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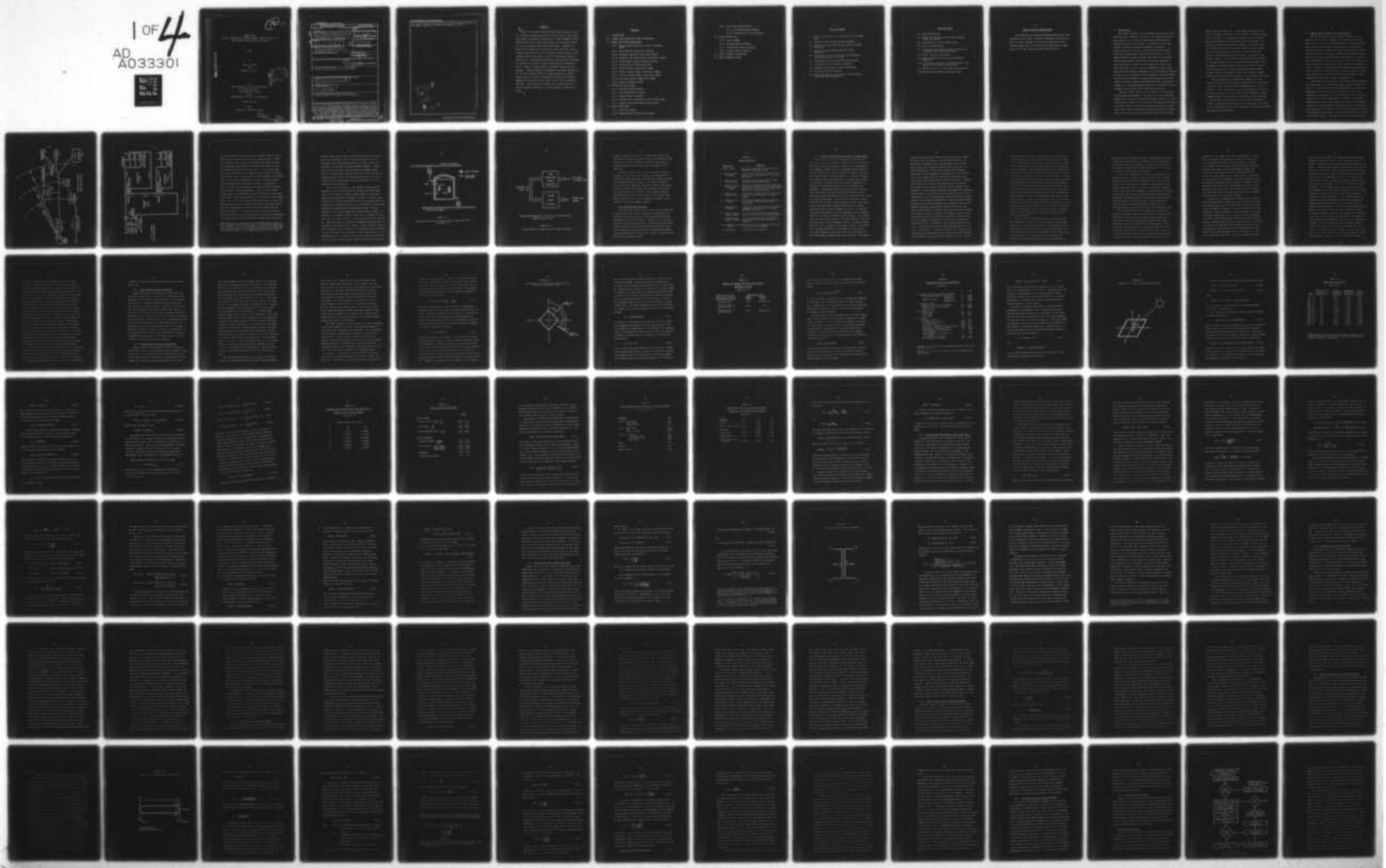

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USERS MANUAL:
TDIST, A PROGRAM FOR COMMUNITY ENERGY DEMAND ANALYSIS AND TOTAL ENERGY SYSTEM RESPONSE SIMULATION

RT 2024

by

John W. Stetkar
and
Michael W. Golay

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TDIST, The Thermal Distribution System Simulation Code, is a computer program analysis of a large developed at MIT to aid in the design and dynamic performance analysis of a large integrated Total Energy System (TES) supplying thermal and electrical energy to a multi-consumer-type metropolitan area. Included in this User's Manual are derivations of the detailed consumer energy demand models and of the Thermal Utility System (TUS) component models developed in each of the system analysis subroutines. Comprehensive modelling scenarios are presented to illustrate how these ogram components are combined to yield a range of steady-state and dynamic sys- analysis options. Program execution information included descriptions of the ree primary modes of program operation, complete documentation of input requirements and data card formats, examples of avaiable data output options, and a

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20. listing of the code. Sample data is included for the execution of a 24-hour dynamic simulation of a TES serving a community of 50,000.

ABSTRACT

TDIST, the Thermal Distribution System Simulation Code, is a computer program developed at MIT to aid in the design and dynamic performance analysis of a large integrated Total Energy System (TES) supplying thermal and electrical energy to a multi-consumer-type metropolitan area. Included in this User's Manual are derivations of the detailed consumer energy demand models and of the Thermal Utility System (TUS) component models developed in each of the system analysis subroutines. Comprehensive modelling scenarios are presented to illustrate how these program components are combined to yield a range of steady-state and dynamic system analysis options. Program execution information includes descriptions of the three primary modes of program operation, complete documentation of input requirements and data card formats, examples of available data output options, and a listing of the code. Sample data is included for the execution of a 24-hour dynamic simulation of a TES serving a community of 50,000.

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SPECIAL NOTE ON NOMENCLATURE

For convenience in cross-referencing between the descriptions of the code's operation presented in Section A.3 and the actual listing of the code in Section A.8, all variable names used in this manual are the same as those used in the code, and are defined in Section A.7.

A.1 Introduction

The primary function of the Thermal Distribution System Simulation Code (TDIST) is to aid in the design and performance analysis of a Total Energy System (TES) supplying thermal and electrical energy to a metropolitan area containing a variety of energy consumption categories. To achieve this end, the code is concerned with the steady-state and time-dependent energy flow modelling of up to twenty different energy consumer types and of the thermal utility system (TUS) serving them with high temperature water (HTW) from a central total energy power plant site. Since the major costs of such an integrated energy supply system are particularly sensitive to the TUS design, emphasis is placed upon simulating the time-dependent TUS performance. No provisions are made for specifically modelling the associated electrical energy distribution network, although the community's electrical energy demands are calculated and are included in the overall TES energy supply analysis.

Briefly, TDIST consists of two distinct, but interconnected, modelling packages. The first is a set of building energy flow calculation subroutines which determine the space conditioning, domestic hot water, and non-space-conditioning electrical loads for each of the specified energy consumer types, based upon steady-state demand calculations scheduled over time according to building usage characteristics and ambient weather conditions. These demands are applied to a range of end-use equipment types available for each building in the community, the aggregate demands of which comprise the time-varying loads to be supplied by the thermal and electrical energy distribution networks. The second modelling package utilizes the computed thermal energy demands and the thermal energy output of the central TES power plant as driving functions for the TUS. Included in the dynamic models of this system's components are descriptions of the major piping loops, the HTW circulation pumps, heat exchangers, thermostatically-controlled fluid flow regulation circuitry, and a central stratified thermal energy storage reservoir designed to smooth the system's thermal energy supply and demand imbalances over a 24-hour duty cycle.

Various conceptually independent segments of these models are developed in separate program units to allow flexibility in their formulation and integration into the two packages. These sub-program units are discussed in detail at a later point when the derivations of the individual system component models are presented. However, a brief overview of the general characteristics of the overall TES model is useful in understanding how each of the sub-units is related to the others and how they are integrated to yield the desired TES behavioral information.

A.2 Overall TES Simulation Model Description

For the purposes of energy demand modelling, it is assumed that all the buildings in the community are aggregated into a set of up to 20 representative energy consumption categories based upon similarities in construction characteristics and usage patterns. Building units typifying each of these consumption categories are further aggregated into from one to twenty-five Consumer Load Centers, the distribution of which reflects the type and intensity of use to which each geographical region within the community is put. Figure A.1 illustrates a unidirectional grouping of these load centers postulated for a typical large U.S. military installation, which is fairly representative of small industrial or suburban civilian communities [1].

The assumed configuration for the TUS piping connecting the load centers to the central power station is shown in Fig. A.2. Each Load Center Heat Exchanger is a single heat exchanger which supplies a load center with water at a temperature consistent with the requirements of the end-use equipment in the buildings which it serves. All thermal energy distribution in the piping loops shown in the figure is through the HTW medium, although the use of low pressure steam generators for certain process heating applications is not precluded in sections of the utility system not included in the TDIST models. The Load Center Heat Exchangers may

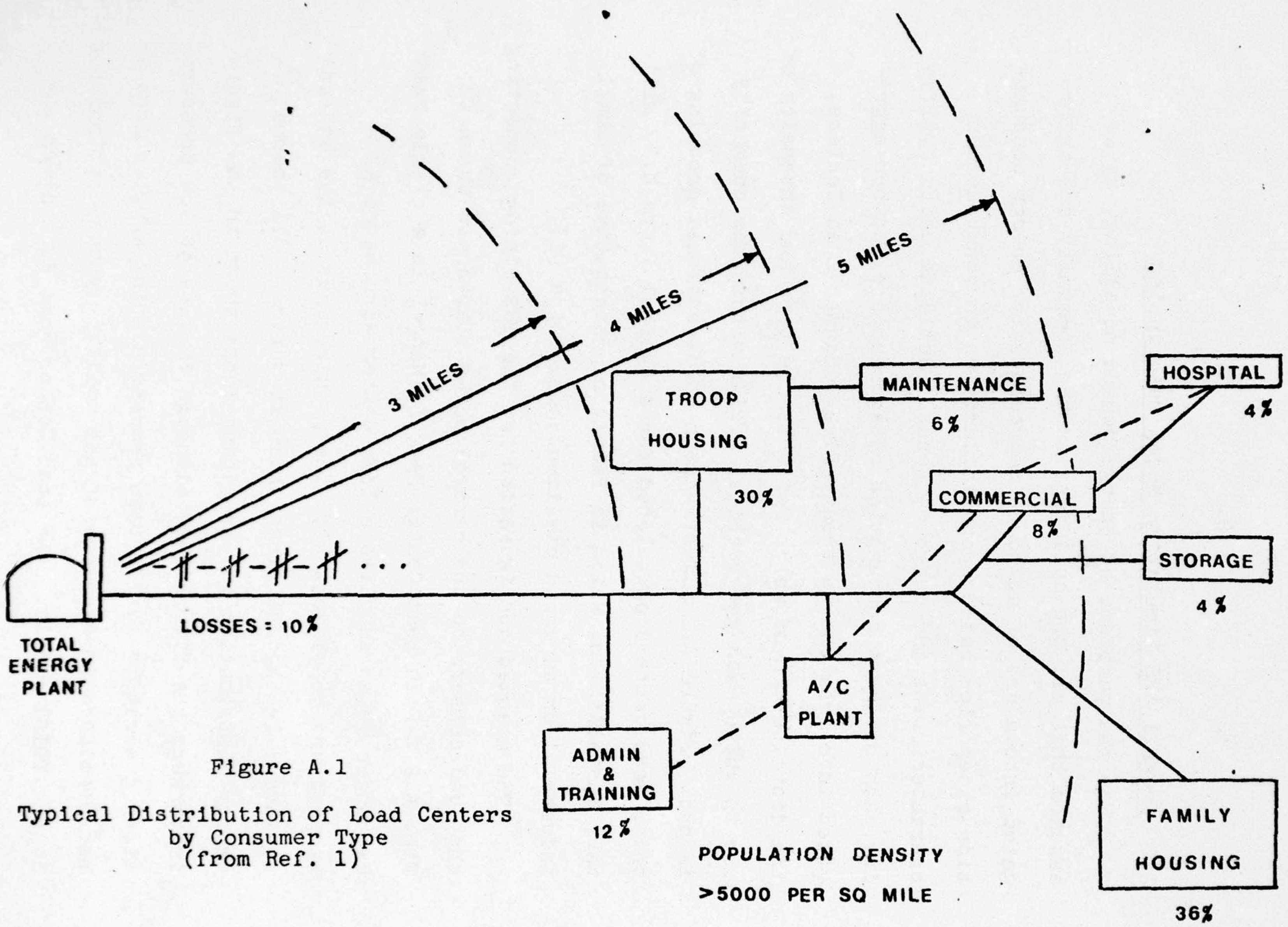


Figure A.1

Typical Distribution of Load Centers
by Consumer Type
(from Ref. 1)

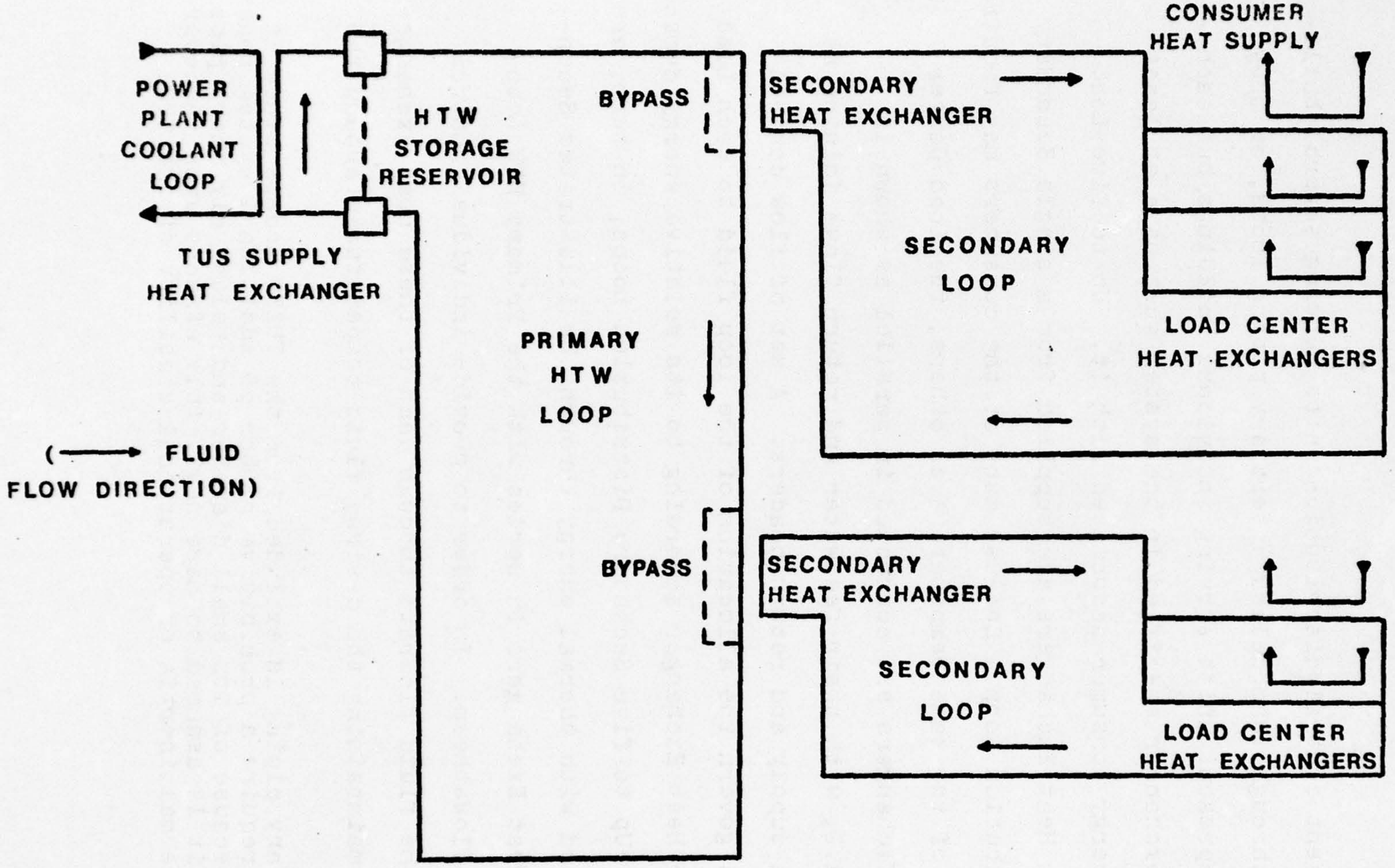


Figure A.2

Thermal Utility System Piping Schematic

represent central distribution units serving several buildings through (unmodelled*) tertiary piping loops, or they may represent units serving individual buildings, but each heat exchanger specified in the system must have at least one energy consumer associated with it. Up to five Load Center Heat Exchangers are supplied from a single Secondary Distribution Loop. Because many of the consumers may require water of the same temperature as others, the Load Center Heat Exchangers are connected in parallel as shown in Fig. A.2, with their feedwater and return flows joining at common supply and return headers. A set of flow control valves govern the allocation of the loop fluid to each Load Center Heat Exchanger according to its relative energy demand rate. Up to five Secondary Distribution Loops, in turn, are supplied with thermal energy through the illustrated Secondary Heat Exchangers in series with the Primary HTW Loop fluid flowstream. In order to provide individual control over the fluid flowrate through each of these heat exchangers while maintaining the desired fluid temperatures around the

---

*Tertiary piping is excluded from the TDIST models since it would require a prohibitive number of additional system nodes and, because of its small diameter and relatively short pipe runs, it is assumed to have negligible effects upon the overall thermal inertia or operational stability of the TUS.

primary loop, bypass loops are provided around each Secondary Heat Exchanger, with the relative bypass and heat exchanger fluid flowrates governed by control valves set according to the heat exchanger thermal demands. Control over the total primary and secondary loop energy supply rates is accomplished through variations in the various circulation pump pressure settings, adjusting the loop fluid flowrates while maintaining relatively fixed loop fluid temperature distributions.

As is shown in Fig. A.2, the thermal energy Storage Reservoir serves as an interface between the Primary HTW Loop and the system's thermal energy supply at the power plant's TUS Supply Heat Exchanger. Figure A.3 shows a more detailed view of this reservoir, while the schematic Fig. A.4 illustrates the method by which the two different temperature sections are separated for modelling purposes. During periods of low thermal demand and excess thermal supply, the reservoir is charged, with the temperature interface moving into the cold water section, and the hot water volume increases. When necessary, hot water is withdrawn from the tank to supplement the power plant's output. Because modern technology is limited to the production of pressurized steel cylinders of the type shown with dimensions of approximately 20 ft. in diameter and 70 ft. long [2], the actual reservoir would consist of a set of these smaller tanks connected in parallel to

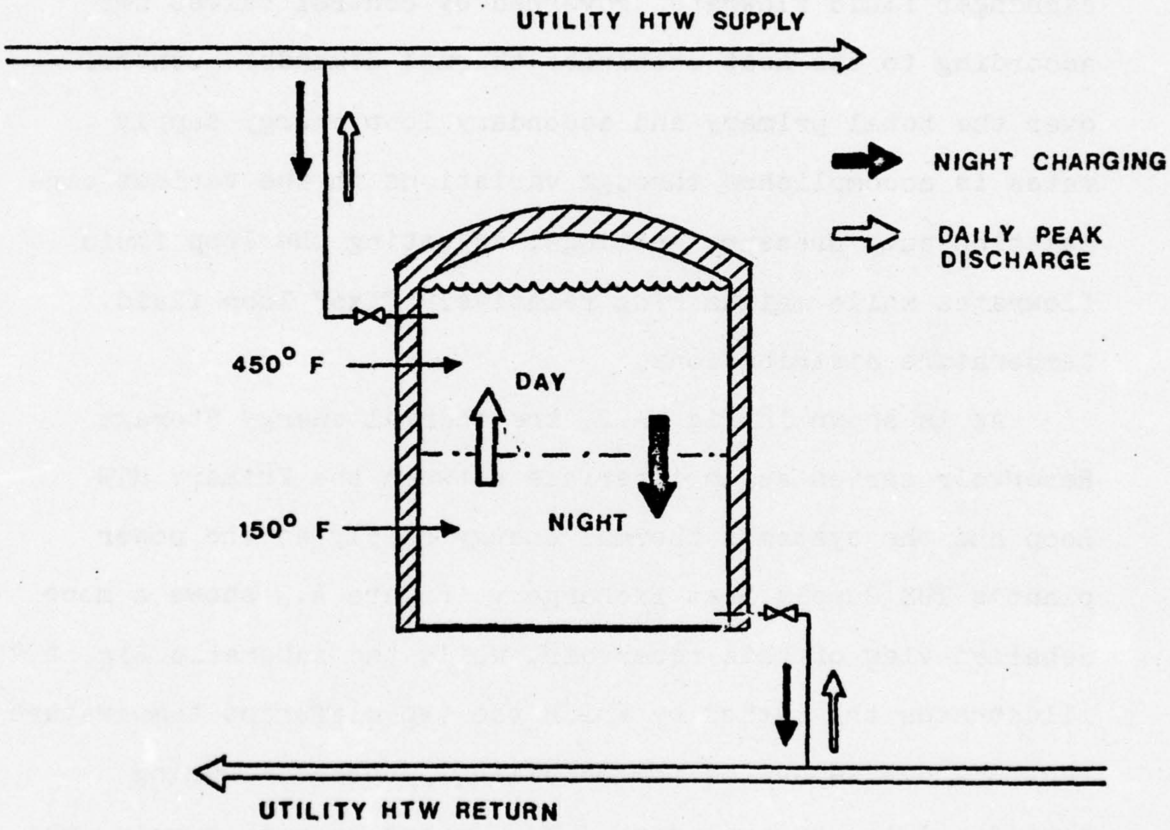
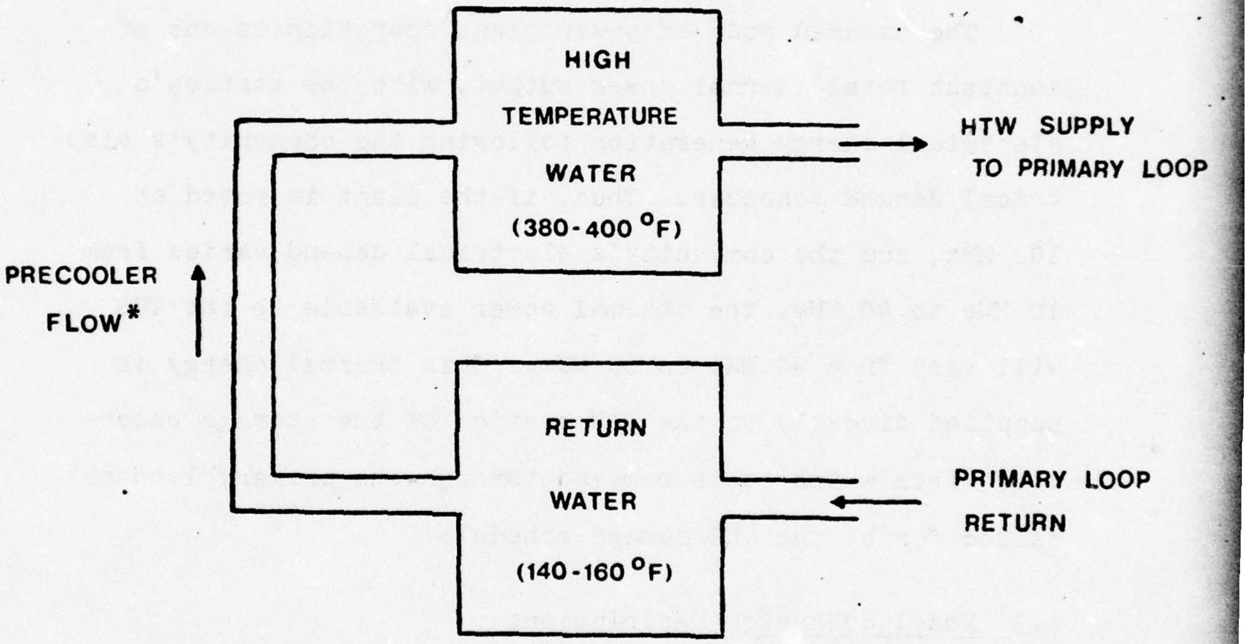


Figure A.3

Underground Stratified Thermal Energy Storage Reservoir
(from Ref. 3)



*Determined independently of Primary Loop flow to allow the storage volume to vary

Figure A.4

Thermal Energy Storage Reservoir Model Schematic produce a large storage field. European experience with this method of energy storage indicates that minimal mixing between the two fluid temperature regions takes place if charge/discharge cycling times are on the order of 4-12 hours [3].

The assumed mode of power plant operation is one of constant total thermal power output, with the station's electrical energy generation following the community's electrical demand schedule. Thus, if the plant is rated at 100 MWt, and the community's electrical demand varies from 10 MWe to 40 MWe, the thermal power available to the TUS will vary from 90 MWt to 60 MWt. This thermal energy is supplied directly to the HTW section of the storage reservoir, from which it is removed through the primary loop as called for by the TUS demand schedule.

A.3 Model Subsystem Descriptions

As is stated above, the overall energy system model can be broken down into several conceptually independent subsystems whose behavior can be studied separately and then reintegrated into the full model. Table A.1 lists the subsections of the program which are concerned with each of the separate modelling tasks and describes briefly their functions within the total system model; more detailed descriptions and derivations of the specific models used are presented in the following sections.

TABLE A.1

TDIST SUBROUTINES

Subroutine	Function
1. Main (MAIN)	Data input, program flow control, time monitor, thermostat control
2. Input Scaling (CSCALE)	Scales input fluid mass flowrates according to case run multiplier (not fully developed)
3. Consumer Heat Flow (QLOAD)	Calculates space heating and cooling loads for all building types
4. Building Load Distribution (DLOAD)	Calculates domestic hot water loads and distributes building total energy demands among specified mixture of thermal and electrical end-use equipment
5. Steady-State System (STDY)	Establishes steady-state flow rates and temperature distribution throughout system
6. Initialization (SET)	Initializes dynamic analysis sections to converged steady-state system conditions
7. Fluid Flowrate (FLOWS)	Calculates instantaneous fluid flowrates throughout system, monitors storage reservoir heat flow
8. System Pressure Drops (PRESS)	Calculates fluid frictional pressure losses, sets circulation pump pressures
9. Dynamic Energy Balance (ENRG)	Sets instantaneous system temperature distribution based upon heat flow analyses
10. Precooler Monitor (PREC)	Monitors heat flow through power plant TUS supply heat exchanger
11. Output (PRV)	Prints system parameters

A.3.1 Energy System Simulation Control (Program MAIN)

To simplify the calculation procedure in each program unit, the entire model system as shown in Fig. A.3 is broken down into a set of nodes whose boundaries are determined by such elements as pipes and heat exchangers having different physical properties, fluid flow and heat transfer characteristics and transient thermal behavior. A typical secondary loop serving three load center heat exchangers thus consists of six nodes: the three load center heat exchangers, two lengths of distribution piping, and one secondary heat exchanger. Appropriate boundary conditions are invoked in each subroutine to ensure the physical continuity of the piping loop being analyzed, but all calculations are performed on a purely nodal basis. All nodes are indexed for simple identification of their parameters and locations within the system, and since heat transfer between the two nodes on opposite sides of a heat exchanger is vital to the dynamic simulation development, each heat exchanger is also indexed separately by both its hot-and cold-side nodes. The program input for each node consists of its index numbers, codes for its type (pipe or heat exchanger, series or parallel branch, whether or not it contains a circulation pump), its overall heat transfer coefficient, and estimates of the initial fluid mass flowrate, inlet and outlet fluid temperatures, and fluid density, specific heat and viscosity. Additional distribution system input data includes the initial volumes of the hot and cold regions of the storage reservoir, the HTW storage temperature, and specifications of the power plant coolant mass flowrate, specific heat, and inlet and outlet temperatures at the system supply heat exchanger. The ambient earth temperature is specified for the determination of heat losses from the distribution piping and heat conduction to the earth from the various buildings. Consumer sector input data includes the exposed areas and thermal resistances of all exterior features (walls, windows, roof, basement) of each specified building type within the community, specifications of infiltration crack dimensions and air flow coefficients, the building heights, the wall and roof surface material types, peak ventilation air flowrates, peak internal non-space-conditioning equipment heat generation rates, peak domestic hot water usage rates, shading coefficients and solar absorbtivities of the walls and roofs, and the building orientations relative to North. The number of units of each building type served by each load center heat exchanger and the total number of buildings of each type not connected to the TUS are input in conjunction with specifications of the types and distribution of space conditioning equipment to be used in the system. The desired building room temperatures, building usage specifications and domestic hot water demands are provided in the form of hourly schedules and are used in conjunction with hourly air temperatures, wind velocities and wind directions for the specified time period - in addition to seasonal solar position and radiation intensity data - to determine the hourly energy demands for the buildings, which are applied to the thermal and electrical energy distribution networks after being scaled according to the specified end-use equipment coefficients of performance. Finally, a fixed power plant thermal output power level and electrical generation efficiency are input in conjunction with hourly non-space-conditioning electrical energy demand data (e.g., loading from lights, appliances, motors, etc.) to determine the net energy available from the power plant to supply the building-specific space conditioning and domestic hot water energy demands. Control codes indicating the type of calculation to be made (building load analysis, TUS design initialization, steady-state TUS analysis, full dynamic system analysis), the simulation time step interval, and the desired output frequency determine the overall program flow and information transfer.

In the building load analysis mode of operation, the code computes and prints out the hourly space conditioning loads and their components for each of the specified building types to allow verification of the building input parameters prior to the use of these demands in the dynamic system simulations. The first hourly set of demands are scaled by the specified end-use equipment coefficients of performance and the resulting loads are aggregated according to the given distribution of buildings and are displayed at the load center heat exchangers to allow the calculation of TUS system initialization or design parameters to be used as input data for the dynamic simulations.

If only the steady-state TUS analysis is required in a given run (e.g., to check a design for adhering to desired limits on fluid flowrates or temperatures), the model calculates only a single set of consumer loads, applies these loads to specified supply and return temperature conditions at the load center heat exchangers, and determines the resulting steady-state fluid flows and temperature distributions throughout the HTW transmission system based upon specified system thermal and electrical energy supply conditions. (See the section describing Subroutine STDY for a more detailed analysis of the actual calculation procedures used.)

If, as will generally be the case, it is desired to study the dynamics of the TUS behavior over a period of time during which both the energy supply and demand conditions will vary, Program MAIN becomes the overall control and time-monitor for the remainder of the subprograms. Unless a detailed system description including all the nodal flowrates and temperatures for the specified initial conditions is known, the model calculates the steady-state system distributions for these conditions and uses them as the input parameters to the dynamic calculation subroutines. A clock is set and Program MAIN sweeps the system at a rate fixed by the specified transient time step interval. At each time increment, the previously computed building load distributions are used to yield instantaneous thermal and electrical energy demands through linear interpolation between the hourly data points. These loads are applied to the load center heat exchangers, and nodal energy and momentum transfer calculations are performed to determine the net imbalances during the time step between the system thermal demands and the power plant thermal energy output (given by the total station power rating, less the electrical energy produced to meet the electrical demands).

In addition to performing the program flow control and monitoring functions, Program MAIN also contains the thermostat models which govern the TUS response to thermal energy supply and demand variations. Chosen as temperatures to be monitored by these thermostats are the consumer fluid supply and return temperatures at the load center heat exchangers (to insure uniform operational parameters for the consumers' end-use equipment) and the outlet temperatures on the primary loop side of the secondary heat exchangers (to insure the maintenance of sufficiently high fluid temperatures at the supply to the last secondary loop in the system). At the end of each time step, after the system temperatures have been adjusted according to the energy transfers occurring during the increment, each of these reference points is checked to determine if the temperatures have exceeded their limits. (Consumer water supply temperatures are allowed to vary ± 5 °F from their initial design values; return temperatures are allowed to vary from the minimum room temperature in any of the buildings served to 5 °F above their initial design values. Primary loop heat exchanger outlet temperatures are allowed to vary ± 5 °F from their design settings.) If any temperature is found to have surpassed its tolerances, steps are taken to re-adjust the loop fluid flowrates to correct the causal energy flow imbalances. To accomplish this re-adjustment, a set of dummy loop fluid flowrates are calculated which satisfy the instantaneous energy demand conditions within the desired loop fluid temperature distributions. Valves in the secondary distribution loops are reset to allocate the total loop dummy fluid mass flowrates among the load center heat exchangers according to their relative energy demands. Independent dummy flowrates are calculated for each of the primary-side secondary heat exchanger nodes based upon their thermal demands and desired inlet and outlet temperatures. The largest of these flowrates is assumed to occur under conditions of no bypass flow (i.e., the total primary loop fluid mass flowrate is applied to one of the heat exchangers), and bypass flowrates are established around each of the other heat exchangers such that the dummy heat exchanger flowrates are maintained at their calculated values and continuity of the total loop fluid flowstream is insured. (i.e., Any excess fluid over that required to supply the load for a given heat exchanger is shunted around that heat exchanger and re-joins the total loop flow downstream of the heat exchanger outlet). A series of subroutines is then called which calculate the loop circulation pump pressures corresponding to these desired dummy flowrates, and the existing pump pressures are adjusted to accelerate or decelerate the observed fluid flowrates over a period of time governed by the input pump response sensitivity factor. Valve models adjust the relative heat exchanger flowrates to the desired flow split conditions. (See Subroutine FLOWS for further details of the adjustment process). The system thus responds to load variations primarily through adjustment of the loop fluid flowrates, allowing constrained fluid temperature variations to provide secondary compensation through changes in the instantaneous nodal heat storage and supply rates.

During intervals in which the thermostat is not activated, Program MAIN calls the dynamic simulation subroutines which calculate the instantaneous fluid flows, temperatures and pressures throughout the distribution network. A full printout of these TUS parameters and the consumer load distribution is given at regular intervals as specified by the output print code.

A.3.2 Input Scaling (Subroutine CSCALE)

Originally conceived as a means for simplifying the input data requirements for a series of simulations investigating the effects upon system operation of varying only the community's thermal/electrical energy demand ratio, this subroutine is only partially completed. The use of an input mass flowrate scale factor (CSFAC) other than 1.0 will result in the specified initial flowrates being multiplied by that factor prior to their use in the TUS initialization calculations. Since neither the heat exchanger ratings nor the fluid temperatures are scaled internally, it is necessary to re-punch a significant portion of the input data when varying the demand ratio and, to avoid errors, it is recommended that the input mass flowrates be similarly repunched, with the value of CSFAC input as 1.0 until the internal scaling routine has been completed.

A.3.3 Consumer Heat Flow (Subroutine QLOAD)

Using a combination of American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) recommendations [4] and simplifications of procedures employed in the National Bureau of Standards Load Determination code (NBSLD) [5], Subroutine QLOAD calculates the hourly net heat losses (gains) from each building type in the community based upon a steady-state energy flow analysis including the effects of heat conduction from the building to its surroundings, infiltration and ventilation air flows, solar radiation absorption and transmission, and internal heat generation from lights, appliances, people, etc. Due to the aggregate nature of the building units chosen to typify the large numbers of individual structures classified in each consumer grouping, emphasis in the development of Subroutine QLOAD has been placed upon the computation of building energy demand schedules reflecting the major components of the total building loads, but it is not as detailed nor as dynamically rigorous as the energy transfer function analyses performed by NBSLD. A major criterion in the derivation of the QLOAD demand models has been the minimization of complex building parameter specifications which would inordinately restrict the applicability of a given building unit as being "typical" of a fairly diverse mixture of structures. However, enough detail is included in the calculations that, if it is desired and is statistically valid, sensitivity analyses upon the building energy demands may be performed by varying certain design and construction specifications on a wall-by-wall basis.

Some basic assumptions made in the demand calculations are that all buildings specified are square and have symmetrical walls (i.e., that each of a given building's four walls is constructed identically to the others); that the roofs are flat (or that the input data describes a horizontal projection of the actual roof); that building occupancy, appliance and lighting usage, and forced-air ventilation requirements are closely correlated and may be scheduled according to the same building use function; and that a single temperature setting is to be maintained throughout all the rooms of each building type. All loads are calculated under instantaneous steady-state heat transfer conditions, and no consideration is made of such effects as the thermal inertia of the building walls or of energy transfers among regions within the building.

The first component of the building heat loads calculated in Subroutine QLOAD is that due to the combined effects of infiltration and ventilation air exchanges. For the purposes of this analysis, infiltration is defined as any air flow occurring as a result of wind and stack effect induced pressure differentials across cracks permeating the building's exterior surfaces. Ventilation air flows are those air exchanges scheduled by a building's occupants, either by the use of air circulation equipment or by opening windows. Infiltration is calculated in Subroutine QLOAD according to the carck factor method described in the User's Manual for NBSLD [6]. In general, the pressure loading on a given wall consists of two components: that due to differences in the temperature and density of the air between the base and top of the wall (stack effect air convection) and that due to wind pressure on the wall's exterior surface. A simplified formula for determining the net stack effect pressure on a wall is given by Eq. (A.1).

$$PC = 5.3508\ BH\ (\frac{1}{TOAB} - \frac{1}{TIAB}) \qquad (A.1)$$

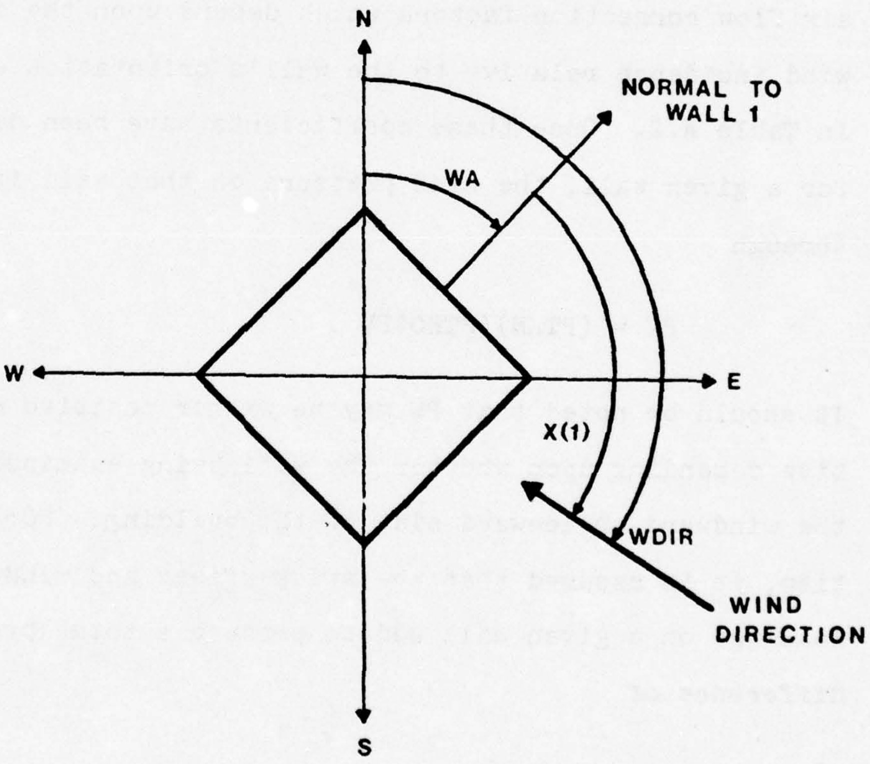
The conversion factor of 5.3508 includes the dimensional conversion factor of 7.644 (in. H_2O-°K/ft) multiplied by 0.7, since, according to ASHRAE, the net effects of a distributed stack effect pressure loading may be approximated by a single load concentrated at 70% of the building's height [4]. The theoretical direct normal wind-induced pressure loading on a wall is given by Eq. (A.2),

$$PV = 0.000482(WV)^2 \qquad (A.2)$$

where the multiplier of 0.000482 converts $(mph)^2$ to a pressure difference in inches of water, relative to normal atmospheric pressure. However, since the ideal conditions under which this theoretical loading is derived are seldom observed in practice, the pressure computed in Eq. (A.2) must be scaled to account for the actual building orientation and for empirically-determined wall surface pressure reduction effects [6]. Figure A.5 illustrates the definition of the relative

Figure A.5

Definition of Wall Normal and Wind Incidence Directions Relative to North



wind incidence and wall normal directions as they are used in Subroutine QLOAD. Walls are numbered clockwise from the North, with #1 being the reference wall for normal angle WA. Because the air flow will, in general, be neither normal nor parallel to a given wall, the normal pressure term computed in Eq. (A.2) must be multiplied by normal and oblique air flow correction factors which depend upon the angle of wind incidence relative to the wall's orientation as shown in Table A.2. Once these coefficients have been determined for a given wall, the wind pressure on that wall is computed through

$$PW = (PTKN)(PTKO)PV \; . \qquad (A.3)$$

It should be noted that PW may be wither positive or negative depending upon whether the wall being examined is on the windward or leeward side of the building. For conservatism, it is assumed that the stack effect and wind pressure loadings on a given wall add to produce a total pressure difference of

$$PT = PW + PC \; . \qquad (A.4)$$

Once the total pressure difference across a crack is known, the volumetric air flowrate through the crack may be determined through the use of infiltration coefficients based upon ASHRAE tabulated air flow measurements [6]. Table A.3

TABLE A.2

NORMAL AND OBLIQUE AIR FLOW WIND PRESSURE CORRECTION FACTORS

(from Ref. 6)

Angle Between Wind Incidence Direction and Normal to Wall i	Correction Factor	
	Normal (PTKN)	Oblique (PTKO)
$-45° < x(i) < +45°$	0.60	$\cos(\lvert x(i)\rvert)$
$90° < x(i) < 270°$, or $-90° < x(i) < -270°$	-0.35	1.0
$45° < x(i) < 90°$, or $-45° < x(i) < -90°$	-0.70	$\cos(\lvert x(i)\rvert)$

lists the air flow coefficients - determined for several types of cracks - which are used in the general infiltration formula

$$(LI)_i = (CL)_i(C_i)(PT)^{N_i} . \qquad (A.5)$$

In Subroutine QLOAD, infiltration air flowrates are computed in this manner on a wall-by-wall basis for cracks around doors, windows and in the structural walls, and the resulting components are summed to produce a net total infiltration air leakage for the building.

For many types of small buildings, such as single family homes, infiltration heat losses dominate those due to ventilation. However, for large commercial buildings, which are generally better constructed and are regulated by municipal building codes, ventilation is the dominant mode of air exchange. In Subroutine QLOAD, ventilation is scheduled according to each building's occupancy-related use factor as is shown in Eq. (A.6).

$$VLEAK = (BUF)(AINFL) \qquad (A.6)$$

During every simulation time step, each building's infiltration and ventilation air flowrates are compared, and the larger is used to determine the building's instantaneous air exchange heat loss rate through

TABLE A.3

INFILTRATION AIR FLOW COEFFICIENTS

(from Ref. 6)

		C	N
1. Double-hung wooden windows(locked)*			
non-weatherstripped	loose fit	6	0.66
	average fit	2	0.66
weatherstripped	loose fit	2	0.66
	average fit	1	0.66
2. Window frames*			
masonry frame with no caulking		1.2	0.66
masonry frame with caulking		0.2	0.66
wooden frame		1	0.66
3. Swinging doors*			
1/2" crack		160	0.5
1/4" crack		80	0.5
1/8" crack		40	0.5
4. Walls**			
8" plain brick		1	0.8
8" brick and plaster		0.01	0.8
13" plain brick		0.8	0.8
13" brick and plaster		0.004	0.7
13" brick, furring, lath and plaster		0.03	0.9
frame wall, lath and plaster		0.01	0.55
24" shingles on 1x6 boards on 14" centers		9	0.66
16" shingles on 1x4 boards on 5" centers		5	0.66
24" shingles on shiplap		3.6	0.7
16" shingles on shiplap		1.2	0.66

*Values of C listed for these openings are per linear foot of crack length.

**Values of C listed for the walls are per square foot of surface area.

$$\mathrm{QLEAK} = (\rho_a C_{pa})(\mathrm{ALEAK})\mathrm{TSB} - \mathrm{TAIR}) \; . \qquad \text{(A.7)}$$

(The infiltration and ventilation flowrates are not summed, since it is assumed that, to some extent, one substitutes for the other in determining overall building comfort levels. A comparison between the two components allows, for example, ventilation to be turned off at night, with infiltration remaining high due to high winds).

In order to determine the effects of solar radiation absorption and transmission upon a building's total space conditioning energy demands, it is necessary to first determine the direction and intensity of the sun's rays striking the four walls and roof of the building. In Subroutine QLOAD, the direction cosines of a direct solar beam are referred to the normal to a horizontal surface as is shown in Fig. A.6. At any time during the day, the solar hour angle relative to the horizontal surface normal is

$$\mathrm{H} = 15\ (\mathrm{TIME} - 12) \; . \qquad \text{(A.8)}$$

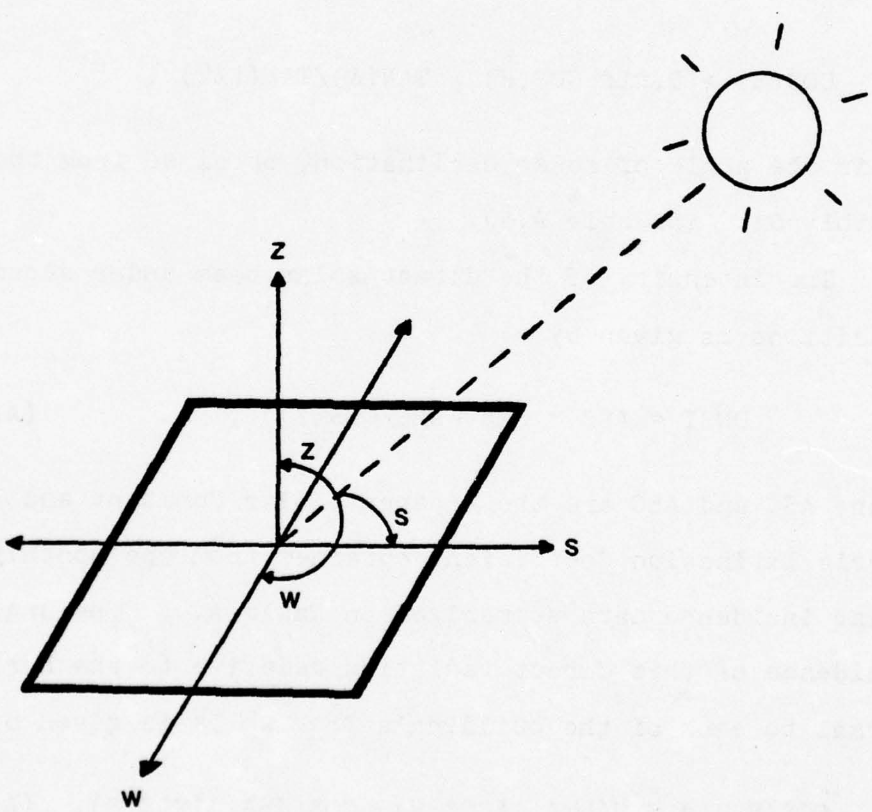
If

$$|\mathrm{COS(H)}| > |-\mathrm{TAN(LAT)}*\mathrm{TAN}(\delta)|$$

the sun has risen above the horizon, and the direct solar beam direction cosines are defined by

Figure A.6

Definition of Solar Beam Direction Cosines



$$\mathrm{COS}(Z) \doteq \mathrm{SIN}(LAT)*\mathrm{SIN}(\delta)+\mathrm{COS}(LAT)*\mathrm{COS}(\delta)*\mathrm{COS}(H), \quad \text{(A.9a)}$$

$$\mathrm{COS}(W) = \mathrm{COS}(\delta)*\mathrm{SIN}(H), \text{ and} \quad \text{(A.9b)}$$

$$\mathrm{COS}(S) = (1 - \mathrm{COS}^2(Z) - \mathrm{COS}^2(W))^{0.5} \;, \quad \text{(A.9c)}$$

where

$$\mathrm{COS}(S) > 0, \text{ if } \mathrm{COS}(H) > \mathrm{TAN}(\delta)/\mathrm{TAN}(LAT) \;.$$

(δ is the angle of solar declination, obtained from the monthly data in Table A.4).

The intensity of the direct solar beam under cloudless conditions is given by

$$DNSI = ASC * \exp(-AEC/\mathrm{COS}(Z)) \;, \quad \text{(A.10)}$$

where ASC and AEC are the Apparent Solar Constant and Atmospheric Extinction Coefficient obtained from the monthly solar incidence data summarized in Table A.4. The angle of incidence of this direct radiation relative to the horizontal normal to each of the building's four walls is given by

$$\mathrm{COS}(\theta_i) = \mathrm{SIN}(SWA_i)*\mathrm{COS}(W) + \mathrm{COS}(SWA_i)*\mathrm{COS}(S), \quad \text{(A.11a)}$$

where SWA is the orientation of the wall being studied relative to South (i.e., angle WA as defined in Fig. A.5, minus 180 degrees). The cosine of the angle of direct solar incidence upon the building's (flat) roof is

TABLE A.4

SOLAR INCIDENCE DATA(1)

(from Ref. 7)

Date	Apparent Solar Constant (BTU/hr-ft^2)	Solar Declination (Degrees)	Atmospheric Extinction Coefficient	Sky Diffuse Factor
Jan. 21	390	-20.0	0.142	0.058
Feb. 21	385	-10.8	0.144	0.060
Mar. 21	376	0.0	0.156	0.071
Apr. 21	360	11.6	0.180	0.097
May 21	350	20.0	0.196	0.121
June 21	345	23.45	0.205	0.134
July 21	344	20.6	0.207	0.136
Aug. 21	351	12.3	0.201	0.122
Sept. 21	365	0.0	0.177	0.092
Oct. 21	378	-10.5	0.160	0.073
Nov. 21	387	-19.8	0.149	0.063
Dec. 21	391	-23.45	0.142	0.057

(1)Data values listed are for the Northern Hemisphere; for Southern Hemisphere locations, the values of AEC and SDF should be shifted by six months.

$$\mathrm{COS}(\theta_r) = \mathrm{COS}(Z)\ . \qquad (A.11b)$$

The intensity of the direct solar radiation striking each of these surfaces is determined by the intensity of the direct normal solar radiation at the computed incidence angle, modified by any existing surface shading.

$$\mathrm{DSI}_i = \mathrm{FWLIT}_i*\mathrm{DNSI}*\mathrm{COS}(\theta_i) \qquad (A.12)$$

Diffuse solar radiation striking the building's surfaces under cloudless conditions obtains from diffusion of the direct solar beam as it passes through the atmosphere,

$$I_{da} = \mathrm{DNSI}*\mathrm{SDF}\ , \qquad (A.13a)$$

where the Sky Diffuse Factor SDF is obtained from Table A.4, and from radiation reflected from the ground,

$$I_{dg} = \rho_g(I_{da} + \mathrm{DNSI}*\mathrm{COS}(Z))\ , \qquad (A.13b)$$

where for most surfaces the ground reflectivity $\rho_g \simeq 0.2$. For a horizontal surface, the incident diffuse solar radiation intensity is I_{da}. For a vertical surface, a scattering factor must be computed to yield an effective angle of incidence for the radiation [8].

$$Y_i = 0.55 + 0.437\ \mathrm{COS}(\theta_i) + 0.313\ \mathrm{COS}^2(\theta_i), \qquad (A.14a)$$

or, if $\mathrm{COS}(\theta_i) \leq -0.2$,

$$Y_i = 0.45. \qquad \text{(A.14b)}$$

The total intensity of the diffuse radiation striking each of the building's walls is thus

$$DFSI_i = (I_{da}*Y_i + 0.5I_{dg})*FWLIT_i \;, \qquad \text{(A.15a)}$$

and of that striking the roof,

$$DFSIR = I_{da}*FWLIT_r \;. \qquad \text{(A.15b)}$$

Heat gained by a building from the sun may be attributed to two effects: the internal absorption of radiation transmitted through windows, and the absorption of radiation by the walls and roof. The solar heat gain through a building's windows is obtained through the calculation of a window solar heat gain factor based upon polynomial expansions of the window's solar transmissivity and absorptivity [9,10].

$$SHGF_i = DSI_i*F_{i1} + 2*DFSI_i*F_{i2} + 0.267(\,DSI_i*F_{i3} + 2*DFSI_i*F_{i4}) \qquad \text{(A.16)}$$

The factors F_{i1}-F_{i4} are the transmission and absorption coefficients obtained from the expansions for 1/8" thick single plate glass:

Direct transmission $F_{i1} = \sum_{j=0}^{5} T_j \cos^j(\theta_i)$, (A.17a)

Diffuse transmission $F_{i2} = \sum_{j=0}^{5} T_j/(j+2)$, (A.17b)

Direct absorption $F_{i3} = \sum_{j=0}^{5} A_j \cos^j(\theta_i)$, and (A.17c)

Diffuse absorption $F_{i4} = \sum_{j=0}^{5} A_j/(j+2)$; (A.17d)

where the polynomial coefficients A_j and T_j are given in Table A.5. The factor of 0.267 multiplying the radiation absorption term in Eq. (A.16) arises from a comparison of typical inner and outer glass surface thermal resistances, and it is used to approximate the ratio of inward to outward heat flows due to radiation absorbed by the glass [10]. The rate of solar heat gain through the windows in wall i is given by the product of the solar heat gain factor for those windows, the window area in that wall (assumed to be 1/4 of the total building window area due to the symmetrical wall assumption), and an internal window shading coefficient depending upon such factors as double glazing, tinted glass, and the use of drapes, blinds, etc.

$$QWDSG_i = AWD_i*SHGF_i*WDSC \qquad (A.18)$$

Representative shading coefficients are listed in Table A.6

TABLE A.5

POLYNOMIAL COEFFICIENTS USED IN CALCULATION OF WINDOW SOLAR HEAT GAIN FACTORS

(from Ref. 9)

Single Glazing, 1/8" sheet

j	A_j	T_j
0	0.01154	-0.00885
1	0.77674	2.71235
2	-3.94657	-0.62062
3	8.57881	-7.07329
4	-8.38135	9.75995
5	3.01188	-3.89922

TABLE A.6

WINDOW SHADING COEFFICIENTS

		WDSC
TYPE OF GLASS		
Regular sheet:	3/32 - 1/4	0.95 - 1.00
	1/4 - 1/2	0.88 - 0.95
Grey sheet:	1/8	0.78 - 0.80
	1/4	0.86 - 0.88
Heat-absorbing plate:	1/4	0.70 - 0.74
	1/2	0.50 - 0.57
TYPE OF SHADING		
Venetian blinds:	medium	0.42 - 0.64
	light	0.40 - 0.55
Roller shade:	dark opaque	0.36 - 0.59
	white opaque	0.25 - 0.28
	translucent	0.31 - 0.39
Draperies		0.35 - 0.80
Louvered sun screens		0.15 - 0.40

for a variety of common glass types and room decors; more extensive tabulations are found in ASHRAE [4], pp. 402-408. The individual-wall solar heat gains are added to produce a total window solar heat gain for the building.

