ESL-TR-01/03-01

AIR-SIDE ENERGY USE CALCULATIONS FOR FOUR HVAC SYSTEMS: DUAL DUCT CONSTANT VOLUME (DDCAV), DUAL DUCT VARIABLE VOLUME (DDVAV), CONSTANT VOLUME WITH REHEAT (CAVRH), VARIABLE VOLUME WITH REHEAT (VAVRH).

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ENERGY SYSTEMS
LABORATORY

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ABSTRACT

This report contains engineering calculations for four (4) air-side, heating, ventilating and air-conditioning systems (HVAC) systems, including: dual duct constant volume (DDCAV), dual duct variable volume (DDVAV), constant volume with reheat (CAVRH), and variable volume with reheat (VAVRH). These calculations are presented in spreadsheets that include a running commentary so that the reader can trace through the calculations to see what is being performed. Each system also contains a one-line diagram that shows the system being simulated and the location of the variables used in the calculation.

These calculations are useful for developing educational materials, and can be used to check the values obtained from a computer simulation program that contain the exact same schematic as is shown for each system. With only a few exceptions, the formulas for the calculations have come from the ASHRAE Handbook, as indicated in the spreadsheet narrative.

These spreadsheets were developed in Lotus *.wk1 format and can be run in any spreadsheet that accepts Lotus *.wk1 format. To use the spreadsheets the user loads the spreadsheet, updates only the values needed and recalculates the spreadsheet manually. Calculations are repeated column-wise in the spreadsheet to reach convergence. Each calculation represents one set of conditions. To obtain answers for multiple conditions the user will need to enter the new conditions and recalculate for each set of conditions.

1.0 GENERAL INSTRUCTIONS FOR USING THE SPREADSHEETS.

The spreadsheets that are used to perform the air-side calculations are formatted as shown in Figure 1.1. Input values are entered into the cells in the upper left corner of the spreadsheet. The output from the spreadsheet is posted directly to the right of the input section. The calculations are performed in the columns below the input-output section. Since the air-side calculations often require an iterative solution, the calculations are repeated in columns across the spreadsheet from left to right using the values from the columns that were previously calculated. The "answer" is posted from the rightmost set of columns in the output section. These spreadsheets are provided in an unprotected mode. Hence the user should only enter values into the "input" section shown. Changing values in other parts of the spreadsheet can cause incorrect answers.

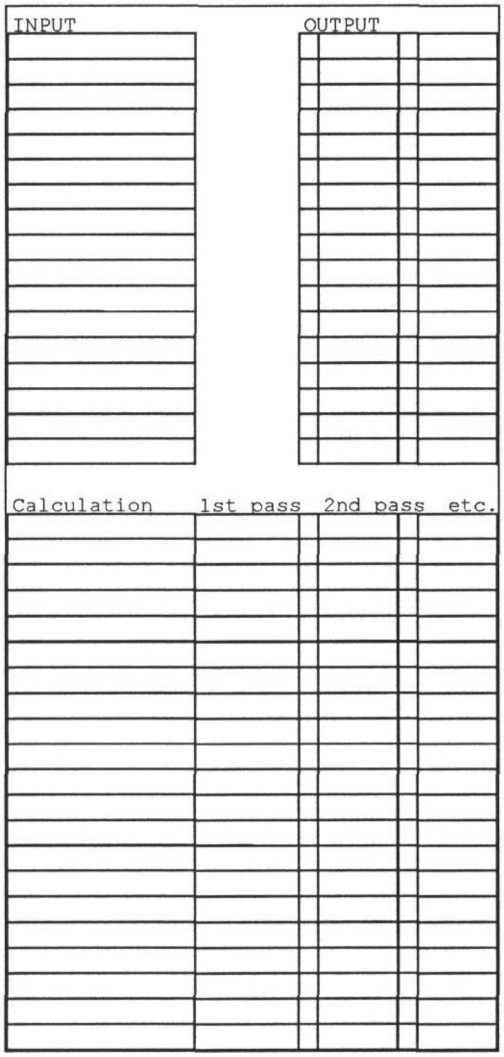
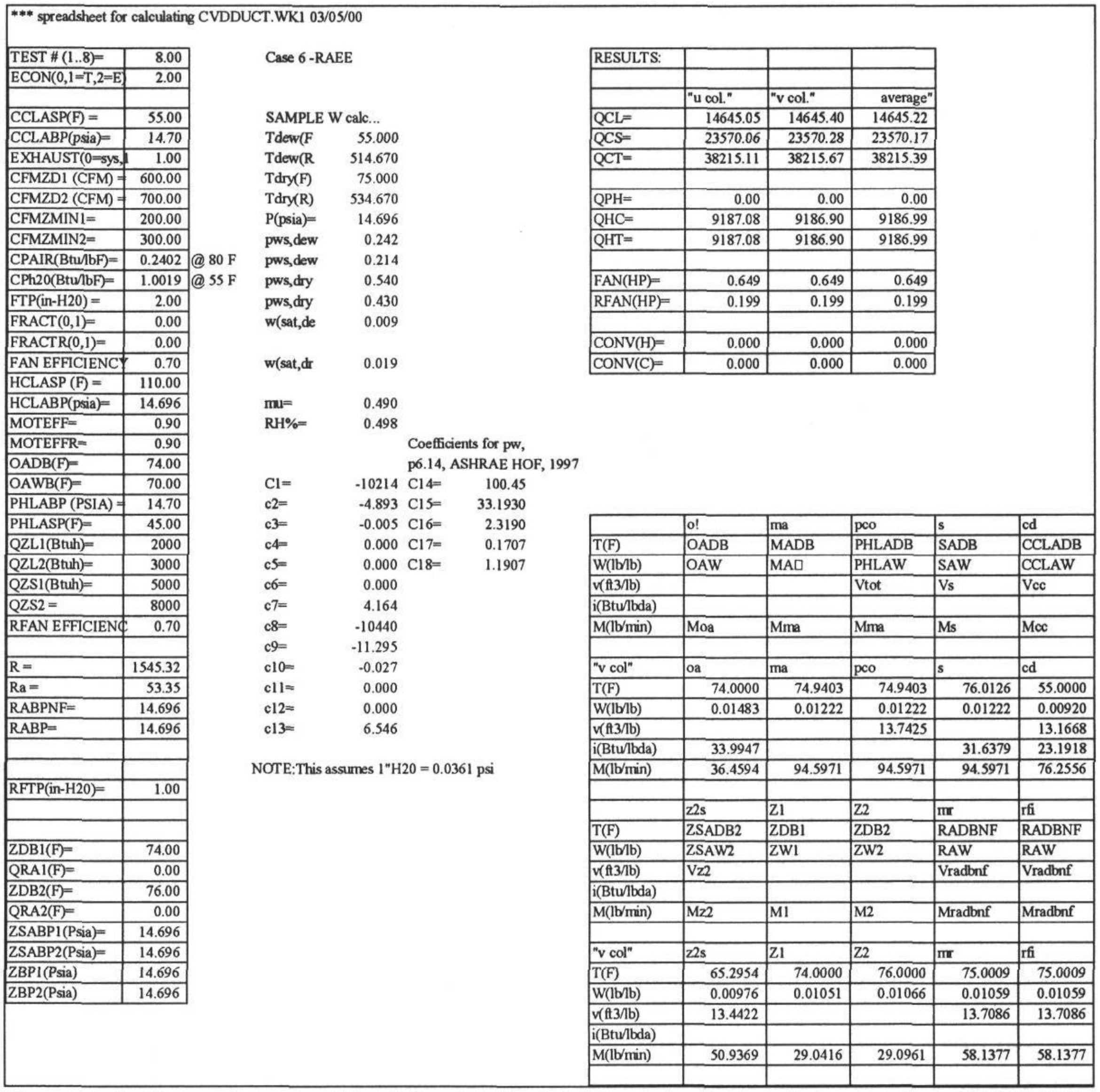


Figure 1.1: General layout of the spreadsheets used for the air-side calculations.



*** spreadsheet for calculating CVDDUCT.WK1 03/05/00

TEST # (1..8)=	8.00	
ECON(0,1=T,2=E)	2.00	
CCLASP(F) =	55.00	
CCLABP(psia)=	14.70	
EXHAUST(0=sys,1	1.00	
CFMZD1 (CFM) =	600.00	
CFMZD2 (CFM) =	700.00	
CFMZMIN1=	200.00	
CFMZMIN2=	300.00	
CPAIR(Btu/lbF)=	0.2402	@ 80 F
CPh20(Btu/lbF)=	1.0019	@ 55 F
FTP(in-H20) =	2.00	
FRACT(0,1)=	0.00	
FRACTR(0,1)=	0.00	
FAN EFFICIENCY	0.70	
HCLASP (F) =	110.00	
HCLABP(psia)=	14.696	
MOTEFF=	0.90	
MOTEFFR=	0.90	
OADB(F)=	74.00	
OAWB(F)=	70.00	
PHLABP (PSIA) =	14.70	
PHLASP(F)=	45.00	
QZL1(Btuh)=	2000	
QZL2(Btuh)=	3000	
QZS1(Btuh)=	5000	
QZS2 =	8000	
RFAN EFFICIENC	0.70	
R =	1545.32	
Ra =	53.35	
RABPNF=	14.696	
RABP=	14.696	
RFTP(in-H20)=	1.00	
ZDB1(F)=	74.00	
QRA1(F)=	0.00	
ZDB2(F)=	76.00	
QRA2(F)=	0.00	
ZSABP1(Psia)=	14.696	
ZSABP2(Psia)=	14.696	
ZBP1(Psia)	14.696	
ZBP2(Psia)	14.696	

Case 6 -RAEE

SAMPLE W calc...

