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Parametric Sensitivity Study for Solar-Assisted Heat-Pump Systems

Final Report

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PARAMETRIC SENSITIVITY STUDY
FOR SOLAR-ASSISTED HEAT-PUMP
SYSTEMS

FINAL REPORT

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FOREWORD

This report presents a sensitivity study of the engineering and economic parameters affecting life-cycle costs for solar-assisted heat pump systems. The change in energy usage resulting from each engineering parameter varied has been developed from computer simulations, and is compared with results from a stand-alone heat pump system. Three geographical locations were considered: Washington, D.C., Fort Worth, Texas, and Madison, Wisconsin.

Results indicate that most engineering changes do not provide significant energy savings. The most promising parameters to vary are the solar collector parameters $\tau\alpha$ and U_L , the heat pump capacity at design point, and the minimum utilizable evaporator temperature. Costs associated with each change are estimated, and life-cycle costs computed for both engineering parameters and economic variations in interest rate, discount rate, tax credits, fuel unit costs and fuel inflation rates.

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Lyle Groome
Program Manager

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- For the collector-to-load heat exchanger variations, only 2 to 4 x 10⁵ KJ/year savings were found when the effectiveness was increased over the base values of .7 (for the collector to tank exchanger) and .77 for the tank to load exchanger.
- Rotating of the heat pump performance around the design point provided 10³ BTU additional at 0°F and -10³ BTU at 66°F. This rotation of performance curve gave savings for the series system and gave increased energy purchases for both the stand-alone heat pump and the parallel system..
- The series system was favorably affected by increasing the storage volume, although not significantly. Increases and decreases in storage volume from 0.2 m³/m² for the parallel system were not beneficial.

ECONOMIC ANALYSIS AND RESULTS

For life-cycle costing estimates, tables were developed for each parameter changed showing the dollar/m² change in acquisition costs. Using these tables, life-cycle costs were produced for each parameter changed. None of the size parameter variations studied significantly reduced life-cycle costs. Maximum effects included a 25 percent increase in LCC costs for increased storage volume ratios, a 15 percent decrease for lowering the TAU-ALPHA product, a 19 percent increase in costs for the stand-alone heat pump system when the performance curve was rotated, and a 5-10 percent reduction in costs for increasing U_L.

In addition to the engineering parameter changes which were life cycle costed, the following economic incentives were investigated: 1) interest rates, 2) discount rates, 3) tax credits, 4) maintenance costs, 5) unit fuel costs, and 6) fuel inflation rates. Results may be summarized as follows:

- Increasing the interest rate from 0 to 20 percent increased life-cycle costs by as much as 34 percent.
- The lower the discount rate, the higher the life-cycle costs. At essentially a zero discount rate, life-cycle costs doubled over the base case discount rate of 8.5 percent.
- Both increasing unit fuel costs and increasing fuel inflation rates increased life-cycle costs. These costs continued to increase for all of the systems but the stand-alone heat pump costs increased at a faster rate.
- When maintenance costs (as a fixed percent of the original investment) were reduced from 5 percent to 2 percent, a 42 percent savings in life-cycle costs resulted.

SUMMARY

BACKGROUND AND SCOPE

The purpose of this study was to determine the thermal and economic effects induced by systematically varying major parameters involved in solar-assisted heat pump systems. This study builds on the work of Reference (1), utilizing the same geographic locations (Washington, D.C., Fort Worth, Texas, and Madison, Wisconsin), the same equipment sizing and housing units, and the same engineering models for the heat pump and load modules in TRNSYS. Domestic hot water systems have been included along with the liquid series solar, liquid parallel solar and stand-alone heat pump systems. Nine base cases were developed - one for each system (of which there were three) at each of the three locations.

THERMAL ANALYSIS RESULTS

The focus of the thermal analyses included four energy quantities: work input to the heat pump in the heating mode; work input to the heat pump in the cooling mode; the auxiliary energy transferred to the space heating load; and the change in energy purchased (either + or -) between the base system and the specific parametric case. Base values for these parameters were determined from good engineering practice. By focusing on the individual parameter's sensitivity, areas of improvement in both LCC and thermal performance were expected to be determined expeditiously.

The engineering parameters varied included the storage volume ratio (from $.05 \text{ m}^3/\text{m}^2$ to $.6 \text{ m}^3/\text{m}^2$), the collector-to-tank heat exchanger effectiveness (from $.55$ to $.8$), the tank-to-load heat exchanger effectiveness ($.65$ to $.85$), the delivered air temperature (32 to 38°C), the collector parameters $\tau\alpha$ (from $.6$ to $.88$), and U_L (from 15 to $50 \text{ KJ/HR} - \text{M}^2^\circ\text{C}$), a heat pump capacity increase (7500 and 15000 BTU/hr), and a heat pump performance curve slope change to improve low end operating characteristics. Results may be summarized as follows:

- Increasing the heat pump capacity above the rating of 30200 BTU/hr for the parallel system and 39500 for the liquid series system did not significantly affect annual energy purchased, nor did changing the tank-to-load heat exchanger effectiveness.
- The delivered air temperature, if reduced to 32°C from 35°C , indicates savings in energy purchased for the stand-alone heat pump and liquid-based parallel systems on the order of $2.5\text{--}4.25 \times 10^6 \text{ KJ/year}$. This is a savings of around $\$25\text{--}50$ per year in energy costs (about 3-5%).
- Decreases in the TAU-ALPHA product from the maximum values of $.88$ for the series and $.83$ for the parallel system collector resulted in increases in energy purchased from $3\text{--}10.5 \times 10^6 \text{ KJ/year}$. Increasing U_L also increased energy purchased, as much as $9.8 \times 10^6 \text{ KJ/year}$. Decreasing U_L brought savings of up to $7.5 \times 10^6 \text{ KJ/year}$.

- For a first-year tax credit of 75 percent, both the life-cycle costs and the payback period approached those of the stand-alone heat pump. Payback period was 7 years against 5 years for the heat pump and life-cycle costs were within a \$2000 band for all the systems.

CONCLUSIONS

The best incentives for accelerating the commercialization of solar-assisted heat pump systems appear to be keeping maintenance costs low and providing large first-year tax credits. None of the thermal parameters investigated appear promising for further development of a cost-competitive solar heat pump system.

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SECTION 1.0

INTRODUCTION

There have been many simulation studies comparing solar heat pump systems with each other, with stand-alone heat pumps and with conventional methods. This analysis differs from other studies in that it is a systematic variation of major parameters for both series and parallel solar and stand-alone heat pump systems. In addition, these variations are performed in several different geographic locations, which allows an estimate of climatic effect to be included.

1.1 BACKGROUND

A simplified schematic and typical space heating performance map for both a series system and a parallel system are shown in Figures 1-1 and 1-2. In a series system, the heat pump is essentially an energy transfer device between the solar system and the required load. The heat pump can also be bypassed and the load met with solar energy whenever the storage tank is warm enough. If the heat pump is deprived of a heat source (i.e., no collector area case), all of the load is met with auxiliary heat. At increasing collector areas, the fraction of the load met by free energy increases, as does the amount of free energy delivered directly from the solar system.

For a parallel system, the heat pump and the solar system both interface with the load directly. Even at zero collector area, the system still has free energy from the heat pump. At larger areas, the free energy supply increases, but the relative contribution of the heat pump decreases.

1.2 OBJECTIVES AND SCOPE

The purpose of this study is to determine the thermal and economic verification of effects induced by systematically varying the major parameters involved in solar-assisted heat pump systems. This study concentrates on the two systems shown in Figure 1-3 - a liquid based series, and a liquid based parallel system. It has been assumed that parameters shown to be important for liquid systems will also be worth considering in air-based systems.

The series system includes a liquid collector, a series connected solar heat pump system for heating and cooling, electric resistance backup heating, and a separate solar domestic hot water heating system with electric backup (Figure 1-3(a)). The parallel system has a liquid based solar space and water heating system in parallel with a heat pump for backup space heating and for cooling. In addition, there is electric resistance backup space and water heating (Figure 1-3(b)).

a) Simple Schematic

b) Typical Space Heating Performance Map

Figure 1-1. SERIES SYSTEM CHARACTERISTICS

a) Simple Schematic

b) Typical Space Heating Performance Map

Figure 1-2. PARALLEL SYSTEM CHARACTERISTICS

a) Liquid Series

b) Liquid Parallel

Figure 1-3. SCHEMATIC DIAGRAMS OF COMBINED SOLAR HEAT PUMP SYSTEMS

Water heating was included in both systems since it is the most competitive of residential solar applications; thus a solar space heating and cooling system would be expected to provide water heating as well. Since water heating integrates differently into parallel and series configurations, it was felt that meaningful comparisons could only be made for systems including hot water heating along with space heating and cooling.

1.3 APPROACH, MODELING, AND SIZING CONSIDERATIONS

System comparisons were made for three locations: Washington, D.C., Fort Worth, Texas, and Madison, Wisconsin. In each location, residences typical of single-family construction in the near future were defined. Typical meteorological year (TMY) hourly data were used to characterize the weather forcing function for load and system simulation. Nine base cases were defined (three for each location) based on the optimally sized configurations developed in Reference [1], which incorporated one series, one parallel, and one stand-alone heat pump system for the residence.

For the engineering modeling study, TRNSYS with suitably reformulated heat pump and load modules was used. This program was chosen not only for its ability to impose thermal comfort standards on the systems modeled, its thorough documentation, its flexibility and varied data output, but also to provide continuity with the other heat pump system studies which provided base case data for this particular survey. Using temperature level control allowed the imposition of thermal comfort standards. Loads were calculated simultaneously with the system simulation to allow dynamic interaction and maximum accuracy. Parasitic energy consumptions of blowers and pumps were also included in the analysis. Details of TRNSYS and the load and heat pump modules can be found in Reference [1].

SECTION 2.0

DESCRIPTION OF ENVIRONMENTS

This section describes the environmental conditions, the heating/cooling and hot water loads, and the systems which were analyzed in this study. The descriptions are of a general nature since detailed descriptions are presented in Reference [1].

The environmental conditions are presented in terms of three chosen geographical locations. The rationale for choosing these locations and the meteorological specifications at these locations are presented below. The space heating and cooling loads are described through the use of "typical" detached, single-family residences at each of the three locations. The domestic water heating load is a standard volume-use profile combined with the local supply water temperature. The heating/cooling/hot water systems are generally described using simplified system schematic drawings.

2.1 ENVIRONMENTS - SELECTION OF LOCATIONS

The initial criterion used to determine the locations for simulating heat pump systems was based on grouping the 26 TMY cities by heating and cooling load. The heating load was assumed to be related to the number of heating degree days, while the cooling load was assumed to be related to the number of seasonal cooling hours. In Reference [1], the 26 cities were grouped by heating and cooling load into three general load types: 1) Group A (low heating/high cooling), 2) Group B (medium heating/medium cooling), and 3) Group C (high heating/low cooling).

After the above three groups were identified, each was examined for its existing and potential market for solar-assisted heat pump systems [2]. The market was assumed to be represented by a large regional population and/or a large number of air conditioner and heat pump sales. Each remaining location was examined as a region, with the surrounding states included in its region. When the largest potential markets had been identified, one market city from each group was selected.

Final selection was also based on climatic considerations which might influence economical utilization of solar-assisted heat pump systems. The final cities chosen were Washington, D.C, Fort Worth, Texas, and Madison, Wisconsin. These cities are the studied locations in the present work.

2.2 METEOROLOGY

For this report, tapes utilizing a modified format of the standard TMY weather data were used. The details of the modifications can be found in Reference [1]. Essentially, these changes simplify the data reading, smooth out discontinuities in the data, and eliminate non-useful information. Validation of the use of the TMY weather tapes can be found in Reference [3].

2.3 LOAD DESCRIPTIONS

The heating and cooling loads were fixed by specifying a set of building thermal characteristics. The selection of building characteristics is presented below in Table 2.1 below for the "typical" housing types for each location. The hot water loads are also discussed in this section.

2.3.1 Selection of Houses

A "typical" single-family residence for each of the three locations was selected for analysis in this study. The standards set forth for the regional housing types and their building characteristics were established primarily from information supplied by the U.S. Department of Commerce, Bureau of the Census [4]. The only city not located well within one of the four Bureau of the Census sections is Washington, D.C., which is located at the northeastern tip of the South. However, it was felt that the house types found in the Washington, D.C., area are more typical of what is common in the Northeast section. Accordingly, the house characteristics of the Northeast section were used to define a typical house in Washington, D.C.

The gross information available for the Bureau of Census was refined to a more local (SMSA or state) level through communications with the National Association of Home Builders [5]. This led to a definition of a "typical" residence for each of the three locations utilized in this study. The "typical" house in each location was defined by a set of building characteristics wherein each characteristic is the dominant one for that locale. The building characteristics are generally described in Table 2-1 for the type of house chosen to represent each location.

Thermal insulation characteristics were obtained by utilizing ASHRAE 90-75 and Reference [5]. The values developed were based on an economic analysis which states that a payback period of 7 years will result if these insulating guidelines are followed. This procedure specifies houses that are well designed and exceed the minimum guidelines of ASHRAE 90-75. For the purpose of this study, it was assumed that the major axis of the house is on an east-west orientation. The structure is thus assured to lend itself to active solar systems. No assumptions were made as to whether the front or rear of the house has the desired southern exposure. Equipment sizing for these three residences was done through the use of standard ASHRAE Procedures [6]. Details of the resulting equipment sizes can be found in Reference [1].

2.3.2 Domestic Hot Water Profile

The domestic hot water daily use profile was based on a 4-person consumption of 300 liters (80 gallons) per day. The hourly consumption was generated by using the Rand [7] profile, which distributes the hourly hot water consumption as shown in Table 2-2.

Since the hot water load is directly dependent on the temperature rise of the water from inlet to delivery, the monthly average water supply temperatures were used in each location. The supply water temperatures used in this study are presented in Table 2-3.

Table 2-1. GENERAL DESCRIPTION OF HOUSING TYPES CHOSEN FOR EACH LOCATION

<u>Characteristics</u>	Washington, D.C./ N.Y. City Corridor	Madison, Wisconsin Area	Fort Worth, Texas Area
<u>House Type:</u>			
House style	Colonial	Rambler	Rancher
Type of construction	Wood frame	Wood frame	Frame, brick veneer
Foundation	Basement	Basement	Slab
Number of stories	Two	One	One
Heating system	Warm air-oil	Warm air-gas	Warm air-electric
Cooling system	Central A/C	Central A/C	Central A/C
<u>House Size:</u>			
Living area	161 m ²	158 m ²	167 m ²
Outside wall area	162 m ²	109 m ²	112 m ²
Window area	28 m ²	19 m ²	20 m ²
<u>Thermal Characteristics:</u>			
Roof insulation	Batt, 9 in.	Batt, 9 in.	Batt, 6 ¹ / ₂ in.
Wall insulation	Batt, 6 ¹ / ₂ in.	Batt, 6 ¹ / ₂ in.	Batt, 3 ¹ / ₂ in.
Floor insulation	Batt, 3 ¹ / ₂ in.	Batt, 3 ¹ / ₂ in.	N/A
Window type	Double pane	Triple pane	Double pane

Table 2-2. HOURLY PROFILE OF DOMESTIC HOT WATER CONSUMPTION

Time	Consumption (Liters)	Time	Consumption (Liters)
12-1 a.m.	6.4	12-1 p.m.	10.8
1-2 a.m.	0	1-2 p.m.	15.2
2-3 a.m.	0	2-3 p.m.	8.0
3-4 a.m.	0	3-4 p.m.	7.2
4-5 a.m.	0	4-5 p.m.	6.4
5-6 a.m.	0	5-6 p.m.	11.2
6-7 a.m.	4.4	6-7 p.m.	20.4
7-8 a.m.	14.0	7-8 p.m.	34.8
8-9 a.m.	21.6	8-9 p.m.	28.8
9-10 a.m.	25.6	9-10 p.m.	20.8
10-11 a.m.	20.8	10-11 p.m.	16.4
11-12 a.m.	13.6	11-12 p.m.	13.6

Table 2-3. MONTHLY AVERAGE WATER SUPPLY TEMPERATURES

	J	F	M	A	M	J	J	A	S	O	N	D
Fort Worth, TX (28)												
°F	42	49	58	65	73	80	82	83	78	63	53	49
°C	6	9	14	18	23	27	28	28	26	17	12	9
Washington, D.C. (29)												
°F	42	42	52	56	63	67	67	78	79	68	55	46
°C	6	6	11	13	17	19	19	26	26	20	13	8
Madison, WI (30)												
°F	52	Constant Year-Round										
°C	11											

SECTION 3.0

SYSTEMS

In the following paragraphs, each system is described in enough detail to provide a basic understanding of its operation. Again, further detail concerning the system description is to be found in Reference [1] .

3.1 CONVENTIONAL HEAT PUMP

The conventional heat pump system is shown schematically in Figure 3-1. An air-to-air split system heat pump is used with staged auxiliary electric resistance heaters built into the indoor unit. A two-stage heating thermostat controls delivery of heated air to the conditioned space as described later in the operating modes descriptions. A single-stage cooling thermostat causes the heat pump to operate in reverse so as to chill and dehumidify air being delivered to space. The electric water heater maintains a sufficient volume of water at a given set temperature to meet normal demand.

3.2 LIQUID SERIES SYSTEM

The liquid series system employs a liquid-to-air heat pump which uses the solar storage tank as a source (heating mode) or sink (cooling mode). When used as a source, the solar collector system attempts to replenish the energy extracted by the heat pump. When used as a sink, a fan coil is used to reject to ambient the energy which accumulated in the tank. The system schematic for the liquid series configuration is given in Figure 3-2.

Solar energy collection can occur simultaneously with either heat pump heating or direct solar heating. However, heat pump and direct solar heating never occur simultaneously since air-to-air heat pumps are not designed for the high indoor-unit entering air temperatures which would occur during simultaneous heating mode operation with the direct solar coil upstream of the heat pump in the conditioning air stream. Alternatively, operating with the heat pump coil upstream of the solar coil would degrade the amount of heat transfer from the solar tank and could even cause reverse heat transfer (into the tank). Further, the indoor unit of an air-to-air heat pump is designed for entering air which is near room temperature. Elevated temperatures can cause mechanical problems. Heat pump cooling and rejection to ambient can occur independently or simultaneously.

The domestic water heating system operates completely independently of the space heating and cooling system. The collector operates whenever it can contribute energy to the preheater.

3.3 LIQUID PARALLEL SYSTEM

The liquid parallel system, shown in Figure 3-3, combines a typical liquid-based active solar space and water heating system with a conventional air-to-air heat pump. The two subsystems operate independently, with the solar

FIGURE 3-1. CONVENTIONAL (STAND-ALONE) HEAT PUMP SYSTEM

Figure 3-2. LIQUID SERIES COMBINED SOLAR HEAT PUMP SYSTEM

Figure 3-3. LIQUID PARALLEL COMBINED SOLAR HEAT PUMP SYSTEM

system being the preferred heat source for space heating. When neither the solar system nor the heat pump can meet the heating load, electric resistance backup is provided.

Solar energy collection can occur simultaneously with heat pump heating, direct solar heating, heat pump cooling, or domestic water heating. The solar energy collection and domestic water heating subsystems operate independently. Heat pump heating and direct solar heating are not allowed to occur simultaneously.

In the series systems described previously, the main collector array is disabled in the summer, and energy delivered to the tank by the heat pump is rejected via a fan coil. In the parallel system, the main bank of collectors could be active year round. This allows a larger portion of the year-round domestic water load to be met by solar, but also can result in larger cooling loads if storage losses transfer into the conditioned space.

SECTION 4.0

SIMULATION BACKGROUND DATA

The operating modes of the stand-alone, series, and parallel systems are described below.

4.1 HEAT PUMP OPERATION

The heat pump model utilized for both series and parallel configurations interfaces with TRNSYS via temperature level control. This allows studying the effects of delivered air temperature and control dynamics. The model uses both user-specified and manufacturers' data for the heating and cooling performance characteristics. Performance data must be provided for the range of source or sink temperatures expected to be encountered during the simulation. Details of data preparation are given in Reference [1]. The heat pump model is general in the sense that any air-to-air or liquid-to-air heat pump can be studied given the operating characteristics and conditions. The model also has provisions for the system controls, auxiliary strip heaters and direct source water heating. Performance characteristics of the heat pumps are listed in Table 4-1 and Table 4-2.

4.2 SYSTEM OPERATING MODES

The system models were formulated so that each can be controlled to deliver energy to the load at or above a specified minimum temperature. Each system is controlled differently. Descriptions are given below.

4.2.1 Stand-Alone Heat Pump

Preliminary system studies with the conventional heat pump controls indicated that delivered air temperature was often too low during first-stage heating under low source (ambient) temperature conditions. To force the heat pump to meet the same comfort criteria as the other systems, an option was included to cause the heat pump to respond to both first- and second-stage heating with the second-stage algorithm described below.

Second stage heating actuates the heat pump if the source temperature is in the allowable range. In addition, auxiliary strip heaters are staged-in to obtain the specified delivered air temperature, while the maximum energy input from the auxiliary heaters cannot exceed a specified maximum. It is assumed that the modeler has chosen the outlet temperature, auxiliary capacity, and the room air flow rate such that the design heating load can be met. Set points and deadbands are adjustable on both stages of the thermostat.

In the cooling mode, the heat pump/load interface is controlled by the cooling thermostat. Control is open ended in that room temperature will float if the machine is undersized, and room humidity is not explicitly controlled.

Table 4-1. HEAT PUMP PERFORMANCE DATA
(LIQUID TO AIR) - LIQUID SERIES SYSTEM

HEATING MODE (2-SPEED COMPRESSOR)			
Source Temperature (°F)	Dry Coil Capacity (BTU/hr)	Work (KW)	
35	39500	3.82	
45	49374	4.10	
55	60347	4.32	
65	71319	4.55	
75	82290	4.78	
85	49374	2.96	
95	60347	3.02	
105	71319	3.08	
COOLING MODE			
Sink Temperature (°F)	Dry Coil Cooling Capacity (BTU/hr)	Break Point Temperature (°F)	Work (KW)
72	39752	58.5	3.11
77	38642	58.5	3.18
82	37228	58.5	3.27
87	35966	58.5	3.38
92	35588	58.5	3.49
97	33064	58.5	3.58

Table 4-2. HEAT PUMP PERFORMANCE DATA
(AIR TO AIR) - LIQUID PARALLEL SYSTEM*

HEATING MODE (2-SPEED COMPRESSOR)			
Source Temperature (°F)	Dry Coil Capacity (BTU/hr)	Work (KW)	
-3	23000	4.93	
7	27750	5.14	
17	32500	5.35	
27	37200	5.56	
37	25500	2.17	
47	30200	2.33	
57	35000	2.50	
67	39600	2.58	
COOLING MODE			
Sink Temperature (°F)	Dry Coil Cooling Capacity (BTU/hr)	Break Point Temperature (°F)	Work (KW)
85	28800	61.0	2.72
95	27300	61.5	2.89
105	25900	61.8	3.03
115	24300	61.8	3.16

*Air-to-air heat pump used in both stand-alone and liquid parallel systems.

4.2.2 Liquid Series System

The heat pump/load interface is controlled by a two-stage thermostat. In the first stage, direct heating from the liquid source occurs if the liquid source temperature is greater than a specified minimum. Otherwise the heat pump is actuated. The system remains idle if the source temperature is outside the allowable range. In second stage heating, all first-stage actions occur plus auxiliary strip heaters are also staged in to maintain a minimum outlet temperature.

For cooling, heat is rejected to the storage tank rather than to ambient air (as in a stand-alone heat pump system). Energy from the liquid tank must be further rejected to ambient air via a crossflow heat exchanger. Rejection occurs whenever tank temperature exceeds ambient by a specified deadband. No attempt was made to limit this operation to off-peak hours or to hours when the compressor was idle.

Control of the collector loop is independent of the rest of the system. A differential controller compares the collector outlet and tank temperatures, initiating fluid flow whenever the temperature difference exceeds the deadband.

