)
C
C       WRITE(33,2345)
C 2345  FORMAT(1X,'  TIME  DAY   INSIDE TEMP',30X,'WALL LAYER TEMPS',
C       1        T120,'OUTSIDE TEMP')
        WRITE(32,9898)
 9898   FORMAT(1X,'TIM   TAO   VPO   TA1    VP  EXVP    RH ',
        8  '   TS RHSUFF   TC     CONW      CONC',
        9  '          VEN       Q1         Q3        WP        ACR')
C
C****************************************************************************
C
C       RUN THROUGH A NUMBER (KAC) OF 24 HOUR PERIODS
C****************************************************************************
        IF (IACH.EQ.0)THEN
C       ONLY ONE ACR CALCULATION (48 HOURS)
          KAC=2
        ELSE
C       FOR OTHER CALCULATIONS 24 HOURS TO REACH STEADY STATE
          KAC=1
        END IF




C
        IF(IACH.EQ.0) GO TO 219
C
C       SET AIR CHANGE RATE
        DO 22 JAC=1,12
        ACH=ACCH(JAC)*ACH/ABS(ACH)
C
C       TAO2 AND VPO2 ARE THE LATEST OUTSIDE TEMP AND VP'S
C       TAO1 AND VPO1 ARE THE PREVIOUS VALUES
 219    TAO2=XTO

        CALL VAPRES(TAO2,VPO2,GA)
        VPO2=VPO2*XRHO/100.
        VP=10.
        WS2=XWS
        WD2=XWD
        STEP=60.
C       PRESENT TIME ITTT AND DATE IDAY
        ITTT=0.
        IDAY=0.
C
C       FOR FIRST HOUR INITIALIZE THE WALL LAYER TEMPS
        CALL SETWAL(TA1,TAO2)
        CALL SETDAT(1)
C
C       MVAPCK - WATER VAPOUR MASS PRODUCTION FROM OCCUPANTS ACTIVITIES
C       VEN - EXTRACT FAN RATE ; TAO OUTSIDE TEMP ; TA ROOF TEMP ;
C       TA1,TA2, ETC - TEMP IN OTHER PARTS OF DWELLING
        RHSET=60.
        CONW=0.
        CONG=0.
```

```
      WS1=0.
      TS=12.
      TC=8.
      VP=10.
C
C     START OF HOURLY CALCULATION LOOP
C
      DO 21 K=1,KAC
      IDAY=K
C
C   READ IN HOURLY OUTSIDE WIND (DIRECTION & SPEED) TEMP AND HUMIDITY VALUES
C    UNLESS WE ARE DOING STEADY STATE CALCULATION
C
      IF((IWPCON.EQ.0) .OR. (IACH.EQ.0)) THEN
        READ(28,1001)(IWD(I),I=1,24)
        READ(29,1001)(IWS(I),I=1,24)
        READ(30,1000)(ITAAO(I),I=1,24)
        READ(31,1000)(IRHO(I),I=1,24)
      END IF
 1000 FORMAT(24I3)
 1001 FORMAT(1X,24I3)
C
C     THIS IS THE START OF THE DAY!!
      DO 20 J=1,24
      ITTT=J
C
C     SAVE LATEST OUTSIDE CONDITIONS
 100  TAO1=TAO2