Tdew(F	55.000
Tdew(R	514.670
Tdry(F)	75.000
Tdry(R)	534.670
P(psia)=	14.696
pws,dew	0.242
pws,dew	0.214
pws,dry	0.540
pws,dry	0.430
w(sat,de	0.009
w(sat,dr	0.019
mu=	0.490
RH%=	0.498

Coefficients for pw,
p6.14, ASHRAE HOF, 1997

Cl=	-10214	C14=	100.45
c2=	-4.893	C15=	33.1930
c3=	-0.005	C16=	2.3190
c4=	0.000	C17=	0.1707
c5=	0.000	C18=	1.1907
c6=	0.000		
c7=	4.164		
c8=	-10440		
c9=	-11.295		
c10=	-0.027		
cl1=	0.000		
c12=	0.000		
c13=	6.546		

NOTE:This assumes 1"H20 = 0.0361 psi

RESULTS:			
	"u col."	"v col."	average"
QCL=	14645.05	14645.40	14645.22
QCS=	23570.06	23570.28	23570.17
QCT=	38215.11	38215.67	38215.39
QPH=	0.00	0.00	0.00
QHC=	9187.08	9186.90	9186.99
QHT=	9187.08	9186.90	9186.99
FAN(HP)=	0.649	0.649	0.649
RFAN(HP)=	0.199	0.199	0.199
CONV(H)=	0.000	0.000	0.000
CONV(C)=	0.000	0.000	0.000

	o!	ma	pco	s	cd
T(F)	OADB	MADB	PHLADB	SADB	CCLADB
W(lb/lb)	OAW	MA□	PHLAW	SAW	CCLAW
v(ft3/lb)			Vtot	Vs	Vcc
i(Btu/lbda)					
M(lb/min)	Moa	Mma	Mma	Ms	Mcc
"v col"	oa	ma	pco	s	cd
T(F)	74.0000	74.9403	74.9403	76.0126	55.0000
W(lb/lb)	0.01483	0.01222	0.01222	0.01222	0.00920
v(ft3/lb)			13.7425		13.1668
i(Btu/lbda)	33.9947			31.6379	23.1918
M(lb/min)	36.4594	94.5971	94.5971	94.5971	76.2556
	z2s	Z1	Z2	mr	rfi
T(F)	ZSADB2	ZDB1	ZDB2	RADBNF	RADBNF
W(lb/lb)	ZSAW2	ZW1	ZW2	RAW	RAW
v(ft3/lb)	Vz2			Vradbnf	Vradbnf
i(Btu/lbda)					
M(lb/min)	Mz2	M1	M2	Mradbnf	Mradbnf
"v col"	z2s	Z1	Z2	mr	rfi
T(F)	65.2954	74.0000	76.0000	75.0009	75.0009
W(lb/lb)	0.00976	0.01051	0.01066	0.01059	0.01059
v(ft3/lb)	13.4422			13.7086	13.7086
i(Btu/lbda)					
M(lb/min)	50.9369	29.0416	29.0961	58.1377	58.1377

Figure 1.2: Example spreadsheet for the dual duct constant air volume system (DDCAV).

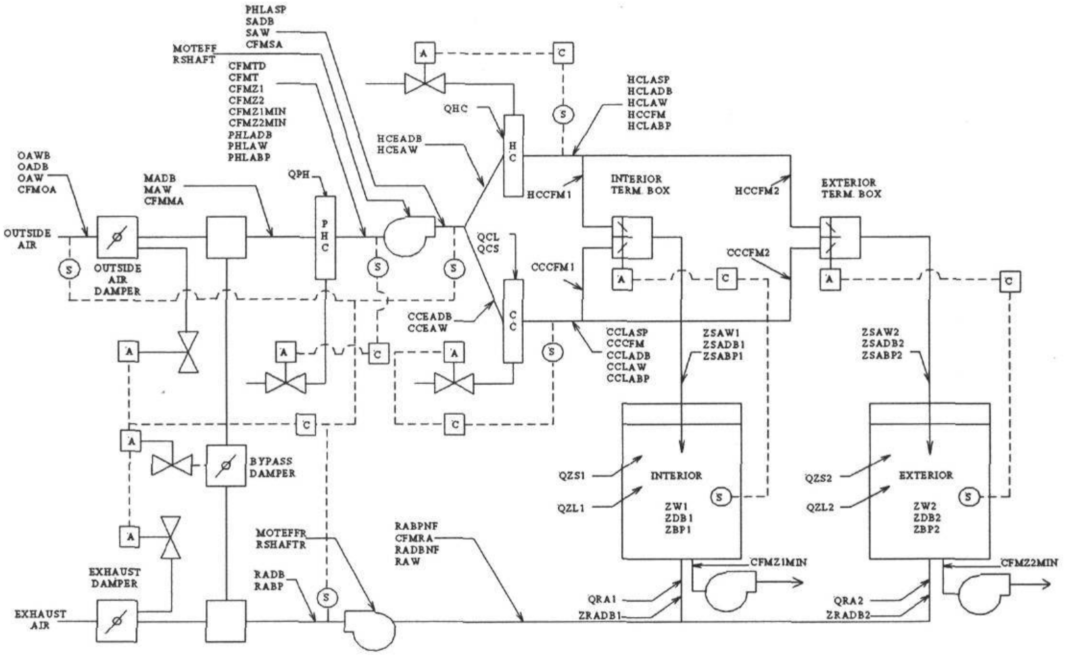
2.0 FILES INCLUDED WITH THIS REPORT.

This report includes a CDROM with four spreadsheets that contain the air-side energy use calculations for four HVAC systems, including: dual duct constant volume (DDCAV), dual duct variable volume (DDVAV), constant volume with reheat (CAVRH), and variable volume with reheat (VAVRH).

The file names and contents of the four files on the CDROM are included in the table below. The spreadsheets were written with Lotus 123 and can be executed with any spreadsheet that can read .wk1 format files. No external calls or macros are used in the files.

ITEM NO:	FILENAME:	DESCRIPTION:
1.	CVDDUCT.WK1	Spreadsheet containing energy use calculations for the dual duct constant volume system (DDCAV).
2.	VVDDUCT.WK1	Spreadsheet containing energy use calculations for the dual duct variable volume system (DDVAV).
3.	CVREHEAT.WK1	Spreadsheet containing energy use calculations for the constant volume with reheat system (CAVRH).
4.	VVREHEAT.WK1	Spreadsheet containing energy use calculations for the variable volume with reheat system (VAVRH).

3.0 DUAL DUCT CONSTANT VOLUME (DDCAV).



Constant Volume Dual Duct System (DDCAV)

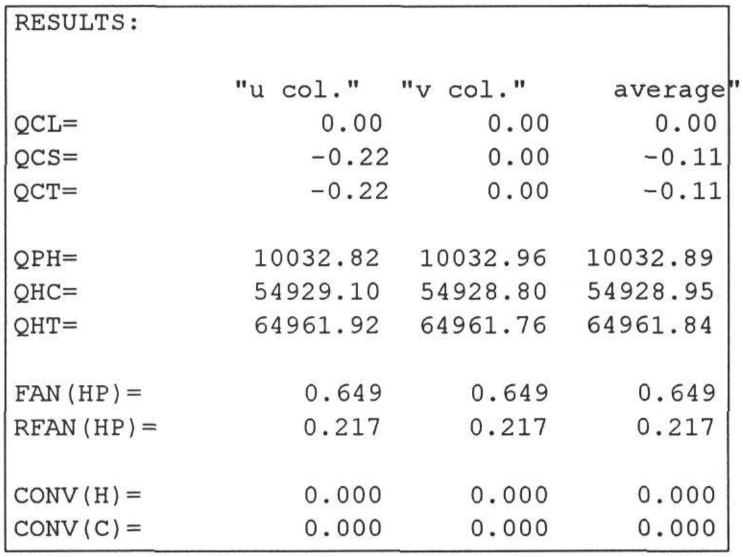
The input values for the DDCAV spreadsheet are as follows:

TEST # (1..8)=	8.00	This switch is used for cosmetic purposes only. It is used to change the label that appears directly to the right of the input cell and creates a set of "canned" labels used for one of the tests that the spreadsheet was developed for.
ECON(0,1=T,2=E)	2.00	This switch turns the economizer "on" or "off". It is also used to select whether the temperature (T) or enthalpy (E) economizer is used.
CCLASP(F) =	55.00	This variable is the cooling coil leaving air setpoint temperature (F).
CCLABP(psia)=	14.70	This variable is the cooling coil leaving air barometric pressure (PSIA).
EXHAUST(0=sys,1=zone)	1.00	This switch is used to calculate 'zone air exhaust' or 'system air exhaust'. This will cause a difference in the mass flow rates returning from the zone, and heat gain from the return fan.
CFMZD1 (CFM) =	600.00	This is the design air flow for zone 1 (CFM).
CFMZD2 (CFM) =	700.00	This is the design air flow for zone 2 (CFM).
CFMZMIN1=	200.00	This is the exhaust air for zone 1 (CFM)
CFMZMIN2=	300.00	This is the exhaust air for zone 2 (CFM)
CPAIR(Btu/lbF)=	0.2402	This is the constant that is used for the specific heat of air (80F).
CPh20(Btu/lbF)=	1.0019	This is the constant that is used for the specific heat of water (55F).
FTP(in-H20) =	2.00	This is the total fan pressure across the supply fan (in-H20).
FRACT(0,1)=	0.00	This is the switch that is used to place the supply fan in the air stream (1) or outside of the air stream (0).
FRACTR(0,1)=	0.00	This is the switch that is used to place the return fan in the air stream (1) or outside of the air stream (0).
FAN EFFICIENCY=	0.70	This is the constant fan efficiency (%).
HCLASP (F) =	110.00	This is the heating coil leaving air setpoint temperature (F).

HCLABP(psia)=	14.696	This variable is the heating coil leaving air barometric pressure (PSIA).
MOTEFF=	0.90	This variable is the constant motor efficiency of the supply fan (%).
MOTEFFR=	0.90	This variable is the constant motor efficiency of the return fan (%).
OADB(F)=	74.00	This variable is the outside air dry bulb temperature (F).
OAWB(F)=	70.00	This variable is the outside air wet bulb temperature (F).
PHLABP (PSIA) =	14.70	This variable is the preheat coil leaving air barometric pressure (PSIA).
PHLASP(F)=	45.00	This variable is the setpoint temperature of the preheat coil (F).
QZL1(Btuh)=	2000	This variable is the latent load of zone 1 (BTUH).
QZL2(Btuh)=	3000	This variable is the latent load of zone 2 (BTUH).
QZS1(Btuh)=	5000	This variable is the sensible load of zone 1 (BTUH).
QZS2 =	8000	This variable is the sensible load of zone 2 (BTUH).
RFAN EFFICIENCY=	0.70	This variable is the constant fan efficiency of the return fan (%).
R =	1545.32	This variable is the gas constant for dry air (currently not used).
Ra =	53.35	This variable is the gas constant for dry air (ft-lbf/R-lb).
RABPNF=	14.696	This variable is the barometric pressure at a point in front of the return fan (PSIA).
RABP=	14.696	This variable is the barometric pressures at at point in back of the return fan (PSIA).
RFTP(in-H20)=	1.00	This is the total fan pressure across the supply fan (in-H20).
ZDB1(F)=	74.00	This variable is the zone temperature for zone 1 (F).
QRA1(F)=	0.00	This variable is the heat gain of the ducts returning from zone 1 (F).
ZDB2(F)=	76.00	This variable is the zone temperature for zone 2 (F).
QRA2(F)=	0.00	This variable is the heat gain of the ducts returning from zone 2 (F).

