Chapter III

CALCULATION OF BACKUP REQUIREMENTS

Chapter III.- CALCULATION OF BACKUP REQUIREMENTS

Page

LIST OF TABLES

LIST OF FIGURES

Chapter III

Calculation of Backup Requirements

The calculations presented in the previous chapter required an analysis of conventional and solar energy equipment operating in real environments. The techniques used to perform such an analysis were discussed generically in previous chapters. The following discussion reviews the analytical method in some detail. The Fortran programs used to perform the calculations reported elsewhere in this study are based on the methods described in this chapter and are reproduced in full in appendix III-B.

The analysis of system performance requires three basic steps:

1. Determine the onsite energy demand of the building (In the case of residences, this includes heating, cooling, hot water, and miscellaneous electrical demands.)
2. Determine the out put of solar collectors.
3. Determine the fraction of the on site energy demand that can be met from solar energy directly or from storage and the fraction that must be supplied from external energy sources (utility electricity, gas, or oil).

These three steps were performed for each hour of the year using measurements of the air temperature and available sunlight recorded during 1962 (1963 in the case of Boston). The calculation of the heating and cooling requirements of buildings was based on: the external temperature; an assumed pattern of occupancy and appliance use; and, assumed thermodynamic characteristics of the buildings. A program (E-cube) developed by the American Gas Association was used to convert the weather data and building descriptions into an hourly estimate of the demand for heating and cooling. Chapter V discusses the assumptions made about the buildings, and the assumptions made about patterns of occupancy, appliance usage, hot water demands, etc.

The performance of collectors was discussed generically in chapter VIII of the first volume and the methods actually used in the analysis are discussed in the final section of this chapter.

A critical question in the operation of a solar energy system is the amount of backup energy required and the pattern of this backup demand. Assessing the performance of an integrated system is a complex problem, however, and techniques have not yet been developed for optimizing the performance of such systems. The next few pages discuss techniques for approximating the optimum performance of several tyyes of solar cogeneration systems including the optimum operation of Possible combinations Of storage equipment.

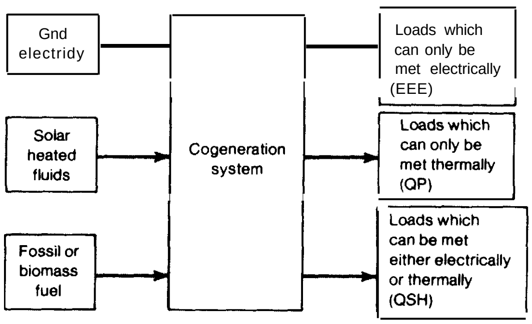
CONTROL STRATEGIES FOR COGENERATION SYSTEMS

Minimizing the energy required to operate both solar and fossil-fired cogeneration or total energy systems requires a careful control strategy. For example, it is necessary to: 1) optimally allocate the space-conditioning load between electrically powered heating or cooling equipment and heat-driven equipment (e.g., electric versus absorption chilling for heat pumps versus direct heating); 2) determine the optimum ratio between thermal energy and electric energy produced by the cogeneration engines; 3) determine the best strategy for charging and discharging storage; and 4) determine the best strategy for buying energy from or selling energy to an electric utility or other backup power source. (Optimizing this last choice requires considering how the cogeneration strategy affects costs everywhere in the utility, which is a much more complex problem than the one addressed here.) In general, the more flexible the system, the less backup the system will require since complex controls can ensure that the system is operated as close as possible to the thermodynamic optimum for providing the necessary work. Greater flexibility and sophistication of controls often mean an increase in system costs, and the economic merits of these control systems will need to be determined on a case-by-case basis. The problem of optimizing system designs and control strategies taking full account of all of the real choices and constraints has not been fully solved. All that is offered here is a reasonable technique for approaching an optimum allocation, More work needs to be done in this area.

The following discussion presents algorithms for minimizing fuel use for a variety of different types of equipment. In most cases, controls for providing the kind of switching called for in the calculations are not now available; however, there is no reason to believe that such controls could not be developed if a demand for the systems emerged. Control systems can probably be manufactured quite inexpensively using modern electronics. Unfortunately, the control systems used on contemporary cogeneration systems have been relatively primitive, and there are few standardized designs.

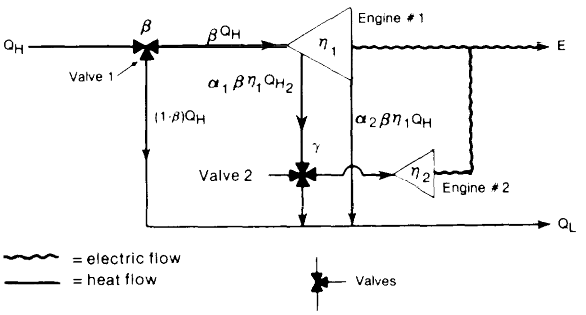
Figure Ill-1 illustrates the general problem. Energy enters from three sources: 1) high-temperature heat from a solar collector, 2) high-temperature heat from fossil fuel available as backup, and 3) electricity used as a backup. Three kinds of energy demands must be met: 1) demands that can only be met electrically (e. g., artificial lighting), which is called EEE; 2) demands that can be met either with electrical equipment or with thermal energy (e.g., refrigeration can be achieved with an electrically driven compressor or with thermally driven absorption equipment, and space heating can be achieved using thermal energy directly or with electric heating), which is called QSH; and, 3) loads that can be best met with direct thermal energy when it is available (e.g., domestic hot water or process heat), which is called QP.

Figure Ill-1 .—The Problem



The problem can best be understood by following the flow of energy from the initial source of high-temperature energy (Q_H) to the demands, examining the decisions that must be made at each point. The first choice needed is whether the high-temperature energy should be sent to the engines or be used directly. Figure III-2 shows valve #1 which splits the high-temperature heat sending $ßQ_H$ to the engines and (1 – $ßQ_H$ to the thermal loads where ß represents the valve setting. The high-temperature heat enters the first engine and is converted into an electrical output of ßQHql, where η_1 is the efficiency of the first engine. Some of the energy not converted to electricity is available as heated fluids. In a completely general case, two waste heat streams may be available: a "low-quality" waste heat stream at a temperature too low for use in a bottoming cycle; and, a "high-quality" stream, which can be used in a second engine. In the calculations that follow, the ratio between the energy available as "high-quality" heat and the electrical output of the first 'engine is called α_1, and the ratio of the energy available as "low-quality" heat to the electrical output of the first engine is called α_2.

Figure III-2.—Simplified System Diagram



If a second, or bottoming cycle, engine is available, a choice must be made about the optimum use of the high-quality waste heat stream. The second valve can be used to send part of this energy to the second engine and part directly to thermal loads. The setting of this valve is indicated through the variable γ. When γ is 1, all of the high-quality waste heat is sent to the second engine.

With this notation, the net thermal (Q_T) and electrical (E) output of the system can be written as follows:

$$(E/Q_H) = \beta\eta_1(1 + \gamma\alpha_1\eta_2) \tag{1}$$

$$(Q_T/Q_H) = (1 - \beta) + \beta\eta_1((1 - \gamma)\alpha_1 + \alpha_2) \tag{2}$$

Here η_2 is the efficiency of the second engine. The problem becomes one of minimizing Q_H for fixed energy demands E and Q_T. If there is no thermal demand, clearly the optimum valve settings are β = 1 and γ =1. It can be shown that as thermal demands increase, the best strategy will use the following procedure: 1) leave β = 1 and γ = 1 until the waste heat generated in this way cannot meet the thermal demands, 2) reduce the energy entering the second engine (i. e., γ <1) while leaving β = 1 until the thermal demand cannot be met with β =1, 3) meet additional thermal demands by leaving γ = O and reducing β. (See appendix I I I-A.)

The method for determining Q_H, β, and γ for a given E and Q_L is as follows:

If $Q_L \leq \alpha_2 E/(1 + \alpha_1\eta_2)$, then

$$\beta = 1$$
$$\gamma = 1 \tag{3}$$
$$Q_H = E/(\eta_1(1 + \alpha_1\eta_2))$$

If $\alpha_2 E/(1 + \alpha_1\eta_2) \leq Q_L < (\alpha_1 + \alpha_2)E$, then

$$\beta = 1 \tag{4}$$
$$\gamma = [E(\alpha_1 + \alpha_2) - Q_L]/[\alpha_1(Q_L\eta_2 + E)]$$

If $(\alpha_1 + \alpha_2)E < Q_L$, then

$$\beta = E/[E(1 - \eta_1(\alpha_1 + \alpha_2)) + \eta_1 Q_L]$$
$$\gamma = 0 \tag{5}$$
$$Q_H = E/\beta\eta_1$$

Another layer of complexity now has to be added to describe optimum use of E and Q_L to meet the demands EEE, QSH, and QP. The QSH load can be met electrically or thermally. The performance of the electric units is described by the electric coefficient of performance COPE. Similarly, the coefficient of performance for the thermal unit is called CO PA.

If COPA > η_1 (COPE + (α_1+ α_2) COPA), it is more efficient to use high-temperature thermal energy directly than to run it through the heat engine and use the waste heat and electricity. If this condition is not true, it is more efficient to meet some of the space-conditioning load (QSH) electrically, If two engines are available, the best use of the high-quality waste heat must be determined (e. g., is it more efficient to run it through the second heat engine or to use it directly?). If η_2COPE > COPA, it is more efficient to run the high-quality waste heat through engine #2 and then use the electricity generated to meet the space-conditioning load instead of using the high-quality waste heat directly (through COPA) to meet the space-conditioning load.

The availability of storage equipment adds another dimension of complexity. Three types of storage are possible in cogeneration systems: 1) high-temperature storage; 2) low-temperature storage; and 3) electric storage. It is assumed that storage is never charged with backup power except in the cases where backup fossil heat is used to meet electric needs and excess waste heat produced in the process is available to charge the low-temperature storage.

Low-temperature storage should not be charged directly from collector output; it is only charged when there is excess waste heat or when there is overflow from high-temperature storage. The use of high-temperature energy is minimized if all available energy in low-temperature storage is used before any high-temperature energy is used. High-temperature energy is kept in reserve since storing energy in this high-quality form maximizes the flexibility of using the available energy. A special problem arises when both batteries and high-temperature storage are available. It is assumed that batteries will be more expensive than high-temperature storage and therefore batteries should be kept charged whenever possible to maximize their use. This in turn assumes that the batteries were sized in an optimum way. When the high-temperature storage is filled, the overflow is sent to be stored in low-temperature storage. When low-temperature storage is filled, the overflow is discarded in a cooling tower or in some other way. If it is possible to sell excess electricity to an electric utility grid, however, this analysis assumes that an attempt is made to use the amount of high-temperature energy that exceeds the capacity of high-temperature storage to generate electricity for sale. The amount of electricity that can be sold is limited by the maximum generating capacity specified for the engines. In no case is electricity sold when high-temperature storage (when available) is not filled to capacity.

It should be noticed that in the analysis displayed here, it has been necessary to specify the hierarchy with which the storage units are charged and discharged. The priorities for using energy are: 1) meet onsite energy demands; 2) charge batteries; 3) charge high-temperature storage; 4) sell electricity to the grid; and, 5) charge low-temperature storage. In some cases meeting the electrical requirements results in a situation where low-temperature storage is charged because excess waste heat is available. The priorities for discharging storage are: 1) discharge low-temperature storage; 2) discharge high-temperature storage; and, 3) discharge battery storage. Given this set of priorities, it is possible to optimize the use of available energy. While a reasonable case can be made for the priorities specified, it is entirely possible that system performance could be improved with a more sophisticated strategy. Solving this problem, and thereby allowing an optimum choice of storage types and capacities, would require that economic factors be considered along with the analysis of energy use. Such an optimization has not been attempted in this study.

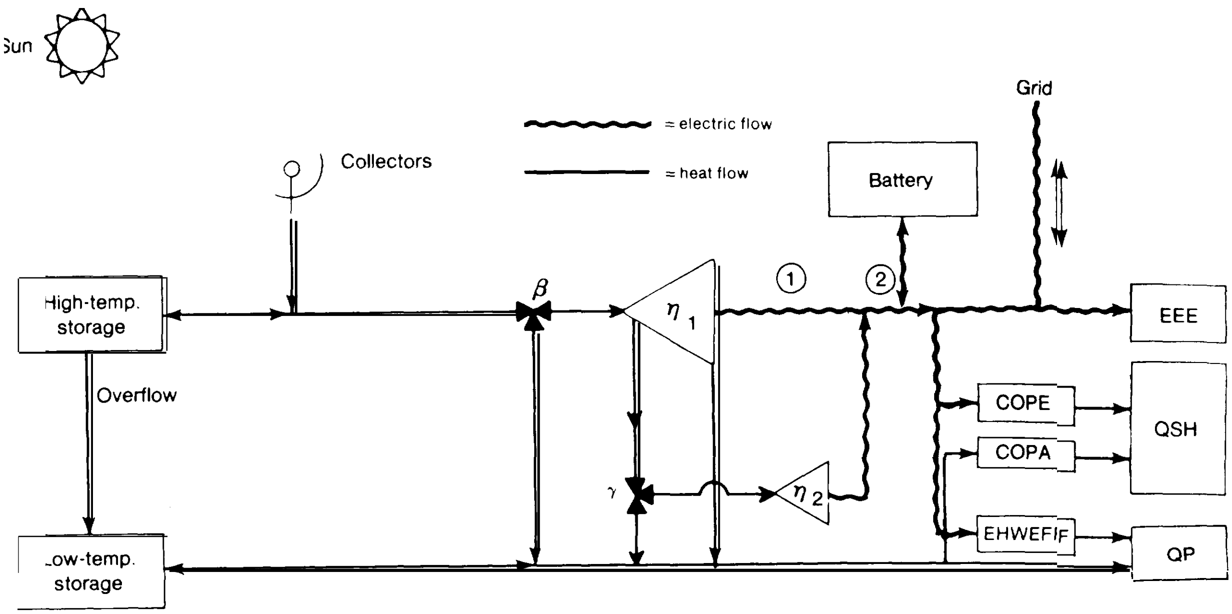
It can be seen that optimizing a generalized cogeneration system can be complex. The following sections present a detailed description of the logic used in a computer program designed to simulate the performance of optimized systems (a listing of this program is in appendix III-B). The logic depends on the type of backup energy available.

COGENERATION SYSTEM WITH ELECTRIC BACKUP

Figure III-3 shows the most general form for a cogeneration system which relies entirely on an electric utility for backup. As the loads must be met either from the output of the solar collectors, storage devices, or by backup electricity purchased from the grid, COPE and EHWEFF (the efficiency of the electric hot water heater) must always be non-zero. In a system with electric backup, energy from the collectors or storage is used to meet onsite energy demands with the following priorities: QP loads, QSH loads, EEE loads.

In the calculations, the system is optimized for each hour of the year. At the beginning of each hour the problem is as follows: Loads EEE, QSH, and QP must be met; the amount of energy in storage is known, and, the amount of high-temperature energy from direct solar energy is known. The problem is one of efficiently using the stored energy and the direct solar energy, and mini-

Figure III-3.—Cogeneration System With Grid Backup



mizing the energy that must be purchased.

The first step is to meet as much of the process load QP (and the space-conditioning load if COPA is non-zero) as possible with the energy available in low-temperature storage. If only part of these loads can be met from low-temperature storage, the process load QP is met first and any remaining energy is used for the QSH load.

The second step is to determine whether enough high-temperature energy is available to meet any QP load remaining after step one. Available high-temperature energy is the sum of the energy in high-temperature storage and the energy available directly from the collector. If the QP loads cannot be met by high-temperature energy (the remaining QP is called QP‘), high-temperature storage is set to zero, and electricity is purchased from the grid in order to meet the remaining loads. The backup electricity which must be purchased in this case (EBU) is given by:

$$EBU = EEE + QSH + QP'/EHWEFF \qquad (6)$$

where EHWEFF is the efficiency of the electric heater used to provide energy for the remaining QP loads [e. g., an electric hot water heater). If the amount of high-temperature energy exceeds QP one of three paths must be taken depending on the relative values of COPA, COPE, η_1, η_2, α_1, and α_2.

A Case Where Thermal Energy Cannot Be Used To Meet the Space. Conditioning Load

If the available high-temperature energy exceeds the process load, it may be possible to meet some of the electrical demands using the available high-temperature energy. A check must first be made to determine whether it is possible to meet the QSH loads with thermal energy (i.e., whether COPA is non-zero). It is assumed that for heating purposes, COPA is always 1.0; therefore COPA can only be zero for a cooling load. If the QSH load cannot be met thermally; a check is then made to determine whether the optimum approach is to use all available high-temperature thermal energy to generate electricity and set β and γ to minimize the output of thermal energy (subject to the constraint that the remaining QP load is met). The available high-temperature thermal energy consists of all energy in high-temperature storage and the energy available directly from the collectors.

A check must then be made to determine whether this results in the output of the first engine exceeding the maximum generating capacity specified. If the maximum is exceeded, it is necessary to recompute $\beta, \gamma,$ and the amount of high-temperature energy used with the constraint that the electricity reaching point 1 in figure II I-3 is equal to the maximum capacity of the first engine.

The next check that must be made is to determine whether the electricity generated now exceeds onsite demands for electricity. These onsite demands consist of: 1) the remaining QP loads; 2) QSH loads; 3) EEE loads; and, 4) charging the batteries at the maximum rate allowed by the power conditioner capacity specified. If the electricity that could be generated during the hour in question exceeds these onsite demands, it might be possible to sell electricity to the utility. A check must first be made, however, to determine whether selling electricity would result in a situation where the high-temperature storage unit was not filled to capacity at the end of the hour. If high-temperature storage would not be full, the amount of energy entering the engines and the valve settings are adjusted to reduce the amount of electricity and leave the high-temperature storage completely filled.

With this check the sequence is completed and the problem can be solved again for the next hour.

A Case Where Thermal Energy Is Used To Meet the Space= Conditioning Load

The previous discussion was limited to cases where QSH could not be met with thermal energy. If the following inequality holds:

$$COPA > \eta_1 (COPE + COPA (\alpha_1 + a_,)) \qquad (7)$$

it is more efficient to meet the QSH loads with direct thermal energy than it is to meet these loads with a cogeneration approach where both thermal (CO PA) and electrical (COPE) equipment are used to meet thermal demands. This case can be treated using a method that is completely analogous to the case explained previously. Al I that is necessary is to define an "effective process load" QP' and an "effective QSH load" QSH' as follows:

$$QP' = QP + QSH/COPA \qquad (8)$$
$$QSH' = O$$

All other steps follow as described above.

A Case Where Using Thermal Energy To Meet the Space-Conditioning Load Is More Efficient Than Using Electricity Generated by the Second Heat Engine

If the following conditions hold:

$$\eta_1 (COPE + 'COPA (\alpha_1 + \alpha_2)) < COPA \qquad (9)$$
$$COPA \geq \eta_2 COPE$$

it is more efficient to meet QSH loads with direct thermal energy from the high-quality waste heat stream than it is to generate electricity with the second engine and use the electrical conversion unit characterized by COPE. Generating electricity with the first engine and using this electricity in the electrical conversion unit and all available waste heat to meet QSH demands thermally is more efficient than using the available high-temperature energy directly to meet the QSH demands.

The first step is to use all energy available in low-temperature storage to meet the QP and QSH demands. The second step is to determine whether the high-temperature energy available (i.e., the solar energy received directly during the hour plus any energy available from high-temperature storage; this sum is called SOLE in the remainder of this discussion) is sufficient to meet the remaining QP load. If the remaining QP cannot be met in this way, QP is reduced by the available energy and backup electricity must be purchased. The amount purchased can be computed using equation (6).

If the available high-temperature energy is greater than the remaining QP, a somewhat complex procedure must be used to determine the optimum valve settings. The steps follow the sequence as outlined in equations (3) through (5), where an attempt is made to use all available high-temperature energy.

It is first determined whether sending all of SOLE through the first engine and all high-quality waste heat through the second engine (i. e., γ = 1 and ß = 1) produces enough waste heat to meet the thermal loads. If the condition:

$$(SOLE)\ \eta_1\alpha_2 \geq QP + QSH/COPA \qquad (10)$$

holds, all QP and QSH loads can be met with low-quality waste heat. γ = 1 and ß = 1 are the best valve settings, and the calculations can proceed to test whether engine maxima are exceeded.

If the inequality in (10) does not hold, it is necessary to send some of the high-quality waste heat directly to the thermal loads or, equivalently, the value of γ must be less than 1. (The theorem proved in appendix III-A shows that it is better to adjust γ than to adjust ß). If the condition:

$$SOLE\ \eta_1(\alpha_1 + \alpha_2) \geq QP + QSH/COPA \qquad (11)$$

holds, then the QP and QSH demands can be met entirely with thermal energy without the need to divert any high-temperature energy from the input of the first engine, although some high-quality waste heat must be diverted from the second engine. The valve settings are then given by:

$$\beta = 1 \qquad (12)$$

$$\gamma = \frac{SOLE\ \eta_1(\alpha_1 + \alpha_2) - QP - QSH/COPA}{SOLE\ \eta_1\alpha_1}$$

If the condition shown in equation (11) is not met, it is necessary to meet some of the QSH loads with electricity. The condition specified in equation (9) implies that it is more efficient to use high-temperature energy in the first engine and run the electricity through an electrical converter with COPE than to use it directly through the thermal conversion equipment characterized by COPA. The next step, therefore, is to determine whether it is possible to meet the QP load with valves set so that ß = 1 and γ = 0. This is possible if the following inequality holds:

$$SOLE\ \eta_1(\alpha_1 + \alpha_2) \geq QP \qquad (13)$$

Some QSH loads may be met thermally with the remainder met electrically from the output of the first engine or (if necessary) from backup electricity.

The amount of QSH that can be met thermally (QCT) is given as follows:

$$QCT = [SOLE\ \eta_1(\alpha_1 + \alpha_2) - QP]\ COPA \qquad (14)$$

If the inequality in equation (13) does not hold, it is not possible to meet the QP loads without diverting some high-temperature energy from the input of the first engine. In this case all of the QSH loads must be met electrically from the output of the first heat engine (or, if necessary, from backup electricity) and the optimum valve settings are as follows:

$$\gamma = 0 \qquad (15)$$

$$\beta = \frac{SOLE - QP}{SOLE\,(1 - \eta_1(\alpha_1 + \alpha_1))}$$

(The quantity ß will never be zero since it was necessary to determine that SOLE was greater than QP in order to reach the sequence of tests just described.)

Having determined the optimum valve settings it is again necessary to determine whether the use of SOLE with the optimum valve settings results in a situation where the first engine is required to produce electricity at a rate which exceeds the specified maximum capacity (ENGMAX). If the following inequality holds,

$$\beta\eta_1\ SOLE > ENGMAX \qquad (16)$$

the engine maximum is exceeded and it is necessary to readjust the valves.

The new valve settings are computed

following a sequence of tests similar to those indicated in equations (10) through (16):

A)

If $QP + QSH/COPA \leq \alpha_2$ ENGMAX, then

$$\beta = 1 \quad \gamma = 1 \qquad (17)$$

B)

If $QP + QSH/COPA \leq (\alpha_1 + \alpha_2)$ ENGMAX

$$\beta = 1 \qquad (18)$$

$$\gamma = \frac{ENGMAX(\alpha_1 + \alpha_2)\, QP - QSH/COPA}{\alpha_1\ ENGMAX}$$

C)

If $QP + QSH/COPA > (\alpha_1 + \alpha_2)$ ENGMAX

$QP \leq (\alpha_1 + \alpha_2)$ ENGMAX (19)

$QSH \leq$ (ENGMAX - EEE)COPE + (ENGMAX$(\alpha_1 + \alpha_2)$ – QP)COPA

Then $\beta = 1$

$\gamma = 0$

The third test involving the miscellaneous electrical load (E E E) is necessary to ensure that there is enough electrical output to meet the QSH loads, which are not met thermally.

D)

If $QP + QSH/COPA > \alpha_2$ ENGMAX **(20)**

$QP \leq (\alpha_1 + \alpha_2)$ ENGMAX

QSH > (ENGMAX - **EEE)COPE +**

ENGMAX $(\alpha_1 + \alpha_2)$ – QP(COPA)

Then

β = [COPA(ENGMAX)] / [η_1QSH + η_1COPE[EEE-ENG MAX] + COPA [QPη_1 + ENGMAX(1 -$(\alpha_1 + \alpha_2)\,\eta_1$)]]

$\gamma = 0$

E)

If $QP > (\alpha_1 + \alpha_2)$ ENGMAX, then (21)

$$\beta = \frac{ENGMAX}{ENGMAX(1-\eta_1(\alpha_1 + \alpha_2)) + \eta_1 QP}$$

$\gamma = 0$

In each case a check must be made to determine the amount of electricity available for charging the battery.

With this, the correct valve settings have been determined. As before, however, a check must be made to determine whether using the specified settings will leave the high-temperature storage filled. If the high-temperature storage is not filled at the end of the hour, and if the use of the optimum valve settings results in a situation where electricity would be sold to the utility, the system should be adjusted to use less high-temperature energy. (A similar recalculation is required if excess electricity cannot be sold to an electric utility grid.) The first step in such a recalculation is to determine the valve settings that would be used if the system met only the minimum electrical demands. This will be called EOUT where

EOUT = EEE + (the maximum amount of electricity which can be placed in the batteries) (22)

The maximum amount of electricity that can be put in the batteries is the smaller of the following two quantities: 1) the specified capacity of the power conditioner; and, 2) the difference between the maximum specified battery capacity and the amount of electrical energy stored in the battery at the beginning of the hour.

The valve settings, which optimize production in the case where the system only produces electricity for EOUT, can be computed in the following sequence of steps:

A)

If $QP + QSH/COPA \leq \alpha_2\, EOUT/(1 + \alpha_1\eta_2)$

Then $\beta = 1$ (23)

$\gamma = 1$

B)

If $QP + QSH/COPA > EOUT\ (\alpha_1 + \alpha_2)$ (24)

Then

$\beta = 1$

$$\gamma = \frac{(\alpha_1 + \alpha_2)\ EOUT - QP - QSH/COPA}{\alpha_1[EOUT + \eta_2\ (QP + QSH/COPA)]}$$

C)

If $QP + QSH/COPA$ $EOUT(\alpha_1 + \alpha_2)$ (25)

$QP \leq EOUT(\alpha_1 + \alpha_2)$

$QSH \leq$ (EOUT - EEE) COPE + (E OUT $(\alpha_1 + \alpha_2)$ – QP)COPA

Then $\beta = 1$

$\gamma = 0$

D)

If $QP + QSH/COPA > EOUT(\alpha_1 + \alpha_2)$ (26

$QP \leq EOUT(\alpha_1 + \alpha_2)$

QSH > (EOUT – EEE) COPE + (EOUT $(\alpha_1 + \alpha_2)$ – QP) COPA

Then β and γ are given by equation *(20) using* EOUT instead of ENGMAX,

E)

If QP $(\alpha_1 + \alpha_2)$ EOUT (27)

Then

$$\beta = \frac{EOUT}{EOUT\ (1 - \eta_1(\alpha_1 + \alpha_2)) + \eta_1 QP}$$

$\gamma = 0$

With the valve settings calculated **in equations (23)** through (27), it is possible to calculate the minimum amount of high-temperature energy that must enter the system to meet the loads. If the difference between the amount of solar energy produced during the hour and this minimum amount can be placed **in high-temperature storage, the computation is complete for the hour. If high-temperature storage would be exceeded, another step must be taken. The amount of high-temperature energy available after the high-temperature storage is filled can be calculated and the optimum technique for using this energy computed by using equations (10) through** (21) (assuming that electricity can be sold). If no electricity can be sold, the excess high-temperature **energy is transferred to the low-temperature** storage. **The low-temperature storage is filled to capacity and the remaining energy discarded.**

A Case Where Using Electricity To Meet the Space-Conditioning Load Is Always More Efficient Than Using Thermal Energy

If the inequality:

COPA< η_2COPE *(28)*

holds, it will **be more efficient to meet the QSH loads using electricity from the second engine than it will be to use thermal energy to meet QSH loads directly. The thermal units characterized by COPA will, therefore, only be used if** α_2 **is sufficiently large to justify the installation of thermal conversion equipment. The basic procedure followed in this case is identical to the one described previously with small differences resulting from the relative values of COPA and** η_2COPE. **The steps which are equivalent to equations (1 O) through (15) are as follows:**

A)

If SOLE $\eta_1\alpha_2 \geq$ QP **(29)**

Then ,13 = 1

$\gamma = 1$

(It should be noted that if COPA is not zero and SO LE$\eta_1\alpha_2$ **> QP, any "excess" low-quality waste heat is used to meet the space-conditioning load.)**

B)

If SOLE $\eta_1(\alpha_1 + \alpha_2) \geq$ **QP > SOLE** $\eta_1\alpha_2$ **(30)**

Then ß = 1

$$\gamma = \frac{\text{SOLE } \eta_1(\alpha_1 + \alpha_2) - \text{QP}}{\text{SOLE } \eta_1\alpha_1}$$

c)

If QP SOLE $\eta_1(\alpha_1 + \alpha_2)$ **(31)**

$$\text{Then ß} = \frac{\text{SOLE}\eta_1(\alpha_1 + \alpha_2) - \text{QP}}{\text{SOLE } [\eta_1(\alpha_1 + \alpha_2) -1]}$$

$\gamma \equiv 0$

The remainder of the calculation can be readily derived following this pattern.

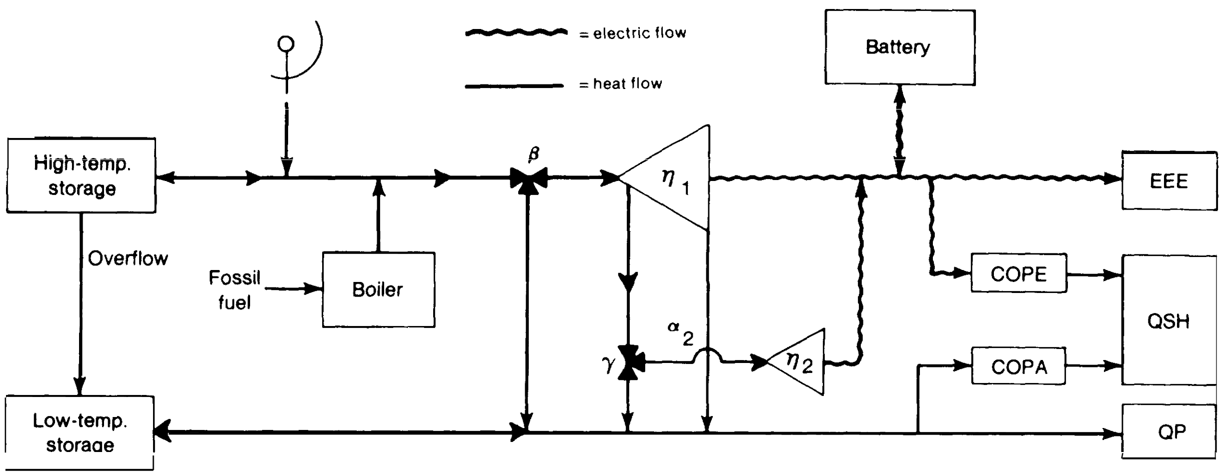
At the end of each hour, the net amount of electricity and low-temperature thermal energy produced from the high-temperature inputs and valve settings can be determined. These are used to meet the EEE, QSH, and QP loads. Any remaining low-temperature energy is placed in low-temperature storage. Any remaining electricity is placed in the batteries or sold to the utility if the batteries are filled. Onsite demands that cannot be met with the onsite power are met by purchasing electricity.