The domestic water heating portion of the series systems is completely separate from the space conditioning system, both physically and in its control. It consists of a preheat tank which supplies solar preheated water to a conventional water heater. The conventional water heater supplies water to the load at the required temperature. A mixing valve between the cold and hot water lines prevents the delivery of over-heated water. The domestic water heating collector loop operates whenever the temperature rise through the collector exceeds a specified deadband.

In order to run a continuous, 12-month simulation of the liquid series system, it is necessary to decide when system operation should switch from summer to winter. In summer operation, the space heating collector array is disabled and the rejection loop is allowed to run; in winter, the reverse is true. Heat pump operation is unaffected by season, since it is controlled by a two-stage heating thermostat and one-stage cooling thermostat for the whole year. The domestic water subsystem is also unaffected by season. For lack of a better alternative, the spring and fall switchover dates which yielded maximum solar contribution were determined through trial and error.

4.2.3 Liquid Parallel System

The heating system/load interface is again controlled by a two-stage thermostat. Since solar energy is the preferred heat source, the heat pump is idle in first stage and is initiated only if the solar system cannot provide energy at a temperature above a specified minimum; otherwise, the system remains idle. In second stage, the solar system is idle while the heat pump operates, unless the source (ambient) temperature is outside of the allowable range. If necessary, auxiliary heat is staged in to ensure that the delivered air temperature equals the specified minimum.

The cooling mode operation is identical to the stand-alone heat pump, and collector loop control is identical to that for the liquid series system. The domestic water heating system consists of a preheat tank which supplies solar preheated water to the load at the required temperature. A mixing valve between the cold and hot water lines prevents the delivery of over-heated water. The preheat tank obtains energy from the main storage tank. Whenever the main temperature exceeds the preheat tank temperature by a specified deadband, the water heating loop is activated. The liquid parallel system operates with the same control year round.

SECTION 5.0

THERMAL ANALYSIS

While many performance measures and energy quantities important to the overall systems used were tracked during the TRNSYS simulation, this study's focus is primarily on the following annual energy outputs and load quantities:

- (1) WHPH - work input to the heat pump in the heating mode (KJ)
- (2) WHPC - work input to the heat pump in the cooling mode (KJ)
- (3) QA-L - the auxiliary energy transferred to the space heating load
- (4) DELEP - the delta change in energy purchased (either + or -) as defined by the equation (KJ):

$$E_p = (WHPH + WHPC + (QA-L)) \begin{matrix} \text{Parameter} \\ \text{Variation} \end{matrix} \\ - (WHPH + WHPC + (QA-L)) \begin{matrix} \text{Base} \\ \text{Case} \end{matrix}$$

where the base cases used were the collector-area-optimized systems in Reference [1]. TRNSYS deck listings of the 9 base decks' characteristics are provided in the appendix. All initial collector base case sizing was devised by minimizing the initial system cost per unit of purchased energy displaced.

For the series system the heat pump were sized (Reference [1]) so that auxiliary energy was never required unless the heat pump was starved (i.e., the storage tank temperature was below the minimum). The heat pump also had to meet delivered air temperature requirements.

A preliminary survey of parameters considered important produced the listing in Table 5-1. The range of the parameters was devised so as to use the previously simulated parameter results of Reference [1] as a starting point.

The parameter changes suggested for the heat pumps involved variations in the performance data decks and not in the TRNSYS decks listed in the appendix. For the capacity increases, the compressor work required was calculated by keeping the COP at each temperature level the same for both new and old capacities.

Table 5-1. SINGLE-PARAMETER VARIATIONS AND RANGES

Parameter	Stand-Alone Heat Pump	Liquid Series	Liquid Parallel
Storage Volume (m ³ / m ² c)	_____	.6, .4, .2*, .1, .075, .05	.6, .4, .2*, .2, .075, .05
Heat Exchanger Effectiveness			
1) Collector to tank	_____	.8, .7, .55	.8, .7*, .55
2) Tank to load	_____	.85, .77, .65	.85, .77*, .65
Control Temperatures °C (delivered air)	32, 35*, 38	32, 35*, 38	32, 35*, 38
Collector			
$\tau\alpha$	_____	.88*, .8, .7, .6	.83*, .7, .6
U_L (KJ/HR-°C-M ²)	_____	50, 40, 30*, 20	40, 30, 20*, 15
Heat Pump			
1) Capacity Increase (BTU/HR)	0*, 7500, 15000	0*, 7500, 15000	0*, 7500, 15000
2) Capacity Scope Change (one case only)	+10 ³ BTU ₃ @ 0°F with -10 ³ BTU @ 66°F	+10 ³ BTU ₃ @ 40°F with -10 ³ BTU @ 66°F	+10 ³ BTU @ 0°F with -10 ³ BTU @ 66°F

* INDICATES BASE CASE VALUES

SECTION 6

PRESENTATION AND DISCUSSION OF RESULTS

The results of the thermal and economic investigations of the various parameters are presented graphically in Figures 6-1 through 6-20. Base energy consumption levels can be found in Table 6.1. Table 6.2 contains base system life-cycle costs.

6.1 THERMAL RESULTS

Increasing the heat pump capacity over the base case did not significantly affect the annual purchased energy for the stand-alone and parallel system. The series system indicated a slight reduction in energy usage as seen in Figure 6-1. The tank to load heat exchanger changes also produced no effect on energy purchased.

The delivered air temperature parameter changes indicated greatest possibilities for energy savings in the stand-alone heat pump (4.25×10^6 KJ/year), while the parallel system showed smaller savings (2.5×10^6 KJ/year), and the liquid series system changes were so small as to be within the noise range of the simulation's capabilities. Results are given here only for the stand-alone heat pump and the parallel system (Figures 6-2 and 6-3).

Any change in the TAU-ALPHA product of the collector resulted in an increase of energy purchased over the base case. All results were fairly substantial, from 3 to 10.5×10^6 KJ/year. Results are shown in Figure 6-4 and 6-5.

For changes in the collector loss coefficient U_L , results were also pretty much as expected. Decreasing the loss coefficient decreased the energy purchased on both series and parallel systems. The parallel system was particularly sensitive to this type of variation with an energy savings of almost 7.5×10^6 KJ/year for a U_L of 15 in Fort Worth. Madison data illustrated the effect of increasing the U_L , with a gain in energy purchased of 9.8×10^6 KJ/year for the parallel system. The series system was less sensitive but indicated the same trend. Results for the U_L variations are shown in Figures 6-6 and 6-7.

For the collector-to-load heat exchanger variations which increased the effectiveness, only minor energy savings (2 to 4×10^5 KJ/year) for either solar-assisted system was noted. Decreasing the effectiveness, however, brought a quick increase in energy usage (particularly for Madison). The most dramatic increases were for the liquid series system. This is shown in Figure 6-8; the overall quantities of energy involved, however, are small.

Table 6-1. TOTAL ENERGY PURCHASED FOR BASE SYSTEMS

SOLAR ASSISTED SYSTEMS			STAND-ALONE HEAT PUMP
TOTAL ENERGY PURCHASED (KJ/YR)			TOTAL ENERGY PURCHASED (KJ/YR)
	Liquid Series	Liquid Parallel	
Wash.	25.55×10^6	25.06×10^6	37.57×10^6
Mad.	32.33×10^6	36.26×10^6	53.03×10^6
Ft. W.	19.71×10^6	20.48×10^6	28.59×10^6

Table 6-2. LIFE-CYCLE COSTS FOR BASE SYSTEM

LIFE CYCLE COSTS FOR BASE SYSTEMS			
	LIQUID SERIES	LIQUID PARALLEL	STAND ALONE HEAT PUMP
Wash.	40624	39418	15259
Mad.	43428	45346	18168
Ft. W.	34727	31946	12323

Figure 6-1. HEAT PUMP CAPACITY INCREASE
LIQUID SERIES SYSTEMS -
ALL CITIES

Figure 6-2. DELIVERED AIR TEMPERATURE (°C)
STAND-ALONE HEAT PUMP - ALL CITIES

Figure 6-3. DELIVERED AIR TEMPERATURE (°C)
LIQUID PARALLEL SYSTEM - ALL CITIES

Figure 6-4. TAU-ALPHA PRODUCT FOR $U_L = 20$
LIQUID PARALLEL SYSTEMS - ALL CITIES

Figure 6-5. TAU-ALPHA PRODUCT FOR $U_L = 30$
LIQUID SERIES SYSTEMS - ALL CITIES

Figure 6-6. U_L OF COLLECTOR AT $\tau\alpha = .88$
LIQUID SERIES SYSTEM - ALL CITIES

Figure 6-7. U_L OF COLLECTOR AT $\tau\alpha = .83$
LIQUID PARALLEL SYSTEMS - ALL CITIES

Figure 6-8. COLLECTOR TO TANK HEAT EXCHANGER EFFECTIVENESS
LIQUID SERIES SYSTEMS - ALL CITIES

Figure 6-9. ROTATED PERFORMANCE CURVE
LIQUID PARALLEL - ALL CITIES

Figure 6-10. ROTATED PERFORMANCE CURVE
LIQUID SERIES - ALL SYSTEMS

Figure 6-11. ROTATED PERFORMANCE CURVE
STAND ALONE HEAT PUMP - ALL CITIES

The "rotated" heat pump performance curve results were very interesting (see Figures 6-9 to 6-11). Both the stand-alone heat pump and parallel systems showed an increase in energy used when the performance curve was "rotated" to provide better low end performance. The series system, however, indicated a decrease in energy purchased (as much as 1×10^6 KJ/year).

The storage volume changes studies indicate an advantage for the series configuration, but not for the parallel. The energy purchased increased for the parallel system, no matter whether a smaller or larger storage ratio over the base case was employed. However, the results were generally small changes ($<10^6$ KJ/year), and not judged significant for cost purposes. The series systems provides a savings in energy when a larger storage capacity is used. The savings are moderate, but combined with other possible suggested changes, could aid in generally improving series efficiency. Results for the storage volume are shown in Figures 6-12 and 6-13.

6.2 INDIVIDUAL PARAMETER COST RESULTS

The cost estimates associated with the specific SAHP parametric variations identified in Table 3-1 are presented in Table 6-3 to 6-7. These tables show the change in cost per m^2 of collector area. Table 6-6 shows the capital acquisition costs (including overhead and profit) for the optimized base system collector areas. This information is presented in two forms: total cost and cost per m^2 with fixed costs. Using data given in Table 6-8 simple addition or subtraction will give new $\$/m^2$ costs for the parameter variations. (References for this material are (8-12)).

It is felt that while these cost estimates are realistic, they are somewhat optimistic in that they assume existence of a mature solar industry. All costs are in 1979 dollars and include a 25 percent overhead and profit allowance for the mechanical/electrical contractor. Were a general contractor to be involved, an additional 10 percent overhead and profit should be included.

Cost estimates are not presented for several of the possible parametric variations. There are two reasons for this. For delivered air temperature it is felt that the (equipment) cost impact is negligible. Although there will be a cost increase for changing the heat pump capacity slope, it is felt that an accurate estimate of such costs is presently impossible. As a rough guideline, a net 10 percent cost increase for each such change would be reasonable. Accordingly, instead of attempting to predetermine the cost effectiveness of such improvements, it is hoped that this study will provide a guideline for justifiable cost increases associated with a given improvements. For example, were the identified change in heat pump capacity slope to result in a net system life-cycle cost reduction of \$500, then the upper limit for allowable equipment cost increases could be set.

Figure 6-12. STORAGE VOLUME m^3/m_c^2
LIQUID SERIES SYSTEMS - ALL CITIES

Figure 6-13. STORAGE VOLUME m^3/m_c^2
LIQUID PARALLEL SYSTEMS - ALL CITIES

Table 6-3. STORAGE TANK MATERIAL AND INSTALLATION COSTS

Storage Volume (M^3) to Collector Area (M^2) Ratio	Liquid Series SAHP \$/ M^2 of Collector	Liquid Parallel SAHP \$/ M^2 of Collector
.05	-26.00	-31.30
.075	-21.70	-26.0
.10	-17.30	-20.90
(Base) .20	0.0	0.0
.40	+34.70	+41.70
.60	+69.40	+83.40

- Notes: 1. The series SAHP storage tank has no insulation or covering other than a red zinc primer. Installation of the storage tank subsystem represents about 11 percent of its total cost.
2. The parallel SAHP storage tank has 3 inches of fiberglass insulation. Installation of the storage tank subsystem accounts for about 8 percent of the total cost.

Table 6-4. HEAT EXCHANGER MATERIAL COSTS
(Collector to Storage Heat Exchanger Only)

Effectiveness	\$/ M^2 of Collector
.55	-12.88
.70 (BASE)	0.0
.80	+14.43

- Notes 1. These material costs are for both types of SAHP systems.
2. Installation costs are \$85 per unit - regardless of effectiveness.

Table 6-5. FACTORY BUILT SOLAR COLLECTOR MATERIAL COSTS
 (\$/M² of Collector Area)
 COLLECTOR PARAMETER $\tau\alpha$

Collector Parameter U_L (KJ/HR-m ² -°C)	$\tau\alpha$ PRODUCT				
	.88	.83	.8	.7	.6
50	-32	-54	-54	-64	-64
40	-21	-32	-32	-54	-64
30	0	-11	-21	-43	-64
20	+11	0	-11	-32	-54
15	+33	-22	0	-21	-32

- Notes: 1. The above cost estimates assume that the collectors are mounted flat against a tilted roof. A factor for mounting material is included.
2. Installation costs for all collectors are \$16/m² of collector area (OH&P included).
3. Base Cases: LS: $\tau\alpha = .88$ $U_L = 30$, LP: $\tau\alpha = .83$ $U_L = 20$

Table 6-6 SITE BUILT SOLAR COLLECTOR MATERIAL COSTS
 (\$/M² of Collector Area)
 COLLECTOR PARAMETER $\tau\alpha$

Collector Parameter U_L (KJ/HR-m ² -°C)	$\tau\alpha$ PRODUCT				
	.88	.83	.8	.7	.6
50	-11	-11	-11	-22	-33
40	0	0	-11	-22	-22
30	0	0	0	-11	-11
20	-	-	-	-11	-11

- Notes: 1. The above cost estimates assume that the collectors are mounted flat against a tilted roof. A factor for mounting materials is included.
2. Installation cost for all collectors is \$22/M² of collector area (OHP included).
3. Bases Cases: LS: $\tau\alpha = .88$ $U_L = 30$, LP: $\tau\alpha = .83$ $U_L = 20$

Table 6-7. HEAT PUMP EQUIPMENT COSTS
(\$/Unit)

Rated Heating Capacity Increase Btu/hr	Stand Alone Heat Pump and Liquid Parallel SAHP	Liquid Series SAHP
None	0	0
7,500	+310.00	+320.00
15,000	+610.00	+630.00

Notes: 1. Installation costs are \$375 for the stand-alone and parallel SAHP system, and \$350 for the liquid series system (OH+P included).

Table 6-8. CAPITAL ACQUISITION COSTS
(1979 \$)

System Location	Stand Alone Heat Pump	Liquid Series Total Cost	Liquid Parallel Total Costs	Liquid Series Cost Breakdown	Liquid Parallel Cost Breakdown
Washington	2,913	18,618 (Collector area 60 m ²)	18,188 (Collector area 43 m ²)	\$142.00/m ² + 10,098	\$222/m ² + 8,642
Madison	2,876	19,551 (Collector area 69 m ²)	20,286 (Collector area 53 m ²)	\$138.00/m ² + 10,029	\$220.00/m ² + 8,626
Fort Worth	2,829	16,400 (Collector area 50 m ²)	14,875 (Collector area 30 m ²)	\$134.00/m ² + 9,700	\$217.00/m ² + 8,365

Notes: 1. The numbers are based on Reference 1 information (from its Table 4.3).

6.3 LIFE-CYCLE COSTING ECONOMIC RESULTS

For the economic runs the following base parameters were assumed: a 20-year period of analysis; a 20 percent downpayment on the system with a 20-year loan and 11 percent interest; a market discount rate of 8.5 percent, a 7.5 percent general inflation rate over the 20-year period; a 5 percent fraction of investment costs as maintenance; a unit cost of \$11.35 (Washington, D.C.) per 10^6 KJ for fuel with a 10 percent separate fuel inflation rate; no insurance costs or property tax; and no salvage value or tax credit. Life-cycle costs for the base cases may be found in Table 6-2.

6.3.1 Economic Variations Due to Engineering Changes

None of the size parameter variations studied significantly reduced life-cycle costs. The maximum effect was found on the collector parameter TAU-ALPHA. Lowering the TAU-ALPHA product did reduce life-cycle costs. The difference between base system life-cycle costs and the varied parameter costs, however, was less than 15 percent.

When storage volume was enlarged, changes indicated up to a 25 percent increase in life-cycle costs over the base systems. Reduction of storage volume below the base ratio of $0.2\text{m}^3/\text{m}^2$, however, showed only a 7 to 8 percent reduction in overall costs.

Rotating the performance curve produced essentially no difference in life-cycle costs for the liquid series system. For the stand-alone heat pump up to a 19 percent increase over base costs was found. The liquid parallel system showed up to an 8 percent increase overall.

Lowering the collector to tank heat exchanger effectiveness did provide some savings in life-cycle costs - up to 7 percent in both liquid parallel and liquid series systems.

The delivered air temperature curve was essentially flat for the liquid series system. For the liquid parallel systems the overall variance was 4 percent. For the stand-alone heat pump, increasing the delivered air temperature (to 38°C) raised costs by a maximum of 8 percent. Lowering the delivered air temperature decreased costs by no more than 8 percent.

Increasing the capacity of the heat pump did not provide significant savings either. For Washington and Madison, cost increases occurred of 3 to 4 percent. For Fort Worth, the liquid parallel system increased in cost up to 6 percent. The cost increase for the other parallel systems was less than 3 percent. For the stand-alone heat pump system cost increases ran approximately 28 percent in Fort Worth, 13 percent in Washington, and 17 percent in Madison. Considering the very slight reduction in energy savings, increasing heat pump capacity does not appear to be a viable alternative.

Finally, for the collector parameter U_L , increasing the loss coefficient did reduce costs. In the liquid series system costs dropped 7 percent over base for Madison and Washington, and 10 percent in Fort Worth. For the liquid parallel systems, however, costs only ranged over a 5 percent difference in Washington, 6 percent in Madison, and 3 percent in Fort Worth.

The major differential, however, was not found with any parameter variation; it was the difference in overall life-cycle costs between stand-alone heat pump systems and the solar-assisted systems. In Madison, the solar-assisted systems were two and one half times more expensive than a stand-alone heat pump. In Washington the factor difference was 2.6 and in Fort Worth, it was 2.8. Under these circumstances it will be along time before solar-assisted systems are competitive with the stand-alone heat pump.

6.3.2 Economic Parameter Variations

Along with individual system parameters, life-cycle cost variations were done with five major economic parameters: 1) the interest rate, 2) the discount rate, 3) a first-year tax credit, 4) a unit fuel cost; and 5) a fuel inflation rate.

The interest rate was varied from zero to 20 percent. The increase in interest rate increased life-cycle costs for all the systems considered. A 20 percent interest rate increased overall costs for the stand-alone heat pump system 14 percent compared to a 0 percent interest rate case. For the other systems the increase was much steeper. For the solar-assisted systems there was a 34 percent increase in life-cycle costs over a range from 0 to 20 percent interest rate (See Figure 6-14).

The effects of changing the discount rate were even more dramatic. As the discount rate approached zero, costs over base systems (as shown on the parameter variation graphs) more than doubled. At a base case discount rate of 8-1/2 percent, life cycle costs for a solar-assisted system were about \$40,000. At a discount rate essentially zero, life-cycle costs were \$95,000. For larger discount rates, however, the decrease in costs was much less steep. For a 20 percent discount rate, costs were about half of the base case. The results are shown in Figure 6-15.

For the first year tax credit, two comparisons were made - the tax credit size and the payback period resulting from the lowered overall costs. At a 75 percent tax credit, LC costs approached those of the stand-alone heat pump. This may be one way to make purchase of the solar systems acceptable to home owners, since the solar system payback period became 7 years as opposed to 5 years for the stand-alone heat pump (See Figure 6-16 and 6-17).

For changes in the unit fuel cost, shown in Figure 6-18, there appears to be a straight line relation between that parameter and life-cycle costs. A doubling of the unit cost produced a 16 percent increase in life-cycle

Figure 6-14. LIFE CYCLE COSTS VS. INTEREST RATES - ALL SYSTEMS

Figure 6-15. LIFE CYCLE COSTS VS. DISCOUNT RATE - ALL SYSTEMS

Figure 6-16. LIFE CYCLE COSTS VS. FIRST YEAR TAX CREDIT - ALL SYSTEMS

Figure 6-17. PAYBACK PERIOD VS. FIRST YEAR TAX CREDIT - ALL SYSTEMS

Figure 6-18. LIFE CYCLE COSTS VS. UNIT FUEL COSTS - ALL SYSTEMS

Figure 6-19. LIFE CYCLE COSTS VS. FUEL INFLATION RATE - ALL SYSTEMS

costs for both solar-assisted configurations, and also produced a 65 percent rise in life-cycle costs for the stand-alone heat pump system. The stand-alone configuration clearly is more sensitive than either solar arrangement to fuel costs, as would be expected.

This increased sensitivity to fuel costs was also evident in the fuel inflation rate comparison. Fuel inflation rates from 5 to 20 percent were examined. Life-cycle costs rose continuously for all systems at rates between 10 to 20 percent. The stand-alone heat pump system life-cycle costs, however, showed a steeper rise through the entire range examined. (see Figure 6-19).

Finally, maintenance costs were examined in terms of a fixed percent of the original investment in the system. A percentage range of 2 to 10 percent was examined. The relation with life-cycle costs is fairly linear. A reduction of maintenance costs from 5 to 2 percent of investment gave approximately a 42 percent saving, and an increase to 10 percent increased costs about 40 percent for the two solar-assisted systems. For the stand-alone heat pump the relationship of maintenance to life-cycle was also linear, but much less steep, with a 12 percent rise for increasing maintenance costs from 5 percent to 10 percent. Results are shown in Figure 6-20.

Figure 6-20. LIFE CYCLE COSTS VS. MAINTENANCE COSTS - ALL SYSTEMS

SECTION 7.0

CONCLUSIONS

The purpose of this study was to determine the thermal and economic effects induced by systematically varying major parameters involved in solar-assisted heat pump systems. The results of the thermal analyses may be summarized as follows:

- Increasing the heat pump capacity did not significantly affect annual energy purchased, nor did changing the tank-to-load or the collector-to-load heat exchanger effectiveness.
- The delivered air temperature, if reduced to 32°C, indicates savings in energy purchased for the stand-alone heat pump and liquid-based parallel systems on the order of $2.5-4.25 \times 10^6$ KJ/year.
- Decreases in the TAU-ALPHA products of the collector resulted in increases in energy purchased from $3-10.5 \times 10^6$ KJ/year. Increasing U_L also increased energy purchased, as much as 9.8×10^6 KJ/year; decreasing U_L brought savings of up to 7.5×10^6 KJ/year.
- Rotating the performance curve gave savings for the series system and gave increased energy purchases for both the stand-alone heat pump and the parallel system.

Life-cycle costs were produced for each parameter changed, and none of the engineering parameter variations studied significantly reduced life-cycle costs. Maximum effects included a 25 percent increase in costs for increased storage volume ratios, a 15 percent decrease for lowering the TAU-ALPHA product, a 19 percent increase in costs for the stand-alone heat pump system when the performance curve was rotated, and a 5-10 percent reduction in costs for increasing U_L .

In addition to the engineering parameter changes which were life cycle costed, the following economic incentives were investigated: 1) interest rates, 2) discount rates, 3) tax credits, 4) maintenance costs, 5) unit fuel costs, and 6) fuel inflation rates. Results may be summarized as follows:

- Increasing the interest rate from 0 to 20 percent increased life-cycle costs by as much as 34 percent.
- The lower the discount rate, the higher the life-cycle costs. At essentially a zero discount rate, life-cycle costs doubled over the base case discount rate of 8.5 percent.
- Both increasing unit fuel costs and increasing fuel inflation rates increased life-cycle costs. These costs leveled out for the solar-assisted heat series and parallel systems, but continued to increase for the stand-alone heat pump.

