AVAILABLE ENERGY ANALYSIS OF SOLAR-ASSISTED HEAT PUMP

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OF

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ABSTRACT

The aim of this study is to perform the second law analysis for solar-assisted heat pump system. For this purpose, the computer simulation of solar-assisted heat pump system is performed and the results are obtained for typical days of each month of December, January, February and March. Also, the same task is performed for solar collector system and heat pump system. During the analysis, five different solar collector areas are used for both the solar-assisted heat pump system and solar collector system, summing up to eleven different systems consisting three main systems. The conventional boiler is used as auxiliary energy source for all of the systems.

The exergetic efficiency, or, second law efficiency is defined, formulated and reduced for each of the systems. The exergetic efficiencies and coefficient of performances are calculated by computer using fifteen minutes computer steps and comparison is performed among the systems.

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LIST OF SYMBOLS

Ac	:	Solar collector area (m2)
By	:	Longitude
Cp	:	Specific heat (kJ/kg ^oC)
d	:	Sun's declination
Di	:	Inside diameter of the collector tubes (m)
e	:	Carnot efficiency
Ea	:	Available energy (kJ/hr)
Eu	:	Unavailable energy (kJ/hr)
E	:	Electrical or mechanical power (kJ/hr)
Eq	:	Heat exergy (kJ/hr)
Ew	:	Transformation exergy (kJ/hr)
F_R	:	Heat removal factor of the collector
F'	:	Collector efficiency factor
g	:	Gibb's free energy kJ/kg)
$h_{f,i}$	:	Convection heat transfer coefficient (kJ/hr m2)
H_{TH}	:	Daily total radiation on horizontal surface (kJ/m^2 day)
H_b	:	Daily beam radiation on horizontal surface (")
H_d	:	Daily diffuse " " " " (")
h	:	Enthalpy (kJ/kg)
h'	:	Hour angle (deg)
h_f	:	Enthalpy of formation (Kj/kg)
ΔH_L	:	Lower heating value of fuel (kJ/kg)
I_{bT}	:	Instantenous beam radiation on tilted surface (W/m2)
I_d	:	" diffuse radiation on horizontal surface (W/m2)
I_{dT}	:	" " " " tilted surface (W/m2)
I_{TH}	:	" total " " horizontal surface (W/m2)
I_{TT}	:	" " " " tilted surface (W/m2)
I_{rr}	:	Irreversibility (kJ/kg)

I_b	:	Instantaneous beam radiation on horizontal surface (W/m2)
ℓ	:	Length of the collector tubes (m)
L	:	Exergy loss (kJ/hr)
ML	:	mass of the water in the cold water tank (kg)
MR	:	" " " " " the hot water tank (kg)
m	:	mass flow rate (kg/hr)
P	:	Electric power consumed for pumping (kJ/hr)
P'	:	Pressure (kPa)
Q	:	Heat (kJ/hr)
Q_B	:	Heat delivered by boiler (kJ/hr)
Q_L	:	Heat extracted by load (i.e.house) (kJ/hr)
Q_E	:	Heat extracted by evaporator (kJ/hr)
Q_c	:	Heat delivered by condensor (kJ/hr)
Q_u	:	Useful energy delivered by solar collector (kJ/hr)
r_t	:	ratio of total instantaneous radiation per total daily radiation
r_d	:	" " diffuse " " " diffuse daily radiation
R_d	:	" " " radiation on tilted surface per horizontal surface
R_b	:	" " beam " " " " " " "
R	:	" " total " " " " " " "
R_{p-f}	:	Heat transfer resistance $(kJ/hr)^{-1}$
S'	:	Collector tilt angle (deg)
S	:	Entropy (kJ/kg ^oK)
ΔSp	:	Entropy production (kJ/kg ^oK)
T	:	Temperature (^oC)
Tp	:	Collector plate temperature (^oC)
T_{L2}	:	Return water temperature from house (^oC)
T_{E2}	:	Return water temperature from evaporator (^oC)
T_{K2}	:	Return water temperature from condensor (^oC)
T_{C2}	:	Return water temperature from collector (^oC)
T_{B2}	:	Return water temperature from boiler (^oC)

$T_{H.T}$: Temperature of hot water tank (^{o}C)

$T_{C.T}$: Temperature of cold water tank (^{o}C)

Δt : Computation time inter val (min)

TS : Standart time (o'clock)

td : Day length

To : Ambient temperature. (^{o}C)

$T_{f,m}$: Mean working fluid temperature of the collector (^{o}C)

$T_{p,m}$: Mean plate temperature of the collector (^{o}C)

Uc : Heat loss cofficient of the collector (kJ/hr ^{o}c)

UU : Heat loss cofficient of the house (kJ/hr ^{o}c)

UR : Heat loss cofficient of the hot water tank (kJ/hr ^{o}c)

UL : Heat loss cofficient of the cold water tank (kJ/hr ^{o}c)

U_{rp} : internal energy of combustion (kJ/mol)

w : work (kJ/hr)

W_{rev} : reversible work (kJ/hr)

Z : Solar time

ZD : equation of time

$\tau\alpha$: Transmittance-absorbtance product of the collector

η_B : Boiler first law efficiency

η_c : Isentropic efficiency of the compressor

η_m : Mechanical efficiency of the compressor

η_e : Electrical efficiency of the compressor electric motor

η_{ex} : Exergetic efficiency

θ' : Carnot coefficient

θ : Angle of incidence of beam radiation

θ_z : Zenith angle

α : Solar altitude

γ : Surface azimuth angle

$\emptyset$: Latitude

0- INTRODUCTION

The awareness that widely used energy resources are approaching exhaustion has stimulated interest in applying the second law of thermodynamics to the analysis of energy conversion efficiency. This is not surprising, since traditional first law efficiency is silent on irreversibility. As nonrenewable fuels become more scarce, their ability to produce useful work become more precious.

Availability, the thermodynamic term for this ability, is characterized in terms of the second law. This renewed interest in second law analysis has produced a range of opinions on its utility and a variety of parameters for its expression. Even, the available energy and unavâilable energy are expressed ih Europe with different names as exergy and anergy, respectively. As it is too hard to choose, and so as to prevend restricting ourselves from using broader types of analysis, in this study these concepts have been reviewed while both terminologies are used trying to be consistent with-to some extent-different approaches of second law analysis.

Solar energy systems and heat pumps are two promising means of reducing the consumption of nonrenewable energy sources. A logical extention of each is to try to combine the two to further reduce the cost of delivered energy. The efficiency of a solar panel is inversely propotional to the temperature of its working fluid, while the requirements for space heating necessiate a fluid at a relatively high temperature.

By introducing a heat pump as an intermediate system element, it is possible to operate the panels at a more efficient temperature and to have heat exchange with the room air occur more efficiently. To provide for heating at night and during extended cloudy periods, a thermal storage element such as a liquid filled tank must be employed.

In most geographical regions, weather conditions will require a conventional (non-solar) heating system as backup. This backup system might be eliminated if the thermal storage element is large enough, but its required dimensions would render it impractical. This study assumes a conventional backu system, a boiler.

Extensive studies regarding performance analysis and cost analysis of solar assisted heat pump systems have been examined previously. The study presented here is a second law analysis of this system fulfilling heating task of a house in İstanbul. Also, the heat pump with boiler backup and solar colle with boiler backup have been examined from this point of view to be able to compare which system renders the least irreversibility, which in sense means, the most convenient one.

I- HISTORICAL INTRODUCTION

Availibility, conceived in its broadest sense, is one of those concepts not infrequent in thermodynamics-which has been discovered and rediscovered independently by a string of physicists and engineers. This nature of discovery has led to a variety in terminology, as will be seen later.

Many writers trace this concept to M. Gouy (1889), many others to J.W. Gibbs (1873,1875). Some see its beginning in P.G. Tait (1868), J.C. Maxwell (1871), and Lord Kelvin (1879). The concept was certainly known and used by A. Stodola (1898,1905) and M.E. Jouget (1907), both of whom quoted Gouy. The cause of availibility and the closely related concept of exergy was also taken up by J.H.Keenan (1932) (who referres to G.Darrieus (1930)), and later by H.D. Baehr (1962) who based much of his work on Ż.Rant (1956) and F.Bosnjakovic (1935). R.B.Evans (1969) reintroduced the term for chemical work and mixing first mentioned by J.W.Gibbs. A line of developement is represented by the untranslated treatises of J.Szargut (1965) and J.Madejski (1977). The concept is presented clearly in the recent textbook of V.A.Kirillin, V.V.Sychev, and A.E.Sheindlein (1976).

K.W. Ford (1975) and G.M. Reistad (1974) have examined many thermal processes, as well as the entire U.S. energy economy, by means of the second law thermodynamics.

With the contribution of researchers among which are A.Bejan, A.B. Cambel, R A. Gaggidi, J.Kestin , A.K.Oppenheim, F.Kreith, J.E.Ahern, M.V. Sussman, J.Szargut, a workshop (second law analysis of energy devices and processes) was held on 14-16 August 1979 at the George Washington University.

Today, the method is updated and more organized, such that, it is coupled with the other methods for optimization of processes.

The heat pump concept was conceived by Lord Kelvin over 120 years ago. Since that time the use of such devices has often been advocated because heat pumps can reduce power comsumption compared with conventional heating systems. For contribution to this reduction (i.e. high C.O.P.), solar collectors are introduced to work coupled with the heat pump.

Jordan and Threlkeld (1954), P.Sporn and E.R.Ambose (1955), G.O.G.Löf (1956), C.P.Davices, Jr.and R.I.Lipper (1958), F.H.Bridges, D.Paxton and Haines (1958), G.R.Maory (1964), Calvert and Harden (1973), Bosia and Suryanarayan (1975), F.L.Freeman (1975), V.D.Karman , F.L.Freeman and J.W.Mitchell (1976), J.W.Mc Arthur, W.J.Palm and R.C.Lessman (1978), ant others researched the applicability of the solar-assisted heat pump. Some of these explorations were held on theoretical base using computer simulations whereas some were practically established as Albert' and Holt's study (1976). Though the system hasn't yet proved itself both economically and technically, the obtained high coefficient of performance encourages to survive the studies at least hoping improvement so that it can be advocated without any hesitation.

II- SYSTEM DESCRIPTION

A. Solar-assisted heat pump

The solar-assisted heat pump used in this study is shown schematically in Fig.2.1

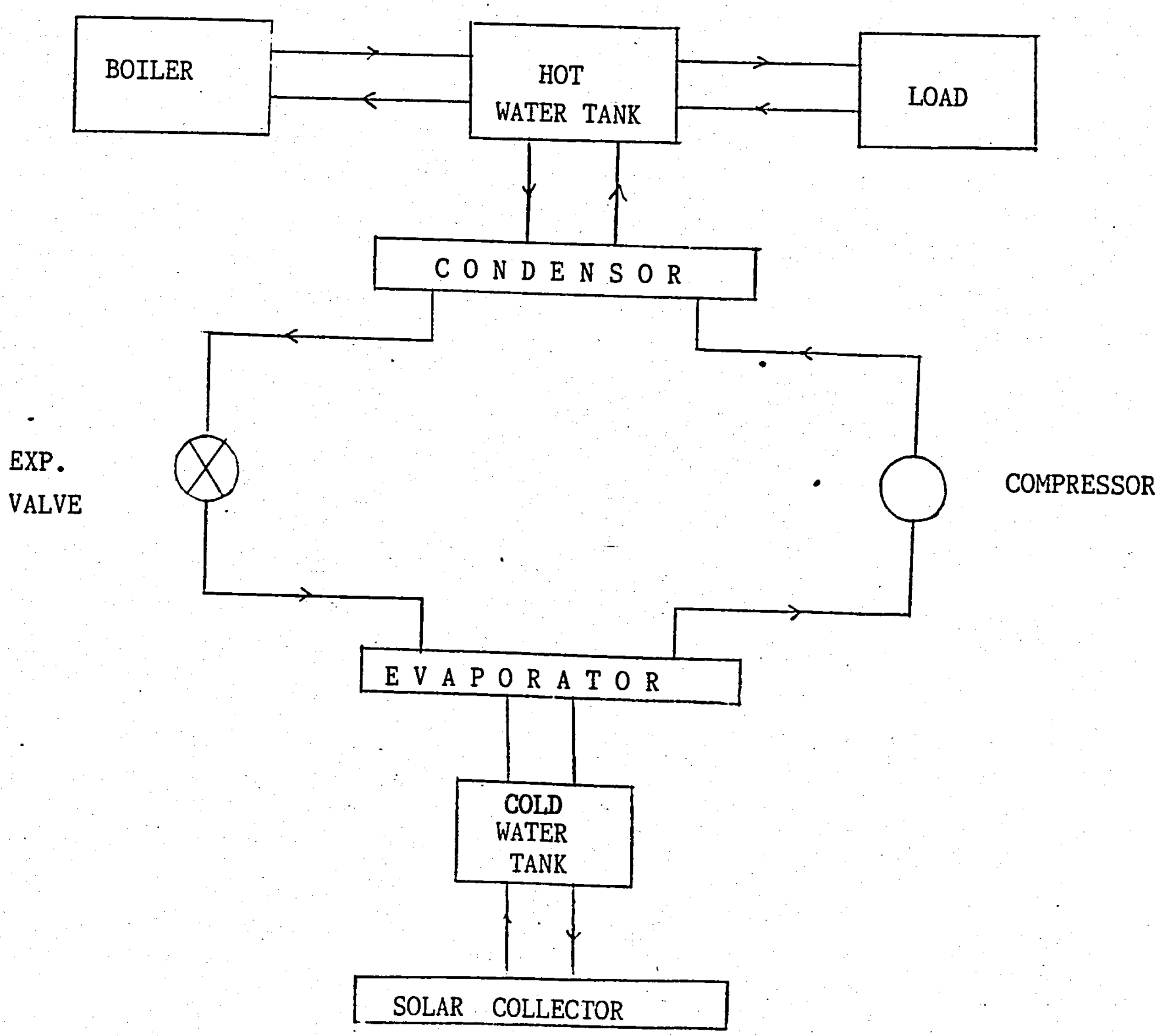


Fig.2.1 Description of Solar-assisted heat pump

Briefly, the solar collector exchanges energy with the cold water tank which in turn gives energy to the evaporator. The condensor and boiler are in parallel giving energy to the hot water tank from which the energy is extracted to be delivered to the load. All the devices extract water from the tanks directly, without using any coils.

System control logic

The solar collector works during the day time and delivers hot water to the cold water tank.

The heat pump works as long as the cold water tank temperature is equal to or above 10 ^oC.

The boiler works whenever the heat pump doesn't work.

All the three systems work between 6 a.m. up to 23.p.m.

B. Heat pump and boiler

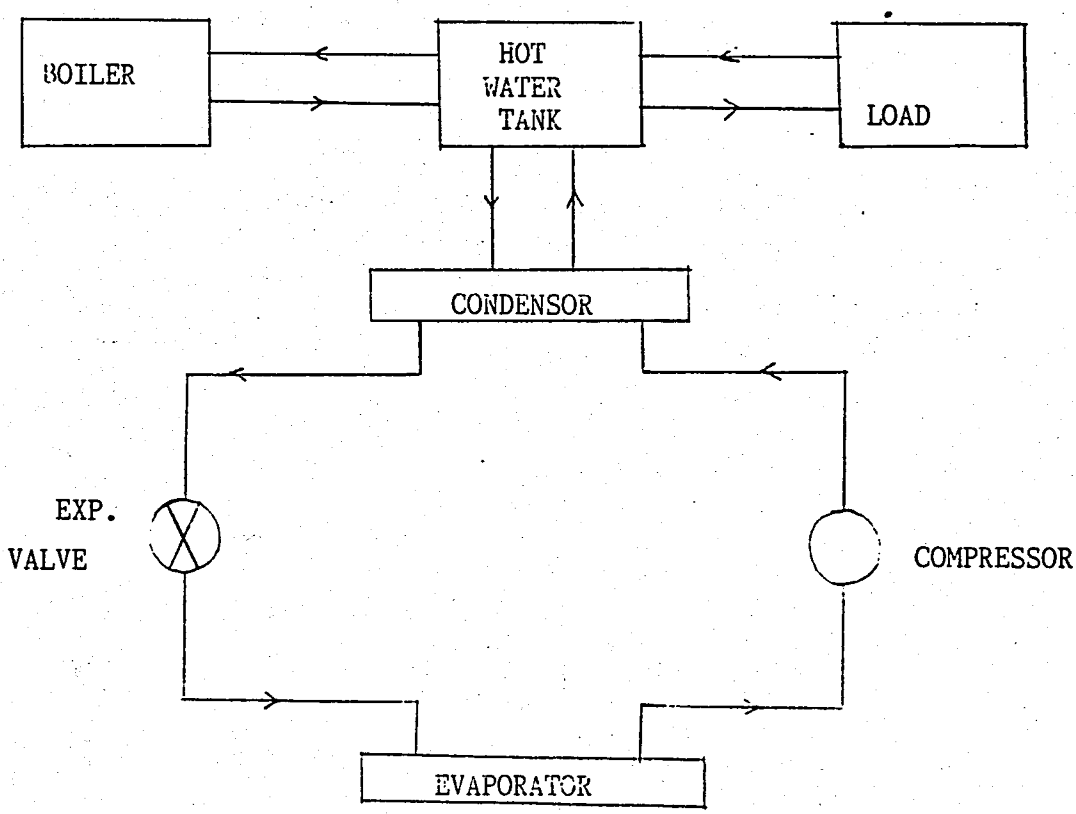


Fig.2.2 Description of heat pump and boiler

The evaporator receives heat from the ambient air and via condensor the heat pump delivers heat to the hot water tank. The boiler also delivers energy to the hot water tank. All the devices extract water from the tank directly, without using any coils.

System control Logic

The heat pump works as long as the ambient air temperature is equal or above 5 ^{o}C .

The boiler works whenever the heat pump doesn't work.

The system delivers energy to the load between 6 a.m. -23 p.m.

C. Solar collector and boiler

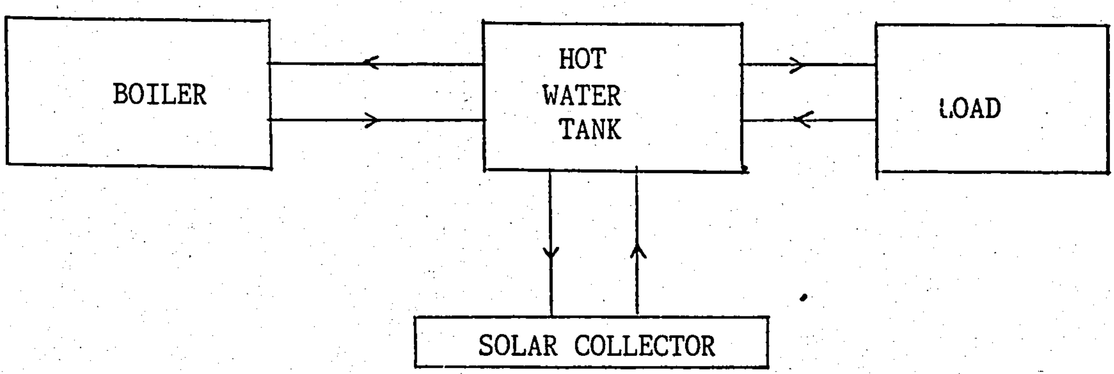


Fig.2.3 Description of solar collector and boiler

The solar collector and boiler are in parallel connection with the hot water tank which delivers heat to the load. All the devices extract water from the tank directly, without using any coils.

System control logic

The solar collector works during the day time as long as it delivers hot water to the cold water tank.

The boiler works whenever the hot water tank temperature is equal to or below 40 ^{o}C .

III- THEORY AND PRINCIPLES

3.1. Definition of the problem

The second law, like the first, is a consequence of experience and logic. It is founded on the work of Carnot. A macroscobic phenomenon which violates the second law has never been observed; hence, we say that it is most improbable that a violation will ever be observed. There are so many facets to this law that it is being stated in different ways below :

Kelvin : It is impossible by means of inanimate material agency to derive mechanical effect from any portion of matter by cooling it below the temperature of the coldest of the surrounding objects.

Kelvin-Planck : It is impossible to contruct an engine which while operating in a cycle produces no effect except to do work and exchange heat with a single reservoir.

No actual or ideal heat engine operating in cycles can convert into work all the heat supplied to the working substance; must discharge some heat into a naturally accessible sink. Because of this aspect, the second law is often aptly referred as the LAW OF DEGRADATION OF ENERGY.

The question is: How much does the energy degrade as we apply a process through a certain system. How do we approach the ideal as we apply a different system that will perform the same task. The final and perhaps the most important question is : Is the system well-matched to the task ?

3.2 Available and Unavailable Energy

Since one of the more important endeavors of an engineer is to obtain the maximum amount of work from a process or cycle and to use the minimum work in reversed operations, it behooves us to inquire into conditions which ideally produce the maximum work. We already know what this is for a reversible engine, but in asmuch as most engines do not propose to be reversible, even ideally, we need to set up standarts for other situations. From the two expressions of the Carnot efficiency,

$$e= 1-\frac{T_2}{T_1} \quad \text{and} \quad e=1-\frac{Q_R}{Q_A} \qquad (3.2.1)$$

we write

$$\frac{Q_R}{Q_A} = \frac{T_2}{T_1} \quad \text{or} \quad Q_R=T_2\left(\frac{Q_A}{T_1}\right) \qquad (3.2.2)$$

This value of QR is the heat that must be discharged by a reversible engine, the most perfect conceivable, operating between T_1 and T_2. Since no imaginable engine could convert a larger portion of heat into work, we say that this Q_R is UNAVAILABLE ENERGY or as synonym, ANERGY. None of the unavailable energy can be converted into work-unless a colder sink becomes available.

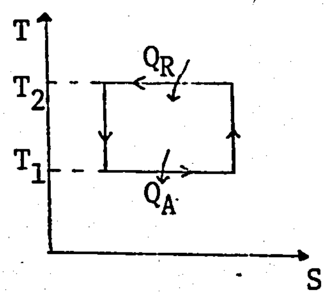


Fig.(3.2.1) Carnot cycle

Equation (3.2.2) is useful only when the heat Q_A is added at constant temperature. To get a more general expression, let the heat be added in accordance with some internally reversible path ab (Fig.3.2.1) and consider an infinitesimal Carnot cycle 1-2-3-4

The working substance is a closed system. Since the width of this cycle S is very small, heat is effectively added at constant temperature along 4-1 ; call this temperature T. The sink at temperature T_2 is some natural heat reservoir, such as the atmosphere, a river, or a lake.

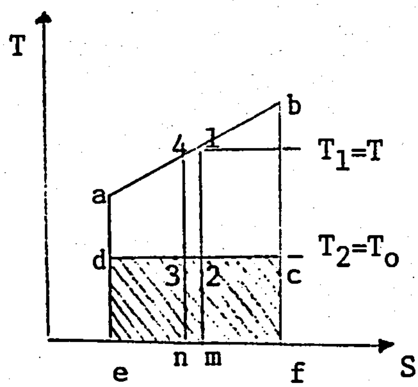


Fig.(3.2.2) Reversible process

Let the natural sink temperature be designated by To. Now, in equation (3.2.2), let $Q_A = dQ$, $Q_R = dQ_R$, $T_1 = T$, and $T_2 = T_o$, a constant and get.

$$\frac{dQ_R}{T_o} = \frac{dQ}{T} \quad \text{or} \quad Q_R = T_o \int \frac{dQ}{T} \qquad (3.2.3)$$

In words, this equation says that when heat Q is transferred to a system whose temperature T is variable (or constant), the portion Q_R as defined by equation (3.2.3) is the minimum heat that must be rejected as heat in case we try to obtain work from the heat Q. For this reason, we call this particular rejected heat the unavailable energy. Thus, the unavailable energy Eu may be defined as that portion of any transferred heat which cannot be converted into work when the heat is used in a frictionless engine for which all processes are ideal. Since the Q_R of equation (3.2.3) has this special significance, it will be designated by Eu .

Moreover, recalling that $\int dQ/T = \Delta S$ for a reversible process, ref (1,pg.199) , we can write

$$Eu = T_o \int \frac{dQ}{T} = T_o \, \Delta S \qquad (3.2.4)$$

where ΔS is the system's change of entropy during the transfer of heat Q.

AVAILABLE ENERGY or EXERGY, Ea, may now be found as the transferred heat minus the unavailable energy,

$$Ea = Q - Eu = Q - T_o \, \Delta S \qquad (3.2.5)$$

Available energy is energy which is convertible %100 into work in the absence of irreversibilities, and in this case, it is that portion of the heat transferred to a system during an internally reversible process which is available for conversion into work in a closed cycle and its amount is given by equation (3.2.5) whether or not the system remains at constant temperature while receiving heat. After heat has been added ab (Fig.3.2.2) , the available energy, area abcd, can be realized as work by completing the cycle with two insentropics ,bc and da , and an isothermal cd. The area cdef represents the unavailable energy. The actual work obtained from any heat Q will always be less than the available energy.

3.3 Entropy Production

For the cycle of internally reversible processes abcd (Fig.3.2.2) which is any cycle chosen at random, the system's increase in entropy during ab is balanced by the system's decrease cd, and

$$\int \frac{dQ}{T} - \frac{Q_R}{T_o} = \sum \int \frac{dQ}{T} = 0 \qquad (3.3.1)$$

Now let us suppose that the expansion from b is irreversible instead of reversible, along some path bc' ; and for convenience, let bc' be adiabatic (Q=0). Since the process bc' is irreversible, less work is done than in process bc; therefore, more energy remains in the system than when the expansion is reversible and point C' is consequently to the right of qoint c. Thus, since more heat Q'_R is rejected after the irreversible expansion, Q'_R/T_o is a larger number than QR/T_o.

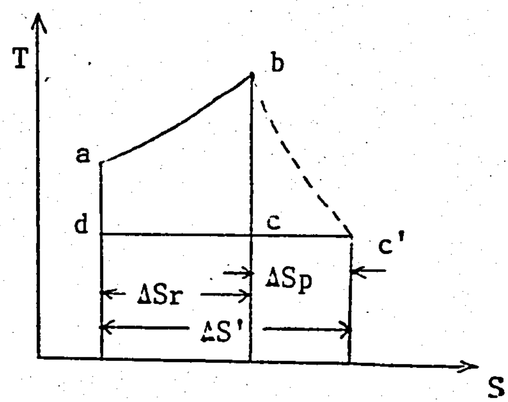


Fig.3.3.1 Irreversible Proces

Then

$$\int \frac{dQ}{T} - \frac{Q'_R}{T_o} = \sum \int \frac{dQ}{T} < 0 \qquad (3.3.2)$$

and it is less than zero (a negative quantity) because Q'_R/T_o is a larger number than $\frac{dQ}{T}$. In other words, this equation says that the system discharged ($\Delta S'$) more entropy than it received (ΔSr) from the surroundings; it is PRODUCING ENTROPY (ΔSp).

Combination of the preceding two equation gives

$$\sum \int \frac{dQ}{T} \leq 0 \qquad (3.3.3)$$

which is simply the Clausis Inequality.

The net result of irreversibility is an increase in entropy. This increase of entropy due to irreversibility is called the ENTROPY PRODUCTION or ENTROPY GROWTH. From Fig (3.3.1) , we may write the equation,

$$\sum \int \frac{dQ}{T} + S_{bc'} = \int_a^b \frac{dQ}{T} - \frac{Q_R'}{T_o} + \Delta Sp = 0 \qquad (3.3.4)$$

where ΔSp is the entropy production during process bc' ,and the entire internal production of entropy during this particular cycle, because the other processes are internally reversible.

For a cyclic operation, the entropy of the system returns to its initial value Sa every time a cycle is completed. That is, the internal change of entropy is zero for irreversible as well as reversible cycles. The entropy production during a cycle is the growth of entropy of the surroundings. We may say in accordance with the second law that

$$\Delta S \text{ system} + \Delta S \text{ surroundings} \geq 0 \qquad (3.3.5)$$

where the equals sign applies only when the processes are internally and externally reversible. For all actual processes therefore, we can write

$$\Delta Sp = \Delta S \text{ system} + \Delta S \text{ surroundings} \qquad (3.3.6.a)$$

$$\Delta Sp = \Delta S \text{ system} + \Delta S \text{ source} + \Delta S \text{ sink} \qquad (3.3.6.b)$$

where ΔSp is the net increase in entropy and ΔS system = 0 for a cycle and the other changes are algebraic (Δ S source is negative when it supplies heat, positive when it receives heat in a reversed cycle).

Since for any process, the actual change of entropy of the system is $\Delta S' \geq dQ/T$, where the equal sign applies for internal reversibility, we may write

$$\Delta S' = \int \frac{dQ}{T} + \Delta Sp , \qquad (3.3.7)$$

the actual change of entropy, applicable to a process or a series of processes.