The effects of solar radiation absorption and reflection at the building's wall and roof surfaces may be approximated by the use of a surface "sol-air" temperature in the building component's steady-state heat conduction equation [4]. The sol-air temperature for a surface is given by

$$TSA_i = TAIR + SAB_i*(DSI_i + DFSI_i)*HO_i \;, \qquad (A.19)$$

where SAB_i is the solar absorptivity of the surface and HO_i is the surface convection heat transfer coefficient. Table A.7 lists several absorptivities for typical building materials, a more extensive summary of which is given in Table C6 of NBSLD [5]. The convection heat transfer coefficient for a surface depends primarily upon the velocity of the wind striking the surface and the roughness of the surface material:

$$HO_i = \frac{1}{C_{ai}*(WV)^2 + C_{bi}*(WV) + C_{ci}} \;, \qquad (A.20)$$

where the coefficients in this formula are functions of the surface material type as given in Table A.8. To determine the net heat conduction rate out of the building through its walls and roof, including the effects of solar heating, the

TABLE A.7

SOLAR ABSORPTIVITIES OF TYPICAL BUILDING MATERIALS

(from Ref. 5)

MATERIAL		SAB
Brick:	red common	0.68
	light buff	0.36
	white glazed	0.26
Tiles:	dark clay	0.82
	red	0.67
	brown concrete	0.85
Roofing:	asphalt	0.91
	bituminous felt	0.89
	black matte sheet	0.97
	blue slate	0.86
Wood		0.78
Marble		0.58
White plaster		0.29

TABLE A.8

COEFFICIENTS USED IN CALCULATING SURFACE CONVECTION HEAT TRANSFER COEFFICIENTS

(from Ref. 5)

MATERIAL	C_a	C_b	C_c
Stucco	0.0	0.464	2.04
Brick, rough plaster	0.001	0.320	2.20
Concrete	0.0	0.330	1.90
Clear pine	-0.002	0.315	1.45
Smooth plaster	0.0	0.244	1.80
Glass, white paint on pine	-0.00125	0.262	1.45

wall and roof material heat transfer coefficients are calculated by

$$AUW_i = \frac{AW_i}{RTW_i + WHO_i} + \frac{AWD_i}{RTWD_i} \qquad (A.21a)$$

and

$$AUR = \frac{AR}{RTR + RHO} \; . \qquad (A.21b)$$

The total heat conduction rate to the ambient air is obtained by adding the components for the four walls and the roof:

$$QCOND_a = \sum_{i=1}^{4} AUW_i*(TSB - TSA_i) + AUR*(TSB - TSAR) \; . \qquad (A.22)$$

The heat conducted from the building to the earth is

$$QCOND_g = AUG*(TSB - \frac{TSB + TAMB}{2}) \; , \qquad (A.23)$$

where the average between the desired building temperature and the ambient earth temperature is used to account for heating of the soil in direct contact with the building. The total heat conduction rate from the building is given by the sum of this ground loss and the heat lost to the air.

Energy flows due to the production of heat within a building are lumped into a single term accounting for lighting, appliances, people, etc., which are scheduled according to the building's occupancy-related use factor as

$$QLIG = (BUF)(POL) \ . \qquad (A.24)$$

Finally, the net total heat loss from a building due to these component energy flows is given by

$$QL = QCOND + QLEAK - QWDSG - QLIG \ . \qquad (A.25)$$

It should be noted that, as defined here, a positive heat flow indicates a net heat loss from the building to its surroundings.

A.3.4 Building Load Distribution (Subroutine DLOAD)

In Subroutine DLOAD, the building heat losses (gains) computed in Subroutine QLOAD are applied to the TUS load center heat exchangers and the electrical supply network according to the specified distributions of buildings and end-use equipment in the community being studied. When translating the heat losses to utility system demands, care is taken to include the effects of variations in the end-use equipment coefficients of performance with changes in the building room and ambient air temperatures. A printout of the community load distribution is provided at regular intervals during the simulation as specified by the user-defined output code. Since the demands in Subroutine QLOAD are calculated only at hourly intervals, Subroutine DLOAD computes hourly load distributions which are used as inputs to linear interpolation equations in Program MAIN to produce the continuous load schedules required for the dynamic system analysis. (Instantaneous distributions may be calculated by Subroutine DLOAD at any time during the simulation as called for by the output schedule, but these instantaneous values are based upon linear interpolations between previously computed hourly data points.)

Associated with each load center heat exchanger in the TUS are a set of six numbers for each building type in the community: the number of units of that building type served by the heat exchanger, and the numbers of compressive air conditioners, absorptive air conditioners, heat pumps, hot water space heating units and resistance heaters within these buildings. (e.g., load center heat exchanger #5 might serve 20 units of building type 1, of which 11 have absorptive air conditioners, 9 have compressive air conditioners, 7 have heat pumps, 13 have hot water heat, and 0 have resistance heaters.) At each hourly interval, all the specified building types are examined at each heat exchanger to determine how many, if any, of each type have equipment connected to the TUS at that point. The total space-conditioning heat loss from these buildings is then calculated by

$$Q_i^k = NU_i^k * QL_i \ , \qquad (A.26)$$

where QL_i is the net heat loss (gain) from one unit of building type i computed in Subroutine QLOAD (or is an off-hour load obtained through linear interpolation between two hourly values), and the superscript indicates the calculation is performed for buildings served by heat exchanger k. Domestic hot water energy demands are also computed in Subroutine DLOAD for each of the building types according to the user-specified water consumption schedules through

$$QDHW_i^k = NU_i^k * WUF_i * DHW_i \ . \qquad (A.27)$$

(The service hot water demands are computed here rather than in Subroutine QLOAD as a matter of convenience. They are added to the net space conditioning loads and cannot be used to offset building heat losses computed in QLOAD).

After computing the aggregate space conditioning demand for a given building type at a given load center heat exchanger, Subroutine DLOAD determines whether this demand is due to space heating or cooling and applies it to the appropriate end-use equipment for that building type. If the load is due to space cooling, it may be supplied by either electric compression air conditioners or by hot water (or low pressure steam) liquid absorption chillers, <u>if</u> the outside air temperature is greater than that desired within the building. If the outside air temperature is lower than the desired room temperature (the cooling load resulting from internal heat generation or solar heating), it is assumed that ventilation will be increased to cool the building, and no loads are applied to either type of air conditioning equipment. (This criterion may be employed by the user to insure certain buildings of not being cooled by simply specifying their desired temperatures to vary exactly with the known ambient air temperature schedule). If the outside air temperature exceeds the room temperature, the nominal coefficient of performance of each air conditioning unit (defined at an air temperature of 90 °F and a room temperature of 75 °F) is scaled according to the theoretical Carnot cycle performance for a refrigerator:

$$COP' = COP_o \left(\frac{0.028037}{\frac{TOAB}{TIAB} - 1}\right) , \qquad (A.28)$$

where the 0.028037 factor is defined by the ideal Carnot heat engine efficiency at the specification temperatures:

$$\frac{1}{COP_s} = \frac{TOAB}{TIAB} - 1 = \frac{90+460}{75+460} - 1 = 0.028037 .$$

It should be noted that COP_o, the nominal coefficient of performance for the given air conditioning unit at TOAB = 550 °K and TIAB = 535 °K, should not be the theoretical Carnot cycle COP under those conditions, but should reflect the manufacturer's specifications for the actual units installed in the system. The Carnot cycle efficiency is merely used by Subroutine DLOAD as an approximate indicator of the relative behavior of the actual COP as the room and air temperatures vary over time. Applying the COP' computed for each of the air conditioning units to the aggregate loads to be met by those units, the total energy demands for space cooling are determined by

electric compression: $QCMP_i^k = F_{ei}^k * Q_i^k / BCMP$, and (A.29a)

thermal absorption: $QABS_i^k = (1 - F_{ei}^k) * Q_i^k / BABS$, (A.29b)

where F_{ei}^k is the ratio of electrically supplied space cooling to the total space cooling loads for building type i at heat exchanger k:

$$F_{ei}^k = \frac{NCMP_i^k}{NCMP_i^k + NABS_i^k} \quad . \qquad (A.30)$$

(BCMP and BABS are the scaled COP's for the compressive and absorptive air conditioning units, respectively).

Space heating demands are treated analagously to cooling loads. If the outside air temperature exceeds the desired room temperature for a given building type, no space heating demand for that building type is applied to the energy distribution networks. Heat pump COP's are defined at conditions of 32 °F air temperature and 68 °F room temperature, with the ideal Carnot cycle efficiency factor being

$$\frac{1}{COP_s} = 1 - \frac{TOAB}{TIAB} = 1 - \frac{32+460}{58+460} = 0.068182.$$

Variations in either temperature from these set-point conditions cause the COP to be modified according to

$$COP' = COP_o \left(\frac{0.068182}{1 - \frac{TOAB}{TIAB}}\right) . \tag{A.31}$$

The space heating demands may be supplied by heat pumps, hot water heat, or by electric resistance heaters, with the loads applied to the utility systems being determined by

electric heat pumps: $QHPM_i^k = F_{hpi}^k * Q_i^k / BHPM,$ (A.32a)

hot water: $QHWS_i^k = F_{hwi}^k * Q_i^k / EHWS,$ and (A.32b)

resistance: $QRES_i^k = F_{ri}^k * Q_i^k / ERES,$ (A.32c)

where the load fractions for building type i at heat exchanger k are defined, in general, by

$$F_{xi}^k = \frac{N_{xi}^k}{NHPM_i^k + NHWS_i^k + NRES_i^k} . \tag{A.33}$$

All heat pumps in the system are assumed to be provided with auxiliary resistance heating coils. At each hourly interval, the scaled heat pump COP (BHPM) is compared with the COP of a resistance heating unit (ERES, assumed to be 1.0), and if the heat pump COP is less than that of the resistance heater, all heat pump loads are transferred to their resistance back-up units.

Domestic hot water demands are assumed to be supplied through the use of hot water heat exchangers in buildings supplied with hot water heat from the TUS, or through the use of electric hot water heaters in buildings containing heat pumps or resistance space heaters. The service hot water demands represent an additional heating load which may be conceptually applied to the same type of equipment as that supplying the space heating requirements. Therefore, for buildings with domestic hot water loads, the equipment energy demands computed on Eqs. (A.32b,c) are modified to yield

$$\text{hot water:}\quad QHWS_i^k = QHWS_i^k(\text{space heating}) + F_{hwi}^k * QDHW_i^k/EHWS, \text{ and} \tag{A.34a}$$

$$\text{resistance:}\quad QRES_i^k = QRES_i^k(\text{space heating}) + (F_{hpi}^k + F_{ri}^k) * QDHW_i^k/ERES. \tag{A.34b}$$

This load analysis is performed for every building type at each load center heat exchanger for each hour of the simulation period. The resulting thermal demands define the distributed hourly load schedules to be met by the TUS, and the electrical demands are aggregated to form one component of the community's electrical load schedule. In addition to the buildings served by the TUS and distributed among its load center heat exchangers, there may be several buildings in the community which are not provided with HTW service but which are supplied with electricity from the TES power plant. For the purposes of calculating these "external system" loads in Subroutine DLOAD, all of the units of a given building type not served by the TUS are aggregated into a single grouping, independently of their actual geographical locations within the community. (Since no detailed analysis is performed on the electrical distribution network, there is no need to specify transmission distances to these consumers.) Proceeding analogously to the computations described above for those buildings connected to the TUS, the external system energy demands are calculated as follows.

1) Total space conditioning demand for all units of building type i not served by the TUS:

$$QEXT_i = NUEX_i*QL_i \ , \qquad (A.35)$$

where QL_i is the hourly demand computed in Subroutine QLOAD, or is an interpolated load if the demands are being computed during one of the simulation hours.

2) Total domestic hot water energy demand for all units of building type i not served by the TUS:

$$QDEXT_i = NUEX_i*WUF_i*DHW_i \ . \qquad (A.36)$$

3) Total compressive air conditioning energy demand for all units of building type i not served by the TUS:

$$QCEXT_i = QEXT_i/BCMP \ , \qquad (A.37)$$

where $QCEXT_i$ is defined for $TOAB > TIAB_i$, and BCMP is the air conditioner COP scaled according to the relation in Eq. (A.28). It should be noted that all buildings in the external system requiring cooling are assumed to be served by compressive air conditioning units. Those few building not served by the TUS using absorption chillers will also have in-house fossil-fired furnaces to supply their heating loads - due to the high cost of installing and operating dual heating and cooling systems - and, for the purposes of this TES analysis, will have no effect upon the overall energy system design.

4) Total heat pump energy demand for all units of building type i not served by the TUS:

$$QHEXT_i = FHPEX_i * QEXT_i/BHPM \ , \qquad (A.38)$$

where all space heating demands are defined only for $TOAB < TIAB_i$, and $QHEXT_i$ is zero if the scaled COP (BHPM, from Eq. (A.31)) is less than 1.0.

5) Total resistance heating energy demand for all units of building type i not served by the TUS:

$$\dot{Q}REXT_i = FREXT_i * QEXT_i / ERES + (FREXT_i + FHPEX_i) * QDEXT_i / ERES \ , \qquad (A.39)$$

and $QREXT_i$ includes the heat pump space heating demands if the heat pump COP is less than ERES.

6) Total hot water energy demand for all units of building type i not served by the TUS:

$$QHWEX_i = (1 - FHPEX_i - FREXT_i) * (QEXT_i + QDEXT_i) / EHWS \ . \qquad (A.40)$$

This demand is assumed to be supplied by in-house fossil fuel furnaces and is not applied to the TES analysis (other than as an entry in the external system building load distribution summary). Although, as is described above, it is assumed that any external system buildings containing absorptive air conditioning units will also contain fossil-fired furnaces and will not affect the TES analysis, present construction practices demonstrate that it is very likely that a building having an in-house fossil furnace will also have compressive air conditioning. These buildings will affect the total electrical loads to be met by the TES power plant, and they must therefore be included in this demand analysis.

In order to compute the total system hourly electrical energy demands, the electrical demands computed in Eqs. (A.29a), (A.32a), and (A.34b), summed over all the building types and all the load center heat exchangers, are added to the total external system electrical demands. These hourly space conditioning and domestic hot water loads are transmitted to Program MAIN, where they are added to the aggregate non-space-conditioning electrical load for the community to produce the hourly total electrical demands to be met by the TES power plant electrical output.

A.3.5 Steady-State System (Subroutine STDY)

Subroutine STDY is an iterative steady-state heat flow subprogram which establishes the nodal fluid flowrates and temperatures throughout the TUS for given thermal load and supply conditions. The essence of the routine lies in a steady-state heat balance performed on each of the nodes which requires equality between the convective and conductive heat flows from the node. The further requirements of continuity of the temperature profiles and fluid flows across the boundaries between consecutive nodes within each loop serve to physically join the separate nodal parameters and to insure conservation of energy and momentum around the loops. The loop flows and temperatures resulting from the heat balance are adjusted iteratively until the system converges to the conditions satisfying both nodal and total system energy balance.

The bases of the nodal heat balance calculation are the steady-state convection and conduction equations given by:

$$\text{convection:} \quad \dot{Q} = MASS*CAP*(TI - TO) \text{ , and} \qquad (A.41)$$

$$\text{conduction:} \quad \dot{Q} = AUF*DTLM \text{ .} \qquad (A.42)$$

DTLM is the log-mean temperature difference between the fluid in the node and the fluid to which heat is being transferred and is expressed by:

$$DTLM = \frac{TN - TD}{\ln\left(\frac{TN}{TD}\right)} \text{ ,} \qquad (A.43)$$

where TN = temperature difference across the node inlet, and

TD = temperature difference across the node outlet.

For a length of pipe transferring heat to the earth, Eq. (A.42) becomes:

$$\dot{Q} = (AUF) * \left[\frac{TI - TO}{\ln\left(\frac{TI - TAMB}{TO - TAMB}\right)}\right] \qquad (A.44)$$

since the earth temperature is assumed to be constant along the length of the pipe. Combining Eqs. (A.41) and (A.44) yields the following expressions for the nodal inlet and outlet fluid temperatures for a length of pipe:

$$TI = TO \exp[AUF/(MASS*CAP)] + TAMB\left[1 - \exp[AUF/(MASS*CAP)]\right], \tag{A.45a}$$

and

$$TO = TI \exp[-AUF/(MASS*CAP)] + TAMB\left[1 - \exp[-AUF/(MASS*CAP)]\right], \tag{A.45b}$$

All heat exchangers are assumed to be of the single-pass counterflow type*. Designating the node being analyzed as the "1" or "primary" side of the heat exchanger and the opposite node as the "2" or "secondary" side,** the conductive heat flow out of the primary side can be expressed by: (see Fig. A.7 for reference)

$$Q = (AUF) * \left[\frac{(TI_1 - TO_2) - (TO_1 - TI_2)}{\ln\left(\frac{TI_1 - TO_2}{TO_1 - TI_2}\right)}\right] . \tag{A.46}$$

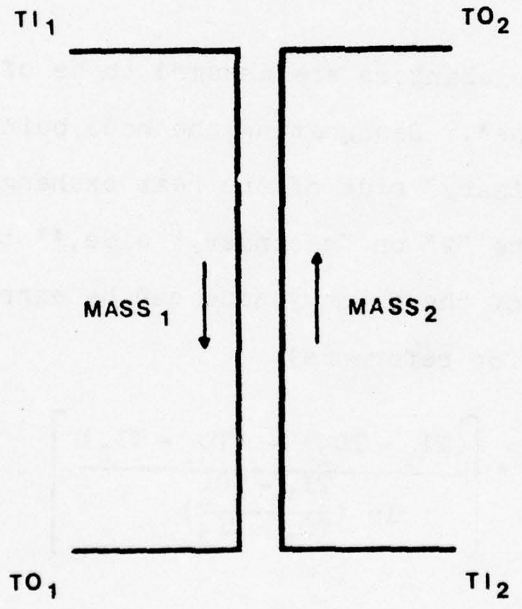
---

*If it is desired to use a different configuration in the actual TUS design, a conversion factor may be applied to the heat transfer coefficient of the actual heat exchanger to transform it to an equivalent counterflow heat exchanger for the purposes of this model. [11]

**In this context, "primary" and "secondary" are not necessarily synonymous with hot and cold. The analysis developed here is independent of the side of the heat exchanger being studied; if the "1" side is the cold side, the heat transfer out of the node will simply be negative.

Figure A.7

Counterflow Heat Exchanger Schematic



The steady-state convective heat transfer rates on both sides of this heat exchanger must be equal to the conductive heat flowrate between them and are given by:

$$\dot{Q} = MASS_1 * CAP_1 * (TI_1 - TO_1), \text{ and} \tag{A.47a}$$

$$\dot{Q} = MASS_2 * CAP_2 * (TO_2 - TI_2) . \tag{A.47b}$$

Combining Eqs. (A.46), (A.47a), and (A.47b) to eliminate TO_1, the primary nodal inlet temperature is determined by the relation:

$$TI_1 = \frac{\left[\dfrac{MASS_2 * CAP_2}{MASS_1 * CAP_1} - 1\right] (TO_2 - TI_2)}{1 - \exp\left[AUF\left(\dfrac{1}{MASS_2 * CAP_2} - \dfrac{1}{MASS_1 * CAP_1}\right)\right]} + TO_2 \tag{A.48}$$

A closed solution for all the nodal fluid mass flowrates and temperatures can be obtained only when information is available regarding the total thermal demands at each load center heat exchanger and the TUS steady-state heat input. In practice, Subroutine STDY requires as input data the inlet and outlet temperatures and fluid flowrates on the consumer sides of all the load center heat exchangers, the primary HTW loop fluid flowrate, and the primary loop fluid supply temperature at the storage reservoir. (See Fig. A.2 for a schematic representation of the TUS.) Subroutines QLOAD and DLOAD determine the steady-state loads to be applied to each load center heat exchanger, and the required fluid flowrates are calculated to supply these loads within the user-defined heat exchanger temperature limits. The primary loop steady-state energy supply data are specified by the user according to the desired system design. Estimates of the total loop fluid flowrate and of the load center heat exchanger parallel branch flow splits in each of the secondary distribution loops may also be supplied to Subroutine STDY by the user, and will speed the convergence of the iterative solutions if chosen properly.

The system calculations are divided into two sections corresponding to the two sets of heat exchangers at the secondary loop and consumer supplies. For each secondary loop, Subroutine STDY first calculates a load center heat exchanger supply header reference temperature through the use of Eq. (A.48), the computed load center heat exchanger consumer-side demand data, and an estimated value of the first secondary loop parallel branch mass flowrate. Since all the load center heat exchangers are supplied from a common point in the secondary loop, the inlet temperatures on their supply sides must all be equal to the calculated reference temperature. Therefore, trial inlet temperatures computed through Eq. (A.48) for each of the load center heat exchangers are compared with the reference, and the branch flowrates are adjusted until the calculated temperatures are within 0.001%

of the required value.* When the temperatures have converged, they are set exactly equal to the reference value to avoid instabilities in future iterations, and the nodal outlet temperatures are calculated by requiring equality between the convective heat flows on both sides of the heat exchangers. Upon completion of this iterative process for each of the load center heat exchangers served by the secondary loop, the parallel branch fluid flowrates are added to produce the total secondary loop flow, and the parallel nodal outlet temperatures are combined to yield a mass-flow-averaged inlet temperature to the secondary loop return pipe. The outlet temperature on the secondary loop side of the secondary supply heat exchanger is then calculated from Eq.(A.45a) using the parallel branch supply header reference temperature as TO; the inlet temperature to the secondary supply heat exchanger is calculated using Eq. (A.45b) and the mass-flow-averaged return header temperature.

The inlet temperature on the primary loop side of the first secondary supply heat exchanger is computed by using in Eq. (A.45b) the specified loop fluid flowrate and the HTW supply temperature at the storage reservoir. Since the

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*Due to round-off errors in the calculations, the two values will never become exactly equal; a higher degree of precision than the 0.001% chosen leads to much longer times for final system convergence.

primary HTW loop fluid flowrate and supply temperature are fixed by the system design, this inlet temperature is constant and defines the HTW reference temperature for the first secondary supply heat exchanger. The loop fluid flowrate and the inlet and outlet temperatures on the secondary side of the heat exchanger calculated in the iterative analysis of the load center heat exchangers are then used in Eq. (A.48) to yield a trial primary-side supply temperature which is compared with the reference. If the difference between these values is greater than the 0.001% convergence limit, the secondary loop fluid flowrate is adjusted to decrease the error. The new secondary loop flow is split among the parallel load center heat exchangers in proportion to their loads, a new supply header reference temperature is calculated, and the load center heat exchanger iteration process is begun again.

This double iteration procedure continues until all the calculated temperatures for the first secondary distribution loop fall within the required convergence limits. The outlet temperature on the primary loop side of the secondary supply heat exchanger is then set by requiring the specified primary loop fluid mass flowrate to supply the total heat load, including losses, of the secondary loop being examined. A reference HTW inlet temperature for the next secondary supply heat exchanger is calculated using Eq. (A.45b) and the first heat exchanger outlet temperature, and the entire loop iteration procedure is started for the next secondary distribution loop. When all the loops have converged, the steady-state heat flows across each of the heat exchangers are calculated, and the nodal fluid mass flowrates and temperature data are printed out in a TUS steady-state design summary.

A.3.6 Initialization (Subroutine SET)

Subroutine SET is an intermediate program flow control subroutine which is called to control the building load analysis section of TDIST, to initialize the dynamic system simulation parameters to the converged steady-state conditions computed in Subroutine STDY, or to control the program flow when the Program MAIN thermostat model requires adjustment of the loop fluid flowrates.

During system initialization or steady-state design analyses (KODE = 0), Subroutine SET assumes control from Program MAIN and causes the hourly (or single time instant) building energy demands and the resulting TUS load distributions to be computed by Subroutines QLOAD and DLOAD. If only an analysis of the building loads is desired (IDES = 1), Subroutine SET causes the building energy demand schedules and the desired load distribution to be printed out and then returns control to Program MAIN, from whence the design run is terminated.

If it is desired to use the loads computed at the beginning hour of the simulation period as input data to the steady-state TUS calculations performed in Subroutine STDY (IDES = 0), Subroutine SET uses the load distribution from Subroutine DLOAD and the user-specified load center heat exchanger supply and return temperatures to compute the fluid mass flowrates on the consumer sides of all the load center heat exchangers. To prevent destruction of the existing system temperature and flowrate data in the event of non-convergence in Subroutine STDY, a set of dummy flowrates and temperatures are initialized to the existing system conditions and are transmitted to Subroutine STDY as the input data required by the heat balance analyses. Upon return of the converged steady-state TUS parameters, Subroutine SET transmits the loop fluid flowrates to Subroutine PRESS, in which the loop fluid frictional pressure losses and required circulation pump pressure settings are computed. Initialization of the TUS nodes to the computed steady-state conditions begins with the resetting of the actual nodal temperatures and fluid mass flowrates to the values returned from Subroutine STDY. The temperature of the cold water section of the thermal energy storage reservoir (see Fig. A.4) is set equal to the fluid temperature at the outlet of the last pipe node in the primary HTW loop; the hot water section temperature is fixed at the desired system HTW supply temperature specified by the user, and the fluid mass flowrate on the TUS side of the power plant thermal energy supply heat exchanger is calculated so as to absorb the net rate of thermal energy production by the power plant after meeting the steady-state system electrical demands. (The interfacing heat exchanger between the power plant and the TUS is not modelled in detail by TDIST and is simply assumed to have an "extremely large" heat transfer coefficient. It is included as a separate item in the system energy flow analysis to emphasize its existence and to provide a mathematical means for transferring energy between two physically different fluid flowstreams). Following the computation of this TUS supply fluid flowrate, Subroutine PREC, which monitors the TUS supply heat exchanger to insure that the Second Law of Thermodynamics is always obeyed by its combined energy flows, is called to verify the validity of the system supply conditions. Subroutine SET then calculates measures of the energy stored in each of the reservoir sections, based upon their initial volumes and fluid temperatures. (In the present form of the code, these are not true measures of the actual BTUs of energy stored, since the computations are performed in degrees Fahrenheit, referred to 0 °F rather than 0 °K. As a result, the printout data summarizing the reservoir energy storage should only be used as an indicator of the relative supply/demand variations of the system over time.

Since the reservoir volume output data is a correct measure of the actual amount of water stored in each reservoir section at any given instant, this data may be used, if necessary, to calculate the true energy storage variations over time.) Steady-state TUS nodal temperature and mass flowrate data and the distribution of the steady-state building energy demands are printed out in the steady-state system summary. Finally, the pressure settings of all the loop circulation pumps are initialized to the steady-state loop fluid frictional losses, and program control is returned to Program MAIN for either the beginning of the dynamic simulation or for termination of the run if only the steady-state system analysis output is desired.

If Subroutine SET is called during the dynamic system analysis (KODE = 1), its function is to transfer the desired nodal fluid mass flowrates computed by the thermostat model in Program MAIN to Subroutine PRESS, where they are translated into a set of corresponding loop pressure losses. These pressures are then shuttled to Subroutine FLOWS, in which they determine the desired settings of the loop circulation pumps to compensate for the out-of-balance energy flows detected by the thermostat.

A.3.7 Fluid Flowrate (Subroutine FLOWS)

As was mentioned previously, the primary mechanism employed in the TUS model to adjust for changes in the system loads and supply conditions is the variation of the loop fluid flowrates. Subroutine FLOWS contains the model for this flowrate adjustment mechanism and also serves as the calling routine for the dynamic energy balance and fluid pressure loss calculation subroutines. Since the consumer tertiary distribution piping is assumed to have negligible fluid and thermal inertia, the fluid flows in the consumer sides of the load center heat exchangers are allowed to vary instantaneously with the thermal demands. However, since the secondary distribution and primary HTW loops contain a considerable volume of fluid, circulation pump models are provided for each of these loops which determine their steady-state fluid flowrates and the rates of fluid acceleration during transients.

At the end of the initiating steady-state calculations, the fluid friction pressure losses corresponding to the converged flows are calculated for each of the loops (see Subroutine PRESS), and the pump pressures are set to maintain these flowrates. When the thermostat is activated, a set of desired fluid flowrates is calculated in Program MAIN by requiring instantaneous energy balance across each of the heat exchangers in the system. The circulation pump pressures corresponding to these desired flows are calculated in Subroutine PRESS and are supplied to Subroutine FLOWS, where they are adjusted to speed system response before being applied to the actual pumps. If the thermal loads increase, setting the pump pressures to the values necessary merely to maintain the projected loop fluid flowrates will cause the fluids to accelerate relatively slowly and to asymptotically approach the desired conditions over a fairly long period of time. Since it is desired to have the system respond as quickly as possible to changes in the thermal demands, the fluid acceleration rates are increased by setting the actual pumps at pressures somewhat higher than the required steady-state values. The factor by which the pressures are adjusted is proportional to the difference between the existing and the required pressures and, therefore, varies with the magnitude of the change in the thermal demands. By adjusting the proportionality constant in this correction factor, it is possible to achieve any desired degree of load following in the system fluid flowrates. However, very short reaction times (i.e., nearly instantaneous adjustment of the flows to exactly match the load conditions) tend to cause instabilities in the system because the time increments over which they occur must be of finite size and the thermal inertia of the system does not allow instantaneous adjustment of the fluid temperatures. In the current model, the pump pressure adjustment equation used is:

$$PEX = PP + PSENS*(PP - PS) \, , \qquad (A.49)$$

where PP is the desired pressure setting computed in Subroutine PRESS from the desired loop flowrates, PS is the existing pump pressure setting, and a value for the pump response sensitivity factor PSENS of 2.0 has been found to be capable of maintaining realistic pressure variations and system stability while allowing fairly rapid response to demand changes. When the fluids have accelerated to within 1% of their projected flowrates, the pump pressures (PEX) are reduced to their required values (PP) to prevent exceeding the projected conditions and possible instabilities in the resulting heat flows.

If the thermostat is not activated, Subroutine FLOWS controls the dynamic energy and momentum transfer calculations which yield the instantaneous fluid temperatures and flowrates throughout the TUS. In these dynamic calculations, it is assumed that system conditions remain constant during each time interval, and new values for the fluid temperatures, pressures and flowrates are calculated at the end of a time step, based upon the instantaneous system thermal energy supply and demand conditions, and upon the overall energy flows and fluid momentum transfers during the preceding interval. Since this is a step-wise approximation to the continuous variation of these parameters, it is important that the specified simulation time step size be small compared with the time constants of the externally-varying heat demand and thermal energy supply functions to maintain system stability.

The instantaneous nodal fluid temperatures are determined in dynamic energy flow calculations in Subroutine ENRG, which is called from Subroutine FLOWS before any of the nodal fluid flowrates are changed. The existing fluid flows in the secondary distribution and primary HTW loops are then supplied to Subroutine PRESS, where the total fluid friction pressure losses, including the effects of flow regulation valves, are calculated for each of the loops. These pressure losses are returned to Subroutine FLOWS and are compared with the circulation pump pressure settings to determine the acceleration or deceleration of the fluid during the preceding time interval. The instantaneous loop flows at the end of the time step are obtained by adjusting the flowrates at the beginning of the interval according to the calculated acceleration rate through:

$$\mathrm{DM} = \mathrm{MASS} + \mathrm{DTIME}*\mathrm{FCTR}*(\mathrm{PEX} - \mathrm{PP}) \ , \qquad (\mathrm{A.50})$$

where PP is used here as the instantaneous fluid friction pressure loss calculated in Subroutine PRESS for the beginning-of-interval fluid mass flowrate MASS, and

$$\mathrm{FCTR} = \frac{\pi g_c (\mathrm{DIA})^2}{4(\mathrm{LONG})} \ , \qquad (\mathrm{A.51})$$

with $g_c = 4.147\times10^8$ lbm-ft/lbf-hr^2. The relative flows in the parallel branches of the secondary distribution loops are determined by the new total loop flowrates given by Eq. (A.50) and the settings of the branch flow regulation valves, which divide the loop flows according to the individual load center heat exchanger thermal demands. The relative bypass and heat exchanger flowrates at each secondary supply heat exchanger in the primary HTW loop are similarly determined according to the thermal demands at those heat exchangers.

Subroutine FLOWS also performs the energy transfer calculations for the thermal energy storage reservoir. As was mentioned previously, the reservoir is modelled physically as two separate storage volumes in series with the primary loop supply and return nodes at the TUS supply heat exchanger (see Fig. A.2). The initial hot water storage section temperature is specified in the input data as the desired HTW supply temperature for the primary loop. Since large variations in the primary loop inlet temperature, coupled with the continuous variation of the fluid flowrate to compensate for load changes, tend to cause instabilities in the system heat flows during periods of peak or minimum demand, this temperature is held constant throughout the simulation. The cold water storage temperature is initialized to the primary loop steady-state fluid return temperature. The fluid flowrate between the two reservoir sections is then calculated by requiring equality between the convective heat transfer rates on both sides of the TUS supply heat exchanger. The energy transferred to the water in the heat exchanger from the power plant coolant flow is equal to the difference between the constant power plant total thermal energy output and the instantaneous energy demand for electrical generation. Since the supply heat exchanger outlet temperature is constant and the inlet temperature varies relatively slowly - as determined by the variations in the primary loop return fluid temperature, buffered by the large volume of fluid in the cold water section of the reservoir - the fluid flowrate between the two reservoir sections effectively follows the system thermal energy supply. At the end of each simulation time step, the water volume in each of the storage sections is adjusted according to the net fluid transfer during the interval. (e.g., if the primary loop flowrate is greater than that in the supply heat exchanger, there will be a loss of fluid from the hot water section and an increase in the volume of the cold water section.) If either of the sections is emptied during a given time step, the primary loop fluid flowrate is constrained to be equal to the flowrate through the thermal energy supply heat exchanger to satisfy conservation of mass and momentum around the continuous piping loop. The energy contained in each of the reservoir sections varies with both the volume and the average temperature of the water being stored. At the end of each time step, this energy storage is adjusted by comparing the thermal energy flows into and out of the section during the interval. (In this calculation, it is assumed that heat conduction losses from the reservoir will be small compared with the convective heat flows from the precooler and the primary loop, and conduction effects are ignored. It should also be noted that, in the present version of the code, these energy terms are only relative measures of the actual energy stored in each section, since they are computed relative to 0 °F rather than 0 °K. Since the volume terms depend only upon the mass flowrates into and out of each section, they are rigorously correct indicators of the actual reservoir behavior). Thus, during periods in which the power plant thermal energy supply exceeds the system demands, the volume of water in the hot water storage section increases. During periods of higher demand, this stored energy supplements the power plant supply, and the water volume decreases.

A.3.8 System Pressure Drops (Subroutine PRESS)

Subroutine PRESS calculates the total fluid friction pressure losses for the secondary distribution and primary HTW loops, sets the circulation pump pressures to compensate for these friction losses, and controls the flow regulation valves in the secondary loop parallel supply branches to divide the loop flows according to the relative load center heat exchanger thermal demands. The subroutine is called during the initial steady-state system calculations to establish the initial pump pressures and valve settings, when the thermostat is activated to determine the desired pressures and flow splits for the projected system flowrates, and at the end of each simulation time step to calculate the instantaneous fluid pressure losses in each loop. The basis of the nodal fluid friction pressure loss calculation is the Darcy formula [12]:

$$DP = F*(LONG/DIA)*\left(\frac{MASS^2}{2*G*RHO*NTB^2*AC^2}\right) , \qquad (A.52)$$

where the familiar form of the equation has been modified slightly by expressing the fluid velocity in terms of the mass flowrate (MASS), the flowchannel cross-section (AC), and the number of parallel flowchannels (NTB). The factor F is the Darcy-Weisbach friction factor

$$F = \frac{0.184}{RE^{0.2}} ; \qquad (A.53)$$

RE is the fluid Reynolds number

$$RE = \frac{4*MASS}{\pi*NTB*DIA*MU} , \qquad (A.54)$$

with the fluid velocity again expressed in terms of the mass flowrate, and the conversion constant $G = 4.147x10^8$ lbm-ft/ lbm-hr^2.

In a simple series loop, such as the primary HTW loop, the total frictional pressure loss is simply the sum of the nodal losses determined through Eq. (A.52). Since the circulation pump for the loop must compensate exactly for these losses in steady-state, the pump pressure necessary to maintain the given loop fluid flowrate is set equal to the calculated total loop frictional pressure loss.

In calculating the friction losses for a secondary distribution loop, consideration must be given to the fact that the total fluid flow is split among several parallel branches serving the load center heat exchangers. Since all the branches in a given loop have common supply and return headers, the fluid flowing through each branch must experience the same total pressure drop. The flow regulation valve model employed in Subroutine PRESS uses this fact to introduce external pressure losses into selected branches in order to maintain different flowrates in similar flowchannel geometries. The desired nodal fluid flowrates are supplied to Subroutine PRESS from either the steady-state system calculation (Subroutine STDY) or the thermostat-controlled system projection (Program MAIN). Since all the calculations which establish these flowrates are based upon instantaneous energy balances across each of the heat exchangers in the system, the flows are divided among the parallel branches according to the relative thermal loads which they must supply. In each secondary distribution loop, the nodal friction pressure losses are calculated through Eq. (A.52), and the largest parallel branch pressure drop is taken as the reference for the remainder of the branches. It is assumed that the valve in this reference branch is fully open, and the valves in the remaining branches are set by adding a valve friction term to each nodal friction factor to make all the parallel branch pressure losses equal to the reference. This parallel branch pressure drop is then added to the series node frictional losses to determine the total fluid pressure drop for the loop and to establish the circulation pump pressure necessary to maintain the desired flowrates.

During normal simulation periods, the instantaneous flowrates determined in Subroutine FLOWS are applied to Subroutine PRESS, where the loop fluid friction pressure losses corresponding to these flows are calculated. These frictional losses are then compared with the loop circulation pump pressure settings to determine the rates of fluid acceleration or deceleration as indicated in the section describing Subroutine FLOWS. The parallel branch flow regulation valves are set at the beginning of the simulation and every time the thermostat is activated to adjust the pump pressures. During normal dynamic calculations, however, their settings (i.e., the added terms in the parallel branch friction factors) remain constant as determined by the desired flow conditions, while the fluid friction losses for each of the nodes change as the loop flowrate varies. The valves thus establish the relative parallel branch fluid flow splits based upon the desired system energy supply conditions and maintain these flow ratios until they are reset by the thermostat. (No models of the bypass valves in the primary loop are contained in Subroutine PRESS, since those valves are set through the combined effects of the thermostat flow split calculations in Program MAIN and the pump pressure resetting section of Subroutine FLOWS.)

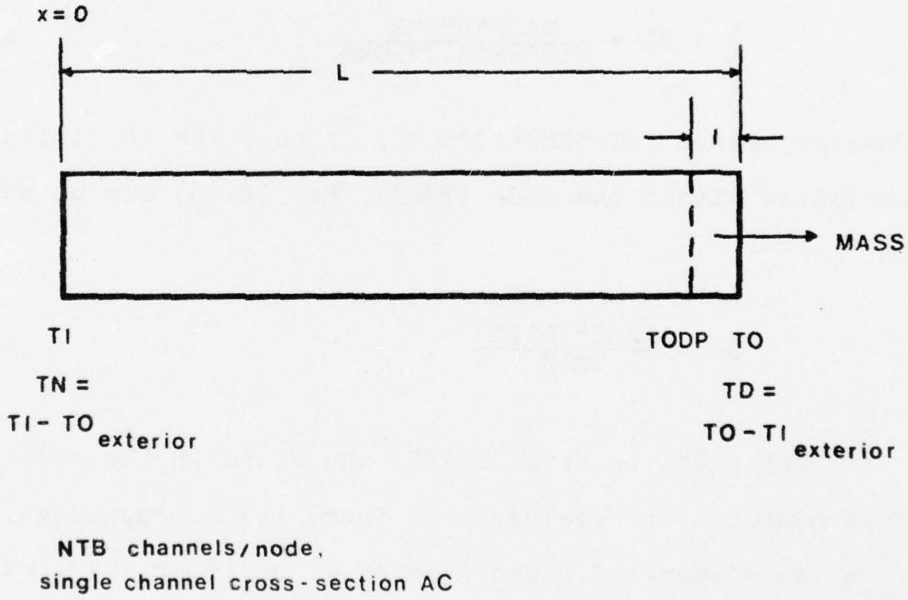
A.3.9 Dynamic Energy Balance (Subroutine ENRG)

The dynamic energy flow calculations in Subroutine ENRG form the basis for the entire time-dependent TUS simulation since they determine the rate at which the distribution system follows the thermal energy supply and demand variations. The system fluid flowrates and nodal temperatures are assumed to be constant during each time interval according to the net imbalances in the heat flowrates and momentum transfers computed during the time step. Subroutine ENRG calculates the nodal inlet and outlet fluid temperatures throughout the TUS based upon an analysis of the nodal thermal energy flows during each time step. It is called from Subroutine FLOWS before any other system parameters are adjusted because, unless the thermostat is activated, the fluid flowrates vary independently of the fluid temperatures, while the energy flows and temperature variations depend strongly upon the fluid mass flowrates existing during the interval being studied.

All energy transfer calculations in Subroutine ENRG have been derived under the assumption that the fluid in a given node travels only a relatively small fraction (e.g., 10-20%) of the length of the node during a single time step. (This criterion should be the dominant factor in the determination of the time step size specified for a given simulation.) During transients, the fluid inlet and outlet temperatures on either side of a heat exchanger may be perturbed so as to cause the temperature profiles to deviate from their steady-state shapes. In order to follow such perturbations along the entire length of a node, it is rigorously necessary to incorporate into the analysis an incremental flow indexing scheme which traces the time history of each element of fluid as it travels through each node in its respective piping loop. However, the effects of these continuous variations in the fluid temperature profiles may be modelled adequately for most situations encountered under normal system operating conditions by concentrating only upon the incremental energy flow variations at the inlet and outlet of each node. Subroutine ENRG therefore examines only the thermal energy transferred into and out of the incremental volume of fluid displaced during the time interval being studied. In Fig. A.8, it is assumed that a particle of fluid at $x = L - \ell$ at the beginning of a time step $(t = 0)$

Figure A.8

Dynamic Nodal Energy Transfer Parameters



flows to $x = L$ at the end of the interval ($t = \mathrm{DTIME}$); thus

$$\ell = v{*}\mathrm{DTIME} \; , \tag{A.55}$$

where v is the nodal fluid velocity. Expressing the fluid velocity in terms of the nodal mass flowrate, the fraction of the length of the node travelled by the fluid in DTIME is

$$\frac{\ell}{L} \equiv \mathrm{DL} = \frac{\mathrm{MASS{*}DTIME}}{\mathrm{NTB{*}RHO{*}AC{*}LONG}} \; . \tag{A.56}$$

However, since (NTB*RHO*AC*LONG) is just the total fluid mass contained within the node (TMAS), Eq. (A.56) can be rewritten as

$$\mathrm{DL} = \frac{\mathrm{MASS{*}\ DTIME}}{\mathrm{TMAS}} \; . \tag{A.57}$$

During the interval DTIME, the fluid in the node transfers heat to (or receives heat from) its surroundings. Therefore, an element of fluid located at position $x = L - \ell$ at the beginning of a time step will experience a temperature change during the interval due to the net heat loss or gain it experiences while traversing the distance ℓ. Denoting the temperature of the fluid at $t = 0$, $x = L - \ell$, as TODP, the temperature of the fluid at $t = \mathrm{DTIME}$, $x = L$, as TOP, and the temperature change of the fluid as it passes from $x = L - \ell$ to $x = L$ as DTC, the basic equation for determining the new nodal fluid outlet temperature at t = TDIME is

$$TOP = TODP - DTC \ . \tag{A.58}$$

At any given instant, the only parameters specified for each node are the fluid mass flowrate, the inlet and oulet temperatures, and the external conditions affecting the heat transfer rate from the node (e.g., the ambient earth temperature for a pipe node or the fluid mass flowrate and inlet and outlet temperatures on the opposite side of a heat exchanger). The detailed nodal temperature profiles are not calculated, necessitating an approximation to be made in the determination of the fluid temperature TODP. An exponential temperature difference profile is assumed for each node, having the general form:

$$T_d(x) = TN \exp(-\alpha x) \ , \tag{A.59}$$

where $T_d(x)$ = temperature difference between the fluid in the node and its surroundings at position x,

TN = temperature difference between the fluid in the node and its surroundings at the node inlet, and

α = temperature difference decay constant.

Since the nodal outlet temperature difference, TD, is also known, Eq. (A.59) can be solved to yield a value for α in terms of the instantaneous values of TN and TD:

$$-\alpha L = \ln\left(\frac{TD}{TN}\right) , \qquad (A.60)$$

and the temperature difference profile becomes*

$$T_d(x) = TN \exp[\ln(\frac{TD}{TN})*\frac{x}{L}] . \qquad (A.61)$$

It is also assumed that the slope of the fluid temperature profile at any point along the length of a node is directly proportional to the heat transfer rate from the node at that point and, hence, to the difference between the nodal fluid

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*It should be noted that this exponential difference profile will yield the well-known log-mean temperature difference for steady-state heat conduction in a counterflow heat exchanger:

$$\pi dU\int_o^L T_d(x)dx = \pi dUL\left[\frac{TN}{\ln\left(\frac{TD}{TN}\right)}\right]\left[\frac{TD}{TN} -1\right]$$

$$= AU\left[\frac{TD - TN}{\ln\left(\frac{TD}{TN}\right)}\right]$$

$$= AU\ \Delta T_{\ell mc} .$$

This profile is thus valid for steady-state heat transfer calculations and can be extended to transient calculations of the type made in the current model with little error in the resulting heat flows.

and external surroundings temperatures at that point. If the average slope of the fluid temperature profile for the entire node

$$T_S(av) = \frac{TI - TO}{L} \tag{A.62}$$

is the result of heat conduction from the node at the average log-mean temperature difference between the fluid and its surroundings

$$DTLM = \frac{TD - TN}{\ln\left(\frac{TD}{TN}\right)} , \tag{A.63}$$

then the ratio of the average slope of the temperature profile in the region between $x = L - \ell$ and $x = L$ to the average slope for the entire node is given by the ratio of the log-mean temperature difference over that region to the average nodal difference. (i.e., The ratio of the profile slopes is equal to the ratio of the heat conduction rates.) Since the log-mean temperature difference over the region of the node from $x = L - \ell$ to $x = L$ is given by:

$$DTLMX = \frac{TD - TDX}{\ln\left(\frac{TD}{TDX}\right)} , \tag{A.64}$$

with TDX being calculated through Eq. (A.61) at $x = L - \ell$, the average slope of the nodal fluid temperature profile over this region of the node can be approximated by

$$T_S(x) = T_S(av)\left[\frac{DTLMX}{DTLM}\right] \quad . \qquad (A.65)$$

Knowing the average slope of the temperature profile and the nodal fluid outlet temperature, it is possible to estimate the temperature of the fluid at $x = L - \ell$ to be:

$$TODP = TO + DL*(TI - TO)*(\frac{DTLMX}{DTLM}) \quad . \qquad (A.66)$$

In order to calculate the temperature change of the fluid due to heat conduction effects as it flows from $x = L - \ell$ to $x = L$, it is necessary to determine the average heat transfer rate from the fluid to its surroundings over this region. Integrating the assumed exponential temperature difference profile from $x = L - \ell$ to $x = L$ yields the result that the average conduction heat transfer rate from the fluid is

$$\dot{Q}_c = AUF\left[\frac{TD - TDX}{\ln(\frac{TD}{TN})}\right] \quad , \qquad (A.67)$$

where AUF is the overall heat transfer coefficient for the total node. If it is assumed that the heat lost from the incremental volume of fluid in node length ℓ during DTIME results in a change in the average fluid temperature of magnitude DTC, energy conservation requries

$$Q_c*DTIME = NTB*RHO*AC*\ell*CAP*DTC \quad . \qquad (A.68)$$

Using Eq. (A.56) to express ℓ in terms of the fluid mass flowrate and simplifying the resulting expression yields the average temperature change of the fluid due to conduction heat losses:

$$DTC = \frac{\dot{Q}_c}{MASS*CAP} \quad . \qquad (A.69)$$

The expressions for the nodal fluid outlet temperature assuming no heat loss (Eq. (A.66)) and for the temperature change due to heat conduction effects (Eq. (A.69)) are combined through Eq. (A.58) to yield a new value for the nodal fluid outlet temperature at the end of the time step being studied. As indicated by the preceding discussion, the calculations leading to this temperature essentially consist of a comparison between the convective and conductive heat flowrates from the fluid in the final volume increment of the node. If the nodal thermal energy demand increases over its steady-state value, DTC will increase in magnitude and the outlet temperature will decrease as heat is removed from the fluid at a rate faster than it is supplied to the node by the steady-state fluid flowrate. If the demand decreases, the outlet temperature will increase as the fluid is swept through the node faster than heat is removed from it through conduction.

The basic nodal analysis outlined above for heat exchanger nodes is also employed in the adjustment of pipe node outlet temperatures, with the only modifications being that the temperature "profile" of the "opposite node" is the constant earth temperature TAMB and that - due to the generally small differences between the pipe node inlet and outlet temperatures - all exponential temperature relations are approximated by linear functions.

Following computation of all the revised nodal outlet temperatures, the nodal inlet temperatures are set by requiring continuity of the fluid temperature profiles across the boundaries between adjacent nodes. For series nodes, the inlet temperature of a node is simply set equal to the new outlet temperature of the preceding node in the loop. The inlet temperatures to the pipe nodes following the primary loop secondary supply heat exchangers are given by the heat exchanger and bypass fluid mass-flowrate-average of the preceding node's inlet and outlet temperatures. The inlet temperature to the return pipe in a secondary distribution loop is the mass-flowrate-averaged outlet temperature from the parallel load center heat exchanger branches. The inlet temperatures to the consumer-side nodes of the load center heat exchangers are calculated in Program MAIN from the heat exchanger fluid flowrates, the fluid outlet temperature computed through the dynamic heat exchanger analysis in this subroutine, and the thermal demands obtained from linear interpolation of the hourly loads computed in Subroutine DLOAD.

During the computation of the new nodal temperatures, Subroutine ENRG institutes a fairly complicated system of temperature monitoring and adjustment calculations to insure that the approximations made do not violate physical heat transfer laws or lead to mathematical relations exceeding the computational capabilities of the computer. The heat exchanger inlet and outlet temperature differences, TN and TD, are allowed to have minimum magnitudes of 10^{-6} °F to insure the finiteness of calculations involving logarithms of their ratio. Similarly, if the ratio TN/TD is within 10^{-6} of 1.0 (i.e., if the fluid temperature profiles are virtually parallel along the entire length of the heat exchanger), the energy flow calculations described above are performed using linear approximations to all the exponential relations, thereby avoiding the calculation of logarithms of 0, dividing by 0, etc. Although TN and TD are allowed to have opposite signs (indicating a crossing of the temperature profiles due to instantaneous transient conditions at either end of the heat exchanger), if this condition is detected, linear approximations to the exponential relations are employed to return the parameters to the unidirectional energy flow conditions satisfying the Second Law of Thermodynamics. Finally, if the computed nodal outlet temperatures are found to violate the Second Law of Thermodynamics (e.g., if the outlet fluid temperature on the supply side of a heat exchanger is lower than the inlet fluid temperature on the demand side), finitely small temperature differences of magnitude 10^{-6} °F and of the correct sign are assigned between the errant values, and the system is allowed to correct itself through the continuing transient temperature adjustments made during the succeeding time intervals.