- When maintenance costs (as a fixed percent of the original investment) were reduced from 5 percent to 2 percent, a 42 percent savings in life-cycle costs resulted.
- For a first-year tax credit of 75 percent, both the life-cycle costs and the payback period approached those of the stand-alone heat pump. Payback period was 7 years against 5 years for the heat pump and life-cycle costs were within a \$2000 band for all the systems.

In conclusion, this study appears to indicate that neither significant cost nor energy savings can be attained through the single parameter variations studied here. Solar-assisted heat pump systems can, however, be made economically attractive through a very large tax credit of about 75 to 80 percent. The stand-alone heat pump systems are more fuel cost sensitive than the solar configurations, but the cost for such a system is still well below that for solar-assisted arrangements. Finally, it would also appear that maintenance costs can be a significant factor in this residential application, and reliability of the system should be a criterion of recommendation for the buyer.

SECTION 8.0

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APPENDIX A

TRNSYS LISTINGS OF
BASE SYSTEM

TRNSYS - A TRANSIENT SIMULATION PROGRAM
FROM THE SOLAR ENERGY LAB AT THE UNIVERSITY OF WISCONSIN
VERSION 9.2 2/1/78

*FORT. WORTH - STAND ALONE HEAT PUMP - BASE CASE

*STAND ALONE HEAT PUMP

SIMULATION 0. 8.759E+03 1.250E+01

TOLERANCES 1.000E-03 1.000E-03

LIMITS 30 10

WIDTH 132.

UNIT 9 TYPE 4 DATA READER

PARAMETERS 10

9.000E+00 1.000E+00 6.000E+00 1.000E+00 -2.732E+02 7.000E+00 1.000E-05 0. 2.000E+01

1.000E+00

(2X,3F2.0,F5.0,F5.0,E4.1,BX,F4.0,2X,F3.1,2X,F5.2)

UNIT 1 TYPE 14 WINTER/SUMMER FORCING FUNCTION

* SUMMER = 0, WINTER = 1

PARAMETERS 12

0. 1.000E+00 2.880E+03 1.000E+00 2.880E+03 0. 6.889E+03 0. 6.889E+03

1.000E+00 8.759E+03 1.000E+00

UNIT 3 TYPE 25 PRINTER - ROOM TEMP, HUMIDITY

PARAMETERS 4

1.000E+00 0. 8.759E+03 9.000E+00

INPUTS 2

29, 1 29, 2

T

H

UNIT 16 TYPE 16 SOLAR RADIATION PROCESSOR

PARAMETERS 18

4.000E+00 1.000E+00 3.300E+01 4.871E+03 2.000E-01 -7.500E+00 4.300E+01 0. 9.000E+01

9.000E+01 4.300E+01 1.800E+02 9.000E+01 -9.000E+01 9.000E+01 0. 9.000E+01 1.800E+02

INPUTS 2

9, 5 9, 4

0. 0.

UNIT 2 TYPE 2 1ST STAGE HEATING

PARAMETERS 3

5.000E+00 1.000E+00 -1.000E+00

INPUTS 3

0, 0 29, 1 2, 1

2.100E+01 2.200E+01 0.

UNIT 4 TYPE 2 2ND STAGE HEATING

PARAMETERS 3

5.000E+00 1.000E+00 -3.000E+00

INPUTS 3

0, 0 29, 1 4, 1

1.900E+01 2.200E+01 0.

UNIT 6 TYPE 2 COOLING
PARAMETERS 3
5.000E+00 1.000E+00 -1.000E+00
INPUTS 3
29, 1 0, 0 6, T
2.200E+01 2.550E+01 0.

UNIT 20 TYPE 20 STAND ALONE HEAT PUMP
PARAMETERS 17
4.000E+00 3.500E+01 -1.944E+01 1.944E+01 2.100E+01 2.200E+01 8.000E+00 4.000E+00 0.
0. 9.120E+02 1.900E+03 1.490E+02 3.950E+04 2.296E+03 2.111E+01 2.667E+01
INPUTS 7
29, 1 29, 2 29, 3 2, 1 4, 1 6, 1 9, 6
2.200E+01 1.000E-02 0. 0. 0. 0. 1.000E+01

UNIT 29 TYPE 29 COMBINED LOAD MODEL
PARAMETERS 41
2.000E+00 1.012E+00 -1.300E+01 -1.840E+02 -3.698E+02 2.300E+01 2.000E+04 -5.000E+02 -1.000E+00
2.000E+00 3.700E-02 5.000E-01 8.000E-01 4.162E+01 2.378E+01 1.500E-01 1.500E-01 1.500E-01
0. 7.620E-01 1.524E+00 2.000E+00 1.138E+02 2.218E+01 1.138E+02 1.672E+02 7.646E+02
4.300E+01 4.300E+01 4.000E+00 3.000E+00 5.100E-01 5.100E-01 5.100E-01 1.309E-04 5.070E-03
8.815E-03 1.846E-03 -9.813E-01 1.815E-01 -9.642E-03
INPUTS 19
20, 1 20, 2 20, 3 9, 6 9, 7 0, 0 9, 8 16, 16 16, 17
16, 10 16, 11 16, 18 16, 19 16, 14 16, 15 16, 12 16, 1 16, 8
16, 9
8.000E+01 1.000E-02 0. 0. 1.000E-02 0. 0. 0. 0.
0. 0. 0. 0. 0. 0. 0. 0.
0.
DERIVATIVES 2
2.000E+01 1.000E-02

UNIT 24 TYPE 24 INTEGRATOR
INPUTS 9
20, 4 20, 5 20, 6 20, 7 20, 8 20, 9 29, 4 29, 5 29, 6
0. 0. 0. 0. 0. 0. 0. 0. 0.

UNIT 25 TYPE 25 PRINTER 1
PARAMETERS 4
7.200E+02 0. 8.759E+03 0.
INPUTS 8
24, 1 24, 2 24, 3 24, 4 24, 5 24, 6 20, 17 20, 18
QHC WH GAUX QSCC QLCC WC WHCYC NCCYC

UNIT 15 TYPE 15 SOURCE TEMP. WHEN HP ON IN HTG MODE
PARAMETERS 16
0. -1.000E+00 5.000E-01 4.000E+00 -1.000E+00 -1.000E+00 1.000E+00 8.000E+00 -1.000E+00
1.000E+00 1.000E+00 -1.000E+00 1.000E+00 3.000E+00 0. 1.000E+00
INPUTS 2
20, 10 9, 6
0. 0.

UNIT 19 TYPE 15 .OP.
PARAMETERS 1
1.200E+01
INPUTS 2
2, 1 4, 1
0. 0.

UNIT 17 TYPE 15 DELIVERY TEMP WHEN ON IN HTG MODE

PARAMETERS 1
 1.000E+00
 INPUTS 2
 19, 1 20, 1
 0. 0.

UNIT 14 TYPE 15 ELEC INPUT OF INDOOR FAN WHEN COMPRESSOR IS 1
 *DELIVER TEMP IN COOLING
 *QSLQAD + QLLQAD

*THIRD PARAMETER = ELEC INPUT TO RUN FAN (KJ/HR)

PARAMETERS 22
 0. -1.000E+00 6.710E+02 1.000E+00 -3.000E+00 0. 0. 1.000E+00 -3.000E+00
 0. 0. 3.000E+00 -3.000E+00 0. 7.000E+00 -3.000E+00 3.000E+00 -3.000E+00
 0. 0. 1.000E+00 -3.000E+00
 INPUTS 8
 20, 12 20, 1 20, 11 29, 5 29, 6 29, 4 9, 6 20, 11
 0. 0. 0. 0. 0. 0. 0. 0.

UNIT 13 TYPE 15 ADDER = TOTAL ELECTRIC
 PARAMETERS 16

0. 0. 1.000E+00 0. 3.000E+00 0. 3.000E+00 -3.000E+00 -1.100E+01
 1.000E+01 -1.200E+01 1.000E+00 3.000E+00 0. 3.000E+00 -3.000E+00
 INPUTS 5
 1, 1 14, 1 20, 6 20, 5 20, 9
 0. 0. 0. 0. 0.

UNIT 27 TYPE 27 HIST PLOT(MODE 1) -- EDB,TR,TS,LENGTH,LENGC,E

PARAMETERS 29
 1.000E+00 8.759E+03 8.759E+03 0. 8.759E+03 2.000E+01 6.800E+01 2.400E+01 1.500E+01
 3.900E+01 2.400E+01 -2.000E+01 2.400E+01 2.200E+01 1.000E+01 1.210E+01 2.400E+01 1.000E+01
 1.210E+01 2.400E+01 5.000E+02 6.050E+04 2.400E+01 1.800E+01 4.200E+01 2.400E+01 1.000E+03
 2.500E+02 2.400E+01
 INPUTS 8
 17, 1 29, 1 15, 1 20, 19 20, 20 13, 2 14, 6 29, 2
 0 0 0 0 0 0 0 0

UNIT 26 TYPE 27 HIST PLOT(MODE 2) -- AUX,WH,WC,TOTAL ELEC,COO

PARAMETERS 8
 2.000E+00 8.759E+03 8.759E+03 0. 8.759E+03 0. 2.400E+01 2.400E+01
 INPUTS 6
 20, 6 20, 5 20, 9 13, 2 14, 3 14, 4
 0 0 0 0 0 0

UNIT 28 TYPE 28 SIMULATION SUMMARIZER - MONTHLY

*HEATING MODE OPERATION

PARAMETERS 23
 -1.000E+00 0. 8.759E+03 0. 0. -3.000E+00 0. -3.000E+00 2.000E+00
 -2.000E+00 0. -3.000E+00 0. -3.000E+00 -1.000E+00 1.000E+00 0. 0.
 2.000E+00 4.000E+00 -3.000E+00 0. -3.000E+00
 INPUTS 7
 20, 4 20, 5 20, 6 29, 4 13, 1 14, 4 14, 1
 LABELS 7
 QHP=L WMPH COPH QA=L QLOAD FSSH SHCPAR

UNIT 32 TYPE 28 SIMULATION SUMMARIZER - MONTHLY
 *COOLING MODE OPERATION
 PARAMETERS 20
 -1.000E+00 0. 8.759E+03 0. 0. -3.000E+00 0. -3.000E+00 3.000E+00
 -3.000E+00 0. -3.000E+00 2.000E+00 -4.000E+00 0. -3.000E+00 0. -3.000E+00
 3.000E+00 -3.000E+00
 INPUTS 5
 20, 7 20, 8 20, 9 29, 5 29, 6
 LABELS 8
 QSCC QLCC QTCC WHPC COPC QSLOAD QLLOAD QTLOAD

UNIT 30 TYPE 28 SIMULATION SUMMARIZER - MONTHLY
 *ENERGY BALANCE AND RUN TIMES
 PARAMETERS 22
 -1.000E+00 0. 8.759E+03 0. 0. 0. 4.000E+00 0. 4.000E+00
 0. 4.000E+00 0. 4.000E+00 -3.000E+00 0. -3.000E+00 0. -3.000E+00
 0. -3.000E+00 0. -3.000E+00
 INPUTS 9
 14, 5 20, 4 20, 6 20, 7 20, 8 19, 1 20, 10 20, 12 20, 11
 LABELS 5
 EBLOAD HRHTG HRHPH HRIFAN HRHPC

UNIT 31 TYPE 28 SIMULATION SUMMARIZER - MONTHLY
 *AVERAGE STATE VARIABLES
 PARAMETERS 28
 -1.000E+00 0. 8.759E+03 0. 0. -2.000E+00 2.000E+00 -3.000E+00 0.
 -2.000E+00 2.000E+00 -3.000E+00 0. -2.000E+00 2.000E+00 -3.000E+00 0. -2.000E+00
 2.000E+00 -3.000E+00 0. 0. 2.000E+00 -3.000E+00 0. 0. 2.000E+00
 -3.000E+00
 INPUTS 8
 29, 1 29, 2 9, 6 9, 7 17, 1 19, 1 14, 2 20, 11
 LABELS 6
 ATR AWR ATAMB AWAMB ATDELH ATDELC

END

TRNSYS - A TRANSIENT SIMULATION PROGRAM
FROM THE SOLAR ENERGY LAB AT THE UNIVERSITY OF WISCONSIN
VERSION 9.2 2/1/78

*MADISON - STAND ALONE HEAT PUMP - BASE CASE

*STAND ALONE HEAT PUMP

SIMULATION 0. 8.759E+03 1.250E+01

TOLERANCES 1.000E-03 1.000E-03

LIMITS 30 10

WIDTH 132

UNIT 9 TYPE 9 DATA READER

PARAMETERS 10

9.000E+00 1.000E+00 6.000E+00 1.000E+00 -2.732E+02 7.000E+00 1.000E-05 0. 2.000E+01
1.000E+00
(2X,3E2,0,E5,0,F5,0,EA,1.8X,F4,0,2X,F3,1,2X,F5,2)

UNIT 1 TYPE 14 WINTER/SUMMER FORCING FUNCTION

* SUMMER = 0, WINTER = 1

PARAMETERS 12

0. 1.000E+00 3.960E+03 1.000E+00 3.960E+03 0. 5.838E+03 0. 5.838E+03
1.000E+00 8.759E+03 1.000E+00

UNIT 3 TYPE 25 PRINTER - ROOM TEMP, HUMIDITY

PARAMETERS 4

1.000E+00 0. 8.759E+03 9.000E+00

INPUTS 2

29, 1 29, 2

1 H

UNIT 16 TYPE 16 SOLAR RADIATION PROCESSOR

PARAMETERS 18

4.000E+00 1.000E+00 4.300E+01 4.871E+03 2.000E-01 -7.500E+00 5.300E+01 0. 9.000E+01
9.000E+01 5.300E+01 1.800E+02 9.000E+01 -9.000E+01 9.000E+01 0. 9.000E+01 1.800E+02

INPUTS 2

9, 5 9, 4

0. 0.

UNIT 2 TYPE 2 1ST STAGE HEATING

PARAMETERS 3

5.000E+00 1.000E+00 -1.000E+00

INPUTS 3

0, 0 29, 1 2, 1

2.100E+01 2.200E+01 0.

UNIT 4 TYPE 2 2ND STAGE HEATING

PARAMETERS 3
 5.000E+00 1.000E+00 -3.000E+00
 INPUTS 3
 0, 0 29, 1 4, 1
 1.900E+01 2.200E+01 0.

UNIT 6 TYPE 2 COOLING

PARAMETERS 3
 5.000E+00 1.000E+00 -1.000E+00
 INPUTS 3
~~29, 1~~ ~~0, 0~~ ~~8, 1~~
 2.200E+01 2.550E+01 0.

UNIT 20 TYPE 20 STAND ALONE HEAT PUMP

PARAMETERS 17
 4.000E+00 3.500E+01 -1.944E+01 1.944E+01 2.100E+01 2.200E+01 8.000E+00 4.000E+00 0.
 0. 9.120E+02 1.900E+03 1.490E+02 3.950E+04 2.296E+03 2.111E+01 2.667E+01
 INPUTS 7
 29, 1 29, 2 29, 5 2, 1 4, 1 6, 1 9, 6
 2.200E+01 1.000E-02 0. 0. 0. 0. 1.000E+01

UNIT 29 TYPE 29 COMBINED LOAD MODEL

PARAMETERS 41
 2.000E+00 1.012E+00 6.000E+00 1.346E+02 3.698E+02 2.300E+01 2.000E+04 5.000E+02 1.000E+00
 3.000E+00 3.700E-02 5.000E-01 8.000E-01 4.088E+01 2.304E+01 1.500E-01 1.500E-01 1.500E-01
 0. 7.620E-01 1.524E+00 3.000E+00 1.316E+02 2.962E+01 1.316E+02 1.579E+02 7.221E+02
 5.300E+01 5.300E+01 4.000E+00 3.000E+00 5.100E-01 5.100E-01 5.100E-01 2.478E-04 6.633E-03
 8.314E-03 1.150E-03 -7.305E-01 8.735E-02 -2.010E-03
 INPUTS 19
 20, 1 20, 2 20, 3 9, 6 9, 7 0, 0 9, 8 16, 16 16, 17
 16, 10 16, 11 16, 18 16, 19 16, 14 16, 15 16, 12 16, 1 16, 8
 16, 9
 8.000E+01 1.000E-02 0. 0. 1.000E-02 0. 0. 0. 0.
 0. 0. 0. 0. 0. 0. 0. 0.
 0.
 DERIVATIVES 2
 2.000E+01 1.000E-02

UNIT 24 TYPE 24 INTEGRATOR

INPUTS 9
 20, 4 20, 5 20, 6 20, 7 20, 8 20, 9 29, 4 29, 5 29, 6
 0. 0. 0. 0. 0. 0. 0. 0. 0.

UNIT 25 TYPE 25 PRINTER 1

PARAMETERS 4
 7.200E+02 0. 8.759E+03 0.
 INPUTS 8
 24, 1 24, 2 24, 3 24, 4 24, 5 24, 6 20, 17 20, 18
 QHC WH QAUX GSCC GLCC WC NHCYC NCCYC

UNIT 15 TYPE 15 SOURCE TEMP. WHEN HP ON IN HTG. MODE

PARAMETERS 16
 0. -1.000E+00 5.000E-01 4.000E+00 -1.000E+00 -1.000E+00 1.000E+00 8.000E+00 -1.000E+00
 1.000E+06 1.000E+00 -1.000E+00 1.000E+00 3.000E+00 0. 1.000E+00
 INPUTS 2
 20, 10 9, 6
 0. 0.

UNIT 14 TYPE 15 .CR.
 PARAMETERS 1
 1.200E+01
 INPUTS 2
 2, 1 4, 1
 0. 0.

UNIT 17 TYPE 15 DELIVERY TEMP WHEN ON IN HIG MODE
 PARAMETERS 1
 1.000E+00
 INPUTS 2
 19, 1 20, 1
 0. 0.

UNIT 14 TYPE 15 ELEC INPUT OF INDOOR FAN WHEN COMPRESSOR IS I
 *DELIVER TEMP IN COOLING
 *QSLOAD + QLOAD

*THIRD PARAMETER = ELEC INPUT TO RUN FAN (KJ/HR)

PARAMETERS 22
 0. -1.000E+00 6.710E+02 1.000E+00 -3.000E+00 0. 0. 1.000E+00 -3.000E+00
 0. 0. 3.000E+00 -3.000E+00 0. 7.000E+00 -3.000E+00 3.000E+00 -3.000E+00
 0. 0. 1.000E+00 -3.000E+00
 INPUTS 8
 20, 12 20, 1 20, 11 29, 5 29, 6 29, 1 9, 6 20, 11
 0. 0. 0. 0. 0. 0. 0. 0.

UNIT 13 TYPE 15 ADDER = TOTAL ELECTRIC
 PARAMETERS 16
 0. 0. 1.000E+00 0. 3.000E+00 0. 3.000E+00 -3.000E+00 -1.100E+01
 1.000E+01 -1.200E+01 1.000E+00 3.000E+00 0. 3.000E+00 -3.000E+00
 INPUTS 5
 1, 1 14, 1 20, 6 20, 5 20, 9
 0. 0. 0. 0. 0.

UNIT 27 TYPE 27 HIST_PLOT(MODE 1) -- EDB, TR, IS, LENGTH, LENG, E
 PARAMETERS 29
 1.000E+00 8.759E+03 8.759E+03 0. 8.759E+03 2.000E+01 6.800E+01 2.400E+01 1.500E+01
 3.900E+01 2.400E+01 -2.400E+01 2.400E+01 2.200E+01 1.250E+01 1.213E+01 2.400E+01 1.250E+01
 1.213E+01 2.400E+01 5.000E+02 6.050E+01 2.400E+01 1.800E+01 4.200E+01 2.400E+01 1.000E+03
 2.500E+02 2.400E+01
 INPUTS 8
 17, 1 29, 1 15, 1 20, 19 20, 20 13, 2 14, 6 29, 2
 0 0 0 0 0 0 0 0

UNIT 26 TYPE 27 HIST PLOT(MODE 2) -- AUX, WH, WC, TOTAL ELEC, COO
 PARAMETERS 8
 2.000E+00 8.759E+03 8.759E+03 0. 8.759E+03 0. 2.400E+01 2.400E+01
 INPUTS 6
 20, 6 20, 5 20, 9 13, 2 14, 3 14, 4
 0 0 0 0 0 0

UNIT 28 TYPE 28 SIMULATION SUMMARIZER - MONTHLY
 *HEATING MODE OPERATION
 PARAMETERS 23
 -1.000E+00 0. 8.759E+03 0. 0. -3.000E+00 0. -3.000E+00 2.000E+00
 -4.000E+00 0. -3.000E+00 0. -3.000E+00 -1.000E+00 1.000E+00 0. 0.
 2.000E+00 4.000E+00 -3.000E+00 0. -3.000E+00
 INPUTS 7
 20, 4 20, 5 20, 6 29, 4 13, 1 14, 4 14, 1
 LABELS 7
 QHP=L WHPH COPH QA=L QLOAD FSSH SHCPAR

UNIT 32 TYPE 28 SIMULATION SUMMARIZER - MONTHLY
*COOLING MODE OPERATION

PARAMETERS 20

-1.000E+00	0.	8.759E+03	0.	0.	-3.000E+00	0.	-3.000E+00	3.000E+00
-3.000E+00	0.	-3.000E+00	2.000E+00	-4.000E+00	0.	-3.000E+00	0.	-3.000E+00
3.000E+00	-3.000E+00							
INPUTS 5								
20, 7	20, 8	20, 9	29, 5	29, 6				
LABELS 8								
QSCC	QLCC	QTCC	WHPC	COPC	QSLOAD	QLLOAD	QTLOAD	

UNIT 30 TYPE 28 SIMULATION SUMMARIZER - MONTHLY
*ENERGY BALANCE AND RUN TIMES

PARAMETERS 22

-1.000E+00	0.	8.759E+03	0.	0.	0.	4.000E+00	0.	4.000E+00
0.	4.000E+00	0.	4.000E+00	-3.000E+00	0.	3.000E+00	0.	-3.000E+00
0.	-3.000E+00	0.	-3.000E+00					
INPUTS 9								
14, 5	20, 4	20, 6	20, 7	20, 8	19, 1	20, 10	20, 12	20, 11
LABELS 5								
EBLOAD	HRHTG	HRHPH	HRIFAN	HRHPC				

UNIT 31 TYPE 28 SIMULATION SUMMARIZER - MONTHLY
*AVERAGE STATE VARIABLES

PARAMETERS 28

-1.000E+00	0.	8.759E+03	0.	0.	-2.000E+00	2.000E+00	-3.000E+00	0.
-2.000E+00	2.000E+00	-3.000E+00	0.	-2.000E+00	2.000E+00	-3.000E+00	0.	-2.000E+00
2.000E+00	-3.000E+00	0.	0.	2.000E+00	-3.000E+00	0.	0.	2.000E+00
-3.000E+00								
INPUTS 8								
29, 1	29, 2	9, 6	9, 7	17, 1	19, 1	14, 2	20, 11	
LABELS 6								
ATR	AWR	ATAMB	AWAMB	ATDELH	ATDELC			

END

TRNSYS - A TRANSIENT SIMULATION PROGRAM
FROM THE SOLAR ENERGY LAB AT THE UNIVERSITY OF WISCONSIN
VERSION 9.2 2/1/78

*WASHINGTON - STAND ALONE HEAT PUMP - BASE CASE
*STAND ALONE HEAT PUMP

SIMULATION 0. 8.759E+03 1.250E+01

TOLERANCES 1.000E+03 1.000E+03

LIMITS 30 10

WIDTH 132

UNIT 9 TYPE 9 DATA READER

PARAMETERS 10

9.000E+00 1.000E+00 6.000E+00 1.000E+00 -2.752E+02 7.000E+00 1.000E+05 0. 2.000E+01

1.000E+00

(2X,3F2.0,F5.0,F5.0,F4.1,8X,F4.0,2X,F3.1,2X,F5.2)

UNIT 1 TYPE 14 WINTER/SUMMER FORCING FUNCTION

* SUMMER = 0 * WINTER = 1

PARAMETERS 12

0. 1.000E+00 3.207E+03 1.000E+00 3.207E+03 0. 6.553E+03 0. 6.553E+03

1.000E+00

8.759E+03 1.000E+00

UNIT 3 TYPE 25 PRINTER - ROOM TEMP, HUMIDITY

PARAMETERS 4

1.000E+00 0. 8.759E+03 9.000E+00

INPUTS 2

29, 1 29, 2

T H

UNIT 16 TYPE 16 SOLAR RADIATION PROCESSOR

PARAMETERS 18

4.000E+00 1.000E+00 3.800E+01 4.871E+03 2.000E+01 -7.500E+00 4.800E+01 0. 9.000E+01

9.000E+01 4.800E+01 1.800E+02 -9.000E+01 -9.000E+01 9.000E+01 0. 9.000E+01 1.800E+02

INPUTS 2

9, 5 9, 4

0. 0.

