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FINAL REPORT

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DOCUMENTATION OF
SYSTEM AND EQUIPMENT
SIMULATION PROGRAM

ENGINEERING MANUAL WITH FLOWCHARTS
APRIL 1975
VOLUME I

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DOCUMENTATION OF SYSTEM AND EQUIPMENT SIMULATION PROGRAM

ENGINEERING MANUAL WITH FLOWCHARTS

APRIL 1975

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Champaign, Illinois

Prepared by

GENERAL AMERICAN RESEARCH DIVISION
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SYSTEM AND EQUIPMENT SIMULATION PROGRAM

OBJECTIVE AND DESCRIPTION

Due to outside air requirements and the limitations imposed by various component control schedules, the hourly heating and cooling requirements of a building's boilers and chillers may differ markedly from the summation of hourly heating and cooling space loads. The System and Equipment Simulation Program, therefore, performs two functions. First, it translates hourly space loads, including the ventilation air requirements, by means of the individual performance characteristics of each fan system, into the hourly thermal requirements imposed upon the heating and cooling plants. Second, it converts these hourly energy requirements into fuel and power requirements based upon the part-load characteristics of the heating and cooling plant equipment.

The System and Equipment Simulation Program is made up of a number of functions and subroutines. (See Table   for a description of these routines.) The main routine, SYSSIM, directs the flow of logic through the program and controls the order in which calculations are to be performed. The sequence of the calculations is as follows. First, the zone air flows are determined using the peak hourly heating and cooling zone loads. Next, fans and fan motors are sized based on air flows and system pressures. In this segment, central equipment is also sized. Then, an hour-by-hour analysis of the building's energy distribution systems is performed. Each system is examined each hour and the hourly heating and/or cooling loads calculated and summed to give the building's heating and/or cooling requirements. At the end of an hour's calculations, after the last thermal distribution system has been examined and any snow-melting load accounted for, the EQUIP subroutine is called upon to convert the hourly building thermal requirements into hourly heating, cooling, and on-site generation (if applicable) energy requirements. This series of calculations is repeated hourly for the length of time called for (up to one year). The output is organized in terms of monthly energy and resource requirements for the building equipment combination in question. An annual summary of the energy and resource consumption is then printed out as a permanent record.

The sequence of calculations outlined above is the same for a heat conservation equipment combination, except that: (1) zone air flows are sized differently, (2) other supplemental heating requirements must be accounted for, and (3) specialized treatment of the double-bundled condenser refrigeration machines is necessary.

In order to follow the notations of the engineering manual, an understanding of variable organization as it pertains to zone labeling is required (see Figure '). The re-numbering of zones internally by the program has resulted in increased flexibility to the user and a reduction of computer storage requirements. As regards assigning zones to energy distribution systems, the user need not be concerned with zone sequence when generating the load tape. They may be specified in any order. Zones may be omitted or repeated.

Regarding the program structure, a storage requirement savings is realized since variables which were once doubly-subscripted may now be singly subscripted. An example of this potential savings using the example of Figure zone/system relationships is illustrated in Figure Input tape variables ("z" numbers) are assigned via variable $SPACN_{k,j}$. Each zone "j" of system "k" has a corresponding "i". Thus, one doubly-subscripted variable ($SPACN_{k,j}$) is used to identify the particular "z" variable location of a given zone on a given system.

LOAD PROGRAM SPACE NUMBERING	(z)	1	2	3	4	5	6	7	8	9	10				
SIMULATION PROGRAM INTERNAL NUMERING	(i)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
LOAD PROGRAM NUMBERING	($SPACN_{k,j}=z$)	4	10	1	3	5	5	8	7	6	2	4	6	4	3
ZONE NUMBERING	(j)	1	2	3	4	5	1	2	3	1	2	3	1	2	1
SYSTEM NUMBERING	(k)	1					2			3			4		5

Figure ' SYSTEM SIMULATION PROGRAM NUMBERING ORGANIZATION w/example

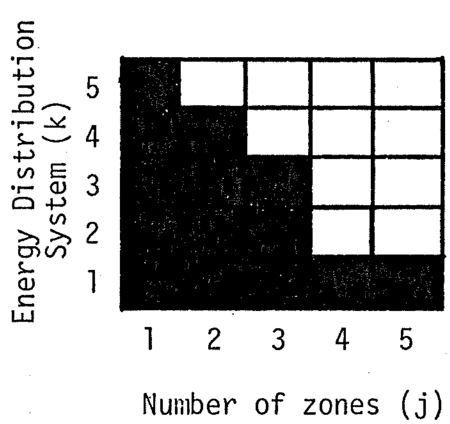


Figure ' SYSTEM/ZONE MATRIX using doubly-subscripted variables (k,j)

TABLE

SYSTEM AND EQUIPMENT SIMULATION
SUBROUTINES AND FUNCTIONS

NAME	FUNCTION
ABSØR	Steam absorption water chiller
AHU	Air Handling Unit simulation
ALØG1	Base 10 logarithms
BRAD2	Baseboard radiation simulation
CCØIL	Cooling coil simulation
CDATA	Reads card input
CENT	Centrifugal water chiller
DENSY	Air density calculation
ECØNØ	Economizer cycle simulation
ENGYC	Energy consumption output table
EQUIP	Boilers, chillers and on-site generation systems
ERRØR	Prints error messages
FANØF	Load handler when fan system is off
FCØIL	Fancoil unit simulation (2- and 4-pipe)
FHTG2	Floor panel heating systems
FSIZE	Fan sizing
HTCON	Heat conservation
H2ØZN	Zone moisture change and requirement calculation
HUM1	Humidity ratio calculation
IDUC	Induction unit fan system simulation (2- and 4-pipe)
MAX	Maximum value calculation

TABLE (CONT'D)

NAME	FUNCTION
MXAIR	Mixed air calculation
MZDD	Multi-zone and dual duct fan system simulation
PPWVM	Psychrometrics
PSYCH	Psychrometrics
PSY1	Psychrometrics
PSY2	Psychrometrics
PTLD	Part load fan power calculation
RECIP	Reciprocating water chiller
RHFS2	Simulation of: Single-zone fan system w/face and bypass dampers, Unit ventilator, Unit heater, Constant volume reheat fan system
SNØWM	Snow melting
STTUR	Steam turbine
SYSSIM	Main routine
SZRHT	Single-zone/sub-zone reheat fan system
TDATA	Reads off header data from LOAD tape
TEMP	Temperature calculation
TRSET	Linear interpolation routine
VARVL	Variable volume fan system simulation
WZNEW	Humidity ratio calculation
ZLØ3	Zone load organizer: calculates reheating and recooling loads

MAIN ROUTINE: SYSSIM

The main routine of the System and Equipment Simulation Program. SYSSIM controls the flow through the program. This routine is divided roughly into three sections.

- Initial Sizing. Subroutines are called to read card input data (CDATA) and to read off header data from the LOAD tape (TDATA). A third subroutine (FSIZE) is then called to size zone and system air flows. Finally, central system power consuming equipment (i.e., pumps, fans, cooling towers, motors, engine generators, steam turbines) are sized.

- Hourly Calculations. The function of this mode is to first read hourly weather data and zone loads from the LOAD tape. Secondly, the appropriate energy distribution subroutines are called to calculate energy conversion system loads (heating, cooling, water and power requirements). Thirdly, subroutine EQUIP is called to calculate resource requirements necessary to satisfy heating, cooling and power needs. An account of energy distribution and conversion system loads not met is kept and printed in this mode at the end of each month.

- Monthly Summaries. The third mode indicates the activity of the program by printing a central equipment size summary and a table of energy and resource requirements (demand and consumption) for each month.

INPUT

Cards - A description of card input variables will be found in the discussion of Subroutine CDATA.

Tape - Hourly data required by the program is defined in Table . This includes both weather and zone load information.

OUTPUT

Printer - Printed output is presented and discussed in Table .

Tape - The organization and definition of the System and Equipment Simulation output tape is given in Figure and Table . This tape serves as input to system and equipment analysis programs.

COMMON

The system and Equipment Simulation Program is organized such that use of COMMON by second-, third-, etc. order subroutines and functions is the exception rather than the norm. However, most of the variables required by first-order subroutines are located in COMMON. These variables are defined in Table .

TABLE

ORGANIZATION OF INPUT LOAD TAPE TO SYSTEM AND EQUIPMENT SIMULATION PROGRAM

On the input tape, after the header data, the following variables appear for each hour:

IHØUR	-	Hour number, hour of year
IMØY	-	Month of year
IDØM	-	Day of month
NDØW	-	Day of the week
IHØD	-	Hour of the day
ISUN	-	Sun index which indicates whether or not the sun is up (0 = sun up; 1 = sun not up)
TØA	-	Outside air dry-bulb temperature (^{o}F)
TWB	-	Outside air wet-bulb temperature (^{o}F)
VEL	-	Wind velocity (knots)
WØA	-	Outside air humidity ratio (lb water/lb dry air)
PATM	-	Barometric pressure (inches of mercury)
DØA	-	Outside air density (lbm/ft^3)
HØA	-	Enthalpy of outside air (Btu/lb dry air)
JSC	-	Day type (i.e., weekday, Saturday, Sunday, Holiday, Christmas)
CCM	-	Cloud cover modifier

For each zone, the following variables appear on the input tape:

IS	-	Space number
QS_z	-	Zone sensible load (Btu/hr)
QL_z	-	Zone latent load (Btu/hr)
$QLITE_z$	-	Zone lighting load picked up by return air (Btu/hr)
$SLPØW_z$	-	Zone internal lighting and machinery power consumption (KW)

TABLE (CONT'D)

$QSINF_z$	-	Zone sensible infiltration load (Btu/hr)
$QLINF_z$	-	Zone latent infiltration load (Btu/hr)
$STEMP_z$	-	Zone temperature (^oF) (calculated in Variable Temperature Program)
$UCFM_z$	-	Air flow if zone is a ceiling plenum (ft^3/min) (calculated in Variable Temperature Program)

TABLE

PRINTED OUTPUT OF SYSTEM AND EQUIPMENT SIMULATION PROGRAM

(NOTE: optional printout not covered here)

PROGRAM VARIABLE		DESCRIPTION
Report 1: Input Recap		
Recapitulation of input card data		
Report 2: Energy Analysis Header		
FAC	-	Building or project name
CITY	-	Location
ENGR	-	Name of user
PROJ	-	Project number
DATE	-	Date
Report 3: Energy Distribution System Summary		
$FBHPS_k$	-	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)
$JMAX_k$	-	Number of zones on system k
$CFMAX_k$	-	Supply air, system k (CFM)
$CFMIN_k$	-	Minimum outside air, system k (CFM)
$CFMEX_k$	-	Exhaust air, system k (CFM)
$ALPCT_k$	-	Minimum outside air percent of supply air, system k
Report 4: Zone Air Flow Summary		
$CFMS_i$	-	Supply air zone i (CFM)
$CFMX_i$	-	Exhaust air, zone i (CFM)
TSP_z	-	Set point temperature, zone i (°F)

TABLE (CONT'D)

PROGRAM VARIABLE	DESCRIPTION
Report 5: Load Not Met Summary	
$QCLNM_i$ -	Monthly accumulation of cooling loads not met, zone i (MBTU)
$QCPNM_i$ -	Peak cooling load not met, zone i (MBH)
$IHCNM_i$ -	Number of hours in month cooling load not met, zone i
$QHLNM_i$ -	Monthly accumulations of heating loads not met, zone i (MBTU)
$QHPNM_i$ -	Peak heating load not met, zone i (MBH)
$IHHNM_i$ -	Number of hours in month heating load not met, zone i
QRCNM -	Monthly accumulation of central cooling system loads not met due to undersized equipment (MBTU)
QRCNM -	Peak central cooling system load not met (MBH)
IHRNM -	Number of hours in month central cooling system load not met
QBCNM -	Monthly accumulations of boiler loads not met due to undersized equipment (MBTU)
QBPNM -	Peak boiler load not met (MBH)
IHBNM -	Number of hours in month boiler load not met

NOTE: Loads not met are tabulated only once (i.e., zone loads not met are not carried over into central equipment loads not met).

TABLE (CONT'D)

PROGRAM VARIABLE		DESCRIPTION
Report 6: Summary of Equipment Sizes		
NUMC	-	Number of chillers
SZC	-	Size of chillers (tons)
NUMB	-	Number of boilers
SZB	-	Size of boilers (MBH)
NUMT	-	Number of steam turbines
SZT	-	Size of steam turbines (HP)
M4	-	Number of on-site generation engines (KW)
SZE	-	Size of on-site generation engines
CAPH	-	Total heating capacity (MBH)
CAPC	-	Total cooling capacity (tons)
CFMCT	-	Cooling tower air flows (CFM)
HPCTF	-	Horsepower of cooling tower fan motor (HP)
HPBLA	-	Horsepower of boiler auxiliaries (HP)
GPMCL	-	Chilled water flow (gpm)
HPCLP	-	Chilled water pump horsepower (HP)
GPMCN	-	Condenser water flow (gpm)
HPCNP	-	Condenser water pump horsepower (HP)
GPMBL	-	Boiler water flow (gpm)
HPBLP	-	Boiler water pump horsepower (HP)

TABLE (CONT'D)

PROGRAM VARIABLE	DESCRIPTION
Report 7: Monthly Energy and Resource Demand and Consumption Table	
ENGY	- Monthly resource consumptions and demands. A 12 x 12 x 18 matrix with indices defined as indicated below. This variable is transferred to subroutine ENGYC where the monthly tabulation is printed. FIRST SUBSCRIPT: MONTH 1 is January 2 is February 3 is March 4 is April 5 is May 6 is June 7 is July 8 is August 9 is September 10 is October 11 is November 12 is December SECOND SUBSCRIPT: MODE OF ENERGY 1 is Demand 2 is Consumption THIRD SUBSCRIPT: TYPE OF ENERGY 1 is Maximum monthly heating demand 2 is Maximum monthly cooling demand 3 is Electric, internal lights and building equipment 4 is Electric, external lights 5 is Electric heat (boiler and auxiliaries, and hot water pumps) 6 is Electric cool (chillers, chilled water pumps, and cooling tower fan) 7 is Gas heat 8 is Gas cooling 9 is Gas generation 10 is Steam heat 11 is Steam cooling 12 is Oil heat 13 is Oil cooling 14 is Diesel fuel generation 15 is Monthly heating consumption

TABLE (CONT'D)

PROGRAM VARIABLE	DESCRIPTION
	16 is Monthly cooling consumption 17 is City water 18 is Fan power

VARIABLE	FORTRAN FORMAT
FAC	35A1
CITY	35A1
ENGR	35A1
PRØJ	15A1
DATE	15A1
j=1, NCASE	
ISYS, KMAX, IHSRT, IHSTP	4I10
i=IHSRT, IHSTP	
IHØUR, IMØY, IDØM, IHØD	I4, 3I2, 2I4,
ITØA, ITWB, WØA, PATM	3F8.5, 4F8.1
DØA, TNFBP, TABCD, BGAS, ØILH	
k=1, KMAX	
$KFAN_k$, QKC_k, QKH_k, $QKKW_k$, $PWLK_k$	I3, 3F12.0,
$H2ØK_k$, ZERØ, $TKHL_k$, $TKCD_k$	3FI0.1, 2F5.1

Figure ORGANIZATION OF SYSTEM AND EQUIPMENT SIMULATION PROGRAM OUTPUT TAPE

TABLE

DEFINITION OF SYSTEM AND EQUIPMENT SIMULATION PROGRAM OUTPUT TAPE VARIABLES

VARIABLE	DESCRIPTION
FAC	Facility
CITY	Location
ENGR	User Name
PRØJ	Project ID.
DATE	Date
ISYS	System Combination No.
KMAX	No. Distribution Systems
IHSRT	Start Hour (hour of year)
IHSTP	Stop Hour (hour of year)
IHØUR	Current Hour (hour of year)
IMØY	Month of Year (1 - 12)
IDØM	Day of Month (1 - 31)
IHØD	Hour of Day
ITØA	Ambient Dry-Bulb Temperature (°F)
ITWB	Ambient Wet-Bulb Temperature (°F)
WØA	Ambient Humidity Ratio (lbs-H_2O/lb-dry air)
PATM	Barometric Pressure (in. Hg.)
DØA	Ambient Air Density (lbm/ft^3)
TNFBP	Total Net Fan Brake horsepower (bhp)
TABCD	Total Power of Building (KW)
BGAS	Building Natural Gas Requirement (therms)
ØILH	Building Heating Oil Requirements (gals)
$KFAN_k$	Energy Distribution System No. 1 - 13)
QKC_k	System Cooling Requirement (Btu)
QKH_k	System Heating Requirement (less elect. resist. rehtg.)(Btu)
$QKKW_k$	Electric Resistance Reheat Requirement (Btu)
$PWLK_k$	Base Power Requirement of Zones served by this system (KW)
$H2ØK_k$	Humidifcation Water Requirements (lbs.H_2O)
ZERO	Reserved (=0.0)
$TKHL_k$	Hot Deck Temperature or AHU Leaving Temperature(°F)
$TKCD_k$	Cold Deck Temperature (°F)

TABLE

DEFINITION OF

VARIABLES IN COMMON

IPRT1	-	Optional print flag-1
IPRT2	-	Optional print flag-2
IPRT3	-	Optional print flag-3
KØ	-	Line printer unit number
IC	-	Card reader unit number
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)
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)
$STEMF_z$	-	Space temperature at a given hour (^oF)
$UCFM_z$	-	Air flow through zone if it is a plenum space (ft^3/min)
TSP_z	-	Zone set point temperature (^oF)
$VØL_z$	-	Zone volume (ft^3)
TØA	-	Outside air dry-bulb temperature (^oF)
WØA	-	Outside air humidity ratio ($\frac{\text{lbm-H20}}{\text{lbm-dry air}}$)
HØA	-	Outside air enthalpy (Btu/lbm)
DØA	-	Outside air density (lbm/ft^3)
PATM	-	Barometric pressure (in.Hg.)
TCØ	-	Changeover temperature (^oF)
KBLDG	-	Heat conservation building flag
KMAX	-	Number of energy distribution systems
IZNMX	-	Number of zones to be studied
MSTRT	-	Month in which study begins

TABLE (CONT'D)

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)
$ALFAM_k$	-	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 ($\frac{\text{lbm-H20}}{\text{lbm-dry air}}$)
$DAVE_k$	-	Average air density, system k (lbm/ft^3)
WRA_k	-	Return air humidity ratio, system k ($\frac{\text{lbm-H20}}{\text{lbm-dry air}}$)
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 (^oF)
$DTFNR_k$	-	Air temperature rise across return fan, system k, at full load (^oF)
$MXAØ_k$	-	Mixed air option, system k
$IVVRH_k$	-	Variable volume reheat option, system k

TABLE (CONT'D)

$ICZN_k$	-	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
$NVFC_k$	-	Type of fan damper control, system k
$VVMIN_k$	-	Minimum air flow through variable volume boxes, system k
$TCØFC_k$	-	Two-pipe fancoil unit system changeover temperature (°F)
TØACØ	-	Two-pipe induction unit fan system changeover temperature or floor panel heating system hot water shut-off temperature, system k (°F)
$TFIX1_k$	-	Fixed hot deck or AHU discharge temperature, system k (°F)
$TFIX2_k$	-	Fixed cold deck temperature, system k (°F)
$RIPA_k$	-	Ratio of induced to primary air, system k
CFM_i	-	Supply air flow rate, zone i (constant)(cu ft/min)
$CFMS_i$	-	Supply air flow rate, zone i (variable) (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)
$ZMAS_i$	-	Supply air mass flow, zone i (variable)(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)
QSI_i	-	Sensible thermal load, zone i (Btu/hr)
TS_i	-	Supply air temperature, zone i (^oF)
WZ_i	-	Calculated humidity ratio, zone i (lbm-H2O/lbm-dry air)
$WREQD_i$	-	Required 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)

TABLE (CONT'D)

$QHPNM_i$	-	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 (^oF)
$TØAHI_n$	-	High outside air temperature at which system temperature is TLO_n, reset schedule n (^oF)
$TLØ_n$	-	Low system fluid temperature, reset schedule n (^oF)
THI_n	-	High system fluid temperature, reset schedule n (^oF)
$ISET_{k,m}$	-	Reset temperature schedule index, system k, reset item m (an "n" number)
TFBHP	-	Total fan brake horsepower (bhp)
EFF	-	Pump and fan motor efficiency
$PLØC_k$	-	Location of floor heating panels, system k
$PAREA_k$	-	Floor area covered by heating panels, system k (ft^2)
$PERIM_k$	-	Exposed perimeter of floor, system k (lin.ft)
KFLCV	-	Type of floor covering (1=bare concrete; 2=tile; 3=carpeting)
CINSL	-	Floor insulation conductance (Btu/hr-sq-ft-^oF)
DINSL	-	Floor insulation thickness (ft)
TLCHL	-	Chilled water set point temperature (^oF)
TPS	-	Steam turbine entering steam temperature (^oF)
PPS	-	Steam turbine entering steam pressure (psig)
TESTM	-	Boiler supply and absorption chiller entering steam temperature (^oF)
PESTM	-	Boiler supply and absorption chiller entering steam pressure (psig)
SZT	-	Steam turbine size (hp)

TABLE (CONT'D)

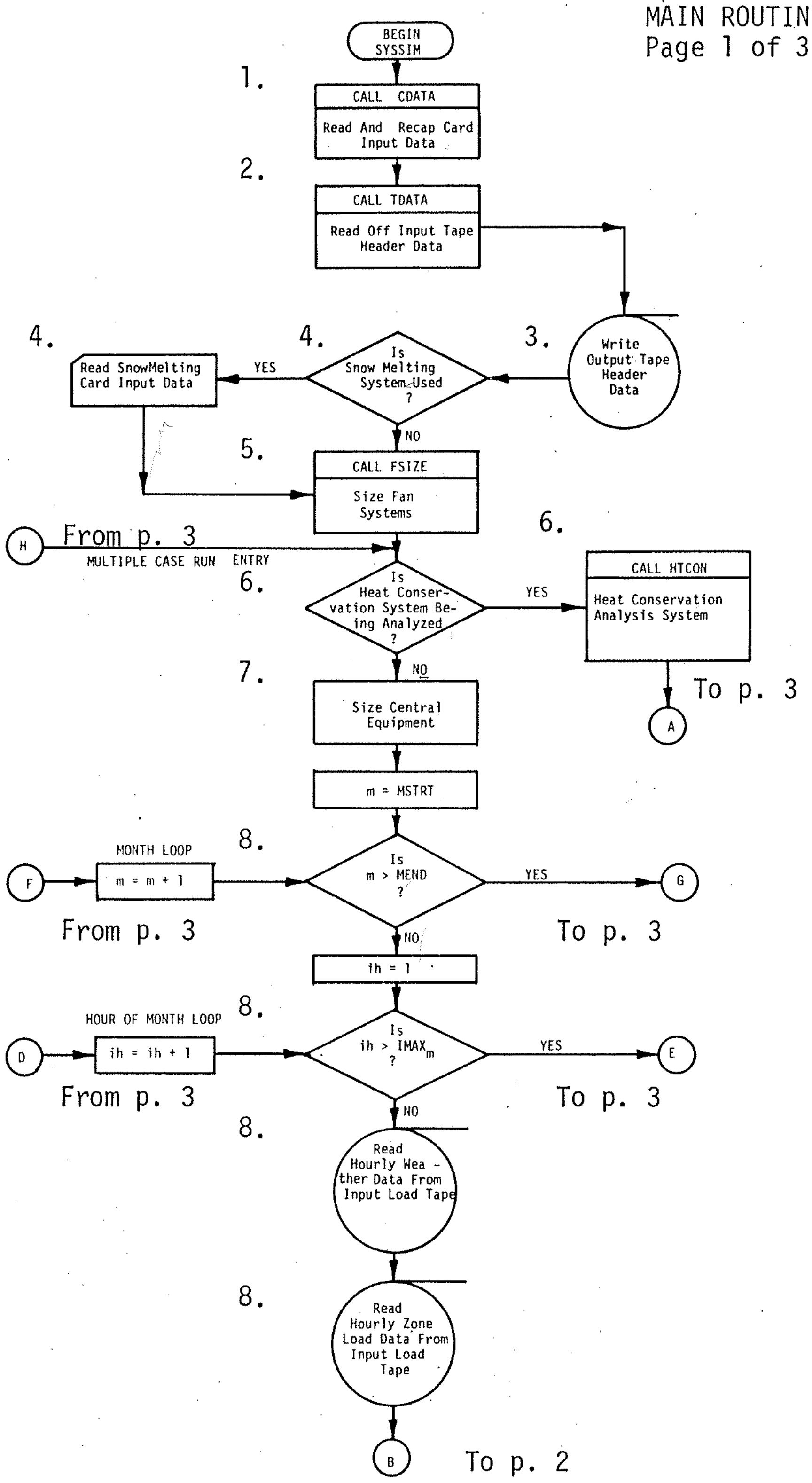
NUMT	-	Number of steam turbines
RPM	-	Steam turbine speed (rpm)
SZE	-	Engine/Generator set size (KW)
FFLMN	-	Minimum part load cut-off for chillers
KREHT	-	Source of reheat coil energy
HVDF	-	Heating value of diesel fuel (Btu/gal)
HVHØ	-	Heating value of heating oil (Btu/gal)
CFMBN	-	Building total minimum outside air (cu ft/min)
CFMBX	-	Building total design load supply air (cu ft/min)
CFMBE	-	Building total exhaust air (cu ft/min)
PWBIL	-	Building peak base power load (KW)
PWØL	-	Power of external lighting (KW)
TLCNM	-	Maximum allowable condenser water temperature (^{o}F)
TLCMN	-	Well or city water design return water temperature (^{o}F)
TCWIN	-	City water supply temperature (^{o}F)
TWWIN	-	Well water supply temperature (^{o}F)
TECMN	-	Cooling tower water low limit temperature (^{o}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)
GPMCL	-	Chilled water flow rate (gpm)
GPMCN	-	Condenser water flow rate (gpm)
GPMBL	-	Boiler water flow rate (gpm)
GPMWW	-	Well water flow rate (gpm)
HPCLP	-	Chilled water pump power (bhp)
HPCNP	-	Condenser water pump power (bhp)

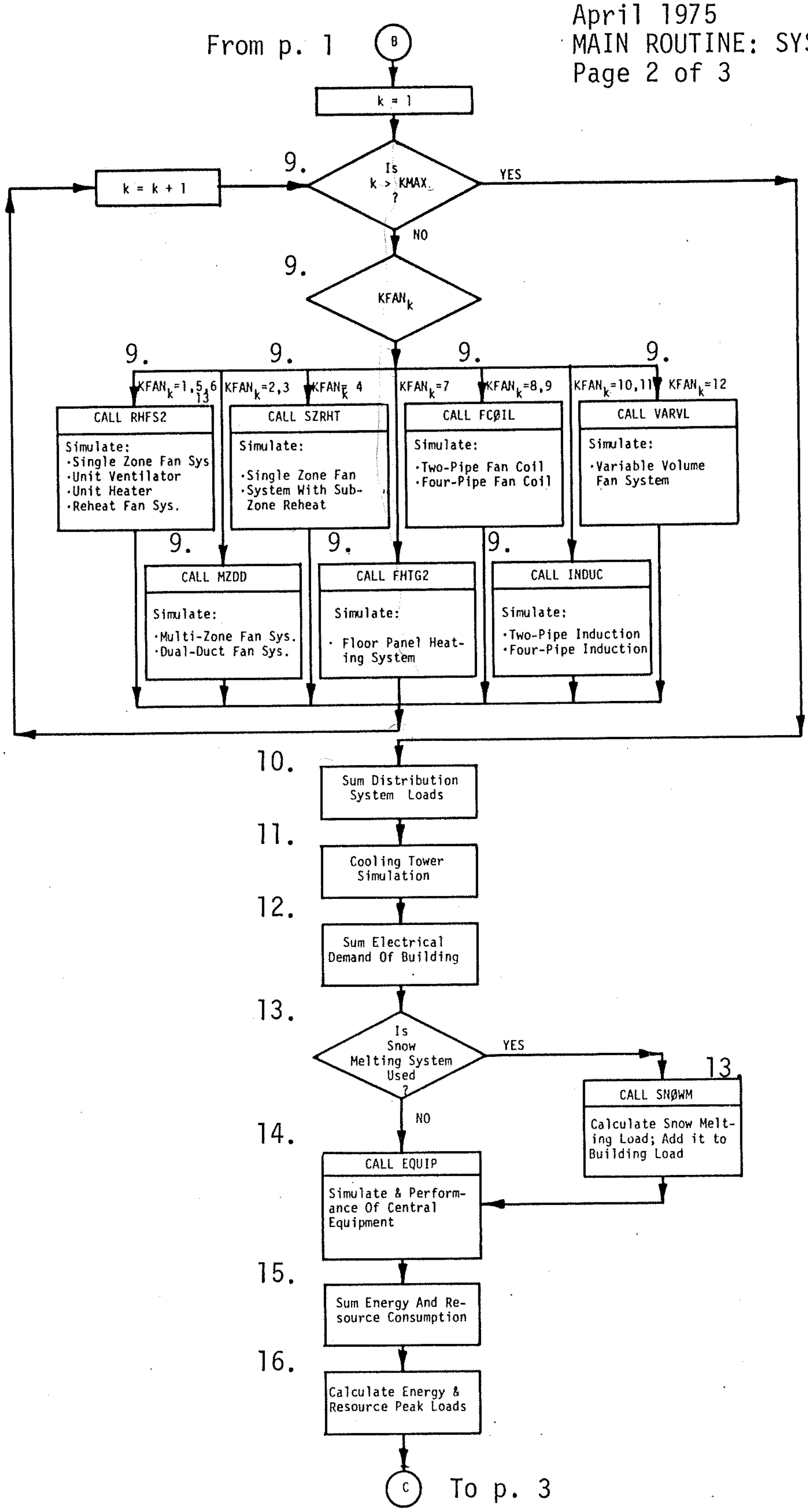
TABLE (CONT'D)

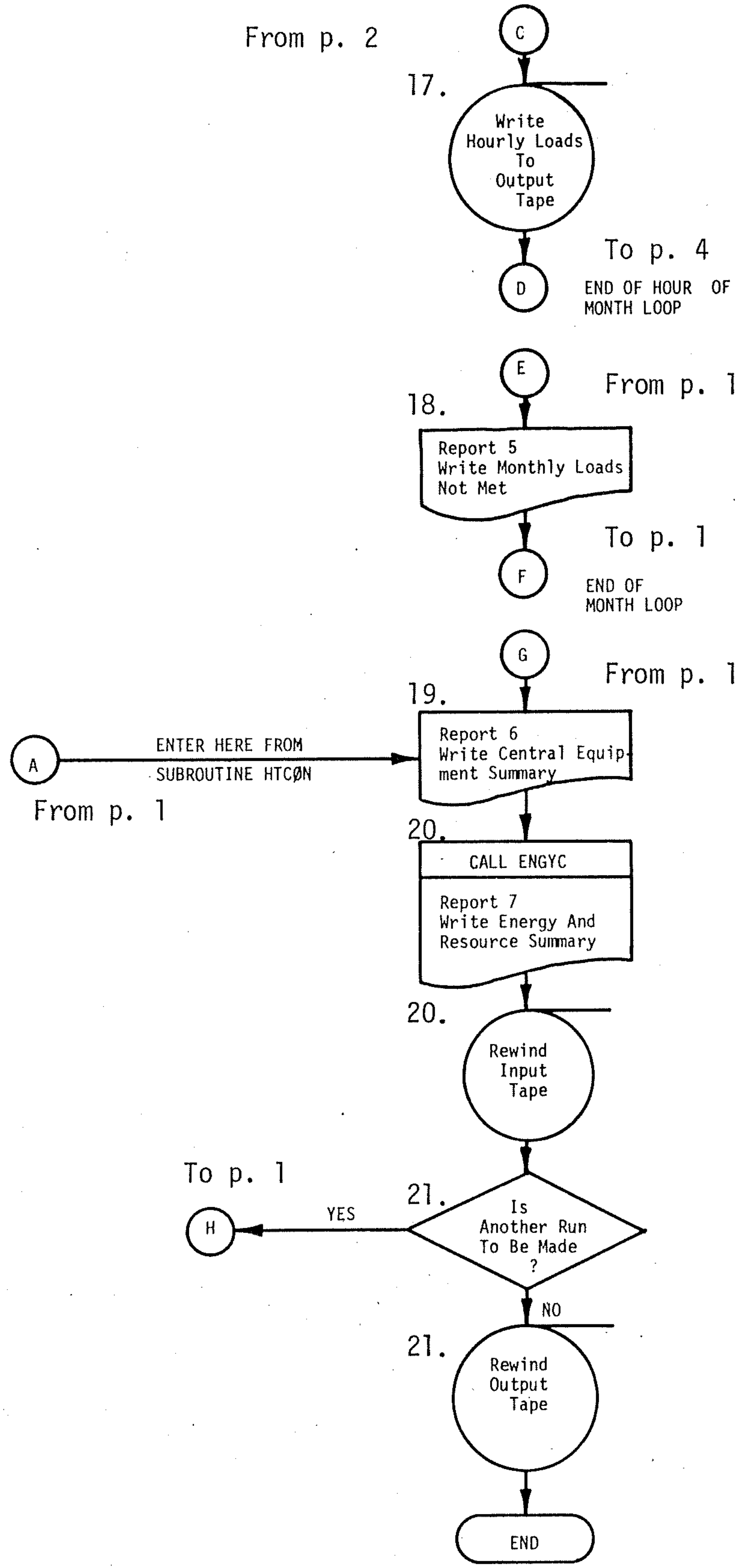
HPBLP	-	Boiler water pump power (bhp)
HPWWP	-	Well water pump power (bhp)
HPCTF	-	Cooling tower fan power (bhp)
HPBLA	-	Boiler accessory power (bhp)
CFMCT	-	Cooling tower air flow (cu ft/min)
IHSRT	-	Hour of year at which simulation may begin
IHSTP	-	Hour of year at which simulation may end
NCASE	-	Number 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 shut-down (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 shut-down (hour of year)
KSNØW	-	Type of snow melting system
QSNØW	-	Snow melting system design load (Btu/hr)
SAREA	-	Snow melting slab area (sq ft)
$ASYS_{nc}$	-	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

TABLE (CONT'D)

$AM6_{nc}$	-	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
QRCNM	-	Monthly accumulation of chiller loads not met due to undersizing (MBTU)
QRPNM	-	Monthly peak chiller load not met (MBH)
IHRNM	-	Number of hours chiller load not met
QBCNM	-	Monthly accumulation of boiler loads not met due to undersizing (Btu)
QBPNM	-	Monthly peak boiler load not met (Btu)
IHBNM	-	Number of hours boiler load not met


BEGIN SYSSIM
1.
CALL CDATA
Read And Recap Card Input Data
2.
CALL TDATA
Read Off Input Tape Header Data
3.
Write Output Tape Header Data
4.
Is Snow Melting System Used ?
YES
4.
Read SnowMelting Card Input Data
NO
5.
CALL FSIZE
Size Fan Systems
H
From p. 3
MULTIPLE CASE RUN ENTRY
6.
Is Heat Conservation System Being Analyzed ?
YES
6.
CALL HTCON
Heat Conservation Analysis System
A
To p. 3
NO
7.
Size Central Equipment
m = MSTRT
8.
MONTH LOOP
F
m = m + 1
From p. 3
Is m > MEND ?
YES
G
To p. 3
NO
ih = 1
8.
HOUR OF MONTH LOOP
D
ih = ih + 1
From p. 3
Is ih > IMAX m ?
YES
E
To p. 3
NO
8.
Read Hourly Weather Data From Input Load Tape
8.
Read Hourly Zone Load Data From Input Load Tape
B
To p. 2


From p. 1
B
k = 1
k = k + 1
9.
Is k > KMAX ?
YES
NO
KFAN_k
KFAN_k=1,5,6,13
CALL RHFS2
Simulate:
·Single Zone Fan Sys
·Unit Ventilator
·Unit Heater
·Reheat Fan Sys.
KFAN_k=2,3
CALL SZRHT
Simulate:
·Single Zone Fan
·System With Sub-Zone Reheat
KFAN_k=4
CALL MZDD
Simulate:
·Multi-Zone Fan Sys.
·Dual-Duct Fan Sys.
KFAN_k=7
CALL FHTG2
Simulate:
· Floor Panel Heating System
KFAN_k=8,9
CALL FCØIL
Simulate:
·Two-Pipe Fan Coil
·Four-Pipe Fan Coil
KFAN_k=10,11
CALL INDUC
Simulate:
·Two-Pipe Induction
·Four-Pipe Induction
KFAN_k=12
CALL VARVL
Simulate:
·Variable Volume Fan System
10.
Sum Distribution System Loads
11.
Cooling Tower Simulation
12.
Sum Electrical Demand Of Building
13.
Is Snow Melting System Used ?
YES
CALL SNØWM
Calculate Snow Melting Load; Add it to Building Load
NO
14.
CALL EQUIP
Simulate & Performance Of Central Equipment
15.
Sum Energy And Resource Consumption
16.
Calculate Energy & Resource Peak Loads
C
To p. 3


From p. 2
C
17.
Write Hourly Loads To Output Tape
To p. 4
D
END OF HOUR OF MONTH LOOP
E
From p. 1
18.
Report 5 Write Monthly Loads Not Met
To p. 1
F
END OF MONTH LOOP
G
From p. 1
19.
A
ENTER HERE FROM SUBROUTINE HTCØN
From p. 1
Report 6 Write Central Equip-ment Summary
20.
CALL ENGYC
Report 7 Write Energy And Resource Summary
20.
Rewind Input Tape
To p. 1
H
YES
21.
Is Another Run To Be Made ?
NO
21.
Rewind Output Tape
END

CALCULATION SEQUENCE

1. Call subroutine CDATA to read and recap card input data.

2. Call subroutine TDATA to read off input tape header data stopping before hourly weather and building load information is encountered.