ZSABP1(Psia)=	14.696	This variable is the barometric pressure of the supply air for zone 1 (PSIA).
ZSABP2(Psia)=	14.696	This variable is the barometric pressure of the supply air for zone 2 (PSIA).
ZBP1(Psia)	14.696	This variable is the barometric pressure of the air in zone 1 (PSIA).
ZBP2(Psia)	14.696	This variable is the barometric pressure of the air in zone 2 (PSIA).

The output from the DDCAV is listed in two tables to the left of the input table. In the upper table that is shown below, the coil loads and fan loads are shown. The QCL, QCS and QCT rows indicate the main latent (QCL) and sensible (QCS) cooling coil loads. The "u col" and "v col" show the values for the last two iterations of the spreadsheet and the "average" shows the average of the last two columns of calculations.



```
RESULTS:

                "u col."   "v col."     average"
QCL=                0.00       0.00        0.00
QCS=               -0.22       0.00       -0.11
QCT=               -0.22       0.00       -0.11

QPH=            10032.82   10032.96    10032.89
QHC=            54929.10   54928.80    54928.95
QHT=            64961.92   64961.76    64961.84

FAN(HP)=           0.649      0.649       0.649
RFAN(HP)=          0.217      0.217       0.217

CONV(H)=           0.000      0.000       0.000
CONV(C)=           0.000      0.000       0.000
```

The QPH, QHC and QHT are the totals of the preheating coil load (QPH), the main heating coil load (QHC) and the total of the preheat and main coil loads (QHT).

The power required by the supply (FAN) and return fans (RFAN) is indicated in horsepower (HP).

The CONV(H) and CONV(C) values indicate the difference between the calculations in the last two columns (i.e., a convergence indicator.

The second table indicates the psychrometric properties at various points around the simulation. The location of these points is shown in the DDCAV one-line schematic.

In the second table the values are listed in two rows. The units are listed in the vertical leftmost column. The variable names are listed across the rows. In the first row the OADB, MADB, PHLADB, SADB, CCLADB, HCLADB and ZSADB1 are shown. Where the OADB are the outside air conditions, the MADB are the mixed air conditions just before the preheating coil, the PHLADB are the conditions after the preheating coil. The SADB are the conditions after the main supply fan, the CCLADB are the conditions after the cooling coil, the HCLADB are the conditions after the heating coil, and the ZSADB1 are the conditions of the air entering zone 1.

```
              o!         ma         pco        s          cd         hd         z1s
T(F)          OADB       MADB       PHLADB     SADB       CCLADB     HCLADB     ZSADB1
W(lb/lb)      OAW        MA_        PHLAW      SAW        CCLAW      HCLAW      ZSAW1
v(ft3/lb)                           Vtot       Vs         Vcc        Vhc        Vz1
i(Btu/lbda)
M(lb/min)     Moa        Mma        Mma        Ms         Mcc        Mhc        Mz1

"v col"       oa         ma         pco        s          cd         hd         z1s
T(F)           -20.0000    38.1894    45.0000    46.0093    46.0093   110.0000    84.7077
W(lb/lb)        0.00026    0.00157    0.00157    0.00157    0.00157    0.00157    0.00157
v(ft3/lb)                             12.7550               12.7805    14.3978    13.7586
i(Btu/lbda)     -4.5284                          12.7483    12.7523
M(lb/min)       37.2204   101.9206   101.9206   101.9206    42.5330    59.3879    47.0403

              z2s        Z1         Z2         mr         rfi        rfo
T(F)          ZSADB2     ZDB1       ZDB2       RADBNF     RADBNF     RADB
W(lb/lb)      ZSAW2      ZW1        ZW2        RAW        RAW        RAW
v(ft3/lb)     Vz2                              Vradbnf    Vradbnf    Vradb
i(Btu/lbda)
M(lb/min)     Mz2        M1         M2         Mradbnf    Mradbnf    Mradb

"v col"       z2s        Z1         Z2         mr         rfi        rfo
T(F)            82.0853    70.0000    72.0000    71.0072    71.0072    71.5378
W(lb/lb)        0.00157    0.00222    0.00241    0.00232    0.00232    0.00232
v(ft3/lb)       13.6923                          13.4284    13.4284
i(Btu/lbda)                                                            19.7198
M(lb/min)       54.8803    32.1158    32.5844    64.7002    64.7002    64.7002
```

In the second row, the ZSADB2, ZDB1, ZDB2, RADBNF, and RADB conditions are indicated. The ZSADB2 are the conditions entering zone 2, the ZDB1 are the conditions in the zone (i.e, the set point temperature), the ZDB2 are the setpoint conditions of zone 2, the RADBNF are the conditions just prior to the return fan (if used), and the RADB are the conditions immediately after the return fan (if used).

Listing of example DDCAV spreadsheet.

The spreadsheet for the dual duct constant air volume system is listed in the following pages. These calculations begin directly below the input-output section and continue down the spreadsheet for the first iteration. The second iteration then uses the calculations from the first column, and so forth across the columns until the last column is reached. The number of columns was determined by a convergence of less than 1% for this type of system.

The spreadsheets were written in a narrative format to allow them to be easily traced. The actual calculations take place in the "First pass", "second pass" … etc… columns.

NOTE: In certain systems, oscillation has been observed. In such a case it is recommended to use the average value of the last two columns.

Calculations begin here... First Pass Second Pass

[STEP 1a:]--

Calculate the supply air temperature for Zone#1 necessary
for meeting the sensible loads on the zone.

(First pass) Assume a supply air temperature = 55 F.
and assume a RH = 100% to start the simulation.

ZSADB1 = 55 55.0 66.5
ZSADB1(R) = 514.7 526.2

Calculate (w= ZSAW1) with assumed ZSADB1.
assume that Tdew = Tdry = ZSADB1.

First, calculate Pws<32, Pws>32.

Pws,dew(<32)= 0.2
Pws,dew(>32)= 0.2

Now, calculate the (W = ZSAW1) with assumed ZSADB1
and Tdew = Tdry = ZSADB1.

ZSAW1 = 0.0092

NOTE: in the 2nd and following passes...one can calculate the ZSAW1

using a moisture balance from the first pass

First, calculate the mass flow rate of the cold air entering
the terminal box.

Mcold#1 = Mmix#1 - Mhot#1

Now, solve a moisture balance around terminal box #1 using values from

the first pass.

Wmix#1 = Mhot#1 x HCLAW + Mcold#1 x CCLAW / Mmix#1

ZSAW1= 0.0087

Calculate (v) the specific volume w/ T = 55F.

NOTE: 7/99 OLD METHOD USES (v) at SADB1... First, convert the ZSABP1 from psia to inHg.

using 1 psia = 2.036 in Hg

v = Ra x T (1 + 1.6078 x W)/(70.7262 x Pzsabp1) 13.2 13.5

NOTE: This is the 7/99 change to move mass calc. to the supply fan.

Copy the specific volume from the previously calculated fan...

using the conditions at PHLADB which are in front of the fan...

Use this "v" instead of the "v" calc'd at the diffuser on 2,3,4 calcs.

Vphladb = Ra x Tphladb (1 + 1.6078 x Wphlaw) / (70.7262 x Pfan,enter)

Vphladb= 13.73

Next, calculate the air mass flow rate for Zone #1 using

NOTE: This uses Vsabp1 for #1 calc, and Vphladb for #2,#3,#4...etc.

m = CFMZ1 x 60 x 1/v m1 = 2734.2 2621.1

NOTE: 7/99 Changed to include sensible heat of moisture in the air .444xW

This next equation assumes that Wzdb1 = Wzsadb1...i.e. moisture at room conditions.

Calculate the ZSADB1 = ZDB1 - QZS1/(m x (cp + .444 W))

ZSADB1 = 66.5 66.18

[Step 1b:]--

Now, repeat the calculations for the Zone #2

(First pass) Assume a supply air temperature = 55 F.
and assume a RH = 100% to start the simulation.

(2nd pass) Use the calculated ZSADB1 temperature from the end

of this step.

ZSADB2 = 55 55.0 65.7
ZSADB2(R) = 514.7 525.4

Calculate (w= ZSAW2) with assumed ZSADB2.
assume that Tdew = Tdry = ZSADB2.

First, calculate Pws<32, Pws>32.

Pws,dew(<32)= 0.2
Pws,dew(>32)= 0.2

Now, calculate the (W = ZSAW2) with assumed ZSADB2
and Tdew = Tdry = ZSADB2.

ZSAW2 = 0.0092

NOTE: in the 2nd and following passes...one can calculate the ZSAW2

using a moisture balance from the first pass

First, calculate the mass flow rate of the cold air entering
the terminal box.

Mcold#2 = Mmix#2 - Mhot#2

Now, solve a moisture balance around terminal box #2 using values from

the first pass.

Wmix#2 = (Mhot#2 x HCLAW + Mcold#2 x CCLAW) / Mmix#2

ZSAW2= 0.009

Calculate (v) the specific volume w/ T = 55F.

First, convert the ZSABP2 from psia to inHg.
using 1 psia = 2.036 in Hg

v = Ra x T (1 + 1.6078 x W)/(70.7262 x Pzsabp2) 13.2 13.4

Next, calculate the air mass flow rate for Zone #2 using

NOTE: This is the 7/99 change to move mass calc. to the supply fan.

Copy the specific volume from the previously calculated fan...

using the conditions at PHLADB which are in front of the fan...

Use this "v" instead of the "v" calc'd at the diffuser on 2,3,4 calcs.

Vphladb = Ra x Tphladb (1 + 1.6078 x Wphlaw) / (70.7262 x Pfan,enter)

Vphladb= 13.73

Next, calculate the air mass flow rate for Zone #1 using
NOTE: This uses Vsabp1 for #1 calc, and Vphladb for #2,#3,#4...etc.

m = CFMZ2 x 60 x 1/v m2 = 3189.8 3058.0

NOTE: 7/99 Changed to include sensible heat of moisture in the air .444xW

Now, calculate the ZSADB1 = ZDB1 - QZS1/(m x cp + .444 W)

NOTE: 7/99 Changed to include sensible heat of moistu2e in the air .444xW

This next equation assumes that Wzdb2 = Wzsadb2...i.e. moisture at room conditions.

