1100-209

1100-209

FINAL REPORT

DOCUMENTATION OF
SYSTEM AND EQUIPMENT
SIMULATION PROGRAM

ENGINEERING MANUAL WITH FLOWCHARTS
APRIL 1975
VOLUME II

SUBROUTINE: HTCØN

GENERAL DESCRIPTION

This subroutine simulates the performance of heat conservation systems. A heat conservation system is one where the refrigeration machines have double-bundled condensers. During the summer months, the system acts as a conventional refrigeration system whereby the building heat gains are picked up in the chilled water coils, returned to the refrigeration machines, and rejected through condensers and the cooling towers to the outside air. During winter months, the refrigeration machines act as a heat pump wherein the building internal heat gains are picked up by the chilled water coils and returned to the refrigeration machines. Then, instead of being rejected to the outside through the cooling tower, this heat is redistributed by the hot condenser water through the building to those areas that require heating. Supplemental heaters are provided in the chilled water return line to provide heat when the internal gains are insufficient to offset the heat loss of the building at peak heating conditions. See Figure for Heat Conservation System Schematic.

LIST OF VARIABLES

INPUT

M1	-	Type of chiller
M2	-	Source of chiller energy
M3	-	Source of heating energy
M4	-	Number of on-site generation engines
M5	-	Type of on-site generation engines
M6	-	Type of auxiliary chiller
M7	-	Source of supplemental heat

COMMON

KØ	-	Line printer unit number
IC	-	Card reader unit number

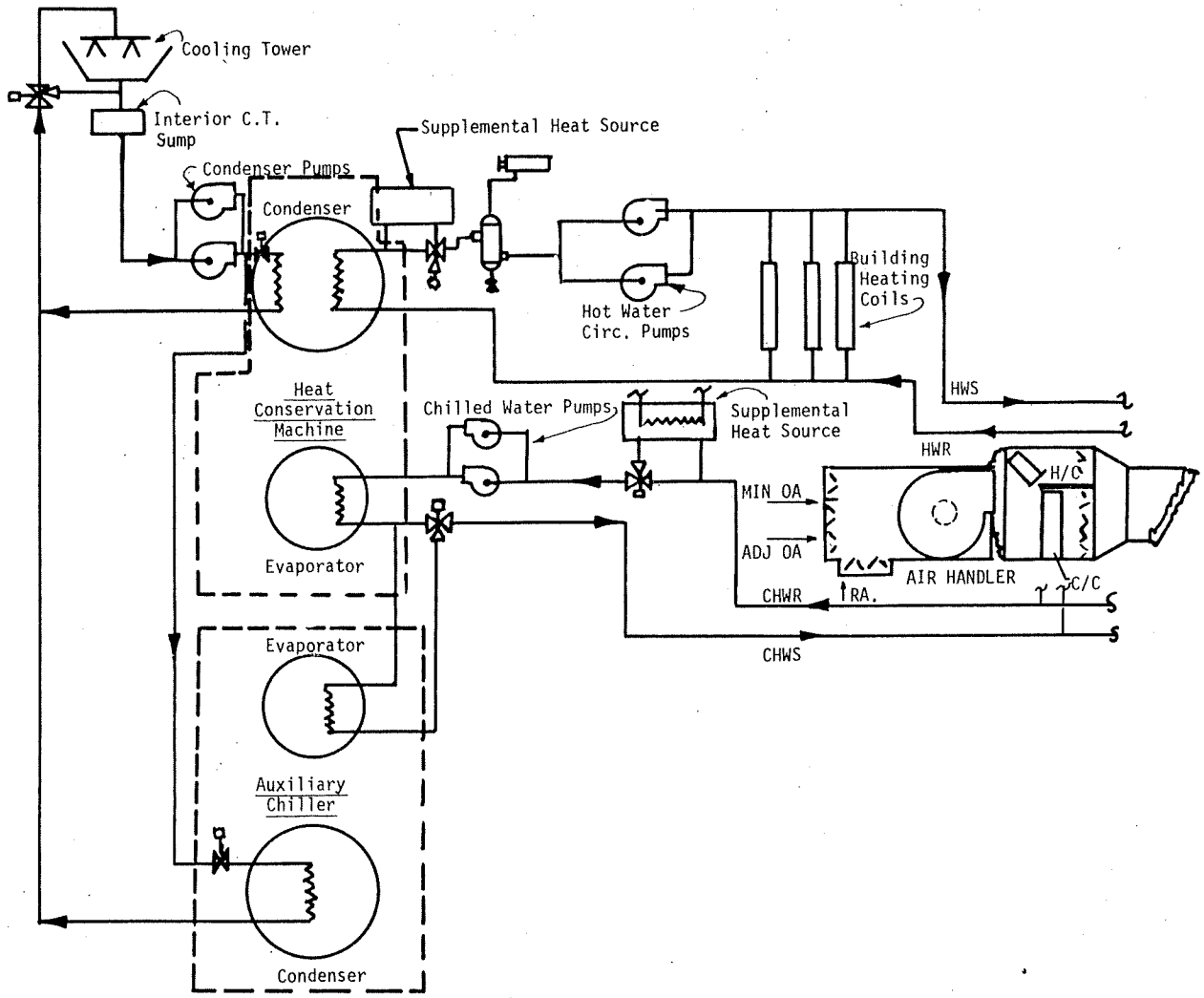


Figure HEAT CONSERVATION SYSTEM SCHEMATIC DIAGRAM

IT	-	Input tape unit number
IBØIL	-	Boiler on/off flag (1=on; 0=off)
ICHIL	-	Chiller on/off flag (1=on; 0=off)
IFAN	-	Fan system shut-off flag (0=fans run continuously 1=fans may be shut off 2=fans and baseboard radiators may be shut off)
TCØ	-	Changeover temperature (°F)
KBLDG	-	Heat conservation building flag
KMAX	-	Number of energy distribution systems
IZNMX	-	Number of zones to be studied
MSTRT	-	Month in which study begins
NDAYS	-	Length of study (days)
MEND	-	Last month of study
$IMAX_m$	-	Number of hours in month m (m = 1,12)
$KFAN_k$	-	Energy distribution system index
$JMAX_k$	-	Number of zones on system k
$CFMAX_k$	-	Design supply air of system k (ft^3/min)
$CFMEX_k$	-	Exhaust air, system k (ft^3/min)
$FBHPS_k$	-	Supply fan brake horsepower, system k (bhp)
$FBHPR_k$	-	Return fan brake horsepower, system k (bhp)
$FBHPE_k$	-	Exhaust fan brake horsepower, system k (bhp)
CFM_i	-	Supply air flow rate, zone i (constant)(ft^3/min)
$CFMS_i$	-	Supply air flow rate, zone i (variable)(ft^3/min)
$CFMR_i$	-	Return air flow rate, zone i (ft^3/min)
$CFMX_i$	-	Exhaust air flow rate, zone i (ft^3/min)
$SPACN_{k,j}$	-	Number of space as per LOAD program, applied to system k, zone j

$MULT_i$	-	Multiplication factor, zone i
EFF	-	Pump and fan motor efficiency
TLCHL	-	Chilled water setpoint temperature (°F)
PWØL	-	Power of external lighting (KW)
TLCNM	-	Maximum allowable condenser water temperature (°F)
TLCMN	-	Well or city water design return water temperature (°F)
TCWIN	-	City water supply temperature (°F)
TWWIN	-	Well water supply temperature (°F)
TECMN	-	Cooling tower water low limit temperature (°F)
HDCLP	-	Total chilled water pump head (ft)
HDCNP	-	Total condenser water pump head (ft)
HDBLP	-	Total boiler water pump head (ft)
HDWWP	-	Total well water pump head (ft)
IHSRT	-	Hour of year at which simulation may begin
IHSTP	-	Hour of year at which simulation may end
NCASE	-	Number of cases to be run
NRSET	-	Number of reset schedules to be read
KHCST	-	Heat conservation system flag
NUMB	-	Number of boilers
SZB	-	Size of each boiler (MBH)
BØN	-	Hour of seasonal boiler start-up (hour of year)
BØFF	-	Hour of seasonal boiler shutdown (hour of year)
NUMC	-	Number of chillers
SZC	-	Size of each chiller (tons)
CØN	-	Hour of seasonal chiller start-up (hour of year)
CØFF	-	Hour of seasonal chiller shutdown (hour of year)
CFMBX	-	Building total design load supply air (ft^3/min)

$ASYS_{nc}$ - System identification number, run nc

$ABLDG_{nc}$ - Heat conservation flag (1=no; 2=yes), run nc

$AM1_{nc}$ - Type of chiller, run nc

$AM2_{nc}$ - Source of chiller energy, run nc

$AM3_{nc}$ - Source of general heating energy, run nc

$AREHT_{nc}$ - Source of reheat coil energy, run nc

$AM6_{nc}$ - Type of auxiliary chiller, run nc

$AM7_{nc}$ - Type of supplemental heat, run nc

$AM4_{nc}$ - Number of engine/generator sets, run nc

$AM5_{nc}$ - Type of engine/generator set, run nc

OUTPUT

NUMHC - Number of heat conservation machines

SZHC - Size of each heat conservation machine (tons)

CAPH - Total heating capacity (MBH)

SNØWF - Inches of snow water equivalent (inches)

CAPC - Total cooling capacity (tons)

SZSCL - Size of supplementary heating unit in chilled water circuit (MBH)

ENGY - Energy resource peak and consumption matrix.

COMMON

TS_i - Supply air temperature, zone i (°F)

GPMCL - Chilled water flow rate (gpm)

GPMCN - Condenser water flow rate (gpm)

GPMWW - Well water flow rate (gpm)

HPCLP - Chilled water pump power (BHP)

HPCNP - Condenser water pump power (bhp)

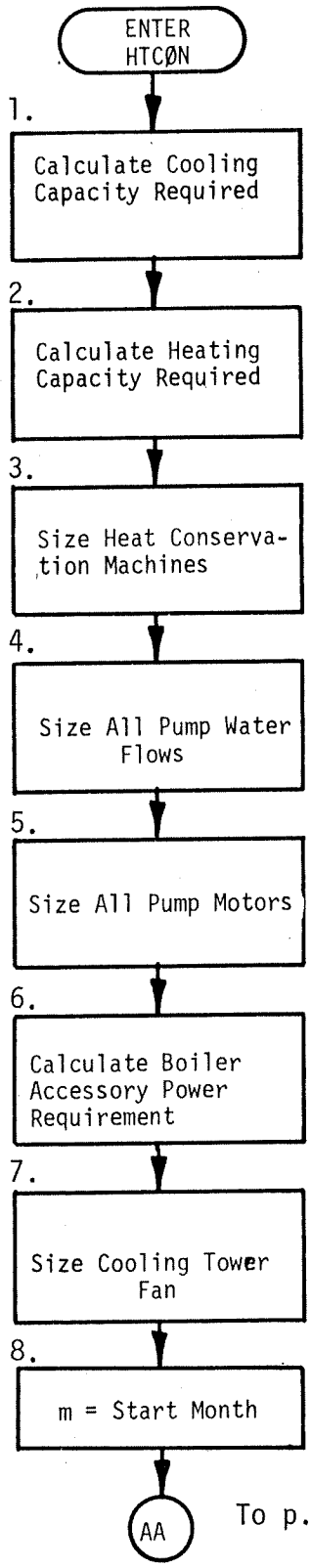
HPBLP - Boiler water pump power (bhp)

HPWWP - Well water pump power (bhp)

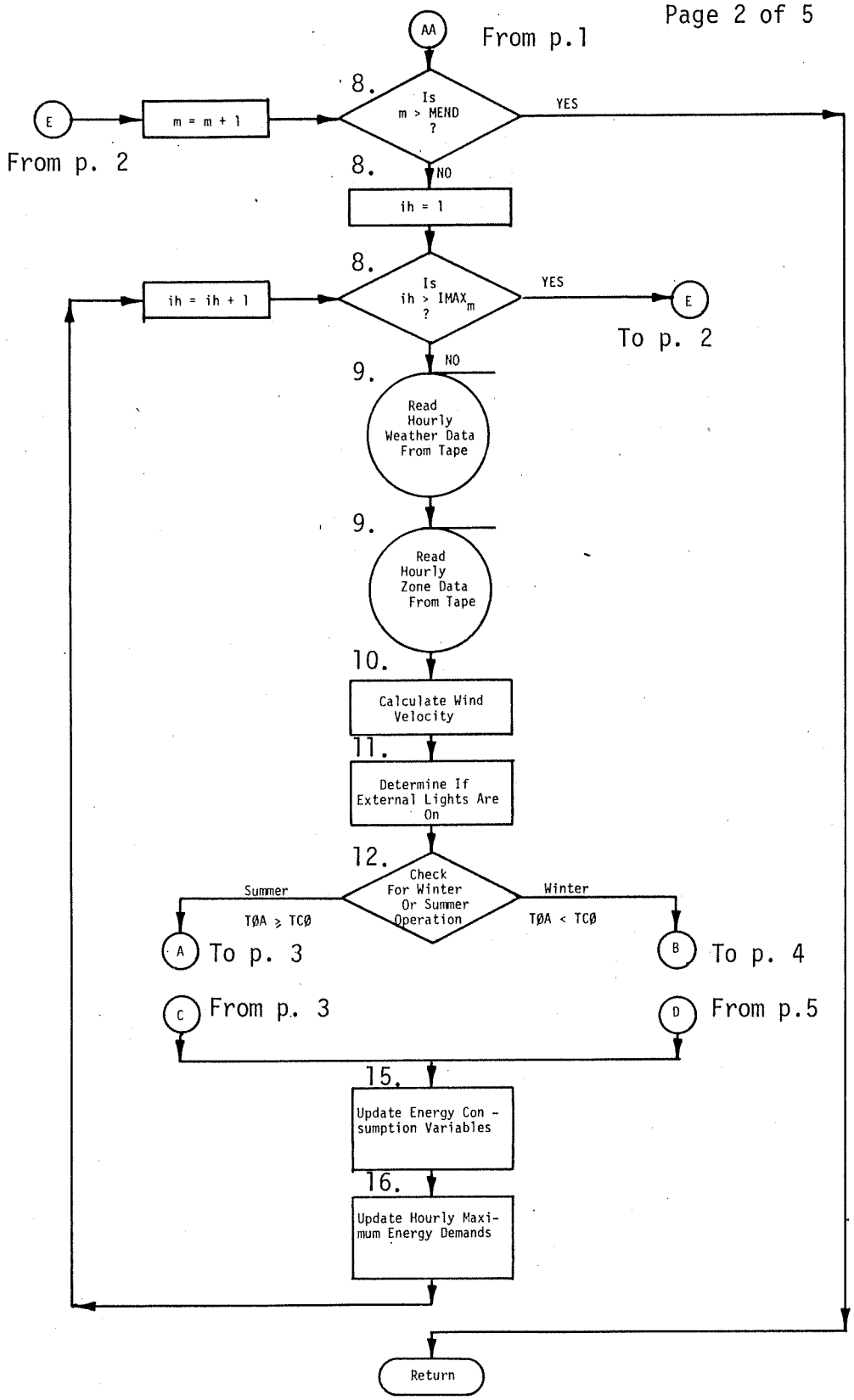
HPCTF - Cooling tower fan power (bhp)

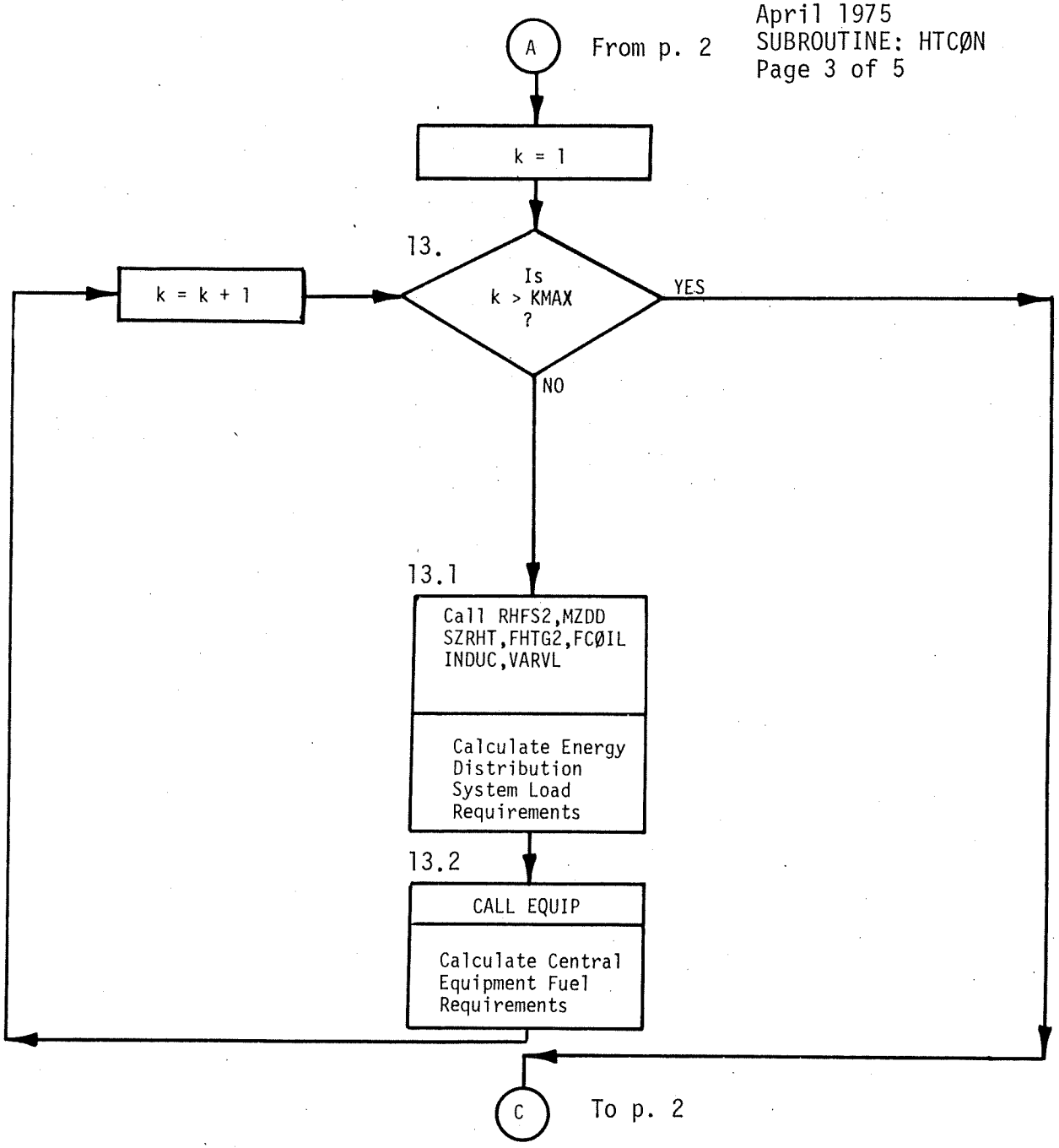
HPBLA - Boiler accessory power (bhp)

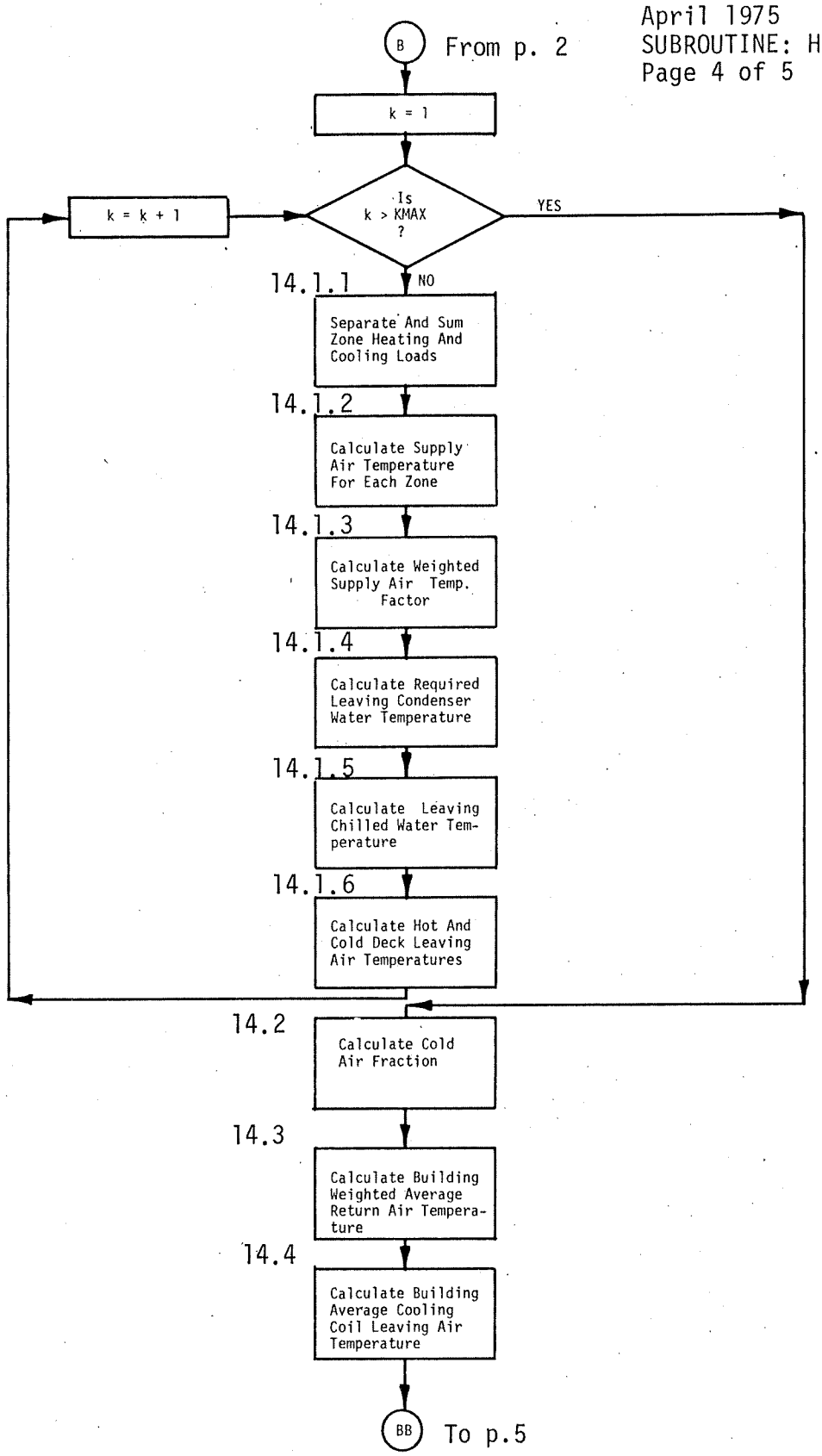
CFMCT - Cooling tower air flow (ft^3/min)

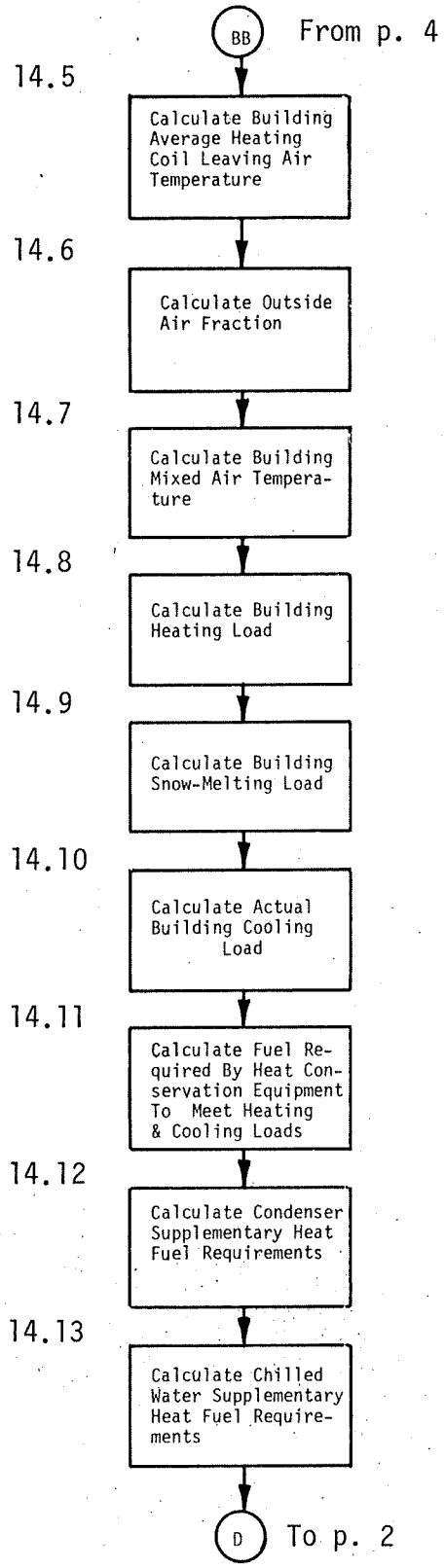

ENTER HTCØN
1.
Calculate Cooling Capacity Required
2.
Calculate Heating Capacity Required
3.
Size Heat Conservation Machines
4.
Size All Pump Water Flows
5.
Size All Pump Motors
6.
Calculate Boiler Accessory Power Requirement
7.
Size Cooling Tower Fan
8.
m = Start Month
AA

To p. 2


AA
From p.1
E
From p. 2
m = m + 1
8.
Is m > MEND ?
YES
NO
8.
ih = 1
8.
ih = ih + 1
Is ih > IMAX$_m$?
YES
E
To p. 2
NO
9.
Read Hourly Weather Data From Tape
9.
Read Hourly Zone Data From Tape
10.
Calculate Wind Velocity
11.
Determine If External Lights Are On
12.
Check For Winter Or Summer Operation
Summer
TØA ≥ TCØ
Winter
TØA < TCØ
A
To p. 3
B
To p. 4
C
From p. 3
D
From p.5
15.
Update Energy Con - sumption Variables
16.
Update Hourly Maxi- mum Energy Demands
Return


A
From p. 2
k = 1
13.
Is
k > KMAX
?
YES
NO
k = k + 1
13.1
Call RHFS2,MZDD
SZRHT,FHTG2,FCØIL
INDUC,VARVL
Calculate Energy
Distribution
System Load
Requirements
13.2
CALL EQUIP
Calculate Central
Equipment Fuel
Requirements
C
To p. 2


B
From p. 2
k = 1
k = k + 1
Is k > KMAX ?
YES
NO
14.1.1
Separate And Sum Zone Heating And Cooling Loads
14.1.2
Calculate Supply Air Temperature For Each Zone
14.1.3
Calculate Weighted Supply Air Temp. Factor
14.1.4
Calculate Required Leaving Condenser Water Temperature
14.1.5
Calculate Leaving Chilled Water Temperature
14.1.6
Calculate Hot And Cold Deck Leaving Air Temperatures
14.2
Calculate Cold Air Fraction
14.3
Calculate Building Weighted Average Return Air Temperature
14.4
Calculate Building Average Cooling Coil Leaving Air Temperature
BB
To p.5


BB
From p. 4
14.5
Calculate Building Average Heating Coil Leaving Air Temperature
14.6
Calculate Outside Air Fraction
14.7
Calculate Building Mixed Air Temperature
14.8
Calculate Building Heating Load
14.9
Calculate Building Snow-Melting Load
14.10
Calculate Actual Building Cooling Load
14.11
Calculate Fuel Required By Heat Conservation Equipment To Meet Heating & Cooling Loads
14.12
Calculate Condenser Supplementary Heat Fuel Requirements
14.13
Calculate Chilled Water Supplementary Heat Fuel Requirements
D
To p. 2

CALCULATION SEQUENCE

1. Calculate cooling capacity required (QCR).

   QCR = NUMC * SZC * 12000.

   where QCR has units of Btu/hr.

2. Calculate heating capacity required (QHR).

   QHR = -1000. * NUMB * SZB

   where QHR has units of Btu/hr.

   The input variable QSNØW should be set equal to 0.0 if snow-melting is not to be considered or if snow-melting is considered, but the engineer does not with to have a snow-melting load added to the capacity of the boiler. If a snow-melting load is to be added to the capacity of the boiler, QSNØW can be obtained from the 1967 ASHRAE Guide and Data Book, Systems and Equipment Volume, Chapter 27, Table 2.

3. Compare peak cooling requirement to the peak heating requirement expressed as equivalent cooling and size heat conservation machines based upon the smaller of the two. Assume 1.3 heat rejection ratio between condenser and evaporator, and a 0.5 ratio of winter cooling capacity to summer cooling capacity.

   If QCR $\geq$ |QHR/(1.3 * 0.5)|,

   Go to calculation 3.2.

   If QCR < |QHR/(1.3 * 0.5)|,

   Go to calculation 3.1.

   3.1 Size heat conservation machine based upon peak cooling load.

   3.1.1 Compute total cooling capacity required (CAPC).

   CAPC = QCR/12000.

   where CAPC has units of tons.

   3.1.2 Set NUMHC = 2 (number of heat conservation machines).

   SZHC = CAPC * 1.3 * 0.5/NUMHC

   where SZHC is the heat rejected at the condenser expressed in tons during winter operation of heat conservation machines.

If necessary, increase NUMHC until SZHC < 600.0.

3.1.3 Compute heat conservation machine heating capacity (CAPH).

CAPH = SZHC * NUMHC * 12000./1000.

3.1.4 Compute total heating requirements (QHR).

QHR = NUMB * SZB

3.1.5 Compute size of boilers (SZB) required in condenser water circuit. This is for supplemental heat.

SZB = (QHR - CAPH)/NUMB

where SZB has units of MBH. Note that the definitions of SZB and NUMB have changed from those at entry to HTCØN. The number value of NUMB does not change.

3.1.6 Compute size of supplementary heat element (SZSCL) required in chilled water circuit.

SZSCL = CAPH/1.3

where SZSCL has units of MBH.

Go to calculation 4.

3.2 Size heat conservation machine based upon peak heating load.

3.2.1 Compute the total heating capacity required (CAPH).

CAPH = -QHR/1000.

where CAPH has units of MBH.

3.2.2 Set NUMHC = 2 (number of heat conservation machines).

SZHC = CAPH/(12.0 * NUMHC)

where SZHC is the heat rejected at the condenser expressed in tons during winter operation of heat conservation machines.

If necessary, increase NUMHC until SZHC < 600.0.

3.2.3 Compute amount of cooling available from heat conservation machines during summer operation (QCA).

QCA = (SZHC * NUMHC) * 12000./(1.3 * 0.5)

3.2.4 Compute amount of cooling which must be provided by auxiliary chillers (QDIF1).

QDIF1 = QCR - QCA

3.2.5 Compute size of auxiliary chillers (SZC).
Set NUMC = 1 (number of auxiliary chillers).

SZC = QDIF1/(12000. * NUMC)

where SZC has units of tons. Note that the definitions and number values of SZC and NUMC have changed from those at HTCØN entry.

3.2.6 Compute total cooling capacity (CAPC).

CAPC = QCA/12000. + NUMC * SZC

where CAPC has units of tons.

3.2.7 Compute size of supplementary heating element in chilled water circuit (SZSCL).

SZSCL = CAPH/1.3

4. Size all pump water flows (GPM).

4.1 Chilled water flow rate (GPMCL).

GPMCL = 2.4 * CAPC

4.2 Condenser water flow rate (GPMCN).

GPMCN = 3.0 * CAPC

4.3 Boiler water flow rate (GPMBL).

GPMBL = CAPH * 1000./(500. * 20.)

4.4 Well water flow rate, if used (GPMWW).

GPMWW = SZSCL * 1000./60. * 8.3 * 1. * (TWWIN - TCLMN))

5. Size all pump motors assuming pump efficiency of 60%.

5.1 Chilled water pump horsepower (HPCLP).

HPCLP = GPMCL * HDCLP/(3962. * 0.6 * EFF)

5.2 Condenser water pump horsepower (HPCNP).

HPCNP = GPMCN * HDCNP/(3962. * 0.6 * EFF)

5.3 Boiler water pump horsepower (HPBLP).

HPBLP = GPMBL * HDBLP/(3962. * 0.6 * EFF)

5.4 Well water pump horsepower (HPWWP).

HPWWP = GPMWW * HDWWP/(3962. * 0.6 * EFF)

6. Calculate the horsepower requirement for motors running boiler auxiliary equipment such as fans, blowers, pumps, etc. (HPBLA). From American Standard Catalog for packaged boilers ranging in size from 20 to 750 horsepower, the auxiliary horsepower requirement was approximately 1/20 of the total boiler horsepower capacity. Therefore,

HPBLA = CAPH * 1000./(33472. * 20.)

7. Size cooling tower fan.

7.1 Cooling tower air flow requirement (CFMCT).

CFMCT = 300. * CAPC

7.2 Cooling tower fan horsepower requirement (HPCTF) assuming 1.0 inch of water total pressure.

HPCTF = CFMCT * 1./(6346. * EFF)

8. Begin hourly energy consumption analysis, repeating calculations 9 through 16 for every hour of the year.

9. Read hourly weather and space load data.

10. Calculate wind velocity in units of mph (VWIND).

VWIND = 1.151 * VEL

11. Determine if external lights are ON.

11.1 If ISUN = 0, set

PWEL = 0.0

11.2 If ISUN = 1, set

PWEL = PWØL

12. Check outside air temperature (TØA) to determine if summer or winter operation.

If TØA $\geq$ TCØ, summer operation; therefore,

Go to calculation 13.

If TØA < TCØ, winter operation; therefore,

Go to calculation 14.

13. Summer operation of heat conservation machines.

13.1 Begin fan system analysis repeating the following calculations for each fan system within the building.

3.1.1 Check type of fan system.

If $KFAN_k$	= 1, call RHFS2	= 8, call FCØIL
	= 2, call MZDD	= 9, call FCØIL
	= 3, call MZDD	= 10, call INDUC
	= 4, call SZRHT	= 11, call INDUC
	= 5, call RHFS2	= 12, call VARVL
	= 6, call RHFS2	= 13, call RHFS2
	= 7, call FHTG2	

13.1.2 Keep running total of building cooling, heating, and power loads.

$$QHBC = \sum_{k=1,KMAX} QFPC_k$$

$$QHBH = \sum_{k=1,KMAX} (QFPH_k + QFPPH_k + TQB_k)$$

$$QHBRH = \sum_{k=1,KMAX} QFPRH_k$$

$$PWILM = \sum_{k=1,KMAX} PWL_k$$

13.2 Calculate hourly energy consumption. Call EQUIP, which calculates the following:

GASC	STMC	
GASH	STMH	
GASG	ELEC	See subroutine ENGYC for explanation of these variables.
ØILC	ELEH	
ØILH	FUEL	

13.3 Go to calculation 15.

14. Winter operation of heat conservation machines.

14.1 Begin fan system analysis, repeating calculation 14.1.1 through 14.1.6 for each fan system k.

14.1.1 Form the following zone load summations:

$$QT_i = QS_z + QSINF_z$$

$$QSUMC = \sum_{j=1,JMAX_k} QT_i \text{ (pos)} * MULT_i$$

$$QSUMH = \sum_{j=1,JMAX_k} QT_i \text{ (neg)} * MULT_i$$

(See note below for explanation of subscript variables i, j, k, z.)

14.1.2 Calculate supply air temperature required for each zone (TS_i).

$$TS_i = TSP_z - QT_i/(1.08 * CFM_i)$$

14.1.3 Form the summation SUMCT.

$$SUMCT = \sum_{j=1,JMAX_k} (CFM_i * TS_i)$$

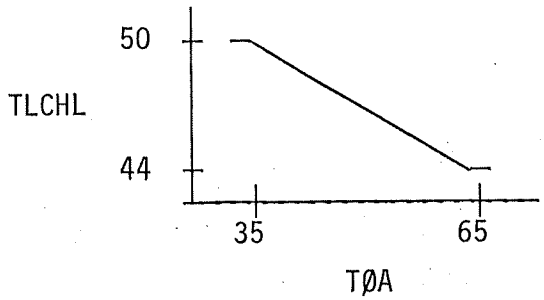
where SUMCT is the weighted summation of required zone temperature.

NOTE: There is a corresponding z for each i, a relationship defined by the variable SPACN(k,j).

14.1.4 Calculate required leaving-condenser water temperature (TLCØN) assuming schedule below which is a function of the hourly heating requirement of the building.

$$TLCØN = TLCNM - 22.5 * (1. - QSUMH/QHR)$$

14.1.5 Calculate leaving chilled water temperature (TLCHL) assuming the schedule shown below.



This schedule can be expressed in equation form as:

$$TLCHL = 44. + (65. - TØA)/5.$$

If TLCHL as calculated by above equation is greater than 50°F, set

$$TLCHL = 50.0$$

If TLCHL as calculated by above equation is less than 44°F, set

$$TLCHL = 44.0$$

14.1.6 Determine the ratio of cold air cfm to total cfm circulated by fan system k. Let this ratio be called $GAMA_k$. By definition, therefore,

$$GAMA_k = \frac{\sum_{j=1,}^{JMAX_k} (BETA_i + CFM_i)}{CFMAX_k}$$

where $BETA_i$ is the fraction of total air flowing through the cold duct to zone i.

A heat balance around any fan zone j yields

$$TS_i = TCD * BETA_j + THD(1. - BETA_j)$$

where TS_i is the zone supply air temperature required (°F)

TCD is the temperature of air leaving the cooling coil (°F)

THD is the temperature of air leaving the heating coil (°F)

Solving for $BETA_i$ gives

$$BETA_i = (THD - TS_i)/(THD - TCD)$$

The heating and cooling coils used in heat conservation systems are deep coils which are sized such that the discharge air temperature approaches to within 5°F the entering water temperature at maximum air flow. At partial air flow, it is assumed that the discharge air temperature varies linearly with the air flow rate through the coil.

The temperature of air leaving the heating coil (THD) is then

$$THD = TLCØN - 5. * (1. - GAMA_k)$$

The temperature of air leaving the cooling coil (TCD) is then

$$TCD = TLCHL + 5. * GAMA_k$$

Substituting the equation for $BETA_i$, THD and TCD into the equation for $GAMA_k$ results in

$$GAMA_k = \frac{CFMAX_k * (TLCØN - 5.) - SUMCT}{CFMAX_k * (TLCØN - TLCHL - 10.)}$$

where

$$SUMCT = \sum_{j=1,JMAX_k} (CFM_i * TS_i * MULT_i)$$

14.2 Calculate fraction of total air circulated within building that is passing through cooling coils (GAMAB).

Calculate the quantity SUMGX.

$$SUMGX = \sum_{k=1,KMAX} (GAMA_k * CFMAX_k)$$

$$GAMAB = SUMGX/CFMBX$$

14.3 Determine a weighted average return air temperature for the building (TPLB).

$$TPLB = 75. + QL1TB/(1.08 * (CFMBX - CFMEX))$$

14.4 Determine a weighted average cooling coil leaving air temperature for building (TCDB).

$$TCDB = TLCHL + 5. * GAMAB$$

14.5 Calculate a weighted average heating coil leaving air temperature for the building (THDB).

$$THDB = TLCØN - 5. * (1. - GAMAB)$$

14.6 Determine the amount of outside air required to create a cooling load that will produce the required heating at the condenser.

A heat balance about the building's heating coils, cooling coils, and outside air-return air damper system yields the following three equations:

$$TMAB = TPLB * (1. - ALFA) + TØA * ALFA$$

$$QHBC = 1.08 * CFMBX * GAMAB * (TMAB - TCDB)$$

$$QHBH = 1.08 * (1. - GAMAB) * (THDB - TMAB)$$

where

QHBC	is hourly building cooling load
QHBH	is hourly building heating load
TMAB	is mixed air temperature
ALFA	is fraction of outside air mixing with return air

Since the heat rejection ratio at the condenser of a heat conservation machine is approximately 1.3 times the cooling load, find the fraction of outside air, ALFA, required such that

$$QHBH = 1.3 * QHBC$$

Substituting the equations for QHBC, QHBH, and TMAB into the equation yields

ALFA = TPLB/(TPLB - TØA) - (THDB * (1. - GAMAB)

+ 1.3 * GAMAB * TCDB)/((TPLB - TØA)

* (1. + 0.3 * GAMAB))

If ALFA > 1.0, the heating requirement can be obtained with 100% outside air; therefore, reset

ALFA = 1.0

If 0.0 $\leq$ ALFA $\leq$ 1.0, the heating requirement can be obtained with no need for supplementary heat.

If ALFA < 0.0, supplementary heat is required; therefore, reset

ALFA = 0.0

14.7 Calculate actual building mixed air temperature (TMAB).

TMAB = TØA * ALFA + TPLB * (1. - ALFA)

14.8 Calculate actual building heating load (QHBH).

QHBH = 1.08 * CFMBX * (1. - GAMAB) * (TMAB - THDB)

14.9 Calculate any snow-melting load, if applicable (QTØT).

14.9.1 If KSNØW = 0, no snow-melting system.

Go to calculation 14.10.

14.9.2 If KSNØW = 1 or 2, snow-melting is to be considered.

14.9.2.1 Calculate amount of snowfall for the hour assuming that 1/24 of the day's total fell during the hour.

SNØW = 0.1 * SNØWF(ID)/24.

where SNØW has units of equivalent inches of water, SNØWF(ID) has units of inches of snow, and ID is the day number of the year, calculated as follows:

ID = 1 + IHØUR/24

14.9.2.2 Call SNØWM subroutine which calculates QTØT, the snow-melting load.

14.9.2.3 Add QTØT to the heating requirement of the building.

If KSNØW = 1, liquid-type snow-melting system; therefore,

QHBH = QHBH - QTØT

If KSNØW = 2, electric-type snow melting system; therefore,

ELEH = QTØT/3413.