For a more comprehensive understanding, let us examine the control volume in Fig.3.3.2

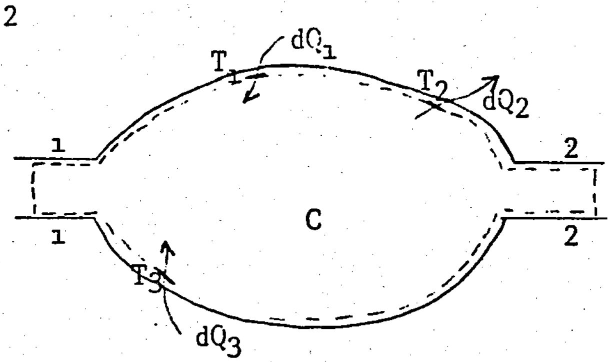


Fig. 3.3.2 Entropy production in a control volume

For a control volume with several inflows and outflows, the definition of entropy production can readily be extended on a rate basis as, ref (2,pg 189)

$$\Delta Sp = \frac{dS}{dt} + \left(\sum_{out} (S_i\ m_i) + \sum_{out} \frac{Q_i}{T_i}\right) - \left(\sum_{in} (S_i m_i) + \sum_{in} \frac{Q_i}{T_i}\right) \qquad (3.3.8)$$

rate of entropy storage — rate of entropy outflow — rate of entropy inflow

Here ΔSp is the rate of entropy production within the control volume. The terms $S_i\ m_i$ represent rates of convective entropy transfer, and the terms Q/T represent rates of entropy transfer with heat.

We should note that

$\Delta Sp=0$

for reversible processes and is always positive.

For steady-state steady flow condition, eq.(3.3.8) diminishes to

$$\Delta Sp=\left(\sum_{out}(S_i\, m_i)+\sum_{out}\frac{Q_i}{T_i}\right)-\left(\sum_{in}(S_i\, m_i)+\sum_{in}\frac{Q_i}{T_i}\right) \qquad (3.3.9)$$

where it reduces entropy production for a system if we let $m_i=0$

3.4 Irreversibility

If a system's entropy change is a loss, the gain of entropy of the surroundings will be greater than the loss, resulting in a net gain. Thus, entropy, like time, is unidirectional and always increasing, and moreover, the change of entropy is a measure of the change of unavailable energy (T_o S); the greater the increase of unavailable energy and the greater the loss of available energy. Hence, defining IRREVERSIBILITY as increment of unavailable energy, we can meause its amount with respect to a heat source at temperature T_o as (3,pg.686)

$$Irr=T_o \cdot \Delta Sp \qquad (3.4.1)$$

Hence, we obtain an absulute measurement for irreversibility taking place in a certain process with respect to our specified state of temperature T_o .

The main causes of irreversibility are as follows:

-Dissipation (friction) ;

-heat-transfer under temperature reduction;

-chemical reactions (combustion) ;

-physical mixtures.

3.5 Exergy and exergetic efficiency

If we apply the first and second principles of thermodynamics to any system, we obtain the exergetic balance in power according to (4,pg.52)

$$E^- + E_q^- + E_w^- = E^+ + E_q^+ + E_w^+ - L \qquad (3.5.1)$$

where:

E is mechanical or electric power, (mechanical or electrical energy is the same as mechanical or electrical exergy)

Eq is heat-exergy (or available energy)

Ew is transformation-exergy (eg.combustion)

L is exergy losses (or irreversibility)

The exponents + or - indicate that exergy is received by the system from outside respectively given by the system to the outside.

Heat-exergy Eq is defined by the relation :

$$\dot{E}q = \theta' . Q \qquad (3.5.2)$$

where:

Q is heat-power received or given by the system to the outside

θ' is the CARNOT coefficient defined by:

$$\theta' = 1 - \frac{T_o}{T} \qquad (3.5.3)$$

In this definition:

To is the temperature of the atmosphere

T is the temperature of which heat-power Q is transferred.

Heat-exergy Eq is the maximum equivalent mechanical power that can be obtained reversibly from heat power Q .

Transformation exergy is the maximum equivalent mechanical power that can be obtained reversibly from the thermodynamic transformation of a material.

Exergy losses L are exergy reductions due to imperfections of the system. In the energy sense, any imperfection gives rise to a thermodynamic irreversibility and any irreversibility results in a deterioration of energy. This sequence of events can be expressed quantitatively as a reduction of exergy (recall that it is increment of available energy which is the same thing).

Considering the exergy balance expressed by relation (3.5.1) , we can define the exergetic efficiency of any system by the relation:

$$\eta_{ex} = \frac{E^- + Eq^- + Ew^-}{E^+ + Eq^+ + Ew^+} \qquad (3.5.4)$$

which can be expressed as follows:

$$\eta ex = \frac{N}{D} \qquad (3.5.5.a)$$

$$= \frac{N}{N+L} \qquad (3.5.5.7)$$

$$= \frac{D-L}{D} \qquad (3.5.5.c)$$

$$= 1 - \frac{L}{D} \qquad (3.5.5.d)$$

when N and D are the numerator and the deminimator of eq . (3.5.4)

3.6 Heat-Exergy

In the previous section (3.5) , we have defined heat-exergy as

$$Eq = Q \cdot (1- \frac{To}{T})$$

if we let

$$Q= m\ Cp\ dT \qquad (3.6.1)$$

we obtain

$$Eq= \int_{T_1}^{T2} m\ Cp\ dT(1- \frac{To}{T}) \qquad (3.6.2)$$

Taking the integral, we have

$$Eq= m\ Cp\ (T2-T_1) - m\ Cp\ To\ Ln\ (\frac{T2}{T_1}) \qquad (3.6.3)$$

However, equating (5,pg.43)

$$\dot{Q} = \dot{m}\, Cp\, (T2-T1) \qquad (3.6.4)$$

$$= \dot{m}\,(h2-h1)$$

and,

$$S_2 = Cp\, Ln\, T_2 \qquad (3.6.5)$$

$$S_1 = Cp\, Ln\, T_1$$

we can write

$$Eq = \dot{m} \left\{ (h_2 - T_o S_2) - (h_1 - T_o S_1) \right\} \qquad (3.6.6)$$

which is the definition given in same textbooks as in ref. (1,pg.278) as reversible work (Wrev).

3.7 Transformation Exergy

It is indicated in ref. (1, pg.289) that when an steady state steady flow chemical reaction takes place in such a manner that both the reactants and products are in temperature equilibrium with the surroundings, the Gibbs function

$$g = h - Ts \qquad (3.7.1)$$

becomes a significant variable. For such a process, in the absence of changes in kinetic and potential energy, the reversible work is given by the relation (1,pg.513)

$$W_{rev} = \sum_R n_i \bar{g}_i - \sum_P n_e \bar{g}_e \qquad (3.7.2)$$

where R and P denote reactants and products, respectively, and, superscript $(\overline{\ \ })$ denotes division by number of moles.

The internal energy of combustion is defined as (1,pg.504)

$$U_{RP} = \sum_P n_e \left[\bar{h}^o_f + \Delta \bar{h} - P'\bar{v} \right]_e - \sum_R n_i \left[\bar{h}^o_f + \Delta \bar{h} - P'\bar{v} \right]_i$$

$$(3.7.3)$$

where $h^o{}_f$ is the enthalpy of formation as defined in ref (1,pg.493) and P' is the pressure.

Frequently, the term "heating value" or "heat of reaction" is used as synonym of internal energy of combustion.

However, the difference between the decrease in Gibbs function and the heating value is small for hydrocarbon fuels and the efficiency defined in terms of heating value is essentially equal to that defined in terms of decrease in Gibbs function ref (1,pg.515).

Since in this study hydrocarbon fuels are used, we can depict transformation exergy as (4,pg.56)

$$Ew = m \, \Delta H_L \tag{3.7.4}$$

where m is the mass flow rate of fuel and ΔH_L is the lower heating value of the fuel.

3.8 Exergetic efficiency of solar-assisted heat pump: system A

As depicted in Fig. (3.8.1), we can set up exergetic balance as follows:

$$\text{Exergy Input} = (Eq)\ \text{solar radiation} + (E)_{\text{electricity}} + (Ew)_{\text{fuel}} \tag{3.8.1}$$

$$\text{Exergy Output} = (Eq)_{\text{load}} \tag{3.8.2}$$

$$(Eq)_{\text{solar radiation}} = I.R.A_c \left(1 - \frac{T_o}{T_p}\right) \tag{3.8.3}$$

where,

A_c = Collector area

IR = Solar radiation incident on the collector per m^2 collector area

T_p = Collector plate temperature

T_o = Ambient temperature

$$(E)_{\text{electricity}} = \text{Electricity delivered to pumps+Compressor work}/\ \eta m.\eta e \tag{3.8.4}$$

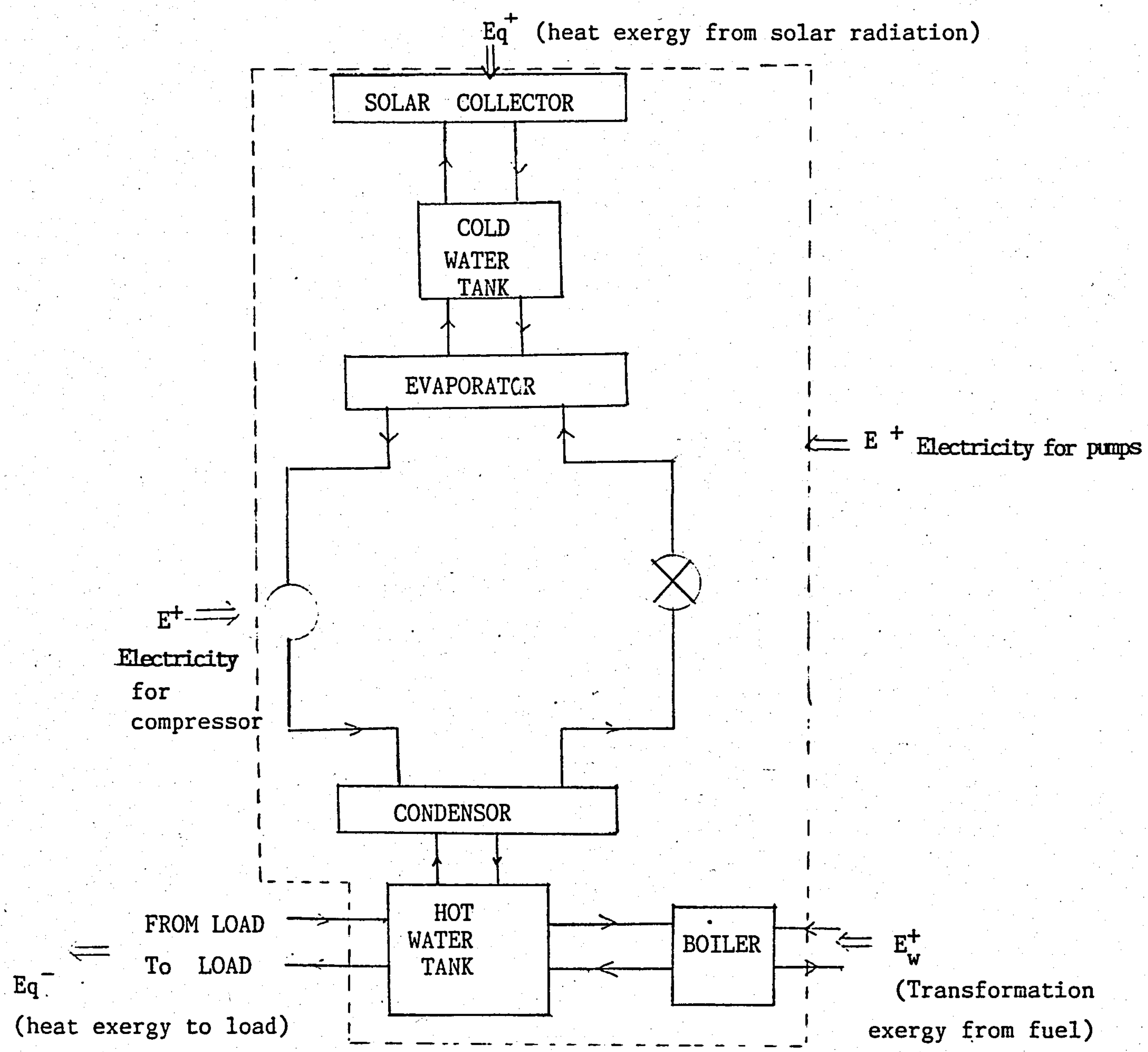


Fig. 3.8.1 Exergetic interpretation of solar assisted heat pum

where,

η_m= mechanical efficiency of the compressor

η_e= electrical efficiency of the electric motor

$$(E_w)_{fuel} = m_{fuel} \cdot \Delta H_L \qquad (3.8.5)$$

$$= Q_B / \eta_B$$

where,

η_B= efficiency of the boiler

$= Q_B / (m_{fuel} \cdot \Delta H_L)$

Q_B= heat given by the boiler

$$(Eq)_{load} = Q_L - T_o \; mCp \; Ln\left(\frac{T_{HT}}{T_{L2}}\right) \qquad (3.8.6)$$

Here, we use eqn. (3.6.3), and from 1 st law of thermodynamics,

$$mCp\,(T_{L2} - T_{HT}) = m\,(h_2 - h_{HT}) \qquad (3.8.7)$$

$$= Q_L$$

where,

Q_L= Heat given to load

m = mass flow rate of the stream delivered to load

T_{HT} = Temperature of the hot water tank, since we deliver stream to load directly from the hot water tank

T_{L2} = the temperature of the stream returning back from load

Thus, we set up the exergetic efficiency for the system as

$$(\eta ex)_{sys} = \frac{Q_L - T_o \; m\,Cp\,\ell n\left(\frac{T_2}{T_{HT}}\right)}{I.R.A_c\left(1 - \frac{T_o}{T_p}\right) + E + QB/\eta_\theta} \qquad (3.8.8)$$

$$= \frac{\text{Exergy output}}{\text{Exergy input}}$$

3.9. Exergetic efficiency of the solar collector

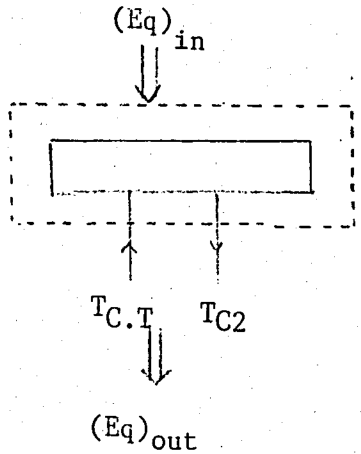


Fig. 3.9.1 Exergetic interpretation of solar collector

For the solar collector, if ve set up exergy balance:

$$\text{Exergy in} = I.R.A_c \left(1 - \frac{T_o}{T_p}\right) \qquad (3.9.1)$$

as in eqt (3.8.3)

$$\text{Exergy out} = Qu - T_o\, m\, Cp\, Ln\left(\frac{T_{C2}}{T_{CT}}\right) \qquad (3.9.2)$$

where,

Qu = useful energy collected from the solar collector

$$= m\, Cp\, (T_{C2} - T_{C.T.}) \qquad (3.9.3)$$

$$= m\, (h_{c2} - h_{C.T})$$

$T_{C.T}$ = Temperature of the inlet stream to collector, since it is delivered directly from the cold water tank.

T_{C2} = Temperature of the returning stream from the collector.

Here, similar approach is performed as $(Eq)_{load}$ in section (3.8)

Thus, we set up exergetic efficiency as:

$$(\eta ex)\cdot SOL.COL = \frac{Qs - To\, m\, Cp\, Ln\left(\frac{T_{C2}}{T_{CT}}\right)}{I.R.A_c \left(1 - \frac{T_o}{T_p}\right)} \qquad (3.9.4)$$

3.10 Exergetic efficiency of the boiler

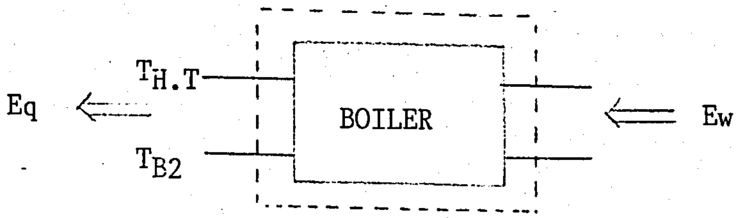


Fig. 3.10.1 Exergetic interpretation of boiler

For the boiler, the exergy balance is set up as:

$$\text{Exergy in} = E_w \qquad (3.10.1)$$

$$= m_{fuel} \cdot H_L$$

$$= Q_B / \eta_B$$

as shown also in eqt. (3.8.5)

Here, the boiler efficiency is the efficiency term given in practice (1,pg.515).

$$\text{Exergy out} = Q_B - m\, C_p\, T_o \ln \left(\frac{T_{B2}}{T_{HT}}\right) \qquad (3.10.2)$$

where,

T_{B2} = temperature of the stream returning back from the boiler

T_{HT} = temperature of the hot water tank from where the water is directly pumped into the boiler

m = mass flow rate of the stream

Here, the exergy out term is set up using the same treatise as in eqt. (3.8.6)

Thus, we obtain the exergetic efficiency for the boiler as:

$$(\eta_{ex})_{boiler} = \frac{Q_B - m\, C_p\, T_o \ln \left(\frac{T_{B2}}{T_{HT}}\right)}{Q_B / \eta_B} \qquad (3.10.3)$$

3.11 Exergetic efficiency of the heat pump

For the heat pump, the exergy balance is set as follows:

Exergy in = E + $(Eq)_{evaporator}$ (3.11.1)

Exergy out= $(Eq)_{condensor}$ (3.11.2)

$E = W/ (\eta m . \eta e)$ (3.11.3)

where,

W = work of compressor

ηm = mechanical efficiency of the compressor

ηe = electrical efficiency of the electric motor

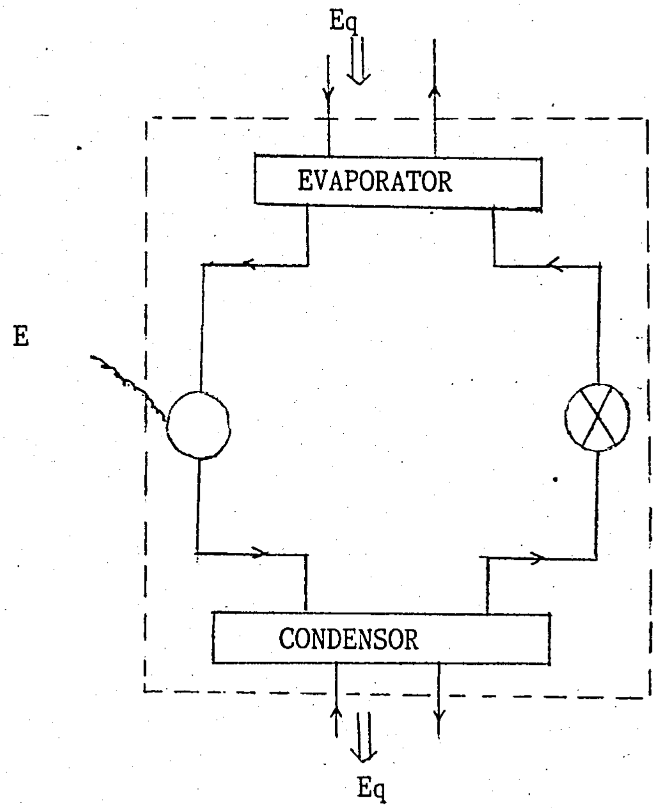


Fig. 3.11.1 Exergetic interpretation of heat pump

$$(Eq)_{evaporator} = Q_E - m\ Cp\ T_o\ Ln\ (\frac{T_{CT}}{T_{E2}}) \quad (3.11.4)$$

where,

QE = Heat delivered to the evaporator by the stream

T_{E2} = Temperature of the stream at the outlet of the evaporator

T_{CT} = Temperature of the cold water tank from where the stream is delivered to the evaporator directly.

m = mass flow rate of the stream

$$(Eq)_{condensor} = Q_C - m\ Cp\ T_o\ Ln\ (\frac{T_{K2}}{T_{HT}}) \qquad (3.11.5)$$

where,

Q_c = Heat delivered by the condensor to the stream

T_{K2} = Temperature of the stream at the outlet of the condensor

T_{HT} = Temperature of the hot water tank from where the stream is delivered directly to the condensor

Hence, we set up the exergetic efficiency for the heat pump as :

$$(\eta ex)_{heat\ pump} = \frac{Qc - m\ Cp\ T_o\ Ln\ (\frac{T_{K2}}{T_{HT}})}{W/(\eta m.\eta e) + Q_E - m\ Cp\ T_o\ Ln\ (\frac{T_{CT}}{T_{E2}})} \qquad (3.11.6)$$

3.12 Exergetic efficiency of heat pump and boiler: system B

For this system, the exergy balance is:

$$E_{input} = (E)_{to\ compressor} + (E)_{to\ pumps} + (Eq)\ _{to\ evaporator} + (Ew)_{fuel} \qquad (3.12.1)$$

$$E_{output} = (Eq)_{to\ load} \qquad (3.12.2)$$

Here, E to compressor and pumps are the same as treated in sect.(3.8)

Also, Ew to boiler is the same as the mentioned section.

$$(Eq)_{to\ evaporator} = Q_E\ (1 - \frac{T_o}{T_o}) \qquad (3.12.3)$$

$$= 0$$

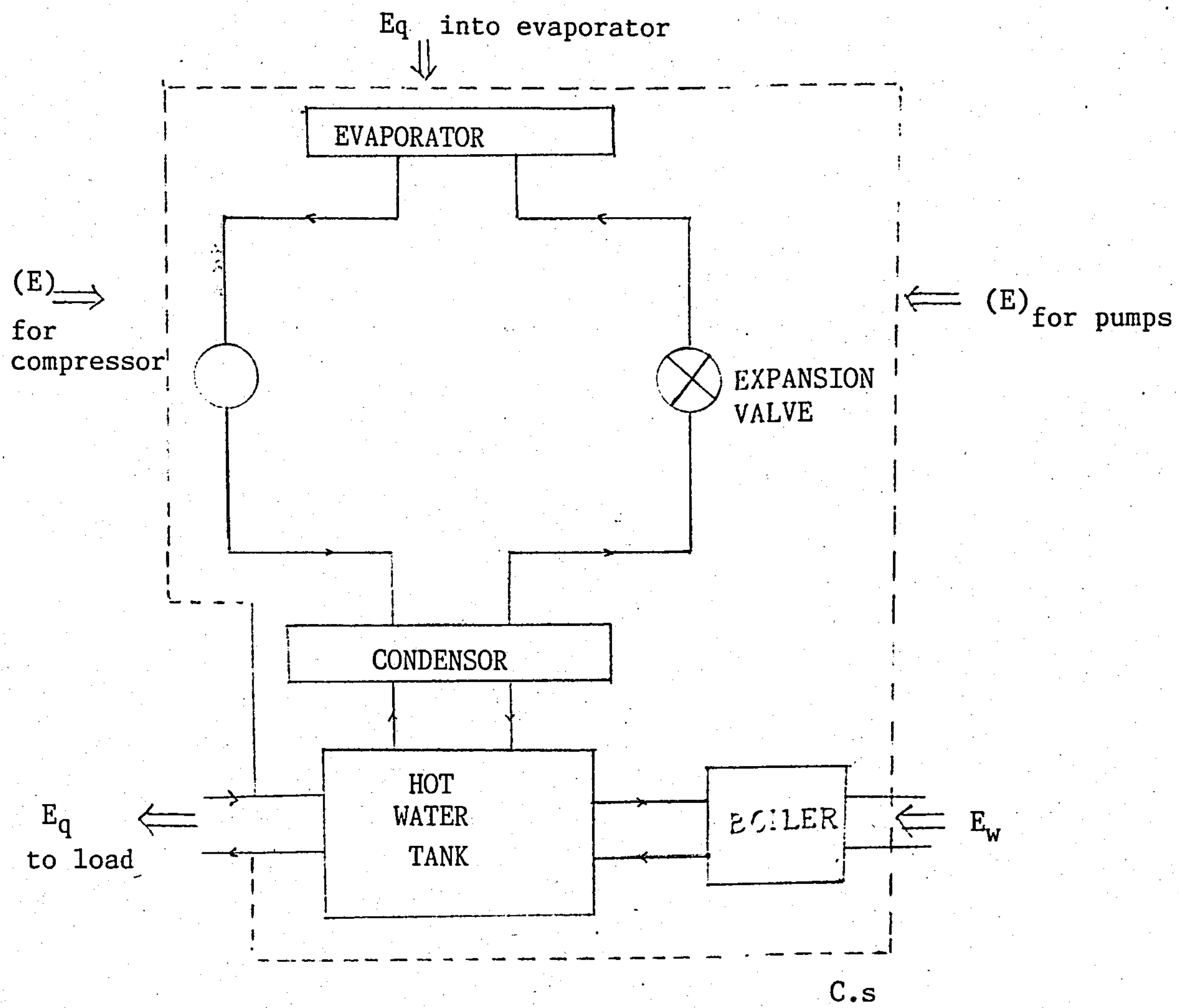


Fig. 3.12.1 Exergetic interpretation of heat pump and boiler

since , the evaporator receives heat from the ambient air.

(Eq) to load is the same as the above mentioned section.

thus,

$$(\eta_{ex})_{sys} = \frac{Q_L - m\, Cp\, T_o \,\mathrm{Ln}\,(\frac{T_{L2}}{T_{HT}})}{(E)_{pumps} + W/\eta_m \eta_e + Q_B/\eta_B} \qquad (3.12.4)$$

So as to analyze the exergetic efficiencies of heat pump and boiler consisting the system, they are given as:

$$(\eta ex)_{heat\ pump} = \frac{Q_c - m\ Cp\ T_o\ Ln\ (\frac{T_{C2}}{T_{HT}})}{W/\eta m\ \eta e} \tag{3.12.5}$$

since, $(Eq)_{evaporator} = 0$ as shown above. The exergetic efficiency of the boiler is the some as given in eqt. (3.10.3)

3.13 Exergetic efficiency of solar collector and boiler : system C

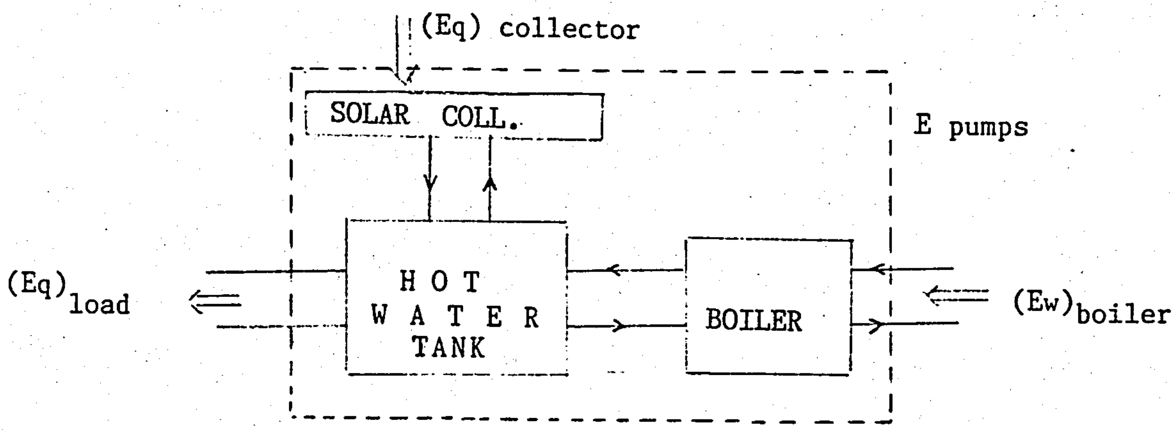


Fig. 3.13.1 Exergetic interpretation of solar collector and boiler

For this system, exergy balance can be set up as follows:

$$\text{Exergy input} = (Eq)_{collector} + (Ew)_{fuel} + (E)_{pumps} \tag{3.13.1}$$

$$\text{Exergy output} = (Eq)_{load} \tag{3.13.2}$$

$(Eq)_{collector}$, $(Ew)_{fuel}$, and $(Eq)_{load}$ are given in eqts (3.8.3) , (3.8.5) and (3.8.6) , respectively

Thus, we set up the exergetic efficiency as :

$$(\eta ex)_{sys} = \frac{Q_L - m\ Cp\ T_o\ Ln\ (\frac{T_{L2}}{T_{HT}})}{I.R.A_c\ (1-\frac{T_o}{T_c})+E+ Q_B/\eta_B} \tag{3.13.3}$$

For the exergetic efficiencies of the solar sollector and boiler taking part in the system, the exergetic efficiency of the boiler is same as given in eqtn (3.10.3).