UNIT 2 TYPE 2 1ST STAGE HEATING

PARAMETERS 3

5.000E+00 1.000E+00 -1.000E+00

INPUTS 3

0, 0 29, 1 2, 1

2.100E+01 2.200E+01 0.

UNIT 4 TYPE 2 2ND STAGE HEATING

PARAMETERS 3

5.000E+00 1.000E+00 -3.000E+00

INPUTS 3

0, 0 29, 1 4, 1

1.900E+01 2.200E+01 0.

UNIT 6 TYPE 2 COOLING
 PARAMETERS 3
 5.000E+00 1.000E+00 -1.000E+00
 INPUTS 3
 29, 1 0, 0 6, 1
 2.200E+01 2.550E+01 0.

UNIT 20 TYPE 20 STAND ALONE HEAT PUMP
 PARAMETERS 17
 4.000E+00 3.500E+01 -1.944E+01 1.944E+01 2.100E+01 2.200E+01 8.000E+00 4.000E+00 0.
 0. 9.120E+02 1.900E+03 1.490E+02 3.950E+04 2.296E+03 2.111E+01 2.667E+01
 INPUTS 7
 29, 1 29, 2 29, 3 2, 1 4, 1 6, 1 9, 6
 2.200E+01 1.000E-02 0. 0. 0. 0. 1.000E+01

UNIT 29 TYPE 29 COMBINED LOAD MODEL
 PARAMETERS 41
 2.000E+00 1.012E+00 1.300E+01 1.373E+02 3.698E+02 2.300E+01 2.000E+04 5.000E+02 1.000E+00
 2.000E+00 3.700E-02 5.000E-01 8.000E-01 5.686E+01 3.790E+01 1.500E-01 1.500E-01 1.500E-01
 0. 7.620E+01 2.440E+00 3.000E+00 6.000E+01 1.486E+01 6.000E+01 8.036E+01 3.674E+02
 4.800E+01 4.800E+01 4.000E+00 3.000E+00 5.100E+01 5.100E-01 5.100E-01 2.478E-00 6.633E-03
 8.314E-03 1.150E-03 -7.305E-01 8.735E-02 -2.010E-03
 INPUTS 19
 20, 1 20, 2 20, 3 9, 6 9, 7 0, 0 9, 8 16, 16 16, 17
 16, 10 16, 11 16, 18 16, 19 16, 14 16, 15 16, 12 16, 1 16, 8
 16, 9
 8.000E+01 1.000E-02 0. 0. 1.000E-02 0. 0. 0. 0.
 0. 0. 0. 0. 0. 0. 0. 0.
 0.
 DERIVATIVES 2
 2.000E+01 1.000E-02

UNIT 24 TYPE 24 INTEGRATOR
 INPUTS 9
 20, 4 20, 5 20, 6 20, 7 20, 8 20, 9 29, 4 29, 5 29, 6
 0. 0. 0. 0. 0. 0. 0. 0. 0.

UNIT 25 TYPE 25 PRINTER 1
 PARAMETERS 4
 7.200E+02 0. 8.759E+03 0.
 INPUTS 8
 24, 1 24, 2 24, 3 24, 4 24, 5 24, 6 20, 17 20, 18
 QHC WH QAUX QSCC QLCC WC NHCYC NCCYC

UNIT 15 TYPE 15 SOURCE TEMP. WHEN HP ON IN HTG. MODE
 PARAMETERS 16
 0. -1.000E+00 5.000E-01 4.000E+00 -1.000E+00 -1.000E+00 1.000E+00 8.000E+00 -1.000E+00
 1.000E+00 1.000E+00 -1.000E+00 1.000E+00 3.000E+00 0. 1.000E+00
 INPUTS 2
 20, 10 9, 6
 0. 0.

UNIT 19 TYPE 15 .CR.
 PARAMETERS 1
 1.200E+01
 INPUTS 2
 2, 1 4, 1
 0. 0.

UNIT 17 TYPE 15 DELIVERY TEMP WHEN ON IN HTG MODE

PARAMETERS 1

1.000E+00

INPUTS 2

19, 1 20, 1

0. 0.

UNIT 14 TYPE 15 ELEC INPUT OF INDOOR FAN WHEN COMPRESSOR IS I

*DELIVER TEMP IN COOLING

*QSLOAD + QLLOAD

*THIRD PARAMETER = ELEC INPUT TO RHN FAN (KJ/HR)

PARAMETERS 22

0. -1.000E+00 6.710E+02 1.000E+00 -3.000E+00 0. 0. 1.000E+00 -3.000E+00

0. 0. 3.000E+00 -3.000E+00 0. 7.000E+00 -3.000E+00 3.000E+00 -3.000E+00

0. 0. 1.000E+00 -3.000E+00

INPUTS 8

20, 12 20, 1 20, 11 29, 5 29, 6 29, 4 9, 6 20, 11

0. 0. 0. 0. 0. 0. 0. 0.

UNIT 13 TYPE 15 ADDER - TOTAL ELECTRIC

PARAMETERS 16

0. 0. 1.000E+00 0. 3.000E+00 0. 3.000E+00 -3.000E+00 -1.100E+01

1.000E+01 -1.200E+01 1.000E+00 3.000E+00 0. 3.000E+00 -3.000E+00

INPUTS 5

1, 1 14, 1 20, 6 20, 5 20, 9

0. 0. 0. 0. 0.

UNIT 27 TYPE 27 HIST PLOT(MODE 1) -- EDB,TR,TS,LENGTH,LENGC,E

PARAMETERS 29

1.000E+00 8.759E+03 8.759E+03 0. 8.759E+03 2.000E+01 6.800E+01 2.400E+01 1.500E+01

3.900E+01 2.400E+01 -2.000E+01 2.400E+01 2.200E+01 1.250E+01 1.213E+01 2.400E+01 1.250E+01

1.213E+01 2.400E+01 5.000E+02 6.050E+04 2.400E+01 1.800E+01 4.200E+01 2.400E+01 1.000E+03

2.500E+02 2.400E+01

INPUTS 8

17, 1 29, 1 15, 1 20, 19 20, 20 13, 2 14, 6 29, 2

0 0 0 0 0 0 0 0

UNIT 26 TYPE 27 HIST PLOT(MODE 2) -- AUX,WH,WC,TOTAL ELEC,COO

PARAMETERS 8

2.000E+00 8.759E+03 8.759E+03 0. 8.759E+03 0. 2.400E+01 2.400E+01

INPUTS 6

20, 6 20, 5 20, 9 13, 2 14, 3 14, 4

0 0 0 0 0 0

UNIT 28 TYPE 28 SIMULATION SUMMARIZER - MONTHLY

*HEATING MODE OPERATION

PARAMETERS 23

-1.000E+00 0. 8.759E+03 0. 0. -3.000E+00 0. -3.000E+00 2.000E+00

-4.000E+00 0. -3.000E+00 0. -3.000E+00 -1.000E+00 1.000E+00 0. 0.

2.000E+00 4.000E+00 -3.000E+00 0. -3.000E+00

INPUTS 7

20, 4 20, 5 20, 6 29, 4 13, 1 14, 4 14, 1

LABELS 7 QHP=L WHPH COPH QA=L QLOAD FSSH SHCPR

UNIT 32 TYPE 28 SIMULATION SUMMARIZER - MONTHLY

*COOLING MODE OPERATION

PARAMETERS 20

-1.000E+00 0. 8.759E+03 0. 0. -3.000E+00 0. -3.000E+00 3.000E+00

-3.000E+00 0. -3.000E+00 2.000E+00 -4.000E+00 0. -3.000E+00 0. -3.000E+00

3.000E+00 -3.000E+00

INPUTS 5

20, 7 20, 8 20, 9 29, 5 29, 6

LABELS 8 QSCC QLCC QTCC WHPH COPC QSLOAD QLLOAD QTLOAD

UNIT 30 TYPE 28 SIMULATION SUMMARIZER - MONTHLY

*ENERGY BALANCE AND RUN TIMES

PARAMETERS 22

-1.000E+00	0.	8.759E+03	0.	0.	0.	4.000E+00	0.	4.000E+00
0.	4.000E+00	0.	4.000E+00	-3.000E+00	0.	-3.000E+00	0.	-4.000E+00
0.	-3.000E+00	0.	-3.000E+00					

INPUTS 9

14, 5	20, 4	20, 6	20, 7	20, 8	19, 1	20, 10	20, 11	20, 11
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LABELS 5

EBLOAD	HRHTG	HRMPH	HRIFAN	HRMPC
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UNIT 31 TYPE 28 SIMULATION SUMMARIZER - MONTHLY

*AVERAGE STATE VARIABLES

PARAMETERS 28

-1.000E+00	0.	8.759E+03	0.	0.	-2.000E+00	2.000E+00	-3.000E+00	0.
-2.000E+00	2.000E+00	-3.000E+00	0.	-2.000E+00	2.000E+00	-3.000E+00	0.	-2.000E+00
2.000E+00	-3.000E+00	0.	0.	2.000E+00	-3.000E+00	0.	0.	2.000E+00
-3.000E+00								

INPUTS 8

29, 1	24, 2	9, 6	9, 7	17, 1	19, 1	14, 2	20, 11
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LABELS 6

ATR	AWR	ATAMB	AWAMB	ATDELH	ATDELC
-----	-----	-------	-------	--------	--------

END

TRNSYS - A TRANSIENT SIMULATION PROGRAM
FROM THE SOLAR ENERGY LAB AT THE UNIVERSITY OF WISCONSIN
VERSION 9.2 2/1/78

*FORT WORTH - LIQUID PARALLEL SYSTEM - BASE CASE

*LIQUID BASED SOLAR SYSTEM W/ PARALLEL HEAT PUMP AND DHW

SIMULATION 0. 0.759E+03 1.250E+01

TOLERANCES 1.000E-03 1.000E-03

LIMITS 30 10

WIDTH 152

UNIT 9 TYPE 9 DATA READER

PARAMETERS 10

4.000E+00 1.000E+00 0.000E+00 1.000E+00 -2.730E+02 7.000E+00 1.000E-05 0. 2.000E+01

1.000E+00

(A,3F2.0,F5.0,F5.0,F4.1,8A,F4.0,2A,F3.1,2A,F5.2)

UNIT 16 TYPE 16 SOLAR RADIATION PROCESSOR

PARAMETERS 18

4.000E+00 1.000E+00 3.300E+01 4.0/1E+03 2.000E-01 -7.500E+00 4.500E+01 0. 9.000E+01

4.000E+01 4.500E+01 1.000E+02 9.000E+01 -9.000E+01 9.000E+01 0. 9.000E+01 1.800E+02

INPUTS 2

4. 5

0. 5

UNIT 14 TYPE 14 SUMMER/WINTER FORCING FUNCTION

*SUMMER = 1, WINTER = 0

PARAMETERS 12

0. 0. 2.001E+03 0. 2.881E+03 1.000E+00 6.889E+03 1.000E+00 6.889E+03

0. 0.760E+03 0.

UNIT 2 TYPE 2 1ST STAGE HEATING

PARAMETERS 3

5.000E+00 1.000E+00 -1.000E+00

INPUTS 3

0. 0 24. 1 2. 1

2.100E+01 2.200E+01 0.

UNIT 4 TYPE 2 2ND STAGE HEATING

PARAMETERS 3

5.000E+00 1.000E+00 -3.000E+00

INPUTS 3

0. 0 24. 1 4. 1

1.900E+01 2.200E+01 0.

UNIT 6 TYPE 2 COOLING

PARAMETERS 3

5.000E+00 1.000E+00 -1.000E+00

INPUTS 3

24. 1 0. 0 0. 1

2.200E+01 2.550E+01 0.

UNIT 15 TYPE 15 .NOT. AND .AND. OPERATON
 PARAMETERS 4
 0. 0. 1.000E+01 1.100E+01
 INPUTS 2
 2, 1 4, 1
 0. 0.

UNIT 8 TYPE 2 MIN TEMP FOR DIRECT SOLAR HTG
 PARAMETERS 3
 5.000E+00 1.000E+00 -1.000E+00
 INPUTS 3
 21, 1 0, 0 8, 1
 4.000E+01 4.020E+01 0.

UNIT 1 TYPE 15 .AND.
 PARAMETERS 1
 1.100E+01
 INPUTS 2
 8, 1 15, 1
 0. 0.

UNIT 3 TYPE 3 DIRECT SOLAR HEATING LOOP PUMP
 PARAMETERS 1
 2.425E+03
 INPUTS 3
 5, 1 5, 3 1, 1
 2.200E+01 0. 0.

UNIT 50 TYPE 14 MAIN WATER FORCING SUPPLY TEMPERATURE
 PARAMETERS 48
 0. 0.000E+00 7.440E+02 0.000E+00 7.440E+02 9.000E+00 1.416E+03 9.000E+00 1.416E+03
 1.400E+01 2.160E+03 1.400E+01 2.160E+03 1.800E+01 2.880E+03 1.800E+01 2.880E+03 2.300E+01
 3.674E+03 2.300E+01 3.624E+03 2.700E+01 4.344E+03 2.700E+01 4.344E+03 2.800E+01 5.088E+03
 2.800E+01 5.088E+03 2.800E+01 5.832E+03 2.800E+01 5.832E+03 2.800E+01 6.552E+03 2.600E+01
 6.552E+03 1.700E+01 7.296E+03 1.700E+01 7.296E+03 1.200E+01 8.016E+03 1.200E+01 8.016E+03
 9.000E+00 8.760E+03 9.000E+00

UNIT 23 TYPE 23 DHW SUBSYSTEM
 *FLOW RATE IS PARAMETER IN UNIT 13
 PARAMETERS 14
 -3.000E+02 4.500E+01 1.000E+03 4.190E+00 2.000E+00 1.500E+00 6.000E+01 4.190E+00 4.500E+02
 7.000E+01 5.000E+00 1.000E+00 2.000E+01 9.800E+01
 INPUTS 4
 21, 1 0, 0 50, 1 0, 0
 4.000E+01 4.500E+02 1.000E+01 2.110E+01

UNIT 11 TYPE 11 IEE PIECE
 PARAMETERS 1
 1.000E+00
 INPUTS 4
 3, 1 3, 2 23, 1 23, 2
 4.000E+01 4.500E+02 4.000E+01 0.

UNIT 21 TYPE 21 LIQUID SUBSYSTEM
*COLLECTOR AREA IS PARAMETER IN UNIT 28

PARAMETERS 15

3.000E+01	1.688E+03	3.350E+00	1.350E+03	4.190E+00	8.600E-01	8.300E-01	1.890E+01	1.000E+02
7.000E-01	6.000E+00	1.000E+03	2.000E+00	1.000E+00	2.000E+01			

INPUTS 6

10, 1	9, 0	11, 1	11, 2	0, 0	0, 0			
0.	1.000E+01	4.000E+01	0.	2.000E+01	0.			

UNIT 5 TYPE 5 CROSSFLOW HEAT-EXCHANGER (CUNTSANT EFF.)

PARAMETERS 4

4.000E+00	7.660E-01	4.190E+00	1.012E+00
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INPUTS 4

21, 1	3, 2	29, 1	29, 3
4.000E+01	0.	2.200E+01	0.

UNIT 20 TYPE 20 TEMP. LEVEL CONTROL HEAT PUMP

PARAMETERS 17

1.000E+00	3.500E+01	-1.944E+01	1.944E+01	2.100E+01	2.200E+01	8.000E+00	4.000E+00	0.
0.	9.120E+02	1.900E+03	1.490E+02	3.950E+04	2.296E+03	2.111E+01	2.667E+01	

INPUTS 7

5, 3	29, 2	5, 4	1, 1	4, 1	6, 1	9, 6		
2.200E+01	1.000E-02	0.	0.	0.	0.	1.000E+01		

UNIT 29 TYPE 29 COMBINED LOAD MODEL

PARAMETERS 41

2.000E+00	1.012E+00	1.300E+01	-1.840E+02	3.698E+02	2.300E+01	2.000E+04	5.000E+02	1.000E+00
2.000E+00	3.700E-02	5.000E-01	8.000E-01	4.162E+01	2.378E+01	1.500E-01	1.500E-01	1.500E-01
0.	7.620E-01	1.524E+00	2.000E+00	1.138E+02	2.218E+01	1.138E+02	1.672E+02	7.646E+02
4.500E+01	4.500E+01	4.000E+00	3.000E+00	5.100E-01	5.100E-01	5.100E-01	1.309E-04	5.070E-03
8.015E-03	1.846E-03	-9.813E-01	1.815E-01	-9.842E-03				

INPUTS 19

20, 1	20, 2	20, 3	9, 6	9, 7	0, 0	9, 8	16, 16	16, 17
16, 10	16, 11	16, 18	16, 19	16, 14	16, 15	16, 12	16, 1	16, 8
16, 9								
6.000E+01	1.000E-02	0.	0.	1.000E-02	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.
0.								

DERIVATIVES 2

2.000E+01	1.000E-02
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UNIT 24 TYPE 24 INTEGRATOR 1

INPUTS 9

20, 4	20, 5	20, 6	20, 7	20, 8	20, 9	29, 4	29, 5	29, 6
0.	0.	0.	0.	0.	0.	0.	0.	0.

UNIT 34 TYPE 24 INTEGRATOR 2

INPUTS 6

10, 1	21, 3	21, 4	21, 5	21, 7	5, 5
0.	0.	0.	0.	0.	0.

UNIT 25 TYPE 25 PRINTER 1

PARAMETERS 4

7.200E+02	0.	8.759E+03	0.
-----------	----	-----------	----

INPUTS 9

24, 1	24, 2	24, 3	24, 4	24, 5	24, 6	24, 7	24, 8	24, 9
QML	QW	GAUX	GSCC	QLCC	WC	QHEAT	QSENS	QLAT

UNIT 35 TYPE 25 PRINTER 2

PARAMETERS 4

7.200E+02	0.	8.759E+03	0.
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INPUTS 9

34, 1	34, 2	34, 3	34, 4	21, 6	34, 5	20, 17	20, 18	23, 9
HI	QU	QENV	QTNK	DELE	QDUMP	NMCCYC	NCCYC	QHNDE

*UNIT 36 TYPE 25 PRINTER 3

*PAK 4

*1. 0. 24. 0.

*INPUTS 9

*29,1 29,2 29,3 5,3 20,1 20,2 2,1 4,1 0,1

*TN WR FLOWR THP1 THPU WHPU IH1 IH2 IC

UNIT 17 TYPE 15 .UR. OPERATOR

PARAMETERS 1

1.200E+01

INPUTS 2

1, 1 4, 1

0. 0.

UNIT 18 TYPE 15 DELIVERED AIR TEMP WHEN HEATING

PARAMETERS 1

1.000E+00

INPUTS 2

17, 1 20, 1

0. 0.

UNIT 19 TYPE 15 SOURCE TEMP DURING HP HEATING MODE

PARAMETERS 21

0.	-1.000E+00	5.000E-01	4.000E+00	-1.000E+00	-1.000E+00	1.000E+00	8.000E+00	-1.000E+00
-1.000E+00	1.000E+00	-1.000E+00	1.000E+00	3.000E+00	0.	1.000E+00	-3.000E+00	0.
0.	1.000E+00	-3.000E+00						

INPUTS 4

20,10 9, 0 10, 1 21, 8

0. 0. 0. 0.

UNIT 37 TYPE 15 ALGEBRAIC OPERATOR

*1. PRODUCES SINK TEMP WHEN HP ON IN COOLING MODE

*2. TANK TEMP. IN HEATING SEASON

*3. WHEAT

PARAMETERS 12

0.	0.	1.000E+00	-3.000E+00	0.	0.	1.000E+01	1.000E+00	-3.000E+00
0.	7.000E+00	-3.000E+00						

INPUTS 5

9, 0 0, 1 21, 1 14, 1 29, 4

0. 0. 0. 0. 0.

UNIT 13 TYPE 15 ALGEBRAIC OPERATOR

* OUTPUTS 1. DSLHT

* 2. SPACE HEATG AND COOLG PARASITICS(SHCPAR)

* 3. GAUX + WH + WC + PARASITICS

* 4. DHW RUN TIME

* 5. DOMESTIC HW PARASITICS(DHWPAP)

* 6. DHW GAUX + PARASITICS

* 7. DHW GAUX + PARASITICS + GAUX + WH + WC + PARASITICS

* 8. WSENS + GLAT

*THIRD PARAMETER IS (AUXILIARY FAN) KJ/HR

*SEVENTH PARAMETER IS (COLLECTOR LOOP PUMP) KJ/HR

*NINETEENTH PARAMETER IS (DIRECT SOLAR LOOP PUMP) KJ/HR

*THIRTYTHIRD PARAMETER IS FLOW RATE IN DHW SOURCE LOOP

*THIRTYSEVENTH PARAMETER IS DHW LOOP KJ/HR

*FORTYTHIRD PARAMETER IS COLLECTOR LOOP PUMP KJ/HR

PARAMETERS 54

0.	-1.000E+00	1.342E+03	1.000E+00	0.	-1.000E+00	2.685E+03	1.000E+00	0.
1.000E+01	1.000E+00	3.000E+00	0.	-1.000E+00	1.000E-04	9.000E+00	-3.000E+00	-1.000E+00
1.342E+03	1.000E+00	3.000E+00	-3.000E+00	0.	3.000E+00	0.	3.000E+00	0.
3.000E+00	-3.000E+00	0.	0.	-1.000E+00	4.500E+02	2.000E+00	-3.000E+00	-1.000E+00
2.685E+03	1.000E+00	-1.200E+01	-1.300E+01	1.000E+00	-1.000E+00	2.685E+03	1.000E+00	3.000E+00
-3.000E+00	3.000E+00	-3.000E+00	3.000E+00	-3.000E+00	0.	0.	3.000E+00	-3.000E+00

INPUTS 11

20,12 21, 8 14, 1 5, 5 20, 6 20, 5 20, 9 23, 7 23, 2

29, 5 29, 0 0. 0. 0. 0. 0. 0. 0.

0. 0. 0. 0. 0. 0. 0.

0. 0. 0. 0. 0. 0. 0.

UNIT 39 TYPE 15 ALGEBRAIC OPERATOR

*1. QSLUAD + QLLUAD = QLUAD

*2. EBLUAD

*3. AIDELC

*4. UA=L + WMPH + SHPAR

PARAMETERS 28

0.	0.	4.000E+00	-3.000E+00	0.	4.000E+00	0.	4.000E+00	0.
4.000E+00	0.	4.000E+00	0.	4.000E+00	-3.000E+00	0.	0.	1.000E+00
-3.000E+00	0.	0.	1.000E+01	1.000E+00	0.	3.000E+00	-1.500E+01	3.000E+00
-5.000E+00								
INPUTS 12								
13, 0	29, 4	20, 4	5, 5	20, 6	20, 7	20, 8	20, 1	20, 11
13, 2	14, 1	20, 5						
0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.						

UNIT 27 TYPE 27 HISTOGRAM PLOTTER (MODE 1)

*1. PHS.

*2. TR

*3. ISOURCE

*4. HEATING CYCLE LENGTH

*5. COOLING CYCLE LENGTH

*6. DMH QUAUX + DMH PARASITICS + QUAUX + WM + WC + PARASITICS

*7. (QUAUX + WM + WC + PARASITICS)

*8. SINK TEMP.

