```
  (A)               (B)
   |                 |
   |  NO             |
--------           Error
                 acceptable?

                     |
                     |YES
                     |
                                Check that calculated
      NO           Tdb-T3>      Tadp does not exceed
--------           Tdiff ?      specified coil limit.
|
|                    |
|                    |YES
|                    |
|   -------------------------------------
|   |   Set Tadp to coil limits        |
|   -------------------------------------
-------------------->|
                  ----------
                  | SUBEND |
                  ----------
```

Figure A2.1 : (Cont)

A.2.2 EQUATIONS USED FOR COMPUTER PROPERTIES

The computation of the plant loads involves the determining of moist air properties. These properties are determined using the equations of statistical mechanics, in conjunction with the best experimental results, to yield accurate evaluations of the properties of dry air and water vapour [3]. These equations were developed by taking into account the forces between like molecules, in terms of viral coefficients, and between unlike molecules in terms of interaction coefficients and are used in subroutines in the program as follows:

Sub Prop (Patm, Tdb, Rh, W, Hdb, SVOA)

This subroutine determines the humidity ratio (W), enthalpy (Hdb) and specific volume (Svoa) of moisture given the atmospheric pressure (Patm), dry bulb temperature (Tdb) and relative humidity (Rh). The relationships are as follows:

T = Tdb + 273.15 .... (1)

Pss = (10 (30.59 051 - 8.2 Ln(T)
+ 0.0024804 x T - 3142.31/T)) .... (2)

Ps = Rh * Pss .... (3)

Z = -0.00000662 * Tdb3-0.000194 * Tdb2+
1.8375 * Tdb + 2500.83

W = 0.62198 * 1.004 * Ps/
(Patm - 1.004 * Ps) .... (4)

Hdb = 1.005 * Tdb + W * Z .... (5)

Svoa = 2.87055 * T * (1 + 1.607 * W)/Patm ...... (6)

where

T = absolute temperature (K)

Pss = vapour pressure of steam air water up to 100 °C (bars)

Ps = partial pressure of dry air (bars)

Sub Humid (Patm, Tdb, Twb, Rh)

This subroutine calculates the relative humidity (Rh) of moisture air given the atmospheric pressure (Patm), dry bulb temperature (Tdb) and wet bulb temperature (Twb) [3]. The equations are:

Ps = Pss - Patm * E * (Tdb - Twb) .... (7)

Rh = Ps/Pws .... (8)

where

Pws = vapour pressure of steam over water at the wet bulb temperature (bars)

E = 0.000666 if Twb > = 0 or 0.000594 if E < 0

Sub Relhumid (Patm, W, Tdb, Rh)

This subroutine determines the relative humidity given the atmospheric pressure, humidity ratio and dry bulb temperature. An iterative procedure is necessary for this routine. The initial estimate is Rh = 0.8. The algorithm is :

```
REPEAT

P  =  Ps
Ps =  W * (Patm - 1.004 * Ps)/(0.62198 * 1.004) ....   (9)

ERROR = ABS (P - Ps)/Ps

Rh = Ps/PSS

UNTIL ERROR < 0.0001
```

where Ps and Pss are as before

Sub Wet-bulb (Patm, Tdb, Rh, Twb)

This subroutine determines the wet bulb temperature (Twb) given the atmospheric pressure, dry bulb temperature and relative humidity. An iterative solution is necessary for this subroutine. The subroutine uses equation (9) in a rearranged form solving for the dry-bulb temperature for estimates of wet-bulb temperature until a bracket stranding the known dry-bulb temperature is located[1].

$$W = \frac{(2501 - 2.381\ Twb) * Wwb - (Tdb - Twb)}{2501 + 1.805\ Tdb - 4.186\ Twb} \quad \ldots\ldots \quad (10)$$

where

Wwb = humidity ratio at the wet-bulb temperature
W = humidity ratio at the dry-bulb temperature.