The exergetic efficiency of the solar collector is :

$$(\eta ex)_{coll} = \frac{Q_S - m\ Cp\ T_o\ Ln\ (\frac{T_{C2}}{T_{HT}})}{I.R.A_c\ (1-\frac{T_o}{T_c})}$$

3.14 A Comparison of two types of second law analysis

An example of second law analysis is given in ASHRAE (1,pg.15) for a vapor compression cycle with the task of refrigeration as shown in Fig. (3.14.1). We quote below the table given in the reference as table 5,pg.15.

PROCESS: Pipe (1-1.1) (heat transfer to atmosphere)

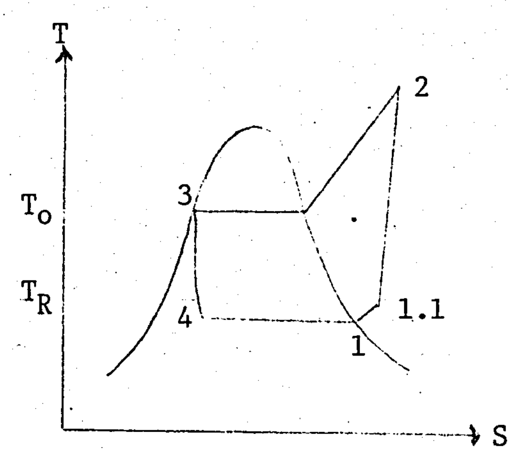


Fig. 3.14.1 T-S diagram of refrigeration cycle

$$Irr = T_o\ \Delta\ S_{total} = T_o\ (S_{1.1}-S_1) + \frac{-Q_{1.1}}{T_o} \qquad (3.14.1)$$

$$= T_o\ (S_{1.1}-S_1) + \frac{h_1-h_{1.1}}{To}$$

PROCESS: Compressor (1.1-2) (adiabatic)

$$Irr = T_o (S_2 - S_{1.1}) \qquad (3.14.2)$$

PROCESS: Condensor (2-3) (heat transfer to atmosphere)

$$Irr= T_o (S_3 - S_2) + \frac{-{}_2Q_3}{T_o} \qquad (3.14.3)$$

$$= T_o (S_3 - S_2) + \frac{h_2 - h_3}{T_o}$$

PROCESS: Expansion Value (3-4) (adiabatic)

$$Irr= T_o (S_4 - S_3) \qquad (3.14.4)$$

PROCESS: Evaporator (4-1) (heat transfer from refrigeration load at temperature T_R)

$$Irr = T_o (S_1 - S_4) + \frac{-{}_4Q_1}{T_R} \qquad (3.14.5)$$

$$= T_o (S_1 - S_4) + \frac{h_4 - h_1}{T_R}$$

$$\text{Total } Irr= T_o (S_{1.1} - S_1 + S_2 - S_{1.1} + S_3 - S_2 + S_4 - S_3 + S_1 - S_4) + {}_2Q_3 - {}_1Q_{1.1} - \frac{{}_4Q_1}{T_R} \cdot T_o$$

$$= {}_2Q_3 - {}_1Q_{1.1} - \frac{T_o}{T_R} \cdot {}_4Q_1 \qquad (3.14.6)$$

$$= m(h_2 - h_3 + h_1 - h_{1.1}) \; m \frac{T_o}{T_R} (h_4 - h_1)$$

Since this is a steady state steady flow process, careful analysis with equation (3.3.9) shows that each irreversibility is found out the some where the mentioned equation is applied. Recalling that equation,

$$\Delta Sp = \sum_{out}(S_i\ m_i) + \sum_{out}\frac{Q_i}{T_i} - \sum_{in}(S_i\ m_i) + \sum_{in}\frac{Q_i}{T_i}$$

we can set

$${}_1Q_{1.1} = (h_{1.1}-h_1)\ m$$

$${}_2Q_3 = (h_2-h_3)\ m$$

$${}_1Q_4 = (h_1-h_4)\ m$$

where m is the some for each of the processes

Thus, for the pipe

$$\sum_{out} S_i\ m_i = S_{1.1}\ m$$

$$\sum_{out}\frac{Q_i}{T_i} = 0$$

$$\sum_{in} S_1\ m_1 = S_1\ m$$

$$\sum_{in}\frac{Q_i}{T_i} = \frac{Q_1}{T_o} = \frac{(h_{1.1}-h_1)}{T_o}\ m$$

and,

$$\Delta Sp = m(S_{1.1} + \frac{(h_1-h2)}{T_o} - S_1)$$

$$Irr = T_o \Delta Sp$$

for the compressor

$$\sum_{out} S_i\ m_i = S_2\ m$$

$$\sum_{out}\frac{Q_i}{T_i} = \sum_{in}\frac{Q_i}{T_i} = 0$$

$$\sum_{in}\frac{Q_i}{T_i} = 0$$

$$\sum_{in} S_i\ m_i = S_{1.1}\ m$$

$$\Delta Sp = m(S_2 - S_{1.1})$$

$$Irr = T_o\ \Delta\ Sp$$

for the condensor,

$$\sum_{out} S_i m_i = S_3 m$$

$$\sum_{out} \frac{Q_i}{T_i} = \frac{2Q_3}{T_o} = m \frac{(h_2-h_3)}{T_o}$$

$$\sum_{in} S_i m_i = S_2 m$$

$$\sum_{in} \frac{Q_i}{T_i} = 0$$

and,

$$\Delta Sp = m \left(S_3 + \frac{(h_2-h_3)}{T_o} - S_2\right)$$

$$Irr = T_o \Delta Sp$$

for the expansion value,

$$\sum_{out} S_i m_i = S_4 m$$

$$\sum_{out} \frac{Q_i}{T_i} = \sum_{in} \frac{Q_i}{T_i} = 0$$

$$\sum_{in} S_i m_i = S_3 m$$

and,

$$\Delta Sp = m (S_4 - S_3)$$

$$Irr = T_o \Delta Sp$$

for the evaporator,

$$\sum_{out} S_i m_i = S_1 m$$

$$\sum_{out} \frac{Q_i}{T_i} = 0$$

$$\sum_{in} S_i m_i = S_4 m$$

$$\sum_{in} \frac{Q_i}{T_i} = \frac{{}_1Q_4}{T_R}$$

and,

$$\Delta Sp = m\,(S_1 - S_4 - \frac{(h_1-h_4)\ m}{T_R})$$

$$Irr = T_o\ \Delta Sp$$

$$\text{Total } Irr = T_o\ m(S_{1.1}-S_1+S_2-S_{1.1}+S_3-S_2+S_4-S_3+S_1-S_4)+T_o\ m(\frac{h_1-h_{1.1}+h_2-h3}{T_o} - \frac{(h_1-h_4)}{T_R})$$

$$= m\ (h_2-h_3+h_1-h_{1.1})+ m\,\frac{T_o}{T_R}(h_4-h_1) \qquad (3.14.7)$$

Thus, we reach the same conclusion.

Now, how can we relate the exergy balance for the whole system with the previous analysis ?

If we set up the exergy balance,

$$\text{Exergy in} = (Eq)_{\text{into the condensor}} + (E)_{\text{compressor}}$$

$$\text{Exergy out} = (Eq) \text{ into the evaporator}$$

where,

$$(Eq)_{\text{from the condensor}} = Q_c \cdot (1-\frac{T_o}{T_o}) = 0$$

$$(E)_{\text{compressor}} = W = m\,(h_2-h_{1.1})$$

$$(Eq)_{\text{into the evaporator}} = m\,(h_4-h_1)\,(1-\frac{T_o}{T_R})$$

Thus, we obtain the irreversibility

$$L = \text{Exergy in} - \text{Exergy out}$$

$$= m\,(h_2-h_{1.1}) - m(h_4-h_1) + m(h_4-h_1)\,\frac{T_o}{T_R}$$

$$= m\,(h_2-h_{1.1}-h_4+h_1) + m\,\frac{T_o}{T_R}(h_4-h_1)$$

$$= m(h_2 - h_3 + h_1 - h_{1.1}) + m\frac{T_o}{T_R}(h_4 - h_1) \qquad (h_4 = h_3) \qquad (3.14.8)$$

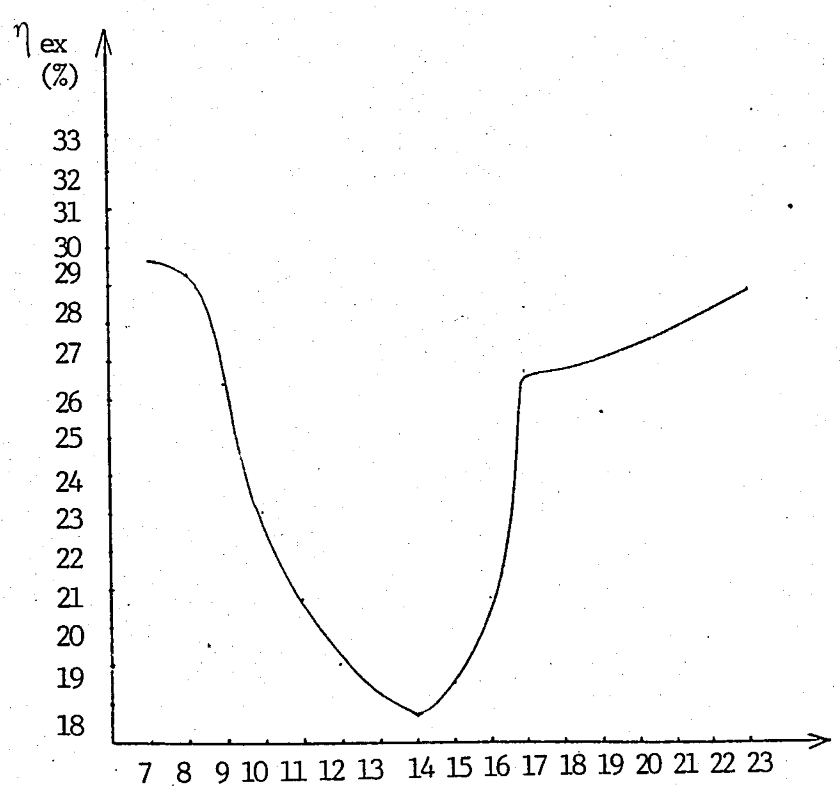
which is the same expression we have obtained in eqts. (3.14.6) and (3.14.7).

IV- DISCUSSION

As it is mentioned before, availibility or exergy analysis is a good indicator how we use the energy to perform the specified task. Though it may be expressed in terms of the irreversibility or the amount of energy deterioted, in this analysis, it is expressed in terms of availibility efficiency or exergetic efficiency.

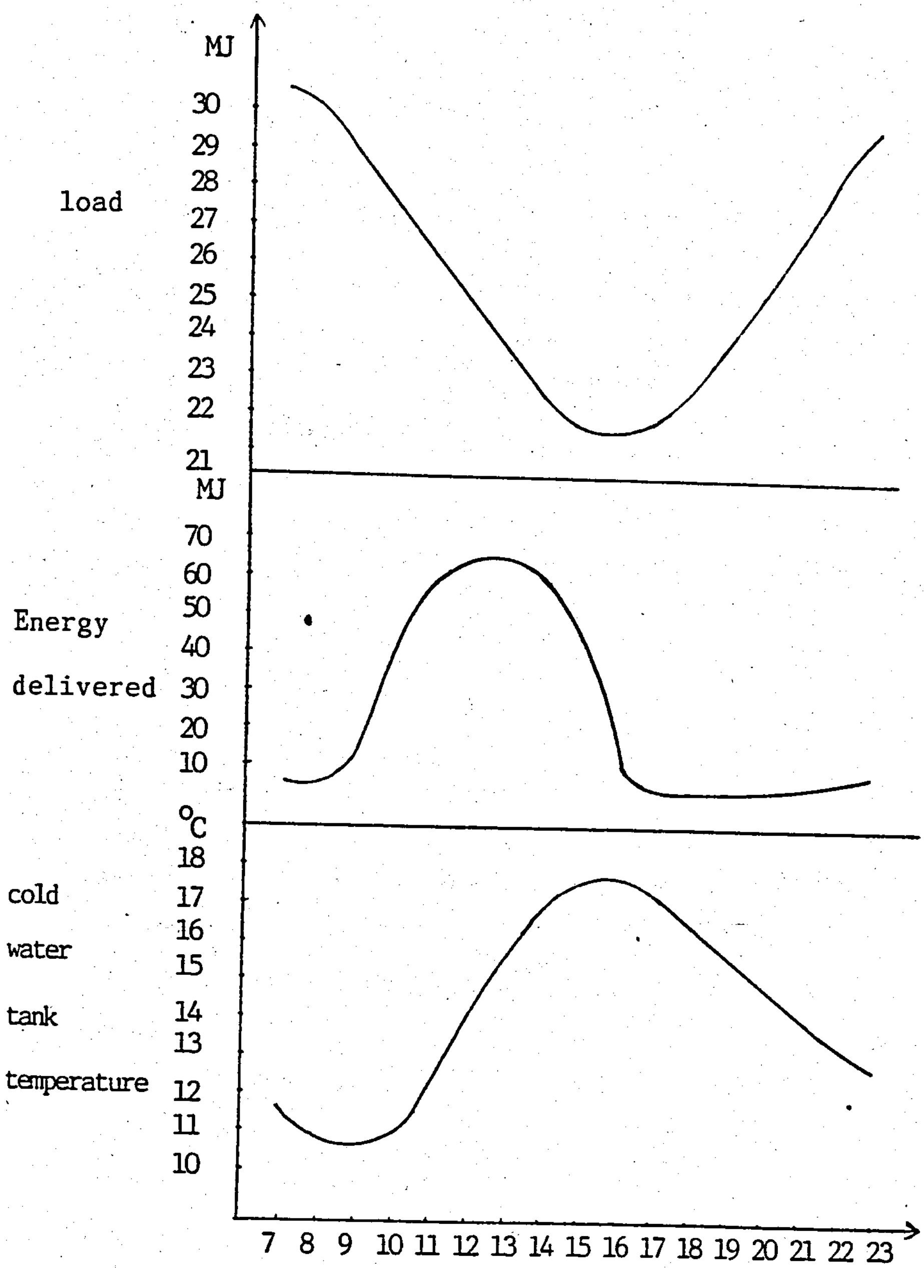
Although each system could be analyzed for comparison by the averaging method as the F-charts method for the solar collector, it is favoured to analyze by observing the response of the system as time proceeds throughout the typical days chosen for specified months.

So as to have a look at what we have obtained , let us examine the graph for the change of exergetic efficiency of solar assisted heat pump system with 90 m^2 collector area at the typical day on January.



The first thing we observe is that, there is a sharp decrease between hours 8-14, and a sharp increase between hours 14-17. Why ?

Fig. 4.1 Time versus exergetic efficiency graph for solar assisted heat pump during January with 90 M^2 collector area.



When we examine the graph on the left, we are sure of the reason. The energy delivered which is depicted on the graph consists of the energy delivered by the sun and electricity delivered to the compressor of the heat pump.

The solar energy delivered is used just to rise the temperature of the cold water tank so that it does not fall beyond the working temperature limit of the evaporator. Thus, we have excessive energy at hand that will be used even after the sunset and which is captured for the sake of maintaining the working of a very efficient device-heat pump.

Fig. 4.2. Graph for solar assisted heat pump system with 90 m^2 collector area during January

As it can be observed in computer outputs and also previous works (4,pg.55) the heat pump exergetic efficiency is superior over the boiler exergetic efficiency. Therefore, even though the exergetic efficiency of the system falls for certain period, it is high on the average by using the non-efficient mean of supply of energy , i.e. boiler, at least amount .

So, we have seen that the exergy analysis is very sensitive regarding the way how we use the energy conversion systems. It can be observed also with the aid of the following graph:

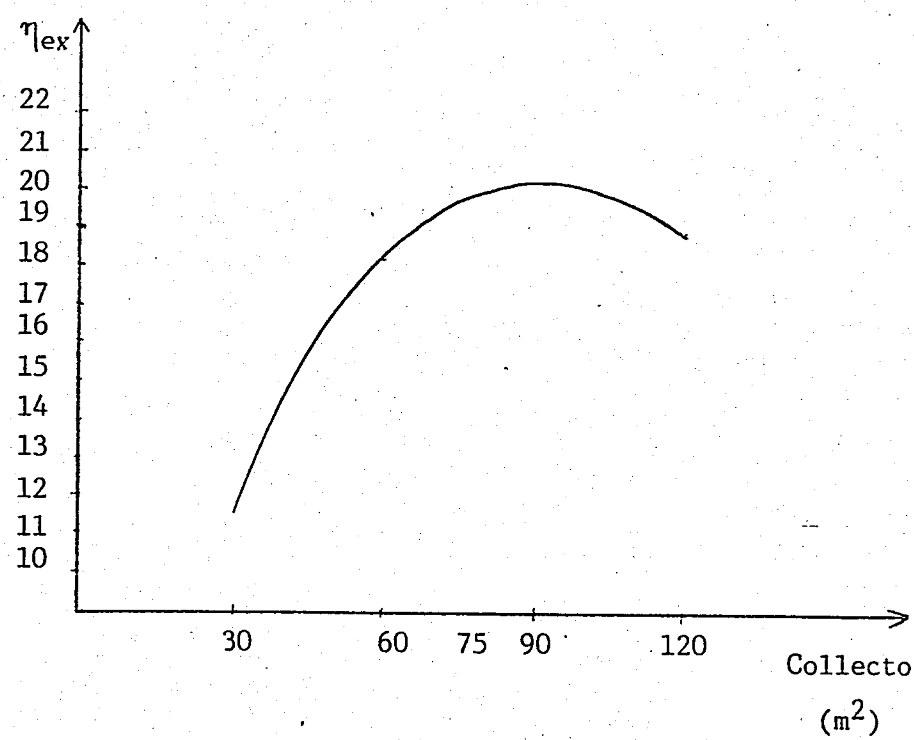


Fig. 4.3 Four months avarage exergetic efficiency versus collector area graph for solar assisted heat pump system.

As it can be observed easily, the exergetic efficiency takes its maximum value at 90 m^2 collector area. Afterwards , it falls at 120 m^2 collector area. This has the implication that we do not use a system that is well matched to the task. If examine the cold water tank temperature on fig.(4.4) for 120 m^2 collector area on January, we see that it is excessively high compared with the temperatures we obtained with 90 m^2 collector area shown on fig. (4.2) . On the other hand, so as to examine cleary what happens for the case with 60 m^2 collector area, let us have a look at the fig. (4.5) .

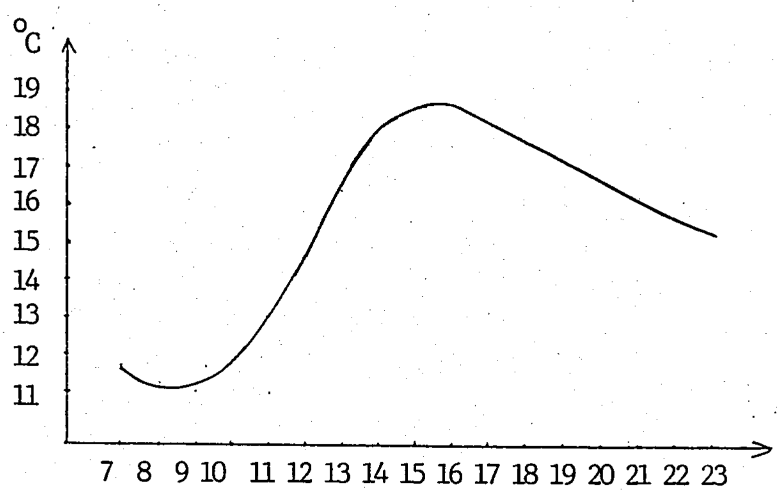


Fig. 4.4 Cold water tank temperature versus time graph for solar assisted heat pump system with 120 m^2 collector area during January

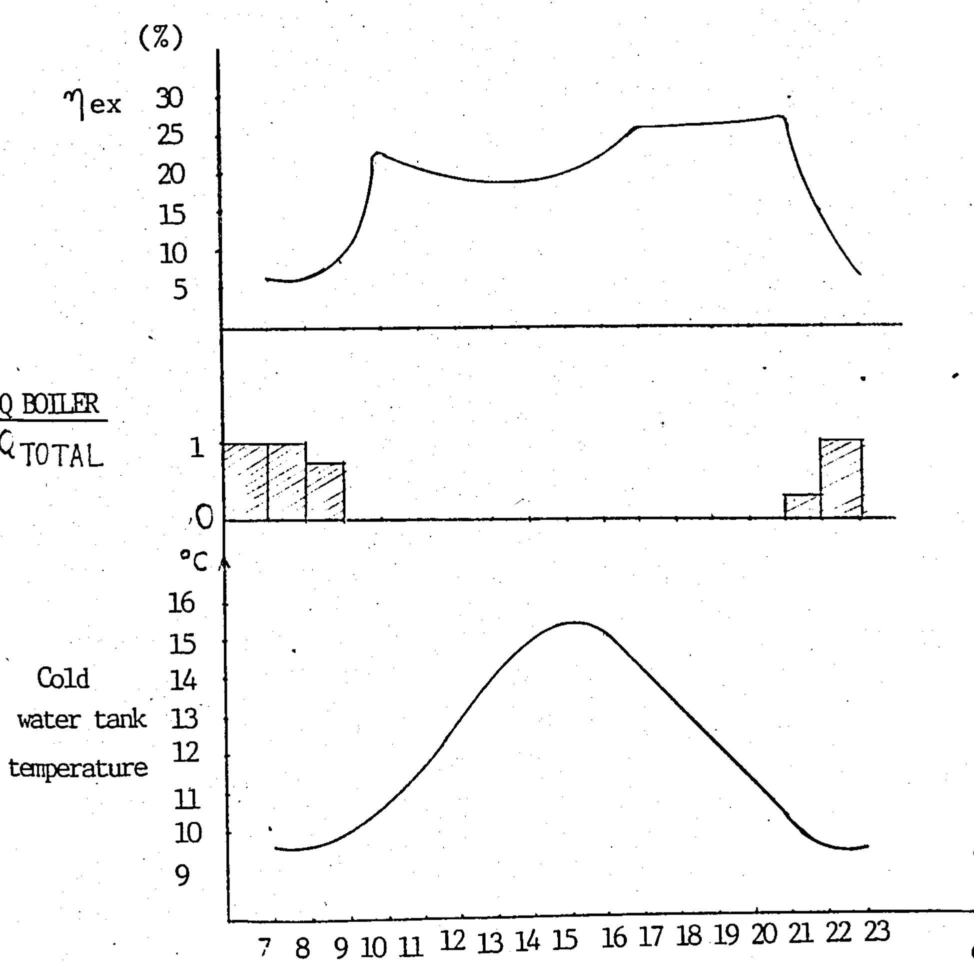


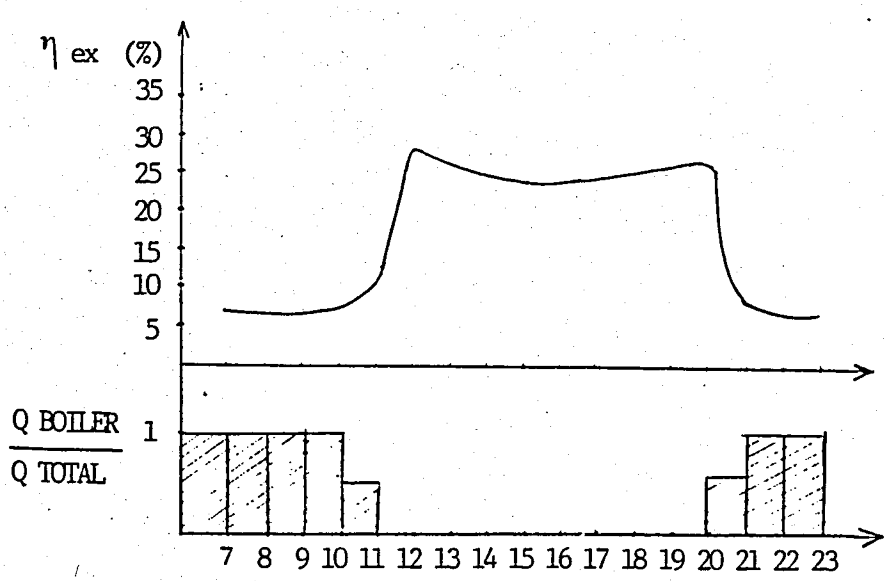
Fig. 4.5 Graph for solar collector heat pump with 60 m^2 collector area for January

As it can be observed easily, between hours 6-8 where the boiler deliveres the total load, the exergetic efficiency is at its lowest value. As it mentioned before, the boiler has an exergetic efficiency which is relatively very low compared with heat pump and solar collector. Between hours 8-9 the partition of the boiler falls and ve observe an increase in the exergetic efficiency. Between hours 9-21 the exergetic efficieny of the system is high while the changes can be explained by the change in the cold water tank temperature. Observing that the exergetic efficiency is high in case during hours the solar collector works, it may be asked why shouldn't 60 m^2 collector area be used. However, in this case the cold water tank temperature drops so that finally between hours 22-23 we cannot use the heat pump.

This means that the solar energy collected during the day time is not enough to maintain the cold water tank temperature over the limit for the whole day to allow working of the heat pump. Therefore, between hours 21-23 the boiler takes part in giving the necessary energy.therefore there is drastic fall in exergetic efficiency. This means that, the collector area is not enough.

Finally, if we examine the results given in sect. VI ve see that the solar assisted heat pump has the maximum exergetic efficiency of 20.83 % as avarage of 4 months, the solar collector + boiler has 8.33 % and heat pump + boiler has 16.5 %. These results indicate that solar assisted heat pump is the most convenient means for heating compared with the other systems.

For the exergetic efficiency tendency of the other systems throught the chosen typical days, the same argument holds. There is a hierarchy of conveniency among different systems and when we fall to the category of less convenient system, the exergetic efficiency falls.



Therefore, when the boiler does not work, we have high exergetic efficiency of the heat pump.

Fig. 4.6 Graph for heat pump and boiler system for January.

V- CONCLUSION AND RECOMMENDATIONS

The results indicate that for the chosen heating load and systems, the best exergetic efficiency has been obtained with the solar assisted heat pump system of 90 m^2 collector area. Second alternative for this task is the heat pump and boiler, and the third alternative is the solar collector and boiler with 75 m^2 collector area.

The highest coefficient of performance is obtained again with the solar assisted heat pump system of 90 m^2 collector area as 3.13, confirming the fact that this system is the most convenient one for this task. It is important here to recognise that exergy analysis is a useful method to complement, not to replace, energy analysis. They together help define the optimum system which satisfies the imposed thermal and economic constraints and minimizes exergy loss , i.e, irreversibility.

It is recommended that this analysis should be broadened up to examine the overall energy use of the country . Thus, we can improve our systems and use our energy resources conveniently concluding with a contribution to national economy.