      VPO1=VPO2
      WS1=WS2
      WD1=WD2
      IF((IWPCON.EQ.0) .AND. (IACH.EQ.0)) THEN
C        (WIND SPEED FILE IS IN KNOTS)
        WS2=FLOAT(IWS(J))*0.5148
        WD2=FLOAT(IWD(J))
        TAO2=FLOAT(ITAAO(J))/10.
        RHO=FLOAT(IRHO(J))
      ELSE
        WS2=XWS
        WD2=XWD
        TAO2=XTO
        RHO=XRHO
      END IF
C
C     CALC NEW OUTSIDE VAPOUR PRESSURE VPO2
      CALL VAPRES(TAO2,VPS,QS)
      VPO2=VPS*RHO/100.
C
C     VALUES OF OUTSIDE CONDITIONS FOR CALCULATIONS DURING
C     A GIVEN HOUR ARE INTERPOLATED FROM THE PREVIOUS
C     AND LATEST HOURLY READINGS
C
      WSSLOP=(WS2-WS1)/NUM
      IF(ABS(WD2-WD1).LE.180.) THEN
        WDSLOP=WD2-WD1
      ELSE
         IF (WD1.LE.WD2) THEN
           WDSLOP=360.-(WD2-WD1)
         ELSE
           WDSLOP=-360.+(WD2-WD1)
         END IF
      END IF
C
      TSLOP=(TAO2-TAO1)/NUM
      VSLOP=(VPO2-VPO1)/NUM
      MVCK=MVAPCK
 200  CONTINUE
C
C     RMSLOP=MVCK/5.
C     RQSLOP=QCK/5.
C
C     SET HOURLY TOTALS OF MOISTURE MIGRATION TO/FROM OUTSIDE;
C     OTHER ROOMS AND THROUGH THE FAN, RESPECTIVELY.
C
      TMVO=0.
      TMV2=0.
      TMVEN=0.
C
C     PERFORM VARIOUS CALCULATIONS AT INTERVALS OF "STEP" SECONDS
C     I.E. THERE ARE NUM CALCULATIONS PER HOUR
C
```

```
          DO 10 IJK=1,NUM
            WS=WS1+WSSLOP*IJK
            WD=WD1+WDSLOP*IJK
            IF(WD.LT.0.) THEN WD=360.+WD
C
C         CALCULATE THE PRESENT WIND DRIVING FORCE FOR VENTILATION
C         IF WIND PRESS. IS NOT CONSTANT (I.E. IF IWPCON=0)



C           IF(IWPCON.EQ.0) THEN
              CALL WINDP(WS,WD,XORIEN,WP,WPMIN)
C           END IF
C
            TAO=TAO1+TSLOP*IJK
            VPO=VPO1+VSLOP*IJK
            MVCK=XMCO(ITTT)
            QFIREN=QFI(ITTT)
            CALL VAPRES(TA1,VPA,QA)
            RH=VP/VPA*100.
C
C         HUMIDISTAT CONTROLLED FAN
C
            FP1=0.
            IF(RH.GE.RHSET) FP1=1.
C           CALL NISTOR(QFIRE,TA1,ION,STEP)
C*************************************************************************
            CALL ROOM(1,TA1,TS,TG,VEN,TAO,VP,VPO,QFIREN,QCK,MVCK,
         1               STEP,ITTT,IDAY,FP1,IDG)
C*************************************************************************
            TMVO=TMVO+MVAPO
            TMV2=TMV2+MVAP2
          TMVEN=TMVEN+MVAP01
C
          CALL VAPRES(TA1,VPS,QS)
          RH=VP/VPS*100.
C
C         CALC. EXCESS VAPOUR PRESSURE AND RH AT WALL
C
          EXVP=VP-VPO
          CALL VAPRES(TS,VSS,QS)
          RHSURF=VP/VSS*100.
          IF(RHSURF.GT.100.) THEN
          RHSURF=100.
          END IF
C
C         CALCULATE AIR CHANGE RATE (ACR)
          QQ=ABS(Q1)
          IF(ABS(Q3).GT.QQ) THEN QQ=ABS(Q3)
          IF(ABS(VEN).GT.QQ) THEN QQ=ABS(VEN)
          ACR=QQ/VOL*3600.
C
C         NO PRINTING IF WE ARE DOING AIR CHANGE RATES
          IF((ACH.EQ.0) THEN
C
C         LETS WRITE OUT INFO AT THE BEGINNING OF COOKING PERIODS
C            (IF IIHRON=1)
            IF((J.EQ.8.OR.J.EQ.17).AND.((JK.LE.30).AND.(IHRON.EQ.1)) THEN
            WRITE(32,112)JJK,TAO,VPO,TA1,VP,EXVP,RH,TS,RHSURF,TG,
          1     CONW,CONG,VEN,Q1,Q3,WP
 112        FORMAT(2X,I3,8(1X,F5.1),E9.2,6E9.2)
            END IF
          END IF
C
 10       CONTINUE
C
C         WRITE OUT HOURLY DATA
C
          IF(IACH.EQ.0) THEN
          WRITE(32,2)J,TAO,VPO,TA1,VP,EXVP,RH,TS,RHSURF,TG,