The subroutine makes use of the interval-halving method (5) to determine the wet-bulb temperature. The subroutine computes the dry-bulb temperature initially for guesses of wet-bulb temperature until a bracket is located stranding the known dry bulb temperature. This bracket is the last two calculated values. The interval halving method is then used to obtain greater accuracy.

```
SET Twbb = Tdb - 8

DO WHILE  T new < Tdb
   Twbb = Twb
   Twb  = Twb - 8

   T_new = (2501 * (Ws-W) + Twb * (4.186 * W - 2.381 * Ws
   + 1)) / (1.805 * W+1)
END DO

   Set T1 = Twb
   Set T2 = Twbb

DO WHILE  |T-new -Tdb | or |T_new - Tdb | /Tdb < 0.001
   T3 = (T1 + T2)/2

   Determine T_new

IF T_new > Tdb
   Set T2 = T3

ELSE

   Set T1 = T3

END IF

   Set Twb = T3

END DO
```

SUB RETURN (NOPLANT, N2, VEC (*), PLANT (*), Rh (*), T3 (*), L, Tret (*), Rhret (*))

This subroutine determines the return air temperature and humidity for each plant based on the average room conditions of each zone.

SUB Oatemp (L, START, END, TOAMA X, TOAMIN, TOASUM, PATM, TOA (*), HOA (*), WOA (*), SVOA (*)

This subroutine determines hourly dry-bulb temperature (Toa (*)) by approximating a sine curve through maximum and minimum passed temperature values (Toamax, Toamin). Subroutine humid is called to calculate the outdoor relative humidity (Rh) and subroutine Prop is called to calculate the hourly humidity ratio (WOA), enthalpy (HOA) and specific volume (SVOA) for the dry-bulb temperatures.

The hourly outdoor dry-bulb temperature is determined using

TOA = TOAM - TOAM2 x SIN (15 x (J+3)*Cf)

WHERE:

TOA = Outdoor dry-bulb temperature peaking at 3 pm

TOAM = Average outdoor temperature

= (Toamax + Toamin)/2

TOAM2 = Average difference of the maximum and minimum outdoor dry-bulb temperature.

= (Toamax - Toamin)/2

CF = Radian factor

SUB VENT (NOPLANT, PLANT (*) NZ, In (*), R (*), VEC (*), VOA (*))

This subroutine determines the minimum fresh air quantity (Voa) required to comply with government regulations and to maintain adequate oxygen levels in the zones. Ventilation rates are calculated according to the number of occupants and the zone surface area; the selected rate is then the larger of the two.

The program assumes ventilation rates of 12 litres/s person and 1.66 litres/square metre of floor area unless otherwise stipulated by the user.

SUB RADP (Tdiff, Patm, Tdb, Rh, Shf, Wg, Hg, Radp, Message)

This subroutine calculates the room apparatus psychrometric values (moisture content (Wg), enthalpy (Hg) and temperature (Radp)) given the coil temperature difference limit (Tdiff), atmospheric pressure (patm), room dry-bulb temperature (Tdb), room enthalpy (Rh) and sensible heat ratio factor (Shf).

The room moisture content and enthalpy are calculated first using equations (2), (4) and (5). The program then assumes saturated temperature values until a bracket stranding the acceptable saturation temperature is located. A temperature bracket is formed when the ratio of the saturated moisture content (Wssg) at the iterated dry-bulb temperature to the moisture content (Wg) at the room sensible heat ratio line at the same dry-bulb temperature exceeds 1 (i.e. when U = Wg/Wssg) 1, see figure A2.2.1 below)

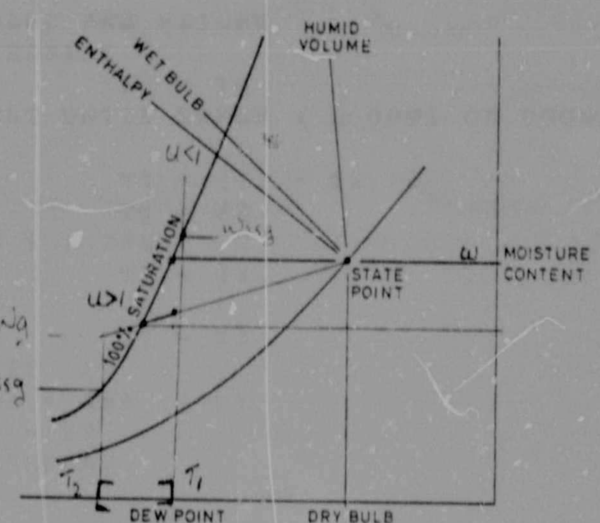

Figure A2.2.1 - Graphical illustration of room apparatus dewpoint temperature state