VI- RESULTS

MONTH	DECEMBER	JANUARY	FEBRUARY	MARCH
HEATING LOAD (kJ/day)	355210	440000	420000	370000

Table 6.1 Heating load of the house

Exergetic eff (%) \ Month		DECEMBER	JANUARY	FEBRUARY	MARCH	AVARAGE
SOLAR ASSISTED HEAT PUMP						
COLLECTOR AREA (m^2)	30	9.62	9.03	11.51	17.6	11.94
	60	18	13.8	23.6	19.1	18.63
	75	23.2	17.4	22.4	17.6	20.15
	90	21.3	24.4	21.3	16.3	20.83
	120	19.7	23	19.4	14.2	19.08
HEAT PUMP AND BOILER		24.5	10.6	12.2	18.6	16.48
SOLAR COLLECTOR, BOILER						
COLLECTOR AREA (m^2)	30	6.95	7.1	7.94	9	7.75
	60	7.5	7.36	8.8	9.57	8.31
	75	7.59	7.6	8.87	9.24	8.33
	90	7.58	7.75	8.76	8.86	8.24
	120	7.4	7.73	8.3	8	7.86

Table 6.2 Exergetic efficiencies of each system each typical day of months

C.O.P \ Months		DECEMBER	JANUARY	FEBRUARY	MARCH	AVARAGE
SOLAR ASSISTED HEAT PUMP						
COLLECTOR AREA (m^2)	30	1.17	1.04	1.19	2.25	1.41
	60	2.27	1.64	3.16	3.15	2.56
	75	3.14	2.12	3.15	3.13	2.89
	90	3.13	3.15	3.13	3.11	3.13
	120	3.1	3.12	3.1	3.07	3.1
HEAT PUMP AND BOILER		2.95	1.21	1.42	2.22	1.95
SOLAR COLLECTOR AND BOILER						
COLLECTOR AREA (m^2)	30	0.84	0.804	0.75	1.09	0.87
	60	0.93	0.85	1.07	1.2	1.01
	75	0.97	0.91	1.09	1.22	1.05
	90	0.97	0.94	1.1	1.23	1.06
	120	0.99	0.96	1.12	1.25	1.08

Table 6.3 Coefficient of performance of each system each typical day of months

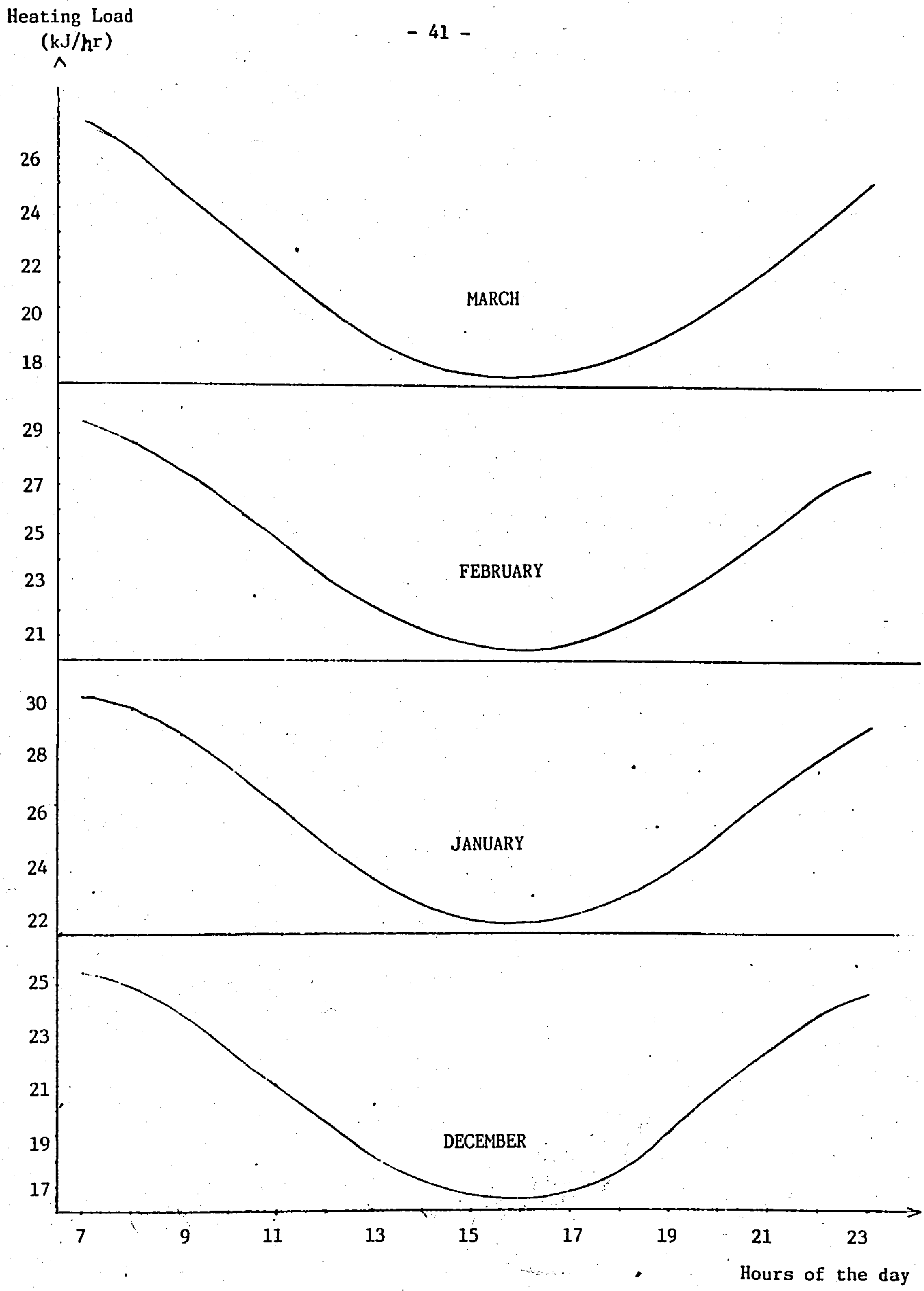


Fig. 6.1 Heating load distribution throughout the day

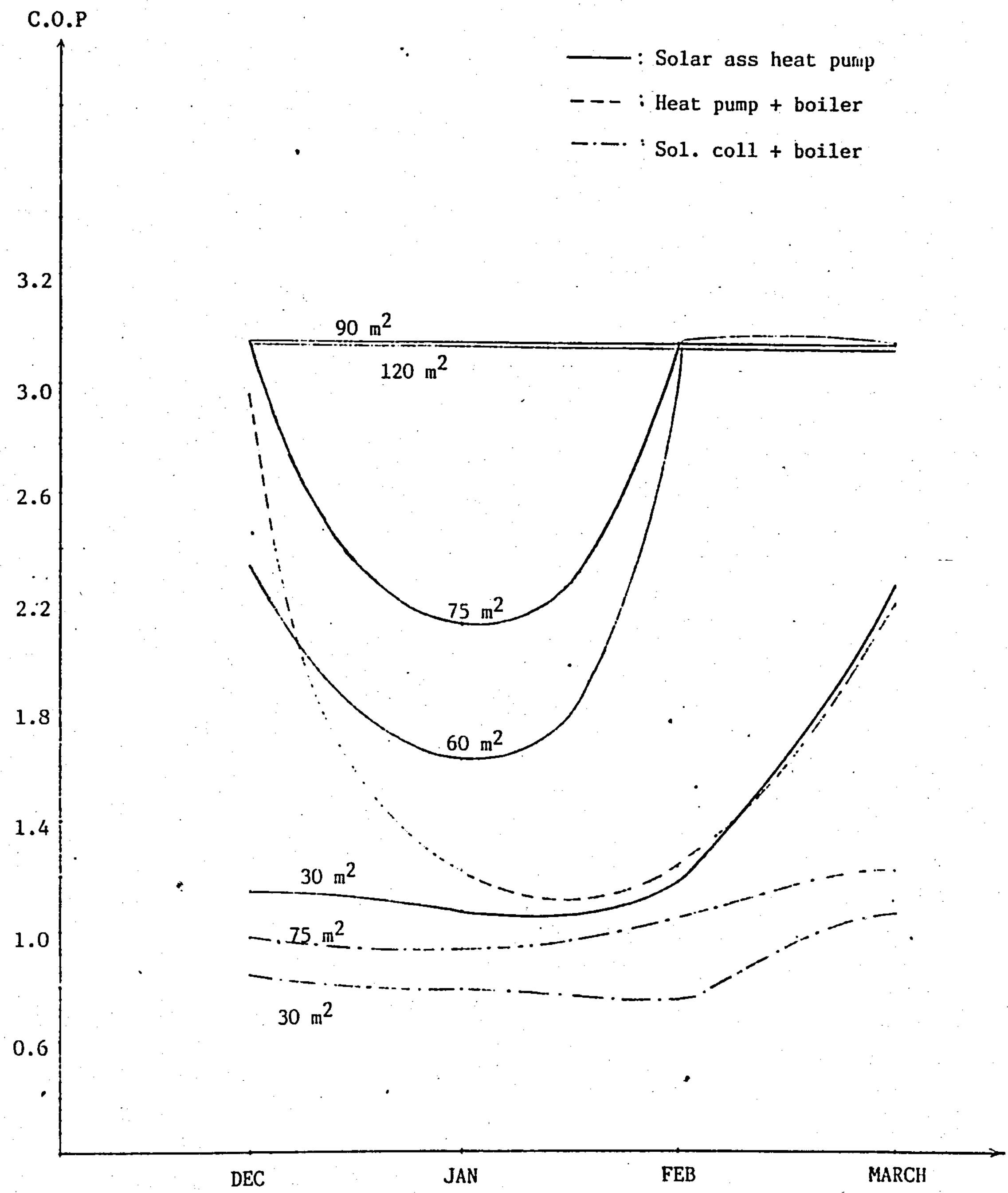


Fig. 6.2 C.O.P distribution through months

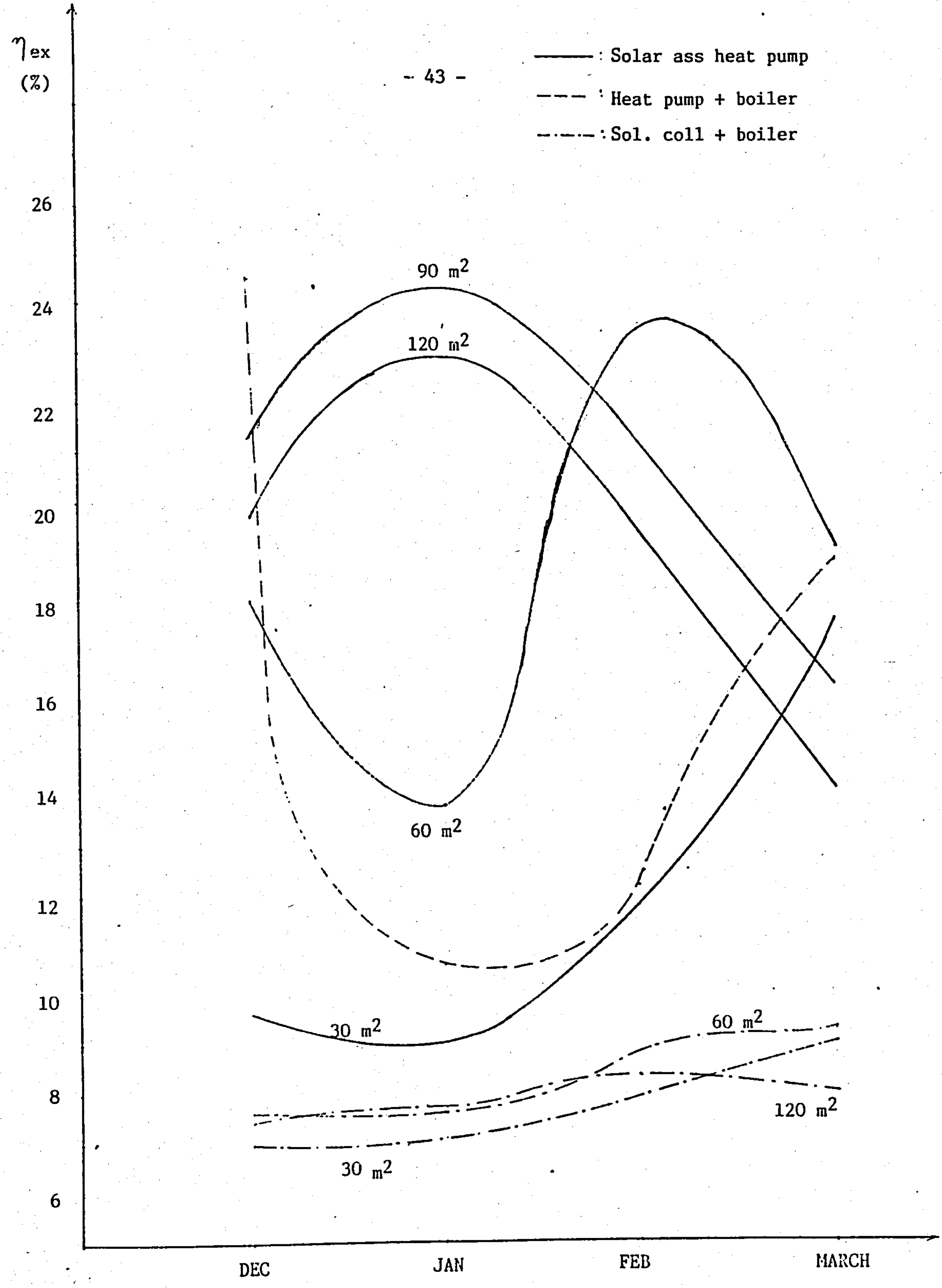


Fig. 6.3 Exergetic efficiency distribution through months

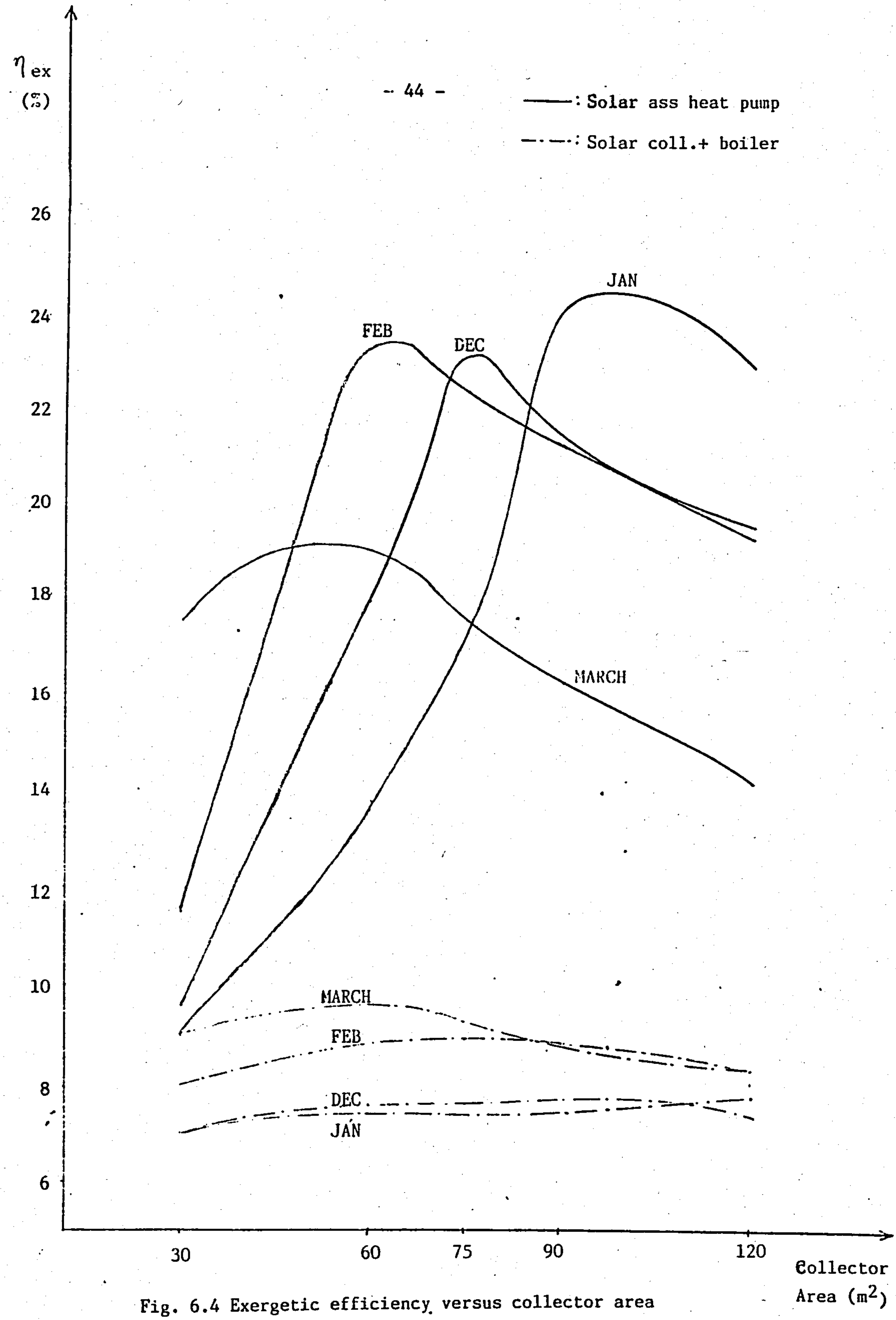


Fig. 6.4 Exergetic efficiency versus collector area

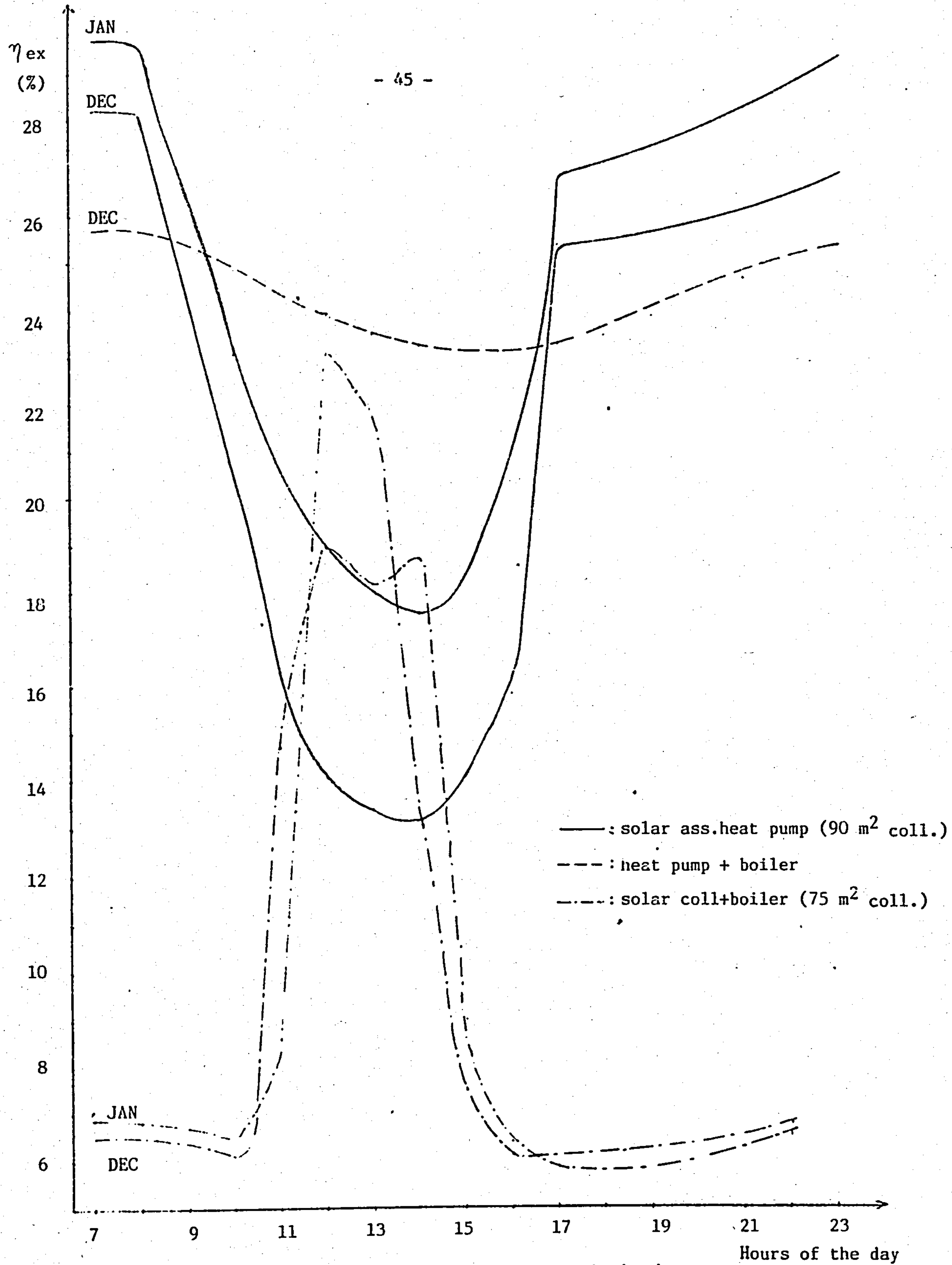


Fig. 6.5 Exergetic efficiency distribution through the day

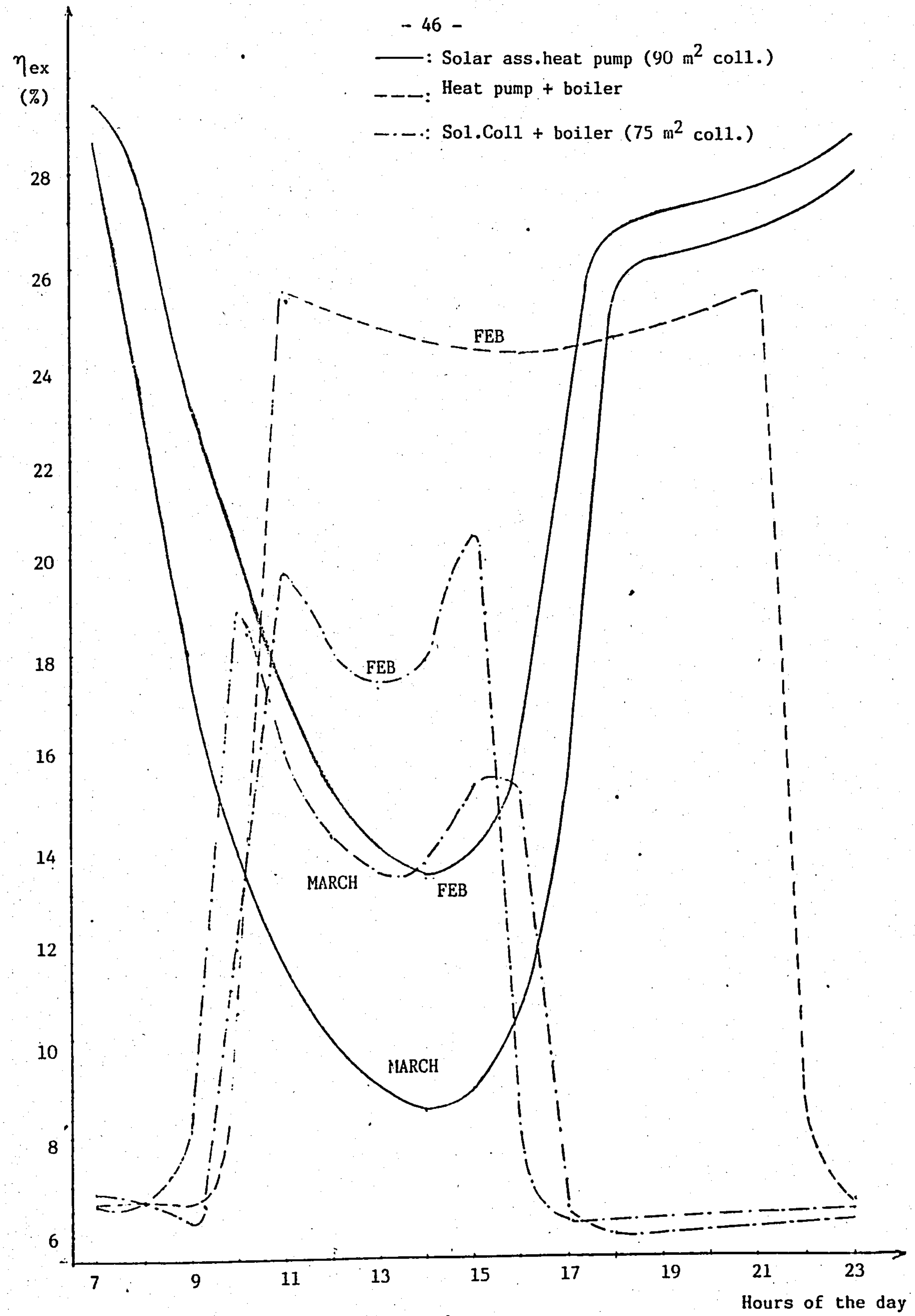


Fig. 6.6 Exergetic efficiency distribution through the day

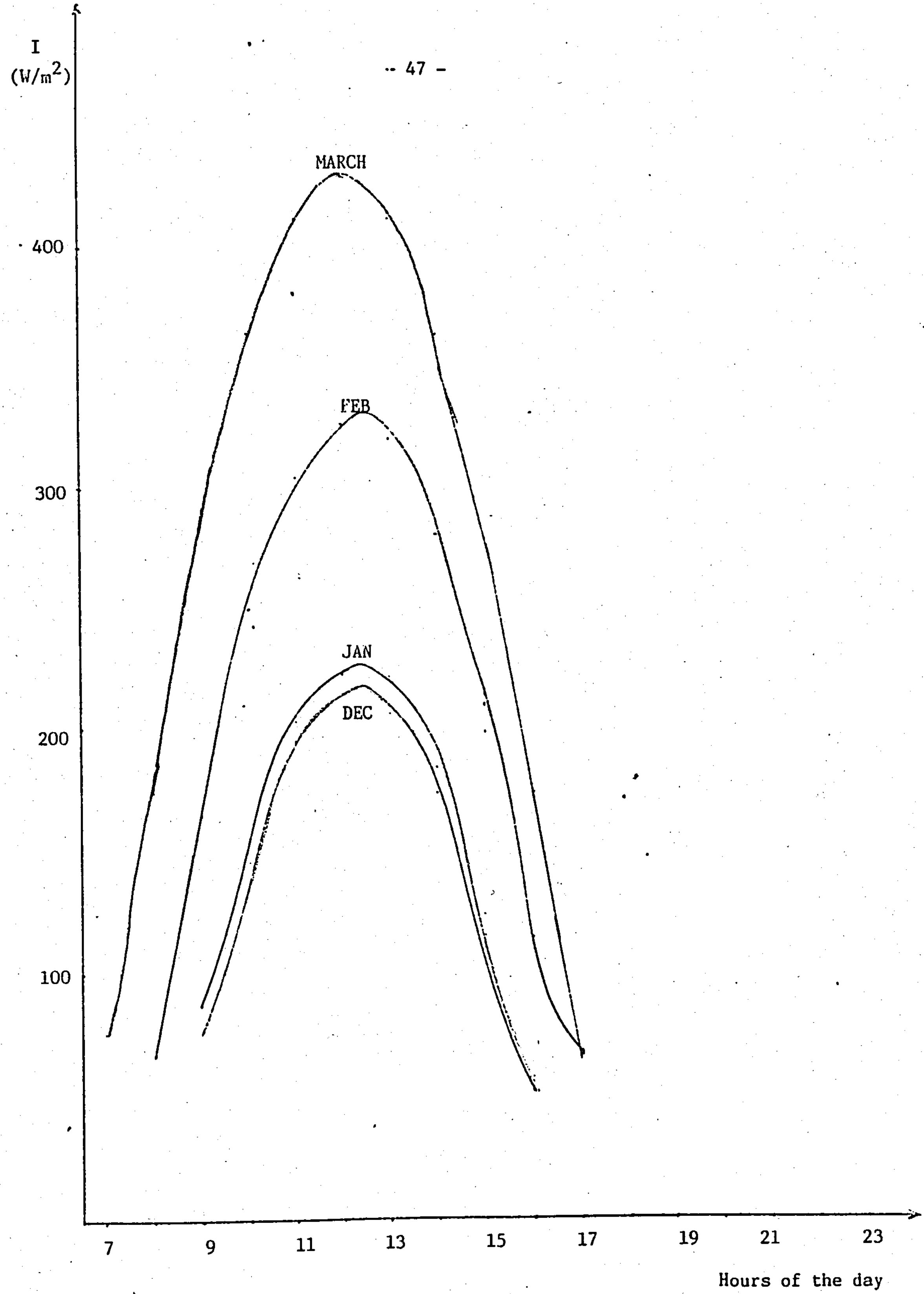


Fig. 6.7 Radiation distribution throughout the day

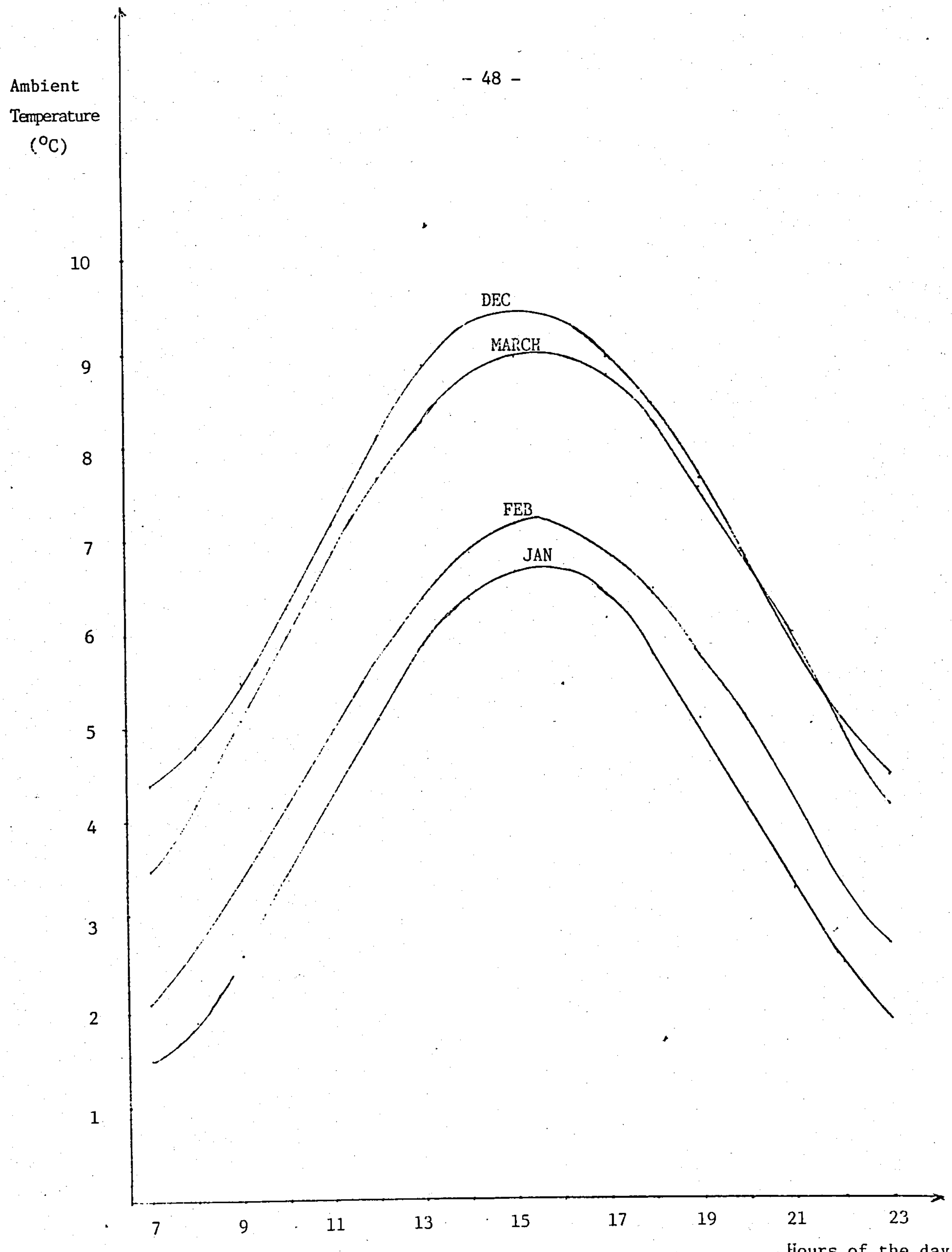


Fig.6.8 Ambient air temperature distribution through the day

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APPENDIX A

ESTIMATION OF SOLAR RADIATION AND AMBIENT TEMPERATURE

The external thermal environment of a locality results from the combined infliences of solar radiation and meteorological effects. Physical influences such as topography and ocean currents may also be of great importance to the climate of a given locality.