          1   CONW,CONG,VEN,Q1,Q3,WP,ACR
 2        FORMAT(1X,I3,9(1X,F5.1),7(1X,E9.2))
C
```

```
C
C        wall temperature data file
C        WRITE(33,3456)ITTT,IDAY,TA1,(TLY(1,LLL),LLL=1,11),TAO
C 3456   FORMAT(1X,I3,2X,I4,F6.2,11F5.2,F6.2)
         END IF
C
         IF((K.EQ.KAC).AND.(J.EQ.24).AND.(IACH.NE.0)) THEN
C        WRITE OUT DATA AT END OF STEADY STATE CALCULATION
C
         WRITE(32,2)J,TAO,VPO,TA1,VP,EXVP,RH,TS,RHSURF,TC,
         1  CONW,CONG,VEN,Q1,Q3,WP,ACR
         END IF
 20      CONTINUE
 21      CONTINUE
C
 22      CONTINUE
C
 999     CLOSE(UNIT=30)
         CLOSE(UNIT=31)
         CLOSE(UNIT=32)
C        CLOSE(UNIT=33)
         CLOSE(UNIT=34)
         STOP
         END
C*****************************************************************************************
                    SUBROUTINE SETWAL(TA1,TAO)
C*****************************************************************************************
C
C        TO INITIALIZE THE WALL LAYER TEMPERATURES
C
         COMMON/SWALL/TLY(2,11),K1,K2,D1,D2,RML,CL,AW,ROCP
         FX=(TA1-TAO)
         DO 10 I=1,11
         DO 10 J=1,2
         TLY(J,I)=TA1-FX/10.*(I-1)
 10      CONTINUE
         RETURN
         END
C
C
         SUBROUTINE ROOM(N,TA,TS,TC,VEN,TAO,VP,VPO,QFIRE,QCOOK,MVAPCK,
         1  STEP,ITTT,IDAY,FP1,IDG)
C***************************************************************************************
C
C        TO CALCULATE THE ENVIRONMENTAL CONDITIONS IN THE ROOM
C        OUTSIDE WALL HEAT CAPACITY IS TAKEN INTO ACCOUNT
C        AND IS ANALYSED AS SLABS WITH CRANK NICHOLSON SOLUTION
C
C*************************************************************************************

         COMMON/OUT/CONW,CONG,Q1,Q3,MVAP0,MVAP2
         COMMON/OTHER/TA2X(24),VP2X(24),TA3X(24),TA4X(24),
         1   U2,U3,U4,A2,A3,A4,AG,PI,VOL,TA2,TA3,TA4,VP2
         2    ,XMCO(24),QFI(24)
         COMMON/VENTL/WP,WPMIN,FP,XKA1,XKA3,XKAV,ACH,ACCH(17)
         COMMON/SWALL/TLY(2,11),K1,K2,D1,D2,RML,CL,AW,ROCP
         DIMENSION A(11,11),B(11)
         REAL MVAPW,MVAPG,MVAP0,MVAP01,MVAP2,MVAPCK,K1,K2




C
C        NELEM - NO. OF ELEMENTAL SLABS IN WALL INCLUDING SURFACES
         NELEM=11
C
C          SET AIR FLOWS THROUGH DWELLIING
C
         IF(ABS(ACH).LT.1.E-6) THEN
           CALL VENT(VEN,Q1,Q3,FP1)
         ELSE
C        CONSTANT AIR CHANGE RATE
           VEN=0.
           Q1=ACH*VOL/3600.
           Q3=-Q1
         END IF
C
C        SET CURRENT SURROUNDING CONDITIONS
C
```