3. Write output tape header data which includes variables FAC, CITY, ENGR, PRØJ, and DATE.

4. Read daily snowfall data, if snow-melting system is used.

5. Call subroutine FSIZE to calculate the following quantities:

PWBIL	- Peak building base power (KW)
CFM_i	- Peak supply air volume, zone i (CFM)
$CFMR_i$	- Return air volume, zone i (CFM)
$CFMAX_k$	- Total air supplied by fan system k (CFM)
$CFMEX_k$	- Auxiliary exhaust air removed from zones served by system k (CFM)
$CFMIN_k$	- Minimum outside air required, fan system k (CFM)
$ALFAM_k$	- Fraction of minimum outside air required for fan system k (CFM)
$ØACFM_k$	- Minimum outside air, system k (CFM)
DRA_k	- Initialize return air density, system k (lbm/ft^3)
WRA_k	- Initialize return air humidity ratio, system k (lbm-H_2O/lbm-dry air)
$FBHPS_k$	- Supply fan brake horsepower required, fan system k (bhp)
$FBHPR_k$	- Return fan brake horsepower required, fan system k (bhp)
$FBHPE_k$	- Exhaust fan brake horsepower required, fan system k (bhp)
TFBHP	- Summation of fan brake horsepowers, all systems (bhp)
$DTFNS_k$	- Temperature rise across supply fan, system k (°F)
$DTFNR_k$	- Temperature rise across return fan, system k (°F)

$ZMAS_i$ - Supply air mass flow to zone i at design load (lbm/hr)

$ZMASX_i$ - Exhaust air madd flow from zone i (lbm/hr)

$ZMASR_i$ - Return air mass flow from zone i at design load (lbm/hr)

$FMASS_k$ - Total supply air mass flow of system k at design conditions (lbm/hr)

$FMASX_k$ - Total exhaust air mass flow of system k (lbm/hr)

$FMASR_k$ - Total return air mass flow of system k at design conditions (lbm/hr)

CFMBE - $\sum_{k=1,\ KMAX} CFMEX_k$

CFMBX - $\sum_{k=1,KMAX} CFMAX_k$

CFMBN - $\sum_{k=1,KMAX} CFMIN_k$

6. Check type of system.

   If conventional or on site generation, go to calculation 7.

   If heat conservation, call HTCØN, and then go to calculation 19.

7. Size Central Equipment.

   7.1 Size heating and cooling capacities (CAPH, CAPC)

   CAPH = SZB * NUMB (in MBH)

   CAPC = SZC * NUMC (in tons)

   7.2 Steam turbines (to drive centrifugal chillers).

   If M1 = 5, determine number of steam turbines required (NUMT).

   NUMT = NUMC

   Determine size of steam turbines required (SZT), if used, assuming 1 HP per ton of cooling.

   SZT = SZC (in horsepower)

   7.3 Compute total heating capacity required (CAPH).

   Check boiler size with steam turbine requirements for possible updating. Steam turbine requirements based upon peak cooling hour assuming 20 lbs steam per ton of cooling

CAPH1 = CAPC * 20.0 * 33.472/34.5

If CAPH less than CAPH1

CAPH = CAPH1

SZB = CAPH/NUMB

7.4 Size all pump water flows (gpm).

Chilled water flow rate (GPMCL)

GPMCL = 2.4 * CAPC

Condenser water flow rate (GPMCN).

If M1 $\neq$ 4, GPMCN = 3.0 * CAPC

If M1 = 4 (steam absorption chiller),

GPMCN = 3.5 * CAPC

Boiler water flow rate (GPMBL)

GPMBL = CAPH * 1000.0/(500.0 * 20.0)

7.5 Size pump motors assuming a pump efficiency of 60%

Chilled water pump horsepwoer (HPCLP)

HPCLP = GPMCL * HDCLP/(3962.0 * 0.6 * EFF)

Condenser water pump horsepower (HPCNP)

HPCNP = GPMCN/(3962.0 * 0.6 * EFF)

Boiler water pump horsepower (HPBLP)

HPBLP = GPMBL * HDBLP/(3962.0 * 0.6 * EFF)

7.6 Horespower requirement for motors running boiler auxiliary equipment such as fans, blowers, pumps, etc. should be computed. From American Standard catalog for packaged boilers ranging in size from 20 to 750 HP, the auxiliary horsepower requirement was approximately 1/20 of the total boiler horsepower capacity; therefore

HPBLA = CAPH * 1000.0/(33472.0 * 20.0)

7.7 Size cooling tower fan.

Cooling tower air flow requirement (CFMCT).

For all chillers except steam absorption, use 300 cfm per ton of cooling; therefore

CFMCT = 300.0 * CAPC

For steam absorption system, use 350 cfm per ton of cooling; therefore

CFMCT = 350.0 * CAPC

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

HPCTF = CFMCT * 1.0/(6346.0 * EFF)

7.8 Sum heating and cooling equipment brake horsepower demand (HPHEQ, HPCEQ).

HPHEQ = HPBLA + HPBLP

HPCEQ = HPCTF + HPCLP + HPCNP

7.9 Size on-site generation plants.

Calculate maximum building electrical demand assuming all electrical equipment operating (electric resistance heating and electrically-driven compressive cooling not allowable with on-site generation).

BKWDM = PWBIL + PWØL + (TFBHP + HPCEQ + HPHEQ)

* 0.7457

Calculate number and size of on-site generation units.

If M4 $\neq$ 0, set

NUME = M4 where NUME is number of engines.

Size of engines is then

SZE = BKWDM/NUME

If SZE > 500.0 KW, increase the number of engines until SZE $\leq$ 500.0 KW

Finally, set M4 = NUME.

If M4 = 0, set

NUME = 2 where NUME is number of engines

Size of engines is then

SZE = BKWDM/NUME

If SZE > 500.0 KW, increase NUME until SZE $\leq$ 500.0 KW.

Finally, set M4 = NUME.

8. Begin hourly energy consumption analysis repeating calculations 8 through 18 for every hour of the analysis.

Read hourly weater data which includes:

IHØUR - Hour number, hour of year

IMØY - Month of year

IDØM - Day of month

NDØW - Day of the week

IHØD - Hour of the day

ISUN - Sun index which indicates whether or not the sun is up

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

TWB - Outside air wet-bulb temperature (°F)

VEL - Wind velocity (knots)

WØA - Outside air humidity ratio (lb water/ lb dry air)

PATM - Barometric pressure (inches of mercury)

DØA - Outside air density (lbm/ft^3)

HØA - Enthalpy of outside air (Btu/lb dry air)

JSC - Day type (i.e., weekday, Saturday, Sunday, Holiday, Christmas)

CCM - Cloud cover modifier (0 - opaque, 1 = clear)

Read zone load data for all zones on tape.

IS_z - Space number

QS_z - Zone sensible load (Btu/hr)

QL_z - Zone latent load (Btu/hr)

$QLITE_z$ - Zone lighting load picked up by return air (Btu/hr)

$SLPØW_z$ - Zone internal lighting and machinery power consumption (KW)

$QSINF_z$ - Zone sensible infiltration load (Btu/hr)

$QLINF_z$ - Zone latent infiltration (Btu/hr)

$STEMP_z$ - Zone temperature (°F)

$UCFM_2$ - Zone air flow if plenum space (CFM)

Initialize total net fan brake horsepower (TNFBP).

TNFBP = TFBHP

9. Call energy distribution systems.

Check type of fan system.

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

Each of the above subroutines simulates the performance of a given system and returns the following quantities:

$QFPC_k$ - system cooling requirement (Btu/hr)

$QFPH_k$ - system primary heating requirement (Btu/hr)

$QFPRH_k$ - system reheat coil heating requirement (Btu/hr)

$QFPPH_k$ - system preheat coil heating requirement (Btu/hr)

TQB_k - heating requirement of baseboard radiation in zones served by system k (Btu/hr)

$WATER_k$ - steam humidifier water requirement (lbm/hr)

PWL_k - base power (KW)

TNFBP - total net fan brake horsepower, all fan systems (bhp)

SYSTEM TEMPERATURES - as defined in Table below.

TABLE DISTRIBUTION SYSTEM OUTPUT TEMPERATURE DESCRIPTION

System Number	Type	HOT DECK		COLD DECK[1]	
		Variable	Description	Variable	Description
1	SZFB	TLVG	AHU Leaving Air Temperature	-	-
2	MZS	THD	Hot Deck Air Temperature	TCD	Cold Deck Air Temperature
3	DDS	THD	Hot Deck Air Temperature	TCD	Cold Deck Air Temperature
4	SZRH	TLVG	AHU Leaving Air Temperature	-	-
5	UVT	TLVG	" " " "	-	-
6	UHT	TLVG	" " " "	-	-
7	FPH	TPAN	Floor Panel Temperature	-	-
8	2PFC	TSA	Discharge Temperature of Last Zone's Fancoil	-	-
9	4PFC			-	-
10	2PIU	TLVG	AHU Leaving Air Temperature	-	-
11	4PIU	TLVG	" " " " (Constant)	-	-
12	VAVS	TLVG	AHU Leaving Air Temperature (Constant)	-	-
13	RHFS	TLVG	AHU Leaving Air Temperature	-	-

1 where cold deck does not apply, deck temperature is set equal to 0.0

10. Sum building hourly cooling, heating, reheat, zone power, and water resource requirements.

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

$$QHBH = \sum_{k=1,KMAX} (QFPH_k + QFPPH_k + TQB_k + (-WATER_k * 1000.))$$

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

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

$$H2Ø = \sum_{k=1,KMAX} WATER_k$$

11. Cooling tower simulation.

11.1 If chiller is off (ICHIL=0), set cooling tower on/off switch (KCTF) equal 0, and go to calculation 12.

11.2 If chiller is on (ICHIL=1), assume a 7°F approach for tower, therefore temperature of water entering condenser is

TECØN = TWB + 7.0

If TECØN less than TECMN, reset TECØN = TECMN

If from previous hour, tower is on (KCTF=1), and if (TECØN ≥ TECMN + 10), set KCTF=1; otherwise KCTF=0.

If from previous hour, tower is off (KCTF=0), and if (TECON ≤ TECMN), set KCTF=0; otherwise KCTF=1.

12. Determine hourly electrical demand of the building (ELDEM) for on-site generation, if used.

If ISUN = 0, exterior lights are OFF; therefore, set

PWEL = 0.0

If ISUN = 1, exterior lights are ON; therefore, set

PWEL = PWØL

If cooling equipment only is ON,

ELDEM = PWILM + PWEL + (TNFBP + HPCLP + HPCNP

+ HDCTF * KCTF) * 0.7457

If heating equipment only is ON,

ELDEM = PWILM + PWEL + (TNFBP + HPHEQ) * 0.7457

If heating and cooling equipment are ON,

ELDEM = PWILM + PWEL + (TNFBP + HPCLP + HPCNP

+ HDCTF * KCTF + HPHEQ) * 0.7457

13. Check type of snow-melting system.

If KSNØW = 0, no snow-melting system. Go to calculation 14.

If KSNØW = 1 or 2, snow-melting considered.

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)/24.0

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

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

Add QTØT to heating requirement of building.

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

QHBH = QHBH - QTØT

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

ELEH = ELEH + QTØT/3413.0

14. Calculate hourly energy consumption.

Call EQUIP which calculates the following:

GASC GASH GASG ØILC ØILH STMC STMH	See subroutine EQUIP algorithms for discussion of these variables

ELEC
ELEH
FUEL
Chiller loads not met due to undersized equipment
Boiler loads not met due to undersized equipment

15. Keep running total of hourly energy and resource consumption for each month. Update the following quantities each hour.

    ENGY (M, 2, 3)
    ENGY (M, 2, 4)
    ENGY (M, 2, 5)
    ENGY (M, 2, 6)
    ENGY (M, 2, 7)
    ENGY (M, 2, 8)
    ENGY (M, 2, 9)
    ENGY (M, 2, 10)
    ENGY (M, 2, 11)
    ENGY (M, 2, 12)
    ENGY (M, 2, 13)
    ENGY (M, 2, 14)
    ENGY (M, 2, 15)
    ENGY (M, 2, 16)
    ENGY (M, 2, 17)
    ENGY (M, 2, 18)

16. Keep a record of maximum hourly energy and resource demands by checking, at the end of each hour's calculation, and updating the following energy demand quantities.

    ENGY (M, 1, 1)
    ENGY (M, 1, 2)
    ENGY (M, 1, 3)
    ENGY (M, 1, 4)
    ENGY (M, 1, 5)
    ENGY (M, 1, 6)
    ENGY (M, 1, 7)
    ENGY (M, 1, 8)
    ENGY (M, 1, 9)
    ENGY (M, 1, 10)
    ENGY (M, 1, 11)
    ENGY (M, 1, 12)
    ENGY (M, 1, 13)
    ENGY (M, 1, 14)
    ENGY (M, 1, 15)
    ENGY (M, 1, 16)
    ENGY (M, 1, 17)
    ENGY (M, 1, 18)

17. Write hourly weather and system loads to output tape. These include the following variables:

IHØUR - Current Hour (hour of year)

IMØY - Month of Year (1 - 12)

IDØM - Day of Month (1 - 31)

IHØD - Hour of Day

ITØA - Ambient Dry-Bulb Temperature (°F)

ITWB - Ambient Wet-Bulb Temperature (°F)

WØA - Ambient Humidity Ratio (lbs-H_2O/lb-dry air)

PATM - Barometric Pressure (in. Hg)

DØA - Ambient Air Density (lbm/ft^3)

TNFBP - Total Net Fan Brake horsepower (bhp)

TABCD - Total Power of Building (KW)

BGAS - Building Natural Gas Requirement (therms)

ØILH - Building Heating Oil Requirement (gals)

Repeat for each distribution system

- $KFAN_k$ - Energy Distribution System Type No. (1 - 13)
- QKC_k - System Cooling Requirement (Btu)
- QKH_k - System Heating Requirement (less elect. resist. rehtg.) (Btu)
- $QKKW_k$ - Electric Resistance Reheat Requirement (Btu)
- $PWLK_k$ - Base Power Requirement of Zones served by this system (KW)
- $H2ØK_k$ - Humidification Water Requirement (lbs. H_2O)
- ZERØ - Reserved (= 0.0)
- $TKHL_k$ - Hot Deck Temperature or AHU Leaving Temperature (°F)
- $TKCD_k$ - Cold Deck Temperature (°F)

END OF HOURLY ANALYSIS FOR ENTIRE YEAR

18. Write loads not met for current month. See Report 5 for description of this information.

19. Write out summary of equipment sizes. See Report 6 for list of the items printed out.

20. Call ENGYC to write out annual summary of building monthly energy and resource consumption and demands (see Report 7).

21. Check to see if there is another case to be run.

    If YES, go to calculation 6 and continue.

    If NO, PROGRAM FINISHED.

SUBROUTINE: ABSØR

GENERAL DESCRIPTION

Simulates the operation of a steam absorption water chiller by calculating the hourly steam consumption as a function of part load, entering condensing water temperature, leaving chilled water temperature, and steam supply pressure.

LIST OF VARIABLES

INPUT

QHBC - Hourly building cooling load (tons)

TECØN - Temperature of entering condenser water (°F)

TLCHL - Temperature of leaving chilled water (°F)

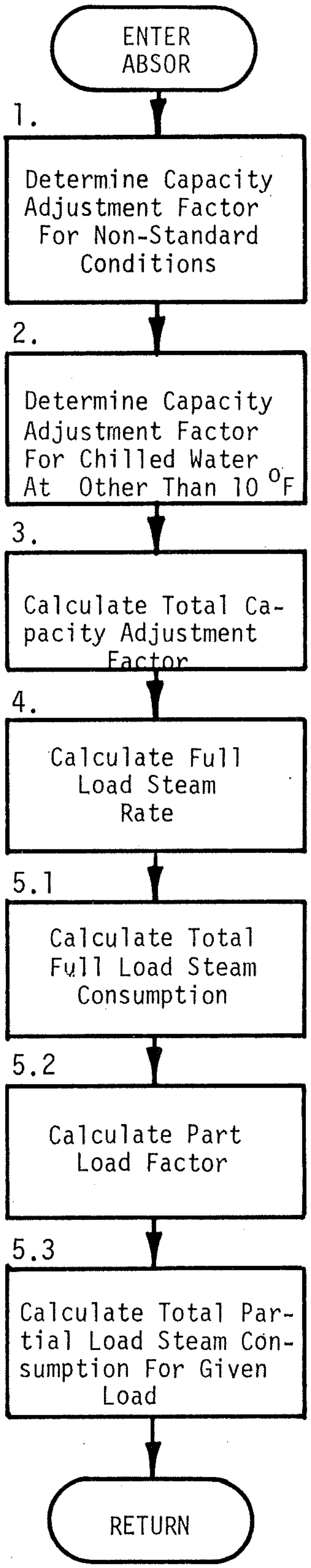
TDRØP - Chilled water temperature drop at full load (°F) (set equal to 10°F in program.)

FFL - Fraction of full load (decimal)

PESTM - Pressure of low pressure steam (psig)

OUTPUT

STEAM - Hourly steam consumption (lbs/hr)


ENTER ABSOR
1.
Determine Capacity Adjustment Factor For Non-Standard Conditions
2.
Determine Capacity Adjustment Factor For Chilled Water At Other Than 10 °F
3.
Calculate Total Capacity Adjustment Factor
4.
Calculate Full Load Steam Rate
5.1
Calculate Total Full Load Steam Consumption
5.2
Calculate Part Load Factor
5.3
Calculate Total Partial Load Steam Consumption For Given Load
RETURN

CALCULATION SEQUENCE

1. Determine the capacity factor which adjusts nominal capacity of Carrier Absorption Water Chiller, Model 16HA, 52 to 1000 tons, for operation at conditions other than the standard of 12 psig inlet steam, 85°F entering condenser water, and 44°F leaving chilled water.

RAT = -2.8246 + 0.06575 * TECØN - 0.06011 * PESTM + 0.06433 * TLCHL + 0.0011862 * TECØN * PESTM + 0.00023232 * TECØN * TLCHL + 0.00025421 * PESTM * TLCHL - 0.0006438 * TECØN * TECØN - 0.0015887 * PESTM * PESTM - 0.0006199 * TLCHL * TLCHL

This equation developed from curve fit of tabular data contained in catalog.

2. Find the capacity factor which adjusts for chilled water temperature drop other than 10°F.

CMULT = 0.9190 + 0.010333 * TDRØP - 0.0002222 * TDRØP * TDRØP

This equation is a curve fit of following data contained in catalog.

Table

CHILLED WATER TEMPERATURE DROP FACTORS

Chilled Water Temp Drop (°F)	14	12	10	8
Capacity Factor	1.02	1.01	1.00	0.99

3. Calculate the total capacity factor.

RAT = 0.91 * CMULT * RAT

where 0.91 is the assumed average fouling factor.

4. Calculate the full load steam rate (lb/hr-ton).

SRATE = 22.169 + 0.592 * PESTM - 0.0196 * PESTM * PESTM

- 6.9384 * RAT

(See table in calculation 5.2 for data used to perform curve fit.)

5. Determine the part load steam consumption for given load.

5.1 Calculate total full load steam consumption.

TØTSM = SRATE * (QHBC/FFL)

where (QHBC/FFL) represents total capacity of absorption chillers operating.

5.2 Calculate partial load factor.

PLF = 0.0136 + 0.7928 * FFL + 0.11843 * FFL * FFL

+ 0.0752 * FFL * FFL * FFL

where PLF was determined by curve fit of data shown below, taken from catalog.

Table

STEAM RATES [lb/(hr)(ton)]

STEAM PRESS. (Psig)	PERCENT NOMINAL CAPACITY*										
	20	30	40	50	60	70	80	90	100	110	120
4	22.8	22.1	21.4	20.7	20.0	19.2	18.6	17.8	17.2	16.4	15.7
8	–	–	22.8	22.1	21.8	20.6	19.9	19.3	18.5	17.8	17.1
12	–	–	–	23.0	22.2	21.5	20.7	20.0	19.3	18.5	17.7

*Percent Nominal Capacity = $\frac{\text{required tons}}{\text{nominal capacity}}$ = FFL * 100

Nominal Capacity = capacity at 12 psig, 44 F leaving chilled water, 85 F condensing water.

5.3 Calculate total steam consumption.

STEAM = TØTSM * PLF

SUBROUTINE: AHU

GENERAL DESCRIPTION

A routine to simulate the performance of air handling units calculating thermal requirements of heating and cooling coils, and steam humidifier. The simulation also accounts for the addition of heat by the fan.

LIST OF VARIABLES

INPUT

NAHU - Air handling unit type:

1) Draw-through unit: heating coil, cooling coil, fan, humidifier. See Figure for schematic.

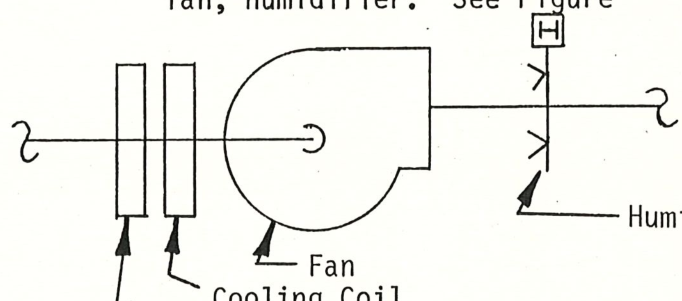


Fig. AHU TYPE #1

2) Draw-through unit: heating coil, cooling coil with face and bypass dampers, fan, and humidifier.

Control Sequence: When heating required, bypass full open and heating coil modulates to meet load, cooling coil off. When cooling required, heating coil locked out, cooling coil runs wild, dampers modulate to meet required dry bulb temperature. See Figure for schematic.

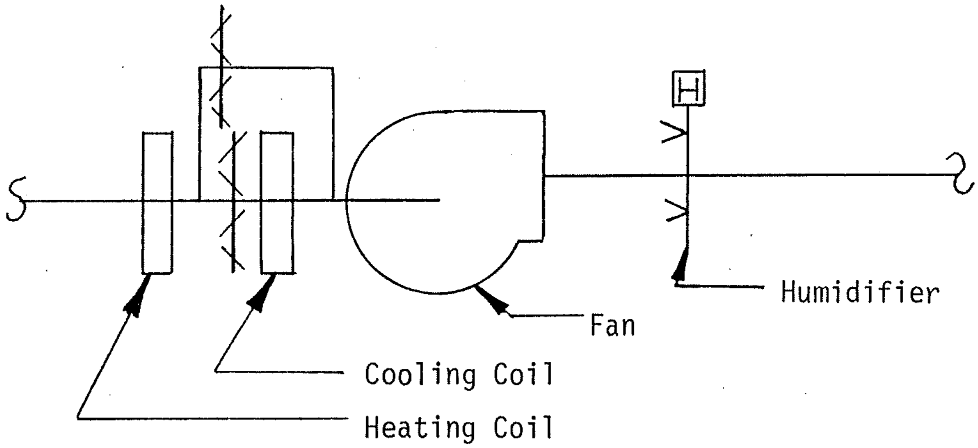


Fig AHU TYPE #2

PATM	-	Barometric pressure (in. Hg)
MFAN	-	Fan mass air flow (lbm-air/hr)
NVFC	-	Fan volume control index (see PTLD)
PCTLD	-	Fan full load fraction
DTFAN	-	Temperature rise across fan at full load (°F)
TLVG	-	Desired air temperature leaving AHU (°F)
TCD	-	Cold deck temperature (°F)
H2ØRD	-	Net humidity control zone water requirement
MZØNE	-	Humidity control zone mass air flow (lbm-air/hr)
WZ	-	Humidity control zone humidity ratio (lbm-H_2O/lbm-dry air)
TMA	-	Inlet dry bulb temperature (°F)
WMA	-	Inlet humidity ratio (lbm-H_2O/lbm-dry air)
DMA	-	Inlet air density (lbm/ft^3)

<u>OUTPUT</u>

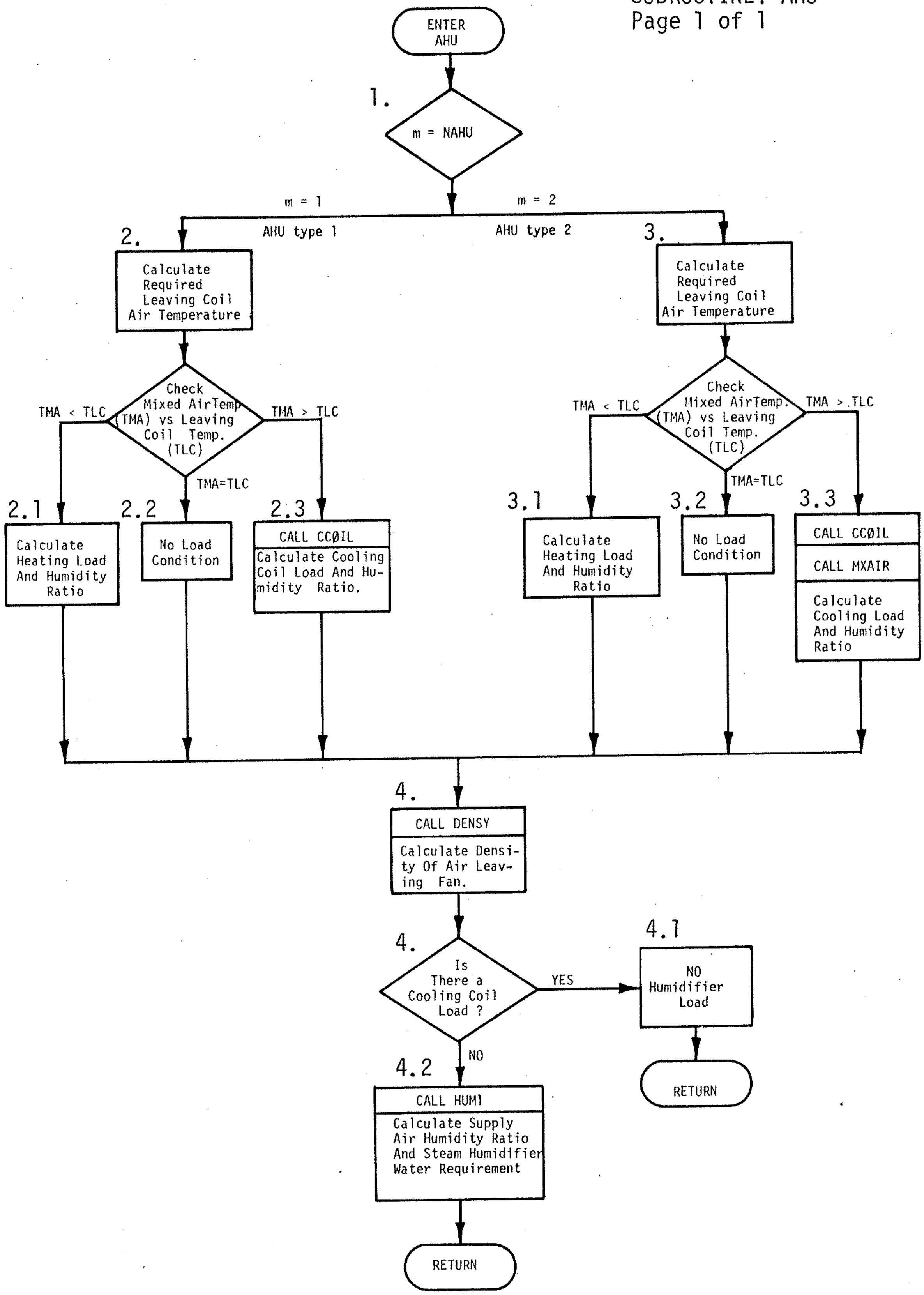
QCC	-	Cooling coil load (Btu/hr)
SHR	-	Sensible heat ratio
QHC	-	Heating coil load (Btu/hr)

WLVG - Humidity ratio entering humidifier section ($lbm-H_2O/lbm$-dry air)

DLVG - Air density entering humidifier section (lbm/ft^3)

WSUP - Humidity ratio after humidifier section ($lbm-H_2O/lbm$-Air)

WATER - Water added to air by humidifier ($lbm-H_2O/hr$)


ENTER AHU
1.
m = NAHU
m = 1
m = 2
AHU type 1
AHU type 2
2.
Calculate Required Leaving Coil Air Temperature
3.
Calculate Required Leaving Coil Air Temperature
Check Mixed AirTemp (TMA) vs Leaving Coil Temp. (TLC)
TMA < TLC
TMA > TLC
TMA=TLC
Check Mixed AirTemp. (TMA) vs Leaving Coil Temp. (TLC)
TMA < TLC
TMA > TLC
TMA=TLC
2.1
Calculate Heating Load And Humidity Ratio
2.2
No Load Condition
2.3
CALL CCØIL
Calculate Cooling Coil Load And Humidity Ratio.
3.1
Calculate Heating Load And Humidity Ratio
3.2
No Load Condition
3.3
CALL CCØIL
CALL MXAIR
Calculate Cooling Load And Humidity Ratio
4.
CALL DENSY
Calculate Density Of Air Leaving Fan.
4.
Is There a Cooling Coil Load ?
YES
NO
4.1
NO Humidifier Load
RETURN
4.2
CALL HUMI
Calculate Supply Air Humidity Ratio And Steam Humidifier Water Requirement
RETURN

CALCULATION SEQUENCE

1. Determine air handler type.

   If NAHU = 1 (single draw-through unit),

   Go to calculation 2.

   If NAHU = 2 (draw-through unit with bypass around cooling coil),

   Go to calculation 3.

2. Simple draw-through unit simulation (AHU Type 1).

   Calculate required leaving coil air temperature (TLC).

   TLC = TLVG - DTFAN * PTLD(NVFC,PCTLD)

   where PTLD is a function which calculates fan power at partial air flow.

   2.1 If mixed air temperature (TMA) less than required leaving coil temperature (TLC), heating is required. The following calculation sequence is used.

   QHC = MFAN * 0.245 * (TMA - TLC)

   QCC = 0.0

   WLVG = WMA

   SHR = 1.0

   Go to calculation 4.

   2.2 If mixed air temperature (TMA) equals required leaving coil temperature (TLC), there is no thermal load. The following calculation sequence is used.

   QHC = 0.0

   QCC = 0.0

   WLVG = WMA

   SHR = 1.0

   Go to calculation 4.

2.3 If mixed air temperature (TMA) is greater than required leaving coil temperature (TLC), cooling is required. The following calculation sequence is used.

> Call subroutine CCØIL to calculate WLVG, QCC, and SHR.
>
> QHC = 0.0
>
> Go to calculation 4.

3. Draw-through unit with bypass around cooling coil (AHU Type 2).

Calculate leaving coil air temperature (TLC).

TLC = TLVG - DTFAN * PTLD(NVFC,PCTLD)

3.1 If mixed air temperature (TMA) is less than the required leaving coil temperature (TLC), heating is required. The following calculation sequence is used.

> QHC = MFAN * 0.245 * (TMA - TLC)
>
> QCC = 0.0
>
> WLVG = WMA
>
> SHR = 1.0
>
> Go to calculation 4.

3.2 If mixed air temperature (TMA) equals required leaving coil temperature (TLC), there is no load. The following calculation sequence is used.

> QHC = 0.0
>
> QCC = 0.0
>
> WLVG = WMA
>
> SHR = 1.0
>
> Go to calculation 4.

3.3 If mixed air temperature (TMA) is greater than the required leaving coil temperature (TLC), cooling is required. The following calculation sequence is used.

> Call subroutine CCØIL to calculate cooling coil performance for 1.0 lbm-air/hr (QCC1).

Call subroutine MXAIR to calculate position of face and bypass campers (ALFA = portion of air through bypass) and fan discharge humidity ratio (WLVG).

QCC = MFAN * (1.0 - ALFA) * QCC1

Go to calculation 4.

4. Humidifier simulation.

Using function DENSY, calculate density of air leaving fan (DLVG).

4.1 If cooling coil load (QCC) is greater than zero (0.0), the following sequence is used.

WATER = 0.0

WSUP = WLVG

4.2 If cooling coil load (QCC) is less than or equal to zero, the following sequence is used.

WSUP = -H2ØRD/MZØNE + WZ

(Limit WSUP by high limit switch on humidifier set at 80% R.H. This is calculated by subroutine HUM1.)

WATER = -MFAN * (WLVG - WSUP)

FUNCTION: ALØG1

GENERAL DESCRIPTION

Calculate the logarithm to the base 10 for a given number.

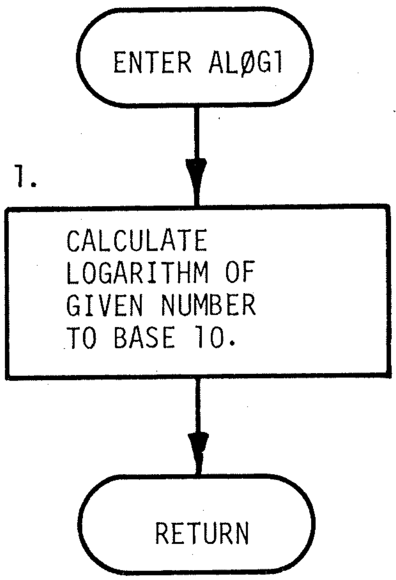
LIST OF VARIABLES

INPUT

X - Number of which logarithm to base 10 is desired

OUTPUT

ALØG1 - Logarithm to base 10 for given X.


ENTER ALØG1
1.
CALCULATE LOGARITHM OF GIVEN NUMBER TO BASE 10.
RETURN

CALCULATION SEQUENCE

1. Calculate logarithm of X to base 10.

$$AL\emptyset G1 = 0.434294481 * \mathrm{Log}_e (X)$$

SUBROUTINE: BRAD2

GENERAL DESCRIPTION

A subroutine to calculate the heat (QB) added to a zone by a baseboard radiation heating system and to correspondingly adjust the zone's base sensible heat load (QS). Heat output of baseboard radiation is adjusted as a function of ambient temperature via a hot water temperature reset. When outside temperature exceeds the ambient high limit, the baseboard heating system is turned off.

LIST OF VARIABLES

INPUT

QS - Base sensible thermal load (Btu/hr)

TSP - Setpoint temperature of zone (°F)

CBTU - Heat output of baseboard radiation at standard conditions (215°F average water temperature, 65°F entering air temperature) (Btu/hr-linear ft)

ALFBR - Active length baseboard radiation (linear ft)

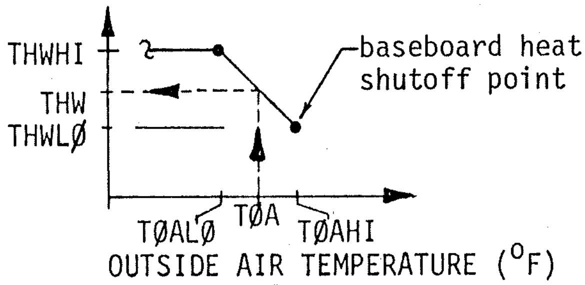
TØA - Dry-bulb temperature outside air (°F)

THWHI - Hot water maximum temperature. This is the value used at or below ambient temperature TØALØ (°F)

THWLØ - Hot water minimum temperature. This is the value used at or above ambient temperature TØAHI (°F)

TOAHI - Ambient air temperature at which the hot water temperature is THWLØ

TØALØ - Ambient air temperature at or below which the hot water temperature is THWHI (°F)

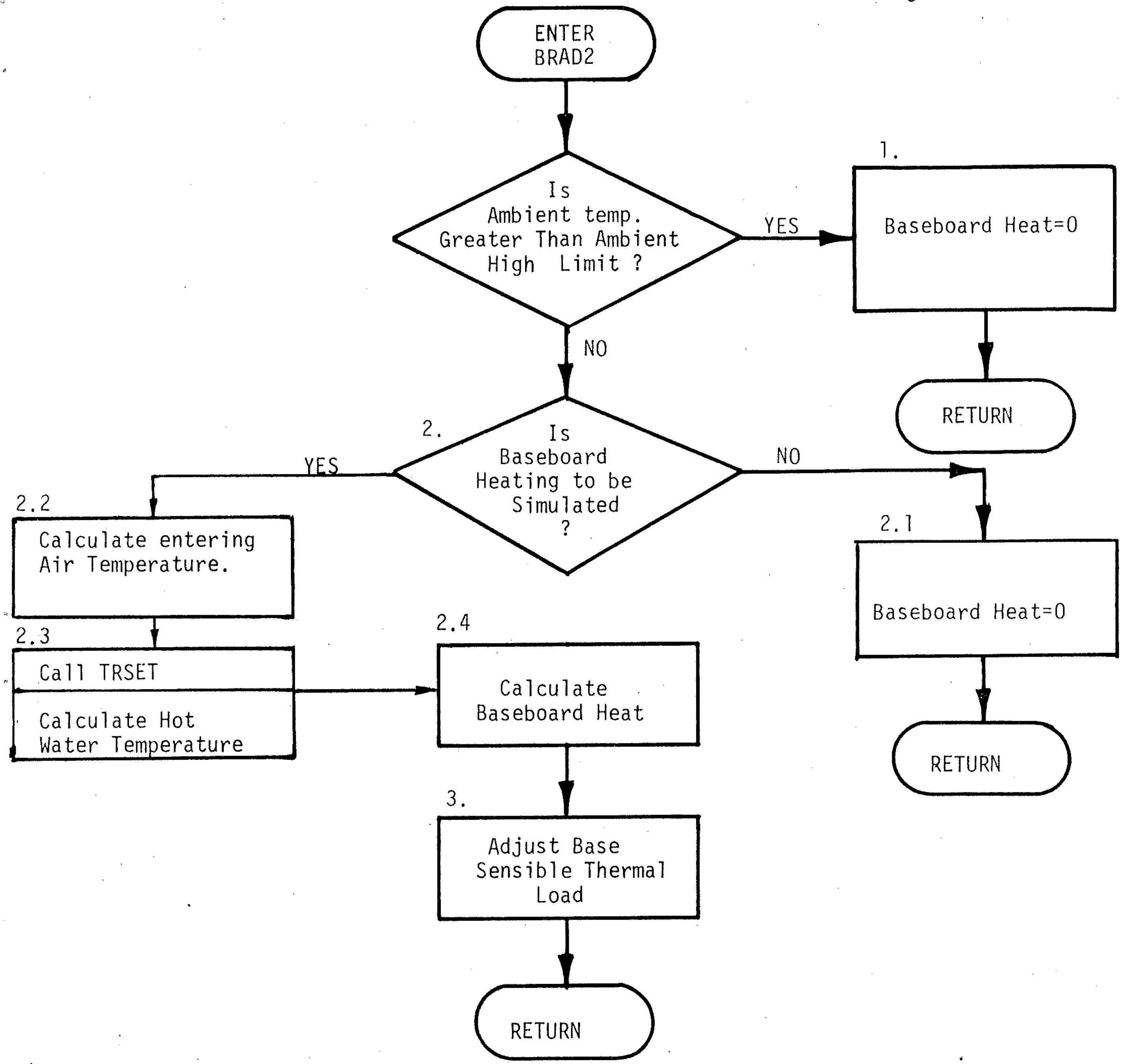


Graphic illustration of baseboard hot water temperature reset as function of outside air temperature.