14.10 Calculate actual building cooling load (QHBC).

QHBC = 1.08 * CFMBX * GAMAB * (TMAB - TCDB)

14.11 Calculate energy required to produce the building heating and cooling required.

14.11.1 If |QHBH| $\geq$ |SZHC * NUMHC * 12000.|, supplementary heat in condenser water line is required.

14.11.1.1 Calculate condenser water supplementary heat requirement (QSHCN).

QSHCN = QHBH + CAPHC

where

CAPHC = SZHC * NUMHC * 12000.

and QHBH is negative.

14.11.1.2 If |QHBC| $\geq$ |CAPHC/1.3|, then no supplementary heating is required in chilled water line; therefore, set

QSHCL = 0.0

If |QHBC| < |CAPHC/1.3|, then calculate supplementary heat required in chilled water line, Btu/hr.

QSHCL = -(CAPHC/1.3 - QHBC)

14.11.1.3 Heat conservation machines are operating at 100% capacity, therefore

FFL = 1.0

14.11.1.4 Calculate energy consumption required by heat conservation machines.

For SZHC < 200 tons:

PØWER = QEVAP * (0.3371 + 0.01233 * TECØN - 0.00974 * TLCHL) * (0.868 + 0.133 * FFL * 16.)

For SZHC $\geq$ 200 tons:

PØWER = QEVAP * (1.74 - 1.0234 * FFL + 0.3707 * FFL * FFL - 0.010025 * TDIF + 0.000175 * TDIF * TDIF)

where

QEVAP = QHBC/12000.

TECØN = TLCØN + 16.

TDIF - TECØN -TLCHL

14.11.1.5 Update monthly electric heat energy consumption totals.

ELEH = ELEH + PØWER

Go to calculation 14.12.

14.11.2 If |QHBH| $\leq$ |SZHC * NUMHC * 12000.|, then heat conservation machines are operating at part load.

14.11.2.1 Calculate chilled water supplementary heat requirement.

For |QHBH| > |1.3 * QHBC|, then

QSHCL = QHBH/1.3 + QHBC

For |QHBH| $\leq$ |1.3 * QHBC|, then

QSHCL = 0.0

14.11.2.2 Calculate the number of heat conservation machines operating.

Estimated number operating is

ENHCM = -QHBH/(1.3 * (12000. * 0.9 * SZHC))

Round ENHCM up to next whole number and set equal to NHCØN.

14.11.2.3 Calculate fraction of full load on each machine operating.

FFL = QEVAP/(NHCØN * SZHC/1.3)

where

QEVAP = QHBC/12000. + QDIF2

QDIF2 = (-QHBH/1.3 - QHBC)/12000.

14.11.2.4 Calculate energy consumption of heat conservation machines operating.

For SZHC < 200 tons:

PØWER = QEVAP * (0.3371 + 0.01223 * TECØN - 0.00974 * TLCHL) * (0.868 + 0.133 * FFL * 16.)

For SZCH $\geq$ 200 tons:

PØWER = QEVAP * (1.74 - 1.0234 * FFL + 0.3707 * FFL * FFL - 0.010025 * TDIF + 0.000175 * TDIF * TDIF)

14.11.2.5 Calculate condenser heat available based upon evaporator load and work done (QCØND).

QWØRK = 0.2844 * PØWER

QCØND = QEVAP + QWØRK

14.11.2.6 Compare actual condenser heat available (QCØND) to that required (QHBH).

ERRØR = 0.5 * (-QHBH/12000.

- QCØND)

If |ERROR| > |0.005 * SZHC|, set

QDIF2 = QDIF2 + ERRØR

Go to calculation 14.11.2.3, and repeat procedure until

|ERROR| $\leq$ |0.005 * SZHC|

14.11.2.7 Check to see if FFL is below FFLMN.

If FFL $\geq$ FFLMN,

Go to calculation 14.12.

If FFL < FFLMN, heat conservation machine not allowed to operate; therefore, set

QSHCL = 0.0

QHBH = 0.0

QHBC = 0.0

QHBRH = 0.0

Go to calculation 14.12.

14.12 Convert condenser supplementary heat requirement into fuel requirements.

If M3 = 1, gas heating; therefore

GASH = GASH - QSHCN/80000.

If M3 = 2, oil heating; therefore

ØILH = ØILH - QSHCN/(0.8 * HVHØ)

If M3 = 3, steam heating; therefore

STMH = STMH - QSHCN/(HESTM - HLSTM)

If M3 = 4, electric heating; therefore

ELEH = ELEH - QSHCN/3413.

14.13 Convert chilled water supplementary heat requirement into fuel requirements.

If M7 = 1, gas heating source; therefore

GASH = GASH - QSHCL/80000.

If M7 = 2, oil heating source; therefore

ØILH = ØILH - QSHCL/(0.8 * HVHØ)

If M7 = 3, electric heating source; therefore

ELEH = ELEH - QSHCL/3413.

If M7 = 4, well water heating source; therefore

ELEH = ELEH = HPWWP * 0.7457

If M7 = 5, city water heating source; therefore

GALCW = -QSHCL/(8.3 * (TCWIN - TLCMN))

15. Update the running totals of the following monthly energy consumption variables

ENGY (M,2,3)
ENGY (M,2,4)
ENGY (M,2,5)
ENGY (M,2,6)
ENGY (M,2,7)
ENGY (M,2,10)
ENGY (M,2,12)
ENGY (M,2,15)
ENGY (M,2,16)
ENGY (M,2,17)
ENGY (M,2,18)

See subroutine ENGY for an explanation of these quantities.

16. Keep a record of maximum hourly energy demands by checking and updating if necessary the following monthly demand variables.

```
ENGY (M,1,1)
ENGY (M,1,2)
ENGY (M,1,3)
ENGY (M,1,4)
ENGY (M,1,5)
ENGY (M,1,6)        See subroutine ENGY for explanation of
ENGY (M,1,7)        these quantities.
ENGY (M,1,10)
ENGY (M,1,12)
ENGY (M,1,15)
ENGY (M,1,16)
ENGY (M,1,17)
ENGY (M,1,18)

        END OF HOURLY ANALYSIS

RETURN
```

SUBROUTINE: H2ØZN

GENERAL DESCRIPTION

This subroutine calculates hourly moisture changes and net moisture requirements for zone air.

LIST OF VARIABLES

INPUT

QL - Latent load from zone (Btu/hr)

ZMASS - Mass flow of air through zone (lbm-air/hr)

WSP - Zone humidity ratio set point (lbm-H_2O/lbm-dry air)

QLINF - Latent load due to inflation of outside air into zone (Btu/hr)

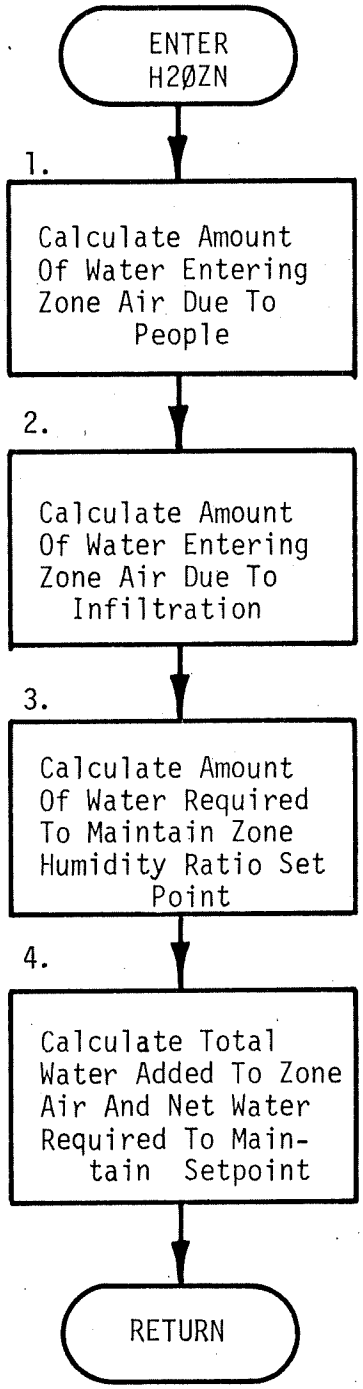
WZØN - Zone humidity ratio from previous hour (lbm-H_2O/lbm-dry air)

WØA - Outside air humidity ratio (lbm-H_2O/lbm-dry air)

OUTPUT

H2ØAD - Zone water change in current hour (lbm-H_2O)

H2ØRD - Net zone water required to reach zone humidity ratio set point (lbm-H_2O)


ENTER
H2ØZN
1.
Calculate Amount Of Water Entering Zone Air Due To People
2.
Calculate Amount Of Water Entering Zone Air Due To Infiltration
3.
Calculate Amount Of Water Required To Maintain Zone Humidity Ratio Set Point
4.
Calculate Total Water Added To Zone Air And Net Water Required To Maintain Setpoint
RETURN

CALCULATION SEQUENCE

1. Calculate water added to zone air and/or process load due to people

   H2ØRM = QL/1090.0

   Where 1090.0 is latent heat of water.

2. Calculate water added to zone air due to infiltration

   H2ØIN = (QLINF/1090.0)*(WØA-WZØN)/WØA-WSP)

   Where the ratio

   $$\frac{(WØA-WZØN)}{(WØA-\ WSP)}$$

   is an approximation to adjust QLINF from set point humidity ratio (WSP) to current humdiity ratio (WZØN) conditions. Conditions assumed by LOAD program in calculating QLINF approach humidity ratio set point (WSP).

3. Calculate the amount of water (H2ØVL) maintain the zone set point humidity ratio

   H2ØVL = (WZØN-WSP)*ZMASS

4. Calculate total zone air water change (H2ØAD) for the hour and total water required to recover zone humidity set point (H2ØRD)

   H2ØAD = H2ØRM + H2ØIN

   H2ØRD = H2ØAD + H2ØVL

SUBROUTINE: HUM1

GENERAL DESCRIPTION

Calculates the humidity ratio (lb-H_2O/lbm-dry air) of moist air as a function of dry-bulb temperature, relative humidity, and barometric pressure.

LIST OF VARIABLES

INPUT

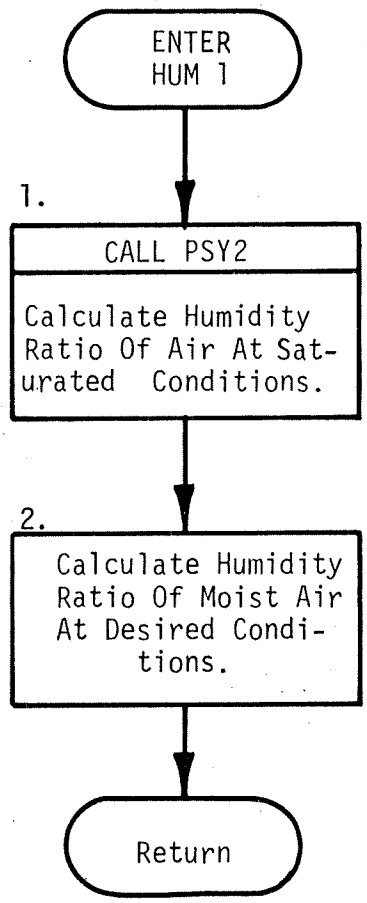
T - Dry-bulb temperature (°F)

RH - Relative humidity (%)

PATM - Barometric pressure (in. Hg)

OUTPUT

W - Humidity ratio of air (lb-H_2O/lbm-dry air)


ENTER
HUM 1
1.
CALL PSY2
Calculate Humidity Ratio Of Air At Saturated Conditions.
2.
Calculate Humidity Ratio Of Moist Air At Desired Conditions.
Return

CALCULATION SEQUENCE

1. Call subroutine PSY2 to calculate the humidity ratio of saturated air (WSAT) at temperature, T.

2. Calculate humidity of moist air at the desired condition.

   W = RH * 0.01 * WSAT

   (The above equation follows from the basic definition for relative humidity, i.e., REL. HUM. = W/W_{sat}, where REL. HUM. is a fraction from 0.0 to 1.0.)

SUBROUTINE: INDUC

GENERAL DESCRIPTION

This is a subroutine to simulate the operation of two and four pipe induction unit fan systems having induction units whose primary and induced room air streams mix after induced air is tempered. Induction unit cooling coil is limited to sensible cooling only.

TWO-PIPE INDUCTION UNIT FAN SYSTEM

The two-pipe induction system utilizes air and circulated water to achieve temperature control. The induction unit itself consists of a nozzle which injects primary air into a mixing chamber. The primary air jet which induces room air into it is the driving force in drawing room air through a coil. As this is a changeover type system (i.e., hot water supplied to terminal units in winter, cold water in summer), the dry-bulb temperature of air leaving the air handling unit (primary air), as well as water temperature, varies with outside air temperature. Final temperature control is achieved via a stage thermostat which operates a throttling valve located on the coil in the induction unit. See Figure for System Schematic.

Air-side central equipment for this system consists of an air handler having heating and cooling coils, a mixed air section, and a humidifier. Additional characteristics of the system are as follows:

- Three outside air/return air options
- Optional return air fan
- Humidifier
- Baseboard heating as supplemental heat to each zone.

Depending on the specific design of the system, it is often possible that a building requiring nominal amounts of primary air may be moderately pressurized and the return air network eliminated. This may be simulated by not including a return air fan as input and by setting minimum outside air equal to 100%.

FOUR-PIPE INDUCTION UNIT FAN SYSTEM

The four-pipe induction system is comprised of a primary supply air and hot and chilled water distribution networks feeding air-water induction-type terminal devices. The primary air which is held at a constant temperature (at about 55°F) serves to control humidity in the space as well as provide ventilation air as required. This primary air is mixed with recirculated room air at the terminal unit. Room air is tempered by first passing it through a coil in the induction unit which may heat or cool it as required such that the mixed air delivered to the space satisfies thermal requirements. The coil is controlled by a thermostat which modulates the flow of either hot or chilled water through the coil. See Figure 1 for System Schematic.

Air-side central equipment for this system consists of an air handler having heating and cooling coils, a mixed air section, and a humidifier. Additional characteristics of the system are as follows :

- Three outside air/return air options
- Optional return air fan
- Humidifier
- Baseboard heating as supplemental heating to each zone.

LIST OF VARIABLES

INPUT

k - Energy distribution system number

IHØUR - Hour of the year

TNFBP - Total net fan brake horsepower (Bhp)

COMMON

IBØIL - Boiler on/off flag (1=on;0=off)

ICHIL - Chiller on/off flag (1=on;0=off)

IFAN - Fan system shut-off flag (0=fans run continuously
1=fans may be shut off
2=fans and baseboard radiators may be shut off)

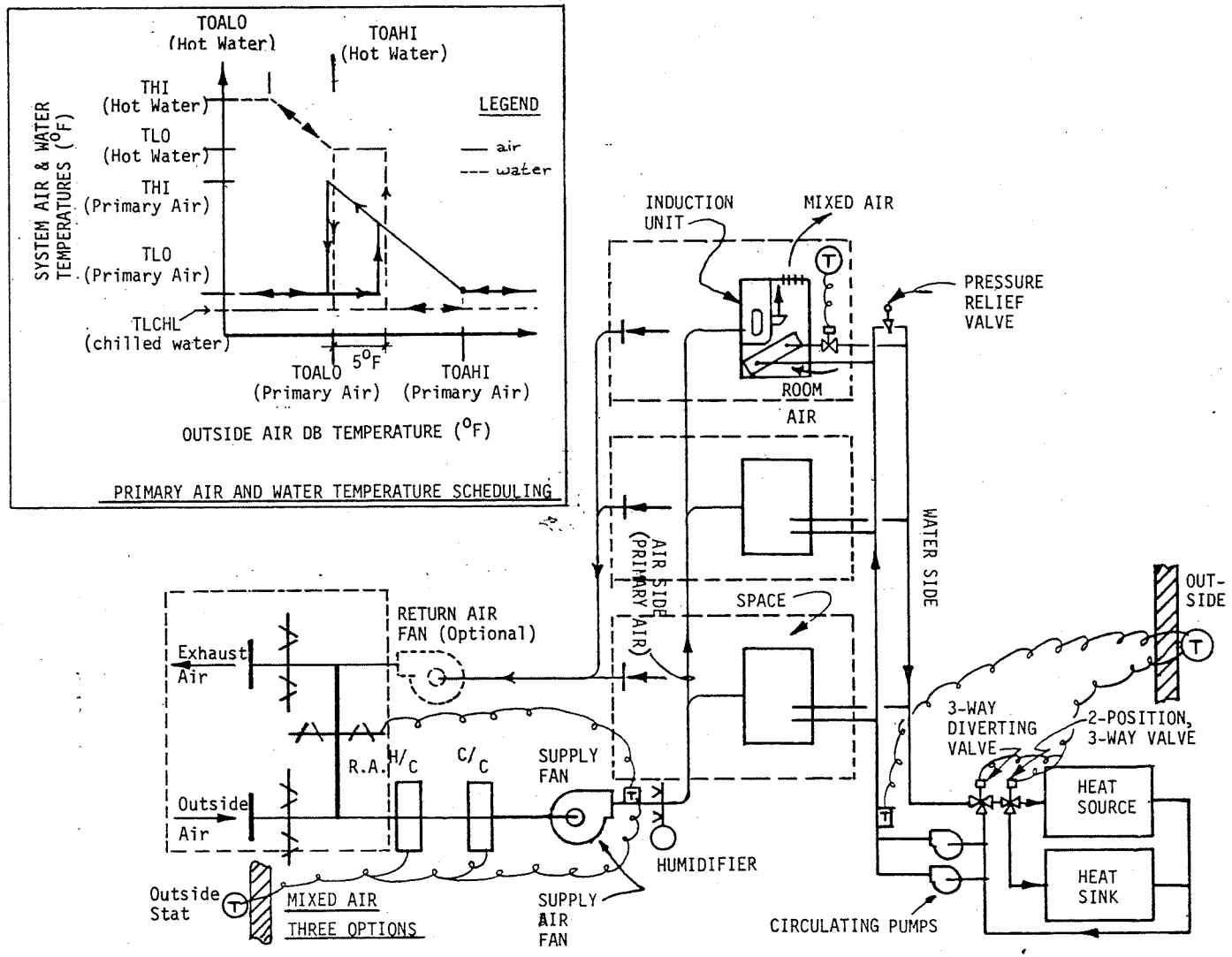
QS_z - Zone sensible load (Btu/hr)

QL_z - Zone latent load (Btu/hr)

$QLITE_z$ - Light heat into ceiling plenum above zone (Btu/hr)

$SLPØW_z$ - Space light and power (KW)

$QSINF_z$ - Zone sensible loss due to infiltration (Btu/hr)



1. Fixed Dampers
2. Enthalpy/temp. type Economizer cycle
3. Temperature type Economizer cycle

Figure TWO-PIPE INDUCTION UNIT FAN SYSTEM (DISTRIBUTION SYSTEM NO. 10)

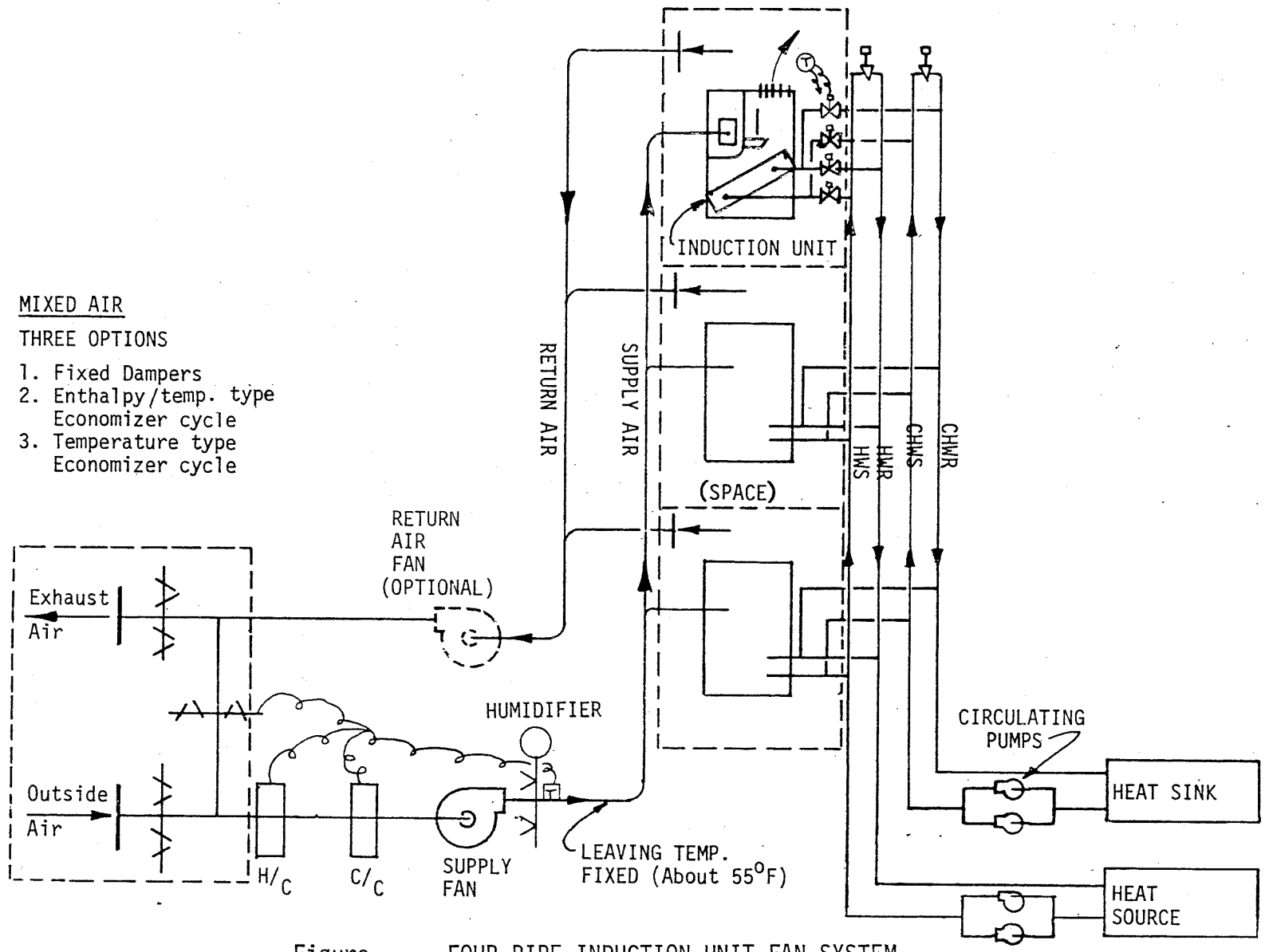


Figure FOUR-PIPE INDUCTION UNIT FAN SYSTEM (DISTRIBUTION SYSTEM NO. 11)

$QLINF_z$ - Zone latent loss due to infiltration (Btu/hr)

$STEMP_z$ - Space temperature at a given hour (°F)

$UCFM_z$ - Air flow through zone if it is a plenum space (ft^3/min)

TSP_z - Zone setpoint temperature (°F)

$VØL_z$ - Zone volume (ft^3)

TØA - Outside air dry-bulb temperature (°F)

WØA - Outside air humidity ratio (lbm-H_2O/lbm-dry air)

HØA - Outside air enthalpy (Btu/lbm)

DØA - Outside air density (lbm/ft^3)

PATM - Barometric pressure (in. Hg)

KMAX - Number of energy distribution systems

$KFAN_k$ - Energy distribution system index

$JMAX_k$ - Number of zones on system k

$CFMAX_k$ - Design supply air of system k (ft^3/min)

$CFMEX_k$ - Exhaust air, system k (ft^3/min)

$ALFAM_k$ - Minimum fraction outside air, system k

$ØACFM_k$ - Minimum ventilation air, system k (ft^3/min)

$RHSP_k$ - Relative humidity setpoint, system k (% R.H.)

WSP_k - Humidity ratio setpoint, system k (lbm-H_2O/lbm-dry air)

$DAVE_k$ - Average air density, system k (lbm/ft^3)

WRA_k - Return air humidity ratio, system k (lbm-H_2O/lbm-dry air)

DRA_k - Return air density, system k (lbm/ft^3)

$PWGAL_k$ - Process water volume, system k (gals)

$FMASS_k$ - Supply air mass, system k (lbm-air/hr)

$FMASR_k$ - Return air mass, system k (lbm-air/hr)

$FMASX_k$ - Exhaust air mass, system k (lbm-air/hr)

$TFNPS_k$ - Total supply fan pressure, system k (inches)

$TFNPR_k$ - Total return fan pressure, system k (inches)

$TFNPE_k$ - Total exhaust fan pressure, system k (inches)

$FBHPS_k$ - Supply fan brake horsepower, system k (bhp)

$FBHPR_k$ - Return fan brake horsepower, system k (bhp)

$FBHPE_k$ - Exhaust fan brake horsepower, system k (bhp)

$DTFNS_k$ - Air temperature rise across supply fan, system k, at full load (°F)

$DTFNR_k$ - Air temperature rise across return fan, system k, at full load (°F)

$ICZN_k$ - Zone in which humidistat is located, system k, (a "j" number)

$TCØFC_k$ - Two-pipe induction unit fan system changeover temperature or floor panel heating system hot water shut-off temperature, system k (°F)

$TFIX1_k$ - AHU discharge temperature, system k (°F)

$RIPA_k$ - Ratio of induced to primary air, system k

CFM_i - Supply air flow rate, zone i (constant)(ft^3/min)

$CFMS_i$ - Total induction unit air flow rate, zone i (ft^3/min)

$CFMR_i$ - Return air flow rate, zone i (ft^3/min)

$CFMX_i$ - Exhaust air flow rate, zone i (ft^3/min)

$ZMASS_i$ - Supply air mass flow, zone i (constant)(lbm-air/hr)

$ZMAS_i$ - Induced air mass flow, zone i (lbm-air/hr)

$ZMASR_i$ - Return air mass flow, zone i (lbm-air/hr)

$ZMASX_i$ - Exhaust air mass flow, zone i (lbm-air/hr)

$ALFBR_i$ - Active length baseboard radiation, zone i (lin. ft)

$CBTU_i$ - Baseboard radiation heat output per linear foot at standard conditions, zone i (Btu/hr-lin. ft)

$IPLEN_i$ - LOAD program space number of plenum above zone i

WZ_i - Calculated humidity ratio, zone i (lbm-H_2O/lbm-dry air)

$SPACN_{k,j}$ - Number of space as per LOAD program, applied to system k, zone j

$MULT_i$ - Multiplication factor, zone i

I - Variable subscript i

$TØALØ_n$ - Low outside air temperature at which system temperature is THI_n, reset schedule n (°F)

$TØAHI_n$ - High outside air temperature at which system temperature is $TLØ_n$, reset schedule n (°F)

$TLØ_n$ - Low system fluid temperature, reset schedule n (°F)

THI_n - High system fluid temperature, reset schedule n (°F)

$ISET_{k,m}$ - Reset temperature schedule index, system k, reset item m (an "n" number)

TFBHP - Total fan brake horsepower (bhp)

OUTPUT

QCC - Total cooling load. Includes AHU, induction unit, and changeover cooling loads (Btu/hr)

QHC - Heating load at AHU (also includes changeover heating load) (Btu/hr)

QTRHC - Sum of zone induction unit heating loads (Btu/hr)

QPHC - Not used; set equal to 0.0

TQB - Baseboard heating load (Btu/hr)

WATER - Steam humidification supplied at air handling unit (lbs-H_2O/hr)

BPKW - Base power (KW)

TNFBP - Total net [updated] fan brake horsepower (bhp)

TLVG - Air handling unit leaving dry bulb temperature (°F)

COMMON

QSI_i - Sensible heating load, zone i (Btu/hr)

TS_i - Supply air temperature, zone i (°F)

WZ_i - Calculated humidity ratio, zone i (lbm-H_2O/lbm-dry air)

$WREQD_i$ - Required humidity ratio, zone i (lbm-H_2O/lbm-dry air)

$QCLNM_i$ - Monthly accumulation of cooling loads not met, (zone i) * $MULT_i$ (Btu)

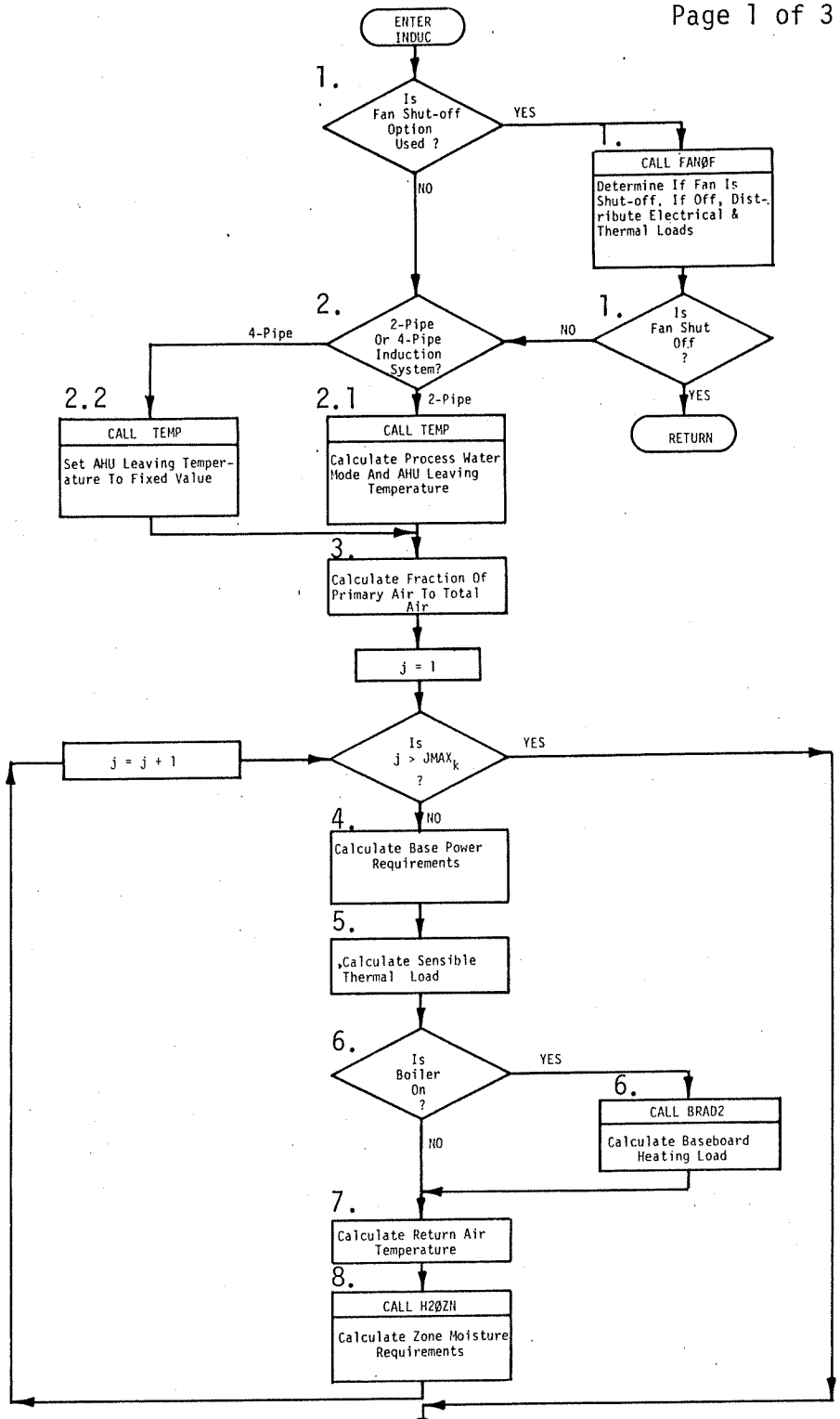
$QCPNM_i$ - Monthly peak cooling load not met, zone i (Btu/hr)

$IHCNM_i$ - Number of hours cooling load not met, zone i (hrs)

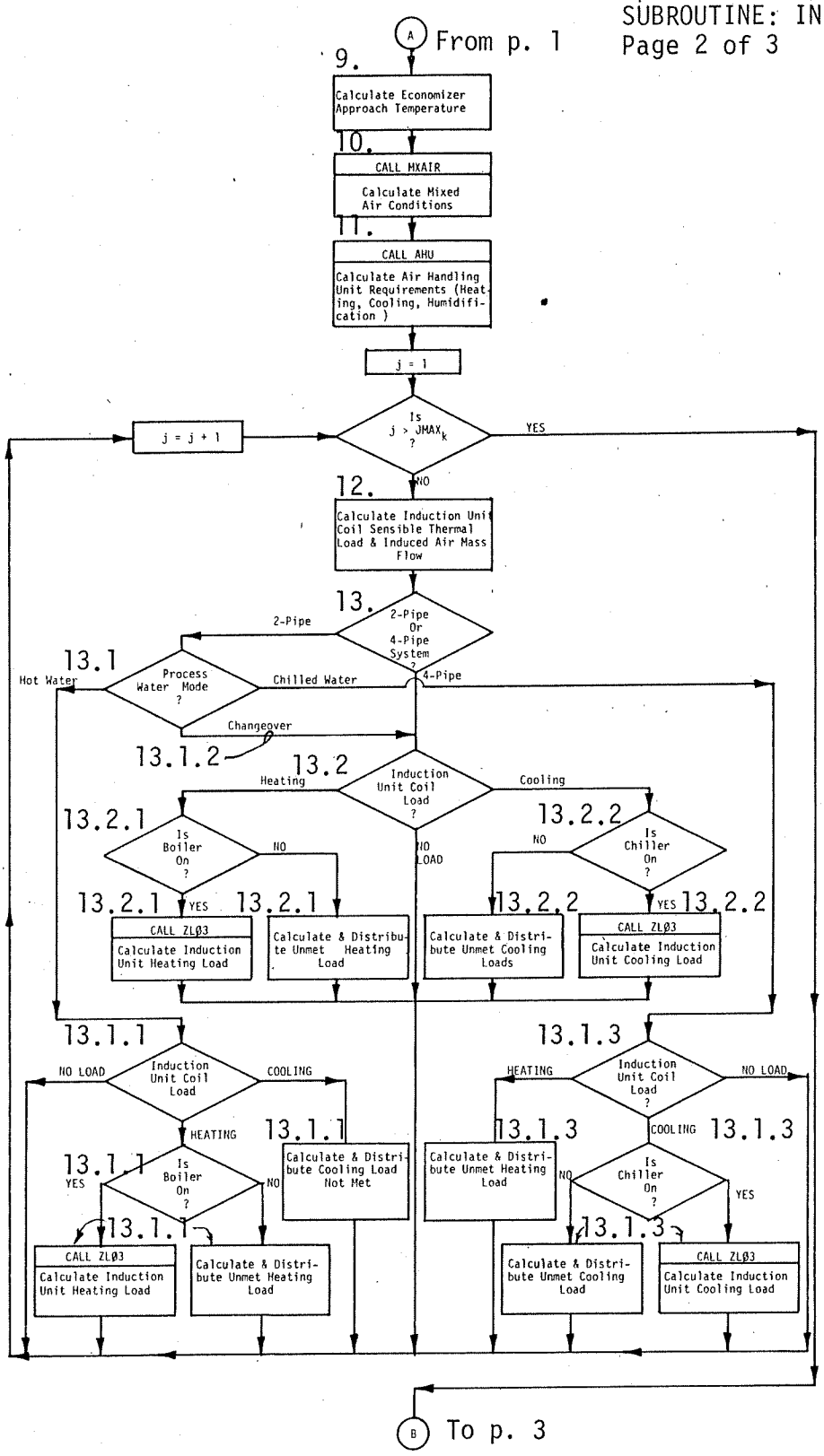
$QHLNM_i$ - Monthly accumulation of heating load not met, (zone i) * $MULT_i$ (Btu)

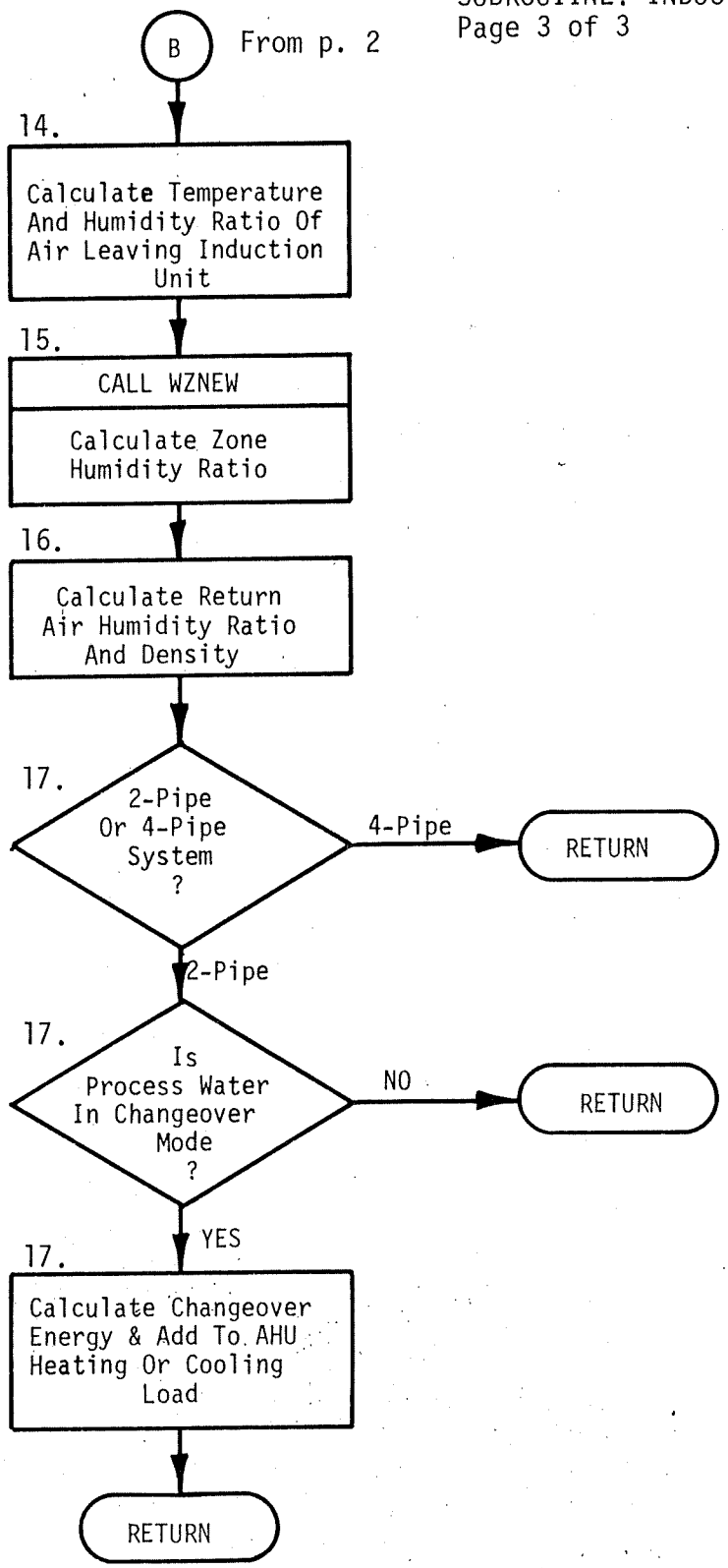
$QHPNM_i$ - Monthly peak heating load not met, zone i (Btu/hr)

$IHHNM_i$ - Number of hours heating load not met, zone i (hrs)


ENTER INDUC
1.
Is Fan Shut-off Option Used ?
YES
NO
1.
CALL FANØF
Determine If Fan Is Shut-off. If Off, Distribute Electrical & Thermal Loads
1.
Is Fan Shut Off ?
NO
YES
RETURN
2.
2-Pipe Or 4-Pipe Induction System?
4-Pipe
2-Pipe
2.2
CALL TEMP
Set AHU Leaving Temperature To Fixed Value
2.1
CALL TEMP
Calculate Process Water Mode And AHU Leaving Temperature
3.
Calculate Fraction Of Primary Air To Total Air
j = 1
j = j + 1
Is j > JMAX_k ?
YES
NO
4.
Calculate Base Power Requirements
5.
Calculate Sensible Thermal Load
6.
Is Boiler On ?
YES
NO
6.
CALL BRAD2
Calculate Baseboard Heating Load
7.
Calculate Return Air Temperature
8.
CALL HØZN
Calculate Zone Moisture Requirements
A

To p. 2


A From p. 1
9.
Calculate Economizer Approach Temperature
10.
CALL MXAIR
Calculate Mixed Air Conditions
11.
CALL AHU
Calculate Air Handling Unit Requirements (Heating, Cooling, Humidification)
j = 1
j = j + 1
Is j > JMAX_k ?
YES
NO
12.
Calculate Induction Unit Coil Sensible Thermal Load & Induced Air Mass Flow
13.
2-Pipe Or 4-Pipe System ?
2-Pipe
4-Pipe
13.1
Process Water Mode ?
Hot Water
Chilled Water
Changeover
13.1.2
13.2
Induction Unit Coil Load ?
Heating
Cooling
NO LOAD
13.2.1
Is Boiler On ?
NO
YES
13.2.1
CALL ZLØ3
Calculate Induction Unit Heating Load
13.2.1
Calculate & Distribute Unmet Heating Load
13.2.2
Is Chiller On ?
NO
YES
13.2.2
Calculate & Distribute Unmet Cooling Loads
13.2.2
CALL ZLØ3
Calculate Induction Unit Cooling Load
13.1.1
Induction Unit Coil Load
NO LOAD
COOLING
HEATING
13.1.1
Calculate & Distribute Cooling Load Not Met
13.1.1
Is Boiler On ?
YES
NO
13.1.1
CALL ZLØ3
Calculate Induction Unit Heating Load
13.1.1
Calculate & Distribute Unmet Heating Load
13.1.3
Induction Unit Coil Load ?
HEATING
NO LOAD
COOLING
13.1.3
Calculate & Distribute Unmet Heating Load
13.1.3
Is Chiller On ?
NO
YES
13.1.3
Calculate & Distribute Unmet Cooling Load
13.1.3
CALL ZLØ3
Calculate Induction Unit Cooling Load
B To p. 3


B
From p. 2
14.
Calculate Temperature And Humidity Ratio Of Air Leaving Induction Unit
15.
CALL WZNEW
Calculate Zone Humidity Ratio
16.
Calculate Return Air Humidity Ratio And Density
17.
2-Pipe Or 4-Pipe System ?
4-Pipe
RETURN
2-Pipe
17.
Is Process Water In Changeover Mode ?
NO
RETURN
YES
17.
Calculate Changeover Energy & Add To AHU Heating Or Cooling Load
RETURN

CALCULATION SEQUENCE

1. Fan off/on check.

   If it is desired to turn off fan when possible (IFAN > 0), call subroutine FANØF to determine whether the fnn can be turned off for the current hour (IØØ = 1 is off; IØØ = 0 is on). Otherwise, go to calculation 2.