Calculate the ZSADB2 = ZDB2 - QZS2/(m x (cp + .444 W))

ZSADB2 = 65.7 65.28

[Step 2a:]

Calculate the return air temperature for zone#1 (ZRADB1) including any return air heat gain (QRA1).

NOTE: This next calculation assumes QRA1 is entered in degrees F.

ZRADB1 = ZDB1 + QRA1 74.0 74.0

Now, calculate the humidity ratio leaving the zone

ZW1 = ZSAW1 + QZL1 / [(1061 + .444 (ZDB1)) m1]

ZW1 = 0.0099 0.0094

[Step 2b:]---

Calculate the return air temperature for zone#2 (ZRADB2) including any return air heat gain (QRA2).

NOTE: This next calculation assumes QRA2 is in degrees F.

ZRADB2 = ZDB2 + QRA2/(m2 x cp2)
ZRADB2= 76.0 76.0

Now, calculate the humidity ratio leaving the zone

ZW2 = ZSAW2 + QZL2 / [(1061 + .444 (ZDB2)) m2]

ZW2 = 0.0101 0.0095

[Step 3]:---

NOTE: 7/99 This next calc. has been modified to include air leaving the zone...at the zone exhaust...this is controlled by the "EXHAUST" variable that is set = 0 for system exhaust (no zone exhaust) or set =1 for zone exhaust = minimum air for each zone.

First, calculate the exhaust air = minimum ventilation air for each zone. using the conditions at each zone for (v) calc.

Calc. the (v) for zone#1

v = Ra x ZDB1 (1 + 1.6078 x ZW1)/(70.7262 x Pzone#1)

v = 13.7 13.7

Calc. the (v) for zone#2

v = Ra x ZDB2 (1 + 1.6078 x ZW2)/(70.7262 x Pzone#2)

v = 13.7 13.7

m1,min = CFMZMIN1 x 60 x 1/v 878.0 878.7

m2,min = CFMZMIN2 x 60 x 1/v 1311.7 1312.8

Now, depending upon value of EXHAUST = 0,1 calc. m1 + m2 = mra

EXHAUST (0=sys, 1=zone) =	1.00	1.00
From previously, m1 =	2734.15	2621.13
From previously, m2 =	3189.84	3057.99
Mma =	5924.00	5679.12
m1,w/exh =	1856.15	1742.48
m2,w/exh =	1878.15	1745.17

Calculate the average return air dry bulb temperature before the return fan RADBNF

RADBNF = (ZRADB1 x m1 x cp1 + ZRADB2 x m2 x cp2)/(mradb x cpradb)

Where it is assumed cp1 = cp2 = cpradb...(CP+.444W) has small effect.

mradb = m1 + m2

RADBNF = (ZRADB1 x m1 + ZRADB2 x m2)/(m1 + m2)

RADBNF= 75.0 75.0

Now, calculate the humidity ratio in the return air duct from both

zones by calculating a humidity balance.

NOTE: 9/18/99 the equation below uses the M1 & M2 air flow into the zone...versus M1 & M2 (EXHAUST) above...?

RAW = (ZW1 x m1 + ZW2 x m2) / (m1 + m2)

RAW = 0.0100 0.0095

Now calculate the return air temperature after the fan (RADB)

First, calculate the specific volume (v)

Vra = Ra x Tra (1 + 1.6078 x Wra) / (70.7262 x Pfan,enter)

P = RABPNF = see above in variables...

Vra= 13.7 13.7

Next, calculate the total CFM across the return fan (CFMT)

CFMTr = Mradb x 1/60 x vra

Mradbnf = M1 + M2 Mradbnf = 3734.3 3487.6

CFMTr = 852.4 795.4

NOTE: 7/99 This now includes the sensible heating of the dry air (CP)

and moisture contained in the moist air (.444W)

Now, calculate the temperature rise across the fan
using DTRAF = QFAN/Mra x (cp+.444W)

NOTE: 2/12...new FAN equations from Knebel, checked against p. 207 Kreider,Rabl

First, assume constant volume, design conditions...calculate FanHP, Motor HP, DTFAN

then calculate conditions for variable speed fan using Brandemuehl's equations.

for VSD, Inlet vane, discharge dampers, etc.

Fan HP(design) = 0.0001573 x CFM x TP / EFFfan

where Fan HP is calculated on CFMTD = total design CFM
where TP = FTP = total pressure across fan inH2O
EFFfan = fan efficiency

CFMdesign = value from above

Fan HP(design) = 0.19 0.18

Next, calculate the Motor HP for the constant volume system

Motor HP = Fan HP(design)/EFFmotor

where Motor HP = HP of constant volume design conditions
EFFmotor = electric motor efficiency

Motor HP(design) = 0.21 0.20

Next calculate DTFAN(design) using FRACT = 0,1
where FRACT = 1 (motor in air), 0 (motor not in air)

DTFAN = FanHP x 2544.85 / [Mdesign x (CP + .444xRAW)]

for the motor NOT in the air stream...

DTFAN = FanHP x 2544.85 / [Mdesign x (CP + .444xRAW)] x EFFm

for the motor in the air stream...use FRACT = 0,1 as choice...

where

Mdesign = (CFMdesign)*60/Vradb= 3734.3 3487.6

DTFAN(design,motor out) = 0.53 0.53

DTFAN(design,motor in) = 0.59 0.59

FRACT= 0

DTRAF(F) = 0.53 0.53

Now, calculate the return air dry bulb temperature after the fan

RADB = RADBNF + DTRAF

RADB = 75.5 75.5

[Step 4]:--

These next set of equations are for temperature-base economizer.

Next, precalculate all possible MADB temperatures
depending upon economizer mode...then select economizer type

[Cold range]--

First, we need to calculate the minimum mass flow rate of the

ventilation air for zone #1 and zone#2. This requires
recalculating (v1) at ZW1 and ZDB1 for zone #1 and etc. for zone#2.

NOTE: 7/99 This calculation was left alone...since it appears that PSU

is calculating the conditions at the zone conditions for min air.

This therefore assumes ZDB1, ZDB2, etc...for calc. (v).
Vphladb is not used here...

Zone#1

v = Ra x T (1 + 1.6078 x W)/(70.7262 x P)

where

v = Ra x ZDB1 (1 + 1.6078 x ZW1)/(70.7262 x Pzone#1)

v= 13.7 13.7

Vphladb = Ra x Tphladb (1 + 1.6078 x Wphlaw) / (70.7262 x Pfan,enter)

Vphladb= 13.73

Next, calculate the ventilation air mass flow rate for Zone #1 using

m1,min = CFMZMIN1 x 60 x 1/v

m1,min= 878.0 878.7

Zone#2

v = Ra x T (1 + 1.6078 x W)/(70.7262 x P)

where

v = Ra x ZDB2 (1 + 1.6078 x ZW2)/(70.7262 x Pzone#2)

NOTE: 7/99 this assumes zone conditions for min air..as Zone #2.

v= 13.7 13.7

Next, calculate the ventilation air mass flow rate for Zone #2 using

m2,min = CFMZMIN2 x 60 x 1/v	m2,min =	1311.7	1312.8
moa,(zone#1+#2)=(m1,min + m2,min)	moa,1+2=	2189.7	2191.5

Next, calculate the mass of the return air = mra = (m1+m2)

NOTE: 7/99 this copies down the prev. calc. mradbnf

mra = 3734.3 3487.6

NOTE: 7/99 This had to be changed to account for zone exhaust.

The next equation only works when EXHAUST = 0.
This is because it assumes Mma = Mra since there is no zone exhaust.

Now, calculate the mixed air dry bulb temperature (cold range, w/sys exhaust)

MADB = (moa x OADB + (mra - moa)xRADB)/mra

(w/system exhaust) MADB,cold range = 74.6 74.6

NOTE: 8/99...NEW...Now, calculate the mixed air dry bulb for zone exhaust...

Knowing that Mra = Mma - (Moa#1 + Moa#2)
Where Moa#1 and Moa#2 was exhausted at the zone.
MADB=[Moa(cp+.444Woa)OADB+Mra(cp+.444Wra)RADB]/[Mma(cp+.444Wma)]

(w/zone exhaust) MADB,cold range = 75.0 74.9

Now, choose which one based on EXHAUST(0=sys,1=zone)

EXHAUST = 1.00 1.00

(either system) MADB,cold range = 75.02 74.91

SADB = MADB + DTSAF

Assume DTSAF = 1 F for first iteration, calc. for 2,3,4th.

SADB,cold range 76.0 76.0

Next, calculate the humidity ratio of the mixed air

First, calculate the saturation vapor pressure at (Pws(OAWB))

	OAWB(F)=	70.0	70.0
	OAWB(R)=	529.7	529.7
<32	Pws,dew(<32)=	0.4	0.4
>32	Pws,dew(>32)=	0.4	0.4

Now, calculate the (Wwb = at T = OAWB).

Wwb = 0.0 0.0

Next, calculate the Woa using

Woa = [(1093 - 0.556 * OAWB)*Wwb - (0.24(OADB-OAWB))]/(1093+0.444*OADB-OAWB)

Woa = 0.0148 0.0148

This next calculation fixes the ASHRAE Handbook when OAW < 0 at cold, dry temps

by replacing the ASHRAE value with a slightly positive value = 0.0000001

Woa = OAW OAW= 0.0148 0.0148

Now, calculate the humidity ratio of the mixed air using:

NOTE: 7/99 This also needs two equations with EXHAUST as a 0,1 variable.

This equation works for EXHAUST =0

Wma = (moa x Woa +mbp x wbp)/mma = MAW

MAW = [moa x OAW + (mra-moa) x RAW]/mra

(w/sys. exhaust) MAW,cold range = 0.0128 0.0128

This new equation works with EXHAUST = 1 = zone exhaust

MAW = (Moa x OAW + (Mra)RAW)/Mma

(w/zone exhaust) MAW,cold range = 0.0118 0.0115

EXHAUST = 1.0 1.0

(either system) MAW,cold range = 0.0118 0.0115

NOTE: 7/99 Enthalpy calculation added here for cold range

Calc. the enthalpy at OADB,OAW using p. 6.13 of HOF

where h = 0.24T + W(1061+.444T)

h(OADB,OAW)= 33.99 33.99

Calc. the enthalpy at RADB,RAW

h(RADB,RAW)= 29.05 28.50

Calc. the enthalpy at SADB,MAW, where SADB = MADB + DTSAF

h(SADB,MAW)= 31.14 30.88

Calc. the enthalpy at PHLASP,MAW

h(PHLASP,MAW)= 23.53 23.27

[Free cooling range]: ---

Free cooling range MADB = SADB - DTSAF
until SADB reaches CCLASP (i.e. 55 F)...then the system enters Economizer range.