OUTPUT

QS - Adjusted base sensible thermal load (Btu/hr)

QB - Heat given off by baseboard radiation (Btu/hr)


ENTER BRAD2
Is Ambient temp. Greater Than Ambient High Limit ?
YES
1.
Baseboard Heat=0
RETURN
NO
2.
Is Baseboard Heating to be Simulated ?
YES
NO
2.2
Calculate entering Air Temperature.
2.1
Baseboard Heat=0
RETURN
2.3
Call TRSET
Calculate Hot Water Temperature
2.4
Calculate Baseboard Heat
3.
Adjust Base Sensible Thermal Load
RETURN

CALCULATION SEQUENCE

1. Baseboard heating off.

    If TØA > TØAHI

    QB = 0.

    RETURN

2. Baseboard heating on.

    2.1 If CBTU = 0. or ALFBR = 0

    QB = 0.

    RETURN

    2.2 If outside air temperature (TØA) less than or equal to ambient high limit (TØAHI)

    TAIR = TSP - 10.

    (NOTE: In simulating baseboard heating performance, the entering air temperature used is 10°F less than the space setpoint.)

    2.3 Call function TRSET to calculate hot water temperature (JHWRD). If THWRD is less than TAIR, THWRD = TAIR.

    2.4 Calculate baseboard radiation heat transfer from the 1967 ASHRAE Guide and Databook, Systems and Equipment, page 348, the function expressing heating unit output is given.

    $$H = c(t_s - t_a)^n$$

    where

    H - Heat output (Btu/hr)

    c - A constant determined by test (Btu/hr-°F^n)

    t_s - Average temperature of heating medium (°F)

    t_a - Entering air temperature (°F)

    n - Temperature difference exponent equals:

    1.3 for cast iron radiators
    1.4 for baseboard radiation
    1.5 for convectors

The variable "c" per unit length is established by manufacturer's test under standard temperature conditions. Adjusting for other than standard conditions yields:

$$H = c \left[\frac{(t_s - t_a)}{(215.-65.)} \right]^n$$

where:

215. - Average hot water temperature at standard conditions (°F)

65. - Entering air temperature at standard conditions (°F)

For baseboard radiation, this equation is expressed in subroutine BRAD2 as:

$$QB = - \left[\frac{(THW - TAIR)}{(215.-65.)} \right]^{1.4} * CBTU * ALFBR$$

3. Adjust base sensible thermal load (QS).

$$QS = QS - QB$$

SUBROUTINE: CDATA

GENERAL DESCRIPTION

This subroutine reads and prints card input data required to run the System and Equipment Simulation program. The routine also checks input data and assigns default values to certain variables. The format and definitions of input variables are given in Table . Figure illustrates the input data printout page.

LIST OF VARIABLES

INPUT

COMMON

KØ - Line printer unit number

IC - Card reader unit number

OUTPUT

COMMON

IPRT1 - Optional print flag-1

IPRT2 - Optional print flag-2

IPRT3 - Optional print flag-3

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

$KFAN_k$ - Energy distribution system index

$JMAX_k$ - Number of zones on system k

The variable "c" per unit length is established by manufacturer's test under standard temperature conditions. Adjusting for other than standard conditions yields:

$$H = c\left[\frac{(t_s - t_a)}{(215.-65.)}\right]^n$$

where:

215. - Average hot water temperature at standard conditions (°F)

65. - Entering air temperature at standard conditions (°F)

For baseboard radiation, this equation is expressed in subroutine BRAD2 as:

$$QB = -\left[\frac{(THW - TAIR)}{(215.-65.)}\right]^{1.4} * CBTU * ALFBR$$

3. Adjust base sensible thermal load (QS).

$$QS = QS - QB$$

TABLE SYSTEM AND EQUIPMENT SIMULATION PROGRAM CARD INPUT VARIABLE DESCRIPTION

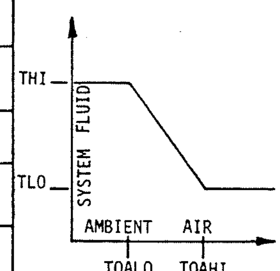
READING ORDER	COLUMNS	INPUT VARIABLE DESCRIPTION	PROGRAM SYMBOL	UNITS	LIMIT VALUES	CODE	EXAMPLE	COMMENTS
SS-1	1 to 10	Hour of year at which simulation may begin	IHSRT	HOUR OF YEAR	0. to 8784.		0.	Default value-begin with first hour on load tape
	11 to 20	Hour of year at which simulation may end	IHSTP	HOUR OF YEAR	0. to 8784. IHSRT $\leq$ IHSTP		0.	Default value-end with last hour on load tape
	21 to 30	Number of primary equipment combinations to be run	NCASE		1. to 10.		1.	
	31 to 40	Number of reset schedules to be read (card type SS-3)	NRSET		0. to 10.		3.	
	41 to 50	Fan system shut-off flag	IFAN		0., 1., or 2.	0 = Fans run continuously 1 = Fans may be shut off 2 = Fans & Basebd.htg. may be shut off	0.	If IFAN = 1 and $\Sigma\|Qs\|=0.$, then system(s) shut-off occurs
	51 to 60	Heat conservation system indicator. Does one case use heat conservation system?	KHCST		1. or 2.	1. = No 2. = Yes	1.	
	61 to 70	Number of energy distribution systems	KMAX				6.	Limited by value of dimension statements within program
SS-2	1 to 10	Optional print flag-1--hourly summaries	IPRT1		0. or 1.	0. = Do not print 1. = Print	1.	Recommended maximum run length w/IPRT1 ON = a few months
	11 to 20	Optional print flag-2--zone summaries	IPRT2		0. or 1.		0.	Recommended maximum run length w/IPRT2 ON = a few weeks
	21 to 30	Optional print flag-3--system component performance	IPRT3		0. or 1.		0.	Recommended maximum run length w/IPRT3 ON = a few days.
REPEAT CARD TYPE SS-3 "NRSET" TIMES.								
SS-3	1 to 10	Low outside air temperature at which system temp. is THI	TOALO(NR)	$^oF.$			-15.	All reset schedules are defined here and are referenced to the energy distribution systems via the variable ISET (see SS-4C). The schedules define hot and cold deck air temps., primary air temp. and boiler water temp. as a function of ambient air temp.
	11 to 20	High outside air temperature at which system temp. is TLO	TOAHI(NR)	$^oF.$			55.	
	21 to 30	Low system fluid temperature	TLO(NR)	$^oF.$			140.	
	31 to 40	High system fluid temperature	THI(NR)	$^oF.$			210.	
	41 to 50	Reset schedule label (alpha-numeric)	ZNAME				Hot Water	

TABLE SYSTEM AND EQUIPMENT SIMULATION PROGRAM CARD INPUT VARIABLE DESCRIPTION (CONT'D)

READING ORDER	COLUMNS	INPUT VARIABLE DESCRIPTION	PROGRAM SYMBOL	UNITS	LIMIT VALUES	CODE	EXAMPLE	REQUIRED FOR THE FOLLOWING SYSTEM TYPES	COMMENTS
READ CARD TYPES SS-4 AND SS-5 AS FOLLOWS: SS-4A,B,C,D, SS-5 (REPEATING SS-5 "JMAX(K)" TIMES). REPEAT ABOVE PROCEDURE "KMAX" TIMES. (SYSTEM-1 CARDS, ZONE-1 CARDS; SYSTEM-2 CARDS, ZONE-2 CARDS; ETC.)									
SS-4A	1 to 10	Type of energy distribution system	KFAN(K)		1. to 13.	1-Single Zone Fan System With Face And By-Pass Dampers. 2-Multi-Zone Fan System. 3-Dual Duct Fan System. 4-Single Zone Fan System With Sub-Zone Reheat. 5-Unit Ventilator. 6-Unit Heater 7-Floor Panel Heating 8-Two-pipe Fancoil System. 9-Four-pipe Fancoil System. 10-Two-pipe Induction Unit Fan System. 11-Four-pipe Induction Unit Fan System. 12-Variable Volume Fan System With Optional Reheat. 13-Constant Volume Reheat Fan System.	13.	ALL	
	11 to 20	Number of zones on system	JMAX(K)				10.	ALL	Limited by dimension statements
	21 to 30	System relative humidity set point	RHSP(K)	%R.H.			50.	1,2,3,4,10,11,12,13	
	31 to 40	System zone in which humidistat controlling central humidifier is located	ICZN(K)				1.	1,2,3,4,10,11,12,13	
	41 to 50	Minimum outside air volume	OACFM(K)	cfm			3000.	1,2,3,4,5,8,9,10,11,12,13	If exh.air exceeds OACFM, OACFM will be set equal to exh. air.
	51 to 60	Mixed air option	MXAO(K)		1.,2., or 3.	1.Fixed percent outside air 2.Enth.temp.econo.control 3.Temp.econo.control	3.	1,2,3,4,10,11,12,13	
	61 to 70	Variable volume fan control option	NVFC(K)		1.,2., or 3.	1.Variable speed motor 2.Inlet vane damper 3.Discharge damper	2.	4,12	Default value = 2.
SS-4B	1 to 10	Hot deck temp. control mode (KFAN(K)=2 or 3) AHU LVG temp. control mode (KFAN(K)=13)	ITMPC(K,1)		1. or 6. 1. or 2.	1.Predefined constant (TFIX1 or TFIX2) 2.Determined by zone with coldest supply air reqmt. 6.Determined by zone with warmest supply air reqmt.	6.	2,3,13	
	11 to 20	Cold deck temp. control mode	ITMPC(K,2)		1. or 2.		2.	2,3	
	21 to 30	Total supply fan pressure	TFNPS(K)	in.H_2O	Non-negative		3.8	1,2,3,4,5,6,8,9,10,11,12,13	
	31 to 40	Total return fan pressure	TFNPR(K)	in.H_2O	Non-negative		2.1	1,2,3,4,10,11,12,13	
	41 to 50	Total exhaust fan pressure	TFNPE(K)	in.H_2O	Non-negative		1.6	1,2,3,4,5,6,8,9,10,11,12,13	
	51 to 60	Are reheat coils located after variable volume boxes?	IVVRH(K)		0. or 1.	0. - No 1. - Yes	1.	12	
	61 to 70	Minimum air flow through variable volume boxes	VVMIN(K)	%	0. to 100.		25.	12	

TABLE SYSTEM AND EQUIPMENT SIMULATION PROGRAM CARD INPUT VARIABLE DESCRIPTION (CONT'D)

READING ORDER	COLUMNS	INPUT VARIABLE DESCRIPTION	PROGRAM SYMBOL	UNITS	LIMIT VALUES	CODE	EXAMPLE	REQUIRED FOR THE FOLLOWING SYSTEM TYPES	COMMENTS
SS-4C	1 to 10	Fixed hot deck temp.(KFAN(K) = 2,3) Fixed AHU Discharge temp.(KFAN(K) = 4,11, 12,13	TFIX1(K)	$^oF.$			95.	2,3,4,11,12,13	For system types 2, 3 & 13, this variable is functional only if ITMPC(K,1)=1
	11 to 20	Fixed cold deck temperature	TFIX2(K)	$^oF.$			55.	1,2,3,	For system types 2 & 3, this variable is functional only if ITMPC(K,2) = 1.
	21 to 30	Hot deck air temp. reset schedule index (KFAN(K) = 2,3) Primary air temp. reset schedule index (KFAN(K) = 10) AHU discharge air temp. reset schedule index (KFAN(K) - 13)	ISET(K,1)		1. to 10.		1.	2,3,10,13	ISET (K,N) keys a specific outside air reset schedule to control the temperature of a specified portion of system. See Table 6.4 for ISET/system type matrix.
	31 to 40	Cold deck air temp. reset schedule index	ISET(K,2)		1. to 10.		2.	2,3,	
	41 to 50	Baseboard radiation water temperature reset schedule index	ISET(K,3)		1. to 10		3.	1,2,3,4,8,9, 10,11,12,13	
	51 to 60	Two-pipe fancoil system & two-pipe induction unit system hot water temperature reset schedule index	ISET(K,4)		1. to 10.		1.	8,10	
	61 to 70	Ratio of induced to primary air	RIPA(K)				2.7	10,11	Induced air = RIPA primary air
SS-4D	1 to 10	Two-pipe fancoil system changeover temp.	TCOFC(K)	$^oF.$			53.	8.	At +2.5^oF LAG inhibits repeated changeover in temperate weather
	11 to 20	Two-pipe induction unit fan system change-over temperature.	TOACO(K)	$^oF.$			53.	10.	
		Floor panel heating system hot water shut-off temperature					53.	7	
	21 to 30	Volume of water in changeover type system (2-pipe fancoil or 2-pipe induction)	PWGAL(K)	Gals.	Non-negative		1000.	8,10	The changeover load is calculated by the program
	31 to 40	Location of floor heating panels	PLOC(K)			1. - Slab on grade. 2. - Intermediate floor slab	1.	7	More than one zone may be included on the floor panel heating system only if they all have the same set point temperature
	41 to 50	Floor area covered by heating panels	PAREA(K)	Sq.Ft.				7	
	51 to 60	Exposed perimeter of floor	PERIM(K)	Ft.				7	

TABLE SYSTEM AND EQUIPMENT SIMULATION PROGRAM CARD INPUT VARIABLE DESCRIPTION (CONT'D)

READING ORDER	COLUMNS	INPUT VARIABLE DESCRIPTION	PROGRAM SYMBOL	UNITS	LIMIT VALUES	CODE	EXAMPLE	REQUIRED FOR THE FOLLOWING SYSTEM TYPES	COMMENTS
	REPEAT CARD TYPE SS-5 "JMAX(K)" TIMES.								
SS-5	1 to 10	Space number used in load and variable temperature programs	SPACN(K,J)				87.	All	Spaces are renumbered internally by this program. Only those spaces specified will be included. Load space types may be used more than once or not at all.
	11 to 20	Zone multiplication factor	MULT(I)		Non-negative whole numbers		2.	All	
	21 to 30	Air exhausted from zone	CFMX(I)	CFM			500.	1,2,3,4,5,8,9,10,11,12,13	This value is considered to be held constant unless the fan system is off (see SS-1,IFAN)
	31 to 40	Heat output of baseboard radiation per linear ft. at design conditions	CBTU(I)	BTU/Hr. Lin.Ft.			700.	1,2,3,4,8,9,10,11,12,13	Design conditions: 65°F incoming air; 215°F heating medium temperature.
	41 to 50	Active length of baseboard radiation	ALFBR(I)	Ft.			10.	1,2,3,4,8,9,10,11,12,13	
	51 to 60	Load program space number of plenum above this space	IPLEN(I)				88.	1,2,3,4,5,10,11,12,13	If a ceiling plenum(esp.return air ceiling plenum) was modeled in load program as a separate space above this zone, enter its load program space number here.
	61 to 70	Zone name	ZNAME				A236	All	Alpha-numeric characters may be used here
	REPEAT CARD TYPES SS-6 AND SS-7 "NCASE" TIMES USING THE FOLLOWING ORDER: SS-6(1), SS-7(1); SS-6(2), SS-7(2); ETC. NOTE: PLACE ALL HEAT CONSERVATION SYSTEMS LAST IN THE DECK.								
SS-6	1 to 10	System identification number	ISYS(NC)				160900101.		
	11 to 20	Is this a heat conservation building?	KBLDG(NC)		1. or 2.	1. - No 2. - Yes	1.		
	21 to 30	Type of chiller	M1 (NC)		1 thru 5.	1.-Reciprocating 2.-Hermetic centrifugal 3.-open centrifugal 4.-Steam absorption 5.-Centrifugal/Steam turbine	2.		
	31 to 40	Source of chiller energy	M2(NC)			1.-Gas 2.-Oil 3.-Steam 4.-Electric	4.		
	41 to 50	Source of general heating energy	M3(NC)				1.	Includes heating and pre-heating coils, baseboard radiation and floor panel heating.	
	51 to 60	Source of reheat coil energy	KREHT(NC)			0.-None 1.-Gas(Hot water or steam) 2.-Oil(Hot water or steam) 3.-Steam(Hot water or steam) 4.-Electric(Resistance hot water or steam)	1.		

TABLE SYSTEM AND EQUIPMENT SIMULATION PROGRAM CARD INPUT VARIABLE DESCRIPTION (CONT'D)

READING ORDER	COLUMNS	INPUT VARIABLE DESCRIPTION	PROGRAM SYMBOL	UNITS	LIMIT VALUE	CODE	EXAMPLE	COMMENTS
SS-7	1 to 10	Type of auxilliary chiller	M6(NC)			0. - None 1. - Reciprocating 2. - Hermetic centrifugal 3. - Open centrifugal	0.	For heat conservation buildings only
	11 to 20	Source of supplemental heat	M7(NC)			0. - None 3. - Electric 1. - Gas 4. - Well water 2. - Oil 5. - City water	0.	
	21 to 30	Number of engine/generator sets	M4(NC)				0.	If left 0., the program will calculate this quantity
	31 to 40	Type of engine/generator sets	M5(NC)			0. - None 1. - Diesel 2. - Gas	1.	
SS-8	1 to 10	Number of boilers	NUMB				2.	Default value = 1.
	11 to 20	Size of each boiler	SZB	MBH			350.	
	21 to 30	Hour of seasonal boiler start-up	BON	Hour of year	0. to 8784.		0.	
	31 to 40	Hour of seasonal boiler shut-down			0. to 8784. $\leq$ BON		0.	If left 0.0, boiler is available for entire year
	41 to 50	Heating value heating oil (for boiler)	HVHO	BTU/Gal	Non-negative		147,000.	Default value = 150,000. BTU/Gal
SS-9	1 to 10	Number of chillers	NUMC				2.	Default value = 1.
	11 to 20	Size of each chiller	SZC	Tons			100.0.	
	21 to 30	Hour of seasonal chiller start-up	CON	Hour of year			2161.	
	31 to 40	Hour of seasonal chiller shut-down	COFF	Hour of year			5833	Default value = 8785. which causes chiller availability from CON thru the end of the year
	41 to 50	Minimum part load chiller cut-off	FFLMN	%	0. to 100.		20.	Default value = 10.%
	51 to 60	Chilled water set point temperature	TLCHL	^{o}F	40. to 50.		44.	Default value = 45. ^{o}F
	61 to 70	Cooling tower water low limit temperature	TECMN	^{o}F	75. to 90.		80.	Default value = 75.^{o}F

TABLE SYSTEM AND EQUIPMENT SIMULATION PROGRAM CARD INPUT VARIABLE DESCRIPTION (CONT'D)

READING ORDER	COLUMNS	INPUT VARIABLE DESCRIPTION	PROGRAM SYMBOL	UNITS	LIMIT VALUE	CODE	EXAMPLE	COMMENTS
SS-10	1 to 10	Total boiler water pump head	HDBLP	Ft.	Non-negative		50.	
	11 to 20	Total chilled water pump head	HDCLP	Ft.	Non-negative		40.	
	21 to 30	Total condenser water pump head	HDCNP	Ft.	Non-negative		30.	
SS-11	1 to 10	External lighting power	PWOL	KW	Non-negative		0.	
	11 to 20	Fan and pump motor efficiency	EFF	%	1. to 100.			Default value = 85.%
	21 to 30	Building changeover temperature	TCO	^oF			56.	Default value = 55. ^oF
	31 to 40	Heating value diesel fuel (for engine/ generator)	HVDF	BTU/Gal.			139000.	Default value = 140,000 BTU/Gal.
SS-12	1 to 10	Boiler supply and absorption chiller entering steam pressure	PESTM	PSIG	2. to 12.		12.	Default value if PESTM out of range: PESTM = 12.0 Psia TESTM = 245. ^oF
	11 to 20	Boiler supply and absorption chiller entering steam temperature	TESTM	^oF			245.	
	21 to 30	Steam turbine entering steam pressure	PPS	PSIG			125.	Default values if PPS not defined: PPS = 125. PSIG TPS = 353. ^oF
	31 to 40	Steam turbine entering steam temperature	TPS	^oF			353.	
	41 to 50	Steam turbine speed	RPM	Rpm			3500.	Default value 3600. Rpm
SS-13	1 to 10	Type of floor covering	KFLCV			1. - Bare concrete 2. - Tile 3. - Carpeting	3.	These variables apply to floor panel heating systems only
	11 to 20	Floor insulation conductance	CINSL	BTU/Hr-SQ.FT.-^oF			0.2	
	21 to 30	Floor insulation thickness	DINSL	Ft.			0.5	

TABLE SYSTEM AND EQUIPMENT SIMULATION PROGRAM CARD INPUT VARIABLE DESCRIPTION (CONT'D)

READING ORDER	COLUMNS	INPUT VARIABLE DESCRIPTION	PROGRAM SYMBOL	UNITS	LIMIT VALUES	CODE	EXAMPLE	COMMENTS
SS-14	1 to 10	maximum allowable condenser water temp.	TLCNM	^oF			115.	
	11 to 20	Well or city water design return water temperature	TLCMN	^oF			50.	
	21 to 30	City water supply temperature	TCWIN	^oF			60.	
	31 to 40	Well water supply temperature	TWWIN	^oF			60.	
	41 to 50	Total well water pump head	HDWWP	Ft.			50.	
SS-15	1 to 10	Type of snow melting system	KSNOW			0. - None 1. - Liquid 2. - Electric	0.	
	11 to 20	Snow melting system design load	QSNOW	BTU/Hr.			5000.	
	21 to 30	Snow melting slab area	SAREA	Ft.^{2}			800.	

```
************************************************ RECAP OF CARD INPUT DATA ************************************************
                                                                              NOTE--ALTHOUGH SOME VARIABLES APPEAR
CARD TYPE-1.                                                                        AS INTEGERS IN THIS LISTING,
      1  IHSRT - HOUR OF YEAR AT WHICH SIMULATION MAY BEGIN.                         ALL NUMERIC CARD INPUT DATA ARE
   8785  IHSTP - HOUR OF YEAR AT WHICH SIMULATION MAY END.                           READ AS REAL NUMBERS.
      1  NCASE  - NUMBER OF CASES TO BE RUN.                                         DEFAULT VALUES FOR CERTAIN VARIABLES
      5  NRSET - NUMBER OF RESET SCHEDULES TO BE READ.                               ARE SUBSTITUTED AS REQUIRED
      0  IFAN  - FAN SHUT-OFF FLAG.                                                  AND APPEAR IN THIS LISTING.
      1  KHCST - HEAT CONSERVATION SYSTEM FLAG.
      1  KMAX  - NO. OF ENERGY DISTRIBUTION SYSTEMS.

CARD TYPE-2.
      0  IPRT1 - OPTIONAL PRINT FLAG, LEVEL 1...HOURLY SUMMARIES.
      0  IPRT2 - OPTIONAL PRINT FLAG, LEVEL 2...ZONE SUMMARIES.
      0  IPRT3 - OPTIONAL PRINT FLAG, LEVEL 3...SYSTEM COMPONENT PERFORMANCE.

CARD TYPE-3.
TEMPERATURE RESET SCHEDULES.
  SCHEDULE      TOALO       TOAHI        TLO         THI         ** LABEL **
   NUMBER
      1         -15.0        60.0       220.0       140.0        HOT WATER
      2          55.0        85.0        55.0        95.0        2PIU AIR-S
      3          55.0        95.0        55.0        70.0        PRIMARYAIR
      4         -15.0        55.0        90.0       115.0        HOT DECK
      5          55.0        85.0        55.0        65.0        COLD DECK
*****************************************************************************************************************************
CARD TYPE-4.
SYSTEM NUMBER  1.
KFAN =      13.0 JMAX =        5.0 RHSP =        50.0 ICZN =        1.0 OACFM=     6000.0 MXAO =       3.0 NVFC =       0.0
ITMPC=       2.0 ITMPC=        0.0 TFNPS=        4.00 TFNPR=        2.00 TFNPE=       1.50 IVVRH=       0. VVMIN=        0.0
TFIX1=       0.0 TFIX2=        0.0 ISET =         1.0 ISET =        0.0 ISET =        1.0 ISET =       0.0 RIPA =       0.0
TCOFC=       0.0 TOACO=        0.0 PWGAL=         0.0 PLOC =        0.0 PAREA=        0.0 PERIM=       0.0

CARD TYPE-5.
ZONE DATA.
     J     SPACN(K,J)   MULT(I)   CFMX(I)    CBTU(I)  ALFBR(I)   IPLFN(I)    ZONE LABEL
  (CALC'D)
     1        1.0        1.0      1500.0      0.0       0.0          0       CENTR ZONE
     2        2.0        1.0         0.0      0.0       0.0          0       PERIM.OFF.
     3        3.0        1.0         0.0      0.0       0.0          0       PERIM.OFF.
     4        4.0        1.0         0.0      0.0       0.0          0       PERIM.OFF.
     5        5.0        1.0         0.0      0.0       0.0          0       PERIM.OFF.
*****************************************************************************************************************************
PRIMARY EQUIPMENT DESCRIPTION.
CASE NUMBER  1.
CARD TYPE-6.
    102.  ISYS  - SYSTEM COMBINATION NUMBER.
      1.  KBLDG - BUILDING TYPE (1.=CONVENTIONAL OR ON-SITE, 2.=HEAT CONSERVATION).
      3.  M1    - TYPE OF CHILLER.
      4.  M2    - SOURCE OF CHILLER ENERGY.
      1.  M3    - SOURCE OF HEATING ENERGY.
      1.  KREHT - SOURCE OF REHEAT COIL ENERGY.

CARD TYPE-7.
      0.  M6    - TYPE OF AUXILIARY CHILLER.
      0.  M7    - SOURCE OF SUPPLEMENTAL HEAT.
      0.  M4    - NUMBER OF ON-SITE ENGINE GENERATOR SETS.
      0.  M5    - TYPE OF E/G SET.
*****************************************************************************************************************************
```

Figure RECAP OF CARD INPUT DATA

```
CARD TYPE-8.
         2  NUMB  - NUMBER OF BOILERS.
     100.0  SZB   - SIZE OF EACH BOILER (MBH).
       0.0  BON   - HOUR OF SEASONAL BOILER START-UP.
       0.0  BOFF  - HOUR OF SEASONAL BOILER SHUT-DOWN.
  150000.0  HVHO  - HEATING VALUE HEATING OIL

CARD TYPE-9.
         2  NUMC  - NUMBER OF CHILLERS.
     100.0  SZC   - SIZE OF EACH CHILLER (TONS).
       0.0  CON   - HOUR OF SEASONAL CHILLER START-UP.
    8785.0  COFF  - HOUR OF SEASONAL CHILLER SHUT-DOWN.
      10.0  FFLMN - MINIMUM PART LOAD CUT-OFF FOR CHILLERS (PER CENT).
      45.0  TLCHL - CHILLED WATER SET POINT TEMP.
      75.0  TECMN - COOLING TOWER WATER LOW LIMIT TEMPERATURE.

CARD TYPE-10.
      40.0  HDBLP - TOTAL BOILER WATER PUMP HEAD (FT.).
      50.0  HDCLP - TOTAL CHILLED WATER PUMP HEAD (FT.).
      30.0  HDCNP - TOTAL CONDENSER WATER PUMP HEAD (FT.).

CARD TYPE-11.
       0.0  PWOL  - EXTERNAL LIGHTING POWER.
      85.0  EFF   - FAN AND PUMP MOTOR EFFICIENCY (PER CENT).
      55.0  TCO   - BLDG CHANGEOVER TEMP.
  140000.0  HVDF  - HEATING VALUE DIESEL FUEL

CARD TYPE-12.
      12.0  PESTM - BOILER SUPPLY AND ABSORPTION CHILLER ENTERING STEAM PRESSURE (PSIG).
     245.0  TESTM - BOILER SUPPLY AND ABSORPTION CHILLER ENTERING STEAM TEMPERATURE (DEG.F.).
     125.0  PPS   - STEAM TURBINE ENTERING STEAM PRESSURE (PSIG.).
     353.0  TPS   - STEAM TURBINE ENTERING STEAM TEMPERATURE (DEG.F.).
    3600.0  RPM   - STEAM TURBINE SPEED (RPM).

CARD TYPE-13.
         0  KFLCV - TYPE OF FLOOR COVERING.
   0.0      CINSL - FLOOR INSULATION CONDUCTANCE.
   0.0      DINSL - FLOOR INSULATION THICKNESS.

CARD TYPE-14.
       0.0  TLCNM - MAXIMUM ALLOWABLE CONDENSER WATER TEMPERATURE (DEG.F.).
       0.0  TLCMN - WELL OR CITY WATER DESIGN RETURN WATER TEMPERATURE (DEG.F.).
       0.0  TCWIN - CITY WATER SUPPLY TEMPERATURE (DEG.F.).
       0.0  TWWIN - WELL WATER SUPPLY TEMPERATURE (DEG.F.).
       0.0  HDWWP - TOTAL WELL WATER PUMP HEAD (FT.).

CARD TYPE-15.
         0  KSNOW - TYPE OF SNOW MELTING SYSTEM.
       0.0  QSNOW - SNOW MELTING SYSTEM DESIGN LOAD.
       0.0  SAREA - SNOW MELTING SLAB AREA.
```

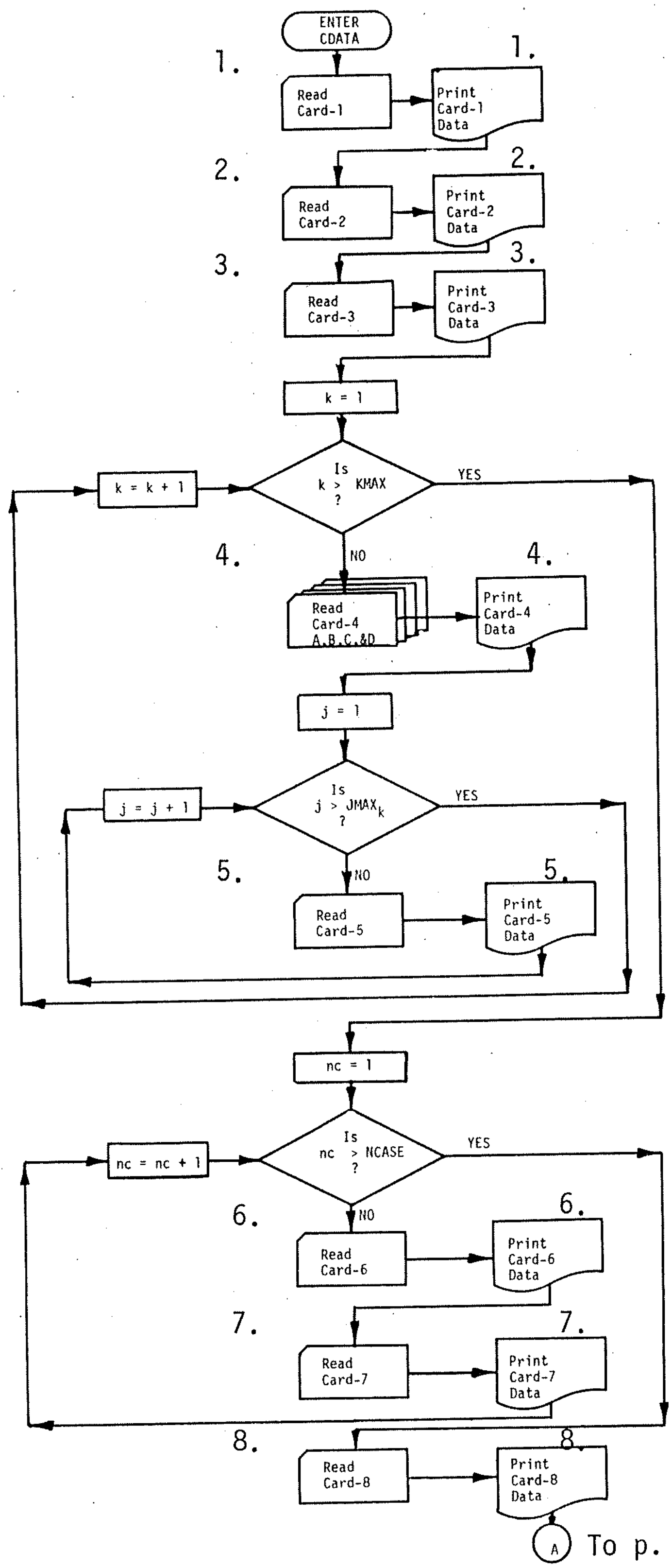
Figure RECAP OF CARD INPUT DATA, CONTINUED

$ØACFM_k$	-	Minimum ventilation air, system k (ft^3/min)
$RHSP_k$	-	Relative humidity set point, system k (% R.H.)
$PWGAL_k$	-	Process water volume, system k (gals)
$TFNPS_k$	-	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)
$MXAØ_k$	-	Mixed air option, system k
$IVVRH_k$	-	Variable volume reheat 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
$NVFC_k$	-	Type of fan airflow control, system k
$VVMIN_k$	-	Minimum air flow through variable volume boxes, system k
$TCØFC_k$	-	Two-pipe induction unit fan system changeover temperature or floor panel heating system hot water shut-off temperature, system k (°F)
$TFIX1_k$	-	Fixed hot deck or AHU discharge temperature, system k (°F)
$TFIX2_k$	-	Fixed cold deck temperature, system k (°F)
$RIPA_k$	-	Ratio of induced to primary air, system k
$CFMX_i$	-	Exhaust air flow rate, zone i (cu ft/min)
$ALFBR_i$	-	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

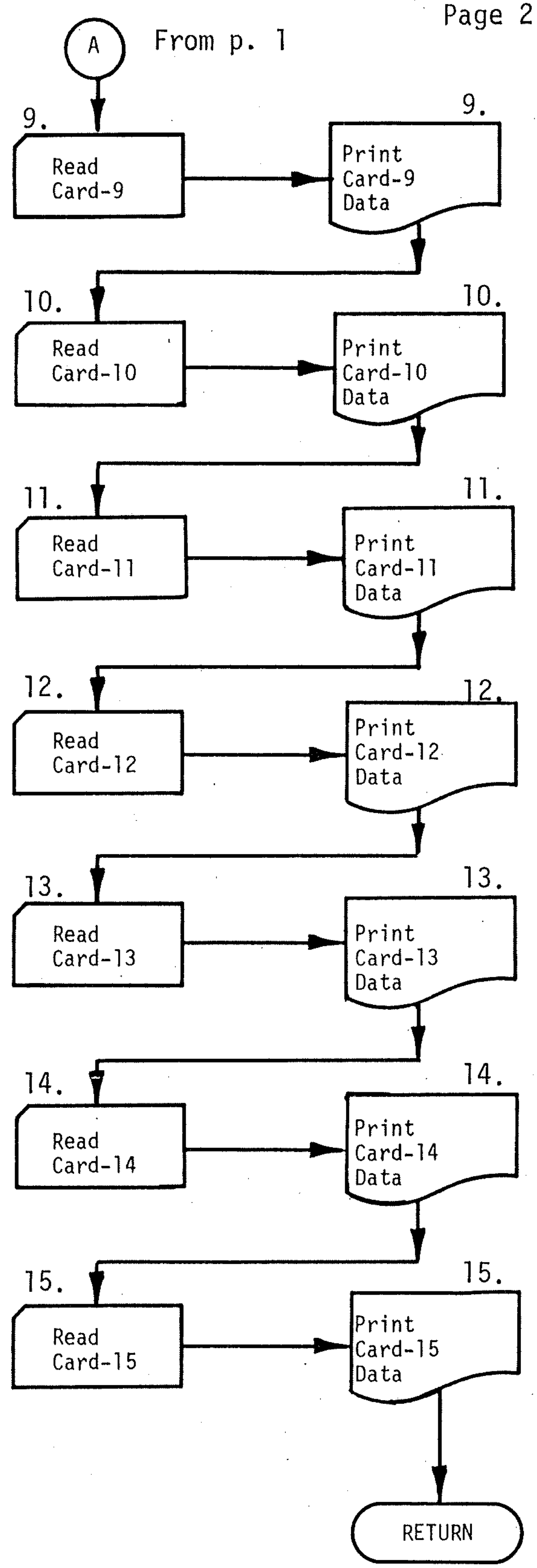
$MULT_i$	-	Multiplication factor, zone i
$TØALØ_n$	-	Low outside air temperature at which system temperature is THI_n, reset schedule n (°F)
$TØAHI_n$	-	High outside air temperature at which system temperature is TLO_n, reset schedule n (°F)
$TLØ_n$	-	Low system fluid temperature, reset schedule n (°F)
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)
EFF	-	Pump and fan motor efficiency
$PLØC_k$	-	Location of floor heating panels, system k
$PAREA_k$	-	Floor area covered by heating panels, system k (ft^2)
$PERIM_k$	-	Exposed perimeter of floor, system k (lin.ft)
KFLCV	-	Type of floor covering (1=bare concrete; 2=tile; 3=carpeting)
CINSL	-	Floor insulation conductance (Btu/hr-sq-ft-°F)
DINSL	-	Floor insulation thickness (ft)
TLCHL	-	Chilled water set point temperature (°F)
TPS	-	Steam turbine entering steam temperature (°F)
PPS	-	Steam turbine entering steam pressure (psig)
TESTM	-	Boiler supply and absorption chiller entering steam temperature (°F)
PESTM	-	Boiler supply and absorption chiller entering steam pressure (psig)
NUMT	-	Number of steam turbines
RPM	-	Steam turbine speed (rpm)

FFLMN	-	Minimum part load cut-off for chillers
KREHT	-	Source of reheat coil energy
HVDF	-	Heating value of diesel fuel (Btu/gal)
HVHØ	-	Heating value of heating oil (Btu/gal)
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 shut-down (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 shut-down (hour of year)
KSNØW	-	Type of snow melting system
QSNØW	-	Snow melting design load (Btu/hr)
SAREA	-	Snow melting slab area (sq ft)
$ASYS_{nc}$	-	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


ENTER CDATA
1.
Read Card-1
1.
Print Card-1 Data
2.
Read Card-2
2.
Print Card-2 Data
3.
Read Card-3
3.
Print Card-3 Data
k = 1
Is k > KMAX ?
YES
k = k + 1
NO
4.
Read Card-4 A,B,C,&D
4.
Print Card-4 Data
j = 1
Is j > JMAX_k ?
YES
j = j + 1
NO
5.
Read Card-5
5.
Print Card-5 Data
nc = 1
Is nc > NCASE ?
YES
nc = nc + 1
NO
6.
Read Card-6
6.
Print Card-6 Data
7.
Read Card-7
7.
Print Card-7 Data
8.
Read Card-8
8.
Print Card-8 Data
A

To p. 2


A
From p. 1
9.
Read Card-9
9.
Print Card-9 Data
10.
Read Card-10
10.
Print Card-10 Data
11.
Read Card-11
11.
Print Card-11 Data
12.
Read Card-12
12.
Print Card-12 Data
13.
Read Card-13
13.
Print Card-13 Data
14.
Read Card-14
14.
Print Card-14 Data
15.
Read Card-15
15.
Print Card-15 Data
RETURN

CALCULATION SEQUENCE

1. Read and print card type 1 - Job Control Parameters defining the following variables:

   IHSRT, IHSTP, NCASE, NRSET, IFAN, KHCST, KMAX.