*9. TANK TEMP.

*10. RUGH HUMIDITY RATIO

PARAMETERS 35

1.000E+00	8.759E+03	8.759E+03	0.	8.759E+03	2.000E+01	6.800E+01	2.400E+01	1.500E+01
5.400E+01	2.400E+01	-2.000E+01	2.000E+01	2.000E+01	1.000E-01	1.210E+01	2.400E+01	1.000E-01
1.210E+01	2.400E+01	5.000E+02	9.650E+04	2.400E+01	5.000E+02	9.650E+04	2.400E+01	1.500E+01
4.400E+01	2.400E+01	2.000E+00	9.800E+01	2.400E+01	1.000E-03	2.500E-02	2.400E+01	
INPUTS 10								
10, 1	29, 1	19, 1	20, 19	20, 20	13, 1	13, 3	37, 1	37, 2
29, 2	0	0	0	0	0	0	0	0
0								

UNIT 26 TYPE 21 HISTOGRAM PLOTTER (MODE 2)

*PLUITS: 1. QUAUX.

*2. QUAUX DMH.

*3. WMPH

*4. WMPC

*5. (QUAUX + WM + WC + PARASITICS).

*6. QUAUX + WM + WC + PARASITICS + DMH QUAUX + DMH PARASITICS

*7. (QSENS + QLAT).

*8. QHEAT

PARAMETERS 24

2.000E+00	8.759E+03	8.759E+03	0.	8.759E+03	0.	2.400E+01	2.400E+01	0.
2.400E+01	2.400E+01	0.	2.400E+01	2.400E+01	0.	2.400E+01	2.400E+01	0.
2.400E+01	2.400E+01	0.	2.400E+01	2.400E+01	0.	2.400E+01	2.400E+01	0.
2.400E+01	2.400E+01							
INPUTS 8								
20, 0	23, 1	20, 5	20, 9	13, 3	13, 7	13, 8	37, 3	
0.	0.	0.	0.	0.	0.	0	0	

UNIT 28 TYPE 28 SIMULATION SUMMARIZER-MONTHLY

* HEATING MODE OPERATION

* PARAMETERS 9 AND 16 ARE COLLECTOR AREA

PARAMETERS 39

-1.000E+00	0.	8.759E+03	0.	0.	-3.000E+00	0.	-1.000E+00	3.000E+01
1.000E+00	2.000E+00	-4.000E+00	-1.100E+01	0.	-1.000E+00	3.000E+01	1.000E+00	2.000E+00
-4.000E+00	0.	-3.000E+00	0.	-3.000E+00	0.	-3.000E+00	2.000E+00	-4.000E+00
0.	-3.000E+00	-1.000E+00	1.000E+00	0.	-4.000E+00	0.	0.	7.000E+00
2.000E+00	4.000E+00	-3.000E+00						
INPUTS 10								
21, 5	16, 1	19, 2	5, 5	20, 4	20, 5	20, 6	29, 4	39, 4
29, 4								
LABELS 10								
NO	COLEFF	CEFFON	QUICK=L	QHP=L	WHPH	COPH	QA=L	QLOAD
FSSH								

UNIT 31 TYPE 28 SIMULATION SUMMARIZER - MONTHLY

* COOLING MODE AND DOMESTIC WATER HEATING SUBSYSTEM OPERATION

PARAMETERS 27

-1.000E+00	0.	8.759E+03	0.	0.	-3.000E+00	0.	-3.000E+00	3.000E+00
-3.000E+00	0.	-3.000E+00	2.000E+00	-3.000E+00	0.	-3.000E+00	0.	-3.000E+00
3.000E+00	-3.000E+00	-1.000E+00	2.090E+02	0.	1.000E+00	-3.000E+00	0.	-3.000E+00
INPUTS 7								
20, 7	20, 8	20, 9	29, 5	29, 6	23, 4	23, 5		
LABELS 10								
WSOC	WLCC	WLCC	WHPC	CUPC	WSLOAD	QLLOAD	WTLOAD	DHMLD
DHWIN								

UNIT 32 TYPE 28 SIMULATION SUMMARIZER - MONTHLY

* DOMESTIC HOT WATER HEATING OPERATION AND ENERGY BALANCES

PARAMETERS 29

-1.000E+00	0.	8.759E+03	0.	0.	-3.000E+00	0.	-4.000E+00	0.
-4.000E+00	-1.000E+00	2.090E+02	0.	1.000E+00	2.000E+00	-3.000E+00	0.	-3.000E+00
0.	-3.000E+00	0.	-4.000E+00	0.	4.000E+00	-3.000E+00	0.	-3.000E+00
0.	-3.000E+00							
INPUTS 10								
23, 6	23, 8	23, 7	23, 4	21, 7	21, 5	21, 4	5, 5	39, 2
13, 5								
LABELS 10								
DHWINK	DHGENV	DHWAUX	FSDHW	QDUMP	QTNK	GENV	EBTANK	EBLOAD
DHWPAN								

UNIT 33 TYPE 28 SIMULATION SUMMARIZER-MONTHLY

* RUN TIMES

PARAMETERS 20

-1.000E+00	0.	8.759E+03	0.	0.	-3.000E+00	0.	-3.000E+00	0.
-3.000E+00	0.	-3.000E+00	0.	-3.000E+00	0.	-3.000E+00	0.	-3.000E+00
0.	-3.000E+00							
INPUTS 8								
17, 1	13, 1	13, 4	20, 10	20, 12	21, 8	20, 11	13, 2	
LABELS 8								
HRHIG	HRDSL	HRDHW	HRHPH	HRIFAN	HRCOLL	HRHPC	SHCPAR	

UNIT 36 TYPE 28 SIMULATION SUMMARIZER - MONTHLY

* AVERAGE STATE VARIABLES

PARAMETERS 36

-1.000E+00	0.	8.759E+03	0.	0.	-2.000E+00	2.000E+00	-3.000E+00	0.
-2.000E+00	2.000E+00	-3.000E+00	0.	-2.000E+00	2.000E+00	-3.000E+00	0.	-2.000E+00
2.000E+00	-3.000E+00	0.	-2.000E+00	2.000E+00	-3.000E+00	0.	0.	2.000E+00
-3.000E+00	0.	0.	2.000E+00	-3.000E+00	0.	-2.000E+00	2.000E+00	-3.000E+00
INPUTS 10								
29, 1	29, 2	9, 6	9, 7	21, 1	18, 1	17, 1	39, 3	20, 11
23, 3								
LABELS 8								
ATK	AWK	ATAMB	AWAMB	ATTANK	ATDELH	ATDELC	ATPHT	

UNIT 48 TYPE 25 PRINTER
* PRINT ROOM TEMP. HUMIDITY RATIO ON FILE

PARAMETERS 4

1.000E+00	0.	8.759E+03	9.000E+00
INPUTS 2			
29, 1	29, 2		
TR	WR		

END

TRNSYS - A TRANSIENT SIMULATION PROGRAM
FROM THE SOLAR ENERGY LAB AT THE UNIVERSITY OF WISCONSIN
VERSION 9.2 2/1/78

*MADISON - LIQUID PARALLEL SYSTEM - BASE CASE

*LIQUID BASED SOLAR SYSTEM W/ PARALLEL HEAT PUMP AND DHW

SIMULATION 0. 8.759E+03 1.250E-01

TOLERANCES 1.000E-03 1.000E-03

LIMITS 30 10

WIDTH 132

UNIT 9 TYPE 9 DATA READER

PARAMETERS 10

9.000E+00 1.000E+00 6.000E+00 1.000E+00 -2.730E+02 7.000E+00 1.000E-05 0. 2.000E+01
1.000E+00
(2X,F2.0,F5.0,F5.0,F4.1,8X,F4.0,2X,F3.1,2X,F5.2)

UNIT 16 TYPE 16 SOLAR RADIATION PROCESSOR

PARAMETERS 18

4.000E+00 1.000E+00 4.300E+01 4.871E+03 2.000E-01 -7.500E+00 5.300E+01 0. 9.000E+01
9.000E+01 5.300E+01 1.800E+02 9.000E+01 -9.000E+01 9.000E+01 0. 9.000E+01 1.800E+02
INPUTS 2
9. 5 9. 4
0. 0.

UNIT 14 TYPE 14 SUMMER/WINTER FORCING FUNCTION

*SUMMER = 1, WINTER = 0

PARAMETERS 12

0. 0. 3.961E+03 0. 3.961E+03 1.000E+00 5.833E+03 1.000E+00 5.833E+03
0. 8.760E+03 0.

UNIT 2 TYPE 2 1ST STAGE HEATING

PARAMETERS 3

5.000E+00 1.000E+00 -1.000E+00
INPUTS 3
0. 0 29. 1 2. 1
2.100E+01 2.200E+01 0.

UNIT 4 TYPE 2 2ND STAGE HEATING

PARAMETERS 3

5.000E+00 1.000E+00 -3.000E+00
INPUTS 3
0. 0 29. 1 4. 1
1.900E+01 2.200E+01 0.

```

UNIT 6      TYPE 2      COOLING
PARAMETERS 3
5.000E+00   1.000E+00   -1.000E+00
INPUTS 3
29, 1      0, 0      6, 1
2.200E+01   2.550E+01   0.

UNIT 15     TYPE 15     .NOT. AND .AND. OPERATOR
PARAMETERS 4
0.          0.          1.000E+01   1.100E+01
INPUTS 2
2, 1      4, 1
0.        0.

UNIT 8      TYPE 2      MIN TEMP FOR DIRECT SOLAR HTG
PARAMETERS 3
5.000E+00   1.000E+00   -1.000E+00
INPUTS 3
21, 1      0, 0      8, 1
4.000E+01   4.020E+01   0.

UNIT 1      TYPE 15     .AND.
PARAMETERS 1
1.100E+01
INPUTS 2
8, 1      15, 1
0.        0.

UNIT 3      TYPE 3      DIRECT SOLAR HEATING LOOP PUMP
PARAMETERS 1
2.425E+03
INPUTS 3
5, 1      5, 3      1, 1
2.200E+01   0.        0.

UNIT 50     TYPE 14     MAIN WATER FORCING SUPPLY TEMPERATURE
PARAMETERS 48
0.          1.100E+01   7.440E+02   1.100E+01   7.440E+02   1.100E+01   1.416E+03   1.100E+01   1.416E+03
1.100E+01   2.160E+03   1.100E+01   2.160E+03   1.100E+01   2.880E+03   1.100E+01   2.880E+03   1.100E+01
3.624E+03   1.100E+01   3.624E+03   1.100E+01   4.344E+03   1.100E+01   4.344E+03   1.100E+01   5.088E+03
1.100E+01   5.088E+03   1.100E+01   5.832E+03   1.100E+01   5.832E+03   1.100E+01   6.552E+03   1.100E+01
6.552E+03   1.100E+01   7.296E+03   1.100E+01   7.296E+03   1.100E+01   8.016E+03   1.100E+01   8.016E+03
1.100E+01   8.760E+03   1.100E+01

UNIT 23     TYPE 23     DMW SUBSYSTEM
*FLOW RATE IS PARAMETER IN UNIT 13
PARAMETERS 14
-3.000E+02   4.500E+01   1.000E+03   4.190E+00   2.000E+00   1.500E+00   6.000E+01   4.190E+00   4.500E+02
7.000E+01   5.000E+00   1.000E+00   2.000E+01   9.800E+01
INPUTS 4
21, 1      0, 0      50, 1      0, 0
4.000E+01   4.500E+02   1.000E+01   2.110E+01

UNIT 11     TYPE 11     TEE PIECE
PARAMETERS 1
1.000E+00
INPUTS 4
3, 1      3, 2      23, 1      23, 2
4.000E+01   4.500E+02   4.000E+01   0.

```

UNIT 21 TYPE 21 LIQUID SUBSYSTEM
 *COLLECTOR AREA IS PARAMETER IN UNIT 28
 PARAMETERS 15
 5.300E+01 3.312E+03 3.350E+00 2.650E+03 4.190E+00 8.600E-01 8.300E-01 1.890E+01 1.000E+02
 7.000E-01 1.060E+01 1.000E+03 2.000E+00 1.000E+00 2.000E+01
 INPUTS 6
 16, 1 9, 6 11, 1 11, 2 0, 0 0, 0
 0. 1.000E+01 4.000E+01 0. 2.000E+01 0.

UNIT 5 TYPE 5 CROSSFLOW HEAT-EXCHANGER (CUNISANT EFF.)
 PARAMETERS 4
 4.000E+00 7.660E-01 4.190E+00 1.012E+00
 INPUTS 4
 21, 1 3, 2 29, 1 29, 3
 4.000E+01 0. 2.200E+01 0.

UNIT 20 TYPE 20 TEMP. LEVEL CONTROL HEAT PUMP
 PARAMETERS 17
 1.000E+00 3.500E+01 -1.944E+01 1.944E+01 2.100E+01 2.200E+01 8.000E+00 4.000E+00 0.
 0. 9.120E+02 1.900E+03 1.490E+02 3.950E+04 2.296E+03 2.111E+01 2.667E+01
 INPUTS 7
 5, 3 29, 2 5, 4 1, 1 4, 1 6, 1 9, 6
 2.200E+01 1.000E-02 0. 0. 0. 0. 1.000E+01

UNIT 29 TYPE 29 COMBINED LOAD MODEL
 PARAMETERS 41
 2.000E+00 1.012E+00 6.000E+00 1.346E+02 3.698E+02 2.300E+01 2.000E+04 5.000E+02 1.000E+00
 3.000E+00 3.700E-02 5.000E-01 8.000E-01 4.088E+01 2.304E+01 1.500E-01 1.500E-01 1.500E-01
 0. 7.620E-01 1.524E+00 3.000E+00 1.316E+02 2.962E+01 1.316E+02 1.579E+02 7.221E+02
 5.300E+01 5.300E+01 4.000E+00 3.000E+00 5.100E-01 5.100E-01 5.100E-01 2.478E-03 6.633E-03
 8.314E-03 1.150E-03 -7.305E-01 8.735E-02 -2.010E-03
 INPUTS 19
 20, 1 20, 2 20, 3 9, 6 9, 7 0, 0 9, 8 16, 16 16, 17
 16, 10 16, 11 16, 18 16, 19 16, 14 16, 15 16, 12 16, 1 16, 8
 16, 9
 8.000E+01 1.000E-02 0. 0. 1.000E-02 0. 0. 0. 0.
 0. 0. 0. 0. 0. 0. 0. 0.
 0.
 DERIVATIVES 2
 2.000E+01 1.000E-02

UNIT 24 TYPE 24 INTEGRATOR 1
 INPUTS 9
 20, 4 20, 5 20, 6 20, 7 20, 8 20, 9 29, 4 29, 5 29, 6
 0. 0. 0. 0. 0. 0. 0. 0. 0.

UNIT 34 TYPE 24 INTEGRATOR 2
 INPUTS 6
 16, 1 21, 3 21, 4 21, 5 21, 7 5, 5
 0. 0. 0. 0. 0. 0.

UNIT 25 TYPE 25 PRINTER 1
 PARAMETERS 4
 7.200E+02 0. 8.759E+03 0.
 INPUTS 9
 24, 1 24, 2 24, 3 24, 4 24, 5 24, 6 24, 7 24, 8 24, 9
 QMC QH QAUX QSCC QLCC QC QHEAT QSENS QLAT

```

UNIT 35      TYPE 25      PRINTER 2
PARAMETERS 4
7.200E+02    0.          8.759E+03    0.
INPUTS 9
34, 1        34, 2        34, 3        34, 4        21, 6        34, 5        20,17        20,18        23, 9
HT           UU          QENV          QTNK          DELE          QDUMP          NHCYC          NCCYC          DMWDE
*UNIT 36 TYPE 25 PRINTER 3
*PAR 4
*1. 0. 24. 0.
*INPUTS 9
*29,1 29,2 29,3 5,3 20,1 20,2 2,1 4,1 6,1
*TR WR FLOWR THPI THPU WMPU IH1 IH2 IC

UNIT 17      TYPE 15      .UR. OPERATOR
PARAMETERS 1
1.200E+01
INPUTS 2
1, 1        4, 1
0.          0.

UNIT 18      TYPE 15      DELIVERED AIR TEMP WHEN HEATING
PARAMETERS 1
1.000E+00
INPUTS 2
17, 1       20, 1
0.          0.

UNIT 19      TYPE 15      SOURCE TEMP DURING HP HEATING MODE
PARAMETERS 21
0.          -1.000E+00    5.000E-01    4.000E+00    -1.000E+00    -1.000E+00    1.000E+00    8.000E+00    -1.000E+00
-1.000E+06    1.000E+00    -1.000E+00    1.000E+00    3.000E+00    0.          1.000E+00    -3.000E+00    0.
0.          1.000E+00    -3.000E+00
INPUTS 4
20,10       9, 6        16, 1       21, 8
0.          0.          0.          0.

UNIT 37      TYPE 15      ALGEBRAIC OPERATOR
*1. PRODUCES SINK TEMP WHEN HP ON IN COOLING MODE
*2. TANK TEMP. IN HEATING SEASON
*3. QHEAT
PARAMETERS 12
0.          0.          1.000E+00    -3.000E+00    0.          0.          1.000E+01    1.000E+00    -3.000E+00
0.          7.000E+00    -3.000E+00
INPUTS 5
9, 6        6, 1        21, 1       14, 1       29, 4
0.          0.          0.          0.          0.

```

UNIT 13 TYPE 15 ALGEBRAIC OPERATOR
 * OUTPUTS 1. DSLRT
 * 2. SPACE HEATS AND COOLG PARISITICS(SHCPAR)
 * 3. GAUX + WH + WC + PARASITICS
 * 4. DHW RUN TIME
 * 5. DOMESTIC HW PARISITICS(DHWPAP)
 * 6. DHW GAUX + PARASITICS
 * 7. DHW GAUX + PARASITICS + GAUX + WH + WC + PARASITICS
 * 8. USENS + QLAI

*THIRD PARAMETER IS (AUXILIARY FAN) KJ/HR
 *SEVENTH PARAMETER IS (COLLECTOR LOOP PUMP) KJ/HR
 *NINETEENTH PARAMETER IS (DIRECT SOLAR LOOP PUMP) KJ/HR
 *THIRTYTHIRD PARAMETER IS FLOW RATE IN DHW SOURCE LOOP
 *THIRTYSEVENTH PARAMETER IS DHW LOOP KJ/HR
 *FORTYTHIRD PARAMETER IS COLLECTOR LOOP PUMP KJ/HR

PARAMETERS 54

0.	-1.000E+00	1.342E+03	1.000E+00	0.	-1.000E+00	2.685E+03	1.000E+00	0.
1.000E+01	1.000E+00	3.000E+00	0.	-1.000E+00	1.000E-04	9.000E+00	-3.000E+00	-1.000E+00
1.342E+03	1.000E+00	3.000E+00	-3.000E+00	0.	3.000E+00	0.	3.000E+00	0.
3.000E+00	-3.000E+00	0.	0.	-1.000E+00	4.500E+02	2.000E+00	-3.000E+00	-1.000E+00
2.685E+03	1.000E+00	-1.200E+01	-1.300E+01	1.000E+00	-1.000E+00	2.685E+03	1.000E+00	3.000E+00
-3.000E+00	3.000E+00	-3.000E+00	3.000E+00	-3.000E+00	0.	0.	3.000E+00	-3.000E+00

INPUTS 11

20, 12	21, 8	14, 1	20, 13	20, 6	20, 5	20, 9	23, 7	23, 2
29, 5	29, 6							
0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.							

UNIT 39 TYPE 15 ALGEBRAIC OPERATOR
 *1. GSLUAD + QLLUAD = QLUAD
 *2. EHLUAD
 *3. ATDELCC
 *4. QA=L + WHPH + SHPAR

PARAMETERS 27

0.	0.	4.000E+00	-3.000E+00	0.	4.000E+00	0.	4.000E+00	0.
4.000E+00	0.	4.000E+00	0.	4.000E+00	-3.000E+00	0.	0.	1.000E+00
-3.000E+00	0.	0.	1.000E+01	1.000E+00	0.	3.000E+00	-1.500E+01	3.000E+00

INPUTS 12

13, 8	29, 4	20, 4	5, 5	20, 6	20, 7	20, 8	20, 1	20, 11
13, 2	14, 1	20, 5						
0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.						

UNIT 27 TYPE 27 HISTOGRAM PLOTTER (MODE 1)
 * 1. EDB.
 * 2. TH
 * 3. TSOURCE
 *4. HEATING CYCLE LENGTH
 *5. COOLING CYCLE LENGTH
 *6. DHW GAUX + DHW PARASITICS + GAUX + WH + WC + PARASITICS
 *7. (GAUX + WH + WC + PARASITICS)
 *8. SINK TEMP.
 *9. TANK TEMP.
 *10. ROOM HUMIDITY RATIO

PARAMETERS 35

1.000E+00	8.759E+03	8.759E+03	0.	8.759E+03	2.000E+01	6.800E+01	2.400E+01	1.500E+01
3.900E+01	2.400E+01	-2.000E+01	2.000E+01	2.000E+01	1.000E-01	1.210E+01	2.400E+01	1.000E-01
1.210E+01	2.400E+01	5.000E+02	9.650E+04	2.400E+01	5.000E+02	9.650E+04	2.400E+01	1.500E+01
4.900E+01	2.400E+01	2.000E+00	9.800E+01	2.400E+01	1.000E-03	2.500E-02	2.400E+01	

INPUTS 10

18, 1	29, 1	19, 1	20, 19	20, 20	13, 7	13, 3	37, 1	37, 2
29, 2								
0	0	0	0	0	0	0	0	0
0								

UNIT 26 TYPE 27 HISTOGRAM PLOTTER (MODE 2)
 *PLOTS: 1. GAUX,
 *2. GAUX DHW,
 *3. WHPH
 *4. WHPC
 *5. (GAUX + WH + WC + PARASITICS),
 * GAUX + WH + WC + PARASITICS + DHW GAUX + DHW PARASITICS
 * 7. (QSSENS + QLAT),
 *8. UHEAT

PARAMETERS 29								
2.000E+00	8.759E+03	8.759E+03	0.	8.759E+03	0.	2.400E+01	2.400E+01	0.
2.400E+01	2.400E+01	0.	2.400E+01	2.400E+01	0.	2.400E+01	2.400E+01	0.
2.400E+01	2.400E+01	0.	2.400E+01	2.400E+01	0.	2.400E+01	2.400E+01	0.
2.400E+01	2.400E+01							
INPUTS 8								
20, 6	23, 7	20, 5	20, 9	13, 3	13, 7	13, 8	37, 3	
0.	0.	0.	0.	0.	0.	0	0	

UNIT 28 TYPE 28 SIMULATION SUMMARIZER-MONTHLY

* HEATING MODE OPERATION

*PARAMETERS 9 AND 16 ARE COLLECTOR AREA

PARAMETERS 39								
-1.000E+00	0.	8.759E+03	0.	0.	-3.000E+00	0.	-1.000E+00	5.300E+01
1.000E+00	2.000E+00	-4.000E+00	-1.100E+01	0.	-1.000E+00	5.300E+01	1.000E+00	2.000E+00
-4.000E+00	0.	-3.000E+00	0.	-3.000E+00	0.	-3.000E+00	2.000E+00	-4.000E+00
0.	-3.000E+00	-1.000E+00	1.000E+00	0.	-4.000E+00	0.	0.	7.000E+00
2.000E+00	4.000E+00	-3.000E+00						
INPUTS 10								
21, 3	16, 1	19, 2	5, 5	20, 4	20, 5	20, 6	29, 4	39, 4
29, 4								
LABELS 10								
QU	CELEFF	CEFFON	QDIR-L	QMP-L	WHPH	COPH	QA-L	QLOAD
FSSH								