In the final analysis, the sun is the source of most energy on the earth and is a primary factor in determining the thermal environment of a locality. Therefore, it will be convenient to treatise the estimation of ambient air temperature and solar radiation intensity under the same title.

A.1 Estimation of solar radiation

The earth revolves about the sun in an approximately circular path, with the sun located slightly off center of the circle.

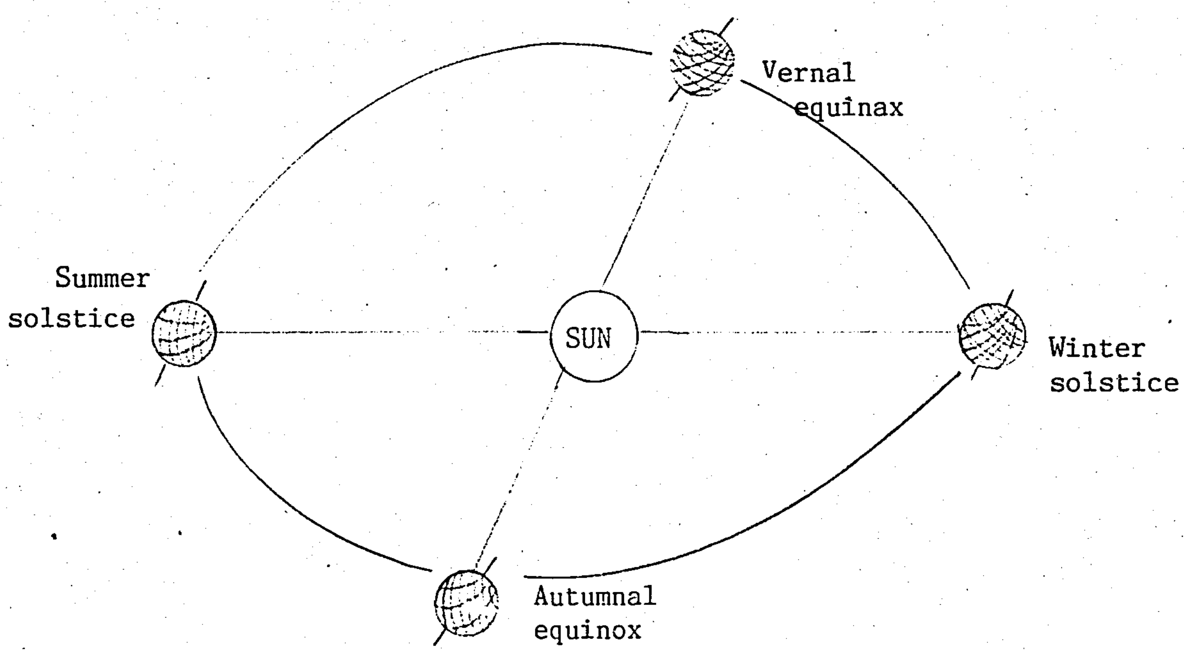

Fig. A.1.1 The earth's revolution about the sun

The earth's mean distance to the sun is about $1.5x10^8$ kms. About January 1, the earth is closest to the sun while on about July 1 it is most remote, being about 3.3 percent farther, away. Since intensity of solar radiation incident upon the top of the atmosphere varies inversely with the square of the earth-sun distance, the earth receives about seven per cent more radiation in January than in July.

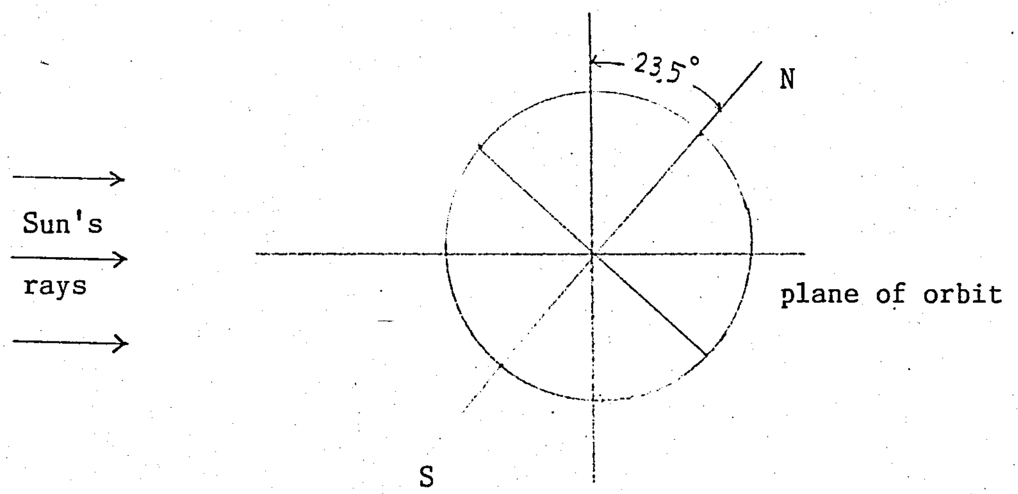

Fig. A.1.2 Position of earth in relation to suns rays at the time of winter solstice

The earth's axis of rotation is tilted 23.5 degrees with respect to its orbit about the sun. The earth's tilted position is of profound significance, for, togather with the earth's daily rotation and yearly revolution, it accounts for the distribution of solar radiation over the earth's surface, the changing length of hours of day light and darkness, and the changing of the seasons.

<u>BASIC Earth-sun angles</u>

The position of a point P on the earth's surface with respect to the sun's rays is known at any instant if the latitude ϕ and hour angle h' for the point, and the sun's declination d are known. These fundamental angles are shown by Fig (A.1.1.3). Point represents a location on the northern hemisphere.

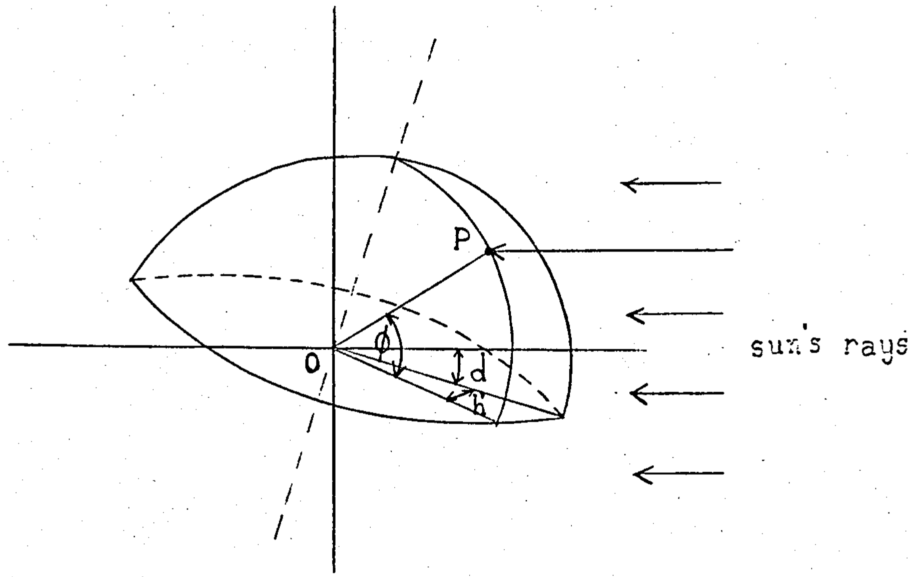

Fig. A.1.3 Latitude, hour angle, and sun's declination.

The latitude Ø is the angular distance of the point P north (or south) of the equator. It is angle between the line OP and the projection of OP on the equatorial plane. Point O represents the center of the earth.

The hour angle h' is the angle measured in the earth's equatorial plane between the projection of OP and the projection of a line from the center of the sun to the center of the earth. At solar noon, the hour angle is zero. The hour angle expresses the time of day with respect to solar noon. One hour of time is represented by 360/24 or 15 degrees of hour angle. We can formulate it as (9,pg.15)

$$h'=(12-TS).15 \quad (A.1.1)$$

where

$$TS= \text{standart time} \cdot \frac{5}{3}$$

The sun's declination d is the angular distance of the sun's rays north (or south) of the equator. h' is the angle between a line extending from the center of the sun to the center of the earth and the projection of this line upon the earth's equatorial plane. The declination, d, can be found from the approximate equation of Cooper (9,pg.15)

$$d=23.45 \sin \left(360 \frac{284+n}{365}\right) \qquad (A.1.2)$$

where n is the day of the year.

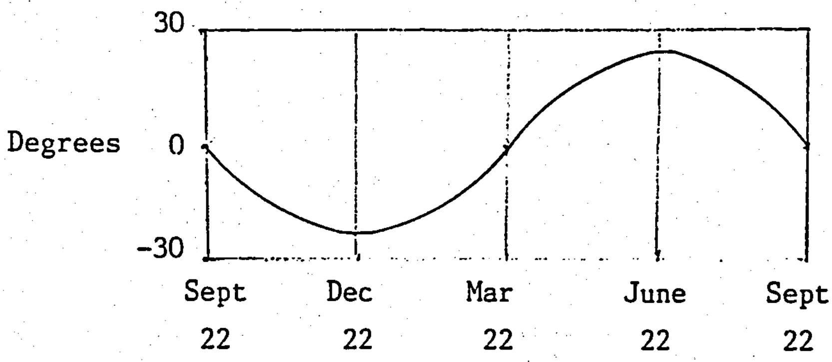

Fig. A.1.4 Variation of sun's declination

The monthly avarage values of declination can be found by the table (A.1.1) (8,pg.19)

Month	The day of the month	n (eqt)	d
January	17	17	-20.92
February	16	47	-13.29
March	16	75	- 2.42
April	15	105	- 9.41
May	15	135	18.79
June	11	162	23.09
July	17	198	21.18
August	16	228	13.45
September	15	258	2.22
October	15	288	- 9.60
November	14	318	-18.91
December	10	344	-23.05

Table A.1.1 Sun's declination through months.

Solar time and equation of time

It is to be noted that the time specified in all the sun angle relationships is solar time, which does not coincide with local clock time. It is necessary to convert standart time to solar time by applying two corrections. First, there is a constant correction for any difference in longitude between the location and the latitude on which the local standard time is based. The second correction is from the equation of time which takes into account the various pertubations in the earth's orbit and rate of rotation which affect the time the sun appears to cross the observer's latitude. This correction is obtained from published charts.

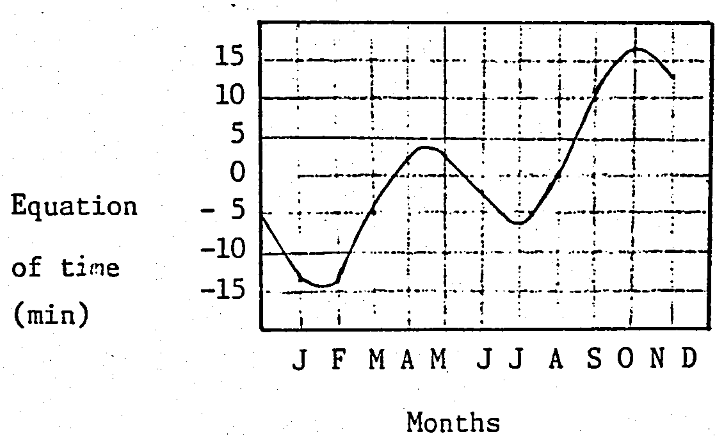

Fig. A.1.5 The equation of time, ZD, in minutes, as a function time of year

Thus, solar time can be obtained from standart time by this relation.(9,pg.18)

$$Z= TS+ZD \mp 4((By)_{st} - (By)_{loc}) \quad (A.1.3)$$

where, Z= solar time, in minutes

TS= standart time, in minutes

$(By)_{st}$= the standart meridion for the local time zone

$(By)_{loc}$ = the longitude of the location in question

The sign is + for west longitudes and - for east longitudes. Since Turkey is at 45^{o} east meridian for the local time zone, for Turkey it may be written as (8,pg.32)

$$Z= TS - 4(45-By)+ZD \tag{A.1.4}$$

The derived solar angles

The geometric relation ships between a plane of any particular orientation relative to the earth at any time (whether that plane is fixed or moving relative to the earth) and the incoming beam solar radiation, that is, the position of the sun relative to that plane, can be described in terms of several angles. For thepurposes of this study, only the angles taking place in final formulation will be illustrated, and only the definitions for the others will be given. For a more extensive study regarding this subject, ref (10, pg.287) may be referred.

γ= the surface azimuth angle, that is, the deviation of the normal to the surface from the local meridian , the zeropoint being due south, east positive, and west negative;

θ = the angle of incidence of beam radiation, the angle being measured between the beam and the normal to the plane.

θ_z= the zenith angle, the angle between the beam from the sun and the vertical;

= solar altitude, the angle between the beam from sun and the horizontal equal to $(90^{o}-\theta_z)$

In many cases, the equation relating these angles is simplified.

For horizontal surfaces (i.e,s=0^{o}) the relation is given as (9,pg.16)

$$\cos \theta_z = \sin d \sin \phi + \cos d \cos \phi \cos h' \tag{A.1.4}$$

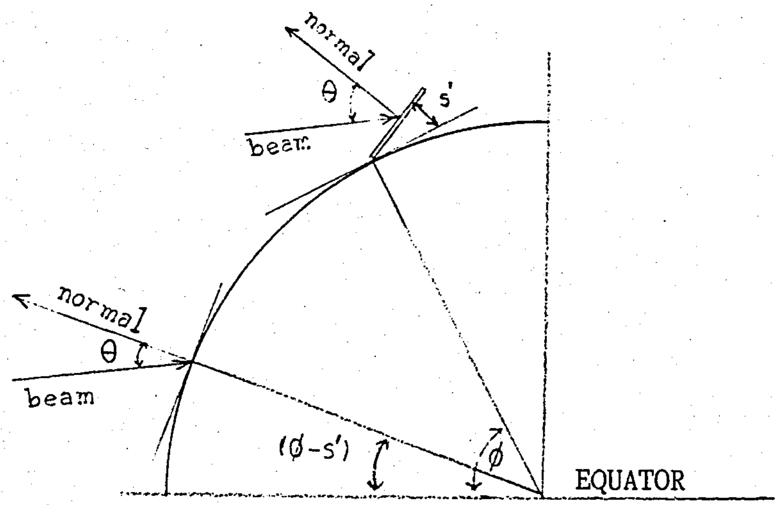

Fig. A.1.6 Section of earth showing definitions S',θ,∅, and (∅-S')

Solving this equation for the sunrise hour angle, h', when $\theta_z = 90^\circ$ -

$$\cos h' = \frac{-\sin \emptyset \sin d}{\cos \emptyset \cos d}$$

$$= -\tan \emptyset \tan d \qquad \text{(A.1.5)}$$

It also follows that the day length is given by (9,pg.17)

$$td = \frac{2}{15} \cos (-\tan \emptyset \tan d) \qquad \text{(A.1.6)}$$

Useful relationships for the angle of incidence on surfaces sloped to the north or south can be derived from the fact that surfaces with slopes to the north or south have the same angular relation ship to beam radiation as a horizontal surface at an artificial latitude of (∅-s). Then, modifying Eq. (A.1.4)

$$(\cos \theta)_{\text{tilted surface}} = \cos (\emptyset - s') \cos d \cos h' + \sin (\emptyset - s') \sin d \qquad \text{(A.1.7)}$$

Note that the slope, s', is measured from the horizontal to the plane of the surface in question, and is positive when slope is toward the south.

Instantaneous solar radiation incident on tilted flat plate collector

For purposes of solar process design, it is often necessary to convert radiation data, which is measured and given in tables, incident on a horizontal surface to radiation an a tilted surface.

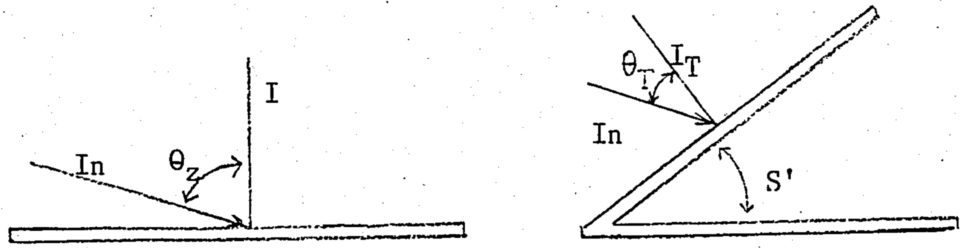

Fig. A.1.7 Radiation on horizontal and tilted surfaces

From Fig. A.1.7 it follows that, for the beam component

$$I_b = In \cos \theta_z \qquad (A.1.8)$$

and,

$$I_{bT} = In \cos \theta_T \qquad (A.1.9)$$

The ratio of radiation on the tilted surface, I_{bT}, to that on the horizontal surface, I_b, is given in terms of the angles θ_z and θ_T and radiation normal to beam, In, by

$$R_b = \frac{I_{bT}}{I_b} = \frac{In \cos \theta_T}{In \cos \theta_z} \qquad (A.1.10)$$

where $\cos \theta_T$ is given in Eq (A.1.7) for flat plate facing south and $\cos \theta_z$ is given in Eq (A.1.4). Inserting the expressions we obtain (9,pg.49)

$$R_b = \frac{\cos (\emptyset - s') \cos d \cos h + \sin (\emptyset - s') \sin d}{\cos \emptyset \cos d \cos h + \sin \emptyset \sin d} \qquad (A.1.11)$$

for the diffuse component, the ratio of diffuse radiation on the tilted surface, I_{dT}, to that on the horizontal surface, I_d, is given by (9,pg.54)

$$R_d = \frac{I_{dT}}{I_d} = \frac{1+\cos s'}{2} \qquad (A.1.12)$$

Considering the radiation on the tilted surface to be made up of three components: the beam radiation, diffuse radiation, and solar radiation reflected from the ground which the tilted surface sees, we can set up the ratio of total incident radiation on the tilted surface, I_{TT} to the total incident radiation on horizontal surface, I_{TH} as (9,pg.54)

$$R = \frac{I_{TT}}{I_{TH}} = \frac{I_b}{I_{TH}} R_b + \frac{I_d}{I_{TH}} \frac{(1+\cos s')}{2} + \rho \frac{(1-\cos s')}{2} \qquad (A.1.13)$$

where the ground reflectance is 0.2 when there is no snow and 0.7 when there is a snow cover (9,pg.54)

Instantaneous Total Solar Radiation

In engineering problems like the thermal analysis of solar collectors, many years's avarage of instantaneous total solar radiation is needed. Practically instantenous total solar radiation can be calculated in relation with daily total solar radiation. Jordan (11,pg.1) has given a diagragm prepared by the measured data, and Munroe (12,pg.23) has given an analytical expression assuming the ratio changes exponentially between sunrise and sunset. Thus, if we let

$$A = \arccos(-\tan\phi \tan d) \qquad (A.1.14)$$

and,

$$\psi = \exp\left(-4\left(1-\frac{h'}{A}\right)^2\right) \qquad (A.1.15)$$

the ratio is given as (8,pg.73)

$$r_t = \frac{I_{TH}}{H_{TH}} = \frac{\pi}{4t_d}\left(\cos\left(90\frac{h'}{A}\right) + \frac{2}{\sqrt{\pi}}(1-\psi)\right) \qquad (A.1.16)$$

where t_d is the day length, I_{TH} is the total instantaneous solar radiation and H_{TH} is the daily total solar radiation, on horizontal surface. Avarage values of H_{TH} for all the months are given in ref (8,pg.286).

Instantanoeus Diffuse and Beam Solar Radiation

For the instantaneous diffuse solar radiation, the relation has been given at ref. (8,pg.79) as

$$r_d = \frac{\pi}{24} \frac{\cos h' - \cos A}{\sin A - \frac{\pi}{180} A \cos A}$$

$$= \frac{I_d}{H_d}$$

where Hd is the daily diffuse solar radiation on horizontal surface.

The instantaneous beam solar radiation can be calculated by (8,pg.79)

$$I_b = I_{TH} - I_d \qquad (A.1.18)$$

$$= r_t H_{TH} - r_d H_d$$

since,

$$H_{TH} = H_b + H_d \qquad (A.1.19)$$

where H_b is the daily beam radiation on a horizontal surface.

Avarage values of H_b for all the months are given in ref (8,pg.286).

A.2 The ambient temperature

For the ambient temperature change throughout a typical day of a specified month, the expression is given in ref. (8,pg.164) as:

$$T_{amb} = T_{mean} + \frac{\Delta T}{2} \cos \frac{180}{td} (Z-14) \qquad (A.2.1)$$

Tamb = ambient temperature (^{o}C)

T_{mean} = mean daily ambient temperature (^{o}C)

ΔT = mean daily maximum and minimum temperature difference (^{o}C)

Z = solar time given in eqt. (A.1.1.4)

t_d = day length given in eqt. (A.1.1.6)

T_{mean} and ΔT values for all of the cities of Turkey are given in ref (8,pg.316).

APPENDIX B

MODELLING AND CHARACTERISTIC DATA OF THE SYSTEMS

B.1 House

The house is located in Istanbul and has a design load of 40000 kJ/hr. The heating load for each hour is supposed to change by,

$$Q_L = UU\ (20 - T_{ambient}) \qquad (B.1.1)$$

UU is the heat loss coefficient of the house in kJ/hr °C determined by

$$UU = Q_L / (20-(-3)) \qquad (B.1.2)$$

where 20 °C is the ambient temperature inside the house and -3 °C is the design temperature for Istanbul. In eqt (B.1.1), $T_{ambient}$ is the ambient temperature outside the house. UU is assumed to be constant.

The water is delivered from the hot water tank which is maintained at 40 °C by a circulation pump with mass flow rate of

$$m = 383 \text{ kg/hr.}$$

and electricity consumed for this job is

$$P = 4 \text{ kJ/hr.}$$

The outlet temperature returning back to the tank is calculated as:

$$T_{out} = \frac{Q_L}{m\ Cp} + T_{in}$$

where $T_{in} = T_{HOT\ WATER\ TANK}$ (°C)

B.2 Solar Collector

The solar collector is the essential item of equipment which transforms solar radiant energy to some other useful energy form. Solar collectors may be used with or without radiation con centration. For flat-plate collectors the area absorbing solar radiation is the same as the area intercepting solar radiation.

Two important parts of a typical flat-plate solar collector, as shown in Fig.B.2.1, are: the "black" solar energy absorbing surface, with means for transferring the absorbed energy to a fluid; envelopes transparent to solar radiation over the solar absorber surface which reduce convection and radiation losses to the atmosphere; and back insulation to reduce conduction losses as the geometry of the system permits.

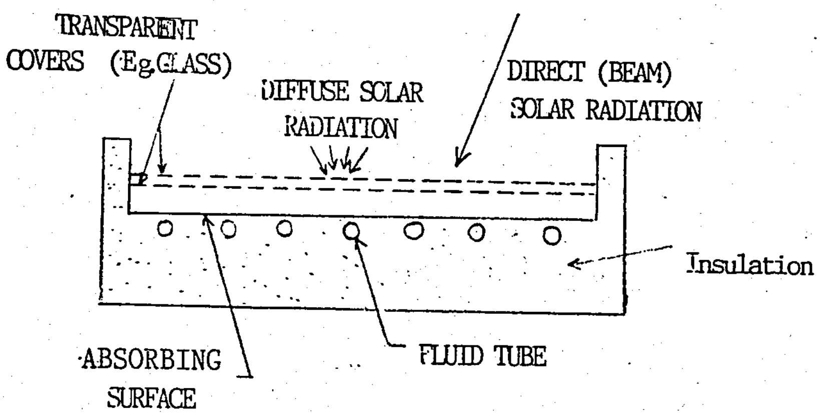

Fig. B.2.1 BASIC FLAT-PLATE SOLAR COLLECTOR

The performance of a solar collector is described by an energy balance that indicates the distribution of incident solar energy into useful energy gain and various losses. The energy balance on the whole collector can be written as

$$A_c \left\{ I\,R(\tau\alpha)_b + IR(\tau\alpha)_d \right\} = Q_u + Q_{LC} + Q_S \qquad \text{(B.2.1)}$$

where,

$\tau\alpha$ = transmittance-absorptance product of cover system for beam or diffuse radiation;

A_c = collector area;

Q_u = rate useful heat transfer to a working fluid in the solar exchanger;

Q_{LC} = rate of energy losses from the collector to the surroundings by reradiation, convection, and by conduction through supports for the absorber plate, and so on. The losses due to reflection from the covers are included in the ($\tau\alpha$) term above;

Q_s = rate of energy storage in the collector.

The detailed analysis of a solar collector is a very complicated problem.Fortunately , a relatively simple analysis will yield very useful results. The analysis presented in ref (9, chapter 7) follows the basic derivation by Hottel and Whillier (1958), Bliss (1959), Whillier (1953,1967). In this analysis, the useful energy Qu is given as (9,pg.147)

$$Q_u = A_c \, F_R \, (IR \, \tau\alpha \; - U_c (T_{f,i} - T_{amb}) \;) \qquad \text{(B.2.2)}$$

where F_R, the heat, removal factor, is defined as the ratio of the actual rate of heat transfer to the working fluid to the rate of heat transfer at the minimum temperature difference between the absorber and the environment (13,pg.215). $T_{f,i}$ is the inlet temperature of the working fluid. U_c is the heat loss coefficient of the plate

F_R is related to the collector efficiency factor F' as: (9,pg.147)

$$F_R = \frac{m \, Cp}{Uc} \left(1 - e^{-[U_c F'/m \, Cp]}\right) \qquad \text{(B.2.3)}$$

where m is the mass flow rate of the working fluid.

Thus, we can have the energy balance

$$Q_u = mCp \, (Tf,o - Tf,i) \qquad \text{(B.2.4)}$$

where Tf,o is the outlet temperature of the working fluid.

The mean fluid temperature is given in ref (9,pg.152) as

$$Tf,m = Tf,i + \frac{Qu/Ac}{Uc \, F_R} \left[1 - \frac{F_R}{F'} \right] \qquad \text{(B.2.5)}$$

and the mean plate temperature as

$$T_{p.m} - T_{f.m} = Qu\ R_{p-f} \tag{B.2.6}$$

where Rp-f is the heat transfer resistance between the plate and the fluid. For liquid flowing in tubes, it is given as (9,152)

$$Rp\text{-}f = 1/(h_{f,i}\ \ D_i\ nL) \tag{B.2.7}$$

where $h_{f,i}$ is the convection heat transfer coefficient, n and L the number of tubes and their lengths, respectively.