COGENERATION WITH FOSSIL FUEL OR BIOMASS BACKUP

Figure II I-4 illustrates a completely general cogeneration system, which is not tied to a utility grid but is backed up with a fossil or biomass **fuel source. Notice (although not shown in figure 3) that in the general case there are three different kinds of boilers: 1) a boiler used in the system providing backup to the heat engine (this could be a coal-fired steam boiler to back up a solar-powered steam engine, the burner efficiency in the backup unit used in a Stirling engine, etc); 2) a boiler efficiency for the QSH loads (this could** be the burner **efficiency in an adsorption chiller),** and 3) the **boiler used to produce QP.**

The logic of the fossil backup case is very similar to the logic employed in the electrically backed up system and details are not shown here. The program which per-

Figure III-4.—Cogeneration System With Fossil Fuel Backup



forms the necessary calculations is reproduced in appendix III-B. The major differences between the fossil and the electrical case are:

- Either COPA or COPE (but not both) can be zero in the case of fossil backup.
- It is assumed that the loads will be met at all times. If an engine size is specified which does not permit meeting the loads, the calculation performed in this analysis will correct the initial estimate as necessary.
- In some cases high-temperature energy from several different sources must be used to meet the onsite loads. It is assumed that the highest temperatures available to the system are obtained from burning fossil fuels or biomass, fluids emerge from collectors at a lower temperature, and fluids emerging from high-temperature storage are at a still lower temperature. (In most cases examined, it is assumed, however, that all three provide identical temperatures but an option for using different temperature is kept open. The efficiency of the first engine must be adjusted to reflect the different fluid temperatures.) The highest temperature fluids are used in the engine whenever possible.

A COMPUTER ANALYSIS OF COGENERATION

A Fortran computer program was prepared for this analysis which performs the optimization procedure just described. A sample of the data, which the program requires to perform an evaluation of a cogeneration system, is illustrated in table 111-1 and a sample of the formatted output of the program is illustrated in table II 1-2. A listing of the package of programs is shown in appendix 1 I I-B. An operating manual explaining the use and operation of these programs in greater detail is available as a separate Volume.

CALCULATION OF COLLECTOR PERFORMANCE

The techniques used to compute the thermal output of different kinds of collectors were explained in the appendix to chapter VIII of volume I and the equations used to compute the thermal and electrical output of photovoltaic devices were discussed in chapter X of volume 1. The following section describes how the formulas developed in volume I were used to evaluate the systems analyzed.

Collector output is computed in three

Table III-1 .—Sample Input

```
TOT IO . JB
-----------------------------------------------------------------------------
TITLE : PHOTOVOLTAIC COGENERATION--HIGH RISE, ALB (TEST SYSTEM)
SAVE HOURLY ELECTRICAL OUTPUT: NO
PRINT MONTHLY TOTALS OF SOLAR/DEMAND VARIABLES: YES
PRINT AVERAGE AND END OF MONTH VALUES OF STORAGE: YES
PRINT INPUT SUMMARY: YES
USE SEASONAL PARAMETERS: NO
FILE NUMBER FOR SYSTEM COEFFICIENTS: 90
LIST/CHANGE VARIABLES AND VALUES: NON
MAXIMUM PUMP/FAN LOAD--HEATING, COOLING (KW FAN/TOTAL OUTPUT): 59.24 59.24
HEAT LOSS FOR LT TANK OF LOW TEMP STORAGE (KWH/DEG CENT/HR): 0.001
AMBIENT TEMP. FOR LT STORAGE (DEG CENT): 25
FILE NUMBER FOR COLLECTOR COEFFICIENTS: 91
LIST/CHANGE VARIABLES AND VALUES: NON
FILES FOR ELECTRIC H/C COP'S: 43 44
INITIAL. VALUES OF LOW TEMP> HIGH TEMP, AND ELEC STORAGE (KWH): 5131/
```

subroutines:

COLL1, which is used for flat-plate collectors and two-axis tracking collectors (except heliostats]

COLL2, which is used for one-axis tracking collectors; and

COLL3, which is used for heliostats.

The three programs are very similar in basic structure. As a result, only the **COLL1 program is discussed in detail the discussion of the other two subroutines concentrates** primarily on features that differ from COLL1.

Each subroutine can be entered **in four different ways. These entry points are illustrated in figure III-5. The collector subroutine is called initially to read information from external** files and to convert this data into a form that can be **used in the computation. The subroutines obtain information in two steps. First two files are read; one containing the solar declination for each day of the year and one containing information about the performance of the collector. A sample file of collector performance characteristics required to operate the program was shown** in table III-2. After **these files are read, the performance characteristics can be changed as necessary. The revised set of performance characteristics can be saved in a new file for later use if this is desired.**

The program is then entered for each hour of the year to compute the electrical and thermal output of collectors **given information about ambient air temperature, the temperature of fluids entering the collector, and (if a fixed output temperature is specified)** the output temperature of the collector.

At the end of the yearly computation the program is entered two more times to print a description of the collector and to summarize the assumptions made about collector performance.

The COLL1 Collector Subroutine

The COLL1 subroutine computes the output of either flat-plate collectors or two-axis tracking collectors. It can be **used to compute the output of collectors that provide only thermal energy, of photovoltaic collectors that provide only electrical output, or of photovoltaic cogeneration systems that provide both thermal and electric output. A** listing of the program is given in appendix III-B.

Figure III-6 shows a flow diagram for the section of the program which reads and converts the initial data (entry point 1 on figure III-5).

The first input read is a table of declina-

Table III-2.—Sample Output

```
PHOTOVOLTAIC COGENERATION--HIGH RISE, ALB (TEST SYSTEM)        DATE :  8/17/78
                                                               TIME:  lb:  9:14
```

PHOTOVOLTAIC SYSTEM
ELECTRIC BACKUP
TWO-AXIS TRACKING SYSTEM
COMBINED THERMAL AND ELECTRIC COLLECTOR
CONSTANT OUTPUT TEMPERATURE
LOADS SET UP FOR HIGH RISE APARTMENT BUILDING
THE MISCELLANEOUS ELECTRIC LOADS AND THE HOT WATER LOADS
ARE NOT SMOOTHED

SYSTEM COEFFICIENTS:

REAL NUMBERS

#	VALUE	DEFINITION
1	0.	:ABSORPTION A/C COP (DIM)
2	8.000E-01	:ELECTRIC HOT WATER HEATER EFFICIENCY .LE. ,00)
3	1.000E+OO	:MULTIPLIER FOR ELECTRIC HEATING COP'S (DIM
4	1.000E+OO	:MULTIPLIER FOR ELECTRIC COOLING COP'S (DIM
5	0.	:BOILER EFFICIENCY (.LE. 1.00)
6	0.	:MAXIMUM TOPPING ENGINE OUTPUT (KU)
7	0.	:EFFICIENCY OF ENGINE #1 (.LE. 1.00)
8	0.	:EFFICIENCY OF ENGINE #2 (.LE. 1.00)
9	0.	:ALPHA l--HIGH TEMP WASTE HEAT COEFF. DIM)
10	0.	:ALPHA 2--LOW TEMP WASTE HEAT COEFF. (1 (DIM)
11	0.	:CAPACITY OF HIGH TEMPERATURE STORAGE (KWH)
12	5.380E+02	:LOW TEMP. OF HIGH TEMP. STORAGE (DEG CENT)
13	7.600E+02	:HIGH TEMP. OF HIGH TEMP. STORAGE (DEG CENT)
14	1.000E+04	:CAPACITY OF LOW TEMPERATURE STORAGE (KWH)
15	2.700E+01	:LOW TEMP. OF LOW TEMP. STORAGE (DEG CENT)
16	6.600E+0l	:HIGH TEMP. OF LOW TEMP. STORAGE (DEG CENT)
17	0.	:HEAT LOSS--HIGH TEMP. STORAGE (KWH/DEG CENT/HR)
18	0.	:EFFICIENCY OF FOSSIL HOT WATER HEATER (.LE. 1.00)
19	1.000E-03	:HEAT LOSS--LOW TEMP. STORAGE (KWH/DEG., CENT/HR)
20	0.	:ENGINE BOILER EFFICIENCY (.LE. 1.00)
21	1.200E+03	:CAPACITY OF ELECTRIC STORAGE (KWH)
22	7.500E-01	:EFFICIENCY OF ELECTRIC STORAGE (.LE. 1.00)
23	1.000E+06	:CAPACITY OF ELECTRIC POWER CONDITIONER (KU)
24	9.500E-01	:EFFICIENCY OF POWER CONDITIONING (.LE. 1.00)
25	8.305E+02	:MAXIMUM HEATING LOAD (KU)
26	5.037E+02	:MAXIMUM COOLING LOAD (KU)
27	0.	:FAN COEFFICIENT (KW FAN/KW OUTPUT)
28	7.000E+01	:LOW TEMP. FOR OPEN WINDOWS--A/C CUTOFF (DEG F)
29	7.700E+01	:HIGH TEMP. FOR OPEN WINDOWS--HT CUTOFF (DEG F)

INTEGERS

#	VALUE	DEFINITION
1	1	:HIGH TEMPERATURE STORAGE (MIX(2), NO MIX(l))
2	1	:LOW TEMPERATURE STORAGE (MIX(2), NO MIX(l))
3	1	:BACKUP (FOSSIL FUEL(0), ELECTRIC(I), BOTH(3))
4	3	:SOLAR COLLECTOR (NONE(0),FP(1),1D(2),2D(3),HEL(4)
5	1	:AIR CONDITIONING ON(1) OR OFF(2)
6	o	:REGULAR LOADS(0) OR SMOOTHED LOADS(1)
7	1	:SINGLE FAMILY(O), HIGH RISE(l), SHOPPING CENTER(2
8	o	:BUY OFFPEAK ELECTRICITY (NO(0), YES(l))

COLLECTOR_ COEFFICIENTS:

REAL NUMBERS

#	VALUE	DEFINITION
1	5.000E+02	:CONCENTRATION RATIO (DIM)
2	7.600E-01	:OPTICAL EFFICIENCY OR TRANSMISS. (.LE. 1.00)
3	2.500E+03	:COLLECTOR AREA (M**2)
4	3.508E+01	:LATITUDE (DEG)
5	1.066E+02	:LONGITUDE (DEG)
6	1.050E+02	:STANDARD LONGITUDE (DEG)
7	3.508E+01	:COLLECTOR TILT ABOVE HORIZONTAL (DEG)
8	0.	:COLLECTOR ANGLE WRT SOUTH (DEG)
9	5.000E+00	:COLLECTOR HEAT REMOVAL FACTOR (KW/(M**2*C))
10	2.100E-O3	:CELL TEMP COEFF (1/DEG CENT)
11	2.200E-01	:CELL EFFIC @ 28C (.LE. 1.00)
12	9.500E-01	:CELL ABSORPTIVITY (.LE. 1.00)
13	1.000E.+00	:FRAC OF RECEIVER COVERED WITH CELLS (.LE. 1.00)
14	1.500E-O.2	:THERMAL LOSS COEFF (KW/M**2*C)
15	1.000E+OO	:NUMBER OF GLASS COVERS (DIM)
16	1.000E+OO	:COLLECTOR HEAT REMOVAL FACTOR (.LE. 1.00)
17	9.800E-01	:ABSORB OF THERMAL-ONLY SURFACES (.LE. 1.00)
18	l.000E+0l	:FLOW RATE (CM**3/SEC*M**2)
19	1.000E.+00	:FLUID DENSITY (GM/CM**3)
20	1.000E+00	:FLUID SPEC. HEAT (CAL/GM*C)

INTEGERS

#	VALUE	DEFINITION
1	2	:OUTPUT--ELEC(1) , ELEC & THERMAL(2), THERMAL(3)
2	2	:CONST FLOW RATE(1) , CONST OUTPUT TEMP(2)

STORAGE HEAT LOSS COEFFICIENTS

	HEAT LOSS (KWH/DEG CENT/HR)	AMB. TEMP (DEG. CENT)
UT STORAGE	O. -- 0.	25.0
LT STORAGE	1.000E-03 -- 1.000E-03	25.0

NOTE: FIRST HEAT LOSS NUMBER IS FOR HT TANK OF THE PARTICULAR STORAGE; SECOND IS FOR LT TANK OF THE SAME STORAGE.

ELECTRIC H/C COP'S (KWH/KWH)

TEMP	HEAT	TEMP	COOL
10.0	1.00	75.0	2.50
20.0	1.00	80.0	2.35
30.0	1.00	90.0	2.07
40.0	1.00	100.0	1.86
50.0	1.00	110.0	1.67
60.0	1.00	120.0	1.52
70.0	1.00	--	--

Table III-2.—Sample Output (Continued) (Cont.)

PHOTOVOLTAIC COGENERATION--HIGH RISE, ALB (TEST SYSTEM) DATE: 8/17/78
TIME: 16: 9:14

ELECTRICITY AND FOSSIL FUEL BACKUP DEMANDS (KWH)

MONTH	ELEC. BUY	ELEC. SELL	FUEL USE	EXCESS LT ENERGY
1	1.574E+05	0.	0.	1.146E+04
2	5.055E+04	0.	0.	5.891E+04
3	6.922E+04	8.798E+00	0.	6.670E+04
4	2.857E+04	1.302E+02	0.	2.212E+05
5	3.627E+04	1.326E+03	0.	3.429E+05
6	6.383E+04	0.	0.	3.651E+05
7	8.756E+04	0.	0.	2.677E+05
8	1.042E+05	0.	0.	3.261E+05
9	7.361E+04	0.	0.	1.618E+05
10	3.959E+04	4.195E+02	0.	1.711E+05
11	5.916E+04	4.442E+02	0.	9.554E+04
12	8.179E+04	0.	0.	3.596E+04
TOTAL	8.517E+05	2.329E+03	0.	2.105E+06

TOTAL MONTHLY VALUES (KWH)

MONTH	PHOTOVOLT ELECTRIC	SOLAR THERMAL	INTERNAL DEMANDS: ELECTRIC	INTERNAL DEMANDS: HEAT/COOL	INTERNAL DEMANDS: HOT WATER	AVER TEMP (F.)
1	6.367E+04	2.564E+05	1.090E+05	2.63/0. E+05	7.610E+04	30.5
2	6.294E+04	2.508E+05	9.129E+04	1.35/0. E+05	6.865E+04	41.5
3	7.063E+04	2.778E+05	1.018E+05	1.63/0. E+05	7.081E+04	41.4
4	8.283E+04	3.260E+05	9.241E+04	[illegible] 1.63E+04	5.962E+04	58.
5	1.043E+05	4.183E+05	9.912E+04	2.39/6.11E+04	5.092E+04	65.
6	1.027E+05	4.115E+05	1.022E+05	.16/1.21E+05	4.024E+04	72.
7	7.771E+04	3.074E+05	1.045E+05	.13/1.19E+05	3.619E+04	74.
8	8.637E+04	3.438E+05	1.043E+05	.01/1.61E+05	3.619E+04	77.
9	5.517E+04	2.145E+05	9.553E+04	1.27/6.23E+04	4.024E+04	68.
10	6.761E+04	2.675E+05	9.393E+04	4.59/ .38E+04	5.090E+04	57.
11	6.140E+04	2.440E+05	9.514E+04	1.10/0. E+05	5.961E+04	46.
12	6.752E+04	2.640E+05	1.041E+05	1.95/0. E+05	7.081E+04	36.
TOTAL	9.028E+05	3.592E+06	1.198E+06	1.01/ .55E+06	6.603E+05	

Month	LOAD FACTOR OF STORAGE (KWH): ELECTRIC	LOAD FACTOR OF STORAGE (KWH): LOW TEMP	LOAD FACTOR OF STORAGE (KWH): HIGH TEMP	END OF MONTH VALUES OF STORAGE (KWH): ELECTRIC	END OF MONTH VALUES OF STORAGE (KWH): LOW TEMP	END OF MONTH VALUES OF STORAGE (KWH): HIGH TEMP
1	1 .53.E - 01	3.465E-01	0.	1.351E+02	8.044E+03	0.
2	1.955 E - 01	5.596E-01	0.	3.776E+00	5.291E+03	0.
3	1.967E-01	6.088E-01	0.	3.807E+02	9.018E+03	0.
4	2.266E-01	9.329E-01	0.	4.825E+02	9.246E+03	0.
5	2.463E-01	9.675E-01	0.	3.178E+02	9.788E+03	0.
6	8.299E-02	9.873E-01	0.	0.	9.704E+03	0.
7	3.461E-02	9.824E-01	0.	0.	9.727E+03	0.
8	2.241E-02	9.844E-01	0.	0.	9.705E+03	0.
9	4.305E-02	8.776E-01	0.	0.	9.447E+03	0.
10	1.672E-01	9.040E-01	0.	0.	9.076E+03	0.
11	1.825E-01	7.153E-01	0.	0.	1.976E+03	0.
12	1.900E-01	5.318E-01	0.	0.	5.131E+03	0.

STORAGE VALUES

	ELECTRIC	LOW TEMP	HIGH TEMP
LOAD FACTOR (DIM):	1.466E-01	7.916E-01	0.
INITIAL VALUE (KWH):	0.	5.131E+03	0.
FINAL VALUE (KWH):	0.	5.131E+03	0.
MINIMUM VALUE (KWH):	0.	-5.570E-01	0.
MAXIMUM VALUE (KWH):	1.200E+03	1.000E+04	0.
TOTAL ENERGY PUT INTO (KWH):	2.340E+05	9.853E+05	0.
TOTAL ENERGY TAKEN OUT OF (KWH):	2.340E+05	9.843E+05	0.
MAXIMUM INPUT INTO PC (KWH/HR):	1.961E+02	1.583E+03	0.
MAXIMUM OUTPUT INTO PC (KWH/HR):	3.648E+02	9.999E+02	0.

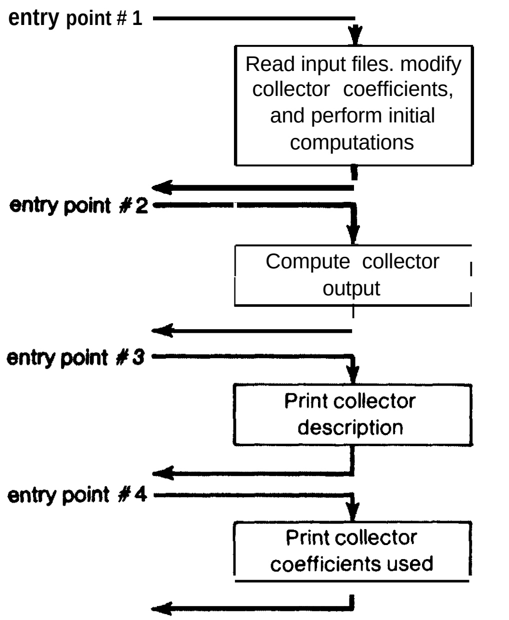
MAXIMUM SPACE CONDITIONING LOADS

	ELECTRIC	THERMAL	TOTAL
COOLING(KWH):	5.040E+02	0.	5.040E+02
HEATING(KWH):	8.306E+02	8.306E+02	8.306E+02

MAXIMUM SOLAR THERMAL OUTPUT (KWH): 1.598E+03
MAXIMUM SOLAR ELECTRIC OUTPUT (KWH): 3.802E+02
MAXIMUM ENGINE BOILER OUTPUT (KWH): 0.
MAXIMUM NONENGINE BOILER OUTPUT (KWH): 0.
MAXIMUM HOT WATER FUEL USE (KWH): 0.
FOSSIL HEAT PUT INTO ENGINE (KWH): 0.
SOLAR HEAT PUT INTO ENGINE (KWH): 0.
STORAGE HEAT PUT INTO ENGINE (KWH): 0.
MAXIMUM ELECTRICITY BOUGHT IN AN HOUR (KWH): 1.559E+03
MAXIMUM ELECTRICITY SOLD IN AN HOUR (KWH): 2.201E+02
MAXIMUM FUEL BOUGHT IN AN HOUR (KWH): 0.
TOTAL ELECTRICITY BOUGHT (KWH): 8.517E+05
TOTAL ELECTRICITY SOLD (KWH): 2.329E+03
TOTAL FUEL BOUGHT (KWH): 0.

STOP
SRU'S:56.4

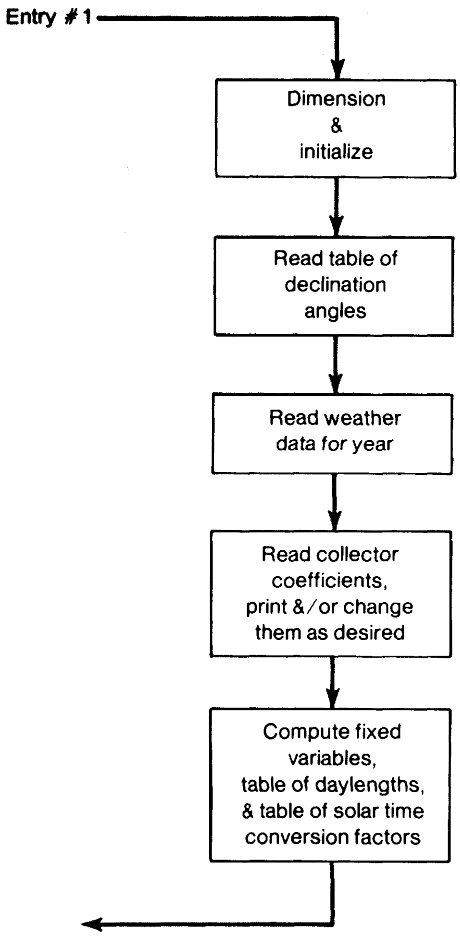
Figure III-5.—Entries to Collector Subroutines COLL1, COLL2, and COLL3



tion angles for each day of the year (line 2014). The direct normal radiation (RADDN) and the hourly total horizontal radiation (RADTH) for the first hour in the year are read from file 25, which contains RADDN and RADTH for each hour of the year in the region being studied. (This file also contains temperature and wind velocity data, which are read into the RADDN array but are then overlaid.) The file containing the collector coefficients is then specified from the terminal or from a stored file. A negative number will set all coefficients to zero. Lines 2020 to 2025 allow the operator to list the collector coefficients read from the file, and to make changes in the assumed collector performance characteristics if this is required.

Changes to the collector coefficients are input using lines 2057 to 2066. The COMMON statement (lines 2005 to 2008) places the variables named in the COMMON statement into the computer's memory space in the order given. The EQUIVALENCE statement [line 201 O) then creates arrays SCEL and ISCEL, which contain the collector coefficient variables in exactly the order given in the COMMON statement. Lines 2057 to 2061 allow the values of any real coefficient to be changed by specifying the coefficient number (as given in the left column of lines 2033 to 2052) and the new value. Input of a negative value will make the program move to the integer variables. The integer variables of lines 2055 to 2056 are changed using lines 2062 to 2066. The modified coefficient files can be stored (lines 2067 to 2070) by specifying a positive file number. Zero or a negative number causes the modified values to be retained until execution of the main program terminates.

Figure hi-6.-Flow Diagram for Entry Point #1 to COLL1, COLL2, and COLL3



The program then calculates several quantities for use in the hourly computations of collector output. The latitude angle (LAT), collector tile angle (TILT), and the collector azimuth angle (AZ), which were input in degrees, are converted to radians for use in the Fortran program.

The collector absorber area AREACR is calculated by dividing the collector area by the concentration ratio. The quantity XMASSF = (fluid flow volume) x (specific heat) x (density) is computed.

ALPHAV is the effective thermal absorptivity computed from the absorptivity of the photovoltaic cells, (ELECAB), the absorptivity of the portion of the collector not covered with cells, (ALPHA), and the fraction of the collector absorber covered with cells, (FC). The program then calculates the length of each day of the year, (DAYLEN (l)), and the correction factor used to convert local time to solar time, (SONOON (1)). EQ(J) is the equation of time discussed in chapter VIII of volume 1. SONOON (1) converts the hour number to solar time using EQ(J), a constant shifting the time to the middle of the hour and accounting for the fact that hour #1 in each day in the weather arrays (RADDN and RADTH) corresponds to the hour from midnight to 1 a.m. and a term that accounts for locations at longitudes other than standard time zone longitudes.

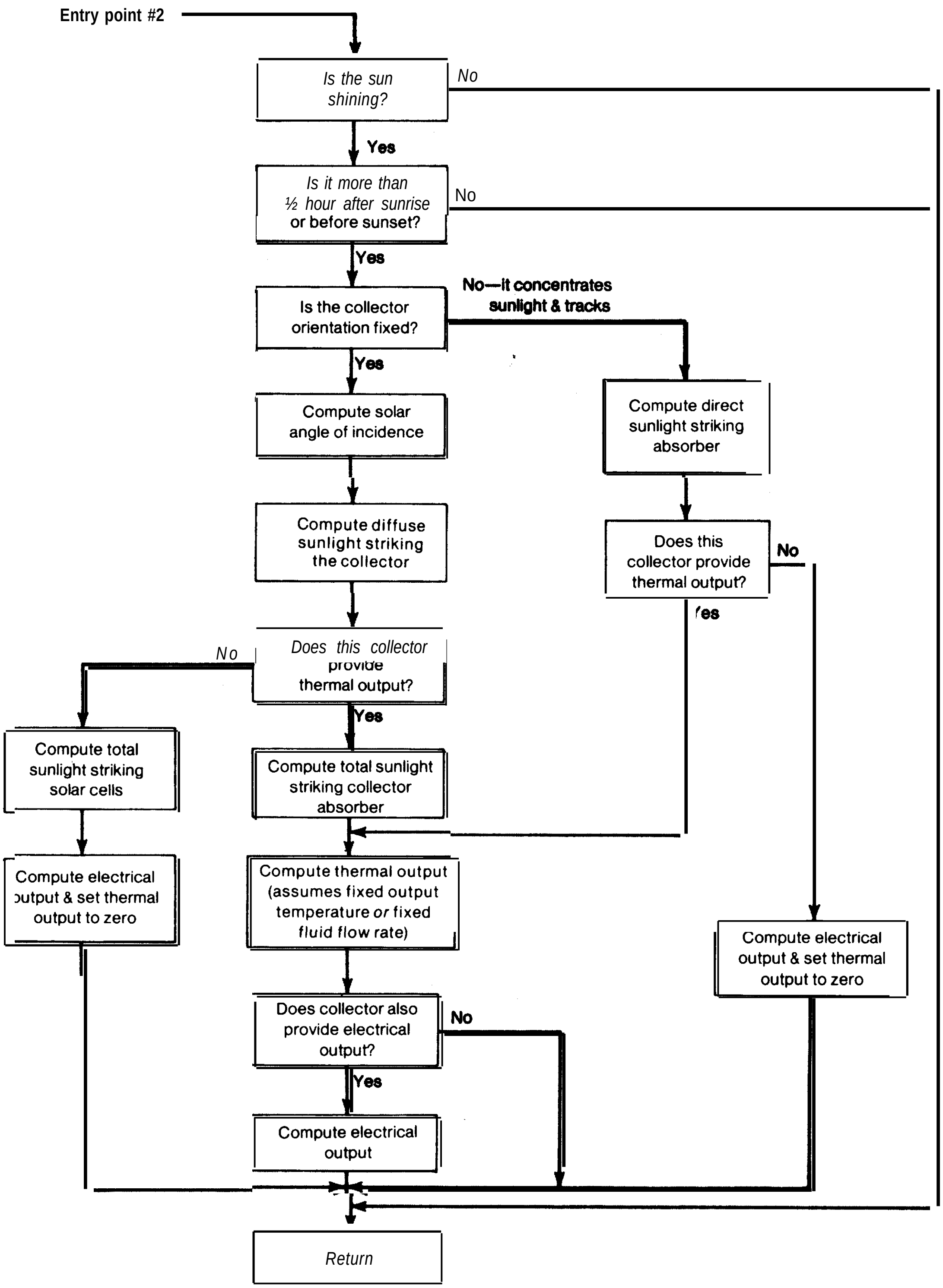
The hourly computation of collector output begins with line 2101. The pattern of this computation is shown in figure I I 1-7. First RADTH and RADDN are checked to see if the Sun is shining. If both are small, the program sets the collector output(s) to zero, and the computation is complete for the hour. If there is sunlight available the program must compute the hour of the day (J) from the hour of the year (K). It does this by first computing the day number (1). The program next determines whether the hour being examined is less than half an hour after sunrise or before sundown; if this is the case, the program sets the output to zero and returns. (These hours are excluded from the calculation since the algorithm used to compute diffuse radiation can give anomalously high values under these conditions and the amount of energy available during these hours is negligibly small on an annual basis.) RI SANG (line 2110) is the solar hour angle at sunrise.

If it is determined that collector output should be calculated for hour K, the program must first determine what kind of collector is used. It is assumed that the collector is a flat-plate device if a concentration ratio (C RATIO) less than 1.5 is specified; otherwise, the collector is assumed to be a two-axis tracking collector that can collect only the direct radiation. If the collector is a concentrator, the program either branches to 222 to compute thermal output or goes to 224 to compute electric output if the collector provides only photovoltaic electric output (ISYS = 1).

The total useful sunlight striking a square meter of collector absorber (RADTOT) is calculated for concentrators at normal incidence to the Sun. For fiat-plate collectors, the program calculates the cosine of the incident angle (COSINC) on lines 2115 to 2127. If COSTHE is negative, representing an instance where the Sun is behind the Collector, the program Sets the output(s) to zero and exits. The diffuse radiation (RADDIF-lines 2128, 2129) striking the tilted collector is calculated as given in equations VII I-A-l 4 and VII I-A-l 5 of volume 1, and is set to zero if it is calculated to be negative. If the collector is a passively cooled photovoltaic array (ISYS = 1), the program skips to line 2149 to calculate the electric output. Calculation of the total radiation striking the collector absorber (RADTOT) depends on whether there are one or two covers (COVERN less than or greater than 1.5). The exponents of COSINC (lines 2132, 21 34) are greater than one to represent the angular dependence of the cover transmission on the incident angle and the factors ‘0.89 and 0.80 represent this angular dependence integrated over a hemisphere for the diffuse radiation as given by equations VII I-A-I 7 and VI I I-A-I 8 of volume 1.

The total collector output is computed in lines 2135 to 2152. The output of collectors

Figure III-7 .–Flow Diagram for Computing Hourly Collector Output Using COLL1



that provide only thermal output is computed with the fractional cell coverage ratio (FC) set to zero in the expressions used for collectors that also provide electric output.

The useful thermal output Q_A of a unit area of collector absorber operated at constant output temperature can be computed from the heat balance equation:

$$\alpha I = F_c \eta I + Q_A + U_L (T - T_a) \quad (32)$$

where α is the average absorptivity for the collector (ALPHAV), I is the level of insolation on the absorber (RADTOT), η is the photovoltaic cell efficiency, F_c is the fraction of the absorber area covered with cells (FC), U_L is the thermal loss coefficient (U LOSS), T is the average temperature of the collector absorber and photovoltaic cells (TCELL), and T_a is the ambient air temperature (TAIR).

The value of I is given by the following relations for flat-plates or concentrating systems:

$$I = I_D \cos\theta_i \tau(\theta_i) + I_d \tau_d \quad \text{(flat plates)}$$

$$I = I_D C_r \eta_o \quad \text{(concentrating systems)}$$

where:

I_D = direct normal solar intensity (kW/m^2),

θ_i = angle between the Sun and the normal to the Collector,

$\tau(\theta_i)$ = transmissivity of cell covers for direct radiation (at angle θ_i),

I_d = intensity of diffuse solar radiation (kW/m^2),

τ_d = transmissivity of cell covers for diffuse radiation ($\tau(\theta_i)$ integrated over all incident angles),

C_r = geometric concentration ratio of concentrator optics, and

η_o = optical efficiency of the concentrator.