```
      VP2=VP2X(ITTT)
      TA2=TA2X(ITTT)
      TA3=TA3X(ITTT)
      TA4=TA4X(ITTT)
C
C     SET THE SURFACE HEAT TRANSFER COEFFICIENTS
C
      HCW=1.43*(ABS(TA-TS))**0.33
      HRW=4.
      HRO=0.
      HCO=18.2
C
C     CALC RATE OF CONDENSATION ON TOTAL OUTSIDE WALL SURFACE
C
      CALL VAPRES(TS,VPW,QW)
      MVAPW=AW*HCW*(VP-VPW)/1.62E6
C
C     CONW, CONG ARE THE ACTUAL MASSES OF CONDENSATE ON THE WALL AND
C     WINDOW AT ANY GIVEN TIME (KG)
C
      IF(IACH.EQ.1) THEN CONW=0.
      CONW=CONW+MVAPW*STEP
      IF(CONW.GT.0.)GOTO 11
      CONW=0.
      MVAPW=0.
 11   CONTINUE
C*****************************************************************************
C     CALCULATE THE TEMPERATURE OF THE WALL LAYERS
C*****************************************************************************
C
C     CALC F - FOURIER NUMBER AND BI ,BO - THE BIOT
C     NUMBERS FOR THE INTERIOR AND EXTERIOR WALL SURFACES
C
      F=STEP*K1/ROCP/D1**2.
      BI=(HCW+HRW)*D1/K1
      BO=(HCO+HRO)*D1/K1
      CHKK=F*(1.+BI)
      CHJJ=F*(1.+BO)
      IF((CHKK.LE.0.5).AND.(CHJJ.LE.0.5)) GO TO 333
      WRITE(32,3232)CHKK,CHJJ,F,BI,BO
 3232 FORMAT(1X,'TIME STEP IS TOO LARGE!!!',/,
     1 ' F*(1+BI)=',E10.4,'  F*(1+BO)=',E10.4,'  F=',E10.4,
     2 '  BI=',E10.4,'  BO=',E10.4,/,' RUN ABORTED!!!')




      STOP
 333  CONTINUE
C
C     QLATW - HEAT FLUX (PER M2) DUE TO CONDENSATION/EVAPORATION
      QLATW=MVAPW/AW*2.45E6
      QLATW=0.
      MVAPW=0.
C
C     SET MATRIX OF COEFFICIENTS TO ZERO
C
      DO 200 I=1,NELEM
      DO 200 J=1,NELEM
        A(I,J)=0.0
 200  CONTINUE
C
C     SET COEFFICIENTS FOR INSIDE AND OUTSIDE SURFACES
C
      B(1)=2.*F*BI*TA + (1.-F*(1.+BI))*TLY(N,1) + F*TLY(N,2)
     1                 +2.*QLATW/(D1*ROCP)
      A(1,1)= 1. + F*(1.+BI)
      A(1,2)= -F
      A(NELEM,NELEM)= 1. + F*(1.+BO)
      A(NELEM,NELEM-1)= -F
      B(NELEM)= 2.*F*BO*TAO + (1.- F*(1.+ BO))*TLY(N,NELEM)
     1                  + F*TLY(N,NELEM-1)
C
C     SET COEFFICIENTS FOR INTERIOR LAYERS IN WALL.
C
      DO 500 I=2,NELEM-1
        A(I,I-1)=-1.
        A(I,I)  = 2./F+2.
        A(I,I+1)= -1.
        B(I)    = TLY(N,I-1) + (2./F - 2.)*TLY(N,I) + TLY(N,I+1)
 500  CONTINUE
```

```
C         WRITE(5,3356)ITTT,IDAY,TA,(TLY(1,LLL),LLL=1,11),TAO
C 3356   FORMAT(1X,I3,2X,I4,F6.2,11F6.2,F6.2)
C
C         SOLVE MATRIX EQUATION [A][TLY]=[B] FOR NEW LAYER TEMPS
          CALL GAUSS(N,NELEM,NELEM,A,TLY,B)
C
C         WRITE(5,3456)ITTT,IDAY,TA,(TLY(1,LLL),LLL=1,11),TAO
C 3456   FORMAT(1X,I3,2X,I4,F6.2,11F6.2,F6.2,/)
C
          TS=TLY(N,1)
C*************************************************************************
C
C CALCULATE CONDENSATION 'RATE' AND HEAT LOSS ON WINDOW
C
          CALL VAPRES(TG,VPG,QG)
          TG1=TG
C
C         RADIATIVE HEAT TRANSFER COEFFICIENT
 30       HRO=2.0408E-7*(TG-273.15)**3.
C
          HCO=17
          HCG=1.430*(ABS(TA-TG))**0.33
          HRG=HRO
          MVAPG=HCG*AG*(VP-VPG)/1.62E6
C
C    IF WE ARE LOOKING AT STEADY STATE WE ONLY WANT CONDENSATE