The characteristic data for the collector used in the study is as follows:

Type	: Flat plat
No of glasses	: 2
No of tubes, n	: 6
Length of tubes, L	: 2 m.
Diameter of tubes, D_i	: 0.016 m.
Conv.heat tr. coeff., $h_{f,i}$	: 1500 $W/^oK\ m^2$
Heat remo val factor, F_R	: 0.9
Heat loss coefficient, Uc	: 4.Ac $W/^oK$
Transpa-absorb.product,	: 0.8
Mass flow rate, m	: 0.015, Ac/sec
Direction and slope,s	: Facing south and 51^o with horizontal
Electiricity consumed for pumping	: (5.4) Ac kJ/kr.

The inlet temperature of the collector is simply the temperature of the water in the tank energy is exchanged. Therefore, the outlet temperature from the collector field is found from eqt. (B.2.4) as :

$$Tf,o = \frac{Qu}{m\ Cp} + Tf,i \tag{B.2.8}$$

where

Tf,i = T cold water tank in solar assisted heat pump

Tf,i = T_{Hot} water tank in solar collector and boiler system

B.3 Heat Pump

The heat pump is shown in Fig. B.3.1 below

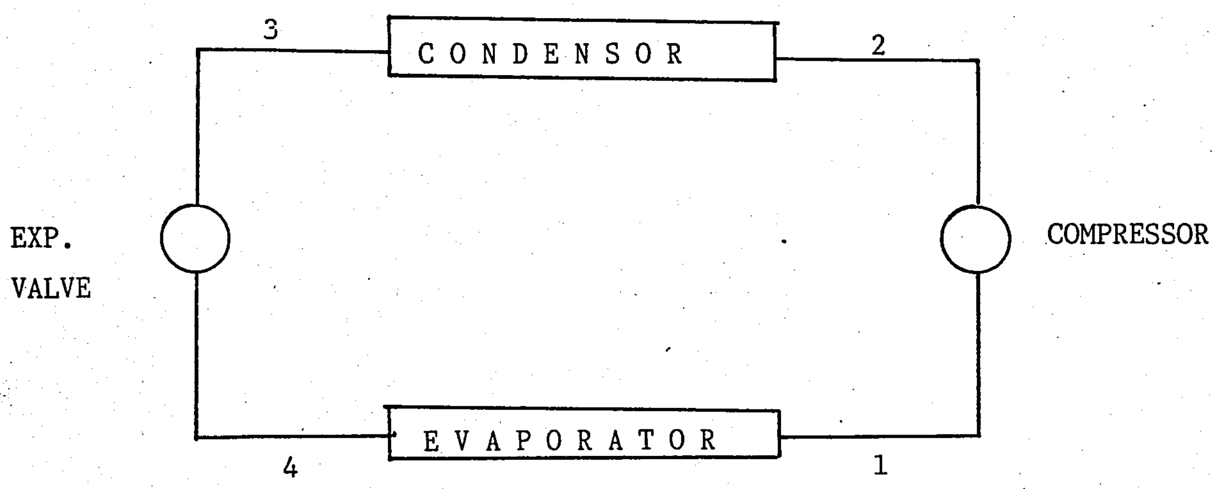

Fig. B.3.1 The heat pump

The T-S diagragm of the heat pump is shown in Fig. B.3.2 below.

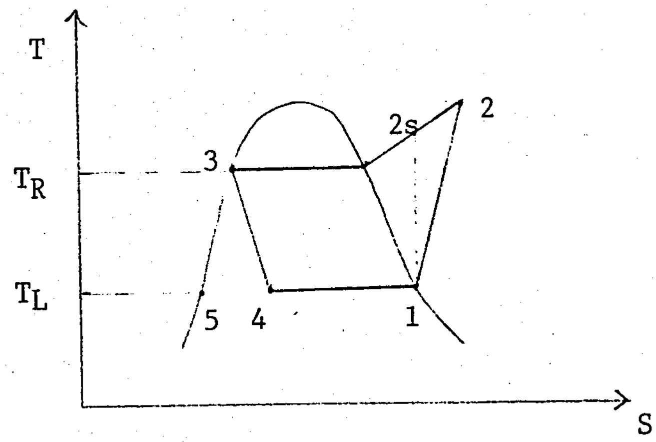

Fig. B.3.2 T-S diagram of the heat pump

Since the expansion process 3-4 is adiabatic,

h3=h4

where,

h3 is h_f at saturation temperature T_R

The quality of refrigerant at state 4 is

$$x = \frac{h4-h5}{(h_1-h_5)} \quad (B.3.1)$$

where, h_1 is hg and h5 is h_f at saturation temperature T_L.

Thus,

$$S4 = S5 + (S_1-S_5).x \quad (B.3.2)$$

the entropy at state 4 is found.

For an isentropic compression,

$$S_2 = S_{2s} \quad (B.3.3)$$

Hence, given the pressure P_R corresponding to staturation temperature T_R, and S_{2s}, we can find h_{2s}

The isentropic efficiency of the compressor is defined as

$$\eta_c = \frac{h_{2s}-h_1}{h_2-h_1} \quad (B.3.4)$$

Thus, we can find

$$h_2 = h_1 + \frac{(h_{2s}-h_1)}{\eta_c} \quad (B.3.5)$$

the enthalpy and the entropy of state 2.

Now, we are in a position to find the energy values of condensor, compressor and evaporator.

$$Qc = Q_L + Q_{LOSS\ H.W.T} \quad (B.3.6)$$

where Qc is the heat delivered by the condensor, Q_L is the heating load of the house and $Q_{LOSS\ H.W.T}$ is the heat loss of the hot water tank. Thus, we can find the mass flow rate of the refrigerant as

$$m = \frac{Qc}{(h2-h3)} \tag{B.3.7}$$

The heat received by the evaporator Q_E, and the work of compressor W is found as :

$$Q_E = m(h1-h4)$$
$$W = m(h2-h1) \tag{B.3.8}$$

here, the compression process is assumed to be adiabatic.

If we define

ηm= mechanical efficiency of the compressor

ηc= electrical efficiency of the electric drive of the compressor

then, we find the electricity consumed to drive the compressor as :

$$E = \frac{W}{(\eta m \ \eta e)} \tag{B.3.9}$$

For the inlet and outlet temperatures of the water circulated through the condensor and evaporator, if we let

m_c = mass flow rate of the water circulated through the condensor

m_E = mass flow rate of the water circulated through the evaporator

T_{CWT}= temperature of the cold water tank

T_{HWT}= temperature of the hot water tank

T_{CD} = the outlet temperature of the condensor

T_{ED}= the outlet temperature of the evaporator

we find

$$T_{CD} = \frac{Qc}{m_c \cdot C_p} = T_{HWT} \tag{B.3.10}$$

$$T_{EO} = \frac{Q_E}{M_E \ C_p} = T_{C.W.T}$$

The state properties are found by interpolating properties of Freon-12:

Given= T_L, T_R

$P_L = .3164 \exp (0.0283\ T_L)$

$P_R = .3944 \exp (0.02246\ T_R)$

$h3 = 30.88 + 1.083\ T_R$

$S_3 = 0.135 + 0.034\ T_R$

$h_1 = 187.5 + 0.4\ T_L$

$h_5 = 35.6 + 0.97\ T_L$

$S_1 = 0.7 - 3.63\ T_L\ 10^{-4}$

$S_5 = 0.14 + 0.0033\ T_L$

$h_2 = -267.7 + 30.61\ P_R + 640.4\ S_2$

The data for the heat pump used in this study is as follows:

The heat pump in the solar assisted heat pump system:

$T_L = 0^oC$

$T_R = 50^oC$

The heat pump in the heat pump and boiler system:

$T_L = -5^oC$

$T_R = 50^oC$

The heat pumps used in both system :

$\eta c = 0.7$

$\eta e . \eta m = 0.9$

$m_c = 1000$ kg/kr

$m_E = 1052$ kg/kr

$P_c = 0.2$ kJ/kr

$P_E = 0.2$ kJ/kr

working fluid = Freon 12

B.4 Boiler

The efficiency of the boiler is defined as :

$$\eta_B = \frac{Q_B}{m_{fuel} \;\; \Delta HL} \qquad \text{(B.4.1)}$$

where Q_B is the heat delivered by the boiler, m_{fuel} is the mass flow rate of the boiler and AHL is the lower heating value of the fuel. If we let

m_B = mass flow rate of the water circulating through the boiler

T_{B2} = temperature of the water outlet the boiler

we obtain

$$T_{B2} = \frac{Q_B}{m_B \; C_p} + T_{H.T} \qquad \text{(B.4.2)}$$

where T_{B2} is the outlet temperature of the water and $T_{H.T}$ is the hot water tank temperature.

The data for the boiler is as follows:

$\eta_B = 0.75$

m_B = 383 kg/hr.

P_B = 4 kJ/hr.

B.5 Hot Water Tank

The heat loss from the hot water tank is as follows:

$$Q_{LOSS} = UR \; (T_{HWT} - T_{amb}) \qquad \text{(B.5.1)}$$

where UR is the heat loss coefficient of the tank. The mass of the water inside the tank, MR is found as

$$M_R = Q_{LD} \; . \; 0.02 \qquad \text{(B.5.2)}$$

where Q_{LD} is the design heating load of the house.

UR is found by interpolating the change of UR with volume of a cylindrical tank for insulation thickness of 3 cm. (8,pg.210)

Thus,

$$UR = 17.763 \times \left(\frac{MR}{1000}\right)^{.643} \quad (kJ/hr^\circ K) \qquad (B.5.3)$$

We can set up energy balance for the tank as follows (9,pg.244)

$$MR.Cp \frac{(T_{final} - T_{initial})}{\Delta t} = Q_{delivered} - Q_{extracted} - Q_{loss} \qquad (B.5.4)$$

where Δt is the increment of time we consider, $T_{initial}$ is the initial temperature of the water in the tank and T_{final} is the final temperature of the water in the tank after the time Δt passes.

For solar assisted heat pump and boiler systems,

$$Q_{delivered} = Qc + Q_B \qquad (B.5.5)$$

$$Q_{extracted} = Q_L$$

and we can rewrite eqt (B.5.4) as

$$T_{final} = T_{initial} + \frac{\Delta t}{MR.Cp}.(Q_C + Q_B - Q_L - Q_{LOSS}) \qquad (B.5.6)$$

For solar collector and boiler system,

$$Q_{delivered} = Q_s + Q_B \qquad (B.5.7)$$

$$Q_{extracted} = Q_L$$

and thus,

$$T_{final} = T_{initial} + \frac{\Delta t}{MR.Cp}(Q_S + Q_B - Q_{LOSS}) \qquad (B.5.8)$$

As it is stated before, Δt is 15 min, since this is the computing time step.

B.6 Cold Water Tank

The mass of the water in the cold water tank is chosen by (14,pg.127)

$$ML = 75 \quad Ac \qquad (B.6.1)$$

which is sized in accordance with recommendations for conventional solar systems.

Setting,

UL = heat loss coefficient of the cold water tank

and with the same analysis for hot water tank,

$$UL = 17.763 \times \left(\frac{ML}{1000}\right)^{0.643} \qquad (B.6.2)$$

$$ML.Cp \, \frac{(T_{final} - T_{initial})}{\Delta t} = Q_{delivered} - Q_{extracted} - Q_{Loss} \qquad (B.6.3)$$

we obtain for solar assisted heat pump system

$$T_{final} = T_{initial} + \frac{\Delta t}{ML.Cp} \, (Q_S - Q_E - Q_{LOSS}) \qquad (B.6.4)$$

where,

$$Q_{Loss} = UL \, (T_{CWT} - T_{amb}) \qquad (B.6.5)$$

APPENDIX C

CALCULATION OF COEFFICIENT OF PERFORMANCE

The coefficient of performance for each system is calculated as follows:

A. Solar assisted heat pump

Energy delivered : Electricity for pumping + Electricity to compressor + Fuel to Boiler

$$= P + W/\eta_m \eta_e + Q_B/\eta_B$$

Energy extracted : Heating load of the house

$$= Q_L$$

In our thesis, $\eta_m \eta_e = 0.9$ and $\eta_B = 0.75$

thus,

$$C.O.P. = \frac{Q_L}{P + W/0.9 + Q_B/0.75}$$

B. Heat Pump and boiler

Energy delivered : Electricity for pumping + Electricity to compressor + Fuel to Boiler

$$= P + W/0.9 + Q_B/0.75$$

Energy extracted : Heating load of the house

$$= Q_L$$

Thus,

$$C.O.P. = \frac{Q_L}{P + W/0.9 + Q_B/0.75}$$

C. Solar Collector and Boiler

Energy delivered : $P + Q_B/0.75$

Energy extracted : Q_L

$$C.O.P = \frac{Q_L}{P + Q_B/0.75}$$

APPENDIX D

THE COMPUTER PROGRAM INTERPRETATION

The flowcharts of the computer programs for each of the systems is shown on Figs (D.1), (D.2), (D.3). The calculation time step is 15 min. and solutions are printed every hour. The program is in BASIC language and the main steps can be summarized as follows.

INPUT DATA : The computer reads the data input

CALCULATION OF STATE POINTS OF HEAT PUMP CYCLE : The state points of the heat pump are calculated by the interpolation formulas for freon-12 given in appendix B.3

AMBIENT TEMPERATURE : The ambient temperature regarding each time of the day is calculated.

LOAD ROUTINE : The heating load of the house, the electrical power consumed for pumping the water into the house, and the outlet water temperature are calculated in this routine.

CONDENSOR : The heat load of the condensor, mass flow rate of freon-12, the electrical power consumed for pumping the circulating water, and the outlet water temperature are calculated.

EVAPORATOR AND COMPRESSOR : The heat load of the evaporator, the electrical power consumed by pump which circulates the water and by compressor, the outlet water temperature are calculated.

SOLAR COLLECTOR : The solar radiation at the time concerned, the useful heat delivered by collector, the electrical power consumed for pumping the water and the outlet water temperature are calculated.

EXERGY AND C.O.P CALCULATIONS : The total exergy input and output during the time interval, exergetic efficiency for the whole system and for devices consisting system and C.O.P for the whole system are calculated.

FINAL CALCULATIONS : The exergetic efficiency and C.O.P for the day's cumulative, the total heat outputs are calculated.

D.1 LIST OF SYMBOLS FOR COMPUTER PROGRAM INPUT DATA

AR : Solar collector area (m^2)

BY : longitude

D : sun's declination

DT : mean ambient temperature difference (^oC)

E : latitude

HD : mean beam solar radiation per day per horizontal area (kJ/m^2 day)

HT : mean total solar radiation per day per horizontal area (kJ/m^2 day)

NC : compressor isentropic efficiency

Q : design heat load of the house (kJ/hr)

S : collector tilt angle (deg)

T3 : condensation temperature (^oC)

T4 : evaporation temperature (^oC)

TA : transmittance-absorbtance product of the collector

TL : cold water tank temperature (^oC)

TM : mean ambient temperature for the specified month (^oC)

TR : hot water tank temperature (^oC)

ZD : equation of time

D.2 LIST OF SYMBOLS FOR THE OUTPUT OF THE COMPUTER

BO : exergetic efficiency of the boiler

EF or EFF : coefficient of performance of the system

EX : The system's daily exergetic efficiency

HP : Exergetic efficiency of the heat pump

LA : Heat delivered to the house (kJ/hr or kJ/day)

P : electricity consumed for pumping (kJ/hr or kJ/day)

QB : heat delivered by the boiler (kJ/hr or kJ/day)

QC : heat delivered by the condensor (kJ/hr)

QE : heat extracted by the evaporator (kJ/hr)

QS : heat delivered by the boiler (kJ/hr or kJ/day)

SO : exergetic efficiency of the solar collector

SYS : system's hourly exergetic efficiency

TB : return water temperature from boiler (°C)

TC : return water temperature from solar collector (°C)

TE : return water temperature from evaporator (°C)

TH : ambient air temperature (°C)

TK : return water temperature from condensor (°C)

TL : cold water tank temperature (°C)

TP : collector plate temperature (°C)

TR : hot water tank temperature (°C)

TS : standart time of the day (o'clock)

TY : return water temperature from house (°C)

W : electricity delivered to the compressor (kJ/hr or kJ/day)

Y : solar radiation incident on the collector plate (kJ/hr or kJ/day)