The following equations are used:

$$Hg = Hdb - 1.0048 * (Tdb-Tg)/Shf \quad \ldots\ldots\ldots\ldots\ldots \quad (11)$$

$$Wg = (Hg - 1.0048 * Tg)/(2501 + 1.84 * Tg) \quad \ldots\ldots \quad (12)$$

Wssg = as per egn (4)

U = Wg/Wssg

WHERE

Hg = Saturated enthalpy

Hdb = Room enthalpy value

Shf = Room sensible heat factor

Tg = Saturated dry-bulb temperature

Wg = Humidity ratio at Tg on the Shf line

Wssg = Saturated humidity ratio at Tg

The interval-halving method is then used to determine the Radp temperature within the acceptable relative error.

```
Determine W
          Hdb
          Tg
REPEAT UNTIL U > 1
          T1 = Tg
          Tg = Tg-10
          U  = Wg/Wssg
IF  U  <  1  AND  (Tdb  -  Tg)  > Tdiff THEN PRINT
MESSAGE AND RETURN
END REPEAT
          T2 = Tg
REPEAT UNTIL ERROR < 0.0001 OR COUNT = 20

          T3 = (T1 + T2)/2
          Tg = T3
IF U > 1 THEN
          T2 = T3
ELSE
          T1 = T3
END IF
ERROR = ABS (1-U)
Radp - T3
END REPEAT
```

SUB CONSVOL (Tran (*), Hrm, Tdiff, X, Patm, Vsup, Msup, Rload, Tdbon, Turbon, Tdboff, Twboff, Hon, Hoff, Tsup, Tret, Adpt, Wadp, Hadp, Won, Woff, Svsup)

This subroutine determines the peak cooling parameters for the given outdoor and room conditions. The program terminates if a cooling cycle is not required. Use is made initially of subroutine Radp to determine whether the effective sensible heat factor (Eshf) intersects the saturation curve on the psychrometric chart. The message "NOT" is returned if the Eshf does not intersect the saturation curve. If the curve is intersected but the temperature drop across the cooler coil exceeds the allowable value, the message "LIMIT" is returned.

The subroutine sequence is as follows:

Terminate if Tsh < 0 or Gth <= 0 or Eshf >= 1.0 or

Eshf < 0

Call Radp

EXIT IF MESSAGE = "LIMIT" OR "NOT "

ELSE

Msup = Tsh / (1.0048 * (Trm - Tsup)*(1-x)) .... (13)

END IF

Determine whether outdoor ventilation flowrate exceeds total flowrate.

IF Msup < Moa then Msup = Moa; Mret = 0

Determine on coil states.

Hon = (Hret * Mret + Hoa * Moa)/Msup .... (14)

Tdbon = (Hon-Hret)*(Toa-Tret)/(Hoa-Hret) + Tret ... (15)

Won = (Hon-Hret)*(Woa-Wrm)/(Hoa-Hret) + Wrm .... (16)

Determine off coil states

Tdboff = Adpt + X * (Tdbon-Adpt) .... (17)

Woff = Wadp + X * (Won-Wadp)

Call Relhumid

Call Wet-bulb

Add supply fan heat gains

Determine resulting off coil states

Calculate refrigeration load

Rload = Msup * ((Hon-Hoff)-42.11 * (Won-Woff)) ..... (18)

Sub Cv-pload (Trans (*), Des-Woff, Des-toffwb, Des-cap, Des-toffdb, A, B, Vsup, Patm, Rload, Tdbon, Twbon, Tdboff, Twboff, Hon, Hoff, Msup, X1, X2, Hload)

This subroutine determines the partial load operating states for the constant volume flowrate plant operating on a cooling and dehumidification with reheat control cycle.

The off coil conditions determined by subroutine consvol are fixed.

The summarized subroutine logic is as follows:

Find whether cooling or heating is required.

IF Rsh < 0 then heating is required.

Calculate mass flowrate for the given volume flowrate by determining the specific volumes at the room and supplying temperatures.

REPEAT

Msup = Vsup * 2/(Svm + Svsupw) .... (19)

UNTIL ERROR < .001 OR COUNT > 10

ELSE

Cooling cycle is required.

Calculate mass flowrate based on the design off-coil and room temperature specific volumes.