The cell efficiency η is given by:

$$\eta = \eta(28.0)(1 - \beta[\bar{T} - 28]) \quad (33)$$

where η (28.0) is the cell efficiency at 28°C (CELLEF) and ß is the cell temperature coefficient (BETA).

The average absorber temperature (TCELL) is:

$$\bar{T} = T_f + Q_A / k_e \quad (34)$$

where T_f is the average collector fluid temperature (TTEMP) and k_e is the thermal conductivity (XKE) between the absorber surface and the fluid.

Combining equations (32) through (34) and multiplying by the total absorber area, the thermal output QSR (line 2142) is given by:

$$QSR = A_A F_R \frac{I[\alpha - F_c \eta(28)(1 - \beta[T_f - 28])] - U_L (T_f - T_a)}{1 - (F_c I \eta (28)\beta - U_L)/k_e} \quad (35)$$

where A_A is the absorber area (AR EACR). Note that the program sets FR = 1 (line 2096) for this case.

For the case of constant flow rate, QSR is developed somewhat differently. The output Q_A can now be written (see discussion of equation VII I-A-27 of volume I).

$$Q_A = F_r [\alpha I - \eta F_c I - U_L (T_i - T_a)] \quad (36)$$

where F_r is the collector heat removal factor and T_i is the temperature of the fluid at the Collector inlet. The cell efficiency can be expressed as:

$$\eta = \eta(28)[1 - \beta(T_i + \Delta T/2 + Q_A k_e - 28)] \quad (37)$$

where the fluid temperature rise across the collector is:

$$\Delta T = \frac{"}{\varrho C_p f} \quad (38)$$

where ϱ is the fluid density, C_p is the fluid specific heat, and f is the fluid flow rate. XMASSF (lines 2086, 2140, 2146 corresponds to the denominator of equation (38). CRATIO and the constant are required to convert the inputs provided to the units kW/°CM2 [absorber).

The electric output for those collectors that provide both thermal and electric output Q_E (ESR) is (line 2147).

$$Q_E = A_A F_c I \eta \quad (39)$$

The electric output of passively cooled Colectors can also be computed from equation (39). However, the cell temperature T is:

$$\bar{T} = T_a + \frac{\alpha I - F_c \eta I}{k_e} \quad (40)$$

where k_e is now the overall thermal conductivity between the cells and ambient air. Combining (33), (39), and (40), the electric output (lines 2151, 21 52) is:

$$Q_E = \frac{A_A F_c I \eta(28)\ [1\ ß(T_a + \alpha I/k_e\ -28)]}{1 - F_c I \beta \eta(28)/k_e} \quad (41)$$

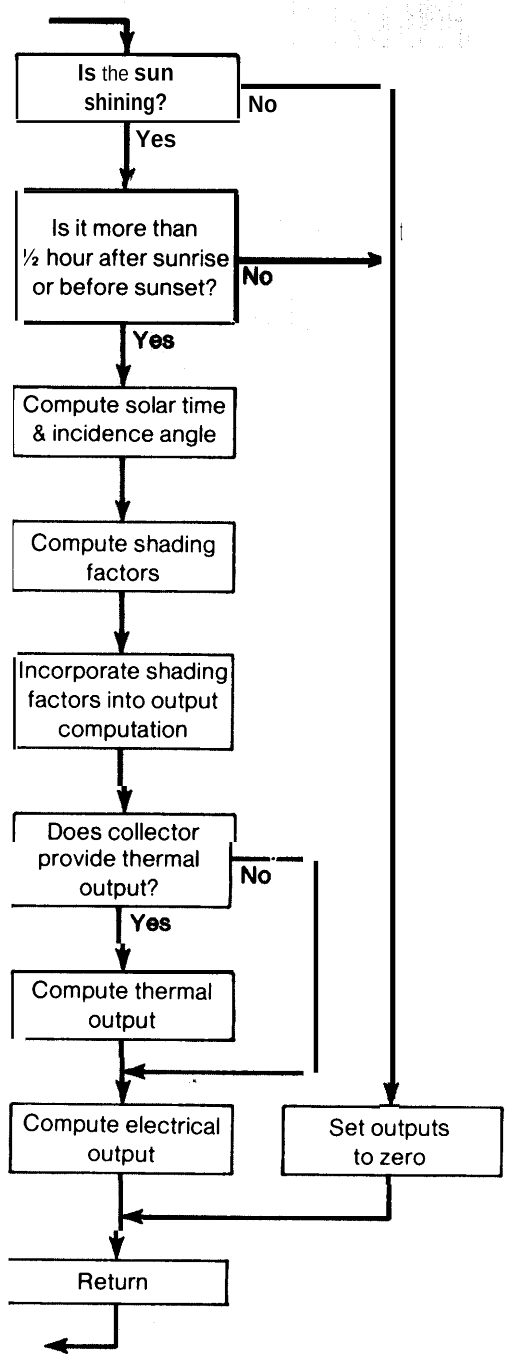
The output(s) are passed back to the main program after ensuring that they are nonnegative (lines 2153 to 21 54). The exit at line 2158 is used if the output computation is skipped for lack of sunlight.

The "output statements" (lines 2162 to 2178) are simply a brief description of the type of collector that has been modeled. The monthly and annual totals of collector output are given in the main program. The "output summary" provides a printout of the collector coefficients that were used in making the run, if requested in the operating instructions for the main program. The three angles shown (lines 2184 to 2186) are converted back to degrees before writing the output summary.

The COLL2 Collector Subroutine

This subroutine computes the output of single axis-tracking collectors with either a north-south polar axis orientation or with a horizontal east-west collector axis. The collectors may provide thermal output, electricity from photovoltaic cells, or both thermal and electric output. This subroutine differs from COLL1 principally in the hourly computations performed. Computation of the incident angle is simpler, computation of shading by adjacent collectors is performed, and a slightly more elaborate computation of thermal losses is performed (to increase accuracy if the Collector is operated over a wide range of output temperatures). A listing of the program appears in appendix I I I-B and a flow diagram for the entry which calculates collector output is shown in figure I I 1-8.

Figure III-8.—Flow Diagram for Computing Hourly Collector Output Using COLL2



The first part of the program (lines 2000 to 2025) again initializes and contains the first two input prompts. A few variable names differ from COLL1.

The second part of the program contains the format for reading and revising values of collector coefficients.

The section starting with line 2082 differs from the COLL1 program because COLL2 does not require a specified collector tilt and azimuth angle. XMINV is simply 1/(2 • XMASSF) with XMASSF as defined in COLL1. RRR is the fraction of the collector **absorber-pipe length that is covered with photovoltaic cells and is zero for collectors that provide only thermal output.**

Computation of incident angles is simpler than in COLL1. Line 2113 computes the cosine of the Sun's incident angle for a north-south polar axis collector using equation VII I-A-8. If the collector has an east-west axis, (IEW =1) COSINC is recomputed in line 2118 using equation VII I-A-9.

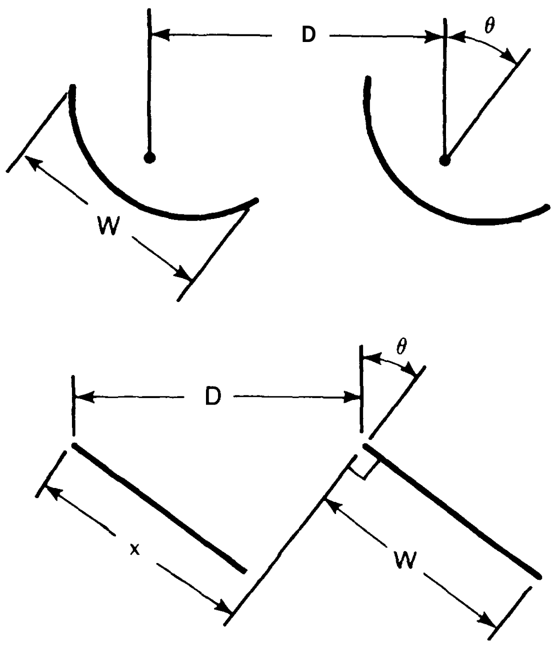
Collector Shading

Two types of shading can occur in any array of the troughs or single-axis tracking collectors treated in COLL2: 1) shading caused by a row of collectors located to the south of another row of polar-axis collectors; and 2) shading by the adjacent collector during early morning and late afternoon hours (e. g., the collector to the north or south of an east-west axis collector). In theory both of these factors can be eliminated by increasing the spacing between collectors, but in most cases this is not a practical solution because of the great increase in land use that it **requires.**

For polar tracking arrays, shading of northerly rows by southern rows of collectors **is minirna[if the space between the rows is equal to the row width and spacing within a row is reasonable. For east-west tracking arrays, the trough axes are horizontal, and only shading by adjacent collectors** is **significant. The program therefore assumes that row shading can be eliminated by proper spacing.**

The geometry of adjacent-collector shading is illustrated in figure I I 1-9. Assuming that the collector aperture width is W (APWID) and the collector spacing is D (COSPAC), it can be shown that for long collectors the unshaded fraction of the collector is:

Figure III-9.—Sectional View of Parabolic Trough Collectors for Shading Computation



$$\Gamma_1 = \begin{cases} 1 & \text{if } x \geq D \\ x/D, & \text{if } x < D \end{cases} \qquad (42)$$

where $x = D\cos\theta$, and θ is the rotation of the collector about its axis (PHI).

The end losses of one-axis collectors are given by equation VII I-A-20 in volume 1. The fraction of light which can reach the absorber is:

$$\Gamma_2 = 1 - (D/L_t)f|\tan\theta_i|[1 + 1/(48f^2)] \qquad (43)$$

where f = F/D is the f-number of the system and L_t is the collector length. The combined effect of both types of shading and end losses is computed in the line 2132. **Note**

that line 2125 tests for a condition where the Sun is behind a polar axis collector and sends the program to a RETURN statement if this occurs.

The section beginning with line 2136 completes the computation of the sunlight absorbed by the collector and begins the calculation of thermal output. TRANSM is the fraction of light transmitted through the absorber cover assuming that the cover is approximately perpendicular to the light ray when the collector is pointing directly at the Sun. It is assumed that there is a single cover and TRANS is the transmissivity of the cover at normal incidence. FCIONO is non-zero only if the collector contains photovoltaic cells and if the entire length of the cells is illuminated. It is zero when some cells are shaded by end effects since the electrical output in this case would be very small. When FCIONO is non-zero, it is the product of the cell efficiency (CELLEF), the fraction FC of the absorber width covered with cells, the light intensity incident on the cells, and the ratio of cell length to the collector length (C EL L/CO LEN).

ALPHIO is the average energy absorbed by a unit area (M') of the absorber and corresponds to the product αI discussed for COLL1. ALPHIO is given by (lines 2141 to 21 50):

$$\text{ALPHIO} = \begin{cases} (C_r/L_t)\,\varrho\Gamma_1\tau I_D\cos\theta_i[\alpha(\Gamma_2 L_t - F_c L_c) + F_c\alpha_c L_c] & \text{if } (\Gamma_2 - 0.5)L_t \geq L_c/2 \\ C_r\varrho\tau I_D\cos\theta_i\alpha\Gamma_1\Gamma_2 & \text{if } (\Gamma_2 - 0.5)L_t < -L_c/2 \\ (C_r/L_t)\varrho\tau I_D\cos\theta_i\left\{\alpha(L_t - F_c L_c)/2 + F_c\alpha_c[(\Gamma_2 - 0.5)L_t + L_c/2]\right\}\Gamma_1 & \text{if } |\Gamma_2 - 0.5|L_t < L_c/2 \end{cases} \quad (44)$$

where:

C_r = ratio of collector aperture to absorber area (concentration ratio, (C RATIO))

L_t = total length of collector absorber (COLEN)

L_c = absorber length covered with photovoltaic cells (CELLL)

$\cos\theta_i$ = cosine of incident angle to Sun (COSINC)

α = absorptivity of absorber surface not covered with cells (ALPHA)

α_c = absorptivity of cells (ELECAB)

F_c = fraction of area L_c x (width) actually covered with cells.

It is assumed that a row of photovoltaic cells of length L_c are centered in the l i near absorber whose length is L_t. It can be seen that $(\Gamma_2 - 0.5)L_t \geq L_c/2$ corresponds to the entire cell length, one end section and part of the other end section receiving sunlight. $(\Gamma_2 - 0.5)L_t < -L_c/2$ corresponds to less than one end section being illuminated, and $|\Gamma_2 - 0.5|L_t < L_c/2$ corresponds to one end section and part of the cell length being in the reflected sunlight.

If the collector provides only electric output, (ISYS = 1), the computation of thermal output is skipped. otherwise, the appropriate collector temperature TTEMP is computed. The calculation of TTEMP depends on whether the collector operates with fixed flu id flow rate (1 FLOW = 1) or with fixed output temperature (I FLOW =2).

The thermal output of collectors operated with fixed output temperature is computed in lines 2159 to 2163. The computation of QL2, which is proportional to the thermal losses (equal to, if there are no solar cells), utilizes two thermal loss coefficients. The efficiency of a collector is not a linear function of temperature; a typical efficiency function is illustrated in figure I I I-10. Particular care must be taken to account for the nonlinearity if the collectors are operated over a wide 'range of temperatures. The algorithm used by the program approximates the efficiency curve with two straight line segments as shown in the figure. The effective incremental thermal losses in the two temperature ranges are computed as follows:

$$U_1 = \frac{(\eta_o - \eta_1)C_r I_D}{T_1 - T_O} \quad (45)$$

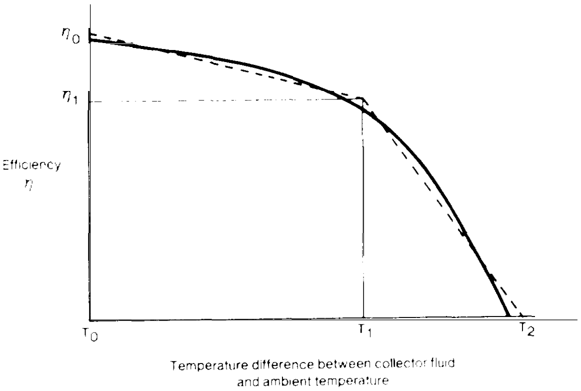
$$U_2 = \frac{\eta_1 C_r I_D}{T_2 - T_1}$$

If the difference between the average collector temperature and the air temperature ($T_f - T_a$ is greater than the difference $T_1 - T_o$, then both U_1 and U_2 are used to compute the thermal output. Using the notation which has **been developed in the discussions of COLL1 and COLL2, the thermal output is**

$$QSR = \frac{A_c}{C_r} \frac{\alpha I - F_c I \eta(28)[1-\beta(T_f - 28)] - U_1(T_1 - T_0) - U_2[T_f - T_a - (T_1 - T_0)]}{1 - F_c I \eta(28)\beta/k_e} \quad (46)$$

$$\text{if } T_f - T_a > T_1 - T_0$$

Figure III-10.—Typical Collector Efficiency Curve



This equation can be derived in a fashion similar to that used in the discussion of COLL1. If $T_f - T_a \leq T_1 - T_0$, then U_2 is not **used and the thermal loss portion of the equation reduces to $U_1(T_f - T_a)$. If one wishes to run the program using a single thermal loss coefficient, set $U_1 = U_2$ and set T_o and T_1 to arbitrary values.**

The thermal output of collectors operated at a fixed flow rate is calculated in lines 2168 to 2173. For this case, the **thermal output is given by:**

$$QSR = \frac{A_c}{C_r} \frac{\alpha I - F_c I \eta(28)[1-\beta(T_i - 28)] - U_1(T_1 - T_0) - U_2[T_i - T_a - (T_1 - T_0)]}{1 + U_2/(2\varrho f C_p C_r) - F_c I \eta(28)\beta[1/k_e + 1/(2\varrho f C_p C_r)]} \quad (47)$$

if $T_i - T_a$ $T_1 - T_o$, As for fixed output temperature, the thermal loss portion reduces to $U_1(T_i - T_a)$ if $T_i - T_a < T_1 - T_0$. The program can also be operated with $U_1 = U_2$ as above. This algorithm implicitly assumes that the flow rate is great enough that the temperature rise across the collector is not so large that the loss calculation will be significantly affected if $T_i - T_a$ is nearly as large as $T_1 - T_o$.

The electric output of collectors that also provide thermal output is computed on line 2175 as:

$$ESR = (A_c/C_r) F_c I \eta(28)[1-\beta(T_i + \frac{C_r QSR}{k_e A_c} - 28)] \quad (48)$$

The electric output of **passively cooled Colectors is calculated on line** *2178* **as:**

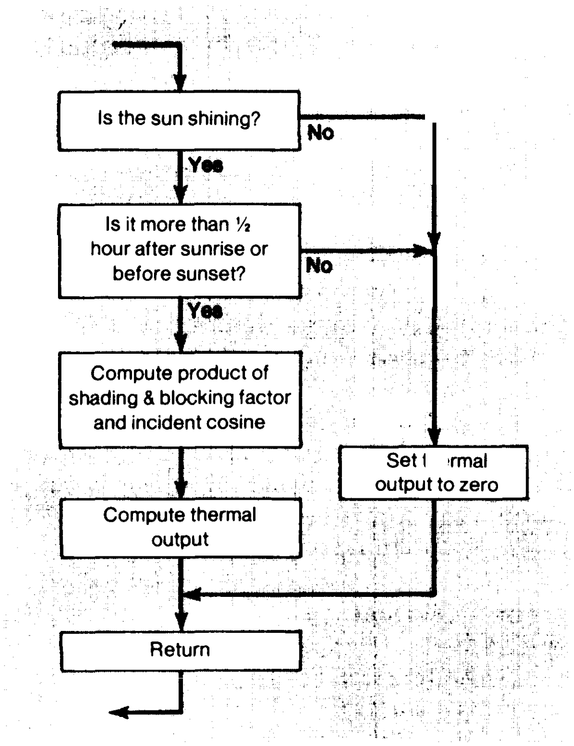
$$ESR = \frac{A_c}{C_r} \frac{F_c I \eta(28)[1-\beta(T_a + \alpha I/k_e - 28)]}{1 - F_c I \eta(28)\beta/k_e} \quad (49)$$

Collector Subroutine COLL3

This subroutine computes the thermal output of a heliostat field. It does **not perform a detailed computation of the shading, blocking, and incidence angles for each heliostat in the field, but rather utilizes output curves computed for a particular field by the University of Houston and modifies these results to account for different latitudes. Since it computes only thermal output and uses a rather simple approximation for the shading and incident angle factors, this subroutine is both shorter and simpler than the other two collector subroutines. The program is listed in appendix III-B and the flow diagram for the output computation of COLL3 is shown in figure I I 1-11.**

The first part of the subroutine again performs initializations and reads input data.

Figure III-11.—Flow Diagram for Computing Hourly Output of a Hellostat Field



Lines 2013 to 2015 contain data for use in the computation of the absorbed sunlight. Since this subroutine is considerably simpler, it requires only about a third of the input coefficients (lines 2035 to 2042) of the other two subroutines. The solar time and other quantities used in the hourly computation are calculated in lines 2055 to 2065.

This subroutine performs checks to see if the Sun is shining and if it is more than half an hour after sunrise or before sunset just as the other subroutines. The major difference is the manner in which the incident sunlight is computed. N, TD, TB, and TC are all used to compute the factor GAMCOS, which represents the average incident cosine factor and shading factor for the entire heliostat field. GAMCOS is calculated using line segments to determine the maximum input available at each time of the day as discussed in chapter VII I-A and shown in figure VI II-A-4 of volume 1. Once GAMCOS is known, the thermal output QSR is simply the absorbed radiation minus the thermal losses:

$$QSR = \varrho \alpha A_c I_D GAMCOS - (A_c/C_r) U_L (T_{fo} - T_a) \quad (50)$$

where T_{fo} is the Collector output temperature.

Note that this subroutine uses the collector area AREAC instead of the absorber area AREACR in the computation, The thermal losses are based on the output temperature TFOUT since it is assumed that these systems will operate at fixed output temperature and the thermal loss coefficient ULOSS was specified for a particular temperature. Since radiation is the major thermal loss in many such systems, ULOSS is a strong function of the output temperature.

Proof of Valve Opening Sequence

For a given set of valve settings in the diagram illustrated in figure 2, the amount of electricity (E) and the amount of thermal energy (Q) provided by the system can be written in terms of the amount of high-temperature energy entering the system (Q_H) as follows:

$$E = Q_H \beta \eta_1 (1 + \gamma \alpha_1 \eta_2) \quad \text{(A-1)}$$

$$Q = Q_H[\beta \eta_1 (\alpha_2 + (1-\gamma)\alpha_1) + (1-\beta)] \quad \text{(A-2)}$$

The valve settings depend on the ratio of Q to E, the energy required to meet the loads. Clearly if Q =0 the optimum valve settings are Y= I and ß=1. This situation also holds as long as the minimum amount of thermal energy exhausted in producing the needed electrical output exceeds Q.

Therefore,

If $0 \leq Q/E \leq \alpha_2/(1 + \alpha_1\eta_2)$ **(A-3)**
Then ß = 1
$\gamma = 1$

If Q/E exceeds $\alpha_2/(1+\alpha_1\eta_2)$, either γ or β must be less than one. At the point where Q/E equals $\alpha_2/(1+\alpha_1\eta_2)$ it is known that the optimum settings are $\gamma=1$ and $\beta=1$. If E is held constant and Q is increased by an incremental amount (ΔQ), and incremental change will be required in Q_H and either γ or β or possibly both γ and β. The incremental change in Q_H required to meet a load E and Q + ΔQ can be computed from equation (A-1) as follows:

$$\Delta E = 0$$
$$= (\Delta Q_H/Q_H)E + (\Delta\beta/\beta)E + \Delta\gamma\,[Q_H \beta\eta_1\eta_2\alpha_1] \quad \text{(A-4)}$$

$$-\Delta Q_H/Q_H = [1/\beta]\Delta\beta + \frac{\alpha_1\eta_2}{1+\gamma\alpha_1\eta_2}\Delta\gamma \quad \text{(A-5)}$$

As both $\beta=1$ and $\gamma=1$, equation (A-5) reduces to:

$$-\Delta Q_H/Q_H = \Delta\beta + \frac{\alpha_1\eta_2}{1+\alpha_1\eta_2}\Delta\gamma \quad \text{(A-6)}$$

In the case γ is not equal to 1, the coefficient of $\Delta\gamma$ would still be less than the coefficient of $\Delta\beta$ if $\alpha_1\eta_2$ is less than one. This will always be the case if η_1 is greater than η_2 (a situation which will hold in all practical cases.) Because energy is conserved we know that

$$\eta_1 + \alpha_1\eta_1 \leq 1 \quad \text{(A-7)}$$

or equivalently that

$$\alpha_1\eta_1 < 1 \quad \text{(A-8)}$$

Therefore, if $\eta_2 > \eta_1$ it must be true that $\alpha_1\eta_2 < 1$. Since the coefficient of $\Delta\gamma$ is always less than the coefficient of $\Delta\beta$ in equation (A-5), Q_H is minimized by changing γ while holding β constant at its initial value of one. Therefore:

If $Q/E > \alpha_2/(1+\alpha_1\eta_2)$, and
$Q/E < (\alpha_1 + \alpha_2)$, then

$$ß = 1$$
$$\gamma = \frac{E(\alpha_1 + \alpha_2) - Q}{\alpha_1(Q\eta_2 + E)} \quad \text{(A-9)}$$

When (A-9) indicates that $\gamma < 0$ (i.e., $Q > E(\alpha_1 + \alpha_2)$, β must be adjusted. Therefore, if:

$Q/E > (\alpha_1 + \alpha_2)$, then **(A-10)**

$$\gamma = 0$$
$$ß = \frac{E}{E(1 - \eta_1(\alpha_1 + \alpha_2)) + \eta_1 Q}$$

This proves the sequence stated in the text VIZ, For small values of Q_0/E_0 both ß and γ are one. As the ratio increases to a point where demands cannot be met with this valve setting without discarding electrical energy, the valve characterized by γ should be adjusted first, keeping ß=1. The quantity ß should only be reduced from 1 when the optimum setting for γ =0.

```
TOTIO.PB-PNC/UGFO02  08/17/78  14:41:56

% PROGRAM NAME: TOTIO.JB
% JOHN C. BELL
% ENERGY PROGRAM
% OFFICE OF TECHNOLOGY ASSESSMENT
%  COMPILED
z     DATE:   l/12/78
z     TIME: 13: 6: 1
% PROGRAM TOTIO.JB FOR RUNNING SOLAR AND NON-SOLAR SYSTEMS
% FILE HANDLING REQUIREMENTS:
%     12—FILE NUMBER FOR GENERAL INPUT IN TOTIO.JB, THE LOAD
%         SUBROUTINES, AND THE COLLECTOR SUBROUTINES.  NORMALLY
%         THIS IS EQUATED TO IN$ FOR TERMINAL INPUT.
%     13--FILE NUMBER FOR GENERAL OUTPUT IN TOTIO.JB, THE LOAD
%         SUBROUTINES, AND THE COLLECTOR SUBROUTINES.  NORMALLY
%         THIS IS EQUATED TO OUT$ FOR TERMINAL OUTPUT.
%     20--FILE HOLDING HEATING/COOLING LOADS, PROCESS LOADS, AND
%         MISCELLANEOUS ELECTRIC LOADS
%     25—FILE HOLDING WEATHER AND INSOLATION DATA
%     50-—FILE FOR OUTPUTTING HOURLY ELECTRIC BACKUP/SELL  DATA
%         (REQUIRED ONLY FOR UTILITY IMPACT ANALYSIS AND DEBUGGING)
%     XX-—FILES HOLDING SYSTEM COEFFICIENTS, CELL COEFFICIENTS, AND
%         ELECTRIC HEATING/COOLING COP’S ARE PROMPTED FOR IN THE
%         MAIN PROGRAM
%
%
% TOTIO.JB MUST BE LINKED TO THE FOLLOWING:
z         UPDATE.JB--ALWAYS
%         ONE LOAD SUBROUTINE
z           LOADS.JB--SINGLE FAMILY HOUSE, INSULATED SINGLE FAMILY
%                     HOUSE, TOWNHOUSE, HIGH OR LOW RISE APARTMENT
%           LOADSC.  JB--SHOPPING  CENTER
%         ONE COLLECTOR SUBROUTINE
%           COLL1.JB--FLJT PLATE COLLECTORS AND TWO-DIMENSIONAL
%                      TRACKING COLLECTORS
%           coLL?.JB  ONE DIMENSIONAL  TRACKING  COLLECTORS
%           COLL3.JB-—HELIOSTATS
%         ONE SYSTEM SUBROUTINE
%           HFSYS—HEAT ENGINES WITH FOSSIL BACKUP
%           HESYS--HEAT ENGINES WITH ELECTRIC BACKUP
%           PVSYS--ALL PHOTOVOLTAIC SYSTEMS
%           HWSYS--SOLAR HOT WATER SYSTEMS
%
%

% MISCELLANEOUS INFORMATION
z     --ALL LOADS AND MAXIMUM OUTPUTS ARE IN KILOWATT-HOURS AND
%         KILOWATTS
%     --QSH HOLDS THE SPACE CONDITIONING LOAD
%         --NEGATIVE MEANS A HEATING LOAD
%         --POSITIVE MEANS A COOLING LOAD
%     --HWLOAD HOLDS THE PROCESS (HOT WATER)  LOAD
%     --E HOLDS THE MISCELLANEOUS ELECTRIC LOAD PLUS THE FAN AND
%         PUMP LOAD
z     --ELLOAD HOLDS THE MISCELLANEOUS ELECTRIC LOAD
%
DIMENSION  E(8760),HWLOAD(  168)  ,M(13),IMTH(12)
DIMENSION  COEF(30),ICOEF(8)  ,TITLE(15)
DIMENSION FUELMO(12),TOTEM(  12)  ,TOTSM(  12),TALTE(12)
DIMENSION ESRM(12),QSRM(  12),QCCM(  14),QCHM(  14),EEEM(12)  ,QPM(12),  %
          TEMPM(12)
```

```
TOT10.PB-PNC/UGF002  08/17/78  14:41:56

DIMENSION  CPH(2,25),CPC(2,  25)
DIMENSION  ESE(12),LSE(12),HSE(  12)  ,ESM(12),LSM(12)  ,HSM(12),0LDST(3)
IMPLICIT  REAL(L)
COMMON/AXXX/COPA,  EHWEFF,  HCOPM,CCOPM,EFFB,ENGMAX,  EFF1,EFF2,ALPHA1,  %
            ALPHA2,HTQSTM,LTHTS,HTHTS,   LTQSTM,LTLTS,HTLTS,HLHTH,   %
            FHWEFF,HLLTH,  EFFBE,ESTORM,  EFFBAT,  PCSIZ,  EFFPC,HEATMX,  %
            COOLMX,FAN,TL,TH,KXX,NHTQ,NLTQ,   IGRID,   ISOIAR,IA,ISMTH,   %
            IHR,IOFFPK
EQUIVALENCE  (COEF(l),COPA)  ,(ICOEF(l),NHTQ)
COMMON/CXXX/COPAA,COPEE  ,EBM,  EBEM,EEE,EFFEX,TENCM,  BENGM,ENGM,  %
            ESR,  ESTOR,EEFF,FFHW,  FHET,  FUEL,HTSSTM,HTQ,HTQI,HT@  ,  %
            HTQSO,  HTQSTO,LTQI,LTQO  ,LTQSO,LTQSTO,QA,  QC,QC I,QC2,  %
            QC2z,QE,QP,QS,QSR,RESID9,   SHET,STHET,TOTTEO,TOTBEO,   %
            TOTEO,HLHTL,HLLTL,EFFLOT,    EFFST,IPRINT
COMMON/DXXX/BOLMAX,CPC  ,CPH,EEEM,EHM,  EKMAX,EKMIN,  ESE,ESI,ESIM,  %
            ESM,ESO,ESOM,  ESRM,ESTMAX,  ESTMIN,  ESTORI,FUELMO,  %
            HRRUN,  HSE,HSM,HTMAX,  HTMIN,HTQIM,HTQOM,  HTQSTI ,  %
            IEC,IEH,  IEOMST,IHRAV,  IHRCT,  IOUTS,  J1O,J2O,J3O,LSE,  LSM,  %
            LTMAX,LTMIN,LTQIM,  LTQOM,  LTQSTI,AMESR,AMQSR,QCCM,  QCHM,  %
            QC1W,QC1X,QC1Y,QC2W,QC2X,    QC2Y,QPM,QSRM,TALTE,TBAT,    %
            TEEE,TEMPM,TESR,THTQ,TLTQ,TOTE,TOTEM,TOTS,TOTSM,   %
            TQP,TQSR,TTEMP
COMMON/EXXX/TAIRF
COMMON/XDATA/E,HWLOAD
DATA  M/1,745,1417,2161,2881  ,3625,4345,5089,  5833,6553,7297,8017,8761  /
DATA ITBOUT,HTSSTM/1, 1.0E+30/ @HTSSTM IS TEMPORARY HT STORAGE
READ(12,  98,PROMPT=’TITLE:  ‘)  TITLE
98    FORMAT(15A4)
READ(12,  99,PROMPT=’SAVE  HOURLY  ELECTRICAL  OUTPUT:  ‘)  ITST
IF (ITST.NE.`YES’) GO TO 9081
IHROUT=l
READ(12,  99,PROMPT=’PRINT  OUTPUT  TABLES:  ‘)  ITST
IF (ITST.EQ.’NO’) ITBOUT=O
IF (ITBOUT.EQ.0) GO TO 4113
9081    READ(12,  99,PROMPT=%
             ‘PRINT MONTHLY TOTALS OF SOLAR/DEMAND VARIABLES: ‘) ITST
IF  (ITST.EQ.’YES’)  IHRAV=l
READ(12,99,PROMPT= %
      ‘PRINT AVERAGE ANE END OF MONTH VALUES OF STORAGE: ‘) ITST
IF  (ITST.EQ.’YES’)  IEOMST=1
READ(12,99,PROMPT=’PRINT INPUT SUMMARY: ‘) ITST
IF (ITST.EQ. ’YES’) IOUTS=l
4113   READ(12,  99,PROMPT=’USE  SEASONAL  PARAMETERS:  ‘)  ITST
IF (ITST.NE.’YES`) GO TO 1112
READ(12,  *,PROMPT=’MONTHS  TO  INPUT  CHANGES:  ‘)  IMTH
1112   READ(12,*,PROMPT-’FILE NUMBER FOR SYSTEM COEFFICIENTS: ‘) IF
IF (IF.LE.0) GO TO 1066
REWIND IF
READ(IF) COEF,ICOEF
1066   READ(12, 99,PROMPT=’LIST/CHANGE VARIABLES AND VALUES: ‘) ITST
99   FORMAT(A4)
IF (ITST.EQ.’YES’) GO TO 1081
IF (ITST.EQ.’NO’) GO TO 1082
IF (ITST.EQ. ’NON’) GO TO 1080
GO TO 1066
1081   WRITE(13,909)  (COEF(I),I-1,29)
909   FORMAT(’ ______REAL NUMBERS_  ’  /  %
‘ #’,4X,’VALUE’,4X,’DEFINITION’ /%
’  1’ ,IPEIO. 3,’  :ABSORPTION A/C COP (DIM)’/%
’  2’, IPEI0.3, ’  :ELECTRIC HOT WATER HEATER EFFICIENCY (.LE.l.00)’/%
```

```
        3 ',IRE10. 3,'  :MULTIPLIER FOR ELECTRIC HEATING COP'"S (DIM)'/%
   '    4 ',IPE10. 3,'  :MlLTLTIPLIER FOR ELECTRIC COOLING COP"S (DIM)'/%
   '    5 ',1FE10.3, '  :BOILER EFFICIENCY (.LE.l.00)'/%
   '    6 ',lPE10. 3,'  :MAXIMUM TOPPING ENGINE OUTPUT (KW)'/%
   '    7 ',1PE10.3, '  :EFFICIENCY OF ENGINE #1 (.LE.l.00)'/Z
   '    8 ',lPE10. 3,'  :EFFICIENCY OF ENGINE #2 (.LE.l.00)'/%
   '    9 ',lPE10. 3,'  :ALPHA 1--HIGH TEMP WASTE HEAT COEFF. (DIM)'/%
   ' 10 ',lPE10. 3,'  :ALPHA 2--LOW TEMP WASTE HEAT COEFF. (DIM)'/%
   '11',1PE10. 3,'  :CAPACITY OF HIGH TEMPERATURE STORAGE (KWH)'/%
   ' 12 ',lPE10. 3,'  :LOW TEMP. OF HIGH TEMP. STORAGE (DEG CENT)'/%
   '13',1PE10.3,'  :HIGH TEMP. OF HIGH TEMP. STORAGE (DEG CENT)'/%
   ' 14 ',lPE10. 3,'  :CAPACITY OF LOW TEMPERATURE STORAGE (KWH)'/%
   ' 15 ',1PE10.3,'  :LOW TEMP. OF LOW TEMP. STORAGE (DEG CENT)'/%
   ' 16 ',1PE10.3,'  :HIGH TEMP. OF LOW TEMP. STORAGE (DEG CENT)'/%
   '17',1PE10.3, '  :HEAT LOSS--HIGH TEMP. STORAGE (KWH/DEG CENT/HR)'/%
   ' 18 ',lPE10. 3,'  :EFFICIENCY OF FOSSIL HOT WATER HEATER (.LE.l.00)'/%
   ' 19 ',lPE10.3,'  :HEAT LOSS--LOW TEMP. STORAGE (KWH/DEG CENT/HR) '/%
   ' 20 ', 1PE10.3,'  :ENGINE BOILER EFFICIENCY (.LE.l.00)'/%
   ' 21 ', lPE10.3,'  :CAPACITY OF ELECTRIC STORAGE ('KWH)'/%
   ' 22 ',lPE10.3,'  :EFFICIENCY OF ELECTRIC STORAGE (-LE.l.00)'/%
   ' 23 ', 1PE10.3,'  :CAPACITY OF ELECTRIC POWER CONDITIONER (l(W)'/%
   ' 24 ",lPE10.3,'  :EFFICENCY OF POWER CONDITIONING (.LE.l-00)'/Z
   , 25 ', 1PE10.3,'  :MAXIMUM HEATING LOAD (KW)'/%
   ' 26 ',lPEl0.3,'  :MAXIMUM COOLING LOAD (KW)'/%
   ',27 ', IPEl0.3,'  :FAN COEFFICIENT (KW FAN/KW OUTPUT)'/%
   ' 28 ', 1PEl0.3,'  :LOW TEMP. FOR OPEN WINDOWS--A/C CUTOFF (DEG F)'/%
   , 29 ', 1PE10.3,'  :HIGH TEMP. FOR OPEN WINDOWS--HT CUTOFF (DEG F)')
   WRITE(13,910) (ICOEF(J).J=l. H)
   910  FORMAT('_________INTEGERS_    _ ' %
   '  #',4X, "VALUE',4x,'Definition'/%
   '  1 ',16,4x, '  :HIGH TEMPERATURE STORAGE (MIX(2), NO MIX(l))'/%
   '  2 ',16 ,4X,'  :LOW TEMPERATUEE STORAGE (MIX(2), NO MIX(l))'/%
   '  3 ',16 ,4X,' :BACKUP (FOSSIL FUEI,(0), ELECTRIC(l), BATH)'/%
   '  4 ",16 ,4x,'  :SOLAR COLLECTOR (NONE(0),FP(l) ,1D(2), 2D(3),HEL(4))' /%
   `  5 ',16 ,4X,' :AIR CONDITIONING ON(1) OR OFF(2)'/%
      6 ',16,4X, ' :REGULAR LOADS(0) OR SMOOTHED LOADS(l)'/%
   '  7', 16,4X,'  :SINGLE FAMILY(0), HIGH RISE(l), SHOPPING center'/%
   `  8 ',16,4X, ' :BUY OFFPEAK ELECTRICITY (NO(0), YES(l))')
   1082  READ(12,*,PROMPT=,VAR. # AND VARIBLE: ') IV,V
   IF (IV.LE.0) GO To 1067
   IF (IV.GT.30) GO TO 1082
   COEF(IV)=V
   Go TO 1082
   1067  READ(l2,*,PROMPT'VAR. # AND IVARIABLE: ') IV,I
   IF (IV.LE.0) GO TO 1077
   IF (IV.GT.8) GO To 1067
   ICOEF(IV)-I
   CO TO 1067
   1077  READ(12,*,PROMPT- 'FILE NUMBER To STORE SYSTEM COEFF: ') IV
   IF (IV.LE.0) GO To 108O
   REWIND IV
   WRITE(IV) COEF,ICOEF
   1080  CALL LOADS (TL,TH,FAN,HFATMX, COOLMX, ISMTH, IHR)
   IF ((NHTQ.NE.1).OR. (HLHTH.LE.1.E-9) .OR. %
      (HTQSTM.LE. lE-9)) GO TO 876
   READ(5,*,PROMPT= %
     'HEAT LOSS FOR LT TANK OF HIGH TEMP STORAGE (KWH/DEG CENT/HR): ') %
     HLHTL
   876  IF ((NLTQ.NE. 1).OR. (HLLTH. LE.1.E-9).OR. %
      (LTQSTM.LE. lE-9)) GO TO 877
```

TOTIO.PB-PNC/UGFO02 08/17/78 14:41:56

```
   READ(5,*,PROMPT- %
     'HEAT LOSS FOR LT TANK OF LOW TEMP STORAGE (KWH/DEG CENT/HR): ') %
     HLLTL
   877  ATEMPH=25
   ATEMPL=25
   IF ((HLHTH.GT.0).AND. (HTQSTM.GT.0)) %
      READ(5,*,PROMPT='ANBIENT TEMP. FOR HT STORAGE (DEG CENT): ') %
       ATEMPH
   IF ((HLLTH.GT.0).AND. (LTQSTM.GT.0)) %
      READ(5,*,PROMPT-'AMBIENT TEMP. FOR LT STORAGE (DEG CENT): ') %
       ATENPL
   TEMP=HTLTS
   IF (NHTQ.EQ.0) NHTQ-2
   IF (NLTQ.EQ.0) NLTQ-2
   IF (HTQSTM.GT.O.1) TEMP-HTHTS
   IF (ISOLAR.NE.0) CALL COLL(ISYS)
   IF (IOFFPK.EQ.1) CALL OFFPK
   READ(12,*,PROMFT-'FILES FOR ELECTRIC H/C COP''S: ')IEH,IEC
   IF (IEH.LE.0) Go To 6654
   REWIND IEH
   READ(IEH) CPH
   6654  IF (IEC.LE.0) GO TO 6655
   REWIND IEC
   READ(IEC) CPC
   6655  00 114 1-1,25
   IF (IEH.GT.0) cPH(2,1)-HCOPM*cPH(2,I) /(1-HCOPM*cPH(2,I)*FAN)
   IF (IEC.GT.0) CPC(2,I)-CCOPM*CPC(2,I) /(I-2. 5*CCOPM*CPC(2,I)*FAN)
   114  CONTINUE
   READ(12,*,PROMPT-%
    'INITIAL VALUES OF LOW TEMP, HIGH TEMP, AND ELEC STORAGE (KWH): ') %
    LTQSTO,HTQSTO,ESTOR
   ESTORI-ESTOR
   ESTO=ESTOR
   LTQSTI-LTQSTO
   LTQSO=LTQSTO
   HTQSTI-HTQSTO
   HTQSO=HTQSTO
   EFFEX-1.
   EFFLOT=l.O
   EFFST-1.O
   LTMIN-LTQSTM
   HTMIN-HTQSTM
   ESTMIN=ESTORM
   EEFF-EFFPC*EFFBAT
   KKK-1
   Jl0-1        @FIRST MONTH
   J20-12       @LAST MONTH
   J30=1        @INTERVAL
   K10-1        @FIRST HOUR
   K2X-O        @LAST HOUR-ZERO FOR WHOLE MONTH
   K30-I        @INTERVAL
   1111  CONTINUE @CHANGE MONTHS AND HOURS HERE
   ~*************************************************************
   % BEGIN CYCLING THROUGH THE MONTHS
   %*************************************************************
   DO 1000 I-J1O,J2O,J3O
   M3-N(I+l)-M(I)
   K20-K2X
   IF (K2X.EQ.0) K20+M3
   M31-(K20-K10+l)/K30 @ TOTAL HOURS IN THE MONTH
```

TOTI0.PB-PNC/UGFO02 08/17/78 14:41:56

```
%***************************************************************
% BEGIN CYCLING THROUGH THE HOURS OF THE MONTH
%***************************************************************
DO 100 J-K10,K2O,K3O
K-M(I)+J-1 @ K IS THE HOUR OF THE YEAR
KCT-(K-1)/168
KCT-K-168*KCT
IDAY-l+(K-1)/24
QP-HWLOAD(KCT)*(1+0.372*COS (.017214*(IDAY-30)))
CALL LOADS1(K,EEE,QSH,TA)
TAIRF=-459.4+1. 8*TA
IF(QSH.GT.0. ) GO TO 20
QC=QSH   @SETS QC POSITIVE FOR HEATING CASE
COPAA=l.0
COPEE=0
IF(IEH.GT.0) CALL COPT(TAIRF,CPH,COPEE)
GO TO 30
20   QC-QSH
IF (IA.EQ.2) QC=0
COPEE-0
COPAA-COPA
IF (IEC.GT.0) CALL COPT(TAIRF,CPC,COPEE)
30   IF(ISOLAR.EQ.0) GO TO 146
IF (HTQSTM.GE.0.1) GO TO 133
IF (LTQSTM.LE.0. l) GO TO 4140
F-LTQSTO/LTQSTM
IF (NLTQ.EQ.1) co TO 4135
TIN=LTLTS+F*(HTLTS-LTLTS  )
GO TO 140
4135   TIN=LTLTS
IF (F.LT.0) TIN=LTLTS+F*(HTLTS-LTLTS  )
GO TO 140
133   F-HTQSTO/HTQSTM
IF (NHTQ.EQ.1) GO TO 135
TIN=LTHTS+F*(HTHTS-LTHTS  )
GO TO 140
135   TIN=LTHTS
IF (F.LT.0) TIN=LTHTS+F*(HTHTS-LTHTS)
GO TO 140
4140   TIN-LTLTS
140   IF ((LTQSTO.GT.O.99*LTQSTM) .AND. (COPAA.LE.0.001) .AND. %
     (QSH.GE.0) .AND. (ISYS.EQ. 2)) TIN=TA-263
CALL COLL01(K,TIN,TEMP,TA,QSR,  ESR)
AMQSR=AMAX1(AMQSR,QSR)
ANESR=AMAX1  (AMESR,ESR)
LX) TO 147
146 QSR=O
ESR=0
147 E(K)=0.
TESR=TESR+ESR
TQSR=TQSR+QSR
TEEE=TEEE+EEE
IF (QSH.GT.0) QCCM(14)-QCCM(14)+QC
IF (QSH.LT.0) QCHM(14)=QCHM(14)+QC
TQP=TQP+QP
TTEMP=TTEMP+TAIRF
IHRCT=IHRCT+l
EEEM(I)-EEE14(I)+EEE
QPM(I)-QPM(I)+QP
IF (QSH.GT.0) QCCM(I)=QCCM(I)+QC
```

TOTIO.PB-PNC/UGFO02 08/17/78 14:41:56

```
IF (QSH.LT.0) QCHM(I)-QCHM(I)+QC
QSRM(I)-QSRM(I)+QSR
ESRM(I)=ESRM(I  )+ESR
TEMPM(I)-TEMPM(I)+TAIRF/M3   1
LTQSO=LTQSTO
HTQSO=HTQSTO
%********************************************************h*****
CALL SYSTEM(K,QSH)
%**************************************************************
IF (QSH.LE.0) GO TO 9911
QC1X-AMAX1 (QC1X,QC1)
QC2X=AMAX1(QC2X,QC2+QC2Z  )
GO TO 9910
9911   QC1Y=M1(QC1Y,QC1)
QC2Y=AMAX1(QC2Y,QC2+QC2Z)
9910   IF (QSH.LT.0) QCIW=AMAXl (QClW,QCl+QC2tQC2Z)
IF (QSH.GT.0) QC2W,AMAX1 (QC2W, QC1+QC2+QC2Z)
IF (IGRID.NE.1) EHM=AMAXl (EHM,FFHW)
TBAT=TBAT+ESTOR
THTQ=THTQ+HTQSTO
TLTQ=TLTQ+LTQSTO
BOLMAX=AMAX1   (BOLMAX,FUEL-FUELII)
HTMAX-AMAX1  (HTMAX,HTQSTO)
HTMIN=AMIN1  (HTMIN,HTQSTO)
LTMAX-AMAX1  (LTMAX,LTQSTO)
LTMIN=AMIN1(LTMIN,LTQSTO)
ESTMAX=AMAX1  (ESTMAX,ESTOR)
ESTMIN=AMIN1  (ESTMIN,ESTOR)
IF (IGRID.EQ.0) GO TO 906
EKMAX=AMAX1(  EKMAX,E(K))
EKMIN=AMIN1  (EKMIN,E(K))
906   FUELII=FUEL
LTQ-LTQSTO-LTQSO
ES=ESTOR-ESTO
ESTO=ESTOR
IF (LTQ.LT.0)  GO TO 9400
LTQI=LTQI+LTQ
LTQIM=AMAX1  (LTQIM,LTQ)
GO TO 940l
9400   LTQ0=LTQ0-LTQ
LTQOM=AMAX1(LTQOM,-LTQ)
9401   IF (HTQ.LT.0) GO TO 9402
HTQI=HTQI+HTQ
HTQIM=AMAX1  (HTQIM,HTQ)
GO TO 9403
9402   HTQO=HTQ0-HTQ
HTQOM-MAX1 (HTQ0M,-HTQ)
9403   IF (ES.LT.0) GO TO 9404
ESI=ESI+ES
ESIM=AMAX1 (ESIM,ES)
CO TO 9405
940&   ESO=ESO-ES
ESOM=AMAX1 (ESOM,-ES)
9405   IF (E(K) .LT.0) GO TO 7011
IF (IGRID.EQ.0) GO TO 101
TOTE=TOTE+E(K)
GO TO 101
7011  TOTS=TOTS-E(K)
101   ESM(I)=ESM(I)+ESTOR
IF (HTQSTM.LE.1.E-9) GO TO 3052
```

```
      F=HTQSTO/HTQSTM
      IF (ICOEF(1).EQ.2) GO TO 3053
      IF (F.GT.1) GO TO 3053
      IF (F.LT.0) GO TO 3058
      HTQSTO=HTQSTO-(F*HLHTH*(HTHTS-ATEMPH)+(1-F)*HLHTL*(LTHTS-ATEMPH))
      GO TO 3052
3058  HTQSTO=HTQSTO-(HLHTL*((HTHTS-LTHTS)*F+LTHTS-ATEMPH))
      GO TO 3052
3053  HTQSTO=HTQSTO-(HLHTH*((HTHTS-LTHTS)*F+LTHTS-ATEMPH))
3052  IF (LTQSTM.LE.1.E-9) GO TO 3061
      F=LTQSTO/LTQSTM
      IF (ICOEF(2).EQ.2) GO TO 3056
      IF (F.GT.1) GO TO 3056
      IF (F.LT.0) GO TO 3060
      LTQSTO=LTQSTO-(F*HLLTH*(HTLTS-ATEMPL)+(1-F)*HLLTL*(LTHTS-ATEMPL))
      GO TO 3061
3060  LTQSTO=LTQSTO-(HLLTL*((HTLTS-LTLTS)*F+LTLTS-ATEMPL))
      GO TO 3061
3056  LTQSTO=LTQSTO-(HLLTH*((HTLTS-LTLTS)*F+LTLTS-ATEMPL))
3061  LSM(I)=LSM(I)+LTQSTO
      HSM(I)=HSM(I)+HTQSTO
100   CONTINUE
%****************************************************************
% END CYCLE OF HOURS THROUGH THE MONTH
% CALCULATE VARIOUS MONTHLY TOTALS
%****************************************************************
      ESE(I)=ESTOR
      LSE(I)=LTQSTO
      HSE(I)=HTQSTO
      TOTEM(I)=TOTE-TOTEI
      TOTEI=TOTE
      TOTSM(I)=TOTS-TOTSI
      TOTSI=TOTS
      FUELMO(I)=FUEL-FUELI
      FUELI=FUEL
      TALTE(I)=RESID9-RESID8
      RESID8=RESID9
      ESM(I)=ESM(I)/(AMAX1(1,ESTORM)*M31)
      LSM(I)=LSM(I)/(AMAX1(1,LTQSTM)*M31)
      HSM(I)=HSM(I)/(AMAX1(1,HTQSTM)*M31)
      HRRUN=HRRUN+M31
      IF (I+1.NE.IMTH(KKK)) GO TO 1000
      WRITE(13,3777) IMTH(KKK)
3777  FORMAT(' ENTER SEASONAL PARAMETERS FOR MONTH: ',I2)
      DO 447 KZJ=1,3
447   OLDST(KZJ)=COEF(13+KZJ)
      KKK=KKK+1
1113  READ(12,*,PROMPT='VAR. # AND VARIABLE: ') IV,V
      IF (IV.LE.0) GO TO 3778
      COEF(IV)=V
      GO TO 1113
3778  LTQSTO=(LTQSTM/(OLDST(3)-OLDST(2)))* %
      (((LTQSTO/LTQSTM)*(OLDST(3)-LTLTS))+ %
      ((1-LTQSTO/LTQSTM)*(OLDST(2)-LTLTS)))
      LTQSTM=LTQSTM*(HTLTS-LTLTS)/(OLDST(3)-OLDST(2))
1000  CONTINUE
%****************************************************************
% END CYCLE OF MONTHS THROUGH THE YEAR
% CALCULATE VARIOUS YEARLY TOTALS AND DO OUTPUT
%****************************************************************
```