C         PRODUCED IN THE LAST HOUR
          IF(IACH.EQ.1) THEN CONG=0.
          CONG=CONG+MVAPG*STEP
          IF(CONG.GT.0.)GOTO 31
          CONG=0.
          MVAPG=0.
 31       CONTINUE
          QLATG=MVAPG*2.454E6/AG
          QLATG=0.
          MVAPG=0.
C
          IF(IDG.EQ.0) THEN
C
C         SINGLE GLAZING
          TG=((HCG+HRG)*TA+(HRO+HCO)*TAO+QLATG)/(HCG+HRG+HRO+HCO)
C
          ELSE
C         DOUBLE GLAZING (DGH IS THE CONDUCTANCE OF THE
C         TWO PANES AND AIR GAP)
C
          DGH= 1./((.006/1.05*2.) + 0.18 +1./(HRO+HCO))
          TG=((HCG+HRG)*TA + DGH*TAO + QLATG)/(HCG+HRG+DGH)
          END IF
C
C          Calculate Air Heat and Moisture Balance
C
          VPIO=VP
          TAIO=TA
 40       WQO=1.
          IF(VEN.GT.0.)WQO=0.
          WQ1=1.
          IF(Q1.LT.0.)WQ1=0.
          WQ3=1.
          IF(Q3.LT.0.)WQ3=0.
C
C         CALCULATE THE NEW ROOM AIR TEMPERATURE
          TAA=TA
          TA=(U2*A2*TA2+U3*A3*TA3+U4*A4*TA4+(HCG+HRG)*AG*TG+
          1  (HCW+HRW)*AW*TS+1184.5*Q3*WQ3*TAO+1184.5*Q1*WQ1*TA2-
          2  1184.5*VEN*WQO*TAO+QFIRE+QCOOK)/
          3  (U2*A2+U3*A3+U4*A4+(HCG+HRG)*AG+(HCW+HRW)*AW-1184.5*VEN*WQO+
          4  1184.5*Q3*WQ3+1184.5*Q1*WQ1)
C
C*************************************************************************
C         CAL NEW VAPOUR PRESS. WHICH RESULTS FROM ADDITION OF WATER MASS
C*************************************************************************
C
C         CALC RATES OF NET MASS INFLUX OF MOISTURE TO ROOM DURING STEP FROM:-
C            FROM/TO OUTSIDE THROUGH CRACKAGE
          MVAP0=0.21668*Q3*(WQ3*VPO/(TAO+273.)+(1.-WQ3)*VP/(TA+273.))
C
C           FROM/TO OUTSIDE THROUGH FAN
          MVAP01=0.21668*VEN*((1.-WQO)*VP/(TA+273.)+VPO*WQO/(TAO+273.))
C
```

```
C
C          FROM/TO REST OF DWELLING
        MVAP2=0.21668*Q1*(WQ1*VP2/(TA2+273.)+(1.-WQ1)*VP/(TA+273.))
C
C     NEW VAPOUR PRESSURE
C
        VP=(MVAP0-MVAP01+MVAP2-MVAPC-MVAPW+MVAPCK)