A.3.10 Precooler Monitor (Subroutine PREC)

The precise identification assigned to the TUS supply heat exchanger will depend upon the method and location in which heat is extracted from the power plant's coolant flowstream. However, for many plant types, this heat exchanger could take the form of a coolant precooler inserted into the turbine exhaust flowstream upstream of the fluid compressors [13]. Although this heat exchanger is not modelled by TDIST in the detail afforded to the TUS distribution loop units, its temperature and fluid flowrate parameters are monitored during each simulation time step to insure that the power plant-TUS energy interchange is at least obeying the physical constraints of the Second Law of Thermodynamics. The heat transfer coefficient of this heat exchanger is assumed to be "very large", such that any variations in the fluid temperatures on one side are immediately reflected in a temperature variation on the opposite side. In the current version of

TDIST, Subroutine PREC simply adjusts the power plant coolant flowstream inlet and outlet temperatures and the coolant flowrate to insure that the coolant temperatures are always greater than (or in the limiting case, equal to) the water temperatures on the TUS side of the heat exchanger and that the rate of heat transfer matches the power plant's net rate of thermal energy production.

A.3.11 Output (Subroutine PRV)

Subroutine PRV provides the primary output function for the code and is called at regular intervals specified by the user-defined print frequency code. Output data includes the nodal fluid mass flowrates and inlet and outlet temperatures, the instantaneous heat flowrates through each heat exchanger, information on the volume of water stored in both sections of the reservoir, the temperatures and flowrates on both sides of the TUS supply heat exchanger, and the instantaneous loop circulation pump pressure settings.

A.4 Simulation Run Options

Figure A.9 is a simplified flowchart for TDIST illustrating the major program components and decision control branches. Depending upon the type and extent of the system analysis desired, the code provides the flexibility of three general run options: (1) the calculation and distribution of the individual building thermal and electrical energy demands,

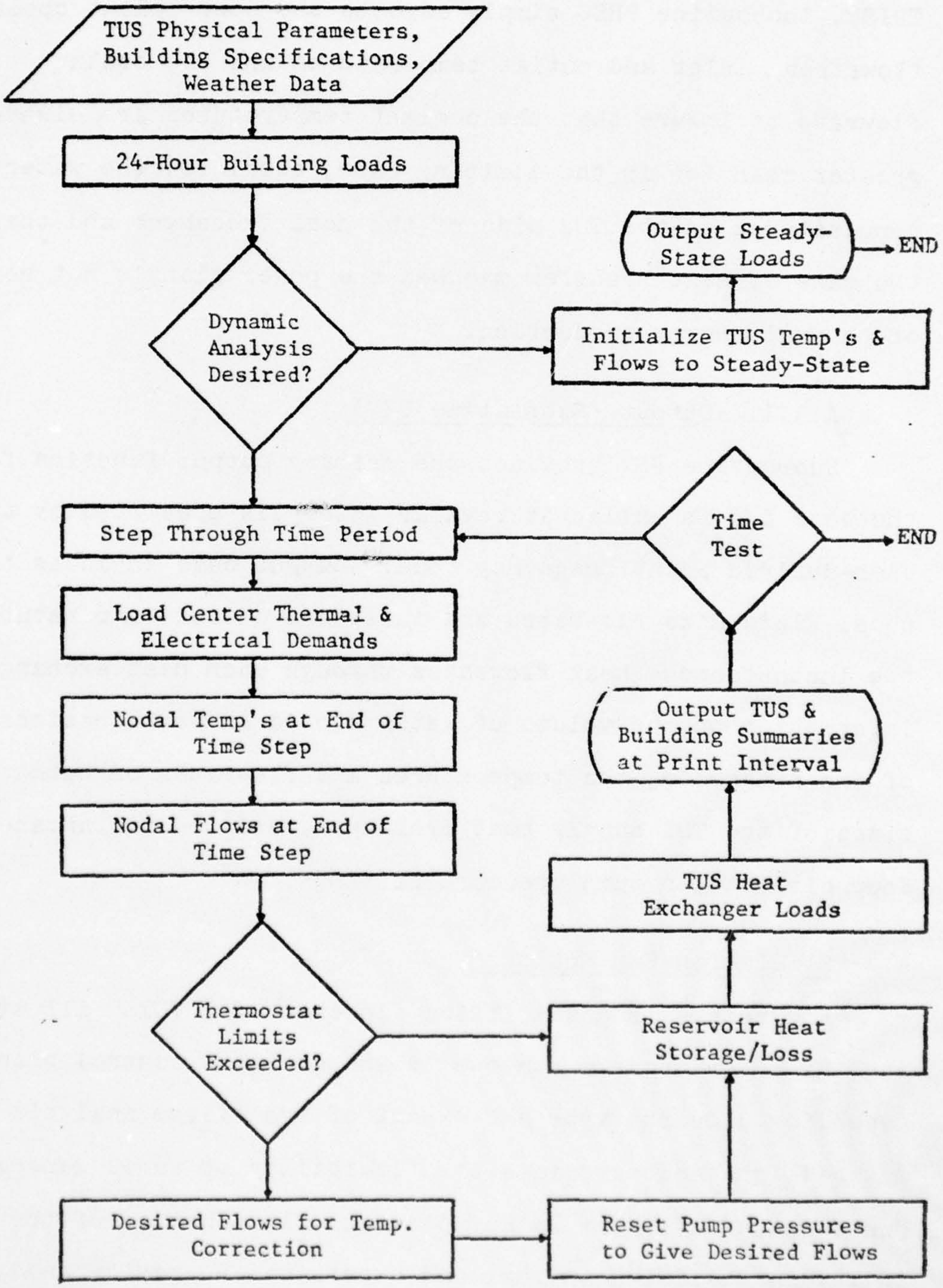

Figure A.9

Simplified TDIST Flowchart

(2) the iterative steady-state convergence of the TUS nodal temperatures and fluid flowrates, and (3) the full time-dependent TUS energy flow analysis. The following sub-sections describe briefly the computation format and parameter specifications for each of these options. Detailed input data requirements and output listings for the code are described in sections A.5 and A.6.

Two user-defined program flow control codes determine the simulation option(s) chosen for a given computer run and set the paths for the inter-subroutine data transfer and information outputs. The primary run control code is KODE, which determines the type of analysis to be performed. KODE = 0 allows either the calculation and output of the hourly building energy demands and the distribution of the initial loads according to the TUS load center heat exchanger locations or, depending upon the value of the second control code (IDES), it causes the TUS steady-state analysis to be performed. KODE = 1 indicates that the hourly building use and weather data specifications should be read in and, unless it is over-ridden by IDES, causes the dynamic system simulation to be performed. KODE = 2 indicates that the run is to be terminated. Whenever the value KODE = 0 is input to the program, the design run option code IDES must be specified. IDES = 0 indicates that the run to be made is simply the TUS steady-state analysis, based upon a computed single time instant building load distribution. IDES = 1

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TDIST, A PROGRAM FOR COMMUNITY ENERGY DEMAND ANALYSIS AND TOTAL--ETC(U)
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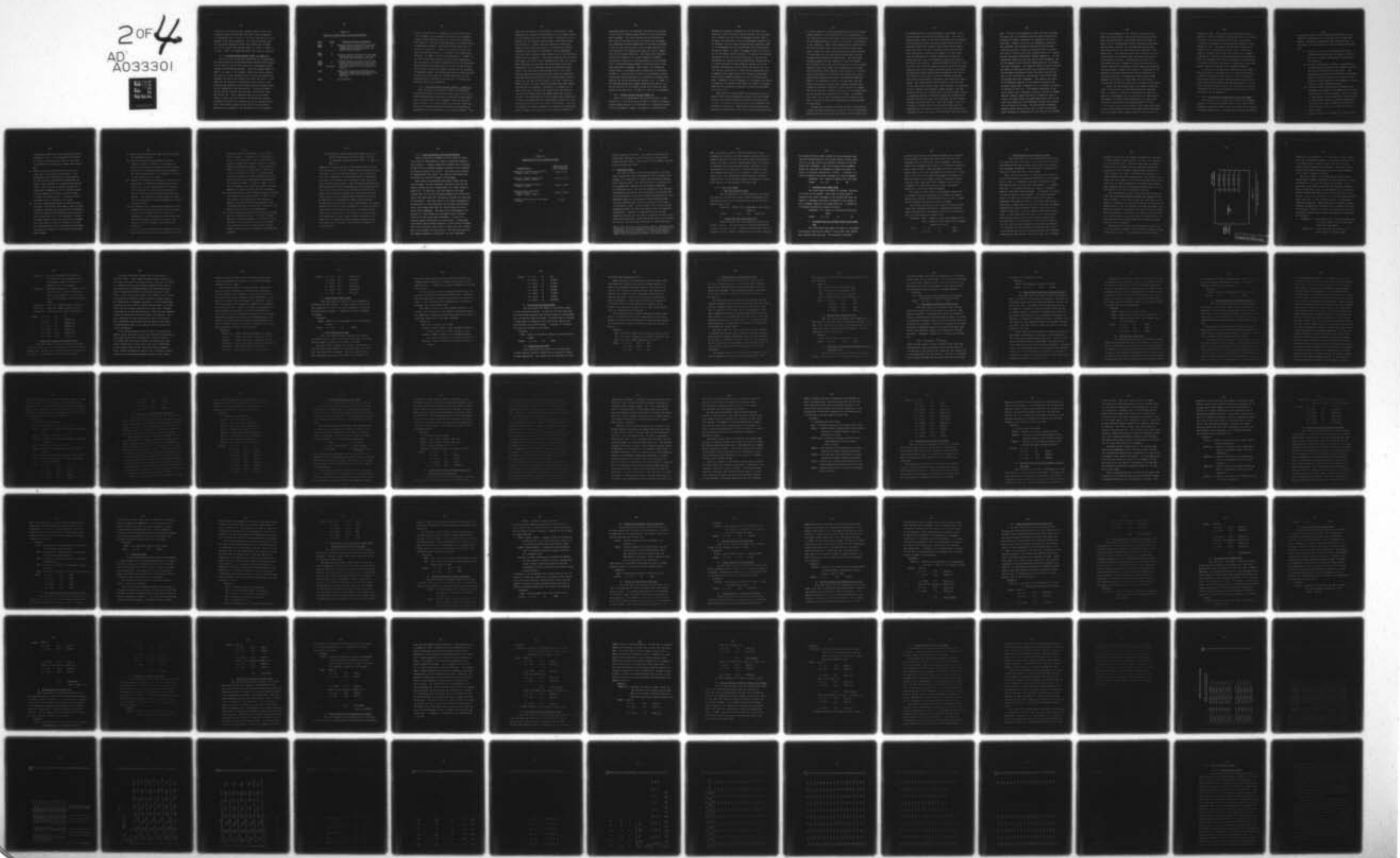

allows the calculation of the building loads and their distribution among the specified load center heat exchangers, but terminates the run prior to the actual application of the demands to the heat exchangers. The hourly building loads for the entire simulation period are computed and printed out if the control code sequence KODE = 0, IDES = 1, KODE = 1 is input. Table A.9 summarizes these basic control functions.

A.4.1 Building Energy Demands (KODE = 0, IDES = 1)

This run option allows the calculation of the magnitudes and distribution of the building energy demands without applying the loads to the TUS load center heat exchangers or performing any TUS-related analyses. When the sequence KODE = 0, IDES = 1 is input to the program, single time instant values are read in for each building type's desired room temperature, equipment use factor and domestic hot water use factor. Also input are the ambient air temperature, wind velocity, wind direction and non-space-conditioning electrical demand factor for the community at the time instant. Subroutine QLOAD is called, and the computed building space conditioning loads are printed out. These loads are supplied to Subroutine DLOAD, in which they are scaled by the appropriate end-use equipment coefficients of performance and are aggregated into load center thermal energy demands and a total electrical demand for the community. The distribution of the building

TABLE A.9

TDIST RUN OPTION CONTROL CODE SPECIFICATIONS

Code	Value	Resulting Program Performance
KODE IDES	0 0	Building demands calculated at one time instant and distributed to TUS: TUS steady-state analysis performed and system summary printed
KODE IDES	0 1	Building demands calculated at one time instant and distributed to TUS: building loads and distribution printed
KODE IDES KODE	0 1 1 (sequence)	Building demands calculated at one time instant and distributed to TUS: building loads and distribution printed; hourly buildings loads calculated and printed
KODE	1	Dynamic TUS simulation performed; TUS parameter summary and load distribution printed at user-specified output intervals
KODE	2	Run terminated

loads is printed out by building type at each load center heat exchanger, and a summary is provided of the aggregate thermal energy demands at each load center heat exchanger. When control is returned to Program MAIN, a succeeding value of KODE must be input. This value of KODE should not, in general, be equal to 0, unless it is desired to repeat the same calculation sequence or to perform a TUS steady-state analysis. If KODE = 2, the run is terminated. If KODE = 1, up to 24 hourly data values for the building temperatures and use factors, the hourly weather data, and the hourly non-space-conditioning demand factors are read in, are printed out in a set of input data summary tables, and are supplied to Subroutine QLOAD. An hour-by-hour space conditioning load calculation is performed for each building type, and the resulting hourly load data is printed out. Following this printout, the run is terminated.

A.4.2 TUS Steady-State Analysis (KODE = 0, IDES = 0)

This run option initializes the TUS to steady-state energy and momentum flow conditions based upon a set of computed building energy demands and a specified energy supply rate at the TUS supply heat exchanger. When the sequence KODE = 0, IDES = 0 is input, single time instant values are read in for each building type's desired room temperature, equipment use factor and domestic hot water use factor. Also input are the ambient air temperature, wind velocity, wind direction and non-space-conditioning electrical demand factor for the community at that time instant. Subroutine QLOAD is called, and the computed building space conditioning loads are printed out. These loads are supplied to Subroutine DLOAD, in which they are scaled by the appropriate end-use equipment coefficients of performance and are aggregated into load center thermal energy demands and a total electrical demand for the community. From these loads and the user-specified supply and return water temperatures at each load center heat exchanger are calculated the steady-state fluid mass flowrates in all the consumer energy distribution piping nodes. The total space conditioning, domestic hot water, and non-space-conditioning electrical loads are subtracted from the specified power plant total thermal power output to obtain the net rate of heat supply to the TUS. Subroutine STDY is called, in which iterative steady-state heat balance calculations are employed to determine a converged set of nodal fluid mass flowrates and temperatures which satisfy the combined energy supply and demand conditions faced by the TUS. The resulting loop fluid flowrates are transmitted to Subroutine PRESS, and the corresponding steady-state loop circulation pump pressure settings are determined. Although the primary loop heat exchangers are analyzed in steady-state with no bypass flows around them, the parallel branch flow regulation valves in the secondary loops are set according to the relative thermal energy demands at each load center heat exchanger. The fluid temperatures and flowrates on both sides of the power plant's TUS supply heat exchanger are determined, and the temperatures of the water contained in the hot and cold sections of the storage reservoir are initialized to the steady-state supply and return temperatures in the primary HTW loop. The steady-state TUS parameters are printed out in a nodal energy flow summary, followed by a printout of the distribution of the building space conditioning energy demands by building type at each load center heat exchanger. When control is returned to Program MAIN, a succeeding value of KODE must be specified. If KODE = 0, the user has the option of performing a second steady-state system analysis or of calling the building load analysis run option described in Section A.4.1. If KODE = 1, the computed steady-state nodal parameters are used to initialize the TUS for the dynamic energy flow simulation described in Section A.4.3. If KODE = 2, the run is terminated.

A.4.3 Dynamic System Analysis (KODE = 1)

Unless it is suppressed by the condition IDES = 1 (see section A.4.1), an input value of KODE = 1 causes the dynamic energy system analysis to be performed for a simulation period of up to 24 hours in length. Although it is theoretically possible to specify a consistent set of TUS input data which will allow the dynamic system analysis to be successfully started the first time the program requires KODE to be input, the stability of the time-dependent simulation is so dependent upon the system initialization parameters that it is recommended that the steady-state TUS initialization run option (KODE = 0, IDES = 0) always be used as the front end of the dynamic system analysis. In addition to reducing the amount of hand calculations required of the user and minimizing the chances for TUS instabilities developing due to poorly specified initial parameter values, use of the internal initialization option allows the user to run low cost design calculations to insure system convergence prior to gambling the larger sums of time and money associated with the full dynamic analysis on a set of untested input data. Therefore, in the following, it is assumed that KODE = 1 is read into the computer upon return of control to Program MAIN from the steady-state analysis calculations described in Section A.4.2.

Input data for each building type consists of up to 24 hourly desired room temperatures, domestic hot water usage factors, and occupancy-related building use factors which are used to schedule internal equipment heat generation and forced air ventilation. Weather data inputs include hourly ambient air temperatures, wind velocities and wind directions.

An hourly community non-space-conditioning electrical energy demand schedule is also required for the determination of the components of the power plant load not directly associated with providing heating, cooling, or hot water to each person in the community. These hourly schedules are printed out in input data summary tables and are supplied to Subroutine QLOAD. Hourly net space heating and cooling energy demands are determined for each specified building type, and the building load schedules are printed out. The individual building demands are also supplied to Subroutine DLOAD, which computes and stores the resulting set of hourly thermal demands at each load center heat exchanger and the hourly total electrical energy demand for the community. Initialization calculations in Subroutine SET transfer the steady-state nodal parameters calculated in Subroutines STDY and PRESS to the appropriate nodes in the TUS model, and the primary loop and load center heat exchanger consumer-side thermostat reference temperature limits are set in Program MAIN based upon the converged steady-state fluid temperatures and the design values specified by the user. An internal time clock is set, and the dynamic analysis begins at the hour of the day at which the steady-state system parameters are specified.

During each simulation time step, linear interpolations between the stored hourly data values for the air temperature, system electrical loads, and load center heat exchanger thermal demands provide the instantaneous energy demand conditions applied to the TUS and the power plant. The rate of thermal energy supply to the TUS is determined by subtracting the instantaneous total electrical energy demand from the specified power plant constant total thermal power output. Subroutine ENRG is called to determine the instantaneous fluid temperature distribution throughout the TUS, based upon the assumption of constant energy flow conditions during the time step, with temperature adjustments made at the end of the interval. Subroutine PRESS is called to determine the fluid friction pressure losses in each of the piping loops for the fluid flowrates existing during the time step, and Subroutine FLOWS adjusts these flowrates at the end of the interval, based upon a comparison between the actual circulation pump pressure settings and the computed pressure losses. The instantaneous fluid flowrate in the TUS side of the power plant thermal supply heat exchanger is calculated so as to transfer the available thermal energy to the TUS storage reservoir, and the hot and cold water storage volumes are adjusted through a comparison between the inter-section flowrate through the supply heat exchanger and the flowrate through the primary HTW loop. When the program control is returned to Program MAIN, the new fluid temperatures are compared with the reference values at the load center heat exchangers and at the outlets of the primary loop heat exchangers. If none of the temperature limits has been exceeded, the time clock is incremented and the linear interpolation procedure is begun to determine the demands for the next time step. However, if any of the temperature limits has been exceeded, the thermostat-controlled fluid flowrate correction process is begun by calculating for the entire TUS a set of desired fluid mass flowrates which will exactly satisfy the given instantaneous thermal demands at: (1) the temperature limits for the load center heat exchangers, and (2) the desired fluid reference temperatures at the primary loop heat exchangers. The computed parallel branch flowrates are added to form desired total loop flowrates for each of the secondary distribution loops, and these flowrates are used in the calculation of the required flow splits among the primary loop heat exchangers. The primary loop nodal fluid flowrates computed in this manner for each of the secondary supply heat exchangers will, in general, be uniquely defined for each unit. To preserve continuity of the total primary loop flowstream, therefore, the heat exchanger with the largest computed flowrate is assumed to have no bypass, and bypass flows are established around each of the other units based upon the difference between this maximum and the desired unit flows. The desired heat exchanger/bypass flowrate ratio is then used to scale the existing nodal flowrates to effectively set the required flow splits (but not the magnitudes of the flows) at the end of the time step being studied. The computed desired fluid flowrates are transmitted to Subroutines PRESS and FLOWS, in which a set of corresponding desired circulation pump pressure settings, scaled by the user-defined pump response sensitivity factor, are calculated and are applied to the system pumps. The existing system fluid flowrates are then re-calculated for the given time step based upon these revised pressure settings. (Waiting until the end of the following time step to update the flows could result in an overall inability to adequately follow large load variations occurring during a single time interval.) Following the resetting of the pump pressures and the re-calculation of the fluid flowrates, the thermostat model returns normal program flow control to Program MAIN, the time clock is incremented, and the next time step's calculations are begun.

Output from the program during the dynamic system analysis is controlled by a user-defined printout frequency code. At regular intervals (as frequently as every time step or as infrequently as once each hour) an instantaneous TUS summary is printed which includes all the nodal fluid flowrates, temperatures, and energy demands, the total system thermal and electrical energy supply and demand conditions, the instantaneous circulation pump pressure settings, and the thermal energy storage reservoir fluid volume and temperature data. Power plant sizing information is also printed to indicate whether the specified power plant thermal rating and electrical generation efficency are adequate to supply the community's total electrical demands at that instant in time. Also output at each print interval is a summary of the instantaneous building space conditioning loads by building type at each load center heat exchanger. A summary of the thermal energy supply/demand mismatches at each heat exchanger in the TUS is provided to allow the user to monitor how closely the system is operating to ideal heat balance conditions throughout the simulation period.

At the end of the specified simulation period, KODE = 2 should be input to terminate the run. (Although provision is made for reading in other values of KODE at this time, the analysis re-setting and continuation functions have not as yet been fully developed, and specification of 0 or 1 for KODE would most probably lead to the calculation of invalid information due to residual parameters being held over from the dynamic system analysis.)

A.4.4 Coordination of Options to Aid in TES Design

When TDIST is used to aid in the design and performance analysis of a proposed community Total Energy System (TES) , excessive computation effort, time and expense may be avoided by using a combination of the three basic program run options to yield successively more detailed specifications of the community's demands and of the energy system design parameters. Some general guidelines which have been found to be helpful in the development of such an energy system model are:

(1) Identify a set of up to 20 different building classifications which span the range of architectural and occupancy characteristics observed in the community.

(2) For each classification, define a representative building unit which exhibits the typical structural and usage characteristics of its class. This building may be either an existing unit whose parameters are deemed typical, or it may be a representative model composed of the aggregate characteristics of several individual units.

(3) Distribute these representative building units throughout the community according to the observed distribution of actual buildings. The total number of representative units specified at each location in the community should be chosen to approximate the total floor area (or some other equivalent energy demand index) of the actual buildings at that location.

(4) Aggregate groups of buildings into energy demand

load centers, based upon their number density and similarity of use. In sizing these load centers, it should be remembered that each one connected to the TUS will be served by a single heat exchanger.

(5) Design a proposed TUS piping layout which will supply HTW to the desired load centers. (Not necessarily every load center will be served by the TUS, since the economically optimum TES may require some buildings to be supplied all-electrically.) Each load center should be served by a single heat exchanger, up to five of which should be piped together in parallel to form a single secondary distribution loop. A maximum of five secondary loops is allowed in the system.

(6) Once this rough system design has been specified, estimates of pipe sizes and lengths, pumps and heat exchanger locations, and pipe insulation parameters should be coded into the TDIST TUS input data formats (see Section A.5). The distribution (number of units served by each load center heat exchanger and total number of units not served by the TUS) and specifications of each representative building type should be coded into the TDIST building input data formats.

(7) Specify the hourly weather data to be used during the simulation period.

(8) Use the building design analysis run option (KODE = 0, IDES = 1, KODE = 1) to provide the space conditioning load profile for each building type over the simulation period and to aggregate the total energy demands to be supplied by the TUS at the beginning of the period.

(9) Examine the computed load profiles to identify any questionable or invalid building data specifications (i.e., if the load profile is not "reasonable", identify the controlling load component and the building parameters determining that component). Any parameter revisions should be verified by re-running the code and generating a corrected set of loads.

(10) If necessary, due to significant imbalances in the thermal load distribution within a given secondary loop, the load centers should be redefined or rearranged to yield reasonably uniform loads among the heat exchangers in each loop, and the code should be re-run to generate the revised load distribution.

(11) Once the building loads have been verified, use the given demand distribution and specifications of the

desired TUS fluid temperatures to size the TUS heat exchangers. In general, it is advisable to run the code twice during this sizing exercise, unless the peak hourly demands occur at the beginning of the simulation period. One run (KODE = 0, IDES = 1, KODE = 1, as summarized in steps 8-10) is used to generate the hourly building demands and the TUS loads to be used in specifying the required initial system temperatures and flowrates; the second run (KODE = 0, IDES = 1, KODE = 2) is used to determine the single time instant TUS peak demands to be used in sizing the heat exchangers.

(12) After specifying the heat exchanger designs, perform the steady-state analysis (KODE = 0, IDES = 0) of the system at the beginning of the simulation period to insure that the system design is self-consistent and that the system will converge to the desired fluid flowrates and temperatures.

(13) If necessary, make design revisions (such as changing heat exchanger ratings, the initial primary HTW loop fluid mass flowrate, or the sizes of the distribution loop piping) and re-run the steady-state analysis until the desired fluid flowrate, pressure loss, and fluid temperature conditions are achieved.

(14) Perform the time-dependent TES simulation by calling the steady-state analysis option, followed by the dynamic system analysis (KODE = 0, IDES = 0), KODE = 1).

Expansion of the run options in this manner from the building load analysis to the full dynamic system simulation allows the user to clearly define the community loads (which are, of course, independent of the assumed method of energy supply) prior to performing any TES analyses other than choosing a proposed piping layout. Once the proper building models have been specified and the appropriate TUS configuration has been chosen, the resulting heat exchanger designs and proposed fluid flowrate and temperature specifications may be fully tested, and any required system design revisions may be made prior to performing the dynamic system analysis. Following full specification of the system design, the dynamic analysis run option provides information as to how the particular design chosen behaves over time. Although possibly seeming over-conservative in its approach to system design, this methodology allows a logical system development and, based upon the computation time estimates outlined in the following section, provides a cost-effective sequence of system analysis.

A.4.5 Computer Execution Time Specifications

TDIST is written in FORTRAN IV and is directly compatible with the IBM System 370 computer using the FORTRAN H-level compiler. Program compilation requires the allocation of 288 K bytes of working storage; execution of the compiled load module requires 128 K bytes. The source deck consists of approximately 1800 cards. The compiled load module may be stored on a total of 8 tracks of disk space.

When using a pre-compiled load module called from reserve storage, the user may expect execution times for the various program options to approximate the values listed in Table A.10. In each case, the time shown is the total elapsed time for the run, including program set-up and blocking of the output data for subsequent printing; all times are in CPU-minutes. The lower limit of the range corresponds to the analysis of a TUS containing two secondary distribution loops, one serving three and the other serving five load center heat exchangers. The upper limit corresponds to the analysis of a TUS having four secondary loops, serving a total of 18 load center heat exchangers. A total of 11 building types are specified for each system. Steady-state system input data includes estimates of the initial secondary loop fluid flowrates, which serve to reduce the total convergence time required for each system. The time step size for the dynamic analyses is 0.001 hour, and each simulation

TABLE A.10

REPRESENTATIVE OPTION EXECUTION TIMES

Program Option	Execution Time (CPU - minutes)
Single-time building load analysis (KODE=0, IDES=1, KODE=2)	0.096 - 0.112
24-hour building load analysis (KODE=0, IDES=1, KODE=1)	0.110 - 0.123
Steady-state system analysis (KODE=0, IDES=0)	0.105 - 0.108
24-hour dynamic simulation (DTIME = 0.001) (KODE=0, IDES-0, KODE=1)	4.374 - 8.691
Program compilation and load module storage	0.692

covers a period of 24 hours. The dynamic simulations are initialized internally by first calling the steady-state system analysis option. Data output for the dynamic analyses occurs at every half hour.

A.5 TDIST Input Data

All input to TDIST is from cards supplied by the user. Since fixed-format input statements are used throughout the program, it is important to follow the data format instructions outlined below. The data which must be specified for each program run* consists of four general categories: (1) specifications of the physical parameters, heat transfer coefficients, and average fluid conditions in each TUS node, (2) specifications of the heat transfer characteristics, time-dependent usage, and distribution of each building type, (3) hourly weather data, and (4) program run control and initialization codes. To some extent, these categories are segregated within the input data deck for ease of parameter modification. However, the segregation is by no means complete, and care must be taken to formulate the deck in the exact order presented. Input diagnostics exist, but are minimal and are only available during runs in which Subroutine

*Input data flexibility is extremely limited. Depending upon the type of run to be performed, some data values may be left unspecified, but their locations in the data deck must be filled with blanks or dummy values to facilitate correct input of all the required information (see Section A.5.3.)

STDY is executed; errors in data specification or card punching will appear in the input summary printed with each program execution, but will not usually cause termination of a given run until a serious computational error is detected. To minimize costly input-related errors, therefore, it is recommended that the data deck be checked carefully before each program execution, and, if possible, a short program option (e.g., the steady-state system analysis) should be executed prior to any extended dynamic simulations to internally verify the correctness of the input data.

A.5.1 Data Card Format

1. Run Identification Cards

For the purposes of run identification, the first two cards in the data deck should contain alphanumeric run descriptions which will be printed at the top of the first page of output data.

Variables: TITLE, CITY - alphanumeric run identifications

Format: c.c. 1-80 20A4 TITLE,CITY

2. Primary HTW Loop Node Number Card

This card inputs the total number of nodes in the primary HTW loop. For the purposes of system determination, a node is defined as either a length of pipe having constant diameter and heat transfer characteristics or a heat exchanger.

The primary HTW loop nodes include the pipes supplying heat from and returning heat to the thermal energy storage reservoir, but do not include the reservoir sections or the TUS supply heat exchanger. Pipe runs between heat exchangers within the loop must be included, no matter how short, to result in effective calculation of losses. A maximum of 13 nodes is allowed, including a maximum of 5 heat exchangers.

Variables: NH - number of primary HTW loop nodes

Format: c.c. 1-3 I3 NH

3. Secondary Loop Number Card

This card inputs the number of secondary distribution loops in the system. Since each of these loops is supplied from a heat exchanger in the primary HTW loop, the number of secondary loops must correspond to the number of heat exchanger nodes in the primary HTW loop. A maximum of 5 secondary distribution loops is allowed.

Variables: LS - number of secondary distribution loops

Format: c.c. 1-3 I3 LS

4. Secondary Loop and Consumer Branch Node Number Card

This card inputs the number of nodes in a secondary distribution loop and the number of load center heat exchangers supplied from the loop. The secondary loop nodes specified must include the primary/secondary heat exchanger, the secondary loop supply and return pipes for this heat exchanger, and the load center heat exchangers. The load center heat exchangers are assumed to be supplied in parallel from a common header. Nodes including the pipes from this supply header to the heat exchangers and from the heat exchangers to the loop return header should not be included; each parallel branch in a secondary loop will therefore contain only the single load center heat exchanger node it serves. A maximum of 13 nodes per loop is allowed, including a maximum of 5 load center heat exchangers.

The number of load center heat exchangers supplied by a secondary loop must correspond to the number of parallel branch heat exchanger nodes specified for the loop. A maximum of 5 parallel branches per loop is allowed.

Since this card specifies the number of nodes and load center heat exchangers for only one secondary distribution loop, one card must be supplied for each of the loops specified on the Secondary Loop Number card.

Variables: ND(L) - number of nodes in secondary loop L

NB(L) - number of load center heat exchangers supplied by loop L

Format:	c.c. 1-3	I3	ND(L)
	c.c. 4-6	I3	NB(L)

5. Node Dimension and Location Code Card

This card inputs the node identification and location codes for any of the nodes in the system and the physical dimensions and heat transfer coefficient for the pipe or heat exchanger represented. One card must be supplied for each of the nodes specified in the system.

Basic node identification is accomplished through the use of three indicators, generally designated in the program as K, L, and N. K identifies the major subsection of the distribution system in which the node appears: 1 = primary HTW loop, 2 = secondary distribution loops, 3 = consumer sides of load center heat exchangers. L indicates the specific loop in which the node appears: for the primary HTW loop L ≡ 1; each of the secondary distribution loops is numbered in the order in which it is supplied from the primary loop, L ranges from 1-5; the load center heat exchangers supplied from a given secondary loop are coded with the L number of that loop. N is the specific node number within a loop: in the primary HTW loop, node 1 is the outlet pipe from the hot water section of the storage reservoir and the last node is the return pipe to the cold water section from the final secondary supply heat exchanger (maximum of N = 13 nodes); in each secondary distribution loop, node 1 is the outlet pipe from the primary/secondary heat exchanger supplying the loop and the last node is that heat exchanger;

parallel branch nodes are numbered consecutively according to their schematic representation (see Fig. A.10) (maximum of N = 13 nodes per loop). The load center heat exchangers served by each secondary loop are numbered consecutively according to their schematic representation (maximum of 5 heat exchangers per loop). Following this convention, a nodal parameter with the designation X(2,3,8) would be associated with node number 8 in the third secondary distribution loop; Y(3,2,4) would correspond to the fourth load center heat exchanger served by the second secondary loop; Z(1,1,1) would apply to the first primary HTW loop node.

The identification codes on this card must include the N for the node being specified (K and L are supplied internally according to the order in which the nodal data is supplied), an indicator for whether the node is a series flow or parallel branch node (all primary loop nodes are series, the parallel secondary loop branches and load center heat exchangers are parallel), an indicator for whether or not the node is a heat exchanger, and an indicator for whether or not the node contains the circulation pump for the loop (one pump node per loop is allowed).

Dimensional data which must be supplied includes the nodal flow channel diameter (in feet) and the physical length of the node (in feet). For pipe nodes, the flow channel

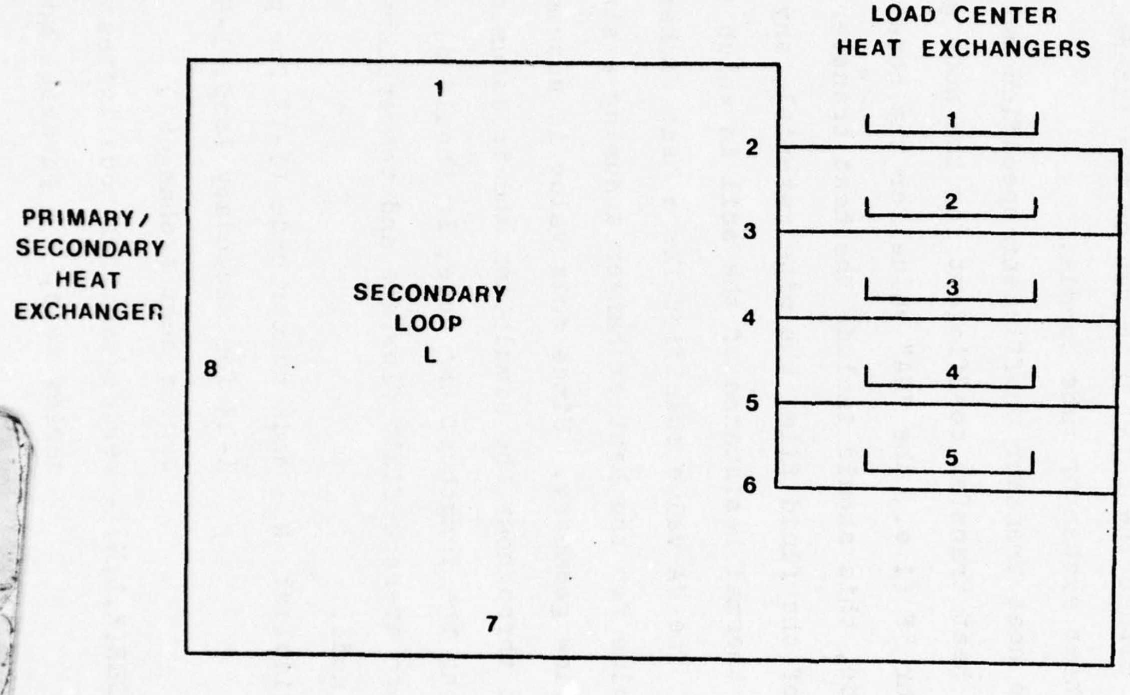

Figure A.10

Secondary Loop and Load Center Heat Exchanger Node Numbering Conventions diameter is the specified I.D. of the pipe; for heat exchangers, the flow channel diameter to be specified is the I.D. of a single tube or channel between the tubes (not the overall heat exchanger shell diameter). The length of the node is either the total pipe run or the lateral dimension of the heat exchanger tube bundle.

The heat transfer coefficient specified must be the overall heat transfer coefficient for the node given in units of BTU/hr-°F (i.e., the "UA" value for the node). For a pipe node, this should include the heat transfer characteristics of the fluid film, the pipe material, any insulation, and the thermal resistance of the soil in which the pipe is buried. The UA value specified for a heat exchanger must be the total value for the heat exchanger assuming a single-pass counterflow geometry. Since this value is assumed to remain constant throughout the simulation and is assumed to be uniform along the length of the node, it should be specified at the design average fluid flowrate and temperature conditions for the node.

Variables: N - node number code (1-13 for primary loop, 1-13 for secondary loop, 1-5 for load center heat exchangers)

ISER(K,L,N) - series/parallel node indicator (0 = series node, 1 = parallel node)

IEX(I,L,N) - pipe/heat exchanger node indicator (0 = pipe node, heat exchanger nodes are numbered consecutively from 1 to a maximum of 31 for the system)

IPMP(K,L,N) - pump node indicator (0 = no pump in node, pump nodes are numbered consecutively from 1 to a maximum of 6, at one node each for the primary loop and secondary loops)

DIA(K,L,N) - nodal flow channel diameter (in feet)

LONG(K,L,N) - nodal flow channel length (in feet)

AUF(K,L,N) - nodal overall UA value (in BTU/hr°F)

Format:	c.c. 1-3	I3	N
	c.c. 4-6	I3	ISER(K,L,N)
	c.c. 7-9	I3	IEX(K,L,N)
	c.c. 10-12	I3	IPMP(K,L,N)
	c.c. 13-19	F7.4	DIA(K,L,N)
	c.c. 20-30	E11.4	LONG(K,L,N)
	c.c. 31-41	E11.4	AUF(K,L,N)

6. Nodal Fluid Parameter Information Card

This card inputs the initial fluid mass flowrate, nodal fluid inlet and outlet temperatures, and average fluid specific heat, density and viscosity for any of the nodes in the system. One card must be supplied for each node.

The nodal fluid mass flowrate must be specified in units of lbm/hr. Nodal values supplied should correspond to the design values for the system initial conditions and should be consistent with the flow channel geometry within each of the loops (e.g., the series primary loop nodes should each have the same mass flowrate to preserve continuity of the flow). In all cases, the primary loop flowrate must be given as accurately as possible, since it serves as basic input to the steady-state convergence subroutine. If the steady-state subroutine is to be used for system initialization, the flowrates for the secondary loop and load center heat exchanger nodes need not be specified precisely, since they are computed internally during the system convergence calculations. However, estimates of these flowrates are used to initialize the steady-state calculations, and the data provided should be approximately equal to the expected values to speed the system convergence.

If the steady-state analysis is used to initialize the dynamic system calculations, the only temperatures required as input data are the inlet temperature to the first node in the primary HTW loop (which becomes the constant TUS fluid supply temperature) and the supply and return temperatures on the consumer sides of the load center heat exchangers. These consumer temperatures should be set according to specifications for the end-use equipment served, and the actual temperatures are allowed to vary from these design values during the simulation according to the internally-defined thermostat control limits.

The specified nodal fluid specific heat, density and viscosity should correspond to design values calculated from the average fluid temperature conditions for the node. The specific heat must be given in units of BTU/lbm-°F, the density in lbm/ft^3, and the viscosity in lbm/ft-hr. These values are assumed to be constant throughout the simulation and uniform along the length of the node; discontinuities at nodal boundaries are allowed to account for variations in the average nodal fluid temperature around each of the loops. Since these parameters are used in the determination of the specific nodal heat and fluid momentum transfer rates, the values specified should be as precise as possible within the nodal averaging constraints outlined above.

Variables:

MASS(K,L,N) - nodal fluid mass flowrate (in lbm/hr)
TI(K,L,N) - nodal fluid inlet temperature (in °F)
TO(K,L,N) - nodal fluid outlet temperature (in °F)
CAP(K,L,N) - nodal fluid specific heat (in BTU/lbm-°F)
RHO(K,L,N) - nodal fluid density (in lbm/ft^3)
MU(K,L,N) - nodal fluid viscosity (in lbm/ft-hr)

Format:	c.c. 1-11	E11.4	MASS(K,L,N)
	c.c. 12-18	F7.2	TI(K,L,N)
	c.c. 19-25	F7.2	TO(K,L,N)
	c.c. 26-32	F7.4	CAP(K,L,N)
	c.c. 33-39	F7.4	RHO(K,L,N)
	c.c. 40-46	F7.4	MU(K,L,N)

7. Heat Exchanger Number Card

This card inputs the number of heat exchangers in the HTW distribution system. Included should be the secondary supply and the load center heat exchangers, but not the TUS supply heat exchanger. A maximum of 31 heat exchangers is allowed.

Variables:

NEXCH - number of heat exchangers in the distribution system

Format:	c.c. 1-3	I3	NEXCH

8. Heat Exchanger Data Card

This card inputs the heat exchanger code number, the identification codes for its supply and demand side nodes, and the number of parallel flow tubes it contains.

The system heat exchangers are numbered consecutively from the first heat exchanger in the primary HTW loop to the last load center heat exchanger. The code number for the heat exchanger given on this card should correspond to the values for IEX(K,L,N) given on the two Node Dimension and Location Cards containing its dimensions and heat transfer characteristics. A maximum of 31 heat exchangers are allowed in the system.

For the purposes of heat exchanger identification, the supply-side nodes for the primary/secondary heat exchangers are the primary HTW loop nodes serving them; the supply-side nodes for the load center heat exchangers are the parallel secondary loop nodes serving them.

The number of tubes in a heat exchanger should be consistent with the specified heat transfer coefficient, physical dimensions, single-pass counterflow geometry, and design fluid flow conditions for the heat exchanger.

Variables:

NEX - heat exchanger code number

K1(NEX),L1(NEX), N1(NEX) - heat exchanger supply-side identification codes [NEX = IEX(K1, L1, N1)]

K2(NEX), L2(NEX), N2(NEX) - heat exchanger demand-side node identification codes [NEX = IEX(K2,L2,N2)]

NTB(NEX) - number of parallel flow tubes in heat exchanger

Format:	c.c. 1-3	I3	NEX
	c.c. 9-11	I3	K1(NEX)
	c.c. 12-14	I3	L1(NEX)
	c.c. 15-17	I3	N1(NEX)
	c.c. 23-25	I3	K2(NEX)
	c.c. 26-28	I3	L2(NEX)
	c.c. 29-31	I3	N2(NEX)
	c.c. 37-41	I5	NTB(NEX)

9. Circulation Pump Number Card

This card inputs the number of circulation pumps in the distribution system. To simplify the loop pump pressure requirement analysis and fluid acceleration calculations, only one pump per loop is allowed. The pumps must be located in pipe nodes as indicated by the IPMP(K,L,N) code on the Node Dimension and Location Cards. A maximum of 6 circulation pumps are allowed in the system.

Variables:

NPMP - number of circulation pumps in the distribution system

Format:	c.c. 1-3	I3	NPMP

10. Storage Reservoir Card

This card inputs the initial hot and cold water storage reservoir section volumes and the initial hot water storage temperature. The volumes must be specified in units of ft^3 and the temperature in °F.

Since variations in the hot water section volume during the simulation determine the required storage capacity for system load smoothing, the exact values of the initial volumes are not critical to the system heat flow calculations. However, the volumes should be specified large enough to preclude emptying of either section during the time period under investigation. The reservoir sections are assumed to be located between the TUS supply heat exchanger and the primary loop supply and return pipes; no node identification codes are required for the reservoir.

The initial hot water storage temperature should correspond to the specified fluid inlet temperature for the first primary loop node. This temperature is held constant throughout the simulation unless the hot water reservoir section is emptied.

Variables:

HVO - hot water storage section initial volume (in ft^3)

CVO - cold water storage section initial volume (in ft^3)

THW - hot water storage temperature (in °F)

Format:	c.c. 1-11	E11.4	HVO
	c.c. 12-22	E11.4	CVO
	c.c. 23-29	F7.2	THW

11. TUS Supply Heat Exchanger Data Card

This card inputs the power plant coolant inlet and outlet temperatures, the initial fluid mass flowrate, and the fluid specific heat on the supply-side of the TUS supply heat exchanger. The temperatures must be specified in °F, the flowrate in lbm/hr, and the specific heat in BTU/lbm-°F.

The supply side inlet and outlet temperatures are held constant throughout the simulation unless the heat flow across the heat exchanger demands that either one or both be modified to comply with the Second Law of Thermodynamics. The inlet temperature should be specified high enough to provide heat transfer to the primary HTW loop inlet fluid; the outlet temperature should be as low as possible for efficient power plant operation, yet high enough to provide heat transfer to the primary loop return fluid.

The exact value for the coolant mass flowrate required to transfer the available heat within the specified temperature limits is computed internally during the initialization of the system. However, a non-zero value for this parameter should be supplied to the program to avoid the possibility of computational overflow errors during this portion of the simulation.

The specific heat of the fluid should correspond to the value calculated for the average fluid temperature in the heat exchanger; the specific heat remains unchanged during the simulation.

Variables:

THG - coolant inlet temperature (°F)

TCG - coolant outlet temperature (°F)

MGAS - coolant mass flowrate (lbm/hr)

CAPG - coolant specific heat (BTU/lbm-°F)

Formate:	c.c.1-7	F7.2	THG
	c.c.8-14	F7.2	TCG
	c.c.15-25	E11.4	MGAS
	c.c.26-32	F7.4	CAPG

12. Ambient Earth Temperature Card

This card inputs the ambient earth temperature at the average burial depth for the distribution piping. It is used in the calculation of heat losses from buried pipes and conduction losses to the earth from buildings. The earth tamperature must be given in °F.

Variables:

TAMB - ambient earth temperature (in °F)

Format:	c.c. 1-7	F7.4	TAMB

13. Power Plant Thermal/Electric Energy Conversion Efficiency Card

This card inputs the overall power plant thermal/electric energy conversion efficiency as the ratio of the electrical energy output from the generators to the thermal energy content of the fuel burned. It is used in determining the total energy consumption for electricity production in conjunction with the heat available to the thermal system. The efficiency should be given as a decimal fraction.

Variables:

EFF - power plant overall thermal/electric energy conversion efficiency (decimal fraction)

Format: c.c. 1-7 F7.4 EFF

14. Pump Response Sensitivity Factor Card

This card inputs the circulation pump response sensitivity factor for all the pumps in the system. This factor is applied to the difference between the projected pressure settings and the existing pump pressures to provide an accelerated response to the loop fluid flowrates when the thermostat is activated. A factor of F results in the pumps being set at pressures equal to the required pressure plus F times the difference between the required and existing pressures. Therefore, a factor of 2.0 results in settings of:

$$P_{set} = 3P_{required} - 2P_{existing}$$

Higher factors result in faster response times; very fast response times should be avoided since they can result in overshooting of the desired flow conditions and instabilities in subsequent heat flow calculations. The factor is dropped from the pump settings when the loop flows have accelerated to within 1% of the desired values.

Variables:

PSENS - pump response sensitivity factor

Format: c.c.1-7 F7.4 PSENS

15. Time Increment and Print Interval Data Card

This card inputs the number of time increments per hour to be used in the transient calculations, the number of increments between system information printout, and the size of one time step. The number of increments per hour and the number of increments between printouts should be given as integer numbers; the number of increments per hour must be a whole number multiple of the number of increments per printout. A minimum of 1 printout per hour is allowed (i.e., the number of steps between printouts = the number of steps per hour). The time step size should be given as a decimal fraction of an hour.

A small time step size results in increased accuracy in the dynamic calculations by allowing a closer modelling of the continuously varying system conditions. However, short time steps also result in considerable increases in the total computational time for any given simulation. Conversely, longer time steps reduce both computation time and modeling accuracy. For each simulation, a compromise value must be chosen which reflects the more important of the computational parameters desired for the given run.

Although it is possible to print the entire set of system parameters for every time step in the simulation, it is advisable both for run time and data reduction purposes to print out this data only at a frequency high enough to give meaningful output. If the system excitation conditions vary greatly from hour to hour, a print interval of once every quarter hour may be necessary to yield the desired detail in the output; for slowly varying conditions, an output listing once every hour could be sufficient.

Variables:

NSTEP - number of time steps per hour

NPRNT - number of time steps between printouts

DTIME - single time step size (as a decimal fraction of an hour)

Format:			
	c.c. 1-5	I5	NSTEP
	c.c. 6-10	I5	NPRNT
	c.c. 11-18	F8.5	DTIME

16. Building Type Number Card

This card inputs the number of different building types to be served by the total energy system. For the purposes of determining this number, a distinct building type is defined as one having representative physical dimensions, occupancy, room temperature requirements, and materials heat transfer characteristics. Buildings used for similar purposes and having similar physical characteristics should be placed in a single type class, even though there may be differences in their detailed construction or layout. A maximum of 20 different building types is allowed.

Variables:

NTYPE - number of building types served by system

Format: c.c. 1-3 I3 NTYPE

17. Bulding Material Heat Transfer Parameter Card

This card inputs the exposed areas and thermal resistances of the walls, windows, roof, and ground-contact material for the building type specified by its building code number. The areas must be given in ft^2 and the thermal resistances in $(BTU/hr\text{-}ft^2\text{-}°F)^{-1}$. One card must be input for each building type as specified on the Building Type Number Card.

The building type code number is simply an integer which identifies the particular building type being specified. Types should be numbered consecutively for any given simulation; a maximum of 20 building types is allowed.

The areas specified should be the total exposed surfaces for each component of the building. TDIST assumes all buildings to be square and symmetrical and it will use 25% of the total specified areas of the walls and windows when calculations are performed on a per-wall basis. The ground-contact area of the building should be the total basement surface area in contact with the surrounding soil or the surface area of the building's base slab, if no basement exists. The roof area, if the roof is not flat, should be the horizontal projection of the total pitched-roof area. The parameter values should be typical for the similar buildings within the type class being specified. It is recommended that buildings within the community being studied first be classified according to type and then that a representative building be chosen as the norm for each grouping. Physical dimensions and construction materials specified for each building type should be consistent with actual data for these norms. Care should be taken to include in the specified areas only those sections of the building exposed to the external elements, since the heat transfer calculations assume losses from the building only to the surrounding air and the earth. The heat transfer characteristics for compound materials must be correctly combined to produce a single coefficient for the particular section of the building specified. Wall and roof thermal resistances should include the inner surface film convection resistance and the composite thermal resistance of the materials from which they are constructed; the code computes the outer surface convection resistance based upon a specified surface roughness coefficient and the instantaneous wind velocity, and adds this surface term to the user-supplied resistance to produce a total heat transfer coefficient for the component being analyzed. If walls are constructed differently throughout the building, the various section values should be combined to produce a single average wall coefficient for the building. When specifying these parameters, it should be remembered that all factors influencing the net transfer of heat from the interior of the building to its surroundings must be included but that heat transfer within the building itself is neglected.

Variables:

I - building type code number

AW(I) - building exposed wall area (in ft^2)

RTW(I) - average wall thermal resistance (in hr-ft^2-°F/BTU)

AWD(I) - building window area (in ft^2)

RTWD(I) - average window thermal resistance (in hr-ft^2-°F/BTU)

AR(I) - building roof area (in ft^2)

RTR(I) - average roof thermal resistance (in hr-ft^2-°F/BTU)

AF(I) - building exposed floor/basement area (in ft^2)

RTF(I) - ground-contact material thermal resistance (in hr-ft^2-°F/BTU)

Format:	c.c. 1-2	I2	I
	c.c. 3-10	F8.2	AW(I)
	c.c. 11-18	F8.3	RTW(I)
	c.c. 19-26	F8.2	AWD(I)
	c.c. 27-34	F8.3	RTWD(I)

c.c. 35-42	F8.2	AR(I)
c.c. 43-50	F8.3	RTR(I)
c.c. 51-58	F8.2	AF(I)
c.c. 59-66	F8.3	RTF(I)

18. Building Air Infiltration Factor Card

This card inputs the infiltration air flow coefficients C and N and the infiltration crack dimensions for the windows and doors of the building type specified by its code number. Also input are the coefficients C and N for the building's walls. One card must be supplied for each building type as specified on the Building Type Number Card.

The coefficients C and N (obtained from Table A.3) are used to translate the combined effects of wind and stack effect induced pressure differences into air flowrates in CFM per linear foot of crack (or, in the case of the walls, CFM per square foot of surface area). Since the infiltration air flowrate for the building is directly proportional to C, extreme care should be exercised in selecting values from the extremely wide range of available specifications which accurately reflect the representative building's construction characteristics. The value of C input for the windows should be the sum of the window and frame coefficients; N should be the average of the window and frame coefficients.

Because air generally flows into a building on one side and out of the building on the opposite side, the crack lengths specified around doors and windows should be 50% of the total cracks measured for the building to avoid double volume counting in the flow calculations.