2. Read and print card type 2 - Print Codes defining the following variables:

   IPRT1, IPRT2, IPRT3.

3. Read and print card type 3 - Reset Schedules defining the following variables:

   $TØALØ_{nr}$, $TØAHI_{nr}$, $TLØ_{nr}$, THI_{nr}.

   Repeat this card type "NRSET" times.

4. Read and print card type 4 - Distribution System Data defining the following variables:

   4.1 CARD TYPE 4A

   $KFAN_k$, $JMAX_k$, $RHSP_k$, $ICZN_k$, $ØACFM_k$, $MXAØ_k$, $NVFC_k$.

   4.2 CARD TYPE 4B

   $ITMPC_{k,1}$, $ITMPC_{k,2}$, $TFNPS_k$, $TNFPR_k$, $TNFPE_k$, $IVVRH_k$, $VVMIN_k$.

   4.3 CARD TYPE 4C

   $TFIX1_k$, $TFIX2_k$, $ISET_{k,1}$, $ISET_{k,2}$, $ISET_{k,3}$, $ISET_{k,4}$, $RIPA_k$.

   4.4 CARD TYPE 4D

   $TCØFC_k$, $TØACØ_k$, $PWGAL_k$, $PLØC_k$, $PAREA_k$, $PERIM_k$.

5. Read and print card type 5 - Zone Characteristics. The following variables are defined:

   $SPACN_{k,j}$, $MULT_i$, $CFMX_i$, $CBTU_i$, $ALFBR_i$, $IPLEN_i$, ZNAME.

   Repeat card type 5 "$JMAX_k$" times.

   Repeat card types 4 and 5 "KMAX" times.

6. Read and print card type 6 - Energy Conversion Equipment Data. The following variables are defined:

$ISYS_{nc}$, $KBLDG_{nc}$, $M1_{nc}$, $M2_{nc}$, $M3_{nc}$, $KREHT_{nc}$.

7. Read and print card type 7 - Energy Conversion Equipment Data. The following variables are defined:

$M6_{nc}$, $M7_{nc}$, $M4_{nc}$, $M5_{nc}$.

Repeat card types 6 and 7, sequentially, "NCASE" times.

8. Read and print card type 8 - Boiler Data. The following variables are defined:

NUMB, SEB, BØN, BØFF, HVHØ.

9. Read and print card type 9 - Chiller Data. The following variables are defined:

NUMC, SZC, CØN, CØFF, FFLMN, TLCHL, TECMN.

10. Read and print card type 10 - Pump Data. The following variables are defined:

HDBLP, HDCLP, HDCNP.

11. Read and print card type 11 - Miscellaneous. The following variables are defined:

PWØL, EFF, TCØ, HVDF.

12. Read and print card type 12 - Steam Data. The following variables are defined:

PESTM, TESTM, PPS, TPS, RPM.

13. Read and print card type 13 - Floor Panel Heating Data. The following variables are defined:

KFLCV, CINSL, DINSL.

14. Read and print card type 14 - Heat Conservation Data. The following variables are defined:

TLCNM, TLCMN, TCWIN, TWWIN, HDWWP.

15. Read and print card type 15 - <u>Snow Melting Data</u>. The following variables are defined:

KSNØW, QSNØW, SAREA.

RETURN

SUBROUTINE: CCØIL

GENERAL DESCRIPTION

This subroutine simulates the performance of a cooling coil. It calculates the sensible and latent heat extracted by a cooling coil assuming it to be of adequate capacity. The coil cools air to dry bulb temperature (TDBØ) and calculates the humidity ratio at that condition. See Figure for illustration of CCØIL simulation.

LIST OF VARIABLES

INPUT

- MASS - Rate of air flow through coil (lbm-air/hr)
- PATM - Barometric pressure (inches Hg)
- TDBI - Dry bulb temperature of entering air (°F)
- WI - Humidity ratio of entering air (lb H_2O/lb-dry air)
- TDBØ - Dry bulb temperature of leaving air (°F)

OUTPUT

- WØ - Humidity ratio of leaving air (lb-H_2O/lb-dry air)
- QCC - Total heat extracted by coil (Btu)
- SHR - Sensible heat ratio

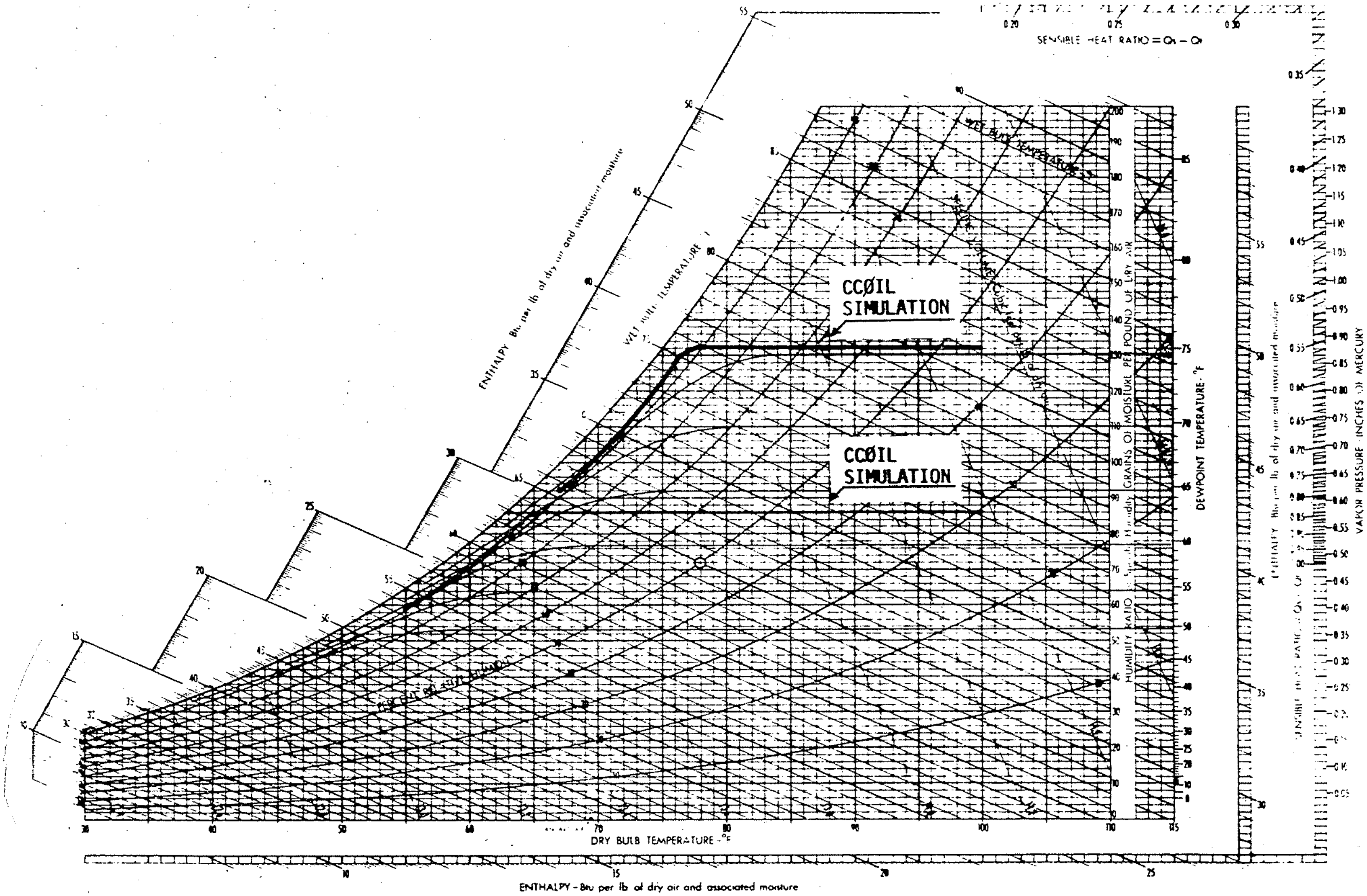
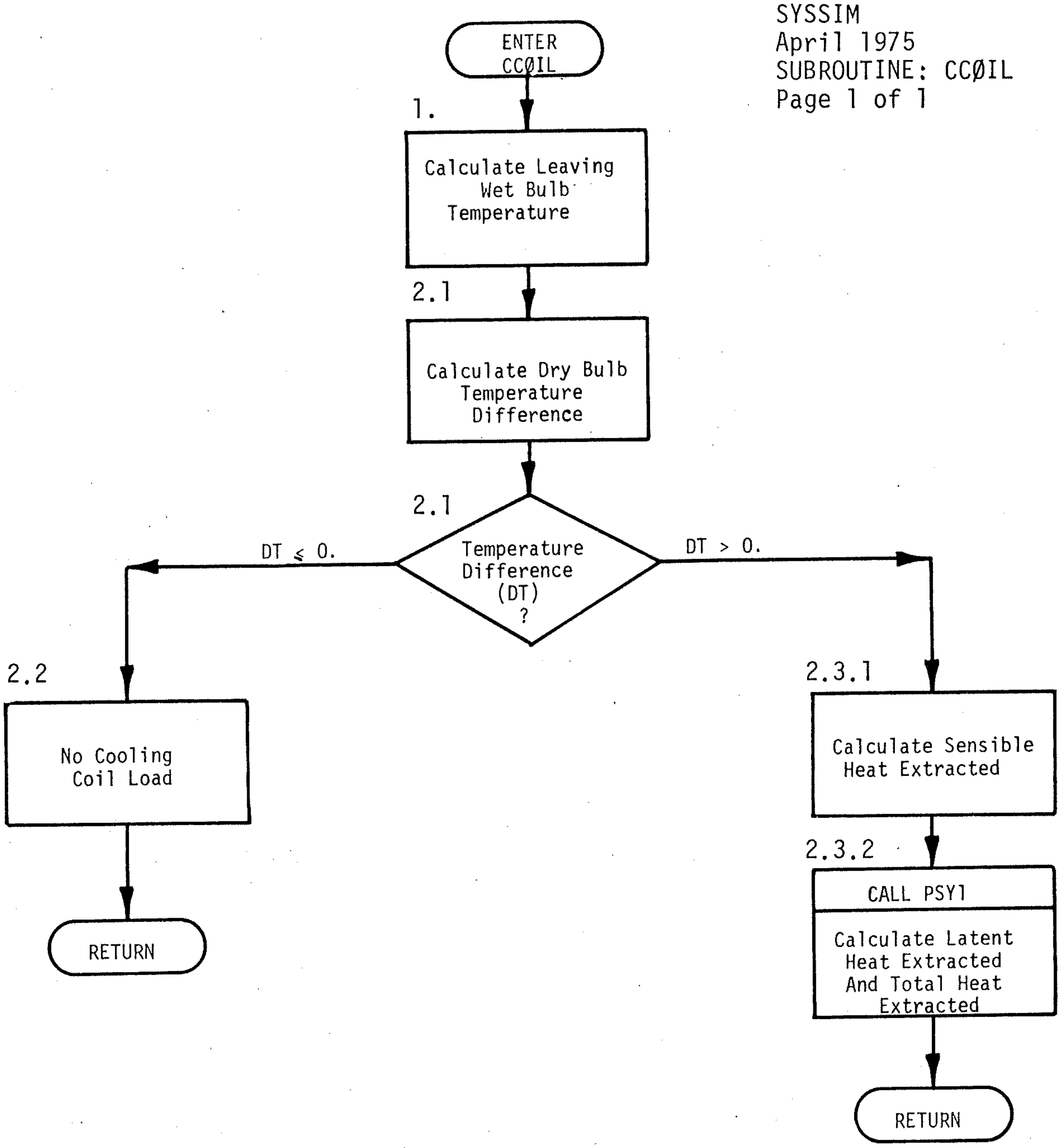


Figure MANUFACTURER'S PSYCHROMETRIC CHART ILLUSTRATING THE PERFORMANCE OF CCØIL


ENTER CCØIL
1.
Calculate Leaving Wet Bulb Temperature
2.1
Calculate Dry Bulb Temperature Difference
2.1
Temperature Difference (DT) ?
DT ≤ 0.
DT > 0.
2.2
No Cooling Coil Load
RETURN
2.3.1
Calculate Sensible Heat Extracted
2.3.2
CALL PSY1
Calculate Latent Heat Extracted And Total Heat Extracted
RETURN

CALCULATION SEQUENCE

1. Calculate leaving wet bulb temperature (TWBØ).

   TWBØ = TDBØ - 1.5

2. Simulate cooling coil.

   2.1 Calculate dry bulb temperature difference (DT) across coil.

   DT = TDBI - TDBØ

   2.2 If temperature difference (DT) less than or equal to 0.0, no cooling coil load.

   QCC = 0.0

   SHR = 1.0

   WØ = WI

   RETURN

   2.3 If temperature difference (DT) greater than 0.0, calculate thermal load (QCC).

   Calculate sensible cooling load (ASC)

   QSC = MASS * 0.245 * DT

   Use subroutine PSY1 to calculate leaving air humidity ratio (WØ)

   Calculate humidity ratio difference (DW).

   If DW less than or equal to 0.0,

   WØ = WI

   QCC = QSC

   SHR = 1.0

   RETURN

   If DW greater than 0.0,

   QLC = MASS * 1090.0 * DW

   where 1090.0 is the latent heat of vaporization (Btu/lbm-H_2O)

QCC = QSC + QLC

SHR = QSC/QCC

RETURN

The functioning of the cooling coil simulation is illustrated graphically in Figure , where it is plotted on an HVAC equipment manufacturer's (Trane) psychrometric chart.

It shows a strong correlation with the manufacturer's published cooling coil performance curves and it is also in accord with recommendations of Stoecker, et.al. (1973) (ASHRAE Publication No. 2290-RP-131), recommending cooling coil discharge air conditions to be 90% R.H. for simulation purposes when latent heat is being extracted.

SUBROUTINE: CENT

GENERAL DESCRIPTION

Simulates the operation of an electric hermetic centrifugal 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)

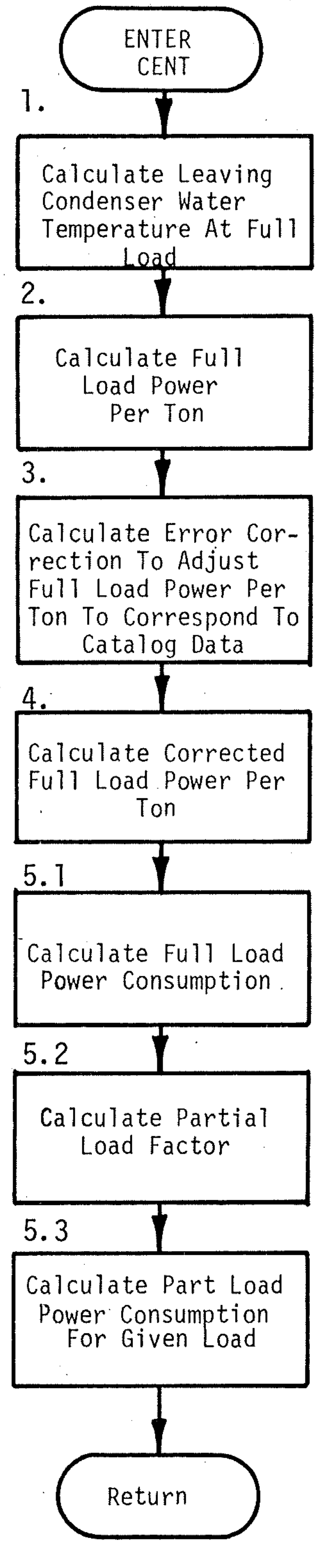
TECØN - Temperature of entering condenser water (°F)

TLCHL - Temperature of leaving chilled water (°F)

FFL - Fraction of full load (decimal)

OUTPUT

PØWER - Hourly electrical power consumption (kilowatt hours)


ENTER CENT
1.
Calculate Leaving Condenser Water Temperature At Full Load
2.
Calculate Full Load Power Per Ton
3.
Calculate Error Correction To Adjust Full Load Power Per Ton To Correspond To Catalog Data
4.
Calculate Corrected Full Load Power Per Ton
5.1
Calculate Full Load Power Consumption
5.2
Calculate Partial Load Factor
5.3
Calculate Part Load Power Consumption For Given Load
Return

CALCULATION SEQUENCE

1. Calculate the temperature of leaving condenser water at full load.

   TLCØN = TECØN + 10.0

2. Calculate the full load power consumption (KW/Ton).

   PØPTN = 0.049 * ALØG (TLCØN/TLCHL) * TLCHL ** 0.8

   (This equation was excerpted from personal correspondence from R. S. Arnold of Carrier)

3. Determine the error correction to be applied to the above equation to make it conform with Carrier Hermetic Centrifugal Liquid Chilling Packages, Model 19C, 357-2000 tons. Equation for ERRØR was derived using curve fitting techniques.

   ERRØR ≐ 2.4531 - 0.041229 * TLCØN - 0.0273842 * TLCHL

   + 0.000118191 * TLCØN * TLCØN + 0.00047537

   * TLCHL * TLCØN - 0.000197535 * TLCHL * TLCHL

4. Calculate the corrected full load power per ton.

   PØPTN = PØPTN - ERRØR

5. Determine the total hourly part load power consumption.

   5.1 Calculate total full load power consumption.

   TØTPW = PØPTN * (QHBC/FFL)

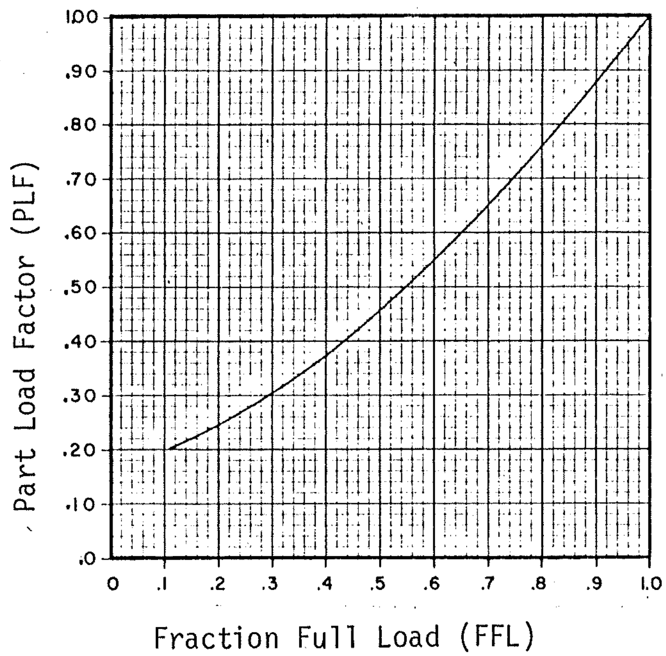
   where (QHBC/FFL) is total cooling capacity of chillers operating.

   5.2 Calculate partial load factor (PLF).

   PLF = 0.1641 + 0.2543 * FFL + 0.73965 * FFL

   * FFL - 0.15835 * FFL * FFL * FFL

   This equation is a 3rd order equation fit of partial load power requirement curve contained in Carrier catalog and indicated below.



5.3 Calculate total power consumption for given load.

PØWER = TØTPW * PLF

FUNCTION: DENSY

GENERAL DESCRIPTION

Calculate the density of moist air (lb-dry air/ft^3) as a function of dry-bulb temperature, humidity ratio, and barometric pressure.

LIST OF VARIABLES

INPUT

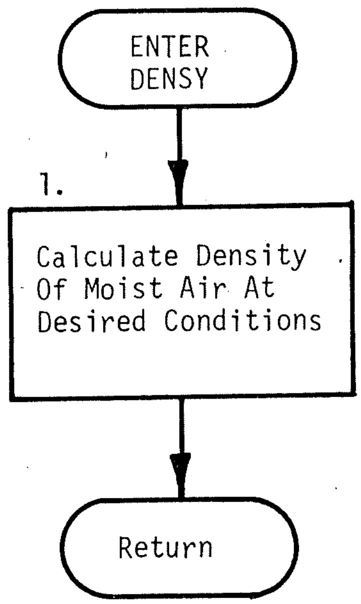
T - Dry-bulb temperature (°F)

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

PATM - Barometric pressure (in. Hg)

OUTPUT

DENSY - Density of moist air at desired conditions, (lb-dry air/ft^3).


ENTER DENSY
1.
Calculate Density Of Moist Air At Desired Conditions
Return

CALCULATION SEQUENCE

1. Calculate density of moist air for desired conditions.

DENSY = 1.0/(0.754 * (T + 460.) * (1. + 7000. * W/4360.)
/PATM)

(Reference: "Procedure for Determining Heating and Cooling Loads for Computerized Energy Calculations - Algorithms for Building Heat Transfer Subroutines", ASHRAE, 1971, page 66, Item e.)

SUBROUTINE: ECØNØ

GENERAL DESCRIPTION

Simulates the operation of temperature type economizer cycle by calculating the portion of outside air required to yield a mixed air temperature closest to the desired mixed air dry-bulb temperature. See Figure below for control schematic.

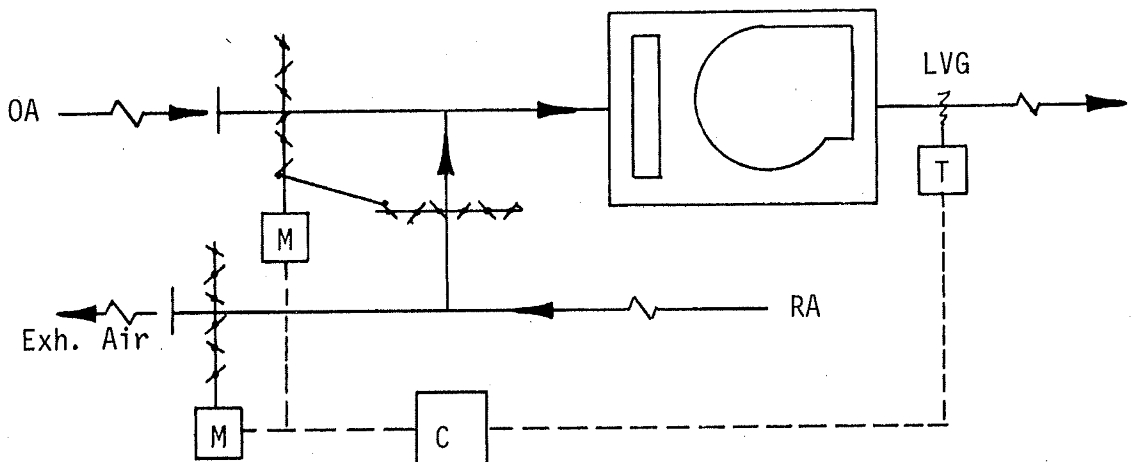


Figure ECONOMIZER CYCLE CONFIGURATION AND CONTROLS SCHEMATIC

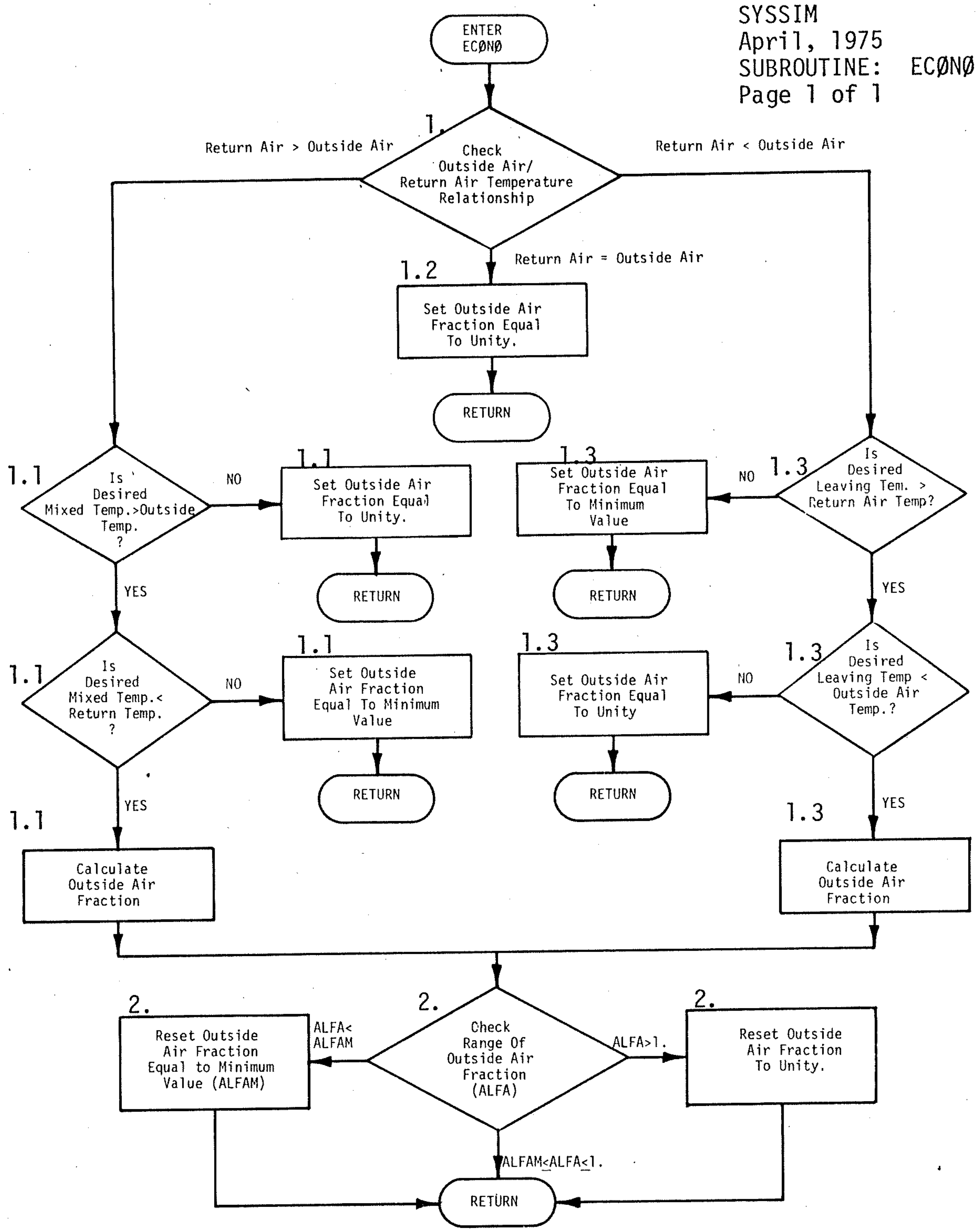
LIST OF VARIABLES

INPUT

- ØA - Outside air dry-bulb temperature (°F)
- DØA - Outside air density (lbm/ft^3)
- RA - Return air dry-bulb temperature (°F)
- DRA - Return air density (lbm/ft^3)
- LVG - Desired mixed air dry-bulb temperature (°F)
- ALFAM - Minimum fraction of outside air

OUTPUT

- ALFA - Fraction of outside air yielding mixed temperature closest to desired mixed air temperature.


ENTER ECØNØ
1.
Check Outside Air/ Return Air Temperature Relationship
Return Air > Outside Air
Return Air < Outside Air
Return Air = Outside Air
1.2
Set Outside Air Fraction Equal To Unity.
RETURN
1.1
Is Desired Mixed Temp.>Outside Temp. ?
NO
1.1
Set Outside Air Fraction Equal To Unity.
RETURN
YES
1.1
Is Desired Mixed Temp.< Return Temp. ?
NO
1.1
Set Outside Air Fraction Equal To Minimum Value
RETURN
YES
1.1
Calculate Outside Air Fraction
1.3
Is Desired Leaving Tem. > Return Air Temp?
NO
1.3
Set Outside Air Fraction Equal To Minimum Value
RETURN
YES
1.3
Is Desired Leaving Temp < Outside Air Temp.?
NO
1.3
Set Outside Air Fraction Equal To Unity
RETURN
YES
1.3
Calculate Outside Air Fraction
2.
Check Range Of Outside Air Fraction (ALFA)
ALFA< ALFAM
2.
Reset Outside Air Fraction Equal to Minimum Value (ALFAM)
ALFA>1.
2.
Reset Outside Air Fraction To Unity.
ALFAM≤ALFA≤1.
RETURN

CALCULATION SEQUENCE

1. Select appropriate return air/outside air temperature relationship.

   1.1 Return air temperature (RA) greater than outside air temperature (ØA).

   If desired mixed air temperature (LVG) less than or equal to outside air temperature (ØA),

   ALFA = 1.0

   RETURN

   If desired mixed air temperature (LVG) greater than outside air temperature (ØA), and

   If desired mixed air temperature (LVG) less than return air temperature (RA),

   ALFA = (DRA * (RA - LVG))/(RA * DRA - ØA * DØA + LVG * (DØA - DRA))

   Go to calculation 2.

   If desired mixed air temperature (LVG) greater than or equal to return air temperature (RA),

   ALFA = ALFAM

   RETURN

   1.2 Return air temperature (RA) equals outside air temperature (ØA).

   ALFA = 1.0

   RETURN

   1.3 Return air temperature (RA) less than outside air temperature (ØA).

   If desired mixed air temperature (LVG) less than or equal to return air temperature (RA),

   ALFA = ALFAM

   RETURN

If desired mixed air temperature (LVG) greater than return air temperature (RA), and

If desired mixed air temperature less than outside air temperature (ØA),

ALFA = (DRA * (RA - LVG))/(RA * DRA - ØA * DØA + LVG * (DØA - DRA))

Go to calculation 2.

(The equation used above is derived from that given in subroutine MXAIR, paragraph 6.1, solving instead for ALFA.)

If desired mixed air temperature greater than or equal to outside air temperature (ØA),

ALFA = 1.0

RETURN

2. Check range of ALFA.

If fraction of outside air (ALFA) less than minimum fraction of outside air (ALFAM).

ALFA = ALFAM

RETURN

If fraction of outside air (ALFA) greater than 1.0,

ALFA = 1.0.

RETURN

SUBROUTINE: ENGYC

GENERAL DESCRIPTION

Prints a four-page report (see Figure   ) summarizing monthly and annual consumption and demand data for all forms of energy used by the building and its HVAC system.

LIST OF VARIABLES

INPUT

FAC - Name of facility

CITY - Location of facility

PRØJ - Project number

DATE - Date of program run

ENGR - User identification

ISYS - System combination number

SF_m - Building electrical demand for each month of year.

ENGY - Monthly energy consumptions and demands. A 12 x 2 x 18 matrix with indices defined as indicated below.

FIRST SUBSCRIPT: MONTH

1 January

2 February

3 March

4 April

5 May

6 June

EQUIPMENT AND ENERGY CONSUMPTION ANALYSIS	FACILITY/ADDRESS LRC SYSTEMS ENGINEERING HAMPTON, VIRGINIA			DATE/PROJECT NOV 26, 1973 SZ, 4W, 3IN	USER AND SYSTEM IDENTIFICATION R.JENSEN SYSTEM NO. 102	
	ENERGY CONSUMPTION					
	JAN.	FEB.	MARCH	APRIL	MAY	JUNE
MONTHLY BTU/1000						
MAX. DEMAND	-489.7	-420.1	-295.1	-60.3	-0.0	-0.0
CONSUMPTION	-191045.1	-155726.3	-114348.4	-60.4	-0.1	-0.0
MAX. DEMAND	0.0	0.0	0.0	1351.6	1386.2	2104.3
CONSUMPTION	0.0	0.0	0.0	43153.9	86051.1	316318.8
ELECTRICITY						
LIGHTS AND BUILDING EQUIPMENT						
INTERNAL						
DEMAND(KW)	212.0	212.0	212.0	212.0	212.0	212.0
CONS.(KWH)	51304.0	44308.0	48972.0	51304.0	51304.0	46640.0
EXTERNAL						
DEMAND(KW)	0.0	0.0	0.0	-0.0	0.0	0.0
CONS.(KWH)	0.0	0.0	0.0	0.0	0.0	0.0
HEAT (INCL. BOILER AND AUXILIARIES, AND HOT WATER PUMPS						
DEMAND(KW)	5.2	5.2	5.2	5.2	5.2	5.2
CONS.(KWH)	3729.7	3481.1	3185.8	2227.5	1434.9	150.2
COOL (INCL. CHILLERS, WATER PUMPS, AND COOLING TOWER FAN						
DEMAND(KW)	0.0	0.0	23.2	92.8	97.3	128.6
CONS.(KWH)	0.0	0.0	2999.2	9135.4	15766.8	33739.0
FANS						
DEMAND(KW)	40.8	40.8	40.8	40.8	40.8	40.8
CONS.(KWH)	29354.3	27397.4	30332.8	29354.3	30332.8	29354.3
TOTAL						
DEMAND(KW)	258.0	258.0	276.0	345.6	350.1	381.4
CONS.(KWH)	84387.9	75186.4	85489.7	92021.1	98838.4	109883.4
GAS						
HEAT						
DEMAND(THERMS)	6.1	5.3	3.7	0.8	0.0	0.0
CONS.(THERMS)	2388.2	1946.7	1429.4	0.8	0.0	0.0
COOL						
DEMAND(THERMS)	0.0	0.0	0.0	0.0	0.0	0.0
CONS.(THERMS)	0.0	0.0	0.0	0.0	0.0	0.0
GENERATION						
DEMAND(THERMS)	0.0	0.0	0.0	0.0	0.0	0.0
CONS.(THERMS)	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL						
DEMAND(THERMS)	6.1	5.3	3.7	0.8	0.0	0.0
CONS.(THERMS)	2388.2	1946.7	1429.4	0.8	0.0	0.0

Figure EXAMPLE OF MONTHLY AND ANNUAL CONSUMPTION AND DEMAND TABLE

EQUIPMENT AND ENERGY CONSUMPTION ANALYSIS
I FACILITY/ADDRESS LRC SYSTEMS ENGINEERING HAMPTON, VIRGINIA
I DATE/PROJECT NOV 26, 1973 SZ, 4W, 3IN
I USER AND SYSTEM IDENTIFICATION R.JENSEN SYSTEM NO. 102

	ENERGY CONSUMPTION JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	TOTAL
MONTHLY BTU/1000							
MAX. DEMAND	-0.0	-0.0	-0.0	-0.0	-0.0	-366.5	
CONSUMPTION	-0.0	-0.0	-0.2	-0.3	-0.2	-52230.1	-513410.8
MAX. DEMAND	2041.2	3066.6	0.0	0.0	0.0	0.0	
CONSUMPTION	381186.0	355371.8	0.0	0.0	0.0	0.0	1182081.0
ELECTRICITY							
LIGHTS AND BUILDING EQUIPMENT							
INTERNAL							
DEMAND(KW)	212.0	212.0	212.0	212.0	212.0	212.0	
CONS.(KWH)	51304.0	51304.0	46640.0	53636.0	46640.0	46640.0	589996.0
EXTERNAL							
DEMAND(KW)	0.0	0.0	0.0	0.8	0.0	0.0	
CONS.(KWH)	0.0	0.0	0.0	0.0	0.0	0.0	-0.0
HEAT (INCL. BOILER AND AUXILIARIES, AND HOT WATER PUMPS							
DEMAND(KW)	0.0	5.2	5.2	5.2	5.2	5.2	
CONS.(KWH)	0.0	36.3	238.3	761.5	3035.6	3823.0	22103.8
COOL (INCL. CHILLERS, WATER PUMPS, AND COOLING TOWER FAN							
DEMAND(KW)	128.8	197.9	23.2	23.2	23.2	23.2	
CONS.(KWH)	38769.3	36836.7	15668.5	13878.6	3115.5	139.5	170048.3
FANS							
DEMAND(KW)	40.8	40.8	40.8	40.8	40.8	40.8	
CONS.(KWH)	30332.8	30332.8	29354.3	30332.8	29354.3	30332.8	489.3
TOTAL							
DEMAND(KW)	381.6	450.7	276.0	276.0	276.0	258.0	
CONS.(KWH)	120406.0	118509.7	91901.0	98608.8	82145.3	80935.1	1138312.0
GAS							
HEAT							
DEMAND(THERMS)	0.0	0.0	0.0	0.0	0.0	4.6	
CONS.(THERMS)	0.0	0.0	0.0	0.0	0.0	652.9	6417.9
COOL							
DEMAND(THERMS)	0.0	0.0	0.0	0.0	0.0	0.0	
CONS.(THERMS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GENERATION							
DEMAND(THERMS)	0.0	0.0	0.0	0.0	0.0	0.0	
CONS.(THERMS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL							
DEMAND(THERMS)	0.0	0.0	0.0	0.0	0.0	4.6	
CONS.(THERMS)	0.0	0.0	0.0	0.0	0.0	652.9	6417.9

Figure EXAMPLE OF MONTHLY AND ANNUAL CONSUMPTION AND DEMAND TABLE, CONTINUED

EQUIPMENT AND ENERGY CONSUMPTION ANALYSIS	FACILITY/ADDRESS LRC SYSTEMS ENGINEERING HAMPTON, VIRGINIA		DATE/PROJECT NOV 26, 1973 SZ, 4W, 3IN		USER AND SYSTEM IDENTIFICATION R.JENSEN SYSTEM NO. 102	
			ENERGY CONSUMPTION			
	JAN.	FEB.	MARCH	APRIL	MAY	JUNE
CITY WATER						
DEMAND (K GALS)	0.1	0.1	0.2	0.1	0.1	0.1
CONS. (K GALS)	30.4	28.2	28.4	15.5	19.6	50.9

EQUIPMENT AND ENERGY CONSUMPTION ANALYSIS	FACILITY/ADDRESS LRC SYSTEMS ENGINEERING HAMPTON, VIRGINIA		DATE/PROJECT NOV 26, 1973 SZ, 4W, 3IN		USER AND SYSTEM IDENTIFICATION R.JENSEN SYSTEM NO. 102		
			ENERGY CONSUMPTION				
	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	TOTAL
CITY WATER							
DEMAND (K GALS)	0.0	0.0	0.2	0.3	0.1	0.1	
CONS. (K GALS)	60.6	57.1	19.1	34.5	24.0	29.1	397.3