This calculation therefore assumes SADB = CCLASP = 55.
For the first calc. use 1 F then DTSAF for 2,3,4...

MADB,free cool = 54.0 53.9

NOTE: 7/99 this was changed to switch between EXHAUST = 0,1

When there is EXHAUST =0 (system) then use the following;
NOTE: this eq. only considers sensible energy (i.e., CP only ... no CP+.444)

Moa = [Mra *(SADB - RADB) - Qfan/(cp)] / (OADB - RADB)

where

SADB = PHLASP = (input variable) = 45.0 45.0

Qfan/cp is assumed = 2000/.2402 lbm-F/hr for first iteration

The second iteration uses the actual Qfan from the first iteration...

where SADB is fixed at CCLADB

(EXHAUST=system) Moa,free,system= 55231 #VALUE!

MAW = [moa x OAW + (mra-moa) x RAW]/mra

(EXHAUST=system) MAW,free cooling = 0.0819 #VALUE!

When there is a zone exhaust (EXHAUST=1) use the following

Calculate the mass flow of the outside air using
an energy balance at the economizer = MADB...and assume Moa & Mbp & iteratively solve...

Assume Moa = M1,min + M2,min from above

Assume Mbp = Mma - (M1,min + M2,min) from above

Calc. the difference in energy balance to determine difference in Moa,est and Moa,act.

and plug into next iteration...assume CPAIR = same...so it cancels.

Mma x MADB = 319896 306173

Moa x OADB + Mbp x RADB= 444125 440576
(2nd,3rd...) Moa,adjust x OADB + Mbp,adjust x RADB=

Adj.to Moa & Mbp = diff./MADB = -2300.53 ########
This is now used in the 2,3,4 calcs...etc.

Moa,adjust = Moa - Moa,adjust for 1st...then look at previous calc.

Mbp,adjust = Mbp + Moa,adjust for 1st...then look at previous calc.

(EXHAUST=zone) Moa,adjust = 4490 6983

Mbp,adjust= 1434 -1059

Finally, calc. the MADB using the above Moa and Mbp

MADB = ((Moa x OADB) + (Mbp x RADB))/Mma

MADB,adjust= 74.37 76.90

MADB,target= 54.00 53.91

MAW = (Moa x OAW + (Mbp)RAW)/Mma

(w/zone exhaust) MAW,cold range = 0.0137 0.0165

Now, choose the Moa depending upon EXHAUST = 1,0

EXHAUST = 1.00 1.00

(EXHAUST=either) Moa,free cool = 4490.24 6983.23

MAW,free cooling = 0.0137 0.0165

NOTE: 7/99 Enthalpy calculation added here for free cooling range

This assumes that h(OADB, OAW) and h(RADB,RAW) are the same as cold range.

Therefore, only h(MADB, MAW) needs to be calculated with values from free cooling.

where h = 0.24T + W(1061+.444T)

Calc. the enthalpy at SADB,MAW note this is the same as PHLASP,MAW

h(PHLASP,MAW) &
h(SADB,MAW)= 25.57 28.61

Calc. the enthalpy at OADB+DTSAF,OAW

h(OADB+DTSAF,OAW)= 34.24 34.26

Calc. the enthalpy at CCLASP/MAW

h(CCLASP,MAW)= 28.03 31.09

[Economizer Range]: ---

In the economizer range the O.A. damper us full open, R.A. damper is closed.

therefore MADB = OADB whenever OADB > SADB and OADB < RADB.

where DTSAF = 1 F assumed for first iteration...and calculated 2nd,3rd,& 4th.

MADB=economizer = 74.0 74.0

In the economizer range MADB = OADB

and Moa = Mma, Mbp = 0, and MAW = OAW.

MAW,economizer = 0.015 0.015

Moa,economizer= 5924.0 5679.1

NOTE: 7/99 Enthalpy calculation added here for economizer range

This assumes that h(OADB, OAW) and h(RADB,RAW) are the same as cold range.

Therefore, only h(MADB, MAW) needs to be calculated with values from economizer.

where h = 0.24T + W(1061+.444T)

Calc. the enthalpy at MADB/MAW

h(MADB,MAW)= 33.99 33.99

Calc. the enthalpy at PHLASP,MAW

h(PHLASP,MAW)= 26.84 26.84

Calc. the enthalpy at CCLASP/MAW

h(CCLASP,MAW)= 29.31 29.31

[Maximum Cooling Range]:---

In the maximum cooling range the o.a. dampers are at minimum

air and the calculation is the same as the cold range.

and OADB > RADB

Therefore, this copies down the equations from the cold range...

MADB,max cooling = 75.0 74.9

and, the humidity ratio is calculated in a similar fashion as the
and therefore the number is copied down from above.

MAW,max cooling = 0.0118 0.0115

NOTE: 7/99 Enthalpy calculation added here for max cooling range

This assumes that h(OADB, OAW) and h(RADB,RAW) are the same as max cooling.

Therefore, only h(MADB, MAW) needs to be calculated with values from economizer.

where h = 0.24T + W(1061+.444T)

Calc. the enthalpy at MADB/MAW

h(MADB,MAW)= 30.89 30.61

[Temperature based economizer selection]----------------------------------

NOTE: 7/99 These temperature equations were modified during the edit.

Now, select which range the economizer is in based on the following

test (assume 1 F for DTSAF for 1st iter):

Cold Range = SADB < 45 (=PHLASP) where SADB = MADB + DTSAF

Free Cooling = SADB > 45 (=PHLASP) and OADB+DTSAF < 55 (=CCLASP)

Economizer = OADB+DTSAF >= CCLASP (55) and OADB < RADB

Max Cool = OADB > RADB.

Now, select the range by showing (=1):

Cold Range=1		0.0	0.0	
Free Cooling=2			0.0	0.0
Economizer=3		3.0	3.0	
Max Cooling=4			0.0	0.0
	------	------		
Total	3.0	3.0		

[Enthalpy based economizer selection]------------------------------------

NOTE: 7/99 Here is the addition of the enthalpy economizer equations.

Now, select which range the economizer is in based on the following

test (assume 1 F for DTSAF for 1st iter):

Now, test the enthalpy at each of the conditions:

Cold Range = h(SADB,MAW) < h(PHLASP,MAW) where SADB = MADB + DTSAF

Free Cooling = h(SADB,MAW) > h(PHLASP,MAW)
and h(OADB+DTSAF,OAW) < h(CCLASP,MAW)

and h(OADB,OAW) < h(RADB,RAW)
Economizer = h(OADB+DTSAF,OAW) >= h(CCLASP,MAW)

and h(OADB,OAW) < h(RADB,RAW)
Max Cool = h(OADB,OAW) > h(RADB,RAW).

Now, select the range by showing (=1,2,3..):

```
                    Cold Range=1              0.0   0.0
                    Free Cooling=2                  0.0     0.0
                    Economizer=3              0.0   0.0
                    Max Cooling=4                   4.0     4.0
                           ------     ------
                       Total          4.0     4.0
```

Now, check to see if the economizer is activated by looking at b3

Finally, select the MADB and MAW according to the economizer schedule

using an @choose(1,2,3,4) statement

```
              ECONOMIZER=                           2.00     2.00

              ECONOMIZER SWITCH=                    4.00     4.00

                       MADB=                  75.0  74.9

                       MAW=          0.0118 0.0115

                       Moa=          2189.7 2191.5
```

[Step 5]:---

NOTE: The DTSAF was removed from the following equations 7/99.

Calculate the preheat coil load (QPHC) and leaving air conditions

depe.ding upon the m)xed air dry bul" temp (MADB) & 0reheat coil sep/int.

IF MADB >= PHLASP=45F then QPHC=0 and PHLADB=MADB

IF MADB < PHLASP = 45 then

NOTE: 7/99 The (CP) changed to (CP+.444W) to ac#ount for sensib,e heating

of the moisture contained in the moist air.

QPHC= mma x (CP+.444w)(PHLASP - MADB) and PHLADB = PHLASP

```
                       Mma =         5924.00        5679.12

                       QPHC=         0.0      0.0

                       PHLADB=                75.0  74.9
```

[Step 6]:---

Calculate the cooling coil (CCEADB) and heating coil (HCEADB) entering air dry bulb temperature, including the temperature rise across the fan.

First, calculate the specific volume (v)

Vphladb = Ra x Tphladb (1 + 1.6078 x Wphlaw) / (70.7262 x Pfan,enter)

Assuming P=atmospheric pressure

Vphladb= 13.7 13.7

Next, calculate the total CFM across the fan (CFMT)

CFMT = Mphladb x 1/60 x v

Mphladb = 5924.0 5679.1

where Mphladb = Mma

CFMT= 1356.1 1299.3

NOTE: 7/99 The (CP) changed to (CP+.444W) to account for sensible heating

of the moisture in the moist air.

Now, calculate the temperature rise across the fan
using DTSAF = QFAN/Mphladb x (cp+.444w)

NOTE: 2/12...new FAN equations from Knebel, checked against p. 207 Kreider,Rabl

First, assume constant volume, design conditions...calculate FanHP, Motor HP, DTFAN

then calculate conditions for variable speed fan using Brandemuehl's equations.

for VSD, Inlet vane, discharge dampers, etc.

Fan HP(design) = 0.0001573 x CFM x TP / EFFfan

where Fan HP is calculated on CFMTD = total design CFM
where TP = FTP = total pressure across fan inH2O
EFFfan = fan efficiency
CFM = CFMT

Fan HP(design) = 0.61 0.58

Next, calculate the Motor HP for the constant volume system

Motor HP = Fan HP(design)/EFFmotor

where Motor HP = HP of constant volume design conditions
EFFmotor = electric motor efficiency

Motor HP(design) = 0.68 0.65

Next calculate DTFAN(design) using FRACT = 0,1
where FRACT = 1 (motor in air), 0 (motor not in air)

DTFAN = FanHP x 2544.85 / [Mdesign x (CP + .444xCCLAW)]

for the motor NOT in the air stream...