Msup = Vsup * 2/(Svsup + Svrm)

Calculate return air states, Tret, Hret, Hon, Won, Tdbon, Rhon, Twbon

Determine whether refrigeration is required.

IF the resulting room temperature is within 1.5 °C of design temperature. If so then exit.

Determine whether heating only is required.

IF so determine whether preheat is required then exit.

Determine whether cooling is required.

If Rsh > 0 cooling is required.

Calculate off coil conditions Tdboff, Twboff, Hoff.

Calculate supply air conditions Tsup, Hsup.

Determine whether reheat in the cooling cycle is required.

If Tl > Tsup reheat cycle is required.

Calculate reheat quantity and resulting room temperature

ELSE

Determine room conditions for the design off coil states.

END IF

APPENDIX 3 : BUILDING EXAMPLE LAYOUT

A3.1 BUILDING EXAMPLE PLAN

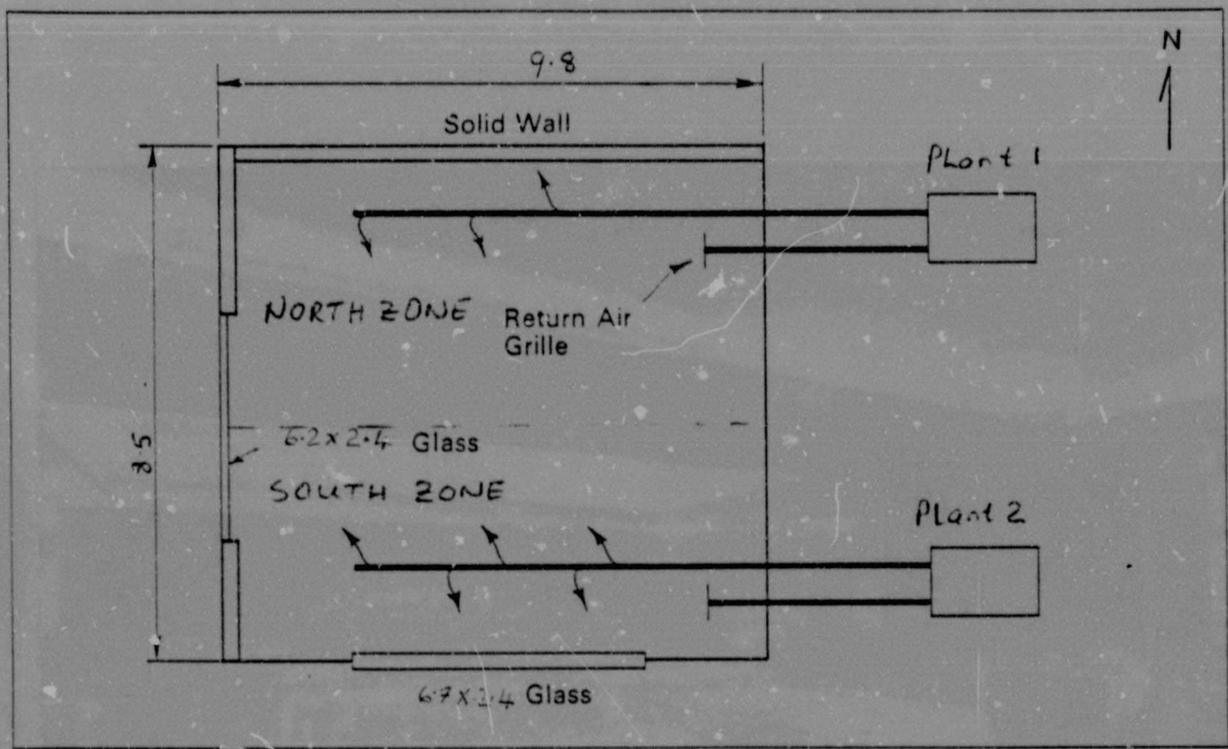

Figure A3.1 - Building example plan

A3.2 BUILDING EXAMPLE INTERIOR

Figure A3.2 - Interior of building example

A3.3 ROOF MOUNTED AIRCONDITIONING UNIT

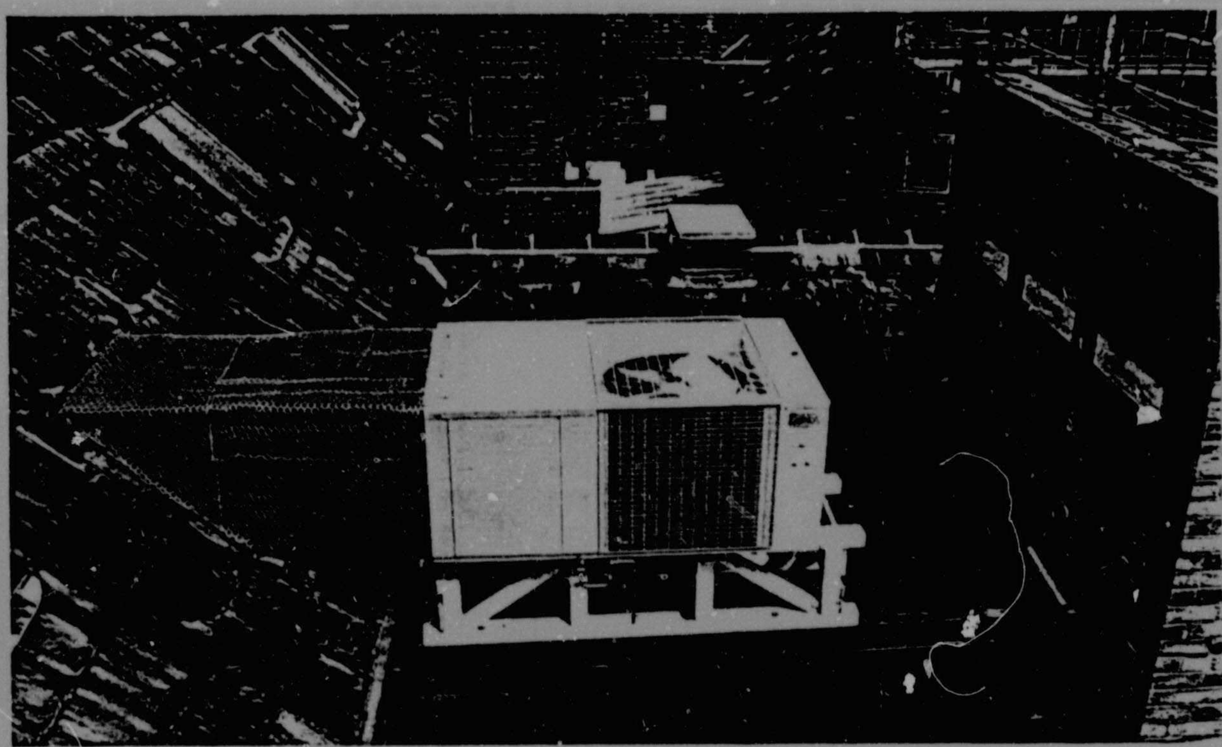

Figure A3.3 - Photograph of roof mounted unit

APPENDIX 4 : INPUT AND BUILDING LOADS FOR THE BUILDING EXAMPLE