Figure EXAMPLES OF MONTHLY AND ANNUAL CONSUMPTION AND DEMAND TABLE, CONTINUED

7 July

8 August

9 September

10 October

11 November

12 December

SECOND SUBSCRIPT: MODE OF ENERGY

1 Demand

2 Consumption

THIRD SUBSCRIPT: TYPE OF ENERGY

1 Maximum monthly heating demand

2 Maximum monthly cooling demand

3 Electric, internal lights and building equipment

4 Electric, external lights

5 Electric heat (boiler and auxiliaries, and hot water pumps)

6 Electric cool (chiller, pumps, and cooling tower fan)

7 Gas heat

8 Gas cool

9 Gas generation

10 Steam heat

11 Steam cool

12 Oil heat

13 Oil cool

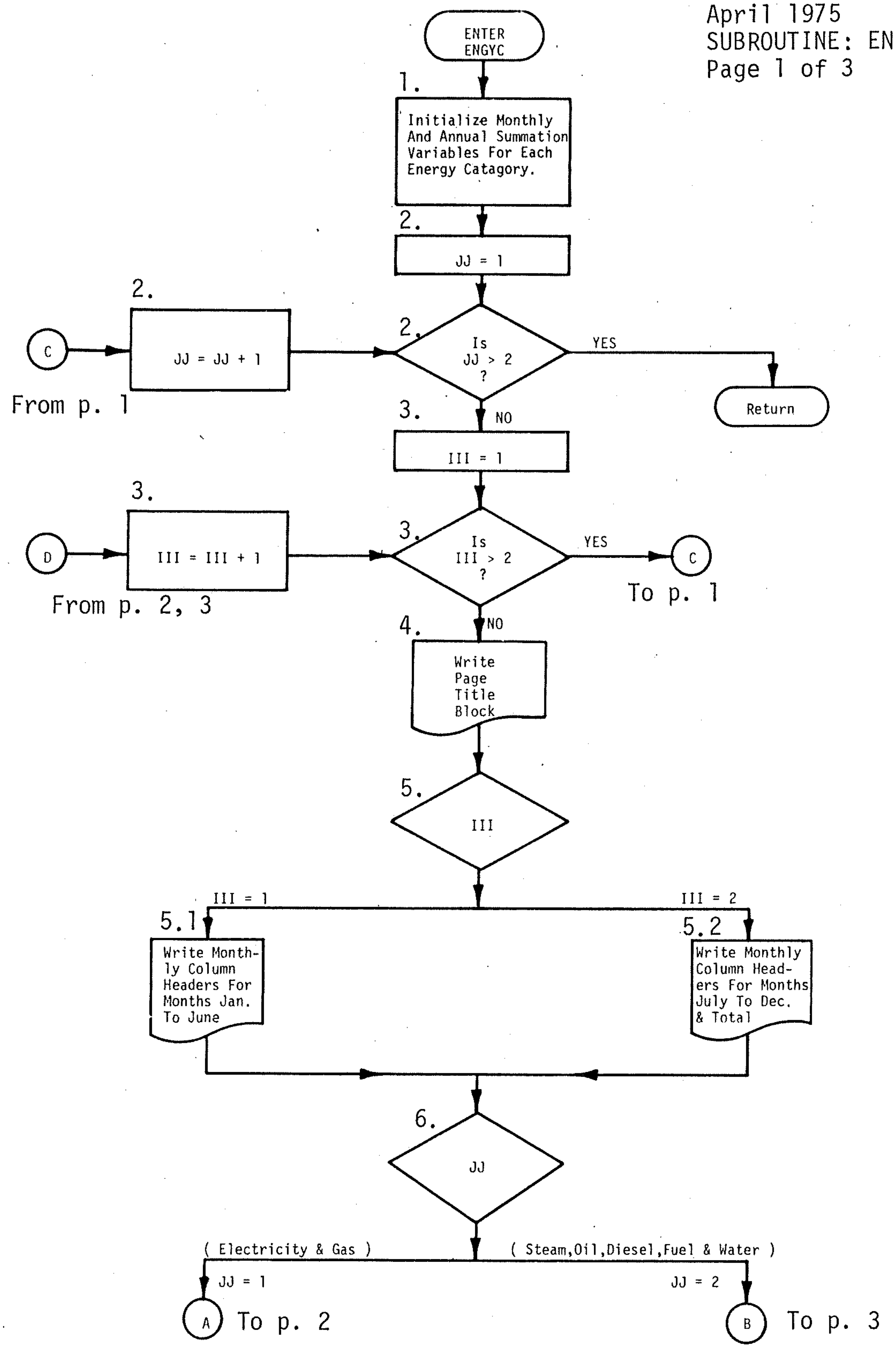
14 Diesel fuel generation

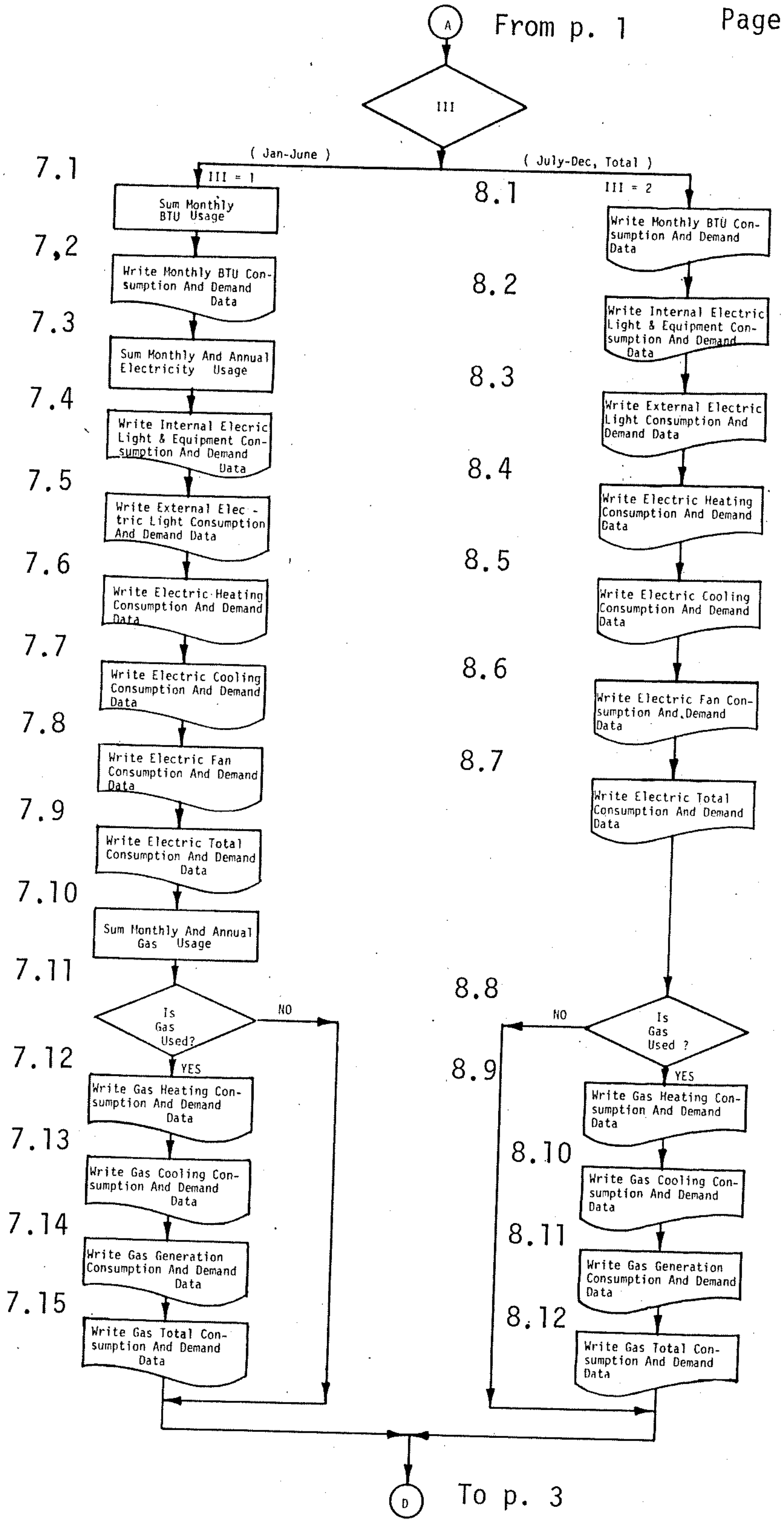
15 Monthly heating consumption

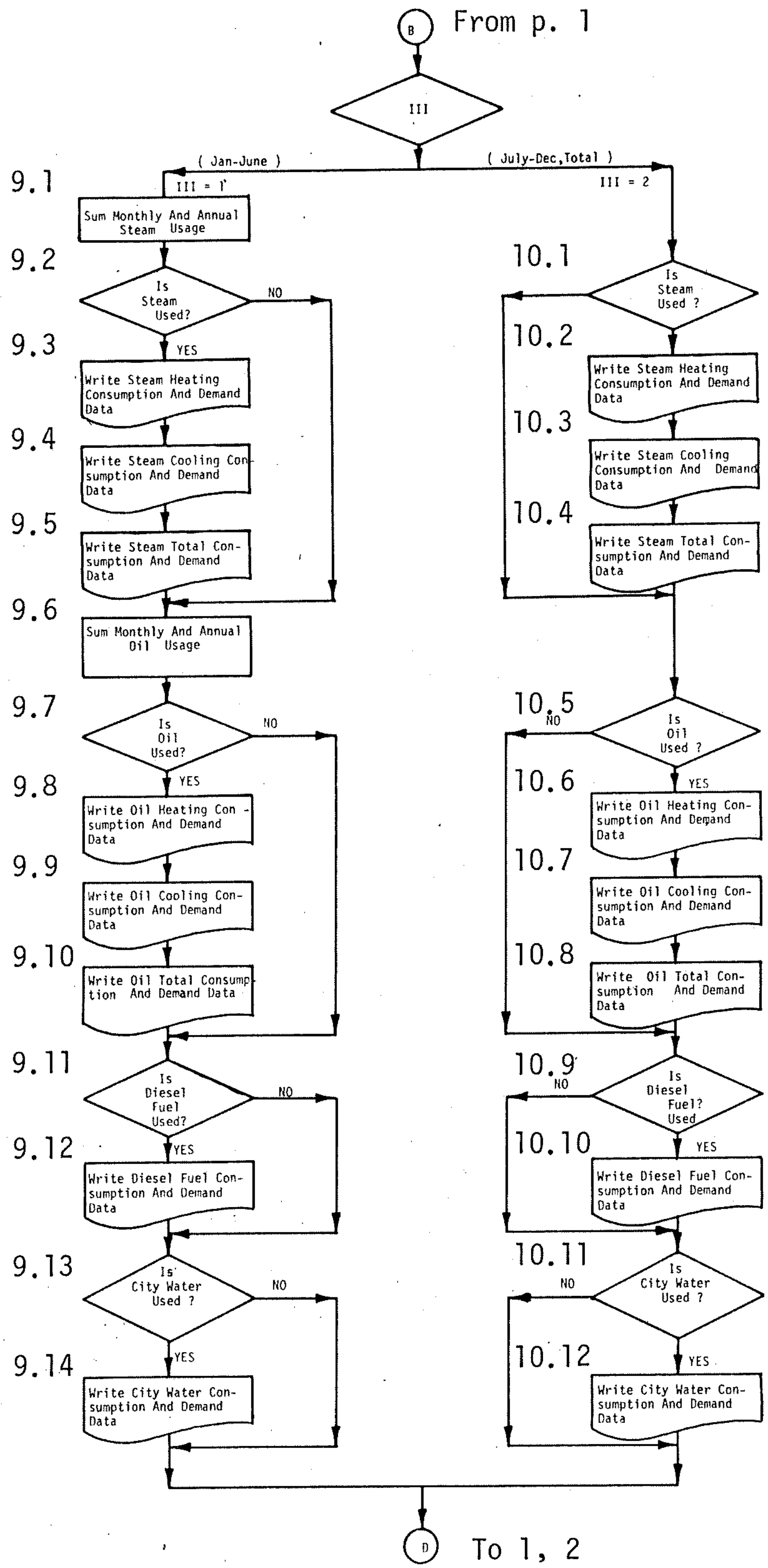
16 Monthly cooling consumption

17 City water

18 Fans


ENTER ENGYC
1.
Initialize Monthly And Annual Summation Variables For Each Energy Catagory.
2.
JJ = 1
2.
JJ = JJ + 1
C
From p. 1
2.
Is JJ > 2 ?
YES
Return
NO
3.
III = 1
3.
III = III + 1
D
From p. 2, 3
3.
Is III > 2 ?
YES
C
To p. 1
NO
4.
Write Page Title Block
5.
III
III = 1
III = 2
5.1
Write Monthly Column Headers For Months Jan. To June
5.2
Write Monthly Column Headers For Months July To Dec. & Total
6.
JJ
(Electricity & Gas)
(Steam,Oil,Diesel,Fuel & Water)
JJ = 1
JJ = 2
A
To p. 2
B
To p. 3


A
From p. 1
III
(Jan-June)
(July-Dec, Total)
III = 1
III = 2
7.1
Sum Monthly BTU Usage
7.2
Write Monthly BTU Consumption And Demand Data
7.3
Sum Monthly And Annual Electricity Usage
7.4
Write Internal Elecric Light & Equipment Consumption And Demand Data
7.5
Write External Electric Light Consumption And Demand Data
7.6
Write Electric Heating Consumption And Demand Data
7.7
Write Electric Cooling Consumption And Demand Data
7.8
Write Electric Fan Consumption And Demand Data
7.9
Write Electric Total Consumption And Demand Data
7.10
Sum Monthly And Annual Gas Usage
7.11
Is Gas Used?
NO
YES
7.12
Write Gas Heating Consumption And Demand Data
7.13
Write Gas Cooling Consumption And Demand Data
7.14
Write Gas Generation Consumption And Demand Data
7.15
Write Gas Total Consumption And Demand Data
8.1
Write Monthly BTU Consumption And Demand Data
8.2
Write Internal Electric Light & Equipment Consumption And Demand Data
8.3
Write External Electric Light Consumption And Demand Data
8.4
Write Electric Heating Consumption And Demand Data
8.5
Write Electric Cooling Consumption And Demand Data
8.6
Write Electric Fan Consumption And Demand Data
8.7
Write Electric Total Consumption And Demand Data
8.8
Is Gas Used ?
NO
YES
8.9
Write Gas Heating Consumption And Demand Data
8.10
Write Gas Cooling Consumption And Demand Data
8.11
Write Gas Generation Consumption And Demand Data
8.12
Write Gas Total Consumption And Demand Data
D
To p. 3


B
From p. 1
III
(Jan-June)
III = 1
(July-Dec,Total)
III = 2
9.1
Sum Monthly And Annual Steam Usage
9.2
Is Steam Used?
NO
YES
9.3
Write Steam Heating Consumption And Demand Data
9.4
Write Steam Cooling Consumption And Demand Data
9.5
Write Steam Total Consumption And Demand Data
9.6
Sum Monthly And Annual Oil Usage
9.7
Is Oil Used?
9.8
Write Oil Heating Consumption And Demand Data
9.9
Write Oil Cooling Consumption And Demand Data
9.10
Write Oil Total Consumption And Demand Data
9.11
Is Diesel Fuel Used?
9.12
Write Diesel Fuel Consumption And Demand Data
9.13
Is City Water Used ?
9.14
Write City Water Consumption And Demand Data
10.1
Is Steam Used ?
10.2
Write Steam Heating Consumption And Demand Data
10.3
Write Steam Cooling Consumption And Demand Data
10.4
Write Steam Total Consumption And Demand Data
10.5
Is Oil Used ?
10.6
Write Oil Heating Consumption And Demand Data
10.7
Write Oil Cooling Consumption And Demand Data
10.8
Write Oil Total Consumption And Demand Data
10.9
Is Diesel Fuel? Used
10.10
Write Diesel Fuel Consumption And Demand Data
10.11
Is City Water Used ?
10.12
Write City Water Consumption And Demand Data
D
To 1, 2

CALCULATION SEQUENCE

1. Initialize working variables:

$SC_i = 0.0$ for $i = 1$ to 12

$SD_i = 0.0$ for $i = 1$ to 12

$S_i = 0.0$ for $i = 1$ to 13

where

SC = total monthly consumption of energy form i

SD = total monthly demand for energy form i

S = total annual consumption of energy form i

2. Print pages 1 through 4 of report by repeating calculations 3 through 10, first for electric and gas energy types (JJ = 1) and then for steam, oil, diesel fuel, and city water energy types (JJ = 2).

3. Print two pages each of report by repeating calculations 4 through 10 first for months January through June (III = 1) and then for July through December (III = 2).

4. Print page title block by writing according to proper format the following variables: FAC, CITY, PRØJ, DATE, ENGR, and ISYS.

5. Print proper monthly column headers:

5.1 If III = 1, print monthly column headers for months January through June.

5.2 If III = 2, print monthly column headers for months July through December and annual totals.

6. Check which page of four-page report is desired.

6.1 If JJ = 1 and III = 1, print page 1.

Go to calculation 7.

6.2 If JJ = 1 and III = 2, print page 2.

Go to calculation 8.

6.3 If JJ = 2 and III = 1, print page 3.

Go to calculation 9.

6.4 If JJ = 2 and III = 2, print page 4.

Go to calculation 10.

7. Print page 1 of report.

7.1 Sum monthly Btu usage to get annual Btu usage. For I = 1 to 12, perform the following:

SS2 = ∑ ENGY (I,2,15) Annual heating consumption

SS4 = ∑ ENGY (I,2,16) Annual cooling consumption

7.2 Print Btu consumption and demand data for heating and cooling for January through June.

```
WRITE   ENGY (I,1,1)    |
WRITE   ENGY (I,2,15)   |
WRITE   ENGY (I,1,2)    |  for I = 1 to 6
WRITE   ENGY (I,2,16)   |
```

7.3 Sum all components of electrical loads to get total monthly and annual electricity usage for building.

```
SC(I)  =  ∑  ENGY (I,2,K) for K = 3,4,5,6,18  |
SD(I)  =  SF(I)                               |
S(4)   =  ∑  ENGY (I,2,3)                     |
S(6)   =  ∑  ENGY (I,2,4)                     |  For
S(8)   =  ∑  ENGY (I,2,5)                     |  I = 1 to 12
S(10)  =  ∑  ENGY (I,2,6)                     |
S(13)  =  ∑  ENGY (I,2,18)                    |
S(12)  =  S(4) + S(6) + S(8) + S(10) + S(13)  |
```

7.4 Print internal electric light and equipment consumption and demand data for January through June.

```
WRITE   ENGY (I,1,3)   |
WRITE   ENGY (I,2,3)   |  for I = 1 to 6
```

7.5 Print external lighting consumption and demand data for January through June.

$$\left.\begin{array}{ll} \text{WRITE} & \text{ENGY (I,1,4)} \\ \text{WRITE} & \text{ENGY (I,2,4)} \end{array}\right\} \text{ for I = 1 to 6}$$

7.6 Print electric heating consumption and demand data for January through June.

$$\left.\begin{array}{ll} \text{WRITE} & \text{ENGY (I,1,5)} \\ \text{WRITE} & \text{ENGY (I,2,5)} \end{array}\right\} \text{ for I = 1 to 6}$$

7.7 Print electric cooling consumption and demand data for January through June.

$$\left.\begin{array}{ll} \text{WRITE} & \text{ENGY (I,1,6)} \\ \text{WRITE} & \text{ENGY (I,2,6)} \end{array}\right\} \text{ for I = 1 to 6}$$

7.8 Print fan electricity consumption and demand data for January through June.

$$\left.\begin{array}{ll} \text{WRITE} & \text{ENGY (I,1,18)} \\ \text{WRITE} & \text{ENGY (I,2,18)} \end{array}\right\} \text{ for I = 1 to 6}$$

7.9 Print total electric consumption and demand data for January through June.

$$\left.\begin{array}{ll} \text{WRITE} & \text{SD(I)} \\ \text{WRITE} & \text{SC(I)} \end{array}\right\} \text{ for I = 1 to 6}$$

7.10 Sum all components of gas usage to get total monthly and annual gas usage for building.

$$\left.\begin{array}{l} \left.\begin{array}{lll} \text{SSC(I)} & = & \sum \text{ENGY (I,2,K)} \\ \text{SSD(I)} & = & \sum \text{ENGY (I,1,K)} \end{array}\right\} \text{ for K = 7,8,9} \\ \\ \begin{array}{lll} \text{SS(2)} & = & \sum \text{ENGY (I,2,7)} \\ \text{SS(4)} & = & \sum \text{ENGY (I,2,8)} \\ \text{SS(6)} & = & \sum \text{ENGY (I,2,9)} \\ \\ \text{SS(8)} & = & \text{SS(2) + SS(4) + SS(6)} \end{array} \end{array}\right\} \begin{array}{c} \text{For} \\ \text{I = 1 to 12} \end{array}$$

7.11 If building used no gas (SS(8) = 0.0), go to calculation 8.

7.12 Print gas heating consumption and demand data for January through June.

```
WRITE   ENGY (I,1,7)  |
                      } for I = 1 to 6
WRITE   ENGY (I,2,7)  |
```

7.13 Print gas cooling consumption and demand data for January through June.

```
WRITE   ENGY (I,1,8)  |
                      } for I = 1 to 6
WRITE   ENGY (I,2,8)  |
```

7.14 Print gas generation consumption and demand data for January through June.

```
WRITE   ENGY (I,1,9)  |
                      } for I = 1 to 6
WRITE   ENGY (I,2,9)  |
```

7.15 Print total gas consumption and demand data for January through June.

```
WRITE SSD(I)          |
                      } for I = 1 to 6
WRITE SSC(I)          |
```

8. Print page 2 of report.

8.1 Print Btu consumption and demand data for heating and cooling for July through December and annual total.

```
WRITE   ENGY (I,1,1)   |
WRITE   ENGY (I,2,15)  |
                       } for I = 7 to 12
WRITE   ENGY (I,1,2)   |
WRITE   ENGY (I,2,16)  |
WRITE   SS2
WRITE   SS4
```

8.2 Print internal electric light and equipment consumption and demand data for July through December and annual total.

```
WRITE   ENGY (I,1,3)  }
                      }  for I = 7 to 12
WRITE   ENGY (I,2,3)  }

WRITE   S(4)
```

8.3 Print external lighting consumption and demand data for July through December and annual total.

```
WRITE   ENGY (I,1,4)  }
                      }  for I = 7 to 12
WRITE   ENGY (I,2,4)  }

WRITE   SS(6)
```

8.4 Print electric heating consumption and demand data for July through December and annual total.

```
WRITE   ENGY (I,1,5)  }
                      }  for I = 7 to 12
WRITE   ENGY (I,2,5)  }

WRITE   SS(8)
```

8.5 Print electric cooling consumption and demand data for July through December and annual total.

```
WRITE   ENGY (I,1,6)  }
                      }  for I = 7 to 12
WRITE   ENGY (I,2,6)  }

WRITE   SS(10)
```

8.6 Print electric fan consumption and demand data for July through December and annual total.

```
WRITE   ENGY (I,1,18)  }
                       }  for I = 7 to 12
WRITE   ENGY (I,2,18)  }

WRITE   SS(13)
```

8.7 Print total electric consumption and demand data for July and December and annual total.

```
WRITE   SD(I)   }
                } for I = 7 to 12
WRITE   SC(I)   }

WRITE   S(12)
```

8.8 If building used no gas (SS(8) = 0.0), go to calculation 9.

8.9 Print gas heating consumption and demand data for July through December and annual total.

```
WRITE   ENGY (I,1,7)   }
                       } for I = 7 to 12
WRITE   ENGY (I,2,7)   }

WRITE   SS(2)
```

8.10 Print gas cooling consumption and demand data for July through December and annual total.

```
WRITE   ENGY (I,1,8)   }
                       } for I = 7 to 12
WRITE   ENGY (I,2,8)   }

WRITE   SS(4)
```

8.11 Print gas generation consumption and demand data for July through December and annual total.

```
WRITE   ENGY (I,1,9)   }
                       } for I = 7 to 12
WRITE   ENGY (I,2,9)   }

WRITE   SS(6)
```

8.12 Print total gas consumption and demand data for July through December and annual total.

```
WRITE   SSD(I)   }
                 } for I = 7 to 12
WRITE   SSC(I)   }

WRITE   SS(8)
```

9. Print page 3 of report.

9.1 Sum all components of steam usage to get total monthly and annual steam usage for building.

$$\left.\begin{array}{l} \left.\begin{array}{lll} SD(I) & = & \sum ENGY\ (I,1,K) \\ SC(I) & = & \sum ENGY\ (I,2,K) \end{array}\right\} \text{for } K = 10,11 \\ \\ \begin{array}{lll} S(2) & = & \sum ENGY\ (I,2,10) \\ S(4) & = & \sum ENGY\ (I,2,11) \end{array} \end{array}\right\} \begin{array}{c} \text{For} \\ I = 1 \text{ to } 12 \end{array}$$

$$S(6) = S(2) + S(4)$$

9.2 If building used no steam (SS(6) = 0.0), go to calculation 9.6.

9.3 Print steam heating consumption and demand data for January through June.

$$\left.\begin{array}{ll} \text{WRITE} & ENGY\ (I,1,10) \\ \text{WRITE} & ENGY\ (I,2,10) \end{array}\right\} \text{for } I = 1 \text{ to } 6$$

9.4 Print steam cooling consumption and demand data for January through June.

$$\left.\begin{array}{ll} \text{WRITE} & ENGY\ (I,1,11) \\ \text{WRITE} & ENGY\ (I,2,11) \end{array}\right\} \text{for } I = 1 \text{ to } 6$$

9.5 Print total steam consumption and demand data for January through June.

$$\left.\begin{array}{ll} \text{WRITE} & SD(I) \\ \text{WRITE} & SC(I) \end{array}\right\} \text{for } I = 1 \text{ to } 6$$

9.6 Sum all components of oil usage to get total monthly and annual oil usage for building.

$$\left.\begin{array}{l} \left.\begin{array}{lll} SSD(I) & = & \sum ENGY(I,1,K) \\ SSC(I) & = & \sum ENGY(I,2,K) \end{array}\right\} \text{for } K = 12,13 \\ \\ \begin{array}{lll} S(8) & = & \sum ENGY(I,2,12) \\ S(10) & = & \sum ENGY(I,2,13) \end{array} \end{array}\right\} \text{For } I = 1 \text{ to } 12$$

$$S1 = S(8) + S(10)$$

9.7 If building used no oil (S1 = 0.0), go to calculation 9.11.

9.8 Print oil heating consumption and demand data for January through June.

$$\left.\begin{array}{ll} \text{WRITE} & ENGY(I,1,12) \\ \text{WRITE} & ENGY(I,2,12) \end{array}\right\} \text{for } I = 1 \text{ to } 6$$

9.9 Print oil cooling consumption and demand data for January through June.

$$\left.\begin{array}{ll} \text{WRITE} & ENGY(I,1,13) \\ \text{WRITE} & ENGY(I,2,13) \end{array}\right\} \text{for } I = 1 \text{ to } 6$$

9.10 Print total oil consumption and demand data for January through June.

$$\left.\begin{array}{ll} \text{WRITE} & SSD(I) \\ \text{WRITE} & SSC(I) \end{array}\right\} \text{for } I = 1 \text{ to } 6$$

9.11 If building used no diesel fuel (S(12) = 0.0), go to calculation 9.13.

9.12 Print diesel fuel consumption and demand data for January through June.

$$\left.\begin{array}{ll} \text{WRITE} & ENGY(I,1,14) \\ \text{WRITE} & ENGY(I,2,14) \end{array}\right\} \text{for } I = 1 \text{ to } 6$$

9.13 If building used no city water (S(3) = 0.0), go to calculation 10.

9.14 Print city water consumption and demand data for January through June.

```
WRITE   ENGY (I,1,17)  }
                       }  for I = 1 to 6
WRITE   ENGY (I,2,17)  }
```

10. Print page 4 of report.

10.1 If building used no steam (SS(6) = 0.0), go to calculation 10.5.

10.2 Print steam heating consumption and demand data for July through December and annual total.

```
WRITE   ENGY (I,1,10)  }
                       }  for I = 7 to 12
WRITE   ENGY (I,2,10)  }

WRITE   S(2)
```

10.3 Print steam cooling consumption and demand data for July through December and annual total.

```
WRITE   ENGY (I,1,11)  }
                       }  for I = 7 to 12
WRITE   ENGY (I,2,11)  }

WRITE   S(4)
```

10.4 Print total steam consumption and demand data for July through December and annual total.

```
WRITE   SD(I)          }
                       }  for I = 7 to 12
WRITE   SC(I)          }

WRITE   S(6)
```

10.5 If building used no oil (S1 = 0.0), go to calculation 10.9.

10.6 Print oil heating consumption and demand data for July through December and annual total.

```
WRITE   ENGY (I,1,12)  }
                       }  for I = 7 to 12
WRITE   ENGY (I,2,12)  }

WRITE   S(8)
```

10.7 Print oil cooling consumption and demand data for July through December and annual total.

$$\left.\begin{array}{ll}\text{WRITE} & \text{ENGY (I,1,13)}\\ \text{WRITE} & \text{ENGY (I,2,13)}\end{array}\right\}\ \text{for I = 7 to 12}$$

WRITE S(10)

10.8 Print total oil consumption and demand data for July through December and annual total.

$$\left.\begin{array}{ll}\text{WRITE} & \text{SSD(I)}\\ \text{WRITE} & \text{SSC(I)}\end{array}\right\}\ \text{for I = 7 to 12}$$

WRITE S1

10.9 If building used no diesel fuel (S(12) = 0.0), go to calculation 10.11.

10.10 Print diesel fuel consumption and demand data for July through December and annual total.

$$\left.\begin{array}{ll}\text{WRITE} & \text{ENGY (I,1,14)}\\ \text{WRITE} & \text{ENGY (I,2,14)}\end{array}\right\}\ \text{for I = 7 to 12}$$

WRITE S(12)

10.11 If building used no city water (S3 = 0.0), RETURN.

10.12 Print city water consumption and demand data for July through December and annual total.

$$\left.\begin{array}{ll}\text{WRITE} & \text{ENGY (I,1,17)}\\ \text{WRITE} & \text{ENGY (I,2,17)}\end{array}\right\}\ \text{for I = 7 to 12}$$

WRITE S3

SUBROUTINE: EQUIP

GENERAL DESCRIPTION

Calculates the energy consumption of conventional heating and cooling equipment, onsite generation equipment, and conventionally operated heat conservation systems.

LIST OF VARIABLES

INPUT

M1 - Type of chiller

1 = Reciprocating
2 = Hermetic centrifugal
3 = Open centrifugal
4 = Steam absorption
5 = Centrifugal/steam turbine

M2 - Source of chiller energy

1 = Gas
2 - Heating oil
3 = Steam
4 = Electric

M3 - Source of Heating energy

1 = Gas
2 = Heating oil
3 = Steam
4 = Electric

M4 - Number of on-site generation engines

M5 - Type of on-site generation engines

0 = None
1 = Diesel
2 = Gas

M6 - Type of auxiliary chiller

0 = None
1 = Reciprocating
2 = Hermetic centrifugal
3 = Open centrifugal

M7 - Source of supplemental heat

0 = None
1 = Gas
2 = Heating oil
3 = Electricity
4 = Well water
5 = City water

NUMAC - Number of auxiliary chillers

SZAC - Size of auxiliary chillers (tons)

QHBC - Hourly building cooling load (Btu/hr)

QHBH - Hourly building heating load (Btu/hr)

QHBRH - Hourly building reheat load (Btu/hr)

TECØN - Entering condensing water temperature (°F)

ELDEM - Hourly electrical demand of the building (KW)

COMMON

KREHT - Source of reheat coil energy

0 = Same as boiler
4 = Electricity

NUMC - Number of chillers

SZC - Size of chillers (tons)

TLCHL - Chilled water set point temperature (°F)

TPS - Temperature of high-pressure purchased steam (°F)

PPS - Pressure of high-pressure purchased steam (psig)

TESTM - Temperature of low pressure generated steam (°F)

PESTM - Pressure of low-pressure generated steam (psig)

SZT - Size of steam turbines (hp)

NUMT - Number of steam turbines

RPM - Speed of steam turbines (rpm)

SZE - Size of on-site generation engines (KW)

HVHØ - Heating value of heating oil (Btu/gal)

HVDF - Heating value of diesel fuel (Btu/gal)

FFLMN - Minimum part load cutoff point for chillers (decimal)

OUTPUT

GASC - Hourly gas consumption for cooling (therms)

GASH - Hourly gas consumption for heating (therms)

GASG - Hourly gas consumption for on-site generation (therms)

ØILC - Hourly oil consumption for cooling (gals)

ØILH - Hourly oil consumption for heating (gals)

STMC - Hourly steam consumption for cooling (lbs)

STMH - Hourly steam consumption for heating (lbs)

ELEC - Hourly electrical consumption for cooling (KW)

ELEH - Hourly electrical consumption for heating (KW)

FUEL - Hourly diesel fuel consumption for on-site generation (gals)

QSAVE - Cooling load carried over to next hour when building cooling load is less than chiller minimum part load point (Btu/hr)

QHBC - Hourly building cooling load handled by chillers (tons)

QRCNM - Monthly accumulation of chiller loads not met due to undersizing (MBTU)

QBCNM - Monthly accumulation of boiler loads not met due to undersiting (MBTU)

COMMON

QRCNM - Monthly accumulation of chiller loads not met due to undersizing (MBTU)

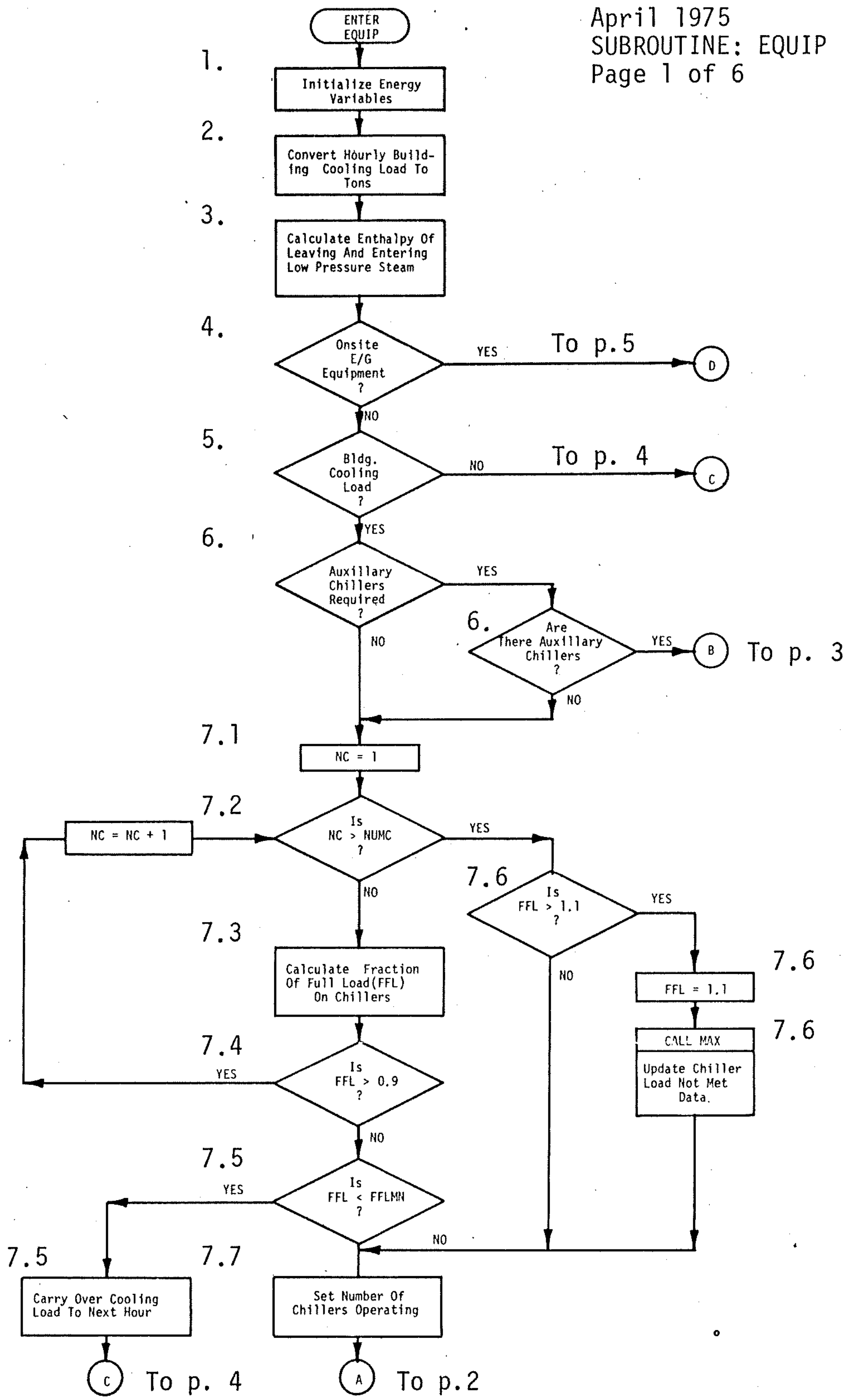
QRPNM - Monthly peak chiller load not met (MBH)