   If the system is off (IØØ = 1), terminate INDUC simulation for the current hour. RETURN.

   If the system is on (IØØ = 0), go to Calculation 2.

   If fans run continuously (IFAN = 0), go to Calculation 2

2. Calculate temperature leaving air handler (TLVG).

   2.1 If two-pipe induction unit fan system is being simulated ($KFAN_k$ = 10), call subroutine TEMP to calculate primary air temperature and induction unit water mode indicator (IPW). This is graphically represented as follows:

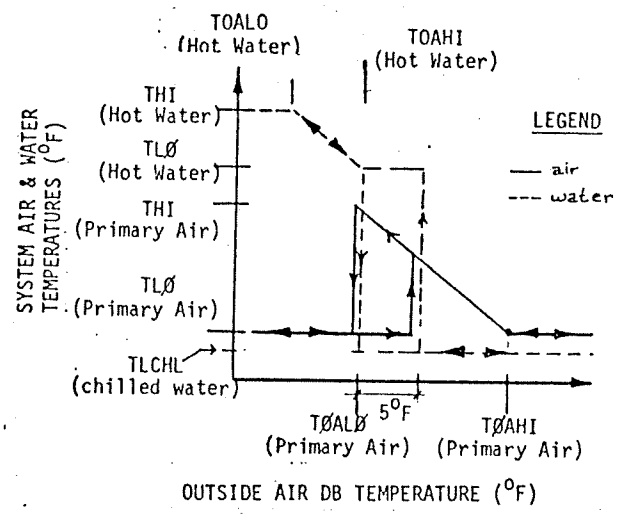


Figure TWO-PIPE INDUCTION UNIT AIR AND WATER SCHEDULING

[NOTE: TØAHI (hot water) should be set equal to TØALØ (primary air).]

Go to calculation 3.

   2.2 If four-pipe induction unit fan system is being simulated ($KFAN_k$ = 11), primary air is held constant (set equal to $TFIX1_k$).

   Go to calculation 3.

3. Calculate fraction of primary to total air (ALFIU).

$$ALFIU = 1./(1. + RIPA_k)$$

4. Calculate base power (BPKW); includes internal power, lights, receptacles, equipment, miscellaneous (KW).

$$BPKW = \sum_{j=1,\ JMAX_k} SLPØW_z * MULT_i$$

[See note below for explanation of variables i and z.]

5. Identify sensible thermal load of each zone on this system (QSI_i).

$$QSI_i = QS_z + QSINF_z$$

6. Baseboard radiation.

If boiler on (IBØIL = 1), call subroutine BRAD2 to calculate baseboard radiation heat (QB_j) and adjust QSI_i for QB_i.

Sum baseboard radiation heat.

$$TQB = \sum_{j=1,\ JMAX_k} QB_j$$

Go to calculation 7.

If boiler off (BØIL = 0), continue.

7. Calculate return air temperature (TRA_k).

NOTE: Since the System and Equipment Simulation Program is capable of using either one of the load tapes produced by NBSLD, the NECAP's (NASA's Energy and Cost Analysis Programs) Load Program, or the Variable Temperature Program as input, the following logic sequence is required.

7.1 If ceiling plenum is calculated as a separate zone,

7.1.1 If LOAD tape is used.

NOTE: There is a corresponding z for each i, a relationship defined by the variable $SPACN_{k,j}$. Hence, i and z are defined by system number (k) and zone number of system (j).

$DTL2_i = 0.0$

$QLITI = QLITE_z + QS_{pl} + QLITE_{pl} + QSINF_{pl}$

Go to calculation 7.2.

7.1.2 If VARIABLE TEMPERATURE tape is used (indicated by $STEMP_{pl} > 0.0$),

$DTL2_i = STEMP_{pl} - TSP_z$

$QLITI = QLITE_z$

Go to calculation 7.2.

7.2 If ceiling plenum is not calculated as a separate zone,

$DTL2_i = 0.0$

$QLITI = QLITE_z$

7.3 Return air temperature calculation (TRA_k).

$DTL_i = QLITI/(0.245 * ZMASR_i)$

$$TRA_k = \frac{\sum_{j=1,}^{JMAX_k} (TSP_z + DTL_i + DTL2_i) * ZMASR_i * MULT_i}{\sum_{j=1,}^{JMAX_k} ZMASR_i * MULT_i} + DTFNR_k$$

where $DTL2_i$ - Difference between zone and plenum temperatures as calculated by VARIABLE TEMPERATURE program.

QLITI - Thermal load of plenum pl above zone z as calculated by LOAD program.

8. Zone humidity calculations.

Using subroutine H2ØZN, calculate total mosture requirements of zone including setpoint recovery load ($H2ØRD_i$) and moisture changes in current hour due to environmental and room effects ($H2ØAD_i$).

9. Calculate economizer approach temperature (EAT).

If TLVG > 125.0°F,

$$TLVG = 125.0°F$$

$$EAT = TLVG - DTFNS_k$$

If EAT < 40.0°F,

$$EAT = 40.0°F$$

$$TLVG = EAT + DTFNS_k$$

10. Calculate mixed air conditions.

Call subroutine MXAIR to simulate the performance of:

1. Fixed outside and return air dampers ($MXA\emptyset_k = 1$).
2. An enthalpy/temperature type economizer cycle ($MXA\emptyset_k = 2$).
3. A temperature type economizer cycle ($MXA\emptyset_k = 3$).

Subroutine MXAIR also calculates the thermal properties (temperature (TMA); humidity ratio (WMA); and density (DMA) of the mixed air stream.

11. Air handling unit.

Call subroutine AHU (mode 1) to simulate the functioning of central system draw-through air handling unit. Calculate heating and cooling coil thermal requirements (QHC and QCC), effect of fan heat, water requirements of steam humidifier on discharge side of unit (WATER), and discharge humidity ratio (WSUP). The following characteristics apply:

The heating coil is locked out when the boiler scheduled off.

The cooling coil is locked out when the chiller scheduled off.

The humidifier is locked out when the cooling coil is functioning.

12. Calculate induction unit coil sensible thermal load ($QSIU_i$) and induced air mass flow ($ZMAS_i$).

$$QSIU_i = QSI_i + ZMASS_i * 0.245 * (TLVG - TSP_z)$$

$$ZMAS_i = ZMASS_i * RIPA_k$$

13. Induction unit simulation.

13.1 Two-pipe induction unit.

13.1.1 If hot water mode (IPW = -1),

If $QSIU_i \leq 0.0$,

If boiler on (IBØIL = 1), calculate temperature of induced air after coil (TLC_i).

$$TLC_i = -QSIU_i/(ZMAS_i + 0.245) + TSP_z$$

Call subroutine ZLØ3 to calculate induction unit heating load and distribute unmet load, if any.

Go to calculation 14.

If boiler off (IBØIL = 0), calculate heating load not met ($QLNM_i$).

$$QLNM_i = QSIU_i$$

Update as required the following variables:

$QHLNM_i$ - Sum of heating loads not met, zone i (Btu)

$QHPNM_i$ - Peak heating load not met, zone i (Btu/hr). Call subroutine MAX to do this.

$IHHNM_i$ - Number of hours heating load not met.

Go to calculation 14.

If $QSIU_i > 0.0$, calculate cooling load not met ($QLNM_i$).

$$QLNM_i = QSIU_i$$

Update as required the following variables:

$QCLNM_i$ - Sum of cooling loads not met, zone i (Btu)

$QCPNM_i$ - Peak cooling load not met, zone i (Btu/hr). Call subroutine MAX to do this.

$IHCNM_i$ - Number of hours cooling load not met.

Go to calculation 14.

13.1.2 If changeover mode (IPW = 0),

During the changeover hour, it is assumed that both heating and cooling loads may be met. Therefore, the four-pipe fan coil system zone analysis is used (See calculation 13.2). In addition, there is a thermal load due to changing the temperature of the hydronic system (See calculation 17).

Go to calculation 14.

13.1.3 If cooling mode (IPW = +1),

If $QSIU_i > 0.0$, cooling required.

If chiller on (ICHIL = 1), calculate temperature of induced air after coil (TLC_i).

$$TLC_i = -QSIU_i/(ZMAS_i * 0.245) + TSP_z$$

Call subroutine ZLØ3 to calculate induction unit cooling load and distribute unmet load, if any.

Go to calculation 14.

If chiller off (ICHIL = 0), calculate cooling load not met ($QLNM_i$).

$$QLNM_i = QSIU_i$$

Update as required the following variables:

$QCLNM_i$ - Sum of cooling loads not met, zone i (Btu)

$QCPNM_i$ - Peak cooling load not met, zone i (Btu/hr). Call subroutine MAX to do this.

$IHCNM_i$ - Number of hours cooling load not met.

Go to calculation 14.

If $QSIU_i < 0.0$, calculate heating load not met ($QLNM_i$).

$$QLNM_i = QSIU_i$$

Update as required the foolowing variables:

$QHLNM_i$ - Sum of heating loads not met, zone i (Btu).

$QHPNM_i$ - Peak heating load not met, zone i (Btu/hr). Call subroutine MAX to do this.

$IHHNM_i$ - Number of hours heating load not met.

Go to calculation 14.

13.2 Four-pipe induction unit.

13.2.1 If $QSIU_i \leq 0.0$, heating required.

If boiler on (IBØIL = 1), calculate temperature of induced air after coil (TLC_i).

$$TLC_i = -QSIU_i/(ZMAS_i * 0.245) + TSP_z$$

Call subroutine ZLØ3 to calculate induction unit heating load and distribute an unmet load, if any.

Go to calculation 14.

If boiler off (IBØIL = 0), calculate heating load not met ($QLNM_i$).

$QLNM_i = QSIU_i$

Update as required the following variables:

$QHLNM_i$ - Sum of heating loads not met, zone i (Btu).

$QHPNM_i$ - Peak heating load not met, zone i (Btu/hr). Call subroutine MAX to do this.

$IHHNM_i$ - Number of hours heating load not met.

Go to calculation 14.

If $QSIU_i > 0.0$, cooling required.

If chiller on (ICHIL = 1), calculate temperature of induced air after coil (TLC_i).

$TLC_i = -QSIU_i/(ZMAS_i * 0.245) + TSP_z$

Call subroutine ZLØ3 to calculate induction unit cooling load and disbribute unmet load, if any.

Go to calculation 14.

If chiller off (ICHIL = 0), calculate cooling load not met ($QLNM_i$).

$QLNM_i = QSIU_i$

Update as required the following variables:

$QCLNM_i$ - Sum of cooling loads not met, zone i (Btu)

$QCPNM_i$ - Peak cooling load not met, zone i (Btu/hr). Call subroutine MAX to do this.

$IHCNM_i$ - Number of hours cooling load not met.

Go to calculation 14.

14. Calculate thermal properties (temperature ($TTLVG_i$) and humidity ratio ($WTLVG_i$) of air leaving the induction unit. This is the mixture of induced air and primary air.

$$TTLVG_i = (TLVG * ZMASS_i + TLC * ZMAS_i)/(ZMASS_i + ZMAS_i)$$

$$WTLVG_i = (WSUP * ZMASS_i + WCLVG * ZMAS_i)/(ZMASS_i + ZMAS_i)$$

15. Calculate zone humidity ratio.

    Using function WZNEW, calculate the humidity ratio of each zone (WZ_i).

16. Calculate return air humidity ratio (WRA_k) and density (DRA_k).

$$WRA_k = (\sum_{j=1,JMAX_k} WZ_i * ZMASR_i * MULT_i)/(\sum_{j=1,JMAX_k} ZMASR_i * MULT_i)$$

$$DRA_k = PATM/((0.754 * (TRA_k + 460.) * (1. + 7000. * WRA_k/4360.))$$

17. Calculate heat of changeover (for two-pipe induction systems only). For four-pipe induction systems, RETURN.

    If IPW = 0 (changeover mode),

    Calculate hot water temperature (THW) using function TRSET.

    Calculate changeover heat (QCØ).

$$QCØ = PWGAL_k * 8.3 * (THW - TLCHL)$$

    where

    $PWGAL_k$ - Water volume of two-pipe induction unit system (gal)

    TLCHL - Chilled water temperature (°F)

    If heating to cooling changeover,

    QCC = QCC + QCØ

    RETURN

    If cooling to heating changeover,

    QHC = QHC - QCØ

    RETURN

    If IPW ≠ 0, RETURN.

SUBROUTINE: MAX

GENERAL DESCRIPTION

Compare current value of A with X and if the absolute value of A exceeds that of X, A is set equal to X and IB is set equal to IY. A and X are real numbers. IB and IY are integers.

LIST OF VARIABLES

INPUT

A - Current value of parameter (real)

IB - Current value of companion parameter (integer)

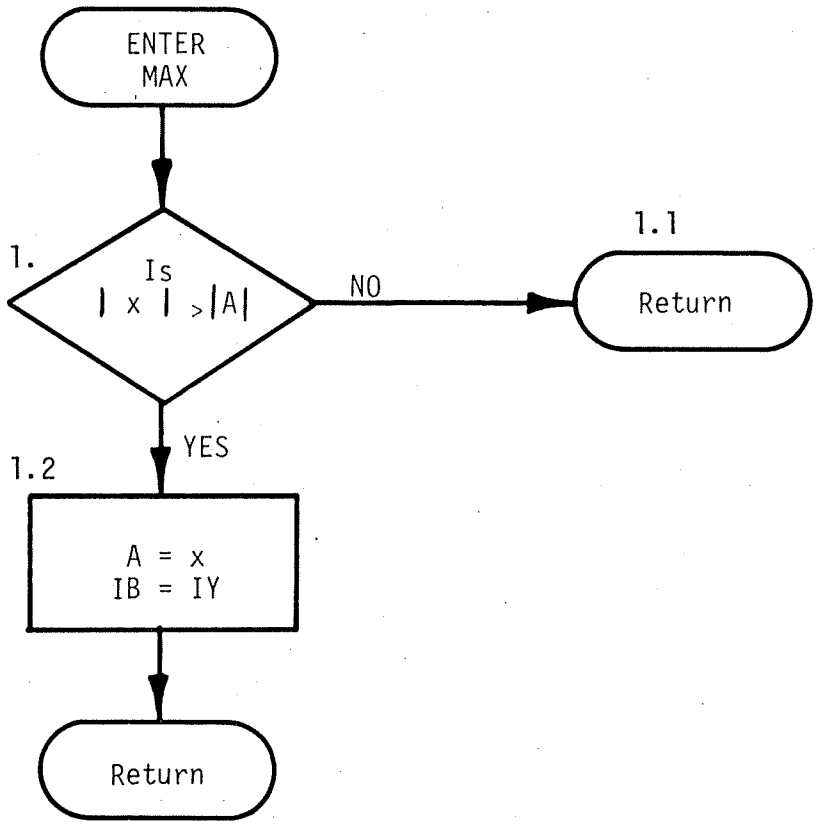
X - Value of test parameter (real)

IY - Value of companion test parameter (integer)

OUTPUT

A - Updated extreme value of X.

IB - Value of companion parameter at extreme value of X.


ENTER
MAX
1.
Is
| x | >|A|
NO
1.1
Return
YES
1.2
A = x
IB = IY
Return

CALCULATION SEQUENCE

1. Compare A with X.

1.1 If $|X| > |A|$, set

$A = X$

$IB = IY$

RETURN

1.2 If $|X| \leq |A|$,

RETURN

SUBROUTINE: MXAIR

GENERAL DESCRIPTION

Given the thermal properties of the two mixing air streams, Figure , this subroutine calculates the thermal properties (temperature, density, humidity ratio) of the resulting mixed air stream. The basic application of this routine is in simulating the function of three types of outside air control modes.

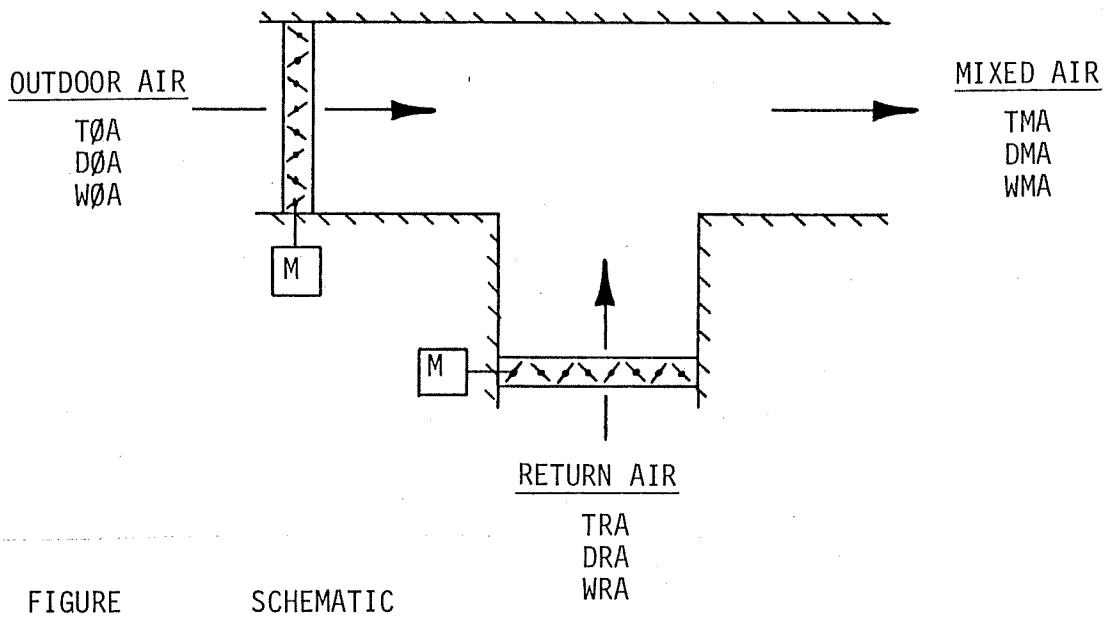


FIGURE SCHEMATIC INDICATING MIXING OF OUTSIDE AIR AND RETURN AIR STREAMS.

LIST OF VARIABLES

INPUT

MXAØ - Type of outside air control

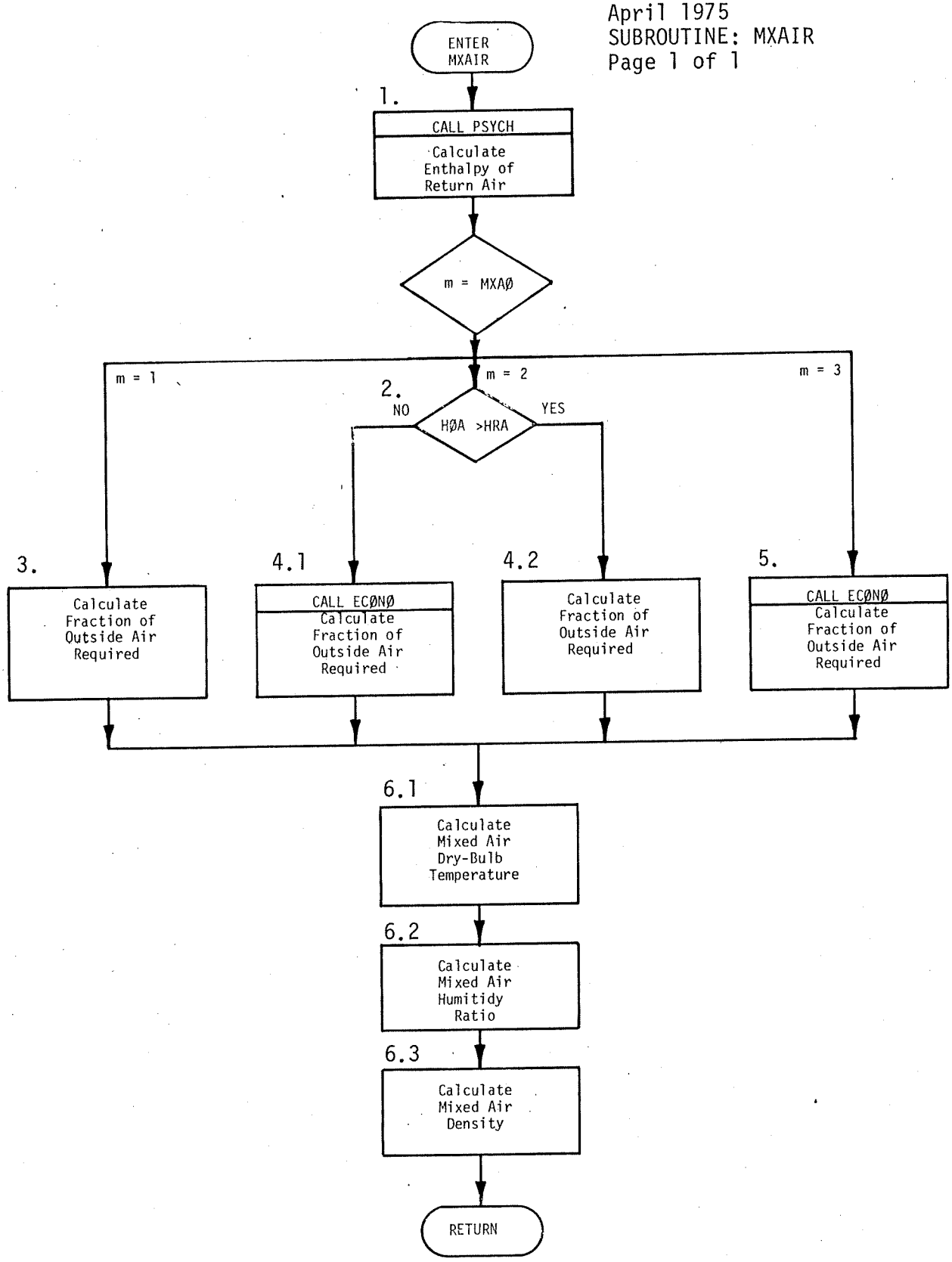
= 1. Fixed percentage of outside air.
= 2. Enthalpy/temperature type economizer cycle control.
= 3. Temperature type economizer cycle control.

Air Stream #1	TØA	-	Outside air dry-bulb temperature (°F)
	DØA	-	Outside air density (lbm/ft^3)
	HØA	-	Outside air enthalpy (Btu/lbm)
	WØA	-	Outside air humidity ratio ($lbm\text{-}H_2O/lbm\text{-dry air}$)
	PATM	-	Barometric pressure (in. Hg)
Air Stream #2	TRA	-	Return air dry-bulb temperature (°F)
	DRA	-	Return air density (lbm/ft^3)
	WRA	-	Return air humidity ratio ($lbm\text{-}H_2O/lbm\text{-dry air}$)
	EAT	-	Desired mixed air temperature (economizer approach temperature) (°F)
	ALFAM	-	Minimum fraction of outside air (for MXAØ = 1, ALFAM is the fixed portion of outside air).

OUTPUT

ALFA	-	Actual fraction of outside air which meets or a approaches EAT.
TMA	-	Mixed air dry-bulb temperature (°F)
WMA	-	Mixed air humidity ratio ($lbm\text{-}H_2O/lbm\text{-dry air}$)
DMA	-	Mixed air density (lbm/ft^3)

SYSSIM
April 1975
SUBROUTINE: MXAIR
Page 1 of 1



CALCULATION SEQUENCE

1. Call subroutine PSYCH to calculate enthalpy of return air (HRA).

2. Check for type of outside air control mode desired.

   If fixed percentage of outside air control (MXAØ = 1),

   Go to calculation 3.

   If enthalpy/temperature type economizer control (MXAØ = 2),

   Go to calculation 4.

   If temperature type economizer control (MXAØ = 3),

   Go to calculation 5.

3. Type 1 outside air control - fixed percent of outside air, therefore set

   ALFA = ALFAM

   Go to calculation 6.

4. Type 2 outside air control - enthalpy/temperature type economizer cycle control mode.

   4.1 If outside air enthalpy (HØA) less than or equal to return air enthalpy (HRA), can use as much outside air as required to reach condition where TMA = EAT. Call subroutine ECØNØ to calculate the value of ALFA required to meet or approach EAT.

   Go to calculation 6.

   4.2 If outside air enthalpy (HØA) greater than return air enthalpy (HRA), outside air heat content is high; use least amount of outside air allowable, therefore

   ALFA = ALFAM

   Go to calculation 6.

5. Type 3 outside air control - temperature type economizer cycle control mode.

   Call subroutine ECØNØ to calculate fraction of outside air (ALFA) required to reach or approach condition where TMA = EAT.

   Go to calculation 6.

6. Calculate resulting thermal properties of mixed air stream.

6.1 Mixed air dry-bulb temperature (°F)

A heat balance of the mixing process yields

$$M_{oa} * C_{pa} * TOA + M_{ra} * C_{pa} * TRA = M_{ma} * C_{pa} * TMA$$

where M_{oa} = mass of outside air (lbm/hr)

M_{ra} = Mass of return air (lbm/hr)

M_{ma} = mass of mixed air (lbm/hr)

C_{pa} = specific heat air (assumed constant for air conditioning applications) (Btu/lbm-°F)

Substituting

$$M_{oa} = CFM_{oa} * 60. * DØA$$

$$M_{ra} = CFM_{ra} * 60. * DMA$$

$$ALFA = CFM_{oa}/CFM_{ma}$$

$$(1.- ALFA) = CFM_{ra}/CFM_{ma}$$

where

CFM_{oa} = volume flow rate of outside air (ft^3/min)

CFM_{ra} = volume flow rate of return air (ft^3/min)

CFM_{ma} = volume flow rate of mixed air (ft^3/min)

finally yields the equation used in subroutine MXAIR:

$$TMA = \frac{TØA * DØA * ALFA + TRA * DRA * (1. - ALFA)}{DØA * ALFA + DRA * (1. - ALFA)}$$

6.2 Similarly, a mass balance of mixing process gives the mixed air humidity ratio (lb-H_2O/lb-dry air)

$$WMA = \frac{WØA * DØA * ALFA + WRA * DRA * (1. - ALFA)}{DØA * ALFA + DRA * (1. - ALFA)}$$

6.3 From ASHRAE "Procedure for Determining Heating and Cooling Loads for Computerized Energy Calculation - Algorithms for Building Heat Transfer Subroutines", page 66, 1971 Edition, the density of mixed air (lbm/ft^3) is

$$DMA = 1/V$$

where V is volume of moist air

$$V = 0.754 * (TMA + 460.) * (1. + 7000. * WMA/4360.)$$

SUBROUTINE: MZDD

GENERAL DESCRIPTION

This subroutine simulates the operation of a multi-zone or dual duct air distribution system and determines heating coil load, cooling coil load, preheat coil load, baseboard radiation load, base power consumption, and humidification water requirement for the hour in question.

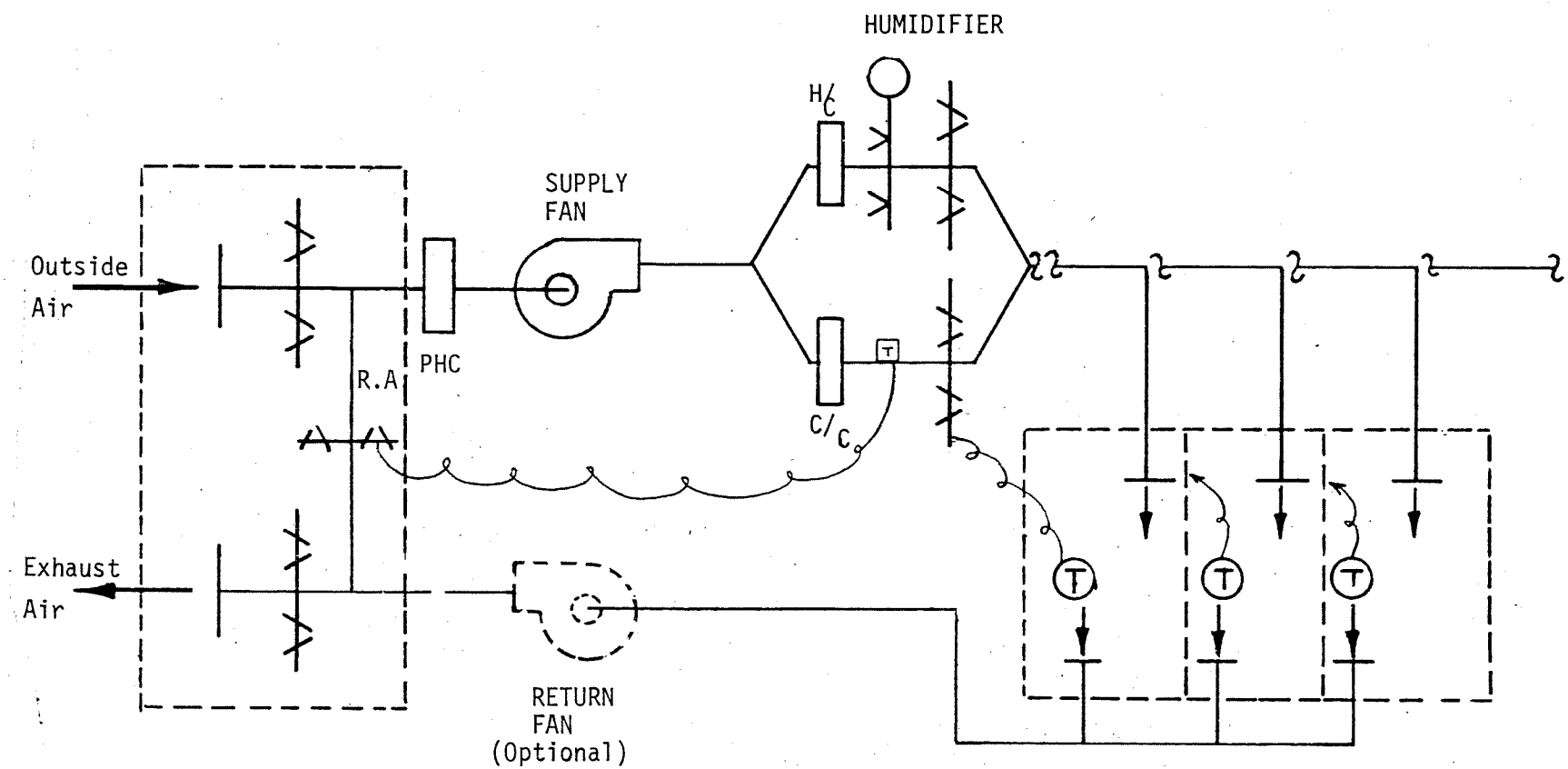
MULTI-ZONE FAN SYSTEM

The components of the multi-zone fan system simulated by this subroutine (See Fig.) include a mixed air section, preheat coil, blow-thru fan section, heating and cooling coils in parallel, and a humidifier. Hot and cold air streams are mixed as required at the unit. The specific functioning and options of this fan system are as follows:

- Optional return air fan simulation
- Humidifier
- Three outside air/return air options with the economizer attempting to equal the required cold deck temperature
- Baseboard heating as supplement heat to each zone
- Preheat coil
- Temperature control options:
    1) Fixed settings for both hot and cold decks
    2) Fixed cold deck temperature but allowing hot deck temperature to vary inversely with outside air temperature
    3) Reset temperature control as governed by spaces. Control for this mode consists of setting the hot deck leaving air temperature equal to that of air supplied to the space requiring the warmest air. The cold deck leaving air temperature is set equal to the temperature of air supplied to the space requiring the coolest air.

DUAL DUCT FAN SYSTEM

The components, operating characteristics, and options of the dual duct system simulated by this subroutine (See Fig.) are similar to those of the multi-zone system described above. The difference between the two systems is that hot and cold air mixing takes place in a mixing box

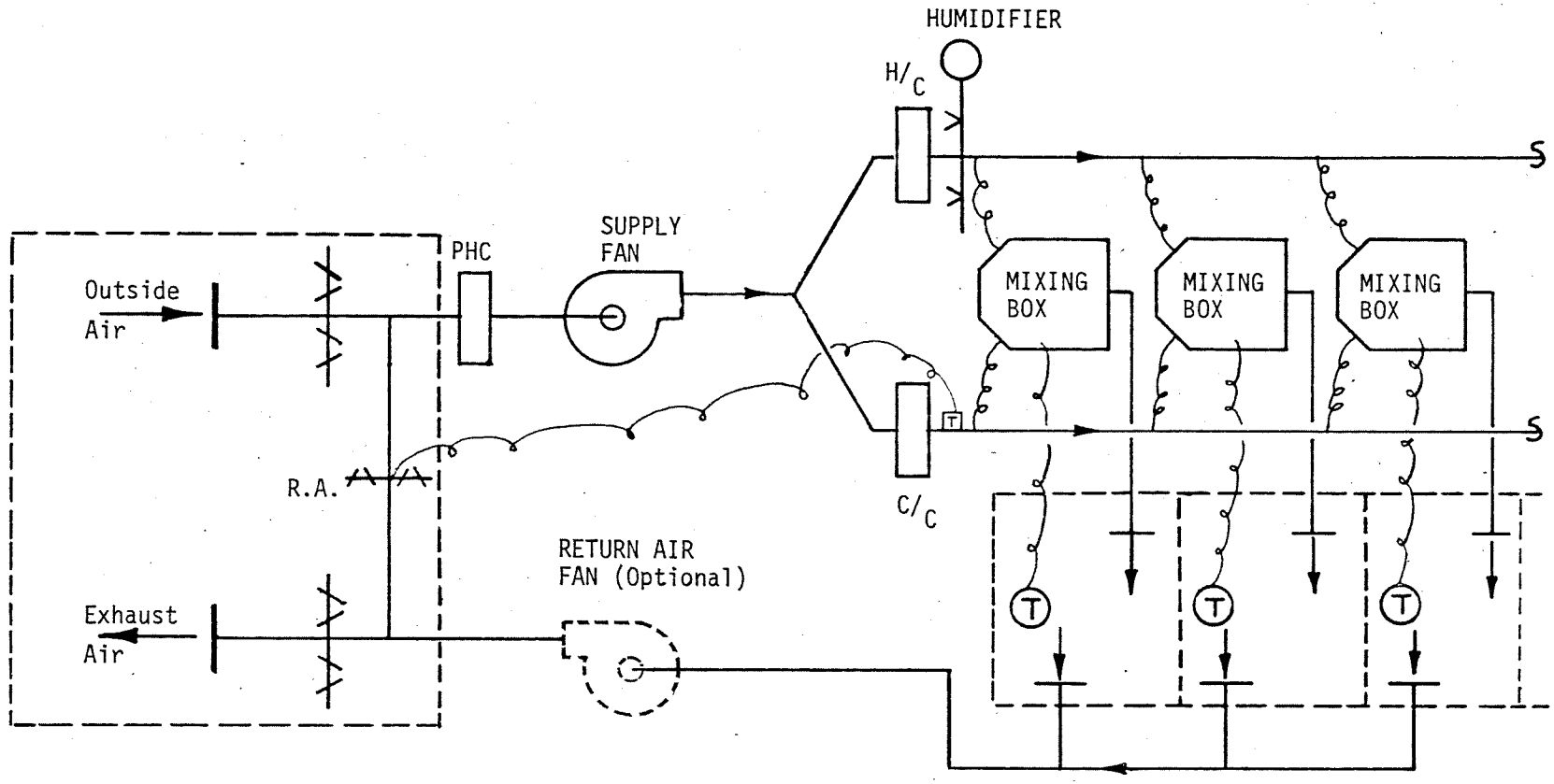


MIXED AIR

THREE OPTIONS

1. Fixed Dampers
2. Enthalpy/temp. type Economizer cycle
3. Temperature type Economizer cycle

Figure MULTI-ZONE FAN SYSTEM (DISTRIBUTION SYSTEM NO. 2)



MIXED AIR

THREE OPTIONS

1. Fixed Dampers
2. Enthalpy/temp. type Economizer cycle
3. Temperature type Economizer cycle

Figure DUAL DUCT FAN SYSTEM (DISTRIBUTION SYSTEM NO. 3)

usually located near the zone it serves and is not part of the air handling unit.

LIST OF VARIABLES

INPUT

K - Energy distribution system number

TNFBP - Total net fan brake horsepower (Bhp)

COMMON

IBØIL - Boiler on/off flag (1=on; 0=off)

ICHIL - Chiller on/off flag (1=on; 0=off)

IFAN - Fan system shut-off flag (0=fans run continuously,
1=fans may be shut off
2=fans and baseboard radiators may be shut off)

QS_z - Zone sensible load (Btu/hr)

QL_z - Zone latent load (Btu/hr)

$QLITE_z$ - Light heat into ceiling plenum above zone (Btu/hr)

$SLPØW_z$ - Space light and power (KW)

$QSINF_z$ - Zone sensible loss due to infiltration (Btu/hr)

$QLINF_z$ - Zone latent loss due to infiltration (Btu/hr)

$STEMP_z$ - Space temperature at a given hour (°F)

$UCFM_z$ - Air flow through zone if it is a plenum space (ft^3/min)

TSP_z - Zone set point temperature (°F)

$VØL_z$ - Zone volume (ft^3)

TØA - Outside air dry-bulb temperature (°F)

WØA - Outside air humidity ratio ($\frac{lbm\text{-}H_2O}{lbm\text{-dry air}}$)

HØA - Outside air enthalpy (Btu/lbm)

DØA - Outside air density (lbm/ft^3)

PATM - Barometric Pressure (in.Hg.)

$KFAN_k$ - Energy distribution system index

$JMAX_k$ - Number of zones on system k

$CFMAX_k$ - Design supply air flow for system k (ft^3/min)

$CFMEX_k$ - Exhaust air for system k (ft^3/min)

$ALFAM_k$ - Minimum fraction outside air, system k

$ØACFM_k$ - Minimum ventilation air, system k (ft^3/min)

$RHSP_k$ - Relative humidity set point, system k (% R.H.)