        1    *STEP*(TA+273.)/(.21668*VOL) + VPIC*(TA+273.)/(TAA+273.)
C
        CALL VAPRES(TA,VPS,QS)
        IF(VP.GT.VPS)VP=VPS
 400    CONTINUE
        RETURN
        END
C
        SUBROUTINE VENT(VEN,Q1,Q3,FP1)
C***********************************************************************
C       TO CALC AIR FLOW THROUGH THE DWELLING
C***********************************************************************
C
        COMMON/SWITCH/SW1,SW2,SW3,SW4
        COMMON/VENTL/WP,WPMIN,FP,XKA1,XKA3,XKAV,ACH,ACCH(.5)
        COMMON/OTHER/TA2X(24),VP2X(24),TA3X(24),TA4X(24),
        1 U2,U3,U4,A2,A3,A4,AC,PI,VOL,TA2,TA3,TA4,VP2
C
C       IF FAN IS ON THEN FP1=1 AND FP IS THE FAN PRESSURE IN Pa
        FP11=FP*FP1
        CBA1=XKA3/XKA1+1.
        CBA2=XKA3/XKAV+1.
        IF(WP.EQ.0.0) THEN
        WPRT=0.
        ELSE
        WPRT=SQRT(ABS(WP))*WP/ABS(WP)
        END IF
C
        IF(FP11.EQ.0.0) THEN
        FPRT=0.
        ELSE
        FPRT=SQRT(ABS(FP11))*FP11/ABS(FP11)
        END IF
C
        VEN=(WPRT+CBA1*FPRT)/(CBA1*(1./XKAV+1./XKA3) - 1./XKA3)
        Q1 =(WPRT*CBA2+FPRT)/(CBA2*(1./XKA1+1./XKA3) - 1./XKA3)
        Q3=Q1-VEN
C
C       BUT MY Q3 GOES IN THE OPPOSITE DIRECTION TO DAVE'S ORIGINAL THUS;
        Q3=-Q3
        RETURN
        END
C
        SUBROUTINE VAPRES(T,P,Q)
C***********************************************************************
C       TO CALC THE SATURATED VAPOUR PRESSURE IN THE ROOM
C***********************************************************************
        REAL LOGP
        TK=T+273.15
        PA=1.01325E3
        IF(T.LE.0.) GOTO 100
        LOGP=30.59051-8.2*ALOG10(TK)+(2.4804E-3*TK)-(3142.31/TK)
        P=10*10**LOGP
        GOTO 10
 100    LOGP=9.5380997-(2663.91/TK)
        P=10*10**LOGP
 10     CONTINUE
        Q=0.62198*P/(PA-1.62198*P)
        RETURN
        END
```

```
        SUBROUTINE GAUSS(IIT,M,N,A,X,B)
C*****************************************************************************
C       TO SOLVE THE SET OF SIMULTANEOUS EQUATIONS [A][X]=[B]
C       BY GAUSSIAN ELIMINATION
C       WHERE X IS AN M-ELEMENT VECTOR AND B N-ELEMENT
C*****************************************************************************
        DIMENSION A(11,11),X(2,11),B(11)
C
C        MODIFY COEFFICIENTS TO PRODUCE UPPER DIAGONAL MATRIX
C
C
        DO 140 I=1,N-1
          XX=A(I,I)
          IF(XX.NE.0.)GO TO 137
        TYPE 444,I
 444    FORMAT(1X,' A(I,I)=0.0 WHEN I=',I3)
 137      DO 140 K=I+1,N
            YY=A(K,I)
            DO 135 L=I,M
              A(K,L)=A(K,L) - YY*A(I,L)/XX
 135        CONTINUE
              B(K) = B(K) - YY*B(I)/XX
  140   CONTINUE
C
C       TYPE 2200
C 2200  FORMAT(1X,' [A].[X] [B] AT HALFWAY GAUSSIAN ELIMINATION')
C       DO 155 I=1,N
C       TYPE 3240,(A(I,J),J=1,M)
C 155   CONTINUE
C 3240  FORMAT(1X,11(2X,E10.3))
C       TYPE 3240,(X(IIT,K),K=1,M)
C       TYPE 3240,(B(K),K=1,N)
        X(IIT,N)=B(N)/A(N,M)
C
C       NOW BACK SUBSTITUTE
C
        DO 500 K=(N-1),1,-1
          TOT=0.
          DO 400 I=K+1,N
            TOT=TOT + A(K,I)*X(IIT,I)
 400      CONTINUE
          X(IIT,K)=(B(K)-TOT)/A(K,K)
 500    CONTINUE
C
C
        RETURN
        END
        SUBROUTINE WINDP(WS,WD,XORIEN,WP,WPMIN)
C******************************************************************************************
C    TO FIND THE PRESSURE ACROSS THE BUILDING DRIVING THE NATURAL VENTILATION
C******************************************************************************************
C
C       BETA IS THE ANGLE BETWEEN THE NORMAL TO THE BUILDING (FROM
C       THE FACE ON ZONE2)
C
        BETA=ABS(WD-XORIEN)
        IF (BETA.GT.22.5) GO TO 234
          WP=1.2*WS
          GO TO 321
 234    IF(BETA.GT.67.5) GO TO 235