IHRNM - Number of hours chiller load not met

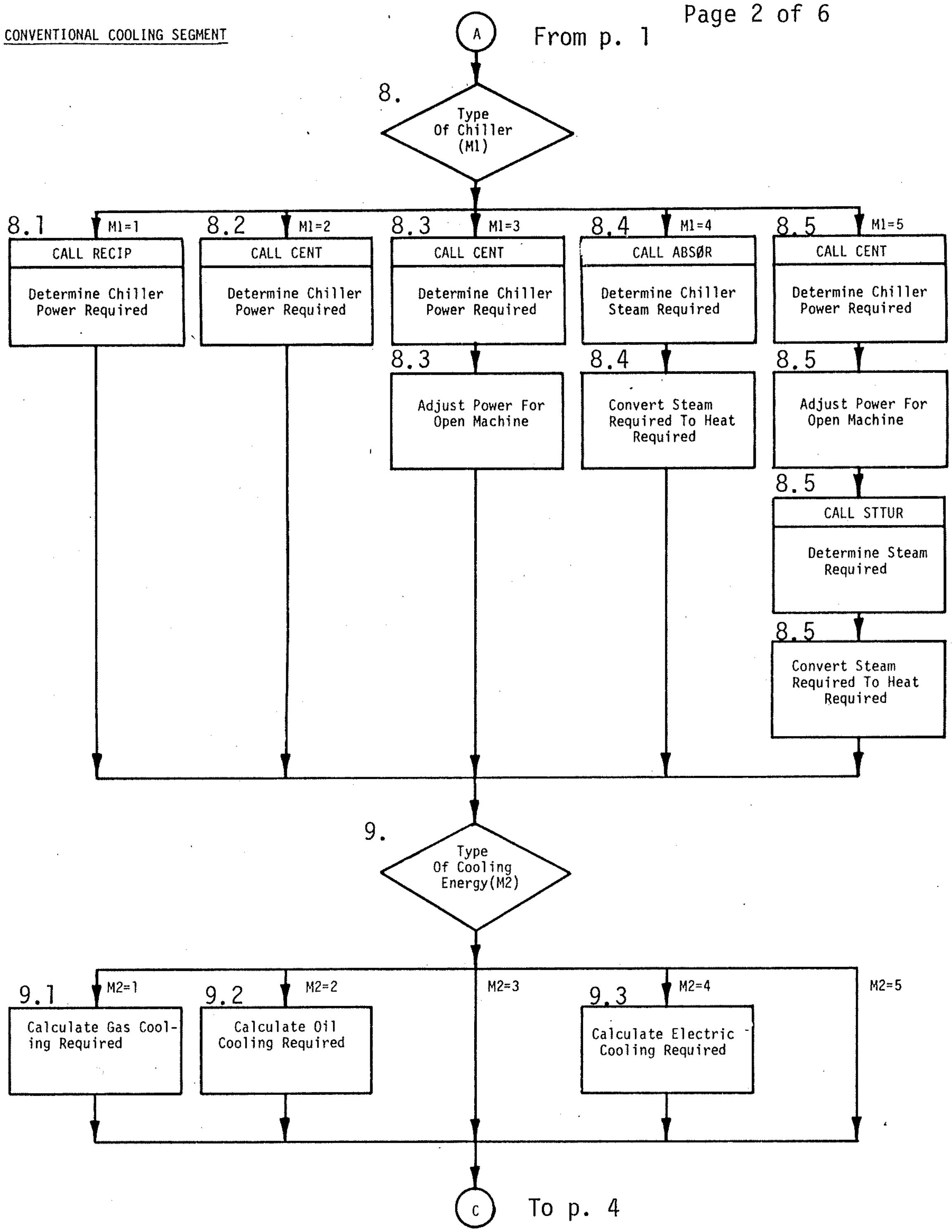
QBCNM - Monthly accumulation of boiler loads not met due to undersizing (MBTU)

QBPNM - Monthly peak boiler load not met (MBH)

IHBNM - Number of hours boiler load not met

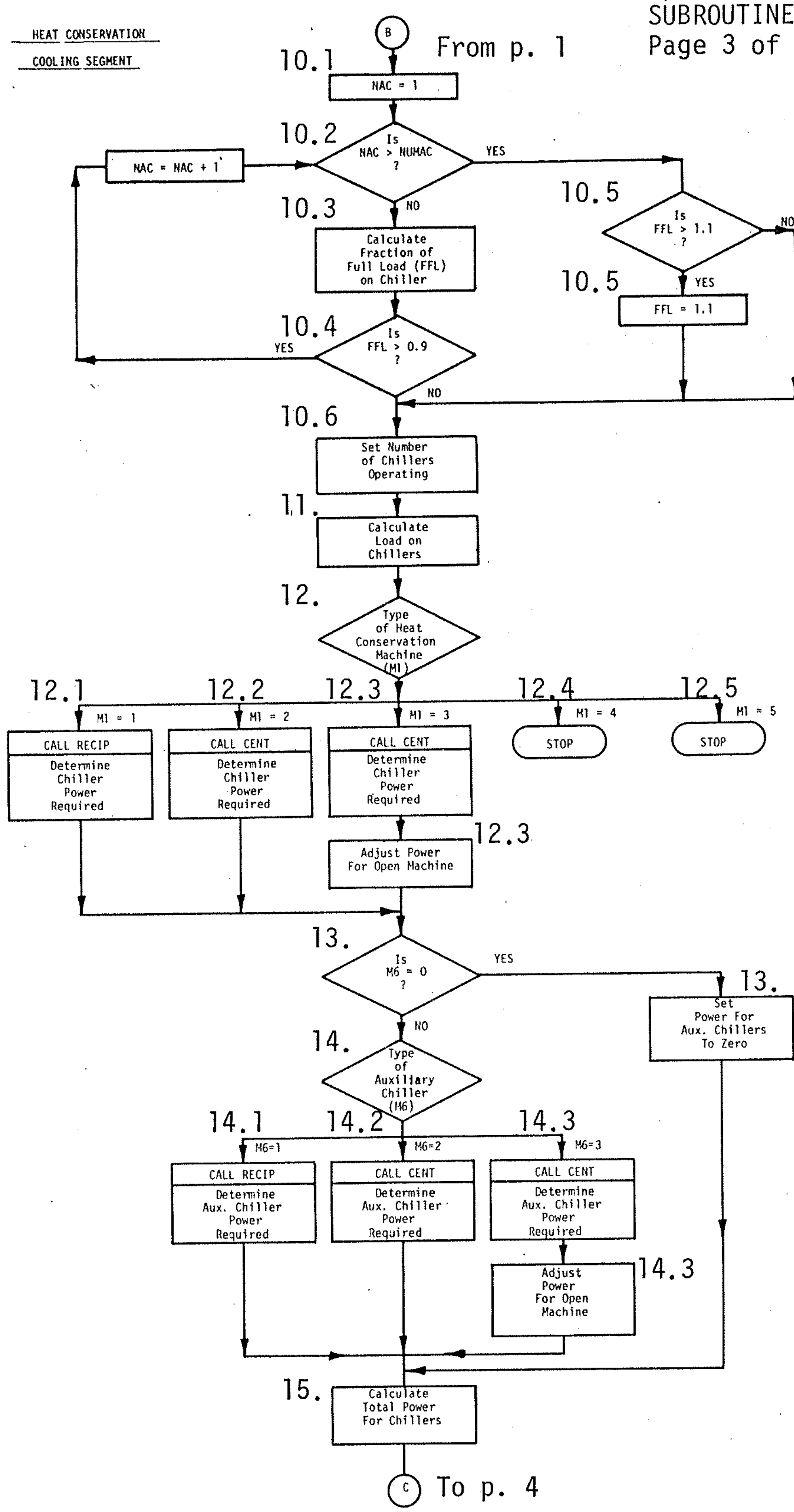

ENTER EQUIP
1.
Initialize Energy Variables
2.
Convert Hourly Building Cooling Load To Tons
3.
Calculate Enthalpy Of Leaving And Entering Low Pressure Steam
4.
Onsite E/G Equipment ?
YES
To p.5
D
NO
5.
Bldg. Cooling Load ?
NO
To p. 4
C
YES
6.
Auxillary Chillers Required ?
YES
6.
Are There Auxillary Chillers ?
YES
B
To p. 3
NO
NO
7.1
NC = 1
7.2
Is NC > NUMC ?
NC = NC + 1
YES
7.6
Is FFL > 1.1 ?
YES
7.6
FFL = 1.1
7.6
CALL MAX
Update Chiller Load Not Met Data.
NO
NO
7.3
Calculate Fraction Of Full Load(FFL) On Chillers
7.4
Is FFL > 0.9 ?
YES
NO
7.5
Is FFL < FFLMN ?
YES
NO
7.5
Carry Over Cooling Load To Next Hour
C
To p. 4
7.7
Set Number Of Chillers Operating
A
To p.2

CONVENTIONAL COOLING SEGMENT

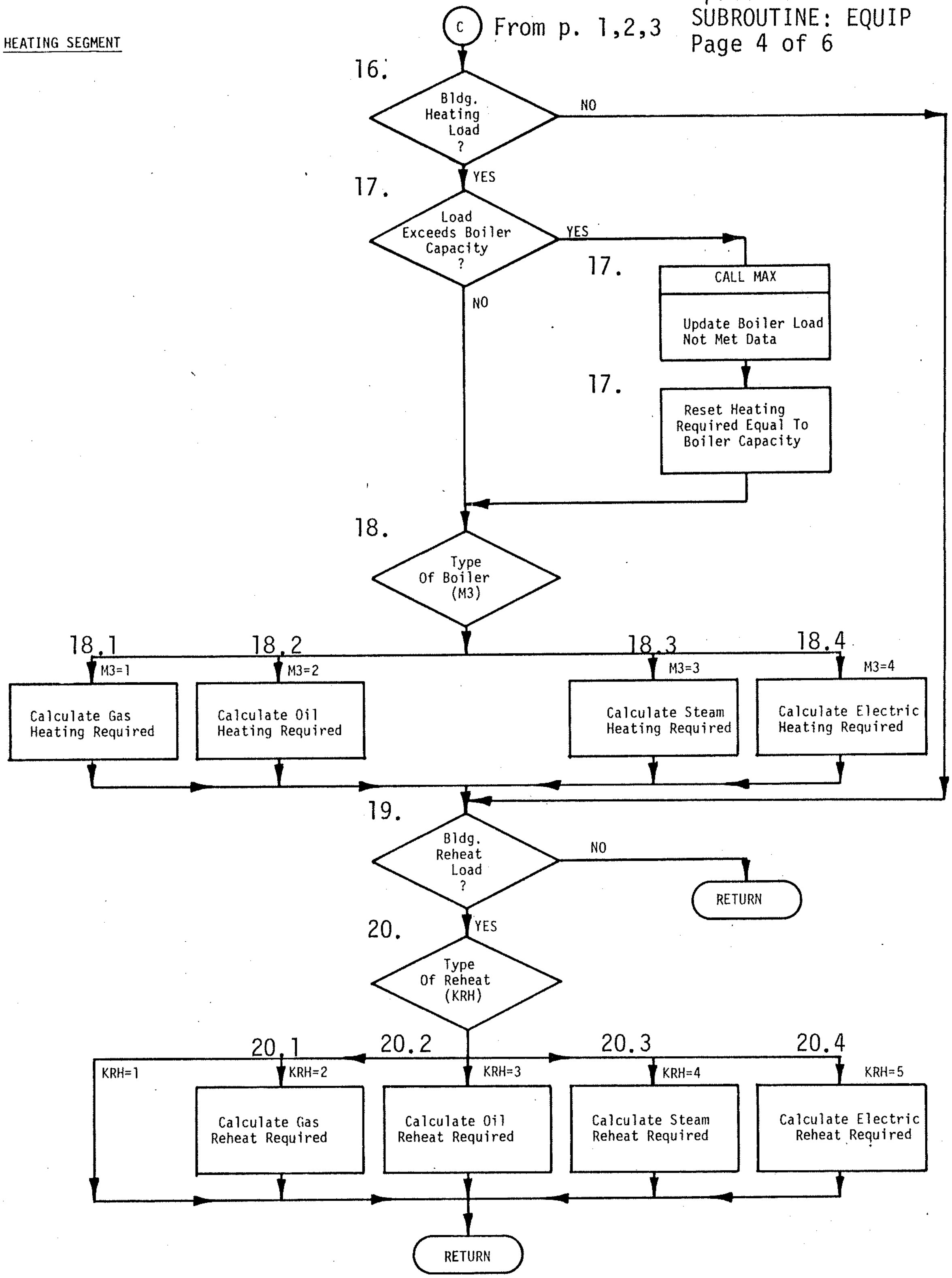


HEAT CONSERVATION

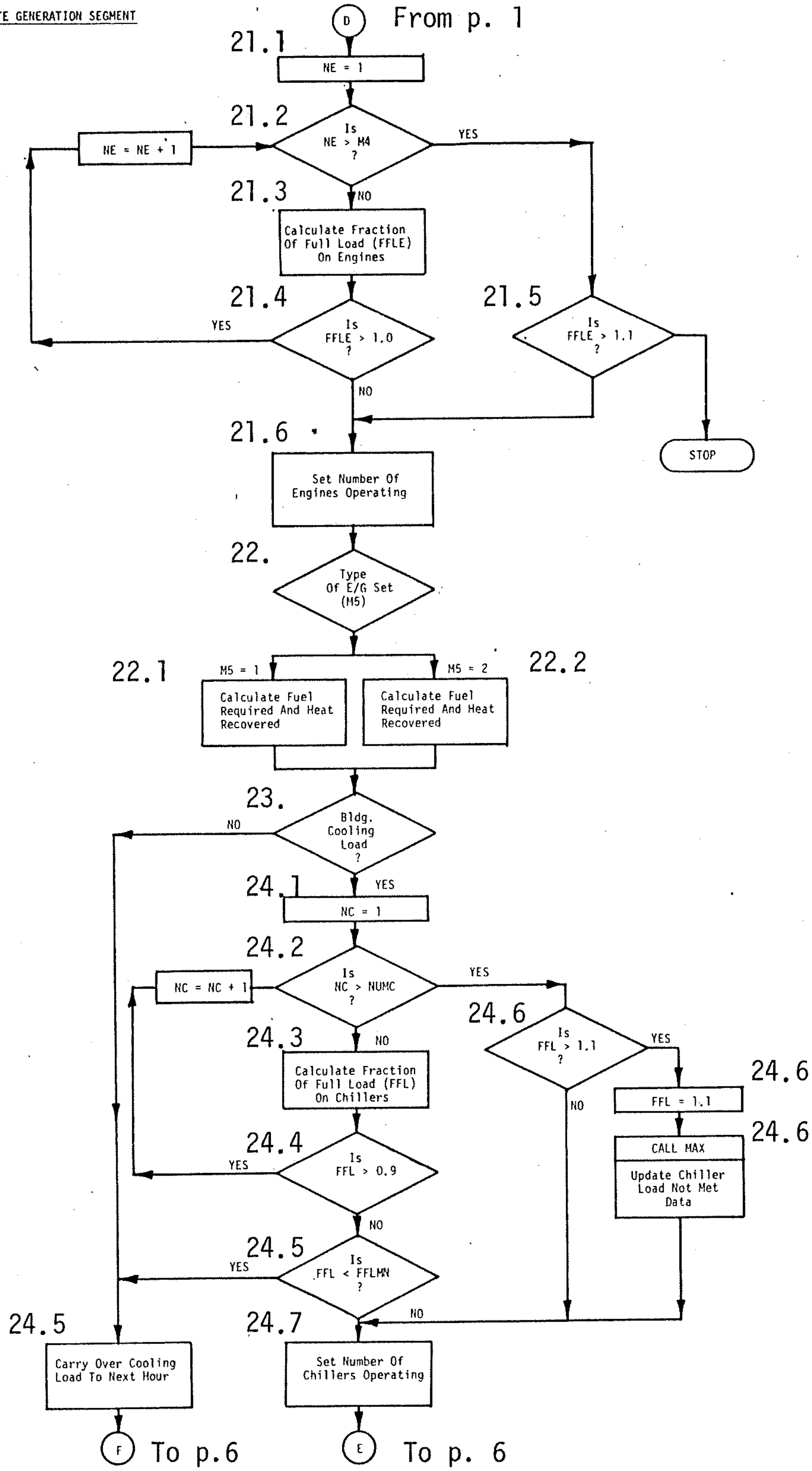
COOLING SEGMENT

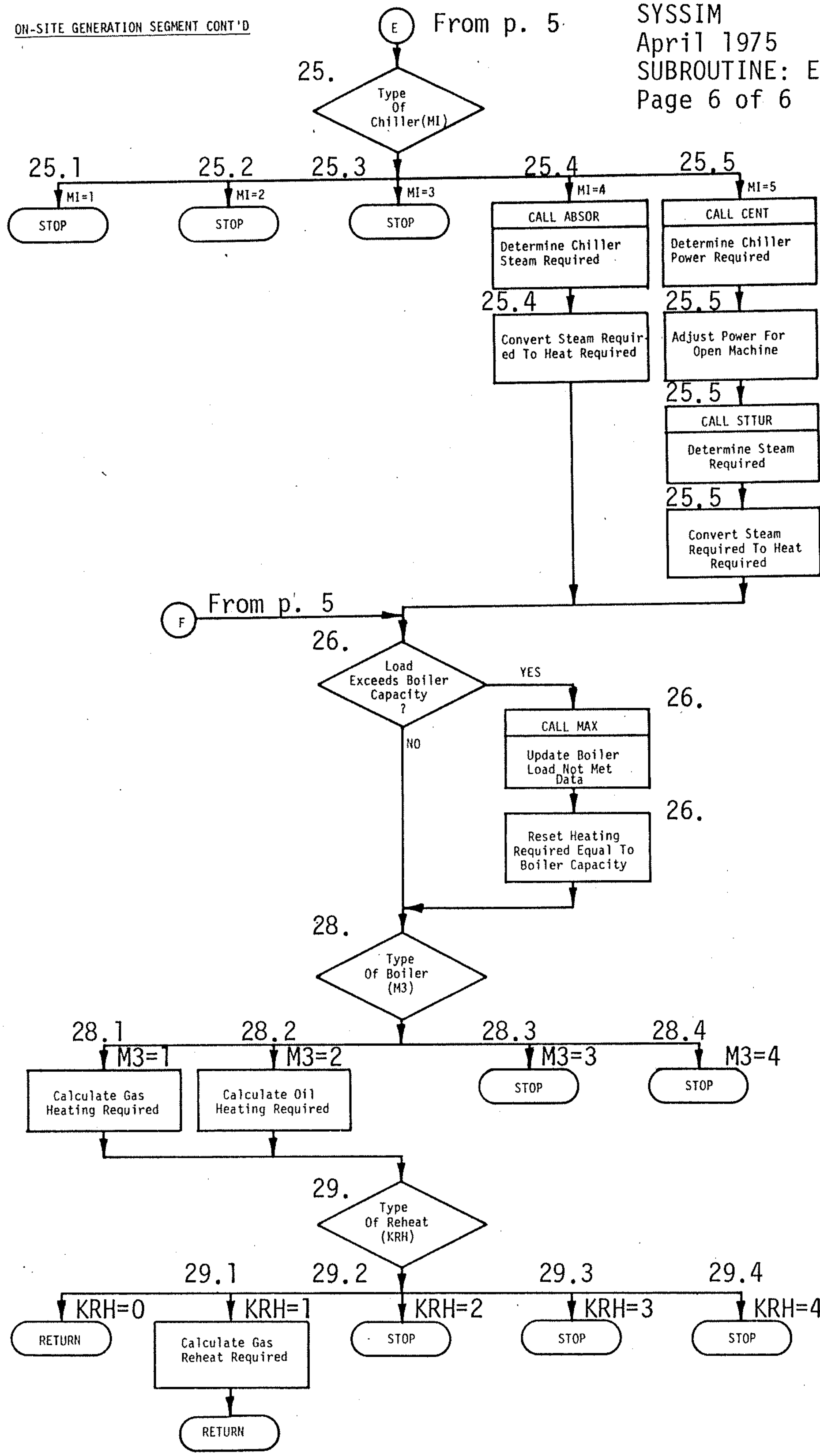


HEATING SEGMENT



ON-SITE GENERATION SEGMENT




E
From p. 5
25.
Type Of Chiller(MI)
25.1
MI=1
STOP
25.2
MI=2
STOP
25.3
MI=3
STOP
25.4
MI=4
CALL ABSOR
Determine Chiller Steam Required
25.4
Convert Steam Required To Heat Required
25.5
MI=5
CALL CENT
Determine Chiller Power Required
25.5
Adjust Power For Open Machine
25.5
CALL STTUR
Determine Steam Required
25.5
Convert Steam Required To Heat Required
F
From p. 5
26.
Load Exceeds Boiler Capacity ?
YES
NO
26.
CALL MAX
Update Boiler Load Not Met Data
26.
Reset Heating Required Equal To Boiler Capacity
28.
Type Of Boiler (M3)
28.1
M3=1
Calculate Gas Heating Required
28.2
M3=2
Calculate Oil Heating Required
28.3
M3=3
STOP
28.4
M3=4
STOP
29.
Type Of Reheat (KRH)
KRH=0
RETURN
29.1
KRH=1
Calculate Gas Reheat Required
RETURN
29.2
KRH=2
STOP
29.3
KRH=3
STOP
29.4
KRH=4
STOP

CALCULATION SEQUENCE

1. Initialize all energy variables.

GASG	=	0.0	gas generation (therms)
GASC	=	0.0	gas cooling (therms)
GASH	=	0.0	gas heating (therms)
ØILC	=	0.0	oil cooling (gals)
ØILH	=	0.0	oil heating (gals)
STMC	=	0.0	steam cooling (lbs)
STMH	=	0.0	steam heating (lbs)
ELEC	=	0.0	electric cooling (KW)
ELEH	=	0.0	electric heating (KW)
FUEL	=	0.0	diesel fuel (gals)
QSAVE	=	0.0	cooling load carryover (Btu/hr)

2. Convert hourly building cooling load into tons.

QHBC = QHBC/12000.0

3. Calculate the enthalpy of entering (HESTM) and leaving (HLSTM) low pressure steam (for boilers and absorption chillers).

HESTM = AH + BH * TESTM + CH * TESTM * TESTM

where:

AH = 1068. - 0.485 * (PESTM + 14.7)

BH = 0.4320 + 0.000953 * (PESTM + 14.7)

CH = 0.000036 - 0.000000496 * (PESTM + 14.7)

These equations were derived by equation fitting data from "Thermodynamic Properties of Steam", Keeman and Keyes. Equation is good for temperatures up to 1000°F and pressures up to 1000 psia.

HLSTM = 180.07

where 180.07 is enthalpy of saturated liquid at 212°F.

4. Check if onsite power generating systems are being used.

If M4 = 0, then conventional system or conventionally-operated heat conservation system.

Go to calculation 5.

If M4 > 0, then onsite generation system.

Go to calculation 21.

5. Check if building requires any cooling.

If QHBC > 0.0, cooling is required.

Go to calculation 6.

If QHBC = 0.0, cooling not required.

Go to calculation 16.

6. Check if auxiliary chillers are required online.

If the quantity (1.0 - QHBC/(0.9 * NUMC * SZC)) is (+), then building system is a conventional system or a conventionally-operated heat conservation system with no auxiliary chillers needed.

Go to calculation 7.

If the quantity (1.0 - QHBC/(0.9 * NUMC * SZC)) is (-) or (0.0), then the system is a conventionally-operated heat conservation system requiring auxiliary chiller operation.

If auxiliary chillers are available (NUMAC > 0),

Go to calculation 10.

If auxiliary chillers are not available (NUMAC = 0),

Go to calculation 7.

BEGIN CONVENTIONAL COOLING SEGMENT

7. Calculate the number of chillers operating.

7.1 Set initial number of chillers operating equal to one (NC = 1).

7.2 If number of chillers operating (NC) is greater than number of chillers available (NUMC),

Go to calculation 7.6.

Otherwise,

Go to calculation 7.3.

7.3 Calculate fraction of full load (FFL) on chillers operating.

$$FFL = QHBC/(NC * SZC)$$

7.4 If chillers operating are loaded to less than or equal to 90% capacity ($FFL \leq 0.9$),

Go to calculation 7.5.

If chillers are loaded to greater than 90% capacity ($FFL > 0.9$),

Increment NC by 1 ($NC = NC + 1$)

Go to calculation 7.2.

7.5 Check if chiller is loaded to minimum limit.

If fraction of full load (FFL) is less than minimum allowable (FFLMN),

Turn chiller off and carry over cooling load to next hour.

$$QSAVE = QHBC * 12000.$$

$$QHBC = 0.0$$

Go to calculation 16.

If fraction of full load (FFL) is greater than or equal to minimum loading (FFLMN),

Go to calculation 7.7.

7.6 All chillers are operating and are loaded to greater than 90% capacity. Check if chillers are overloaded.

If fraction of full load (FFL) is greater than maximum allowable ($FFL = 1.1$),

Reset cooling load and update load-not-met data.

FFL = 1.1

QRNM = (QHBC - NC * SZC * FFL) * 12

QHBC = NC * SZC * FFL

QRCNM = QRCNM + QRNM

IHRNM = IHRNM + 1

CALL MAX to calculate peak chiller load not met(QRPNM)

Go to calculation 7.7.

If fraction of full load (FFL) less than or equal to maximum allowable (FFL = 1.1),

Go to calculation 7.7.

7.7 Set number of chillers operating.

NCHØN = NC

8. Perform chiller simulation for conventional cooling system. Check type of chiller and call appropriate simulation routine.

8.1 <u>Reciprocating Chiller</u> (M1 = 1).

Call RECIP to calculate electrical power (ELEC) required to extract building cooling load (QHBC).

8.2 <u>Hermetic Centrifugal Chiller</u> (M1 = 2).

Call CENT to calculate electrical power (ELEC) required to extract building cooling load (QHBC).

8.3 <u>Open Centrifugal Chiller</u> (M1 = 3).

Call CENT to determine electrical power (ELEC) required for a hermetic machine to extract building cooling load (QHBC). Correct ELEC for an open machine where compressor work does not become a direct load on chiller.

ELEC = ELEC/(1. + 0.02133 * ELEC/QHBC)

where 0.02133 is

$$\frac{[3413\ \text{Btu/hr-KW}]}{[12000\ \text{Btu/hr-ton}]}[1.0 - \text{EFF}]$$

and motor efficiency of a hermetic motor (EFF) is assumed to be 0.925.

8.4 Steam Absorption Chiller (M1 = 4).

Call ABSØR to calculate quantity of steam (STMC) required to extract building cooling load (QHBC) and entering (H1) and leaving (H2) steam enthalpy. Convert steam consumption to equivalent heat requirement (QHMC).

QHMC = STMC * (H1 - H2)

8.5 Steam Turbine Driven Open Centrifugal Chiller Combination (M1 = 5).

Call CENT to determine electrical power (PØWER) required to extract building cooling load (QHBC). Correct PØWER for an open machine where compressor work does not become a direct load on chiller.

PØWER = 0.925 * PØWER/(1. + 0.02133 * PØWER/QHBC)

(See calculation 8.3 for explanation of constants.)

Call STTUR to calculate steam (STMC) required to produce PØWER and entering (H1) and leaving (H2) steam enthalpy. convert steam consumption to equivalent heat requirement.

QHMC = STMC * (H1 - H2)

9. Check type of chiller source energy.

9.1 Gas Cooling (M2 = 1).

GASC = QHMC/80000.

where units are therms and boiler efficiency is assumed to be 80%.

9.2 Oil Cooling (M2 = 2).

ØILC = QHMC/(0.8 * HVHØ)

where units are gallons and boiler efficiency is assumed to be 80%.

9.3 Electric Cooling (M2 = 4)

ELEC = QHMC/3413.0

where units are KW.

Go to calculation 16.

BEGIN HEAT CONSERVATION COOLING SEGMENT

10. Perform chiller simulation for conventionally operated heat conservation machines where auxiliary chillers are required. Calculate number of auxiliary chillers operating. All heat conservation machines are operating.

10.1 Set initial number of auxiliary chillers operating equal to one (NAC = 1).

10.2 If number of auxiliary chillers operating (NAC) is greater than number available (NUMAC),

Go to calculation 10.5.

Otherwise,

Go to calculation 10.3.

10.3 Calculate fraction of full load (FFL) on chillers operating.

FFL = QHBC/(NUMC * SZC + NAC * SZAC)

10.4 If chillers operating are loaded to less than or equal to 90% capacity (FFL $\leq$ 0.9),

Go to calculation 10.6.

If chillers are loaded to greater than 90% capacity (FFL > 0.9),

Increment NAC by 1 (NAC = NAC + 1).

Go to calculation 10.2.

10.5 All chillers are operating and are loaded to greater than 90% capacity. Check if chillers are overloaded.

If fraction of full load (FFL) is greater than maximum allowable (FFL > 1.1), reset cooling load and update load-not-met data.

FFL = 1.1

Go to calculation 10.6.

If fraction of full load (FFL) less than or equal to maximum allowable (FFL $\leq$ 1.1),

Go to calculation 10.6.

10.6 Set number of auxiliary chillers operating.

NACØN = NAC

11. Distribute loads to heat conservation machines (QCC) and auxiliary chillers (QCAC).

QCC = NUMC * SZC * FFL

QCAC = NACØN * SZAC * FFL

12. Complete simulation of conventionally operated heat conservation machine by checking type of machine (M1) and calling appropriate simulation routine.

12.1 Reciprocating Heat Conservation Machine (M1 = 1)

Call RECIP to calculate electrical power (PW1) to produce cooling load (QCC).

12.2 Hermetic Centrifugal Heat Conservation Machine (M1 = 2)

Call CENT to calculate electrical power (PW1) to produce cooling load (QCC).

12.3 Open Centrifugal Heat Conservation Machine (M1 = 3)

Call CENT to determine electrical power (PW1) required to produce cooling load (QCC). Correct PW1 for an open machine where compressor work does not become part of cooling load.

PW1 = PW1/(1.0 + 0.02133 * PW1/QCC)

See calculation 8.3 for explanation of constants in equation.

12.4 Steam Absorption Chiller (M1 = 4)

This is not a valid choice for a heat conservation system. Print error message and STØP.

12.5 Steam Turbine Driven Open Centrifugal (M1 = 5)

This is not a valid choice for a heat conservation system. Print error message and STØP.

13. Check type of auxiliary chillers (M6).

If M6 = 0,

Set auxiliary chiller power consumption to zero (PW2 = 0.0) and go to calculation 15.

If M6 > 0,

Go to calculation 14.

14. Complete simulation of auxiliary chillers by checking type of chiller (M6) and calling appropriate simulation routine.

14.1 Reciprocating Chiller (M6 = 1)

Call RECIP to calculate electrical power (PW2) required to produce building cooling load (QCAC).

14.2 Hermetic Centrifugal Chiller (M6 = 2)

Call CENT to calculate electrical power (PW2) required to produce building cooling load (QCAC).

14.3 Open Centrifugal Chiller (M6 = 3)

Call CENT to determine electrical power (PW2) required for a hermetic machine to produce building cooling load (QCAC). Correct PW2 for an open machine where compressor work does not become a direct load on chiller.

$$PW2 = PW2/(1.0 + 0.02133 * PW2/QCAC)$$

See calculation 8.3 for explanation of constants in equation.

15. Calculate total power (ELEC) required for all chillers.

$$ELEC = PW1 + PW2$$

BEGIN HEATING SEGMENT

16. Check if building requires heating.

If QHBH < 0.0, heating is required.

Go to calculation 17.

If QHBH $\geq$ 0.0, heating is not required.

Go to calculation 19.

17. Check if heating requirement (QHBH) exceeds that of combined boiler capacity (NUMB * SZB * 1000.0).

If (-QHBH) > (NUMB * SZB * 1000.0), heating capacity is exceeded, reset heating load and update load-not-met data.

QBNM = QHBH/1000. + NUMB * SZB

QHBH = SZB * NUMB * 1000.0

QBCNM = QBCNM + QBNM

IHBNM = IHBNM + 1

CALL MAX to calculate peak boiler load not met (QBPNM)

Go to calculation 18.

If (-QHBH) $\leq$ (NUMB * SZB * 1000.0), heating load can be met.

Go to calculation 18.

18. Determine heating energy required by checking type of heating source energy (M3), and performing proper conversion.

18.1 Gas Heating (M3 = 1)

GASH = -QHBH/80000.

where units are in therms and assumed boiler efficiency is 80%.

18.2 Oil Heating (M3 = 2)

ØILH = -QHBH/(0.8 * HVHØ)

where units are in gallons and assumed boiler efficiency is 80%.

18.3 Steam Heating (M3 = 3)

STMH = -QHBH/(HESTM - HLSTM)

where units are in pounds.

18.4 Electric Heating (M3 = 4)

ELEH = -QHBH/3413.0

where units are in KW and assumed efficiency is 100%.

19. Check if building requires reheat.

If QHBRH < 0.0, reheat is required.

Go to calculation 20.

If QHBRH $\geq$ 0.0, reheat is not required.

RETURN

20. Determine return energy required by checking type of reheat source energy (KRH) where

KRH = KREHT + 1

and add it to any heating energy already used.

20.1 Gas Reheat (KRH = 2)

GASH = GASH - QHBRH/80000.

where units are in therms and assumed conversion efficiency is 80%.

RETURN.

20.2 Oil Reheat (KRH = 3)

ØILH = ØILH - QHBRH/80000.

where units are in gallons and assumed conversion efficiency is 80%.

RETURN

20.3 Steam Reheat (KRH = 4)

STMH = STMH - QHBRH/(HESTM - HLSTM)

where units are in pounds.

RETURN

20.4 Electric Reheat (KRH = 5)

ELEH = ELEH - QHBRH/3413.

where units are in KW and assumed conversion efficiency is 100%.

RETURN

BEGIN ONSITE GENERATION SEGMENT

21. Determine number of engine/generator sets that are required to supply electrical load (ELDEM).

21.1 Set initial number of engines operating equal to one (NE = 1).

21.2 If number of engines operating (NE) is greater than number of engines available (M4),

Go to calculation 21.5.

Otherwise,

Go to calculation 21.3.

21.3 Calculate fraction of full load (FFLE) on engines operating.

FFLE = ELDEM/(NE * SZE)

21.4 If engines operating are loaded to less than or equal to 100% capacity (FFLE $\leq$ 1.0),

Go to calculation 21.5.

If engines are loaded to greater than 100% capacity (FFLE > 1.0),

Increment NE by 1 (NE = NE + 1).

Go to calculation 21.2.

21.5 All engines are operating and capacity desired is greater than 100%. Check for overload condition.

If fraction of full load (FFLE) is greater than maximum allowable (FFLE > 1.1), engines have not been sized correctly.

Print error message.

STØP

If fraction of full load (FFLE) is less than or equal to maximum allowable (FFLE $\leq$ 1.1),

Go to calculation 21.6.

21.6 Set number of onsite engine/generator sets operating.

NENØN = NE

22. Perform simulation of engine/generator sets to determine fuel requirements and amount recoverable heat.

22.1 <u>Diesel Fuel Powered Engine/Generator Set</u> (M5 = 1)

Calculate amount of diesel fuel (FUEL) required to supply electrical load (ELDEM).

$$FUEL = (8900. * FFLE + 2000.) * NENØN * SZE/HVDF$$

The above equation was derived by curve fit of performance data contained in the 1967 Caterpillar Tractor Company "Total Energy Handbook" and is applicable for a range of 60 to 600 KW capacity.

Calculate amount of total heat (QEN) that can be recovered from engines operating.

$$QEN = (9590.7 + FFLE * (-14132.2 + FFLE * (12164.87 + FFLE * (-1809.54)))) * FFLE * NENØN * SZE$$

The above equation was derived by curve fit of performance data contained in 1967 Caterpillar Tractor Company "Total Energy Handbook" and represents the total amount of heat that can be recovered from exhaust gas, jacket water, and oil cooler/after-cooler.

22.2 <u>Natural Gas Powered Engine/Generator Set</u> (M5 = 2)

Calculate amount of fuel (GASG) required to supply electrical load (ELDEM).

$$GASG = (0.085 + 0.0289/FFLE) * NENØN * SZE$$

Calculate amount of total heat (QEN) that can be recovered from engine operating.

$$QEN = (60.51 + 16.64/FFLE + 14.0 * FFLE) * ELDEM$$

See calculation 22.1 for comments concerning the above equation.

23. Check if building requires any cooling.

If QHBC > 0.0, cooling is required.

Go to calculation 24.

If QHBC = 0.0, cooling not required.

Set QHMC = 0.0

Go to calculation 26.

24. Calculate number of chillers operating.

24.1 Set initial number of chillers operating equal to one (NC = 1).

24.2 If number of chillers operating (NC) is greater than number of chillers available (NUMC),

Go to calculation 24.6.

Otherwise,

Go to calculation 24.3.

24.3 Calculate fraction of full load (FFL) on chillers operating.

FFL = QHBC/(NC * SZC)

24.4 If chillers operating are loaded to less than or equal to 90% capacity ($FFL \leq 0.9$),

Go to calculation 24.5.

If chillers are loaded to greater than 90% capacity ($FFL > 0.9$),

Increment NC by 1 (NC = NC + 1).

Go to calculation 24.2.

24.5 Check if chiller is loaded to minimum limit.

If fraction of full load (FFL) is less than minimum allowable (FFMN), turn chiller off and carry over cooling load to next hour. Set

QSAVE = QHBC * 12000.

QHBC = 0.0

Go to calculation 26.

If fraction of full load (FFL) is greater than or equal to minimum loading (FFLMN),

Go to calculation 24.7.

24.6 All chillers are operating and are loaded to greater than 90% capacity. Check for overload condition.

If fraction of full load (FFL) is greater than maximum allowable (FFL > 1.1), reset cooling load and update load-not-met data.

```
FFL    =  1.1

QRNM   =  (QHBC - NC * SZC * FFL) * 12.
QHBC   =  NC * SZC * FFL
QRCNM  =  QRCNM + QRNM

IHRNM  =  IHRNM + 1
```

CALL MAX to calculate peak cooling load not met (QRPNM)

Go to calculation 24.7.

If fraction of full load (FFL) less than or equal to maximum allowable (FFL $\leq$ 1.1),

Go to calculation 24.7.

24.7 Set number of chillers operating.

```
NCHØN  =  NC
```

25. Perform chiller simulation. Check type of chiller and call appropriate simulation routine.

25.1 <u>Reciprocating Chiller</u> (M1 = 1)

This is not a valid choice for an onsite generation system. Print error message and STØP.

25.2 <u>Hermetic Centrifugal Chiller</u> (M1 = 2)

This is not a valid choice for an onsite generation system. Print error message and STØP.

25.3 <u>Open Centrifugal Chiller</u> (M1 = 3)

This is not a valid choice for an onsite generation system. Print error message and STØP.

25.4 <u>Steam Absorption Chiller</u> (M1 = 4)

Call ABSØR to calculate quantity of steam (STMC) required to supply cooling load (QHBC) and entering (H1) and leaving (H2) steam enthalpy. Convert steam consumption to equivalent heat requirement (QHMC).

QHMC = STMC/(H1 - H2)

25.5 <u>Steam Turbine Driven Open Centrifugal Chiller Combination (M1 = 5)</u>

Call CENT to determine electrical power (PØWER) required to supply cooling load (QHBC). Correct PØWER for an open machine where compressor work does not become a direct load on chiller.

PØWER = 0.925 * PØWER/(1.0 + 0.02133 * PØWER/QHBC)

(See calculation 8.3 for explanation of constants.)

Call STTUR to calculate steam required (STMC) to supply PØWER. and entering (H1) and leaving (H2) steam enthalpy. Convert to equivalent heat requirement.

QHMC = STMC/(H1 - H2)

26. Check if building requires boiler to operate.

If (-QHBH - QEN + QHMC), the net heating required, is less than or equal to SZB * NUMB * 1000.0, the boiler capacity, heating load can be met; therefore,

Go to calculation 27.

If (-QHBH - QEN + QHMC), the net heating required, is greater than SZB * NUMB * 1000.0, the heating required exceeds the boiler capacity. Reset the heating load and update load-not-met data.