Variables:

I - building type code number
DCL(I) - door crack length (in ft.)
DINC(I) - door crack flow coefficient C
DINN(I) - door crack flow coefficient N
WDCL(I) - window crack length (in ft.)
WDINC(I) - window crack flow coefficient C
WDINN(I) - window crack flow coefficient N
WINC(I) - wall crack flow coefficient C
WINN(I) - wall crack flow coefficient N

Format:	c.c. 1-2	I2	I
	c.c. 3-10	F8.3	DCL(I)
	c.c. 11-18	F8.3	DINC(I)
	c.c. 19-26	F8.3	DINN(I)
	c.c. 27-34	F8.3	WDCL(I)
	c.c. 35-42	F8.3	WDINC(I)
	c.c. 43-50	F8.3	WDINN(I)
	c.c. 51-58	F8.3	WINC(I)
	c.c. 59-66	F8.3	WINN(I)

19. Building Miscellaneous Data Card

This card inputs codes for the surface materials of the walls and roof, the height, and the nominal maximum ventilation air flowrate for the building specified by its type code number. The building height must be specified in ft. and the air flowrate in CFM. One card must be input for each building type as specified on the Building Type Number Card.

The wall and roof surface material type codes are used as indices for internally-stored surface roughness coefficients used in the calculation of the surface convection thermal resistances. The codes should be input as integer values according to the following classifications:

1 - stucco
2 - brick, rough plaster
3 - concrete
4 - clear pine
5 - smooth plaster
6 - glass, white paint on pine

When selecting the appropriate code for the wall or roof material in the building being specified, it should be remembered that the important parameter indicated by these codes is the relative surface roughness and not the exact type of surface material.

The peak ventilation air flowrate is used as an index for the scheduling of ventilation which is compared with the computed infiltration air flowrates to obtain the heat loss due to direct air exchanges between the building's interior and exterior. This flowrate need not be limited to only buildings containing forced-air ventilation equipment, since the code considers the opening of windows to cause a ventilation rather than an infiltration air exchange. The peak value input on this card should generally be obtained from either building code specifications of the required ventilation rates for various structural and occupancy classifications, or it should be based upon measured air exchange data (such as a typical number of air changer per hour) for the specified building.

Variables:

I - building type code number
MTW(I) - wall surface material type code
MTR(I) - roof surface material type code
BH(I) - building height (in ft.)
AINFL(I) - peak ventilation air flowrate (in CFM)

Format:	c.c. 1-2	I2	I
	c.c. 5-6	I2	MTW(I)
	c.c. 9-10	I2	MTR(I)
	c.c. 13-19	F7.2	BH(I)
	c.c. 20-29	F10.2	AINFL(I)

20. Building Solar Data, Internal Heating, and Domestic Hot Water Data Card

This card inputs the building orientation, internal window shading coefficient, wall and roof shading coefficients, wall and roof material solar absorptivities, the nominal maximum rate of non-space-conditioning heat production, and the nominal maximum rate of service hot water consumption for the building specified by its type number code. One card is required for each building type as specified on the Building Type Number Card.

The orientation of the building is measured in degrees clockwise from North, and is referenced to that wall whose normal is closest to North. Thus, if a building has one wall facing north, its orientation angle would be 0°; one wall facing Northeast would result in an orientation of 45°. If the specified building represents an aggregation of several randomly-oriented units, the reference wall angle should approximate any observed trends in the actual orientations. (It should be noted that the orientation must always lie within the range $0° \leq WA < 90°$, since the building is assumed to be square). For the purposes of computing loads on a per-wall basis, the reference wall is designated as #1, and the walls are numbered clockwise from the North.

The internal window shading coefficient input on this card is, in a sense, a "reciprocal shading coefficient" since it actually indicates a measure of the amount of solar energy incident upon a window which is transmitted and converted to heat within the building. The coefficient is input as a decimal fraction, with 0 indicating full shading and 1.0

indicating no shading. Included in this value should be the effects of such fixtures as double glazing, tinted glass, venetian blinds, drapes, shades, etc. (i.e., anything inside the exposed surface of the window which would modify the solar heating obtained from clear 1/8" single pane glass). Table A.6 contains shading coefficients for a range of typical window configurations, and References 4 and 5 contain more complete listings.

Exterior surface shading coefficients (actually, reciprocal shading coefficients or lighted fractions) are input on this card for each of the four walls of the building and its roof. As is discussed above, the walls are numbered consecutively from 1 to 4, clockwise from the North, and the roof is assigned an equivalent wall index of 5. The exterior shading coefficient for each of these surfaces should provide an estimate of the fraction of that surface, under direct sunlight conditions, which is actually lit by solar radiation. Thus, if the building is immediately adjacent to a larger building abutting its southern wall, the coefficient for wall #3 would be 0; conversely, if the North wall is completely free of shading, even though the sun may never actually shine directly upon it due to its position in the sky, the coefficient for that wall should be specified as 1.0 to indicate that any radiation available to the wall will reach it unimpeded. When aggregating several randomly-oriented buildings into a single representative unit, estimates should be made of the net effects of exterior shading upon these buildings and the aggregate data should be used to derive effective wall and roof shading coefficients.

The wall and roof material solar absorptivities are measures of the fraction of the solar radiation incident upon those surfaces which is absorbed and converted to heat within the building. In general, the values specified will depend upon both the color and the composition of the surface. A range of typical absorptivities is listed in Table A.7, which has been extracted from more comprehensive summaries in References 4 and 5.

Also input on this card is a value for the nominal maximum rate of internal building heat generation from all sources not directly associated with space conditioning (e.g., lights, motors, appliances, people). This peak value should be input in kW, and it serves as an index for the scheduling of non-space-conditioning heat generation as a function of building occupancy and intensity of use.

Finally, a measure of the nominal maximum rate of service hot water usage (e.g., showers, wash basins, cooking, etc.) is required to be input in units of BTU/hr. This peak, as are those for ventilation and internal heat generation, is used as an index for an hourly hot water heating demand schedule for the building. Since most tabulations and field measurements of domestic hot water consumption are presented in units of gallons/hour, converting these rates to the data value required on this card necessitates estimates to be made of both the municipal water supply temperature to the building and of the water temperature at the heater outlet to determine the energy demand per unit flow.

Variables:

I - building type code number

WA(I) - building orientation (in degrees from North)

WDSC(I) - window internal shading coefficient (decimal fraction of incident radiation which is transmitted as heat)

FWLIT(I,NN) - fraction of surface NN open to direct solar radiation [NN = 1-4: walls, NN = 5: roof]

WSAB(I) - wall material solar absorptivity (decimal fraction of incident radiation absorbed)

RSAB(I) - roof material solar absorptivity (decimal fraction of incident radiation absorbed)

POL(I) - nominal peak internal heat generation rate from non-space-conditioning sources (in kW)

DHW(I) - nominal peak domestic hot water consumption rate (in BTU/hr)

Format:	c.c. 1-2	I2	I
	c.c. 3-9	F7.2	WA(I)
	c.c. 10-14	F5.2	WDSC(I)
	c.c. 15-19	F5.2	FWLIT(I,1)
	c.c. 20-24	F5.2	FWLIT(I,2)
	c.c. 25-29	F5.2	FWLIT(I,3)
	c.c. 30-34	F5.2	FWLIT(I,4)
	c.c. 35-39	F5.2	FWLIT(I,5)
	c.c. 40-44	F5.2	WSAB(I)
	c.c. 45-49	F5.2	RSAB(I)
	c.c. 50-58	F9.2	POL(I)
	c.c. 59-69	E11.4	DHW(I)

21. Building External Supply Data Card

This card inputs the number of units of a building type which are not served by the TUS and, of that number, the fraction which have electric resistance heaters and the fraction having heat pumps. One card must be supplied for each of the building types specified on the Building Type Number Card.

Those buildings not supplied with HTW are considered to be part of the TES "external system" and have their energy needs supplied electrically. Because no detailed electrical distribution system analysis is performed by the code, only the total number of buildings and their mode of energy supply are required for the calculation of the external system electrical demand. It is assumed that all the specified external system buildings have compressive air conditioners. However, the required resistance and heat pump fractions need not sum to 1.0, since the code allows a fraction of the external buildings to be heated from in-house fossil-fired furnaces which present no load to the TES.

Variables:

I - building type code number

NUEX(I) - number of units not connected to TUS

FREXT(I) - fraction of electrically-supplied units having resistance heat (decimal fraction)

FHPEX(I) - fraction of electrically-supplied units having heat pumps (decimal fraction)

Format:	c.c. 1-2	I2	I
	c.c. 3-7	I5	NUEX(I)
	c.c. 8-12	F5.2	FREXT(I)
	c.c. 13-17	F5.2	FHPEX(I)

22. Building Type and End-Use Equipment Distribution Card

This card inputs the number of buildings of a given type served by a load center heat exchanger. Also given are the total number of compressive and absorptive air conditioning units and the number of electrical resistance heating units, heat pumps and hot water heating units contained in these buildings. Since the program reads these cards according to building type within each heat exchanger area, one card must be supplied for each building type for each load center heat exchanger, even if a particular heat exchanger does not supply every type (e.g., if there are 4 secondary loops with 5 heat exchangers per loop and a total of 6 buildings types in the community, a total of 4x5x6 = 120 Building Type and End-Use Equipment Distribution Cards must be supplied). The order in which these cards should be placed in the data deck is: for the first load center heat exchanger, NTYPE cards should be input consecutively according to the building code numbers defined by the Building Type Number Card; this sequence is then repeated in succession for every load center heat exchanger.

Buildings should be apportioned to the various load center heat exchangers so as to provide a fairly uniform load distribution among the heat exchangers in a given loop and among all the loops in the system. If no buildings of a given type are served by a given heat exchanger, "0" may be specified for the number of buildings on the Building Type and End-Use Equipment Distribution Card, or the card may be left blank.

End-Use equipment should be distributed throughout the system so as to provide an optimum thermal/electric energy utilization efficiency for the community as a whole. The data given on this card for the numbers of individual heating and cooling units serving a particular building type in a given area of the community is used by the program to distribute the space conditioning loads among the various equipment categories provided. The specific numbers given can be the number of buildings served by a particular equipment type or the total number of individual units of that type in the area being specified. However, the numbers should be specified consistently throughout the system and must present a true indication of the relative equipment distribution in each consumer sector.

Variables:

NU(IX,I) - number of building units of type I served by heat exchanger IX

NCMP(IX,I) - number of compressive air conditioning units in buildings of type I for heat exchanger IX

NABS(IX,I) - number of absorptive air conditioning units in buildings of type I for heat exchanger IX

NRES(IX,I) - number of electrical resistance heating units in buildings of type I for heat exchanger IX

NHPM(IX,I) - number of heat pumps in buildings of type I for heat exchanger IX

NHWS(IX,I) - number of hot water heating units in buildings of type I for heat exchanger IX

Format:	c.c. 1-5	I5	NU(IX,I)
	c.c. 6-10	I5	NCMP(IX,I)
	c.c. 11-15	I5	NABS(IX,I)
	c.c. 16-20	I5	NRES(IX,I)
	c.c. 21-25	I5	NHPM(IX,I)
	c.c. 26-30	I5	NHWS(IX,I)

23. End-Use Equipment Efficiency Data Card

This card inputs the efficiencies (or coefficients of performance) of the compressive and absorptive air conditioning units, the electrical resistance heating units, heat pumps, and hot water heating units in the system. For the compressive air conditioning units, heat pumps and electrical resistance heating units, this efficiency should be expressed in terms of the rated BTU/hr heating or cooling capacity per BUT/hr equivalent of the required input electrical power. For the absorptive air conditioning and hot water heating units, the efficiency should be expressed in terms of the rated BTU/hr heating or cooling capacity per BTU/hr of the input thermal power. The specified efficiencies should be consistent with the operating characteristics of the various equipment under system design supply temperature and room space conditioning requirements. The nominal heat pump COP should be specified at an ambient air temperature of 32 °F and a room temperature of 68 °F; nominal compressive and absorptive air conditioning COPs are defined at an air temperature of 90 °F and a room temperature of 75 °F. A non-zero value for the efficiency of each equipment type should be given, even though a given type may not appear anywhere in the system.

Variables:

ECMP - compressive air conditioning unit coefficient of performance (dimensionless)

EABS - absorptive air conditioning unit coefficient of performance (dimensionless)

ERES - electrical resistance heating unit efficiency (dimensionless)

EHPM - heat pump coefficient of performance (dimensionless)

EHWS - hot water heating unit efficiency (dimensionless)

Format:			
	c.c. 1-5	F5.2	ECMP
	c.c. 6-10	F5.2	EABS
	c.c. 11-15	F5.2	ERES
	c.c. 16-20	F5.2	EHPM
	c.c. 21-25	F5.2	EHWS

24. Case Input Mass Flowrate Scale Factor Card

This card inputs the case input mass flowrate scale factor used to scale the fluid mass flowrates specified on the Nodal Fluid Parameter Information Cards. In general, a value for this factor other than 1.0 should not be specified unless the <u>only</u> input parameters to be varied between two given simulations are the nodal mass flowrates, which are scaled uniformly throughout the TUS. In this instance, this factor should be the ratio between the desired flowrates and the originally specified values, and the Nodal Fluid Parameter Information Cards need not be re-punched.

Variables:

CSFAC - case input mass flowrate scale factor

Format:	c.c. 1-7	F7.4	CSFAC

25. Solar Data Card

On this card are input the latitude of the community being studied, and the solar declination angle, the apparent solar constant, the atmospheric extinction coefficient and the sky diffuse factor for the day on which the simulation is performed. Also input is the hour of the day at which the initial system loads are to be calculated and the steady-state system analysis is to be performed.

The latitude should be input in (positive) degrees north or south of the equator.

The solar declination angle, apparent solar constant, atmospheric extinction coefficient and sky diffuse factor are observed insolation parameters which depend upon the time of year as summarized in Table A.4. The solar declination angle should be input in degrees. The apparent solar constant, which measures the intensity of a direct solar beam normally incident upon a horizontal surface under clear skies, is input in BTU/hr-ft^2. The atmospheric extinction coefficient indicates the absorption in the atmosphere of direct solar radiation, and the sky diffuse factor measures the dispersion of the solar beam as it travels through the atmosphere.

The time of day input on this card is the hour at which the initial system calculations are to be performed and is the beginning time of the dynamic analysis. Since all time-dependent data is read sequentially on an hourly basis without specifying the precise time of day with which it is associated, this beginning hour indicator initializes the time clock and is used to assign solar time values to each hourly data point. A continuous 24-hour time clock is employed by the model, with midnight being assigned an hour indicator of 0 and noon an indicator of 12; a simulation covering the 12-hour period between 2 PM and 2 AM, for example, would have 14 as its specified beginning hour and would terminate at hour 2.

Variables:

ALAT - latitude of location (in degrees)
DECL - solar declination angle (in degrees)
ASC - apparent solar constant (in BTU/hr-ft^2)
AEC - atmospheric extinction coefficient
SDF - sky diffuse factor
IBHR - beginning hour of simulation period (0-23)

Format:	c.c. 1-5	F5.2	ALAT
	c.c. 6-11	F6.2	DECL
	c.c. 12-16	F5.0	ASC
	c.c. 17-22	F6.3	AEC
	c.c. 23-28	F6.3	SDF
	c.c. 29-31	I3	IBHR

26. Power Plant Rating and Peak Non-Space-Conditioning Electrical Demand Data Card

This card inputs the power plant thermal rating and the peak non-space-conditioning electrical load for the community. The power plant output must be given in MWt and the electrical load in MWe.

The specified power plant thermal output is held constant throughout the simulation and provides the total power input to both the electrical and thermal energy distribution systems. This output power level should be set approximately equal to the average total energy demand for the community over the period of the simulation. Higher outputs will result in a net storage of energy in the reservoir during the simulation; lower outputs will result in a net removal of heat from the reservoir and possible inability to meet the peak energy demands of the community. The program uses the power plant output as primary input to the dynamic system calculations; the heat available to the thermal distribution system is given by the difference between this constant output and the instantaneous energy demand for electrical power production.

The electrical load specified on this card should be the peak electrical power demand, excluding space conditioning, for the community over the period of the simulation. To eliminate space conditioning effects, the electrical load data specified should be representative of a minimum demand period during the Autumn or Spring, when neither air conditioning nor space heating is required.

Variables:

RTBL - power plant constant total power output (in MWt)

ELBL - peak community electrical load excluding space conditioning (in MWe)

Format:	c.c. 1-10	F10.0	RTBL
	c.c. 11-20	F10.0	ELBL

27. Primary Program Flow Control Code Card

This card inputs the primary program flow control code KODE, which identifies the general type of program execution to be performed according the the following conventions:

KODE=0: Perform building load analysis (if IDES=1) or perform TUS steady-state convergence (if IDES=0),

KODE=1: Perform hourly building load summary (if sequence KODE=0, IDES=1 input previously) or perform dynamic system analysis, and

KODE=2: Terminate program execution.

In limited cases, KODE may be input more than once for a given computer run to transfer control of program execution from one program option to another. Examples of such sequential operations are:

KODE=0, IDES=1, KODE=1: Computes, adds and distributes building loads at one time instant and computes up to 24 hourly building space conditioning loads,

KODE=0, IDES=0, KODE=1: Steady-state system analysis used to internally initialize dynamic simulation TUS parameters, and

Nesting of several combinations of KODE=0 and IDES=0,1 are also possible to analyze several instantaneous system loading conditions within the same TUS configuration without performing any dynamic energy system analyses.

In general, it is recommended that program execution be terminated following the completion of a dynamic system simulation, since the retention of TUS parameter values from the dynamic calculations could invalidate certain portions of directly continued steady-state or building load analyses.

Variables:

KODE - primary program flow control code (0,1,2)

Format:	c.c. 1-3	I3	KODE

28. Building Load Analysis Control Code Card

The building load analysis control code IDES must be input immediately following each specification of KODE=0. As summarized in the description of the Primary Program Flow Control Code Card and in Table A.9,

IDES=0: Perform steady-state TUS convergence and analysis, or

IDES=1: Perform building load analysis and print net building space conditioning demands; aggregate and print initial building loads and distribution, and print initial thermal demands at each load center heat exchanger.

IDES should not be specified following the input of KODE=1 unless the system is re-initialized by reading KODE=0.

Variables:

IDES - building load analysis control code (0,1)

Format:	c.c. 1-3	I3	IDES

29. Initial Air Temperature Data Card

This card inputs the ambient air temperature to be used in determining the initial building space conditioning energy demands. If a dynamic simulation is to be performed by using the steady-state system analysis to initialize the TUS parameters, this temperature must be the initial hourly data point for the period being studied (i.e., the temperature at time t=IBHR). The temperature must be specified in °F.

Variables:

TAIR(25) - air temperature at time t=IBHR (in °F) (the index 25 is reserved by the program for initial conditions data)

Format: c.c. 1-5 F5.2 TAIR(25)

30. Initial Wind Velocity Data Card

Input on this card is the initial wind velocity, in mph, for the location at time t = IBHR.

Variables:

WV(25) - wind velocity at time t = IBHR (in mph)

Format: c.c. 1-5 F5.2 WV(25)

31. Initial Wind Direction Data Card

On this card is input the direction from which the wind is blowing at time t = IBHR. The direction is measured in degrees, clockwise from North (e.g., a wind incident from the Southwest would have a direction angle of 225°).

Variables:

WDIR(25) - wind incidence direction at time t = IBHR (in degrees from North)

Format: c.c. 1-5 F5.2 WDIR(25)

32. Initial Electric Load Factor Data Card

This card inputs the electric load factor which multiplies the peak community demand specified on the Power Plant Rating and Peak Non-Space-Conditioning Electrical

Demand Data Card to determine the non-space conditioning electric load during the steady-state calculations. If a dynamic simulation is to be run using the steady-state subroutines to initialize the system, this load factor must be the initial hourly data point (i.e., the factor at time t = IBHR) for the period being studied. The factor is dimensionless and merely represents the ratio of the instantaneous system electrical load to the peak load for the period under investigation. (Inputting such a combination of a peak load and load factors allows the simple retention of a given load profile while varying the size of the community to be supplied).

Variables:

ELF(25) - electric load factor (ratio of instantaneous to peak non-space-conditioning electric load) at time t = IBHR

Format: c.c. 1-5 F5.2 ELF(25)

33. <u>Initial Building Room Temperature Data Card</u>

This card inputs the room temperatures, by building type, to be used in determining the building space conditioning loads for the steady-state system calculations. If a dynamic simulation is to be run using the steady-state subroutines to initialize the system parameters, these temperatures must be the initial hourly data points (i.e., the temperatures at time t = IBHR) for the period being studied. Each building type is assumed to have a characteristic room temperature throughout all the rooms of that building type in the community. These temperatures are allowed to vary throughout the simulation to correspond to the changing requirements of the people using the buildings. All temperatures must be specified in °F. One temperature is required for each of the building types specified on the Building Type Number Card. A maximum of 20 building types is allowed. If more than 10 building types are specified, two cards must be used to input the temperatures.

Variables:

TSB(25,I) - desired room temperature for building type I at time t = IBHR (in °F) (maximum of I=20)

Format: (Card 1)

c.c. 1-7	F7.2	TSB(25,1)
c.c. 8-14	F7.2	TSB(25,2)
:	:	:
c.c. 64-70	F7.2	TSB(25,10)

(Card 2) (not required if NTYPE $\leq$ 10)

c.c. 1-7	F7.2	TSB(25,11)
c.c. 8-14	F7.2	TSB(25,12)
:	:	:
·	F7.2	TSB(25,NTYPE)

34. Initial Building Use Factor Data Card

On this card are input the occupancy-related building use factors which multiply the peak ventilation air flowrate (from the Building Miscellaneous Data Cards) and the peak non-space-conditioning equipment heat generation rate (from the Building Solar Data, Internal Heating, and Domestic Hot Water Data Cards) to obtain the instantaneous values of these parameters for each building type at time t = IBHR. It is assumed by the code that, in general, ventilation requirements and internal heat generation are functions of building occupancy and intensity of usage. Therefore, these use factors provide a measure of the relative occupancy of each building type and should be given as the ratio of the instantaneous ventilation or internal heating rates to the peaks observed during the simulation period. If more than 10 building types are specified, two cards must be used to input the factors.

Variables:

BUF(25,I) - use factor for building type I at time t = IBHR (decimal fraction of peak use)

Format: (Card 1)

c.c. 1-7	F7.2	BUF(25,1)
c.c. 8-14	F7.2	BUF(25,2)
:	:	:
c.c. 64-70	F7.2	BUF(25,10)

(card 2) (not required if NTYPE $\leq$ 10)

c.c. 1-7	F7.2	BUF(25,11)
c.c. 8-14	F7.2	BUF(25,12)
:	:	:
	F7.2	BUF(25,NTYPE)

35. Initial Domestic Hot Water Use Factor Data Card

This card inputs the use factors which multiply the peak domestic hot water demands from the Building Solar Data, Internal Heating, and Domestic Hot Water Data Cards to obtain the instantaneous energy demands for domestic hot water service at time t = IBHR. Although it is correlated with building occupancy, hot water consumption generally follows a different schedule from that specified by the general building use factor and is therefore allowed to vary independently from the building ventilation and internal heat generation rates determined by BUF. If a building has no domestic hot water consumption (e.g., a warehouse or small commercial building), its use factor should simply be input as 0 or left blank on this card. If more than 10 building types are specified, two cards must be used to input the factors.

Variables:

WUF(25,I) - domestic hot water use factor for building type I at time t = IBHR (decimal fraction of peak use)

Format:	(card 1)		
	c.c. 1-7	F7.2	WUF(25,1)
	c.c. 8-14	F7.2	WUF(25,2)
	:	:	:
	c.c. 64-70	F7.2	WUF(25,10)
	(card 2) (not required if NTYPE $\leq$ 10)		
	c.c. 1-7	F7.2	WUF(25,11)
	c.c. 8-14	F7.2	WUF(25,12)
	:	:	:
	.	F7.2	WUF(25,NTYPE)

36. Hourly Data Point Number Card

This card inputs the number of hourly data points to be used in the dynamic system simulation. The first hourly data point is assumed to be given at time t = IBHR+1. Therefore, the number specified on this card must not include the initial data values used by the steady-state initialization subroutines, and it should correspond to the total duration of the simulation in hours. For example, a 6-hour simulation would require 6 data points in addition to the initialization values, and "6" would be specified on this card. Since the maximum single simulation period is 24 hours, a maximum of 24 hourly data points per simulation is allowed.

Variables:

NTEMP - number of hourly data points in simulation (maximum of 24)

Format: c.c. 1-3 I3 NTEMP

37. Hourly Air Temperature Data Card

This card inputs the hourly external air temperature values to be used in determining the building space conditioning loads during the dynamic system simulation. The first value specified should be the air temperature at time t = IBHR+1 (i.e., one hour into the simulation). One temperature value must be given for each of the data points specified on the Hourly Data Point Number Card. The program uses a linear interpolation routine to determine intermediate temperatures for each simulation time step. Therefore, the specified temperatures should accurately reflect the actual air temperature profile for the time period being studied. The temperatures should be listed consecutively on this card according to the given input format; a maximum of 12 values per card and a maximum of 2 cards per simulation (i.e., a maximum of 24 hourly data points) is allowed. The temperatures must be given in units of °F.

Variables:

TAIR(I) - external air temperature at time I hours into the simulation (maximum of I = 24 values). (in °F)

Format: (card 1)

c.c. 1-5	F5.2	TAIR(1)
c.c. 6-10	F5.2	TAIR(2)
.	.	.
.	.	.
.	.	.
c.c. 56-60	F5.2	TAIR(12)

(card 2) (not required if NTEMP $\leq$ 12)

c.c. 1-5	F5.2	TAIR(13)
c.c. 6-10	F5.2	TAIR(14)
.	.	.
.	.	.
	F5.2	TAIR(NTEMP)

(Max of NTEMP = 24)

38. Hourly Wind Velocity Data Card

This card inputs the hourly wind velocities for the simulation period. The first value specified is assumed to obtain at time t = IBHR+1 (i.e., one hour into the simulation), and the total number of data points must correspond to the number of simulation hours specified on the Hourly Data Point Number Card. Velocities should be in units of miles/hr. If the simulation is to span more than 12 hours, two data cards are required as shown below.

Variables:

WV(I) - wind velocity at time I hours into the simulation (maximum of I=24 values) (in mph)

Format: (card 1)

c.c. 1-5	F5.2	WV(1)
c.c. 6-10	F5.2	WV(2)
:	:	:
c.c. 56-60	F5.2	WV(12)

(card 2) (not required if NTEMP $\leq$ 12)

c.c. 1-5	F5.2	WV(13)
c.c. 6-10	F5.2	WV(14)
:	:	:
.	F5.2	WV(NTEMP)

39. Hourly Wind Direction Data Card

On this card are input the wind directions for each hour of the simulation period. The first hourly data point is defined at time t = IBRH+1 (i.e., one hour into the simulation), and the total number of values specified should correspond to the number of simulation hours input on the Hourly Data Point Number Card. The wind incidence directions should be given in degrees, measured clockwise from North. If the simulation is to cover more than 12 hours, two data cards are required.

Variables:

WDIR(I) - wind incidence direction at time I hours into the simulation (in degrees from North)

Format: (card 1)

c.c. 1-6	F6.2	WDIR(1)
c.c. 7-12	F6.2	WDIR(2)
:	:	:
c.c. 67-72	F6.2	WDIR(12)

(card 2) (not required if NTEMP $\leq$ 12)

c.c. 1-6	F6.2	WDIR(13)
c.c. 7-12	F6.2	WDIR(14)
:	:	:
.	F6.2	WDIR(NTEMP)

40. Hourly Electric Load Factor Data Card

This card inputs the hourly electric load factors which multiply the peak community load specified on the Power Plant Rating and Peak Non-Space-Conditioning Electrical Demand Data Card to determine the non-space conditioning electric loads during the dynamic system simulation. The first value specified should be the load factor at time t = IBHR+1 (i.e., one hour into the simulation). One value must be given for each of the data points specified on the Hourly Data Point Number Card. The program uses a linear interpolation routine to determine intermediate loads for each simulation time step. Therefore, the specified load factors should accurately reflect the actual community electrical load profile for the time period being studied. The factors should be listed consecutively on this card according to the given input format; a maximum of 12 values per card and a maximum of 2 cards per simulation (i.e., a maximum of 24 hourly data points) is allowed.

Variables:

ELF(I) - electrical load factor (ratio of instantaneous total non-space-conditioning electric load to peak for period) at time I hours into the simulation (maximum of I=24 values).

Format: (card 1)

c.c. 1-5	F5.2	ELF(1)
c.c. 6-10	F5.2	ELF(2)
.	.	.
.	.	.
c.c. 56-60	F5.2	ELF(12)

(card 2) (not required if NTEMP $\leq$ 12)

c.c. 1-5	F5.2	ELF(13)
c.c. 6-10	F5.2	ELF(14)
.	.	.
.	.	.
.	F5.2	ELF(NTEMP)

(Max. of NTEMP=24)

41. Hourly Building Room Temperature Data Cards

This card inputs the room temperatures, by building type, to be used in determining the building space conditioning loads for the dynamic system simulation. Each building type is assumed to have a characteristic room temperature which must be maintained by the space heating/cooling systems throughout all the rooms of that building type in the community. These temperatures are allowed to vary on an hourly basis to correspond to the changing requirements of the people using the buildings. (e.g., Business Offices need not be fully heated during unoccupied periods). The program uses a linear interpolation routine to determine intermediate temperatures for each simulation time step. Therefore, the specified temperatures should accurately reflect the actual desired room temperature variations for the time period being studied. All temperatures must be specified in °F. One temperature per card is required for each of the building types specified on the Building Type Number Card; a maximum of 20 building types is allowed, and if the number of types specified exceeds 10, two data cards must be input per simulation hour. One card (or pair of cards, if NTYPE > 10) must be supplied for each of the hourly data points specified on the Hourly Data Point Number Card, with the first card(s) in the set corresponding to time t = IBHR+1 (one hour into the simulation). A maximum of 24 data points per building type is allowed.

Variables:

TSB(I,NN) - internal room temperature at time I hours into the simulation for building type NN (maximum of I=24, NN=20) (in °F)

Format: (card 1)

c.c. 1-7	F7.2	TSB(1,1)
c.c. 8-14	F7.2	TSB(1,2)
:	:	:
c.c. 64-70	F7.2	TSB(1,10)

(card 2, if NTYPE > 10)

c.c. 1-7	F7.2	TSB(1,11)
c.c. 8-14	F7.2	TSB(1,12)
:	:	:
.	F7.2	TSB(1,NTYPE)

(card 2, if NTYPE ≤ 10) (card 3, if NTYPE > 10)

c.c. 1-7	F7.2	TSB(2,1)
c.c. 8-14	F7.2	TSB(2,2)
:	:	:
c.c. 64-70	F7.2	TSB(2,10)

To NTEMP (maximum of 24) cards or pairs of cards.

42. Hourly Building Use Factor Data Cards

This card inputs, for each building type specified on the Building Type Number Card, the building use factor which multiplies both the peak ventilation and the peak internal heat generation rates to determine the instantaneous hourly values of these parameters. If more than 10 building types are specified, two cards must be input per simulation hour. The first card, or pair of cards, in the data set should contain data observed at time t = IBHR+1 (i.e., one hour into the simulation), and the total number of data points per building type should correspond to the number of hours specified on the Hourly Data Point Number Card. If the observed ventilation and internal heating schedules for a given building type differ significantly, attempts should be made to adjust the specified peak values of each so that the net effects of the single schedule will approximate the measured behavior.

Variables:

BUF(I,NN) - building use factor at time I hours into the simulation for building type NN (maximum of I=24, NN=20) (decimal fraction of peak ventilation and internal heating rates)

Format: (card 1)

c.c. 1-7	F7.2	BUF(1,1)
c.c. 8-14	F7.2	BUF(1,2)
:	:	:
c.c. 64-70	F7.2	BUF(1,10)

(card 2, if NTYPE > 10)

c.c. 1-7	F7.2	BUF(1,11)
c.c. 8-14	F7.2	BUF(1,12)
:	:	:
.	F7.2	BUF(1,NTYPE)

(card 2, if NTYPE ≤ 10) (card 3, if NTYPE > 10)

c.c. 1-7	F7.2	BUF(2,1)
c.c. 8-14	F7.2	BUF(2,2)
:	:	:
c.c. 64-70	F7.2	BUF(2,10)

To NTEMP (maximum of 24) cards or pairs of cards.

43. Hourly Domestic Hot Water Use Factor Data Cards

On this card are input, for each building type specified on the Building Type Number Card, the domestic hot water use factors which multiply the peak water consumption rates on the Building Solar Data, Internal Heating, and Domestic Hot Water Data Cards to obtain the hourly hot water service energy demands. If the number of specified building types exceeds 10, two cards must be supplied per simulation hour. The first set of data points should be specified at time t = IBHR+1 (one hour into the simulation), and a set of use factors should be input for each hour specified on the Hourly Data Point Number Card.

Variables:

WUF(I,NN) - domestic hot water use factor at time I hours into the simulation for building type NN (maximum of I=24, NN=20) (decimal fraction of peak use rate)

Format:

(card 1)		
c.c. 1-7	F7.2	WUF(1,1)
c.c. 8-14	F7.2	WUF(1,2)
:	:	:
c.c. 64-70	F7.2	WUF(1,10)
(card 2, if NTYPE > 10)		
c.c. 1-7	F7.2	WUF(1,11)
c.c. 8-14	F7.2	WUF(1,12)
:	:	:
.	F7.2	WUF(1,NTYPE)
(card 2, if NTYPE ≤ 10) (card 3, if NTYPE > 10)		
c.c. 1-7	F7.2	WUF(2,1)
c.c. 8-14	F7.2	WUF(2,2)
:	:	:
c.c. 64-70	F7.2	WUF(2,10)

To NTEMP (maximum of 24) cards or pairs of cards.

A.5.2 Sample 24-Hour Input Data Listing

To familiarize the user with the composition of the data deck, a complete listing of the input data required for a sample 24-hour TES simulation is given below.

The specific input data presented models a thermal energy distribution system consisting of a single primary HTW loop and three secondary distribution loops - the first serving three, the second serving four, and the third serving five load center heat exchangers. The primary loop contains approximately 10 miles of nominal 18" O.D. pipe, while the secondary loops each have 12" O.D. pipe. All heat exchangers contain 1" O.D. tubes having 1" I.D. interstitial flow channels. All circulation pumps are located in the return lines to the loop supply heat exchangers. The system is supplied from the TUS supply heat exchanger at a constant water temperature of 380 °F; consumer end-use equipment is supplied at nominal temperatures of 220 °F and 240 °F, depending upon the type of equipment, the location, and the load to be served.

The consumer sectors contain a total of eleven different building types, representing a community with a resident population of approximately 50,000. The buildings are distributed throughout the community in load centers based upon their general heating and cooling requirements. Also taken into consideration in this distribution are community power plant siting restrictions, with residential areas being located furthest from the plant site and low constant population industrial sectors situated at a minimum radius of approximately three miles from the station. End-use equipment is distributed throughout the community following practices expected to yield an optimum thermal/electrical energy demand ratio affording a minimum required power plant installed capacity. Approximately 75% of the total energy demands of the community are supplied through the TUS.

The given air temperature data corresponds to a relatively severe winter day at Fayetteville, North Carolina. The non-space-conditioning electrical load schedule was taken from demand data for a minimum space conditioning day at Fort Bragg, North Carolina, and the magnitude of the average load was scaled to match the model community size. To illustrate the effects of weather variations during the period, building room temperature requirements are held constant for each building type. General building usage and domestic hot water consumption schedules follow observed conditions throughout typical 24-hour building occupancy cycles.

The "card type" listing shown below refers to the numerical designations of the various input data card descriptions presented in Section A.5.1. These numbers do not appear on any of the actual data cards and are given here merely as a reference for the user to facilitate identification of the required card formats and input variables. As a reference for data position on each card, the "7" shown on the first numerical data card appears in column 3. All data up to and including the first Primary Program Flow Control Code Card (type 27) is required for every run. However, data following this card, and certain parameter values specified in the preceding data sets, may be modified according to the specific program option to be executed as summarized in the following sub-sections. It is recommended that the data format presented here (i.e., use of the steady-state subroutines to initialize the dynamic system calculations - a sequence of KODE=0, IDES=0, KODE=1) be used in all dynamic simulations.

SAMPLE INPUT DATA DECK LISTING

```
                                                                      Card
                                                                      Type
                 SAMPLF 24-HOUR TFS SIMULATION                          1
                 WINTER DAY. SOUTHFASTERN U.S.                          1
7                                                                       2
1  0  0  0   1.406     3.04F04    1.520F04                              5
 1.658E06    380.      0.  1.067  54.47     0.35                        6
2  0  1  0   0.070     8.00F01    1.346E06                              5
 1.658F06      0.      0.  1.056  55.22     0.37                        6
3  0  0  0   1.406     4.00F02    2.000E02                              5
 1.658F06      0.      0.  1.035  56.66     0.42                        6
4  0  2  0   0.070     8.00F01    2.420E06                              5
 1.658E06      0.      0.  1.026  57.62     0.47                        6
5  0  0  0   1.406     9.61F03    4.805F03                              5
 1.658F06      0.      0.  1.015  5[illegible].51     0.57                        6
6  0  3  0   0.070     8.00F01    6.397F06                              5
 1.659E06      0.      0.  1.005  60.13     0.74                        6
7  0  0  1   1.406     2.08F04    6.047F04                              5
 1.658F06      0.      0.  1.000  61.20     1.06                        6
3                                                                       3
6  3                                                                    4
1  0  0  0   0.995     9.24F03    4.620F03                              5
 3.200E05      0.      0.  1.056  55.22     0.37                        6
2  1  4  0   0.070     8.00F01    9.199F05                              5
 1.435E05      0.      0.  1.010  59.37     0.63                        6
3  1  5  0   0.070     8.00F01    5.941E05                              5
 9.305F04      0.      0.  1.010  59.37     0.63                        6
4  1  6  0   0.070     8.00F01    5.941F05                              5
 8.344F04      0.      0.  1.010  59.37     0.63                        6
5  0  0  2   0.995     9.24F03    2.514F04                              5
 3.200F05      0.      0.  0.998  62.00     1.65                        6
6  0  1  0   0.083     8.00F01    1.346F06                              5
```

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                                                                 Card
                                                                 Type
 3.200F05      0.      0.  1.010  59.37   0.63                    6
1  1  4  0   0.083     8.00F01   9.199F05                         5
      F       80.   *240.  1.000  61.01   0.97                    6
2  1  5  0   0.083     8.00F01   5.941F05                         5
      E       80.    240.  1.000  61.01   0.97                    6
3  1  6  0   0.083     8.00F01   5.941F05                         5
      F       80.    240.  1.000  61.01   0.97                    6
7  4                                                              4
1  0  0  0   0.995     2.08F04   9.881F03                         5
 5.404F05      0.      0.  1.029  57.31   0.45                    6
2  1  7  0   0.070     8.00F01   5.472F05                         5
 7.187F04      0.      0.  1.005  60.13   0.74                    6
3  1  8  0   0.070     8.00F01   1.320F06                         5
 1.393E05      0.      0.  1.005  60.13   0.74                    6
4  1  9  0   0.070     8.00F01   1.320F06                         5
 1.548F05      0.      0.  1.005  60.13   0.74                    6
5  1 10  0   0.070     8.00F01   1.320F06                         5
 1.745F05      0.      0.  1.005  60.13   0.74                    6
6  0  0  3   0.995     2.08F04   5.660F04                         5
 5.406F05      0.      0.  0.998  62.00   1.65                    6
7  0  2  0   0.083     8.00F01   2.420F06                         5
 5.406F05      0.      0.  1.005  60.13   0.74                    6
1  1  7  0   0.083     8.00F01   5.472F05                         5
      E       80.    240.  1.000  61.01   0.97                    6
2  1  8  0   0.083     8.00F01   1.320F06                         5
      E       80.    240.  1.000  61.01   0.97                    6
3  1  9  0   0.083     8.00F01   1.320F06                         5
      F       80.    240.  1.000  61.01   0.97                    6
4  1 10  0   0.083     8.00F01   1.320F06                         5
      E       80.    240.  1.000  61.01   0.97                    6
8  5                                                              4
1  0  0  0   0.995     1.59F04   7.593F03                         5
 9.449F05    0.        0.  1.012  59.10   0.60                    6
2  1 11  0   0.070     8.00F01   1.324F06                         5
 9.352E04      0.      0.  1.000  61.01   0.97                    6
3  1 12  0   0.070     8.00F01   3.898F06                         5
```

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                                                                     Card
                                                                     Type
  2.765E05       0.      0.  1.000  61.01     0.97                    6
4  1 13  0    0.070      8.00F01    3.898F06                          5
  2.786E05       0.      0.  1.000  61.01     0.97                    6
5  1 14  0    0.070      8.00E01    1.324E06                          5
  8.481F04       0.      0.  1.000  61.01     0.97                    6
6  1 15  0    0.070      8.00F01    3.898F06                          5
  2.112F05       0.      0.  1.000  61.01     0.97                    6
7  0  0  4    0.995      1.59F04    4.327F04                          5
  9.448E05       0.      0.  0.998  62.09     1.86                    6
8  0  3  0    0.083      8.00F01    6.397F06                          5
  9.448E05       0.      0.  1.000  61.01     0.97                    6
1  1 11  0    0.083      8.00F01    1.324E06                          5
        E        80.   220.  0.999  61.20     1.04                    6
2  1 12  0    0.083      8.00F01    3.898E06                          5
        F        80.   220.  0.999  61.20     1.04                    6
3  1 13  0    0.083      8.00F01    3.898F06                          5
        E        80.   220.  0.999  61.20     1.04                    6
4  1 14  0    0.083      8.00F01    1.324F06                          5
        F        80.   220.  0.999  61.20     1.04                    6
5  1 15  0    0.083      8.00F01    3.898F06                          5
        F        80.   220.  0.999  61.20     1.04                    6
15                                                                    7
1         1  1  2      2  1  6      414                               8
2         1  1  4      2  2  7      745                               8
3         1  1  6      2  3  8     1969                               8
4         2  1  2      3  1  1      283                               8
5         2  1  3      3  1  2      182                               8
6         2  1  4      3  1  3      182                               8
7         2  2  2      3  2  1      168                               8
8         2  2  3      3  2  2      406                               8
9         2  2  4      3  2  3      406                               8
10        2  2  5      3  2  4      406                               8
11        2  3  2      3  3  1      407                               8
12        2  3  3      3  3  2     1200                               8
13        2  3  4      3  3  3     1200                               8
14        2  3  5      3  3  4      407                               8
```

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                                                                                   Card
                                                                                   Type
15         2  3  6        3  3  5      1200                                          8
 4                                                                                   9
   9.0E05      9.0E05   380.                                                        10
  450.   160.     2.83E06  1.248                                                    11
   56.                                                                              12
  0.33                                                                              13
   2.0                                                                              14
1000  500     .001                                                                  15
11                                                                                  16
1  10368.     3.70   4110.     0.89    2060.     14.29    2060.     10.00           17
1     78.     40.     .50      800.     1.7       .66     .004       .70            18
1   1   2     27.5        944.                                                      19
1    45. 0.50 0.80 0.80 0.80 0.80 1.00 0.50 0.80          5.37    1.299E05          20
1    0    0.    1.                                                                  21
2   4784.   10.00     330.     0.89    1519.     16.67    1824.      4.91           17
2     31.     40.     .50      195.     1.7       .66     .010       .80            18
2   2   2     23.0        702.                                                      19
2    45. 0.45 0.70 0.70 0.70 0.70 1.00 0.70 0.80          3.17    1.302E04          20
2  842    0.    1.                                                                  21
3   5250.     4.00    532.     0.89    3664.      4.55    3750.      4.91           17
3    132.     40.     .50      306.     1.7       .66     .004       .70            18
3   2   2     17.5       1103.                                                      19
3    45. 0.50 0.90 0.90 0.90 0.90 1.00 0.70 0.80          6.53    3.905E04          20
3    0    0.    1.                                                                  21
4   5244.     3.45    904.     0.89    2325.     16.67    2074.      4.91           17
4     30.     40.     .50      296.     1.7       .66     .010       .80            18
4   1   5     28.5        987.                                                      19
4    45. 0.50 0.90 0.90 0.90 0.90 1.00 0.70 0.80          2.08    6.509E03          20
4   97    0.    1.                                                                  21
5  73000.     3.70  24333.     0.89   60000.     12.50   60000.      6.50           17
5    230.     40.     .50    12167.     3.2       .66     .004       .70            18
5   3   2     90.0     270033.                                                      19
5     0. 0.40 0.95 0.95 0.95 0.95 1.00 0.91 0.80        337.06    1.153E06          20
5    0    0.    1.                                                                  21
6   7104.     3.70   1420.     0.89   11421.      3.33   11421.      6.00           17
6    176.     40.     .50      222.     2.2       .66     .010       .80            18
```

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                                                                                      Card
                                                                                      Type
 6    3   2      15.8      3001.                                                       19
 6     45. 0.80 1.00 1.00 1.00 1.00 1.00 0.68 0.80     22.84          E                20
 6    13    0.    1.                                                                   21
 7  10556.     3.13     300.     0.89  20369.     5.89  20486.     5.27                17
 7      66.     40.      .50    150.      3.0      .66    .004      .80                18
 7    3   5      15.0      25624.                                                      19
 7     45. 0.70 1.00 1.00 1.00 1.00 1.00 0.68 0.80     30.73          E                20
 7    0    0.     1.                                                                   21
 8  14782.     4.00     5666.    0.89   8135.    20.00   8135.     4.04                17
 8      90.     40.      .50   1304.      3.2      .66    .004      .80                18
 8    3   2      23.0      7813.                                                       19
 8     45. 0.60 0.90 0.90 0.90 0.90 1.00 0.91 0.80     72.34          E                20
 8    18    0.    1.                                                                   21
 9  17800.     2.63     3560.    0.89  41850.     5.26  41850.     4.00                17
 9     158.     40.      .50   3816.      3.2      .66    .004      .80                18
 9    2   2      20.0      13958.                                                      19
 9     45. 0.80 1.00 1.00 1.00 1.00 1.00 0.70 0.80     41.85          E                20
 9    11    0.    1.                                                                   21
10  25598.     2.63     5261.    0.89  18685.     5.26  18685.     4.00                17
10      34.     40.      .50   2368.      3.2      .66    .004      .80                18
10    2   2      28.5      13397.                                                      19
10     45. 0.50 0.80 0.80 0.80 0.80 1.00 0.70 0.80    127.40     4.301E05              20
10    0    0.     1.                                                                   21
11  20590.     2.44     5433.    0.89  17000.     5.26  17000.     4.50                17
11      88.     40.      .50   2264.      3.2      .66    .004      .80                18
11    2   2      30.0      12818.                                                      19
11     45. 0.60 1.00 1.00 1.00 1.00 1.00 0.70 0.80    127.40     3.449E05              20
11     7    0.    1.                                                                   21
   75    0   75    0    0   75                                                         22
                                                                                       22
                                                                                       22
                                                                                       22
                                                                                       22
                                                                                       22
                                                                                       22
   12    0   12    0    0   12                                                         22
```

						Card Type
2	0	2	0	0	2	22
						22
						22
						22
						22
						22
						22
						22
						22
13	0	13	0	0	13	22
10	0	10	0	0	10	22
3	0	3	0	0	3	22
10	0	10	0	0	10	22
						22
9	0	9	0	0	9	22
30	0	30	0	0	30	22
						22
18	0	18	0	0	18	22
1	0	1	0	0	1	22
						22
6	0	6	0	0	6	22
1	0	1	0	0	1	22
						22
						22
						22
						22
						22
76	0	76	0	0	76	22
						22
						22
						22
1	0	1	0	0	1	22
1	0	1	0	0	1	22
						22
						22
						22

						Card Type
						22
363	0	363	0	0	363	22
26	0	26	0	0	26	22
						22
						22
						22
						22
						22
						22
						22
						22
						22
370	0	370	0	0	370	22
41	0	41	0	0	41	22
						22
						22
						22
						22
						22
						22
						22
						22
75	0	75	0	0	75	22
						22
						22
						22
						22
						22
						22
9	0	9	0	0	9	22
3	0	3	0	0	3	22
						22
						22
						22
68	0	68	0	0	68	22
50	0	50	0	0	50	22

						Card Type
						22
						22
						22
						22
						22
						22
						22
						22
						22
						22
						22
						22
						22
						22
						22
12	0	12	0	0	12	22
2	0	2	0	0	2	22
9	0	9	0	0	9	22
						22
28	0	28	0	0	28	22
						22
						22
						22
						22
						22
13	0	13	0	0	13	22
8	0	8	0	0	8	22
1	0	1	0	0	1	22
1	0	1	0	0	1	22
16	0	16	0	0	16	22
17	0	17	0	0	17	22
						22
171	0	171	0	0	171	22
						22
						22
						22
						22

```
                                                                        Card
                                                                        Type
   1    0    1    0    0    1                                           22
   1    0    1    0    0    1                                           22
                                                                        22
                                                                        22
                                                                        22
                                                                        22
                                                                        22
 166    0  166    0    0  166                                           22
                                                                        22
                                                                        22
                                                                        22
                                                                        22
   1    0    1    0    0    1                                           22
                                                                        22
                                                                        22
                                                                        22
 2.0 0.75  1.0  2.4  1.0                                                23
  1.00                                                                  24
 35.  -20. 390.  .142  .058  0                                          25
     150.       35.                                                     26
 0                                                                      27
 0                                                                      28
 22.                                                                    29
 15.                                                                    30
 270.                                                                   31
0.56                                                                    32
   68.    72.    72.    72.    74.    65.    70.    70.    65.    68.   33
   70.                                                                  33
   .81    .81    .81    .81    .53    .10    .15    .05    .15    .20   34
   .20                                                                  34
   .33    .17    .17    .17    .53                                .33   35
   .33                                                                  35
 1                                                                      27
24                                                                      36
 21.  18.  15.  16.  17.  18.  21.  23.  26.  27.  30.  33.             37
 35.  33.  32.  29.  30.  30.  30.  29.  27.  25.  23.  22.             37
```