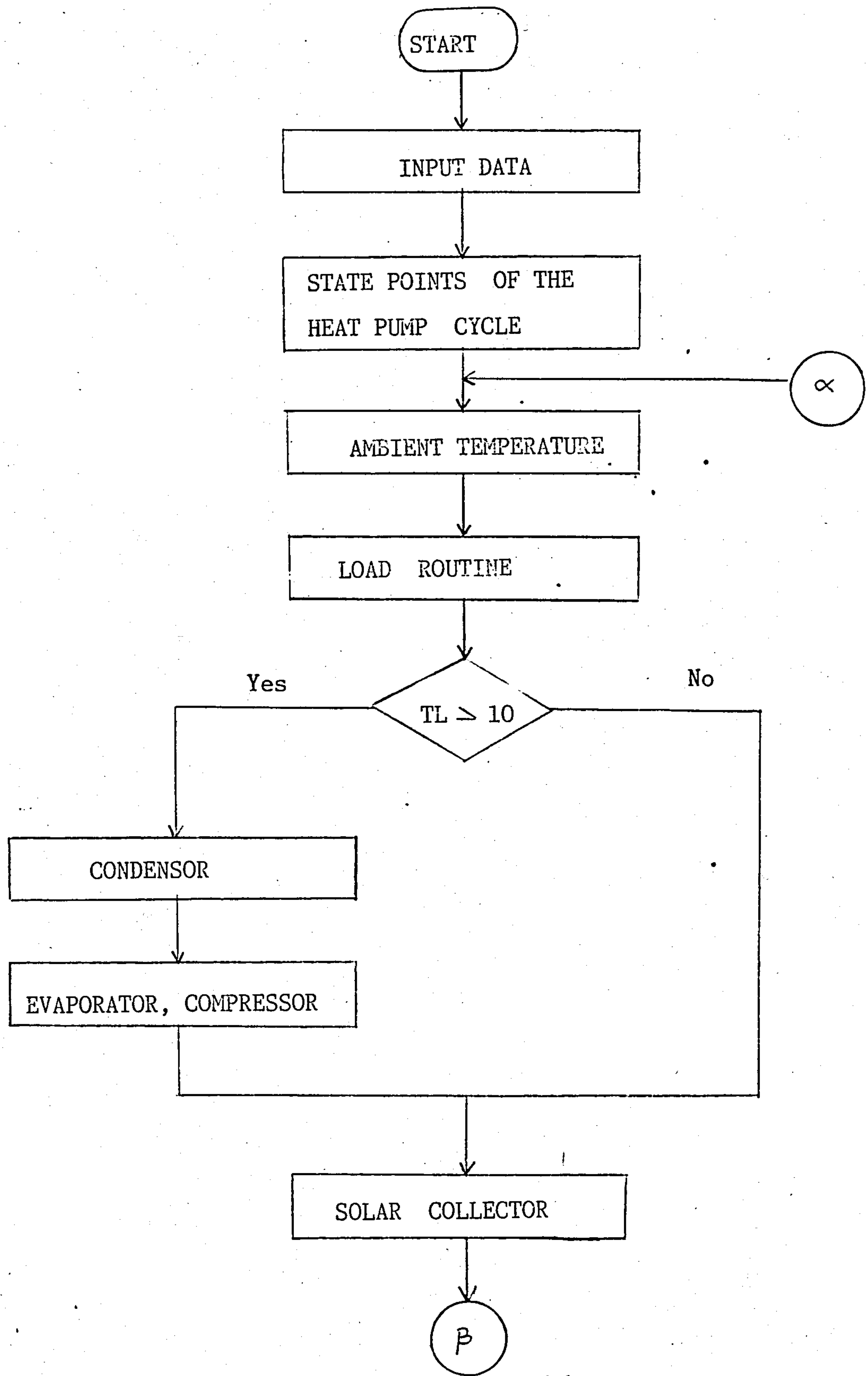

Fig. D.1 Flowchart for solar assisted heat pump

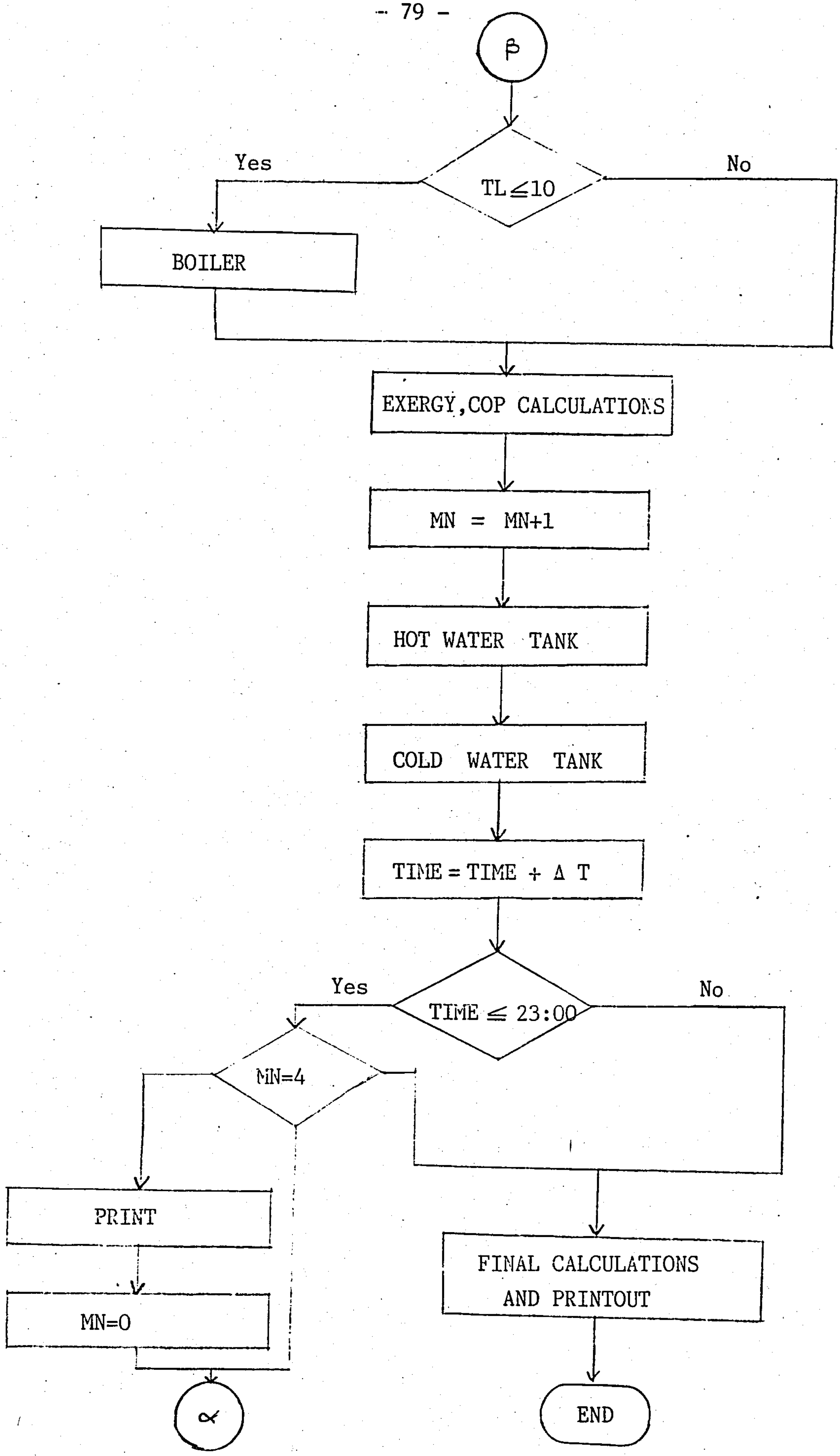

Fig. D.1 Flowchart for solar assisted heat pump

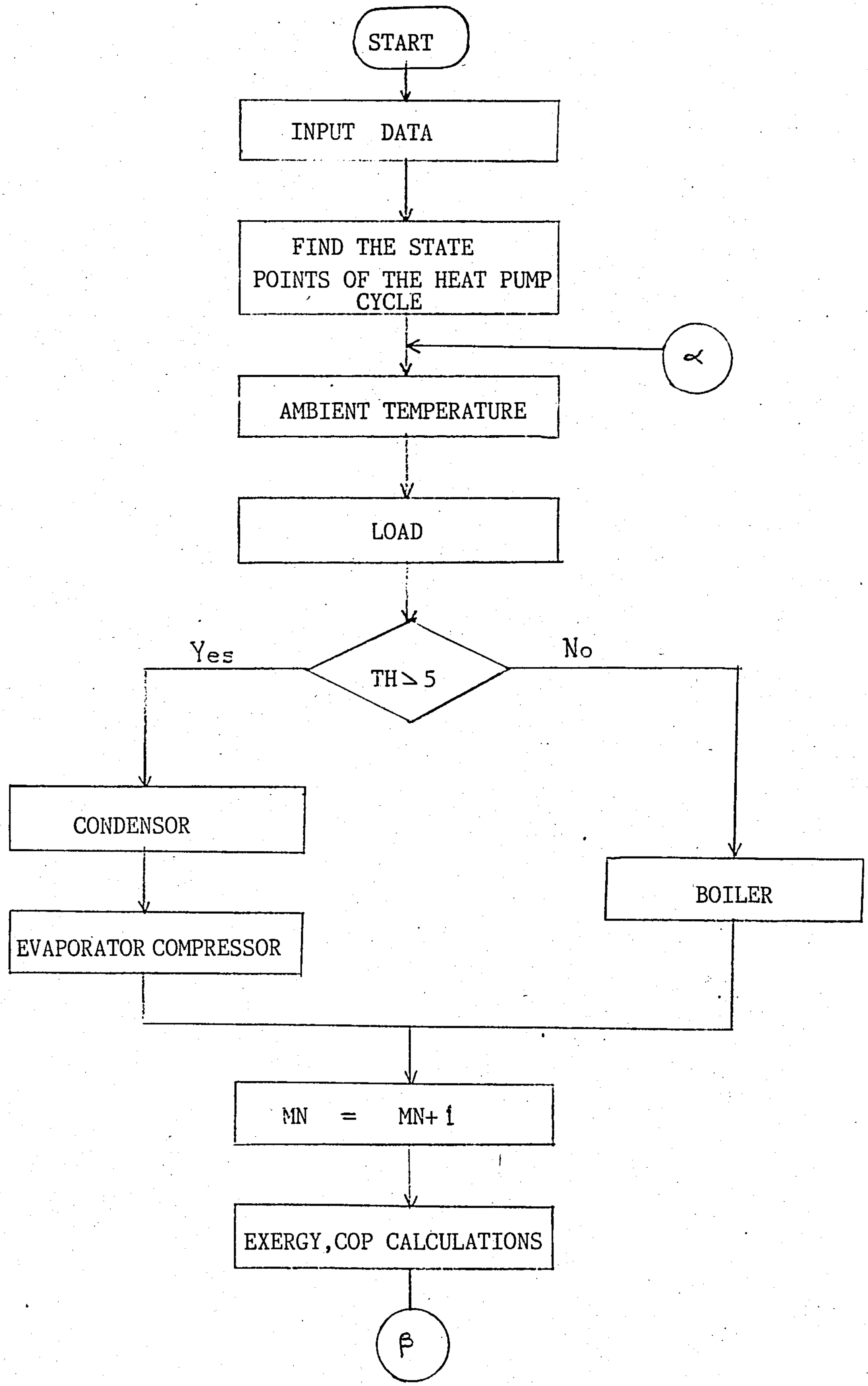

Fig. D.2 Flowchart for heat pump and boiler

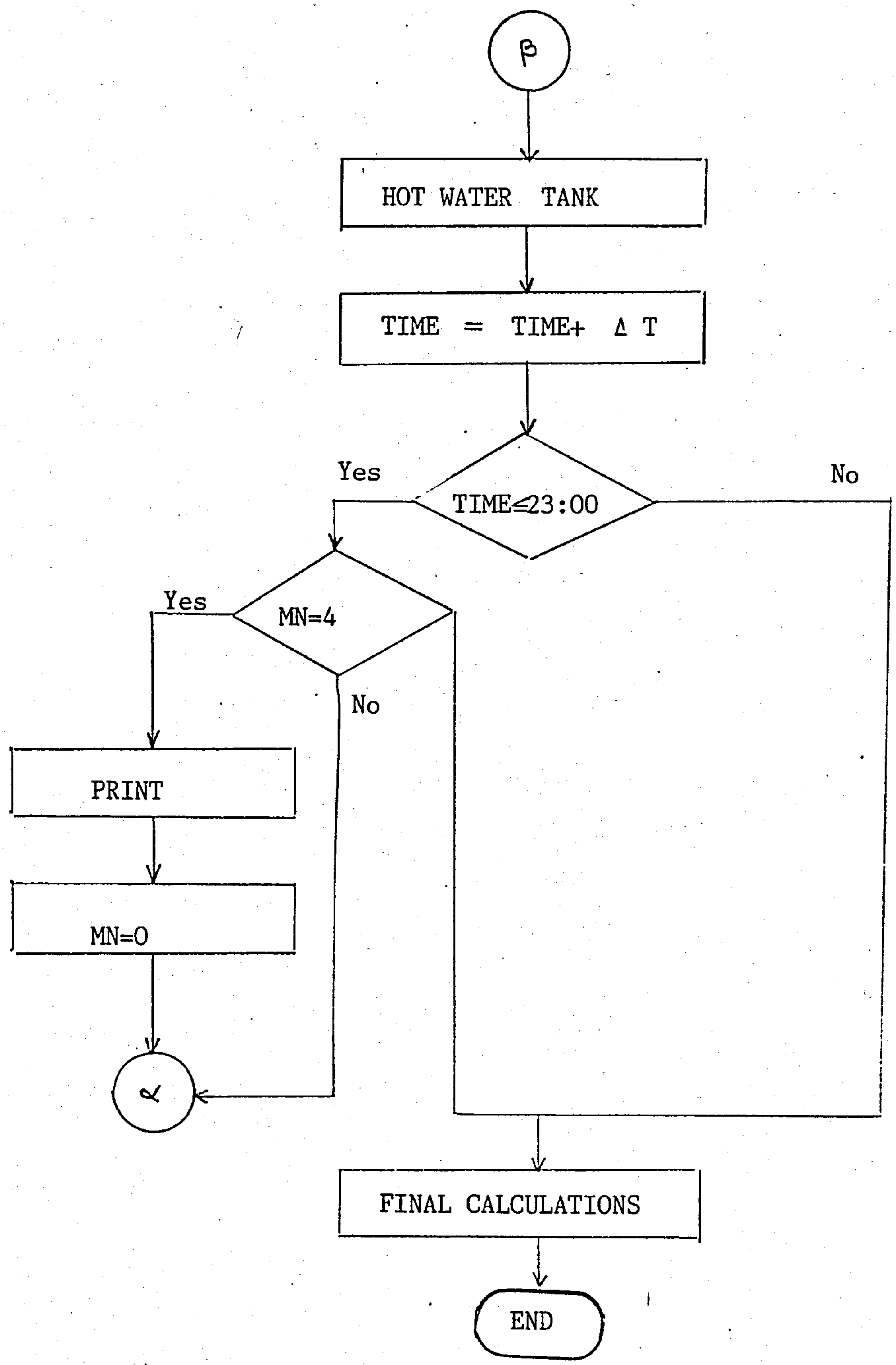

Fig. D.2 Flowchart for heat pump and boiler

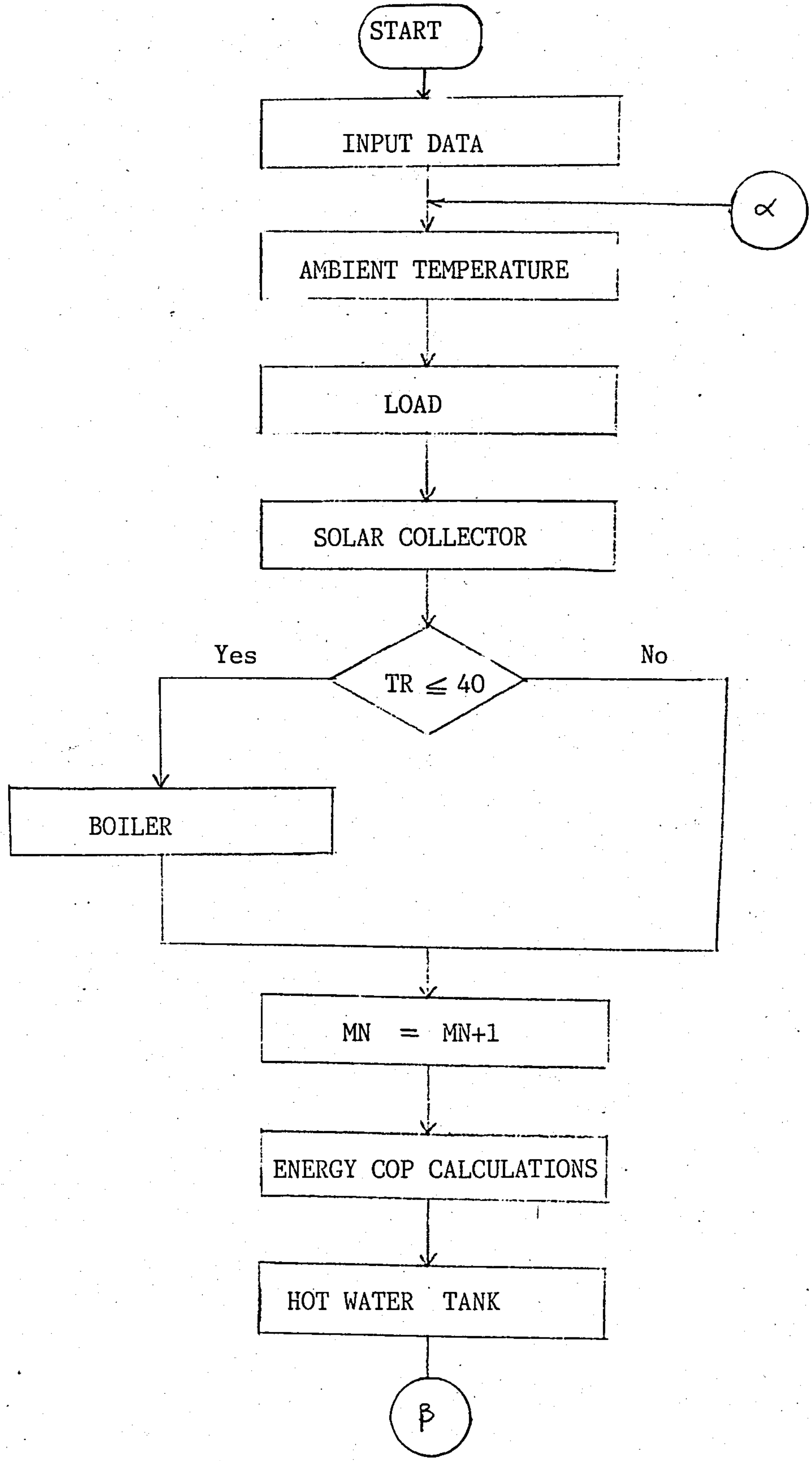

Fig. D.3 Flowchart for solar collector and boiler

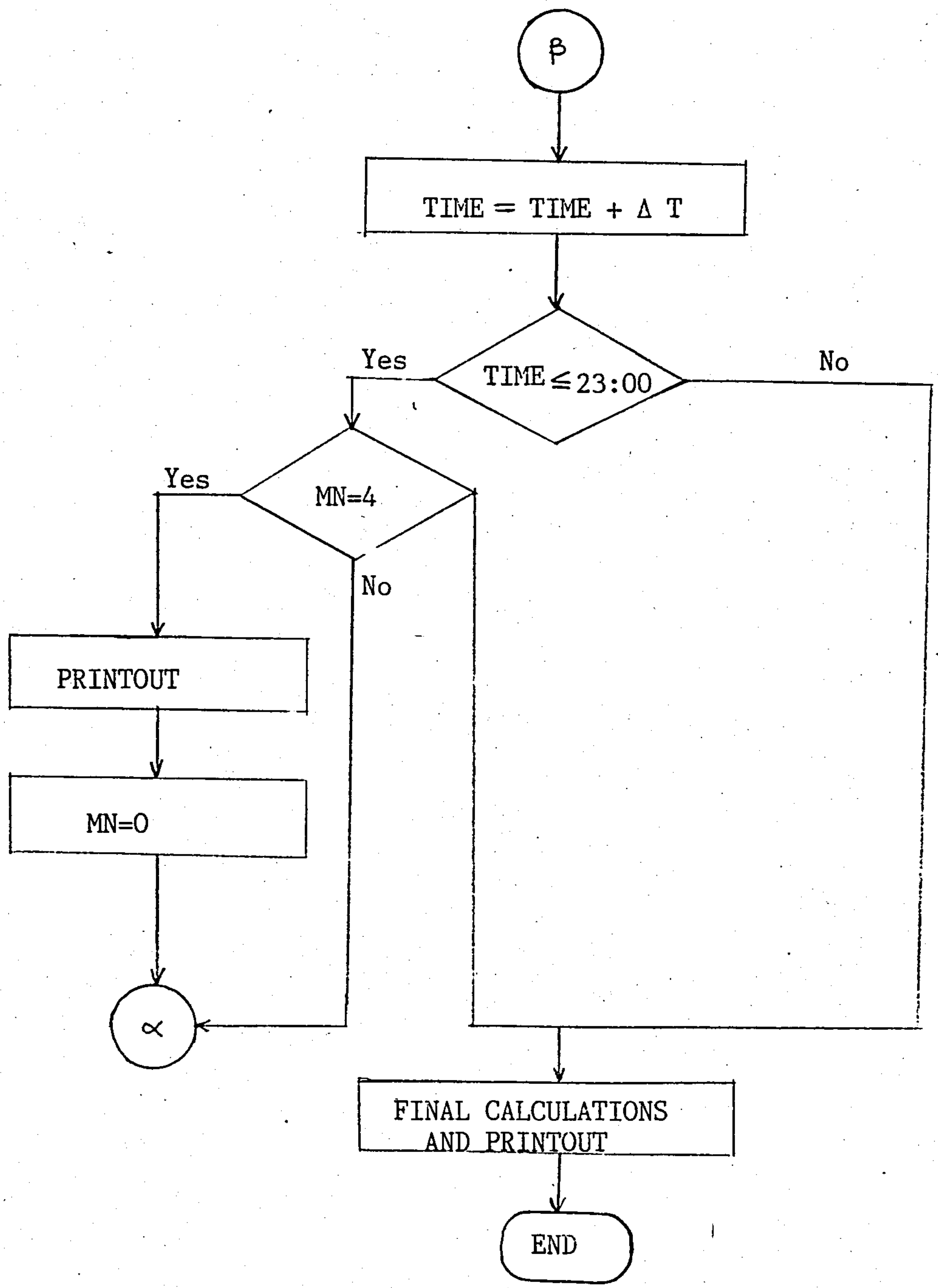

Fig. D.3 Flowchart for solar collector and boiler

COMPUTER LISTINGS AND OUTPUTS

```
READY:
1 REM KULLANILAN SISTEM 3NISAN(SO+HP+BO)
10 CLR
20 OPEN4,4
30 CMD4
40 Z=75
50 DIM LA(Z),P(Z),QC(Z),LE(Z),W(Z),QB(Z),QS(Z),Y(Z),E1(Z),E2(Z),E3(Z),E4(Z)
60 DIM E5(Z),E6(Z),E7(Z),E8(Z)
70 READT3,T4,NC,TL,TR,Q
80 READE,BY,S,D,ZD,TM,DT,HT,HD,AR
90 DATA50,0,.7,12.5,40,40000
100 DATA41,29,51,-13.29,-13.9,5.5,5.5,7.5,3.2,120
110 TS=6
115 PRINT#4,"***************FEBRUARY**********"
116 PRINT#4,"TL="TL"Q="Q"AR="AR
120 PI=3.1415/180
130 X=-TAN(PI*E)*TAN(PI*D)
140 H=(1.5708-ATN(X/SQR(1-X*X)))/PI
150 TG=2/15*H
160 MC=13.5*AR
170 ML=75*AR
180 MR=.002*Q
190 UU=Q/23/60
200 UL=17.763*(ML/1000)↑.643/60
210 UR=17.763*(MR/1000)↑.643/60
220 P4=.3164*EXP(.0283*T4)
230 P3=.3944*EXP(.02246*T3)
240 H3=30.87589+1.08344*T3
250 S3=.13515+.00338*T3
260 H4=H3
270 H1=187.502+.3968*T4
280 H5=35.59425+.9741*T4
290 X8=(H4-H5)/(H1-H5)
300 S1=.69576-3.634*10↑-4*T4
310 S5=.1413+.0033*T4
320 S4=S5+(S1-S5)*X8
330 S2=S1
340 H2=-267.7477+30.611*P3+640.41*S2
350 H2=H1+(H2-H1)/NC
360 S2=.443703+1.5615*10↑-3*H2-4.7799*10↑-2*P3
380 HOUR=(TS-6)*4
390 GOSUB 650:REM AMBIENT TEMP
410 GOSUB 690:REM LOAD
420 IF TL>10 THEN GOSUB 740:REM CONDENSOR
430 IF TL>10 THEN GOSUB 830:REM EVAP&COMP
440 GOSUB 980:REM SOLAR COLL.
450 IF TL<=10 THEN GOSUB 890:REM BOILER
460 MN=MN+1
470 GOSUB 1340
480 GOSUB 800:REM HOT WATER TANK
490 GOSUB 940:REM TANK
500 TS=TS+.25:IFTS>23 THEN GOTO 530
510 IF MN=4 THEN GOSUB 1160
515 IF MN=4 THEN MN=0
520 GOTO 380
530 GOSUB 1200:PRINT#4,"******THE DAY'S CUMULATIVE*****"
531 PRINT#4,"TOTAL HEATING LOAD:LA="USING"######.##";LA
```

```
533 PRINT#4,"W="USING"######.##";W;
534 PRINT#4," QS="USING"######.##";QS;
535 PRINT#4," QB="USING"######.##";QB;
536 PRINT#4," P="USING"####.##";P;
537 PRINT#4," Y="USING"########.##";Y
538 PRINT#4,"EF="USING"##.###";EF;
540 PRINT#4," EX="USING".###";SY
550 END
640 REM *****AMBIENT TEMPERATURE******
650 Z=TS-4/60*(45-BY)+ZD/60
660 TH=TM+DT/2*COS(3.14/TG*(Z-14))
670 RETURN
680 REM ********LOAD****************
690 LA(HOUR)=UU*(20-TH)*15
700 D4=TR-LA(HOUR)*2.5E-3
710 P(HOUR)=1+P(HOUR)
720 RETURN
730 REM *****CONDENSOR***********
740 QC(HOUR)=15*UU*(20-TH)+UR*(TR-TH)*15+MR*(40-TR)*4.18
750 MH=QC(HOUR)/(H2-H3)
760 D1=QC(HOUR)*9.56E-4+TR
770 P(HOUR)=.05+P(HOUR)
780 RETURN
790 REM *********HOT WATER TANK*******
800 TR=TR+.24/MR*(QC(HOUR)-LA(HOUR)-UR*15*(TR-TH)+QB(HOUR))
810 RETURN
820 REM ****COMPRESSOR&EVAPORATOR*****
830 LE(HOUR)=MH*(H1-H4)
840 W(HOUR)=MH*(H2-H1)/.9
850 D2=-LE(HOUR)*9E-4+TL
860 P(HOUR)=.05+P(HOUR)
870 RETURN
880 REM ******BOILER****************
890 QB(HOUR)=LA(HOUR)+UR*15*(TR-TH)+MR*4.18*(40-TR)
900 D3=QB(HOUR)*2.5E-3+TR
910 P(HOUR)=1+P(HOUR)
920 RETURN
930 REM **********TANK**************
940 TL=TL+.239/ML*(QS(HOUR)-LE(HOUR)-UL*15*(TL-TH))
960 RETURN
970 REM ******SOLAR COLLECTOR*******
980 HH=15*(12-TS)
990 FI=EXP(-4*(1-ABS(HH)/H)↑2)
1000 RT=.785/TG*(COS(1.57*HH/H)+1.129*(1-FI))
1010 I=RT*HT*277.8
1020 RY=.131*(COS(PI*HH)-COS(PI*H))/(SIN(PI*H)-PI*H*COS(PI*H))
1030 HY=HT-HD
1040 IY=RY*HY*277.8
1050 ID=I-IY
1060 R1=(COS(PI*(E-S))*COS(PI*D)*COS(PI*HH)+SIN(PI*(E-S))*SIN(PI*D))
1070 R2=(COS(PI*E)*COS(PI*D)*COS(PI*HH)+SIN(PI*E)*SIN(PI*D))
1080 RD=R1/R2
1090 R=RD*ID/I+IY*(1+COS(PI*S))/I/2+.2*(1-COS(PI*S))/2
1100 Y(HOUR)=I*R*.9*AR
1110 TA=.8
1120 QS(HOUR)=.81*(I*R*TA-4*(TL-TH))*AR
1122 IF QS(HOUR)<=0 OR TS>19 THEN QS(HOUR)=0:I=0:R=0:Y(HOUR)=0:GOTO 1150
1125 TP=TL+QS(HOUR)/AR*9E-3+QS(HOUR)/AR*.0022
1130 TC=QS(HOUR)/4.18/MC+TL
1140 P(HOUR)=P(HOUR)+1.35*AR
```

```
1150 RETURN
1160 PRINT#4,"TS="TS"TH="TH"TL="TL"TR="TR;" LA="USING"#####.##";Q1
1161 IF C1<>0 THEN PRINT#4,"HP="USING".###";C2/C1;
1162 IF C1=0 THEN PRINT#4,"HP=0";
1163 IF C3=0 THEN PRINT#4," BO=0";
1164 IF C3<>0 THEN PRINT#4," BO="USING".###";C4/C3;
1165 IF C5=0 THEN PRINT#4," SO=0";
1166 IF C5<>0 THEN PRINT#4," SO="USING".###";C6/C5;
1167 PRINT#4," SYS="USING".###";C8/C7;
1168 PRINT#4," EF="USING"#.###";Q1/(Q7+Q5/.75+Q4)
1169 C1=0:C2=0:C3=0:C4=0:C5=0:C6=0:C7=0:C8=0
1171 IF Q2=0 THEN PRINT#4,"QC=0";:ELSE PRINT#4,"QC="USING"#####.##";Q2;
1172 IF Q3=0 THEN PRINT#4," QE=0";:ELSE PRINT#4," QE="USING"#####.##";Q3;
1173 IF Q4=0 THEN PRINT#4," W=0";:ELSE PRINT#4," W="USING"####.##";Q4;
1174 IF Q5=0 THEN PRINT#4," QB=0";:ELSE PRINT#4," QB="USING"#####.##";Q5;
1175 IF Q6=0 THEN PRINT#4," QS=0";:ELSE PRINT#4," QS="USING"######.##";Q6;
1176 IF Q8=0 THEN PRINT#4," Y=0";:ELSE PRINT#4," Y="USING"#######.##";Q8;
1177 IF Q7=0 THEN PRINT#4," P=0";:ELSE PRINT#4," P="USING"###.##";Q7
1185 Q1=0:Q2=0:Q3=0:Q4=0:Q5=0:Q6=0:Q7=0:Q8=0
1190 RETURN
1200 FOR AA=0 TO 68
1210 LA=LA(AA)+LA
1220 W=W(AA)+W
1230 QB=QB(AA)+QB
1240 QS=QS(AA)+QS
1265 Y=Y+Y(AA)
1270 P=P(AA)+P
1280 E8=E8(AA)+E8
1290 E7=E7(AA)+E7
1300 NEXT AA
1310 EF=LA/(QB/.75+P+W)
1320 SY=E8/E7
1330 RETURN
1340 Y1=TH+273.15
1350 Y2=TL+273.15
1360 Y3=TR+273.15
1370 E1(HOUR)=W(HOUR)+LE(HOUR)-263*4.18*Y1*LOG(Y2/(D2+273.15))
1380 E2(HOUR)=QC(HOUR)-250*4.18*Y1*LOG((D1+273.15)/Y3)
1390 IF QC(HOUR)=0 THEN E1(HOUR)=0
1400 IF QC(HOUR)=0 THEN E2(HOUR)=0
1410 E3(HOUR)=QB(HOUR)/.75
1420 E4(HOUR)=QB(HOUR)-95.7*4.18*Y1*LOG((D3+273.15)/Y3)
1430 IF QB(HOUR)=0 THEN E3(HOUR)=0
1440 IF QB(HOUR)=0 THEN E4(HOUR)=0
1450 E5(HOUR)=Y(HOUR)*(1-Y1/(TP+273.15))
1460 E6(HOUR)=QS(HOUR)-MC*4.18*Y1*LOG((TC+273.15)/Y2)
1470 IF QS(HOUR)=0 THEN E5(HOUR)=0
1480 IF QS(HOUR)=0 THEN E6(HOUR)=0
1490 E7(HOUR)=W(HOUR)+E5(HOUR)+E3(HOUR)+P(HOUR)
1500 E8(HOUR)=LA(HOUR)-95.7*4.18*Y1*LOG(Y3/(D4+273.15))
1510 IF LA(HOUR)=0 THEN E7(HOUR)=0
1520 IF LA(HOUR)=0 THEN E8(HOUR)=0
1631 C1=C1+E1(HOUR)
1632 C2=C2+E2(HOUR)
1633 C3=C3+E3(HOUR)
1634 C4=C4+E4(HOUR)
1635 C5=C5+E5(HOUR)
1636 C6=C6+E6(HOUR)
1637 C7=C7+E7(HOUR)
```

```
1638 C8=C8+E8(HOUR)
1643 Q1=Q1+LA(HOUR)
1644 Q2=Q2+QC(HOUR)
1645 Q3=Q3+LE(HOUR)
1646 Q4=Q4+W(HOUR)
1647 Q5=Q5+QB(HOUR)
1648 Q6=Q6+QS(HOUR)
1649 Q7=Q7+P(HOUR)
1650 Q8=Q8+Y(HOUR)
1660 RETURN

READY.
```

```
***************DECEMBER**********
TL= 11 Q= 40000 AR= 60
TS= 7 TH= 5.42261632 TL= 10.0036774 TR= 40  LA=25473.49
HP=.372 BO=0 SO=0 SYS=.282 EF=3.235
QC=25594.80 QE=18512.86 W=7868.82 QB=0 QS=0 Y=0 P=  4.40
TS= 8 TH= 5.84625626 TL= 9.75005319 TR= 40  LA=24930.18
HP=.372 BO=.098 SO=0 SYS=.080 EF=0.926
QC= 6333.91 QE= 4581.36 W=1947.29 QB=18716.47 QS=0 Y=0 P=  7.10
TS= 9 TH= 6.52345916 TL= 10.1513579 TR= 40  LA=23908.80
HP=0 BO=.096 SO=.518 SYS=.063 EF=0.739
QC=0 QE=0 W=0 QB=24026.95 QS=  7722.68 Y=  14580.02 P=332.00
TS= 10 TH= 7.37449707 TL= 10.6621968 TR= 40  LA=22529.61
HP=.357 BO=0 SO=.619 SYS=.240 EF=3.090
QC=22644.98 QE=16379.25 W=6961.93 QB=0 QS= 26148.16 Y=  33798.29 P=328.40
TS= 11 TH= 8.29917622 TL= 11.9039534 TR= 40  LA=20954.98
HP=.346 BO=0 SO=.626 SYS=.223 EF=3.079
QC=21067.19 QE=15238.01 W=6476.86 QB=0 QS= 38877.98 Y=  57386.68 P=328.40
TS= 12 TH= 9.18863298 TL= 13.5048821 TR= 40  LA=19370.29
HP=.334 BO=0 SO=.626 SYS=.207 EF=3.066
QC=19479.31 QE=14089.50 W=5988.68 QB=0 QS= 44289.17 Y=  65433.76 P=328.40
TS= 13 TH= 9.9381505 TL= 15.1545871 TR= 40  LA=17962.12
HP=.322 BO=0 SO=.624 SYS=.195 EF=3.053
QC=18068.30 QE=13068.91 W=5554.89 QB=0 QS= 44338.71 Y=  66399.11 P=328.40
TS= 14 TH= 10.4594871 TL= 16.5650417 TR= 40  LA=16896.24
HP=.312 BO=0 SO=.616 SYS=.190 EF=3.042
QC=17000.28 QE=12296.40 W=5226.53 QB=0 QS= 39106.75 Y=  60178.48 P=328.40
TS= 15 TH= 10.6912652 TL= 17.3855971 TR= 40  LA=16298.15
HP=.306 BO=0 SO=.590 SYS=.196 EF=3.035
QC=16400.98 QE=11862.92 W=5042.29 QB=0 QS= 27607.36 Y=  45154.38 P=328.40
TS= 16 TH= 10.6061973 TL= 17.2691415 TR= 40  LA=16238.26
HP=.305 BO=0 SO=.466 SYS=.217 EF=3.034
QC=16340.97 QE=11819.52 W=5023.84 QB=0 QS=  9942.65 Y=  21109.15 P=328.40
TS= 17 TH= 10.2142985 TL= 16.6062368 TR= 40  LA=16723.61
HP=.308 BO=0 SO=0 SYS=.255 EF=3.230
QC=16827.30 QE=12171.28 W=5173.35 QB=0 QS=0 Y=0 P=  4.40
TS= 18 TH= 9.56170752 TL= 15.9061478 TR= 40  LA=17697.08
HP=.315 BO=0 SO=0 SYS=.258 EF=3.231
QC=17802.73 QE=12876.81 W=5473.24 QB=0 QS=0 Y=0 P=  4.40
TS= 19 TH= 8.72525478 TL= 15.1540717 TR= 40  LA=19044.04
HP=.324 BO=0 SO=0 SYS=.262 EF=3.232
QC=19152.40 QE=13853.04 W=5888.18 QB=0 QS=0 Y=0 P=  4.40
TS= 20 TH= 7.80341687 TL= 14.341567 TR= 40  LA=20605.93
HP=.335 BO=0 SO=0 SYS=.267 EF=3.233
QC=20717.43 QE=14985.04 W=6369.33 QB=0 QS=0 Y=0 P=  4.40
TS= 21 TH= 6.90472296 TL= 13.4675471 TR= 40  LA=22198.85
HP=.345 BO=0 SO=0 SYS=.272 EF=3.234
QC=22313.56 QE=16139.53 W=6860.04 QB=0 QS=0 Y=0 P=  4.40
TS= 22 TH= 6.13497738 TL= 12.5384076 TR= 40  LA=23635.28
HP=.355 BO=0 SO=0 SYS=.276 EF=3.235
QC=23752.88 QE=17180.59 W=7302.54 QB=0 QS=0 Y=0 P=  4.40
TS= 23 TH= 5.58480326 TL= 11.5672724 TR= 40  LA=24746.09
HP=.363 BO=0 SO=0 SYS=.280 EF=3.235
QC=24865.93 QE=17985.67 W=7644.74 QB=0 QS=0 Y=0 P=  4.40
*****THE DAY'S CUMULATIVE*****
TOTAL HEATING LOAD:LA=355521.76
W= 96751.37 QS=238033.46 QB= 42743.42 P=2674.20 Y=  370039.86
EF= 2.273 EX=.180
```