QBNM = (QHBH + QEN - QHMC) * 0.001 + (NUMB * SZB)

QHBH = NUMB * SZBB* (-1000.)

QBCNM = QBCNM + QBNM

CALL MAX to calculate peak boiler load not met (QBPNM)

IHBNM = IHBNM + 1

Go to calculation 28.

27. Calculate net heating load (QHBH) to be met by boiler.

QHBH = QHBH + QEN - QHMC

28. Perform simulation of boiler by checking type of heating source energy (M3) and performing proper conversion.

28.1 Gas Heating (M3 = 1)

GASH = -QHBH/80000.

where units are in therms and assumed conversion efficiency is 80%. If GASH < 0.0, reset to GASH = 0.0.

28.2 Oil Heating (M3 = 2)

ØILH = -QHBH/(0.8 * HVHØ)

where units are in gallons and assumed conversion efficiency is 80%. If ØILH < 0.0, reset to ØILH = 0.0.

28.3 Steam Heating (M3 = 3)

This is not a valid choice for onsite generation system. Print error message and STØP.

28.4 Electric Heating (M3 = 4)

This is not a valid choice for onsite generation system. Print error message and STØP.

29. Determine reheat energy required by checking type of reheat source energy (KRH) where

KRH = KREHT + 1

and add it to any heating energy already used.

29.1 Gas Reheat (KRH = 2)

GASH = GASH - QHBRH/80000.

where units are in therms and conversion efficiency is assumed to be 80%.

29.2 Oil Reheat (KRH = 3)

Not a valid choice for onsite generation system. Print error message and STØP.

29.3 Steam Reheat (KRH = 4)

Not a valid choice for onsite generation system. Print error message and STØP.

29.4 Electric Reheat (KRH = 5)

Not a valid choice for onsite generation system. Print error message and STØP.

SUBROUTINE: ERRØR

GENERAL DESCRIPTION

Prints terminal and warning messages due to input data abnormalities.

LIST OF VARIABLES

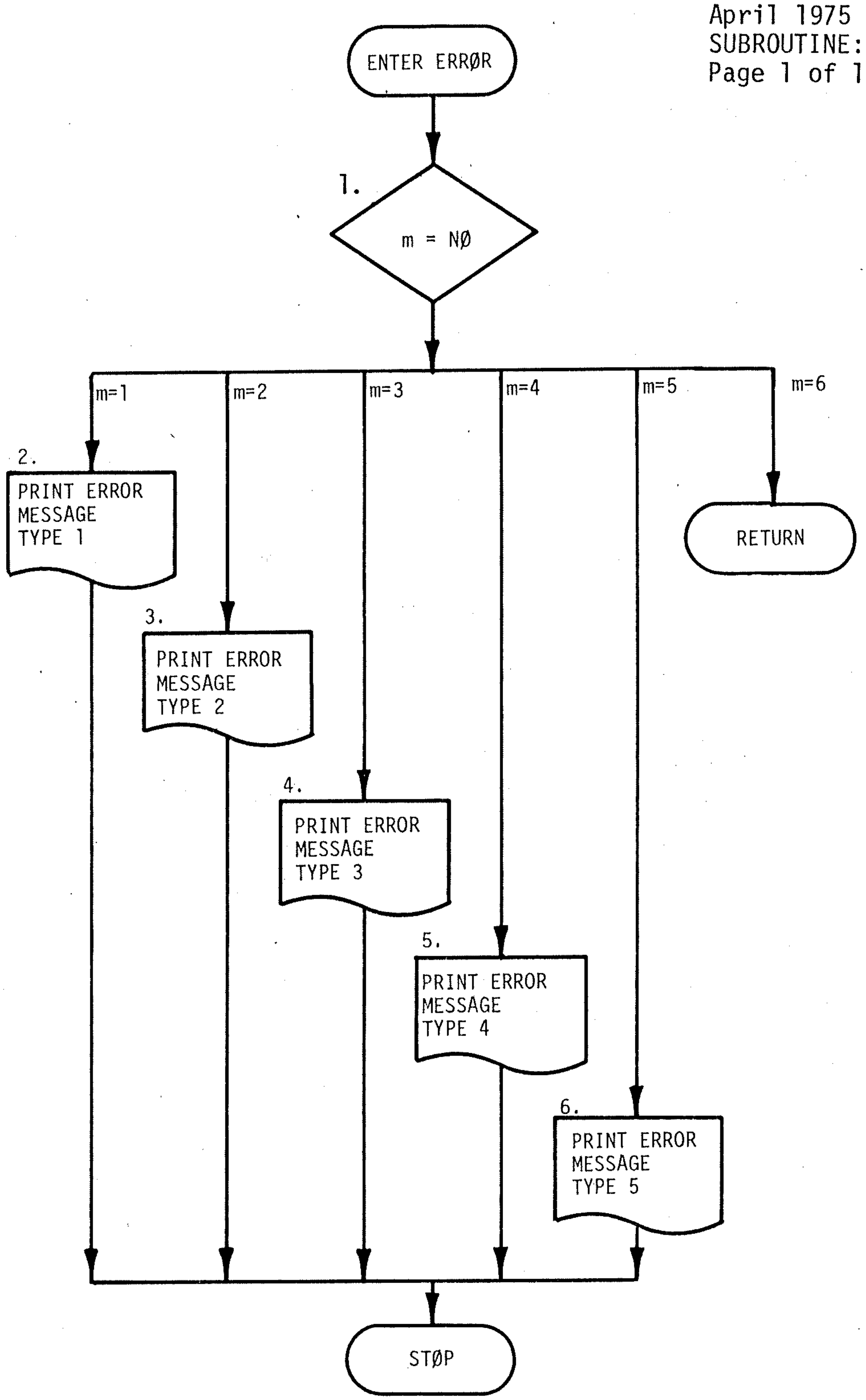
INPUT

NØ - Type of error (1 through 5)

IA - Print output variable 1

IB - Print output variable 2

X - Print output variable 3


ENTER ERRØR
1.
m = NØ
m=1
m=2
m=3
m=4
m=5
m=6
2.
PRINT ERROR MESSAGE TYPE 1
3.
PRINT ERROR MESSAGE TYPE 2
4.
PRINT ERROR MESSAGE TYPE 3
5.
PRINT ERROR MESSAGE TYPE 4
6.
PRINT ERROR MESSAGE TYPE 5
RETURN
STØP

CALCULATION SEQUENCE

1. Check for type of error.

   If NØ = 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, RETURN

2. Print error message type 1.

   "TERMINAL ERROR - NO. 1

   ZONE SETPOINT TEMPERATURE LESS THAN THAT

   OF AIR SUPPLIED BY SYSTEM NO. [IA]

   FOR ZONE NO. [IB]"

   STOP

3. Print error message type 2.

   "TERMINAL ERROR - NO. 2

   ZONE SETPOINT TEMPERATURE GREATER THAN THAT

   OF AIR SUPPLIED BY SYSTEM NO. [IA]

   FOR ZONE NO. [IB]"

   STOP

4. Print error message type 3.

   "TERMINAL ERROR - NO. 3

   NUMBER OF ZONES ON SYSTEM NO. [IA]

   LESS THAN OR EQUAL TO ZERO"

   STOP

5. Print error message type 4.

"TERMINAL ERROR - NO. 4

VALUE OF INDUCED TO PRIMARY AIR RATIO

LESS THAN OR EQUAL TO ZERO FOR

INDUCTION UNIT FAN SYSTEM NO. [IA]"

STOP

6. Print error message type 5.

"TERMINAL ERROR - NO. 5

CEILING PLENUM RETURN AIR SPACE

CANNOT BE SIMULATED WITH THIS

ENERGY DISTRIBUTION SYSTEM TYPE"

STOP

SUBROUTINE: FANØF

GENERAL DESCRIPTION

This subroutine handles loads for a given hour when a fan system is off. This routine will be called only when IFAN = 1 or 2.

LIST OF VARIABLES

INPUT

k - Energy distribution system number.

COMMON

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

IFAN - Fan system shut-off flag (0=fans run continously,
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 it 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)

$JMAX_k$ - Number of zones in system k.

$FBHPS_k$ - 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)

$ALFBR_i$ - 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)

$SPACN_{k,j}$ - 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

IØØ - Fan operation indicator (0=fan on; 1=fan off)

QCC - Cooling load (Btu/hr)

QHC - Heating load (Btu/hr)

QTRHC - Reheat coil load (Btu/hr)

QPHC - Preheat coil load (Btu/hr)

TQB - Baseboard radiation 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

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

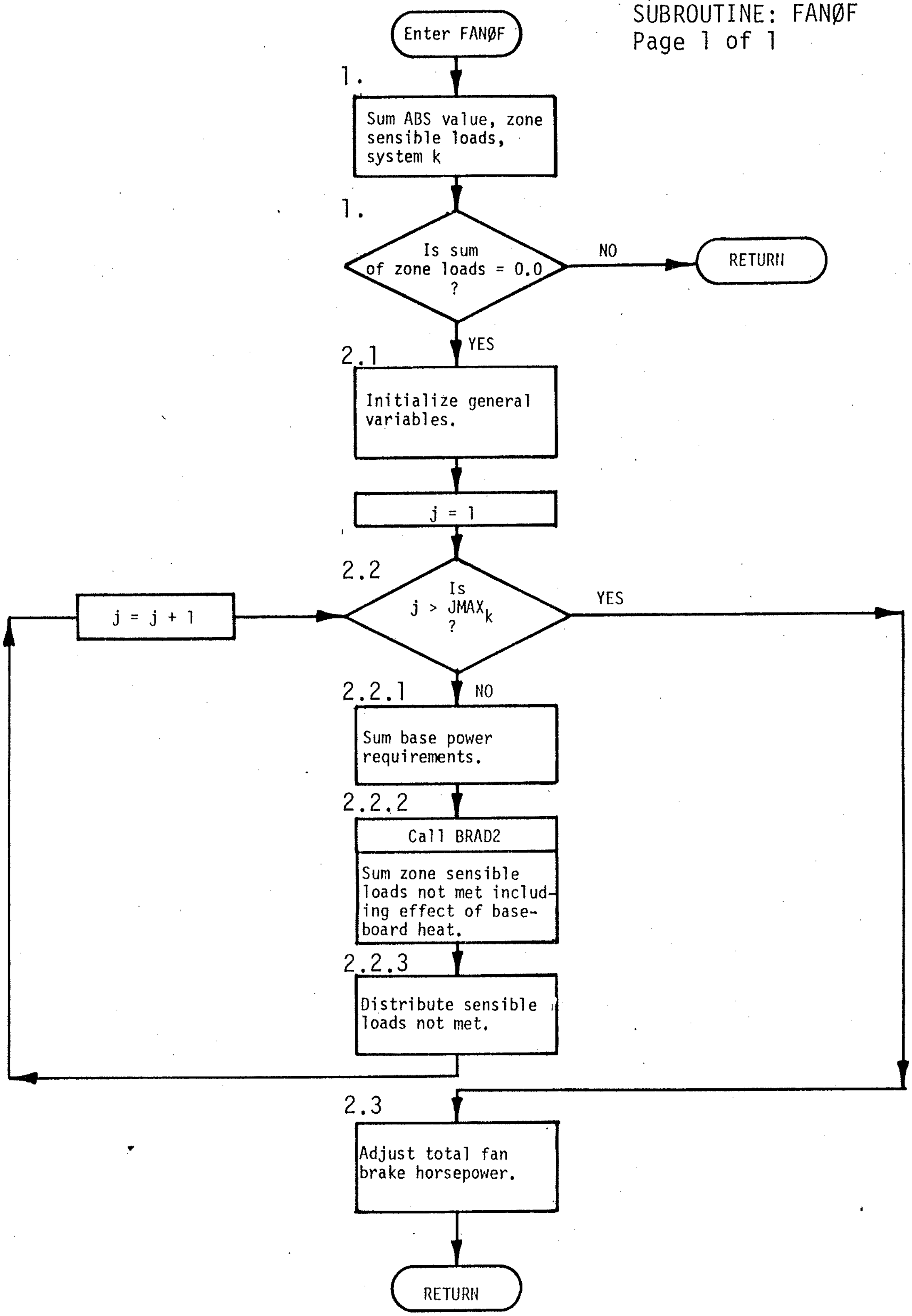
$QCPNM_i$ - Monthly peak cooling load not met, zone i (btu/hr)

$IHCNM_i$ - 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 FANØF
1.
Sum ABS value, zone sensible loads, system k
1.
Is sum of zone loads = 0.0 ?
NO
RETURN
YES
2.1
Initialize general variables.
j = 1
2.2
Is j > $JMAX_k$?
YES
j = j + 1
2.2.1
NO
Sum base power requirements.
2.2.2
Call BRAD2
Sum zone sensible loads not met including effect of baseboard heat.
2.2.3
Distribute sensible loads not met.
2.3
Adjust total fan brake horsepower.
RETURN

CALCULATION SEQUENCE

1. Check for zero sensible zone load.

$$\text{If} \sum_{j=1,\ JMAX_k} |QS_i| \neq 0.0,$$

(See note at bottom of page for explanation of subscript variables i, j, k, z.)

IØØ = 0

RETURN

$$\text{If} \sum_{j=1,\ JMAX_k} |QS_i| = 0.0$$

CONTINUE

2. Fan system turned off, distribute loads not met.

2.1 Initialize general variables.

QCC = 0.0

QHC = 0.0

WATER = 0.0

QTRHC = 0.0

QPHC = 0.0

TQB = 0.0

2.2 Zone load distribution.

2.2.1 Sum base power requirements.

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

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).

2.2.2 Sum zone sensible loads not met ($QLNM_i$) including effect of baseboard heat.

$$QLNM_i = QS_Z + QLITE_Z + QSINF_Z$$

If boiler on (IBØIL = 1), and baseboard heat left on (IFAN = 1), call subroutine BRAD2 to calculate baseboard radiation heat (QB_i) and adjust $QLNM_i$.

If boiler off (IBØIL = 0) or baseboard heat turned off (IFAN = 2),

CONTINUE

2.2.3 Distribute sensible load not met ($QLNM_i$)

If $QLNM_i$ less than 0.0, heating load not met.

Update the following variables as required:

$QHLNM_i$ - 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.

Go to calculation 2.2.4.

If $QLNM_i$ = 0.0,

Go to calculation 2.2.4.

If $QLNM_i$ greater than 0.0, cooling load not met.

Update the following variables as required:

$QCLNM_i$ - Sum of cooling loads not met, zone i.

$QCPNM_i$ - 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.

Go to calculation 2.2.4.

2.3 Turn off all system fans and calculate its effect on total fan brake horsepower (TNFBP).

$$TNFBP = TNFBP - FBHPS_k - FBHPR_k - FBHPE_k$$

IØØ = 1.0

RETURN

SUBROUTINE: FCØIL

GENERAL DESCRIPTION

This is a subroutine to simulate the performance of either a two-pipe or four-pipe fan coil distribution system (see Fig. &).

TWO-PIPE FAN COIL SYSTEM

The two-pipe fan coil system consists of one distribution circuit (2 pipes) serving terminal fan coil units located in the spaces they condition. A changeover mechanism based on ambient air temperature is required to determine whether hot or chilled water is circulated. The fan coil unit, which consists of a blower and water coil, exhibits the following characteristics:

- The blower runs continuously (unless turned off by NBSLD or NECAP's Variable Temperature Program) while a room thermostat cycles a 2-position valve for temperature control.
- Ventilation air may enter the zone through the unit at a constant rate. Outside air flow is input to the program.

FOUR-PIPE FAN COIL SYSTEM

A four-pipe coil system circulates water through two distribution systems (a hot and a chilled water circuit). The fan coil unit, consisting of a blower and usually two coils, is controlled by a space thermostat which regulates coil flow. A net heat gain in the space causes the thermostat to allow flow through the cooling coil and prohibit flow through the heating coil; for a net heat loss, the reverse is taken. Ventilation air entering the zone at a constant rate through the fan coil unit is also simulated. The simulation of this system is for a continuously running blower (unless turned off by NBSLD or NECAP's Variable Temperature Program).

LIST OF VARIABLES

INPUT

k - Energy distribution system number

IHØUR - Hour of the year

TNFBP - Total net fan brake horsepower (Bhp)

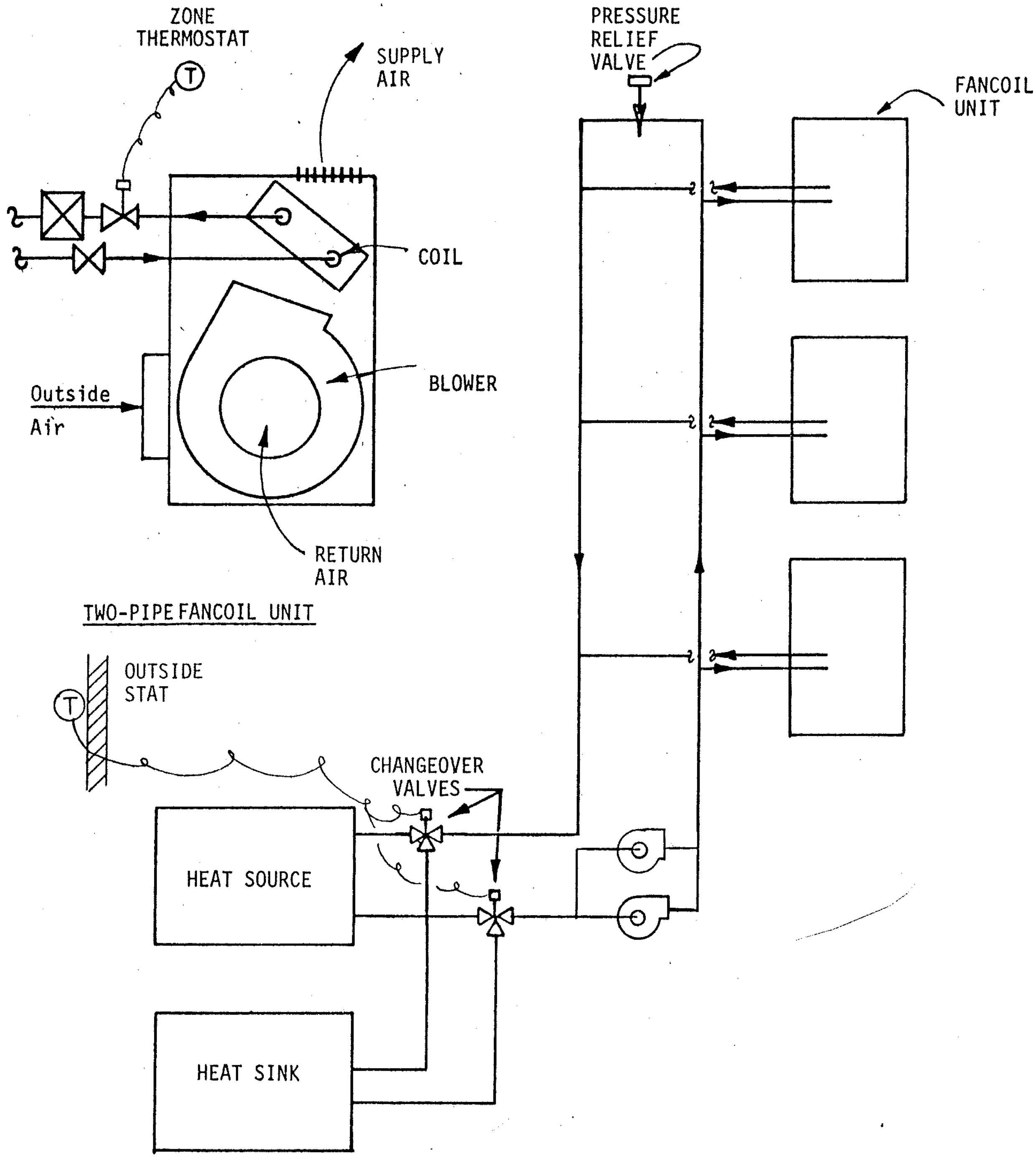


Figure TWO-PIPE FAN COIL DISTRIBUTION SYSTEM
(DISTRIBUTION SYSTEM NO. 8)

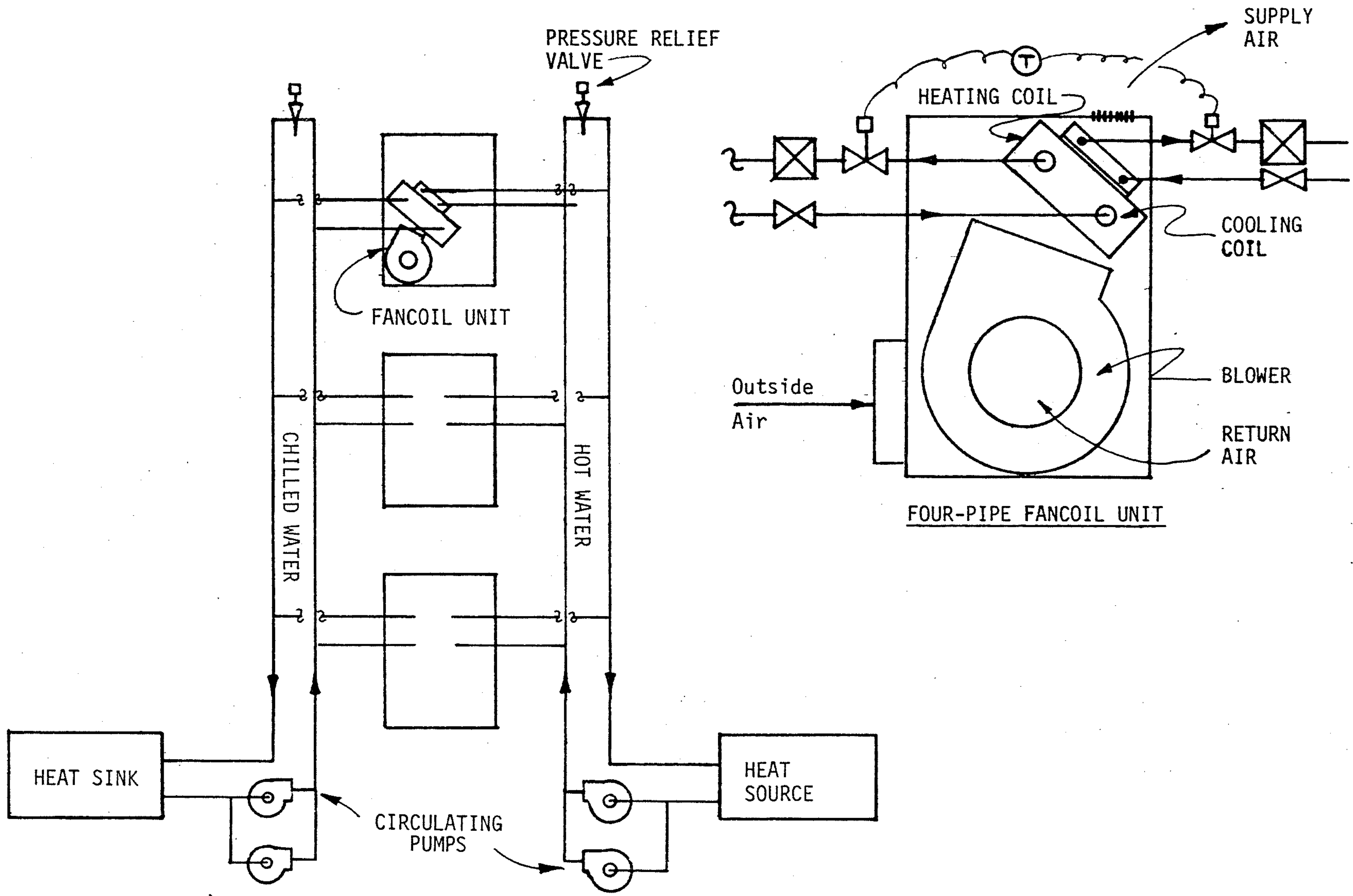


Figure FOUR-PIPE FAN COIL DISTRIBUTION SYSTEM
(DISTRIBUTION SYSTEM NO. 9)

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 (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

$ALFAM_k$ - Minimum fraction outside air, system k

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

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

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

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

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

$FBHPS_k$ - Supply 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)

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

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)

$ZMAS_i$ - 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)

$SPACN_{k,j}$ - 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

QC - Sum of fan coil cooling load (includes changeover energy, if any) (Btu/hr)

QH - Sum of fan coil heating load (includes changeover energy, if any) (Btu/hr)

TQB - Baseboard heating load (Btu/hr)

BPKW - Base power (KW)

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

TSA - Supply air temperature of last fan coil unit, this system (°F)

COMMON

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)

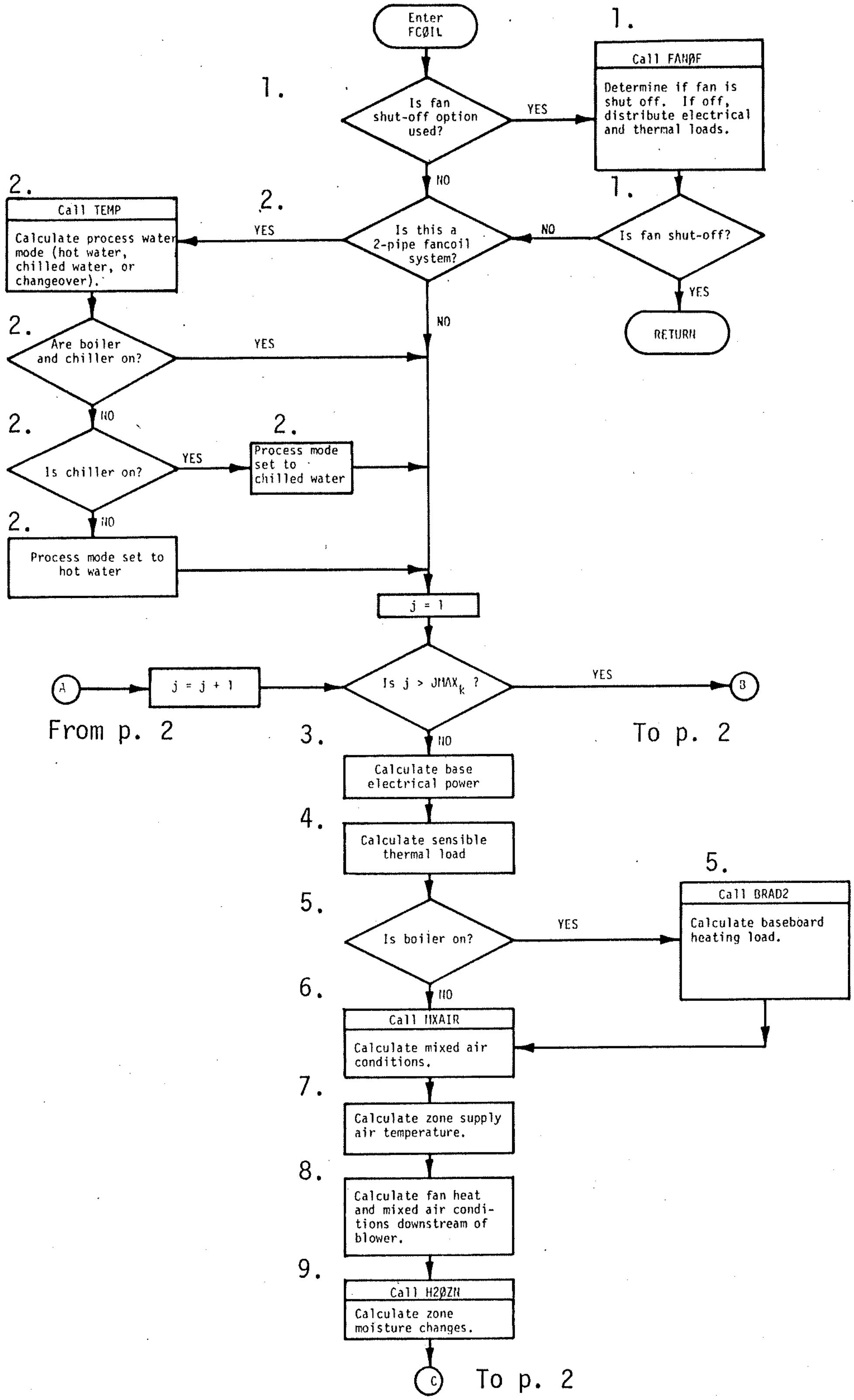
$QCPNM_i$ - Monthly peak cooling load not met, zone i (Btu/hr)

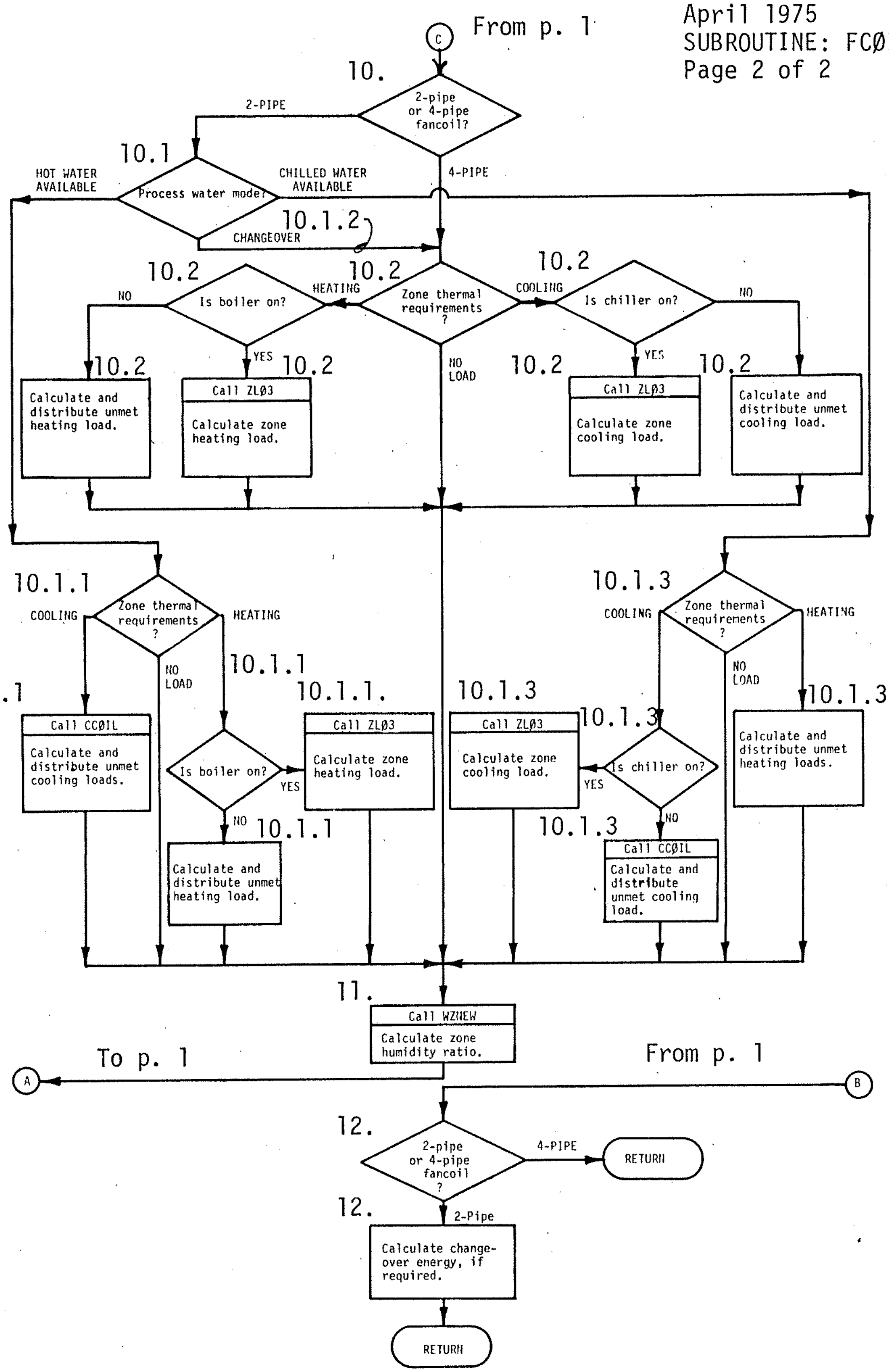
$IHCNM_i$ - Number of hours cooling load not met, zone i (hrs)

$QHLNM_i$ - 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)


Enter FCØIL
1.
Is fan shut-off option used?
YES
1.
Call FANØF
Determine if fan is shut off. If off, distribute electrical and thermal loads.
NO
1.
Is fan shut-off?
NO
YES
RETURN
2.
Is this a 2-pipe fancoil system?
YES
2.
Call TEMP
Calculate process water mode (hot water, chilled water, or changeover).
NO
2.
Are boiler and chiller on?
YES
NO
2.
Is chiller on?
YES
2.
Process mode set to chilled water
NO
2.
Process mode set to hot water
j = 1
A
j = j + 1
From p. 2
Is j > JMAX$_k$?
YES
B
To p. 2
3.
NO
Calculate base electrical power
4.
Calculate sensible thermal load
5.
Is boiler on?
YES
5.
Call BRAD2
Calculate baseboard heating load.
6.
NO
Call MXAIR
Calculate mixed air conditions.
7.
Calculate zone supply air temperature.
8.
Calculate fan heat and mixed air conditions downstream of blower.
9.
Call H2ØZN
Calculate zone moisture changes.
C
To p. 2


From p. 1
10.
2-pipe or 4-pipe fancoil?
2-PIPE
4-PIPE
10.1
Process water mode?
HOT WATER AVAILABLE
CHILLED WATER AVAILABLE
CHANGEOVER
10.1.2
10.2
Is boiler on?
NO
YES
HEATING
Zone thermal requirements ?
COOLING
NO LOAD
Is chiller on?
Calculate and distribute unmet heating load.
Call ZLØ3
Calculate zone heating load.
Calculate zone cooling load.
Calculate and distribute unmet cooling load.
10.1.1
Zone thermal requirements ?
Call CCØIL
Calculate and distribute unmet cooling loads.
Calculate and distribute unmet heating load.
10.1.3
Calculate and distribute unmet heating loads.
Calculate and distribute unmet cooling load.
11.
Call WZNEW
Calculate zone humidity ratio.
To p. 1
A
B
12.
2-pipe or 4-pipe fancoil ?
RETURN
2-Pipe
Calculate change-over energy, if required.
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 FCØIL 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. For two-pipe fan coil units, use subroutine TEMP to determine process water mode (i.e., hot water, chilled water, or changeover) for the current hour. Set indicator variable IPW.

   where IPW = -1 heating mode
   IPW = 0 changeover
   IPW = +1 cooling mode

   If chiller available and boiler not available, reset IPW = +1.

   If chiller not available, reset IPW = -1.

3. Calculate base power (KW), includes internal power, lights, receptacles, equipment, miscellaneous.

$$BPKW = \sum_{j=1,\ JMAX_k} SLP\O W_z * MULT_i$$

(See note at bottom for explanation of i and z).
Calculation sequence 3 through 11 is repeated for each fancoil zone on system k.

4. Calculate sensible thermal load.

$$QSI_i = QS_z + QLITE_z + QSINF_z$$

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 is on (IBØIL = 1), call subroutine BRAD2 to calculate baseboard radiation heat (QB_j) and adjust QSI.

Sum baseboard radiation heat.

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

If boiler is off (IBØIL = 0), continue.

6. Calculate mixed air conditions.

Call subroutine MXAIR to calculate thermal properties (temperature, humidity ratio, and density) of mixing outside air and room air by the fan coil unit.

7. Calculate required supply air temperature (TSA_i).

$$TSA_i = TSP_z - QSI_i/(0.245 * ZMAS_i)$$

8. Calculate fan heat and mixed air temperature downstream of blower.

$$QFAN = CFM_i * TFNPS_k * 0.4014$$

$$TMA = TMA + QFAN/(0.245 * ZMAS_i)$$

9. Calculate 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 ($H2ØAD_i$).

10. Calculate fan coil performance and distribute thermal loads.

10.1 Two-Pipe Fan Coil System

10.1.1 Heating Mode (IPW = -1)

If mixed air temperature (TMA) less than or equal to supply air temperature (TSA), heating required.

If boiler on (IBØIL = 1), call subroutine ZLØ3 to calculate QH and distribute unmet load, if any. Go to 11.
If boiler off (IBØIL = 0), calculate heating load not met ($QLNM_i$).

$$QLNM_i = ZMAS_i * 0.245 * (TMA - TSA)$$

Update as required the following variables:

$QHLNM_i$ - Sum of all heating loads not met, zone i.

$QHPNM_i$ - Peak heating load not met, zone i. Call subroutine MAX to perform this check and update.

$IHHNM_i$ - Hours heating load not met, zone i.

Redefine supply air temperature (TSA) and humidity ratio (WSA).

TSA = TMA

WSA = WMA

Go to 11.

If mixed air temperature (TMA) greater than supply air temperature (TSA), cooling load not met.

Call subroutine CCØIL to calculate cooling load not met.

Update as required the following variables:

$QCLNM_i$ - Sum of all cooling loads not met, zone i.

$QCPNM_i$ - Peak cooling load not met, zone i. Call subroutine MAX to perform this check and update.

$IHCNM_i$ - Hours cooling load not met, zone i.

10.1.2 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 10.2). In addition, there is a thermal load due to changing the temperature of the hydronic system (see 12).

Go to 10.2.

10.1.3 Cooling Mode (IPW = +1)

If mixed air temperature (TMA) less than supply air temperature (TSA), cooling required.

If chiller on (ICHIL = 1), call subroutine ZLØ3 to calculate QC_i and distribute unmet load, if any. Go to 11.

If chiller off (ICHIL = 0), cooling load not met. Call subroutine CCØIL to calculate cooling loads not met.

Update as required the following variables:

$QCLNM_i$ - Sum of all cooling loads not met. zone i.

$QCPNM_i$ - Peak cooling load not met, zone i. Call subroutine MAX to perform this check and update.

$IHCNM_i$ - Hours cooling load not met, zone i.

Redefine supply air temperature (TSA) and humidity ratio (WSA).

TSA = TMA

WSA = WMA

Go to 11.

If mixed air temperature (TMA) greater than supply air temperature (TSA), calculate heating load not met ($QLNM_i$).

$$QLNM_i = ZMAS_i * 0.245 * (TMA - TSA)$$

Update as required the following variables:

$QHLNM_i$ - Sum of all heating loads not met, zone i.

$QHPNM_i$ - Peak heating load not met, zone i. Call subroutine MAX to perform this check and update.

$IHHNM_i$ - Hours heating load not met, zone i.

Redefine supply air temperature (TSA) and humidity ratios (WSA).