WSP_k - Humidity ratio set point, system k ($\frac{lbm\text{-}H_2O}{lbm\text{-dry air}}$)

WRA_k - Return air humidity ratio, system k ($\frac{lbm\text{-}H_2O}{lbm\text{-dry air}}$)

DRA_k - Return air density, system k (lbm/ft^3)

$FMASS_k$ - Supply air mass, system k (lbm-air/hr)

$FMASR_k$ - Return air mass, system k (lbm-air/hr)

$FMASX_k$ - Exhaust air mass, system k (lbm-air/hr)

$TFNPS_k$ - Total supply fan pressure, system k (in, H_2O)

$TFNPR_k$ - Total return fan pressure, system k (in. H_2O)

$TFNPE_k$ - Total exhaust fan pressure, system k (in. H_2O)

$FBHPS_k$ - Supply fan brake horsepower, system k (bhp)

$FBHPR_k$ - Return fan brake horsepower, system k (bhp)

$FBHPE_k$ - Exhaust fan brake horsepower, system k (bhp)

$DTFNS_k$ - Air temperature rise across supply fan, system k, at full load (°F)

$DTFNR_k$ - Air temperature rise across return fan, system k, at full load (°F)

$MXAØ_k$ - Mixed air option, system k

$ICZN_k$ - Zone in which humidistat is located, system k, (a "j" number)

$ITMPC_{k,1}$ - Air temperature control mode, system k

$ITMPC_{k,2}$ - Air temperature control mode, system k

$TFIX1_k$ - Fixed hot deck temperature, system k (°F)

$TFIX2_k$ - Fixed cold deck temperature system k (°F)

CFM_i - Supply air flow, zone i (constant) (cu ft/min)

$CFMR_i$ - Return air flow rate, zone i (cu ft/min)

$CFMX_i$ - Exhaust air flow rate, zone i (cu ft/min)

$ZMASS_i$ - Supply air mass flow, zone i (constant) (lbm-air/hr)

$ZMASR_i$ - Return air mass flow, zone i (lbm-air/hr)

$ZMASX_i$ - Exhaust air mass flow, zone i (lbm-air/hr)

WZ_i - Calculated humidity ratio, zone i (lbm-H_2O/lbm-dry air)

$ALFBR_i$ - Active length baseboard radiation, zone i (lin. ft)

$CBTU_i$ - Baseboard radiation heat output per linear foot at standard conditions, zone i (Btu/hr-lin. ft)

$QCLNM_i$ - Monthly accumulation of cooling loads not met (zone i) * $MULT_i$ (Btu)

$QCPNM_i$ - Monthly peak cooling load not met, zone i (Btu/hr)

$IHCNM_i$ - Number of hours cooling load not met, zone i (hrs)

$QHLNM_i$ - Monthly accumulation of heating loads not met, (zone i)* $MULT_i$ (Btu)

$QHPNM_i$ - Monthly peak heating load not met, zone i (Btu/hr)

$IHHNM_i$ - Number of hours heating load not met, zone i(hrs)

$IPLEN_i$ - LOAD program space number of plenum above zone i

$SPACN_{k,j}$ - Number of space as per LOAD program, applied to system k, zone j

$MULT_i$ - Multiplication factor, zone i

I - Variable subscript i

$TØALØ_n$ - Low outside air temperature at which system temperature is THI_n, reset schedule n (°F)

$TØAHI_n$ - High outside air temperature at which system temperature is TLO_n, reset schedule n (°F)

$TLØ_n$ - Low system fluid temperature, reset schedule n (°F)

THI_n - High system fluid temperature, reset schedule n(°F)

$ISET_{k,m}$ - Reset temperature schedule index, system k, reset item m (an "n" number)

TFBHP - Total fan brake horsepower (bhp)

OUTPUT

QCC - Cooling coil load (Btu/hr)

QHC - Heating coil load (Btu/hr)

QRHC - Reheat coil load (Btu/hr)

QPHC - Preheat coil load (Btu/hr)

TQB - Summation of zone baseboard heating load (Btu/hr)

WATER - Steam humidification required by air handling unit (lbm-H_2O/hr)

TNFBP - Total net [updated] fan brake horsepower (bhp)

THC - Hot deck air temperature (°F)

TCC - Cold deck air temperature (°F)

COMMON

WRA_k - Return air humidity ratio, system k $\left(\frac{\text{lbm-}H_2O}{\text{lbm-dry air}}\right)$

DRA_k - Return air density, system k (lbm/ft^3)

WZ_i - Calculated humidity ratio, zone i ($lbm\text{-}H_2O/lbm$-dry air)

$QCLNM_i$ - Monthly accumulation of cooling loads not met (zone i) * $MULT_i$ (Btu)

$QCPNM_i$ - Monthly peak cooling load not met, zone i (Btu/hr)

$IHCNM_i$ - Number of hours cooling load not met, zone i (Btu/hr)

$QHLNM_i$ - Monthly accumulation of heating loads not met, zone i $MULT_i$ (Btu)

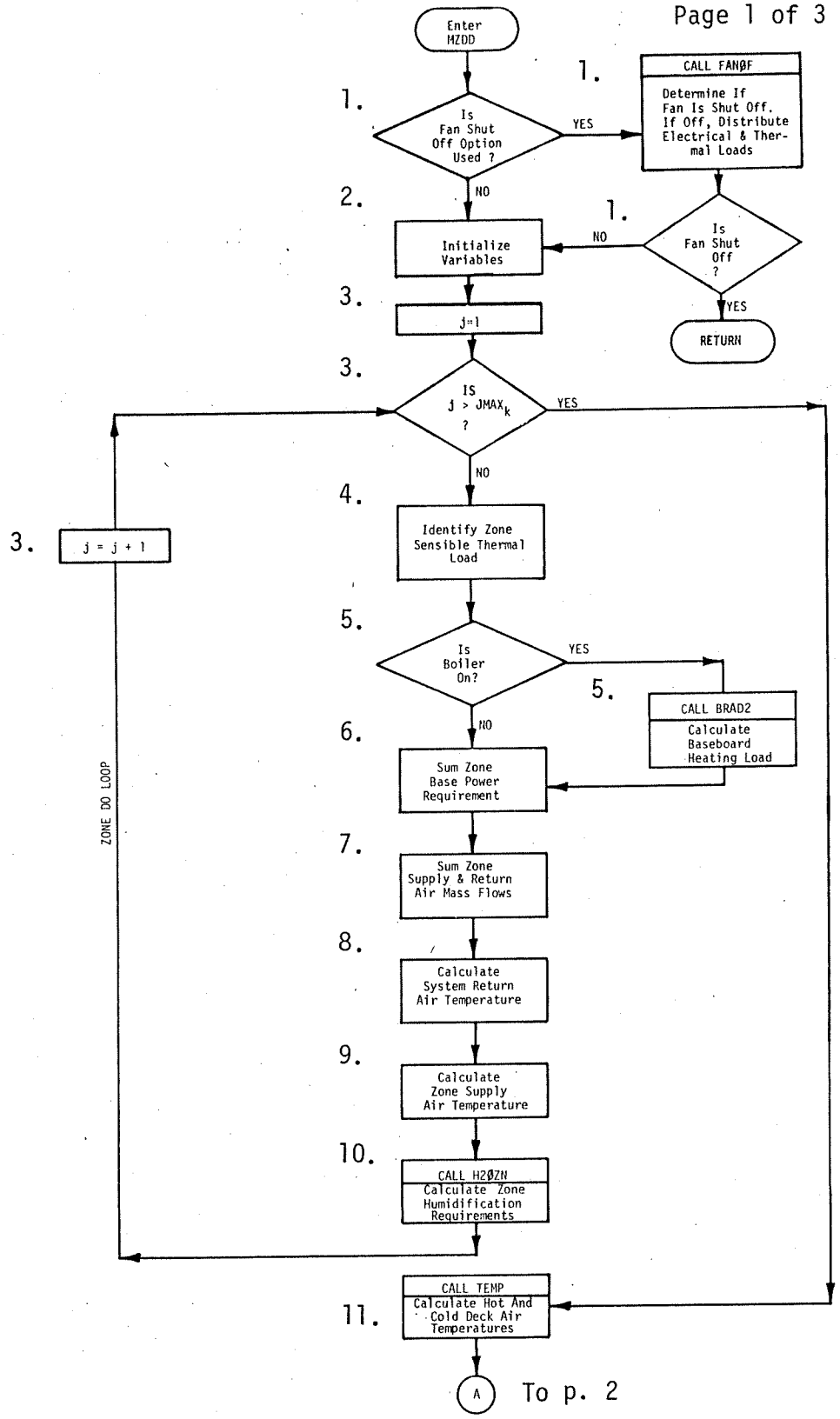
$QHPNM_i$ - Monthly peak heating load not met, zone i (Btu/hr)

$IHHNM_i$ - Number of hours heating load not met, zone i (hrs)

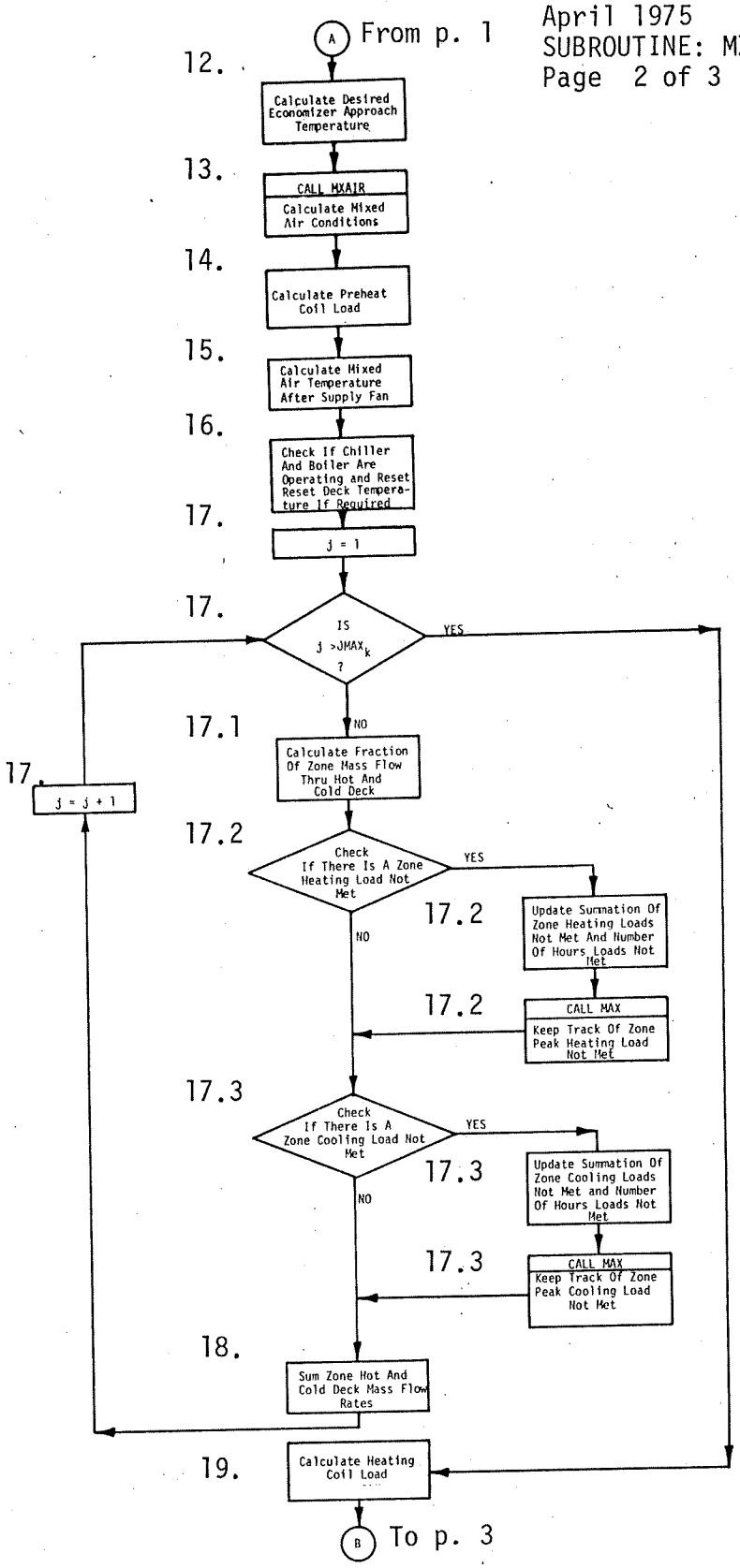
TS_i - Required supply air temperature, zone i (^oF)

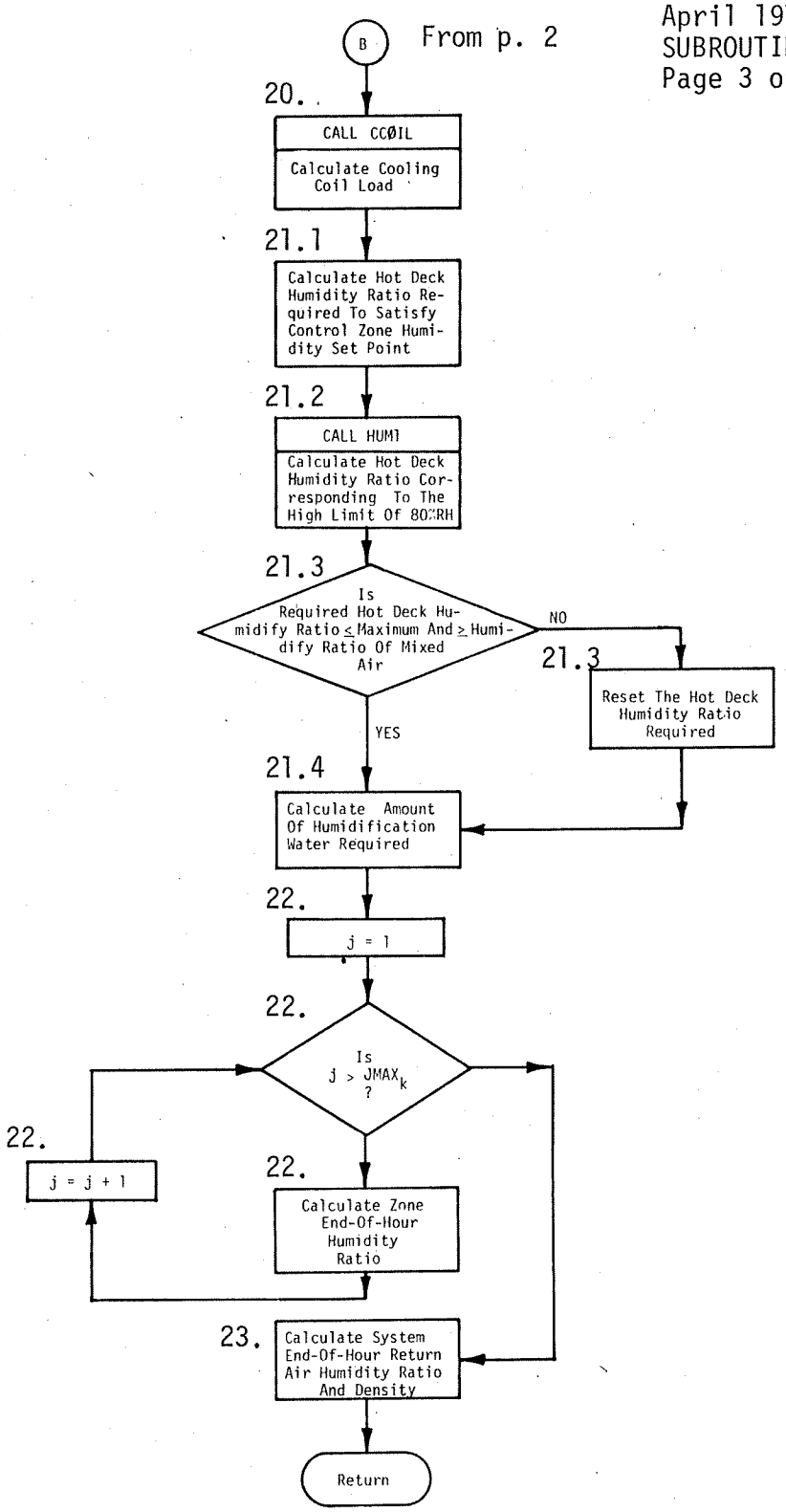
$WREQD_i$ - Required humidity ratio, zone i $\left(\frac{\text{lbm-}H_2O}{\text{lbm-dry air}}\right)$

QSI_i - Sensible thermal load, zone i (Btu/hr)


Enter MZDD
1.
Is Fan Shut Off Option Used ?
YES
NO
1.
CALL FANØF
Determine If Fan Is Shut Off. If Off, Distribute Electrical & Thermal Loads
1.
Is Fan Shut Off ?
NO
YES
RETURN
2.
Initialize Variables
3.
j=1
3.
IS j > JMAXk ?
YES
NO
4.
Identify Zone Sensible Thermal Load
3.
j = j + 1
ZONE DO LOOP
5.
Is Boiler On?
YES
NO
5.
CALL BRAD2
Calculate Baseboard Heating Load
6.
Sum Zone Base Power Requirement
7.
Sum Zone Supply & Return Air Mass Flows
8.
Calculate System Return Air Temperature
9.
Calculate Zone Supply Air Temperature
10.
CALL HZØZN
Calculate Zone Humidification Requirements
11.
CALL TEMP
Calculate Hot And Cold Deck Air Temperatures
A

To p. 2


A
From p. 1
12.
Calculate Desired Economizer Approach Temperature
13.
CALL MXAIR
Calculate Mixed Air Conditions
14.
Calculate Preheat Coil Load
15.
Calculate Mixed Air Temperature After Supply Fan
16.
Check If Chiller And Boiler Are Operating and Reset Reset Deck Temperature If Required
17.
j = 1
17.
IS j >JMAX$_k$?
YES
NO
17.1
Calculate Fraction Of Zone Mass Flow Thru Hot And Cold Deck
17.
j = j + 1
17.2
Check If There Is A Zone Heating Load Not Met
YES
NO
17.2
Update Summation Of Zone Heating Loads Not Met And Number Of Hours Loads Not Met
17.2
CALL MAX
Keep Track Of Zone Peak Heating Load Not Met
17.3
Check If There Is A Zone Cooling Load Not Met
YES
NO
17.3
Update Summation Of Zone Cooling Loads Not Met and Number Of Hours Loads Not Met
17.3
CALL MAX
Keep Track Of Zone Peak Cooling Load Not Met
18.
Sum Zone Hot And Cold Deck Mass Flow Rates
19.
Calculate Heating Coil Load
B
To p. 3


B
From p. 2
20.
CALL CCØIL
Calculate Cooling Coil Load
21.1
Calculate Hot Deck Humidity Ratio Required To Satisfy Control Zone Humidity Set Point
21.2
CALL HUMI
Calculate Hot Deck Humidity Ratio Corresponding To The High Limit Of 80%RH
21.3
Is Required Hot Deck Humidify Ratio ≤ Maximum And ≥ Humidify Ratio Of Mixed Air
NO
21.3
Reset The Hot Deck Humidity Ratio Required
YES
21.4
Calculate Amount Of Humidification Water Required
22.
j = 1
22.
Is j > JMAX_k ?
22.
j = j + 1
22.
Calculate Zone End-Of-Hour Humidity Ratio
23.
Calculate System End-Of-Hour Return Air Humidity Ratio And Density
Return

CALCULATION SEQUENCE

1. Fan off/on check.

   If it is desired to turn off fan when possible (IFAN > 0), call subroutine FANØF to determine whether the fan can be turned off for the current hour (IØØ = 1 is off, IØØ = 0 is on); otherwise, go to calculation 2.

   If the system is off (IØØ = 1), terminate MZDD simulation for the current hour. RETURN.

   If the system is on (IØØ = 0), go to Calculation 2.

   If fans run continuously (IFAN = 0), go to Calculation 2.

2. Initialize variables.

BPKW	=	0.0	(Summation of zone base power, KW)
QRHC	=	0.0	(Reheat coil load, Btu/hr)
TQB	=	0.0	(Summation of zone baseboard heating load, Btu/hr)
SMTRA	=	0.0	(Weighted summation of zone return air temperature quantities, lbm-°F/hr)
FMR	=	0.0	(Fan return air mass flow, lbm/hr)
IBGIN	=	i	(Zone index of this system's first zone - 1)

3. Determine for each zone the baseboard heat, base power, supply air temperature required, weighted return air quantities, and zone humidification requirements by performing calculations 4 through 8 for each zone j = 1 to $JMAX_k$.

4. Identify sensible thermal zone load of each zone.

$$QSI_i = QS_z + QSINF_z$$

(See note at bottom of page for explanation of i and z.)

NOTE: There is a corresponding z for each i; a relationship defined by the variable $SPACN_{k,j}$. Hence, i and z are defined by system number (k) and zone number (j).

5. Baseboard radiation.

If boiler on (IBØIL = 1), call subroutine BRAD2 to calculate baseboard radiation heat (QB_j) and to adjust QSI_i.

Sum baseboard radiation heat.

$$TQB = \sum_{j=1,\ JMAX_k} QB_j$$

If boiler off (IBØIL = 0), continue.

6. Calculate base power (BPKW) which includes internal power, lights, receptacles, equipment, miscellaneous. (SLPØW is read off input load tape.)

$$BPKW = \sum_{j=1,\ JMAX_k} SLPØW_z * MULT_i$$

7. Define system supply and return mass flows which remain constant (lbm-hr).

$$FMAS_k = \sum_{j=1,\ JMAX_k} ZMASS_i * MULT_i$$

$$FMR_k = \sum_{j=1,\ JMAX_k} ZMASR_i * MULT_i$$

8. Calculate return air temperature (TRA_k) (°F).

NOTE: Since the System and Equipment Simulation Program is capable of using either one of the load tapes produced by NBSLD, the NECAP's (NASA's Energy and Cost Analysis Programs) Load Program, or the Variable Temperature Program is input, the following logic sequence is required.

8.1 If zone has a ceiling plenum ($IPLEN_i > 0$)

8.1.1 If LOAD tape by NBSLD or NECAP's Load Program is used (indicated by $STEMP_{pl} = 0.0$),

$$DTL2_i = 0.0$$

$$QLITI = QLITE_z + QS_{pl} + QLITE_{pl} + QSINF_{pl}$$

where pl is space number of plenum above space z.

Go to calculation 8.2.

8.1.2 If VARIABLE TEMPERATURE tape is used (indicated by $STEMP_{pl} > 0.0$),

$$DTL2_i = STEMP_{pl} - TSP_z$$

$$QLITI = QLITE_z$$

Go to calculation 8.2.

8.2 If zone does not have a ceiling plenum ($IPLEN_i = 0$),

$$DTL2_i = 0.0$$

$$QLITI = QLITE_z$$

8.3 Return air temperature calculation. (TRA_k)

$$DTL_i = QLITI/(0.245 * ZMASR_i)$$

$$TRA_k = \frac{\sum_{j=1,JMAX_k} (TSP_z + DTL_i + DTL2_i) * ZMASR_i * MULT_i}{\sum_{j=1,JMAX_k} ZMASR_i * MULT_i} + DTFNR_k$$

where $DTL2_i$ - Difference between zone and plenum temperatures as calculated by VARIABLE TEMPERATURE program.

QLITI - Thermal load of plenum pl above zone z as calculated by LOAD program.

pl - LOAD program space number of plenum above zone z.

9. Calculate required supply air temperature of each zone.

$$TS_i = TSP_z - QSI_i/(0.245 * ZMASS_i)$$

10. Calculate zone humidification requirements.

Call subroutine H2ØZN to calculate total moisture requirements of zone including setpoint recovery load ($H2ØRD_i$) and moisture changes in current hour due to environmental and room effects ($H2ØAD_i$).

11. Calculate hot deck and cold deck air temperatures. User will specify one of three control options available:

    1. Fixed settings for both hot and cold decks. Specified by setting $ITMPC_{k,1} = ITMPC_{k,2} = 1$.

    2. Fixed cold deck temperature but allowing hot deck temperature to vary inversely with outside air temperature. Specified by setting $ITMPC_{k,1} = 3$ and $ITMPC_{k,2} = 1$.

    3. Reset temperature control as governed by the spaces. Control for this mode involves setting the hot deck leaving air temperature equal to that of air supplied to the space requiring warmest air. The cold deck leaving air temperature is set equal to the temperature of air supplied to the space requiring coolest air. Specified by setting $ITMPC_{k,1} = 6$ and $ITMPC_{k,2} = 2$.

    Call subroutine TEMP to calculate hot and cold deck leaving air temperatures (THC and TCC).

12. Calculate desired economizer approach temperature (EAT) entering supply fan.

    $$EAT = TCC - DTFNS_k$$

    where $DTFNS_k$ is the air temperature rise across supply fan k.

13. Calculate mixed air conditions.

    Call subroutine MXAIR to simulate the performance of:

    1. Fixed outside and return air dampers ($MXA\emptyset_k = 1$).

    2. An enthalpy/temperature type economizer cycle $MXA\emptyset_k = 2$).

    or 3. A temperature type economizer cycle ($MXA\emptyset_k = 3$).

    Subroutine MXAIR also calculates the thermal properties (temperature (TMA), humidity ratio (WMA), and density (DMA)) of the mixed air stream.

14. Calculate preheat coil load (QHPC) by comparing mixed air temperature (TMA) desired.with economizer approach temperature (EAT).

If boiler on (IBØIL = 1),

If mixed air temperature (TMA) less than economizer approach temperature (EAT),

$$QPHC = 0.245 * FMASS_k * (TMA - EAT)$$
$$TMABF = EAT$$

If mixed air temperature (TMA) greater than or equal to economizer approach temperature (EAT),

$$QPHC = 0.0$$

$$TMABF = TMA$$

where TMABF is temperature of mixed air before supply fan (°F).

If boiler off (IBØIL = 0),

$$QPHC = 0.0$$

$$TMABF = TMA$$

15. Calculate mixed air temperature after supply fan (TMAAF).

$$TMAAF = TMABF + DTFNS_k$$

16. Check boiler and chiller operation and reset deck temperatures if required.

If chiller off (ICHIL = 0), no cooling available; therefore, reset

$$TCC = TMAAF$$

where TCC is cold deck air temperature (°F).

If boiler off (IBØIL = 0), no heating available; therefore, reset

$$THC = TMAAF$$

where THC is hot deck air temperature (°F).

17. Calculate air mass through hot and cold decks. For each zone j = 1 to $JMAX_k$.

17.1 Calculate fraction of cold deck air required by each zone ($PCTC_i$).

$$PCTC_i = (THC - TS_i)/(THC - TCC)$$

17.2 Check if there is a heating load not met.

If fraction of zone air through cold deck ($PCTC_i$) is less than or equal to 0.0, heating load not met.

$$PCTC_i = 0.0$$

$$QLNM_i = 0.245 * ZMASS_i * (THC - TS_i)$$

where $QLNM_i$ is load not met.

Update as required the following variables:

$QHLNM_i$ - Sum of heating loads not met, zone i (Btu)

$QHPNM_i$ - Peak heating load not met, zone i, (Btu/hr). Call subroutine MAX to do this.

$IHHNM_i$ - Number of hours heating load not met.

$TS_i = TCC$ (Reset zone supply air temperature)

17.3 Check if there is a cooling load not met.

If fraction of zone air through cold deck ($PCTC_i$) greater than 1.0,

$$PCTC_i = 1.0$$

$$QLNM_i = 0.245 * ZMASS_i * (TCC - TS_i)$$

Update as required the following variables:

$QCLNM_i$ - Sum of cooling loads not met, zone i (Btu)

$QCPNM_i$ - Peak cooling load not met, zone i (Btu/hr). Call subroutine MAX to do this.

$IHCNM_i$ - Number of hours cooling load not met.

TS_i = TCC (Reset zone supply air temperature)

18. Sum cold and hot deck mass flows (CMASS and HMASS).

$$CMASS = \sum_{j=1,JMAX_k} ZMASS_i * PCTC_i$$

$$HMASS = FMASS_k - CMASS$$

19. Calculate heating coil load (QHC) and leaving air humidity ratio (WHC).

$$QHC = HMASS * 0.245 * (TMAAF - THC)$$

$$WHC = WMA$$

20. Calculate cooling coil load.

Call subroutine CCØIL to calculate cooling coil load (QCC), cold deck humidity ratio (WCC), and sensible heat ratio (SHR).

21. Calculate humidification requirements. Humidifier allowed to operate only when cooling coil is off (QCC = 0.0).

21.1 Calculate required hot deck humidity ratio (WHRQD) based on humidity control zone (icz) requirements.

$$CMESS = ZMASS_{icz} * PCTC_{icz}$$

(Cold deck mass flow to control zone)

$$HMESS = ZMASS_{icz} * (1. - PCTC_{icz})$$

(Hot deck mass flow to control zone)

$$WZRQD = WZ_{icz} - H2ØRD_{icz}/ZMASS_{icz}$$

(Humidity ratio required at control zone)

$$WHRQD = (ZMASS_{icz} * WZRQD - WCC * CMESS)/HMESS$$

where icz is zone in which humidistat is located.

21.2 Check that WHRQD does not exceed a high limit of 80% R.H. within the duct. Call subroutine HUM1 to calculate humidity ratio (WHMAX) corresponding to this condition.

21.3 Check and reset required hot deck humidity ratio.

If hot deck humidity ratio required (WHRQD) less than or equal to mixed air humidity ratio (WMA),

WHC = WMA

If hot deck humidity ratio required (WHRQD) greater than maximum allowed (WHMAX),

WHRQD = WHMAX

WHC = WHRQD

If hot deck humidity ratio required (WHRQD) is greater than leaving air humidity ratio (WHC) and less than maximum allowed (WHMAX),

WHC = WHRQD

21.4 Calculate amount of humidification water required.

WATER = HMASS * (WHC - WMA)

22. Calculate end-of-hour humidity ratio for each zone by calling function WZNEW to calculate the resulting humidity ratio of each zone (WZ_i).

23. Calculate end-of-hour return air humidity ratio (WRA_k) and density (DRA_k).

$$WRA_k = \left[\frac{\sum_{j=1,\ JMAX_k} WZ_i * ZMASR_i * MULT_i}{\sum_{j=1,\ JMAX_k} ZMASR_i * MULT_i} \right]$$

$$DRA_k = \frac{PATM}{(0.745 * (TRA_k + 460.) * (1. + 7000. * WRA_k/4360.))}$$

FUNCTION: PPWVM

GENERAL DESCRIPTION

A function which calculates the partial pressure of water vapor in moisture-saturated air. For source of equations, consult paper by T. Kusuda, "Algorithms for Psychrometric Calculations", Building Science Series 21, National Bureau of Standards, January 1970.

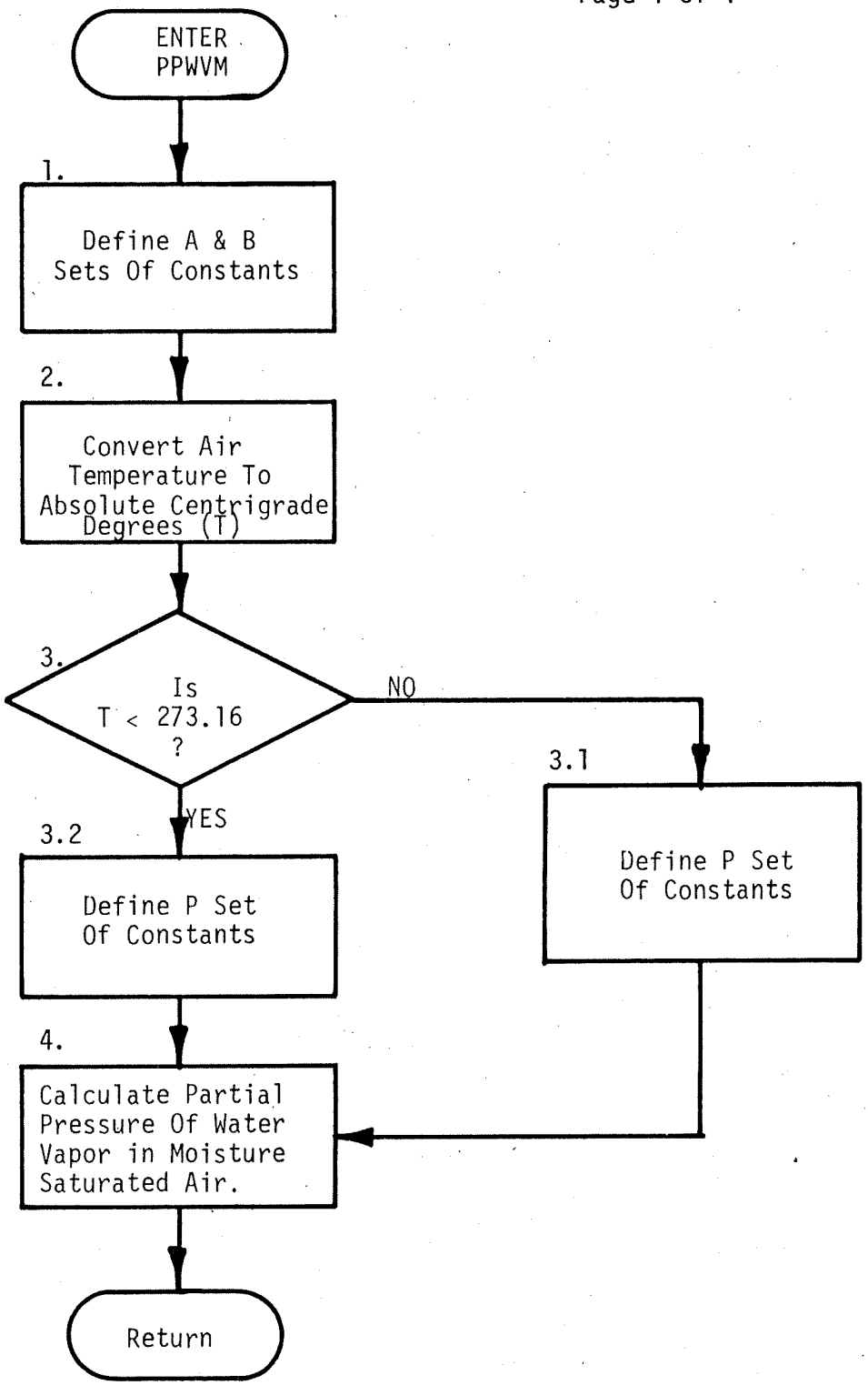
LIST OF VARIABLES

INPUT

TEMP - Temperature for which partial pressure is desired. May be dry-bulb, wet-bulb, or dewpoint temperature (°F).

OUTPUT

PPWVM - Partial pressure of water vapor in moisture-saturated air (in. Hg).


ENTER
PPWVM
1.
Define A & B
Sets Of Constants
2.
Convert Air
Temperature To
Absolute Centrigrade
Degrees (T)
3.
Is
T < 273.16
?
NO
YES
3.1
Define P Set
Of Constants
3.2
Define P Set
Of Constants
4.
Calculate Partial
Pressure Of Water
Vapor in Moisture
Saturated Air.
Return

CALCULATION SEQUENCE

1. Let A(1) = -7.90298
   A(2) = 5.02808
   A(3) = -1.3816 E-7
   A(4) = 11.344
   A(5) = 8.1328 E-3
   A(6) = -3.49149

   B(1) = -9.09718
   B(2) = -3.56654
   B(3) = 0.876793
   B(4) = 0.0060273

2. Let T = (t + 459.688)/1.8 (°C)

3. Check if T is above or below 273.16, and set P constants accordingly.

   3.1 If T greater than or equal to 273.16, set

```
z  = 373.16/T
P1 = A(1) * (z - 1)
P2 = A(2) * Log 10 (z)
P3 = A(3) * (10 ** (A(4) * (1 - 1/z)) - 1)
P4 = A(5) * (10 ** (A(6) * (z - 1)) - 1)
```

   Go to calculation 5.

   3.2 If T less than 273.16, set

```
z  = 273.16/T
P1 = B(1) * (x - 1)
P2 = B(2) * Log 10 (z)
P3 = B(3) * (1 - 1/z)
P4 = Log 10 (B(4))
```

4. Calculate vapor pressure.

```
PPWVM = 29.921 * 10 ** (P1 + P2 + P3 + P4)
```

SUBROUTINE: PSYCH

GENERAL DESCRIPTION

A psychrometric routine to calculate the density and enthalpy of moist air as a function of dry-bulb temperature, humidity ratio, and barometric pressure.

LIST OF VARIABLES

INPUT

T - Dry-bulb temperature (°F)

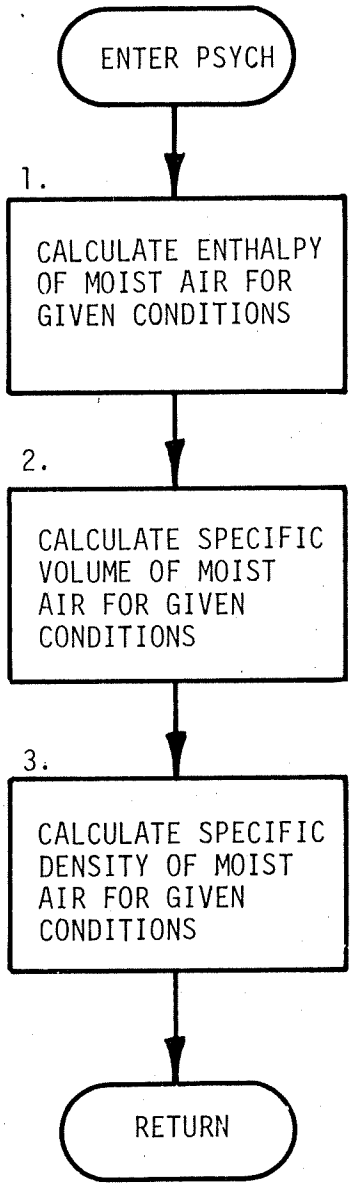
W - Humidity ratio (lb-H_2O/lbm-dry air)

PATM - Barometric pressure (in. Hg)

OUTPUT

H - Enthalpy of moist air (Btu/lb-dry air)

DEN - Density of moist air (lb-dry air/ft^3)


ENTER PSYCH
1.
CALCULATE ENTHALPY OF MOIST AIR FOR GIVEN CONDITIONS
2.
CALCULATE SPECIFIC VOLUME OF MOIST AIR FOR GIVEN CONDITIONS
3.
CALCULATE SPECIFIC DENSITY OF MOIST AIR FOR GIVEN CONDITIONS
RETURN

CALCULATION SEQUENCE

1. Calculate enthalpy of moist air for given conditions.

$$H = 0.24 * T + W * (1061. + 0.444 * T)$$

2. Calculate specific volume of moist air for given conditions.

$$V = 0.754 * (T + 459.688) * (1.0 + 7000. * W/4360.)/PATM$$

(For source of equation, consult paper by T. Kusuda, "Algorithms for Psychrometric Calculations", Building Science Series 21, National Bureau of Standards, January 1970.)

3. Calculate specific density of moist air for given conditions.

$$DEN = 1.0/V$$

SUBROUTINE: PSY1

GENERAL DESCRIPTION

A psychrometric routine to calculate the humidity ratio, density, and enthalpy of moist air having a dewpoint temperature above 32°F as a function of dry-bulb temperature, wet-bulb temperature, and barometric pressure.

LIST OF VARIABLES

INPUT

DBT - Dry-bulb temperature (°F)

WBT - Wet-bulb temperature (°F)

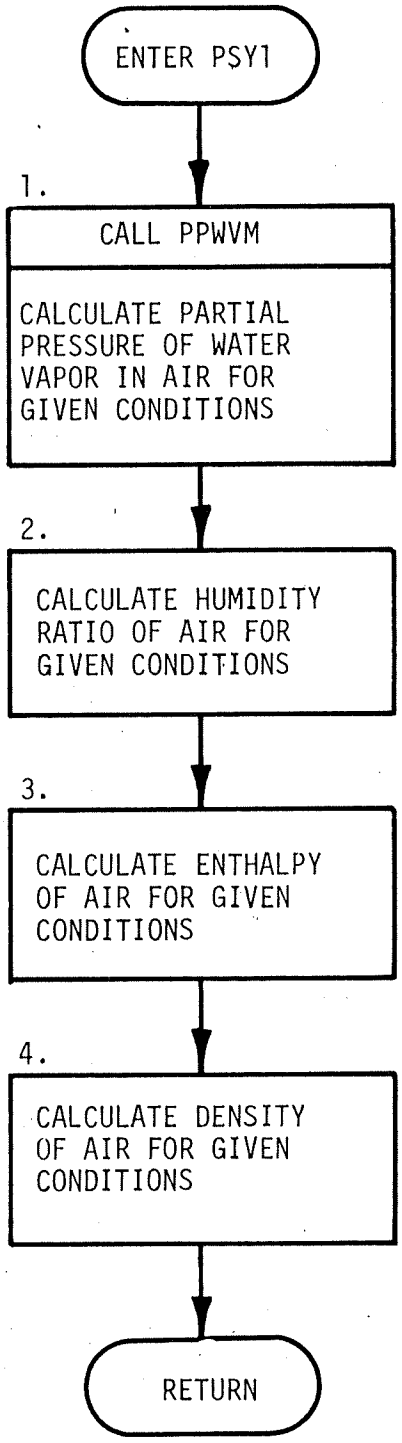
PATM - Barometric pressure (in. Hg)

OUTPUT

HUMRT - Humidity ratio (lb-H_2O/lb-dry air)

ENTH - Enthalpy (Btu/lb-dry air)

DENS - Density (lb-dry air/ft^3)


ENTER PSY1
1.
CALL PPWVM
CALCULATE PARTIAL PRESSURE OF WATER VAPOR IN AIR FOR GIVEN CONDITIONS
2.
CALCULATE HUMIDITY RATIO OF AIR FOR GIVEN CONDITIONS
3.
CALCULATE ENTHALPY OF AIR FOR GIVEN CONDITIONS
4.
CALCULATE DENSITY OF AIR FOR GIVEN CONDITIONS
RETURN

CALCULATION SEQUENCE

1. Calculate the partial pressure of water vapor in moist air for given conditions.

```
PPWV  =  PPWVM(WBT) - 0.000367 * PATM * (DBT - WBT)
                      /(1. + (WBT - 32.)/1571.)
```

   where PPWVM(WBT) is the partial pressure of water vapor in moisture-saturated air at temperature WBT and is calculated by the function routine PPWVM. For source of equations, consult paper by T. Kusuda, "Algorithms for Psychrometric Calculations", Building Science Series 21, National Bureau of Standards, January 1970.

2. Calculate the humidity ratio of moist air for given conditions.

```
HUMRT  =  0.622 * PPWV/(PATM - PPWV)
```

3. Calculate enthalpy of moist air for given conditions.

```
ENTH  =  0.24 * DBT + (1061. + 0.444 * DBT) * HUMRT
```

4. Calculate density of moist air for given conditions.

```
DENS  =  1./(0.754 * (DBT + 460.) * (1. + 7000. * HUMRT/4360.)
                /PATM)
```

SUBROUTINE: PSY2

GENERAL DESCRIPTION

A psychrometric routine to calculate the humidity ratio of moist air having a dewpoint temperature above 32°F as a function of dry-bulb temperature, wet-bulb temperature, and barometric pressure.

LIST OF VARIABLES

INPUT

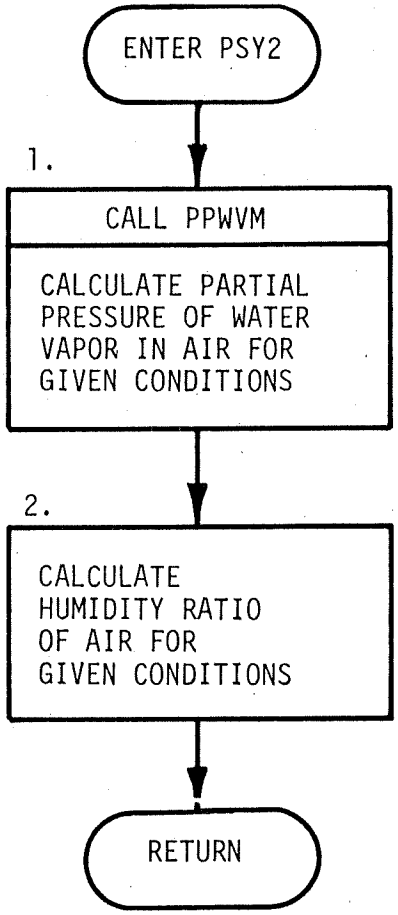
DBT - Dry-bulb temperature (°F)

WBT - Wet-bulb temperature (°F)

PATM - Barometric pressure (in. Hg)

OUTPUT

HUMRT - Humidity ratio (lb-H_2O/lb-dry air)


ENTER PSY2
1.
CALL PPWVM
CALCULATE PARTIAL PRESSURE OF WATER VAPOR IN AIR FOR GIVEN CONDITIONS
2.
CALCULATE HUMIDITY RATIO OF AIR FOR GIVEN CONDITIONS
RETURN

CALCULATION SEQUENCE

1. Calculate the partial pressure of water vapor in moist air for given conditions.

$$PPWV = PPWVM(WBT) - 0.000367 * PATM * (DBT - WBT) / (1. + (WBT - 32.)/1571.)$$

where PPWVM(WBT) is the partial pressure of water vapor in moisture-saturated air at temperature WBT and is calculated by the function routine PPWVM. For source of equations, consult paper by T. Kusuda, "Algorithms for Psychrometric Calculations", Building Science Series 21, National Bureau of Standards, January 1970.