UNIT 31 TYPE 28 SIMULATION SUMMARIZER - MONTHLY

* COOLING MODE AND DOMESTIC WATER HEATING SUBSYSTEM OPERATION

PARAMETERS 27								
-1.000E+00	0.	8.759E+03	0.	0.	-3.000E+00	0.	-3.000E+00	3.000E+00
-3.000E+00	0.	-3.000E+00	2.000E+00	-3.000E+00	0.	-3.000E+00	0.	-3.000E+00
3.000E+00	-3.000E+00	-1.000E+00	2.090E+02	0.	1.000E+00	-3.000E+00	0.	-3.000E+00
INPUTS 7								
20, 7	20, 8	20, 9	29, 5	29, 6	23, 4	23, 5		
LABELS 10								
QSCC	QLCC	QTCC	WHPC	CUPC	QSLOAD	QLLOAD	QTLOAD	DHMLD
DHWIN								

UNIT 32 TYPE 28 SIMULATION SUMMARIZER - MONTHLY

* DOMESTIC HOT WATER HEATING OPERATION AND ENERGY BALANCES

PARAMETERS 29								
-1.000E+00	0.	8.759E+03	0.	0.	-3.000E+00	0.	-4.000E+00	0.
-4.000E+00	-1.000E+00	2.090E+02	0.	1.000E+00	2.000E+00	-3.000E+00	0.	-3.000E+00
0.	-3.000E+00	0.	-4.000E+00	0.	4.000E+00	-3.000E+00	0.	-3.000E+00
0.	-3.000E+00							
INPUTS 10								
23, 6	23, 8	23, 7	23, 4	21, 7	21, 5	21, 4	5, 5	39, 2
13, 5								
LABELS 10								
DHWTNK	DHWEV	DHWAUX	FSDHW	QDUMP	QTNK	QENV	EBTANK	EBLOAD
DHWPAP								

UNIT 33 TYPE 28 SIMULATION SUMMARIZER-MONTHLY

* RUN TIMES

PARAMETERS 20								
-1.000E+00	0.	8.759E+03	0.	0.	-3.000E+00	0.	-3.000E+00	0.
-3.000E+00	0.	-3.000E+00	0.	-3.000E+00	0.	-3.000E+00	0.	-3.000E+00
0.	-3.000E+00							

INPUTS 8							
17, 1	13, 1	13, 4	20, 10	20, 12	21, 8	20, 11	13, 2
LABELS 8							
HRMTG	HRDGL	HRDHW	HRMHP	HRIFAN	HRCOLL	HRMPC	SHCPAR

UNIT 38 TYPE 28 SIMULATION SUMMARIZER - MONTHLY

* AVERAGE STATE VARIABLES

PARAMETERS 36

-1.000E+00	0.	8.759E+03	0.	0.	-2.000E+00	2.000E+00	-3.000E+00	0.
-2.000E+00	2.000E+00	-3.000E+00	0.	-2.000E+00	2.000E+00	-3.000E+00	0.	-2.000E+00
2.000E+00	-3.000E+00	0.	-2.000E+00	2.000E+00	-3.000E+00	0.	0.	2.000E+00
-3.000E+00	0.	0.	2.000E+00	-3.000E+00	0.	-2.000E+00	2.000E+00	-3.000E+00
INPUTS 10								
29, 1	29, 2	9, 6	9, 7	21, 1	18, 1	17, 1	39, 3	20, 11
23, 3								
LABELS 8								
ATK	AKK	ATAMB	AWAMB	ATTANK	ATDELH	ATDELC	ATPHT	

UNIT 48 TYPE 25 PRINTER

*PRINT RUUM TEMP, HUMIDITY RATIO UN FILE

PARAMETERS 4

1.000E+00	0.	8.759E+03	9.000E+00
INPUTS 2			
29, 1	29, 2		
IR	KK		

END

TRNSYS - A TRANSIENT SIMULATION PROGRAM
FROM THE SOLAR ENERGY LAB AT THE UNIVERSITY OF WISCONSIN
VERSION 9.2 2/1/78

*WASHINGTON - LIQUID PARALLEL SYSTEM - BASE CASE

*LIQUID - BASED SERIES SYSTEM - WITH AUTOMATIC SEASON SWITCHOVER

SIMULATION 0. 8.759E+03 1.250E-01
TOLERANCES 1.000E-03 1.000E-03
LIMITS 50 10
WIDTH 132

UNIT 9 TYPE 9 DATA READER
PARAMETERS 10
4.000E+00 1.000E+00 6.000E+00 1.000E+00 -2.732E+02 7.000E+00 1.000E-05 0. 2.000E+01
1.000E+00
(2X,3F2.0,F5.0,F5.0,F4.1,BX,F4.0,2X,F3.1,2X,F5.2)

UNIT 14 TYPE 14 SUMMER/WINTER INDICATOR FORCING FUNCTION
* SUMMER=1, WINTER=0
PARAMETERS 12
0. 0. 3.217E+03 0. 3.217E+03 1.000E+00 6.553E+03 1.000E+00 6.553E+03
0. 8.759E+03 0.

UNIT 1 TYPE 2 SUMMER HEAT REJECT CONTROL
PARAMETERS 3
5.000E+00 7.000E+00 5.000E+00
INPUTS 3
21, 1 9, 0 1, 1
4.000E+01 1.000E+01 0.

UNIT 30 TYPE 15 ALGEBRAIC OPERATOR
* TAKES INPUTS FROM TWO CNTRL FUNCTIONS AND MULTIPLIES THEM
* THEM TOGETHER AND WITH TWO FLOW RATES TO GIVE FLOW RATES FOR FAN COIL
PARAMETERS 18
0. 0. 1.000E+00 -1.000E+00 2.300E+03 1.000E+00 -3.000E+00 -1.100E+01 -1.200E+01
1.000E+00 -1.000E+00 3.275E+03 1.000E+00 -3.000E+00 -1.000E+00 3.275E+03 2.000E+00 -3.000E+00
INPUTS 2
14, 1 1, 1
0. 0.

UNIT 5 TYPE 5 FAN COIL
PARAMETERS 4
4.000E+00 8.000E-01 4.190E+00 1.012E+00
INPUTS 4
21, 1 30, 1 9, 0 30, 2
4.000E+01 0. 1.000E+01 0.

UNIT 11 TYPE 11 TEE PIECE

PARAMETERS 1

1.000E+00

INPUTS 4

20, 14

20, 15

5, 1

5, 2

4.000E+01

0.

1.000E+01

0.

UNIT 16 TYPE 16 SOLAR RADIATION PROCESSOR

PARAMETERS 18

4.000E+00

1.000E+00

3.800E+01

4.871E+03

2.000E-01

-7.500E+00

4.800E+01

0.

9.000E+01

9.000E+01

4.800E+01

1.800E+02

9.000E+01

-9.000E+01

9.000E+01

0.

9.000E+01

1.800E+02

INPUTS 3

9, 5

9, 4

0, 0

0.

0.

0.

UNIT 21 TYPE 21 LIQ. SYSTEM COMBINED COMPONENT

PARAMETERS 15

6.000E+01

3.750E+03

3.350E+00

3.000E+03

4.190E+00

9.000E-01

8.800E-01

3.067E+01

1.000E+02

7.000E-01

1.200E+01

1.000E+03

2.000E+00

1.000E+00

9.000E+00

INPUTS 6

10, 1

9, 6

11, 1

11, 2

0, 0

14, 1

0.

1.000E+01

4.000E+01

0.

2.000E+01

0.

UNIT 2 TYPE 2 1ST STAGE HEATING

PARAMETERS 3

5.000E+00

1.000E+00

-1.000E+00

INPUTS 3

0, 0

29, 1

2, 1

2.100E+01

2.200E+01

0.

UNIT 4 TYPE 2 2ND STAGE HEATING

PARAMETERS 3

5.000E+00

1.000E+00

-3.000E+00

INPUTS 3

0, 0

29, 1

4, 1

1.900E+01

2.200E+01

0.

UNIT 6 TYPE 2 COOLING

PARAMETERS 3

5.000E+00

1.000E+00

-1.000E+00

INPUTS 3

29, 1

0, 0

0, 1

2.200E+01

2.550E+01

0.

UNIT 20 TYPE 20 TEMP LEVEL CONTROL HEAT PUMP

PARAMETERS 21

5.000E+00

3.500E+01

1.670E+00

4.020E+01

2.100E+01

2.200E+01

8.000E+00

6.000E+00

0.

0.

7.790E+02

1.633E+03

0.

3.950E+04

2.296E+03

2.111E+01

2.667E+01

1.700E+03

4.190E+00

4.020E+01

7.600E-01

INPUTS 7

29, 1

29, 2

29, 3

2, 1

4, 1

6, 1

21, 1

2.200E+01

1.000E+02

0.

0.

0.

0.

2.000E+01

UNIT 29 TYPE 29 COMBINED LOAD MODEL

PARAMETERS 41

2.000E+00	1.012E+00	1.500E+01	1.373E+02	3.698E+02	2.300E+01	2.000E+04	5.000E+02	1.000E+00
2.000E+00	3.700E-02	5.000E-01	8.000E-01	5.686E+01	3.790E+01	1.500E-01	1.500E-01	1.500E-01
0.	7.620E-01	2.440E+00	3.000E+00	6.000E+01	1.486E+01	6.000E+01	8.036E+01	3.674E+02
4.800E+01	4.800E+01	4.000E+00	3.000E+00	5.100E-01	5.100E-01	5.100E-01	2.478E-04	6.633E-03
6.314E-03	1.150E-03	-7.505E-01	8.735E-02	-2.010E-03				

INPUTS 19

20, 1	20, 2	20, 3	9, 6	9, 7	0, 0	9, 8	16, 16	16, 17
16, 10	16, 11	16, 18	16, 19	16, 14	16, 15	16, 12	16, 1	16, 8
16, 9								
8.000E+01	1.000E-02	0.	0.	1.000E-02	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.

0.

DERIVATIVES 2

2.000E+01 1.000E-02

UNIT 50 TYPE 25 WRITE TR AND WK TO STOTAPE

PARAMETERS 4

1.000E+00 0. 8.759E+03 9.000E+00

INPUTS 2

29, 1 29, 2
16, 16, 16

UNIT 24 TYPE 24 INTEGRATOR 1

INPUTS 10

20, 4	20, 5	20, 6	20, 7	20, 8	20, 9	20, 13	29, 4	29, 5
29, 6								
0.	0.	0.	0.	0.	0.	0.	0.	0.
0.								

UNIT 34 TYPE 24 INTEGRATOR 2

INPUTS 5

16, 1	21, 3	21, 4	21, 5	21, 7
0.	0.	0.	0.	0.

UNIT 25 TYPE 25 PRINTER 1

PARAMETERS 4

7.200E+02 0. 8.759E+03 0.

INPUTS 7

24, 1	24, 2	24, 3	24, 7	24, 8	24, 9	24, 10
UHC	WM	UAUX	UOIR	UHEAT	USENS	QLAT

UNIT 35 TYPE 25 PRINTER 2

PARAMETERS 4

7.200E+02 0. 8.759E+03 0.

INPUTS 5

34, 1	34, 2	21, 6	20, 17	20, 18
HI	QU	DELE	NHCYC	NCCYC

*UNIT 36 TYPE 25 PRINTER 3

*PAR 4

*1. 0. 24. 0.

*INPUTS 8

*20, 1 20, 2 20, 3 29, 1 29, 2 2, 1 4, 1 6, 1

*THPU WMPD FLUWK TR WK HEAT1 HEAT2 CUUL1

UNIT 15 TYPE 15 1 IS HEATING, 0 IS OFF

PARAMETERS 3

0. 0. 1.200E+01

INPUTS 2

20, 10 20, 12
0. 0.

UNIT 17 TYPE 15 SOURCE TEMP WHEN HP ON IN HTG. MODE
 * -(QA=L)-QLUAD, -(QHP=L)-(QDIR=L), EDB COOLING

PARAMETERS 31
 0. -1.000E+00 5.000E-01 4.000E+00 -1.000E+00 -1.000E+00 1.000E+00 8.000E+00 -1.000E+00
 -1.000E+00 1.000E+00 -1.000E+00 1.000E+00 3.000E+00 0. 1.000E+00 -3.000E+00 0.
 7.000E+00 0. 4.000E+00 -3.000E+00 0. 7.000E+00 0. 4.000E+00 -3.000E+00
 0. 0. 1.000E+00 -3.000E+00
 INPUTS 8
 20, 10 21, 1 20, 6 29, 4 20, 4 20, 13 20, 11 20, 1
 0. 0. 0. 0. 0. 0. 0. 0.

UNIT 18 TYPE 15 DELIVERY TEMP WHEN HEATING

PARAMETERS 1
 1.000E+00
 INPUTS 2
 15, 1 20, 1
 0. 0.

UNIT 19 TYPE 15 ALGEBRAIC OPERATOR
 * PRODUCES SINK TEMP WHEN HP ON IN COOLING MODE AND TANK TEMP DURING
 * WINTER FOR OUTPUT., MT WHEN COLLECTOR ON, TOTAL
 * COOLING LOAD PROVIDED BY HP, TOTAL COOLING LOAD

PARAMETERS 23
 0. 0. 1.000E+00 -3.000E+00 -1.000E+00 1.000E+00 0. 4.000E+00 -1.100E+01
 1.000E+00 -3.000E+00 0. 0. 1.000E+00 -3.000E+00 0. 0. 3.000E+00
 -3.000E+00 0. 0. 3.000E+00 -3.000E+00
 INPUTS 4
 21, 1 6, 1 14, 1 21, 8 16, 1 20, 7 20, 8 29, 5 29, 6
 0. 0. 0. 0. 0. 0. 0. 0. 0.

UNIT 13 TYPE 15 ALGEBRAIC OPERATOR
 *THIRD PARAMETER IS FAN 6 (AUXILIARY FAN) KJ/HR
 *SEVENTH PARAMETER IS PUMPS 1 AND 2 (COLLECTOR LOOP PUMP) KJ/HR
 *SEVENTEENTH PARAMETER IS PUMP 4 (DIRECT SOLAR LOOP PUMP) KJ/HR
 *TWENTYSECOND PARAMETER IS PUMP 3 AND FAN 7 (REJECTION LOOP) KJ/HR

PARAMETERS 40
 0. -1.000E+00 6.710E+02 1.000E+00 0. -1.000E+00 1.342E+03 1.000E+00 3.000E+00
 0. -1.000E+00 1.000E+04 9.000E+00 -1.100E+01 1.100E+01 -3.000E+00 -1.000E+00 6.710E+02
 1.000E+00 3.000E+00 0. -1.000E+00 2.013E+03 1.000E+00 3.000E+00 -3.000E+00 0.
 3.000E+00 0. 3.000E+00 0. 3.000E+00 -3.000E+00 0. 0. 3.000E+00
 -3.000E+00 0. 7.000E+00 -3.000E+00
 INPUTS 10
 20, 12 21, 8 20, 13 30, 3 20, 6 20, 5 20, 9 29, 5 29, 6
 29, 4 0. 0. 0. 0. 0. 0. 0. 0. 0.
 0. 0. 0. 0. 0. 0. 0. 0. 0.

UNIT 48 TYPE 25 PRINT FINAL TANK TEMP
 PARAMETERS 4
 8.759E+03 0.
 INPUTS 1
 21, 1
 TANK

UNIT 49 TYPE 15 COMPUTE HEATING SEASON TOTAL ELEC
 PARAMETERS 11
 0. 1.000E+01 -3.000E+00 0. 1.000E+00 -3.000E+00 0. 3.000E+00 0.
 3.000E+00 -3.000E+00
 INPUTS 4
 14, 1 13, 2 20, 5 20, 6
 0. 0. 0. 1.000E+00

UNIT 27 TYPE 27 HISTOGRAM PLOTTER (MODE 1)
 *PLOTS: EDB(1), TR(2), TSOURCE(3), HEATING CYCLE LENGTH,
 * COOLING CYCLE LENGTH, (QAUX + WH + WC + PARASITICS)
 * SINK TEMP, TANK TEMP, HUMIDITY RATIO
 *
 PARAMETERS 32
 1.000E+00 8.759E+03 8.759E+03 0. 8.759E+03 2.000E+01 6.800E+01 2.400E+01 1.500E+01
 3.400E+01 2.400E+01 0. 4.800E+01 2.400E+01 1.000E+01 1.210E+01 2.400E+01 1.000E+01
 1.210E+01 2.400E+01 5.000E+02 6.050E+04 2.400E+01 7.000E+00 5.500E+01 2.400E+01 1.000E+00
 4.700E+01 2.400E+01 1.000E+03 2.500E+02 2.400E+01
 INPUTS 9
 16, 1 24, 1 17, 1 20, 19 20, 20 13, 3 19, 1 19, 2 29, 2
 0. 0. 0. 0. 0. 0. 0. 0. 0.

UNIT 26 TYPE 27 HISTOGRAM PLOTTER (MODE 2)
 *PLOTS: QAUX, WH, WC, (QAUX + WH + WC + PARASITICS),
 * (USENS + QLAI), GHEAT
 *
 PARAMETERS 23
 2.000E+00 8.759E+03 8.759E+03 0. 8.759E+03 0. 2.400E+01 2.400E+01 0.
 2.400E+01 2.400E+01 0. 2.400E+01 2.400E+01 0.
 2.400E+01 2.400E+01 0. 2.400E+01 2.400E+01
 INPUTS 6
 20, 6 20, 5 20, 9 13, 3 13, 4 13, 5
 0. 0. 0. 0. 0. 0.

UNIT 28 TYPE 28 SIMULATION SUMARIZER-MONTHLY
 * HEATING MODE OPERATION
 PARAMETERS 40
 -1.000E+00 0. 8.759E+03 0. 0. -3.000E+00 0. -1.000E+00 4.300E+01
 1.000E+00 2.000E+00 -3.000E+00 -1.100E+01 -0. -1.000E+00 4.300E+01 1.000E+00 2.000E+00
 -3.000E+00 0. -3.000E+00 0. -3.000E+00 0. -3.000E+00 2.000E+00 -4.000E+00
 0. -3.000E+00 -1.000E+00 1.000E+00 0. 0. 0. -3.000E+00 7.000E+00
 3.000E+00 2.000E+00 4.000E+00 -3.000E+00
 INPUTS 10
 21, 3 16, 1 19, 3 20, 13 20, 4 20, 5 20, 6 13, 3 19, 5
 29, 4
 LABELS 10
 G0 CULEFF CEFFON WDIR=L WMP=L WMPH COPH QA=L QLOAD
 FSSHC

UNIT 31 TYPE 28 SIMULATION SUMMARIZER - MONTHLY

* COOLING MODE OPERATION

PARAMETERS 24

-1.000E+00	0.	8.759E+03	0.	0.	-3.000E+00	0.	-3.000E+00	0.
-3.000E+00	0.	-3.000E+00	2.000E+00	-3.000E+00	0.	-3.000E+00	0.	-3.000E+00
0.	-3.000E+00	0.	-3.000E+00	0.	-3.000E+00			
INPUTS 9								
20, 7	20, 8	19, 4	20, 9	29, 5	29, 6	19, 5	5, 5	13, 2
LABELS 10								
WSCC	WLCC	WTCC	WHPC	CUPC	WSLOAD	QLLOAD	QTLOAD	QREJ
SHCPAR								

UNIT 38 TYPE 28 SIMULATION SUMMARIZER - MONTHLY

* ENERGY BALANCES

PARAMETERS 30

-1.000E+00	0.	8.759E+03	0.	0.	-3.000E+00	0.	-3.000E+00	0.
-3.000E+00	-1.200E+01	0.	3.000E+00	0.	3.000E+00	0.	4.000E+00	0.
3.000E+00	0.	3.000E+00	-3.000E+00	0.	0.	3.000E+00	-1.400E+01	3.000E+00
-1.700E+01	4.000E+00	-3.000E+00						
INPUTS 10								
21, 7	21, 5	21, 4	17, 3	20, 5	5, 5	19, 4	20, 9	19, 5
17, 2								
LABELS 5								
GDUMP	QTNK	QENV	EBTANK	EBLOAD				

UNIT 32 TYPE 28 SIMULATION SUMMARIZER - MONTHLY

* RUN TIMES

PARAMETERS 28

-1.000E+00	0.	8.759E+03	0.	0.	-3.000E+00	0.	-3.000E+00	0.
-3.000E+00	0.	-3.000E+00	0.	-3.000E+00	0.	-3.000E+00	0.	-3.000E+00
-1.000E+00	1.000E+00	0.	0.	7.000E+00	2.000E+00	4.000E+00	-3.000E+00	0.
-3.000E+00								
INPUTS 10								
15, 1	13, 1	20, 10	20, 12	21, 8	20, 11	30, 3	49, 3	29, 4
49, 2								
LABELS 9								
HRHFG	HRDSL	HRMPH	HRIFAN	HRCDLL	HRHPC	HRRL	FSSH	SHPAR

UNIT 33 TYPE 28 SIMULATION SUMMARIZER - MONTHLY

* AVERAGE STATE VARIABLES

PARAMETERS 32

-1.000E+00	0.	8.759E+03	0.	0.	-2.000E+00	2.000E+00	-3.000E+00	0.
-2.000E+00	2.000E+00	-3.000E+00	0.	-2.000E+00	2.000E+00	-3.000E+00	0.	-2.000E+00
2.000E+00	-3.000E+00	0.	-2.000E+00	2.000E+00	-3.000E+00	0.	0.	2.000E+00
-3.000E+00	0.	0.	2.000E+00	-3.000E+00				
INPUTS 9								
29, 1	29, 2	9, 6	9, 7	21, 1	18, 1	15, 1	17, 4	20, 11
LABELS 7								
ATR	AWK	ATAMB	AWAMB	ATTANK	ATDELM	ATDELC		

END

TRNSYS - A TRANSIENT SIMULATION PROGRAM
FROM THE SOLAR ENERGY LAB AT THE UNIVERSITY OF WISCONSIN
VERSION 9.2 2/1/78

*FORT WORTH - LIQUID SERIES SYSTEM - BASE CASE

*LIQUID BASED SOLAR SYSTEM W/ PARALLEL HEAT PUMP AND DHW

SIMULATION 0. 8.759E+03 1.250E-01

TOLERANCES 1.000E-03 1.000E-03

LIMITS 30 10

WIDTH 132

UNIT 9 TYPE 9 DATA READER

PARAMETERS 10

4.000E+00 1.000E+00 6.000E+00 1.000E+00 -2.730E+02 7.000E+00 1.000E-05 0. 2.000E+01

1.000E+00

(2X,3F2.0,F5.0,F5.0,F4.1,8X,F4.0,2X,F3.1,2X,F5.2)

UNIT 16 TYPE 16 SOLAR RADIATION PROCESSOR

PARAMETERS 18

4.000E+00 1.000E+00 3.800E+01 4.871E+03 2.000E-01 -7.500E+00 4.800E+01 0. 9.000E+01

4.000E+01 4.800E+01 1.800E+02 9.000E+01 -9.000E+01 9.000E+01 0. 9.000E+01 1.800E+02

INPUTS 2

9. 5 9. 4

0. 0.

UNIT 14 TYPE 14 SUMMER/WINTER FORCING FUNCTION

*SUMMER = 1, WINTER = 0

PARAMETERS 12

0. 0. 3.217E+03 0. 3.217E+03 1.000E+00 6.553E+03 1.000E+00 6.553E+03

0. 8.759E+03 0.

UNIT 2 TYPE 2 1ST STAGE HEATING

PARAMETERS 3

5.000E+00 1.000E+00 -1.000E+00

INPUTS 3

0. 0 29. 1 2. 1

2.100E+01 2.200E+01 0.

UNIT 4 TYPE 2 2ND STAGE HEATING

PARAMETERS 3

5.000E+00 1.000E+00 -3.000E+00

INPUTS 3

0. 0 29. 1 4. 1

1.900E+01 2.200E+01 0.

UNIT 6 TYPE 2 COOLING
 PARAMETERS 3
 5.000E+00 1.000E+00 -1.000E+00
 INPUTS 3
 29. 1 0. 0 6. 1
 2.200E+01 2.550E+01 0.

UNIT 15 TYPE 15 .NOT. AND .AND. OPERATOR
 PARAMETERS 4
 0. 0. 1.000E+01 1.100E+01
 INPUTS 2
 2. 1 4. 1
 0. 0.