TSA = TMA

WSA = WMA

Go to 11.

10.2 Four-Pipe Fan Coil System

If mixed air temperature (TMA) less than or equal to supply air temperature (TSA), heating required.

If boiler on (IBØIL = 1), call subroutine ZLØ3 to calculate QH_i and distribute unmet load, if any. Go to 11.

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

$$QLNM_i = ZMAS_i * 0.245 * (TMA - TSA)$$

Update as required the following variables:

$QHLNM_i$ - Sum of all heating loads not met, zone i.

$QHPNM_i$ - Peak heating load not met, zone i. Call subroutine MAX to perform this check and update.

$IHHNM_i$ - Hours heating load not met, zone i.

Redefine supply air temperature (TSA) and humidity ratio (WSA).

$$TSA = TMA$$

$$WSA = WMA$$

Go to 11.

If mixed air temperature (TMA) greater than supply air temperature (TSA), cooling required.

If chiller on (ICHIL = 1), call subroutine ZLØ3 to calculate QC_i and distribute unmet load, if any. Go to 11.

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

Update as required the following variables:

$QCLNM_i$ - Sum of all cooling loads not met, zone i.

$QCPNM_i$ - Peak cooling load not met, zone i. Call subroutine MAX to perform this check and update.

$IHCNM_i$ - Hours cooling load not met, zone i.

Redefine supply air temperature (TSA) and humidity ratio (WSA).

TSA = TMA

WSA = WMA

Go to 11.

If mixed air temperature (TMA) equals supply air temperature (TSA), no load condition.

TSA = TMA
WSA = WMA

Go to 11.

11. Calculate zone humidity ratio.

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

12. Calculate heat of changeover (for two-pipe fan coil systems only).

If IPW = 0, changeover.

Calculate hot water temperature (THW) using function TRSET.

Calculate changeover heat (QCØ).

$$QC\emptyset = PWGAL_k * 8.3 * (THW - TLCHL)$$

where $PWGAL_k$ - Water volume of two-pipe system (gals)

TLCHL - Chilled water temperature (°F)

If heating-to-cooling changeover:

QC = QC + QCØ
Return.

If cooling-to-heating changeover:

QC = QH - QCØ
Return.

If IPW ≠ 0, return.

SUBROUTINE: FHTG2

GENERAL DESCRIPTION

This subroutine simulates the performance of a floor panel heating system. The floor panel heating system routine is designed to simulate either on-grade slabs or intermediate slabs as shown in Figure . The simulation calculates the water temperature required to meet zone loads and the resultant heat loss of the system assuming all zones to have the same set point temperature. Surface and edge losses are also included in the simulation of this system.

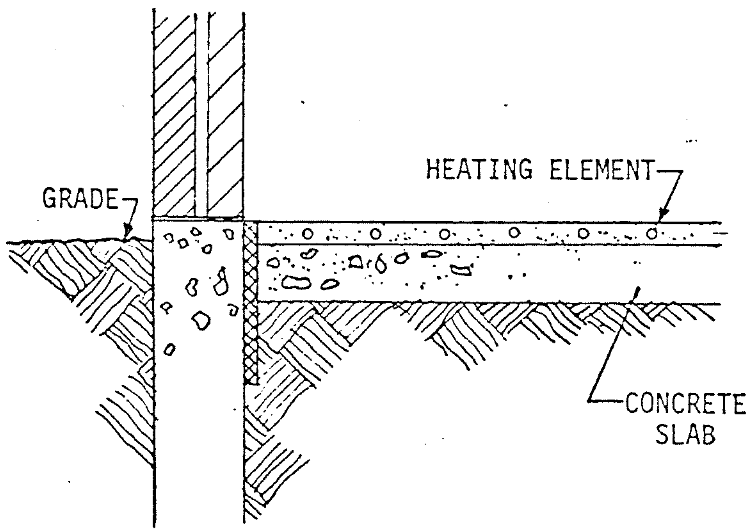
LIST OF VARIABLES

INPUT

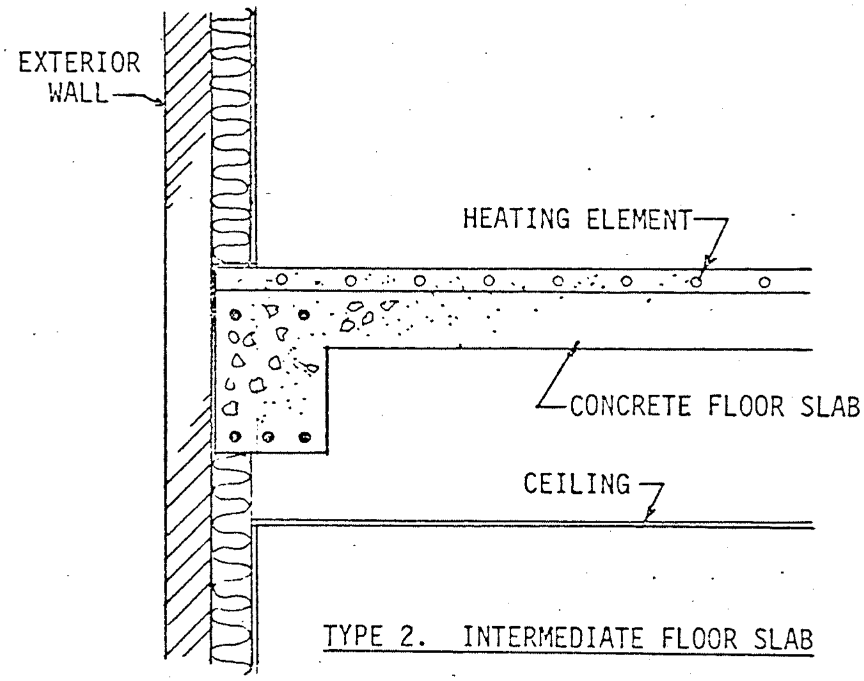
k	-	Fan system number

COMMON

IBØIL	-	Boiler on/off flag (1=on; 0=off)
QS_z	-	Zone sensible 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)
TSP_z	-	Zone set point temperature (°F)
$KFAN_k$	-	Energy distribution system index
$JMAX_k$	-	Number of zones on system k
$SPACN_{k,j}$	-	Number of space as per LOAD program, applied to system k, zone j
$MULT_i$	-	Multiplication factor, zone i



TYPE 1. ON-GRADE FLOOR SLAB



TYPE 2. INTERMEDIATE FLOOR SLAB

Figure FLOOR PANEL HEATING SYSTEM (DISTRIBUTION SYSTEM NO. 7)

I - Variable subscript i

$PLØC_k$ - Location of floor heating panels, system k

$PAREA_k$ - Floor area covered by heating panels, system k (ft^2)

$PERIM_k$ - Exposed perimeter of floor, system k (lin.ft)

KFLCV - Type of floor covering (1=bare concrete; 2=tile; 3=carpeting)

CINSL - Floor insulation conductance (Btu/hr-sq-ft-°F)

DINSL - Floor insulation thickness (ft)

OUTPUT

QFPC - Hourly cooling requirement (Btu/hr)

QFPH - Hourly heating requirement (Btu/hr)

QFPRH - Hourly reheat requirement (Btu/hr)

QPHC - Hourly preheat coil requirement (Btu/hr)

TQB - Hourly baseboard heating requirement (Btu/hr)

WATER - Hourly humidification requirement (lbm-H_2O/hr)

BPKW - Total internal lights and machinery power consumption for zones served by system under consideration (KW)

TNFBP - Total net (updated) fan brake horsepower requirement (Bhp)

TPAN - Panel temperature (°F)

COMMON

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

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

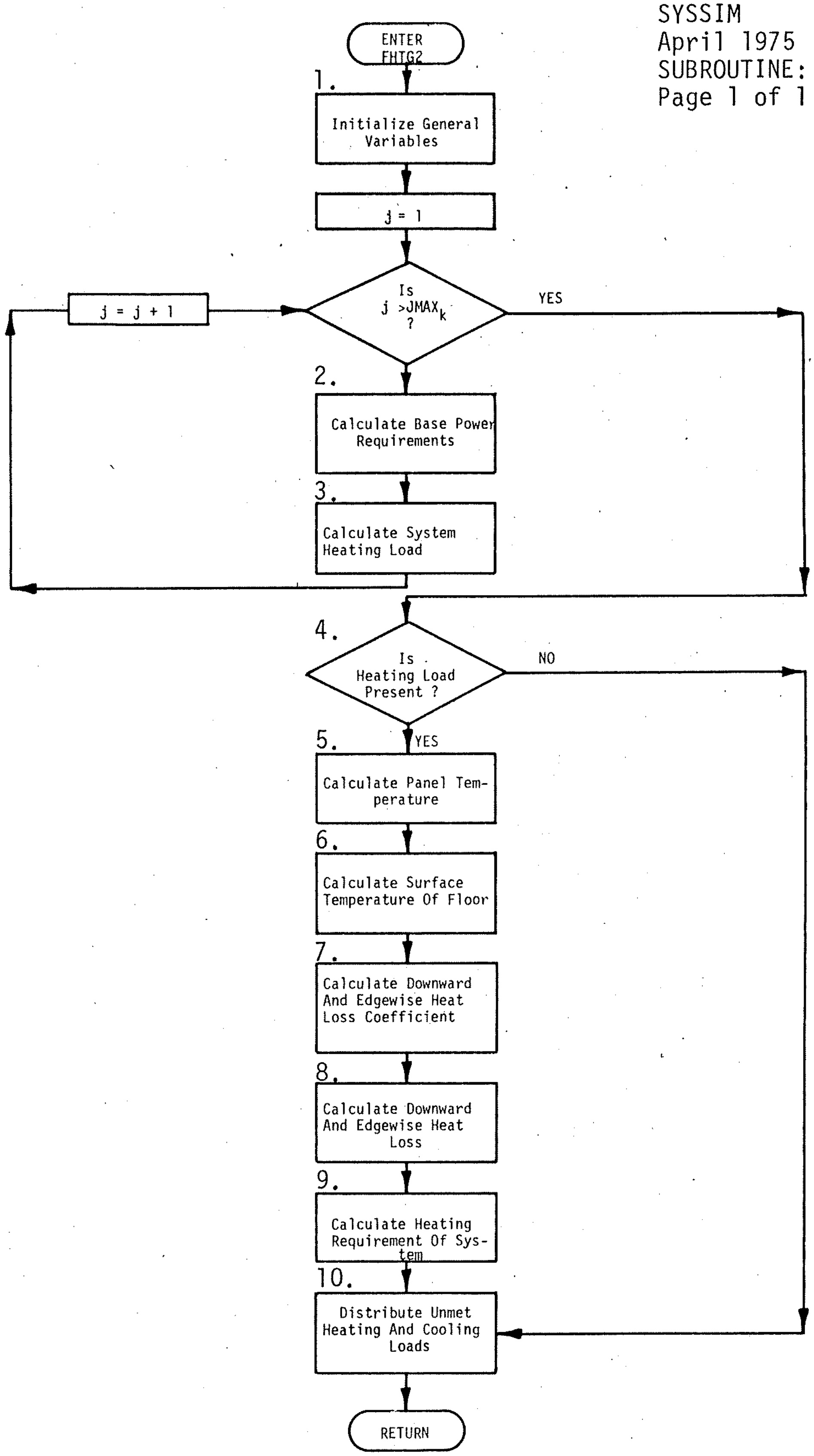
$QCPNM_i$ - Monthly peak cooling load not met, zone i (Btu/hr)

$IHCNM_i$ - 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 FHTG2
1.
Initialize General Variables
j = 1
Is j >JMAX$_k$?
YES
j = j + 1
2.
Calculate Base Power Requirements
3.
Calculate System Heating Load
4.
Is Heating Load Present ?
NO
5.
YES
Calculate Panel Temperature
6.
Calculate Surface Temperature Of Floor
7.
Calculate Downward And Edgewise Heat Loss Coefficient
8.
Calculate Downward And Edgewise Heat Loss
9.
Calculate Heating Requirement Of System
10.
Distribute Unmet Heating And Cooling Loads
RETURN

CALCULATION SEQUENCE

1. Initialize general variables.

   QFPC = 0.0

   QFPRH = 0.0

   QPHC = 0.0

   TQB = 0.0

   WATER = 0.0

   BPKW = 0.0

   QSSUM = 0.0 (Sum of zone sensible heating loads (Btu/hr))

2. Calculate base power $(BPKW)_i$ includes internal power, lights, receptacles, equipment, miscellaneous (KW).

$$BPKW = \sum_{j=1,\ JMAX_k} SLP\text{Ø}W_z * MULT_i$$

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

3. Calculate system heating load (QSSUM).

$$QSI_i = QS_z + QLITE_z + QSINF_z$$

   If $QSI_i > 0.0$, QSI = 0.0.

$$QSSUM = \sum_{j=1,\ JMAX_k} QSI_i$$

4. Check for heating load.

   If heating load not present, go to 10.

   If heating load is present, CONTINUE.

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).

5. Calculate panel temperature (TPAN) required for desired heating flux (QPAN).*

$$QPAN = QSSUM/PAREA_k$$

Calculate set point temperature of system TSPJ1 = TSP_z, where TSP_z is the set point of the first zone (j=1).

Initially, set TPAN = TSPJ1 + 1.

QCALC = 0.15 * ((TPAN + 460.0)/100.0)

** 4.0 - 0.15 ((TSPJ1 + 460.0)/100.0)

** 4.0 + 0.32 * (TPAN - TSPJ1) ** 1.31

If (QPAN - QCALC) is greater than (0.01 * QPAN), calculate a new TPAN

TPAN = TPAN + 0.5 * (QPAN - QCALC)

and repeat above calculation. If necessary, repeat again until QCALC is within (0.01 * QPAN).

6. Calculate surface temperature of floor required (TSUR) as a function of the type of floor covering.

6.1 If KFLCV = 1, bare concrete floor, therefore

TSUR = TPAN

Go to 6.4.

6.2 If KFLCV = 2, tile covering, therefore

TSUR = TPAN + QPAN * 0.05

Go to 6.4.

6.3 If KFLCV = 3, carpeting, therefore

TSUR = TPAN + QPAN * 1.4

Go to 6.4.

6.4 If TSUR as calculated above is greater than 85.0 ^{o}F, reset

TSUR = 85.0.

* See 1967 ASHRAE Guide and Data Book, Systems and Equipment Volume, Chapter 58, for derivation of all equations.

7. Calculate the downward and edgewise loss coefficient (C3).

7.1 If CINSL = 0.0, no insulation, therefore

$$C3 = 1.8$$

Go to calculation 8.

7.2 If CINSL > 0.0, and DINSL = 0.0, then only perimeter insulation, therefore

$$C3 = 1.32 + 0.25 * CINSL$$

Go to calculation 8.

7.3 If CINSL > 0.0 and DINSL > 0.0, then

$$\begin{aligned} C3 = {} & 0.932 + 0.523 * CINSL \\ & - 0.479 * CINSL ** 2.0 \\ & - 0.271 * DINSL + 0.046 * DINSL \\ & \quad ** 2.0 + 0.786 * CINSL * DINSL \\ & - 0.72 * DINSL * CINSL ** 2.0 \\ & - 0.182 * CINSL * DINSL ** 2.0 \\ & + 0.24 * (DINSL * CINSL) ** 2.0 \end{aligned}$$

Go to calculation 8.

8. Calculate downward and edgewise heat loss (QLØSS).

8.1 If $PLØC_k = 1$, then

$$QLØSS = PERIM_k * C3 * (TPAN - TØA)/PAREA_k$$

Go to calculation 9.

8.2 If $PLØC_k = 2$, then

$$\begin{aligned} QLØSS = {} & 0.15 * ((TPAN + 460.0)/100.0) \\ & ** 4.0 - 0.15 * (TSPJ1 + 460.0)/100.0) \\ & ** 4.0 + 0.021 \\ & * (TPAN - TSPJ1) ** 1.25 \end{aligned}$$

Go to calculation 9.

9. Calculate heating requirement of system (QFPH).

$$QFPH = 1.0 * (QPAN + QLØSS) * PAREA_k$$

10. Distribute unmet heating and cooling loads, finding:

    Heating and cooling peak, consumption, and number of hours heating and cooling loads were not met.

SUBROUTINE: FSIZE

GENERAL DESCRIPTION

The purpose of this subroutine is to calculate energy distribution system characteristics. These properties include:

- Zone peak heating and cooling loads
- Zone air flows
- Fan system air quantities and motor brake horsepower
- Fan system minimum outside air percentage
- Peak building power requirements

LIST OF VARIABLES

INPUT

FAC - Name of facility

CITY - Name of city in which facility is located

ENGR - Name of user

PRØJ - Project number

DATE - Date of computer run

FAN_k - Distribution system abbreviations

NRUN - Number of runs

COMMON

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)

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

$ALFAM_k$ - 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.)

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

$TFNPS_k$ - Total supply fan pressure (inches)

$TFNPR_k$ - Total return fan pressure (inches)

$TFNPE_k$ - Total exhaust fan pressure (inches)

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

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

$MULT_i$ - Multiplication factor, zone i

I - Variable subscript i

EFF - Pump and fan motor efficiency

OUTPUT

COMMON

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

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

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)

$FBHPS_k$ - 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)

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)

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

$ZMAS_i$ - Supply air mass flow, zone i (variable) (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)

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)

TFBHP - Total fan brake horsepower (BHP)

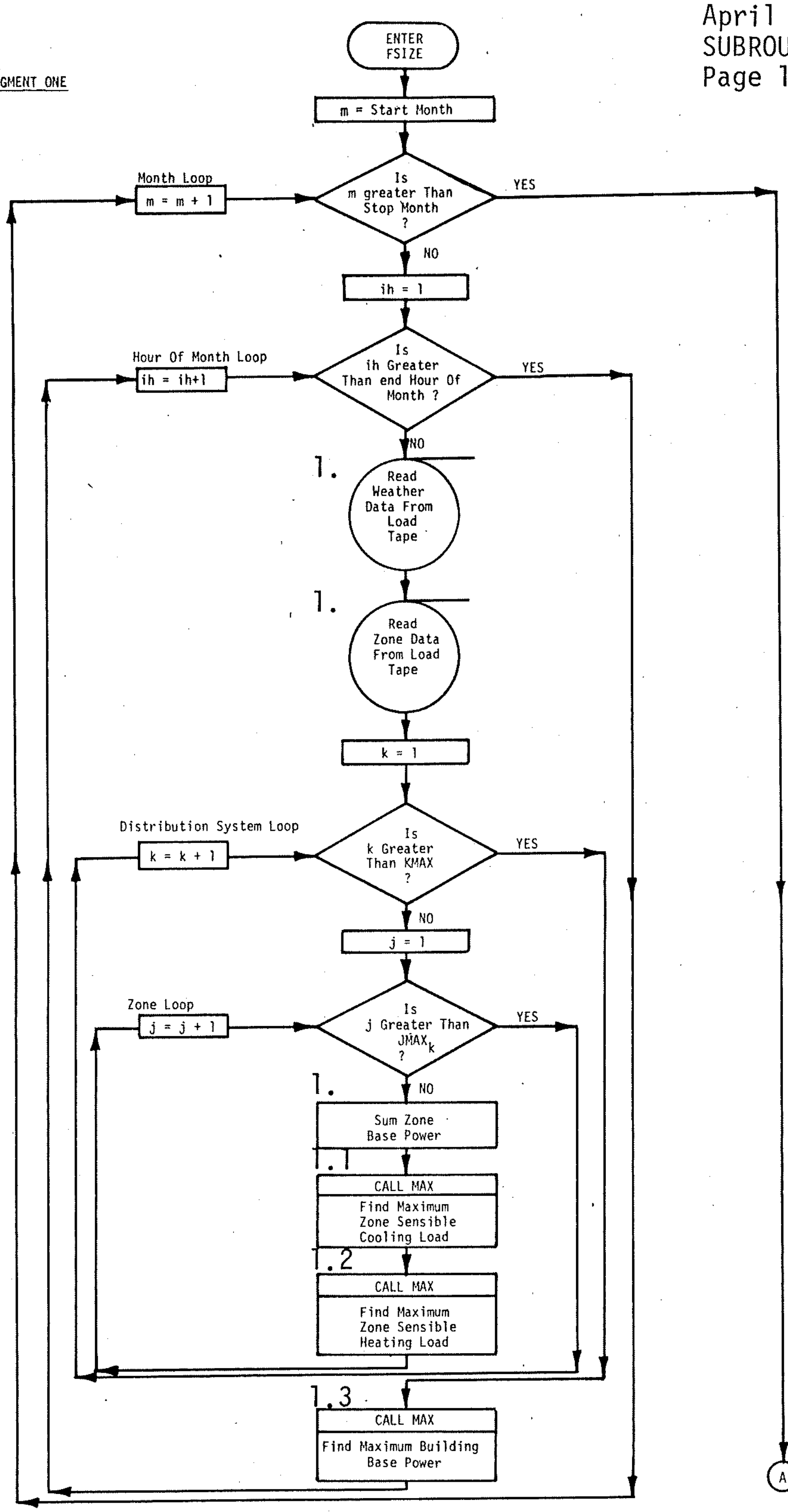
CFMBN - Building total minimum outside air (ft^3/min)

CFMBX - Building total design load supply air (ft^3/min)

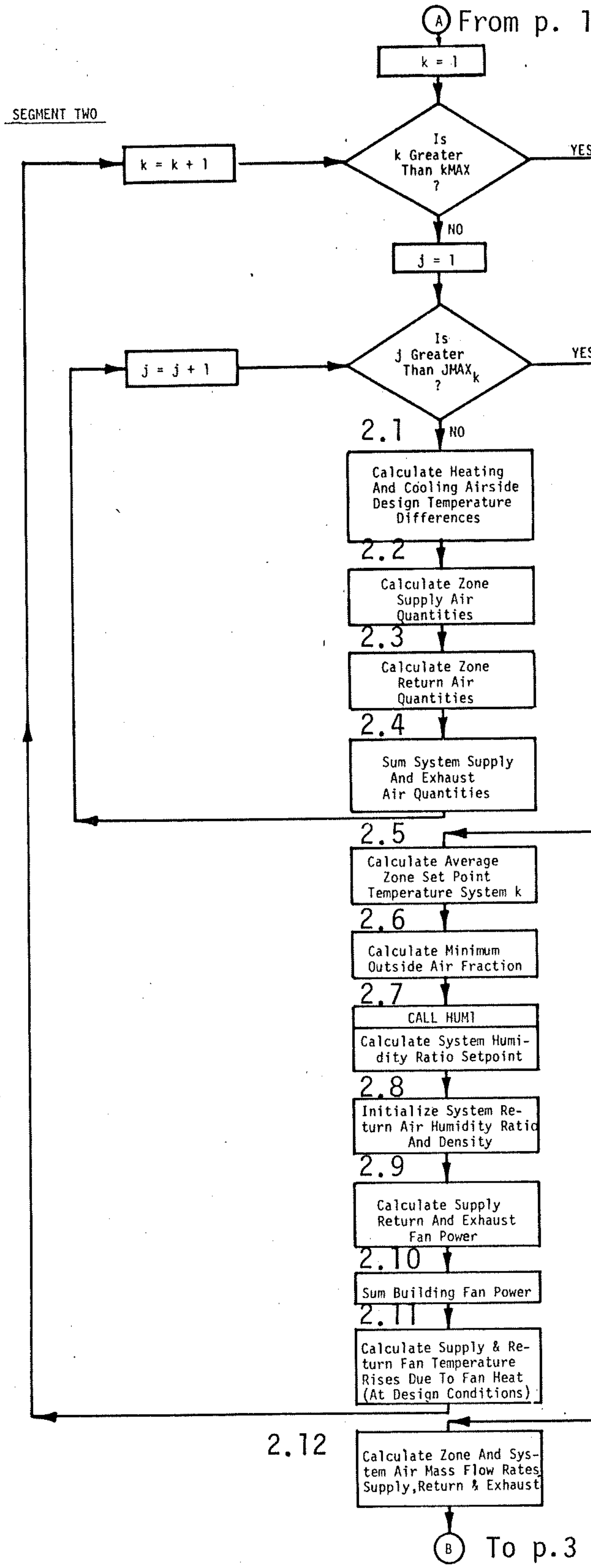
CFMBE - Building total exhaust air (ft^3/min)

PWBIL - Building peak base power load (KW)

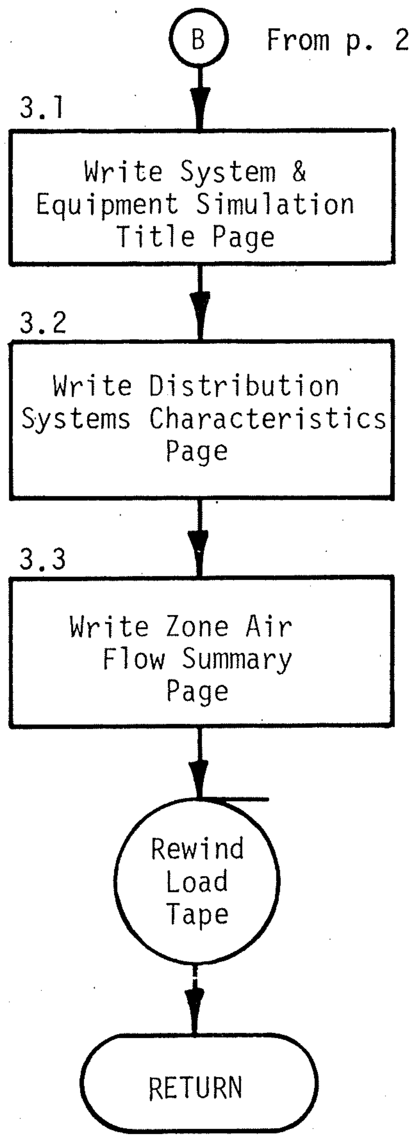
SEGMENT ONE



To p. 2


From p. 1
k = 1
SEGMENT TWO
k = k + 1
Is k Greater Than kMAX ?
YES
NO
j = 1
j = j + 1
Is j Greater Than $JMAX_k$?
YES
NO
2.1
Calculate Heating And Cooling Airside Design Temperature Differences
2.2
Calculate Zone Supply Air Quantities
2.3
Calculate Zone Return Air Quantities
2.4
Sum System Supply And Exhaust Air Quantities
2.5
Calculate Average Zone Set Point Temperature System k
2.6
Calculate Minimum Outside Air Fraction
2.7
CALL HUMI
Calculate System Humidity Ratio Setpoint
2.8
Initialize System Return Air Humidity Ratio And Density
2.9
Calculate Supply Return And Exhaust Fan Power
2.10
Sum Building Fan Power
2.11
Calculate Supply & Return Fan Temperature Rises Due To Fan Heat (At Design Conditions)
2.12
Calculate Zone And System Air Mass Flow Rates Supply, Return & Exhaust
To p.3

SEGMENT THREE



CALCULATION SEQUENCE

1. Segment One. Read through the input load tape and, using subroutine MAX, find the following quantities:

   1.1 $QSZCM_i$ - Maximum zone sensible cooling load for each zone, i (Btu/hr)

   1.2 $QSZHM_i$ - Maximum zone sensible heating load for each zone, i (Btu/hr)

   1.3 PWBIL - Maximum hourly building internal lighting and machinery power consumption (KW)

2. Segment Two. Calculate zone and system peak load air quantities and system peak load power requirements for each zone within the building.

   2.1 Calculate cooling and heating airside temperature design differences.

$$TDC = TSP_z - \frac{(TPAC_k + TIAC * ARIPA_k)}{(1. + ARIPA_k)}$$

$$TDH = TSP_z - \frac{(TPAH_k + TIAH * ARIPA_k)}{(1. + ARIPA_k)}$$

where TDC - terminal unit cooling design temperature difference (°F)

TDH - terminal unit heating design temperature difference (°F)

$ARIPA_k$ - ratio of induced to primary air (equals zero except for induction unit fan systems, where it equals $RIPA_k$), system k

TIAC - design dry-bulb temperature of induced air after passing through coil, cooling mode = 62°F

TIAH - design dry-bulb temperature of induced air after passing through coil, heating mode = 120°F

$TPAC_{kf}$ - primary air design temperature, cooling mode, for system type kf. See table below.

$TPAH_{kf}$ - primary air design temperature, heating mode, for system type kf. See table below.

TABLE HEATING AND COOLING PRIMARY AIR DESIGN TEMPERATURES

SYSTEM TYPE (kf)	SYSTEM SYMBOL	PRIMARY AIR		INDUCED AIR	
		COOL. DESIGN (°F)	HEAT. DESIGN (°F)	HEAT. DESIGN (°F)	COOL. DESIGN (°F)
1	SZFB	55.	120.	--	--
2	MZS	55.	120.	--	--
3	DDS	55.	120.	--	--
4	SZRH	52.	95.	--	--
5	UVT	55.	120.	--	--
6	UHT	55.	120.	--	--
7	FPH	0.	0.	--	--
8	2PFC	55.	110.	--	--
9	4PFC	55.	110.	--	--
10	2PIU	53.	53.	120.	62.
11	4PIU	53.	53.	120.	62.
12	VAVS	55.	120.	--	--
13	RHFS	55.	120.	--	--

2.2 Calculate zone supply air quantities (CFM_i).

2.2.1 Calculate supply air quantities based on thermal requirements.

IF $\left|\frac{QSZCM_i}{TDC}\right| < \left|\frac{QSZHM_i}{TDH}\right|$

$$CFM_i = \frac{QSZHM_i}{(0.245 * 0.075 * 60. * TDH)(1. + ARIPA_k)}$$

If $\left|\frac{QSZHM_i}{TDH}\right| < \left|\frac{QSZCM_i}{TDC}\right|$

$$CFM_i = \frac{QSZCM_i}{(0.245 * 0.075 * 60. * TDC)(1. + ARIPA_k)}$$

where 0.245 = specific heat of moist air (Btu/lbm-°F)

0.075 = density of standard air (lbm/ft^3)

60. = minutes per hour

2.2.2 Check for supply air quantity Reset.

If zone exhaust air ($CFMX_i$) is greater than zone supply air (CFM_i),

$$CFM_i = CFMX_i$$

If $KFAN_k = 7$ (Floor Panel Heating System),

$$CFM_i = 0$$

2.3 Calculate zone return air

$$CFMR_i = CFM_i - CFMX_i$$

2.4 Sum system supply and exhaust air flows

$$CFMAX_k = \sum_{j=1,JMAX_k} CFM_i$$

$$CFMEX_k = \sum_{j=1,JMAX_k} CFMX_i$$

(See note at bottom of page for explanation of i, j, & k.)

2.5 Average system temperature ($TAVE_k$)

$$TAVE_k = \frac{\sum_{j=1,JMAX_k} (CFM_i * TSP_z * MULT_i)}{\sum_{j=1,JMAX_k} (CFM_i * MULT_i)}$$

2.6 Minimum outside air fraction ($ALFAM_k$)

If minimum outside air ($ØACFM_k$) is greater than system exhaust air ($CFMEX_k$) and greater than system supply air ($CFMAX_k$) -- ($CFMEX_k < ØACFM_k > CFMAX_k$)

$$CFM_i = CFM_i * (ØACFM_k / CFMAX_k)$$

$$CFMAX_k = ØACFM_k$$

$$ALFAM_k = ØACFM_k / CFMAX_k$$

Go to 2.7

If minimum outside air ($ØACFM_k$) is greater than system

NOTE: There is a corresponding z for each i; a relationship defined by the variable $SPACN_{k,j}$.

exhaust air ($CFMEX_k$) and less than system supply air ($CFMAX_k$) -- ($CFMEX_k < \text{Ø}ACFM_k > CFMAX_k$)

$$ALFAM = CFMEX_k / CFMAX_k$$

Go to 2.7

If minimum outside air ($\text{Ø}ACFM_k$) is less than system exhaust air ($CFMEX_k$) and less than system supply air ($CFMAX_k$) -- ($CFMEX_k > \text{Ø}ACFM_k < CFMAX_k$)

$$\text{Ø}ACFM_k = CFMEX_k$$

$$ALFAM_k = CFMEX_k / CFMAX_k$$

Go to 2.7

2.7 Calculate system humidity ratio setpoint. Call subroutine HUM1 to calculate distribution system humidity ratio set-point (WSP_k). Input average zone setpoint temperature (TAVE), barometric pressure at sea levels (29.92 in. Hg.), and system relative humidity setpoint ($RHSP_k$).

2.8 Initialize return air humidity ratio (WRA_k) and density (DRA_k).

$$WRA_k = WSP_k$$

$$DRA_k = 0.075$$

2.9 Calculate fan power.

Supply Fan:

$$FBHPS_k = \frac{CFMAX_k * TFNPS_k}{6346 * EFF}$$

Return Fan:

$$FBHPR_k = \frac{(CFMAX_k - CFMEX_k) * TFNPR_k}{6346 * EFF}$$

Exhaust Fan:

$$FBHPE_k = \frac{CFMEX_k * TFNPE_k}{6346 * EFF}$$

2.10 Sum building fan power.

$$TBHP = \sum_{k=1,KMAX} (FBHPS_k + FBHPR_k + FBHPE_k)$$

2.11 Calculate temperature rise across fans at full load due to fan heat.

Supply Fan:

$$DTFNS_k = \frac{(TFNPS_k * 0.4014)}{(0.245 * 0.075 * 60.0)}$$

Return Fan:

$$DTFNR_k = \frac{(TFNPR_k * 0.4014)}{(0.245 * 0.074 * 60.0)}$$

where:

0.245 = Specific heat of moist air (BTU/Lbm - °F)

0.075 = Density of standard air (Lbm/ft^3)

60 = Minutes per hour

.4014 = Fan heat factor $\left(\frac{BTU\text{-}MIN}{hr\text{-}ft^3\text{-}in.\ H_2O}\right)$

This value is derived from the basic

air horsepower eqs:

$$\text{Air HP} = \frac{q * p_t * d_w}{12 \times 33000}$$

$$\text{Air Hp} = q * p_t * \frac{dw}{12 * 33000} \qquad \text{(eq. 1)}$$

Expressing air horsepower as heat (H),

$$H = \text{Air HP} * 42.44 * 60. \qquad \text{(eq. 2)}$$

Substituting eq. 1 into eq. 2,

$$H = q * p_t * \frac{dw}{12 \times 33000} * 42.44 * 60 \qquad \text{(eq. 3)}$$

For dw = 62.4, this reduces to

$$H = q * p_t * 0.4014 \qquad \text{(eq. 4)}$$

where

dw - Density of water (62.4 $\frac{Lbm}{ft^3}$)

H - Heat flow (Btu/hr)

q - Air flow (ft^3/min)

p_t = Total air pressure (in. H_2O)

Substituting eq. 4 into eq. 5:

$$H = Cp_a * q * d_a * dt_a * 60 \qquad \text{(eq. 5)}$$

And solving for air temperature difference (dt_a) is the form of the equation in 2.11.

$$dt_a = \frac{p_t * 0.4014}{Cp_a * d_a * 60}$$

where:

Cp_a - Specific heat of moist air ($\frac{Btu}{Lbm}$ °F)

d_a - Density of air ($\frac{Lbm}{ft^3}$)

2.12 Calculate mass flows:

Zones:

$$ZMASS_i = CFM_i * 0.075 * 60.0$$

$$ZMASX_i = CFMX_i * 0.075 * 60.0$$

$$ZMASR_i = ZMASS_i - ZMASX_i$$

Systems:

$$FMASS_k = CFMAX_k * 0.075 * 60.0$$

$$FMASX_k = CFMEX_k * 0.075 * 60.0$$

$$FMASR_k = FMASS_k - FMASX_k$$

3. Segment Three. Write FSIZE information. See Figures ,

3.1 Write System and Equipment Simulation title page which includes the following:

FAC - Facility name

CITY - Location

ENGR - User

PRØJ - Project No.

DATE - Date

3.2 Write Distribution System characteristics page. This includes the following information for each system:

- k - Distribution system number
- FAN_{kf} - System type
- $FBHPS_k$ - Supply fan brack horsepower
- $FBHPR_k$ - Return fan brake horsepower
- $FBHPE_k$ - Exhuast fan brake horsepower
- $JMAX_k$ - Number of zones on system
- $CFMAX_k$ - Supply air flow (CFM)
- $CFMIN_k$ - Minimum outside air (CFM)
- $CFMEX_k$ - Exhaust air flow (CFM)
- $ALFAM_k$ - Percent minimum outside air to supply air.

3.3 Write Zone Air Flow summary page which includes the following for each zone.

- k - Distribution system number
- j - System zone number
- z - Load program zone number
- $MULT_i$ - Zone multiplication factor
- CFM_i - Supply air (CFM)
- $CFMX_i$ - Exhaust air (CFM)
- TSP_z - Zone set point temperature(°F)

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ANALYSIS OF ENERGY UTILIZATION FOR

LRC SYSTEMS ENGINEERING

HAMPTON, VIRGINIA

ENGINEER   - R.JENSEN
PROJECT NO - SZ, 4W, 3IN
DATE       - NOV 26, 1973
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Figure SYSTEM AND EQUIPMENT SIMULATION PROGRAM TITLE BLOCK

LRC SYSTEMS ENGINEERING HAMPTON, VIRGINIA NOV 26, 1973 SZ, 4W, 3IN
SYSTEM SIMULATION AND ENERGY ANALYSIS

SUMMARY OF ENERGY DISTRIBUTION SYSTEM CHARACTERISTICS.

SYSTEM NO.	TYPE	****** TOTAL FAN BHP ***** SUPPLY	RETURN	EXHAUST	NO. OF ZONES	**TOTAL SYSTEM AIR FLOWS (CFM)** SUPPLY	MIN.O.A.	EXH.SYSTEM	PER-CENT MIN.O.A.
1	RHFS	36.5	17.7	0.4	5	49280.	6000.	1500.	12.2

Figure EXAMPLE DISTRIBUTION SYSTEMS CHARACTERISTICS PAGE

LRC SYSTEMS ENGINEERING HAMPTON, VIRGINIA NOV 26, 1973 SZ, 4W, 3IN
SYSTEM SIMULATION AND ENERGY ANALYSIS

SUMMARY OF ZONE AIR FLOWS

FAN SYSTEM	ZONE NUMBER	LOAD SPACE NUMBER	MULT FACTOR	SUPPLY CFM	EXHAUST CFM	SET POINT TEMP.
1	1	1	1	39070.	1500.	75.
1	2	2	1	2887.	0.	75.
1	3	3	1	2329.	0.	75.
1	4	4	1	2737.	0.	75.
1	5	5	1	2257.	0.	75.

Figure EXAMPLE ZONE AIR FLOW SUMMARY PAGE

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