DTFAN = FanHP x 2544.85 / [Mdesign x (CP + .444xCCLAW)] x EFFm

for the motor in the air stream...use FRACT = 0,1 as choice...

where

Mdesign = (CFMT)*60/Vphladb= 5924.0 5679.1

DTFAN(design,motor out) = 1.09 1.07

DTFAN(design,motor in) = 1.21 1.19

FRACT= 0

DTSAF(F) = 1.09 1.07

Now, calculate the cooling coil & heating coil entering air dry bulb

CCEADB = HCEADB = SADB = PHLADB + DTSAF

CCEADB= 76.1 76.0

HCEADB= 76.1 76.0

[Step 7a,7b]:--

NOTE: 7/99 DTSAF added to thermostat of CCLADB and HCLADB test.

Now, calculate the heating coil and cooling coil leaving air
temperature = HCLASP and CCLASP respectively
Test to see if PHLADB+DTSAF < CCLADB
or if PHLADB+DTSAF > HCLADB

CCLADB= 55.0 55.0

HCLADB= 110.0 110.0

and HCLAW = MAW

HCLAW= 0.0118 0.0115

[Step 8]:--

Calculate the air flow in the hot ducts HCCFM1 & HCCFM2, and

in the cold ducts CCCFM1 & CCCFM2.
First, set Mmix#1 = m1

Mmix#1= 2734.2 2621.1

NOTE: 7/99 In the next equations (CP) replaced with (CP+.444W)

in the terminal box equation to determine air flows for #1 and #2

Mh(cp+.444Wh)Th + Mc(cp+.444Wc)Tc = Mm(cp+.444Wm)Tm

Solve for Mh = [Mm(cp+.444Wm)Tm - Mc(cp+.444Wc)Tc]/[(cp+.444Wh)Th]

or

Mhot#1 = [Mm1(cp+.444xZSAW1)ZSADB1-Mc1(cp+.444xCCLAW)CCLADB]/[(cp+.444xHCLAW)HCLADB]

First, calculat Vcold

Vcold = Ra x Tccladb (1 + 1.6078 x CCLAW) / (70.7262 x CCLABP)

Vcold= 13.0 13.2

Now, calculate Mcold#1 = CCCFM1 x 60 / Vcold
use CCCFM1 = 1/2 CFMZD1 for first pass...then interate using CCCFM1 below

NOTE: 7/19/99...change this to be Mcold#1 = Mmix#1 - Mhot#1 for 2nd,3rd,4th...

1st iteration uses CFMZD1/2

Mcold#1= 1385.06 1682.10

Now calculate Mhot#1 using 0.001 for CCLAW first pass..then interate

Now calculate Mhot#1= 939.04 731.49

Next, calculate Vhot using

Vhot = Ra x Thcladb (1 + 1.6078 x HCLAW) / (70.7262 x Phclabp)

Vhot= 14.6 14.6

Assuming P=atmospheric pressure

Now, calculate HCCFM1 = Mhot#1 x Vhot/60

HCCFM1= 229.0 178.3

NOTE: 7/99 CCCFM1=Mcold#1 x Vcold/60

CCFM1= 300.0 369.1

Now, repeat for zone#2

First, set Mmix#2 = m2

Mmix#2= 3189.8 3058.0

First, set Mmix#2 = m2

Mhot#2 = [Mm2(cp+.444xZSAW)ZSADB2-Mc2(cp+.444xCCLAW)CCLADB]/[(cp+.444xHCLAW)HCLADB]

First, calculate Mcold#2 = CCCFM2 x 60 / Vcold
use CCCFM2 = 1/2 CFMZD2 for first pass...then interate using CCCFM2 below

NOTE: 7/19/99...change this Mcold#2=Mmix#2 - Mhot#2 for 2nd,3,4...

1st iteration uses CFMZD2/2

Mcold#2= 1615.90 1984.60

Now calculate Mhot#2 using CCLAW=0.01 for first and iterate

Mhot#2= 1073.39 817.08

and therefore the Mhot for the heating coil is

Mhot = Mhot#1 + Mhot#2

Mhot= 2012.43 1548.57

And finally calculate the total mass flow...
this just copies down from calculations at zonal level

Mmix(total) = Mmix1 + Mmix2

Mmix= 5924.0 5679.1

Now, calculate HCCFM2 = Mhot#2 x Vhot/60

HCCFM2= 261.8 199.2

NOTE: CCFM1(new#2) uses CCCFM1=Mcold#1 x Vcold/60

CCCFM2= 350.0 435.5

[Step 9]:---

Now, calculate the HCCFM and CCCFM

HCCFM = HCCFM1 + HCCFM2

HCCFM= 490.8 377.5

CCCFM = CCCFM1 + CCCFM2

CCCFM= 650.0 804.6

[Step 10]:---

Calculate the cooling coil sensible cooling load (Qcs)

First, calculate the Mcooling coil = Mmix - Mheating coil

NOTE: 7/99 Mcool = Mcool#1 + Mcool#2

Mcool(#1+#2)= 3001.0 3666.7

Now, calculate the cooling coil load = QCS
using p.21.15 of ASHRAE S&E, 1996.,
Qsensible = Qs+Qw=mair[(hin-hout)-(Win-Wout)(hfg,Tdew,in+hw,Tdew,in)]

First, calculate (pw) using P x W/(.62198 + W)

where P = total pressure of moist air
W = humidity ratio = MAW

pw = 0.2728 0.2675

ln(pw)= -1.30 -1.32

Then, calculate Tdew,in = CCEADB,dewpoint
using p.6.14,HOF,1997, Tdew(>32F)=C14+C15a+C16a^2+C17a^3+C18(pw)^.1984

Tdew(<32F)=90.12+26.412a+0.8927a^2

Then choose Tdew based of 32<T=SADB<32.

Tdew(>32)= 61.79 61.24

Tdew(<32)= 57.32 56.84

Now choose Tdew based on 32<Tdew<32

Tdew = 61.79 61.24

Next, calculate (hfg,Tdew,in) using 1075.15-(T-32)*.56506
NOTE: This expression is only valid for T>32 F...which is o.k. since no

cooling loads are expected at MADB=32.

hfg= 1058.32 1058.63

Now, calculate (hw,Tdew,in) using hw=.02 + 1.000845*(T-32)

hw= 29.83 29.28

Now, calculate the enthalpy using p. 6.13, 1997 HOF
where h = 0.24T + W(1061+.444T)

h(CCEADB)= 31.16 30.87

h(CCLADB)= 23.19 23.19

Finally, calculate the sensible load on the coil using
an estimate for the CCLAW=ZSAW for the first calculation...then use

CCLAW list further down for 2nd calculation....

Now, test to see if PHLADB<(CCLADB-DTSAF If so then QCS=0.

QCS = 15522.1 18849.0

[Step 11a]:---

Now, calculate the latent loads..

QZL= 5000.0 5000.0

Qlatent(#1+#2) = QZL1 + QZL2

The latent heat of vapor hfg is calculated from hfg = 1061 + (.444 x RADB)

hfg= 1094.5 1094.5

First, calculate the saturation vapor pressure at (Pws(CCLASP))

CCLASP(F)= 55.0 55.0
CCLASP(R)= 514.7 514.7

Pws,dew(<32)= 0.2 0.2
Pws,dew(>32)= 0.2 0.2

Now, calculate the (CCLAW = Ws = at T = CCLASP).

For wet coil... CCLAW = Ws = 0.0092 0.0092

Now, test to see whether or not the coil is dry or wet

If coil is wet (CCLAW<MAW) then "coil wet" = 0 and CCLAW=CCLAW

if coil is dry (CCLAW>MAW) and "coil wet"=1, then CCLAW=MAW.

Coil wet? 0.0 0.0

CCLAW = 0.0092 0.0092

[Step 12]:--

Calculate the cooling coil latent load QCL depending upon whether or not the coil is wet or dry. Use the switch "coil wet?" for this.

Wet coil:

QCL = Mcooling x (CCEAW - CCLAW) * Hfg,Tdew,CCEADB

QCLwet= 8156.7 9065.3

Dry coil:

QCLdry= 0.0 0.0

Now, select the wet or dry answer according to "coil wet" above.

QCL= 8156.7 9065.3

[Step 13]:---

Now, calculate the total cooling load = QCT = QCL + QCS

QCS= 15522.1 18849.0

QCT= 23678.7 27914.3

[Step 14]:--

NOTE: 7/99 The (CP) changed to (CP+.444T) to account for sensible heating

of the moisture in the moist air.

Calc. total heating load = QHC = Mheating coil x (CP+.444W) x (HCLADB - HCEADB)

QHC = 16741.1 12930.1

[Step 15]:---

Calculate the total heating load = QHT = QHC + QPHC

QPHC= 0.0 0.0

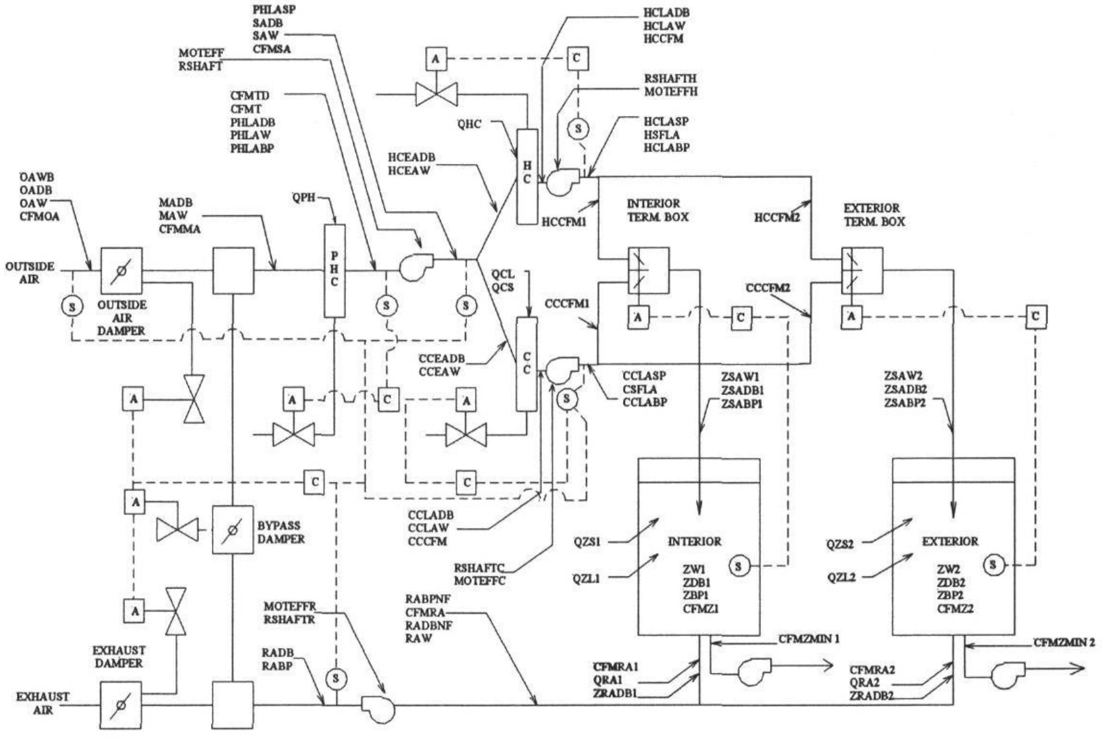
QHT = 16741.1 12930.1

[Step 16]:---

Calculate the convergence...