2. Calculate humidity ratio of moist air for given conditions.

$$HUMRT = 0.622 * PPWV/(PATM - PPWV)$$

FUNCTION: PTLD

GENERAL DESCRIPTION

A function to calculate the part load power requirement of variable volume fans as a function of fraction of full load volume and type of volume control. See Figure for characteristics of each type of control.

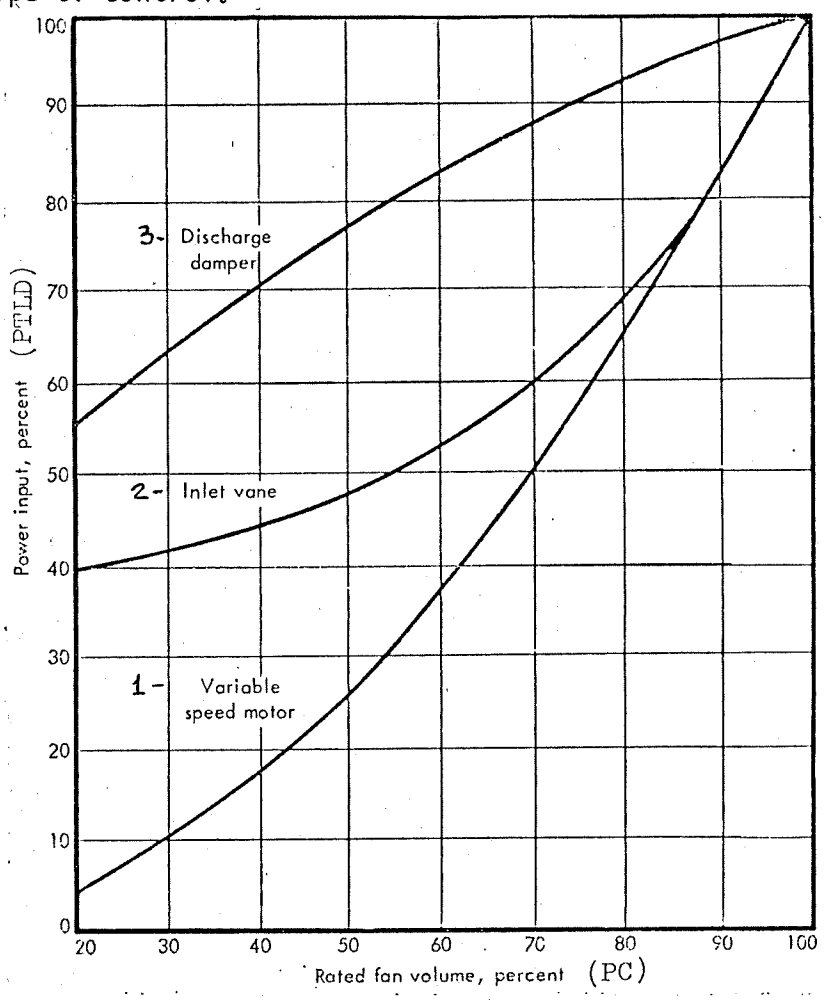


Figure POWER SAVINGS VS. AIR QUANTITY REDUCTION FOR THREE COMMON METHODS OF CONTROLLING DUCT STATIC PRESSURES (Norm Janisse, "How to Control Air Systems", HPAC, April 1969, pp. 129-136)

LIST OF VARIABLES

INPUT

NC - Type of fan volume control

= 1. Variable speed motor

= 2. Inlet vane damper

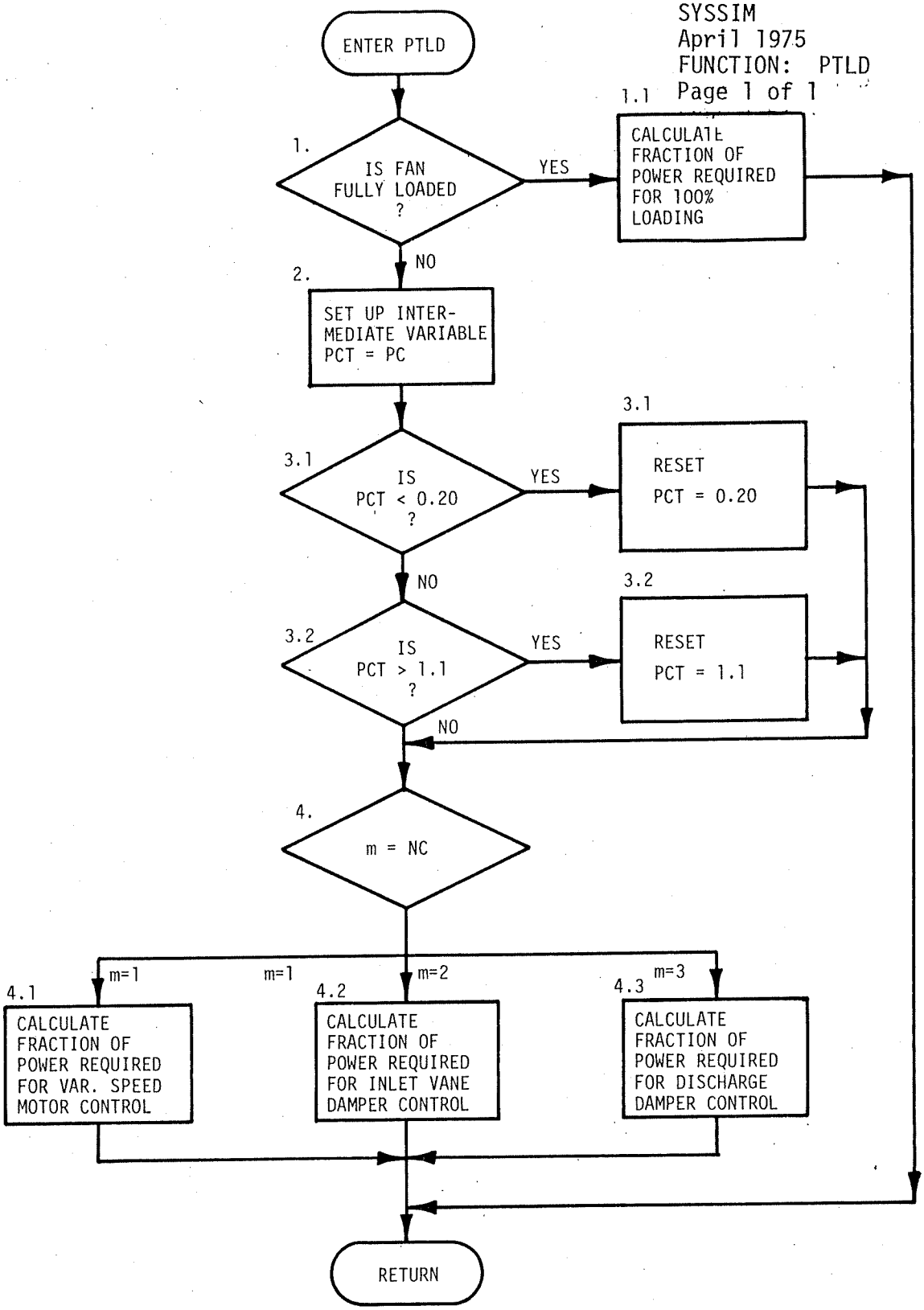
= 3. Discharge damper

PC - Fraction of full load volume (CFM)

OUTPUT

PTLD - Fraction of full load power used

SYSSIM
April 1975
FUNCTION: PTLD
Page 1 of 1



CALCULATION SEQUENCE

1. Check if fan is fully loaded.

   1.1 If fan is operating at 100% capacity (PC = 1.0), set PTLD = 1.0; then RETURN.

   1.2 If fan is operating at less than 100% capacity (PC ≠ 1.0), go to calculation 2.

2. Set up an intermediate working variable PCT = PC.

3. Check if fan is loaded to within allowable limits.

   3.1 If PCT less than 0.20, reset PCT = 0.20.

   3.2 If PCT greater than 1.1, reset PCT = 1.1.

4. Check type of fan volume control.

   If NC = 1, go to calculation 4.1

   = 2, go to calculation 4.2

   = 3, go to calculation 4.3

   4.1 Calculate PTLD for variable speed motor control (Type 1).

   PTLD = 0.0015302776 + PCT * (0.0052080574 + PCT
   * (1.1086242 + PCT * (-0.11635563)))

   RETURN

   4.2 Calculate PTLD for inlet vane damper control (Type 2).

   PTLD = 0.35071223 + PCT * (0.3080535 + PCT
   * (-0.54137364 + PCT * (0.87198823)))

   RETURN

   4.3 Calculate PTLD for discharge damper control (Type 3).

   PTLD = 0.37073425 + PCT * (0.97250253 + PCT
   * (-0.34240761))

   RETURN

SUBROUTINE: RECIP

GENERAL DESCRIPTION

Simulates the operation of an electric hermetic reciprocating water chiller by calculating the energy consumption as a function of part load, entering condenser water temperature and leaving chilled water temperature.

LIST OF VARIABLES

INPUT

QHBC - Hourly building cooling load (tons)

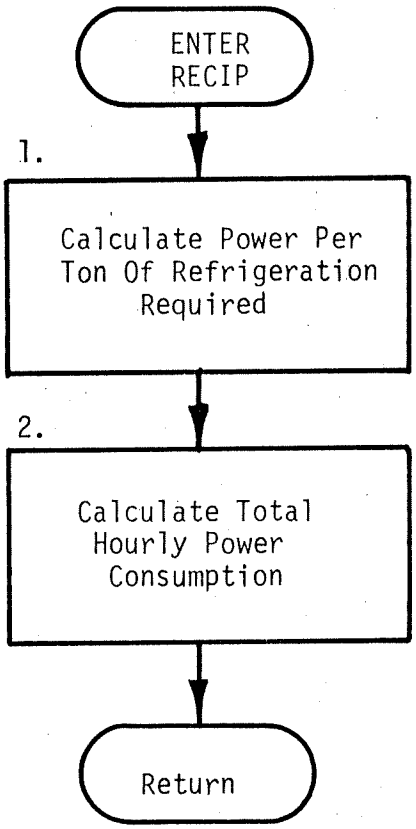
TECØN - Temperature of entering condenser water (°F)

TLCHL - Temperature of leaving chilled water (°F)

FFL - Fraction of full load (decimal)

OUTPUT

PØWER - Hourly electrical consumption (kilowatt hours)


ENTER
RECIP
1.
Calculate Power Per
Ton Of Refrigeration
Required
2.
Calculate Total
Hourly Power
Consumption
Return

CALCULATION SEQUENCE

1. Calculate the power per ton required.

$$PØPTN = (0.3371 + 0.01223 * TECØN - 0.009749 * TLCHL) * (0.868 + 0.133 * FFL)$$

where PØPTN has units of kilowatts per ton.

The above equation is based upon a curve fit of tabular performance data contained in the following Carrier catalogs for reciprocating liquid chilling packages:

a) Model 30 HH,HJ - 15 to 30 tons

b) Model 30 HR,HS - 40 to 60 tons

c) Model 30 HR,HS - 70 to 120 tons

2. Determine total hourly power consumption.

$$PØWER = PØPTN * QBHC$$

SUBROUTINE: RHFS2

A subroutine to simulate the operation of a single-zone fan system with face and bypass dampers, a unit ventilator, a unit heater, or a constant volume reheat fan system (see Figures 24, 25, 26, and 27).

SINGLE ZONE FAN SYSTEM WITH FACE AND BY-PASS DAMPERS

This system consists basically of a draw-thru air handler having heating and cooling coils in series with a by-pass section around the cooling coils in the air handler. Humidification is provided at the unit. The dry-bulb temperature of air leaving the unit is controlled by a thermostat in the first space served by this fan system. The system is designed primarily to serve one zone. If it is used to condition several zones, the first zone controls air handler discharge temperature and other zones' air may be reheated as required. Baseboard heating may also be included as a supplemental heat source.

UNIT VENTILATOR

This system consists of a draw-thru air handler with a heating coil. The coil is controlled by the first zone on the system. The air handler is capable of introducing a fixed amount of outside air. Although primarily designed to serve one zone, more than one may be simulated.

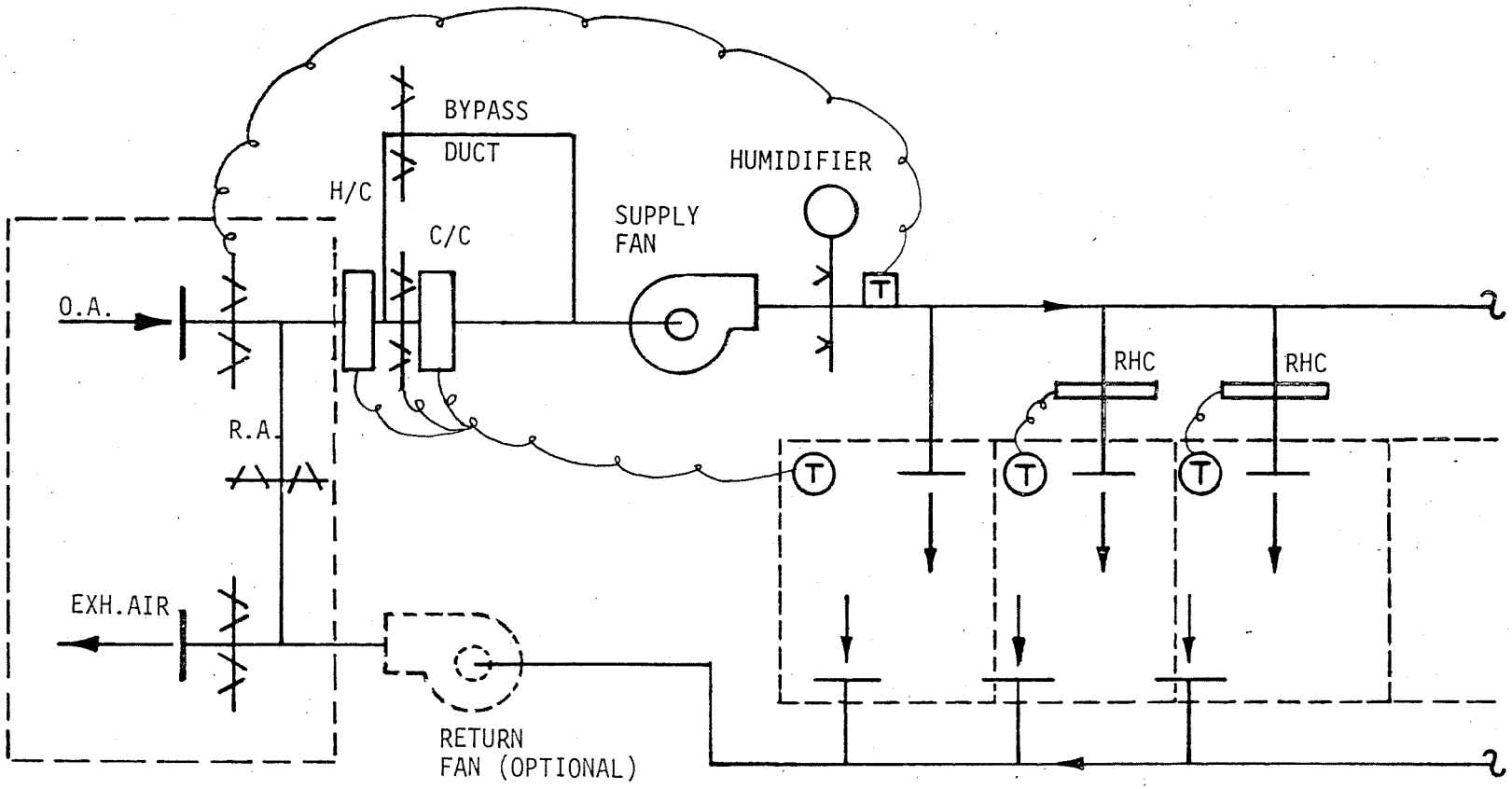
UNIT HEATER

This simulation is primarily designed for a unit heater serving one zone (i.e., a unit heater free-standing in a room). It may however, be extended to simulate a number of zones (i.e., an air handler with supply and return ductwork to several zones). This system is not capable of introducing outside air.

CONSTANT VOLUME REHEAT FAN SYSTEM

The reheat fan system simulated is comprised of a central air handling unit supplying primary air at a constant rate to the spaces. Final temperature control at the space is achieved by reheating supply air as required to meet space loads. The air handling unit includes heating and cooling coils, mixed air section, supply air fan, and humidifier. Operation characteristics and options included in this system simulation are as follows:

- Optional return air fan
- Humidifier



MIXED AIR
THREE OPTIONS

1. Fixed Dampers
2. Enthalpy/temp. type Economizer cycle
3. Temperature type Economizer cycle

Figure SINGLE ZONE FAN SYSTEM WITH FACE AND BYPASS DAMPERS (DISTRIBUTION SYSTEM NO. 1)

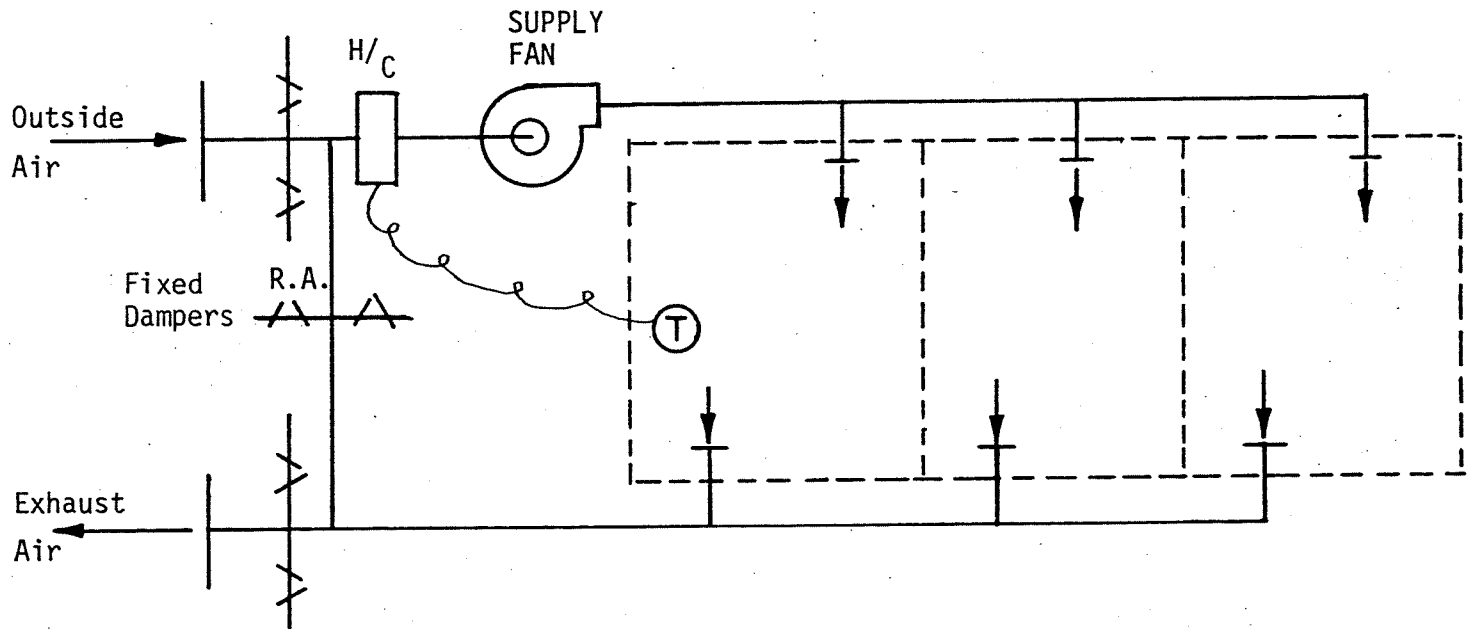
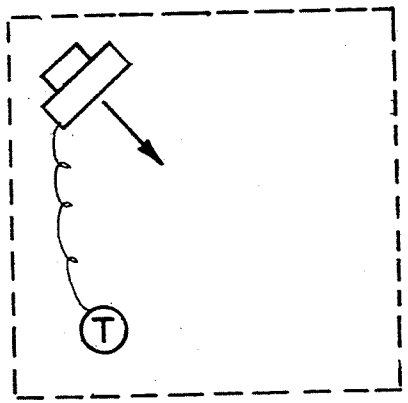
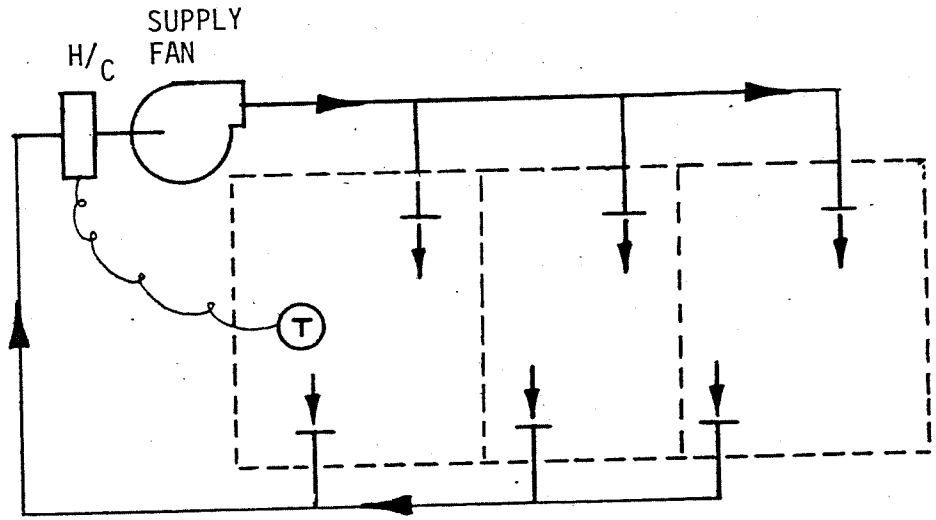


Figure UNIT VENTILATOR (DISTRIBUTION SYSTEM NO. 5)

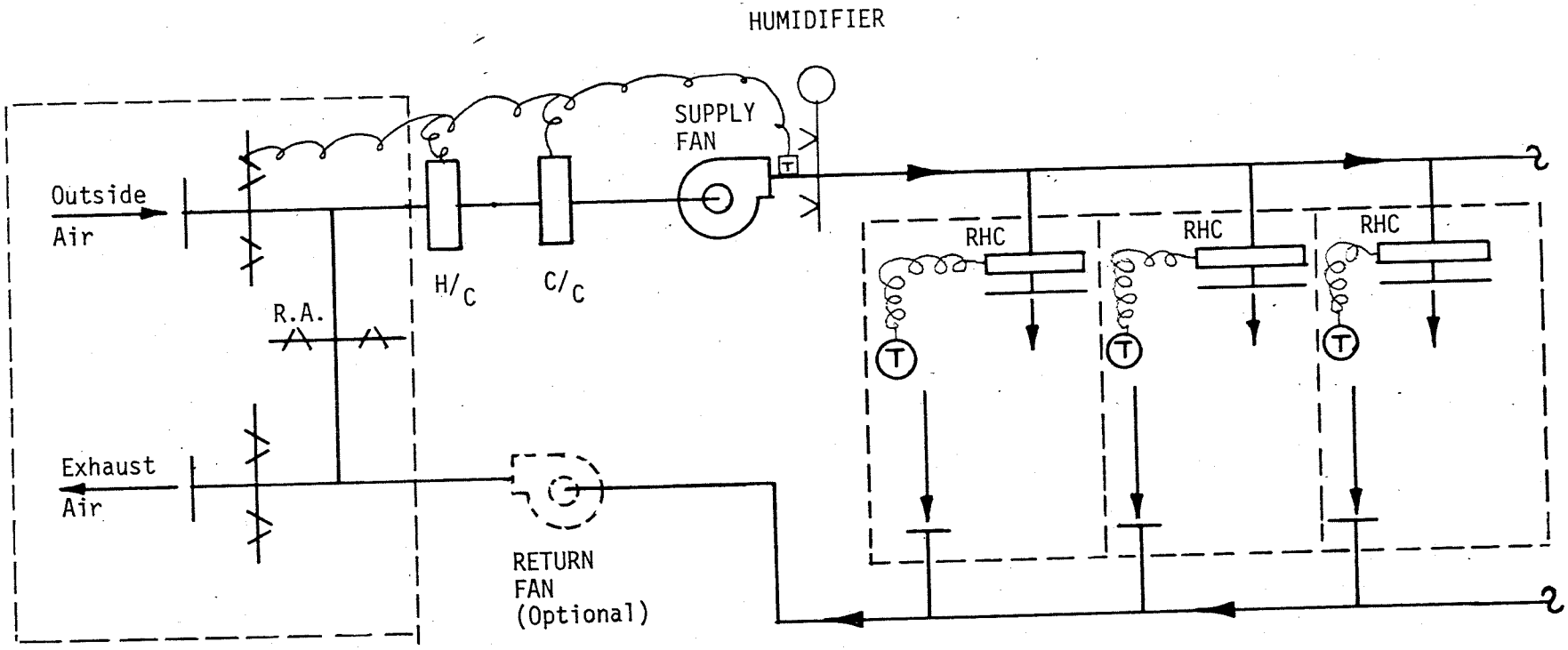


ONE-ZONE SCHEMATIC



MULTIPLE-ZONE SCHEMATIC

Figure UNIT HEATER (DISTRIBUTION SYSTEM NO. 6)



MIXED AIR

THREE OPTIONS

1. Fixed Dampers
2. Enthalpy/temp. type Economizer cycle
3. Temperature type Economizer cycle

Figure CONSTANT VOLUME REHEAT FAN SYSTEM (DISTRIBUTION SYSTEM NO. 13)

- Three outside air/return air options
- Baseboard heating as supplemental heating to each zone
- Primary air temperature control options:
  1) Fixed discharge temperature
  2) Air temperature determined by room requiring coolest air. This is achieved by a solid state-type temperature control system which monitors temperatures of spaces served by the unit.
  3) Reset temperature as an inverse function of outside air temperature.

LIST OF VARIABLES

INPUT

k - Energy distribution system number.

TNFBP - Total net fan brake horsepower (Bhp)

COMMON

IBØIL - Boiler on/off flag (1=on; 0=off)

ICHIL - Chiller on/off flag (1=on; 0=off)

IFAN - Fan system shut-off flag (0=fans run continuously,
1=fans may shut off
2=fans and baseboard radiators may be shut off)

QS_z - Zone sensible load (Btu/hr)

QL_z - Zone latent load (Btu/hr)

$QLITE_z$ - Light heat into ceiling plenum above zone (Btu/hr)

$SLPØW_z$ - Space light and power (KW)

$QSINF_z$ - Zone sensible loss due to infiltration (Btu/hr)

$QLINF_z$ - Zone latent loss due to infiltration (Btu/hr)

$STEMP_z$ - Space temperature at a given hour (°F)

$UCFM_z$ - Air flow through zone if it is a plenum space (ft^3/min)

TSP_z - Zone set point temperature (°F)

$VØL_z$ - Zone volume (ft^3)

TØA - Outside air dry-bulb temperature (°F)

WØA - Outside air humidity ratio $\left(\frac{\text{lbm-}H_2O}{\text{lbm-dry air}}\right)$

HØA - Outside air enthalpy (Btu/lbm)

DØA - Outside air density (lbm/ft^3)

PATM - Barometric pressure (in. Hg.)

$KFAN_k$ - Energy distribution system index

$JMAX_k$ - Number of zones on system k

$CFMAX_k$ - Design supply air of system k (ft^3/min)

$CFMEX_k$ - Exhaust air, system k (ft^3/min)

$ALFAM_k$ - Minimum fraction outside air, system k

$ØACFM_k$ - Minimum ventilation air, system k (ft^3/min)

WSP_k - Humidity ratio set point, system k $\left(\frac{\text{lbm-}H_2O}{\text{lbm-dry air}}\right)$

$FMASS_k$ - Supply air mass, system k (lbm-air/hr)

$FMASR_k$ - Return air mass, system k (lbm-air/hr)

$FMASX_k$ - Exhaust air mass, system k (lbm-air/hr)

$FBHPS_k$ - Supply fan brake horsepower, system k (bhp)

$FBHPR_k$ - Return fan brake horsepower, system k (bhp)

$FBHPE_k$ - Exhaust fan brake horsepower, system k (bhp)

$DTFNS_k$ - Air temperature rise across supply fan, system k, at full load (°F)

$DTFNR_k$ - Air temperature rise across return fan, system k, at full load (°F)

$MXAØ_k$ - Mixed air option, system k

$ICZN_k$ - Zone in which humidistat is located, system k, (a "j" number)

$ITMPC_{k,1}$ - Air temperature control mode, system k

$TFIX1_k$ - Fixed AHU discharge temperature, system k (°F)

$TFIX2_k$ - Fixed cold deck temperature, system k (°F)

CFM_i - Supply air flow rate, zone i (constant)(cu ft/min)

$CFMR_i$ - Return air flow rate, zone i (cu ft/min)

$CFMX_i$ - Exhaust air flow rate, zone i (cu ft/min)

$ZMASS_i$ - Supply air mass flow, zone i (constant)(lbm-air/hr)

$ZMASR_i$ - Return air mass flow, zone i (lbm-air/hr)

$ZMASX_i$ - Exhaust air mass flow, zone i (lbm-air/hr)

$ALFBR_i$ - Active length baseboard radiation, zone i (lin.ft)

$CBTU_i$ - Baseboard radiation heat output per linear foot at standard conditions, zone i (Btu/hr-lin.ft)

$IPLEN_i$ - LOAD program number of plenum above zone i

$SPACN_{k,j}$ - Number of space as per LOAD program, applied to system k, zone j

$MULT_i$ - Multiplication factor, zone i

I - Variable subscript i

KREHT - Reheat coil energy source index

$TØAHØ_n$ - Low outside air temperature at which system temperature is THI_n, reset schedule n (°F)

$TØAHI_n$ - High outside air temperature at which system temperature is $TLØ_n$, reset schedule n (°F)

$TLØ_n$ - Low system fluid temperature, reset schedule n (°F)

THI_n - High system fluid temperature, reset schedule n (°F)

$ISET_{k,m}$ - Reset temperature schedule index, system k, reset item m (an "n" number)

TFBHP - Total fan brake horsepower (bhp)

OUTPUT

QCC - Cooling coil load (Btu/hr)

QHC - AHU heating coil load (Btu/hr)

QTRHC - Reheat coil load (Btu/hr)

QPHC - Not used; Set equal 0.0

TQB - Baseboard heating load (btu/hr)

WATER - Steam humidification supplied at air handling unit (lbm-H_2O/hr)

BPKW - Base power (Kw)

TNFBP - Total net [updated] fan brake horsepower (bhp)

TLVG - Air handler discharge air dry bulb temperature (°F)

COMMON

QSI_i - Sensible thermal load, zone i (Btu/hr)

TS_i - Supply air temperature, zone i (°F)

WZ_i - Calculated humidity ratio, zone i (lbm-H_2O/lbm-dry air)

$WREQD_i$ - Required humidity ratio, zone i (lbm-H_2O/lbm-dry air)

$QCLNM_i$ - Monthly accumulation of cooling loads not met, (zone i) * $MULT_i$ (Btu)

$QCPNM_i$ - Monthly peak cooling load not met, zone i (Btu/hr)

$IHCNM_i$ - Number of hours cooling load not met, zone i (hrs)

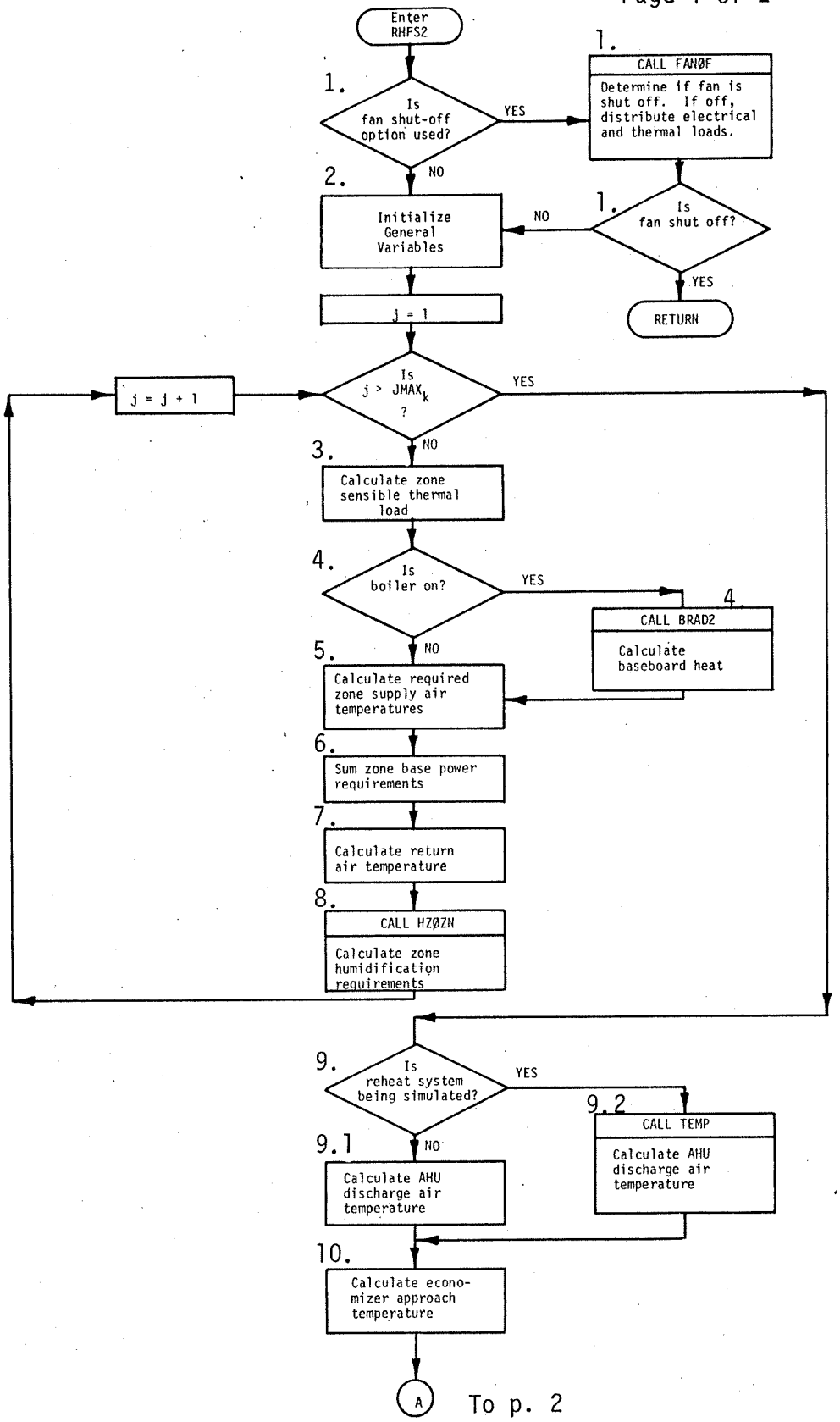
$QHLNM_i$ - Monthly accumulation of heating loads not met, (zone i) * $MULT_i$ (Btu)

$QHPNM_i$ - Monthly peak heating load not met, zone i (Btu/hr)

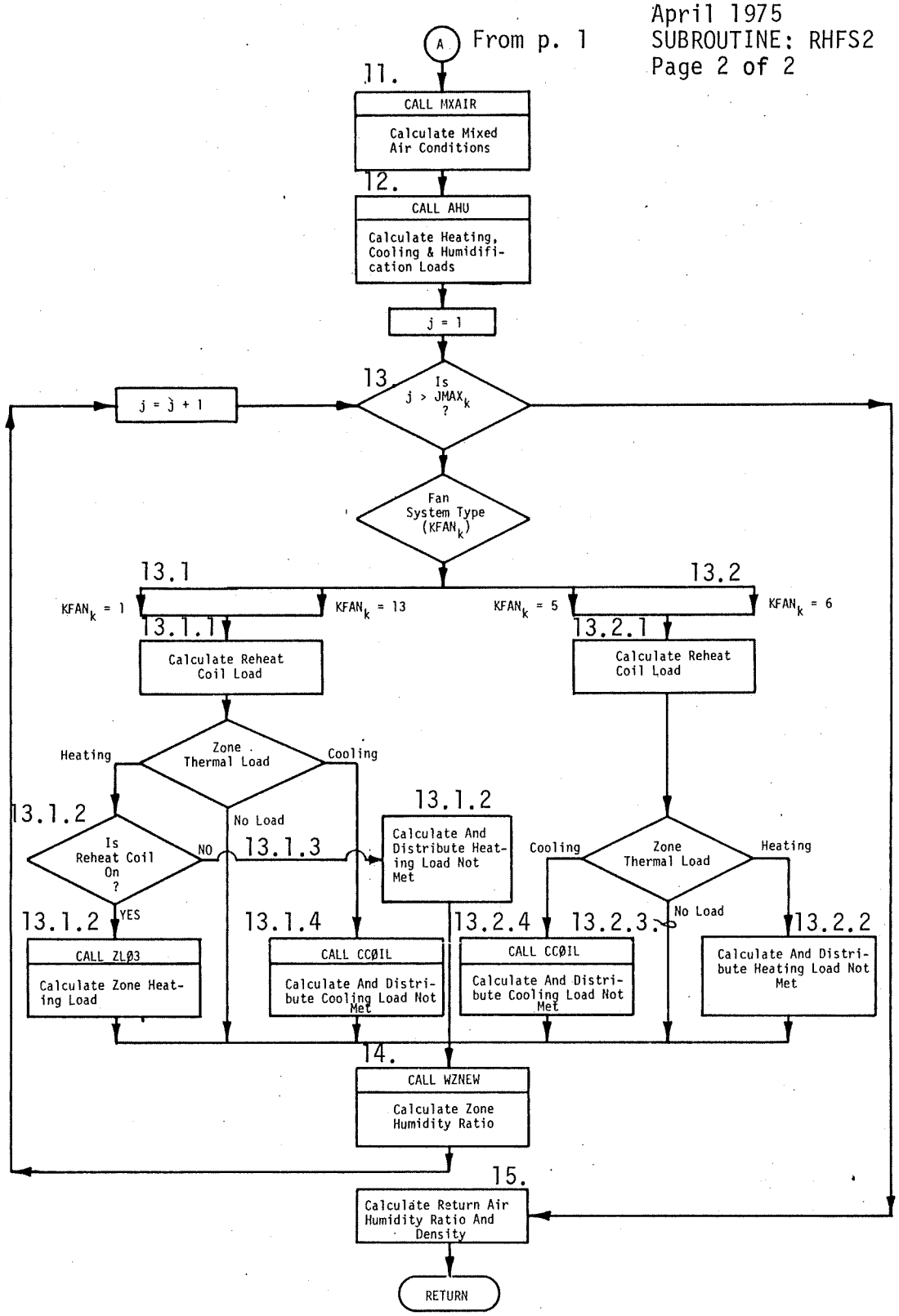
$IHHNM_i$ - Number of hours load not met, zone i (hrs)

WRA_k - Return air humidity ratio, system k $\left(\frac{\text{lbm-}H_2O}{\text{lbm-dry-air}}\right)$

DRA_k - Return air density (lbm/ft^3)


Enter RHFS2
1.
Is fan shut-off option used?
YES
NO
1.
CALL FANØF
Determine if fan is shut off. If off, distribute electrical and thermal loads.
1.
Is fan shut off?
NO
YES
RETURN
2.
Initialize General Variables
j = 1
j = j + 1
Is j > JMAX_k ?
YES
NO
3.
Calculate zone sensible thermal load
4.
Is boiler on?
YES
NO
4.
CALL BRAD2
Calculate baseboard heat
5.
Calculate required zone supply air temperatures
6.
Sum zone base power requirements
7.
Calculate return air temperature
8.
CALL HZØZN
Calculate zone humidification requirements
9.
Is reheat system being simulated?
YES
NO
9.2
CALL TEMP
Calculate AHU discharge air temperature
9.1
Calculate AHU discharge air temperature
10.
Calculate economizer approach temperature
A

To p. 2


A
From p. 1
11.
CALL MXAIR
Calculate Mixed Air Conditions
12.
CALL AHU
Calculate Heating, Cooling & Humidification Loads
j = 1
13
Is j > JMAX_k ?
j = j + 1
Fan System Type (KFAN_k)
13.1
13.2
KFAN_k = 1
KFAN_k = 13
KFAN_k = 5
KFAN_k = 6
13.1.1
Calculate Reheat Coil Load
13.2.1
Calculate Reheat Coil Load
Zone Thermal Load
Heating
Cooling
No Load
13.1.2
Is Reheat Coil On ?
NO
YES
13.1.3
13.1.2
Calculate And Distribute Heating Load Not Met
Zone Thermal Load
Cooling
Heating
No Load
13.1.2
CALL ZLØ3
Calculate Zone Heating Load
13.1.4
CALL CCØIL
Calculate And Distribute Cooling Load Not Met
13.2.4
CALL CCØIL
Calculate And Distribute Cooling Load Not Met
13.2.3
13.2.2
Calculate And Distribute Heating Load Not Met
14.
CALL WZNEW
Calculate Zone Humidity Ratio
15.
Calculate Return Air Humidity Ratio And Density
RETURN

CALCULATION SEQUENCE

1. Fan off/on check

If it is desired to turn off fan when possible (IFAN > 0), call subroutine FANØF to determine whether the fan can be turned off for the current hour (IØØ = 1 is off, IØØ = 0 is on) go to calculation 2.