The following tables are print-outs of the building parameters used in the building load calculation.

TABLE A4.1 OUTDOOR TEMPERATURES AND LOCATION DATA PRINT-OUT

```
************************************ AIR - CONDITIONING LOADS PROGRAM BY A DA SILVA ********************************
STEYN VAN RENSBURG INC
CONSULTING ENGINEERS                                           PROJECT          : MSC PSY PROGRAM
SUNNYSIDE PRETORIA                                             PROJECT LOCATION : WITS UNIVERSITY
                                                               PROJECT NUMBER   : MSC
************************************ DETAILED PROJECT ZONE DATA PRINTOUT ********************************************
```

T E M P E R A T U R E & L O C A T I O N D A T A

	Outdoor Max db Deg C	Outdoor Min db Deg C	Outdoor Max wb Deg C	Site Lat Deg S	Site Alt m ASL	Site Reflec Factor	Zone Design Deg C	Zone Rel h %	Zone Int W Deg C	Zone Floor T Deg C
WINTER DESIGN TEMP	3.0		0.0							
SITE LOCATION DATA				27.0	1552.0	.200				
DECEMBER	33.9	0.0	22.5							
NORTH ZONE							22.0	50.0	28.0	22.0
SOUTH ZONE							22.0	50.0	28.0	22.0