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                                                                                  Card
                                                                                  Type
15.   15.   15.   15.   15.   15.   15.   15.   15.   15.   15.   15.              38
15.   15.   15.   15.   15.   15.   15.   15.   15.   15.   15.   15.              38
270.  270.  270.  270.  270.  270.  270.  270.  270.  270.  270.  270.            39
270.  270.  270.  270.  270.  270.  270.  270.  27ւ.  270.  270.  270.            39
.54   .51   .50   .51   .52   .55   .63   .78   .87   .90   .90   .88              40
.87   .85   .84   .82   .82   .84   .90  1.00   .97   .86   .75   .56              40
  68.     72.     72.     72.     74.     65.     70.     70.     65.     68.      41
  70.                                                                              41
  68.     72.     72.     72.     74.     65.     70.     70.     65.     68.      41
  70.                                                                              41
  68.     72.     72.     72.     74.     65.     70.     70.     65.     68.      41
  70.                                                                              41
  68.     72.     72.     72.     74.     65.     70.     70.     65.     68.      41
  70.                                                                              41
  68.     72.     72.     72.     74.     65.     70.     70.     65.     68.      41
  70.                                                                              41
  68.     72.     72.     72.     74.     65.     70.     70.     65.     68.      41
  70.                                                                              41
  68.     72.     72.     72.     74.     65.     70.     70.     65.     68.      41
  70.                                                                              41
  68.     72.     72.     72.     74.     65.     70.     70.     65.     68.      41
  70.                                                                              41
  68.     72.     72.     72.     74.     65.     70.     70.     65.     68.      41
  70.                                                                              41
  68.     72.     72.     72.     74.     65.     70.     70.     65.     68.      41
  70.                                                                              41
  68.     72.     72.     72.     74.     65.     70.     70.     65.     68.      41
  70.                                                                              41
  68.     72.     72.     72.     74.     65.     70.     70.     65.     68.      41
  70.                                                                              41
  68.     72.     72.     72.     74.     65.     70.     70.     65.     68.      41
  70.                                                                              41
  68.     72.     72.     72.     74.     65.     70.     70.     65.     68.      41
  70.                                                                              41
  68.     72.     72.     72.     74.     65.     70.     70.     65.     68.      41
  70.                                                                              41
```

										Card Type
68.	72.	72.	72.	74.	65.	70.	70.	65.	68.	41
70.										41
68.	72.	72.	72.	74.	65.	70.	70..	65.	68.	41
70.										41
68.	72.	72.	72.	74.	65.	70.	70.	65.	68.	41
70.										41
68.	72.	72.	72.	74.	65.	70.	70.	65.	68.	41
70.										41
68.	72.	72.	72.	74.	65.	70.	70.	65.	68.	41
70.										41
68.	72.	72.	72.	74.	65.	70.	70.	65.	68.	41
70.										41
68.	72.	72.	72.	74.	65.	70.	70.	65.	68.	41
70.										41
68.	72.	72.	72.	74.	65.	70.	70.	65.	68.	41
70.										41
68.	72.	72.	72.	74.	65.	70.	70.	65.	68.	41
70.										41
.67	.67	.67	.67	.41	.10	.15	.05	.10	.20	42
.20										42
.61	.61	.61	.61	.41	.10	.15	.05	.10	.20	42
.20										42
.58	.58	.58	.58	.41	.10	.15	.05	.10	.20	42
.20										42
.52	.52	.52	.52	.41	.10	.15	.05	.10	.20	42
.20										42
.49	.49	.49	.49	.38	.10	.15	.05	.10	.20	42
.20										42
.52	.52	.52	.52	.53	.10	.15	.10	.10	.50	42
.50										42
.59	.59	.59	.59	.60	.30	.15	.30	.10	.90	42
.90										42
.66	.66	.66	.66	.71	.30	.15	.80	.50	.30	42
.30										42
.69	.69	.69	.69	.88	.95	.25	.95	.75	.30	42
.30										42

										Card Type
.79	.79	.79	.79	.94	.95	.50	.95	.80	.30	42
.30										42
.90	.90	.90	.90	.98	.95	1.00	.95	1.00	.50	42
.50										42
.93	.93	.93	.93	.99	.95	1.00	.75	.95	.80	42
.80										42
.96	.96	.96	.96	1.00	.95	1.00	.75	.95	.50	42
.50										42
.96	.96	.96	.96	1.00	.95	1.00	.95	.90	.30	42
.30										42
.93	.93	.93	.93	1.00	.95	1.00	.95	.90	.30	42
.30										42
.95	.95	.95	.95	.99	.95	1.00	.50	.75	.50	42
.50										42
.93	.93	.93	.93	.93	.50	1.00	.30	.75	.70	42
.70										42
.98	.98	.98	.98	.79	.10	1.00	.10	.35	.80	42
.80										42
1.00	1.00	1.00	1.00	.70	.10	1.00	.10	.15	.80	42
.80										42
.99	.99	.99	.99	.70	.10	1.00	.10	.15	.80	42
.80										42
.96	.96	.96	.96	.68	.10	.90	.10	.15	.80	42
.80										42
.93	.93	.93	.93	.59	.10	.90	.05	.15	.50	42
.50										42
.87	.87	.87	.87	.56	.10	.80	.05	.15	.20	42
.20										42
.81	.81	.81	.81	.53	.10	.15	.05	.15	.20	42
.20										42
.26	.14	.14	.14	.41					.26	43
.26										43
.18	.13	.13	.13	.41					.18	43
.18										43
.11	.10	.10	.10	.41					.11	43
.11										43

						Card Type
.03	.11	.11	.11	.41	.03	43
.03						43
.04	.10	.10	.10	.38	.04	43
.04						43
.01	.10	.10	.10	.53	.01	43
.01						43
.11	.13	.13	.13	.60	.11	43
.11						43
.18	.15	.15	.15	.71	.18	43
.18						43
.21	.25	.25	.25	.88	.21	43
.21						43
.22	.21	.21	.21	.94	.22	43
.22						43
.18	.19	.19	.19	.98	.18	43
.18						43
.24	.17	.17	.17	.99	.24	43
.24						43
.16	.18	.18	.18	1.00	.16	43
.16						43
.13	.15	.15	.15	1.00	.13	43
.13						43
.16	.13	.13	.13	1.00	.16	43
.16						43
.24	.12	.12	.12	.99	.24	43
.24						43
.20	.12	.12	.12	.93	.20	43
.20						43
.26	.15	.15	.15	.79	.26	43
.26						43
.30	.19	.19	.19	.70	.30	43
.30						43
.29	.21	.21	.21	.70	.29	43
.29						43
.16	.18	.18	.18	.68	.16	43
.16						43

						Card Type
.26	.15	.15	.15	.59	.26	43
.26						43
.37	.13	.13	.13	.56	.37	43
.37						43
.33	.17	.17	.17	.53	.33	43
.33						43
2						27

A.5.3 Input Data Modifications

A.5.3.1 Building Energy Demands

When performing only the single time instant building load analysis (KODE=0, IDES=1, KODE=2), it is possible to eliminate many of the parameter specifications on the cards describing the TUS(types 5 and 6), since the only information required is the general TUS piping configuration and the locations of the load center heat exchangers. Thus, all fluid flowrates, fluid parameters, and nodal dimensions may be omitted, although it may be desirable to input non-zero dummy values for these parameters to eliminate the possibility of computational overflow errors occurring during the transition from the single time analysis to an hourly load analysis. The consumer fluid supply and return temperatures and the nodal fluid specific heats must be specified if a complete analysis is desired, since the initial load center heat exchanger fluid mass flowrates are computed at the same time the load distribution is printed. All TUS nodal cards must be input, along with their location and type codes, to facilitate heat exchanger identification by the load aggregation section of the program. The number of tubes in each heat exchanger need not be specified (card type 8), but its supply-and demand-side node location codes must be supplied. Initial conditions at the reservoir and on the power plant side of the TUS supply heat exchanger are unnecessary, but dummy values should be input to prevent possible overflows during the initialization calculations. All building parameter specifications and all building distribution data must be supplied to every program run option. Finally, for single time analyses, all initial system data shown in the sample listing between IDES=0 (card type 28) and KODE=1 (card type 27) must be input following IDES=1 to supply the load calculation subroutines with appropriate weather and building requirements specifications. (Of course, KODE=2 would then replace KODE=1 following card type 35, and no further data would be required).

Extension of the single time instant building load analysis to an hourly analysis without performing any TUS calculations requires non-zero (and non-equal) values to be supplied for the consumer fluid supply and return temperatures and non-zero values for the load center heat exchanger fluid specific heats to avoid overflows during the calculation period between the two option executions. Following specification of KODE=1 after the initial weather data and building conditions are input, data must be provided for each hour of the analysis desired. (These hourly data values need not be consistent with continuous functions for a specified time period, since the demands are computed independently at each hourly interval).

AD-A033 301 MASSACHUSETTS INST OF TECH CAMBRIDGE DEPT OF NUCLEAR--ETC F/G 9/2
TDIST, A PROGRAM FOR COMMUNITY ENERGY DEMAND ANALYSIS AND TOTAL--ETC(U)
AUG 76 J W STETKAR, M W GOLAY DAAK02-74-C-0308
UNCLASSIFIED USAFESA-RT-2024 NL

3 OF 4
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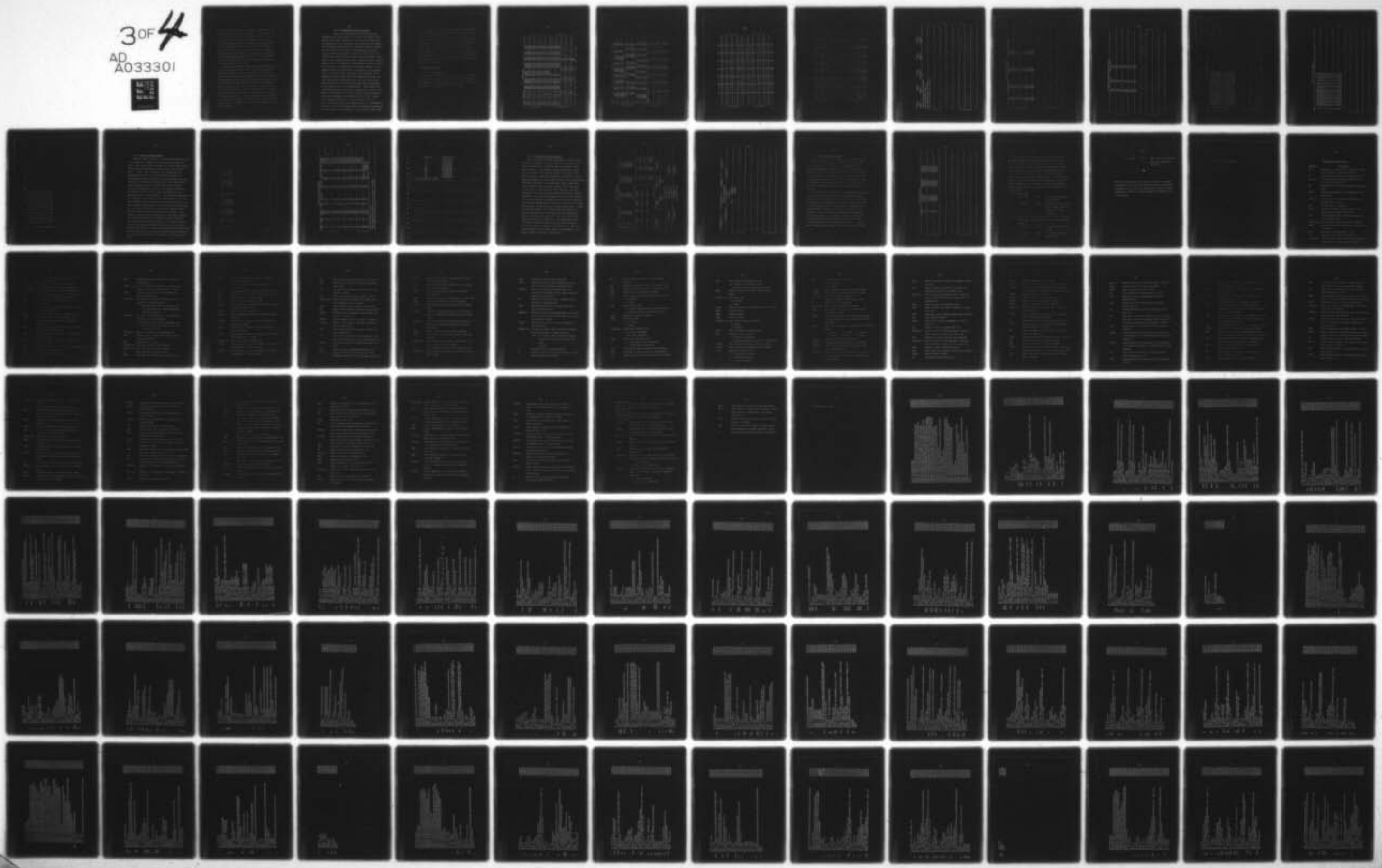
A033301



dummy values should be input to prevent possible overflows during the initialization calculations. All building parameter specifications and all building distribution data must be supplied to every program run option. Finally, for single time analyses, all initial system data shown in the sample listing between IDES=0 (card type 28) and KODE=1 (card type 27) must be input following IDES=1 to supply the load calculation subroutines with appropriate weather and building requirements specifications. (Of course, KODE=2 would then replace KODE=1 following card type 35, and no further data would be required).

Extension of the single time instant building load analysis to an hourly analysis without performing any TUS calculations requires non-zero (and non-equal) values to be supplied for the consumer fluid supply and return temperatures and non-zero values for the load center heat exchanger fluid specific heats to avoid overflows during the calculation period between the two option executions. Following specification of KODE=1 after the initial weather data and building conditions are input, data must be provided for each hour of the analysis desired. (These hourly data values need not be consistent with continuous functions for a specified time period, since the demands are computed independently at each hourly interval).

A.5.3.2 Steady-State System Analysis

Since the steady-state TUS analysis performs essentially the same computations as does the dynamic system analysis (but under steady-state energy and momentum transfer conditions), the input data requirements for the steady-state analysis program execution option are exactly the same as those shown for the dynamic system analysis, with the single exception that KODE=2 is input for the second value of KODE (card type 27) and no hourly data is required. Estimates of the secondary loop fluid flowrates should be approximately equal to the expected converged system values to minimize the number of steady-state iterations required. As is demonstrated by the sample data, all secondary loop temperatures, all consumer-side load center heat exchanger fluid flowrates, and all primary HTW loop temperatures except for the fixed supply temperature at the loop inlet may be left unspecified with no adverse effects upon system convergence or the overall cost of the calculations. Since typical TUS configurations may be expected to converge well within 1 CPU-minute of computing time if the estimated initial conditions are at all reasonable (see Table A.10), use of the steady-state system analysis with a specified upper limit of 1 minute for the CPU time can provide a means for verifying the validity of all but the hourly input data directly associated with the dynamic system analysis. Any mis-punched data cards or input parameters inconsistent with the code assumptions will almost invariably result in generation of an internal computer system data format error, the calculation of converged nodal parameters significantly different from expected conditions, or, in the worst case, non-convergence of the system with no diagnostic output produced. In any event, however, these errors will be identified prior to the initiation of the long and costly dynamic analyses, and will thus be more easily traced to their precise input data source with less expense and frustration than if discovered well into the simulation.

A.6 TDIST Output Data

A.6.1 Input Summary

For every program execution, the first set of output data supplied is a complete summary of the input data for that computer run. The following is the output summary of the sample input data listed in Section A.5.2.

```
                                ***INPUT SUMMARY***
   NODE      ISER IEX  IPMP    DIA        LONG         MASS          AU          CAP      RHO      MU
   1  1  1     0   0    0    1.4060   0.3040E+05   0.1658E+07   0.1520E+05   1.0670   54.470   0.350
   1  1  2     0   1    0    0.0700   0.8000E+02   0.1658E+07   0.1346E+07   1.0560   55.220   0.370
   1  1  3     0   0    0    1.4060   0.4000E+03   0.1658E+07   0.2000E+03   1.0350   56.660   0.420
   1  1  4     0   2    0    0.0700   0.8000E+02   0.1658E+07   0.2420E+07   1.0260   57.620   0.470
   1  1  5     0   0    0    1.4060   0.9610E+04   0.1658E+07   0.4805E+04   1.0150   58.510   0.570
   1  1  6     0   3    0    0.0700   0.8000E+02   0.1658E+07   0.6397E+07   1.0050   60.130   0.740
   1  1  7     0   0    1    1.4060   0.2090E+05   0.1658E+07   0.6047E+05   1.0000   61.200   1.060
   2  1  1     0   0    0    0.9950   0.5240E+04   0.3200E+06   0.4620E+04   1.0560   55.220   0.370
   2  1  2     1   4    0    0.0700   0.8000E+02   0.1435E+06   0.9199E+06   1.0100   59.370   0.630
   2  1  3     1   5    0    0.0700   0.8000E+02   0.5305E+05   0.5941E+06   1.0100   59.370   0.630
   2  1  4     1   6    0    0.0700   0.8000E+02   0.8344E+05   0.5941E+06   1.0100   59.370   0.630
   2  1  5     0   0    2    0.9950   0.5240E+04   0.3200E+06   0.2514E+05   0.9980   62.000   1.650
   2  1  6     0   1    0    0.0830   0.8000E+02   0.3200E+06   0.1346E+07   1.0100   59.370   0.630
   2  2  1     0   0    0    0.9950   0.2080E+05   0.5406E+06   0.9881E+04   1.0290   57.310   0.450
   2  2  2     1   7    0    0.0700   0.8000E+02   0.7187E+05   0.5472E+06   1.0050   60.130   0.740
   2  2  3     1   8    0    0.0700   0.8000E+02   0.1359E+06   0.1320E+07   1.0050   60.130   0.740
   2  2  4     1   9    0    0.0700   0.8000E+02   0.1564E+06   0.1320E+07   1.0050   60.130   0.740
   2  2  5     1  10    0    0.0700   0.8000E+02   0.1745E+06   0.1320E+07   1.0050   60.130   0.240
   2  2  6     0   0    3    0.9950   0.2080E+05   0.5406E+06   0.5660E+05   0.9980   62.000   1.650
   2  2  7     0   2    0    0.0830   0.8000E+02   0.5406E+06   0.2420E+07   1.0050   60.130   0.740
   2  3  1     0   0    0    0.9950   0.1550E+05   0.5448E+06   0.7593E+04   1.0120   59.100   0.600
   2  3  2     1  11    0    0.0700   0.8000E+02   0.5452E+05   0.1324E+07   1.0000   61.010   0.970
   2  3  3     1  12    0    0.0700   0.8000E+02   0.2765E+06   0.3898E+07   1.0000   61.010   0.970
   2  3  4     1  13    0    0.0700   0.8000E+02   0.2786E+06   0.3898E+07   1.0000   61.010   0.970
   2  3  5     1  14    0    0.0700   0.8000E+02   0.8481E+05   0.1324E+07   1.0000   61.010   0.970
   2  3  6     1  15    0    0.0700   0.8000E+02   0.2112E+06   0.3898E+07   1.0000   61.010   0.970
   2  3  7     0   0  [illegible] 0.9950   0.1550E+05   0.5448E+06   0.4327E+05   0.9980   62.090   1.860
   2  3  8     0   3    0    0.0830   0.8000E+02   0.5448E+06   0.6397E+07   1.0000   61.010   0.970
   3  1  1     1   4    0    0.0830   0.8000E+02   0.0          0.9199E+06   1.0000   61.010   0.970
   3  1  2     1   5    0    0.0830   0.8000E+02   0.0          0.5941E+06   1.0000   61.010   0.970
   3  1  3     1   6    0    0.0830   0.8000E+02   0.0          0.5941E+06   1.0000   61.010   0.970
   3  2  1     1   7    0    0.0830   0.8000E+02   0.0          0.5472E+06   1.0000   61.010   0.970
   3  2  2     1   8    0    0.0830   0.8000E+02   0.0          0.1320E+07   1.0000   61.010   0.970
   3  2  3     1   9    0    0.0830   0.8000E+02   0.0          0.1320E+07   1.0000   61.010   0.970
   3  2  4     1  10    0    0.0830   0.8000E+02   0.0          0.1320E+07   1.0000   61.010   0.970
   3  3  1     1  11    0    0.0830   0.8000E+02   0.0          0.1324E+07   0.9990   61.200   1.040
   3  3  2     1  12    0    0.0830   0.8000E+02   0.0          0.3898E+07   0.9990   61.200   1.040
   3  3  3     1  13    0    0.0830   0.8000E+02   0.0          0.3898E+07   0.9990   61.200   1.040
   3  3  4     1  14    0    0.0830   0.8000E+02   0.0          0.1324E+07   0.9990   61.200   1.040
   3  3  5     1  15    0    0.0830   0.8000E+02   0.0          0.3898E+07   0.9990   61.200   1.040

               EXCHANGER            SUPPLY NODE         DEMAND NODE        TUBES
                   1                   1  1  2             2  1  6           414
                   2                   1  1  4             2  2  7           745
                   3                   1  1  6             2  3  8          1969
                   4                   2  1  2             3  1  1           283
                   5                   2  1  3             3  1  2           182
                   6                   2  1  4             3  1  3           182
                   7                   2  2  2             3  2  1           168
                   8                   2  2  3             3  2  2           406
                   9                   2  2  4             3  2  3           406
                  10                   2  2  5             3  2  4           406
                  11                   2  3  2             3  3  1           407
                  12                   2  3  3             3  3  2          1200
                  13                   2  3  4             3  3  3          1200
                  14                   2  3  5             3  3  4           407
                  15                   2  3  6             3  3  5          1200

      HVO          CVO          THW       THG         TCG          HGAS         CAPG        TAMB       DTIMF
```

```
0.9000E+06   0.9000E+06   180.00   450.00   160.00   0.2830E+07   1.2400   56.00   0.00100

TYPE        AW       RTW        AWD     RTWD         AR      RTR         AF      RTF     HEIGHT
  1   10368.00      3.70    4110.00     0.89    2060.00    14.29    2060.00    10.00      27.50
  2    4784.00     10.00     330.00     0.89    1519.00    16.67    1824.00     4.91      23.00
  3    5250.00      4.00     512.00     0.89    3664.00     4.55    3752.00     4.91      17.50
  4    5244.00      3.45     904.00     0.89    2325.00    16.67    2074.00     4.91      28.50
  5   73000.00      3.70   24333.00     0.89   60000.00    17.53   60000.00     6.50      90.00
  6    7104.00      3.70    1420.00     0.89   11421.00     3.33   11421.00     6.00      15.80
  7   10556.00      3.13     300.00     0.89   20369.00     5.89   20486.00     5.27      15.00
  8   14782.00      4.00    5666.00     0.89    8135.00    20.00    8135.00     4.04      23.00
  9   17800.00      2.63    3560.00     0.89   41850.00     5.26   41850.00     4.00      20.00
 10   25598.00      2.63    5261.00     0.89   18685.00     5.26   18685.00     4.00      28.50
 11   20590.00      2.44    5433.00     0.89   17000.00     5.26   17000.00     4.50      30.00

TYPE     DOOR CRACK        C        N     WINDOW CRACK       C        N     WALL AREA       C        N
  1             78.   40.000    0.500             800.   1.700    0.660     10368.00   0.004    0.700
  2             31.   40.000    0.500             195.   1.700    0.660      4784.00   0.010    0.800
  3            132.   40.000    0.500             306.   1.700    0.660      5250.00   0.004    0.700
  4             33.   40.000    0.500             296.   1.700    0.660      5244.00   0.010    0.800
  5            233.   40.000    0.500           12167.   3.200    0.660     73000.00   0.004    0.700
  6            176.   40.000    0.500             272.   2.200    0.660      7104.00   0.010    0.800
  7             66.   40.000    0.500             150.   3.000    0.660     10556.00   0.004    0.800
  8             90.   40.000    0.500            1304.   3.200    0.660     14787.00   0.004    0.800
  9            158.   40.000    0.500            3816.   3.200    0.660     17800.00   0.004    0.800
 10             84    40.000    0.500            2368.   3.200    0.660     25598.00   0.004    0.800
 11             88.   40.000    0.500            2264.   3.200    0.660     20590.00   0.004    0.800

TYPE      AINFI        WOSC    FWLIT(1)  FWLIT(2)  FWLIT(3)  FWLIT(4)   FRLIT    WSAB    RSAB      POI
  1      944.00        0.50      0.80      0.80      0.80      0.80     1.00    0.50    0.80     5.37
  2      702.00        0.50      0.70      0.70      0.70      0.70     1.00    0.70    0.80     3.17
  3     1103.00        0.50      0.90      0.90      0.90      0.90     1.00    0.70    0.80     6.53
  4      937.00        0.50      0.50      0.80      0.50      0.90     1.00    0.70    0.80     2.08
  5   270033.00        0.40      0.95      0.95      0.95      0.95     1.00    0.91    0.80   337.06
  6     3001.00        0.80      1.00      1.00      1.00      1.00     1.00    0.68    0.80    22.84
  7    25624.00        0.70      1.00      1.00      1.00      1.00     1.00    0.68    0.90    30.73
  8     7813.00        0.60      0.50      0.90      0.50      0.90     1.00    0.91    0.80    72.34
  9    13958.00        0.80      1.00      1.00      1.00      1.00     1.00    0.70    0.80    41.85
 10    13397.00        0.50      0.80      0.80      0.80      0.80     1.00    0.70    0.80   127.40
 11    12818.00        0.60      1.00      1.00      1.00      1.00     1.00    0.70    0.80   127.40

EXCHANGER      BLDG TYPE        UNITS        COMP AC        ABS AC        RES HT   .   HT PUMP        HZC HT
   4
                   1             75             0             75             0             0             75
                   2              0             0              0             0             0              0
                   3              0             0              0             0             0              0
                   4              0             0              0             0             0              0
                   5              0             0              0             0             0              0
                   6              0             0              0             0             0              0
                   7              0             0              0             0             0              0
                   8             12             0             12             0             0             12
                   9              2             0              2             0             0              2
                  10              0             0              0             0             0              0
                  11              0             0              0             0             0              0
   5
                   1              0             0              0             0             0              0
                   2              0             0              0             0             0              0
                   3              0             0              0             0             0              0
                   4              0             0              0             0             0              0
                   5              0             0              0             0             0              0
                   6              0             0              0             0             0              0
                   7             13             0             13             0             0             13
                   8             10             0             10             0             0             10
                   9              3             0              3             0             0              3
                  10             10             0             10             0             0             10
                  11              0             0              0             0             0              0
```

Information Processing Center

```
6
          1       9       0       9       0       0       9
          2      30       0      30       0       0      30
          3       0       0       0       0       0       0
          4      18       0      18       0       0      18
          5       1       0       1       0       0       1
          6       0       0       0       0       0       0
          7       6       0       6       0       0       6
          8       1       0       1       0       0       1
          9       0       0       0       0       0       0
         10       0       0       0       0       0       0
         11       0       0       0       0       0       0
7
          1       0       0       0       0       0       0
          2       0       0       0       0       0       0
          3      76       0      76       0       0      76
          4       0       0       0       0       0       0
          5       0       0       0       0       0       0
          6       0       0       0       0       0       0
          7       1       0       1       0       0       1
          8       1       0       1       0       0       1
          9       0       0       0       0       0       0
         10       0       0       0       0       0       0
         11       0       0       0       0       0       0
8
          1       0       0       0       0       0       0
          2     363       0     363       0       0     363
          3      26       0      76       0       0      26
          4       0       0       0       0       0       0
          5       0       0       0       0       0       0
          6       0       0       0       0       0       0
          7       0       0       0       0       0       0
          8       0       0       0       0       0       0
          9       0       0       0       0       0       0
         10       0       0       0       0       0       0
         11       0       0       0       0       0       0
9
          1       0       0       0       0       0       0
          2     370       0     370       0       0     370
          3      41       0      41       0       0      41
          4       0       0       0       0       0       0
          5       0       0       0       0       0       0
          6       0       0       0       0       0       0
          7       0       0       0       0       0       0
          8       0       0       0       0       0       0
          9       0       0       0       0       0       0
         10       0       0       0       0       0       0
         11       0       0       0       0       0       0
10
          1      75       0      75       0       0      75
          2       0       0       0       0       0       0
          3       0       0       0       0       0       0
          4       0       0       0       0       0       0
          5       0       0       0       0       0       0
          6       0       0       0       0       0       0
          7       0       0       0       0       0       0
          8       9       0       9       0       0       9
          9       3       0       3       0       0       3
         10       0       0       0       0       0       0
         11       0       0       0       0       0       0
11
          1       0       0       0       0       0       0
          2      68       0      68       0       0      68
          3      50       0      50       0       0      50
          4       0       0       0       0       0       0
          5       0       0       0       0       0       0
```

Information Processing Center

	6	0	0	0	0	0	0
	7	0	0	0	0	0	0
	8	0	0	0	0	0	0
	9	0	0	0	0	0	0
	10	0	0	0	0	0	0
	11	0	0	0	0	0	0
12							
	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0
	5	0	0	0	0	0	0
	6	0	0	0	0	0	0
	7	12	0	12	0	0	12
	8	2	0	2	0	0	2
	9	9	0	9	0	0	9
	10	0	0	0	0	0	0
	11	28	0	28	0	0	28
13							
	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0
	5	0	0	0	0	0	0
	6	13	0	13	0	0	13
	7	8	0	8	0	0	8
	8	1	0	1	0	0	1
	9	1	0	1	0	0	1
	10	16	0	16	0	0	16
	11	17	0	17	0	0	17
14							
	1	0	0	0	0	0	0
	2	171	0	171	0	0	171
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0
	5	0	0	0	0	0	0
	6	0	0	0	0	0	0
	7	1	0	1	0	0	1
	8	1	0	1	0	0	1
	9	0	0	0	0	0	0
	10	0	0	0	0	0	0
	11	0	0	0	0	0	0
15							
	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	166	0	166	0	0	166
	4	0	0	0	0	0	0
	5	0	0	0	0	0	0
	6	0	0	0	0	0	0
	7	0	0	0	0	0	0
	8	1	0	1	0	0	1
	9	0	0	0	0	0	0
	10	0	0	0	0	0	0
	11	0	0	0	0	0	0
UNSUPPLIED							
	1	0	0	0	0	0	0
	2	842	842	0	0	842	0
	3	0	0	0	0	0	0
	4	97	97	0	0	97	0
	5	0	0	0	0	0	0
	6	13	13	0	0	13	0
	7	0	0	0	0	0	0
	8	18	18	0	0	18	0
	9	11	11	0	0	11	0
	10	0	0	0	0	0	0

```
CCMP AC EFF              ABS AC EFF               RES HT EFF              HT PUMP EFF              H2O HT EFF
    2.00                     0.75                     1.0C                    2.40                     1.00
LATITUDE                 SOLAR DECL           APP SOLAR CCNST             ATM EXT COEFF            SKY DIFF FAC
  35.00                    -20.00                 390.                     0.142                    0.058

THERMAL/ELECTRIC CONVERSION EFFICIENCY: 0.33CC

PUMP RESPONSE SENSITIVITY FACTCR:  2.0

CASE MASS FLOW INPUT SCALE FACTCR: 1.0000

REACTOR TOTAL THERMAL POWER OUTPUT:  150. MW(TH)
```

```
                              ***WEATHER DATA DISTRIBUTION***
      TIME          AIR TEMPERATURE (F)          WIND VELOCITY (MPH)          WIND DIRECTION (FROM NORTH)
      0:00                22.00                         15.00                        270.00
      1:00                21.00                         15.00                        270.00
      2:00                18.00                         15.00                        270.00
      3:00                15.00                         15.00                        270.00
      4:00                16.00                         15.00                        270.00
      5:00                17.00                         15.00                        270.00
      6:00                18.00                         15.00                        270.00
      7:00                21.00                         15.00                        270.00
      8:00                23.00                         15.00                        270.00
      9:00                26.00                         15.00                        270.00
     10:00                27.00                         15.00                        270.00
     11:00                30.00                         15.00                        270.00
     12:00                33.00                         15.00                        270.00
     13:00                35.00                         15.00                        270.00
     14:00                33.00                         15.00                        270.00
     15:00                32.00                         15.00                        270.00
     16:00                29.00                         15.00                        270.00
     17:00                30.00                         15.00                        270.00
     18:00                30.00                         15.00                        270.00
     19:00                30.00                         15.00                        270.00
     20:00                29.00                         15.00                        270.00
     21:00                27.00                         15.00                        270.00
     22:00                25.00                         15.00                        270.00
     23:00                23.00                         15.00                        270.00
     24:00                22.00                         15.00                        270.00
```

```
***ELECTRICAL LOAD DISTRIBUTION (EXCLUDING HEAT)***
 TIME       LOAD (MWE)          BASE LOAD FRACTION
 0:00          19.6                  0.56
 1:00          18.9                  0.54
 2:00          17.8                  0.51
 3:00          17.5                  0.50
 4:00          17.8                  0.51
 5:00          18.2                  0.52
 6:00          19.3                  0.55
 7:00          22.0                  0.63
 8:00          27.3                  0.78
 9:00          30.4                  0.87
10:00          31.5                  0.90
11:00          31.5                  0.90
12:00          30.8                  0.88
13:00          30.4                  0.87
14:00          29.8                  0.85
15:00          29.4                  0.84
16:00          28.7                  0.82
17:00          28.7                  0.82
18:00          29.4                  0.84
19:00          31.5                  0.90
20:00          35.0                  1.00
21:00          33.9                  0.97
22:00          30.1                  0.86
23:00          26.3                  0.75
24:00          19.6                  0.56
```

```
                                        ***BUILDING USE FACTORS***
  TIME      1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20

    0    0.81 0.81 0.81 0.81 0.53 0.10 0.15 0.05 0.15 0.20 0.20
    1    0.67 0.67 0.67 0.67 0.41 0.10 0.15 0.05 0.10 0.20 0.20
    2    0.61 0.61 0.61 0.61 0.41 0.10 0.15 0.05 0.10 0.20 0.20
    3    0.58 0.58 0.58 0.58 0.41 0.10 0.15 0.05 0.10 0.20 0.20
    4    0.52 0.52 0.52 0.52 0.41 0.10 0.15 0.05 0.10 0.20 0.20
    5    0.49 0.49 0.49 0.49 0.38 0.10 0.15 0.05 0.10 0.20 0.20
    6    0.52 0.52 0.52 0.52 0.53 0.10 0.15 0.10 0.10 0.50 0.50
    7    0.59 0.59 0.59 0.59 0.60 0.30 0.15 0.30 0.10 0.90 0.50
    8    0.66 0.66 0.66 0.66 0.71 0.30 0.15 0.80 0.50 0.30 0.20
    9    0.69 0.69 0.69 0.69 0.88 0.95 0.25 0.55 0.75 0.30 0.30
   10    0.79 0.79 0.79 0.79 0.94 0.95 0.50 0.55 0.80 0.30 0.30
   11    0.90 0.90 0.90 0.90 0.98 0.95 1.00 0.55 1.00 0.50 0.50
   12    0.93 0.93 0.93 0.93 0.99 0.95 1.00 0.75 0.95 0.80 0.80
   13    0.96 0.96 0.96 0.96 1.00 0.95 1.00 0.75 0.95 0.50 0.50
   14    0.96 0.96 0.96 0.96 1.00 0.95 1.00 0.55 0.90 0.30 0.30
   15    0.93 0.93 0.93 0.93 1.00 0.95 1.00 0.55 0.90 0.30 0.30
   16    0.95 0.95 0.95 0.95 0.95 0.95 1.00 0.50 0.75 0.50 0.50
   17    0.93 0.93 0.93 0.93 0.93 0.50 1.00 0.30 0.75 0.70 0.70
   18    0.98 0.98 0.98 0.98 0.75 0.10 1.00 0.10 0.35 0.80 0.80
   19    1.00 1.00 1.00 1.00 0.70 0.10 1.00 0.10 0.15 0.80 0.80
   20    0.99 0.99 0.99 0.99 0.70 0.10 1.00 0.10 0.15 0.80 0.80
   21    0.96 0.96 0.96 0.96 0.68 0.10 0.90 0.10 0.15 0.80 0.80
   22    0.93 0.93 0.93 0.93 0.59 0.10 0.90 0.05 0.15 0.50 0.50
   23    0.87 0.87 0.87 0.87 0.56 0.10 0.80 0.05 0.15 0.20 0.20
   24    0.81 0.81 0.81 0.81 0.53 0.10 0.15 0.05 0.15 0.20 0.20
```

```
                              ***SERVICE HOT WATER USE FACTORS***
TIME      1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20

  0    0.33 0.17 0.17 0.17 0.53 0.0  0.0  0.0  0.0  0.33 0.33
  1    0.26 0.14 0.14 0.14 0.41 0.0  0.0  0.0  0.0  0.26 0.26
  2    0.18 0.13 0.13 0.13 0.41 0.0  0.0  0.0  0.0  0.18 0.18
  3    0.11 0.10 0.10 0.10 0.41 0.0  0.0  0.0  0.0  0.11 0.11
  4    0.03 0.11 0.11 0.11 0.41 0.0  0.0  0.0  0.0  0.03 0.03
  5    0.04 0.10 0.10 0.10 0.38 0.0  0.0  0.0  0.0  0.04 0.04
  6    0.01 0.10 0.10 0.10 0.53 0.0  0.0  0.0  0.0  0.01 0.01
  7    0.11 0.13 0.13 0.13 0.60 0.0  0.0  0.0  0.0  0.11 0.11
  8    0.18 0.15 0.15 0.15 0.71 0.0  0.0  0.0  0.0  0.18 0.18
  9    0.21 0.25 0.25 0.25 0.88 0.0  0.0  0.0  0.0  0.21 0.21
 10    0.22 0.21 0.21 0.21 0.94 0.0  0.0  0.0  0.0  0.22 0.22
 11    0.18 0.19 0.19 0.19 0.98 0.0  0.0  0.0  0.0  0.18 0.18
 12    0.24 0.17 0.17 0.17 0.95 0.0  0.0  0.0  0.0  0.24 0.24
 13    0.16 0.18 0.18 0.18 1.00 0.0  0.0  0.0  0.0  0.16 0.16
 14    0.13 0.15 0.15 0.15 1.00 0.0  0.0  0.0  0.0  0.13 0.13
 15    0.16 0.13 0.13 0.13 1.00 0.0  0.0  0.0  0.0  0.16 0.16
 16    0.24 0.12 0.12 0.12 0.95 0.0  0.0  0.0  0.0  0.24 0.24
 17    0.20 0.12 0.12 0.12 0.93 0.0  0.0  0.0  0.0  0.20 0.20
 18    0.26 0.15 0.15 0.15 0.75 0.0  0.0  0.0  0.0  0.26 0.26
 19    0.30 0.19 0.19 0.19 0.70 0.0  0.0  0.0  0.0  0.30 0.30
 20    0.29 0.21 0.21 [illegible] 0.70 0.0  0.0  0.0  0.0  0.29 0.29
 21    0.16 0.18 0.18 0.18 0.68 0.0  0.0  0.0  0.0  0.16 0.16
 22    0.26 0.15 0.15 0.15 0.59 0.0  0.0  0.0  0.0  0.26 0.26
 23    0.37 0.13 0.13 0.13 0.56 0.0  0.0  0.0  0.0  0.37 0.37
 24    0.33 0.17 0.17 0.17 0.53 0.0  0.0  0.0  0.0  0.33 0.33
```

```
                                          ***BUILDING ROOM TEMPERATURES (F)***
TIME      1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20

  0      68.  72.  72.  72.  74.  65.  70.  70.  65.  68.  70.
  1      68.  72.  72.  72.  74.  65.  70.  70.  65.  68.  70.
  2      68.  72.  72.  72.  74.  65.  70.  70.  65.  68.  70.
  3      68.  72.  72.  72.  74.  65.  70.  70.  65.  68.  70.
  4      68.  72.  72.  72.  74.  65.  70.  70.  65.  68.  70.
  5      68.  72.  72.  72.  74.  65.  70.  70.  65.  68.  70.
  6      68.  72.  72.  72.  74.  65.  70.  70.  65.  68.  70.
  7      68.  72.  72.  72.  74.  65.  70.  70.  65.  68.  70.
  8      68.  72.  72.  72.  74.  65.  70.  70.  65.  68.  70.
  9      68.  72.  72.  72.  74.  65.  70.  70.  65.  68.  70.
 10      68.  72.  72.  72.  74.  65.  70.  70.  65.  68.  70.
 11      68.  72.  72.  72.  74.  65.  70.  70.  65.  68.  70.
 12      68.  72.  72.  72.  74.  65.  70.  70.  65.  68.  70.
 13      68.  72.  72.  72.  74.  65.  70.  70.  65.  68.  70.
 14      68.  72.  72.  72.  74.  65.  70.  70.  65.  68.  70.
 15      68.  72.  72.  72.  74.  65.  70.  70.  65.  68.  70.
 16      68.  72.  72.  72.  74.  65.  70.  70.  65.  68.  70.
 17      68.  72.  72.  72.  74.  65.  70.  70.  65.  68.  70.
 18      68.  72.  72.  72.  74.  65.  70.  70.  65.  68.  70.
 19      68.  72.  72.  72.  74.  65.  70.  70.  65.  68.  70.
 20      68.  72.  72.  72.  74.  65.  70.  70.  65.  68.  70.
 21      68.  72.  72.  72.  74.  65.  70.  70.  65.  68.  70.
 22      68.  72.  72.  72.  74.  65.  70.  70.  65.  68.  70.
 23      68.  72.  72.  72.  74.  65.  70.  70.  65.  68.  70.
 24      68.  72.  72.  72.  74.  65.  70.  70.  65.  68.  70.
```

A.6.2 Building Energy Demands

Whenever IDES=1 in input, the first system analysis data to be output is a summary of the individual building type space conditioning loads calculated for the specified initial weather and building usage conditions (i.e., the loads at time t = IBHR). These individual unit demands are then aggregated according to the specified distributions of buildings and end-use equipment, and the resulting load distribution is printed by building type for each load center heat exchanger and for those buildings in the "external system" not supplied by the TUS. (It should be noted that the printed loads are the net heat losses/gains for the buildings prior to being scaled by the end-use equipment COPs and that they include domestic hot water demands). For TUS heat exchanger design and system initialization purposes, the total thermal energy demands at each load center heat exchanger (including the effects of the consumer equipment COPs, but not of heat losses in the piping) are printed. If an hourly building analysis is desired, the individual building type space conditioning load summary is printed for every set of hourly data points provided, but no further distribution data is supplied. Shown below are the outputs of the building space heating demands, the building load distribution, and the load center heat exchanger thermal demands corresponding to the initial conditions specified in the sample input data.

```
TIME    BUILDING     CONDUCTION    INFILTRATION   WINDOW SOLAR     LIGHTING      TOTAL LOAD
  0         1        0.3659E+06     0.5300E+05     0.0            0.1485E+05    0.3815E+06
  0         2        0.4962E+05     0.3071E+05     0.0            0.8761E+04    0.7157E+05
  0         3        0.1385E+06     0.7556E+05     0.0            0.1805E+05    0.1960E+06
  0         4        0.1347E+06     0.4317E+05     0.0            0.5769E+04    0.1721E+06
  0         5        0.2739E+07     0.8037E+07     0.0            0.6095E+06    0.1017E+08
  0         6        0.2982E+06     0.8244E+05     0.0            0.7793E+04    0.3728E+06
  0         7        0.3590E+06     0.1953E+06     0.0            0.1573E+05    0.5426E+06
  0         8        0.5102E+06     0.8474E+05     0.0            0.1234E+05    0.5826E+06
  0         9        0.8289E+06     0.1637E+06     0.0            0.2142E+05    0.9712E+06
  0        10        0.8845E+06     0.1331E+06     0.0            0.8694E+05    0.9307E+06
  0        11        0.8539E+06     0.1329E+06     0.0            0.8694E+05    0.8999E+06
```

```
                                   ***CONSUMER ENERGY DEMAND BREAKDOWN***
  SUPPLY     BUILDING      ROOM        NUMBER OF  AIR CONDITIONING DEMAND (BTU/HR)      TOTAL HEATING DEMAND (BTU/HR)
 EXCHANGER     TYPE     TEMPERATURE      UNITS    ABSORPTIVE            COMPRESSIVE  RESISTANCE   HEAT PUMPS   HOT WATER
     4          1          68.00          75      0.0                   0.0          0.0          0.0          0.3198E+08
     4          8          70.00          12      0.0                   0.0          0.0          0.0          0.2991E+07
     4          9          65.00           2      0.0                   0.0          0.0          0.0          0.1542E+07
     5          7          70.00          13      0.0                   0.0          0.0          0.0          0.7053E+07
     5          8          70.00          10      0.0                   0.0          0.0          0.0          0.5826E+07
     5          9          65.00           3      0.0                   0.0          0.0          0.0          0.2914E+07
     5         10          68.00          10      0.0                   0.0          0.0          0.0          0.1073E+08
     6          1          68.00           5      0.0                   0.0          0.0          0.0          0.3838E+07
     6          2          72.00          30      0.0                   0.0          0.0          0.0          0.2213E+07
     6          4          72.00          18      0.0                   0.0          0.0          0.0          0.3110E+07
     6          5          74.00           1      0.0                   0.0          0.0          0.0          0.1078E+06
     6          7          70.00           6      0.0                   0.0          0.0          0.0          0.3255E+07
     6          8          70.00           1      0.0                   0.0          0.0          0.0          0.5826E+06
     7          3          72.00          76      0.0                   0.0          0.0          0.0          0.1540E+08
     7          7          70.00           1      0.0                   0.0          0.0          0.0          0.5426E+06
     7          8          70.00           1      0.0                   0.0          0.0          0.0          0.5826E+06
     8          2          72.00         363      0.0                   0.0          0.0          0.0          0.2678E+08
     8          3          72.00          26      0.0                   0.0          0.0          0.0          0.5269E+07
     9          2          72.00         370      0.0                   0.0          0.0          0.0          0.2730E+08
     9          3          72.00          41      0.0                   0.0          0.0          0.0          0.8309E+07
    10          1          68.00          75      0.0                   0.0          0.0          0.0          0.3198E+08
    10          8          70.00           5      0.0                   0.0          0.0          0.0          0.5243E+07
    10          9          65.00           3      0.0                   0.0          0.0          0.0          0.2914E+07
    11          2          72.00          68      0.0                   0.0          0.0          0.0          0.5017E+07
    11          3          72.00          50      0.0                   0.0          0.0          0.0          0.1013E+08
    12          7          70.00          12      0.0                   0.0          0.0          0.0          0.6511E+07
    12          8          70.00           2      0.0                   0.0          0.0          0.0          0.1165E+07
    12          9          65.00           5      0.0                   0.0          0.0          0.0          0.8741E+07
    12         11          70.00          28      0.0                   0.0          0.0          0.0          0.2838E+08
    13          6          65.00          13      0.0                   0.0          0.0          0.0          0.4547E+07
    13          7          70.00           8      0.0                   0.0          0.0          0.0          0.4341E+07
    13          8          70.00           1      0.0                   0.0          0.0          0.0          0.5826E+06
    13          9          65.00           1      0.0                   0.0          0.0          0.0          0.9712E+06
    13         10          68.00          16      0.0                   0.0          0.0          0.0          0.1716E+08
    13         11          70.00          17      0.0                   0.0          0.0          0.0          0.1723E+08
    14          2          72.00         171      0.0                   0.0          0.0          0.0          0.1262E+08
    14          7          70.00           1      0.0                   0.0          0.0          0.0          0.5426E+06
    14          8          70.00           1      0.0                   0.0          0.0          0.0          0.5626E+06
    15          3          72.00         166      0.0                   0.0          0.0          0.0          0.3364E+08
    15          8          70.00           1      0.0                   0.0          0.0          0.0          0.5826E+06
   NONE         2          72.00         842      0.0                   0.0          0.1864E+07   0.6026E+08   0.0
   NONE         4          72.00          97      0.0                   0.0          0.1073E+06   0.1670E+08   0.0
   NONE         6          65.00          13      0.0                   0.0          0.0          0.4847E+07   0.0
   NONE         8          70.00          18      0.0                   0.0          0.0          0.1049E+08   0.0
   NONE         9          65.00          11      0.0                   0.0          0.0          0.1068E+08   0.0
   NONE        11          70.00           7      0.0                   0.0          0.7967E+06   0.6299E+07   0.0
 ***OUTSIDE AIR TEMPERATURE:  22.00 F***

 ***TOTAL COMMUNITY SPACE CONDITIONING & DOMESTIC HOT WATER LOAD:  140.86 MW(TH)***

 ***TOTAL ELECTRIC SPACE CONDITIONING & DOMESTIC HOT WATER DEMAND:   18.77 MW(E)***
```

```
       EXCHANGER              LOAD (BTU/HR)
          4                   0.4091E+08
          5                   0.2652E+08
          6                   0.2378E+08
          7                   0.1653E+08
          8                   0.3205E+08
          9                   0.3561E+08
         10                   0.4014E+08
         11                   0.1515E+08
         12                   0.4480E+08
         13                   0.4514E+08
         14                   0.1374E+08
         15                   0.3422E+08
**TERMINATION CODE READ**
```

A.6.3 Steady-State System Analysis

When the steady-state system analysis is executed, the individual building type space conditioning loads are computed and printed as in the building load analysis option described above. The demands are then aggregated, scaled by the equipment COPs, and are applied to the load center heat exchangers. When TUS convergence is achieved, a nodal parameter summary is printed which includes fluid temperatures, fluid mass flowrates, the steady-state nodal energy flows, loop circulation pump pressure settings, fluid conditions on both sides of the TUS supply heat exchanger, and specifications of the heat stored in each section of the thermal reservoir. (It should be remembered that the values printed for the reservoir stored energy are only relative indicators of the actual energy storage trends, and that the water volume data provides the absolute heat storage information). Following this TUS summary, the building load distribution on a per-heat-exchanger basis is printed for the steady-state demand conditions, and overall TUS and power plant energy supply/demand data is summarized. The building loads and the demand distribution data output for this option are identical to those illustrated in Section A.6.2. The converged steady-state TUS nodal summary corresponding to the sample initial conditions is shown below.

```
                                   TIME =   C.0   HR
                               **CONSUMER BRANCH DATA**
LOOP  NODE     INLET TEMPERATURE (F)     OUTLET TEMPERATURE (F)     MASS FLOW (LBM/HR)     HEAT DEMAND (BTU/HR)
  1     1           80.00                      240.00                 0.2557E+06              0.4091E+08
  1     2           80.00                      240.00                 0.1657E+06              0.2652E+08
  1     3           80.00                      240.00                 0.1487E+06              0.2378E+08
  2     1           80.00                      240.00                 0.1033E+06              0.1653E+08
  2     2           80.00                      240.00                 0.2003E+06              0.3205E+08
  2     3           80.00                      240.00                 0.2225E+06              0.3561E+08
  2     4           80.00                      240.00                 0.2509E+06              0.4014E+08
  3     1           80.00                      220.00                 0.1083E+06              0.1515E+08
  3     2           80.00                      220.00                 0.3203E+06              0.4480E+08
  3     3           80.00                      220.00                 0.3227E+06              0.4514E+08
  3     4           80.00                      220.00                 0.9825E+05              0.1374E+08
  3     5           80.00                      220.00                 0.2447E+06              0.3422E+08
                               **SECONDARY LOOP DATA**
LOOP   SUPPLY TEMP   RETURN TEMP   MASS FLOW     HEAT DEMAND      NODE   SUPPLY TEMP   RETURN TEMP   MASS FLOW
           (F)           (F)        (LBM/HR)       (BTU/HR)                  (F)           (F)         (LBM/HR)
  1      368.45        86.27      0.3277E+06    0.9339E+08
                                                                   2       364.31         89.38      0.1473E+06
                                                                   3       364.31         89.49      0.9554E+05
                                                                   4       364.31         86.57      0.8479E+05
  2      315.03        84.34      0.5542E+06    0.1285E+09
                                                                   2       310.59         89.27      0.7430E+05
                                                                   3       310.59         84.68      0.1412E+06
                                                                   4       310.59         86.58      0.1582E+06
                                                                   5       310.59         89.45      0.1806E+06
  3      243.15        83.20      0.9731E+06    0.1557E+09
                                                                   2       241.71         85.07      0.9671E+05
                                                                   3       241.71         85.13      0.2861E+06
                                                                   4       241.71         85.23      0.2884E+06
                                                                   5       241.71         83.91      0.8708E+05
                                                                   6       241.71         82.41      0.2148E+06
                               **HTW LOOP DATA**
SUPPLY TEMPERATURE (F)      RETURN TEMPERATURE (F)      TOTAL HEAT DEMAND (BTU/HR)      MASS FLOW (LBM/HR)
       380.00                      150.83                     0.4054E+09                   0.1658E+07
                        NODE     INLET TEMPERATURE (F)      OUTLET TEMPERATURE (F)
                          2             377.23                      323.89
                          4             323.86                      248.32
                          6             247.77                      154.36
                               **RESERVOIR DATA**
                                HOT WATER STORAGE
            WATER TEMPERATURE (F)          STORAGE VOLUME (CU.FT.)          STORED HEAT (BTU)
                   380.00                        0.9000E+06                     0.1988E+11
                                COLD WATER STORAGE
            WATER TEMPERATURE (F)          STORAGE VOLUME (CU.FT.)          STORED HEAT (BTU)
                   150.83                        0.9000E+06                     0.9308E+10
                             **PRECOOLER GAS-SIDE DATA**
```

```
HELIUM INLET TFMPFRATURF (F)     HELIUM CUTLET TEMPERATURE (F)     HFLIUM MASS FLOW (LBM/HR)     HEAT FLOW (BTU/HR)
         450.00                             16C.00                         0.1052E+07                 0.3809F+09

                                    **PRECOOLER hATER-SIDE DATA**

              INLFT TFMPFRATURE (F)              OUTLFT TEMPFRATURF (F)              MASS FLOW (LBM/HR)
                     150.83                             38C.00                           0.1608E+07

                                           **PUMP CATA**

                                     PUMP           PRESSURF (PSI)
                                       1              0.7324F+02
                                       2              0.6387E+01
                                       3              0.3629F+02
                                       4              0.7809F+02
```

A.6.4 Dynamic System Analysis

When the dynamic system analysis is initialized internally from the converged steady-state TUS parameters, the first block of analysis output data corresponds to the printouts summarized in Sections A.6.2 and A.6.3 for the building load analysis and steady-state TUS analysis program execution options. (In this case, the hourly building load summary and its associated input data are printed following the steady-state system output, since the hourly data is not read into the program until the TUS parameters have converged.)

The output from the dynamic system simulation is scheduled by the user and can be supplied as frequently as every time step or as infrequently as once each hour. Printed output includes the instantaneous TUS nodal summary at the end of the given time step, the instantaneous distribution of building loads at each load center heat exchanger, and a summary of the thermal energy supply/demand mismatches at each heat exchanger in the system. The nodal summary and building load distribution are identical in form to the output illustrated for the steady-state analysis; a sample heat exchanger energy balance output listing is shown below.