If the system is off (IØØ = 1, terminate RHFS2 simulation for the current hour.

If the system is on (IØØ = 0), go to calculation 2.

If fans run continuously (IFAN = 0), go to calculation 2.

2. Initialize general variables

QTRHC = 0. (Reheat coil load, Btu/hr)
QPHC = 0. (Preheat coil load - not used, Btu/hr)
TQB = 0. (Baseboard heating load, Btu/hr)
BPKW = 0. (Sum of zone basepower, kw)
SMTRA = 0. (Weighted sum of zone return air temperature quantities, lbm-°F/hr)
I1 = $ISET_{k,1}$ (Primary air schedule index)
I3 = $ISET_{k,3}$ (Baseboard heating hot water reset schedule index)
I4 = $ISET_{k,4}$ (Two pipe induction system hot water reset schedule index)

3. Calculate sensible thermal loads of each zone on this system.

$$QSI_i = QS_z + QSINF_z$$

(See note below for explanation of variables i, j, and z.)

4. Baseboard radiation.

If boiler on (IBØIL = 1), call subroutine BRAD2 to calculate baseboard radiation heat (QB_j) and to adjust QSI_i for QB_j.

Sum baseboard radiation heat,

$$TQB = \sum_{j=1,\ JMAX_k} QB_j$$

If boiler off (IBØIL = 0) continue.

NOTE: There is a coresponding z for each i; a relationship defined by the variable $SPACN_{k,j}$. Hence, i and z are defined by system number (k) and zone number (j).

5. Calculate required zone supply air temperatures (TS_i)

$$TS_i = TSP_z - QSI_i/(0.245 - ZMASS_i)$$

6. Calculate base power (BPKW); includes internal power, lights receptacles, equipment, misc. (kw)

$$BPKW = \sum_{j=1;\ JMAX_k} SLPØW_z * MULT_i$$

7. Calculate return air temperature (TRA_k)

NOTE: Since the System and Equipment Simulation Program is capable of using either one of the load tapes produced by NBSLD, the NECAP's (NASA's Energy and Cost Analysis Programs) Load Program, or the Variable Temperature Program is input, the following logic sequence is required.

7.1 If ceiling plenum is calculated as a separate zone,

7.1.1 If LOAD tape is used,

$$DTL2_i = 0.$$

$$QLITI = QLITE_z + QS_{pl} + QLITE_{pl} + QSINF_{pl}$$

Go to Calculation 7.3

7.1.2 If VARIABLE TEMPERATURE tape is used,

$$DTL2_i = STEMP_{pl} - TSP_z$$

$$QLITI = QLITE_z$$

Go to Calculation 7.3

7.2 If ceiling plenum is not calculated as a separate zone,

$$DTL2_i = 0$$

$$QLITI = QLITE_z$$

7.3 Return air temperature calculation (TRA_k)

$$DTL_i = QLITI/(0.245 * ZMASR_i)$$

$$TRA_k = \frac{\sum_{j-1,JMAX_k} (TSP_z + DTL_i + DTL2_i) * ZMASR_i * MULT_i}{\sum_{j-1,\ JMAX_k} ZMASR_i * MULT_i} + DTFNR_k$$

where $DTL2_i$ - difference between zone and plenum temperatures as calculated by VARIABLE TEMPERATURE PROGRAM.

QLITI - thermal load of plenum pl above zone z as calculated by LOAD program.
pl - load program number of plenum above zone z.

8. Zone humidity calculations.

Using subroutine H2ØZN, calculate total moisture requirements of zone including setpoint recovery load ($H2ØAD_i$) and moisture changes in current hour due to environmental and room effects ($H2ØAD_i$)

9. Calculate air temperature leaving unit (TLVG)

9.1 For single zone fan system, unit ventilator, and unit heater,

$TLVG = TS_1$ (one)

9.2 For constant volume reheat fan system, air handler discharge temperature (TLVG) is controlled in one of three ways:

1. constant leaving air temperature ($ITMPC_{k,1} = 1$)
2. set equal to lowest TS_i ($ITMPC_{k,1} = 2$)
3. reset as an inverse function of ambient air temperature ($ITMPC_{k,1} = 3$).

Call subroutine TEMP to calculate TLVG for one of the above control modes.

10. Calculate economizer approach temperature (EAT).

10.1 Check discharge temperature (TLVG) against upper limit,

If TLVG greater than 125. °F,

$TLVG = 125.°F$

$EAT = TLVG - DTFNS_k$

10.2 Check economizer approach temperature against lower limit,

If EAT less than 40.°F,

$EAT = 40.°F$

$TLVG = EAT + DTFNS_k$

11. Calculate mixed air conditions.

Call subroutine MXAIR to simulate the performance of:

1. Fixed outside and return air dampers ($MXA\emptyset_k = 1$).

2. An enthalpy/temperature type economizer cycle ($MXA\emptyset_k = 2$)

or

3. A temperature type economizer cycle ($MXA\emptyset_k = 3$)

Subroutine MXAIR also calculates the thermal properties [temperature (TMA), humidity ratio (WMA), and density (DMA)] of the mixed air stream.

12. Air handling unit.

12.1 Single-zone system with face and bypass dampers around cooling coil (Distribution System Type 1).

Call subroutine AHU (mode 2) to simulate the functioning of this air handling unit. Calculate bypass damper operation, heating and cooling coil thermal response (QHC and QCC), effect of fan heat, and steam humidifier functioning (WATER).

12.2 Unit ventilator (Distribution System Type 5).

Heating and the addition of outside air are provided by this system type.

Call subroutine AHU (mode 1) to calculate the functioning of the heating coil (QHC) and effect of fan heat.

12.3 Unit heater (Distribution System Type 6).

Same as unit ventilator, without outside air option.

12.4 Contant volume reheat fan system (Distribution System Type 13).

Call subroutine AHU (mode 1) to simulate the operation of a central system air handling unit. Calculate heating and cooling coil operation (QHC and QCC), the effect of fan heat, and the addition of steam (WATER) by a humidifier on the discharge side of the unit.

12.5 Controls applicable to all system types.

The heating coil is locked out when the boiler is scheduled off (IBØIL = 0).

The cooling coil is locked out when the chiller is scheduled off (ICHIL = 0).

The humidifier is locked out when the cooling coil is functioning (QCC > 0.)

13. Calculate reheat coil loads and distribute loads not met.

13.1 Single-zone fan system ($KFAN_k$ = 1) and constant volume reheat fan systems ($KFAN_k$ = 13).

13.1.1 Calculate reheat coil load (QT_i)

$QT_i = ZMASS_i * 0.245 * (TLVG - TS_i)$

13.1.2 If reheat coil load (QT_i) less than 0., and

If reheat coil on (IBØ1L = 1 or KREHT = 4),

Call subroutine ZLØ3 to calculate and sum reheat coil loads and distribute loads not met, if any, Go to Calculation 14.

If boiler off (IBØIL = 0) and reheat energy from boiler (KREHT = 0), calculate heating load not met ($QLNM_i$)

$QLNM_i = QT_i$

Update as required the following variables:

$QHLNM_i$ - Sum of heating loads not met, zone i (Btu)

$QHPNM_i$ - Peak heating load not met, zone i (Btu/hr). Call subroutine MAX to do this.

$IHHNM_i$ - Number of hours heating load not met, zone i.

$TS_i = TLVG$

$WTLVG_i$ = WSUP (WSUP = supply air humidity ratio which is calculated in subroutine AHU).

Go to Calculation 14.

13.1.3 If reheat load (QT_i) equals 0.,

$WTLVG_i = WSUP$

Go to Calculation 14.

13.1.4 If reheat coil load greater than 0., calculate cooling load not met ($QLNM_i$).

Update as required the following variables:

$QCLNM_i$ - Sum of cooling loads not met, zone i (Btu)

$QCPNM_i$ - Peak cooling load not met, zone i (Btu/hr). Call subroutine MAX to do this.

$IHCNM_i$ - Number of hours cooling load not met, zone i.

$TS_i = TLVG$

$WTLVG_i = WSUP$

Go to Calculation 14.

13.2 Unit ventilator ($KFAN_k = 5$) and unit heat systems ($KFAN_k = 6$).

13.2.1 Calculate reheat coil load (QT_i)

$QT_i = ZMASS_i * 0.245 * (TLVG_i - TS_i)$

13.2.2 If reheat coil load less than 0., calculate heating load not met ($QLNM_i$)

$QLNM_i = QT_i$

Update as required the following variables:

$QHLNM_i$ - Sum of heating loads not met, zone i (Btu)

$QHPNM_i$ - Peak heating load not met, zone i (Btu/hr). Call subroutine MAX to do this.

$IHHNM_i$ - Number of hours heating load not met, zone i

$TS_i = TLVG$

$WTLVG_i = WSUP$

Go to Calculation 14.

13.2.3 If reheat coil load equals 0.,

$WTLVG_i = WSUP$

TS_i = TLVG

Go to Calculation 14.

13.2.4 If reheat coil load greater than 0. calculate cooling load not met ($QLNM_i$),

$QLNM_i = QT_i$

Update as required the following variables:

$QCLNM_i$ - Sum of cooling loads not met, zone i (Btu)

$QCPNM_i$ - Peak cooling load not met, zone i (Btu/hr) Call subroutine MAX to do this.

$IHCNM_i$ - Number of hours cooling load not met, zone i.

TS_i = TLVG

$WTLVG_i$ = WSUP

Go to Calculation 14.

14. Calculate zone humidity ratio.

Using function WZNEW, calculate the humidity ratio of each zone (WZ_i).

15. Calculate return air humidity ratio (WRA_k) and density (DRA_k).

$$WRA_k = \frac{\sum_{j=1,\ JMAX_k} WZ_i * ZMASR_i * MULT_i}{\sum_{j=1,JMAX_k} ZMASR_i * MULT_i}$$

$$DRA_k = \frac{PATM}{(0.754 * (TRA_k + 460.)(1.0 + 7000.0 * WRA_k/4360.)}$$

SUBROUTINE: SNØWM

GENERAL DESCRIPTION

Simulates the operation of snow melting systems by calculating the amount of heat required to melt and evaporate now from concrete surfaces.

LIST OF VARIABLES

INPUT

TØA - Dry-bulb temperature of outside air (°F)

WØA - Humidity ratio of outside air (lb water/lb dry air)

PATM - Barometric pressure (inches of mercury)

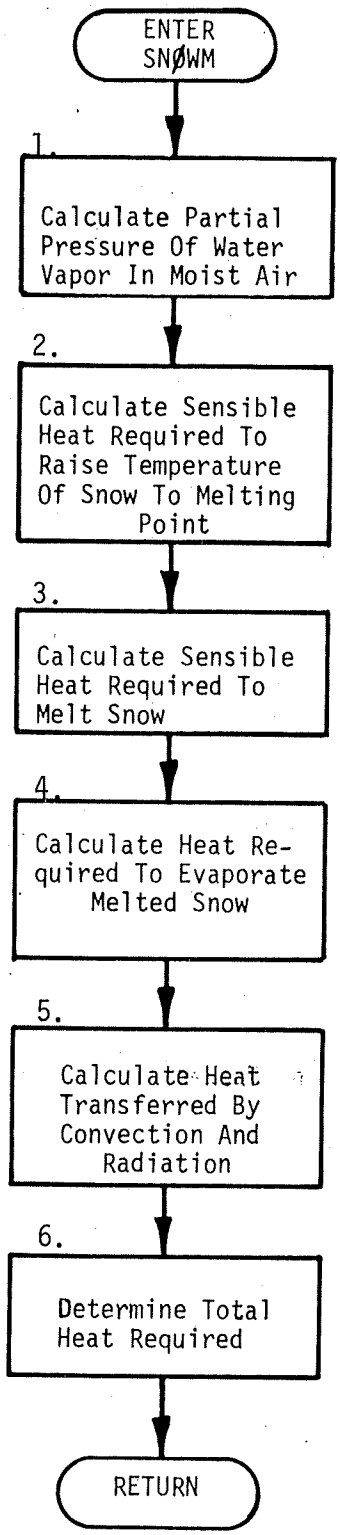
VWIND - Wind velocity (mph)

SAREA - Snow-melting slab area (ft^2)

SNØW - Inches of snow, water equivalent (inches)

OUTPUT

QTØT - Total hourly heating requirement of snow-melting system (Btu/hr)


ENTER SNØWM
1.
Calculate Partial Pressure Of Water Vapor In Moist Air
2.
Calculate Sensible Heat Required To Raise Temperature Of Snow To Melting Point
3.
Calculate Sensible Heat Required To Melt Snow
4.
Calculate Heat Required To Evaporate Melted Snow
5.
Calculate Heat Transferred By Convection And Radiation
6.
Determine Total Heat Required
RETURN

CALCULATION SEQUENCE*

1. Calculate partial pressure of water vapor in moist air (inches Hg).

   VP = (WØA/0.622 * PATM)/(1.0 + WØA/0.622)

2. Calculate sensible heat required to raise temperature of snow from outside air temperature to melting point (Btu/hr-ft^2).

   QSEN = 2.6 * SNØW * (33.0 - TØA)

3. Calculate latent heat required to melt snow (Btu/hr-ft^2).

   QLAT = 746.0 * SNØW

4. Calculate heat required to evaporate melted snow (Btu/hr-ft^2).

   QEVAP = 1075.0 * (0.0201 * VWIND + 0.055) * (0.185 - VP)

5. Calculate heat transferred by convection and radiation (Btu/hr-ft^2).

   QCØNV = 11.4 * (0.0201 * VWIND + 0.055) * (33.0 - TØA)

6. Determine total heat required (Btu/hr).

   QTØT = (SAREA * (QSEN + QLAT + 0.5 * QEVAP + 0.5 * QCØNV))/0.7

   where the edge loss factor is 0.3 and the area ratio of snow-free area to slab area is 0.5.

---

*For derivation and justification of equations, see "Design of Snow-Melting Systems", Heating and Ventilating, April 1952, by William P. Chapman, and 1967 ASHRAE Guide and Data Book, Systems and Equipment Volume, Chapter 67, entitled "Snow Melting".

SUBROUTINE: STTUR

GENERAL DESCRIPTION

Simulates the operation of a single stage condensing steam turbine by determining the energy consumption as a function of the power output desired.

LIST OF VARIABLES

INPUT

PPS - Pressure of high pressure steam (psig)

TPS - Temperature of high pressure steam (°F)

RPM, SPEED - Speed of steam turbine (rpm)

SZT - Size of steam turbine, HP (taken as 1 HP/ton)

NSTØN - Number of steam turbine operating; same as number of chillers operating

PØWER - Total power output required by all turbines (KW)

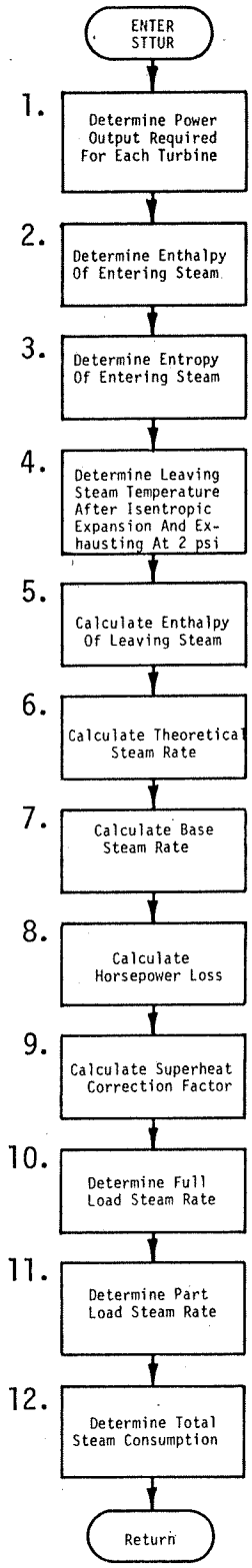
OUTPUT

STEAM - Hourly steam consumption (lb/hr)

H1 - Enthalpy of steam entering turbine (BTU/lb)

H2 - Enthalpy of steam leaving turbine (Btu/lb

SYSSIM
April 1975
SUBROUTINE: STTUR
Page 1 of 1



CALCULATION SEQUENCE

1. Determine power output required for each turbine in terms of HP

```
PØWER = 1.341*POWER/NSTØN
```

2. Determine the enthalpy (H1) of entering steam.

```
H1 = AH + BH * TPS + CH * TPS * TPS
```

where

```
AH = 1068.0 - 0.485 * PPS

BH = 0.432 + 0.000953 * PPS

CH = 0.000036 - .000000496 * PPS
```

The above equations were arrived at by curve fitting data from "Thermodynamic Properties of Steam", Keenan and Keyes. Equation is good for temperatures up to 1000°F and pressure up to 1000 psia.

3. Calculate the entropy(S) of entering steam.

```
S = 2.385 - 0.004398 * TSATI + 0.000008146 * TSAT1
    * TSAT1 - 0.662 * E-08 * (TSAT1 ** 3.0) + 2.0
    * CH * (TPS-TSAT1) + (BH - 920.0 * CH)
    *ALØG((TPS + 460.0)/(TSAT1 + 460.0))
```

Where the saturation temperature (TSAT1) is

```
TSAT1 = 1.0/0.0017887 - 0.00011429 * ALØG(PPS))-460.0
```

Same comment from calculation 2 applies here also, except applicable range is 200 to 700°F

4. Find the temperature of steam (T2) after isentropic expansion and exhausting at 2 psia (condensing turbine).

```
T2 = 1.0/(0.0017887-0.00011429*ALØG (2.0)) - 460.0
```

(simply equation in calculation 3 for TSAT1 but evaluated at PPS = 2.0)

5. Find the enthalpy of leaving steam (H2).

```
H2 = 1.0045 * T2 - 32.448 + (T2 + 460.0) * (S - 1.0045
    * ALØG (T2 + 460.0) + 6.2264
```

6. Calculate the theoretical steam rate (lb/HP-hr).

$$TSR = 2545.0/(H1-H2)$$

where 2545.0 is BTU/HP-HR.

7. Calculate base steam rate (BSR)

$$BSR = SLØPE * TSR + B$$

where

$$B0 = 84.0-0.017*SZT+1.5625*((SZT/1000.0)**2.0))$$

$$B1 = -19.7 + 0.001025 * SZT$$

$$B2 = 1.4$$

$$B = B0+B1*RPM/100.0+B2*((RPM/1000.0)**2.0)$$

$$S0 = 3.88-0.011865*SZT+0.1173*((SZT/1000.0)**2.0)$$

$$S1 = -1.1+0.000533*SZT-0.0581*((SZT/1000.0)**2.0)$$

$$S2 = 0.116-0.000057*SZT+0.00709*((SZT/1000.0)**2.0)$$

$$SLØPE = S0+S1*RPM/1000.0+S2*((RPM/1000.0)**2.0)$$

The base steam rate calculation was made by equation-fitting performance curves that are presented in Bulleting H-31A, Elliott Division of Carrier Corporation for Type YR single stage turbines which range in size from 800 to 7000 HP and range in speeds from 1750 to 6000 RPM.

8. Calculate the horsepower loss (HPLSS)

$$HPLSS = 0.0334 * ((RPM/1000.0)** 2.42)$$
$$* ((SZT/1000.0) ** 1.47)$$

The horsepower loss equation was derived by equation fitting performance curves presented in Elliott Bulletin H-31A.

9. Calculate the superheat correction factor (SC) as indicated in Figure where the superheat (°F) is calculated as follows:

$$SH = TPS - TSAT1$$

and theoretical steam rate (TSR) is that determined in calculation 6. For the series of 20 equations that were developed to represent these curves, see computer listing of the STTUR subroutine.

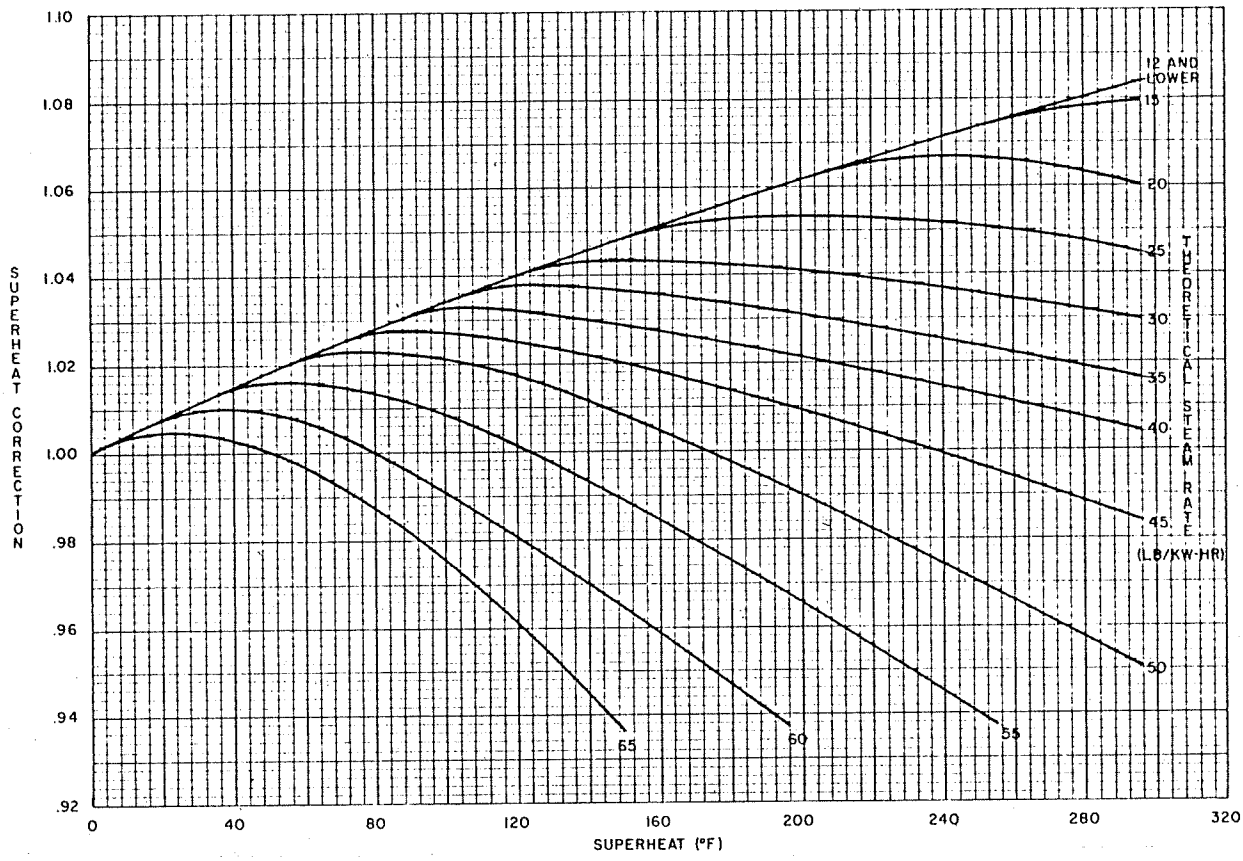


Figure SUPERHEAT CORRECTION FACTOR

10. Determine the full load steam rate (lb/HP-hr).

FLSR = BSR/SC) * ((SZT + HPLSS)/SZT)

11. Determine the part load steam rate for one turbine (lb/hr).

STEAM = FLSR * SZT (PLB + PLM * PØWER/SZT)

where PLB = 0.09163 + 0.0404 * (RPM/SPEED) - 0.00706 * ((RPM/SPEED)**2.0) + 0.0003167 * ((RPM/SPEED) ** 3.0)

PLM = 5.219 - 14.627 *(RPM/SPEED) + 16.62 *((RPM/SPEED)** 2.0) - 6.2524 *((RPM/SPEED) ** 3.0)

PLB and PLM would adjust steam rate for a turbine operating at a RPM other than rated speed, however it is assumed that turbines will always operate at rated speed (RPM = SPEED).

12. Calculate the total hourly steam consumption (lb/hr)

STEAM = STEAM * NSTØN

SUBROUTINE: SZRHT

GENERAL DESCRIPTION

This subroutine simulates the operation of a single-zone fan system with sub-zone reheat. (see Figure).

This fan system is designed to serve a large central zone requiring cooling the entire year and sub-zones which may require reheating. Primary air temperature is controlled by the requirement of the central zone. During the winter and intermediate seasons, the primary air is colder than that required for the sub-zones. Sub-zone all-air induction boxes therefore open to mix return air with primary air. The induction boxes are designed such that up to 50% inducted air can be mixed with primary air. If further heating of primary air is required, the reheat coil is activated.

Elements and operating characteristics of this fan system include:

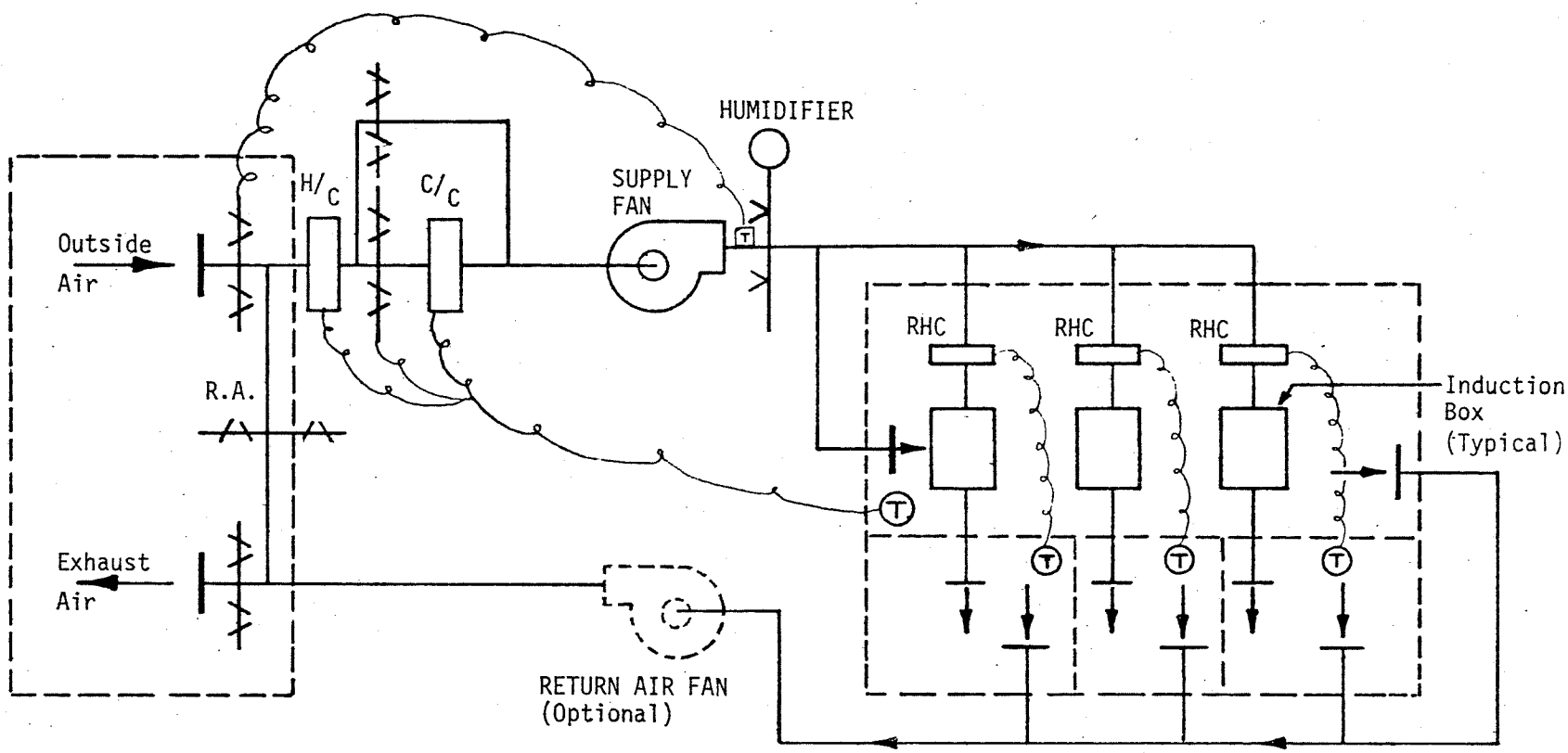
- Optional return air fan simulation
- Humidifier
- Three outside air/return air options with the economizer attempting to equal required cold deck temperature
- Baseboard heating as supplemental heat to each zone
- Primary heating coil
- Cooling coil with face and by-pass dampers
- Air temperature leaving air handler controlled by thermal requirements of central zone
- Fan air quantities vary; zone supply air quantities remain constant due to operation of all-air induction box.
- Reheat coils.

LIST OF VARIABLES

INPUT

k - Energy distribution system number

TNFBP - Total net fan brake horsepower (Bhp)



MIXED AIR

THREE OPTIONS

1. Fixed Dampers
2. Enthalpy/temp. type Economizer cycle
3. Temperature type Economizer cycle

Figure SINGLE ZONE FAN SYSTEM WITH SUB-ZONE REHEAT (DISTRIBUTION SYSTEM NO. 4)

COMMON

IBØIL - Boiler on/off flag (1=on; 0=off)

ICHIL - Chiller on/off flag (1=on;0=off)

IFAN - Fan system shut-off flag (0=fans run continuously
1=fans may be shut off
2=fans and baseboard radiators may be shut off)

QS_z - Zone sensible load (Btu/hr)

QL_z - Zone latent load (Btu/hr)

$QLITE_z$ - Light heat into ceiling plenum above zone (Btu/hr)

$SLPØW_z$ - Space light and power (KW)

$QSINF_z$ - Zone sensible loss due to infiltration (Btu/hr)

$QLINF_z$ - Zone latent loss due to infiltration (Btu/hr)

$STEMP_z$ - Space temperature at a given hour (°F)

$UCFM_z$ - Air flow through zone if it is a plenum space (ft^3/min)

TSP_z - Zone setpoint temperature (°F)

$VØL_z$ - Zone volume (ft^3)

TØA - Outside air dry-bulb temperature (°F)

WØA - Outside air humidity ratio (lbm-H_2O/lbm-dry air)

HØA - Outside air enthalpy (Btu/lbm)

DØA - Outside air density (lbm/ft^3)

PATM - Barometric pressure (in. Hg)

$KFAN_k$ - Energy distribution system index

$JMAX_k$ - Number of zones on system k

$ALFAM_k$ - Minimum fraction outside air, system k

WSP_k - Humidity ratio set point, system k (lbm-H_2O/lbm-dry air)

$FMASS_k$ - Supply air mass, system k (lbm-air/hr)

$FMASR_k$ - Return air mass, system k (lbm-air/hr)

$FMASX_k$ - Exhaust air mass, system k (lbm-air/hr)

$FBHPS_k$ - Supply fan brake horsepower, system k (bhp)

$FBHPR_k$ - Return fan brake horsepower, system k (bhp)

$FBHPE_k$ - Exhaust fan brake horsepower, system k (bhp)

$DTFNS_k$ - Air temperature rise across supply fan, system k, at full load (°F)

$DTFNR_k$ - Air temperature rise across return fan, system k, at full load (°F)

$ICZN_k$ - Zone in which humidistat is located, system k, (a "j" number)

$NVFC_k$ - Type of fan air flow control, system k

CFM_i - Supply air flow rate, zone i (constant)(ft^3/min)

$CFMR_i$ - Return air flow rate, zone i (ft^3/min)

$CFMX_i$ - Exhaust air flow rate, zone i (ft^3/min)

$ZMASS_i$ - Supply air mass flow, zone i (constant)(lbm-air/hr)

$ZMASR_i$ - Return air mass flow, zone i (lbm-air/hr)

$ZMASX_i$ - Exhaust air mass flow, zone i (lbm-air/hr)

$ALFBR_i$ - Active length baseboard radiation, zone i (lin. ft)

$CBTU_i$ - Baseboard radiation heat output per linear foot at standard conditions, zone i (Btu/hr-lin. ft)

$IPLEN_i$ - LOAD program space number of plenum above zone i

$SPACN_{k,j}$ - Number of space as per LOAD program, applied to system k, zone j

$MULT_i$ - Multiplication factor, zone i

I - Variable subscript i

KREHT - Reheat coil energy source index

WZ_i - Calculated humidity ratio, zone i (lbm-H_2O/lbm-dry air)

$TØALØ_n$ - Low outside air temperature at which system temperature is THI_n, reset schedule n (°F)

$TØAHI_n$ - High outside air temperature at which system temperature is $TLØ_n$, reset schedule n (°F)

$TLØ_n$ - Low system fluid temperature, reset schedule n (°F)

THI_n - High system fluid temperature, reset schedule n (°F)

$ISET_{k,m}$ - Reset temperature schedule index, system k, reset item m (an "n" number)

TFBHP - Total fan brake horsepower (bhp)

OUTPUT

QCC - Cooling coil load (Btu/hr)

QHC - AHU heating coil load (Btu/hr)

QTRHC - Reheat coil load (Btu/hr)

QPHC - Not used; set equal to 0.0

TQB - Baseboard heating load (Btu/hr)

WATER - Steam humidification supplied at air handling unit (lbm-H_2O/hr)

BPKW - Base power (KW)

TNFBP - Total net [updated] fan brake horsepower (bhp)

COMMON

WRA_k - Return air humidity ratio, system k (lbm-H_2O/lbm-dry air)

DRA_k - Return air density, system k (lbm/ft^3)

$CFMS_i$ - Supply air flow rate, zone i (variable)(ft^3/min)

QSI_i - Sensible thermal load, zone i (Btu/hr)

TS_i - Supply air temperature, zone i (°F)

WZ_i - Calculated humidity ratio, zone i (lbm-H_2O/lbm-dry air)

$WREQD_i$ - Required humidity ratio, zone i (lbm-H_2O/lbm-dry air)

$QCLNM_i$ - Monthly accumulation of cooling loads not met, (zone i) * $MULT_i$ (Btu)

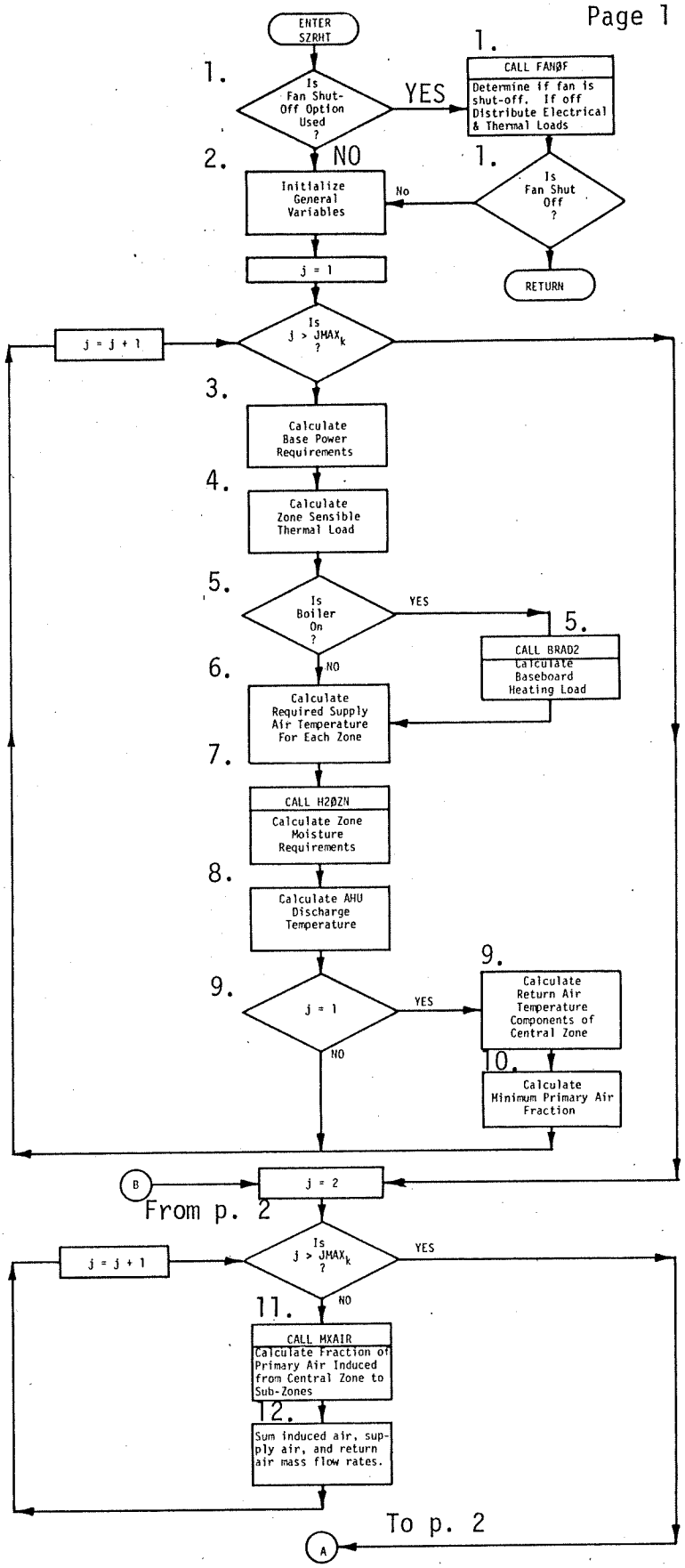
$QCPNM_i$ - Monthly peak cooling load not met, zone i (Btu/hr)

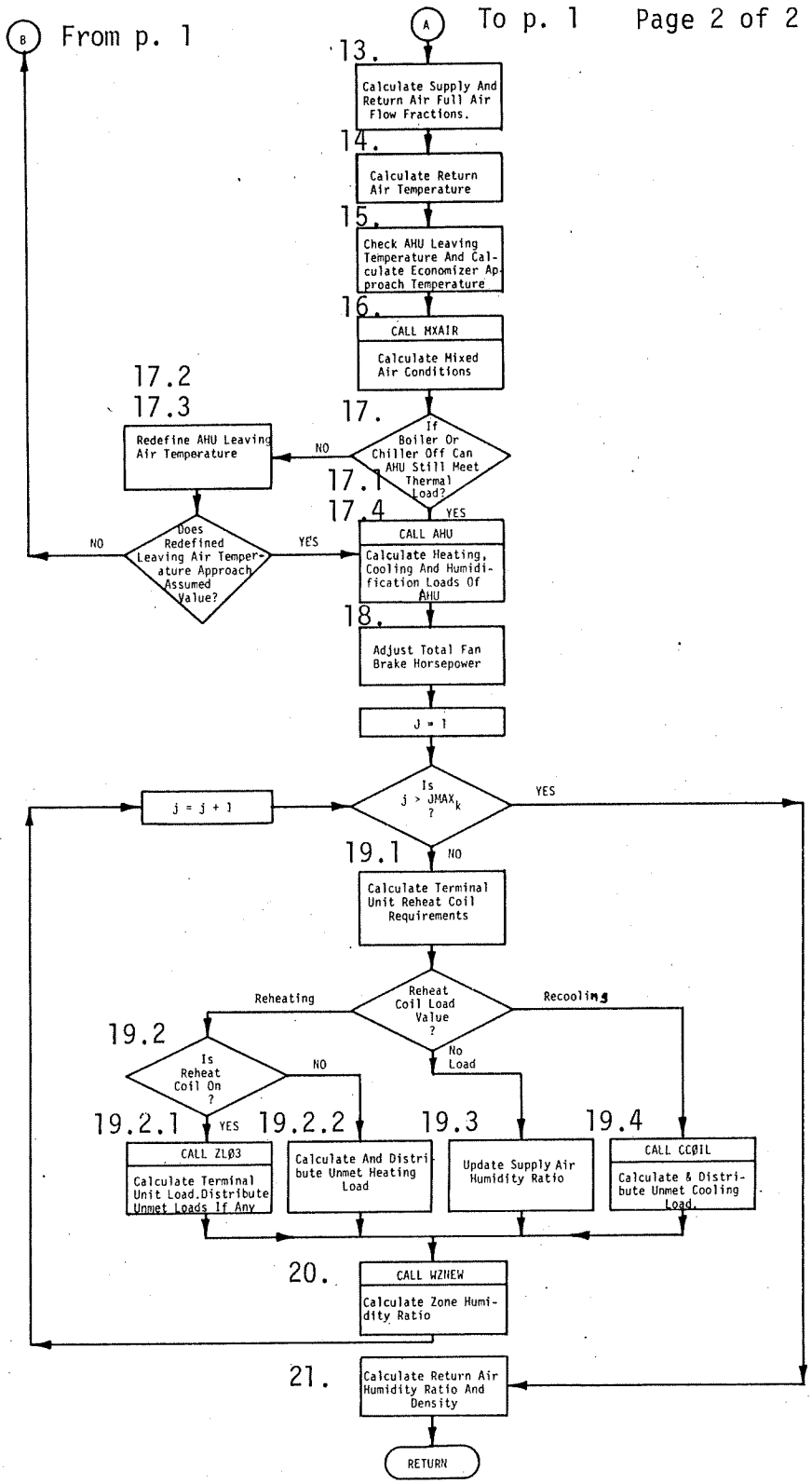
$IHCNM_i$ - Number of hours cooling load not met, zone i (hrs)

$QHLNM_i$ - Monthly accumulation of heating loads not met, (zone i) * $MULT_i$ (Btu)

$QHPNM_i$ - Monthly peak heating load not met, zone i (Btu/hr)

$IHHNM_i$ - Number of hours heating load not met, zone i (hrs)


ENTER SZRHT
1.
Is Fan Shut-Off Option Used ?
YES
NO
1.
CALL FANØF
Determine if fan is shut-off. If off Distribute Electrical & Thermal Loads
1.
Is Fan Shut Off ?
No
RETURN
2.
Initialize General Variables
j = 1
j = j + 1
Is j > JMAXk ?
3.
Calculate Base Power Requirements
4.
Calculate Zone Sensible Thermal Load
5.
Is Boiler On ?
YES
NO
5.
CALL BRAD2
Calculate Baseboard Heating Load
6.
Calculate Required Supply Air Temperature For Each Zone
7.
CALL HØZN
Calculate Zone Moisture Requirements
8.
Calculate AHU Discharge Temperature
9.
j = 1
YES
NO
9.
Calculate Return Air Temperature Components of Central Zone
10.
Calculate Minimum Primary Air Fraction
B
From p. 2
j = 2
j = j + 1
Is j > JMAXk ?
YES
NO
11.
CALL MXAIR
Calculate Fraction of Primary Air Induced from Central Zone to Sub-Zones
12.
Sum induced air, supply air, and return air mass flow rates.
To p. 2
A


B
From p. 1
A
To p. 1
13.
Calculate Supply And Return Air Full Air Flow Fractions.
14.
Calculate Return Air Temperature
15.
Check AHU Leaving Temperature And Calculate Economizer Approach Temperature
16.
CALL MXAIR
Calculate Mixed Air Conditions
17.
If Boiler Or Chiller Off Can AHU Still Meet Thermal Load?
NO
YES
17.1
17.2
17.3
Redefine AHU Leaving Air Temperature
Does Redefined Leaving Air Temperature Approach Assumed Value?
NO
YES
17.4
CALL AHU
Calculate Heating, Cooling And Humidification Loads Of AHU
18.
Adjust Total Fan Brake Horsepower
J = 1
Is j > JMAXk ?
YES
NO
j = j + 1
19.1
Calculate Terminal Unit Reheat Coil Requirements
Reheat Coil Load Value ?
Reheating
Recooling
No Load
19.2
Is Reheat Coil On ?
NO
YES
19.2.1
CALL ZLØ3
Calculate Terminal Unit Load.Distribute Unmet Loads If Any
19.2.2
Calculate And Distribute Unmet Heating Load
19.3
Update Supply Air Humidity Ratio
19.4
CALL CCØIL
Calculate & Distribute Unmet Cooling Load.
20.
CALL WZNEW
Calculate Zone Humidity Ratio
21.
Calculate Return Air Humidity Ratio And Density
RETURN

CALCULATION SEQUENCE

1. Fan on/off check.

   If it desired to turn off fan when possible (IFAN > 0), call subroutine FANØF to determine whether the fan can be turned off for the current hour (IØØ = 1 is off; IØØ = 0 is on); otherwise, go to calculation 2.