Heating	-29.474%
Cooling	15.173%

4.0 DUAL DUCT VARIABLE VOLUME (DDVAV).



Dual Duct Variable Air Volume System Schematic (DDVAV)

The input values for the DDVAV spreadsheet are as follows:

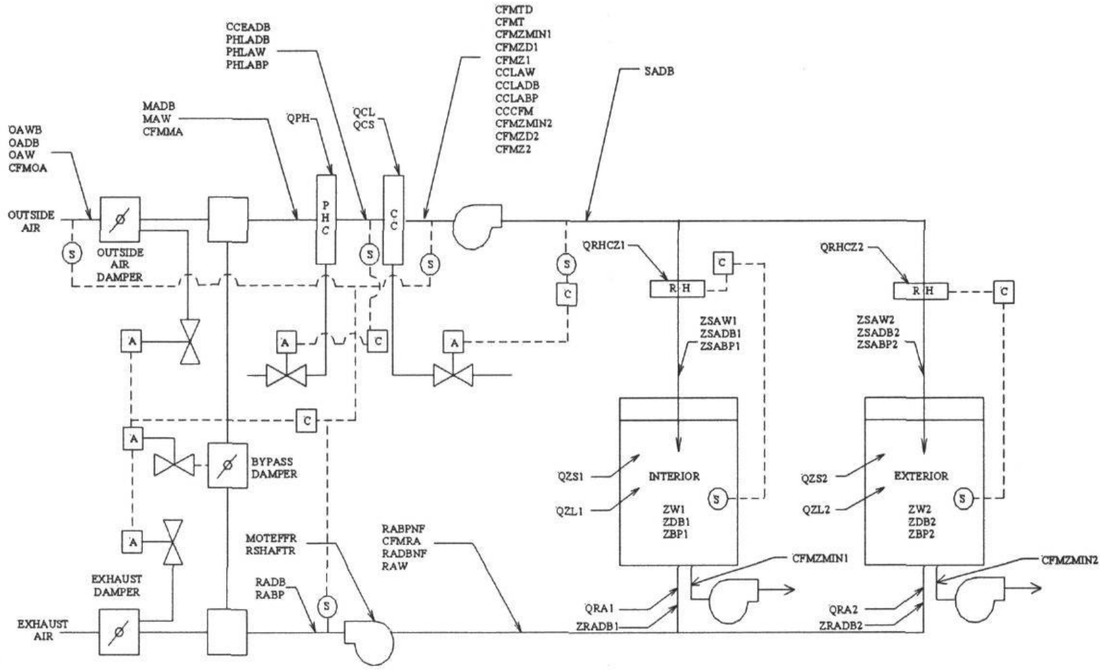
TEST # (1..7)=	7	This switch is used for cosmetic purposes only. It is used to change the label that appears directly to the right of the input cell and creates a set of "canned" labels used for one of the tests that the spreadsheet was developed for.
ECON(0,1=T,2=E)	2	This switch turns the economizer "on" or "off". It is also used to select whether the temperature (T) or enthalpy (E) economizer is used.
AIR CRLR(1,2,3,4)=	3	This switch is used to control the type of variable flow fan that is being used: 1=Inlet Vanes, 2=Discharge Dampers, 3=Var.Speed Drive, 4=Constant
CCLASP(F) =	55.00	This variable is the cooling coil leaving air setpoint temperature (F).
CCLABP(psia)=	14.696	This variable is the cooling coil leaving air barometric pressure (PSIA).
EXHAUST(0=sys,1=zone)	1	This switch is used to calculate 'zone air exhaust' or 'system air exhaust'. This will cause a difference in the mass flow rates returning from the zone, and heat gain from the return fan.
CFMZD1 (CFM) =	600.00	This is the design air flow for zone 1 (CFM).
CFMZD2 (CFM) =	700.00	This is the design air flow for zone 2 (CFM).
CFMFANH (%) =	100%	This variable is used in the fan calculations when the fan is a draw-through fan placed downstream of the heating coil.
CFMFANC (%) =	100%	This variable is used in the fan calculations when the fan is a draw-through fan placed downstream of the cooling coil.
CFMZMIN1=	200.00	This is the exhaust air for zone 1 (CFM)
CFMZMIN2=	300.00	This is the exhaust air for zone 2 (CFM)
CPAIR(Btu/lbF)=	0.2402	This is the constant that is used for the specific heat of air (80F).
CPh20(Btu/lbF)=	1.0019	This is the constant that is used for the specific heat of water (55F).
FTP(in-H20) =	0.00	This is the total fan pressure across the supply fan (in-H20). NOTE: this is set = 0 when a two draw-through fans are being used.
RFTP(in-H20)=	1.00	This is the total fan pressure across the return fan (in-H20).
CFTP(in-H20)=	2.00	This is the total fan pressure across the cold deck supply fan (in-H20). NOTE: this is set = 0 when one blow-through fan is being used.
HFTP(in-H20)=	2.00	This is the total fan pressure across the hot deck

		supply fan (in-H20). NOTE: this is set = 0 when one blow-through fan is being used.
FRACT(0,1)=	0	This is the switch that is used to place the supply fan in the air stream (1) or outside of the air stream (0).
FRACTr(0,1)=	0	This is the switch that is used to place the return fan in the air stream (1) or outside of the air stream (0).
FRACTc(0,1)=	0	This is the switch that is used to place the cold deck supply fan in the air stream (1) or outside of the air stream (0).
FRACTh(0,1)=	0	This is the switch that is used to place the hot deck supply fan in the air stream (1) or outside of the air stream (0).
FAN EFFICIENCY=	0.70	This is the constant fan efficiency for the single supply fan (%).
RFAN EFFICIENCY=	0.70	This is the constant fan efficiency for the return fan (%).
CFAN EFFICIENCY=	0.70	This is the constant fan efficiency for the cold deck fan (%).
HFAN EFFICIENCY=	0.70	This is the constant fan efficiency for the hot deck fan (%).
HCLASP (F) =	110.00	This is the heating coil leaving air setpoint temperature (F).
HCLABP(psia)=	14.696	This variable is the heating coil leaving air barometric pressure (PSIA).
MOTEFF=	0.90	This variable is the constant motor efficiency of the supply fan (%).
MOTEFFR=	0.90	This variable is the constant motor efficiency of the return fan (%).
MOTEFFC=	0.90	This variable is the constant motor efficiency of the cold deck fan (%).
MOTEFFH=	0.90	This variable is the constant motor efficiency of the hot deck fan (%).
OADB(F) =	74.00	This variable is the outside air dry bulb temperature (F).
OAWB(F)=	70.00	This variable is the outside air wet bulb temperature (F).
PHLABP (PSIA) =	14.70	This variable is the preheat coil leaving air barometric pressure (PSIA).
PHLASP(F)=	45.00	This variable is the setpoint temperature of the preheat coil (F).
QZL1(Btuh)=	2000	This variable is the latent load of zone 1 (BTUH).
QZL2(Btuh)=	3000	This variable is the latent load of zone 2 (BTUH).

QZS1(Btuh)=	5000	This variable is the sensible load of zone 1 (BTUH).
QZS2 =	8000	This variable is the sensible load of zone 2 (BTUH).
R =	1545	This variable is the gas constant for dry air (currently not used).
Ra =	53.35	This variable is the gas constant for dry air (ft-lbf/R-lb).
RABPNF=	14.70	This variable is the barometric pressure at a point in front of the return fan (PSIA).
RABP=	14.70	This variable is the barometric pressures at at point in back of the return fan (PSIA).
ZDB1(F)=	74.00	This variable is the zone temperature for zone 1 (F).
QRA1(F)=	0.00	This variable is the heat gain of the ducts returning from zone 1 (F).
ZDB2(F)=	76.00	This variable is the zone temperature for zone 2 (F).
QRA2(F)=	0.00	This variable is the heat gain of the ducts returning from zone 2 (F).
ZSABP1(Psia)=	14.696	This variable is the barometric pressure of the supply air for zone 1 (PSIA).
ZSABP2(Psia)=	14.696	This variable is the barometric pressure of the supply air for zone 2 (PSIA).
ZBP1(Psia)	14.696	This variable is the barometric pressure of the air in zone 1 (PSIA).
ZBP2(Psia)	14.696	This variable is the barometric pressure of the air in zone 2 (PSIA).

The output from the DDVAV is listed in two tables to the left of the input table in a similar fashion as the DDCAV system.