UNIT 8 TYPE 2 MIN TEMP FOR DIRECT SOLAR HTG
 PARAMETERS 3
 5.000E+00 1.000E+00 -1.000E+00
 INPUTS 3
 21. 1 0. 0 8. 1
 4.000E+01 4.020E+01 0.

UNIT 1 TYPE 15 .AND.
 PARAMETERS 1
 1.100E+01
 INPUTS 2
 8. 1 15. 1
 0. 0.

UNIT 3 TYPE 3 DIRECT SOLAR HEATING LOOP PUMP
 PARAMETERS 1
 2.425E+03
 INPUTS 1
 5. 1 5. 3 1. 1
 2.200E+01 0. 0.

UNIT 50 TYPE 14 MAIN WATER FORCING SUPPLY TEMPERATURE
 PARAMETERS 48
 0. 0.000E+00 7.440E+02 0.000E+00 7.440E+02 0.000E+00 1.416E+03 0.000E+00 1.416E+03
 1.100E+01 2.100E+03 1.100E+01 2.100E+03 1.300E+01 2.880E+03 1.300E+01 2.880E+03 1.700E+01
 5.624E+03 1.700E+01 3.624E+03 1.900E+01 4.344E+03 1.900E+01 4.344E+03 1.900E+01 5.088E+03
 1.900E+01 5.088E+03 2.600E+01 5.832E+03 2.600E+01 5.832E+03 2.600E+01 6.552E+03 2.600E+01
 6.552E+03 2.000E+01 7.296E+03 2.000E+01 7.296E+03 1.300E+01 8.016E+03 1.300E+01 8.016E+03
 6.000E+00 6.760E+03 8.000E+00

UNIT 23 TYPE 23 DHW SUBSYSTEM
 *FLOW RATE IS PARAMETER IN UNIT 13
 PARAMETERS 14
 -5.000E+02 4.500E+01 1.000E+03 4.190E+00 2.000E+00 1.500E+00 6.000E+01 4.190E+00 4.500E+02
 7.000E+01 5.000E+00 1.000E+00 2.000E+01 9.800E+01
 INPUTS 4
 21. 1 0. 0 50. 1 0. 0
 4.000E+01 4.500E+02 1.000E+01 2.110E+01

UNIT 11 TYPE 11 TEE PIECE

PARAMETERS 1

1.000E+00

INPUTS 4

3, 1

4.000E+01

3, 2

4.500E+02

23, 1

4.000E+01

23, 2

0.

UNIT 21 TYPE 21 LIQUID SUBSYSTEM
*COLLECTOR AREA IS PARAMETER IN UNIT 28

PARAMETERS 15

4.300E+01

7.000E-01

INPUTS 6

16, 1

0.

2.688E+03

8.600E+00

9, 6

1.000E+01

3.350E+00

1.000E+03

11, 1

4.000E+01

2.150E+03

2.000E+00

11, 2

0.

4.190E+00

1.000E+00

0, 0

2.000E+01

8.600E-01

2.000E+01

0, 0

0.

8.300E-01

1.890E+01

1.000E+02

UNIT 5 TYPE 5 CROSSFLOW HEAT-EXCHANGER (CUNTSANT EFF.)

PARAMETERS 4

4.000E+00

INPUTS 4

21, 1

4.000E+01

7.660E-01

3, 2

0.

4.190E+00

29, 1

2.200E+01

1.012E+00

29, 3

0.

UNIT 20 TYPE 20 TEMP. LEVEL CONTROL HEAT PUMP

PARAMETERS 17

1.000E+00

0.

INPUTS 7

5, 3

2.200E+01

3.500E+01

9.120E+02

29, 2

1.000E-02

-1.944E+01

1.900E+03

5, 4

0.

1.944E+01

1.490E+02

1, 1

0.

2.100E+01

3.950E+04

4, 1

0.

2.200E+01

2.296E+03

6, 1

0.

8.000E+00

2.111E+01

9, 6

1.000E+01

4.000E+00

2.667E+01

0.

UNIT 29 TYPE 29 COMBINED LOAD MODEL

PARAMETERS 41

2.000E+00

2.000E+00

0.

4.800E+01

8.314E-03

INPUTS 19

20, 1

16, 10

16, 9

8.000E+01

0.

0.

0.

DERIVATIVES 2

2.000E+01

1.012E+00

3.700E-02

7.620E-01

4.800E+01

1.150E-03

20, 2

16, 11

16, 10

1.000E-02

0.

0.

0.

1.000E-02

1.300E+01

5.000E-01

2.440E+00

4.000E+00

-7.305E-01

20, 3

16, 18

0.

0.

0.

0.

0.

1.373E+02

8.000E-01

3.000E+00

3.000E+00

8.735E-02

9, 6

16, 19

0.

0.

0.

0.

0.

3.698E+02

5.686E+01

6.000E+01

5.100E-01

-2.010E-03

9, 7

16, 14

0.

0.

0.

0.

0.

2.300E+01

3.790E+01

1.486E+01

5.100E-01

0, 0

16, 15

0.

0.

0.

0.

0.

2.000E+04

1.500E-01

6.000E+01

5.100E-01

0, 0

16, 12

0.

0.

0.

0.

0.

5.000E+02

1.500E-01

8.036E+01

2.478E-04

9, 8

16, 16

16, 1

0.

0.

0.

0.

0.

1.000E+00

1.500E-01

3.674E+02

6.633E-03

16, 17

16, 8

0.

0.

0.

0.

0.

UNIT 24 TYPE 24 INTEGRATOR 1

INPUTS 9

20, 4

0.

20, 5

0.

20, 6

0.

20, 7

0.

20, 8

0.

20, 9

0.

29, 4

0.

29, 5

0.

29, 6

0.

UNIT 34 TYPE 24 INTEGRATOR 2

INPUTS 6

16, 1

0.

21, 3

0.

21, 4

0.

21, 5

0.

21, 7

0.

5, 5

0.

UNIT 25 TYPE 25 PRINTER 1

PARAMETERS 4

7.200E+02

INPUTS 9

24, 1

GMC

0.

24, 2

HM

8.759E+03

24, 3

GAUX

0.

24, 4

GSCC

0.

24, 5

QLCC

0.

24, 6

MC

0.

24, 7

QHEAT

0.

24, 8

QSENS

0.

24, 9

QLAT

```

UNIT 35      TYPE 25      PRINTER 2
PARAMETERS 4
7.200E+02    0.          8.759E+03    0.
INPUTS 9
34, 1        34, 2        34, 3        34, 4        21, 6        34, 5        20,17        20,18        23, 9
HT           GU           GENV          QTNK         DELE         QDUMP        NHCYC        NCCYC        DHWDE
*UNIT 36 TYPE 25 PRINTER 3
*PAR. 4
*1. 0. 24. 0.
*INPUTS 9
*29,1 29,2 29,3 5,3 20,1 20,2 2,1 4,1 6,1
*TR WR FLWR THPI THPU WHPU IH1 IH2 IC

UNIT 17      TYPE 15      .OR. OPERATOR
PARAMETERS 1
1.200E+01
INPUTS 2
1, 1        4, 1
0.          0.

UNIT 18      TYPE 15      DELIVERED AIR TEMP WHEN HEATING
PARAMETERS 1
1.000E+00
INPUTS 2
17, 1       20, 1
0.          0.

UNIT 19      TYPE 15      SOURCE TEMP DURING HP HEATING MODE
PARAMETERS 21
0.          -1.000E+00    5.000E-01    4.000E+00    -1.000E+00    -1.000E+00    1.000E+00    8.000E+00    -1.000E+00
-1.000E+06    1.000E+00    -1.000E+00    1.000E+00    3.000E+00    0.          1.000E+00    -3.000E+00    0.
0.          1.000E+00    -3.000E+00
INPUTS 4
20,10       9, 6        16, 1        21, 8
0.          0.          0.          0.

UNIT 37      TYPE 15      ALGEBRAIC OPERATOR
*1. PRODUCES SINK TEMP WHEN HP ON IN COOLING MODE
*2. TANK TEMP. IN HEATING SEASON
*3. GHEAT
PARAMETERS 12
0.          0.          1.000E+00    -3.000E+00    0.          0.          1.000E+01    1.000E+00    -3.000E+00
0.          7.000E+00    -3.000E+00
INPUTS 5
9, 6        6, 1        21, 1        14, 1        29, 4
0.          0.          0.          0.          0.

```


UNIT 26 TYPE 27 HISTOGRAM PLOTTER (MODE 2)

*PLOTS: 1. GAUX.

*2. GAUX DHW.

*3. WHPH

*4. WHPH

*5. (GAUX + WH + WC + PARASITICS).

* GAUX + WH + WC + PARASITICS + DHW GAUX + DHW PARASITICS

* 7. (QSENS * QLAT).

*8. QHEAT

PARAMETERS 29

2.000E+00	8.759E+03	8.759E+03	0.	8.759E+03	0.	2.400E+01	2.400E+01	0.
2.400E+01	2.400E+01	0.	2.400E+01	2.400E+01	0.	2.400E+01	2.400E+01	0.
2.400E+01	2.400E+01	0.	2.400E+01	2.400E+01	0.	2.400E+01	2.400E+01	0.
2.400E+01	2.400E+01							

INPUTS 8

20, 6	23, 7	20, 5	20, 9	13, 3	13, 7	13, 8	37, 3
0.	0.	0.	0.	0.	0.	0	0

UNIT 28 TYPE 28 SIMULATION SUMMARIZER-MONTHLY

* HEATING MODE OPERATION

*PARAMETERS 9 AND 16 ARE COLLECTOR AREA

PARAMETERS 39

-1.000E+00	0.	8.759E+03	0.	0.	-3.000E+00	0.	-1.000E+00	4.300E+01
1.000E+00	2.000E+00	-4.000E+00	-1.100E+01	0.	-1.000E+00	4.300E+01	1.000E+00	2.000E+00
-4.000E+00	0.	-3.000E+00	0.	-3.000E+00	0.	-3.000E+00	2.000E+00	-4.000E+00
0.	-3.000E+00	-1.000E+00	1.000E+00	0.	-4.000E+00	0.	0.	7.000E+00
2.000E+00	4.000E+00	-3.000E+00						

INPUTS 10

21, 3	16, 1	19, 2	5, 5	20, 4	20, 5	20, 6	29, 4	39, 4
-------	-------	-------	------	-------	-------	-------	-------	-------

29, 4

LABELS 10

QU	COLEFF	CEFFON	QDIR=L	QHP=L	WHPH	COPH	QA=L	QLOAD
----	--------	--------	--------	-------	------	------	------	-------

FSSH

UNIT 31 TYPE 28 SIMULATION SUMMARIZER - MONTHLY

* COOLING MODE AND DOMESTIC WATER HEATING SUBSYSTEM OPERATION

PARAMETERS 27

-1.000E+00	0.	8.759E+03	0.	0.	-3.000E+00	0.	-3.000E+00	3.000E+00
-3.000E+00	0.	-3.000E+00	2.000E+00	-3.000E+00	0.	-3.000E+00	0.	-3.000E+00
3.000E+00	-3.000E+00	-1.000E+00	2.090E+02	0.	1.000E+00	-3.000E+00	0.	-3.000E+00

INPUTS 7

20, 7	20, 8	20, 9	29, 5	29, 6	23, 4	23, 5
-------	-------	-------	-------	-------	-------	-------

LABELS 10

QSCC	QLCC	QTCC	WHPH	CUPC	QSLD	QLLD	QTLD	DHWD
------	------	------	------	------	------	------	------	------

DHWIN

UNIT 32 TYPE 28 SIMULATION SUMMARIZER - MONTHLY
 • DOMESTIC HOT WATER HEATING OPERATION AND ENERGY BALANCES

PARAMETERS 29

-1.000E+00	0.	8.759E+03	0.	0.	-3.000E+00	0.	-4.000E+00	0.
-4.000E+00	-1.000E+00	2.090E+02	0.	1.000E+00	2.000E+00	-3.000E+00	0.	-3.000E+00
0.	-3.000E+00	0.	-4.000E+00	0.	4.000E+00	-3.000E+00	0.	-3.000E+00
0.	-3.000E+00							

INPUTS 10

23, 6	23, 8	23, 7	23, 4	21, 7	21, 5	21, 4	5, 5	39, 2
-------	-------	-------	-------	-------	-------	-------	------	-------

13, 5

LABELS 10

DHWTNK

DHWENV

DHWAUX

FSDHW

QDUMP

QTNK

QENV

EBTANK

EBLOAD

DHWPAR

UNIT 33 TYPE 28 SIMULATION SUMMARIZER-MONTHLY
 • RUN TIMES

PARAMETERS 20

-1.000E+00	0.	8.759E+03	0.	0.	-3.000E+00	0.	-3.000E+00	0.
-3.000E+00	0.	-3.000E+00	0.	-3.000E+00	0.	-3.000E+00	0.	-3.000E+00

0. -3.000E+00

INPUTS 8

17, 1	13, 1	13, 4	20, 10	20, 12	21, 8	20, 11	13, 2
-------	-------	-------	--------	--------	-------	--------	-------

LABELS 8

HRMTG

HRDSL

HRDHW

HRHMH

HRIFAN

HRCOLL

HRMPC

SHCPAR

UNIT 38 TYPE 28 SIMULATION SUMMARIZER - MONTHLY
 • AVERAGE STATE VARIABLES

PARAMETERS 36

-1.000E+00	0.	8.759E+03	0.	0.	-2.000E+00	2.000E+00	-3.000E+00	0.
-2.000E+00	2.000E+00	-3.000E+00	0.	-2.000E+00	2.000E+00	-3.000E+00	0.	-2.000E+00
2.000E+00	-3.000E+00	0.	-2.000E+00	2.000E+00	-3.000E+00	0.	0.	2.000E+00
-3.000E+00	0.	0.	2.000E+00	-3.000E+00	0.	-2.000E+00	2.000E+00	-3.000E+00

INPUTS 10

29, 1	29, 2	9, 6	9, 7	21, 1	18, 1	17, 1	39, 3	20, 11
-------	-------	------	------	-------	-------	-------	-------	--------

23, 3

LABELS 8

ATK

AWK

ATAMB

AWAMB

ATTANK

ATDELH

ATDELC

ATPHT

UNIT 48 TYPE 25 PRINTER
 • PRINT ROOM TEMP, HUMIDITY RATIO ON FILE

PARAMETERS 4

1.000E+00	0.	8.759E+03	9.000E+00
-----------	----	-----------	-----------

INPUTS 2

29, 1	29, 2
-------	-------

TK

WK

END

THNSYS - A TRANSIENT SIMULATION PROGRAM
FROM THE SOLAR ENERGY LAB AT THE UNIVERSITY OF WISCONSIN
VERSION 9.2 2/1/78

*MADISON - LIQUID SERIES SYSTEM - BASE CASE

*LIQUID - BASED SERIES SYSTEM - WITH AUTOMATIC SEASON SWITCHOVER

SIMULATION 0. 6.759E+03 1.250E-01

TOLERANCES 1.000E-03 1.000E-03

LIMITS 30 10

WIDTH 132

UNIT 9 TYPE 9 DATA READER

PARAMETERS 10

9.000E+00 1.000E+00 6.000E+00 1.000E+00 -2.732E+02 7.000E+00 1.000E-05 0. 2.000E+01

1.000E+00

(2X,3F2.0,F5.0,F5.0,F4.1,8X,F4.0,2X,F3.1,2X,F5.2)

UNIT 14 TYPE 14 SUMMER/WINTER INDICATOR FORCING FUNCTION

* SUMMER=1, WINTER=0

PARAMETERS 12

0. 0. 2.881E+03 0. 2.881E+03 1.000E+00 6.889E+03 1.000E+00 6.889E+03

0. 8.759E+03 0.

UNIT 1 TYPE 2 SUMMER HEAT REJECT CONTROL

PARAMETERS 3

5.000E+00 7.000E+00 5.000E+00

INPUTS 3

21. 1 9. 0 1. 1

4.000E+01 1.000E+01 0.

UNIT 30 TYPE 15 ALGEBRAIC OPERATOR

* TAKES INPUTS FROM TWO CNTRL FUNCTIONS AND MULTIPLIES THEM

* THEM TOGETHER AND WITH TWO FLOW RATES TO GIVE FLOW RATES FOR FAN COIL

PARAMETERS 18

0. 0. 1.000E+00 -1.000E+00 2.300E+03 1.000E+00 -3.000E+00 -1.100E+01 -1.200E+01

1.000E+00 -1.000E+00 3.275E+03 1.000E+00 -3.000E+00 -1.000E+00 3.275E+03 2.000E+00 -3.000E+00

INPUTS 2

14. 1 1. 1

0. 0.

```

UNIT 5      TYPE 5      FAN COIL
PARAMETERS 4
4.000E+00   8.000E-01   4.190E+00   1.012E+00
INPUTS 4
21, 1      30, 1      9, 6      30, 2
4.000E+01   0.      1.000E+01   0.

UNIT 11     TYPE 11     TEE PIECE
PARAMETERS 1
1.000E+00
INPUTS 4
20, 14     20, 15     5, 1      5, 2
4.000E+01   0.      1.000E+01   0.

UNIT 16     TYPE 16     SOLAR RADIATION PROCESSOR
PARAMETERS 18
4.000E+00   1.000E+00   3.300E+01   4.371E+03   2.000E-01   -7.500E+00   4.300E+01   0.      9.000E+01
4.000E+01   4.300E+01   1.600E+02   9.000E+01   -9.000E+01   9.000E+01   0.      9.000E+01   1.800E+02
INPUTS 3
9, 5      9, 4      0, 0
0.      0.      0.

UNIT 21     TYPE 21     LIQ. SYSTEM COMBINED COMPONENT
PARAMETERS 15
5.000E+01   3.125E+03   3.350E+00   2.500E+03   4.190E+00   9.000E-01   8.800E-01   3.067E+01   1.000E+02
7.000E-01   1.000E+01   1.000E+03   2.000E+00   1.000E+00   1.300E+01
INPUTS 6
10, 1      9, 6      11, 1      11, 2      0, 0      14, 1
0.      1.000E+01   4.000E+01   0.      2.000E+01   0.

UNIT 2      TYPE 2      1ST STAGE HEATING
PARAMETERS 3
5.000E+00   1.000E+00   -1.000E+00
INPUTS 3
0, 0      29, 1      2, 1
2.100E+01   2.200E+01   0.

UNIT 4      TYPE 2      2ND STAGE HEATING
PARAMETERS 3
5.000E+00   1.000E+00   -3.000E+00
INPUTS 3
0, 0      29, 1      4, 1
1.900E+01   2.200E+01   0.

UNIT 6      TYPE 2      COOLING
PARAMETERS 3
5.000E+00   1.000E+00   -1.000E+00
INPUTS 3
29, 1      0, 0      6, 1
2.200E+01   2.550E+01   0.

UNIT 20     TYPE 20     TEMP LEVEL CONTROL HEAT PUMP
PARAMETERS 21
5.000E+00   3.500E+01   1.670E+00   4.020E+01   2.100E+01   2.200E+01   8.000E+00   6.000E+00   0.
0.      7.790E+02   1.633E+03   0.      3.950E+04   2.296E+03   2.111E+01   2.667E+01   1.700E+03
4.190E+00   4.020E+01   7.660E-01
INPUTS 7
29, 1      29, 2      29, 3      2, 1      4, 1      6, 1      21, 1
2.200E+01   1.000E+02   0.      0.      0.      0.      2.000E+01

```


UNIT 29 TYPE 29 COMBINED LOAD MODEL

PARAMETERS 41

2.000E+00	1.012E+00	1.500E+01	-1.840E+02	3.698E+02	2.300E+01	2.000E+04	5.000E+02	1.000E+00
2.000E+00	3.700E+02	5.000E+01	8.000E+01	4.162E+01	2.378E+01	1.500E+01	1.500E+01	1.500E+01
0.	7.620E+01	2.440E+00	2.000E+00	1.138E+02	2.218E+01	1.138E+02	1.672E+02	7.646E+02
4.300E+01	4.300E+01	4.000E+00	3.000E+00	5.100E+01	5.100E+01	5.100E+01	1.309E+04	5.070E+03
6.615E+03	1.846E+03	7.813E+01	1.815E+01	-9.642E+03				

INPUTS 19

20, 1	20, 2	20, 3	9, 6	9, 7	0, 0	9, 8	16, 16	16, 17
16, 10	16, 11	16, 18	16, 19	16, 14	16, 15	16, 12	16, 1	16, 8
16, 9								
8.000E+01	1.000E+02	0.	0.	1.000E+02	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.
0.								

DERIVATIVES 2

2.000E+01	1.000E+02
-----------	-----------

UNIT 50 TYPE 25 WRITE TR AND WR TO SIOIAPF

PARAMETERS 4

1.000E+00	0.	8.759E+03	9.000E+00
-----------	----	-----------	-----------

INPUTS 2

29, 1	29, 2
TR	WR

UNIT 24 TYPE 24 INTEGRATOR 1

INPUTS 10

20, 4	20, 5	20, 6	20, 7	20, 8	20, 9	20, 13	29, 4	29, 5
29, 6	0.	0.	0.	0.	0.	0.	0.	0.
0.								

UNIT 34 TYPE 24 INTEGRATOR 2

INPUTS 5

16, 1	21, 3	21, 4	21, 5	21, 7
0.	0.	0.	0.	0.

UNIT 25 TYPE 25 PRINTER 1

PARAMETERS 4

7.200E+02	0.	8.759E+03	0.
-----------	----	-----------	----

INPUTS 7

24, 1	24, 2	24, 3	24, 7	24, 8	24, 9	24, 10
WHL	WM	QWUA	GWIR	WHEAT	WSENS	WLAT

UNIT 35 TYPE 25 PRINTER 2

PARAMETERS 4

7.200E+02	0.	8.759E+03	0.
-----------	----	-----------	----

INPUTS 5

34, 1	34, 2	21, 6	20, 17	20, 18
HI	WD	DELE	WMLTC	WCCYC

*UNIT 36 TYPE 25 PRINTER 3

*PAR 4

*1. 0. 24. 0.

*INPUTS 8

*20, 1 20, 2 20, 3 29, 1 29, 2 2, 1 4, 1 6, 1

*THP0 WHPU FLOWR TR WR HEAT1 HEAT2 COOL1

UNIT 15 TYPE 15 1 IS HEATING, 0 IS OFF

PARAMETERS 3

0.	0.	1.200E+01
----	----	-----------

INPUTS 2

20, 10	20, 12
0.	0.

UNIT 17 TYPE 15 SOURCE TEMP WHEN HP ON IN HTG. MODE
 *-(QW-L)=WLOAD, -(QHP-L)=(QDIR-L), EDB COOLING

PARAMETERS 31

0.	-1.000E+00	5.000E-01	4.000E+00	-1.000E+00	-1.000E+00	1.000E+00	8.000E+00	-1.000E+00
-1.000E+00	1.000E+00	-1.000E+00	1.000E+00	3.000E+00	0.	1.000E+00	-3.000E+00	0.
7.000E+00	0.	4.000E+00	-3.000E+00	0.	7.000E+00	0.	4.000E+00	-3.000E+00
0.	0.	1.000E+00	-3.000E+00					
INPUTS 8								
20,10	21, 1	20, 0	29, 4	20, 4	20,13	20,11	20, 1	
0.	0.	0.	0.	0.	0.	0.	0.	

UNIT 18 TYPE 15 DELIVERY TEMP WHEN HEATING

PARAMETERS 1

1.000E+00

INPUTS 2

15, 1 20, 1
 0. 0.

UNIT 19 TYPE 15 ALGEBRAIC OPERATOR
 * PRODUCES SINK TEMP WHEN HP ON IN COOLING MODE AND TANK TEMP DURING
 * WINTER FOR OUTPUT, HT WHEN COLLECTOR ON, TOTAL
 * COOLING LOAD PROVIDED BY HP, TOTAL COOLING LOAD

PARAMETERS 23

0.	0.	1.000E+00	-3.000E+00	-1.000E+00	1.000E+00	0.	4.000E+00	-1.100E+01
1.000E+00	-3.000E+00	0.	0.	1.000E+00	-3.000E+00	0.	0.	3.000E+00
-3.000E+00	0.	0.	3.000E+00	-3.000E+00				
INPUTS 9								
21, 1	0, 1	14, 1	21, 0	10, 1	20, 7	20, 8	29, 5	29, 6
0.	0.	0.	0.	0.	0.	0.	0.	0.