   If the system is off (IØØ = 1), terminate SZRHT simulation for the current hour.

   If the system is on (IØØ = 0), go to Calculation 2.

   If fans run continuously (IFAN = 0), go to Calculation 2.

2. Initialize general variables.

BPKW	=	0.0	(Sum of zone base power, KW)
SMTRA	=	0.0	(Weighted sum of return air temperatures, (°F-lbm-air)/hr)
TQB	=	0.0	(Sum of baseboard heating loads, Btu/hr)
SZW	=	0.0	(Weighted sum of humidity ratios, (lbm-H_2O-lbm-air)/(lbm-dry air-hr))
QTRHC	=	0.0	(Sum of reheat coil loads, Btu/hr)
QPHC	=	0.0	(Preheat coil load. Not used in this subroutine, Btu/hr)
BMIN	=	0.5	(Initialize minimum primary air fraction)

3. Calculate base power requirements (BPKW); includes internal power, lights, receptables, equipment, miscellaneous (KW).

$$BPKW = \sum_{j=1,\ JMAX_k} SLPØW_z * MULT_i$$

(See note below for definition of subscript variables i, j, k, and z.)

NOTE: There is a corresponding z for each i; a relationship defined by the variable $SPACN_{k,j}$. Hence, i and z are defined by system number (k) and zone number (j).

4. Calculate sensible thermal load of each zone on this system.

$$QSI_i = QS_z + QSINF_z$$

5. Baseboard radiation.

If boiler on (IBØIL = 1), call subroutine BRAD2 to calculate baseboard radiation heat (QB_j) and to subtract QB_i from QSI_i.

Sum baseboard radiation heat,

$$TQB = \sum_{j=1,\ JMAX_k} QB_j$$

If boiler off (IBØIL = 0), CONTINUE.

6. Calculate required supply air temperature to each zone.

$$TS_i = TSP_z - QSI_i/(0.245 * ZMASS_i)$$

7. Zone humidity calculations.

Using subroutine H2ØZN, calculate total moisture requirements of zone including setpoint recovery load ($H2ØAD_i$) and moisture changes in current hour due to environmental and room effects ($H2ØAD_i$).

8. Calculate AHU discharge temperature.

TLVG = TS_i
TLVG2 = TLVG

(equals temperature of supply air to central zone (j = 1)).

9. Calculate return air temperature components of central zone.

9.1 If j not equal to 1 (not central zone),

Go to calculation 11.

NOTE: Since the System and Equipment Simulation Program is capable of using either one of the load tapes produced by NBSLD, the NECAP's (NASA's Energy and Cost Analysis Programs) Load Program, or the Variable Temperature Program as input, the following logic sequence is required.

9.2 If j equals 1 (central zone),

9.2.1 If ceiling plenum is calculated as a separate zone,

If LOAD tape is used,

$DTL2_i = 0.0$

$QLITI = QLITE_z + QS_{pl} + QLITE_{pl} + QSINF_{pl}$

Go to calculation 9.3

If VARIABLE TEMPERATURE tape is used,

$$DTL2_i = STEMP_{p1} - TSP_z$$

$$QLITI = QLITE_z$$

Go to calculation 9.3.

9.2.2 If ceiling plenum is not calculated as a separate zone,

$$DTL2_i = 0.0$$

$$QLITI = QLITE_z$$

9.3 Sum central zone return air temperature components:

$$DTL = QLITI/(0.245 * ZMASR_i)$$

$$TRA1 = TSP_z + DTL + DTL2$$

$$TSP1 = TSP_z$$

$$DTL1 = DTL$$

$$DTL21 = DTL2$$

$$AMUL1 = MULT_i$$

$$ZMASR1 = ZMASS_i * MULT_i$$

10. Calculate minimum primary air fraction (BMIN).

$$BMIN2_i = 1. - (FMASS_k - ZMAS1)/ZMASR_i$$

where

$BMIN2_i$ = intermediate BMIN term

ZMAS1 = $(ZMASS_i * MULT_i)$ of first zone (j = 1), system k

If $BMIN2_i$ greater than BMIN and less than 1.0,

$$BMIN = BMIN2_i$$

11. Calculate fraction of primary air induced from central zone into subzones.

Call subroutine MXAIR to calculate fraction of primary air required ($BETA_i$) to meet or approach required temperature (TS_i). Calculate mixed air temperature (TSMIX), humidity ratio (WMIX), and density (DMIX).

12. Sum induced air mass flow rate (RMASI), supply air mass flow rate (FMAS), and return air mass flow rate (FMR).

$$RMASI = \sum_{j=2,}^{JMAX_k} ZMASS_i * (1. - BETA_i) * MULT_i$$

$$FMAS = \left[\sum_{j=2,}^{JMAX_k} ZMASS_i * BETA_i * MULT_i\right] + ZMAS1$$

$$FMR = FMASR_k - RMAS1$$

13. Calculate supply and return air fractions of full air flow (PCTSA, PCTRA).

$$PCTSA = FMAS/FMASS_k$$

$$PCTRA = FMR/FMASR_k$$

14. Calculate return air temperature (TRA_k).

NOTE: Since the System and Equipment Simulation Program is capable of using either one of the load tapes produced by NBSLD, the NECAP's (NASA's Energy and Cost Analysis Programs) Load Program is input, the following logic sequence is required.

14.1 If ceiling plenum is calculated as a separate zone,

14.1.1 If LOAD tape is used,

$$DTL2_i = 0.0$$

$$QLITI = QLITE_z + QS_{pl} + QLITE_{pl} + QSINF_{pl}$$

Go to calculation 14.2.

14.1.2 If VARIABLE TEMPERATURE TAPE IS USED,

$$DTL2_i = STEMP_{pl} - TSP_z$$

$$QLITI = QLITE_z$$

Go to calculation 14.2.

14.2 If ceiling plenum is not calculated as a separate zone,

$$DLT2_i = 0.0$$

$$QLITI = QLITE_z$$

14.3 Return air temperature calculation (TRA_k).

$$DTL_i = QLITI/(0.245 * ZMASR_i)$$

$$TRA_k = [[[_{j=2,}\sum_{JMAX_k} (TSP_z + DTL_i + DTL2_i) * ZMASR_i$$

$$* MULT_i] + (TSP1 + DTL1 + DTL21) * CMASR]$$

$$/ [_{j=1,}\sum_{JMAX_k} ZMASR_i * MULT_i]] + DTFNR_k$$

$$* PTLD(NVFC_k, PCTRA)$$

where $DTL2_i$ - difference between zone and plenum temperatures as calculated by VARIABLE TEMPERATURE program.

QLITI - thermal load of plenum pl above zone z as calculated by LOAD program.

pl - LOAD program space number of plenum above zone z

CMASR - central zone return air mass flow (lbm-air/hr)

PTLD - Part load fan power function

15. Check air handler leaving temperature (TLVG) and calculate economizer approach temperature (EAT).

15.1 If AHU leaving temperature (TLVG) greater than upper limit (125°F), then

$$TLVG = 125.$$

NOTE: TLVG originally set equal to TS_i (for j=1, system k).

15.2 Calculate economizer approach temperature (EAT).

$$EAT = TLVG - DTFNS_k * PTLD(NVFC_k, PCTSA)$$

If EAT less than lower limit (50°F), then

$$EAT = 50.$$

$$TLVG = EAT + DTFNS_k * PTLD(NVFC_k, PCTSA)$$

16. Calculate mixed air conditions entering preheat coil.

Call subroutine MXAIR to simulate the performance of:

1. Fixed outside and return air dampers ($MXAØ_k = 1$).
2. An enthalpy/temperature type economizer cycle ($MXAØ_k = 2$).

or 3. A temperature type economizer cycle ($MXAØ_k = 3$).

Subroutine MXAIR also calculates the thermal properties (temperature (TMA), humidity ratio (WMA), and density (DMA) of the mixed air stream.

17. Air Handling Unit (AHU).

17.1 If boiler and chiller on (IBØIL = 1 and ICHIL = 1), if chiller on and cooling called, or if boiler and heating called,

Call subroutine AHU (mode 2) to simulate the operation of a central system air handling unit. Calculate heating and cooling coil operation (QHC and QCC), the effect of fan heat, and the addition of steam (WATER) by a humidifier on the discharge side of the unit, and leaving air humidity ratio (WSUP).
Go to calculation 18.

17.2 If boiler off (IBØIL = 0) and heating required at AHU,

$$TLVG = TMA + DTFNS_k * PTLD(NVFC_k, PCTSA)$$

Go to calculation 17.4.

17.3 If chiller off (ICHIL = 0) and cooling required at AHU,

$$TLVG = TMA + DTFNS_k * PTLD(NVFC_k, PCTSA)$$

Go to calculation 17.4.

17.4 If $(TLVG - TLVG2)/TLVG < 0.001$,

Call subroutine AHU (mode 2) to simulate the operation of a central system air handling unit. Calculate heating and cooling coil operation (QHC and QCC), the effect of fan heat, and the addition of steam (WATER) by a humidifier on the discharge side of the unit.

Go to calculation 18.

If $(TLVG - TLVG2)/TLVG \geq 0.001$,

$$TLVG2 = TLVG$$

Go to calculation 11.

18. Adjust total fan brake horsepower.

$$TNFBP = TNFBP + (PTLD(NVFC_k, PCTSA) - 1.) * FBHPS_k + (PTLD(NVFC_k, PCTRA) - 1.) * FBHPR_k$$

19. Calculate reheat coil loads and distribute loads not met.

19.1 Calculate reheat coil thermal load (QT_i)

$$QT_i = ZMASS_i * 0.245 * (TLVG - TS_i)$$

19.2 If reheat load (QT_i) less than 0.0,

19.2.1 If reheat coil on (IBØIL = 1 or KREHT = 4), call subroutine ZLØ3 to calculate and sum reheat coil loads and to distribute unmet loads, if any.

Go to calculation 20.

19.2.2 If reheat coil not on (IBØIL = 0 and KREHT = 0), calculate heating load not met ($QLNM_i$).

$$QLNM_i = QT_i$$

Update as required the following variables:

$QHLNM_i$ - Sum of heating loads not met, zone i (Btu)

$QHPNM_i$ - Peak heating load not met, zone i (Btu/hr). Call subroutine MAX to do this.

$IHHNM_i$ - Number of hours heating load not met, zone i

$TS_i = TLVG$

$WTLVG = WSUP$

Go to calculation 20.

19.3 If reheat coil load (QT_i) equals 0.0, update supply air humidity ratio (WTLVG).

$$WTLVG = WSUP$$

Go to calculation 20.

19.4 If reheat coil load (QT_i) greater than 0.0, call subroutine CCØIL to calculate cooling load not met ($QLNM_i$).

Update as required the following variables:

$QCLNM_i$ - Sum of cooling loads not met, zone i (Btu)

$QCPNM_i$ - Peak cooling load not met, zone i (Btu/hr). Call subroutine MAX to do this.

$IHCNM_i$ - Number of hours cooling load not met, zone i.

TS_i = TLVG

WTLVG = WSUP

Go to calculation 20.

20. Calculate zone humidity ratio.

Using function WZNEW, calculate the humidity ratio of each zone (WZ_i).

21. Calculate return air humidity ratio (WRA_k) and density (DRA_k).

$$WRA_k = \frac{\sum_{j=1,JMAX_k} WZ_i * ZMASR_i * MULT_i}{\sum_{j=1,JMAX_k} ZMASR_i * MULT_i}$$

$$DRA_k = \frac{PATM}{(0.754 * (TRA_k + 460.)(1. + 7000. * WRA_k/4360.)}$$

SUBROUTINE: TDATA

GENERAL DESCRIPTION

This subroutine reads off load tape header data (building description information generally used by the Variable Temperature program) and advances the tape to the hourly analysis data. Data read by this subroutine used by the System and Equipment Simulation Program is given in the List of Variables/output.

LIST OF VARIABLES

INPUT

COMMON

IT - Input tape unit number

KØ - Line printer unit number

OUTPUT

FAC - Facility name

CITY - Facility location

ENGR - Name of user

PRØJ - Project number

DATE - Date

COMMON

TSP_z - Zone set point temperature (°F)

$VØL_z$ - Zone volume (ft^3)

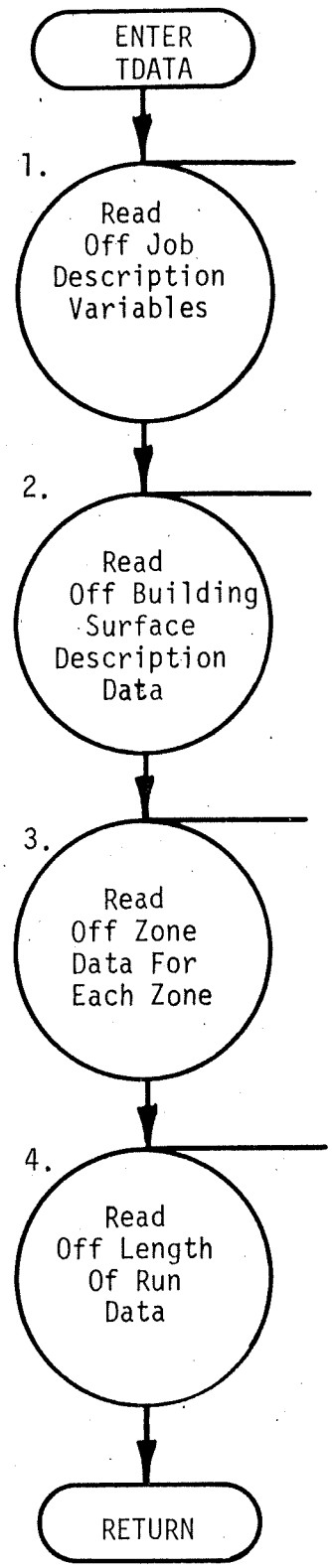
IZNMX - Number of zones to be studied

MSTRT - Month in which study begins

NDAYS - Length of study (days)

MEND - Last month of study

$IMAX_m$ - Number of hours in month m (m = 1,12)


ENTER
TDATA
1.
Read
Off Job
Description
Variables
2.
Read
Off Building
Surface
Description
Data
3.
Read
Off Zone
Data For
Each Zone
4.
Read
Off Length
Of Run
Data
RETURN

CALCULATION SEQUENCE

1. Read job description variables:

   FAC, CITY, ENGR, PRØJ, DATE

2. Read off Building surface description data.

3. Read off zone data for each zone including:

   $VØL_z$, TSP_z

4. Read off length of run data including:

   MSTRT, NDAYS, $IMAX_m$, IZNMX

   RETURN

SUBROUTINE: TEMP

GENERAL DESCRIPTION

A subroutine to calculate the dry bulb air temperature of air leaving an air handler and/or indicate the mode (heating, cooling, or changeover) of process water in a two-pipe distribution system.

LIST OF VARIABLES

INPUT

ICØ - Type of control option selected:

1) Fixed or predefined (constant).
2) Determined by zone with coldest supply air requirement.
3) Reset as inverse function of outside air dry bulb temperature.
4) Reset as direct function of outside air dry bulb temperature to a maximum, then lower to a minimum (spike). For two-pipe induction units with waterside changeover.
5) High/low step function with hysteresis at change-over. Used for two-pipe fancoil waterside change-over.
6) Determined by zone with warmest supply air requirement.

k - Fan system number

JMAXK - Number of zones on currently analyzed system

TØA - Dry bulb outside air temperature (°F)

TFIX - Fixed leaving air temperature for control mode one (°F)

$SPACN_{k,j}$ - Variable which defines zone energy distribution system relationships (calculates variable subscript i)

TS_i - Required supply air temperatures to each zone (°F)

TØACØ - Change over temperature (°F)

Following variables used for control modes (ICØ) three, four, and five:

TLAHI - Highest media temperature (°F)

TLALØ - Lowest media temperature (°F)

TDBLØ - Low ambient DB temperature corresponding to high media temperature (TLAHI) (°F)

TDBHI - High ambient DB temperature corresponding to low media temperature (TLALØ) (°F)

TCØFC - Two-pipe fan coil unit changeover temperature (^{o}F).

OUTPUT

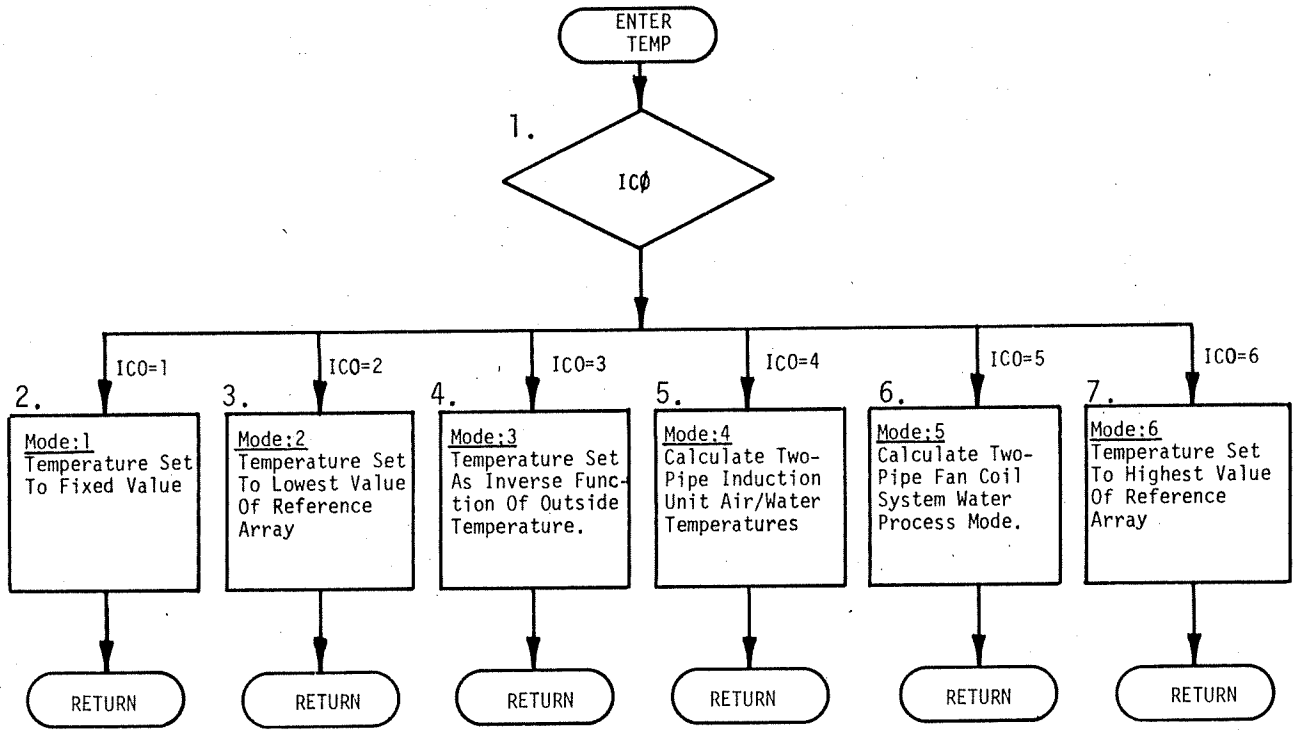
TLVG - Required dry bulb temperature of air leaving air handler (^{o}F).

TØACØ - Current changeover temperature (°F)

IPW - Induction or fan coil unit process water temperature indicator:
-1 = Hot water available.
0 = Changeover condition and/or hot and chilled water available.
+1 = Chilled water available.

CONSTANT

DT = 5. (Changeover hysteresis, °F)


ENTER TEMP
1.
ICØ
ICO=1
ICO=2
ICO=3
ICO=4
ICO=5
ICO=6
2.
Mode:1
Temperature Set To Fixed Value
3.
Mode:2
Temperature Set To Lowest Value Of Reference Array
4.
Mode:3
Temperature Set As Inverse Function Of Outside Temperature.
5.
Mode:4
Calculate Two-Pipe Induction Unit Air/Water Temperatures
6.
Mode:5
Calculate Two-Pipe Fan Coil System Water Process Mode.
7.
Mode:6
Temperature Set To Highest Value Of Reference Array
RETURN
RETURN
RETURN
RETURN
RETURN
RETURN

CALCULATION SEQUENCE

1. If ICØ = 1, go to calculation 2.

   2, go to calculation 3.

   3, go to calculation 4.

   4, go to calculation 5.

   5, go to calculation 6.

   6, go to calculation 7.

2. Mode 1. - Set temperature (TLVG) equal to fixed or predefined value.

   TLVG = TFIX

   RETURN

3. Mode 2. - Set temperature (TLVG) equal to lowest applicable value of TS_i list.

   Scan applicable TS_i variables. Set TLVG equal to lowest TS_i.

   RETURN

4. Mode 3. - Reset temperature (TLVG) as inverse function of variable TØA.

   Use function TRSET to calculate temperature (TLVG) as indicated in Figure

   RETURN

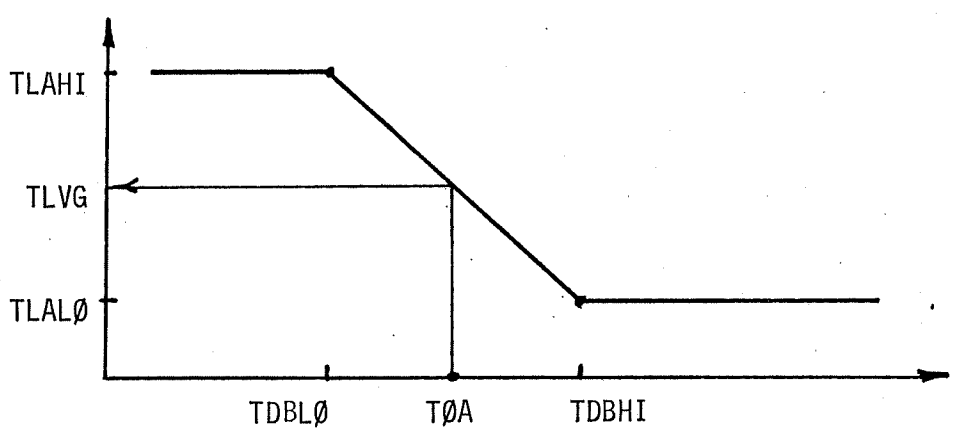


Figure ILLUSTRATION OF MODE 3 TEMPERATURE (TLVG) CALCULATION

5. Mode 4. - Two-pipe induction unit primary air schedule and process water mode indicator. See Figure for graph of this TEMP FUNCTION.

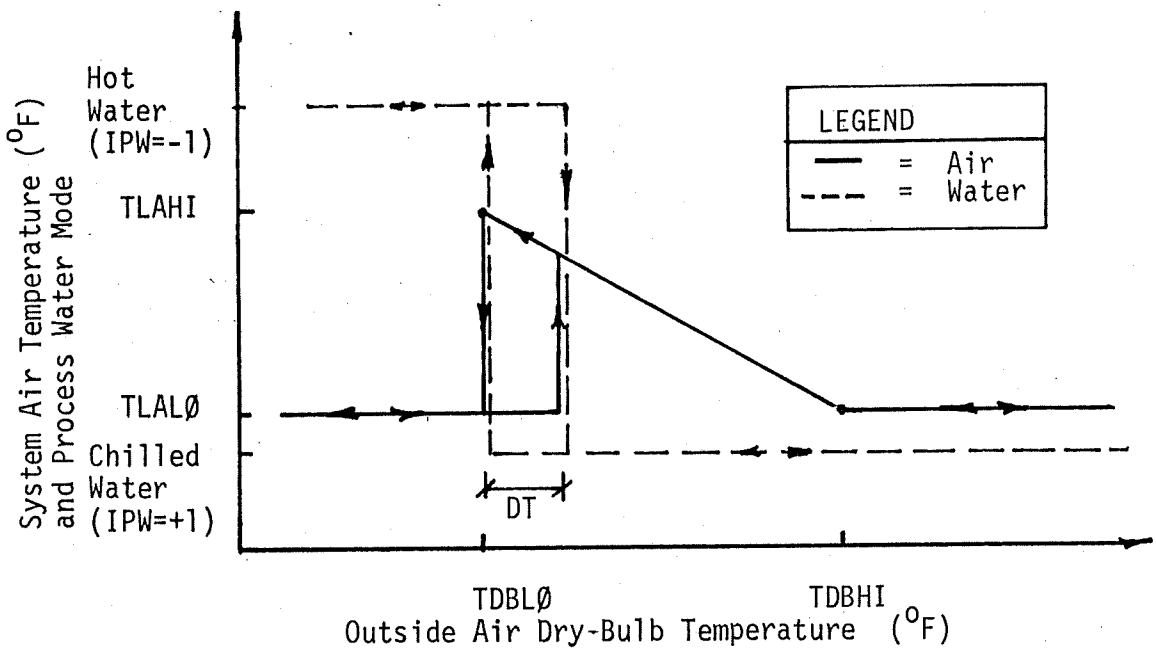


Figure ILLUSTRATION OF MODE 4 TEMP FUNCTION FOR CONTROLLING TWO-PIPE INDUCTION UNIT SYSTEM TEMPERATURES

5.1 If outside air temperature (TØA) greater than changeover temperature (TØACØ),

5.1.1 If changeover temperature (TØACØ) equals changeover low setting (TDBLØ).

Use function TRSET to calculate leaving air temperature (TLVG)

TØACØ = TDBLØ

IPW = +1 (chilled water)

RETURN

5.1.2 If changeover temperature (TØACØ) equals changeover high setting (TDBLØ + DT),

Use function TRSET to calculate leaving air temperature (TLVG).

TØACØ = TDBLØ

IPW = 0 (changeover)

RETURN

5.2 If outside air temperature (TØA) equals changeover temperature (TØACØ),

Use function TRSET to calculate leaving air temperature (TLVG).

5.2.1 If current changeover temperature (TØACØ) equals changeover low setting (TDBLØ),

TØACØ = TDBLØ + DT

IPW = 0 (changeover)

RETURN

5.2.2 If current changeover temperature (TØACØ) equals changeover high setting (TDBLØ + DT),

TØACØ = TDBLØ

IPW = 0 (changeover)

RETURN

5.3 If outside air temperature (TØA) less than changeover temperature (TØACØ),

5.3.1 If changeover temperature (TØACØ) equals changeover low setting (TDBLØ),

TLVG = TLALØ

TØACØ = TDBLØ + DT

IPW = 0 (changeover)

RETURN

5.3.2 If changeover temperature (TØACØ) equals changeover high setting (TDBLØ + DT),

TLVG = TLALØ

TØACØ = TDBLØ + DT

IPW = -1 (hot water)

RETURN

6. Mode 5. - Two-pipe fan coil waterside changeover. Based on changeover temperature with (+) or (-) 2.5°F lag. See Figure for graph of this TEMP function.

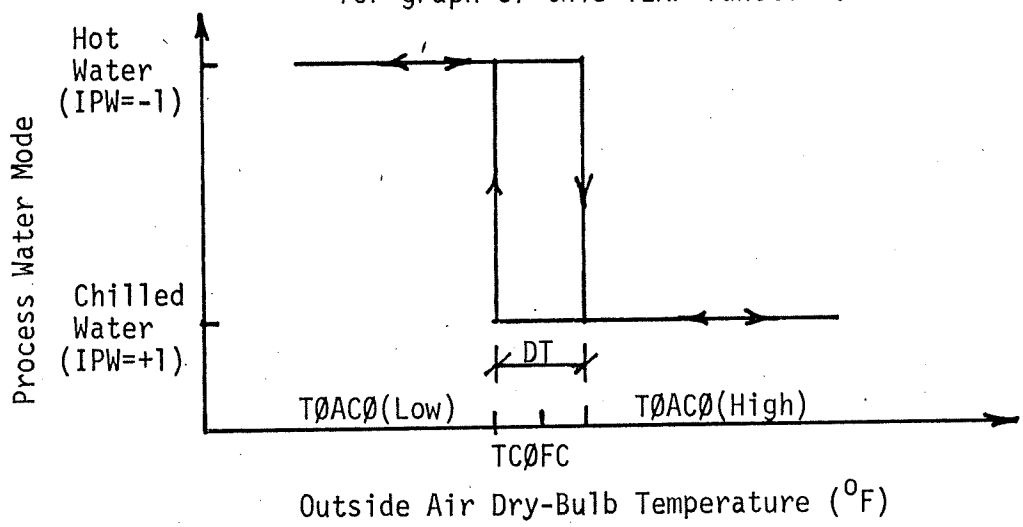


Figure ILLUSTRATION OF MODE 5 TEMP FUNCTION FOR CONTROLLING TWO-PIPE FAN COIL PROCESS WATER MODE

6.1 If outside temperature (TØA) less than changeover temperature (TØACØ),

6.1.1 If changeover temperature (TØACØ) greater than reference C.O. temperature (TCØFC),

IPW = -1 (hot water)

RETURN

6.1.2 If changeover temperature (TØACØ) less than or equal to reference C.O. temperature (TCØFC),

TØACØ = TCØFC + DT * 0.5

IPW = 0 (changeover)

RETURN

6.2 If outside air temperature (TØA) equals changeover temperature (TØACØ),

6.2.1 If changeover temperature (TØACØ) is less than or equal to reference C.O. temperature (TCØFC),

TØACØ = TCØFC + DT * 0.5

IPW = 0 (changeover)

RETURN

6.2.2 If changeover temperature (TØACØ) is greater than reference C.O. temperature (TCØFC),

TØACØ = TCØFC - DT * 0.5

IPW = 0 (changeover)

RETURN

6.3 If outside air temperature (TØA) is greater than changeover temperature (TØACØ),

6.3.1 If changeover temperature (TØACØ) greater than or equal to reference C.O. temperature (TCØFC),

TØACØ = TCØFC - DT * 0.5

IPW = 0 (changeover)

RETURN

6.3.2 If changeover temperature (TØACØ) less than reference C.O. temperature (TCØFC),

IPW = +1 (chilled water)

RETURN

7. <u>Mode 6</u>. - Temperature (TLVG) set equal to highest applicable TS_i variable.

Scan applicable TS_i values. Set TLVG equal to largest TS_i.

RETURN

FUNCTION: TRSET

GENERAL DESCRIPTION

A function to calculate TRSET as an inverse linear function of outside dry-bulb temperature. TRSET is allowed to vary between the limits of THI and TLØ but not to exceed these bounds as illustrated in Figure

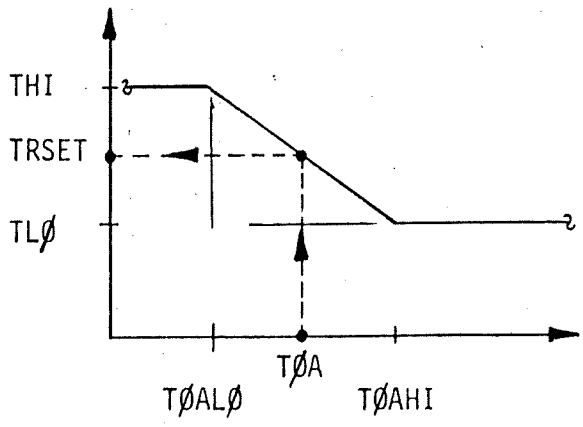


Figure SCHEMATIC OF TEMPERATURE RESET SCHEDULE HANDLED BY FUNCTION TRSET

LIST OF VARIABLES

INPUT

TØA - Outdoor air dry-bulb temperature (°F)

THI - Upper limit of controlled media temperature (°F)

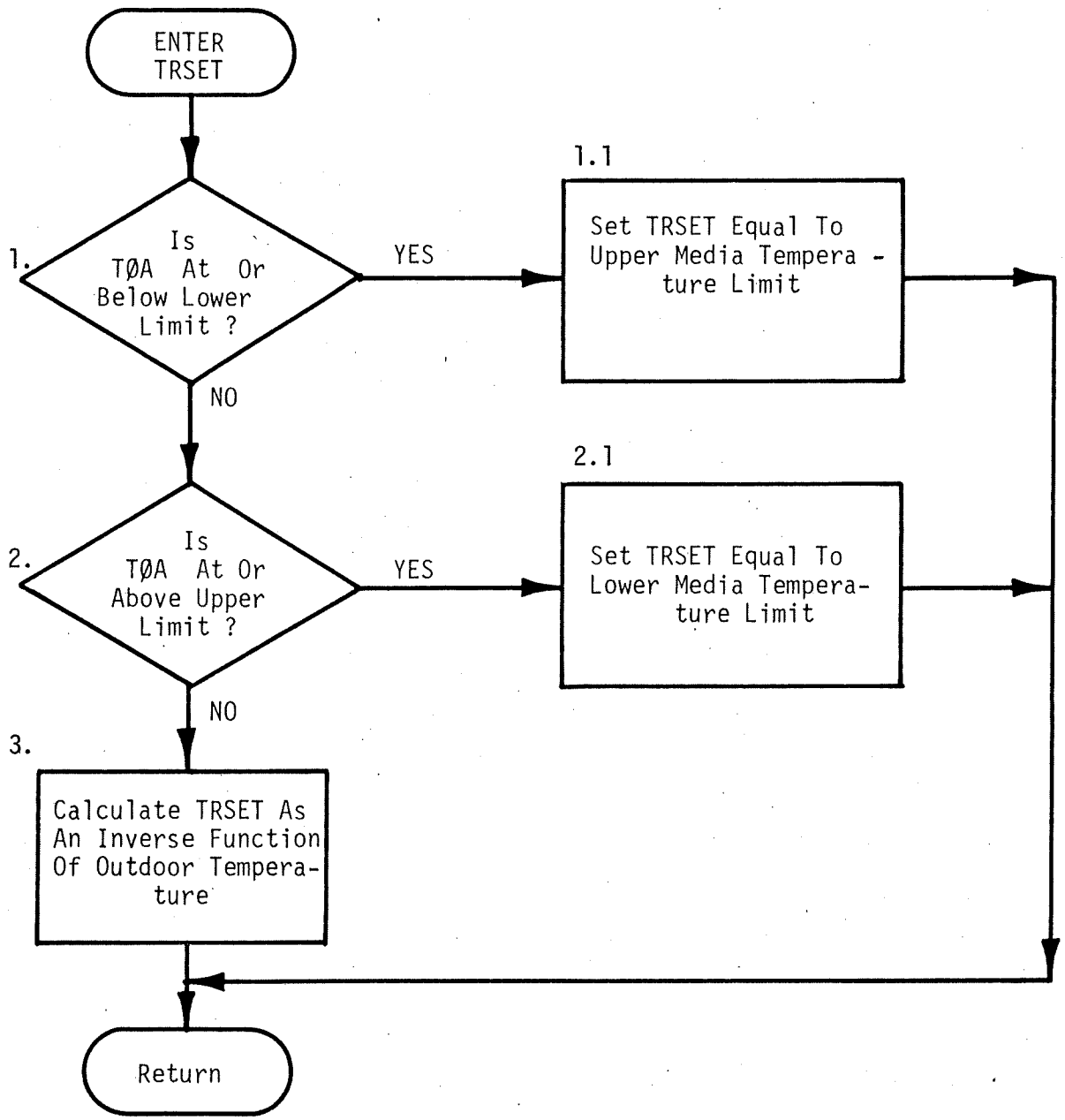
TLØ - Lower limit of controlled media temperature (°F)

TØAHI - Upper limit of outdoor air dry-bulb temperature (°F)

TØALØ - Lower limit of outdoor air dry-bulb temperature (°F)

OUTPUT

TRSET - Resulting temperature of controlled media corresponding to TØA (°F)


ENTER TRSET
1.
Is TØA At Or Below Lower Limit ?
YES
1.1
Set TRSET Equal To Upper Media Tempera - ture Limit
NO
2.
Is TØA At Or Above Upper Limit ?
YES
2.1
Set TRSET Equal To Lower Media Tempera- ture Limit
NO
3.
Calculate TRSET As An Inverse Function Of Outdoor Tempera- ture
Return

CALCULATION SEQUENCE

1. Check if outside air temperature (TØA) is below lower ambient temperature limit (TØALØ) and calculate TRSET.

   1.1 If outside air temperature (TØA) is less than or equal to lower ambient temperature limit (TØALØ), set TRSET = THI; then RETURN.

   1.2 If outside air temperature (TØA) is greater than lower ambient temperature limit (TØALØ), go to calculation 2.

2. Check if outside air temperature (TØA) is above upper ambient limit (TØAHI), and calculate TRSET as follows:

   2.1 If outside air temperature (TØA) is less than or equal to upper ambient limit (TØAHI), set TRSET = TLØ; then RETURN.

   2.2 If outside air temperature (TØA) is less than upper ambient limit (TØAHI), go to calculation 3.

3. TØA is within limits; therefore, calculate TRSET as follows.

   TRSET = (THI - (THI - TLØ) * (TØA - TØALØ))/(TØAHI - TØALØ)

   RETURN

SUBROUTINE: VARVL

GENERAL DESCRIPTION

This subroutine simulates the operation of a variable volume air distribution system. It calculates heating and cooling coil loads, baseboard heating load, reheating coil load (if specified), water requirements for humidification, and base power loads for a one-hour time period (see Figure).

The variable volume system simulated is comprised of a central air handling unit supplying primary air (at a temperature determined by the user) to variable air volume (VAV) terminal units. (See Figure for system schematic.) The air handling unit includes heating and cooling coils, mixed air section, suply air fan, and humidifier. The VAV boxes (controlled by a room thermostat) vary the amount of primary air to the space to achieve temperature control. When the space demands peak cooling, the VAV box allows maximum air flow. As space cooling requirements diminish, the primary air flow is reduced proportionately to a minimum flow rate defined as user input (default minimum = 10%). If less cooling is required that that given at minimum air flow, the reheat coil (if specified) is activated.

Other characteristics and options available with this fan system are as follows:

- Optional return air fan
- Humidifier
- Three outside air/return air options
- Baseboard heating as supplemental heating for each zone.