TOTIO. PB-PNC/UGFO02 08/17/78 14:41:56

```
      CALL MMDDYY (INOM, IYAD, IRY)
      CALL HHMMSS(IRH, INIM, ICES)
      WRITE( 13, 2660) TITLE, INOM, IYAD, IRY
2660  FORMAT ( / /1X, 15A4 , '      DATE :  ', 12,'- /, ,I2, '/' , 12)
      WRITE (13,2666) IRH, INIM,ICES
2666  FORMAT ( 61 X , '      TIME: ',12, ':', 12, ': ',12/)
      IF (ITBOUT. NE.1) GO TO 4112
      IF (IPRINT. EQ.1) WRITE( 13,2777)
2777  FORMAT (/' PHOTOVOLTAIC SYSTEM')
      IF (I PRINT .EQ.2) WHITE (13,2778)
2778  FORMAT (/' HEAT ENGINE SYSTEM')
      IF (I PRINT .EQ.3) WRITE (13,2779)
2779  FORMAT (/' HOT WATER SYSTEM')
      IF (I GRID. EQ.0) WRITE( 13,2780)
2780  FORMAT ( ' FOSSIL FUEL BACKUP' )
      IF (IGRID.EQ.1) WRITE(13,2781)
2781  FORMAT(' ELECTRIC BACKUP')
      IF (IGRID.EQ.3) WRITE(13,2782)
2782  FORMAT(' ELECTRIC AND FOSSIL FUEL BACKUP')
      IF (ISOLAR.NE.0) CALL COLL02
      CALL LOADS2
      IF (I0FFPK.EQ.1) CALL OFFPK2
      IF (IOUTS.NE.1) GO TO 4112
      WRITE(13,3)
3     FORMAT(//' SYSTEM COEFFICIENTS:' )
      WRITE(13,909) (COEF(I), I=1,29)
      WRITE(13,910) (ICOEF(I),I=1,8)
      IF ISOLAR.EQ.0) GO TO 4112
      WRITE(13,4)
4     FORMAT(//' COLLECTOR COEFFICIENTS:')
      CALL COLL03
      IF ((HTQSTM .LE. IE-9).AND. (LTQSTM .LE. lE-9)) GO To 4112
      WRITE(13,950)
950   FORMAT(//llX,'STORAGE HEAT LOSS COEFFICIENTS' //2lX, %
      'HEAT LOSS', 12x, 'AMB. TEMP'/l7x, '(KWH/DEG CENT/HR)'> 7x, %
      '(DEG. CENT)')
      IF (NHTQ.EQ.2) WRITE(13,951) HLHTH,ATEMPH
951   FORMAT(' HT STORAGE',9X, 1PE10.3, 14X,0PF5.1)
      IF (NHTQ.EQ.1) WRITE(13,952) HLHTH,HLHTL,ATEMPH
952   FORMAT(' HT STORAGE", 2X,1PE10. 3,' --', IPE10.3,8X,0PF5. 1)
      IF (NLTQ.EQ.2) WRITE(13,953) HLLTH,ATEMPL
953   FORMAT(' LT STORAGE', 9X,1PE10.3, 14X,0PF5.1)
      IF (NLTQ.EQ.1) WRITE(13,954) HLLTH,HLLTL,ATEMPL
954   FORMAT(' LT STORAGE',2X, 1PE10.3, ' --', lPEI0.3,8x,OPF5.1)
      IF ((NHTQ.EQ.1).OR. (NLTQ.EQ.1)) WRITE(13,955)
955   FORMAT(/' NOTE: FIRST HEAT LOSS NUMBER IS FOR HT TANK' %
      ' OF THE PARTICULAR'/'       STORAGE; ', %
      'SECOND IS FOR LT TANK OF THE SAME STORAGE.')
4112  CALL OUTTAB(ITBOUT, IHROUT)
      END
```

```
OUTTAB . PB-PXL/L'Lk'002 08/ 17 / 78 14 : 44 : 5 1)

          , PROGRAM ': AME : )U T T 113. JB
          % I{) H', ( . BELL
          . ENERGY PROGRAM
           (JFF I C F () F TEC HNO LOGY AS S F S SMENT
           COMPI LED
                DATE :    1 / 1 2/78
                TIM F : 13 : b:25
          ;PROGRAMOUTTAB. JB FOR TABULAR OUT PUT OF DATA
          "              BY US IN C S EGMENT EDIT NKING,THISPROGRAM
                         WILL ALLoW OUTPUT OF ALL DAT A



          SUBROUT I N F OU 1 I AB(ITBOUT,IHROUT)
          DIMENSIONE( 8760 )
          3I'H-(S IONE UE LMO ( 1.!) , TOTEM(12),IOTSM(12),TALTE(12)
          DIMENSIONESRM(12),(j SLY ( 12 ) , QCCM ( 14) , QCHM ( 14 ) , EEEM ( 12 ) , QPM ( 12 ) , '
                    TEMPM(12),IEXP ( 14 )
          DIMENSION C Ph ( 2, .!5 ) , CP( ( 2,25 )
          DIMENS I ON E S E ( 12 ) , LS E ( 12 ) , HSE ( 12) , 1 SM ( 12 ) , LSM ( 12 ) , HSM(12)
          IMPL IC I T PEAL(L)
          COMMON/AXXX /TEM PV 1 ( 10 ) , HTQSTM,T EM PV' 2 ( 2 ) , LTQSTM , TEMPV 3 ( b ) , %
                        ES TORM > TEMPV4 ( 5 ) , FAN, T EMPV 5 ( 3 ) , ITM PV 1 ( 2 ) , IGR ID , %
                        ITMPV2 ( 5 )
          ( OMMON / CXXX /("0 PAA , LO PEE,EBM,EBEM,EEE,EFFEX,TENGM,BENGM,ENGM,%
                        ESR , ES TOR , EE FF , FFHW , FHE I , FUEL , HTS STM, 1iTQ , HTQI , H IQO , %
                        HTQSO , HTQSTO , LTQI , I TQO , LTQSO,LTQSTO,QA,Q(",QC1,QC2,%
                        QC2Z,QE,QP,QS,QSR,RES ID9 , SHET , STHET,TOTTEO,TOTBEO,%
                        IL)IEO, HLHT L, HLLT L, EFFLOT, EFF ST, I PR IN T
          COMMON / DXXX /BOLMAX , C PC , C PH , EEEM , EHM , EKMAX , EKMIN , ES E , ES I , ES IM , %
                        ESM , ESO , ESOM , ESRM , ESTMAX , ESTM I\ , ESTOR I , FL' ELMO , %
                        HR RUN, HS F, HSM, HTMAX, HTM IS, HTQ I M, HTQOM, HTQ ST I , %
                        IEC , I EH , I EOMST , IHRAV , IHRCT , IOUTS , J 10, J2 0, J 30 , 1,S E , LSM , '.
                        LTMAX, LTM I>; , LTQIM, 1. TQOM , LTQST L , AMESR , AMQSR,QCCM,QCHM,%
                        QC 1!+", QC1 X , QC1 Y , QC 2W , QC 2X , QC 2Y , QPM , QSRM , TALT E , TBAT , %
                        TEEE , TEM PM , TESR , THTQ , TLTQ , TO TE , TO I EM, TOTS, TOTS}!, .
                        TQP , TQSR , T TEMP
          COMMON /XDATA/ F , HWLO AD
          IF ( ITBOUT . NE .1 ) GO TO 5000
          I F ( I OUTS. NE. 1 ) GO TO 20 1 1
          IF [ (I E H . L I .1 ) . AND . ( I EC . LT .1 ) ) GO TO 20 11
          .***  ******************** .********************** .****************
          W R IT E ( 1 3, 22 )
          22     FORMAT ( / / 7X, ' EL ECTR I C H / , Co 1' ' ' S ( KWH /KWH ) " )
          W SIT F ( 13, 23 )
          23     F ORMA I (4X, ' TEMP ' ,4X, ' HEAT ' ,8X , 'TEMP ' , .,.\, ' COOL ' )
          1(-S =0
          IHS =0
          I F ( 1 EC . LI .1 ) I (" S= 1
          I F ( IEH. LT .1 ) IHS= 1
          DO 119 I = 1, 25
          I F ( C PC ( 1, I ) .1. I . -99 . ) I C S = 1
          I F ( C PH ( I , I ) . L 1.-99. ) I IIS = 1
          IF ( ( 1 HS . EQ .1 ) . AND . ( I ( S . EQ. 1 ) ) GO TO 1 20 I I
          I F ( ( I HS . NE . 1 ) . AND . ( IC S . NE . 1 ) ) WR IT F ( 1 3 , .!+ )
                 C PH ( 1 , I ) , CPH(2, I) / ( 1+CPH ( 2 , I ) *FAN) , %
                 C PC( 1, I ), CPC ( 2 , I )' ( 1 +.7. 5*C PC ( 2, I) * FAN)
          I F ( I [' S . EQ .1 ) WR IT [ ( I 3,2) ) ( PH ( 1 , I ) , ( PH ( 2 , I)/( 1 +PH ( 2 , I ) * FAN)
          I F ( IHS . EQ .1 ) WR I T E ( 13, 26)CPC(1 ,I),( PC(2,I) / (I +2.5*CPC(2,I)* FAN)
          11 9 CON T INU E
```

```
OUTTAB .PB-PNC/UGF002 08/ 17/78 14: 44: 51

          24    FORMAT ( 3X, F 5.1, 2X, F6 .2, 7X, F5 .1, 2X,F6 . '2)
          25    FORMAT ( 3X, F5 .1, 2X, F6 .2, 9X, ' --' , 6X, ' --' )
          26    FORMAT ( 5X, ' --' , 6X, ' --' ,8X, F5 .1, 2X, F6 . 2 )
          Z****  ************************  *****  **************************
          2011    EFACT=AMAX1 ( 1, ESTORM)
          BATLF=TBAT/ (HRRUN*EFACT )
          EFACT=AMAX 1 ( 1, HTQSTM)
          HTLF=THTQ/ ( HRRUN*EFACT )
          EFACT=AMAX 1 ( 1, LTQSTM )
          LTLF=TLTQ/ (HRRUN*EFACT )
          EFACT=AMAX1 ( 1 ,TENGM)
          ENGLFT=TOTTEO/ (HRRUN*EFACT )
          EFACT=AMAX1 ( 1, BENGM)
          ENG LFB=TOTBEO/ ( HRRUN*EFACT )
          EFACT=AMAX1 ( 1, ENGM)
          ENGLF=TOTEO/ ( HRRUN*EFACT )
          EFACT=O
          Do 4110 I= J10, J20, J30
          IF (ABS (TALTE ( I ) ).LE. 1.00) TALTE ( I ) =0
          4110    EFACT=EFACT+TALTE ( I )
          WRITE (13 ,4113 )
          4113 FORMAT ( / / 7X, ' ELECTRICITY AND FOSS 11, FUEL BACKUP DEMANDS (KWH ) ' )
          WRITE ( 13, 1005)
          1005 FORMAT ( ' MONTH' , 4X, ' ELEC . BUY ' , 4X, ' ELEC . SF. LL ' ,4X , ' FUEL USE ' , %
                3X, ' EXCESS LT ENERGY' )
          WRITE ( 13, 1006) (1, TOTEM(I) , TOTSM ( 1), FUELMO ( I ), TALTE ( I ) , I= 110, J20, J 30 )
          1006 FORMAT( ' ' ,13, 4X, IPE 10.3, 4x, IPE 10.3, 4X, 1PE 10.3, 5X, 1 PE 10.3 )
          WRITE ( 13, 1007) TOTE, TOTS, FUEL, EFACT
          1007 FORMAT ( ' TOTAL' , 2X, IPE 10.3, 4X, 1PE 10.3, 4X, IPE 10.3, 5X, 1PE 10. 3 )
          IF ( ( IGRID . EQ . 0) .AND . ( I PRINT . EQ. 1 ) ) WRITE ( 13, 4007)
          4007 FORMAT ( ' NOTE:   ELEC SELL IS DC ELECTR IC ITY THAT CAN ' ' T ' , %
                         'BE STORED IN THE BATTER}" )
          %*****************  *******************  *******************  ****
          QCHM( 1 3)= QCHM( 14 ) /IHRCT
          QCCM( 13)=QCCM( 14) /IHRCT
          DO 66 1=1, 14
          TEST=QCCM ( I )
          IF (QCHM ( I ) .GT. QCCM( I ) ) TEST= QCHM( I )
          DO 65 J=1 , 10
          IF (TEST/( 10**J) . LT .1. 00) GO TO 64
          65    CONT INUE
          64    IEXP ( I ) =J-1
          DI V= 10** (J-1 )
          QCHM ( I ) =QCHM ( I ) /D IV
          QCCM( I )= QCCM(I ) /D IV
          66    CONTINUE
          IF ( IHRAV. NE. 1 ) GO TO 9059
          WR ITE ( 13, 7 705)
          7705    FORMAT (// 26X , 'TOTAL MONTHLY VALUE S (KWH ) ' , 24X, ' AVER ' / %
                7X, ' PHOTO VOLT' ,6X , ' SOLAR ' ,6X , '___________' , %
                ' INTERNAL DEMANDS ' , '_ -________' , 7X, ' TEM P ' / %
                ' MONTH ' , IX, ' ELECTRIC ' ,6X , ' THERMAL ' , 5X, ' ELECTRIC " , %
                5x, " HEAT/COOL , 5x, 'HO r WATER' , 7x, ' (F. ) ' )
          WRITE ( 13, 7707) (1, ESRM( I ) , QSRM ( I ) , EEEM ( I ) , QCHM( I ) , QCCM( I ) , %
                      IEXP ( I ) , QPM ( I ) , TEMPM ( I ) , I=J 10,J20 , J 30)
          7707    FORMAT ( ( ' ' , IX , I 2 , 2X, 2 ( 1 PE 10.3, 3X) , 1 Pr 10.3, 2X, OPF4 .2, ' / ' , %
                      OPF4 .2, ' E+00' , T 57, I 1, 2X, 1PE 1 0. 3, 7X, OPF4 . 1) )
          %WR I r E ( 13, 7710 ) TF SR / I HRCT, TQSR/ I HRCT, TEEE/ I HRC T, QCHM ( 13 ) , %
          %              QCCM ( 13 ) , T EXP ( 13 ) , TQP/ IHRCT , 1 TEMP/IHRCT
          %7 710    FORMAT ( ' YR AV ' , 2 ( 1 PE 10. 3, 3X ) , 1 PE 10. 3, 2X, OP F4 . 2 , ' / ' , %
```

```
%                    OPF4.2,'E+00',T57,I1,2X,1PE10.3,7X,OPF4.1)
GO TO 9053
9059   WRITE(13,7706)
7706   FORMAT(//31X,'YEARLY TOTAL (KWH)'/ %
       7X,'PHOTOVOLT',6X,'SOLAR',6X,'____________', %
       'INTERNAL DEMANDS','__________',7X,'TEMP'/ %
       7X,'ELECTRIC',6X,'THERMAL',5X,'ELECTRIC', %
       5X,'HEAT/COOL',5X,'HOT WATER',7X,'(F.)')
9053   WRITE(13,7715) TESR,TQSR,TEEE,QCHM(14),QCCM(14),IEXP(14),TQP
7715   FORMAT(' TOTAL',2(1PE10.3,3X),1PE10.3,2X,OPF4.2,'/', %
                   OPF4.2,'E+00',T57,I1,2X,1PE10.3,7X,' -- ')
%****************************************************************
IF (IEOMST.NE.1) GO TO 9054
WRITE(13,4089)
4089   FORMAT(//17X,' LOAD FACTOR  ',19X,'END OF MONTH VALUES'/%
                 7X,'________-' , 'OF S TORAG E ( KWH ) ' , '       _ ',%
                 3X, '________   ' ,  ' OF STORAGI( KWH)_, ' .____'1  -
                 'MON TH ' , 1 X ,- %
                 'ELECTRIC',4X,'LOW TEMP',4X,'HIGH TEMP',3X, %
                 'ELECTRIC',4X,'LOW TEMP',4X,'HIGH TEMP')
WRITE(13,4080) (I,ESM(I),LSM(I),HSM(I),ESE(I),LSE(I),HSE(I), %
                  I=J10,J20,J30)
4080   FORMAT((2X,I2,2X,6(1PE10.3,2X)))
%****************************************************************
9054   WRITE(13,9000)
9000   FORMAT(//47X,'STORAGE VALUES')
WRITE(13,9001)
9001   FORMAT(36X,'ELECTRIC',6X,'LOW TEMP',6X,'HIGH TEMP')
WRITE(13,9002) BATLF,LTLF,HTLF
9002   FORMAT(' LOAD FACTOR (DIM):',14X,3(2X,1PE10.3,2X))
WRITE(13,9003) ESTORI,LTQSTI,HTQSTI
9003   FORMAT(' INITIAL VALUE (KWH):',12X,3(2X,1PE10.3,2X))
WRITE(13,9004) ESTOR,LTQSTO,HTQSTO
9004   FORMAT(' FINAL VALUE (KWH):',14X,3(2X,1PE10.3,2X))
WRITE(13,9006) ESTMIN,LTMIN,HTMIN
9006   FORMAT(' MINIMUM VALUE (KWH):',12X,3(2X,1PE10.3,2X))
WRITE(13,9005  ESTMAX,LTMAX,HTMAX
9005   FORMAT ' MAXIMUM VALUE (KWH):',12X,3(2X,1PE10.3,2X))
WRITE(13,9007  ESI,LTQI,HTQI
9007   FORMAT ' TOTAL ENERGY PUT INTO (KWH):',4X,3(2X,1PE10.3,2X))
WRITE(13,9008  ESO,LTQO,HTQO
9008   FORMAT ' TOTAL ENERGY TAKEN OUT OF (KWH):',3(2X,1PE10.3,2X))
WRITE(13,9009  ESIM , LTQIM , ~iTI'1'1
9009   FORMAT ' MAXIMUM I NPUT IN TO PC  ( KWH/HR ) : ' , 1X, 3 ( 2X, 1 PE 10.3, 2X) )
WRITE(13,9010  F SOM , LTQOM , HTQOM
9010   FORMAT(' MAXIMUM OUTPUT INTO PC (KWH/HR):',3(2X,1PE10.3,2X))
%****************************************************************
IF (TOTEO.LT.0.1) GO TO 8056
WRITE(13,8001)
8001   FORMAT(//47X,'ENGINE VALUES')
WRITE(13,8002)
8002   FORMAT(38X,'LOAD',10X,'TOTAL',8X,'MAXIMUM'/ %
       37X,'FACTOR*',7X,'OUTPUT*',7X,'OUTPUT*')
WRITE(13,8003) ENGLFT,TOTTEO,TENGM
8003   FORMAT(' TOPPING ENGINE:',17X,3(2X,1PE10.3,2X))
WRITE(13,8004) ENGLFB,TOTBEO,BENGM
8004   FORMAT(' BOTTOMING ENGINE:',15X,3(2X,1PE10.3,2X))
WRITE(13,8005) ENGLF,TOTEO,ENGM
8005   FORMAT(' TOTAL ENGINES:',18X,3(2X,1PE10.3,2X))
WRITE(13,8006)
```



```
8006   FORMAT ( ' *NOTE :  LOAD FACTOR 13 ASED ON AC TUAL MAX 1 MUM ' , '
       ', NOT ON DES IGN MAXI IMUM . ' )
%*********************************************************************
8056   WRITE ( 13, 107 I )
1071   FORMAT ( / / 23X, ' MAX IMUM SPAC E COND IT ION 1 NG LOADS ' /
       21X, ' ELECTRIC ' , 7X, ' THE, RMAL ' , XX, ' TOTAL ' )
WRITE ( 13, 9011 ) QC 1X, QC 2X, QC 2W , QC 1 Y , QC 2Y , QC 1W
9011   FORMAT ( ' COOLI NG ( KWH ) : ' , 4X, 3 (2X, 1 PE 1 C. 3, 2X ) / %
              ' HEATING (KWH ) : ' , 4X , 3 ( 2X, 1 PE 10.3, 2X) )
%*********************************************************************
WRITE ( 13, 8886) AMQSR , A.. ESR
8886   FORMAT ( / / " MAXIMUM SOT, AR THERMAL OUT PUT ( KWH ) : ' , 1 PE I 0 .1 / ".
              ' MAXIM UM SOLAR ELECTRIC OUT PUT ( KWH ) : ' , 1 PE 10.3 )
WRITE ( 13, 3031 ) EB EM
3031   FORMAT ( ' MAXIMUM ENG INE BOILER (01' TPUT (KWH ) : ' , 1PE 10.3 )
WRITE ( 13, 302(3) EBM
3020   FORMAT ( ' MAXIMUM NONENG INE BOILER (01' TPUT (KWH ) : ' , 1PE 1 C . 3 )
WRITE ( 13, 3914 ) EHM
3914   FORMAT ( ' MAXIMUM HOT WATER FUE L USE (KWH ) : ' 1 PE 1 0. 3 )
WRIT E ( 13, 8862) FHET , SHET , STHET
88 b.?   FoRMAT ( ' F(3S S IL HEA 1 PUT INTO ENG INE ( KWH ) : ' , 1 PE 10.3 / '.
              ' SOLAR HEAT PUT INTO L-. NGINE (KWH ) : ' , 1 PE 1 0 . 3/ %
              ' STORAGE HEAT PUT INTo ENGINE ( KWH ) : ' , 1PE 10.3 )
WRITE ( 13, 1086) EKMAX, -EKM IN
1086   FORMAT ( ' MAXIMUM ELECTRICI TY BOUGHT IN AN HOUR ( KWH ) : ' 1 PE 10. 3%
           / ' MAXIMUM ELEC TRICITY SOLD IN AN HOUR (KWH) : ' , 1PE 10 .3 )
WRITE ( 13, 1020) BOLMAX
1020   FORMAT ( ' MAXIMUM FUEL BOUGHT IN AS HOUR (KWH ) : ., 1PE 10. 3 )
IF ( IGRID . EQ. 0 ) TOT S=0
WRITE ( 13, 4091 ) TO TE, TO rs, FUEL
4091   FORMAT ( ' TOTAL ELECTRICITY l\ OUGHT ( KWH ) : ' , 1PE 10. 3/%
              ' TOTAL ELECTRICITY SOLD ( KWH ) : ' , 1PE 10. 3/ %
              ' TOTAL FUEL BOUGHT (KWH ) : ' , 1PE 10. 3//// )
%**** ********************** ***** *********************** ********
IF ( IHROUT .NE .1 ) GO TO 4000
5000   WRITE ( 50 ) E, AMQSR, AMESR  @OUT PUT FOR UT ILITY ,\ NALYS I S
X******************   **********************   ********************
4000   RETURN
END
```

```
LOAD S. PB-PNC/UGFOO2 08/17/78 14:44: 17

% PROCRAM NAME: LOADS. JB
% JOHN C. BELL
% F. NERGY PROGRAM
% OFF ICE OF TECHNOLOGY ASSESSMENT
% COMP I LED
%      DATE :   1 / 27/78
%      TIME: 17:29:26
% PROGRAM LOADS. JB FOR SETTING UP THE ELECTRIC, THERMAL, AND
%          PROCESS LOADS FOR:  SINGLE FAMILY, TOWNHOUSE, OR
           LOW RISE APARTMENT BUILDINGS; HIGH RISE APARTMENT
%          BUILDINGS; OR, SHOPPING CENTERS
%
%
SUBROUTINE LOADS(TL,TH,FAN,HEATMX,COOLMX, ISMTH, IHR)
DIMENSION ELLOAD(168),ELOAD1 (24) ,ELOAD2(24),WLOAD 1(24) , %
          WLOAD2(24),HWLOAD( 168) ,E(8760),TA1 (8760)
COMMON/XDATA/E,HWLOAD
EQUIVALENCE (ELOAD1( 1),ELLOAD(1 )), (ELOAD2(1),ELLOAD( 145)), %
            (WLOAD1(1 ),HWLOAD(1)),(WLOAD2( 1),HWLOAD(145))
%
% SET UP LOADS FOR HOURLY COMPUTATION
%
READ(25) TA1,TA1
IF (ISMTH.EQ.1) GO TO 601
READ(20) E, ELOAD1, ELOAD2,WLOAD1,WLOAD2
KCT=0
DO 600 1=25,144
KCT=KCT+1
IF (KCT.EQ.25) KCT=1
HWLOAD(I)=WLOAD1(KCT)
ELLOAD(I)=ELOAD1(KCT)
600  CONTINUE
CO TO 701
601   READ(20) E,ELLOAD,HWLOAD
701   KCT=O @ZERO MEANS THE YEAR STARTS ON MONDAY AS THE 168 MAT. DO
TLOAD=0. 0
IF (IHR.NE.0) GO TO 602
FANH=FAN*HEATMX
FANC=2. 5*FAN*COOLMX
GO TO 702
602   READ(12,*,PROMPT= %
  'MAXIMUM PUMP/FAN LOAD--HEATING, COOLING (KW FAN/TOTAL OUTPUT): ') %
     FANH,FANC
FANHH=-FANH*HEATMX
FANCC=FANC*COOLMX
702   TL1=(459.4+TL)/1.8
TH1=0.001+(459. 4+TH) /1.8
KCT=0
RETURN
%
% SET UP LOADS FOR EACH HOUR
%
ENTRY LOADS 1(K,EEE,QSH,TA)
TA=TA1(K)
KCT=KCT+1
IF (KCT.GE. 169) KCT=1
IF (IHR.EQ.2) GO TO 444
IF((TA.GE.TL1).AND.(TA.LE.TH1 )) GO TO 900
IF((TA.LT.TL1).AND.(TLOAD+E(K).GT.0)) GO TO 900
IF((TA.GT.TH1).AND.(TLOAD+E(K).LT.0)) GO TO 900

LOADS.PB-PNC/UGFOO2 08/17/78 14:44:17

444   TLOAD=TLOAD+E(K)
IF (IHR.NE.2) GO TO 704
KDAY=1+(KCT-1) /24
KHRD=KCT-(KDAY-1 )*24
KDAY=KDAY-7*((KDAY-1)/7)
IF ((KDAY.LE.6).AND.((KHRD.LT.8) OR. (KHRD.GE.23)).AND. %
    (TLOAD.GT.0)) TLOAD=0
IF ((KDAY.EQ. 7).AND.((KHRD. LT.13 .OR.(KHRD.GT. 19)).AND. %
    (TLOAD.GT.0)) TLOAD=0
IF (((K.LE.5831).AND.(K.GT. 3625) .AND.((KHRD.LT.8).OR.(KHRD.GE.23)) %
   .AND.(TLOAD.LT.0) ) TLOAD=0
IF (ABS(TLOAD).LT.0.0001) GO TO 40
FANH=FANHH/TLOAD
FANC=FANCC/TLOAD
704   IF (TLOAD.GT.0) GO TO 20
PCLD=-TLOAD/HEATMX
IF ((PCLD-0.1).LT.0) GO TO 40
EEE=ELLOAD(KCT)+FANH*PCLD
QSH=TLOAD
TLOAD=0.0
GO TO 800
20   PCLD=TLOAD/CDOLMX
IF ((PCLD-0.1).LT.0) GO TO 40
EEE=ELLOAD(KCT)+FANC*PCLD
QSH=TLOAD
TLOAD=0.0
GO TO 800
900   TLOAD=0
40   EEE=ELLOAD(KCT)
QSH=0
800   RETURN
Z
% OUTPUT STATEMENTS
%
ENTRY LOAOS2
IF (IHR.EQ.0) WRITE(13,959)
959   FORMAT(' LOADS SET UP FOR SINGLE FAMILY HOUSE')
IF (IHR.EQ.1) WRITE(13,960)
960   FORMAT(' LOADS SET UP FOR HIGH RISE APARTMENT BUILDING')
IF (IHR.EQ.2) WRITE(13,970)
970   FORMAT(' LOADS SET UP FOR SHOPPING CENTER')
IF ((IHR.NE.0).AND.(FAN.GT. 0)) WRITE(13,961)
961   FORMAT('  CAUTION:  FAN LOAD (#27) IS NOT ZERO')
WRITE(13,971)
971   FORMAT(' THE MISCELLANEOUS ELECTRIC LOADS AND THE HOT WATER LOADS')
IF (ISMTH.EQ.0) WRITE(13,972)
972   FORMAT("      ARE NOT SMOOTHED')
IF (ISMTH.EQ.1) WRITE(13,973)
973   FORMAT('      ARE SMOOTHED')
RETURN
END
```

```
UPDATE. PB-PNC/UGF002 08/17/78 14:49:43

% PROGRAM NAME: UPDATE.JB
% JOHN C. BELL
% ENERGY PROGRAM
% OFFICE OF TECHNOLOGY ASSESSMENT
% COMPILED
%     DATE:  8/ 4/78
%     TIME: 17:29:48
% PROGRAM UPDATE.JB FOR HANDLING STORAGE INPUT/OUTPUT
%
%
%
%        SIZE=ENERGY STORAGE CAPACITY
%        CURRNT=AMOUNT OF ENERGY CURRENTLY IN STORAGE
%        DELTA=ENERGY ADDED TO STORAGE (IF POSITIVE)
%        DELTA=ENERGY REMOVED FROM STORAGE (IF NEGATIVE)
%        RESID= ENERGY WHICH CAN NOT BE STORED (IF NEGATIVE)
%        RESID=ENERGY WHICH CAN NOT BE PROVIDED FROM STORAGE
%              (IF POSITIVE)
%        EFFPC1=ONE-WAY EFFICIENCY OF POWER CONDITIONER
%              OR HEAT EXCHANGER
%        EFFBT=TWO-WAY BATTERY OR THERMAL STORAGE EFFICIENCY
%
%
%
%
SUBROUTINE UPDATE(SIZE, CURRNT, DELTA, RESID, EFFPC1, EFFBT, PCSIZ1)
IF(SIZE.GT.0.01) GO TO 800
RESID=-DELTA
CURRNT=0.0
RETURN
800   RESID=0
IF((CURRNT.GE.SIZE).AND.(DELTA.GT.0)) GO TO 700
IF((CURRNT.LE.0.00).AND.(DELTA.LT.0)) GO TO 700
IF(ABS(DELTA).LT.0.0001) RETURN
```

```
UPDATE. PB-PNC/UGF002 08/17/78 14:49:43

IF(DELTA.LT.0)GO TO 100
TEST0=DELTA-PCSIZ1/EFFPC1
IF(TEST0.GT.0)GO TO 50
TEST1=EFFPC1*EFFBT*DELTA+CURRNT
IF(TEST1.GT.SIZE)GO TO 20
CURRNT=TEST1
RETURN
20 RESID=(SIZE-CURRNT-EFFPC1*EFFBT*DELTA)/(EFFPC1*EFFBT)
CURRNT=SIZE
RETURN
50 TEST2=EFFBT*PCSIZ1+CURRNT
IF(TEST2.GT.SIZE)GO TO 20
RESID=(-1)*TEST0
CURRNT=TEST2
RETURN
100 IF((DELTA+PCSIZ1).LT.0)GO TO 150
TEST3=DELTA+EFFPC1*CURRNT
IF(TEST3.LT.0)GO TO 120
CURRNT=DELTA/EFFPC1+CURRNT
RETURN
120 RESID=(-1)*TEST3
CURRNT=0
RETURN
150 TEST4=CURRNT-PCSIZ1/EFFPC1
IF(TEST4.LT.0)GO TO 220
RESID=-(DELTA+PCSIZ1)
CURRNT=TEST4
RETURN
220   RESID=-DELTA-EFFPC1*CURRNT
CURRNT=0
RETURN
700   RESID=-DELTA
RETURN
END
```

```
COPT.PB-PNC/UGF002 08/17/78 14:48:40

% PROGRAM NAME: COPT.JB
% JOHN C. BELL
% ENERGY PROGRAM
% OF F ICE O F 'L EC HNOLOGY ASS ES SMENT
% COMPILED
%      DATE : L21LOJ77
%      TIME : 14 : 10 : 24
% PROGRAM CO PT. J B FOR OFT ERM IN ING THE COP ( EFF ) FOR A
%     GI VEN TEMPERATURE ( T ) FROM TH F COP CUR VE ( C P ( 2, 25 ) )
%
%
%
%
SUBROUTINE COPT (T ,CP ,EFF )
DIMENS ION CP ( 2, 25)
```

```
COPT . PB-PNC /UGF 00 2 08/ 17/ 78 14 : 48 : 40

IF (T. LE. C p ( 1, 1 ) ) GO TO 112
DO 14 I= 1, 25
IF (CP ( 1, I ) . LT .-99. ) GO TO 113
1X=1
IF ( (T. GE . CP ( 1, I ) ) . AND. (T. LT . CP ( I, I+1 ) ) ) GO To 111
14 CONT INUE
111 EFF=C P(2,I)+(CP(2, I+1 )-L P(2, I) ) %
     * (T-CP ( 1, I ) ) / ( CP ( 1, I+1 ) -CP ( 1, I ) )
RETURN
112 EFF=CP(2, l )
RETURN
113    EFF=C P ( 2, LX)
RETURN
END
```

```
% PROGRAM NAME: HESYS.JB
% JOHN C. BELL
% ENERGY PROGRAM
% OFFICE OF TECHNOLOGY ASSESSMENT
% COMPILED
%      DATE: 12/19/77
%      TIME: 12:58:24
% PROGRAM HESYS.JB FOR RUNNING HEAT ENGINE SYSTEMS WITH
%          ELECTRIC BACKUP



SUBROUTINE SYSTEM ( K , QSH )
DIMENSION E ( 8760 ) , HWLOAD ( 168 )
IMPLICIT REAL (L )
COMMON /AXXX/COPA , EHWEFF , HCOPM , CCOPM , EFFB , ENGMAX , EFF1, EFF2 , ALPHA 1, %
              ALPHA2 , HTQSTM , LTHTS , HTHTS , LTQSTM , I TLTS , HTLTS , HLH I H , %
              FHWEFF , HLLTH , EFFBE , ESTORM , t FFBAT , PCSIZ, EFFPC , HEATMX , %
              COOLMX , FAN , TL , 1 H , XXX, NHTQ , NLTQ , IGR J 1), ISOLAR , IA, I SMTH , %
              I HR , IOFFPK
COMMON /LXIX/COPAA , CO [Jr E , FBM, EBEM , 1" EE , EFFEX , TENGM , BENGM , ENGM , %
              ESR , ESTOR , EFF , FHW , FHEI , FUEL , H TSSTM , HTQ , HTQI , H IQO , %
              HTQSO,HTQSTO,LTQ1,LTQO,LTQSO,LTQSTO,QA,QC,QC 1, QC 2, %
              QC2 / , 0EQPQS,QSR,RESID9 , SHFT,STHtT,TOTTEO , TOTBEO , %
              TOTEO , HLHTL , HLLTL , EFFI (1T , EFFST , I PRINT
COMMON XDATA / E , HWLOAD
DATA IAIPR [ N1, 2 /
QC1 =0
QC2=0
1QC2=1
QHOUR=OFI
IF (U) PAA.?r. 0. 001 ) GO TO 32
QHOUR= (; P+QC / COPAA
32   CALL UPDATE ( LTQSTM , LTQSTO , -QHOUR, RESIDQ, EFFEX ,EFFLOT, LTQSTM)
QP1 =AMAX 1 ( 0, QP- ((j HOUR-RES T DQ ) )
IF ( QP1 .Lh. 0.001 ) QC=QC-COPAA*(QHOUR-RESIDQ-QP )
QP=QP1
IF ( QSH . GT . 0 ) QC2Z=QSH-QC
IF ( QSH . LE .0 ) QC2Z=-QSH-QC
%* *** ******* ************* ************* *********** *********** * *
>********************* *********************** **********
%**** * HEAT ENGINE SECTION--VERY COMPLICATED ! ! !
%* *** ************* ************* **. ******** ** .*************
% **** ********* ********** .******** ********* ********* ********* *
SOLE=QSR+HTQSTO
HTQSTO=0
IF (SOL ! . GT . QP ) GO TO 2 000
'! .28'?    QP=QP-SOL E
SOL E=0
QC1 =QC
IF (QSH . GT .0 ) QC2=QSH-QC
IF (QSH . LE .0 ) QC2=-QSH-QC
EOUT=0
IQC 2=0
EEE=EEE+QP/EHWEFF
QP=0
GO TO 900
2000   IF (COPAA.GT .0.01 ) GO T(3 2100
QC 1 =QC
COPAA= 1.0
```

HESYS.PB-PNC/UGF002 08/17/78 14:43:37

```
%**** ***************************** ***** ***********************  **
z**** C.&~ THE BOTTOM ING CYCLE BE ON ALL I H r WAY
Z****  *************************  *****  **************************
220 I   IF (QP . GT . SOLE*EFF1 *ALPHA.! ) GO To 2001
BETAV= 1
GAMMA= 1
GO TO 2050
Z*******************   *********************   *****************
%***** CAN THF BOTTOMING CYCLE BE ON FART WAY?
Z******************  ********************  *******************  **
2001   IF ( QP. GT. SOLE* EFF1 * (ALPHA1+ALPHA 2 ) ) GO TO 2 002
BETAV=1
GAMMA= ( SOLE *EFF 1* ( ALPHA1+ALPHA2 ) -QP ) / ( SOLE*EFF1 *ALPHA 1 )
GO TO 2050
Z****  **************************  *****  ************************
%***** BOTTOMING CYCLE OFF !
%* ******* ********* ********* .********* ********** ********* *
2002   BETAV= ( SOLE-QP ) / ( SOLE* ( 1-EFF1 * (ALPHA1 +ALPHA2 ) ) )
GAMMA=0
%****  **************************  *****  ************************
%***** CHECK FOR ENGINE CLIPPING
Z****  *************************  *****  ***********************  **
2050   IF ( BETAV*SOLE*EFF1 .GT . ENGMAX) GO To 2090
%****  **************************  *****  ************************
z***** COMPUTE ELECTRIC AND LT THERMAL OUPUTS
%****  **************************  *****  ************************
2051   EOUT=BETAV*SOLE *EFF 1* ( 1+GAMMA*EFF2*ALPHA 1 )
z****  **************************  *****  ************************
%***** CHECK IF ALL ELECTRICITY CAN BE USED
%*** ********** **** * *** ********** **********.*** ********** ** **
XLAX=AMIN 1 ( PC SIZ/EFFPC , ( ESTORM-ESTOR ) / EEFF )
IF (EOUT. GT. EEE+QC1 /COPE E+XLAX) GO TO 2095
%*** **A'**** *** * ***** ******* .**** **** ***** **********.*********
%***** CYCLE AND Go To NEXT HOUR
%**** ***** ******** *********** **** **** *** *** *** ** **** ********
GO TO 900
%*** **** *** *** ***** ******* * *** *** ************** *** ****** ****
z***** FIX ENGINE CLIPPING CONDITION--HAVE TO CHECK
%***** WHETHER REVISION AFFECTS MEETING THE THERMAL LOAD
z***  ***  ***  ***  *.**  ***  **** **** . *** **** ****
2090   IF (QP. GT. ALPHA2*ENGMAX) GO TO 2091
BETAV= 1
GAMMA= 1
GO TO 2058
2091   IF (QP. GT. ENGMAX*(ALPHA 1+ALPHA2) ) GO TO 2094
BETAV= 1
GAMMA= ( ENGMAX* (ALPHA 1+ALPHA2 ) -QP) / (ALPHA 1 *ENGMAX)
GO TO 2058
2094   GAMMA=0
BETAV=ENGMAX/ ( ENGMAX* ( 1-EFF 1 * (ALPHA 1+ALPHA2 ) ) +EFF1 *Qp )
2058   CALL UPDATE (HTQSTM, HTQSTO, SOLE-ENGMAX/(EFF 1* BETAV), %
       RESIDQ , EFFEX, EFFST , HTQSTM)
CALL UPDATE (LTQSTM, LTQSTO, -RESIDQ, RESID, EFFEX, EFFLOT, LTQSTM)
RESID9=RESID9-RESID
SOLE=ENGMAX/ (EFF 1 *BETAV )
GO TO 2051
%**************************************************************
%***** FIx overproduction OF ELECTRICITY IF HI ENERGY
%***** CAN BE STORED; IF HT STORAGE FULL, GO BACK AND
%***** SELL THE AVAILABLE ELECTRICITY TO THF GRID
```