```
                    **EXCHANGER HEAT BALANCE**

     EXCHANGER        SUPPLY (BTU/HR)         DEMAND (BTU/HR)       DIFFERENCE
         1              0.9331E+08              0.9330E+08          0.1546E+05
         2              0.1285E+09              0.1284E+09          0.2056E+05
         3              0.1557E+09              0.1557E+09         -0.1806E+05
         4              0.4117E+08              0.4111E+08          0.6571E+05
         5              0.2670E+08              0.2666E+08          0.4176E+05
         6              0.2301E+08              0.2294E+08          0.6909E+05
         7              0.1679E+08              0.1678E+08          0.1146E+05
         8              0.3173E+08              0.3164E+08          0.9237E+05
         9              0.3526E+08              0.3523E+08          0.3373E+05
        10              0.4034E+08              0.4033E+08          0.1614E+05
        11              0.1519E+08              0.1522E+08         -0.2533E+05
        12              0.4488E+08              0.4496E+08         -0.7862E+05
        13              0.4506E+08              0.4516E+08         -0.9027E+05
        14              0.1349E+08              0.1352E+08         -0.2941E+05
        15              0.3484E+08              0.3476E+08          0.8085E+05
```

Also output from the dynamic simulation is a punched card deck containing specifications of the instantaneous TUS total thermal load (including all losses), the instantaneous TES total electrical demand, and the volume of water contained in the hot section of the thermal energy storage reservoir at the end of each output interval time step. These overall system parameters are output in a format easily adapted to integrated energy consumption analyses (see, for example, Reference 14) or to simple hourly system summary data plotting routines. The composition and format of this data deck is:

1. Header card:

c.c. 1-7	F7.2	power plant electrical rating in MWe
c.c. 8-12	F5.2	power plant thermal/electrical energy conversion efficiency (decimal fraction)

2. System data cards (one punched for initial conditions and at each specified output interval during dynamic analysis)

c.c. 1-8	F8.2	total TUS thermal load in MWt
c.c. 12-19	F8.2	total TES electrical load in MWe

c.c. 23-30	F8.2	water volume in reservoir hot water section in 10^4 ft^3*

---

*For most moderately-sized systems, this unit of storage produces punched values for the water volume of magnitudes comparable to those for the thermal and electrical energy demands and, therefore, easily adapted to a single set of plotting axes.

A.7 TDIST Variable Definitions

TDIST Variable Definitions

Variable	Definition
A(J)	Coefficient in window solar heat gain formula for absorption of incident radiation
AC	Nodal cross-sectional flow channel area (ft^2)
ACC(NP)	Fluid acceleration through pump NP during one time step (lbm/hr^2)
AEC	Atmospheric extinction coefficient (dimensionless)
AF(I)	Area of Building Type I in contact with the earth (ft^2)
AINFL(I)	Maximum rate of forced-air ventilation for Building Type I (CFM)
ALAT	Latitude of site (degrees)
ALEAK	Total air exchanger between interior and exterior of building (CFH or CFM)
ALPL	Heat exchanger fluid temperature decay constant (dimensionless)
AMAS(K,L,N)	Desired nodal fluid mass flowrate (lbm/hr)
AMS(L)	Desired fluid mass flowrate in secondary loop L (lbm/hr)
AR(I)	Roof area of Building Type I (ft^2)
ASC	Apparent solar constant ($BTU/hr\text{-}ft^2$)
ATD(K,L,N)	Linear average difference between nodal fluid temperature and that of surroundings (°F)

ATDP	Linear average temperature difference across heat exchanger (°F)
ATI(ID,JD,KD)	Dummy nodal fluid inlet temperature (°F)
ATO(ID,JD,KD)	Dummy nodal fluid outlet temperature (°F)
AUF(K,L,N)	Nodal heat transfer coefficient (BTU/hr-°F)
AUG	Building ground-contact material conduction heat transfer coefficient (BTU/hr-°F)
AUR	Roof Conduction Heat Transfer Coefficient (BTU/hr-°F)
AUW	Total wall and window conduction heat transfer coefficient (BTU/hr-°F)
AW(I)	Total exposed wall area of Building Type I (ft^2)
AWD(I)	Total window area of Building Type I (ft^2)
B	Heat exchanger heat transfer coefficient (BTU/hr-°F)
BABS	Temperature-adjusted absorptive air conditioner coefficient of performance
BADC	Cooling equipment coefficient of performance adjustment factor
BADH	Heating equipment coefficient of performance adjustment factor
BCMP	Temperature-adjusted compressive air conditioner coefficient of performance
BH(I)	Height of Building Type I (ft)

BHPM	Temperature-adjusted heat pump coefficient of performance
BMAS(1,1,N)	Desired fluid mass flowrate in bypass around primary loop heat exchanger node N (lbm/hr)
BPDIS	Inverse sum of parallel node pressure drop factors (ft^5/hr-lbf)
BUF(I,NN)	Use factor of Building Type NN at hour I of simulation (decimal fraction) 0 = Building unoccupied, no equipment use 1 = Full occupancy, all lights, appliances ventilation in use
BUF(25,I)	Use factor of Building Type I at beginning of simulation (decimal fraction) 0 = Building unoccupied, no equipment use 1 = Full occupancy, all lights, appliances ventilation in use
CAP(K,L,N)	Nodal fluid specific heat (BTU/lbm-°F)
CAPG	Specific heat of power plant coolant in pre-cooler (BTU/lbm-°F)
CITY	Alphanumeric run title
COND(K,L,N)	Nodal heat conduction rate (BTU/hr)
CONV(K,L,N)	Nodal heat convection rate (BTU/hr)
CS	Solar incidence direction cosine
CSFAC	Case input mass flowrate scale factor (1.0)

CTH(I)	Cosine of incident solar radiation relative to normal to surface I I = 1-4 = walls, clockwise from north I = 5 = roof
CVO	Volume of cold water section of reservoir (ft^3)
CVOI	Volume of cold water section of reservoir (ft^3)
CW	Solar incidence direction cosine
CZ	Solar incidence direction cosine
DCL(I)	Total length of cracks around all exterior doors in Building Type I (ft)
DECL	Solar declination (degrees)
DENOM	Heat exchanger heat balance coefficient (dimensionless)
DFSI(NN)	Diffuse solar radiation intensity incident on wall NN (BTU/hr-ft^2)
DFSIR	Diffuse solar radiation intensity incident on roof (BTU/hr-ft^2)
DHW(I)	Maximum energy demand for domestic hot water use in Building Type I (BTU/hr)
DIA(K,L,N)	Nodal flow channel diameter (ft)
DINC(I)	Infiltration air flow coefficient C for doors in Building Type I (CFM/ft-in. H_2O)
DINN(I)	Infiltration air flow coefficient N for doors in Building Type I (dimensionless)

DL	Distance fluid flows during one time step (ft)
DLK	Total air infiltration through cracks around doors (CFM)
DM	Loop fluid mass flowrate at end of time step (lbm/hr) (FLOWS)
DM	Nodal fluid mass flowrate (lbm/hr) (PRESS)
DMAS(1,1,N)	Desired fluid mass flowrate in primary loop heat exchanger node N (lbm/hr)
DNSI	Direct normal solar intensity (BTU/hr-ft^2)
DP	Nodal fluid frictional pressure loss (lbf/ft^2)
DPM(L)	Maximum free-flow parallel node pressure loss for loop L (lbf/ft^2)
DQ(NE)	Thermal demand at heat exchanger NE (BTU/hr)
DSI(NN)	Direct solar radiation intensity incident on wall NN (BTU/hr-ft^2)
DSIR	Direct solar radiation intensity incident on roof (BTU/hr-ft^2)
DTC	Nodal outlet increment fluid temperature loss due to heat conduction to the surroundings (°F)
DTIME	Size of one time step (decimal fraction of an hour)
DTLM	Nodal log-mean temperature difference (°F)
DTLMX	Log-mean temperature difference over heat exchanger outlet fluid flow increment length (°F)

EABS	Nominal coefficient of performance of absorptive air conditioners
ECMP	Nominal coefficient of performance of compressive air conditioners
EFF	Power plant thermal/electrical conversion efficiency (%)
EHPM	Nominal coefficient of performance of heat pumps
EHWS	Nominal efficiency of hot water heating
ELBL	Peak non-space-conditioning electrical demand (MWe)
ELF(I)	Non-space-conditioning electric load factor at hour I of simulation (decimal fraction of peak load)
ELF(25)	Non-space-conditioning electric load factor at beginning of simulation (decimal fraction of peak load)
ERES	Nominal efficiency of resistance heaters
ESCL	Total system electric space conditioning load (BTU/hr)
ETHL(IHR)	Total system electric space conditioning load at simulation hour IHR (BTU/hr)
F	Moody-Weisbach friction factor (dimensionless)
FAC1-FAC4	Coefficients in expansion for window solar heat gain formula

FCTR	Conversion factor (lbm-ft^2/lbf-hr^2)
FF(IX)	Friction factor for heat exchanger IX exclusive of valve resistance (dimensionless)
FHPEX(I)	Fraction of units of Building Type I not served by the Thermal Utility System which are supplied by heat pumps
FP	Nodal fluid friction factor including valve resistance (dimensionless)
FRCN	Incremental/total heat exchanger heat flow ratio (dimensionless)
FREXT(I)	Fraction of units of Building Type I not served by the Thermal Utility System which are supplied by resistance heaters
FV(IX)	Valve friction factor for heat exchanger IX (dimensionless)
FWLIT(I,NN)	Fraction of surface NN lit by direct sunlight for Building Type I (decimal fraction) NN: 1-4 = walls, with 1 defined by normal direction WA, numbered clockwise from north 5 = roof
G	Conversion factor (lbm-ft/lbf-hr^2)
H	Angular position of solar disk relative to noon normal (radians from normal)

HRF	Elapsed fraction of hourly interval being examined
HVO	Volume of hot water section of reservoir (ft^3)
HVOI	Volume of hot water section of reservoir (ft^3)
IBEG	Beginning hour of simulation period
IBHR	Beginning hour of the simulation period (0-23) 0 = midnight 12 = noon
IDES	Design option code 0 = perform standard utility system analysis 1 = perform building load analysis only
IEND	Endpoint of simulation period
IERR	Data error code 0 = no error 1 = error
IEX(K,L,N)	Nodal heat exchanger code 0 = no heat exchanger 1-30 = heat exchanger
IFLO	Fluid flow calculation code 0 = pump reset or initialization 1 = normal time step sequence
IHR	End point of hourly interval being examined
IHRL	Beginning of hourly interval being examined
IIN	Computer system card reader input device number

INIT	Pump pressure initialization code 0 = compute loop pressure losses 1 = reset flow valves and pump settings
IOUT	Computer system line printer output device number
IPMP(K,L,N)	Nodal pump code 0 = no pump 1 = pump
IPNCH	Computer system card punch output device number
IPRE	Unused variable
IPRM	Unused variable
IPRX	Unused variable
ISER(K,L,N)	Nodal series/parallel flow code 0 = series 1 = parallel
ITIM	Hour of simulation being studied
JPM	Thermostat limit indicator 0 = limits not exceeded 1 = limits exceeded, pump reset to take place
K1(NEX)	Heat exchanger NEX supply-side group index
K2(NEX)	Heat exchanger NEX demand-side group index
KODE	Simulation control code 0 = steady-state analysis 1 = transient analysis 2 = end of simulation

KODP	Consumer summary print code 0 = no print 1 = print
L1(NEX)	Heat exchanger NEX supply-side loop index
L2(NEX)	Heat exchanger NEX demand-side loop index
LONG(K,L,N)	Nodal flow channel length (ft)
LS	Number of secondary distribution loops
M	Primary loop node indicator
MASS(K,L,N)	Nodal fluid mass flowrate (lbm/hr)
MGAS	Power plant coolant mass flowrate through precooler (lbm/hr)
MTR(I)	Roof surface material type for Building Type I (surface roughness classes identical to those for MTW(I))
MTW(I)	Wall exterior surface material type for Building Type I 1 = stucco 3 = concrete 5 = plaster 2 = brick 4 = pine 6 = glass
MU(K,L,N)	Nodal fluid viscosity (lbm/hr-ft)
N1(NEX)	Heat exchanger NEX supply-side node index
N2(NEX)	Heat exchanger NEX demand-side node index
NA	Nodal indicator number
NABS(IX,I)	Number of units of Building Type I served by heat exchanger IX which have absorptive air conditioning

NB(L)	Number of consumer load heat exchangers served by loop L
NBOI	Dummy variable for number of consumer heat exchangers served by a secondary loop
NCMP(IX,I)	Number of units of Building Type I served by heat exchanger IX which have compressive air conditioning
ND(L)	Number of nodes in secondary loop L
NDOI	Dummy variable for number of nodes in a secondary loop
NDUM	Load center heat exchanger supply node indicator
NEX	Heat exchanger number
NEXCH	Total number of heat exchangers in utility system
NH	Number of nodes in primary HTW loop
NHPM(IX,I)	Number of units of Building Type I served by heat exchanger IX which have heat pumps
NHR	Endpoint of hourly interval being examined
NHWS(IX,I)	Number of units of Building Type I served by heat exchanger IX which have hot water heat
NITR	Number of print intervals per hour
NMK	Load center heat exchanger supply node indicator
NNODE	Dummy variable, unused
NP	Secondary loop node indicator

NPMP	Number of pumps in utility system
NPRNT	Number of time steps between print intervals
NRES(IX,I)	Number of units of Building Type I served by heat exchanger IX which have resistance heaters
NSTEP	Number of time steps per hour
NTB(NEX)	Number of tubes in heat exchanger NEX
NTEMP	Number of hours in simulation period
NTYPE	Number of building types in community
NU(IX,I)	Number of units of Building Type I served by heat exchanger IX
NUEX(I)	Number of units of Building Type I <u>not</u> served by the Thermal Utility System
PC	Stack-effect pressure on building (in. H_2O)
PC(I)	Percent change in fluid mass flowrate through pump I during one time step
PCI	Percent increase in loop fluid mass flowrate during one time step
PEX(I)	Compensated pressure setting for pump I (lbf/ft^2)
PMF	Precooler fluid mass flowrate (lbm/hr)
PMFI	Precooler fluid mass flowrate (lbm/hr)
POL(I)	Maximum rate of heat generation due to lighting, appliances, people, etc. for Building Type I (KW)
PP(I)	Total fluid frictional pressure head faced by pump I (lbf/ft^2)

PREF(I)	Reference pressure setting for pump I (lbf/ft^2)
PS(I)	Pressure setting for pump I (lbf/ft^2)
PSENS	Pump response sensitivity factor
PT	Total pressure drop across wall (in. H_2O)
PTKN	Normal air flow pressure drop coefficient (dimensionless)
PTKO	Oblique air flow pressure drop coefficient (dimensionless)
PV	Normal wind-induced pressure loading on wall (in. H_2O)
PW	Wind-induced pressure loading on wall (in. H_2O)
Q	Total heat loss from buildings of one type served by a given load center heat exchanger (BTU/hr)
QABS	Energy demand from absorptive air conditioners (BTU/hr)
QAEXT	Energy demand from absorptive air conditioners in buildings not served by Thermal Utility System (BTU/hr)
QCEXT	Energy demand from compressive air conditioners in buildings not served by Thermal Utility System (BTU/hr)
QCI	Heat stored in reservoir cold water section (BTU referenced to 0 °F)
QCMP	Energy demand from compressive air conditioners (BTU/hr)

QCO	Heat stored in reservoir cold water section (BTU referenced to 0 °F)
QCOND(I)	Total heat loss due to conduction from Building Type I (BTU/hr)
QCW	Heat stored in reservoir cold water section (BTU referenced to 0 °F)
QD	Thermal demand at heat exchanger (BTU/hr)
QDEXT	Total domestic hot water energy demand for buildings of a given type not served by Thermal Utility System (BTU/hr)
QDHW	Total domestic hot water energy demand for buildings of one type served by a given load center heat exchanger (BTU/hr)
QDIF	Supply/demand imbalance at heat exchanger (BTU/hr)
QDO(NX)	Thermal demand at heat exchanger NX (BTU/hr)
QEXT	Total heat loss from all buildings of a given type not served by Thermal Utility System (BTU/hr)
QHEXT	Energy demand from heat pumps in buildings not served by Thermal Utility System (BTU/hr)
QHI	Heat stored in reservoir hot water section (BTU referenced to 0 °F)
QHO	Heat stored in reservoir hot water section (BTU referenced to 0 °F)
QHPM	Energy demand from heat pumps (BTU/hr)

QHS	Thermal energy available to thermal utility system after electrical generation (BTU/hr)
QHW	Heat stored in reservoir hot water section (BTU referenced to 0 °F)
QHWEX	Energy demand from hot water heating in buildings not served by Thermal Utility System (BTU/hr)
QHWS	Energy demand from hot water heat (BTU/hr)
QL(IHR,I)	Total heat loss from Building Type I at simulation hour IHR (BTU/hr)
QLEAK(I)	Heat loss rate from Building Type I due to infiltration/ventilation (BTU/hr)
QLIG(I)	Internal heat generation rate for Building Type I due to non-space conditioning equipment and people (BTU/hr)
QRES	Energy demand from resistance heaters (BTU/hr)
QREXT	Energy demand from resistance heaters in buildings not served by Thermal Utility System (BTU/hr)
QS	Thermal supply at heat exchanger (BTU/hr)
QS(L)	Total thermal demand at load center heat exchangers in loop L (BTU/hr)
QTLD	Total thermal demand at load center heat exchangers (BTU/hr)
QTLLD	Total thermal demand at load center heat exchangers (BTU/hr)

QWDSG(I)	Heat gain through windows for Building Type I (BTU/hr)
RE	Fluid Reynold's number (dimensionless)
REFF	Required power plant generation efficiency to meet total system electrical demand at specified thermal power rating
REFM	Reference primary loop fluid mass flowrate (lbm/hr)
REFT	Reference primary loop return temperature (°F)
RHO	Roof surface convective film heat transfer coefficient (BTU/hr-ft^2-°F)
RHO(K,L,N)	Nodal fluid density (lbm/ft^3)
RMAS	Desired fluid mass flowrate in primary loop (lbm/hr)
RPE(L)	Parallel node fluid flow resistance for loop L (lbf-hr/ft^5)
RRSIZ	Power plant rating to meet total system electrical demand at specified generation efficiency (MWt)
RS	Power plant electrical generation capacity (MWe)
RSAB(I)	Roof material solar absorptivity for Building Type I
RTBL	Power plant base - load thermal output (MWt)
RTF(I)	Building Type I ground-contact material thermal resistance (hr-ft^2-°F/BTU)

RTHRM	Power plant base-load thermal output (BTU/hr)
RTR(I)	Roof thermal resistance of Building Type I (hr-ft^2-°F/BTU)
RTW(I)	Wall thermal resistance of Building Type I (hr-ft^2-°F/BTU)
RTWD(I)	Window thermal resistance of Building Type I (hr-ft^2-°F/BTU)
SDF	Sky diffusion factor (dimensionless)
SHGF	Window solar heat gain factor (BTU/hr-ft^2)
STLD	Total thermal utility system load including transmission losses (MWt)
STOR	Reservoir hot water section volume (ft^{3}x10^4)
SUMM	Sum of load center heat exchanger fluid mass flowrates (lbm/hr)
SUMT	Sum of mass-flow-weighted load center heat exchanger outlet temperatures (lbm-°F/hr)
SWA	Building orientation relative to south (radians)
T(J)	Coefficient in window solar heat gain formula for transmission of incident radiation
TAIR(I)	Ambient air temperature at hour I of simulation (°F)
TAIR(25)	Ambient air temperature at beginning of simulation (°F)
TAMB	Ambient earth temperature (°F)

TCG	Power plant coolant temperature at outlet of precooler (°F)
TCW	Reservoir cold water section temperature (°F)
TCWI	Reservoir cold water section temperature (°F)
TD	Nodal outlet temperature difference (°F)
TDX	Temperature difference across nodal boundary one incremental flow length from outlet (°F)
TELD	Total electrical demand from consumer's space conditioning and domestic hot water equipment (BTU/hr, or MWe)
TELLD	Total system electrical load (MWe)
TEO	Secondary loop fluid reference temperature (°F)
THG	Power plant coolant temperature at inlet to precooler (°F)
THI	Reservoir hot water section temperature (°F)
THS	Primary loop fluid reference temperature (°F)
THW	HTW temperature setting at inlet to primary loop (°F)
THWI	Reservoir hot water section temperature (°F)
TI(K,L,N)	Nodal fluid inlet temperature (°F)
TIAB	Absolute temperature to be maintained in building (°K)
TIB(NN)	Temperature to be maintained in Building Type NN (°F)

TIBM	Minimum of temperatures to be maintained in all building types (°F)
TIME	Elapsed time from beginning of simulation (hr)
TIP	Load center heat exchanger fluid inlet temperature at end of time step (°F)
TITLE	Alphanumeric run title
TLD	Total community space conditioning and domestic hot water energy demand (BTU/hr, or MWt)
TLH(IX)	Lower temperature limit setting for supply water to consumers served by heat exchanger IX (°F)
TLP(IX)	Lower temperature limit setting for water at outlet of primary/secondary heat exchanger IX (°F)
TM	Heat exchanger temperature difference ratio
TMAS	Total mass of fluid contained in a node (lbm)
TN	Nodal inlet temperature difference (°F)
TO(K,L,N)	Nodal fluid outlet temperature (°F)
TOAB	Absolute ambient air temperature (°K)
TOB	Ambient air temperature (°F)
TODP	Fluid temperature at one incremental flow length from nodal outlet (°F)
TOP(K,L,N)	Nodal fluid outlet temperature at end of time step (°F)
TPD	Total pressure loss around loop (lbf/ft^2)
TQ(IX)	Thermal demand at load center heat exchanger IX (BTU/hr)

TQL(IHR,IX)	Thermal demand at load center heat exchanger IX at simulation hour IHR (BTU/hr)
TR(L)	Mass-flowrate-averaged fluid temperature at load center heat exchanger return header for loop L (°F)
TRP(IX)	Design temperature setting of water at outlet of primary/secondary heat exchanger IX (°F)
TSAR	Sol-air temperature at roof surface (°F)
TSAW	Sol-air temperature at exterior wall surface (°F)
TSB(I,NN)	Temperature to be maintained in building type NN at hour I of simulation (°F)
TSB(25,I)	Temperature to be maintained in Building Type I at beginning of simulation (°F)
TSET	Heat exchanger steady-state reference temperature (°F)
TTLD	Total thermal demand at a load center heat exchanger (BTU/hr)
TUH(IX)	Upper temperature limit setting for supply water to consumers served by heat exchanger IX (°F)
TUL(IX)	Upper temperature limit setting for return water from consumers served by heat exchanger IX (°F)

TUP(IX)	Upper temperature limit setting for water at outlet of primary/secondary heat exchanger IX (°F)
VLEAK	Total air exchange between interior and exterior of building due to ventilation (CFH)
WA(I)	Orientation of Building Type I with respect to North ($0° \leq WA < 90°$)
WDCL(I)	Total length of cracks around all windows in Building Type I (ft)
WDINC(I)	Infiltration air flow coefficient C for windows in Building Type I (CFM/ft-in. H_2O)
WDINN(I)	Infiltration air flow coefficient N for windows in Building Type I (dimensionless)
WDIR(I)	Wind direction at hour I of simulation (degrees clockwise from north)
WDIR(25)	Wind direction at beginning of simulation (degrees clockwise from north)
WDLK	Total air infiltration through cracks around windows (CFM)
WDSC(I)	Window interior shading coefficient for Building Type I (decimal fraction; 0≡no solar transmission, 1≡no shading)
WHO	Exterior wall convective film heat transfer coefficient (BTU/hr-ft^2-°F)

WHTCA(MTR(I)) WHTCB(MTR(I)) WHTCC(MTR(I))	Surface roughness coefficients for Building Type I roof surface material
WHTCA(MTW(I)) WHTCB(MTW(I)) WHTCC(MTW(I))	Surface roughness coefficients for Building Type I exterior wall material
WINC(I)	Infiltration air flow coefficient C for walls in Building Type I (CFM/ft^2-in. H_2O)
WINN(I)	Infiltration air flow coefficient N for walls in Building Type I (dimensionless)
WLK	Total air infiltration through cracks in walls (CFM)
WSAB(I)	Wall material solar absorptivity for Building Type I
WSGF	Aggregate window solar heat gain factor (BTU/hr-ft^2)
WUF(I,NN)	Use factor for domestic hot water in building type NN at hour I of simulation (decimal fraction) 0 = no hot water use 1 = use at peak demand rate
WUF(25,I)	Use factor for domestic hot water in Building Type I at beginning of simulation (decimal fraction) 0 = no hot water use 1 = use at peak demand rate

WV(I)	Wind velocity at hour I of simulation (mph)
WV(25)	Wind velocity at beginning of simulation (mph)
X	Heat exchanger energy supply scale factor (hr-°F/BTU)
X(I)	Relative direction of wind relative to normal to wall I (radians)
XRAT	Ratio of fluid mass flowrate through primary heat exchanger to primary loop mass flowrate
Y	Diffuse solar radiation incidence coefficient

A.8 TDIST Program Listing

```
      REAL LONG,MASS,MU,MGAS                                            MAIN0001
      DOUBLE PRECISION T,TIME                                           MAIN0002
      DIMENSION ISER(3,5,13),IEX(3,5,13),IPMP(3,5,13),DIA(3,5,13)       MAIN0003
      DIMENSION LONG(3,5,13),AUF(3,5,13),MASS(3,5,13),TI(3,5,13)        MAIN0004
      DIMENSION TO(3,5,13),CAP(3,5,13),RHO(3,5,13),MU(3,5,13),ND(5)     MAIN0005
      DIMENSION NB(5),K1(31),K2(31),L1(31),L2(31),N1(31),N2(31)         MAIN0006
      DIMENSION QDO(31),COND(3,5,13),CONV(3,5,13),NTB(31),RPE(5)        MAIN0007
      DIMENSION AW(20),RTW(20),AWD(20),RTWD(20),AR(20),RTR(20),AF(20)   MAIN0008
      DIMENSION RTF(20),MTW(20),MTR(20),BH(20),WA(20),AINFL(20)         MAIN0009
      DIMENSION WDSC(20),FWLIT(20,5),WSAB(20),RSAB(20),POL(20),NUEX(20) MAIN0010
      DIMENSION FREXT(20),FHPEX(20),TITLE(20),CITY(20),NU(31,20),TIB(20)MAIN0011
      DIMENSION PS(6),PREF(6),PEX(6),PP(6),PC(6),DPM(5),TAIR(25),ELF(25)MAIN0012
      DIMENSION WV(25),WDIR(25),TSB(25,20),BUF(25,20),TQL(25,31),TQ(31) MAIN0013
      DIMENSION TUL(31),QL(25,20),ETHL(25),DHW(20),WUF(25,20)           MAIN0014
      DIMENSION AMAS(3,5,13),AMS(5),TLH(31),TUH(31),NABS(31,20)         MAIN0015
      DIMENSION NCMP(31,20),NRES(31,20),NHPM(31,20),NHWS(31,20)         MAIN0016
      DIMENSION BMAS(3,5,13), DMAS(3,5,13)                              MAIN0017
      DIMENSION DCL(20),DINC(20),DINN(20),WDCL(20),WDINC(20),WDINN(20)  MAIN0018
      DIMENSION WINC(20),WINN(20)                                       MAIN0019
      DIMENSION TRP(10),TUP(10),TLP(10)                                 MAIN0020
      COMMON LS,ND,NH,IOUT,IEX,ISER,NB,CAP,NEXCH,MASS,TI,TO,AUF,K1,K2   MAIN0021
      COMMON L1,L2,N1,N2,RHO,DIA,LONG,NTB,THW,IERR,TAMB,DTIME,COND,CONV MAIN0022
      COMMON KODP,KODE,INIT,IFLO,NTYPE,NU,NPMP,IPMP,MU,TQ,TOB,TIB       MAIN0023
      COMMON DPM,PP,RPE,PS,PREF,PEX,PC,TCW,HVO,CVO,QHW,QCW,THG          MAIN0024
      COMMON TCG,MGAS,CAPG,PMF,THI,QHS,QHO,QCO,QDO,PSENS,AMAS           MAIN0025
      COMMON /ABC/TIME,T                                                MAIN0026
      COMMON /XYZ/BMAS,DMAS                                             MAIN0027
      COMMON /BLD/AW,RTW,AWD,RTWD,AR,RTR,AF,RTF,MTW,MTR,BH,AINFL        MAIN0028
      COMMON /BLD/WSAB,RSAB,POL,WV,WDIR,IBHR,ALAT,DECL                  MAIN0029
      COMMON /BLD/ASC,AEC,SDF,BUF,WA,WDSC,FWLIT                         MAIN0030
      COMMON /DLD/ETHL,TQL,NCMP,NABS,NRES,NHPM,NHWS,ECMP,EABS,ERES,EHPM MAIN0031
      COMMON /DLD/EHWS,NUEX,FREXT,FHPEX,DHW,WUF                         MAIN0032
      COMMON /AID/QL,NTEMP,TAIR,TSB                                     MAIN0033
      COMMON /INFP/DCL,DINC,DINN,WDCL,WDINC,WDINN,WINC,WINN             MAIN0034
      IIN = 5                                                           MAIN0035
      IOUT = 6                                                          MAIN0036
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```
      IPNCH = 7                                                         MAIN0037
      IERR = 0                                                          MAIN0038
      KODP = 1                                                          MAIN0039
      DO 9999 K=1,3                                                     MAIN0040
      DO 9998 L=1,5                                                     MAIN0041
      DO 9997 N=1,13                                                    MAIN0042
      MASS(K,L,N) = 0.0                                                 MAIN0043
      AUF(K,L,N) = 0.0                                                  MAIN0044
 9997 CONTINUE                                                          MAIN0045
 9998 CONTINUE                                                          MAIN0046
 9999 CONTINUE                                                          MAIN0047
      READ (IIN,8300) TITLE                                             MAIN0048
      READ (IIN,8300) CITY                                              MAIN0049
 8300 FORMAT (20A4)                                                     MAIN0050
      WRITE (IOUT,8400)                                                 MAIN0051
 8400 FORMAT (1H1,22X,' *** TDIST - METROPOLITAN THERMAL ENERGY DISTRIBU MAIN0052
     1TION SYSTEM SIMULATION ***')                                      MAIN0053
      WRITE (IOUT,8401) TITLE                                           MAIN0054
      WRITE (IOUT,8401) CITY                                            MAIN0055
 8401 FORMAT (1H0,20X,20A4)                                             MAIN0056
      READ (IIN,1000) NH                                                MAIN0057
 1000 FORMAT (I3)                                                       MAIN0058
      NNODE = NH                                                        MAIN0059
      DO 1 I=1,NH                                                       MAIN0060
      READ (IIN,1001) N,ISER(1,1,N),IEX(1,1,N),IPMP(1,1,N),DIA(1,1,N),  MAIN0061
     1 LONG(1,1,N),AUF(1,1,N)                                           MAIN0062
 1001 FORMAT (4I3,F7.4,2E11.4)                                          MAIN0063
      READ (IIN,1002) MASS(1,1,N),TI(1,1,N),TO(1,1,N),CAP(1,1,N),       MAIN0064
     1 RHO(1,1,N),MU(1,1,N)                                             MAIN0065
 1002 FORMAT (E11.4,2F7.2,3F7.4)                                        MAIN0066
 1    CONTINUE                                                          MAIN0067
      READ (IIN,1000) LS                                                MAIN0068
      DO 4 L=1,LS                                                       MAIN0069
      READ (IIN,1003) ND(L),NB(L)                                       MAIN0070
 1003 FORMAT (2I3)                                                      MAIN0071
      NNODE = NNODE + ND(L) + NB(L)                                     MAIN0072
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```
      NDOI = ND(L)                                                      MAIN0073
      DO 2 I=1,NDOI                                                     MAIN0074
      READ (IIN,1001) N,ISER(2,L,N),IEX(2,L,N),IPMP(2,L,N),DIA(2,L,N),  MAIN0075
     1 LONG(2,L,N),AUF(2,L,N)                                           MAIN0076
      READ (IIN,1002) MASS(2,L,N),TI(2,L,N),TO(2,L,N),CAP(2,L,N),       MAIN0077
     1 RHO(2,L,N),MU(2,L,N)                                             MAIN0078
2     CONTINUE                                                          MAIN0079
      NBOI = NB(L)                                                      MAIN0080
      DO 3 I=1,NBOI                                                     MAIN0081
      READ (IIN,1001) N,ISER(3,L,N),IEX(3,L,N),IPMP(3,L,N),DIA(3,L,N),  MAIN0082
     1 LONG(3,L,N),AUF(3,L,N)                                           MAIN0083
      READ (IIN,1002) MASS(3,L,N),TI(3,L,N),TO(3,L,N),CAP(3,L,N),       MAIN0084
     1 RHC(3,L,N),MU(3,L,N)                                             MAIN0085
3     CONTINUE                                                          MAIN0086
4     CONTINUE                                                          MAIN0087
      READ (IIN,1000) NEXCH                                             MAIN0088
      DO 5 I=1,NEXCH                                                    MAIN0089
      REAC(IIN,1004) NEX,K1(NEX),L1(NEX),N1(NEX),K2(NEX),L2(NEX),       MAIN0090
     1 N2(NEX),NTB(NEX)                                                 MAIN0091
1004  FORMAT (I3,5X,3I3,5X,3I3,5X,I5)                                   MAIN0092
5     CONTINUE                                                          MAIN0093
      READ (IIN,1000) NPMP                                              MAIN0094
      READ (IIN,1006) HVO,CVO,THW                                       MAIN0095
1006  FORMAT (2E11.4,F7.2)                                              MAIN0096
      READ (IIN,1005) THG,TCG,MGAS,CAPG                                 MAIN0097
1005  FORMAT (2F7.2,E11.4,F7.4)                                         MAIN0098
      READ (IIN,1012) TAMB                                              MAIN0099
      FEAD (IIN,1012) EFF                                               MAIN0100
      READ (IIN,1012) PSENS                                             MAIN0101
      READ (IIN,1007) NSTEP,NPRNT,DTIME                                 MAIN0102
1007  FORMAT (2I5,F8.5)                                                 MAIN0103
      READ (IIN,1000) NTYPE                                             MAIN0104
      DO 6 II=1,NTYPE                                                   MAIN0105
      READ (IIN,1008) I,AW(I),RTW(I),AWD(I),RTWD(I),AR(I),RTR(I),AF(I), MAIN0106
     1 RTF(I)                                                           MAIN0107
1008  FORMAT (I2,4(F8.2,F8.3))                                          MAIN0108
```

```
      READ (IIN,10080) I,DCL(I),DINC(I),DINN(I),WDCL(I),WDINC(I),              MAIN0109
     1 WDINN(I),WINC(I),WINN(I)                                                MAIN0110
10080 FORMAT (I2,8F8.3)                                                        MAIN0111
      READ (IIN,10081) I,MTW(I),MTR(I),BH(I),AINPL(I)                          MAIN0112
10081 FORMAT (I2,2X,I2,2X,I2,2X,F7.2,F10.2)                                    MAIN0113
      READ (IIN,10082) I,WA(I),WDSC(I),(FWLIT(I,NN),NN=1,5),WSAB(I),           MAIN0114
     1 RSAB(I),POL(I),DHW(I)                                                   MAIN0115
10082 FORMAT (I2,F7.2,F5.2,5F5.2,F5.2,F5.2,F9.2,E11.4)                         MAIN0116
      WA(I) = WA(I)*3.1416/180.                                                MAIN0117
      READ (IIN,10083) I,NUEX(I),FREXT(I),FHPEX(I)                             MAIN0118
10083 FORMAT (I2,I5,2F5.2)                                                     MAIN0119
6     CONTINUE                                                                 MAIN0120
      DO 8 L=1,LS                                                              MAIN0121
      NBOI = NB(L)                                                             MAIN0122
      DO 7 N=1,NBOI                                                            MAIN0123
      IX = IEX(3,L,N)                                                          MAIN0124
      DO 6001 I=1,NTYPE                                                        MAIN0125
      READ (IIN,1010) NU(IX,I),NCMP(IX,I),NABS(IX,I),NRES(IX,I),               MAIN0126
     1 NHPM(IX,I),NHWS(IX,I)                                                   MAIN0127
1010  FORMAT (6I5)                                                             MAIN0128
6001  CONTINUE                                                                 MAIN0129
7     CONTINUE                                                                 MAIN0130
8     CONTINUE                                                                 MAIN0131
      READ (IIN,1015) ECMP,EABS,ERES,EHPM,EHWS                                 MAIN0132
1015  FORMAT (5F5.2)                                                           MAIN0133
      READ (IIN,1012) CSFAC                                                    MAIN0134
1012  FORMAT (F7.4)                                                            MAIN0135
      READ (IIN,8301) ALAT,DECL,ASC,AEC,SDF,IBHR                               MAIN0136
8301  FORMAT (F5.2,F6.2,F5.0,F6.3,F6.3,I3)                                     MAIN0137
      ALAT = ALAT*3.1416/180.                                                  MAIN0138
      DECL = DECL*3.1416/180.                                                  MAIN0139
      CALL CSCALE(MASS,CSFAC)                                                  MAIN0140
      WRITE (IOUT,8200)                                                        MAIN0141
8200  FORMAT (1H1,50X,' ***INPUT SUMMARY***')                                  MAIN0142
      WRITE (IOUT,8201)                                                        MAIN0143
8201  FORMAT (1H0,2X,' NODE',8X,'ISER',1X,'IEX',2X,'IPMP',5X,'DIA',10X,        MAIN0144
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     1 'LONG',11X,'MASS',12X,'AU',10X,'CAP',8X,'RHO',9X,'MU')             MAINO145
      DO 8010 K=1,3                                                        MAINO146
      IF (K-2) 8001,8002,8002                                              MAINO147
8001  LIM = 1                                                              MAINO148
      GO TO 8003                                                           MAINO149
8002  LIM = LS                                                             MAINO150
8003  DO 8009 L=1,IIM                                                      MAINO151
      IF (K-2) 8004,8005,8006                                              MAINO152
8004  NLIM = NH                                                            MAINO153
      GO TO 8007                                                           MAINO154
8005  NLIM = ND(L)                                                         MAINO155
      GO TO 8007                                                           MAINO156
8006  NLIM = NB(L)                                                         MAINO157
8007  DO 8008 N=1,NLIM                                                     MAINO158
      COND(K,L,N) = 0.0                                                    MAINO159
      CONV(K,I,N) = 0.0                                                    MAINO160
      BMAS(K,L,N) = 0.0                                                    MAINO161
      DMAS(K,I,N) = 1.0                                                    MAINO162
      WRITE (IOUT,8202) K,L,N,ISER(K,L,N),IEX(K,L,N),IPMP(K,L,N),          MAINO163
     1 DIA(K,L,N),LONG(K,L,N),MASS(K,L,N),AUF(K,L,N),CAP(K,L,N),          MAINO164
     2 RHO(K,L,N),MU(K,L,N)                                                MAINO165
8202  FORMAT (3I3,4X,3I5,4X,F7.4,4X,E11.4,4X,E11.4,4X,E11.4,4X,F7.4,4X,    MAINO166
     1 F7.3,4X,F7.3)                                                       MAINO167
8008  CONTINUE                                                             MAINO168
8009  CONTINUE                                                             MAINO169
8010  CONTINUE                                                             MAINO170
      WRITE (IOUT,8214)                                                    MAINO171
8214  FORMAT (1H0,20X,' EXCHANGER',15X,'SUPPLY NODE',10X,'DEMAND NODE',    MAINO172
     1 10X,'TUBES')                                                        MAINO173
      DO 8015 IX=1,NEXCH                                                   MAINO174
      WRITE (IOUT,8215) IX,K1(IX),L1(IX),N1(IX),K2(IX),L2(IX),N2(IX),      MAINO175
     1 NTB(IX)                                                             MAINO176
8215  FORMAT (1H ,24X,I2,21X,3(I2,1X),12X,3(I2,1X),10X,I5)                 MAINO177
8015  CONTINUE                                                             MAINO178
      WRITE (IOUT,8203)                                                    MAINO179
8203  FORMAT (1H0,3X,' HVO',13X,'CVO',11X,'THW',9X,'THG',9X,'TCG',11X,     MAINO180
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      1 'MGAS', 9X,'CAPG',9X,'TAMB',8X,'DTIME')
       WRITE (IOUT,8204) HVO,CVO,THW,THG,TCG,MGAS,CAPG,TAMB,DTIME
8204   FORMAT (E11.4,5X,E11.4,5X,F7.2,5X,F7.2,5X,F7.2,5X,E11.4,5X,F7.4,
      1 5X,F7.2,5X,F8.5)
       WRITE (IOUT,8205)
8205   FORMAT (1H0,' TYPE',12X,'AW',10X,'RTW',8X,'AWD',10X,'RTWD',8X,'AR'
      1,10X,'RTR',9X,'AF',10X,'RTF',10X,'HEIGHT')
       DO 8011 N=1,NTYPE
       WRITE (IOUT,8206) N,AW(N),RTW(N),AWD(N),RTWD(N),AR(N),RTR(N),
      1 AF(N),RTF(N),BH(N)
8206   FORMAT (2X,I2,6X,4(3X,F10.2,6X,F5.2),4X,F10.2)
8011   CONTINUE
       WRITE (IOUT,82061)
82061  FORMAT (1H0,' TYPE',9X,'DOOR CRACK',8X,'C',8X,'N',9X,'WINDOW CRACK
      1',8X,'C',8X,'N',9X,'WALL AREA',8X,'C',8X,'N')
       DO 80111 N=1,NTYPE
       WRITE (IOUT,82062) N,DCL(N),DINC(N),DINN(N),WDCL(N),WDINC(N),
      1 WDINN(N),AW(N),WINC(N),WINN(N)
82062  FORMAT (2X,I2,12X,F7.0,5X,F7.3,2X,F7.3,9X,F7.0,7X,F7.3,2X,F7.3,6X,
      1 F10.2,4X,F7.3,2X,F7.3)
80111  CONTINUE
       WRITE (IOUT,82063)
82063  FORMAT (1H0,' TYPE',7X,'AINFL',10X,'WDSC',6X,'FWLIT(1)',3X,
      1 'FWLIT(2)',3X,'FWLIT(3)',3X,'FWLIT(4)',4X,'FRLIT',6X,'WSAB',7X,
      2 'RSAB',7X,'POL')
       DO 80112 N=1,NTYPE
       WRITE (IOUT,82064) N,AINFL(N),WDSC(N),(FWLIT(N,NN),NN=1,5),
      1 WSAB(N),RSAB(N),POL(N)
82064  FORMAT (2X,I2,5X,F10.2,2X,8(6X,F5.2),4X,F7.2)
80112  CONTINUE
       WRITE (IOUT,8208)
8208   FORMAT (1H0,' EXCHANGER',9X,'BLDG TYPE',9X,'UNITS',9X,'COMP AC',
      1 9X,'ABS AC',9X,'RES HT',9X,'HT PUMP',9X,'H2O HT')
       DO 8014 L=1,LS
       NBOI = NB(L)
       DO 8013 N=1,NBOI
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      IX = IEX(3,L,N)
      WRITE (IOUT,8209) IX
8209  FORMAT (5X,I2)
      DO 8012 I=1,NTYPE
      WRITE (IOUT,8210) I,NU(IX,I),NCMP(IX,I),NABS(IX,I),NRES(IX,I),
     1 NHPM(IX,I),NHWS(IX,I)
8210  FORMAT (23X,I2,13X,I4,11X,I4,11X,I4,11X,I4,12X,I4,11X,I4)
8012  CONTINUE
8013  CONTINUE
8014  CONTINUE
      WRITE (IOUT,82065)
82065 FORMAT (1H ,' UNSUPPLIED')
      DO 80141 NN=1,NTYPE
      NAEX = 0
      NCEX = NUEX(NN)
      NREX = FREXT(NN)*NUEX(NN)
      NPEX = FHPEX(NN)*NUEX(NN)
      NHEX = 0
      WRITE (IOUT,8210) NN,NUEX(NN),NCEX,NAEX,NREX,NPEX,NHEX
80141 CONTINUE
      WRITE (IOUT,8211)
8211  FORMAT (1H0,' COMP AC EFF',16X,'ABS AC EFF',16X,'RES HT EFF',16X,
     1 'HT PUMP EFF',16X,'H2O HT EFF')
      WRITE (IOUT,8212) ECMP,EABS,ERES,EHPM,EHWS
8212  FORMAT (5X,F5.2,21X,F5.2,21X,F5.2,21X,F5.2,22X,F5.2)
      WRITE (IOUT,82066)
82066 FORMAT (1H0,' LATITUDE',15X,'SOLAR DECL',15X,'APP SOLAR CONST',
     1 15X,'ATM EXT COEF',15X,'SKY DIFF FAC')
      BLAT = ALAT*180./3.1416
      BECL = DECL*180./3.1416
      WRITE (IOUT,82067) BLAT,BECL,ASC,AEC,SDF
82067 FORMAT (2X,F6.2,18X,F6.2,21X,F5.0,23X,F6.3,21X,F6.3)
      WRITE (IOUT,8207) EFF
8207  FORMAT (1H0,' THERMAL/ELECTRIC CONVERSION EFFICIENCY:',F7.4)
      WRITE (IOUT,8213) PSENS
8213  FORMAT (1H0,' PUMP RESPONSE SENSITIVITY FACTOR:',F5.1)
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      WRITE (IOUT,8216) CSFAC                                           MAIN0253
8216  FORMAT (1H0,' CASE MASS FLOW INPUT SCALE FACTOR:',F7.4)           MAIN0254
      READ (IIN,1013) RTBL,ELBL                                         MAIN0255
1013  FORMAT (2F10.0)                                                   MAIN0256
      RTHRM = 3.412E06*RTBL                                             MAIN0257
      WRITE (IOUT,217) RTBL                                             MAIN0258
217   FORMAT (1H0,' REACTOR TOTAL THERMAL POWER OUTPUT:',F6.0,' MW(TH)')MAIN0259
9     READ (IIN,1000) KODE                                              MAIN0260
      IF (KODE-1) 11,12,10                                              MAIN0261
11    READ (IIN,1000) IDES                                              MAIN0262
      READ (IIN,1014) TAIR(25)                                          MAIN0263
      READ (IIN,1014) WV(25)                                            MAIN0264
      READ (IIN,10141) WDIR(25)                                         MAIN0265
      WDIR(25) = WDIR(25)*3.1416/180.                                   MAIN0266
      READ (IIN,1014) ELF(25)                                           MAIN0267
1014  FORMAT (F5.2)                                                     MAIN0268
10141 FORMAT (F6.2)                                                     MAIN0269
      READ (IIN,1009) (TSB(25,I), I=1,NTYPE)                            MAIN0270
      READ (IIN,1009) (BUF(25,I),I=1,NTYPE)                             MAIN0271
      READ (IIN,1009) (WUF(25,I),I=1,NTYPE)                             MAIN0272
1009  FORMAT (10F7.2)                                                   MAIN0273
      KODP = 0                                                          MAIN0274
      TOB = TAIR(25)                                                    MAIN0275
      DO 1100 NN=1,NTYPE                                                MAIN0276
      TIB(NN) = TSB(25,NN)                                              MAIN0277
1100  CONTINUE                                                          MAIN0278
      CHS = RTHRM-ELF(25)*ELBL*3.412E06                                 MAIN0279
      CALL SET(IDES)                                                    MAIN0280
      IF (IERR-1) 9,999,9                                               MAIN0281
12    READ (IIN,1000) NTEMP                                             MAIN0282
      IF (NTEMP-12) 13,13,14                                            MAIN0283
13    READ (IIN,1011) (TAIR(I), I=1,NTEMP)                              MAIN0284
      READ (IIN,1011) (WV(I),I=1,NTEMP)                                 MAIN0285
      READ (IIN,10111) (WDIR(I),I=1,NTEMP)                              MAIN0286
      READ (IIN,1011) (ELF(I),I=1,NTEMP)                                MAIN0287
1011  FORMAT (12F5.2)                                                   MAIN0288
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10111 FORMAT (12F6.2)                                                        MAINO289
      GO TC 15                                                               MAINO290
14    READ (IIN,1011) (TAIR(I), I=1,12)                                      MAINO291
      READ (IIN,1011) (TAIR(I), I=13,NTEMP)                                  MAINO292
      READ (IIN,1011) (WV(I),I=1,12)                                         MAINO293
      READ (IIN,1011) (WV(I),I=13,NTEMP)                                     MAINO294
      READ (IIN,10111) (WDIR(I),I=1,12)                                      MAINO295
      READ (IIN,10111) (WDIR(I),I=13,NTEMP)                                  MAINO296
      READ (IIN,1011) (ELF(I),I=1,12)                                        MAINO297
      READ (IIN,1011) (ELF(I),I=13,NTEMP)                                    MAINO298
15    DO 1501 I=1,NTEMP                                                      MAINO299
      READ (IIN,1009) (TSB(I,NN), NN=1,NTYPE)                                MAINO300
      WDIR(I) = WDIR(I)*3.1416/180.                                          MAINO301
1501  CONTINUE                                                               MAINO302
      DO 1502 I=1,NTEMP                                                      MAINO303
      READ (IIN,1009) (BUF(I,NN),NN=1,NTYPE)                                 MAINO304
1502  CONTINUE                                                               MAINO305
      DO 1503 I=1,NTEMP                                                      MAINO306
      READ (IIN,1009) (WUF(I,NN),NN=1,NTYPE)                                 MAINO307
1503  CONTINUE                                                               MAINO308
      WRITE (IOUT,208)                                                       MAINO309
208   FORMAT (1H1,44X,' ***WEATHER DATA DISTRIBUTION***')                    MAINO310
      WRITE (IOUT,209)                                                       MAINO311
209   FORMAT (1H0,10X,' TIME',10X,'AIR TEMPERATURE (F)',10X,'WIND VELOCI     MAINO312
     1TY (MPH)',10X,'WIND DIRECTION (FROM NORTH)')                           MAINO313
      ITIM = IBHR                                                            MAINO314
      BWDIR = WDIR(25)*180./3.1416                                           MAINO315
      WRITE (IOUT,210) ITIM,TAIR(25),WV(25),BWDIR                            MAINO316
      DO 16 I=1,NTEMP                                                        MAINO317
      ITIM = I+IBHR                                                          MAINO318
      BWDIR = WDIR(I)*180./3.1416                                            MAINO319
      WRITE (IOUT,210) ITIM,TAIR(I),WV(I),BWDIR                              MAINO320
210   FORMAT (11X,I2,':00',14X,F6.2,23X,F5.2,23X,F6.2)                       MAINO321
16    CONTINUE                                                               MAINO322
      WRITE (IOUT,214)                                                       MAINO323
214   FORMAT (1H1,35X,' ***ELECTRICAL LOAD DISTRIBUTION (EXCLUDING HEAT)     MAINO324
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     1***')                                                            MAINO325
      WRITE (IOUT,215)                                                 MAINO326
215   FORMAT (1H0,34X,' TIME',10X,'LOAD (MWE)',10X,'BASE LOAD FRACTION')MAINO327
      ITIM = IBHR                                                      MAINO328
      ELD = ELF(25)*ELBL                                               MAINO329
      WRITE (IOUT,216) ITIM,ELD,ELF(25)                                MAINO330
216   FORMAT (35X,I2,':00',8X,F7.1,19X,F5.2)                           MAINO331
      DO 1601 I=1,NTEMP                                                MAINO332
      ITIM = I+IBHR                                                    MAINO333
      ELD = ELF(I)*ELBL                                                MAINO334
      WRITE (IOUT,216) ITIM,ELD,ELF(I)                                 MAINO335
1601  CONTINUE                                                         MAINO336
      WFITE (IOUT,2160)                                                MAINO337
2160  FORMAT (1H1,47X,' ***BUILDING USE FACTORS***')                   MAINO338
      WRITE (IOUT,2161)                                                MAINO339
2161  FORMAT (1H0,' TIME',5X,' 1    2    3    4    5    6    7    8    9MAINO340
     1   10   11   12   13   14   15   16   17   18   19   20')        MAINO341
      ITIM = IBHR                                                      MAINO342
      WRITE (IOUT,2162) ITIM,(BUF(25,NN),NN=1,NTYPE)                   MAINO343
2162  FORMAT (1H0,2X,I2,4X,20(F4.2,1X))                                MAINO344
      DO 16010 I=1,NTEMP                                               MAINO345
      ITIM = IBHR+I                                                    MAINO346
      WRITE (IOUT,2163) ITIM,(BUF(I,NN),NN=1,NTYPE)                    MAINO347
2163  FORMAT (1H ,2X,I2,4X,20(F4.2,1X))                                MAINO348
16010 CONTINUE                                                         MAINO349
      WRITE (IOUT,2164)                                                MAINO350
2164  FORMAT (1H1,42X,' ***SERVICE HOT WATER USE FACTORS***')          MAINO351
      WRITE (IOUT,2161)                                                MAINO352
      ITIM = IBHR                                                      MAINO353
      WRITE (IOUT,2162) ITIM,(WUF(25,NN),NN=1,NTYPE)                   MAINO354
      DO 16011 I=1,NTEMP                                               MAINO355
      ITIM = IBHR+I                                                    MAINO356
      WRITE (IOUT,2163) ITIM,(WUF(I,NN),NN=1,NTYPE)                    MAINO357
16011 CONTINUE                                                         MAINO358
      WRITE (IOUT,2165)                                                MAINO359
2165  FORMAT (1H1,42X,' ***BUILDING ROOM TEMPERATURES (F)***')         MAINO360
```

```
      WRITE (IOUT,2161)
      ITIM = IBHR
      WRITE (IOUT,2166) ITIM,(TSB(25,NN),NN=1,NTYPE)
 2166 FORMAT (1H0,2X,I2,4X,20F5.0)
      DO 16012 I=1,NTEMP
      ITIM = IBHR+I
      WRITE (IOUT,2167) ITIM,(TSB(I,NN),NN=1,NTYPE)
 2167 FORMAT (1H ,2X,I2,4X,20F5.0)
16012 CONTINUE
      DO 1603 L=1,LS
      NBOI = NB(L)
      DO 1602 N=1,NBOI
      IX = IEX(3,L,N)
      TLH(IX) = TO(3,L,N)-5.0
      TUH(IX) = TO(3,L,N)+5.0
      TUI(IX) = TI(3,L,N)+5.0
 1602 CONTINUE
 1603 CONTINUE
      DO 1605 N=1,NH
      IF (IEX(1,1,N)) 1605,1605,1604
 1604 IX = IEX(1,1,N)
      TRP(IX) = TO(1,1,N)
      TUF(IX) = TO(1,1,N)+5.0
      TLP(IX) = TO(1,1,N)-5.0
 1605 CONTINUE
      CALL QLOAD(KODE,NTYPE,TAMB,IOUT)
      IF (IDES) 999,1606,999
 1606 KODP = 0
      CALL DLOAD(KODE,KODP,NHR,IHRL,HRF,IOUT,LS,NB,IEX,NTYPE,NU,TIB,TOB)
      TELLD = ELF(25)*ELBI + ETHL(25)/3.412E06
      STOR = HVO/1.0E04
      STLD = MASS(1,1,1)*(CAP(1,1,1)*TI(1,1,1)-CAP(1,1,NH)*TO(1,1,NH))/
     1 3.412E06
      RS = RTBL*EFF
      WRITE (IPNCH,8217) RS,EFF
 8217 FORMAT (F7.2,F5.2)
```