UNIT 13 TYPE 15 ALGEBRAIC OPERATOR
 *THIRD PARAMETER IS FAN 6 (AUXILIARY FAN) KJ/HR
 *SEVENTH PARAMETER IS PUMPS 1 AND 2 (COLLECTOR LOOP PUMP) KJ/HR
 *SEVENTEENTH PARAMETER IS PUMP 4 (DIRECT SOLAR LOOP PUMP) KJ/HR
 *TWENTYSECOND PARAMETER IS PUMP 3 AND FAN 7 (REJECTION LOOP) KJ/HR

PARAMETERS 40

0.	-1.000E+00	6.710E+02	1.000E+00	0.	-1.000E+00	1.342E+03	1.000E+00	3.000E+00
0.	-1.000E+00	1.000E-04	9.000E+00	-1.100E+01	1.100E+01	-3.000E+00	-1.000E+00	6.710E+02
1.000E+00	3.000E+00	0.	-1.000E+00	2.013E+03	1.000E+00	3.000E+00	-3.000E+00	0.
3.000E+00	0.	3.000E+00	0.	3.000E+00	-3.000E+00	0.	0.	3.000E+00
-3.000E+00	0.	7.000E+00	-3.000E+00					
INPUTS 10								
20,12	21, 8	20,13	30, 3	20, 6	20, 5	20, 9	29, 5	29, 6
29, 4								
0.	0.	0.	0.	0.	0.	0.	0.	0.
0.								

UNIT 48 TYPE 25 PRINT FINAL TANK TEMP

PARAMETERS 4

8.750E+03 0. 8.759E+03 0.

INPUTS 1

21, 1

TNK

UNIT 49 TYPE 15 COMPUTE HEATING SEASON TOTAL ELEC

PARAMETERS 11

0.	1.000E+01	-3.000E+00	0.	1.000E+00	-3.000E+00	0.	3.000E+00	0.
3.000E+00	-3.000E+00							
INPUTS 4								
14, 1	13, 2	20, 5	20, 6					
0.	0.	0.	1.000E+00					

UNIT 27 TYPE 27 HISTOGRAM PLOTTER (MODE 1)

*PLOTS: EDB(1), TR(2), TSOURCE(3), HEATING CYCLE LENGTH,
* COOLING CYCLE LENGTH, (QAUX + WH + WC + PARASITICS)
* SINK TEMP, TANK TEMP, ROOM HUMIDITY RATIO

PARAMETERS 32

1.000E+00	8.759E+03	8.759E+03	0.	8.759E+03	2.000E+01	6.800E+01	2.400E+01	1.500E+01
3.900E+01	2.400E+01	0.	4.800E+01	2.400E+01	1.000E+01	1.210E+01	2.400E+01	1.000E+01
1.210E+01	2.400E+01	5.000E+02	6.050E+04	2.400E+01	7.000E+00	5.500E+01	2.400E+01	2.000E+00
9.800E+01	2.400E+01	1.000E+03	2.500E+02	2.400E+01				
INPUTS 9								
18, 1	29, 1	17, 1	20, 19	20, 20	13, 3	19, 1	19, 2	29, 2
0.	0.	0.	0.	0.	0.	0.	0.	0.

UNIT 26 TYPE 27 HISTOGRAM PLOTTER (MODE 2)

*PLOTS: QAUX, WH, WC, (QAUX + WH + WC + PARASITICS),
* (USENS + GLAT), QHEAT

PARAMETERS 23

2.000E+00	8.759E+03	8.759E+03	0.	8.759E+03	0.	2.400E+01	2.400E+01	0.
2.400E+01	2.400E+01	0.	2.400E+01	2.400E+01	0.	2.400E+01	2.400E+01	0.
2.400E+01	2.400E+01	0.	2.400E+01	2.400E+01				
INPUTS 6								
20, 6	20, 5	20, 9	13, 3	13, 4	13, 5			
0.	0.	0.	0.	0.	0.			

UNIT 28 TYPE 28 SIMULATION SUMARIZER-MONTHLY

* HEATING MODE OPERATION

PARAMETERS 40

-1.000E+00	0.	8.759E+03	0.	0.	-3.000E+00	0.	-1.000E+00	4.300E+01
1.000E+00	2.000E+00	-3.000E+00	-1.100E+01	0.	-1.000E+00	4.300E+01	1.000E+00	2.000E+00
-3.000E+00	0.	-3.000E+00	0.	-3.000E+00	0.	-3.000E+00	2.000E+00	-4.000E+00
0.	-3.000E+00	-1.000E+00	1.000E+00	0.	0.	0.	-3.000E+00	7.000E+00
3.000E+00	2.000E+00	4.000E+00	-3.000E+00					
INPUTS 10								

21, 3	16, 1	19, 3	20, 13	20, 4	20, 5	20, 6	13, 3	19, 5
29, 4								
LABELS 10								
20	CUREFF	CEFFUN	QUIN=L	UMPH=E	WHPH	CUPH	QA=L	QLOAD
ESSHC								

UNIT 31 TYPE 28 SIMULATION SUMMARIZER - MONTHLY

* COOLING MODE OPERATION

PARAMETERS 24

-1.000E+00	0.	8.759E+03	0.	0.	-3.000E+00	0.	-3.000E+00	0.
-3.000E+00	0.	-3.000E+00	2.000E+00	-3.000E+00	0.	-3.000E+00	0.	-3.000E+00
0.	-3.000E+00	0.	-3.000E+00	0.	-3.000E+00			
INPUTS 4								
20, 1	20, 6	19, 4	20, 9	29, 5	29, 6	19, 5	5, 5	13, 2
LABELS 10								
QSCC	QLCC	QTEC	WAPC	DOPC	USLOAD	ULLUAD	QTLUAD	QREJ
SHCFAR								

UNIT 30 TYPE 28 SIMULATION SUMMARIZER - MONTHLY

* ENERGY BALANCES

PARAMETERS 30

-1.000E+00	0.	8.759E+03	0.	0.	-3.000E+00	0.	-3.000E+00	0.
-3.000E+00	-1.200E+01	0.	3.000E+00	0.	3.000E+00	0.	4.000E+00	0.
3.000E+00	0.	3.000E+00	-1.000E+00	0.	0.	3.000E+00	-1.400E+01	3.000E+00
-1.000E+01	4.000E+00	-3.000E+00						
INPUTS 10								
21, 1	21, 5	21, 4	17, 3	20, 5	5, 5	19, 4	20, 9	19, 5
17, 2								
LABELS 5								
WBUMP	WINK	QENV	EBTANK	EBLUAD				

UNIT 32 TYPE 28 SIMULATION SUMMARIZER - MONTHLY

* RUN TIMES

PARAMETERS 20

-1.000E+00	0.	8.759E+03	0.	0.	-3.000E+00	0.	-3.000E+00	0.
-3.000E+00	0.	-3.000E+00	0.	-3.000E+00	0.	-3.000E+00	0.	-3.000E+00
-1.000E+00	1.000E+00	0.	0.	7.000E+00	2.000E+00	4.000E+00	-3.000E+00	0.
-3.000E+00								
INPUTS 10								
15, 1	15, 1	20, 10	20, 12	21, 8	20, 11	30, 3	49, 3	29, 4
49, 2								
LABELS 9								
HRHIG	HRDSL	HRHPH	HRIFAN	HRCOLL	HRHPC	HRRL	FSSH	SHPAN

UNIT 33 TYPE 28 SIMULATION SUMMARIZER - MONTHLY

* AVERAGE STATE VARIABLES

PARAMETERS 32

-1.000E+00	0.	8.759E+03	0.	0.	-2.000E+00	2.000E+00	-3.000E+00	0.
-2.000E+00	2.000E+00	-3.000E+00	0.	-2.000E+00	2.000E+00	-3.000E+00	0.	-2.000E+00
2.000E+00	-3.000E+00	0.	-2.000E+00	2.000E+00	-3.000E+00	0.	0.	2.000E+00
-3.000E+00	0.	0.	2.000E+00	-3.000E+00				
INPUTS 9								
24, 1	24, 2	4, 6	9, 7	21, 1	16, 1	15, 1	17, 4	20, 11
LABELS 7								
ATK	ATK	ATAMB	AWAMP	ATTANK	ATDELM	ATDELC		

END

TRNSYS - A TRANSIENT SIMULATION PROGRAM
FROM THE SOLAR ENERGY LAB AT THE UNIVERSITY OF WISCONSIN
VERSION 9.2 2/1/78

*WASHINGTON - LIQUID SERIES SYSTEM - BASE CASE

*LIQUID - BASED SERIES SYSTEM - WITH AUTOMATIC SEASON SWITCHOVER

SIMULATION 0. 6.759E+03 1.250E-01

TOLERANCES 1.000E-03 1.000E-03

LIMITS 30 10

WIDTH 132

UNIT 9 TYPE 9 DATA READER

PARAMETERS 10

4.000E+00 1.000E+00 6.000E+00 1.000E+00 -2.732E+02 7.000E+00 1.000E-05 0. 2.000E+01

1.000E+00

(2X,3F2.0,F5.0,F5.0,F4.1,BX,F4.0,2X,F3.1,2X,F5.2)

UNIT 14 TYPE 14 SUMMER/WINTER INDICATOR FORCING FUNCTION

* SUMMER=1, WINTER=0

PARAMETERS 12

0. 0. 3.961E+03 0. 3.961E+03 1.000E+00 5.833E+03 1.000E+00 5.833E+03

0. 6.759E+03 0.

UNIT 1 TYPE 2 SUMMER HEAT REJECT CONTROL

PARAMETERS 3

5.000E+00 7.000E+00 5.000E+00

INPUTS 3

21, 1 4, 0 1, 1

4.000E+01 1.000E+01 0.

UNIT 30 TYPE 15 ALGEBRAIC OPERATOR

* TAKES INPUTS FROM TWO CTRL FUNCTIONS AND MULTIPLIES THEM

* THEM TOGETHER AND WITH TWO FLOW RATES TO GIVE FLOW RATES FOR FAN COIL

PARAMETERS 18

0. 0. 1.000E+00 -1.000E+00 2.300E+03 1.000E+00 -3.000E+00 -1.100E+01 -1.200E+01

1.000E+00 -1.000E+00 3.275E+03 1.000E+00 -3.000E+00 -1.000E+00 3.275E+03 2.000E+00 -3.000E+00

INPUTS 2

14, 1 1, 1

0. 0.

UNIT 5 TYPE 5 FAN COIL

PARAMETERS 4

4.000E+00 8.000E-01 4.190E+00 1.012E+00

INPUTS 4

21, 1 30, 1 4, 0 30, 2

4.000E+01 0. 1.000E+01 0.

UNIT 11 TYPE 11 TEE PIECE

PARAMETERS 1

1.000E+00

INPUTS 4

20, 14 20, 15 5, 1 5, 2

4.000E+01 0. 1.000E+01 0.

```

UNIT 16      TYPE 16      SOLAR RADIATION PROCESSOR
PARAMETERS 18
4.000E+00    1.000E+00    4.300E+01    5.371E+03    2.000E+01    -7.500E+00    5.300E+01    0.      9.000E+01
9.000E+01    5.300E+01    1.800E+02    9.000E+01    -9.000E+01    9.000E+01    0.      9.000E+01    1.800E+02
INPUTS 5
9, 5        9, 4        0, 0
0.          0.          0.

UNIT 21      TYPE 21      LIQ. SYSTEM COMBINED COMPONENT
PARAMETERS 15
6.900E+01    4.378E+03    3.350E+00    3.500E+03    4.190E+00    9.000E-01    8.800E-01    3.067E+01    1.000E+02
7.000E-01    1.380E+01    1.000E+03    2.000E+00    1.000E+00    9.000E+00
INPUTS 6
10, 1       9, 6        11, 1       11, 2       0, 0        14, 1
0.          1.000E+01    4.000E+01    0.          2.000E+01    0.

UNIT 2       TYPE 2       1ST STAGE HEATING
PARAMETERS 3
5.000E+00    1.000E+00    -1.000E+00
INPUTS 3
0, 0        29, 1       2, 1
2.100E+01    2.200E+01    0.

UNIT 4       TYPE 2       2ND STAGE HEATING
PARAMETERS 3
5.000E+00    1.000E+00    -3.000E+00
INPUTS 3
0, 0        29, 1       4, 1
1.900E+01    2.200E+01    0.

UNIT 6       TYPE 2       COOLING
PARAMETERS 3
5.000E+00    1.000E+00    -1.000E+00
INPUTS 3
29, 1       0, 0        6, 1
2.200E+01    2.550E+01    0.

UNIT 20      TYPE 20      TEMP LEVEL CONTROL HEAT PUMP
PARAMETERS 21
5.000E+00    5.500E+01    1.670E+00    4.020E+01    2.100E+01    2.200E+01    8.000E+00    6.000E+00    0.
0.          7.790E+02    1.633E+03    0.          3.950E+04    2.296E+03    2.111E+01    2.667E+01    1.700E+03
4.190E+00    4.020E+01    7.660E-01
INPUTS 7
29, 1       29, 2       29, 3       2, 1       4, 1       6, 1       21, 1
2.200E+01    1.000E-02    0.          0.          0.          0.          2.000E+01

UNIT 29      TYPE 29      COMBINED LOAD MODEL
PARAMETERS 41
2.000E+00    1.012E+00    6.000E+00    1.346E+02    3.698E+02    2.300E+01    2.000E+04    5.000E+02    1.000E+00
3.000E+00    3.700E-02    5.000E-01    8.000E-01    4.088E+01    2.304E+01    1.500E-01    1.500E-01    1.500E-01
0.          7.620E-01    1.524E+00    3.000E+00    1.316E+02    2.962E+01    1.316E+02    1.579E+02    7.221E+02
5.300E+01    5.300E+01    4.000E+00    3.000E+00    5.100E-01    5.100E-01    5.100E-01    2.478E-04    6.633E-03
8.314E-04    1.150E-03    -7.305E-01    8.735E-02    -2.010E-03
INPUTS 19
20, 1       20, 2       20, 3       9, 6       9, 7       0, 0       9, 8       16, 16      16, 17
16, 10      16, 11      16, 18      16, 19      16, 14      16, 15      16, 12      16, 1       16, 8
16, 9
5.000E+01    1.000E-02    0.          0.          1.000E-02    0.          0.          0.          0.
0.          0.          0.          0.          0.          0.          0.          0.          0.
0.
DERIVATIVES 2
2.000E+01    1.000E-02

```

UNIT 50 TYPE 25 WRITE TR AND WR TO STOTAPE
 PARAMETERS 4
 1.000E+00 0. 8.759E+03 9.000E+00
 INPUTS 2
 29, 1 29, 2
 TR WR

UNIT 24 TYPE 24 INTEGRATOR 1
 INPUTS 10
 20, 4 20, 5 20, 6 20, 7 20, 8 20, 9 20, 13 29, 4 29, 5
 29, 6 0. 0. 0. 0. 0. 0. 0. 0. 0.
 0. 0. 0. 0. 0. 0. 0. 0. 0.

UNIT 34 TYPE 24 INTEGRATOR 2
 INPUTS 5
 10, 1 21, 3 21, 4 21, 5 21, 7
 0. 0. 0. 0. 0.

UNIT 25 TYPE 25 PRINTER 1
 PARAMETERS 4
 7.200E+02 0. 8.759E+03 0.
 INPUTS 7
 24, 1 24, 2 24, 3 24, 7 24, 8 24, 9 24, 10
 QMC WH GAUX QDIR GHEAT GSENS GLAT

UNIT 35 TYPE 25 PRINTER 2
 PARAMETERS 4
 7.200E+02 0. 8.759E+03 0.
 INPUTS 5
 34, 1 34, 2 21, 6 20, 17 20, 18
 HI GU DELE NHLYC NCCYC

*UNIT 36 TYPE 25 PRINTER 3
 *PAR 4
 *1. 0. 24. 0.
 *INPUTS 8
 *20, 1 20, 2 20, 3 29, 1 29, 2 2, 1 4, 1 6, 1
 *TRP(1) WHP(1) FLWRK TR WR HEAT1 HEAT2 COOL1

UNIT 15 TYPE 15 1 IS HEATING, 0 IS OFF
 PARAMETERS 3
 0. 0. 1.200E+01
 INPUTS 2
 20, 10 20, 12
 0. 0.

UNIT 17 TYPE 15 SOURCE TEMP WHEN HP UN IN HTG. MODE
 *-(QA-L)=QLDAD, -(QHP-L)=(QDIR-L), EUB COOLING
 PARAMETERS 31
 0. -1.000E+00 5.000E+01 4.000E+00 -1.000E+00 -1.000E+00 1.000E+00 8.000E+00 -1.000E+00
 -1.000E+00 1.000E+00 -1.000E+00 1.000E+00 3.000E+00 0. 1.000E+00 -3.000E+00 0.
 7.000E+00 0. 4.000E+00 -3.000E+00 0. 7.000E+00 0. 4.000E+00 -3.000E+00
 0. 0. 1.000E+00 -3.000E+00
 INPUTS 8
 20, 10 21, 1 20, 6 29, 4 20, 4 20, 13 20, 11 20, 1
 0. 0. 0. 0. 0. 0. 0. 0.

UNIT 18 TYPE 15 DELIVERY TEMP WHEN HEATING

PARAMETERS 1

1.000E+00

INPUTS 2

15, 1 20, 1

0. 0.

UNIT 19 TYPE 15 ALGEBRAIC OPERATOR

* PRODUCES SINK TEMP WHEN HP ON IN COOLING MODE AND TANK TEMP DURING

* WINTER FOR OUTPUT, HI WHEN COLLECTOR ON, TOTAL

* COOLING LOAD PROVIDED BY HP, TOTAL COOLING LOAD

PARAMETERS 23

0. 0. 1.000E+00 -3.000E+00 -1.000E+00 1.000E+00 0. 4.000E+00 -1.100E+01

1.000E+00 -3.000E+00 0. 0. 1.000E+00 -3.000E+00 0. 0. 3.000E+00

-3.000E+00 0. 0. 3.000E+00 -3.000E+00

INPUTS 9

21, 1 0, 1 14, 1 21, 8 10, 1 20, 7 20, 8 29, 5 29, 6

0. 0. 0. 0. 0. 0. 0. 0. 0.

UNIT 13 TYPE 15 ALGEBRAIC OPERATOR

* THIRD PARAMETER IS FAN 6 (AUXILIARY FAN) KJ/HR

* SEVENTH PARAMETER IS PUMPS 1 AND 2 (COLLECTOR LOOP PUMP) KJ/HR

* SEVENTEENTH PARAMETER IS PUMP 4 (DIRECT SOLAR LOOP PUMP) KJ/HR

* TWENTYSECOND PARAMETER IS PUMP 3 AND FAN 7 (REJECTION LOOP) KJ/HR

PARAMETERS 40

0. -1.000E+00 0.710E+02 1.000E+00 0. -1.000E+00 1.342E+03 1.000E+00 3.000E+00

0. -1.000E+00 1.000E+04 9.000E+00 -1.100E+01 1.100E+01 -3.000E+00 -1.000E+00 0.710E+02

1.000E+00 3.000E+00 0. -1.000E+00 2.013E+03 1.000E+00 3.000E+00 -3.000E+00 0.

3.000E+00 0. 3.000E+00 0. -3.000E+00 0. 0. 3.000E+00

-3.000E+00 0. 7.000E+00 -3.000E+00

INPUTS 10

20, 12 21, 8 20, 13 30, 3 20, 6 20, 5 20, 9 29, 5 29, 6

24, 4 0. 0. 0. 0. 0. 0. 0. 0. 0.

0. 0. 0. 0. 0. 0. 0. 0. 0.

UNIT 48 TYPE 25 PRINT FINAL TANK TEMP

PARAMETERS 4

0.750E+03 0. 0.750E+03 0.

INPUTS 1

21, 1

END

UNIT 49 TYPE 15 COMPUTE HEATING SEASON TOTAL ELEC

PARAMETERS 11

0. 1.000E+01 -3.000E+00 0. 1.000E+00 -3.000E+00 0. 3.000E+00 0.

3.000E+00 -3.000E+00

INPUTS 4

14, 1 15, 2 20, 5 20, 6

0. 0. 0. 1.000E+00

UNIT 27 TYPE 27 HISTOGRAM PLOTTER (MODE 1)

* PLOTS: EDB(1), TR(2), TSOURCE(3), HEATING CYCLE LENGTH,

* COOLING CYCLE LENGTH, (WAUX + WH + WC + PARASITICS)

* SINK TEMP, TANK TEMP, RUOM HUMIDITY RATIO

PARAMETERS 32

1.000E+00 0.750E+03 0.750E+03 0. 0.750E+03 2.000E+01 0.800E+01 2.400E+01 1.500E+01

3.900E+01 2.400E+01 0. 4.800E+01 2.400E+01 1.000E+01 1.210E+01 2.400E+01 1.000E+01

1.210E+01 2.400E+01 5.000E+02 0.050E+04 2.400E+01 7.000E+00 5.500E+01 2.400E+01 2.000E+00

9.800E+01 2.400E+01 1.000E+03 2.500E+02 2.400E+01

INPUTS 9

10, 1 29, 1 17, 1 20, 19 20, 20 13, 3 19, 1 19, 2 29, 2

0 0 0 0. 0. 0. 0. 0. 0.

UNIT 33 TYPE 28 SIMULATION SUMMARIZER - MONTHLY

AVERAGE STATE VARIABLES

PARAMETERS 32

-1.000E+00	0.	8.759E+03	0.	0.	-2.000E+00	2.000E+00	-3.000E+00	0.
-2.000E+00	2.000E+00	-3.000E+00	0.	-2.000E+00	2.000E+00	-3.000E+00	0.	-2.000E+00
2.000E+00	-3.000E+00	0.	-2.000E+00	2.000E+00	-3.000E+00	0.	0.	2.000E+00
-5.000E+00	0.	0.	2.000E+00	-3.000E+00				
INPUTS 9								
29, 1	29, 2	9, 6	9, 7	21, 1	18, 1	15, 1	17, 4	20, 11
CARDS 7								
AIR	AWK	AIAMB	AWAMB	ATTANK	ATDELH	ATDELC		

END

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7. Author(s) N. M. White; J. H. Morehouse		6.	
9. Performing Organization Name and Address Science Applications, Incorporated Solar Technology Division (347) 1764 Old Meadow Lane McLean, Virginia 22102		8. Performing Organization Rept. No.	
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15. Supplementary Notes Technical Monitor: Lyle Groome		14.	
16. Abstract (Limit: 200 words) A sensitivity study is performed of the engineering and economic parameters affecting life-cycle costs for solar-assisted heat pump systems. The change in energy usage resulting from each engineering parameter varied has been developed from computer simulations, and is compared with results from a stand-alone heat pump system. Three geographical locations are considered: Washington, D.C., Fort Worth, Texas, and Madison, Wisconsin. Results indicate that most engineering changes to the systems studied do not provide significant energy savings. The most promising parameters to vary are the solar collector parameters α and U_L the heat pump capacity at design point, and the minimum utilizable evaporator temperature. Costs associated with each change are estimated, and life-cycle costs computed for both engineering parameters and economic variations in interest rate, discount rate, tax credits, fuel unit costs and fuel inflation rates. Results indicate that none of the feasible engineering changes for the system configuration studied will make these systems economically competitive with the stand-alone heat pump without a considerable tax credit.			
17. Document Analysis a. Descriptors Cost Benefit Analysis; Economic Analysis:Q1; Financial Incentives; Life-Cycle Cost; Sensitivity Analysis:Q1; Solar-Assisted Heat Pumps:T1; Air Conditioners; Appliances; Cost; Economics; Electric Appliances; Heat Exchangers; Heat Pumps; b. Identifiers/Open-Ended Terms Heating Systems; Solar Air Conditioners; Solar Cooling Systems; Solar Heating Systems; Hot Water Systems c. UC Categories 59, 59c			
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