LIST OF VARIABLES

INPUT

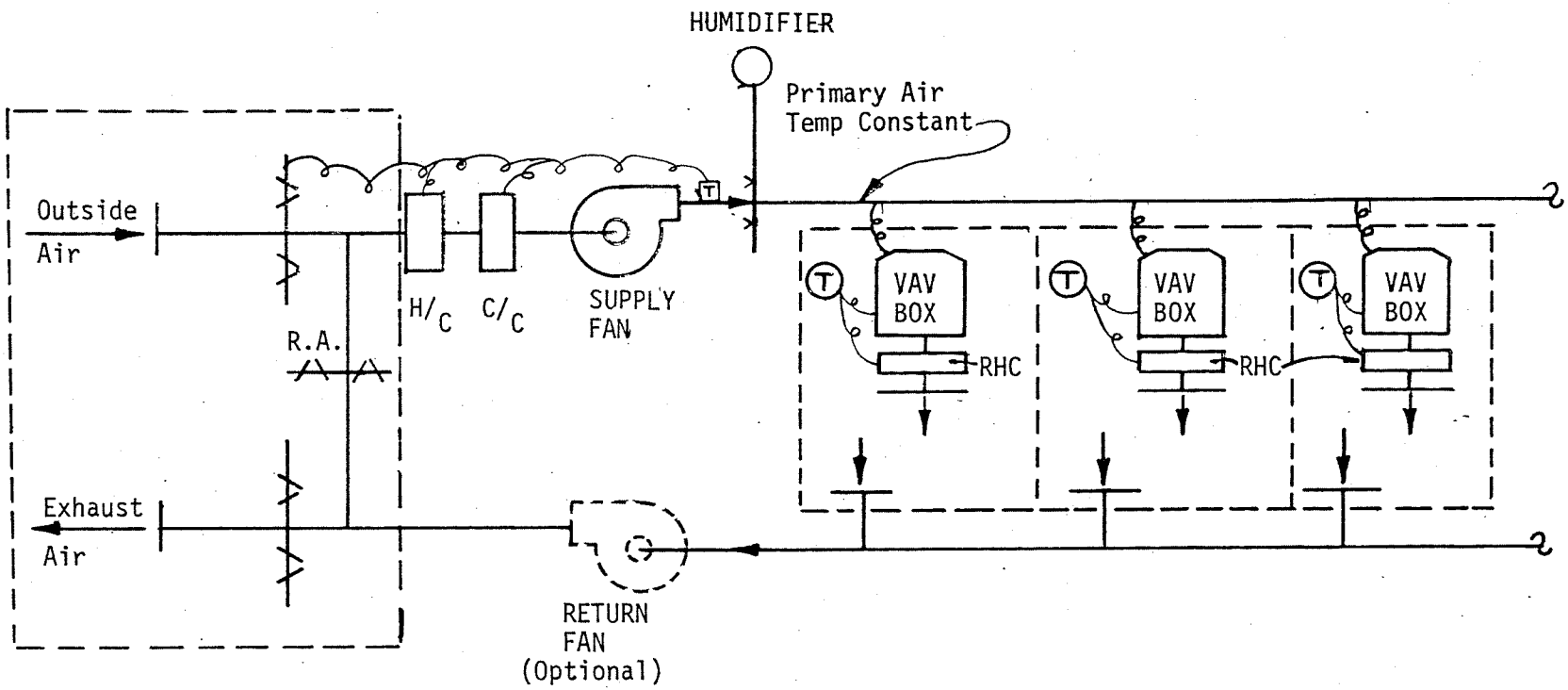
k - Energy distribution system number

TNFBP - Total net fan brake horsepower (Bhp)

COMMON

IBØIL - Boiler on/off flag (1=on; 0=off)

ICHIL - Chiller on/off flag (1=on; 0=off)



MIXED AIR

THREE OPTIONS

1. Fixed Dampers
2. Enthalpy/temp. type Economizer cycle
3. Temperature type Economizer cycle

Figure VARIABLE VOLUME FAN SYSTEM WITH OPTIONAL REHEAT (DISTRIBUTION SYSTEM NO. 12)

IFAN - Fan system shut-off flag (0=fans run continuously
1=fans may be shut off
2=fans and baseboard radiators may be shut off)

QS_z - Zone sensible load (Btu/hr)

QL_z - Zone latent load (Btu/hr)

$QLITE_z$ - Light heat into ceiling plenum above zone (Btu/hr)

$SLPØW_z$ - Space light and power (KW)

$QSINF_z$ - Zone sensible loss due to infiltration (Btu/hr)

$QLINF_z$ - Zone latent loss due to infiltration (Btu/hr)

$STEMP_z$ - Space temperature at a given hour (°F)

$UCFM_z$ - Air flow through zone if it is a plenum space (ft^3/min)

TSP_z - Zone set point temperature (°F)

$VØL_z$ - Zone volume (ft^3)

TØA - Outside air dry-bulb temperature (°F)

WØA - Outside air humidity ratio (lbm-H_2O/lbm-dry air)

HØA - Outside air enthalpy (Btu/lbm)

DØA - Outside air density (lbm/ft^3)

PATM - Barometric pressure (inches Hg)

KMAX - Number of energy distribution systems

$KFAN_k$ - Energy distribution system index

$JMAX_k$ - Number of zones on system k

$CFMAX_k$ - Design supply air of system k (ft^3/min)

$CFMEX_k$ - Exhaust air, system k (ft^3/min)

$ALFAM_k$ - Minimum fraction outside air, system k

$ØACFM_k$ - Minimum ventilation air, system k (ft^3/min)

$RHSP_k$ - Relative humidity set point, system k (% R.H.)

WSP_k - Humidity ratio set point, system k (lbm-H_2O/lbm-dry air)

$FMASS_k$ - Supply air mass, system k (lbm-air/hr)

$FMASR_k$ - Return air mass, system k (lbm-air/hr)

$FMASX_k$ - Exhaust air mass, system k (lbm-air/hr)

$FBHPS_k$ - Supply fan brake horsepower, system k (bhp)

$FBHPR_k$ - Return fan brake horsepower, system k (bhp)

$FBHPE_k$ - Exhaust fan brake horsepower, system k (bhp)

$DTFNS_k$ - Air temperature rise across supply fan, system k, at full load (°F)

$DTFNR_k$ - Air temperature rise across return fan, system k, at full load (°F)

$MXAØ_k$ - Mixed air option, system k

$ICZN_k$ - Zone in which humidistat is located, system k (a "J" number)

$IVVRH_k$ - Variable volume reheat option, system k

$NVFC_k$ - Type of fan damper control, system k

$VVMIN_k$ - Minimum air flow through variable volume boxes, system k

$TFIX1_k$ - Fixed hot deck or AHU discharge temperature, system k (°F)

$CFMX_i$ - Exhaust air flow rate, zone i (ft^3/min)

$ZMASS_i$ - Supply air mass flow, zone i (constant)(lbm-air/hr)

$ZMASX_i$ - Exhaust air mass flow, zone i (lbm-air/hr)

$ALFBR_i$ - Active length baseboard radiation, zone i (lin. ft)

$CBTU_i$ - Baseboard radiation heat output per linear foot at standard conditions, zone i (Btu/hr-lin. ft)

$IPLEN_i$ - LOAD program space number of plenum above, zone i

$SPACN_{k,j}$ - Number of space as per LOAD program, applied to system k, zone j

$MULT_i$ - Multiplication factor, zone i

KREHT - Source of reheat coil energy

WZ_i - Calculated humidity ratio, zone i (lbm-H_2O/lbm-dry air)

I - Variable subscript i

$TØALØ_n$ - Low outside air temperature at which system temperature is THI_n, reset schedule n (°F)

$TØAHI_n$ - High outside air temperature at which system temperature is $TLØ_n$, reset schedule n (°F)

$TLØ_n$ - Low system fluid temperature, reset schedule n (°F)

THI_n - High systmm fluid temperature, reset schedule n (°F)

$ISET_{k,m}$ - Reset temperature schedule index, system k, reset item m (an "n" number)

TFBHP - Total fan brake horsepower (bhp)

OUTPUT

QCC - Cooling coil load (Btu/hr)

QHC - AHU heating coil load (Btu/hr)

QTRHC - Reheat coil load (Btu/hr)

TQB - Baseboard heating load (Btu/hr)

WATER - Steam humidification supplied at air handling unit (lbm-H_2O/hr)

BPKW - Base power (KW)

TNFBP - Total net [updated] fan brake horsepower (bhp)

TLVG - Air handling unit discharge air temperature (°F)

COMMON

WRA_k - Return air humidity ratio, system k, (lbm-H_2O/lbm-dry air)

DRA_k - Return air density, system k (lbm/ft^3)

$CFMS_i$ - Supply air flow rate, zone i (variable)(ft^3/min)

$ZMAS_i$ - Supply air mass flow, zone i (variable)(lbm-air/hr)

$ZMASR_i$ - Return air mass flow, zone i (lbm-air/hr)

TS_i - Supply air temperature, zone i (°F)

QSI_i - Sensible thermal load, zone i (Btu/hr)

WZ_i - Calculated humidity ratio, zone i (lbm-H_2O/lbm-dry air)

$WREQD_i$ - Required humidity ratio, zone i (lbm-H_2O/lbm-dry air)

$QCLNM_i$ - Monthly accumulation of cooling loads not met (zone i) * $MULT_i$ (Btu)

$QCPNM_i$ - Monthly peak cooling load not met, zone i (Btu/hr)

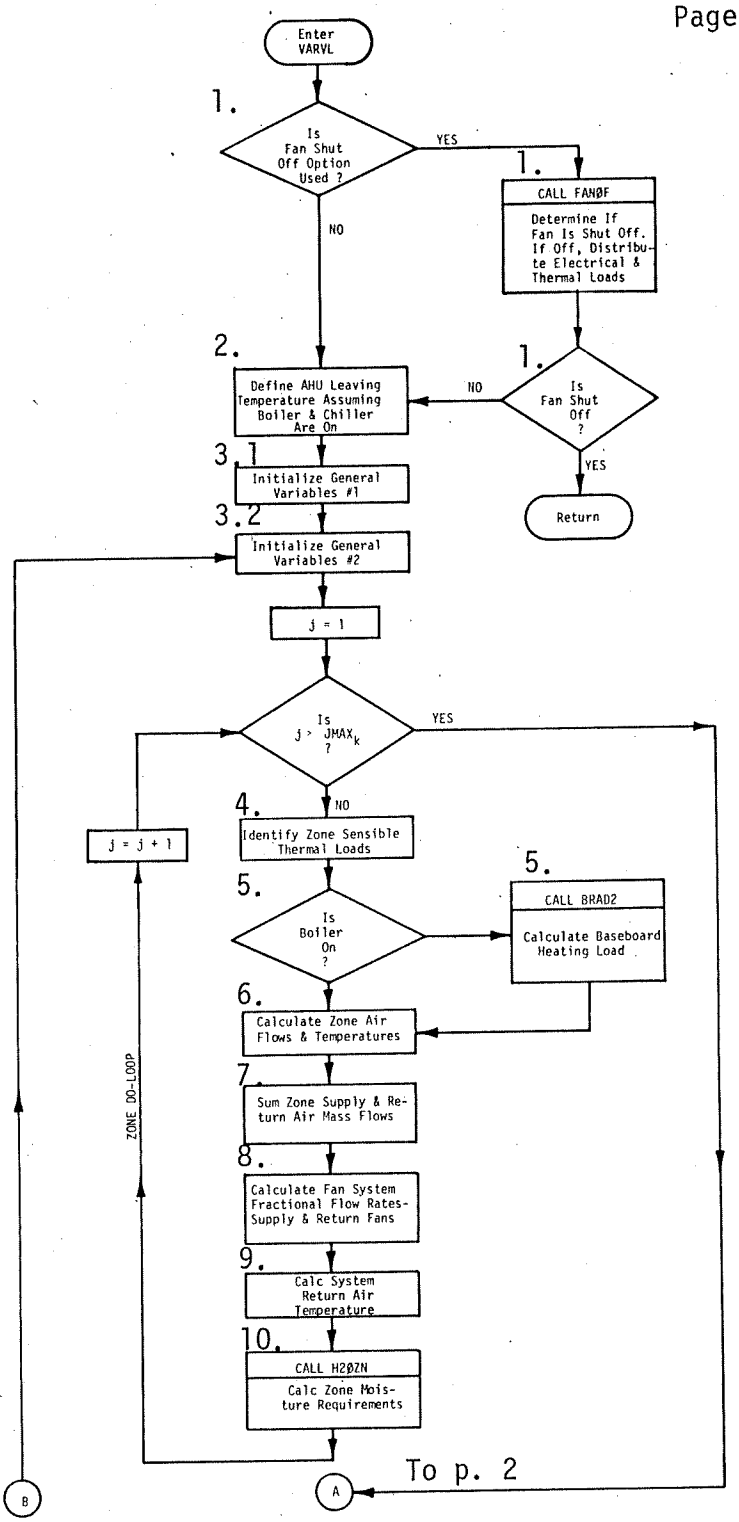
$IHCNM_i$ - Number of hours cooling load not met, zone i (hrs)

$QHLNM_i$ - Monthly accumulation of heating loads not met (zone i) * $MULT_i$ (Btu)

$QHPNM_i$ - Monthly peak heating load not met, zone i (Btu/hr)

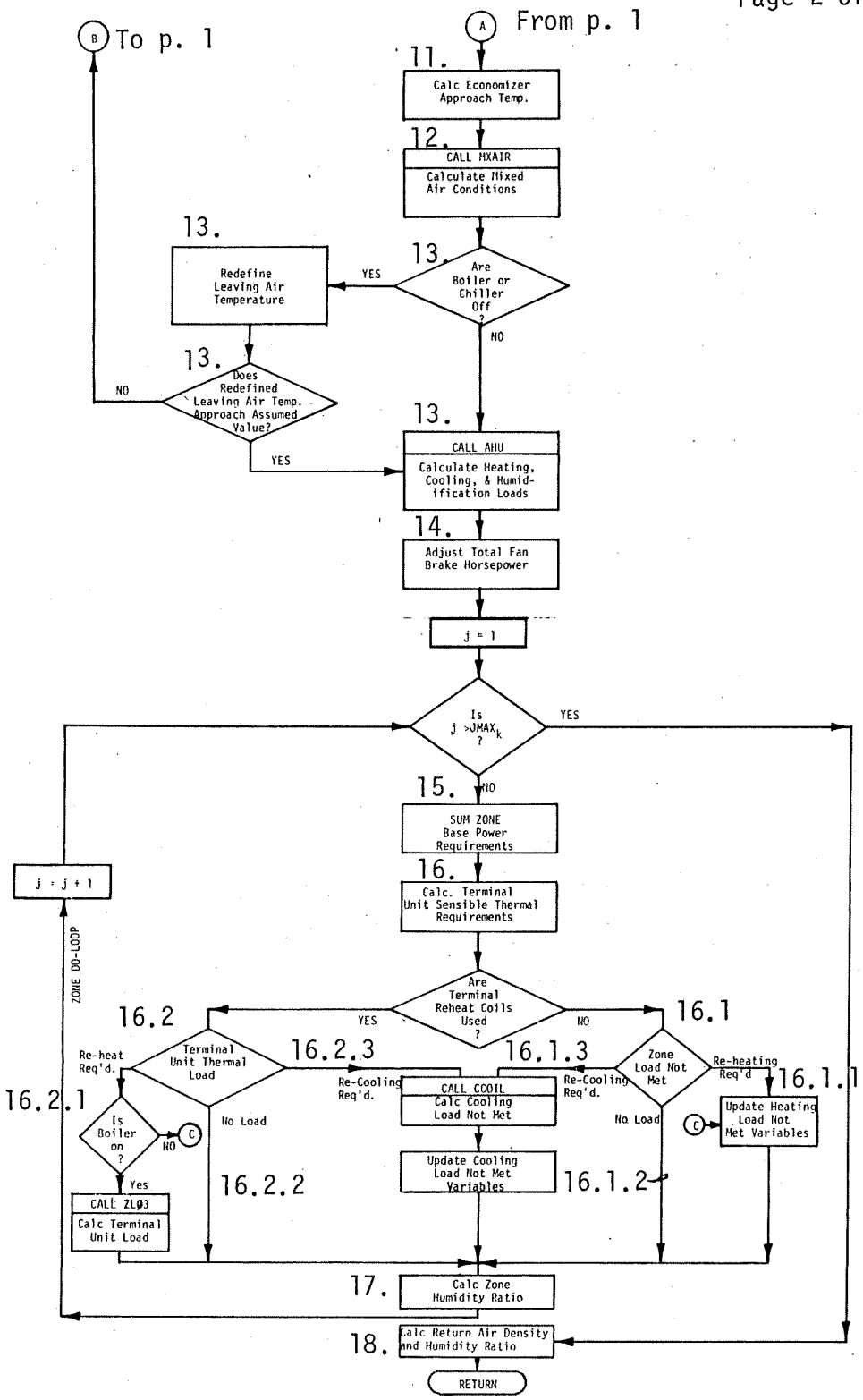
$IHHNM_i$ - Number of hours heating load not met, zone i (hrs)

SYSSIM
April 1975
SUBROUTINE: VARVL



From p. 2

To p. 2


B To p. 1
A From p. 1
11.
Calc Economizer Approach Temp.
12.
CALL HXAIR
Calculate Mixed Air Conditions
13.
Are Boiler or Chiller Off ?
YES
NO
13.
Redefine Leaving Air Temperature
13.
Does Redefined Leaving Air Temp. Approach Assumed Value?
NO
YES
13.
CALL AHU
Calculate Heating, Cooling, & Humidification Loads
14.
Adjust Total Fan Brake Horsepower
j = 1
Is j >JMAX_k ?
YES
NO
15.
SUM ZONE Base Power Requirements
16.
Calc. Terminal Unit Sensible Thermal Requirements
j = j + 1
ZONE DO-LOOP
Are Terminal Reheat Coils Used ?
YES
NO
16.2
16.1
Terminal Unit Thermal Load
16.2.3
16.1.3
Zone Load Not Met
Re-heat Req'd.
Re-Cooling Req'd.
Re-Cooling Req'd.
Re-heating Req'd
16.1.1
16.2.1
Is Boiler on ?
NO
C
No Load
CALL CCOIL
Calc Cooling Load Not Met
No Load
C
Update Heating Load Not Met Variables
Yes
16.2.2
Update Cooling Load Not Met Variables
16.1.2
CALL ZL03
Calc Terminal Unit Load
17.
Calc Zone Humidity Ratio
18.
Calc Return Air Density and Humidity Ratio
RETURN

CALCULATION SEQUENCE

1. Fan off/on check.

   If it is desired to turn off fan when possible (IFAN > 0), call subroutine FANØF to determine whether the fan can be turned off for the current hour (IØØ = 1 is off; IØØ = 0 is on); otherwise, go to calculation 2.

   If the system is off (IØØ = 1), terminate VARVL simulation for the current hour. RETURN

   If the system is on (IØØ = 0), go to calculation 2.

   If fans run continuously (IFAN = 0), go to calculation 2.

2. Identify leaving AHU air temperature.

   TLVG = $TFIX1_k$

   TLVG2 = TLVG

3. Initialize general variables.

   3.1 Variables defined once.

   IBGIN = i (zone index of this system's first zone-1)

   3.2 Variables within leaving temperature conversion loop (see calculation 13.4).

   i = IBGIN

   BPKW = 0.0 (sum of zone base power, KW)

   SMTRA = 0.0 (weighted sum of zone return air temperature quantities, lbm-°F/hr)

   TQB = 0.0 (sum of fan system's baseboard heating requirements, Btu/hr)

   SZW = 0.0 (weighted sum of zone humidity ratios, lbm-H_2O/hr)

   QTRHC = 0.0 (sum of reheat cool loads, Btu/hr)

   QPHC = 0.0 (preheat coil load, Btu/hr)

   FMAS = 0.0 (system supply air mass flow rate, lbm/hr)

   FMR = 0.0 (system return air mass flow rate, lbm/hr)

4. Identify sensible thermal load of each zone on this system (QSI_i).

$$QSI_i = QS_z + QSINF_z$$

(See note below for explanation of i and z.)

5. Baseboard radiation.

If boiler on (IBØIL = 1), call subroutine BRAD2 to calculate baseboard radiation heat (QB_j) and subtract QB_j from QSI_i.

Sum baseboard radiation heat,

$$TQB = \sum_{j=1, JMAX_k} QB_j$$

If boiler off (IBØIL = 0), continue.

6. Calculate air mass flows ($ZMAS_i$, $ZMASR_i$) and temperature (TS_i) for each zone.

6.1 Calculate supply air mass ($ZMAS_i$)

$$ZMAS_i = QSI_i/(0.245 * (TSP_z - TLVG))$$

If $ZMAS_i > ZMASS_i$ (limit zone air flow to maximum (design) value),

$$ZMAS_i = ZMASS_i$$

If $ZMAS_i < ZMASS_i * VVMIN_k$ (limit zone air flow to minimum value),

$$ZMAS_i = ZMASS_i * VVMIN_k$$

6.2 Calculate return air mass flow ($ZMASR_i$).

$$ZMASR_i = ZMAS_i - ZMASX_i$$

If $ZMASR_i < 0.0$ (limit return air flow to nonnegative values),

$$ZMASR_i = 0.0$$

6.3 Calculate required zone supply air temperature (TS_i).

$$TS_i = TSP_z - QSI_i/(0.245 * ZMAS_i)$$

NOTE: There is a corresponding z for each i; a relationship defined by the variable $SPACN_{k,j}$. Hence, i and z are defined by system number (k) and zone number (j).

7. Calculate system supply ($FMAS_k$) and return (FMR_k) mass flow rates.

$$FMAS_k = \sum_{j=1,\ JMAX_k} ZMAS_i * MULT_i$$

$$FMR_k = \sum_{j=1,\ JMAX_k} ZMASR_i * MULT_i$$

8. Calculate fraction of supply (PCTSA) and return (PCTRA) air design load flow rates.

$$PCTSA = FMAS_k/FMASS_k$$

$$PCTRA = FMR_k/FMASR_k$$

9. Calculate return air temperature (TRA_k).

NOTE: Since the System and Equipment Simulation Program is capable of using either one of the load tapes produced by NBSLD, the NECAP's (NASA's Energy and Cost Analysis Programs) Load Program, or the Variable Temperature Program as input, the following logic sequence is required.

If ceiling plenum is calculated as a separate zone,

If LOAD tape is used,

$$DTL2_i = 0.0$$

$$QLITI = QLITE_z + QS_{pl} + QLITE_{pl} + QSINF_{pl}$$

If VARIABLE TEMPERATURE tape is used,

$$DTL2_i = STEMP_{pl} - TSP_z$$

$$QLITI = QLITE_z$$

If ceiling plenum is not calculated as a separate zone,

$$DTL2_i = 0.0$$

$$QLIT_i = QLITE_z$$

$$DTL_i = QLITI/(0.245 * ZMASR_i)$$

$$TRA_k = \frac{\sum_{j=1,\ JMAX_k} (TSR_z + DTL_i + DTL2_i) * ZMASR_i * MULT_i}{\sum_{j=1,\ JMAX_k} ZMASR_i * MULT_i}$$

$$+ DTFNR_k * PTLD\ (NVFC_k, PCTRA)$$

where $DTL2_i$ - difference between zone and plenum temperatures, as calculated by NBSLD or NECAP's VARIABLE TEMPERATURE programs.

QLITI - thermal load of plenum pl above zone z, as calculated by LOAD program.

pl - LOAD program space number of plenum above zone.

PTLD ($NVFC_k$,PCTRA) - return air fan motor fraction of full load power requirement.

10. Zone humidity calculations.

Using subroutine H2ØZN, calculate total moisture requirements including set point recovery load ($H2ØRD_i$) and moisture changes in current hour due to environmental and room effects ($H2ØAD_i$).

11. Calculate economizer approach temperature (EAT).

If TLVG > TLCMX (TLCMX = 125.0°F)

TLVG = TLCMX

EAT = TLVG - $DTFNS_k$ * PTLD ($NVFC_k$,PCTSA)

If EAT < THCMN (THCMN = 40.0°F)

EAT = THCMN

TLVG = EAT + $DTFNS_k$ * PTLD ($NVFC_k$,PCTSA)

12. Calculate mixed air conditions.

Call subroutine MXAIR to simulate the performance of:

1. Fixed outside and return air dampers (MXAØ = 1).
2. An enthalpy/temperature type economizer cycle (MXAØ = 2).

   or

3. A temperature type economizer cycle (MXAØ = 3).

Subroutine MXAIR also calculates the thermal properties (temperature (TMA), humidity ratio (WMA), and density (DMA)) of the mixed air stream.

13. Air Handling Unit (AHU).

13.1 If boiler and chiller on, if chiller on and cooling called, or if boiler and heating called:

Call subroutine AHU (Mode 1) to simulate the operation of a central system air handling unit. Calculate heating and cooling coil operation (QHC and QCC), the effect of fan heat, and the addition of steam (WATER) by a humidifier on the discharge side of the unit.

Go to calculation 14.

13.2 If boiler off (IBØIL = 0) and heating required at AHU,

$$TLVG = TMA + DTFNS_k * PTLD\ (NVFC_k, PCTSA)$$

Go to calculation 13.4.

13.3 If chiller off (ICHIL = 0) and cooling required at AHU,

$$TLVG = TMA + DTFNS_k * PTLD\ (NVFC_k, PCTSA)$$

Go to calculation 13.4.

13.4 If (TLVG - TLVG2)/TLVG < 0.001 (assumed AHU leaving air temperature (TLVG2) approximately equal to calculated temperature (TLVG)),

Call subroutine AHU (Mode 1) to simulate the operation of a central system air handling unit. Calculate heating and cooling coil operation (QHC and QCC), the effect of fan heat, and the addition of steam (WATER) by a humidifier on the discharge side of the unit.

Go to calculation 14.

If (TLVG - TLVG2)/TLVG $\geq$ 0.001 (assumed AHU leaving air temperature (TLVG2) does not approximate calculated leaving air temperature (TLVG)),

$$TLVG = TLVG2 = TLVG$$

Go to calculation 3.2.

14. Adjust total fan brake horsepower (TNFBP).

$$TNFBP = TNFBP + (PTLD\ (NVFC_k, PCTSA) - 1.0) * FBHPS_k + (PTLD\ (NVFC_k, PCTRA) - 1.0) * FBHPR_k$$

15. Sum base power requirements of fan system zones (BPKW); includes internal power, lights, receptacles, equipment, miscellaneous (KW).

$$BPKW = \sum_{j=1,\ JMAX_k} SLPØW_z * MULT_i$$

16. Calculate required terminal unit thermal performance for each zone.

$$QT_i = ZMAS_i * 0.245 * (TLVG - TS_i)$$

16.1 If no reheat coils and,

16.1.1 If QT_i less than 0.0, calculate heating load not met ($QLNM_i$).

$QLNM_i = QT_i$

Update as required the following variables:

$QHLNM_i$ - Monthly consumption, zone heating load not met (includes zone multiplier) (MBTU).

$QHPNM_i$ - Monthly peak, zone heating load not met (MBH). Call subroutine MAX to do this.

$IHHNM_i$ - Monthly hours, zone heating load not met (hours).

$TS_i = TLVG$

$WTLVG_i = WSUP$ (WSUP = Supply air humidity ratio. It is calculated in subroutine AHU.)

Go to calculation 17.

16.1.2 If $QT_i = 0.0$,

$WTLVG_i = WSUP$

Go to calculation 17.

16.1.3 If QT_i greater than 0.0, calculate cooling load not met ($QLNM_i$).

$QLNM_i = QT_i$

Update as required the following variables:

$QCLNM_i$ - Monthly consumption, zone cooling load not met (includes zone multiplier) (MBTU)

$QCPNM_i$ - Monthly peak, zone cooling load not met (MBH). Call subroutine MAX to do this.

$IHCNM_i$ - Monthly hours, zone cooling load not met (hours).

TS_i = TLVG

$WTLVG_i$ = WSUP

Go to calculation 17.

16.2 If terminal has reheat coil,

16.2.1 If QT_i less than 0.0,

If boiler on (IBØIL = 1),

Call subroutine ZLØ3 to calculate and sum reheat coil loads and distribute loads not met, if any.

Go to calculation 17.

If boiler off (IBØIL = 0), calculate heating load not met ($QLNM_i$).

$QLNM_i = QT_i$

Update as required the following variables:

$QHLNM_i$ - Monthly consumption, zone heating load not met (includes zone multiplier) (MBTU).

$QHPNM_i$ - Monthly peak, zone heating load not met (MBH). Call subroutine MAX to do this.

$IHHNM_i$ - Monthly hours, zone heating load not met (hours).

TS_i = TLVG

$WTLVG_i$ = WSUP

Go to calculation 17.

16.2.2 If $QT_i = 0.0$,

$WTLVG_i$ = WSUP

16.2.3 If QT_i greater than 0.0, calculate cooling load not met ($QLNM_i$).

Call subroutine CCØIL to calculate cooling load not met.

Update as required the following variables:

$QCLNM_i$ - Monthly consumption, zone cooling load not met (includes zone multiplier) (MBTU).

$QCPNM_i$ - Monthly peak, zone cooling load not met (MBH). Call subroutine MAX to do this.

$IHCNM_i$ - Monthly hours, zone cooling load not met (hours).

TS_i = TLVG

$WTLVG_i$ = WSUP

Go to calculation 17.

17. Calculate zone humidity ratio.

Using function WZNEW, calculate the humidity ratio of each zone (WZ_i).

18. Calculate return air humidity ratio and density.

$$WRA_k = \frac{\sum_{j=1,}^{JMAX_k} WZ_i * ZMASR_i * MULT_i}{\sum_{j=1,}^{JMAX_k} ZMASR_i * MULT_i}$$

$$DRA_k = \frac{PATM}{(0.754 * (TRA_k + 460.)(1. + 7000. * WRA_k/4360.)}$$

FUNCTION: WZNEW

GENERAL DESCRIPTION

This function calculates the resulting end-of-hour zone humidity ratio based on humidity ratio from previous hour and a water balance of the following moisture sources: people and process loads, infiltration loads, and zone supply air.

LIST OF VARIABLES

INPUT

TSP - Zone set point temperature (°F)

TLC - Zone supply air temperature (°F)

WLC - Zone supply air humidity ratio (lbm-H_2O/lbm-dry air)

PATM - Outside barometric pressure (inches Hg)

CFMS - Zone supply air flow rate (ft^3/min)

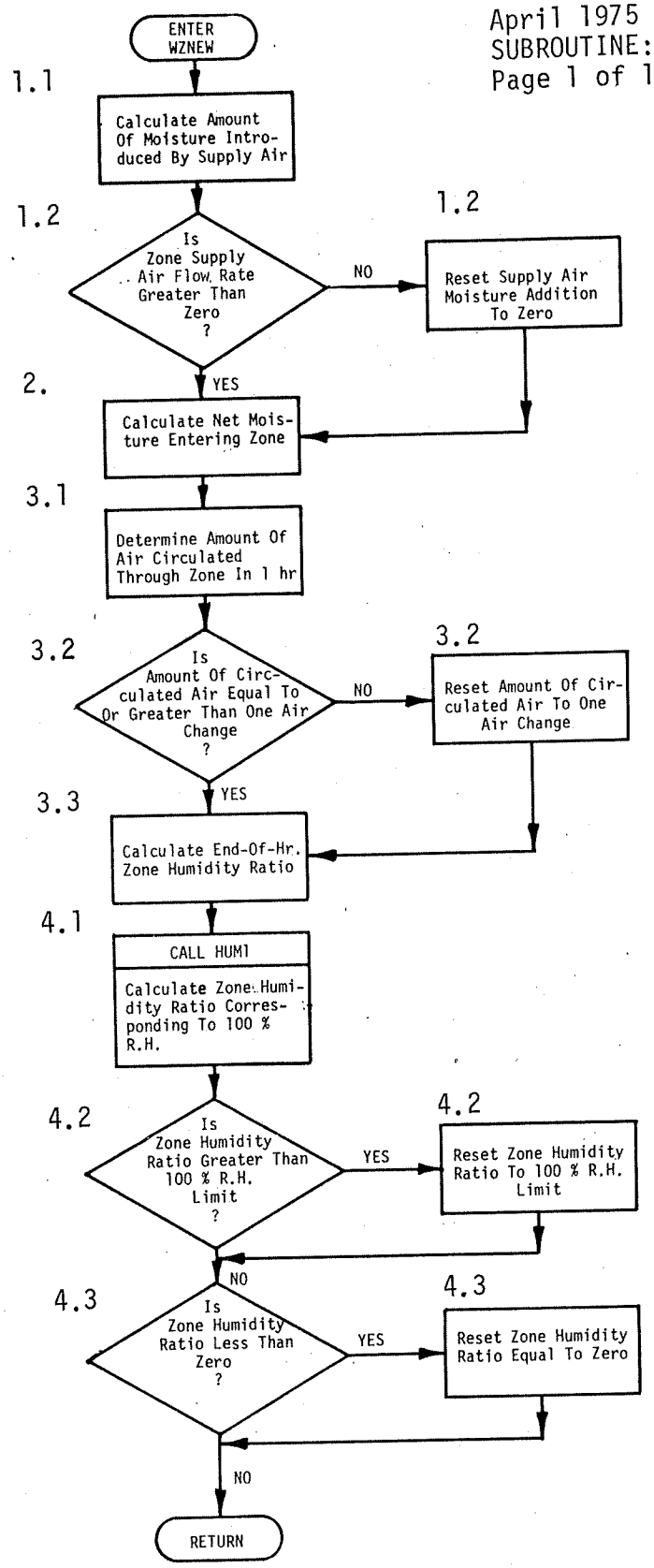
VØL - Zone volume (ft^3)

H2ØAD - Zone air water change for current hour due to people, process, and infiltration load (lbm-H_2O)

WZ - Zone humidity ratio from previous hour (lbm-H_2O/lbm-dry air)

OUTPUT

WZNEW - New zone humidity ratio (lbm-H_2O/lbm-dry air)


ENTER WZNEW
1.1
Calculate Amount Of Moisture Introduced By Supply Air
1.2
Is Zone Supply Air Flow Rate Greater Than Zero ?
NO
1.2
Reset Supply Air Moisture Addition To Zero
YES
2.
Calculate Net Moisture Entering Zone
3.1
Determine Amount Of Air Circulated Through Zone In 1 hr
3.2
Is Amount Of Circulated Air Equal To Or Greater Than One Air Change ?
NO
3.2
Reset Amount Of Circulated Air To One Air Change
YES
3.3
Calculate End-Of-Hr. Zone Humidity Ratio
4.1
CALL HUM1
Calculate Zone Humidity Ratio Corresponding To 100 % R.H.
4.2
Is Zone Humidity Ratio Greater Than 100 % R.H. Limit ?
YES
4.2
Reset Zone Humidity Ratio To 100 % R.H. Limit
NO
4.3
Is Zone Humidity Ratio Less Than Zero ?
YES
4.3
Reset Zone Humidity Ratio Equal To Zero
NO
RETURN

CALCULATION SEQUENCE

1. Calculate moisture (lbm-H_2O/hr) introduced by zone supply air.

   1.1 If CFMS greater than or equal to 0.0,

   H2ØS2 = CFMS * DLVG * 60.0 * (WLC - WZ)

   where DLVG is density of zone supply air and is obtained by calling function DENSY using parameters TLC, WLC, and PATM.

   Go to calculation 2.

   1.2 If CFMS is less than 0.0, set

   H2ØS2 = 0.0

2. Calculate net moisture (DH2Ø) entering zone.

   DH2Ø = H2ØS2 + H2ØAD

3. Calculate new zone humidity ratio (WZNEW).

   3.1 Determine the amount of air circulated in one hour by fan system.

   AIR = CFMS * 60.0

   3.2 To remain within the parameters of the water balance technique, limit the amount of air seen by the zone in one hour (AIR) to a minimum of one air change per hour; therefore, if AIR less than VØL, reset.

   AIR = VØL

   3.3 Calculate zone end-of-hour humidity ratio.

   WZNEW = WZ + DH2Ø/(AIR * DLVG)

4. Check to ensure resulting humidity ratio (WZNEW) is within limits.

   4.1 Call subroutine HUM1 and determine the humidity ratio (WCØND) corresponding to 100% relative humidity.

   4.2 If WZNEW greater than WCØND, reset

   WZNEW = WCØND

   RETURN

4.3 If WZNEW less than 0.0, reset

```
WZNEW = 0.0
RETURN
```

SUBROUTINE: ZLØ3

GENERAL DESCRIPTION

A Zone Load Organizing subroutine to calculate terminal unit thermal loads to reheat and recooling coils. These are then checked against maximum and minimum leaving coil temperatures. Thermal loads met and unmet, positive and negative are broken out and summed.

LIST OF VARIABLES

INPUT

IQ - Coil type index (1 = heating; 2 = cooling)

AMULT - Zone multiplication factor

TLC - Desired leaving coil temperature (°F)

TEC - Entering coil temperature (°F)

WEC - Entering coil humidity ratio (lbm-H_2O/lbm-dry air)

TLCMX - Maximum allowable leaving coil temperature (°F)

TLCMN - Minimum allowable leaving coil temperature (°F)

QTRHC - System reheat load (Btu/hr)

QTRCC - System recooling load (Btu/hr)

COMMON

PATM - Barometric pressure (in. Hg.)

$ZMAS_i$ - Supply air mass flow, zone i (lbm-air/hr)

I - Subscript variable i

OUTPUT

WLVG - Leaving humidity ratio (lbm-H_2O/lbm-dry air)

QTRHC - System reheat load (Btu/hr)

QTRCC - System recooling load (Btu/hr)

COMMON

$QCLNM_i$ - Monthly accumulation of cooling loads not met, (zone i) * $MULT_i$ (Btu)

$QCPNM_i$ - Monthly peak cooling load not met, zone i (Btu/hr)

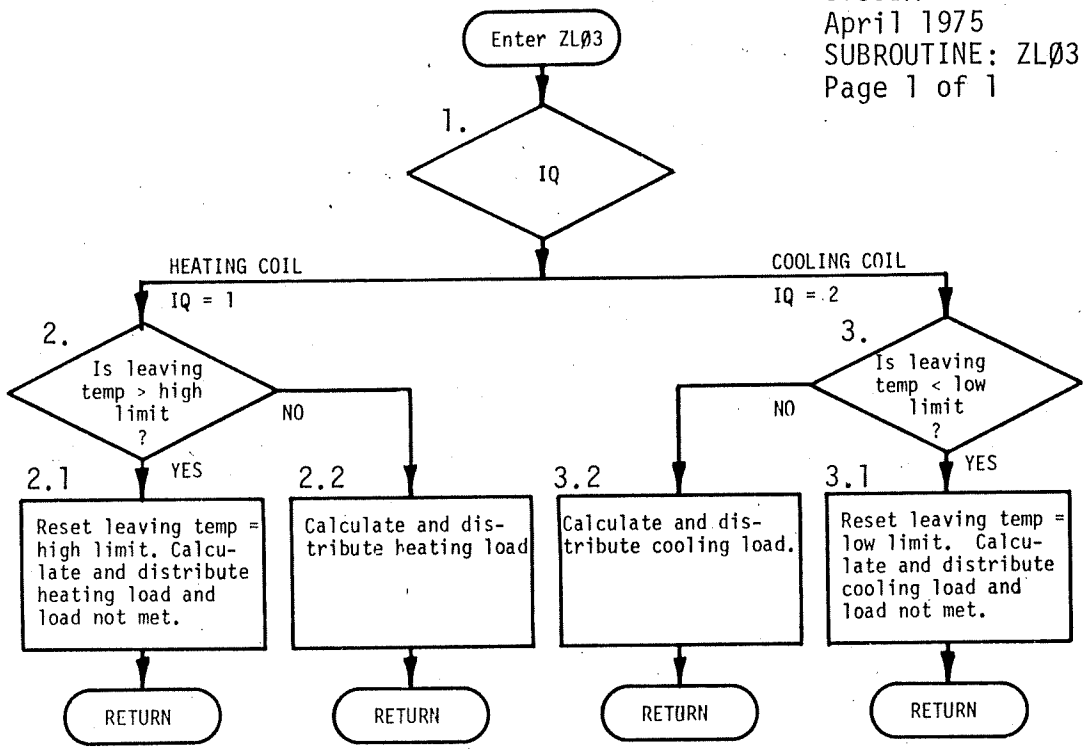
$IHCNM_i$ - Number of hours cooling load not met, zone i (hrs)

$QHLNM_i$ - Monthly accumulation of heating loads not met (zone i) * $MULT_i$ (Btu)

$QHPNM_i$ - Monthly peak heating load not met, zone i (Btu/hr)

$IHHNM_i$ - Number of hours heating load not met, zone i (hrs)

SYSSIM
April 1975
SUBROUTINE: ZLØ3
Page 1 of 1



CALCULATION SEQUENCE

1. Determine type of coil to be simulated.

   IF IQ = 1, GO to calculation 2 (heating).
   IF IQ = 2, GO to calculation 3 (cooling).

2. Heating required.

   2.1 IF required leaving temperature (TLC) greater than high temperature limit (TLCMX), calculate heating load (QT) and add to heating sum (QTRHC). Distribute heating load not met (QTDIF).

   TDIF = TLCMX - TLC

   TLC = TLCMX

   $QTDIF = ZMAS_i * 0.245 * (TDIF - TLC)$

   $QT = ZMAS_i * 0.245 * (TEC - TLC)$

   QTRHC = QTRHC + QT

   Update as required, heating load not met variables.

   $QHLNM_i$ - Sum of heating loads not met, zone i (Btu/hr)

   $QHPNM_i$ - Peak heating load not met, zone i (Btu/hr). Call subroutine MAX to do this.

   $IHHNM_i$ - Hours heating load not met, zone i

   Leaving humidity ratio (WLVG) equals entering humidity ratio (WEC).

   RETURN

   2.2 IF TLC less than or equal TLCMX, calculate heating load (QT) and add to sum (QTRHC).

   $QT = ZMAS_i * 0.245 * (TEC - TLC)$

   QTRHC = QTRHC + QT * AMULT

   Leaving humidity ratio (WLVG) equals entering humidity ratio (WEC).

WLVG = WEC

RETURN

3. Cooling required.

3.1 IF required leaving dry bulb temperature (TLC) less than low temperature limit (TLCMN), calculate cooling load (QT) and add to cooling sum (QTRCC). Distribute cooling loads not met (QTDIF).

Call subroutine CCØIL to calculate cooling load (QCTLC) if TLC were allowed to be met.

Call subroutine CCØIL to calculate cooling load (QT) with TLC limited to TLCMN.

QTRCC = QTRCC + QT * AMULT

TLC = TLCMN

QTDIF = QCTLC - QT

Update the following variables as required:

$QCLMN_i$ - Sum of cooling loads not met, zone i (Btu)

$QCPNM_i$ - Peak cooling load not met, zone i (Btu/hr). Call subroutine MAX to do this.

$IHCNM_i$ - Number of hours cooling load not met, zone i

RETURN

3.2 IF TLC greater than or equal TLCMN, calculate cooling load (QT) and add to cooling sum (QTRCC).

Call subroutine CCØIL to calculate cooling load QT

QTRCC = QTRCC + QT * AMULT

RETURN