```
      WRITE (IPNCH,2426)  STLD,TELLD,STOR                               MAIN0397
      TIME = 0.0                                                        MAIN0398
      NITR = NSTEP/NPRNT                                                MAIN0399
      DO 26 IHR=1,NTEMP                                                 MAIN0400
      NHR = IHR                                                         MAIN0401
      HRF = 0.0                                                         MAIN0402
      IHRL = IHR-1                                                      MAIN0403
      IF (IHRL) 17,17,18                                                MAIN0404
17    IHRL = 25                                                         MAIN0405
18    DO 25 ITR=1,NITR                                                  MAIN0406
      DO 24 NTI=1,NPRNT                                                 MAIN0407
      TIME = TIME+DTIME                                                 MAIN0408
      HRF = HRF+DTIME                                                   MAIN0409
      TOB = TAIR(IHRL)+HRF*(TAIR(IHR)-TAIR(IHRL))                       MAIN0410
      ESCL = ETHL(IHRL)+HRF*(ETHL(IHR)-ETHL(IHRL))                      MAIN0411
      TIBM = 0.0                                                        MAIN0412
      DO 1802 NN=1,NTYPE                                                MAIN0413
      TIB(NN) = TSB(IHRL,NN)+HRF*(TSB(IHR,NN)-TSB(IHRL,NN))             MAIN0414
      IF (TIB(NN)-TIBM) 1802,1802,1801                                  MAIN0415
1801  TIBM = TIB(NN)                                                    MAIN0416
1802  CONTINUE                                                          MAIN0417
      DO 18022 L=1,LS                                                   MAIN0418
      NBOI = NB(L)                                                      MAIN0419
      DO 18021 N=1,NBOI                                                 MAIN0420
      IX = IEX(3,L,N)                                                   MAIN0421
      TO(IX) = TQL(IHRL,IX)+HRF*(TQL(IHR,IX)-TQL(IHRL,IX))              MAIN0422
18021 CONTINUE                                                          MAIN0423
18022 CONTINUE                                                          MAIN0424
      TELLD = ((ELF(IHRL)+HRF*(ELF(IHR)-ELF(IHRL)))*ELBL*3.412E06)+ESCL MAIN0425
      QHS = RTHRM - TELLD                                               MAIN0426
      RBSIZ = TELLD/(EFF*3.412E06)                                      MAIN0427
      IF (QHS) 1803,1803,1804                                           MAIN0428
1803  REFF = EFF                                                        MAIN0429
      QHS = 10.0                                                        MAIN0430
      GO TO 1805                                                        MAIN0431
1804  REFF = TELLD/RTHRM                                                MAIN0432
```

```
1805  MGAS = QHS/(CAPG*(THG-TCG))                                  MAIN0433
19    IFLO = 1                                                      MAIN0434
      CALL FLOWS                                                    MAIN0435
      IF (IERR-1) 2000,999,2000                                     MAIN0436
2000  JPM = 0                                                       MAIN0437
      DO 22 L=1,LS                                                  MAIN0438
      NBCI = NB(L)                                                  MAIN0439
      DO 21 N=1,NBOI                                                MAIN0440
      IX = IEX(3,L,N)                                               MAIN0441
      TIP = TO(3,L,N)-TQ(IX)/(MASS(3,L,N)*CAP(3,L,N))               MAIN0442
      IF (TIP-TIBM) 2001,2001,2002                                  MAIN0443
2001  TI(3,L,N) = TIBM                                              MAIN0444
      MASS(3,L,N) = TQ(IX)/(CAP(3,L,N)*(TO(3,L,N)-TI(3,L,N)))       MAIN0445
      JPM = 1                                                       MAIN0446
      GO TO 2100                                                    MAIN0447
2002  IF (TIP-TUL(IX)) 2004,2003,2003                               MAIN0448
2003  TI(3,L,N) = TUL(IX)                                           MAIN0449
      MASS(3,L,N) = TQ(IX)/(CAP(3,L,N)*(TO(3,L,N)-TI(3,L,N)))       MAIN0450
      JPM = 1                                                       MAIN0451
      GO TO 2100                                                    MAIN0452
2004  TI(3,L,N) = TIP                                               MAIN0453
2100  IF (TO(3,L,N)-TLH(IX)) 2101,2101,2102                         MAIN0454
2101  TO(3,L,N) = TLH(IX)                                           MAIN0455
      MASS(3,L,N) = TQ(IX)/(CAP(3,L,N)*(TO(3,L,N)-TI(3,L,N)))       MAIN0456
      JPM = 1                                                       MAIN0457
      GO TO 21                                                      MAIN0458
2102  IF (TO(3,L,N)-TUH(IX)) 21,2103,2103                           MAIN0459
2103  TO(3,L,N) = TUH(IX)                                           MAIN0460
      MASS(3,L,N) = TQ(IX)/(CAP(3,L,N)*(TO(3,L,N)-TI(3,L,N)))       MAIN0461
      JPM = 1                                                       MAIN0462
21    CONTINUE                                                      MAIN0463
22    CONTINUE                                                      MAIN0464
      DO 2203 N=1,NH                                                MAIN0465
      IF (IEX(1,1,N)) 2203,2203,2201                                MAIN0466
2201  IX = IEX(1,1,N)                                               MAIN0467
      IF (TI(1,1,N+1)-TUP(IX)) 2204,2202,2202                       MAIN0468
```

```
2204  IF (TI(1,1,N+1)-TLP(IX)) 2202,2202,2203                                  MAIN0469
2202  JPM = 1                                                                  MAIN0470
2203  CONTINUE                                                                 MAIN0471
      IF (JPM-1) 24,2005,24                                                    MAIN0472
2005  DO 2006 IX=1,NEXCH                                                       MAIN0473
      KE = K2(IX)                                                              MAIN0474
      LE = L2(IX)                                                              MAIN0475
      NE = N2(IX)                                                              MAIN0476
      K = K1(IX)                                                               MAIN0477
      L = L1(IX)                                                               MAIN0478
      N = N1(IX)                                                               MAIN0479
      AMAS(K,L,N) = (MASS(KE,LE,NE)*CAP(KE,LE,NE)*(TO(KE,LE,NE)-               MAIN0480
     1 TI(KE,LE,NE)))/(CAP(K,L,N)*(TI(K,L,N)-TO(K,L,N)))                       MAIN0481
      IF (AMAS(K,L,N)) 2007,2007,2006                                          MAIN0482
2007  AMAS(K,L,N) = MASS(K,L,N)                                                MAIN0483
2006  CONTINUE                                                                 MAIN0484
      DO 2014 L=1,LS                                                           MAIN0485
      NLIM = ND(L)                                                             MAIN0486
      AMS(L) = 0.0                                                             MAIN0487
      DO 2013 N=1,NLIM                                                         MAIN0488
      IF (IEX(2,L,N)) 2013,2013,2011                                           MAIN0489
2011  IF (ISER(2,L,N)) 2013,2013,2012                                          MAIN0490
2012  AMS(L) = AMS(L)+AMAS(2,L,N)                                              MAIN0491
2013  CONTINUE                                                                 MAIN0492
2014  CONTINUE                                                                 MAIN0493
      DO 2017 L=1,IS                                                           MAIN0494
      NLIM = ND(L)                                                             MAIN0495
      DO 2016 N=1,NLIM                                                         MAIN0496
      IF (ISER(2,L,N)) 2015,2015,2016                                          MAIN0497
2015  AMAS(2,L,N) = AMS(I)                                                     MAIN0498
2016  CONTINUE                                                                 MAIN0499
2017  CONTINUE                                                                 MAIN0500
      RMAS = 0.0                                                               MAIN0501
      DO 2021 N=1,NH                                                           MAIN0502
      IF (IEX(1,1,N)) 2021,2021,2018                                           MAIN0503
2018  IX = IEX(1,1,N)                                                          MAIN0504
```

```
      KE = K2(IX)                                                       MAIN0505
      LE = L2(IX)                                                       MAIN0506
      NE = N2(IX)                                                       MAIN0507
      AMAS(1,1,N)  = MASS(1,1,N-1)                                      MAIN0508
      DMAS(1,1,N)  = (AMAS(KE,LE,NE)*CAP(KE,LE,NE)*(TO(KE,LE,NE)-       MAIN0509
     1 TI(KE,LE,NE)))/(CAP(1,1,N)*(TI(1,1,N)-TRP(IX)))                  MAIN0510
      IF (DMAS(1,1,N)) 2261,2261,2262                                   MAIN0511
 2261 DMAS(1,1,N)  = 10.0                                               MAIN0512
 2262 AMAS(1,1,N)  = DMAS(1,1,N)                                        MAIN0513
      IF (AMAS(1,1,N)-RMAS) 2021,2263,2263                              MAIN0514
 2263 RMAS = AMAS(1,1,N)                                                MAIN0515
 2021 CONTINUE                                                          MAIN0516
      IF (RMAS) 2022,2022,2023                                          MAIN0517
 2022 RMAS = 10.0                                                       MAIN0518
 2023 DO 2024 N=1,NH                                                    MAIN0519
      AMAS(1,1,N)  = RMAS                                               MAIN0520
 2024 CONTINUE                                                          MAIN0521
      DO 2310 N=1,NH                                                    MAIN0522
      IF (IEX(1,1,N)) 2310,2310,2301                                    MAIN0523
 2301 EMAS(1,1,N)  = AMAS(1,1,N)-DMAS(1,1,N)                            MAIN0524
      IF (BMAS(1,1,N)) 2302,2302,2303                                   MAIN0525
 2302 EMAS(1,1,N)  = 0.0                                                MAIN0526
      DMAS(1,1,N)  = AMAS(1,1,N)                                        MAIN0527
 2303 XRAT = DMAS(1,1,N)/AMAS(1,1,N)                                    MAIN0528
      MASS(1,1,N)  = XRAT*MASS(1,1,N-1)                                 MAIN0529
      AMAS(1,1,N)  = DMAS(1,1,N)                                        MAIN0530
 2310 CONTINUE                                                          MAIN0531
      CALL SET(IDES)                                                    MAIN0532
      IF (IERR-1) 24,999,24                                             MAIN0533
 24   CONTINUE                                                          MAIN0534
      T = TIME+IBHR                                                     MAIN0535
      CALL PRV(T,THW,TCW,HVO,CVO,QHW,QCW,THG,TCG,MGAS,CAPG,PMF,THI,PEX, MAIN0536
     1 NPMP)                                                            MAIN0537
      KODE = 1                                                          MAIN0538
      CALL DLOAD(KODE,KODP,NHR,IHRL,HRF,IOUT,LS,NB,IEX,NTYPE,NU,TIB,TOB)MAIN0539
      OTLD = 0.0                                                        MAIN0540
```

```
      DO 2401 NX=1,NEXCH                                                MAIN0541
      KD = K2(NX)                                                       MAIN0542
      IF (KD-2) 2401,2401,2400                                          MAIN0543
 2400 QTLD = QTLD + TQ(NX)                                              MAIN0544
 2401 CONTINUE                                                          MAIN0545
      QTLD = QTLD/3.412E06                                              MAIN0546
      WRITE (IOUT,2423) QTLD                                            MAIN0547
 2423 FORMAT (1H0,' ***TOTAL CONSUMER HEAT DEMAND:',F8.2,' MW(TH)  (THERMMAIN0548
     1AL DISTRIBUTION SYSTEM LOAD)***')                                 MAIN0549
      ELD = TELLD/3.412E06                                              MAIN0550
      WRITE (IOUT,218) ELD                                              MAIN0551
  218 FORMAT (1H0,' ***TOTAL SYSTEM ELECTRICAL LOAD:',F8.2,' MW(E)  (INCLMAIN0552
     1UDING SPACE CONDITIONING)***')                                    MAIN0553
      WRITE (IOUT,2424) EFF,RRSIZ                                       MAIN0554
 2424 FORMAT (1H0,' ***MINIMUM REQUIRED REACTOR SIZE FOR EFFICIENCY OF',MAIN0555
     1 F5.2,' IS',F7.2,' MWT (TO SUPPLY ELECTRICAL LOAD ONLY)***')      MAIN0556
      WRITE (IOUT,2425) RTBL,REFF                                       MAIN0557
 2425 FORMAT (1H0,' ***REQUIRED EFFICIENCY FOR REACTOR SIZE OF',F7.2,   MAIN0558
     1 ' MWT IS',F5.2,'  (TO SUPPLY ELECTRICAL LOAD ONLY)***')          MAIN0559
      STOR = HVO/1.0E04                                                 MAIN0560
      STLD = MASS(1,1,1)*(CAP(1,1,1)*TI(1,1,1)-CAP(1,1,NH)*TO(1,1,NH))/ MAIN0561
     1 3.412E06                                                         MAIN0562
      WRITE (IPNCH,2426) STLD,ELD,STOR                                  MAIN0563
 2426 FORMAT (3(F8.2,3X))                                               MAIN0564
      WRITE (IOUT,2420)                                                 MAIN0565
 2420 FORMAT (1H1,47X,' **EXCHANGER HEAT BALANCE**')                    MAIN0566
      WRITE (IOUT,2421)                                                 MAIN0567
 2421 FORMAT (1H0,30X,' EXCHANGER',10X,'SUPPLY  (BTU/HR)',10X,'DEMAND  (BTMAIN0568
     1U/HR)',10X,'DIFFERENCE')                                          MAIN0569
      DO 2402 NX=1,NEXCH                                                MAIN0570
      K = K2(NX)                                                        MAIN0571
      IK = K1(NX)                                                       MAIN0572
      L = L2(NX)                                                        MAIN0573
      IL = L1(NX)                                                       MAIN0574
      N = N2(NX)                                                        MAIN0575
      IN = N1(NX)                                                       MAIN0576
```

```
      QD = MASS(K,L,N)*CAP(K,L,N)*(TO(K,L,N)-TI(K,L,N))                 MAIN0577
      QS = MASS(IK,IL,IN)*CAP(IK,IL,IN)*(TI(IK,IL,IN)-TO(IK,IL,IN))     MAIN0578
      QDIF = QS-QD                                                      MAIN0579
      WRITE (IOUT,2422) NX,QS,QD,QDIF                                   MAIN0580
2422  FORMAT (1H ,34X,I2,15X,E11.4,14X,E11.4,12X,E11.4)                 MAIN0581
2402  CONTINUE                                                          MAIN0582
25    CONTINUE                                                          MAIN0583
26    CONTINUE                                                          MAIN0584
27    WRITE (IOUT,211)                                                  MAIN0585
211   FORMAT (1H1,' **ANALYSIS COMPLETED FOR GIVEN TEMPERATURE DISTRIBUT MAIN0586
     1ION**')                                                           MAIN0587
      READ (IIN,1000) KODE                                              MAIN0588
      IF (KODE-1) 11,28,10                                              MAIN0589
28    WRITE (IOUT,212)                                                  MAIN0590
212   FORMAT (1H0,' **ANALYSIS CONTINUING FOR NEW TEMPERATURE DISTRIBUTI MAIN0591
     1ON**')                                                            MAIN0592
      TAIR(25) = TAIR(NTEMP)                                            MAIN0593
      ELF(25) = ELF(NTEMP)                                              MAIN0594
      DO 2801 NN=1,NTYPE                                                MAIN0595
      TSB(25,NN) = TSB(NTEMP,NN)                                        MAIN0596
2801  CONTINUE                                                          MAIN0597
      GO TO 12                                                          MAIN0598
10    WRITE (IOUT,200)                                                  MAIN0599
200   FORMAT (1H ,' **TERMINATION CODE READ**')                         MAIN0600
999   WRITE (IOUT,213)                                                  MAIN0601
213   FORMAT (1H1,' ***PROGRAM TERMINATED***')                          MAIN0602
      STOP                                                              MAIN0603
      END                                                               MAIN0604
```

```
      SUBROUTINE CSCALE(MASS,CSFAC)                                     CSCA0001
      REAL MASS                                                         CSCA0002
      DIMENSION MASS(3,5, 13)                                           CSCA0003
      DO 3 K=1,3                                                        CSCA0004
      DO 2 L=1,5                                                        CSCA0005
      DO 1 N=1,13                                                       CSCA0006
      MASS(K,L,N)  = MASS(K,L,N)*CSFAC                                  CSCA0007
    1 CONTINUE                                                          CSCA0008
    2 CONTINUE                                                          CSCA0009
    3 CONTINUE                                                          CSCA0010
      RETURN                                                            CSCA0011
      END                                                               CSCA0012
```

```
      SUBROUTINE QLOAD(KODE,NTYPE,TAMB,IOUT)                            QLOD0001
      DIMENSION BH(20),TAIR(25),TSB(25,20),WV(25),WDIR(25),WA(20),X(4)  QLOD0002
      DIMENSION AW(20),AINFL(20),QLEAK(20),QWDSG(20),DSI(5)             QLOD0003
      DIMENSION DFSI(5),CTH(5),FWLIT(20,5),T(6),A(6),AWD(20),WDSC(20)   QLOD0004
      DIMENSION QCOND(20),MTW(20),MTR(20),WHTCA(6),WHTCB(6),WHTCC(6)    QLOD0005
      DIMENSION RTW(20),RTWD(20),AR(20),RTP(20),WSAB(20),RSAB(20),AF(20) QLOD0006
      DIMENSION RTF(20),POL(20),BUF(25,20),QLIG(20),QL(25,20)           QLOD0007
      DIMENSION DCL(20),DINC(20),DINN(20),WDCL(20),WDINC(20),WDINN(20)  QLOD0008
      DIMENSION WINC(20),WINN(20)                                       QLOD0009
      COMMON /BLD/AW,RTW,AWD,RTWD,AR,RTR,AF,RTF,MTW,MTR,BH,AINFL        QLOD0010
      COMMON /BLD/WSAB,RSAB,POL,WV,WDIR,IBHR,ALAT,DECL                  QLOD0011
      COMMON /BLD/ASC,AEC,SDF,BUF,WA,WDSC,FWLIT                         QLOD0012
      COMMON /ALD/QL,NTEMP,TAIR,TSB                                     QLOD0013
      COMMON /INFP/DCL,DINC,DINN,WDCL,WDINC,WDINN,WINC,WINN             QLOD0014
      DATA T/-.00885,2.71235,-.62062,-7.07329,9.75995,-3.89922/         QLOD0015
      DATA A/.01154,.77674,-3.94657,8.57881,-8.38135,3.01188/           QLOD0016
      DATA WHTCA/0.0,.001,0.0,-.002,0.0,-.00125/                        QLOD0017
      DATA WHTCB/.464,.320,.330,.315,.244,.262/                         QLOD0018
      DATA WHTCC/2.04,2.20,1.90,1.45,1.80,1.45/                         QLOD0019
      WRITE (IOUT,1000)                                                 QLOD0020
 1000 FORMAT (1H1,' TIME',4X,'BUILDING',6X,'CONDUCTION',5X,'INFILTRATION QLOD0021
     1',4X,'WINDOW SOLAR',6X,'LIGHTING',7X,'TOTAL LOAD')                QLOD0022
      IF (KODE-1) 1,2,39                                                QLOD0023
    1 IBEG = 25                                                         QLOD0024
      IEND = 25                                                         QLOD0025
      GO TO 3                                                           QLOD0026
    2 IBEG = 1                                                          QLOD0027
      IEND = NTEMP                                                      QLOD0028
    3 DO 38 IHR=IBEG,IEND                                               QLOD0029
      DO 16 I=1,NTYPE                                                   QLOD0030
      TOAB = TAIR(IHR)+460.                                             QLOD0031
      TIAB = TSB(IHR,I)+460.                                            QLOD0032
      PC = 5.3508*BH(I)*(1.0/TOAB-1.0/TIAB)                             QLOD0033
      PV = .000482*WV(IHR)**2                                           QLOD0034
      X(1) = WDIR(IHR)-WA(I)                                            QLOD0035
      X(2) = X(1)-1.5708                                                QLOD0036
```

```
      X(3) = X(1)-3.1416                                              QLOD0037
      X(4) = X(1)-4.7124                                              QLOD0038
      ALEAK = 0.0                                                     QLOD0039
      DO 14 N=1,4                                                     QLOD0040
      IF (ABS(X(N))-4.7124) 7,4,4                                     QLOD0041
4     IF (X(N)) 5,5,6                                                 QLOD0042
5     X(N) = 6.2832+X(N)                                              QLOD0043
      GO TO 8                                                         QLOD0044
6     X(N) = 6.2832-X(N)                                              QLOD0045
      GO TO 8                                                         QLOD0046
7     IF (ABS(X(N))-1.5708) 8,8,9                                     QLOD0047
8     IF (ABS(X(N))-.7854) 10,10,11                                   QLOD0048
9     PTKN = -0.35                                                    QLOD0049
      PTKO = 1.0                                                      QLOD0050
      GO TO 12                                                        QLOD0051
10    PTKN = 0.6                                                      QLOD0052
      PTKO = COS(X(N))                                                QLOD0053
      GO TO 12                                                        QLOD0054
11    PTKN = -0.7                                                     QLOD0055
      PTKO = COS(X(N))                                                QLOD0056
12    PW = PTKN*PTKO*PV                                               QLOD0057
      PT = ABS(PW) + ABS(PC)                                          QLOD0058
      IF (PT-1.0E-06) 14,14,13                                        QLOD0059
13    DLK = DCL(I)*DINC(I)*EXP(DINN(I)*ALOG(PT))/4.0                  QLOD0060
      WDLK = WDCL(I)*WDINC(I)*EXP(WDINN(I)*ALOG(PT))/4.0              QLOD0061
      WLK = AW(I)*WINC(I)*EXP(WINN(I)*ALOG(PT))/8.0                   QLOD0062
      ALEAK = ALEAK+DLK+WDLK+WLK                                      QLOD0063
14    CONTINUE                                                        QLOD0064
      ALEAK = ALEAK*60.                                               QLOD0065
      VLEAK = AINFL(I)*BUF(IHR,I)*60.                                 QLOD0066
      IF (ALEAK-VLEAK) 15,15,1501                                     QLOD0067
15    ALEAK = VLEAK                                                   QLOD0068
1501  QLEAK(I) = 0.018*ALEAK*(TSB(IHR,I)-TAIR(IHR))                   QLOD0069
16    CONTINUE                                                        QLOD0070
      IF (KODE-1) 17,18,39                                            QLOD0071
17    ITIM = IBHR                                                     QLOD0072
```

```
      GO TO 19                                                  QLOD0073
18    ITIM = IHR+IBHR                                           QLOD0074
      IF (ITIM-24) 19,1801,1801                                 QLOD0075
1801  ITIM = ITIM-24                                            QLOD0076
19    H = .2618*(ITIM-12)                                       QLOD0077
      CZ = SIN(ALAT)*SIN(DECL)+COS(ALAT)*COS(DECL)*COS(H)       QLOD0078
      CW = COS(DECL)*SIN(H)                                     QLOD0079
      IF (1.0-CW**2-CZ**2) 1901,1901,1902                       QLOD0080
1901  CS = 0.0                                                  QLOD0081
      GO TO 21                                                  QLOD0082
1902  CS = EXP(0.5*ALOG(1.0-CW**2-CZ**2))                       QLOD0083
      IF (COS(H)-TAN(DECL)/TAN(ALAT)) 20,20,21                  QLOD0084
20    CS = -CS                                                  QLOD0085
21    DO 35 I=1,NTYPE                                           QLOD0086
      IF (COS(H)+TAN(DECL)*TAN(ALAT)) 22,22,23                  QLOD0087
22    QWDSG(I) = 0.0                                            QLOD0088
      DO 2201 NN=1,4                                            QLOD0089
      DSI(NN) = 0.0                                             QLOD0090
      DFSI(NN) = 0.0                                            QLOD0091
2201  CONTINUE                                                  QLOD0092
      DSIR = 0.0                                                QLOD0093
      DFSIR = 0.0                                               QLOD0094
      GO TO 33                                                  QLOD0095
23    DNSI = ASC/EXP(-AEC/CZ)                                   QLOD0096
      SWA = WA(I)-3.1416                                        QLOD0097
      CTH(1) = SIN(SWA)*CW+COS(SWA)*CS                          QLOD0098
      CTH(2) = SIN(SWA+1.5708)*CW+COS(SWA+1.5708)*CS            QLOD0099
      CTH(3) = SIN(SWA+3.1416)*CW+COS(SWA+3.1416)*CS            QLOD0100
      CTH(4) = SIN(SWA+4.7124)*CW+COS(SWA+4.7124)*CS            QLOD0101
      CTH(5) = CZ                                               QLOD0102
      DO 26 NN=1,5                                              QLOD0103
      IF (CTH(NN)) 25,25,24                                     QLOD0104
24    DSI(NN) = (DNSI*CTH(NN))*FWLIT(I,NN)                      QLOD0105
      GO TO 26                                                  QLOD0106
25    DSI(NN) = 0.0                                             QLOD0107
26    CONTINUE                                                  QLOD0108
```

```
      DSIR = DSI(5)                                                     QLOD0109
      DO 30 NN=1,4                                                      QLOD0110
      IF (CTH(NN)+0.2)  27,27,28                                        QLOD0111
   27 Y = 0.45                                                          QLOD0112
      GO TO 29                                                          QLOD0113
   28 Y = 0.55+0.437*CTH(NN)+0.313*CTH(NN)**2                           QLOD0114
   29 DFSI(NN) = DNSI*(SDF*Y+0.1*(SDF+CZ))*FWLIT(I,NN)                  QLOD0115
   30 CONTINUE                                                          QLOD0116
      DFSIR = SDF*DNSI*FWLIT(I,5)                                       QLOD0117
      WSGF = 0.0                                                        QLOD0118
      DO 32 NN=1,4                                                      QLOD0119
      FAC1 = 0.0                                                        QLOD0120
      FAC2 = 0.0                                                        QLOD0121
      FAC3 = 0.0                                                        QLOD0122
      FAC4 = 0.0                                                        QLOD0123
      DO 31 N=1,6                                                       QLOD0124
      J = N                                                             QLOD0125
      FAC1 = FAC1+T(J)*CTH(NN)**(J-1)                                   QLOD0126
      FAC2 = FAC2+T(J)/(J+1)                                            QLOD0127
      FAC3 = FAC3+A(J)*CTH(NN)**(J-1)                                   QLOD0128
      FAC4 = FAC4+A(J)/(J+1)                                            QLOD0129
   31 CONTINUE                                                          QLOD0130
      SHGF = DSI(NN)*FAC1+2.0*DFSI(NN)*FAC2+0.267*(DSI(NN)*FAC3+        QLOD0131
     1 2.0*DFSI(NN)*FAC4)                                               QLOD0132
      WSGF = WSGF+SHGF                                                  QLOD0133
   32 CONTINUE                                                          QLOD0134
      OWDSG(I) = AWD(I)/4.0*WSGF*WDSC(I)                                QLOD0135
   33 OCOND(I) = 0.0                                                    QLOD0136
      WHO = 1.0/(WHTCA(MTW(I))*WV(IHR)**2+WHTCB(MTW(I))*WV(IHR)+        QLOD0137
     1 WHTCC(MTW(I)))                                                   QLOD0138
      RHO = 1.0/(WHTCA(MTR(I))*WV(IHR)**2+WHTCB(MTR(I))*WV(IHR)+        QLOD0139
     1 WHTCC(MTR(I)))                                                   QLOD0140
      AUW = AW(I)/4.0*(1.0/(RTW(I)+WHO))+AWD(I)/4.0 (1.0/RTWD(I))       QLOD0141
      AUR = AR(I)/(RTR(I)+RHO)                                          QLOD0142
      DO 34 NN=1,4                                                      QLOD0143
      TSAW = TAIR(IHR)+WSAB(I)*(DSI(NN)+DFSI(NN))*WHO                   QLOD0144
```

```
      QCOND(I) = QCOND(I)+AUW*(TSB(IHR,I)-TSAW)                            QLOD0145
34    CONTINUE                                                              QLOD0146
      TSAR = TAIR(IHR)+RSAB(I)*(DSIR+DFSIR)*RHO                             QLOD0147
      QCOND(I) = QCOND(I)+AUR*(TSB(IHR,I)-TSAR)                             QLOD0148
      AUG = AF(I)/RTF(I)                                                    QLOD0149
      QCOND(I) = QCOND(I)+AUG*(TSB(IHR,I)-(TSB(IHR,I)+TAMB)/2.0)            QLOD0150
35    CONTINUE                                                              QLOD0151
      DO 36 I=1,NTYPE                                                       QLOD0152
      QLIG(I) = POL(I)*BUF(IHR,I)*3412.                                     QLOD0153
36    CONTINUE                                                              QLOD0154
      DO 37 I=1,NTYPE                                                       QLOD0155
      QL(IHR,I) = QCOND(I)+QLEAK(I)-QWDSG(I)-QLIG(I)                        QLOD0156
      WRITE (IOUT,1001) ITIM,I,QCOND(I),QLEAK(I),QWDSG(I),QLIG(I),          QLOD0157
     1 QL(IHR,I)                                                            QLOD0158
1001  FORMAT (3X,I2,8X,I2,8X,5(E11.4,5X))                                   QLOD0159
37    CONTINUE                                                              QLOD0160
      WRITE (IOUT,1002)                                                     QLOD0161
1002  FORMAT (1H ,' ')                                                      QLOD0162
38    CONTINUE                                                              QLOD0163
39    RETURN                                                                QLOD0164
      END.                                                                  QLOD0165
```

```
      SUBROUTINE DLOAD(KODE,KODP,IHR,IHRL,HRF,IOUT,LS,NB,IEX,NTYPE,NU,   DLOD0001
     1 TIB,TOB)                                                          DLOD0002
      DIMENSION ETHL(25),NB(5),IEX(3,5,13),TQL(25,31),NU(31,20)          DLOD0003
      DIMENSION QL(25,20),NCMP(31,20),NABS(31,20),NRES(31,20)            DLOD0004
      DIMENSION NHPM(31,20),NHWS(31,20),NUEX(20),FREXT(20),FHPEX(20)     DLOD0005
      DIMENSION TIB(20),TAIR(25),TSB(25,20),DHW(20),WUF(25,20)           DLOD0006
      COMMON /DLD/ETHL,TQL,NCMP,NABS,NRES,NHPM,NHWS,ECMP,EABS,ERES,EHPM  DLOD0007
      COMMON /DLD/EHWS,NUEX,FREXT,FHPEX,DHW,WUF                          DLOD0008
      COMMON /ALD/QL,NTEMP,TAIR,TSB                                      DLOD0009
      TLD = 0.0                                                          DLOD0010
      TELD = 0.0                                                         DLOD0011
      TTLD = 0.0                                                         DLOD0012
      IF (KODE-1) 999,1000,24                                            DLOD0013
999   IBEG = 25                                                          DLOD0014
      IEND = 25                                                          DLOD0015
      GO TO 1001                                                         DLOD0016
1000  IBEG = 1                                                           DLOD0017
      IEND = NTEMP                                                       DLOD0018
1001  IF (KODP-1) 2,1,2                                                  DLOD0019
1     WRITE (IOUT,200)                                                   DLOD0020
200   FORMAT (1H1,41X,' ***CONSUMER ENERGY DEMAND BREAKDOWN***')         DLOD0021
      WRITE (IOUT,201)                                                   DLOD0022
201   FORMAT (1H0,1X,' SUPPLY',5X,'BUILDING',6X,'ROOM',7X,'NUMBER OF',   DLOD0023
     1 3X,'AIR CONDITIONING DEMAND (BTU/HR)',6X,'TOTAL HEATING DEMAND (B DLOD0024
     2TU/HR)')                                                           DLOD0025
      WRITE (IOUT,202)                                                   DLOD0026
202   FORMAT (1H ,' EXCHANGER',5X,'TYPE',5X,'TEMPERATURE',5X,'UNITS',5X, DLOD0027
     1 'ABSORPTIVE',11X,'COMPRESSIVE',3X,'RESISTANCE',3X,'HEAT PUMPS',   DLOD0028
     2 3X,'HOT WATER')                                                   DLOD0029
      NHR = IHR                                                          DLOD0030
      NHRL = IHRL                                                        DLOD0031
      AHRF = HRF                                                         DLOD0032
      GO TO 3                                                            DLOD0033
2     DO 23 NHR=IBEG,IEND                                                DLOD0034
      ETHL(NHR) = 0.0                                                    DLOD0035
      NHRL = NHR                                                         DLOD0036
```

```
      AHRF = 1.0                                                        DLOD0037
3     DO 15 L=1,LS                                                      DLOD0038
      NBOI = NB(I)                                                      DLOD0039
      DO 14 N=1,NBOI                                                    DLOD0040
      IX = IEX(3,I,N)                                                   DLOD0041
      IF (KODP-1) 4,5,4                                                 DLOD0042
4     TOL(NHR,IX) = 0.0                                                 DLOD0043
      TLD = 0.0                                                         DLOD0044
      TFLD = 0.0                                                        DLOD0045
      TTLD = 0.0                                                        DLOD0046
5     DO 12 NN=1,NTYPE                                                  DLOD0047
      IF (NU(IX,NN)) 12,12,6                                            DLOD0048
6     QCMP = 0.0                                                        DLOD0049
      QABS = 0.0                                                        DLOD0050
      QRES = 0.0                                                        DLOD0051
      QHPM = 0.0                                                        DLOD0052
      QHWS = 0.0                                                        DLOD0053
      Q = NU(IX,NN)*(QL(NHRL,NN)+AHRF*(QL(NHR,NN)-QL(NHRL,NN)))         DLOD0054
      TOAB = TAIR(NHRL)+AHRF*(TAIR(NHR)-TAIR(NHRL))+460.                DLOD0055
      TIAB = TSB(NHRL,NN)+AHRF*(TSB(NHR,NN)-TSB(NHRL,NN))+460.          DLOD0056
      QDHW = NU(IX,NN)*DHW(NN)*(WUF(NHRL,NN)+AHRF*(WUF(NHR,NN)-         DLOD0057
     1 WUF(NHRL,NN)))                                                   DLOD0058
      IF (Q) 7,8,8                                                      DLOD0059
7     Q = -Q                                                            DLOD0060
      IF (TOAB/TIAB-(1.0+1.0E-06)) 7001,7001,7002                       DLOD0061
7001  BADC = 1.0E10                                                     DLOD0062
      Q = 0.0                                                           DLOD0063
      GO TO 7003                                                        DLOD0064
7002  BADC = .028037/(TOAB/TIAB-1.0)                                    DLOD0065
7003  BCMP = BADC*BCMP                                                  DLOD0066
      BABS = BADC*BABS                                                  DLOD0067
      QCMP = NCMP(IX,NN)*(Q/BCMP)/(NCMP(IX,NN)+NABS(IX,NN))             DLOD0068
      QABS = NABS(IX,NN)*(Q/BABS)/(NCMP(IX,NN)+NABS(IX,NN))             DLOD0069
      GO TO 9                                                           DLOD0070
8     IF ((1.0-1.0E-06)-TOAB/TIAB) 8001,8001,8002                       DLOD0071
8001  BADH = 1.0E10                                                     DLOD0072
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```
      Q = 0.0                                                           DLOD0073
      GO TO 8003                                                        DLOD0074
8002  BADH = .068182/(1.0-TOAB/TIAB)                                    DLOD0075
8003  BHPM = BADH*EHPM                                                  DLOD0076
      IF (BHPM-ERES) 8004,8004,8005                                     DLOD0077
8004  QRES = (NRES(IX,NN)+NHPM(IX,NN))*(Q/ERES)/(NRES(IX,NN)+           DLOD0078
     1 NHPM(IX,NN)+NHWS(IX,NN))                                         DLOD0079
      QHWS = NHWS(IX,NN)*(Q/EHWS)/(NRES(IX,NN)+NHPM(IX,NN)+NHWS(IX,NN)) DLOD0080
      GO TO 9                                                           DLOD0081
8005  QRES = NRES(IX,NN)*(Q/ERES)/(NRES(IX,NN)+NHPM(IX,NN)+NHWS(IX,NN)) DLOD0082
      QHPM = NHPM(IX,NN)*(Q/BHPM)/(NRES(IX,NN)+NHPM(IX,NN)+NHWS(IX,NN)) DLOD0083
      QHWS = NHWS(IX,NN)*(Q/EHWS)/(NRES(IX,NN)+NHPM(IX,NN)+NHWS(IX,NN)) DLOD0084
9     QRES = QRES+(NRES(IX,NN)+NHPM(IX,NN))*(QDHW/ERES)/(NRES(IX,NN)+   DLOD0085
     1 NHPM(IX,NN)+NHWS(IX,NN))                                         DLOD0086
      QHWS = QHWS+NHWS(IX,NN)*(QDHW/EHWS)/(NRES(IX,NN)+NHPM(IX,NN)+     DLOD0087
     1 NHWS(IX,NN))                                                     DLOD0088
      TLD = TLD+Q+QDHW                                                  DLOD0089
      TELD = TELD+QCMP+QRES+QHPM                                        DLOD0090
      TTLD = TTLD+QABS+QHWS                                             DLOD0091
      IF (KODP-1) 12,10,12                                              DLOD0092
10    QABS = QABS*BABS                                                  DLOD0093
      QCMP = QCMP*BCMP                                                  DLOD0094
      QRES = QRES*ERES                                                  DLOD0095
      QHPM = QHPM*BHPM                                                  DLOD0096
      QHWS = QHWS*EHWS                                                  DLOD0097
      WRITE (IOUT,206) IX,NN,TIB(NN),NU(IX,NN),QABS,QCMP,QRES,QHPM,QHWS DLOD0098
206   FORMAT (5X,I2,10X,I2,8X,F6.2,8X,I4,4X,E11.4,10X,E11.4,3X,E11.4,2X,DLOD0099
     1 E11.4,1X,E11.4)                                                  DLOD0100
12    CONTINUE                                                          DLOD0101
      IF (KODP-1) 13,14,13                                              DLOD0102
13    TOL(NHR,IX) = TTLD                                                DLOD0103
      IF (TOL(NHR,IX)-100.) 1301,1301,1302                              DLOD0104
1301  TOL(NHR,IX) = 100.                                                DLOD0105
1302  ETHL(NHR) = ETHL(NHR)+TELD                                        DLOD0106
14    CONTINUE                                                          DLOD0107
15    CONTINUE                                                          DLOD0108
```

```
      DO 21 NN=1,NTYPE                                                  DLOD0109
      IF (NUEX(NN)) 21,21,1501                                          DLOD0110
1501  QCEXT = 0.0                                                       DLOD0111
      QREXT = 0.0                                                       DLOD0112
      QHEXT = 0.0                                                       DLOD0113
      QAEXT = 0.0                                                       DLOD0114
      QHWEX = 0.0                                                       DLOD0115
      QEXT = NUEX(NN)*(QL(NHRL,NN)+AHRF*(QL(NHR,NN)-QL(NHRL,NN)))       DLOD0116
      TOAB = TAIR(NHRL)+AHRF*(TAIR(NHR)-TAIR(NHRL))+460.                DLOD0117
      TIAB = TSB(NHRL,NN)+AHRF*(TSB(NHR,NN)-TSB(NHRL,NN))+460.          DLOD0118
      QDEXT = NUEX(NN)*DHW(NN)*(WUF(NHRL,NN)+AHRF*(WUF(NHR,NN)-         DLOD0119
     1 WUF(NHRL,NN)))                                                   DLOD0120
      IF (QEXT) 16,17,17                                                DLOD0121
16    QEXT = -QEXT                                                      DLOD0122
      IF (TOAB/TIAB-(1.0+1.0E-06)) 1601,1601,1602                       DLOD0123
1601  BADC = 1.0E10                                                     DLOD0124
      QEXT = 0.0                                                        DLOD0125
      GO TO 1603                                                        DLOD0126
1602  BADC = .028037/(TOAB/TIAB-1.0)                                    DLOD0127
1603  BCMP = BADC*ECMP                                                  DLOD0128
      QCEXT = QEXT/BCMP                                                 DLOD0129
      GO TO 18                                                          DLOD0130
17    IF ((1.0-1.0E-06)-TOAB/TIAB) 1701,1701,1702                       DLOD0131
1701  BADH = 1.0E10                                                     DLOD0132
      QEXT = 0.0                                                        DLOD0133
      GO TO 1703                                                        DLOD0134
1702  BADH = .068182/(1.0-TOAB/TIAB)                                    DLOD0135
1703  BHPM = BADH*EHPM                                                  DLOD0136
      IF (BHPM-ERES) 1704,1704,1705                                     DLOD0137
1704  QREXT = (QEXT/ERES)*(FREXT(NN)+FHPEX(NN))                         DLOD0138
      QHWEX = (1.0-FREXT(NN)-FHPEX(NN))*(QEXT/EHWS)                     DLOD0139
      GO TO 18                                                          DLOD0140
1705  QREXT = (QEXT/ERES)*FREXT(NN)                                     DLOD0141
      QHEXT = (QEXT/BHPM)*FHPEX(NN)                                     DLOD0142
      QHWEX = (1.0-FREXT(NN)-FHPEX(NN))*(QEXT/EHWS)                     DLOD0143
18    QREXT = QREXT+(QDEXT/ERES)*(FREXT(NN)+FHPEX(NN))                  DLOD0144
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      QHWEX = QHWEX+(QDEXT/EHWS)*(1.0-FREXT(NN)-FHPEX(NN))                DLODO145
      IF (KODP-1) 20,19,20                                                DLODO146
19    TLD = TLD+QEXT+QDEXT                                                DLODO147
      TELD = TELD+QCEXT+QREXT+QHEXT                                       DLODO148
      QAEXT = QAEXT*BABS                                                  DLODO149
      QCEXT = QCEXT*BCMP                                                  DLODO150
      QREXT = QREXT*ERES                                                  DLODO151
      QHEXT = QHEXT*BHPM                                                  DLODO152
      QHWEX = QHWEX*EHWS                                                  DLODO153
      WRITE (IOUT,207) NN,TIB(NN),NUEX(NN),QAEXT,QCEXT,QREXT,QHEXT,QHWEX  DLODO154
207   FORMAT (1H ,3X,'NONE',9X,I2,8X,F6.2,8X,I4,4X,E11.4,10X,E11.4,3X,    DLODO155
     1 E11.4,2X,E11.4,1X,E11.4)                                           DLODO156
      GO TO 21                                                            DLODO157
20    ETHL(NHR) = ETHL(NHR)+QCEXT+QREXT+QHEXT                             DLODO158
21    CONTINUE                                                            DLODO159
      IF (KODP-1) 23,22,23                                                DLODO160
22    WRITE (IOUT,208) TOB                                                DLODO161
208   FORMAT (1H0,' ***OUTSIDE AIR TEMPERATURE:',F7.2,' F***')            DLODO162
      TLD = TLD/3.412E06                                                  DLODO163
      WRITE (IOUT,209) TLD                                                DLODO164
209   FORMAT (1H0,' ***TOTAL COMMUNITY SPACE CONDITIONING & DOMESTIC HOT  DLODO165
     1 WATER LOAD:',F8.2,' MW(TH)***')                                    DLODO166
      TELD = TELD/3.412E06                                                DLODO167
      WRITE (IOUT,210) TELD                                               DLODO168
210   FORMAT (1H0,' ***TOTAL ELECTRIC SPACE CONDITIONING & DOMESTIC HOT   DLODO169
     1WATER DEMAND:',F8.2,' MW(E)***')                                    DLODO170
      GO TO 24                                                            DLODO171
23    CONTINUE                                                            DLODO172
24    RETURN                                                              DLODO173
      END                                                                 DLODO174
```

```
      SUBROUTINE STDY(MASS,TI,TO,N1,N2,AUF,TAMB,IERR,KODE)               STDY0001
      REAL MASS                                                          STDY0002
      DIMENSION IEX(3,5,13),MASS(3,5,13),TI(3,5,13),TO(3,5,13)           STDY0003
      DIMENSION AUF(3,5,13),CAP(3,5,13),NB(5),ND(5),ISER(3,5,13),N1(31)  STDY0004
      DIMENSION N2(31),OS(5),DO(31),TR(5)                                STDY0005
      COMMON LS,ND,NH,IOUT,IEX,ISER,NB,CAP,NEXCH                         STDY0006
      M = 1                                                              STDY0007
      DO 99 L=1,LS                                                       STDY0008
      NMK = N1(IEX(3,L,1))                                               STDY0009
1     X = 1.0/(MASS(3,L,1)*CAP(3,L,1))-1.0/(MASS(2,L,NMK)*CAP(2,L,NMK))  STDY0010
      B = AUF(3,L,1)                                                     STDY0011
      DENOM = 1.0-EXP(B*X)                                               STDY0012
      IF (ABS(DENOM)-1.0E-06) 1001,1001,1002                             STDY0013
1001  TSET = MASS(3,L,1)*CAP(3,L,1)*(TO(3,L,1)-TI(3,L,1))/B+TO(3,L,1)    STDY0014
      GO TO 1003                                                         STDY0015
1002  TSET = -MASS(3,L,1)*CAP(3,L,1)*(TO(3,L,1)-TI(3,L,1))*X/DENOM+      STDY0016
     1 TO(3,L,1)                                                         STDY0017
1003  NBOI = NB(L)                                                       STDY0018
      DO 1201 NN=1,NBOI                                                  STDY0019
      NDUM = N1(IEX(3,L,NN))                                             STDY0020
2     X = 1.0/(MASS(3,L,NN)*CAP(3,L,NN)) - 1.0/(MASS(2,L,NDUM)*          STDY0021
     1 CAP(2,L,NDUM))                                                    STDY0022
      B = AUF(3,L,NN)                                                    STDY0023
      DENCM = 1.0-EXP(B*X)                                               STDY0024
      IF (ABS(DENOM)-1.0E-06) 2001,2001,2002                             STDY0025
2001  TI(2,L,NDUM) = MASS(3,L,NN)*CAP(3,L,NN)*(TO(3,L,NN)-TI(3,L,NN))/B  STDY0026
     1 + TO(3,L,NN)                                                      STDY0027
      GO TO 2003                                                         STDY0028
2002  TI(2,L,NDUM) = -MASS(3,L,NN)*CAP(3,L,NN)*(TO(3,L,NN)-TI(3,L,NN))*  STDY0029
     1 X/DENOM + TO(3,L,NN)                                              STDY0030
2003  IF (ABS((TI(2,L,NDUM)-TSET)/TSET)-1.0E-05) 12,12,11                STDY0031
11    MASS(2,L,NDUM) = (TI(2,L,NDUM)/TSET)*MASS(2,L,NDUM)                STDY0032
      GO TO 2                                                            STDY0033
12    TI(2,L,NDUM) = TSET                                                STDY0034
1201  CONTINUE                                                           STDY0035
      OS(L) = 0.0                                                        STDY0036
```

```
      SUMT = 0.0                                                        STDY0037
      SUMM = 0.0                                                        STDY0038
      NBOI = NB(L)                                                      STDY0039
      DO 13 NN=1,NBOI                                                   STDY0040
      NE = IEX(3,L,NN)                                                  STDY0041
      NA = N1(IEX(3,L,NN))                                              STDY0042
      DQ(NE) = MASS(3,L,NN)*CAP(3,L,NN)*(TO(3,L,NN)-TI(3,L,NN))         STDY0043
1202  TO(2,L,NA) = TI(2,L,NA) - DQ(NE)/(MASS(2,L,NA)*CAP(2,L,NA))       STDY0044
      IF (TO(2,L,NA)-TI(3,L,NN)) 1203,1203,1204                         STDY0045
1203  MASS(2,L,NA) = MASS(2,L,NA) + 1.0E-05*MASS(2,L,NA)                STDY0046
      GO TO 1202                                                        STDY0047
1204  QS(L) = QS(L) + DQ(NE)                                            STDY0048
      SUMT = SUMT+MASS(2,L,NA)*TO(2,L,NA)                               STDY0049
      SUMM = SUMM+MASS(2,L,NA)                                          STDY0050
13    CONTINUE                                                          STDY0051
      NDOI = ND(L)                                                      STDY0052
      DO 17 INDX=1,NDOI                                                 STDY0053
      IF (ISER(2,L,INDX)) 16,15,17                                      STDY0054
15    MASS(2,L,INDX) = SUMM                                             STDY0055
      GO TO 17                                                          STDY0056
16    WRITE (IOUT,202) L,INDX,ISER(2,L,INDX)                            STDY0057
202   FORMAT (1H ,' **INCORRECT DATA VALUE-LOOP:',I2,', NODE:',I3,      STDY0058
     1 ', ISER =',I5,' **')                                             STDY0059
      IERR = 1                                                          STDY0060
      GO TO 60                                                          STDY0061
17    CONTINUE                                                          STDY0062
      TR(L) = SUMT/SUMM                                                 STDY0063
      NDUM = N1(IEX(3,L,1))                                             STDY0064
      NDOI = ND(L)                                                      STDY0065
      DO 23 I=1,NDOI                                                    STDY0066
      NP = NDUM - I                                                     STDY0067
      NA = NP+1                                                         STDY0068
      IF (NP) 22,21,20                                                  STDY0069
20    TO(2,L,NP) = TI(2,L,NA)                                           STDY0070
      TI(2,L,NP) = (TO(2,L,NP)-TAMB)*EXP(AUF(2,L,NP)/(MASS(2,L,NP)*     STDY0071
     1 CAP(2,L,NP))) + TAMB                                             STDY0072
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      GC TO 23                                                          STDY0073
21    TEO = TI(2,L,NA)                                                  STDY0074
      GO TO 24                                                          STDY0075
22    WRITE (IOUT,203) L,NP,NDUM                                        STDY0076
203   FORMAT (1H ,' **PROBLEM DETECTED IN LOOP:',I2,', NODE:',I3,       STDY0077
     1 ', FIRST BRANCH NODE:',I3,' **')                                 STDY0078
      IERR = 1                                                          STDY0079
      GO TO 60                                                          STDY0080
23    CONTINUE                                                          STDY0081
24    NBLST = NB(L)                                                     STDY0082
      NDUM = N1(IEX(3,L,NBLST))                                         STDY0083
      NP = NDUM + 1                                                     STDY0084
      TI(2,L,NP) = TR(L)                                                STDY0085
      TO(2,L,NP) = (TI(2,L,NP)-TAMB)*EXP(-AUF(2,L,NP)/(MASS(2,L,NP)*    STDY0086
     1 CAP(2,L,NP))) + TAMB                                             STDY0087
      NDCI = ND(L)                                                      STDY0088
      DO 30 I=2,NDOI                                                    STDY0089
      NP = NDUM + I                                                     STDY0090
      NA = NP-1                                                         STDY0091
      TI(2,L,NP) = TO(2,L,NA)                                           STDY0092
      IF (NP-ND(L)) 25,26,29                                            STDY0093
25    TO(2,L,NP) = (TI(2,L,NP)-TAMB)*EXP(-AUF(2,L,NP)/(MASS(2,L,NP)*    STDY0094
     1 CAP(2,L,NP))) + TAMB                                             STDY0095
      GO TO 30                                                          STDY0096
26    IF (IEX(2,L,NP)) 27,27,28                                         STDY0097
27    WRITE (IOUT,204) L,NP,IEX(2,L,NP)                                 STDY0098
204   FORMAT (1H ,' **INCORRECT DATA VALUE-LOOP:',I2,', NODE:',I3,      STDY0099
     1 ', IEX =',I5,' **')                                              STDY0100
      IERR = 1                                                          STDY0101
      GO TO 60                                                          STDY0102
28    IF (IEX(2,L,NP)-NEXCH) 2801,2801,2802                             STDY0103
2801  TO(2,L,NP) = TEO                                                  STDY0104
      GO TO 31                                                          STDY0105
2802  WRITE (IOUT,204) L,NP,IEX(2,L,NP)                                 STDY0106
      IERR = 1                                                          STDY0107
      GO TO 60                                                          STDY0108
```