              WP=1.05*WS
          GO TO 321
 235    IF (BETA.GT.112.5) GO TO 236
              WP=0.
          GO TO 321
 236    IF (BETA.GT.157.5) GO TO 237
              WP=-1.05*WS
          GO TO 321
 237        WP=-1.20*WS
 321    CONTINUE
C
C       NOW WE NEED TO ENSURE THAT VENTILATION STILL OCCURS WITH ZERO WIND PRESS.
C
          IF (WP.NE.0.) GO TO 444
            WP=WPMIN
          GO TO 500
 444    IF(ABS(WP).LT.WPMIN) THEN  WP=WPMIN*WP/ABS(WP)
 500    RETURN
        END
```

```
      SUBROUTINE SETDAT(N)
C*********************************************************************
C     TO INTIALIZE DATA FOR HUMID PROG
C*********************************************************************
      COMMON/SWALL/TLY(2,11),K1,K2,D1,D2,RML,CL,AW,ROCP
      COMMON/VENTL/WP,WPMIN,FP,XKA1,XKA3,XKAV,ACH
      COMMON/OTHER/TA2X(24),VP2X(24),TA3X(24),TA4X(24),
     1  U2,U3,U4,A2,A3,A4,AC,PI,VOL,TA2,TA3,TA4,VP2
     2    ,XMCO(24),QFI(24)
      REAL K1,K2

      DO 10 I=1,11
      DO 10 J=1,2
      TLY(J,I)=10.
 10   CONTINUE
      K1=.27
      K2=0.7
      CL=900.
      DEN=750.
      D1=.0205
      D2=0.0205
      AW=127.4
      RML=DEN*AW*D2
      ROCP=DEN*CL
C
      XKA1=0.01255
      XKA3=.0116
      XKAV=.00112
C
C     TEMPERATURE AND HUMIDITY PROFILES IN SURROUNDING ROOMS
C
      DATA (TA2X(KL),KL=1,24)/10.,10.,10.,10.,10.,10.,
     1 10.,10.,10.,10.,10.,
     2 10.,10.,10.,10.,10.,10.,10.,10.,10.,10.,10.,10.,10./
      DATA (TA3X(KL),KL=1,24)/10.,10.,10.,10.,10.,10.,
     1 10.,10.,10.,10.,10.,
     2 10.,10.,10.,10.,10.,10.,10.,10.,10.,10.,10.,10.,10./
      DATA (TA4X(KL),KL=1,24)/10.,10.,10.,10.,10.,10.,
     1 10.,10.,10.,10.,10.,
     2 10.,10.,10.,10.,10.,10.,10.,10.,10.,10.,10.,10.,10./
      DATA (VP2X(KL),KL=1,24)/1.0,1.0,1.0,1.0,1.0,1.0,
     1 1.0,1.0,1.0,1.0,1.0,
     2 1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0/
C
C    WATER PRODUCTION PROFILE
      DATA (XMCO(KL),KL=1,24)/ 8.33E-5,8.33E-5,8.33E-5
     1  ,8.33E-5,8.33E-5,8.33E-5,
     1  8.33E-5,8.33E-5,8.33E-5,8.33E-5,8.33E-5,8.33E-5,
     1  8.33E-5,8.33E-5,8.33E-5,8.33E-5,8.33E-5,8.33E-5,
     1  8.33E-5,8.33E-5,8.33E-5,8.33E-5,8.33E-5,8.33E-5/
C
C    HEAT INPUT PROFILE
      DATA (QFI(KL),KL=1,24)/4000.,4000.,4000.,4000.,4000.,
     1  4000.,4000.,4000.,4000.,4000.,4000.,4000.,
     1  4000.,4000.,4000.,4000.,4000.,4000.,
     1  4000.,4000.,4000.,4000.,4000.,4000./
C
C  MISCELLANEOUS DATA
      U2=2.88
      U3=4.07
      U4=1.38
      A2=0.
      A3=0.
      A4=0.
      AC=19.0
      PI=1013
      VOL=220.
      RETURN
      END
```