5.0 CONSTANT VOLUME WITH REHEAT (CAVRH).



<u>Constant Air Volume with Reheat System (CAVRH)</u>

The input values for the CAVRH spreadsheet are as follows:

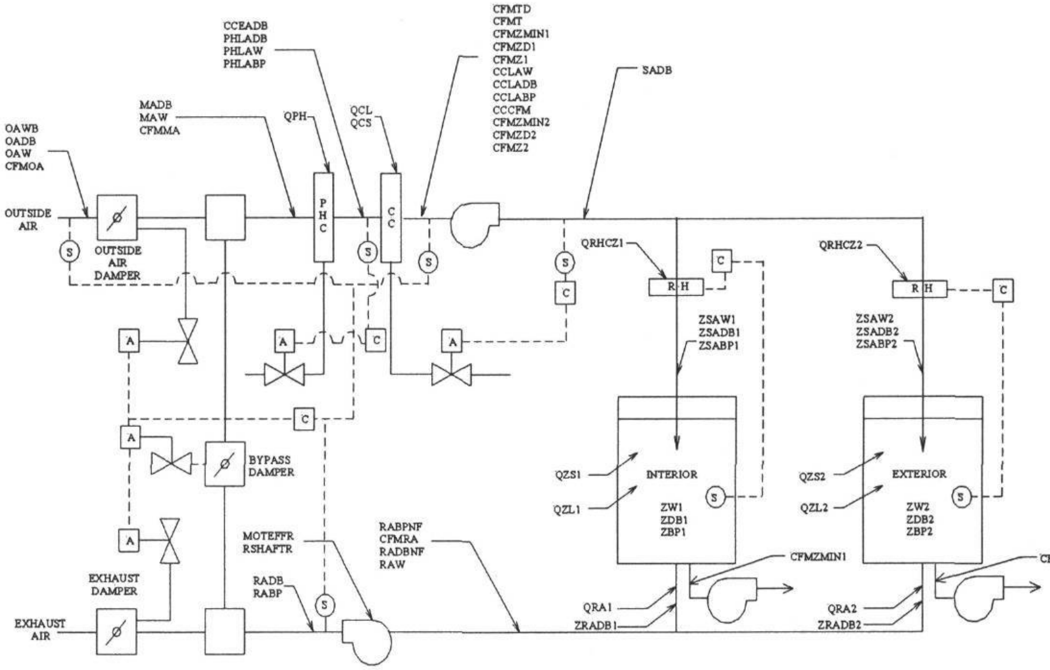
TEST # (1..8)=	1	This switch is used for cosmetic purposes only. It is used to change the label that appears directly to the right of the input cell and creates a set of "canned" labels used for one of the tests that the spreadsheet was developed for.
ECON(0=n,1=T,2=E)=	0	This switch turns the economizer "on" or "off". It is also used to select whether the temperature (T) or enthalpy (E) economizer is used.
CCLASP(F) =	55.00	This variable is the cooling coil leaving air setpoint temperature (F).
CCLABP(psia)=	14.696	This variable is the cooling coil leaving air barometric pressure (PSIA).
EXHAUST(0=sys,1=zone)=	1	This switch is used to calculate 'zone air exhaust' or 'system air exhaust'. This will cause a difference in the mass flow rates returning from the zone, and heat gain from the return fan.
CFMZD1 (CFM) =	600.00	This is the design air flow for zone 1 (CFM).
CFMZD2 (CFM) =	700.00	This is the design air flow for zone 2 (CFM).
CFMZMIN1=	200.00	This is the exhaust air for zone 1 (CFM)
CFMZMIN2=	300.00	This is the exhaust air for zone 2 (CFM)
CPAIR(Btu/lbF)=	0.2402	This is the constant that is used for the specific heat of air (80F).
CPh20(Btu/lbF)=	1.0019	This is the constant that is used for the specific heat of water (55F).
FTP(in-H20) =	2.00	This is the total fan pressure across the supply fan (in-H20).
FRACT(0,1)=	0.00	This is the switch that is used to place the supply fan in the air stream (1) or outside of the air stream (0).
FRACTR(0,1)=	0.00	This is the switch that is used to place the return fan in the air stream (1) or outside of the air stream (0).
FAN EFFICIENCY=	0.70	This is the constant fan efficiency (%).
HCLASP (F) =	110.00	This is the heating coil leaving air setpoint temperature (F).
HCLABP(psia)=	14.696	This variable is the heating coil leaving air barometric pressure (PSIA).

MOTEFF=	0.90	This variable is the constant motor efficiency of the supply fan (%).
MOTEFFR=	0.90	This variable is the constant motor efficiency of the return fan (%).
OADB(F) =	-20.00	This variable is the outside air dry bulb temperature (F).
OAWB(F)=	-20.00	This variable is the outside air wet bulb temperature (F).
PHLABP (PSIA) =	14.696	This variable is the preheat coil leaving air barometric pressure (PSIA).
PHLASP(F)=	45.00	This variable is the setpoint temperature of the preheat coil (F).
QZL1(Btuh)=	2000	This variable is the latent load of zone 1 (BTUH).
QZL2(Btuh)=	3000	This variable is the latent load of zone 2 (BTUH).
QZS1(Btuh)=	-10000	This variable is the sensible load of zone 1 (BTUH).
QZS2 =	-8000	This variable is the sensible load of zone 2 (BTUH).
RFAN EFFICIENCY=	0.70	This variable is the constant fan efficiency of the return fan (%).
R =	1545.32	This variable is the gas constant for dry air (currently not used).
Ra =	53.35	This variable is the gas constant for dry air (ft-lbf/R-lb).
RABPNF=	14.696	This variable is the barometric pressure at a point in front of the return fan (PSIA).
RABP=	14.696	This variable is the barometric pressures at at point in back of the return fan (PSIA).
RFTP(in-H20)=	1.00	This is the total fan pressure across the supply fan (in-H20).
ZDB1(F)=	70.00	This variable is the zone temperature for zone 1 (F).
QRA1(F)=	0.00	This variable is the heat gain of the ducts returning from zone 1 (F).
ZDB2(F)=	72.00	This variable is the zone temperature for zone 2 (F).
QRA2(F)=	0.00	This variable is the heat gain of the ducts returning from zone 2 (F).

ZSABP1(Psia)=	14.696	This variable is the barometric pressure of the supply air for zone 1 (PSIA).
ZSABP2(Psia)=	14.696	This variable is the barometric pressure of the supply air for zone 2 (PSIA).
ZBP1(Psia)	14.696	This variable is the barometric pressure of the air in zone 1 (PSIA).
ZBP2(Psia)	14.696	This variable is the barometric pressure of the air in zone 2 (PSIA).

The output from the CAVRH is listed in two tables to the left of the input table in a similar fashion as the DDCAV system.

6.0 VARIABLE VOLUME WITH REHEAT (VAVRH).



Variable Air Volume System with Reheat (VAVRH)

The input values for the VAVRH spreadsheet are:

TEST # (1..7)=	7	This switch is used for cosmetic purposes only. It is used to change the label that appears directly to the right of the input cell and creates a set of "canned" labels used for one of the tests that the spreadsheet was developed for.
ECON(no=0,T=1,E=2)	2	This switch turns the economizer "on" or "off". It is also used to select whether the temperature (T) or enthalpy (E) economizer is used.
AIR CRLR(1,2,3,4)=	3	This switch is used to control the type of variable flow fan that is being used: 1=Inlet Vanes, 2=Discharge Dampers, 3=Var.Speed Drive, 4=Constant
CCLASP(F) =	55.00	This variable is the cooling coil leaving air barometric pressure (PSIA).
CCLABP(psia)=	14.696	This variable is the cooling coil leaving air barometric pressure (PSIA).
EXHAUST(0=sys,1=zone)=	1	This switch is used to calculate 'zone air exhaust' or 'system air exhaust'. This will cause a difference in the mass flow rates returning from the zone, and heat gain from the return fan.
CFMZD1 (CFM) =	600.00	This is the design air flow for zone 1 (CFM).
CFMZD2 (CFM) =	700.00	This is the design air flow for zone 2 (CFM).
CFMZMIN1=	200.00	This is the exhaust air for zone 1 (CFM)
CFMZMIN2=	300.00	This is the exhaust air for zone 2 (CFM)
CPAIR(Btu/lbF)=	0.2402	This is the constant that is used for the specific heat of air (80F).
CPh20(Btu/lbF)=	1.0019	This is the constant that is used for the specific heat of water (55F).
FTP(in-H20) =	2.00	This is the total fan pressure across the supply fan (in-H20).
FRACT(0,1)=	0	This is the switch that is used to place the supply fan in the air stream (1) or outside of the air stream (0).
FRACTR(0,1)=	0	This is the switch that is used to place the return fan in the air stream (1) or outside of the air stream (0).
FAN EFFICIENCY=	0.70	This is the constant fan efficiency (%).
MOTEFF=	0.90	This variable is the constant motor efficiency of the supply fan (%).
MOTEFFR=	0.90	This variable is the constant motor efficiency of the return fan (%).

OADB(F) =	74.00	This variable is the outside air dry bulb temperature (F).
OAWB(F)=	70.00	This variable is the outside air wet bulb temperature (F).
PHLABP (PSIA) =	14.70	This variable is the preheat coil leaving air barometric pressure (PSIA).
PHLASP(F)=	45.00	This variable is the setpoint temperature of the preheat coil (F).
QZL1(Btuh)=	2000	This variable is the latent load of zone 1 (BTUH).
QZL2(Btuh)=	3000	This variable is the latent load of zone 2 (BTUH).
QZS1(Btuh)=	5000	This variable is the sensible load of zone 1 (BTUH).
QZS2 =	8000	This variable is the sensible load of zone 2 (BTUH).
RFAN EFFICIENCY=	0.70	This variable is the constant fan efficiency of the return fan (%).
RHCZ1SP=	120.00	This is the maximum temperature of the reheat coil leaving air for zone 1 (F).
RHCZ2SP=	120.00	This is the maximum temperature of the reheat coil leaving air for zone 2 (F).
R =	1545.32	This variable is the gas constant for dry air (currently not used).
Ra =	53.35	This variable is the gas constant for dry air (ft-lbf/R-lb).
RABPNF=	14.696	This variable is the barometric pressure at a point in front of the return fan (PSIA).
RABP=	14.696	This variable is the barometric pressures at at point in back of the return fan (PSIA).
RFTP(in-H20)=	1.00	This is the total fan pressure across the supply fan (in-H20).
ZDB1(F)=	74.00	This variable is the zone temperature for zone 1 (F).
QRA1(F)=	0.00	This variable is the heat gain of the ducts returning from zone 1 (F).
ZDB2(F)=	76.00	This variable is the zone temperature for zone 2 (F).
QRA2(F)=	0.00	This variable is the heat gain of the ducts returning from zone 2 (F).
ZSABP1(Psia)=	14.696	This variable is the barometric pressure of the supply air for zone 1 (PSIA).
ZSABP2(Psia)=	14.696	This variable is the barometric pressure of the supply air for zone 2 (PSIA).
ZBP1(Psia)	14.696	This variable is the barometric pressure of the air in zone 1 (PSIA).
ZBP2(Psia)	14.696	This variable is the barometric pressure of the air in zone 2 (PSIA).