HESYS. PB-PNC/UGF002 08/17/78 14:43:37

```
      Z***************************************************************************
 2095 IF (HTQSTO.GE.HTQSTM*0.99) GO TO 900
      EOUT=EEE+QC/COPEE+XLAX
      IF (QP.GT.ALPHA2*EOUT/(1+ALPHA1*EFF2)) GO TO 2098
      GAMMA= 1
      BETAV= 1
      GO TO 2113
 2098 IF ( QP . GT . ( ALPHA 1+ALPHA2  *EOUT ) GO TO 2099
      GAMMA= ( EOUT* ( ALPHA 1 +ALPHA2 ) -QP )  (ALPHA 1 * (EOUT+E FF2*QP )
      BETAV= 1
      GO TO 2113
 2099 GAMMA=0
      BETAV = EOUT / ( EFF 1 *QP+EOUT* ( 1-EFF 1 * ( ALPHA 1+ALPHA2 ) ) )
 2113 CALL 1 PDAT I (HTQSTM, HTQSTO, SOLE. -EOUT/ %
     ( BETAV*EFF 1 * ( 1 +GAMMA*ALPHA 1 *EFF2 ) ) ,RESIDQ , EFFEX, EFFST , HTQSTM)
      SOLE=EOUT / ( BETAV*EFF 1 * ( 1 K; M?' A* LPHA 1 *EF F.? ) ) -RESIDQ
      IF (R) S IDQ . LT. 0 ) GO TO 2201
      GO TO 900
      Z* ****** ********* ********* ***** ********* ************** *******
      Z***** CHECK WHETHER THE THERMAL SPACE COND I r LOX ING
      ,** ** * ROUTE I j THE MOST EF F IC I ENT
      ************************ *********************** **************
 .!100 IF (COPAA. LT . EFF 1 * ( COPEE+ (ALPHA 1+ALPHA2 ) *COPAA) ) GO TO 2101
      IF (SOLE. LT . QP+QC / COPAA ) GO TO 2 Y [) 1
      QP=QP+QC /COPAA
      QC1 =0
      QC2=QC
      T QC 2=0
      QC=0
      GO TO 2 20 1
 2901 SOLE =SOLE-QP
      QP=0
      (/C=, QC-SOLE *COPAA
      SO I r,0
      GO TO 2 202
      .**** ******************* ************************* ************
      Z** *** CHE ["K WHET} I ER THE BOTTOMING CYCLE IS MORE E FF IL IENT
      Z ***** THAN THE TH ERMAL ROUTE--I F THE BOTTOMING CYCLE L S
      * ***** MOR E EFFIC I EN r-- I . E .  EFF2*COPEE >COPAA>0--GO TO
      Z ***** S TATEMENT 2501 ; OTHERWI S E STAY HERE .
      ' *** * * ( NOTE : I T L\ AS SUMED I N THESE SW I TCHES
      ,*** * * THAT E FF2 <EFF 1 )
      Z** *** ** **** ************** ****** ************** ******* ********
 2101 IF ( COPAA. LT . EFF2*COPEE 1 GO TO 2501
      QC 1=0   . QC 1 IS S PACECOND I T IONINGLOADMETELECTRICALLY
      (<C2=QC:QC2 IS S PAC E COND IT ION 1 NG LO An MET  THERMALLY
      IF ( (J P+QC /COPAA . GT . SOLE* EF F 1 *ALPHA? ) GO TO 2402
      BETAV= 1
      GAMMA= 1
      GO TO 2450
 24{02 IF ( Q P+QC / COPAA . GT . SOLE *F F F 1 * ( ALPHA 1 +ALPHA2 ) ) GO TO 2 40 3
      BETAV= 1
      GAMMA= ( SOLE*EFF 1 * (ALPHA 1 +ALPHA 2 ) -Q P-QC /COPAA ) / ( SOLE *1 FF 1 * ALPHA 1 )
      GO TO 24 50
 2403 IF ( QP . GT. SO I F* EFF I * ( ALPHA 1 +ALPHA2 ) ) GO : 0 2 404
      BETAV= 1
      GAMMA=0
      QC1 =(< C-COPAA* ( SOLE *t F F 1 * ( ALPHA 1 +ALPHA2 ) -QP )
      QC 2 =QC-QC I
      GO TO 2450
```

HESYS. PB-PNC/UGF002 08/1 7/78 14: 43: 37

```
 2404 GAMMA=0
      BETAV= (SOLE-QP) / ( SOLE* ( 1-EFF 1 * (ALPHA 1+ALPHA2 ))
      QC2=0
      QC1=QC
 2450 IF (BETAV*SOLE*EFF 1. GT . ENGMAX) GO TO  405
 2451 EOUT=BETAV*SOLE* EFF 1 * ( 1+GAMMA*ALPHA 1*EFF2 )
      XLAX=AMIN1 (PCS IZ/EFFPC, ( ESTORM-ESTOR ) /EEFF)
      IF ( EOUT . GT . EEE+XLAX+QC 1 /COPEE ) GO TO 2410
      GO TO 900
      ~**** ********************k****** ***** ************************
      %***** FIX ENGINE CLIPP ING CONDITION--HAVE TO CHECK
      %***** WHETHER REVISION AFFECTS MEETING THE THERMAL LOAD
      ~**** **************&*********** .****************************
 2405 IF ( EliGELAX. LT . EEE+(QC-AMAX1 ( (ALPHA 1+ALPHA2 ) *ENGMAX-QP ,0 ) %
     *COPAA) /COPEE ) GO TO 2705
      QC 1=0
      QC2=QC
      IF (QP+QC/COPAA. GT .ALPHA2*ENGMAX) GO TO 2406
      BETAV= 1
      GAMMA=1
      GO TO 2458
 2406 IF (QP+QC/COPAA. GT . ENGMAX* (ALPHA 1+ALPHA2 ) ) GO TO 240 7
      BETAV= 1
      GAMMA= (ENGMAX* (ALPHA 1+ALPHA2 ) -QP-QC /COPAA) / (ALPHA1 *ENGMAX)
      GO TO 2458
 2407 IF (QP. GT. ENGMAX* (ALPHA 1+ALPHA2 ) ) GO TO 2408
      BETAV= 1
      GAMMA=0
      QC 1=QC-COPAA* ( ENGMAX*(ALPHA 1+ALPHA2 ) -QP)
      QC2=QC-QC 1
      GO TO 2458
 2408 GAMMA=0
      BETAV=ENGMAX/ (ENGMAX* ( 1 -EFF1* (ALPHA 1+ALPHA2 ) )  EFF1 *QP )
      QC2=0
      QC 1=QC
 2458 CALL UPDATE (HTQSTM , HTQSTO , SOLE-ENGMAX/ BETAV*EFF ) , %
     RESIDQ, EFFEX, EFFST , HTQSTM )
      CALL UPDATE (LTQSTM, LTQSTO , -RESIDQ, RESID, EFFEX, EFFLOT, LTQSTM)
      RESID9=RESID9-RESID
      SOLE= ENGMAX/ (BETA V*EFF1 )
      GO TO 2451
      Z**** ************************** ***** ************************
      %***** FIX OVERPRODUCTION OF ELECTRICITY IF HT ENERGY
      %***** CAN BE STORED ; IF HT STORAGE FUL L, GO BACK AND
      Z***** SELL THE AVAILABLE ELECTR IC ITY TO THE GRID
      Z**** ************************** ***** ***********************
 2410 IF (HTQSTO. GE. HTQSTM*0 . 99) GO TO 900
      QC 1=0
      QC2=QC
      EOUT=EEE+XLAX
      IF (QP+QC/COPAA. GT . ALPHA2*EOUT / ( 1+ ALPHA1*EFF 2) ) GO TO 2416
      BETAV= 1
      GAMMA= 1
      GO TO 2468
 2416 IF (QP+QC /COPAA. GT . EOUT* (ALPHA 1+ALPHA2 ) ) GO TO 2417
      BETAV= 1
      GAMMA= ( EOUT* (ALPHA I +ALPHA2 ) -QP-QC /COPAA ) / (ALPHA 1 * %
     (EOUT+EFF2* (QP+QC/COPAA) ) )
 2417 EOUT=EEE+XLAX+Q C/COPEE
      IF ( QP. GT. EOUT* (ALPHA 1 +ALPHA2 ) ) GO To 2418
```

```
      BETAV= 1
      GAMMA=0
      EOUT=(COPEE*(EEE+XLAX )@ C+QP*COPAA)/ %
                              (COPEE+COPAA* (ALPHA 1 +ALPHA2 ) )
      QC 1=QC-COPAA*(EOUT*(ALPHA1+ALPHA2)-QP)
      QC2=QC-QC1
      GO TO 2468
2418  GAMMA=0
      BETA V= EOUT/ ( EOUT*(1 -EFF 1 * (ALPHA 1 +ALPHA2 ) ) +EFF1 *QP )
      QC2=0
      QC 1 =QC
2468  CALL UPDATE(HTQSTM,HTQSTO, SOLE-EOUT/ %
        (BETAV*EFF1*( 1+GAMMA*ALPHA1*EFF2 )),RESIDQ,EFFEX,EFFST,HTQSTM)
      SOLE=EOUT/ (BETAV*EFF1*( 1+GAMMA*ALPHA1*EFF2))-RESIDQ
      IF (RESIDQ.LT.0) GO TO 2101
      GO TO 900
%***************************************************************
%***************************************************************
%***** REACH THIS SECTION WNEN EFF2*COPEE>COPAA>0
%***************************************************************
%***************************************************************
2501  QC1=0
      QC2=QC
      IF (QP+QC/COPAA.GT.SOLE*EFF1*ALPHA2 ) GOTO 2502
      BETAV=1
      GAMMA=1
      GO To 2550
2502  IF (QP.GT.SOLE*EFF1*ALPHA2 ) GO TO 2503
      BETAV=1
      GAMMA=1
      QC1=QC-COPAA*(SOLE*EFF1*ALPHA2-QP)
      QC2=QC-QC1
      GO TO 2550
2503  IF (QP.GT.SOLE*EFF1* (ALPHA1+ALPHA2 )) GO To 2504
      BETAV=1
      GAMMA= (SOLE*EFF1*(ALPHA1+ALPHA2)-QP) /(SOLE*EFF1*ALPHA1)
      QC1=QC
      QC2=0
      GO TO 2550
2504  GAMMA=0
      BETAV=(SOLE-QP)/ (SOLE* (1-EFF1* (ALPHA1+ALPHA2) ))
      QC1=QC
      QC2=0
2550  IF (BETAV*SOLE*EFF1 .GT.ENGMAX) GO TO 2590
2551  EOUT=BETAV*EFF1*SOLE* (1+GAMMA*ALPHA1*EFF2)
      XLAX=AMIN1 (PCSIZ/EFFPC, (ESTORM-ESTOR)/EEFF)
      IF (EOUT.GT.EEE+XLAX+QC1/COPEE ) GO TO 2595
      Go TO 900
%***************************************************************
%***** FIX ENGINE CLIPPING CONDITION--HAVE TO CHECK
%***** WHETHER REVISION AFFECTS MEETING THE THERMAL LOAD
%***************************************************************
2590  IF (ENGMAX.LT. EEE+(QC-AMAX1 ((ALPHA1+ALPHA2)*ENGMAX-QP, 0) %
          *COPAA)/COPEE) GO TO 2705
      QC1=0
      QC2=QC
      IF (QP+QC/COPAA.GT.ALPHA2*ENGMAX) GO TO 2591
      BETAV=1
      GAMMA=1
      GO TO 2558
```

HESYS.PB-PNC/UGF002 08/17/78 14:43:37

```
2591  IF (QP.GT.ALPHA2*ENGMAX) GO TO 2592
      BETAV=1
      GAMMA-1
      QC1=QC-COPAA*(ALPHA2*ENGMAX-QP)
      QC2=QC-QC1
      GO TO 2558
2592  IF (QP.GT. ENGMAX*(ALPHA1+ALPHA2) ) GO TO 2593
      BETAV=1
      GAMMA=(ENGMAX*(ALPHA1+ALPHA2 )-QP)/(ALPHA1*ENGMAX)
      QC1=QC
      QC2=0
      GO TO 2558
2593  GAMMA=0
      BETAV=ENGMAX/(ENGMAX* (1-EFF1*(ALPHA1+ALPHA2 ))+EFF1*QP)
      QC1=QC
      QC2=0
2558  CALL UPDATE (HTQSTM,HTQSTO, SOLE-ENGMAX/(BETAV*EFF1 ), %
                   RESIDQ,EFFEX, EFFST,HTQSTM)
      CALL UPDATE(LTQSTM,LTQSTO, -RESIDQ,RESID,EFFEX,EFFLOT, LTQSTM)
      RESID9=RESID9-RESID
      SOLE-ENGMAX/ (BETAV*EFF1 )
      GO TO 2551
%***************************************************************
Z***** FIXOVERPRODUCTION OF ELECTRICITY IF HT ENERGY
%***** CAN BE STORED; IF HT STORAGE FULL, GO BACK AND
%***** SELL THE AVAILABLE ELECTRICITY TO THE GRID
%***************************************************************
2595  IF (HTQSTO.GE.HTQSTM*0.99 ) Go To 900
      EOUT=EEE+XLAX
      QC1=0
      QC2=QC
      IF (QP+QC/COPAA.GT.ALPHA2*EOUT/ (1+ALPHA1*EFF2)) GO TO 2596
      BETAV=1
      GAMMA=1
      GO TO 2600
2596  EOUT=EEE+XLAX+QC/COPEE
      IF (QP.GT.ALPHA2*EOUT/(1+ALPHA1*EFF2) ) GO To 2597
      BETAV=1
      GAMMA=1
      EOUT=(COPEE*(EEE+XLAX)+QC+QP*COPAA) / %
            (COPEE+(COPAA*ALPHA2)/(1+ALPHA1*EFF2 ))
      QC1=QC-COPAA*(ALPHA2*EOUT/ (1+ALPHA1*EFF2)-QP)
      QC2=QC-QC1
      GO TO 2600
2597  IF (QP.GT.EOUT* (ALPHA1+ALPHA2) ) GO TO 2598
      BETAV=1
      GAMMA=(EOUT*(ALPHA1+ALPHA2)-QP) /(ALPHA1* (EOUT+EFF2*QP) )
      QC1=QC
      QC2=0
      GO TO 2600
2598  GAMMA-0
      BETAV=EOUT/ (EOUT*(1-EFF1* (ALPHA1+ALPHA2) )+EFF1*QP)
      QC1=QC
      QC2=0
2600  CALL UPDATE(HTQSTM,HTQSTO, SOLE-EOUT/ %
        (BETAV*EFF1*(1+GAMMA*ALPHA1*EFF2) ),RESIDQ,EFFEX,EFFST,HTQSTM)
      SOLE=EOUT/(BETAV*EFF1*  (1+GAMMA*ALPHA1*EFF2 ))-RESIDQ
      IF (RESIDQ.LT.0) GO TO 2501
      GO TO 900
%***************************************************************
```

HESYS . PB-PNC/UCb'002 08/ I 7 / 78 1 4 : 4 3 : 37

```
%**• •* USETHERMALENERGY TO MEETSPACECOND I IIONING
%***" LOAD---THIsIsNOT TH ). MOSTF F  F  IC IENT ROUTE BUT MUS T
Z***** BE I; SE, D AS l_ PIG INE S I ZE PREVE X I S THI(J PTIMALROUTE FROM
Z**** * BE I NG TAKEN !
X***************  ******************  *******************  *******
2705    GAMMA=0
QC 1 =AMAXI ( EN GMAX-EE E , 0 ) *COP EE
QC 2= QC-QC 1
SOLEU=ENGMAX* ( 1 / EFF 1- (ALPHA 1 +ALPHA 2 ) ) +QP+QC 2 /{. OPAA
I F ( SOLEU . GE . SOLE ) GO TO 2710
BETAV=ENGMAX/ ( EFF 1* SOLEU )
CALL UPDATE (HTQSTM , HTQSTO , SOLE-SOLEU , RES IDQ, EFFEX , EFFST , HTQS TM )
CALL U PDATE ( LTQSTM , LTQSTO , -RFS I DQ , RES I D , EFF EX , EFFLOT , LTQSTM )
RESID9=RES ID9-RES ID
SOLE=SOLEU
GO TO 2551
2710    BETAV=ENGMAX/ ( SOL E*EFF 1 )
QC2= ( ( I -B ETAV) *SO LE-QP+ (AL PHA 1+ALPHA2 ) *ENGMAX ) *COPAA
QC 1= QC-QC2
GO TO 2551
.: ****** **********  **********  ************  **********  **********  ****
%  FI SD MAXIMUMENG INE CON D IT ION S AND ST ORAGE MAXIMUM S
Z********************   ***********************   ****************
900    QOUT=SOLE* ( ( 1 -B ETAV ) +B E TAV*EF F 1 * (ALPHA2+ALPHA ! * ( 1 -GAMMA ) ) )
CALL UPDATE ( ESTORM , ESTOR , EOUT-EEE-QC 1 /CO PEE , RES I DE , EFF PC , %
```

HESYS . PB-PNC /UGFOO 2 08/ 17/78 1 4 : 4 3 : 37

```
                          EFFBAT , PCS I/! )
IF (COPAA. LT .0.1 ) COPAA= 1.0
CALL UPDATE ( LTQSTM, LTQSTO , QOUT-QP-IQC 2*(0(" 2/co PAA , RES IDQ , EF FE>: , %
                          EFFLOT , LTQSTM )
RES ID9=RE S ID9-RES I DQ
E (K) =RES IDE
EY=GAMMA*ALPHA 1•EF F2
EZ=EOUT/ ( EFF l * ( 1+EY ) )
TENGM=AMAX 1 (TENGM, EZ*EFF 1 )
BENGM=AMAX 1 (BENGM , EY*EZ*EFF 1 )
ENGM=AMAXl ( ENGM , EOUT )
TOTTEO=TOTTEO+EZ *EFF 1
TOTB EO=TOTBEO+EY*EZ* EFF 1
TOTEO=TOTEO+EOUT
HTQ=HTQSTO-HTQSO
SHE=AMIN 1 (EZ , QSR )
HTQ9=0
IF (HTQ. LT. 0 ) l{ TQ9=-HTQ
STHE=AMIN 1 (EZ-SHE ,HTQ9 )
FHET=O
SHET=SHET+SHE
STHET=STHET+STHE
6813   CONTINUE
RETURN
END
```

```
% PROGRAM NAME: HFSYS.JB
% JOHN C. BELL
% ENERGY PROGRAM
% OFFICE OF TECHNOLOGY ASSESSMENT
% COMPILED
%     DATE: 12/19/77
%     TIME: 12:58:45
% PROGRAM HFSYS.JB FOR RUNNING HEAT ENGINE SYSTEMS WITH
%          FOSSIL FUEL BACKUP



SUBROUTINE SYSTEM(K,QSH)
DIMENSION E(8760),HWLOAD(168)
IMPLICIT REAL(L)
COMMON/AXXX/COPA,EHWEFF,HCOPM,CCOPM,EFFB,ENGMAX,EFF1,EFF2,ALPHA1,%
            ALPHA2,HTQSTM,LTHTS,HTHTS,LTQSTM,LTLTS,HTLTS,HLHTH,%
            FHWEFF,HLLTH,EFFBE,ESTORM,EFFBAT,PCSIZ,EFFPC,HEATMX,%
            COOLMX,FAN,TL,TH,XXX,NHTQ,NLTQ,IGRID,ISOLAR,IA,ISMTH, %
            IHR,IOFFPK
COMMON/CXXX/COPAA,COPEE,EBM,EBEM,EEE,EFFEX,TENGM,BENGM,ENGM, %
            ESR,ESTOR,EEFF,FFHW,FHET,FUEL,HTSSTM,HTQ,HTQI,HTQO, %
            HTQSO,HTQSTO,LTQI,LTQO,LTQSO,LTQSTO,QA,QC,QC1,QC2, %
            QC2Z,QE,QP,QS,QSR,RESID9,SHET,STHET,TOTTEO,TOTBEO, %
            TOTEO,HLHTL,HLLTL,EFFLOT,EFFST,IPRINT
COMMON/XDATA/E,HWLOAD
DATA IPRINT/2/
QC1=0
QC2=0
IQC1=1
QHOUR=QP
IF (COPAA.LE.0.001) GO TO 32
QHOUR=QP+QC/COPAA
32   CALL UPDATE(LTQSTM,LTQSTO -QHOUR, RE S IDQ, EFFEX, EFFLOT, LTQSTM)
QP1=AMAX1(0,QP-(QHOUR-RESIDQ))
IF (QP1.LE.0.001) QC=QC-COPAA* QHOUR-RES IDQ-QP)
QP=QP1
IF (QSH.GT.0) QC2Z=QSH-QC
IF (QSH.LE.0) OC2Z=-QSH-QC
 ***************************************************************
 ***************************************************************
 **** * HEAT ENG I NE SECT ION--VERY COMPL ICA TED !!!
.   ************************   ************************   **********
% ****  *** **** **   ****************  **********  ******  **********  •**
'S OLE=QS R+H TQSTO
H , QSI 0=0
I F (COPAA. , I . 0.0 1 ) GO TO 9829
LEE=EFE+QC /L OPEE
QC1 =QC
QC2=0
I QC1=0
QC =0
COP 1/- 1. 0
9829    XLAX=AMIN 1 (PCS IZ /EFFPC, (E STORM-ES TOR ) /EEFF )
XOUT =AMIN 1 (PCS IZ/EFFPC , ESTOR*EFFPC )
EK=AMIN 1 (EEE/ ( EFF 1 * ( 1+ALPHA 1 *EFF2 ) ) , QP+QC/COPAA)
IF ( SOLE. CT . EK) GO TO 2197
F ( K ) = ( EK-SOL E ) / EFFB
SOLE=F K
 197    IF ( ["OPEL. L1 .0.01 ) GO To 2 1 99
```

HF SYS . PB-PNC /UGF002 08/17/ 78 14 : 42 : 52

```
Z****  **************************  *****  ************************
"g*****  CHECK WHETHER THE THERMAL SPAC E CON U I r ION I NG
%**** * ROUT E I S THE MOS T EFF IC IENT
Y*********************   **********************   ****************
I F ( COPAA . L r . FFF 1 * ( COPEE+ ( ALPHA 1+ALPHA 2 ) *COPAA ) ) GO TO 2401
2199   QHOUR=QP+QC /COPAA
QC1=0
QC2=QC
I F ( QHOUR . GT . ALPHA2*EFF 1 *SOLE ) GO To 2 I () 1
BETAV= 1
GAMMA= 1
GO TO 2109
2101   I F ( QHOUR . GT . SOLE*EFF 1 * (ALPHA 1 +ALPHA 2 ) ) GO TO 2 102
BETAV= 1
GAMMA= ( SOT. E*EFF 1* (ALPHA 1+ALPHA2 ) -QHOUR) / ( SOLE*EFF 1 *ALPHA 1 )
GO TO 2109
2102   GAMMA=0
BETAV= ( SOLE-QHOUR ) / ( SOLE* ( 1 -EFF 1 * (ALPHA 1+ALPHA2 ) ) )
2109   IF (BETAV*SOLE*EFF 1. GT. ENGMAX ) GO TO 7090
9109   EOUT=BETAV*SOLE *EFF 1• ( 1 +GAMMA*ALPHA I *EFF2 )
IF ( EOUT . GT . EEE+XLAX ) GO TO 21 20
IF ( EOUT . LT . EEE-XOUT ) GO TO 2130
GO TO 900
Z****  **************************  *****  ************************
%***** FIX ENGINE CLIPP ING CONDITION--HAVE TO CHECK
%***** WHETHER REVIS ION AFFECTS MEETING THE THERMAL LOAD
Z****  **************************  *****  ************************
7090   IF (QHOUR. GT . ALPHA 2* ENGMAX) GO TO 5091
BETAV= 1
GAMMA= 1
GO TO 7058
5091   IF ( QHOuR. GT. ENGMAX* (ALPHA 1+ALPHA2 ) ) Go TO 7094
BETAV=1
GAMMA= (ENGMAX* (ALPHA 1+ALPHA2 ) -QHOUR) / (ALPHA 1* ENGMAX)
GO TO 7058
7094   GAMMA=0
BETAV=ENGMAX/ ( ENGMAX* ( 1 -EFF1 * (ALPHA 1+ALPHA2 ) )+EFF 1 *QHOUR )
7058   CALL UPDATE ( HTSSTM, HTSSTO , SOLE-ENGMAX/ ( EFF 1 *BETAV) , %
     RESIDQ , EFFEX, EFFST , HTSSTM)
SO LE=ENGMAX/ (EFF1*BETAV)
GO TO 9109
Z****  **************************  *****  ************************
%***** FIX overproduction OF Electricity
Z****  **************************  *****  ************************
2120   EOUT=EEE+XLAX
IF ( QHOUR . GT . ALPHA2*EOUT / ( 1+ALPHA 1 *EFF2 ) ) GO TO 212 1
BETAV=1
GAMMA= 1
GO TO 2129
2121   IF ( QHOUR. GT. EOUT*(ALPHA 1 +ALPHA2 ) ) GO TO 2 1 22
BETAV= 1
GAMMA= (EOUT* (ALPHA 1+ALPHA2 )-QHOUR) / (ALPHA1* ( EOUT+EFF2*QHOUR ) )
GO TO 2129
2122   GAMMA=0
BETAV=EOUT/ (EOUT* ( 1-EFF 1 * (ALPHA 1+ALPHA2 ) )+EFF 1 *QHOUR )
2129   CALL UPDATE (HTQSTM, HTQSTO, SOLE-EOUT/ %
     (BETAV*EFF1 *( 1+GAMMA*ALPHA1 *EFF2 ) ) , RES IDQ, EFFEX, rFFsT, HTQSTM )
CALL UPDATE (LTQSTM, LTQSTO, -RFS IDQ, RFS ID, EFFEX, EFFLOT, LTQS TM )
RESID9=RES ID9-RES ID
GO TO 900
```

HFSYS.PB-PNC/UGF002 08/17/78 14:42:52

```
%****************************************************************
%***** FIX UNDERPRODUCTION OF Electricity--NEED BACKUP!
%****************************************************************
 2130   EOUT=EEE-XOUT
 IF (QHOUR.GT.ALPHA2*EOUT/(1+ALPHA1*EFF2)) GO TO 2131
 BETAV=1
 GAMMA=1
 GO TO 2139
 2131   IF (QHOUR.GT.EOUT*(ALPHA1+ALPHA2)) GO TO 2132
 BETAV=1
 GAMMA=(EOUT*(ALPHA1+ALPHA2)-QHOUR)/(ALPHA1*(EOUT+EFF2*QHOUR))
 GO TO 2139
 2132   GAMMA=0
 BETAV=EOUT/(EOUT*(1-EFF1*(ALPHA1+ALPHA2))+EFF1*QHOUR)
 2139   CALL UPDATE(HTSSTM,HTSSTO,SOLE-EOUT/ Z
         (BETAV*EFF1*( 1+GAMMA*ALPHA1*EFF2 )),RESIDQ,EFFEX,EFFST,HTSSTM)
 E(K)=E(K)+RESIDQ/EFFB
 GO TO 900
 ;:**************************************************************
 %***** CHECK WHETHER THE BOTTOMING CYCLE IS MORE EFFICIENT
 %***** THAN THE THERMAL ROUTE--IF THE BOTTOMING CycLE 1s
 %***** MORE EFFICIENT--I.E. EFF2*COPEE>COPAA>0--GO TO
 %***** STATEMENT 2501; OTHERWISE STAy HERE.
 Z***** (NOTE: IT KS ASSUMED IN THESE SWITCHES
 %***** THAT EFF2<EFF1)
 ;/**************************************************************
 2401   IF (COPAA.LT.EFF2*COPEE) GO TO 2501
 QC1=0  @ QC1 IS SPACE CONDITIONING LOAD MET ELECTRICALLY
 QC2=QC @ QC2 IS SPACE CONDITIONING LOAD MET THERMALLY
 IF (QP+QC/COPAA.GT.SOLE*EFF1*ALPHA2 ) GO TO 2402
 BETAV=1
 GAMMA=1
 GO TO 2450
 2402   IF (QP+QC/COPAA.GT.SOLE*EFF1* (ALPRA1+ALPHA2)) GO TO 2403
 BETAV=1
 GAMMA=(SOLE*EFF1*(ALPHA1+ALPHA2)-QP-QC/COPAA)/( SOLE*EFFl*ALPHAl )
 GO TO 2450
 2403   IF (QP.GT.SOLE*EFF1*(ALPHA1+ALPHA2) ) GO TO 2404
 BETAV=1
 GAMMA=0
 QC1=QC-COPAA*(SOLE*EFF1*(ALPHA1+ALPHA2)-QP)
 QC2=QC-QC1
 GO TO 2&50
 2404   GAMMA=0
 BETAV=(SOLE-QP) /(SOLE* (1-EFF1*(ALPHA1+ALPHA2 )))
 QC2=0
 QC1=QC
 2450   IF (BETAV*SOLE*EFF1 .GT.ENGMAX) GO TO 7405
 9450   EOUT=BETAV*SOLE*EFF 1*( 1+GAMMA*ALPHA1*EFF2)
 IF (EOUT.GT.EEE+XLAX+QC1/COPEE) GO TO 2410
 IF (EOUT. LT. EEE+QC1/COPEE-XOUT ) GO TO 2420
 GO TO 900
 %***************************************************************
 z***** FIx ENGINE CLIPPING CONDITION--HAVE TO CHECK
 z***** WHETHER REVISION AFFECTS MEETING THE THERMAL LOAD
 %***************************************************************
 7405   QC1=0
 QC2=QC
 IF (QP+QC/COPAA.GT.ALPHA2*ENGMAX) Go To 7406
 BETAV=1
```

HFSYS.PB-PNC/UGF002 08/17/78 14:42:52

```
 GAMMA-1
 Go TO 7458
 7406   IF (QP+QC/COPAA.GT.ENGMAX*(ALPHA1+ALPHA2) ) GO TO 7407
 BETAV=1
 GAMMA=(ENGMAX*(ALPHA1+ALPHA2)-QP-QC/COPAA) /(ALPHAl*ENGMAX)
 GO TO 7458
 7407   IF (QP.GT.ENGMAX*(ALPHA1+ALPHA2 )) GO TO 7408
 BETAV=1
 GAMMA-O
 QC1=QC-COPAA*(ENGMAX*(ALPHA1+ALPHA2)-QP)
 QC2=QC-QC1
 GO TO 7458
 7408   GAMMA-O
 BETAV=ENGMAX/(ENGMAX*( 1-EFF1*(ALPHA1+ALPHA2) )- EFF1*QP)
 QC2=0
 QC1=QC
 7458   CALL UPDATE(HTSSTM,HTSSTO, SOLE-ENGMAX/ BETAV*EFF1), %
                   RESIDQ,EFFEX,EFFST,HTSSTM)
 SOLE=ENGMAX/(BETAV*EFFl )
 GO TO 9450
 %***************************************************************
 %*****FIX Overproduction OF ELECTRICITY
 %***************************************************************
 2410   EOUT=EEE+XLAX
 QC1=0
 QC2=QC
 IF (QP+QC/COPAA.GT.ALPHA2*EOUT/ (1+ALPHA1*EFF2)) GO TO 2416
 BETAV=1
 GAMMA=1
 GO TO 2468
 2416   IF (QP+QC/COPAA.GT.EOUT* (ALPHA1+ALPHA2)) GO TO 2417
 BETAV=l
 GAMMA=(EOUT*(ALPHA1+ALPHA2 )-QP-QC/COPAA) /(ALPHA1* %
         (EOUT+EFF2*(QP+QC/COPAA) ))
 GO TO 2468
 2417   EOUT=EEE+XLAX+QC/COPEE
 IF (QP.GT.EOUT*(ALPHA1+ALPHA2) ) GO TO 2418
 BETAV=1
 GAMMA-O
 EOUT=(COPEE*(EEE+XLAX)+QC+QP*COPAA) / %
                       (COPEE+COPAA*(ALPHA1+ALPHA2) )
 QC1=QC-COPAA*(EOUT*(ALPHA1+ALPHA2)-QP)
 QC2=QC-QC1
 GO TO 2468
 2418   GAMMA=0
 BETAV=EOUT/ (EOUT*(l-EFFl* (ALPHA1+ALPHA2) )+EFF1*QP)
 QC2=0
 QC1=QC
 2468   CALL UPDATE(HTQSTM,HTQSTO, SOLE-EOUT/ %
         (BETAV*EFF1*(1+GAMMA*ALPHA1*EFF2 )),RESIDQ,EFFEX,EFFST,HTQSTM)
 CALL UPDATE (LTQSTM,LTQSTO,-RESIDQ,RESID, EFFEX, EFFLOT,LTQSTM)
 RESID9=RESID9-RESID
 GO TO 900
 %***************************************************************
 %***** FIX UNDERPRODUCTION OF ELECTRICITY--NEED BACKUP!
 %***************************************************************
 2420   EOUT=EEE-XOUT
 QC1=0
 QC2=QC
 IF (QP+QC/COPAA.GT.ALPHA2*EOUT/(1+ALPHA1*EFF2)) GO TO 2426
```

```
      BETAV=1
      GAMMA=1
      GO TO 2478
      2426   IF (QP+QC/COPAA.GT.EOUT*(ALPHA1+ALPHA2)) GO TO 2427
      BETAV=1
      GAMMA=(EOUT*(ALPHA1+ALPHA2)-QP-QC/COPAA)/(ALPHA1* %
            (EOUT+EFF2*(QP+QC/COPAA)))
      GO TO 2478
      2427   EOUT=EEE-XOUT+QC/COPEE
      IF (QP.GT.EOUT*(ALPHA1+ALPHA2)) GO TO 2428
      BETAV=1
      GAMMA=0
      EOUT=(COPEE*(EEE-XOUT)+QC+QP*COPAA)/ %
                        (COPEE+COPAA*(ALPHA1+ALPHA2))
      QC1=QC-COPAA*(EOUT*(ALPHA1+ALPHA2)-QP)
      QC2=QC-QC1
      GO TO 2478
      2428   GAMMA=0
      BETAV=EOUT/(EOUT*(1-EFF1*(ALPHA1+ALPHA2))+EFF1*QP)
      QC2=0
      QC1=QC
      2478   CALL UPDATE(HTSSTM,HTSSTO,SOLE-EOUT/ %
             (BETAV*EFF1*(1+GAMMA*ALPHA1*EFF2)),RESIDQ,EFFEX,EFFST,HTSSTM)
      E(K)=E(K)+RESIDQ/EFFB
      GO TO 900
      %************************************************************
      %************************************************************
      %***** REACH THIS SECTION WHEN EFF2*COPEE>COPAA>0
      %************************************************************
      %************************************************************
      2501   QC1=0
      QC2=QC
      IF (QP+QC/COPAA.GT.SOLE*EFF1*ALPHA2) GO TO 2502
      BETAV=1
      GAMMA=1
      GO TO 2550
      2502   IF (QP.GT.SOLE*EFF1*ALPHA2) GO TO 2503
      BETAV=1
      GAMMA=1
      QC1=QC-COPAA*(SOLE*EFF1*ALPHA2-QP)
      QC2=QC-QC1
      GO TO 2550
      2503   IF (QP.GT.SOLE*EFF1*(ALPHA1+ALPHA2)) GO TO 2504
      BETAV=1
      GAMMA=(SOLE*EFF1*(ALPHA1+ALPHA2)-QP)/(SOLE*EFF1*ALPHA1)
      QC1=QC
      QC2=0
      GO TO 2550
      2504   GAMMA=0
      BETAV=(SOLE-QP)/(SOLE*(1-EFF1*(ALPHA1+ALPHA2)))
      QC1=QC
      QC2=0
      2550   IF (BETAV*SOLE*EFF1.GT.ENGMAX) GO TO 7590
      9550   EOUT=BETAV*EFF1*SOLE*(1+GAMMA*ALPHA1*EFF2)
      IF (EOUT.GT.EEE+XLAX+QC1/COPEE) GO TO 2595
      IF (EOUT.LT.EEE+QC1/COPEE-XOUT) GO TO 2590
      GO TO 900
      %************************************************************
      %***** FIX ENGINECLIPPING CONDITION--HAVE TO CHECK
      %***** WHETHER REVISION AFFECTS MEETING THE THERMAL LOAD
```