```
29        NFRST = NDUM-NB(L) +1                                               STDY0109
          WRITE (IOUT,203) L,NP,NFRST                                         STDY0110
          IERR = 1                                                            STDY0111
          GO TO 60                                                            STDY0112
30        CONTINUE                                                            STDY0113
31        DO 34 INDX=M,NH                                                     STDY0114
          NN = INDX                                                           STDY0115
          IF (IEX(1,1,NN)) 33,32,35                                           STDY0116
32        TO(1,1,NN) = (TI(1,1,NN)-TAMB)*EXP(-AUF(1,1,NN)/(MASS(1,1,NN)*      STDY0117
         1 CAP(1,1,NN))) + TAMB                                               STDY0118
          NA = NN+1                                                           STDY0119
          IF (NA-NH) 3201,3201,60                                             STDY0120
3201      TI(1,1,NA) = TO(1,1,NN)                                             STDY0121
          GO TO 34                                                            STDY0122
33        WRITE (IOUT,205) NN,IEX(1,1,NN)                                     STDY0123
205       FORMAT (1H ,' **INCORRECT DATA VALUE-HTW LOOP. NODE:',I3,           STDY0124
         1 ', IEX =',I5,' **')                                                STDY0125
          IERR = 1                                                            STDY0126
          GO TO 60                                                            STDY0127
34        CONTINUE                                                            STDY0128
35        IF (IEX(1,1,NN)-NEXCH) 3502,3502,3501                               STDY0129
3501      WRITE (IOUT,205) NN,IEX(1,1,NN)                                     STDY0130
          IERR = 1                                                            STDY0131
          GO TO 60                                                            STDY0132
3502      NDN = NN-1                                                          STDY0133
          THS = TO(1,1,NDN)                                                   STDY0134
          NP = N2(IEX(1,1,NN))                                                STDY0135
          X = 1.0/(MASS(2,L,NP)*CAP(2,L,NP))-1.0/(MASS(1,1,NN)*CAP(1,1,NN))   STDY0136
          B = AUF(2,L,NP)                                                     STDY0137
          DENOM = 1.0-EXP(B*X)                                                STDY0138
          IF (ABS(DENOM)-1.0E-06) 36,36,37                                    STDY0139
36        TI(1,1,NN) = MASS(2,L,NP)*CAP(2,L,NP)*(TO(2,L,NP)-TI(2,L,NP))/B +   STDY0140
         1 TO(2,L,NP)                                                         STDY0141
          GO TO 38                                                            STDY0142
37        TI(1,1,NN) = -MASS(2,L,NP)*CAP(2,L,NP)*(TO(2,L,NP)-TI(2,L,NP))*     STDY0143
         1 X/DENOM + TO(2,L,NP)                                               STDY0144
```

```
38    IF (ABS((TI(1,1,NN)-THS)/THS)-1.0E-05) 39,39,41                  STDY0145
39    IF (TO(2,L,NP)-THS) 43,40,40                                     STDY0146
40    TI(1,1,NN) = 1.001*THS                                           STDY0147
41    NDOT = ND(L)                                                     STDY0148
      DO 42 INDX=1,NDOT                                                STDY0149
      MASS(2,L,INDX) = (TI(1,1,NN)/THS)*MASS(2,L,INDX)                 STDY0150
42    CONTINUE                                                         STDY0151
      GO TO 1                                                          STDY0152
43    TI(1,1,NN) = THS                                                 STDY0153
      NE = IEX(1,1,NN)                                                 STDY0154
      DQ(NE) = MASS(2,L,NP)*CAP(2,L,NP)*(TO(2,L,NP)-TI(2,L,NP))        STDY0155
      TO(1,1,NN) = TI(1,1,NN)-DQ(NE)/(MASS(1,1,NN)*CAP(1,1,NN))        STDY0156
      DO 47 I=1,NH                                                     STDY0157
      NA = NN+I                                                        STDY0158
      NE = NA-1                                                        STDY0159
      IF (NA-NH) 44,44,60                                              STDY0160
44    TI(1,1,NA) = TO(1,1,NE)                                          STDY0161
      IF (IEX(1,1,NA)) 46,45,48                                        STDY0162
45    TO(1,1,NA) = (TI(1,1,NA)-TAMB)*EXP(-AUF(1,1,NA)/(MASS(1,1,NA)*   STDY0163
     1 CAP(1,1,NA))) + TAMB                                            STDY0164
      GO TO 47                                                         STDY0165
46    WRITE (IOUT,205) NA,IEX(1,1,NA)                                  STDY0166
      IERR = 1                                                         STDY0167
      GO TO 60                                                         STDY0168
47    CONTINUE                                                         STDY0169
48    IF (IEX(1,1,NA)-NEXCH) 50,50,49                                  STDY0170
49    WRITE (IOUT,205) NA,IEX(1,1,NA)                                  STDY0171
      IERR = 1                                                         STDY0172
      GO TO 60                                                         STDY0173
50    M = NA                                                           STDY0174
99    CONTINUE                                                         STDY0175
60    RETURN                                                           STDY0176
      END                                                              STDY0177
```

```
      SUBROUTINE SET(IDES)                                                   SETU0001
      REAL LONG,MASS,MU,MGAS                                                 SETU0002
      DOUBLE PRECISION T,TIME                                                SETU0003
      DIMENSION ISER(3,5,13),IEX(3,5,13),IPMP(3,5,13),DIA(3,5,13)            SETU0004
      DIMENSION LONG(3,5,13),AUF(3,5,13),MASS(3,5,13),TI(3,5,13)             SETU0005
      DIMENSION TO(3,5,13),CAP(3,5,13),RHO(3,5,13),MU(3,5,13),ND(5)          SETU0006
      DIMENSION NB(5),K1(31),K2(31),L1(31),L2(31),N1(31),N2(31)              SETU0007
      DIMENSION QDO(31),AMAS(3,5,13),ATI(3,5,13),ATO(3,5,13)                 SETU0008
      DIMENSION COND(3,5,13),CONV(3,5,13),NTB(31),RPE(5)                     SETU0009
      DIMENSION NU(31,20),TIB(20),PS(6),PREF(6),PEX(6),PP(6),PC(6)           SETU0010
      DIMENSION AW(20),RTW(20),AWD(20),RTWD(20),AR(20),RTR(20),AF(20)        SETU0011
      DIMENSION RTF(20),MTW(20),MTR(20),BH(20),WA(20),AINFL(20)              SETU0012
      DIMENSION WDSC(20),FWLIT(20,5),WSAB(20),RSAB(20),POL(20),NUEX(20)      SETU0013
      DIMENSION FREXT(20),FHPEX(20),TAIR(25),WV(25),WDIR(25),TSB(25,20)      SETU0014
      DIMENSION BUF(25,20),TQL(25,31),TQ(31),DPM(5),NABS(31,20)              SETU0015
      DIMENSION NCMP(31,20),NRES(31,20),NHPM(31,20),NHWS(31,20)              SETU0016
      DIMENSION QL(25,20),ETHL(25),DHW(20),WUF(25,20)                        SETU0017
      COMMON LS,ND,NH,IOUT,IEX,ISER,NB,CAP,NEXCH,MASS,TI,TO,AUF,K1,K2        SETU0018
      COMMON L1,L2,N1,N2,RHO,DIA,LONG,NTB,THW,IERR,TAMB,DTIME,COND,CONV      SETU0019
      COMMON KODP,KODE,INIT,IFLO,NTYPE,NU,NPMP,IPMP,MU,TQ,TOB,TIB            SETU0020
      COMMON DPM,PP,RPE,PS,PREF,PEX,PC,TCW,HVO,CVO,QHW,QCW,THG               SETU0021
      COMMON TCG,MGAS,CAPG,PMF,THI,QHS,QHO,QCO,QDO,PSENS,AMAS                SETU0022
      COMMON /ABC/TIME,T                                                     SETU0023
      COMMON /BLD/AW,RTW,AWD,RTWD,AR,RTR,AF,RTF,MTW,MTR,BH,AINFL             SETU0024
      COMMON /BLD/WSAB,RSAB,POL,WV,WDIR,IBHR,ALAT,DECL                       SETU0025
      COMMON /BLD/ASC,AEC,SDF,BUF,WA,WDSC,FWLIT                              SETU0026
      COMMON /DLD/ETHL,TQL,NCMP,NABS,NRES,NHPM,NHWS,ECMP,EABS,ERES,EHPM      SETU0027
      COMMON /DLD/EHWS,NUEX,FREXT,FHPEX,DHW,WUF                              SETU0028
      COMMON /ALD/QL,NTEMP,TAIR,TSB                                          SETU0029
      IF (KODE-1) 1000,6,999                                                 SETU0030
 1000 CALL QLOAD(KODE,NTYPE,TAMB,IOUT)                                       SETU0031
      KODP = 0                                                               SETU0032
      IHR = 25                                                               SETU0033
      IHRL = 25                                                              SETU0034
      HRF = 0.0                                                              SETU0035
      CALL DLOAD(KODE,KODP,IHR,IHRL,HRF,IOUT,LS,NB,IEX,NTYPE,NU,TIB,TOB)     SETU0036
```

```
      IF (IDES) 1001,1002,1001                                          SETU0037
1001  KODP = 1                                                          SETU0038
      WRITE (IOUT,200)                                                  SETU0039
200   FORMAT (1H1,45X,'***SYSTEM DESIGN CONDITIONS***')                 SETU0040
      CALL DLOAD(KODE,KODP,IHR,IHRL,HRF,IOUT,LS,NB,IEX,NTYPE,NU,TIB,TOB) SETU0041
      WRITE (IOUT,201)                                                  SETU0042
201   FORMAT (1H1,10X,'EXCHANGER',10X,'LOAD (BTU/HR)')                  SETU0043
1002  DO 2 L=1,LS                                                       SETU0044
      NBOI = NB(L)                                                      SETU0045
      DO 1 N=1,NBOI                                                     SETU0046
      IX = IEX(3,L,N)                                                   SETU0047
      IF (IDES) 1003,1004,1003                                          SETU0048
1003  WRITE (IOUT,203) IX,TQL(25,IX)                                    SETU0049
203   FORMAT (13X,I2,14X,E11.4)                                         SETU0050
1004  MASS(3,L,N) = TQL(25,IX)/(CAP(3,L,N)*(TO(3,L,N)-TI(3,L,N)))       SETU0051
1     CONTINUE                                                          SETU0052
2     CONTINUE                                                          SETU0053
      IF (IDES) 1005,1006,1005                                          SETU0054
1005  GO TO 999                                                         SETU0055
1006  QHS = QHS-ETHL(25)                                                SETU0056
2000  DO 5 ID=1,3                                                       SETU0057
      DO 4 JD=1,5                                                       SETU0058
      DO 3 KD=1,13                                                      SETU0059
      AMAS(ID,JD,KD) = MASS(ID,JD,KD)                                   SETU0060
      ATI(ID,JD,KD) = TI(ID,JD,KD)                                      SETU0061
      ATO(ID,JD,KD) = TO(ID,JD,KD)                                      SETU0062
3     CONTINUE                                                          SETU0063
4     CONTINUE                                                          SETU0064
5     CONTINUE                                                          SETU0065
      ATI(1,1,1) = THW                                                  SETU0066
      CALL STDY(AMAS,ATI,ATO,N1,N2,AUF,TAMB,IERR,KODE)                  SETU0067
      IF (IERR-1) 6,999,6                                               SETU0068
6     INIT = 1                                                          SETU0069
      CALL PRESS(AMAS,NTB,DIA,RHO,MU,LONG,IPMP,INIT,IERR,DPM,PP,RPE)    SETU0070
      IF (IERR-1) 7,999,7                                               SETU0071
7     IF (KODE-1) 8,99,999                                              SETU0072
```

```
 8    DO 11 ID=1,3                                                      SETU0073
      DO 10 JD=1,5                                                      SETU0074
      DO 9 KD=1,13                                                      SETU0075
      MASS(ID,JD,KD) = AMAS(ID,JD,KD)                                   SETU0076
      TI(ID,JD,KD) = ATI(ID,JD,KD)                                      SETU0077
      TO(ID,JD,KD) = ATO(ID,JD,KD)                                      SETU0078
 9    CONTINUE                                                          SETU0079
 10   CONTINUE                                                          SETU0080
 11   CONTINUE                                                          SETU0081
      MGAS = QHS/(CAPG*(THG-TCG))                                       SETU0082
      TCWI = TO(1,1,NH)                                                 SETU0083
      THI = THW                                                         SETU0084
      PMF = QHS/(((CAP(1,1,1)+CAP(1,1,NH))/2.0)*(THI-TCWI))             SETU0085
      CALL PREC(TCG,THG,MGAS,CAPG,QHS,TCWI,THI,IOUT,IERR)               SETU0086
      IF (IERR-1) 12,999,12                                             SETU0087
 12   TCW = TCWI                                                        SETU0088
      QHW = RHO(1,1,1)*HVO*CAP(1,1,1)*THW                               SETU0089
      QHC = QHW                                                         SETU0090
      QCW = RHO(1,1,NH)*CVO*CAP(1,1,NH)*TCW                             SETU0091
      QCO = QCW                                                         SETU0092
 16   WRITE (IOUT,202)                                                  SETU0093
 202  FORMAT (1H1,47X,' ***STEADY-STATE SUMMARY***')                    SETU0094
      T = IBHR+0.0                                                      SETU0095
      CALL PRV(T,THW,TCW,HVO,CVO,QHW,QCW,THG,TCG,MGAS,CAPG,PMF,THI,PP,  SETU0096
     1 NPMP)                                                            SETU0097
      IHR = 25                                                          SETU0098
      IHRL = 25                                                         SETU0099
      HRF = 1.0                                                         SETU0100
      KODP = 1                                                          SETU0101
      CALL DLOAD(KODE,KODP,IHR,IHRL,HRF,IOUT,LS,NB,IEX,NTYPE,NU,TIB,TOB) SETU0102
      IF (IERR-1) 17,999,17                                             SETU0103
 17   DO 18 NX=1,NEXCH                                                  SETU0104
      K = K2(NX)                                                        SETU0105
      L = L2(NX)                                                        SETU0106
      N = N2(NX)                                                        SETU0107
      QDO(NX) = MASS(K,L,N)*CAP(K,L,N)*(TO(K,L,N)-TI(K,L,N))            SETU0108
```

```
 18     CONTINUE                                                       SETU0109
        DO 19 I=1,NPMP                                                 SETU0110
        PS(I) = PP(I)                                                  SETU0111
        PREF(I) = PP(I)                                                SETU0112
        PEX(I) = PP(I)                                                 SETU0113
        FC(I) = 0.0                                                    SETU0114
 19     CONTINUE                                                       SETU0115
        GO TO 999                                                      SETU0116
 99     IFLO = 0                                                       SETU0117
        CALL FLOWS                                                     SETU0118
 999    RETURN                                                         SETU0119
        END                                                            SETU0120
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```
      SUBROUTINE FLOWS                                                  FLOW0001
      REAL LONG,MASS,MU,MGAS                                            FLOW0002
      DOUBLE PRECISION T,TIME                                           FLOW0003
      DIMENSION ISER(3,5,13),IEX(3,5,13),IPMP(3,5,13),DIA(3,5,13)       FLOW0004
      DIMENSION LONG(3,5,13),AUF(3,5,13),MASS(3,5,13),TI(3,5,13)        FLOW0005
      DIMENSION TO(3,5,13),CAP(3,5,13),RHO(3,5,13),MU(3,5,13),ND(5)     FLOW0006
      DIMENSION NB(5),K1(31),K2(31),L1(31),L2(31),N1(31),N2(31)         FLOW0007
      DIMENSION COND(3,5,13),CONV(3,5,13),NTB(31),RPE(5)                FLOW0008
      DIMENSION NU(31,20),TIB(20),PS(6),PREF(6),PEX(6),PP(6),PC(6)      FLOW0009
      DIMENSION QDO(31),TQ(31),ACC(6),DPM(5)                            FLOW0010
      DIMENSION BMAS(3,5,13),DMAS(3,5,13)                               FLOW0011
      COMMON LS,ND,NH,IOUT,IEX,ISER,NB,CAP,NEXCH,MASS,TI,TO,AUF,K1,K2   FLOW0012
      COMMON L1,L2,N1,N2,RHO,DIA,LONG,NTB,THW,IERR,TAMB,DTIME,COND,CONV FLOW0013
      COMMON KODP,KODE,INIT,IFLO,NTYPE,NU,NPMP,IPMP,MU,TQ,TOB,TIB       FLOW0014
      COMMON DPM,PP,RPE,PS,PREF,PEX,PC,TCW,HVO,CVO,QHW,QCW,THG          FLOW0015
      COMMON TCG,MGAS,CAPG,PMF,THI,QHS,QHO,QCO,QDO,PSENS                FLOW0016
      COMMON /ABC/TIME,T                                                FLOW0017
      COMMON /XYZ/BMAS,DMAS                                             FLOW0018
      REFM = MASS(1,1,1)                                                FLOW0019
      REFT = TO(1,1,NH)                                                 FLOW0020
      IF (IFLO-1) 1,3,1                                                 FLOW0021
1     DO 2 N=1,NPMP                                                     FLOW0022
      PREF(N) = PP(N)                                                   FLOW0023
      PEX(N) = PP(N) + PSENS*(PP(N)-PS(N))                              FLOW0024
      IF (PEX(N)) 1001,2,2                                              FLOW0025
1001  PEX(N) = PP(N)                                                    FLOW0026
2     CONTINUE                                                          FLOW0027
      IF (IFLO-1) 3000,3,3000                                           FLOW0028
3     IPRE = 0                                                          FLOW0029
      IPRX = 0                                                          FLOW0030
      CALL ENRG                                                         FLOW0031
      IF (IERR-1) 3000,43,3000                                          FLOW0032
3000  INIT = 2                                                          FLOW0033
      CALL PRESS(MASS,NTB,DIA,RHO,MU,LONG,IPMP,INIT,IERR,DPM,PP,RPE)    FLOW0034
      IF (IERR-1) 4,999,4                                               FLOW0035
4     IPRM = 0                                                          FLOW0036
```

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      DO 26 K=1,2                                                       FLOW0037
      IF (K-2) 5,6,6                                                    FLOW0038
5     LIM = 1                                                           FLOW0039
      GO TO 7                                                           FLOW0040
6     LIM = LS                                                          FLOW0041
7     DO 25 L=1,LIM                                                     FLOW0042
      IF (K-2) 8,9,9                                                    FLOW0043
8     NLIM = NH                                                         FLOW0044
      GO TO 10                                                          FLOW0045
9     NLIM = ND(L)                                                      FLOW0046
10    DO 24 N=1,NLIM                                                    FLOW0047
      IF (IPMP(K,L,N)) 11,24,12                                         FLOW0048
11    WRITE (IOUT,204) K,L,N,IPMP(K,L,N)                                FLOW0049
204   FORMAT (1H ,' **INCORRECT DATA VALUE-SECTION:',I2,', LOOP:',I2,   FLOW0050
     1 ', NODE:',I3,', IPMP=',I5,' **')                                 FLOW0051
      IERR = 1                                                          FLOW0052
      GO TO 999                                                         FLOW0053
12    KC = K                                                            FLOW0054
      LC = L                                                            FLOW0055
      NC = N                                                            FLOW0056
      NP = IPMP(KC,LC,NC)                                               FLOW0057
      PS(NP) = PP(NP)                                                   FLOW0058
      IF (ABS(PP(NP)-PREF(NP))/PREF(NP)-.01) 13,13,14                   FLOW0059
13    PEX(NP) = PREF(NP)                                                FLOW0060
14    FCTR = (3.1416*4.147E08*DIA(KC,LC,NC)**2)/(4.0*LONG(KC,LC,NC))    FLOW0061
      DM = MASS(KC,LC,NC)+DTIME*FCTR*(PEX(NP)-PP(NP))                   FLOW0062
      IF (DM) 1401,1401,1402                                            FLOW0063
1401  DM = MASS(KC,LC,NC)/2.0                                           FLOW0064
1402  PCI = (DM-MASS(KC,LC,NC))/MASS(KC,LC,NC)                          FLOW0065
      PC(NP) = PC(NP)+PCI                                               FLOW0066
      ACC(NP) = (DM-MASS(KC,LC,NC))/DTIME                               FLOW0067
      IF (ABS(PC(NP))-.10) 16,15,15                                     FLOW0068
15    IPRM = IPRM                                                       FLOW0069
      PC(NP) = 0.0                                                      FLOW0070
16    MASS(KC,LC,NC) = DM                                               FLOW0071
      IF (KC-2) 17,19,19                                                FLOW0072
```

```
17      DO 18 NN=1,NH                                                    FLOW0073
        IF (IEX(1,1,NN)) 1701,1701,1702                                  FLOW0074
1701    MASS(1,1,NN) = MASS(KC,LC,NC)                                    FLOW0075
        GO TO 18                                                         FLOW0076
1702    MASS(1,1,NN) = (DMAS(1,1,NN)/(DMAS(1,1,NN)+BMAS(1,1,NN)))*       FLOW0077
       1 MASS(KC,LC,NC)                                                  FLOW0078
18      CONTINUE                                                         FLOW0079
        GO TO 24                                                         FLOW0080
19      QTLLD = 0.0                                                      FLOW0081
        NCCR = NB(LC)                                                    FLOW0082
        DO 1901 NIND=1,NCCR                                              FLOW0083
        IX = IEX(3,LC,NIND)                                              FLOW0084
        QTILD = QTILD + TQ(IX)                                           FLOW0085
1901    CONTINUE                                                         FLOW0086
        NDOI = ND(LC)                                                    FLOW0087
        DO 23 NN=1,NDOI                                                  FLOW0088
        IF (ISER(KC,LC,NN)) 20,21,22                                     FLOW0089
20      WRITE (IOUT,205) KC,LC,NN,ISER(KC,LC,NN)                         FLOW0090
205     FORMAT (1H ,' **INCORRECT DATA VALUE-SECTION:',I2,', LOOP:',I2,  FLOW0091
       1 ', NODE:',I3,', ISER =',I5,' **')                               FLOW0092
        IERR = 1                                                         FLOW0093
        GO TO 999                                                        FLOW0094
21      MASS(KC,LC,NN) = MASS(KC,LC,NC)                                  FLOW0095
        GO TO 23                                                         FLOW0096
22      IX = IEX(KC,LC,NN)                                               FLOW0097
        MASS(KC,LC,NN) = MASS(KC,LC,NC)*TQ(IX)/QTLLD                     FLOW0098
23      CONTINUE                                                         FLOW0099
24      CONTINUE                                                         FLOW0100
25      CONTINUE                                                         FLOW0101
26      CONTINUE                                                         FLOW0102
29      T = TIME                                                         FLOW0103
        IF (IFLO-1) 999,30,999                                           FLOW0104
30      CVOI = CVO+DTIME*(REFM-PMF)/RHO(1,1,NH)                          FLOW0105
        IF (CVOI) 3001,3001,3002                                         FLOW0106
3001    CVOI = 0.0                                                       FLOW0107
        PMFI = MASS(1,1,NH)                                              FLOW0108
```

```
      TCWI = TO(1,1,NH)                                                 FLOW0109
      QCI = 0.0                                                         FLOW0110
      GO TO 3003                                                        FLOW0111
 3002 TCWI = (CVO*RHO(1,1,NH)*TCW+DTIME*(REFM*REFT-PMF*TCW))/(CVOI*     FLOW0112
     1 RHO(1,1,NH))                                                     FLOW0113
      QCI = CVOI*RHO(1,1,NH)*CAP(1,1,NH)*TCWI                           FLOW0114
      PMFI = QHS/(((CAP(1,1,1)+CAP(1,1,NH))/2.0)*(THW-TCWI))            FLOW0115
 3003 THI = THW                                                         FLOW0116
      HVOI = HVO+DTIME*(PMF-REFM)/RHO(1,1,1)                            FLOW0117
      IF (HVOI) 3004,3004,3005                                          FLOW0118
 3004 HVOI = 0.0                                                        FLOW0119
      PMFI = MASS(1,1,1)                                                FLOW0120
      THWI = THI                                                        FLOW0121
      QHI = 0.0                                                         FLOW0122
      GO TO 31                                                          FLOW0123
 3005 THWI = THW                                                        FLOW0124
      QHI = HVOI*RHO(1,1,1)*CAP(1,1,1)*THWI                             FLOW0125
 31   CALL PREC(TCG,THG,MGAS,CAPG,QHS,TCWI,THI,IOUT,IERR)               FLOW0126
      IF (TERR-1) 35,43,35                                              FLOW0127
 35   QCW = QCI                                                         FLOW0128
      QHW = QHI                                                         FLOW0129
      TCW = TCWI                                                        FLOW0130
      THW = THWI                                                        FLOW0131
      CVO = CVOI                                                        FLOW0132
      HVO = HVOI                                                        FLOW0133
      PMF = PMFI                                                        FLOW0134
      GO TO 999                                                         FLOW0135
 43   T = TIME                                                          FLOW0136
      CALL PRV(T,THW,TCW,HVO,CVO,QHW,QCW,THG,TCG,MGAS,CAPG,PMF,THI,PEX, FLOW0137
     1 NPMP)                                                            FLOW0138
 999  RETURN                                                            FLOW0139
      END                                                               FLOW0140
```

```
      SUBROUTINE PRESS(MASS,NTB,DIA,RHO,MU,LONG,IPMP,INIT,IERR,DPM,PP,     PRES0001
     1 RPE)                                                               PRES0002
      REAL MASS,MU,LONG                                                   PRES0003
      DIMENSION ND(5),DPM(5),IEX(3,5,13),MASS(3,5,13),NTB(31)             PRES0004
      DIMENSION DIA(3,5,13),MU(3,5,13),ISER(3,5,13),PF(31),FV(31)         PRES0005
      DIMENSION LONG(3,5,13),RHO(3,5,13),IPMP(3,5,13),PP(6),RPE(5)        PRES0006
      COMMON LS,ND,NH,IOUT,IEX,ISER                                       PRES0007
      G = 4.147E08                                                        PRES0008
      DO 29 K=1,2                                                         PRES0009
      IF (K-2) 1,2,2                                                      PRES0010
1     LIM = 1                                                             PRES0011
      GO TO 3                                                             PRES0012
2     LIM = LS                                                            PRES0013
3     DO 28 L=1,LIM                                                       PRES0014
      IF (K-2) 4,5,5                                                      PRES0015
4     NLIM = NH                                                           PRES0016
      GO TO 6                                                             PRES0017
5     NLIM = ND(L)                                                        PRES0018
6     TPD = 0.0                                                           PRES0019
      BPDIS = 0.0                                                         PRES0020
      DPM(L) = 0.0                                                        PRES0021
      DO 27 N=1,NLIM                                                      PRES0022
      IF (IEX(K,L,N)) 7,8,9                                               PRES0023
7     WRITE (IOUT,200) K,L,N,IEX(K,L,N)                                   PRES0024
200   FORMAT (1H ,' **INCORRECT DATA VALUE-SECTION:',I2,', LOOP:',I2,     PRES0025
     1 ', NODE:',I3,', IEX=',I5,' **')                                    PRES0026
      GO TO 99                                                            PRES0027
8     DM = MASS(K,L,N)                                                    PRES0028
      GO TO 10                                                            PRES0029
9     IX = IEX(K,L,N)                                                     PRES0030
      DM = MASS(K,L,N)/NTB(IX)                                            PRES0031
10    RE = 4.0*DM/(3.1416*DIA(K,L,N)*MU(K,L,N))                           PRES0032
      F = 0.184/EXP(0.2*ALOG(RE))                                         PRES0033
      IF (ISER(K,L,N)) 11,14,12                                           PRES0034
11    WRITE (IOUT,201) K,L,N,ISER(K,L,N)                                  PRES0035
201   FORMAT (1H ,' **INCORRECT DATA VALUE-SECTION:',I2,', LOOP:',I2,     PRES0036
```

```
     1 ', NODE:',I3,', ISER=',I5,' **')                                 PRES0037
      GO TO 99                                                          PRES0038
12    IX = IEX(K,L,N)                                                   PRES0039
      FF(IX) = F                                                        PRES0040
      IF (INIT-1) 14,14,13                                              PRES0041
13    F = FF(IX)+FV(IX)                                                 PRES0042
14    AC = 3.1416*DIA(K,L,N)**2/4.0                                     PRES0043
      DP = (F*LONG(K,L,N)*DM**2)/(2.0*RHO(K,L,N)*G*DIA(K,L,N)*AC**2)   PRES0044
      IF (IPMP(K,L,N)) 15,17,16                                         PRES0045
15    WRITE (IOUT,202) K,L,N,IPMP(K,L,N)                                PRES0046
202   FORMAT (1H ,' **INCORRECT DATA VALUE-SECTION:',I2,', LOOP:',I2,   PRES0047
     1 ', NODE:',I3,', IPMP=',I5,' **')                                 PRES0048
      GO TO 99                                                          PRES0049
16    IP = IPMP(K,L,N)                                                  PRES0050
17    IF (ISER(K,L,N)) 11,20,18                                         PRES0051
18    IF (DP-DPM(L)) 21,21,19                                           PRES0052
19    DPM(L) = DP                                                       PRES0053
      GO TO 21                                                          PRES0054
20    TPD = TPD+DP                                                      PRES0055
21    IF (N-NLIM) 27,22,22                                              PRES0056
22    PP(IP) = TPD+DPM(L)                                               PRES0057
      DO 26 NN=1,NLIM                                                   PRES0058
      IF (ISER(K,L,NN)) 11,26,23                                        PRES0059
23    IF (INIT-1) 24,24,25                                              PRES0060
24    AC = 3.1416*DIA(K,L,NN)**2/4.0                                    PRES0061
      IX = IEX(K,L,NN)                                                  PRES0062
      DM = MASS(K,L,NN)/NTB(IX)                                         PRES0063
      FP = (DPM(L)*2.0*RHO(K,L,NN)*G*DIA(K,L,NN)*AC**2)/(LONG(K,L,NN)*  PRES0064
     1 DM**2)                                                           PRES0065
      FV(IX) = FP-FF(IX)                                                PRES0066
25    BPDIS = BPDIS+MASS(K,L,NN)/(RHO(K,L,NN)*DPM(L))                   PRES0067
      RPE(L) = 1.0/BPDIS                                                PRES0068
26    CONTINUE                                                          PRES0069
27    CONTINUE                                                          PRES0070
28    CONTINUE                                                          PRES0071
29    CONTINUE                                                          PRES0072
```

```
      GO TO 999                                                         PRES0073
   99 IERR = 1                                                          PRES0074
  999 RETURN                                                            PRES0075
      END                                                               PRES0076
```

```
      SUBROUTINE ENRG                                                   ENRG0001
      REAL MASS,LONG                                                    ENRG0002
      DIMENSION IEX(3,5,13),MASS(3,5,13),CAP(3,5,13),TI(3,5,13)         ENRG0003
      DIMENSION TO(3,5,13),AUF(3,5,13),K1(31),K2(31),L1(31),L2(31)      ENRG0004
      DIMENSION N1(31),N2(31),ISER(3,5,13),DIA(3,5,13),LONG(3,5,13)     ENRG0005
      DIMENSION RHO(3,5,13),NB(5),ND(5),COND(3,5,13),CONV(3,5,13)       ENRG0006
      DIMENSION NTB(31),TOP(3,5,13),ATD(3,5,13)                         ENRG0007
      DIMENSION BMAS(3,5,13), DMAS(3,5,13),DIFF(3,5,13)                 ENRG0008
      COMMON LS,ND,NH,IOUT,IEX,ISER,NB,CAP,NEXCH,MASS,TI,TO,AUF,K1,K2   ENRG0009
      COMMON L1,L2,N1,N2,RHO,DIA,LONG,NTB,THW,IERR,TAMB,DTIME,COND,CONV ENRG0010
      COMMON /XYZ/BMAS,DMAS                                             ENRG0011
      DO 33 K=1,3                                                       ENRG0012
      IF (K-2) 1,2,2                                                    ENRG0013
    1 LIM = 1                                                           ENRG0014
      GO TO 3                                                           ENRG0015
    2 LIM = LS                                                          ENRG0016
    3 DO 32 L=1,LIM                                                     ENRG0017
      IF (K-2) 4,5,6                                                    ENRG0018
    4 NLIM = NH                                                         ENRG0019
      GO TO 7                                                           ENRG0020
    5 NLIM = ND(L)                                                      ENRG0021
      GO TO 7                                                           ENRG0022
    6 NLIM = NB(L)                                                      ENRG0023
    7 DO 31 N=1,NLIM                                                    ENRG0024
      IF (IEX(K,L,N)) 8,27,9                                            ENRG0025
    8 WRITE (IOUT,200) K,L,N,IEX(K,L,N)                                 ENRG0026
  200 FORMAT (1H ,' **INCORRECT DATA VALUE-SECTION:',I2,', LOOP:',I2,   ENRG0027
     1 ', NODE:',I3,', IEX =',I5,' **')                                 ENRG0028
      GO TO 99                                                          ENRG0029
    9 IX = IEX(K,L,N)                                                   ENRG0030
      TMAS = RHO(K,L,N)*3.1416*(DIA(K,L,N)**2)*NTB(IX)*LONG(K,L,N)/4.0  ENRG0031
      DL = MASS(K,L,N)*DTIME/TMAS                                       ENRG0032
      IF (K-2) 10,11,13                                                 ENRG0033
   10 KE = K2(IX)                                                       ENRG0034
      LE = L2(IX)                                                       ENRG0035
      NE = N2(IX)                                                       ENRG0036
```

```
      GO TO 14                                                          ENRG0037
11    IF (ISER(K,I,N)) 12,13,10                                         ENRG0038
12    WRITE (IOUT,202) K,L,N,ISER(K,L,N)                                ENRG0039
202   FORMAT (1H ,' **INCORRECT DATA VALUE-SECTION: ,I2,', LOOP:',I2,   ENRG0040
     1 ', NODE:',I3,', ISER =',I5,' **')                                ENRG0041
      GO TO 99                                                          ENRG0042
13    KE = K1(IX)                                                       ENRG0043
      LE = L1(IX)                                                       ENRG0044
      NE = N1(IX)                                                       ENRG0045
14    TN = TI(K,L,N)-TO(KE,LE,NE)                                       ENRG0046
      TD = TO(K,L,N)-TI(KE,LE,NE)                                       ENRG0047
15    IF (ABS(TN)-1.0E-6) 1501,1501,16                                  ENRG0048
1501  IF (TN) 1502,1503,1503                                            ENRG0049
1502  TN = -1.0E-6                                                      ENRG0050
      GO TO 16                                                          ENRG0051
1503  TN = 1.0E-6                                                       ENRG0052
16    IF (ABS(TD)-1.0E-6) 1601,1601,17                                  ENRG0053
1601  IF (TD) 1602,1603,1603                                            ENRG0054
1602  TD = -1.0E-6                                                      ENRG0055
      GO TO 17                                                          ENRG0056
1603  TD = 1.0E-6                                                       ENRG0057
 17   IF (ABS(TN/TD-1.0)-1.0E-06) 1705,1705,1704                        ENRG0058
1705  DTLM = TN                                                         ENRG0059
      DTLMX = DTLM                                                      ENRG0060
      COND(K,L,N) = AUF(K,L,N)*DTLM                                     ENRG0061
      CONV(K,L,N) = MASS(K,L,N)*CAP(K,L,N)*(TI(K,L,N)-TO(K,L,N))        ENRG0062
      DTC = AUF(K,I,N)*DL*DTLMX/(MASS(K,L,N)*CAP(K,L,N))                ENRG0063
      GO TO 20                                                          ENRG0064
 1704 TM=TN/TD                                                          ENRG0065
      IF (TM) 1701,1701,1703                                            ENRG0066
1701  ATDP = (TN+TD)/2.0                                                ENRG0067
      COND(K,L,N) = MASS(K,L,N)*CAP(K,L,N)*(TI(K,L,N)-TO(K,L,N))        ENRG0068
      DTLM = COND(K,L,N)/AUF(K,L,N)                                     ENRG0069
      IF (ABS(TN)-ABS(TD)) 18,1702,1702                                 ENRG0070
1702  TDX = 0.0                                                         ENRG0071
      DTLMX=-(TDX+TD)/2.0                                               ENRG0072
```

```
      DTC =  (AUF(K,L,N)*DTIME*TD)/(2.0*TMAS*CAP(K,L,N))                ENRG0073
      CONV(K,L,N)  =  MASS(K,L,N)*CAP(K,L,N)*(TI(K,L,N)-TO(K,L,N))      ENRG0074
      GO TO 20                                                          ENRG0075
1703  DTLM =  (TN-TD)/ALOG(TM)                                          ENRG0076
18    COND(K,L,N)  =  AUF(K,L,N)*DTLM                                   ENRG0077
19    CONV(K,L,N)  =  MASS(K,L,N)*CAP(K,L,N)*(TI(K,L,N)-TO(K,L,N))      ENRG0078
      ALPL =  (TN-TD)/DTLM                                              ENRG0079
      TDX =  TD*EXP(ALPL*DL)                                            ENRG0080
      IF  (ABS(TDX/TD-1.0)-1.0E-06)  1901,1901,1902                     ENRG0081
1901  DTLMX =  TD                                                       ENRG0082
      GO TO 1903                                                        ENRG0083
1902  DTLMX =  (TDX-TD)/ALOG(TDX/TD)                                    ENRG0084
1903  DTC =  AUF(K,L,N)*(TDX-TD)/(MASS(K,L,N)*CAP(K,L,N)*ALPL)          ENRG0085
20    FRCN =  DTLMX/DTLM                                                ENRG0086
      TODP =  TO(K,L,N)+FRCN*DL*(TI(K,L,N)-TO(K,L,N))                   ENRG0087
      TOP(K,L,N)  =  TODP-DTC                                           ENRG0088
      ATD(K,L,N)  =  (TN+TD)/2.0                                        ENRG0089
      IF  (K-K1(IX))  21,21,22                                          ENRG0090
21    IF  (TOP(K,L,N)-TI(KE,LE,NE))  23,23,31                           ENRG0091
22    IF  (TOP(K,L,N)-TI(KE,LE,NE))  31,24,24                           ENRG0092
23    TOP(K,L,N)  =  TI(KE,LE,NE)+1.0E-06                               ENRG0093
      GO TO 31                                                          ENRG0094
24    TOP(K,L,N)  =  TI(KE,LE,NE)  -  1.0E-06                           ENRG0095
      GO TO 31                                                          ENRG0096
27    TMAS =  RHO(K,L,N)*3.1416*(DIA(K,L,N)**2)*LONG(K,L,N)/4.0         ENRG0097
      DL =  MASS(K,L,N)*DTIME/TMAS                                      ENRG0098
      TN =  TI(K,L,N)-TAMB                                              ENRG0099
      TD =  TO(K,L,N)-TAMB                                              ENRG0100
      IF  (ABS(TN-TD)/TN-.0001)  28,28,29                               ENRG0101
28    COND(K,L,N)  =  AUF(K,L,N)*(TN+TD)/2.0                            ENRG0102
      CONV(K,L,N)  =  MASS(K,L,N)*CAP(K,L,N)*(TI(K,L,N)-TO(K,L,N))      ENRG0103
      DTC =  (AUF(K,L,N)*DTIME*TD)/(TMAS*CAP(K,L,N))                    ENRG0104
      TODP =  TO(K,L,N)  +  DL*(TI(K,L,N)-TO(K,L,N))                    ENRG0105
      TOP(K,L,N)  =  TODP-DTC                                           ENRG0106
      ATD(K,L,N)  =  (TN+TD)/2.0                                        ENRG0107
      GO TO 30                                                          ENRG0108
```

AD-A033 301 MASSACHUSETTS INST OF TECH CAMBRIDGE DEPT OF NUCLEAR--ETC F/G 9/2
TDIST, A PROGRAM FOR COMMUNITY ENERGY DEMAND ANALYSIS AND TOTAL--ETC(U)
AUG 76 J W STETKAR, M W GOLAY DAAK02-74-C-0308
UNCLASSIFIED USAFESA-RT-2024 NL

4 OF 4
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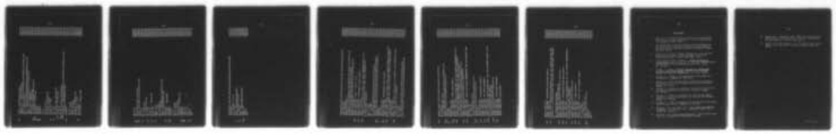

END
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2-77

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29      DTLM =  (TN-TD)/ALOG(TN/TD)                                              ENRG0109
        COND(K,L,N)  = AUF(K,L,N)*DTLM                                           ENRG0110
        CONV(K,L,N)  = MASS(K,L,N)*CAP(K,L,N)*(TI(K,L,N)-TO(K,L,N))              ENRG0111
        TDX = TD+DL*(TN-TD)                                                      ENRG0112
        DTC =  (AUF(K,L,N)*DTIME*(TDX+TD))/(2.0*TMAS*CAP(K,L,N))                 ENRG0113
        TODP = TO(K,L,N)+DL*(TI(K,L,N)-TO(K,L,N))                                ENRG0114
        TOP(K,L,N)  =  TODP-DTC                                                  ENRG0115
        ATD(K,L,N)  =  (TN+TD)/2.0                                               ENRG0116
30      IF  (TOP(K,L,N)-TAMB)  3001,3001,31                                      ENRG0117
3001    TOP(K,L,N)  =  TO(K,L,N)                                                 ENRG0118
31      CONTINUE                                                                 ENRG0119
32      CONTINUE                                                                 ENRG0120
33      CONTINUE                                                                 ENRG0121
        K = 1                                                                    ENRG0122
        L = 1                                                                    ENRG0123
        DO 36 N=1,NH                                                             ENRG0124
        TO(K,L,N)  =  TOP(K,L,N)                                                 ENRG0125
        IF  (N-1)  34,34,35                                                      ENRG0126
34      TI(K,L,N)  =  THW                                                        ENRG0127
        GO TO 36                                                                 ENRG0128
35      NO  =  N-1                                                               ENRG0129
        IF(IEX(K,L,N))  502,502,501                                              ENRG0130
  501   TI(K,L,N)  =  TO(K,L,NC)                                                 ENRG0131
        GO TO 36                                                                 ENRG0132
  502   IF(IEX(K,L,NO))  501,501,503                                             ENRG0133
  503   TI(K,L,N)  =  (DMAS(K,L,NO)*TO(K,L,NO)+BMAS(K,L,NO)*TI(K,L,NO))          ENRG0134
       1 /(DMAS(K,L,NO)+BMAS(K,L,NO))                                            ENRG0135
36      CONTINUE                                                                 ENRG0136
        K = 2                                                                    ENRG0137
        DO 47 L=1,LS                                                             ENRG0138
        NDOI  =  ND(L)                                                           ENRG0139
        DO 46 N=1,NDOI                                                           ENRG0140
        TO(K,L,N)  =  TOP(K,L,N)                                                 ENRG0141
        IF  (N-1)  37,37,38                                                      ENRG0142
37      NO  =  ND(L)                                                             ENRG0143
        TO(K,L,NO)  =  TOP(K,L,NO)                                               ENRG0144
```

```
      GO TO 39                                                          ENRG0145
   38 NO = N-1                                                          ENRG0146
   39 IF (ISER(K,L,NO)) 40,41,42                                        ENRG0147
   40 WRITE (IOUT,202) K,L,NO,ISER(K,L,NO)                              ENRG0148
      GO TO 99                                                          ENRG0149
   41 NS = NO                                                           ENRG0150
      NL = NS+NB(L)                                                     ENRG0151
      IF (N-NL) 43,43,44                                                ENRG0152
   42 NO = NO-1                                                         ENRG0153
      GO TO 39                                                          ENRG0154
   43 TI(K,L,N) = TO(K,L,NS)                                            ENRG0155
      GO TO 46                                                          ENRG0156
   44 SUMT = 0.0                                                        ENRG0157
      SUMM = 0.0                                                        ENRG0158
      NF = N-NB(L)                                                      ENRG0159
      DO 45 NA=NF,NL                                                    ENRG0160
      SUMT = SUMT+MASS(K,L,NA)*TO(K,L,NA)                               ENRG0161
      SUMM = SUMM+MASS(K,L,NA)                                          ENRG0162
   45 CONTINUE                                                          ENRG0163
      TI(K,L,N) = SUMT/SUMM                                             ENRG0164
   46 CONTINUE                                                          ENRG0165
   47 CONTINUE                                                          ENRG0166
      K = 3                                                             ENRG0167
      DO 49 L=1,LS                                                      ENRG0168
      NBOI = NB(L)                                                      ENRG0169
      DO 48 N=1,NBOI                                                    ENRG0170
      TO(K,L,N) = TOP(K,L,N)                                            ENRG0171
   48 CONTINUE                                                          ENRG0172
   49 CONTINUE                                                          ENRG0173
   50 IERR = 0                                                          ENRG0174
      GO TO 51                                                          ENRG0175
   99 IERR = 1                                                          ENRG0176
   51 RETURN                                                            ENRG0177
      END                                                               ENRG0178
```

```
      SUBROUTINE PREC(TCG,THG,MGAS,CAPG,QHS,TCWI,THI,IOUT,IERR)          PREC0001
      REAL MGAS                                                          PREC0002
      IF (TCG-TCWI) 1,1,2                                                PREC0003
1     TCG = TCWI                                                         PREC0004
      MGAS = QHS/(CAPG*(THG-TCG))                                        PREC0005
2     IF (THG-THI) 3,3,999                                               PREC0006
3     THG = THI                                                          PREC0007
      MGAS = QHS/(CAPG*(THG-TCG))                                        PREC0008
999   IERR = 0                                                           PREC0009
      RETURN                                                             PREC0010
      END                                                                PREC0011
```

```
      SUBROUTINE PRV(T,THW,TCW,HVO,CVO,QHW,QCW,THG,TCG,MGAS,CAPG,PMF,     PRVN0001
     1 THI,PP,NEMP)                                                       PRVN0002
      REAL MASS,MGAS                                                      PRVN0003
      DOUBLE PRECISION T                                                  PRVN0004
      DIMENSION NB(5),MASS(3,5,13),CAP(3,5,13),TI(3,5,13),TO(3,5,13)      PRVN0005
      DIMENSION ND(5),ISER(3,5,13),IEX(3,5,13),PP(6)                      PRVN0006
      COMMON LS,ND,NH,IOUT,IEX,ISER,NB,CAP,NEXCH,MASS,TI,TO               PRVN0007
      WRITE (IOUT,200) T                                                  PRVN0008
200   FORMAT (1H1,50X,' TIME = ',F7.3,' HR')                              PRVN0009
      WRITE (IOUT,201)                                                    PRVN0010
201   FORMAT (1H0,48X,' **CONSUMER BRANCH DATA**')                        PRVN0011
      WRITE (IOUT,202)                                                    PRVN0012
202   FORMAT (1H0,' LOOP',2X,'NODE',7X,'INLET TEMPERATURE (F)',7X,        PRVN0013
     1 'OUTLET TEMPERATURE (F)',7X,'MASS FLOW (LBM/HR)',7X,               PRVN0014
     2 'HEAT DEMAND (BTU/HR)')                                            PRVN0015
      DO 2 L=1,LS                                                         PRVN0016
      NBOI = NB(L)                                                        PRVN0017
      DO 1 N=1,NBOI                                                       PRVN0018
      QD = MASS(3,L,N)*CAP(3,L,N)*(TO(3,L,N)-TI(3,L,N))                   PRVN0019
      WRITE (IOUT,203) L,N,TI(3,L,N),TO(3,L,N),MASS(3,L,N),QD             PRVN0020
203   FORMAT (3X,I2,3X,I3,13X,F7.2,22X,F7.2,17X,E11.4,14X,E11.4)          PRVN0021
1     CONTINUE                                                            PRVN0022
2     CONTINUE                                                            PRVN0023
      WRITE (IOUT,204)                                                    PRVN0024
204   FORMAT (1H0,48X,' **SECONDARY LOOP DATA**')                         PRVN0025
      WRITE (IOUT,205)                                                    PRVN0026
205   FORMAT (1H0,' LOOP',4X,'SUPPLY TEMP',4X,'RETURN TEMP',4X,'MASS FLO  PRVN0027
     1W',4X,'HEAT DEMAND',8X,'NODE',4X,'SUPPLY TEMP',4X,'RETURN TEMP',    PRVN0028
     1 4X,'MASS FLOW')                                                    PRVN0029
      WRITE (IOUT,206)                                                    PRVN0030
206   FORMAT (1H ,13X,'(F)',12X,'(F)',9X,'(LBM/HR)',6X,'(BTU/HR)',21X,    PRVN0031
     1 '(F)',12X,'(F)',9X,'(LBM/HR)')                                     PRVN0032
      DO 5 L=1,LS                                                         PRVN0033
      NL = ND(L)                                                          PRVN0034
      QD = MASS(2,L,NL)*CAP(2,L,NL)*(TO(2,L,NL)-TI(2,L,NL))               PRVN0035
      WRITE (IOUT,207) L,TO(2,L,NL),TI(2,L,NL),MASS(2,L,NL),QD            PRVN0036
```

```
207   FORMAT (4X,I1,7X,F7.2,8X,F7.2,5X,E11.4,3X,E11.4)                    PRVN0037
      DO 4 N=1,NL                                                         PRVN0038
      IF (ISER(2,L,N)) 4,4,3                                              PRVN0039
3     WRITE (IOUT,208) N,TI(2,L,N),TO(2,L,N),MASS(2,L,N)                  PRVN0040
208   FORMAT (73X,I2,7X,F7.2,8X,F7.2,5X,E11.4)                            PRVN0041
4     CONTINUE                                                            PRVN0042
5     CONTINUE                                                            PRVN0043
      WRITE (IOUT,209)                                                    PRVN0044
209   FORMAT (1H0,51X,' **HTW LOOP DATA**')                               PRVN0045
      WRITE (IOUT,210)                                                    PRVN0046
210   FORMAT (1H0,' SUPPLY TEMPERATURE (F)',9X,'RETURN TEMPERATURE (F)',  PRVN0047
     1 9X,'TOTAL HEAT DEMAND (BTU/HR)',9X,'MASS FLOW (LBM/HR)')           PRVN0048
      QD = MASS(1,1,1)*CAP(1,1,1)*(TI(1,1,1)-TO(1,1,NH))                  PRVN0049
      WRITE (IOUT,211) TI(1,1,1),TO(1,1,NH),QD,MASS(1,1,1)                PRVN0050
211   FORMAT (9X,F7.2,24X,F7.2,22X,E11.4,20X,E11.4)                       PRVN0051
      WRITE (IOUT,212)                                                    PRVN0052
212   FORMAT (1H0,30X,' NODE',6X,'INLET TEMPERATURE (F)',6X,'OUTLET TEMP  PRVN0053
     1ERATURE (F)')                                                       PRVN0054
      DO 7 N=1,NH                                                         PRVN0055
      IF (IEX(1,1,N)) 7,7,6                                               PRVN0056
6     WRITE (IOUT,213) N,TI(1,1,N),TO(1,1,N)                              PRVN0057
213   FORMAT (33X,I2,13X,F7.2,21X,F7.2)                                   PRVN0058
7     CONTINUE                                                            PRVN0059
      WRITE (IOUT,214)                                                    PRVN0060
214   FORMAT (1H0,51X,' **RESERVOIR DATA**')                              PRVN0061
      WRITE (IOUT,215)                                                    PRVN0062
215   FORMAT (1H0,51X,' HOT WATER STORAGE')                               PRVN0063
      WRITE (IOUT,2150)                                                   PRVN0064
2150  FORMAT (1H0,14X,' WATER TEMPERATURE (F)',15X,'STORAGE VOLUME (CU.F  PRVN0065
     1T.)',15X,'STORED HEAT (BTU)')                                       PRVN0066
      WRITE (IOUT,2151) THW,HVO,QHW                                       PRVN0067
2151  FORMAT (21X,F7.2,27X,E11.4,25X,E11.4)                               PRVN0068
      WRITE (IOUT,216)                                                    PRVN0069
216   FORMAT (1H0,51X,' COLD WATER STORAGE')                              PRVN0070
      WRITE (IOUT,2150)                                                   PRVN0071
      WRITE (IOUT,2151) TCW,CVO,QCW                                       PRVN0072
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      WRITE (IOUT,217)                                                  PRVN0073
 217  FORMAT (1H0,46X,' **PRECOOLER GAS-SIDE DATA**')                   PRVN0074
      WRITE (IOUT,218)                                                  PRVN0075
 218  FORMAT (1H0,' HELIUM INLET TEMPERATURE (F)',6X,'HELIUM OUTLET TEMP PRVN0076
     1ERATURE (F)',6X,'HELIUM MASS FLOW (LBM/HR)',6X,'HEAT FLOW (BTU/HR) PRVN0077
     2')                                                                PRVN0078
      QD = MGAS*CAPG*(THG-TCG)                                          PRVN0079
      WRITE (IOUT,219) THG,TCG,MGAS,QD                                  PRVN0080
 219  FORMAT (10X,F7.2,28X,F7.2,23X,E11.4,17X,E11.4)                    PRVN0081
      WRITE (IOUT,220)                                                  PRVN0082
 220  FORMAT (1H0,45X,' **PRECOOLER WATER-SIDE DATA**')                 PRVN0083
      WRITE (IOUT,221)                                                  PRVN0084
 221  FORMAT (1H0,14X,' INLET TEMPERATURE (F)',15X,'OUTLET TEMPERATURE ( PRVN0085
     1F)',15X,'MASS FLOW (LBM/HR)')                                     PRVN0086
      WRITE (IOUT,222) TCW,THI,PMF                                      PRVN0087
 222  FORMAT (21X,F7.2,30X,F7.2,25X,E11.4)                              PRVN0088
      WRITE (IOUT,223)                                                  PRVN0089
 223  FORMAT (1H0,53X,' **PUMP DATA**')                                 PRVN0090
      WRITE (IOUT,224)                                                  PRVN0091
 224  FORMAT (1H0,45X,' PUMP',10X,'PRESSURE (PSI)')                     PRVN0092
      DO 8 I=1,NPMP                                                     PRVN0093
      P = PP(I)/144.0                                                   PRVN0094
      WRITE (IOUT,225) I,P                                              PRVN0095
 225  FORMAT (48X,I2,12X,E11.4)                                         PRVN0096
 8    CONTINUE                                                          PRVN0097
      RETURN                                                            PRVN0098
      END                                                               PRVN0099
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