HFSYS.PB-PNC/UGF002 08/17/78 14:42:52

```
      %************************************************************
      7590   QC1=0
      QC2=QC
      IF (QP+QC/COPAA.GT.ALPHA2*ENGMAX) GO TO 7591
      BETAV=1
      GAMMA=1
      GO TO 7558
      7591   IF (QP.GT.ALPHA2*ENGMAX) GO TO 7597
      BETAV=1
      GAMMA=1
      QC1=QC-COPAA*(ALPHA2*ENGMAX-QP)
      QC2=QC-QC1
      GO TO 7558
      7597   IF (QP.GT.ENGMAX*(ALPHA1+ALPHA2)) GO TO 7593
      BETAV=1
      GAMMA=(ENGMAX*(ALPHA1+ALPHA2)-QP)/(ALPHA1*ENGMAX)
      QC1=QC
      QC2=0
      GO TO 7558
      7593   GAMMA=0
      BETAV=ENGMAX/(ENGMAX*(1-EFF1*(ALPHA1+ALPHA2))+EFF1*QP)
      QC1=QC
      QC2=0
      7558   CALL UPDATE(HTSSTM,HTSSTO,SOLE-ENGMAX/(BETAV*EFF1), %
                        RESIDQ, EFFEX,EFFST,HTSSTM)
      SOLE=ENGMAX/(BETAV*EFF1)
      GO TO 9550
      %************************************************************
      %*****FIX OVERPRODUCTION OF ELECTRICITY
      %*******************************************     ***************
      2595   EOUT=EEE+XLAX
      QC1=0
      QC2=QC
      IF (QP+QC/COPAA.GT.ALPHA2*EOUT/(1+ALPHA1*EFF2) ) GO TO 2596
      BETAV=1
      GAMMA=1
      GO TO 2600
      2596   EOUT=EEE+XLAX+QC/COPEE
      IF (QP.GT.ALPHA2*EOUT/(1+ALPHA1*EFF2)) GO TO 2597
      BETAV=1
      GAMMA=1
      EOUT=(COPEE*(EEE+XLAX)+QC+QP*COPAA )/ %
           (COPEE+(COPAA*ALPHA2)/(1+ALPHA1*EFF2) )
      QC1=QC-COPAA*(ALPHA2*EOUT/(1+ALPHA1*EFF2)-QP)
      QC2=QC-QC1
      GO TO 2600
      2597   IF (QP.GT.EOUT*(ALPHA1+ALPHA2 )) GO TO 2598
      BETAV=1
      GAMMA=(EOUT*(ALPHA1+ALPHA2)-QP)   /(ALPHA1*(EOUT+EFF2*QP) )
      QC1=QC
      QC2=0
      GO TO 2600
      2598   GAMMA=0
      BETAV=EOUT/(EOUT*(1-EFF1*(ALPHA1+ALPHA2 ))+EFF1*QP)
      QC1=QC
      QC2=0
      2600   CALL UPDATE(HTQSTM, HTQSTO, SOLE-EOUT/ %
         (BETAV*EFF1*(1+GAMMA*ALPHA1*EFF2)),RESIDQ, EFFEX,EFFST, HTQSTM)
      CALL UPDATE(LTQSTM, LTQSTO, -RESIDQ,RESID, EFFEX,EFFLOT, LTQSTM)
      RESID9=RESID9-RESID
```

HFSYS. PB-PNC/UGF002 08/17 /78 14:42 :52

```
      GO TO 900
%*****************************************************************
%***** FIX UNDERP RODUCTION OF ELEC TRIC IT}' --NEED BACKUP!
 .**** ****************** *7%****************** ****************
      2590    EOUT=E E E-XOU T
      QC l =0
      QC 2=QC
      I F ( QP+QC /CO PAA . GT . AI PHA2*EOUT ' ( 1 +ALPHA 1 *EF F2 ) ) GO TO 2696
      BET AV= 1
      GAMMA= 1
      GO TO 2601
      2696    EOUT=EE E-XOUT+QC /CO PEE
      I F ( QP . GT . ALPHA 2 * EOUT / ( 1 +AL PHA 1 *EFF 2 ) ) GO TO 2697
      BETA\'= 1
      GAMMA= 1
      EOUT = ( COPEE* ( E EF -XOUT ) +QC+QP *CO PAA ) / %
                ( LOPE E+(COPAA*ALPHA2 ) / ( 1 +ALPHA 1*EFF 2 ) )
      QC 1=QC-CO PAA* ( AL PHA 2* EOUT / ( 1 +ALPHA 1 *EFF2 ) -QP )
      QC 2 =QC-QC 1
      GO TO 2601
      2697    IF(QP. G 1. EOUT* (ALPHA 1 +ALPHA 2 ) ) GO TO 2698
      BETAV= 1
      GAMMA= ( EOUT* ( ALPHA 1+ALPHA2 ) -QP ) / (ALPHA 1 * ( EOUT+EFF2*QP ) )
      QC 1 =QC
      QC 2=0
      GO TO 2601
      2698    GAMMA=0
      BETAV=EOUT/ ( EOUT* (  -EFF 1 * ( ALPHA 1+ALPHA2 ) ) +EFF  *QP )
      QC 1 =QC
      QC2=0
      2601    CALL U PDATE (HTSSTM, HTSSTO, SO LE-EOUT / %
              ( BETA V*EFF 1 * ( 1 +GAMMA*ALPHA 1 *EFF2 ) ) , RES IDQ , EFFEX , EFFST , HTSSTM )
      E(K) =E (K )+RESIDQ/ FFFB
      GO TO 900
%** **** ** *** * ***** ** ** * ****** * * ************ ******** * ******** * **
%  FIND MAXIMUM ENG IN E CONDIT ION S AND STORAGE MAXIMUMS
%******** ********** ********** ********** ********** *********** **
      900    SOL E= EOUT / ( BETAV* EFF 1 * ( 1 +GAMMA*ALPHA 1 *EF F2 ) )
      QOUT=SOLE* ( ( 1 -B ETA\' )+ BETA V*EFF 1* ( ALPHA 2+ALPHA 1 * ( 1-GAMMA ) ) )
      IF ( CO PEE . LT. 0 .1 ) CO PEE=1 .0
```

HFSYS. PB-PNC/UGF002 08117178 14:42:52

```
      CALL UPDATE ( ESTORM , ES TOR , EOUT-EEE-IQC 1 *QC 1 /COPEE , %
                          RES IDE , EFFPC , EFFBAT , PCS IZ )
      IF ( COPAA. LT .0.1 ) COPAA=1 .0
      CALL UPDATE ( LTQSTM, LTQSTO , QOUT-QP-QC 2/ COPAA, RES IDQ , %
                        EFFEX , EFFLOT , LTQSTM )
      RES ID9=RES ID9-RES IDQ
      EY=GAMMA*ALPHA 1 *EFF 2
      E Z= EOUT/ ( EFF 1 * ( 1 +EY ) )
      TENGM=AMAX1 (T ENGM, EZ *EFF 1 )
      BENGM=AMAX1 ( BENGM , EY*EZ*EFF 1 )
      ENGM=AMAX 1 ( ENGM, EO UT )
      TOT TEO=TOTTEO+EZ*EFF 1
      TOTB EO=TOTB EO+EY*EZ *EFF 1
      'TOT EO=TOTEO+EOUT
      EBM=AMAX1 ( EBM, E(K ) *EFFB-EZ )
      CALL U PDATE ( HTQSTM , HTQSTO , HTSSTO , RES IDQ , EFFEX, EFFST, HTQSTM )
      CALL U PDATE ( L TQSTM , LTQSTO, -RES IDQ, R . i D , EFF EX, EFFLoT , LTQSTM )
      RES ID9=RES ID9-RES I D
      HTSSTO=0
      HTQ=HTQSTO-HTQSO
      FHE=AMIN 1 (E (K) *EFFB , EZ )
      EBEM=AMAX1 (EBEM, FHE )
      SHE=AMIN 1 (EZ-FHE , QSR )
      HTQ9=0
      IF (HTQ. LT . 0) HTQ9=-HTQ
      STHE=AMIN1 (EZ-FHE-SHE , HTQ9 )
      FHET=FHET+FHE
      SHET=SHET+SHE
      STHET=STHET+STHE
      IF (E (K) . LE . . 1E-9 ) GO TO 6813
      DELTA=QP 1-AMAX1 (0, LTQSO-LTQSTO ) -AMAX (0, -HTQ)
      IF (DELTA. LE .0 ) GO TO 6814
      FFHW=DELTA/FHWEFF
      6814    IF ( EFFB*E (K ) . LT . EZ ) GO TO 68 2
      E (K)=E (K)+EZ* ( 1 /EFFBE-1 /EFFB )
      GO TO 6811
      6812    E (K) =E (K ) *EFFB/EFFBE
      6811    FULL= FUEL+E (K)
      6813    CONTINUE
      RETURN
      END
```

HWSYS.PB-PNC/UGF002 08/17/78 14:43:57

```
      % PROGRAM NAME : HWSYS . JB
      % JOHN C . BELL
      % ENERGY PROGRAM
      % OFFICE OF TECHNOLOGY ASSESSMENT
      %, COMPILED
             DATE : 12/ 19/77
             TIME: 12: 59: 7
      % PROGRAM HWSYS . JB FOR RUNNING SOLAR HOT WATER SYSTEMS
                 AND CONVENTIONAL SYSTEMS WITH ELECTRIC BACKUP
      %          OR ELECTRIC AND FOSSIL FUEL BACKUP .

      %
      SUBROUTINE SYSTEM(K,QSH)
      DIMENSION E(8760),HWLOAD(168)
      IMPLICIT REAL(L)
      COMMON/AXXX/COPA,EHWEFF,HCOPM,CCOPM,EFFB,ENGMAX,EFF1,EFF2,ALPHA1,%
                  ALPHA2,HTQSTM,LTHTS,HTHTS,LTQSTM,LTLTS,HTLTS,HLHTH,%
                  FHWEFF,HLLTH,EFFBE,ESTORM,EFFBAT,PCSIZ,EFFPC,HEATMX,%
                  COOLMX,FAN,TL,TH,XXX,NHTQ,NLTQ,IGRID,ISOLAR,IA,ISMTH, %
                  IHR,IOFFPK
      COMMON/CXXX/COPAA,COPEE,EBM,EBEM,EEE,EFFEX,TENGM,BENGM,ENGM, %
                  ESR,ESTOR,EEFF,FFHW,FHET,FUEL,HTSSTM,HTQ,HTQI,HTQO, %
                  HTQSO,HTQSTO,LTQI,LTQO,LTQSO,LTQSTO,QA,QC,QC1,QC2, %
                  QC2Z,QE,QP,QS,QSR,RESID9,SHET,STHET,TOTTEO,TOTBEO, %
                  TOTEO,HLHTL,HLLTL,EFFLOT,EFFST,IPRINT
      COMMON/XDATA/E,HWLOAD
      DATA IPRINT/3/
      %**********************************************************
```

HWSYS.PB-PNC/UGF002 08/17/78 14:43:57

```
      QC1=0
      QC2=0
      CALL UPDATE(LTQSTM,LTQSTO,QSR-QP,RESIDQ,EFFEX,EFFLOT,LTQSTM)
      QP=AMAX1(RESIDQ,0)
      IF (RESIDQ.LT.0) RESID9=RESID9-RESIDQ
      IF (IGRID.EQ.3) GO TO 600
      %*************************************************************
      E(K)=EEE+QC/COPEE+QP/EHWEFF
      QC1=QC
      GO TO 900
      %*************************************************************
      600   IF (COPEE.GT.0.01) GO TO 650
      E(K)=EEE
      FFHW=QP/FHWEFF
      FUEL=FUEL+QC/(COPAA*EFFB)+FFHW
      QC2=QC
      GO TO 900
      %*************************************************************
      650   E(K)=EEE+QC/COPEE
      FFHW=QP/FHWEFF
      FUEL=FUEL+FFHW
      QC1=QC
      GO TO 900
      %**************************************************************
      %  FIND MAXIMUM ENGINE CONDITIONS AND STORAGE MAXIMUMS
      %*************************************************************
      900   CONTINUE
      RETURN
      END
```

PVSYS. PB-PNC/UGFO02 08/17/78 14:42:21

```
% PROGRAY NAME: PVSYS.JB
% JOHN C. BELL
% ENERGY PROGRAM
% OFFICE OF TECHNOLOGY ASSESSMENT
% COMPILED
%     DATE:  1/12/78
%     TIME: 13: 6:43
% PROGRAM PVSYS.JB FOR RUNNING PHOTOVOLTAIC SYSTEMS WITH
%          ELECTRICITY, FOSSIL FUEL, OR BoTH FOR BACKUP
%
%
%
SUBROUTINE SYSTEM(K,QSH)
DIMENSION E(8760),HWLOAD( 168)
IMPLICIT REAL(L)
COMMON/AXXX/COPA,EHWEFF,HCOPM,CCOPM, EFFB,ENGMAX,EFF1,EFF2,ALPHA1 ,%
            ALPHA2, HTQST?!,LTHTS, HTHTS, LTQSTM, LTLTS,HTLTS, HLHTH,%
            FHWEFF,HLLTH,EFFBE, ESTORM,EFFBAT,PCSIZ, EFFPC,HEATMX,%
            COOLMX, FAN,TL,TH,XXX, NHTQ,NLTQ, IGRID, ISOLAR, IA, ISMTH, %
            IHR,IOFFPK
COMMON/CXXX/COPAA,COPEE, EBM,EBEM, EEE,EFFEX,TENGM, BENGM,ENGM, %
            ESR, ESTOR,EEFF,FFHW,FHET ,FUEL,HTSSTM,HTQ,HTQI ,HTQO, %
            HTQSO,HTQSTO,LTQI,LTQO ,LTQSO, LTQSTO,QA,QC,QC 1,QC2, %
            QC2Z,QE,QP,QS,QSR,RESID9, SHET, STHET,TOTTEO,TOTBEO, %
            TOTEO,HLHTL,HLLTL, EFFLOT,EFFST, IPRINT
COMMON/XDATA/E,HWLOAD
DATA IPRINT/1/
QC1=0
QC2=0
QHOUR=QP
IF (COPAA.LE.O.001) GO TO 32
QHOUR=QP+QC/COPAA
32  CALL UPDATE(LTQSTM,LTQSTO,QSR-QHOUR, RESIDQ,EFFEX,EFFLOT,LTQSTM)
IF (RESIDQ.LT.O) RESID9=RESID9-RESIDQ
XTEMP=AMAX1(0,QP-(QHOUR-RESIDQ) )
IF (XTEMP.LE.0.001 ) QC=AMAX1(0,QC-COPAA*(QHOUR-AMAX1(0,RESIDQ)-QP) )
QP=XTEMP
IF (QSH.GT.0) QC2Z=QSH-QC
IF (QSH.LE.0) QC2Z=-QSH-QC
%*************************************************************
% PHOTOVOLTAIC CALCULATIONS
%*************************************************************
ESR=ESR*EFFPC
XTEMP=AMIN1  (ESR,EEE)
ESR=ESR-XTEMP
EEE=EEE-XTEMP
IF (IGRID.EQ.0) GO TO 550
IF (IGRID.EQ.3) GO TO 570
XTEMP=AMIN1(ESR,QC/COPEE)
ESR=ESR-XTEMP
QC=QC-XTEMP*COPEE
XTEMP=AMIN1(ESR,QP/EHWEFF)
ESR=ESR-XTEMP
QP=QP-EHWEFF*XTEMP
CALL UPDATE (ESTORM, ESTOR,ESR/(EFFPC**2)-QC/COPEE-QP/EHWEFF-EEE , %
            RESIDE, EFFPC, EFFBAT,PCSIZ )
E(K)=RESIDE
IF (RESIDE.LT.0) E(K)=RESIDE*EFFPC
QC1=QC
Go To 900
```

PVSYS.PB-PNC/UGFO02 08/17/78 14:42:21

```
570  IF (COPEE.LT.0.001) GO TO 571
QC1=QC
XTEMP=AMIN1(QC/COPEE,ESR )
ESR=ESR-XTEMP
QC=QC-COPEE*XTEMP
CALL UPDATE(ESTORM, ESTOR,ESR/(EFFPC**2)-QC/COPEE-EEE,RESIDE, %
            EFFPC, EFFBAT,PCSIZ)
E(K)=RESIDE
IF (RESIDE.LT.0) E(K)=RESIDE*EFFPC
FFHW=QP/FHWEFF
FUEL=FUEL+FFHW
GO TO 900
571  CALL UPDATE(ESTORM, ESTOR,ESR/(EFFPC**2)-EEE,RESIDE, EFFPC, %
            EFFBAT,PCSIZ)
E(K)=RESIDE
IF (RESIDE.LT.0) E(K)=RESIDE*EFFPC
FFHW=QP/FHWEFF
QA=QC/(COPAA*EFFB)
FUEL=FL!EL+QA+FFHW
EBM=AMAX1(EBM,QA*EFFB)
QC2=QC
GO TO 900
550  IF (COPEE.LT.0.001) GO TO 555
QCS=QC
XTEMP=AMIN1(QC/COPEE, ESR)
ESR=ESR-XTEMP
QC=QC-COPEE*XTEMP
CALL UPDATE(ESTORM,ESTOR, ESR/(EFFPC**2)-QC/COPEE-EEE,RESIDE, %
            EFFPC, EFFBAT,PCSIZ)
QC1=QCS
IF (RESIDE.LE.0) GO TO 559
XTEMP=AMAX1(0, RESIDE-QC/COPEE)
IF (XTEMP.LT.0. 0001) QC=RESIDE*COPEE
QC1=QCS-QC
EEE=XTEMP
GO TO 672
555  CALL UPDATE(ESTORM, ESTOR,ESR/ (EFFPC**2)-EEE,RESIDE, EFFPC, Z
            EFFBAT,PCSIZ)
IF (RESIDE.LE.0) GO TO 558
EEE=RESIDE
GO TO 672
559  QC=0
558  EEE=0
XTEMP=AMIN1(QP,-RESIDE*EHWEFF)
QP=QP-XTEMP
RESIDE=RESIDE+XTEMP/EHWEFF
CALL UPDATE (LTQSTM,LTQSTO, -RESIDE ,RESIDQ, EFFEX,EFFLOT,LTQSTM)
RESID9=RESID9-RESIDQ
E(K)=RESIDE
672 FFHW=0
IF (COPAA.GT.0.001) GO TO 673
EEE=EEE+QC/COPEE
COPAA=1
QC1=QC1+QC
QC=0
673  IF (ALPHA2*EEE.GE.QC/COPAA+QP) GO TO 6722
IF (COPEE.GT.0. .1) GO TO 6721
6729  X=QP-ALPHA2*EEE
IF (X.LT.0) GO TO 6728
FFHW=X/FHWEFF
```

PVSYS.PB-PNC/UGF002 08/17/78 14:42:21

```
      QA=FFHW+(QC/COPAA ) /EFFB
      GO TO 6727
6728  QA=(QC/COPAA+X)/EFFB
6727  QS=0
      GO TO 6723
6722  QA=0
      QS=ALPHA2*EEE -QP-QC /COPAA
6723  QE=EEE/EFF1
      QC2=QC
      GO TO 6730
6721  IF (EFF1 * ( COPEE+ALPHA2*COPAA ) . LE . COPAA*EFFB ) GO TO 6722
      IF ( ALPHA2* ( EEE+QC / COPEE ) . LT . QP ) GO TO 6725
      QA=0
      QE=(EEE+ (QP+QC /COPAA-ALPHA2 *EEE ) / (ALPHA 2+COPEE/COPAA) ) /EFF 1
      QS=0
      QC1=QC 1+COPEE* ( EFF 1 *QE-EEE )
      QC2=QC-QC 1
      GO TO 6730
6725  QE= (EEE+QC/COPEE) /EFF1
      QA=(QP-ALPHA2* (EEE+QC /COPEE ) ) /FHWEFF
      FFHW=QA
```

PVSYS.PB-PNC/UGF002 08/17/78 14:42:21

```
      QS=0
      QC1=QC 1+QC
6730  FUEL= FUEL+QA+QE/ EFFBE
      CALL UPDATE (LTQSTM, LTQSTO , QS , RESIDQ , EFFFX , EFFLOT , LTQSTM )
      RESID9=RESID9-RESIDQ
      EZ=QE*EFF 1
      TENGM=AMAX1 (TENGM , EZ )
      ENGM=TENGM
      TOTTEO=TOTTEO+EZ
      TOTEO=TOTTEO
      EBM=AMAX1 ( EBM, (QA-FFHW) *EFFB )
      EBEM=AMAX1 (EBEM, QE )
      GO TO 900
%********************* ********************** ********************
Z FIND MAXIMUM ENGINE CONDITIONS AND STORAGE MAXIMUMS
Z**** ********************** *************** ********************
900   CONTINUE
      IF ( IOFFPK . EQ .1 ) CALL OFFPK1 (K, QP , QC , QSH, COPEE , EHWEFF )
      RETURN
      END
```

COLL1.PB-PNC/UGF002 08/17/78 14:46:07

```
% PROGRAM NAME:COLL1.JB
% JOHN C . BELL
% ENERGY PROGRAM
% OFF IC E OF TECHNOLOGY ASSESSMENT
% COMP 1 LED
%      DATE : 12/ 30/77
%      TIME :   1 : 18:6
% PROGRAM COLL 1. JB FOR RUNNING FLAT PLATE COLLECTORS AND
%          TWO DIMENSIONAL TRACKING COLLECTORS WITH
%          ELECTRIC AND THERMAL OUTPUT
%


SUBROUTINE LOLL (I SYS1)
DIMENSION DAYLEN( 365) ,SONOON( 365) ,DECL( 365)
DIXENS1ON RADDN (8760) ,RADTH (8760)
DIMENSION EQ(4), A(4) ,B(4)
IMPLICIT  REAL(L)
COMMON /B XXX/CRATIO , TRANS , AREAC , LAT , LONG , LONGST , TILT , AZ , XKE, BETA, %
            CELLEF , ELECAB , FC , ULOSS , COVERN , FR , ALPHA , FLOUR ,DENS , CP , %
            ABC, ,ABD,APWID,COLEN,FOCLEN,COSPAC,RIMANG,REFLEC,CELLL, %
            ALPHAV,YYY(5),ISYS, IFLOW,IEW,IYYY(5)
DIMENSION SCEL(37), ISCEL(8)
EQUIVALENCE (SCEL(1),CRATIO) ,(ISCEL(1),ISYS)
DATA A,B/-.2E-3,.4197,-.32265E1,-.903E-1,0.,-.7351E1,-.93912E1,-. 3661/
PIE2=6.2831853
PIEV=360/(PIE2)
READ(24) DECL
REWIND 25
READ(25) RADDN,RADDN,RADDN,RADTH
READ(12,*,PROMPT='FILE NUMBER FOR COLLECTOR COEFFICIENTS: ') IF
IF (IF.LE.0) GO TO 1120
REWIND IF
READ(IF) SCEL,ISCEL
1120   READ(12, 99, PROMPT='LIST/CHANGE VARIABLES AND VALUES: ') ITST
99   FORMAT(A4)
IF (ITST.EQ.'YES') GO TO 1123
IF (ITST.EQ.'NO') GO TO 1124
IF (ITST.EQ.'NON') Go TO 1140
Go TO 1120
1123   WRITE(13,900) CRATIO,TRANS,AREAC,LAT ,LONG,LONGST,TILT, Z
                  AZ,XKE,BETA,CELLEF, ELECAB,FC,ULOSS,COVERN ,%
                  FR,ALPHA,FLOWR>DENS ,CP
WRITE(13,901) ISYS,IFLOW
900   E. RMAT('  ______REAL NUMBERS________'/%
'  #",4x, 'VALUE' ,4x,'DEFINITI ON"/Z
'  1 ',1PE10.3,' :CONCENTRATION RATIO (DIM)'/%
'  2 ',1PE10.3, '  :OPTICAL EFFICIENCY OR TRANSMISS.(.LE.1.00) '/%
'  3' ,1PE10.3, "  :COLLECTOR AREA (M**2)'/%
'  4 ',1FE10.3, '  :LATITUDE (DEG)'/%
'  5' ,1PE10.3,'  :LONGITUDE (DEG)' /'Z
'  6', 1PE10.3, "  :STANDARD LONGITUDE (DEG)'/%
   1' ,LPE10.3,'  :COLLECTOR TILT ABOVE HORIZONTAL (DEG)'/%
'  8', 1PE10.3, '  :COLLECTOR ANGLE WRT SOUTH (DEG)'/%
'  9', 1PE10.3,'  :COLLECTOR HEAT REMOVAL FACTOR (KW/(M**2*C))' /%
' 10 ', 1PE10.3, '  :CELL TEMP COEFF (1/DEG CENT)'/%
' 11 ',1PE10.3,'  :CELL EFFIC @ 28C (.LE. 1.00)'/%
' 12 ',1PE10.3, '  :CELL ABSORPTIVITY (.LE.1.00)'/%
'13', 1PE10.3,'  :FRAC OF RECEIVER COVERED WITH CELLS (.LE.1.00)'/%
'14', 1PE10.3, '  :THERMAL LOSS COEFF (KW/M**2*C)'/%
```

COLL1.PB-PNC/UGF002 08/17/78 14:46:07

```
' 15', 1PE10.3, '  :NUMBER OF GLASS COVERS (DIM)'/%
' 16 ',1PE10.3, "  :COLLECTOR HEAT REMOVAL FACTOR (.LE.1.00)'/%
' 17', 1PE10.3, '  :ABSORB OF THERMAL-ONLY SURFACES (.LE. 1.00)'/%
' 18 ',1PE10.3,'  :FLOW RATE (CM**3/SEC*M**2)' /%
' 19 ', 1PE10.3, '  :FLUID DENSITY (GM/CM**3)'/%
' 20 ', 1PE10.3,'  :FLUID SPEC. HEAT (CAL/GM*C)')
901   FORMAT('  ________INTEGERS__________'1%
'  #',4X,'VALUE' ,4x,'DEFINITION' /%
'  1 ',16,4X, '  :OUTPUT--ELEC(1 ),  ELEC & THERMAL(2), THERMAL(3) "/Z
'  2 ',16,4x,'  :CONST FLOW RATE(1), CONST OUTPUT TEMP(2)')
1124   READ(12,*,PROMPT='VAR # AND VARIABLE: ') IV,V
IF (IV.LE.0) GO TO 1125
IF (IV.GT.37) GO TO 1124
SCEL(IV)=V
GO TO 1124
1125   READ(12, *,PROMPT='VAR # AND IVARIABLE: ') IV,I
IF (IV.LE.0) GO TO 1126
IF (IV.GT.8) GO TO 1125
ISCEL(IV)=I
GO TO 1125
1126   READ(12,*,PROMPT='FILE NUMBER TO STORE COLLECTOR COEFF: ") IV
IF (IV.LE.0) GO TO 1140
REWIND IV
WRITE(IV) SCEL,ISCEL
%
%    COMPUTE RISETIME AND SETTING TIME OF SUN AND SOLAR ANGLES
%
1140   LAT=LAT/PIEV
TILT=TILT/PIEV
AZ=AZ/PIEV
ISYS1=ISYS
SINLAT=SIN(LAT)
COSLAT=COS(LAT)
TANLAT=TAN(LAT)
SINTLT=SIN(TILT)
COSTLT=COS(TILT)
SINAZ=SIN(AZ)
COSAZ=COS(AZ)
AREACR=AREAC/CRATIO
XFLASSF=0.004186*FLOWR*CP*DENS*CRATI0
ALPHAV=FC*ELECAB+(1-FC )*ALPHA
DO 50 1=1,365,1
DO 2500 J=1,4
EQ(J)=A(J)*COS((PIE2*(J-1)*I)/365.25)+B(J)*SIN((PIE2*(J-1)*I)/365.25)
2500   CONTINUE
RISANG=ACOS ((-TANLAT)*TAN(DECL (I)))
DAYLEN(I)=PIEV*RISANG/7 .5
SONOON(I)=13.5-((EQ(1)+EQ(2)+EQ(3)+EQ(4)+4*(LONGST-LONG) )/60)
50 CONTINUE
IF (IFLOW.NE.1) FR=1
RETURN
%
% HOURLY COMPUTATION BEGINS
%
ENTRY COLL01(K,TFIN,TFOUT,TA,QSR, ESR)
IF (RADTH(K).LE.0) GO TO 38
IF (RADDN(K)+RADTH(K).LE. 0.0001) GO TO 38
TAIR=TA-273
I=(K-1)/24
J=K-24*(I)
```

```
      I=I+1
      TD=J-0.5-SONOON(I)+DAYLEN(1)/2
      IF((TD.LT.0).OR.(TD.GT.DAYLEN(1)))GO TO 38
      RISANG=ACOS(-TANLAT*TAN(DECL(I)))
      IF(CRATIO.LT.1.5)GO TO 61
      RADTOT=TRANS*RADDN(K)*CRATIO
      IF(ISYS.EQ.1)GO TO 224
      GO TO 2..
   61 HRANG=(SONOON(I)-1)*RISANG/(DAYLEN(I)/2)
      SINDEC=SIN(DECL(I))
      COSDEC=COS(DECL(I))
      COSHRA=COS(HRANG)
      C1=SINDEC*SINLAT
      C2=COSDEC*COSLAT*COSHRA
      COSTHE=C1+C2
      IF(COSTHE.LE.0) GO TO 38
      COSINC=C1*COSTLT-SINDEC*COSLAT*SINTLT*COSAZ+                    %
             C2*COSTLT+                                               %
             COSDEC*SINLAT*SINTLT*COSAZ*COSHRA+                       %
             COSDEC*SINTLT*SINAZ*SIN(HRANG)
      COSINC=AMAX1(0,COSINC)
      RADDIF=AMAX1(((RADTH(K)-RADDN(K)*COSTHE)*(1+COSTLT)/2)          %
       +RADTH(K)*(1-COSTLT)/10,0)
      IF(ISYS.EQ.1)GO TO 223
      IF(COVERN.GE.1.5)GO TO 221
      RADTOT=TRANS*RADDN(K)*(COSINC**.25)+RADDIF*0.89*TRANS
      GO TO 222
  221 RADTOT=TRANS*RADDN(K)*(COSINC**1.5)+RADDIF*0.80*TRANS
  222 IF(IFLOW.EQ.1)GO TO 225
      TTEMP=(TFIN+TFOUT)/2
      DENOM=1-(FC*RADTOT*CELLEF*BETA-ULOSS)/XKE
      GO TO 226
  225 TTEMP=TFIN
      DENOM=1-FR*FC*BETA*CELLEF*RADTOT*(1/XKE+0.5/XMASSF)
  226 ATEMPO=RADTOT*(ALPHAV-FC*CELLEF*(1-BETA*(TTEMP-28)))
      QSR=AMAX1(FR*AREACR*(ATEMPO-ULOSS*(TTEMP-TAIR))/DENOM,0)
      IF((IFLOW.EQ.2).AND.(ATEMPO-ULOSS*(TFOUT-TAIR).LE.0))QSR=0.
      IF(ISYS.NE.2)GO TO 321
      IF(IFLOW.EQ.1)TCELL=TTEMP+QSR/(XKE*AREACR)
      IF(IFLOW.EQ.2)TCELL=TFIN+QSR*(0.5/XMASSF+1/XKE)/AREACR
      ESR=AREAC*FC*RADTOT*CELLEF*(1-BETA*(TCELL-28))
      GO TO 321
  223 RADTOT=RADDN(K)*COSINC+RADDIF
```



```
  224 QSR=0
      XNUMER=AREACR*RADTOT*FC*CELLEF*(1-BETA*(TAIR+ALPHAV*RADTOT/XKE-28))
      ESR=XNUMER/(1-CELLEF*BETA*RADTOT/XKE)
  321 IF(QSR.LE.0)QSR=0.
         IF(ESR.LE.0)ESR=0.
      RETURN
   38 QSR=0
      ESR=0
      RETURN
%
% OUTPUT STATEMENTS
%
      ENTRY COLLO2
      IF(ISYS.EQ.1)GO TO 17
      IF(IFLOW.EQ.2)GO TO 17
   17 IF(CRATIO.GT.1.5)WRITE(13,454)
  454 FORMAT(' TWO-AXIS TRACKING SYSTEM ')
      IF(CRATIO.LT.1.1) WRITE(13,&50)
  450 FORMAT(' FLAT PLATE COLLECTOR')
      IF(ISYS.EQ.1) WRITE(13,451)
  451 FoRMAT(1X,' PASSIVE ELECTRIC-ONLY COLLECTOR')
      IF(ISYS.EQ.2) WRITE(13>452)
  452 FORMAT(1X,'COMBINED THERMAL AND ELECTRIC COLLECTOR')
      IF(ISYS.EQ.3) WRITE(13,45))
  453 FORMAT(1X,'THERMAL-ONLY COLLECTOR ')
      IF(IFLOW.EQ.1) WRITE(13,455)
  455 FORMAT(' CONSTANT FLOW RATE')
      IF(IFLOW.EQ.2) WRITE(13,456)
  456 FORMAT(' CONSTANT OUTPUT TEMPERATURE')
      RETURN
%
% OUTPUT SUMMARY
%
      ENTRY COLL03
      LAT=LAT*PIEV
      AZ==AZ*PIEV
      TILT=TILT*PIEV
      WRITE(13.900) CRATIO,TRANS,AREAC,LAT,LONG,LONGST,TILT,          %
                    AZ,XKE,BETA,CELLEF,ELECAB,FC,ULOSS,COVERN,        %
                    FR,ALPHA,FLOWR,DENS,CP
      WRITE(13,901) ISYS,IFLOW
      RETURN
      END
```

```
COLL2. PB-PNC/UGF002 08/17/78 14:47:14

Z PROGRAM NAME: COLL2.JB
% JOHN C. BELL
% EN ERGY PROGRAM
% OFFICE OF TECHNOLOGY ASSESSMENT
% COMPILED
%     DATE:  1/ 4/78
%     TIME:  23:51:24
% PROGRAM COLL2.JB FOR RUNNING ONE-DIMENSIONAL TRACKING
%         COLLECTORS WITH THERMAL AND ELECTRIC OUTPUT
%

%
%
SUBROUTINE COLL(ISYS1)
DIMENSION DAYLEN(365),SONOON(365),DECL(365)
DIMENSION RADDN(8760),RADTH(8760)
DIMENSION EQ(4),A(4),B(4)
IMPLICIT REAL(L)
COMMON/BXXX/CRATIO,TRANS,AREAC,LAT,LONG,LONGST,U1,U2,XKE,BETA,%
            CELLEF,ELECAB,FC,ULOSS,COVERN,FR,ALPHA,FLOWR,DENS,CP,%
            T0,T1,APWID,COLEN,FOCLEN,COSPAC,RIMANG,REFLEC,CELLL, %
            ALPHAV,YYY(5),ISYS,IFLOW,IEW,IYYY(5)
DIMENSION SCEL(37),ISCEL(8)
Equivalence (SCEL(1),CRATIO),(ISCEL(1),ISYS)
DATA A,B/-.2E-3,.4197,-.32265E1,-.903E-1,0.,-.7351E1,-.93912E1,-.3661 /
PIE2=6.2831853
PIEV=360/(PIE2)
READ(24) DECL
REWIND 25
READ(25) RADDN,RADDN,RADDN,RADTH
READ(12,*,PROMPT=' FILE NUMBER FOR COLLECTOR COEFFICIENTS: ") IF
IF (IF.LE.0) GO TO 1120
REWIND IF
READ(IF) SCEL,ISCEL
1120   READ(12,99,PROMPT=' LIST/CHANGE VARIABLES AND VALUES: ') ITST
99   FORMAT(A4)
IF (ITST.EQ.'YES') GO TO 1123
IF (ITST.EQ.'NO') GO TO 1124
IF (ITST.EQ. 'NON') GO TO 1140
GO TO 1120
1123   WRITE(13,900) CRATIO,TRANS,AREAC,LAT ,LONG,LONGST,U1,%
                    U2,XKE,BETA,CELLEF,ELECAB,FC ,%
                    ALPHA,FLOWR,DENS,CP, T0,T1,APWID,COLEN, Z
                    FOCLEN,COSPAC,RIMANG, REFLEC,CELLL
WRITE(13,901) ISYS,IFLOW,IEW
900   FORMAT(' ______REAL NUMBERS_______'/%
 ' #',4X,'VALUE' ,4x,'Definition '/Z
 ' 1', 1PE10.3, ' :CONCENTRATION RATIO (DIM)'/%
 ' 2 ',1PE10.3,' :OPTICAL EFFICIENCY OR TRANSMISS. (.LE.1.00)'/%
 ' 3', 1PE10.3,' :COLLECTOR AREA (M**2)'/%
 ' 4 ',1PE10.3,' :LATITUDE (DEG)'/%
 ' 5 ',1PE10.3," :LONGITUDE (DEG) '/Z
 ' b', 1PE10.3, ' :STANDARD LONGITUDE (DEG) '/Z
 ' 7', 1PE10.3, ' :U1--THERMAL LOSS COEFF PARAMETER (KW/(M**2*C) )'/%
 ' 8', 1PE10.3,' :U2--THERMAL LOSS COEFF PARAMETER (KW/(M**2*C))'/%
 ' 9', 1PE10.3,' :CELL HEAT REMOVAL FACTOR (KW/C*M**2)'/%
 ' 10 ', 1PE10.3, ' :CELL TEMP COEFF (1/DEG CENT)'/%
 '11', 1PE10.3,' :CELL EFFIC @ 28C (.LE.1.00)'/%
 ' 12 ', 1PE10.3, ' :CELL ABSORPTIVITY (.LE.1.00)'/%
 ' 13 ',1PE10.3,' :FRAC OF CELL AREA COVERED WITH CELLS (.LE.1.00)'/%
```

COLL2. PB-PNC/UGF002 08/17/78 14:47:14

```
 ' 17 ' ,1PE10.3,' :ABSORP OF THERMAL-ONLY SURFACES (.LE.1.00)'/%
 ' 18' ,1PE10.3, ' :FLOW RATE (CM**3/SEC*M**2)'/%
 ' 19 ', 1PE10.3,' :FLUID DENSITY (GM/CM**3)'/%
 ' 20 ' ,1PE10.3,' :FLUID SPEC. HEAT (CAL/GM-C)'/%
 ' 21 ' ,1PE10.3, ' :T0--THERMAL COEFF TEMPERATURES (DEG CENT)'/%
 ' 22 ', 1PE10.3,' :T1--THERMAL COEFF TEMPERATURES (DEG CENT)'/%
 ' 23 ',1PE10.3,' :COLLECTOR WIDTH(M)'/%
 " 24 ', 1PE10.3, ' :COLLECTOR LENGTH(M)'/%
 ' 25 ' ,1PE10.3," :FOCAL LENGTH (H)'/%
 ' 26 ' ,1PE10.3,' :CENTER TO CENTER SPACING OF COLLECTORS(M)"/%
 ' 27 ' ,1PE10.3,' :RIM ANGLE--EDGE-FP-CENTER (DEG)'/%
 " 28 ' ,1PE10.3, ' :OPTICAL REFLECTIVITY (.LE.1.00)'/%
 ' 29 ', 1PE10.3,' :CELL LENGTH (M)')
901   FORMAT(' ________INTEGERS_________'/%
 ' #',4X,'VALUE' ,4x, 'DEFINITION'/%
 ' 1 ',16,4X, ' :OUTPUT--ELEC(1 ), ELEC & THERMAL(2), THERMAL(3)'/%
 ' 2 ",16,4X, ' :CONST FLOW RATE(1), CONST OUTPUT TEMP(2) '/%
 ' 3 ',I6,4X,' :EAST-WEST AXIS(1), NORTH-SOUTH POLAR AxIs(2)')
1124   READ(12,*,PROMPT=' VAR # AND VARIABLE: ') IV,V
IF (IV.LE.0) GO TO 1125
IF (IV.GT.37) GO TO 1124
SCEL(IV)=V
GO TO 1124
1125   READ(12,*,PROMPT='VAR # AND IVARIABLE: ') IV,I
IF (IV.LE.0) GO TO 1126
IF (IV.GT.8) GO TO 1125
ISCEL(IV)=I
GO TO 1125
1126   READ(12,*,PROMPT='FILE NUMBER TO STORE COLLECTOR COEFF: ") IV
IF (IV.LE.0) GO TO 1140
REWIND IV
WRITE(IV) SCEL,ISCEL
%
%   COMPUTE RISETIME AND SETTING TIME OF SUN AND SOLAR ANGLES
%
1140   ISYS1=ISYS
LAT=LAT/PIEV
RIMANG=RIMANG/PIEV
TANLAT=TAN(LAT)
SINRIM=SIN(RIMANG)
COSRIM=COS(RIMANG)
DO 50 1=1,365,1
DO 2500 J=1,4
EQ(J)=A(J)*COS((PIE2*(J-1 )*1)/ 365.25)+B(J)*SIN((PIE2*(J-1 )*1)/365.25)
2500   CONTINUE
RISANG=ACOS( (-TANLAT)*TAN (DECL(I)))
DAYLEN(I)=PIEV*RISANG/ 7.5
SONOON(I ).13. 5-((EQ(1)+EQ( 2)+EQ(3)+EQ(4)+4*(LONGST-LONG ))/60)
50 CONTINUE
U11=U1/CRATIO
U22=U2/CRATIO
XMINV=1/(.008372*FLOWR*CP*DENS*CRATIO)
AREACR=AREAC/CRATIO
RRR=CELLL/COLEN
RETURN
%
% DAILY COMPUTATION BEGINS
%
ENTRY COLL01(K,TFLN,TFOUT,TA,QSR,ESR)
IF ((RADTH(K).LE.0).OR.(RADDN(K).LE.0)) GO To 38
```

```
      TAIR=TA-273
      I= (K-1)/24
      J=K-24*(I)
      I=I+1
      TD=J-0.5-SONOON(I)+DAYLEN (I)/2
      IF ((TD.LT. 0) .OR. (TD.GT.DAYLEN (I))) GO To 38
      COSINC=COS (DECL(I))
      RISANG=ACOS ((-TANLAT) *TAN(DECL(I)))
      HRANG=( SONOON(I )-J)*RISANG/ (DAYLEN(I)/2)
      IF(IEW.EQ. 1)GO TO 350
      GO TO 360
 350  COSINC=( 1-((COSINC) **Z)*((SIN(HRANG) )**2))**0.5
%
% COMPUTE SHADING
z
      PHI=LAT-ATAN( (TAN(DECL(I )))*(1. /COS(HRANG)))
      THE=ACOS(COSINC)
      GO TO 370
 360  IF(ABS(HRANG) .GT.PIE2/4)GO TO 38
      PHI=HRANG
      THE=DECL(I)
 370  SHAD1=AMIN1(1,COSPAC*ABS (COS(PHI))/APWID)
      RADIUS=( 2*FOCLEN)/(1 .+COSRIM)
      SHAD2=FOCLEN+( ((RADIUS*SINRIM)**2) /(12*FOCLEN))
      SHAD2=AMAX1 (0, 1-( (SHAD2*ABS (TAN(THE) ))/COLEN))
      SHADTO=SHAD1*SHAD2
%
% COMPUTE THERMAL LOSSES
z
      TRANSM=TRANS*(COSINC**0. 25)
      FCIONO=0
      IF  (SHAD2.GE.(RRR/2)+.5) %
         FCIONO=(CRATIO/COLEN)*CELLL*REFLEC*TRANSM*SHAD1*   %
                CELLEF*FC*RADDN(K)*COSINC
 762  IF  ((SHAD2-.5)*COLEN.GE.CELLL/2) %
         ALPHIO=(CRATIO/COLEN)*REFLEC*SHAD1*TRANSM*RADDN(K)%
                *COSINC*(ALPHA*(SHAD2*COLEN-FC*CELLL)+(FC*ELECAB*CELLL) )
      IF  ((SHAD2-0.5)*COLEN.LT.-CELLL/2) %
         ALPHIO=CRATIO*REFLEC*TRANSM*RADDN(K)   %
                *COSINC*ALPHA*SHADTO
      IF (ABS((SHAD2-.5)*COLEN) .LE.CELLL/2) %
         ALPHIO=(CRATIO/COLEN)*REFLEC*TRANSM*RADDN  (K)*  %
                COSINC*(ALPHA*((COLEN-FC*CELLL) /2)+      %
                FC*ELECAB*( (SHAD2-0. 5)*COLEN+CELLL/2) )*SHAD1
      IF(ISYS.EQ.1)GO TO 7bl
      TTEMP=TFIN
      IF(IFLOW.EQ. 2)TTEMP=(TFIN+TFOUT )/2
      QL1=ALPHIO-FCIONO*(1-BETA*(TTEMP-28))
      IF(IFLOW.EQ.1)GO To 763
%
% CALCULATE OUTPUT FOR SYSTEM WITH FIXED OUTPUT TEMPERATURE
%
      IF(TTEMP-TAIR.GE.T1-T0) %
         QL2=U11*CRATIO*(T1-T0)+U22*CRATIO*(TTEMP-TAIR-(T1-T0) )
      IF(TTEMP-TAIR.LT.T1-T0) %
         QL2=U11*CRATIO*(TTEMP-TAIR)
```

COLL2.PB-PNC/UGF002 08/17/78 14:47:14

```
      QSR=AREACR*(QL1-QL2)/(1-FCIONO*BETA/XKE)
      GO TO 764
%
Z CALCULATE OUTPUT FOR FIXED FLOW RATE
%
 763  QL2=U11*CRATIO*(T1-T0)+U22*CRATIO*(TTEMP-TAIR-(T1-T0) )
      QSR=AREACR*(QL1-QL2)/(1+U22*XMINV-FCIONO*BETA* (1/XKE+XMINV/CRATIO))
      TTEMP=TFIN+QSR*XMINV/AREAC
      IF(TTEMP-TAIR.LT.T1-T0) %
      QSR=AREACR*(QL1-U1 1*CRATIO*(TFIN-TAIR) )/(1+U1 1*XMINV-FCIONO%
         *BETA*( 1/XKE+XMINV/CRATIO) )
      TTEMP=TFIN+QSR*XMINV/AREAC
 764  ESR=AREACR*FCIONO*( 1-BETA* (TTEMP+QSR/ (XKE*AREACR) -28))
      GO TO 766
 761  QSR=0
      ESR=AREACR*FCIONO*( 1-BETA*(TAIR-28+ALPHIO/XKE ))/(1-FCIONO*BETA/ (XKE*FC ))
 766  QSR=AMAX1(0,QSR)
      ESR=AMAX1(0,ESR)
      RETURN
 38   QSR=0.
      ESR=0.
      RETURN
%
% OUTPUT STATEMENTS
%
      ENTRY COLL02
      IF (IEW.EQ.1) WRITE(13,1132)
 1132 FORMAT(' EAST-WEST AXIS TRACKING COLLECTOR')
      IF (IEW.NE.1) WRITE(13,459)
 459  FORMAT(' ONE-AXIS POLAR NORTH-SOUTH TRACKING COLLECTOR')
      IF(ISYS.EQ.1)      WRITE(13,451)
 451  FORMAT(1X, 'PASSIVE ELECTRIC-ONLY COLLECTOR')
      IF(ISYS.EQ.2)      WRITE(13,452)
 452  FORMAT( 1X,'COMBINED THERMAL AND ELECTRIC COLLECTOR')
      IF(ISYS.EQ.3)      WRITE(13,453)
 453  FORMAT( 1X,'THERMAL-ONLY COLLECTOR')
      IF(IFLOW.EQ.1) WRITE(13,455)
 455  FORMAT(' CONSTANT FLOW RATE')
      IF(IFLOW.EQ.2) WRITE(13,456)
 456  FORMAT(' CONSTANT OUTPUT TEMPERATURE')
      RETURN
z
Z OUTPUT SUMMARY
z
      ENTRY COLL03
      LAT=LAT*PIEV
      RIMANG=RIMANG*PIEV
      WRITE(13,900) CRATIO,TRANS,AREAC,LAT,LONG,LONGST,U1 ,%
                    U2,XKE,BETA,CELLEF,ELECAB,FC ,%
                    ALPHA,FLOWR,DENS,CP,TO,T1 ,APWID,COLEN,%
                    FOCLEN,COSPAC,RIMANG,REFLEC,CELLL
      WRITE(13,901) ISYS,IFLOW,IEW
      RETURN
      END
```

```
COLL3.PB-PNC/UGF002 08/17/78 14:48:14

% PROGRAM NAME: COLL3.JB
% JOHN C. BELL
% ENERGY PROGRAM
% OFFICE OF TECHNOLOGY ASSESSMENT
% COMPILED
%     DATE: 12/29/77
%     TIME: 12:29:42
% PROGRAM COLL3.JB FOR RUNNING HELIOSTAT FIELDS
%         WITH THERMAL OUTPUT ONLY
%
%
%
%
SUBROUTINE COLL(ISYS1)
DIMENSION DAYLEN(365),SONOON(365) ,DECL(365)
DIMENSION RADDN(8760),RADTH(8760)
DIMENSION EQ(4),A(4),B(4)
IMPLICIT REAL(L)
COMMON/BXXX/CRATIO,TRANS ,AREAC,LAT,LONG,LONGST,TILT,AZ ,XKE,BETA,%
           CELLEF,ELECAB,FC,ULOSS,COVERN,FR,ALPHA,FLOWR,DENS,CP,%
           ABC,ABD,APWID,COLEN,FOCLEN,COSPAC.RIMANG.REFLEC ,CELLL,%
           ALPHAV,YYY(5),ISYS,IFLOW,  IEW,IYYY(5)
DIMENSION SCEL(37),ISCEL(8)
EQUIVALENCE (SCEL(1),CRATIO) ,(ISCEL(1),ISYS)
DATA A,B/-.2E-3, .4197,-.32265E 1,-.903E-1,0. ,-.7351E1,-. 93912E1,-.3661 /
DIMENSION GAMMA(3, 7),DAYTIM(3, 7),NZDAY(365)
DATA GAMMA/.92,.56,0.,.92, .58, 0., .92, .68,0.,.91,.72,0.,.87,.7,0.,.82,
          .58,0. ,. 78, .49,0./
DATA DAYTIM/ 1.7,5.36,7. 18,1.7,5.1,6.96, 1.7,3.93,6.56, 1.48,3.6,6.03, 1.51,
          3.48,5.57,1.74,3.6,5.17   ,1.39,3.6,4.781
DATA NZDAY/4*7,  31*6,30*5,31*4,  30*3,31*2,29*1,31*2,30*3,  31*4,30*5,31*6,26*7/
PIE2=6.2831853
PIEV=360/(PIE2)
READ(24) DECL
REWIND 25
READ(25)  RADDN,RADDN,RADDN,RADTH
READ(12,*,PROMPT='FILE NUMBER FOR COLLECTOR COEFFICIENTS: ') IF
IF (IF.LE.0) GO TO 1120
REWIND IF
READ(IF) SCEL,ISCEL
1120   READ(12,99,PROMPT='LIST/CHANGE VARIABLES AND VALUES: ') ITST
99   FORMAT(A4)
IF (ITST.EQ. 'YES') GO To 1123
IF (ITST.EQ.'NO') GO TO 1124
IF (ITST.EQ. 'NON') GO TO 1140
GO TO 1120
1123   WRITE(13,900)  CRATIO,AREAC,LAT,LONG,LONGST,ULOSS,  %
                   ALPHA,REFLEC
900   FORMAT('  ______REAL NUMBERS_______'/%
    #',4X,'VALUE' ,4X,'Definition '/Z
    ' 1 ',1PE1O.3,'  :CONCENTRATION RATIO (DIM)"/%
    ' 3 ',1PE10.3,'  :COLLECTOR AREA (M**2)'/%
    ' 4 ',1PE10.3, '  :LATITUDE (DEG)'/%
    ' 5", IPE10.3,'  :LONGITUDE (DEG)'/%
    ' 6', 1PE10.3, '  :STANDARD LONGITUDE (DEG)'/%
    ' 14 ', IPE10.3, '  :THERMAL LOSS COEFF (KW/C*M**2)'/%
    ' 17 ',1PE10.3,'  :ABSORB OF THERMAL-ONLY SURFACES (.LE.1.00)'/%
    ' 28 ', 1PE10.3,'  :COLLECTOR REFLECTIVITY (.LE. 1.00)')
1124   READ(12,*,PROMPT='VAR # AND VARIABLE: ') IV,V
IF (IV.LE.0) GO TO 1126
IF (IV.GT.37) GO TO 1124
```

```
COLL3.PB-PNC/UGF002 08/17/78 14:48:14

SCEL(IV)=V
GO TO 1124
1126   READ(12,*,PROMPT='FILE NUMBER TO STORE COLLECTOR COEFF: ') IV
IF (IV.LE.0) GO TO 1140
REWIND IV
WRITE(IV) SCEL,ISCEL
%
% FINISH INITIAL COMPUTATIONS
%
1140 LAT=LAT/PIEV
TANLAT=TAN(LAT)
ISYS1=ISYS
DO 50 1-1,365,1
DO 2500 J-1,4
EQ(J)=A(J)*COS((PIE2* (J-1)*1)/365. 25)+B(J)*SIN((PIE2*(J-1 )*1)/365.25)
2500   CONTINUE
RISANG=ACOS((-TANLAT)*TAN(DECL(I)))
DAYLEN(I)=PIEV*RISANG/7.5
SONOON(I)=13.5-((EQ(1)+EQ(2)+EQ( 3)+EQ(4)+4*(LoNGsT-LoNG)  )/60)
50 CONTINUE
RETURN
%
% DAILY COMPUTATION BEGINS
%
ENTRY  COLLO1(K,TFIN,TFOUT,TA,QSR,ESR)
IF ((RADTH(K).LE.0).OR.(RADDN(K).LE.0)) GO T O 38
TFIN=TFOUT
TAIR=TA-273
I=(K-1)/24
J=K-24*(I)
I=I+1
N=NZDAY(I)
TD=J-0.5-SONOON(I)+DAYLEN (1)/2
IF ((TD.LT.0).OR.(TD.GT.DAYLEN(I))) GO TO 38
TDAY=ABS(SONOON(I)-J)
TD=DAYLEN(I)/2.
TB=(TD/(DAYTIM(3,N)))*DAYTIM(1,N)
TC=(TD/(DAYTIM(3,N)))*DAYTIM(2,N )
IF(TDAY.LT.TB)GO TO 25
IF(TDAY.LE.TC)GO TO 26
GO TO 27
25   GAMCOS=0
GO TO 30
26   GAMCOS=(GAMMA(1,N)-GAMMA( 2,N))/(TC-TB)
TD=TB
GO TO 30
27   GAMCOS=(GAMMA(2,N)-GAMMA(3 ,N))/(TD-TC)-  %
          (GAMMA(2,N)-GAMMA(1,N))/(TDAY-TC) @correction FACTOR
TD=TC
30   GAMCOS=GAMMA(1,N)-GAMCOS*(TDAY-TD)
QSR=REFLEC*ALPHA*AREAC*GAMCOS*M.DDN  (K)-%
     (TFOUT-TAIR)*ULOSS*AREAC/CRATIO
GO TO 39
38 QSR=0.
39 IF(QSR.LE.0) QSR=0.
RETURN
%
% OUTPUT STATEMENTS
%
ENTRY COLL02
WRITE(13,250)
```

```
      250   FORMAT ('  HELIOSTAT FIELD' )
      RETURN
      z
      % OUTPU I SUMMARY
      %
      ENTRY COLL03
```

COLL3. PB-PNC/UGF002 08/17/78 14:48:14

```
      LAT=LAT*PIEV
      WRITE(13,900) CRATIO,AREAC,LAT,LONG, LONGST,ULOSS, Z
                    ALPHA,REFLEC
      RETURN
      END
```

```
OFFPK.PB-PNC/UGF002 08117178 14:45:20

% PROGRAM NAME OFFPK.JB
% JOHN C. BELL
% ENERGY PROGRAM
% OFFICE OF TECHNOLOGY ASSESSMENT
% COMPILED
%     DATE:   3/25/78
%     TIME: 15:30:21
% PROGRAM OFFPK.JB FOR BUYING OFFPEAK ELECTRICITY
%
%
%
%
%
%
%
SUBROUTINE OFFPK
DIMENSION E(8760),CPC(2,25)
COMMON/DXXX/BOLMAX,CPC
COMMON/EXXX/TAIRF
COMMON/XDATA/E
DATA XMAX,ONE/1.0E10, l./
READ(12, 99,PROMPT='HEATING, COOLING, AND HOT WATER: ') ITST
99   FORMAT(A4)
IF (ITST.EQ.'YES') IHC=1
READ(12,*,PROMPT='OFFPEAK CHARGING HOURS--BEGIN AND END: ') IHRB,IHRE
IHRTOT=IHRE-IHRB+1
RETURN
ENTRY OFFPK1(K,QP,QC,QSH,COPEE, EHWEFF)
IHR=K-((K-1 )/24)*24
IF ((IHR.GE.IHRB) .AND. (IHR.LE.IHRE)) GO TO 200
H2ON=H2ON+QP
CALL  UPDATE(XMAX,WSTOR,-QP,RESID,ONE,ONE,XMAX)
E(K)=E(K)-(QP-RESID)/EHWEFF
IF (QSH.GT.0) GO TO 100
HEATN=HEATN+QC
CALL UPDATE(XMAX,HSTOR,-QC,RESLD,ONE,ONE,XMAX)
CO TO 101
100   IF (IHC.NE.1) RETURN
COOLN=COOLN+QC
```

```
OFFPK. PB-PNC/UGFO02 08/17/78 14:45:20

CALL UPDATE(XMAX,CSTOR,-QC,RESID,ONE,ONE,XMAX)
101   RESID=(QC-RESID)/COPEE
E(K)=E(K)-RESID
QC2=QC2+RESID
QC1=QC1-RESID
RETURN
200   IF (IHR.NE.IHRB) CO TO 250
OFFBYH=AMAX1(0, (HEATN-HSTOR) /IHRTOT)
OFFBYC=AMAX1(0, (COOLN-CSTOR)/IHRTOT)
OFFBYW=AMAX1(0, (H2ON-WSTOR) /IHRTOT)
HEATN=0
COOLN=0
H2ON=0
250   E(K)=E(K)+OFFBYW/EHWEFF+OFFBYH
IF (IHC.NE.1) GO TO 275
CALL  COPT(TAIRF,CPC,COPC)
E(K)=E(K)+OFFBYC/COPC
CSTOR=CSTOR+OFFBYC
TOFFPC=TOFFPC+OFFBYC/COPC
275   HSTOR=HSTOR+OFFBYH
TOFFPH=TOFFPH+OFFBYH
WSTOR=WSTOR+OFFBYW
TOFFPW=TOFFPW+OFFBYW/EHWEFF
IF (IHR.NE.IHRE) RETURN
HSTORM=AMAX1 (HSTOR,HSTORM)
CSTORM=AMAXI  (CSTORM,CSTOR)
WSTORM=AMAX1  (WSTORM,WSTOR)
RETURN
ENTRY OFFPK2
IF (IHC.EQ.1) WRITE(13,7)
7   FORMAT(//' OFFPEAK BUYING FOR HEATING,COOLING, AND HOT WATER')
IF (IHC.NE.1) WRITE(13,8)
8   FORMAT(//' OFFPEAK BUYING FOR HEATING AND HOT WATER')
WRITE(13,9)  HSTORM,TOFFPH,CSTORM,TOFFPC,WSTORM,TOFFPW
9   FORMAT( 15X, 'MAXIMUM' ,5x, 'TOTAL' /15X,'STORAGE' ,2x,'Electricity"/%
    ' HEATING:',4X,2( 1PE10.3,2X)/' COOLING: ',4X,2(1PE10. 3,2x)/%
    ' HOT WATER:  ',2(1PE10.3,2X))
RETURN
END
```