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**************JANUARY************
TL= 10 Q= 40000 AR= 60
TS= 7 TH= 2.53563095 TL= 9.98131117 TR= 40  LA=30501.31
 HP=0 BO=.109 SO=0 SYS=.069 EF=0.747
QC=0 QE=0 W=0 QB=30632.74 QS=0 Y=0 P=  8.00
TS= 8 TH= 2.95367916 TL= 9.96344842 TR= 40  LA=29954.43
 HP=0 BO=.108 SO=0 SYS=.068 EF=0.747
QC=0 QE=0 W=0 QB=30084.76 QS=0 Y=0 P=  8.00
TS= 9 TH= 3.60836832 TL= 10.0618882 TR= 40  LA=28961.97
HP=.390 BO=.106 SO=.419 SYS=.082 EF=0.914
QC= 7238.06 QE= 5235.33 W=2225.26 QB=21852.23 QS= 7397.71 Y=  17415.02 P=331.1
TS= 10 TH= 4.42751619 TL= 10.302446 TR= 40  LA=27633.35
HP=.384 BO=0 SO=.586 SYS=.249 EF=3.118
QC=27759.01 QE=20078.25 W=8534.18 QB=0 QS=24886.60 Y=  41014.25 P=328.40
TS= 11 TH= 5.32080824 TL= 11.2389331 TR= 40  LA=26115.06
HP=.375 BO=0 SO=.613 SYS=.232 EF=3.111
QC=26237.66 QE=18977.85 W=8066.46 QB=0 QS=36873.54 Y=  57294.48 P=328.40
TS= 12 TH= 6.18975525 TL= 12.5146354 TR= 40  LA=24574.50
HP=.364 BO=0 SO=.616 SYS=.219 EF=3.103
QC=24693.93 QE=17861.31 W=7591.88 QB=0 QS=42153.29 Y=  64844.77 P=328.40
TS= 13 TH= 6.93855214 TL= 13.8561987 TR= 40  LA=23181.52
HP=.353 BO=0 SO=.613 SYS=.210 EF=3.095
QC=23298.21 QE=16851.73 W=7162.76 QB=0 QS=42408.19 Y=  65763.16 P=328.40
TS= 14 TH= 7.48464087 TL= 14.9867914 TR= 40  LA=22089.70
HP=.344 BO=0 SO=.603 SYS=.207 EF=3.087
QC=22204.19 QE=16060.42 W=6826.41 QB=0 QS=37675.21 Y=  59896.36 P=328.40
TS= 15 TH= 7.76781285 TL= 15.5854506 TR= 40  LA=21419.42
HP=.338 BO=0 SO=.574 SYS=.214 EF=3.083
QC=21532.56 QE=15574.62 W=6619.93 QB=0 QS=27200.78 Y=  45369.27 P=328.40
TS= 16 TH= 7.75684718 TL= 15.3265375 TR= 40  LA=21244.58
HP=.336 BO=0 SO=.459 SYS=.233 EF=3.081
QC=21357.37 QE=15447.90 W=6566.07 QB=0 QS=10936.40 Y=  23590.07 P=328.40
TS= 17 TH= 7.45295296 TL= 14.4745369 TR= 40  LA=21584.46
HP=.339 BO=0 SO=0 SYS=.270 EF=3.234
QC=21697.93 QE=15694.24 W=6670.77 QB=0 QS=0 Y=0 P=  4.40
TS= 18 TH= 6.89963554 TL= 13.592156 TR= 40  LA=22401.58
HP=.346 BO=0 SO=0 SYS=.273 EF=3.234
QC=22516.70 QE=16286.46 W=6922.49 QB=0 QS=0 Y=0 P=  4.40
TS= 19 TH= 6.12900333 TL= 12.6638805 TR= 40  LA=23605.86
HP=.355 BO=0 SO=0 SYS=.276 EF=3.235
QC=23723.40 QE=17159.27 W=7293.48 QB=0 QS=0 Y=0 P=  4.40
TS= 20 TH= 5.25491914 TL= 11.6797299 TR= 40  LA=25064.51
HP=.365 BO=0 SO=0 SYS=.281 EF=3.235
QC=25194.99 QE=18216.45 W=7742.83 QB=0 QS=0 Y=0 P=  4.40
TS= 21 TH= 4.36375446 TL= 10.6361131 TR= 40  LA=26616.72
HP=.376 BO=0 SO=0 SYS=.296 EF=3.236
QC=26740.33 QE=19341.43 W=8221.00 QB=0 QS=0 Y=0 P=  4.40
TS= 22 TH= 3.55376397 TL= 9.81219025 TR= 40  LA=28091.35
HP=.385 BO=.106 SO=0 SYS=.157 EF=1.750
QC=21035.48 QE=15215.08 W=6467.11 QB= 7182.44 QS=0 Y=0 P=  5.30
TS= 23 TH= 2.91425255 TL= 9.79564241 TR= 40  LA=29325.81
 HP=0 BO=.107 SO=0 SYS=.068 EF=0.747
QC=0 QE=0 W=0 QB=29454.86 QS=0 Y=0 P=  8.00
*****THE DAY'S CUMULATIVE*****
TOTAL HEATING LOAD:LA=439848.81
W= 99310.91 QS=229531.72 QB=126722.29 P=2693.20 Y=375787.39
EF= 1.638 EX=.138
```

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**************FEBRUARY***********
TL= 12.5 Q= 40000 AR= 60
TS= 7 TH= 3.17849708 TL= 11.3392587 TR= 40  LA=29502.88
HP=.388 BO=0 SO=0 SYS=.294 EF=3.237
QC=29632.30 QE=21433.21 W=9110.10 QB=0 QS=0 Y=0 P=  4.40
TS= 8 TH= 3.72060401 TL= 10.3541723 TR= 40  LA=28691.07
HP=.387 BO=0 SO=.351 SYS=.281 EF=3.179
QC=28818.85 QE=20844.84 W=8860.01 QB=0 QS= 2643.90 Y=   7455.13 P=166.40
TS= 9 TH= 4.42305666 TL= 10.3884097 TR= 40  LA=27566.24
HP=.383 BO=0 SO=.569 SYS=.252 EF=3.113
QC=27691.76 QE=20029.60 W=8513.50 QB=0 QS=20960.46 Y=  35727.69 P=328.40
TS= 10 TH= 5.2225553 TL= 11.4882074 TR= 40  LA=26229.75
HP=.375 BO=0 SO=.615 SYS=.228 EF=3.111
QC=26352.57 QE=19060.97 W=8101.79 QB=0 QS=40039.99 Y=  61887.52 P=328.40
TS= 11 TH= 6.04705515 TL= 13.2951493 TR= 40  LA=24802.03
HP=.364 BO=0 SO=.620 SYS=.206 EF=3.104
QC=24921.98 QE=18026.21 W=7661.97 QB=0 QS=52346.59 Y=  79602.46 P=328.40
TS= 12 TH= 6.82225853 TL= 15.433436 TR= 40  LA=23411.74
HP=.351 BO=0 SO=.618 SYS=.187 EF=3.096
QC=23528.89 QE=17018.58 W=7233.68 QB=0 QS=57631.72 Y=  88192.23 P=328.40
TS= 13 TH= 7.47830997 TL= 17.5959196 TR= 40  LA=22184.16
HP=.339 BO=0 SO=.612 SYS=.174 EF=3.088
QC=22298.85 QE=16128.88 W=6855.52 QB=0 QS=57266.21 Y=  89270.38 P=328.40
TS= 14 TH= 7.95603108 TL= 19.4696521 TR= 40  LA=21229.92
HP=.329 BO=0 SO=.597 SYS=.168 EF=3.081
QC=21342.68 QE=15437.28 W=6561.55 QB=0 QS=51209.21 Y=  82506.72 P=328.40
TS= 15 TH= 8.21254783 TL= 20.7246888 TR= 40  LA=20634.99
HP=.322 BO=0 SO=.567 SYS=.174 EF=3.077
QC=20746.56 QE=15006.10 W=6378.28 QB=0 QS=39191.04 Y=  67250.15 P=328.40
TS= 16 TH= 8.22457028 TL= 21.0140798 TR= 40  LA=20453.00
HP=.319 BO=0 SO=.482 SYS=.195 EF=3.075
QC=20564.20 QE=14874.20 W=6322.22 QB=0 QS=20915.37 Y=  42742.13 P=328.40
TS= 17 TH= 7.99107506 TL= 20.3312707 TR= 40  LA=20700.34
HP=.321 BO=0 SO=.259 SYS=.243 EF=3.153
QC=20812.03 QE=15053.46 W=6398.41 QB=0 QS= 2790.95 Y=  10788.91 P=166.40
TS= 18 TH= 7.533103 TL= 19.4760729 TR= 40  LA=21354.72
HP=.329 BO=0 SO=0 SYS=.269 EF=3.233
QC=21467.73 QE=15527.73 W=6600.99 QB=0 QS=0 Y=0 P=  4.40
TS= 19 TH= 6.99192307 TL= 18.5830124 TR= 40  LA=22357.17
HP=.333 BO=0 SO=0 SYS=.273 EF=3.234
QC=22472.20 QE=16254.27 W=6908.31 QB=0 QS=0 Y=0 P=  4.40
TS= 20 TH= 6.12531355 TL= 17.6419044 TR= 40  LA=23617.37
HP=.342 BO=0 SO=0 SYS=.276 EF=3.235
QC=23734.94 QE=17167.61 W=7297.02 QB=0 QS=0 Y=0 P=  4.40
TS= 21 TH= 5.30235551 TL= 16.647186 TR= 40  LA=25021.75
HP=.351 BO=0 SO=0 SYS=.281 EF=3.225
QC=25142.14 QE=18185.45 W=7729.85 QB=0 QS=0 Y=0 P=  4.40
TS= 22 TH= 4.4972077 TL= 15.5380081 TR= 40  LA=26443.75
HP=.361 BO=0 SO=0 SYS=.285 EF=3.236
QC=26567.01 QE=19216.07 W=8157.71 QB=0 QS=0 Y=0 P=  4.40
TS= 23 TH= 3.79242384 TL= 14.4930497 TR= 40  LA=27755.25
HP=.371 BO=0 SO=0 SYS=.289 EF=3.236
QC=27881.15 QE=20166.59 W=8571.73 QB=0 QS=0 Y=0 P=  4.40
*****THE DAY'S CUMULATIVE*****
TOTAL HEATING LOAD:LA=413075.42
W=129470.40 QS=344035.44 QB=     0.00 P=2331.90 Y=565423.31
EF= 3.164 EX=.236
```

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****************MARCH***********
TL= 20 Q= 40000 AR= 60
TS= 7 TH= 4.51463996 TL= 18.9063561 TR= 40  LA=27354.38
HP=.357 BO=0 SO=0 SYS=.288 EF=3.236
QC=27479.47 QE=19876.06 W=8448.24 QB=0 QS=0 Y=0 P=  4.40
TS= 8 TH= 5.28214198 TL= 18.2348976 TR= 40  LA=26114.52
HP=.354 BO=0 SO=.336 SYS=.247 EF=3.141
QC=26237.11 QE=18977.45 W=8066.29 QB=0 QS=  6963.50 Y=  20514.86 P=247.40
TS= 9 TH= 6.15081625 TL= 18.7186947 TR= 40  LA=24661.73
HP=.347 BO=0 SO=.522 SYS=.205 EF=3.103
QC=24781.40 QE=17924.52 W=7618.75 QB=0 QS= 27618.23 Y=  51866.15 P=328.40
TS= 10 TH= 7.05867792 TL= 20.2203031 TR= 40  LA=23099.67
HP=.337 BO=0 SO=.576 SYS=.174 EF=3.094
QC=23216.19 QE=16792.40 W=7137.54 QB=0 QS= 45649.27 Y=  76898.62 P=328.40
TS= 11 TH= 7.94094587 TL= 22.388275 TR= 40  LA=21539.80
HP=.325 BO=0 SO=.589 SYS=.149 EF=3.084
QC=21653.19 QE=15661.87 W=6657.02 QB=0 QS= 57106.65 Y=  93766.66 P=328.40
TS= 12 TH= 8.73468525 TL= 24.8738212 TR= 40  LA=20093.44
HP=.313 BO=0 SO=.587 SYS=.131 EF=3.072
QC=20203.91 QE=14613.60 W=6211.45 QB=0 QS= 62106.93 Y= 102309.15 P=328.40
TS= 13 TH= 9.38319965 TL= 27.3693369 TR= 40  LA=18863.78
HP=.301 BO=0 SO=.577 SYS=.119 EF=3.062
QC=18971.78 QE=13722.40 W=5832.65 QB=0 QS= 61487.99 Y= 103403.99 P=328.40
TS= 14 TH= 9.84027245 TL= 29.5587615 TR= 40  LA=17938.58
HP=.292 BO=0 SO=.557 SYS=.114 EF=3.053
QC=18044.71 QE=13051.84 W=5547.63 QB=0 QS= 55141.55 Y=  96608.47 P=328.40
TS= 15 TH= 10.0732689 TL= 31.1364923 TR= 40  LA=17383.84
HP=.285 BO=0 SO=.519 SYS=.119 EF=3.047
QC=17488.86 QE=12649.79 W=5376.74 QB=0 QS= 43300.17 Y=  81963.02 P=328.40
TS= 16 TH= 10.0655633 TL= 31.7788364 TR= 40  LA=17239.15
HP=.283 BO=0 SO=.432 SYS=.137 EF=3.045
QC=17343.88 QE=12544.93 W=5332.17 QB=0 QS= 25637.89 Y=  58691.20 P=328.40
TS= 17 TH= 9.81770558 TL= 31.3551424 TR= 40  LA=17514.84
HP=.284 BO=0 SO=.225 SYS=.186 EF=3.092
QC=17620.13 QE=12744.74 W=5417.10 QB=0 QS=  5794.14 Y=  25674.29 P=247.40
TS= 18 TH= 9.34738178 TL= 30.5987818 TR= 40  LA=18191.24
HP=.288 BO=0 SO=0 SYS=.260 EF=3.231
QC=18297.88 QE=13234.96 W=5625.47 QB=0 QS=0 Y=0 P=  4.40
TS= 19 TH= 8.68815216 TL= 29.8032612 TR= 40  LA=19220.08
HP=.295 BO=0 SO=0 SYS=.263 EF=3.232
QC=19328.79 QE=13980.62 W=5942.41 QB=0 QS=0 Y=0 P=  4.40
TS= 20 TH= 7.88705654 TL= 28.9575501 TR= 40  LA=20527.94
HP=.303 BO=0 SO=0 SYS=.267 EF=3.233
QC=20639.28 QE=14928.51 W=6345.30 QB=0 QS=0 Y=0 P=  4.40
TS= 21 TH= 7.00125766 TL= 28.0543673 TR= 40  LA=22021.50
HP=.312 BO=0 SO=0 SYS=.272 EF=3.234
QC=22135.86 QE=16010.99 W=6805.41 QB=0 QS=0 Y=0 P=  4.40
TS= 22 TH= 6.09396233 TL= 27.0907003 TR= 40  LA=23594.20
HP=.321 BO=0 SO=0 SYS=.276 EF=3.235
QC=23711.72 QE=17150.82 W=7289.89 QB=0 QS=0 Y=0 P=  4.40
TS= 23 TH= 5.22991125 TL= 26.0680197 TR= 40  LA=25133.80
HP=.331 BO=0 SO=0 SYS=.281 EF=3.235
QC=25254.42 QE=18266.66 W=7764.17 QB=0 QS=0 Y=0 P=  4.40
*****THE DAY'S CUMULATIVE*****
TOTAL HEATING LOAD:LA=367002.04
W=113428.91 QS=390302.31 QB=     0.00 P=3153.90 Y= 711696.40
EF= 3.148 EX=.191
```

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***************DECEMBER**********
TL= 20 Q= 40000 AR= 90
TS= 7 TH= 5.42261632 TL= 19.3136126 TR= 40  LA=25473.49
HP=.348 BO=0 SO=0 SYS=.282 EF=3.235
QC=25594.80 QE=18512.86 W=7868.82 QB=0 QS=0 Y=0 P=  4.40
TS= 8 TH= 5.84625626 TL= 18.6433017 TR= 40  LA=24930.18
HP=.347 BO=0 SO=0 SYS=.280 EF=3.235
QC=25050.38 QE=18119.09 W=7701.44 QB=0 QS=0 Y=0 P=  4.40
TS= 9 TH= 6.52345916 TL= 18.1613776 TR= 40  LA=23908.80
HP=.343 BO=0 SO=.283 SYS=.247 EF=3.132
QC=24026.95 QE=17378.83 W=7386.80 QB=0 QS=  4505.34 Y=  15842.01 P=247.40
TS= 10 TH= 7.37449707 TL= 18.6161177 TR= 40  LA=22529.61
HP=.336 BO=0 SO=.493 SYS=.192 EF=3.023
QC=22644.98 QE=16379.25 W=6961.93 QB=0 QS= 29302.33 Y=  53697.44 P=490.40
TS= 11 TH= 8.29917622 TL= 19.7902645 TR= 40  LA=20954.98
HP=.326 BO=0 SO=.556 SYS=.163 EF=3.008
QC=21067.19 QE=15238.01 W=6476.86 QB=0 QS= 49070.11 Y=  86080.01 P=490.40
TS= 12 TH= 9.18863298 TL= 21.2948916 TR= 40  LA=19370.29
HP=.315 BO=0 SO=.568 SYS=.145 EF=2.990
QC=19479.31 QE=14089.50 W=5988.68 QB=0 QS= 57280.23 Y=  98150.64 P=490.40
TS= 13 TH= 9.9381505 TL= 22.8406636 TR= 40  LA=17962.12
HP=.304 BO=0 SO=.562 SYS=.134 EF=2.971
QC=18068.30 QE=13068.91 W=5554.89 QB=0 QS= 57466.22 Y=  99598.66 P=490.40
TS= 14 TH= 10.4594871 TL= 24.1385093 TR= 40  LA=16896.24
HP=.296 BO=0 SO=.539 SYS=.132 EF=2.955
QC=17000.28 QE=12296.40 W=5226.53 QB=0 QS= 49743.81 Y=  90267.72 P=490.40
TS= 15 TH= 10.6912652 TL= 24.8440295 TR= 40  LA=16298.15
HP=.290 BO=0 SO=.475 SYS=.144 EF=2.946
QC=16400.98 QE=11862.92 W=5042.29 QB=0 QS= 32627.75 Y=  67731.57 P=490.40
TS= 16 TH= 10.6061973 TL= 24.6562773 TR= 40  LA=16238.26
HP=.289 BO=0 SO=.268 SYS=.190 EF=3.011
QC=16340.97 QE=11819.52 W=5023.84 QB=0 QS=  7376.49 Y=  27473.45 P=368.90
TS= 17 TH= 10.2142985 TL= 24.1950477 TR= 40  LA=16723.61
HP=.293 BO=0 SO=0 SYS=.255 EF=3.230
QC=16827.30 QE=12171.28 W=5173.35 QB=0 QS=0 Y=0 P=  4.40
TS= 18 TH= 9.56170752 TL= 23.7086439 TR= 40  LA=17697.08
HP=.299 BO=0 SO=0 SYS=.258 EF=3.231
QC=17802.73 QE=12876.81 W=5473.24 QB=0 QS=0 Y=0 P=  4.40
TS= 19 TH= 8.72525478 TL= 23.1870828 TR= 40  LA=19044.04
HP=.307 BO=0 SO=0 SYS=.262 EF=3.232
QC=19152.40 QE=13853.04 W=5888.18 QB=0 QS=0 Y=0 P=  4.40
TS= 20 TH= 7.80341687 TL= 22.6246645 TR= 40  LA=20605.93
HP=.316 BO=0 SO=0 SYS=.267 EF=3.233
QC=20717.43 QE=14985.04 W=6369.33 QB=0 QS=0 Y=0 P=  4.40
TS= 21 TH= 6.90472296 TL= 22.0206435 TR= 40  LA=22198.85
HP=.325 BO=0 SO=0 SYS=.272 EF=3.234
QC=22313.56 QE=16139.53 W=6860.04 QB=0 QS=0 Y=0 P=  4.40
TS= 22 TH= 6.13497738 TL= 21.3793157 TR= 40  LA=23635.28
HP=.334 BO=0 SO=0 SYS=.276 EF=3.235
QC=23752.88 QE=17180.59 W=7302.54 QB=0 QS=0 Y=0 P=  4.40
TS= 23 TH= 5.58480326 TL= 20.7095126 TR= 40  LA=24746.09
HP=.341 BO=0 SO=0 SYS=.280 EF=3.235
QC=24865.93 QE=17985.67 W=7644.74 QB=0 QS=0 Y=0 P=  4.40
*****THE DAY'S CUMULATIVE*****
TOTAL HEATING LOAD:LA=355521.76
W=109892.33 QS=287972.29 QB=     0.00 P=3599.40 Y=  544841.50
EF= 3.133 EX=.213
```

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**************JANUARY************
TL= 12.5 Q= 40000 AR= 90
TS= 7 TH= 2.53563095 TL= 11.6945809 TR= 40  LA=30501.31
HP=.392 BO=0 SO=0 SYS=.297 EF=3.237
QC=30632.74 QE=22156.83 W=9417.67 QB=0 QS=0 Y=0 P=  4.40
TS= 8 TH= 2.95367916 TL= 10.9055893 TR= 40  LA=29954.43
HP=.392 BO=0 SO=0 SYS=.296 EF=3.237
QC=30084.76 QE=21760.48 W=9249.20 QB=0 QS=0 Y=0 P=  4.40
TS= 9 TH= 3.60835832 TL= 10.5104249 TR= 40  LA=28961.97
HP=.389 BO=0 SO=.441 SYS=.264 EF=3.110
QC=29090.30 QE=21041.18 W=8943.47 QB=0 QS=10325.22 Y=  23054.23 P=368.90
TS= 10 TH= 4.42751619 TL= 11.0834219 TR= 40  LA=27633.35
HP=.383 BO=0 SO=.578 SYS=.231 EF=3.062
QC=27759.01 QE=20078.25 W=8534.18 QB=0 QS=36658.26 Y=  61521.37 P=490.40
TS= 11 TH= 5.32080824 TL= 12.3188564 TR= 40  LA=26115.06
HP=.372 BO=0 SO=.605 SYS=.208 EF=3.052
QC=26237.66 QE=18977.85 W=8066.46 QB=0 QS=54265.59 Y=  85941.73 P=490.40
TS= 12 TH= 6.18975525 TL= 13.8613502 TR= 40  LA=24574.50
HP=.361 BO=0 SO=.608 SYS=.191 EF=3.041
QC=24693.99 QE=17861.31 W=7591.88 QB=0 QS=61850.81 Y=  97267.15 P=490.40
TS= 13 TH= 6.93355214 TL= 15.4408994 TR= 40  LA=23181.52
HP=.349 BO=0 SO=.602 SYS=.180 EF=3.029
QC=23298.21 QE=16851.73 W=7162.76 QB=0 QS=61934.96 Y=  98644.74 P=490.40
TS= 14 TH= 7.48464087 TL= 16.7857541 TR= 40  LA=22089.70
HP=.340 BO=0 SO=.587 SYS=.176 EF=3.019
QC=22204.19 QE=16060.42 W=6826.41 QB=0 QS=54568.80 Y=  89844.54 P=490.40
TS= 15 TH= 7.76781285 TL= 17.5812649 TR= 40  LA=21419.42
HP=.333 BO=0 SO=.547 SYS=.185 EF=3.012
QC=21532.56 QE=15574.62 W=6619.93 QB=0 QS=38615.48 Y=  68953.91 P=490.40
TS= 16 TH= 7.75684718 TL= 17.5086679 TR= 40  LA=21244.58
HP=.331 BO=0 SO=.393 SYS=.213 EF=3.011
QC=21357.37 QE=15447.90 W=6566.07 QB=0 QS=13994.54 Y=  35385.11 P=490.40
TS= 17 TH= 7.45295286 TL= 16.9321388 TR= 40  LA=21584.46
HP=.334 BO=0 SO=0 SYS=.270 EF=3.234
QC=21697.93 QE=15694.24 W=6670.77 QB=0 QS=0 Y=0 P=  4.40
TS= 18 TH= 6.88963554 TL= 16.3348844 TR= 40  LA=22401.52
HP=.339 BO=0 SO=0 SYS=.273 EF=3.234
QC=22516.70 QE=16286.46 W=6922.49 QB=0 QS=0 Y=0 P=  4.40
TS= 19 TH= 6.12900333 TL= 15.7065451 TR= 40  LA=23605.86
HP=.347 BO=0 SO=0 SYS=.276 EF=3.235
QC=23723.40 QE=17159.27 W=7293.48 QB=0 QS=0 Y=0 P=  4.40
TS= 20 TH= 5.25491914 TL= 15.0403519 TR= 40  LA=25064.51
HP=.356 BO=0 SO=0 SYS=.281 EF=3.235
QC=25184.99 QE=18216.45 W=7742.83 QB=0 QS=0 Y=0 P=  4.40
TS= 21 TH= 4.36375446 TL= 14.3338725 TR= 40  LA=26616.72
HP=.366 BO=0 SO=0 SYS=.286 EF=3.236
QC=26740.33 QE=19341.43 W=8221.00 QB=0 QS=0 Y=0 P=  4.40
TS= 22 TH= 3.55376397 TL= 13.589279 TR= 40  LA=28091.35
HP=.375 BO=0 SO=0 SYS=.290 EF=3.236
QC=28217.92 QE=20410.12 W=8675.26 QB=0 QS=0 Y=0 P=  4.40
TS= 23 TH= 2.91425255 TL= 12.8131085 TR= 40  LA=29325.81
HP=.384 BO=0 SO=0 SYS=.294 EF=3.237
QC=29454.86 QE=21304.87 W=9055.55 QB=0 QS=0 Y=0 P=  4.40
*****THE DAY'S CUMULATIVE*****
TOTAL HEATING LOAD:LA=439848.81
W=135869.87 QS=332213.62 QB=     0.00 P=3842.40 Y=560612.83
EF= 3.148 EX=.244
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**************FEBRUARY***********
TL= 12.5 Q= 40000 AR= 90
TS= 7 TH= 3.17849708 TL= 11.7214152 TR= 40  LA=29502.88
HP=.388 BO=0 SO=0 SYS=.294 EF=3.237
QC=29632.30 QE=21433.21 W=9110.10 QB=0 QS=0 Y=0 P=  4.40
TS= 8 TH= 3.72060401 TL= 11.0940804 TR= 40  LA=28691.07
HP=.386 BO=0 SO=.320 SYS=.275 EF=3.150
QC=28818.85 QE=20844.84 W=8860.01 QB=0 QS= 3608.78 Y=  11182.70 P=247.40
TS= 9 TH= 4.42305666 TL= 11.4475147 TR= 40  LA=27566.24
HP=.381 BO=0 SO=.554 SYS=.234 EF=3.062
QC=27691.76 QE=20029.60 W=8513.50 QB=0 QS=30435.28 Y=  53591.54 P=490.40
TS= 10 TH= 5.2225553 TL= 12.8358858 TR= 40  LA=26229.75
HP=.372 BO=0 SO=.606 SYS=.201 EF=3.053
QC=26352.57 QE=19060.97 W=8101.79 QB=0 QS=58695.62 Y=  92831.28 P=490.40
TS= 11 TH= 6.04705515 TL= 14.9012328 TR= 40  LA=24802.03
HP=.360 BO=0 SO=.613 SYS=.173 EF=3.042
QC=24921.98 QE=18026.21 W=7661.97 QB=0 QS=76832.24 Y= 119403.69 P=490.40
TS= 12 TH= 6.82225853 TL= 17.2697149 TR= 40  LA=23411.74
HP=.347 BO=0 SO=.610 SYS=.152 EF=3.031
QC=23528.89 QE=17018.58 W=7233.68 QB=0 QS=84471.12 Y= 132288.34 P=490.40
TS= 13 TH= 7.47830997 TL= 19.6375509 TR= 40  LA=22184.16
HP=.335 BO=0 SO=.600 SYS=.138 EF=3.020
QC=22298.85 QE=16128.88 W=6855.52 QB=0 QS=83665.59 Y= 133905.57 P=490.40
TS= 14 TH= 7.95609108 TL= 21.6963288 TR= 40  LA=21229.92
HP=.325 BO=0 SO=.582 SYS=.133 EF=3.011
QC=21342.68 QE=15437.28 W=6561.55 QB=0 QS=74349.90 Y= 123760.08 P=490.40
TS= 15 TH= 8.21254783 TL= 23.121445 TR= 40  LA=20634.99
HP=.317 BO=0 SO=.544 SYS=.139 EF=3.004
QC=20746.56 QE=15006.10 W=6378.28 QB=0 QS=56113.87 Y= 100875.23 P=490.40
TS= 16 TH= 8.22457028 TL= 23.5716326 TR= 40  LA=20453.00
HP=.314 BO=0 SO=.440 SYS=.164 EF=3.002
QC=20564.20 QE=14874.20 W=6322.22 QB=0 QS=28506.56 Y=  64113.19 P=490.40
TS= 17 TH= 7.99107506 TL= 23.1007231 TR= 40  LA=20700.34
HP=.315 BO=0 SO=.166 SYS=.229 EF=3.115
QC=20812.03 QE=15053.46 W=6398.41 QB=0 QS= 2683.36 Y=  16183.37 P=247.40
TS= 18 TH= 7.533103 TL= 22.5183699 TR= 40  LA=21354.72
HP=.320 BO=0 SO=0 SYS=.269 EF=3.233
QC=21467.73 QE=15527.73 W=6600.00 QB=0 QS=0 Y=0 P=  4.40
TS= 19 TH= 6.89192307 TL= 21.9103239 TR= 40  LA=22357.17
HP=.326 BO=0 SO=0 SYS=.273 EF=3.234
QC=22472.20 QE=16254.27 W=6908.81 QB=0 QS=0 Y=0 P=  4.40
TS= 20 TH= 6.12531355 TL= 21.2697139 TR= 40  LA=23617.37
HP=.334 BO=0 SO=0 SYS=.276 EF=3.235
QC=23734.94 QE=17167.61 W=7297.02 QB=0 QS=0 Y=0 P=  4.40
TS= 21 TH= 5.30235551 TL= 20.5927353 TR= 40  LA=25021.75
HP=.342 BO=0 SO=0 SYS=.281 EF=3.235
QC=25142.14 QE=18185.45 W=7729.65 QB=0 QS=0 Y=0 P=  4.40
TS= 22 TH= 4.4972077 TL= 19.8789931 TR= 40  LA=26443.75
HP=.351 BO=0 SO=0 SYS=.285 EF=3.236
QC=26567.01 QE=19216.07 W=8167.71 QB=0 QS=0 Y=0 P=  4.40
TS= 23 TH= 3.78242394 TL= 19.1315365 TR= 40  LA=27755.25
HP=.359 BO=0 SO=0 SYS=.289 EF=3.236
QC=27881.15 QE=20166.59 W=8571.73 QB=0 QS=0 Y=0 P=  4.40
*****THE DAY'S CUMULATIVE*****
TOTAL HEATING LOAD:LA=419075.42
W=129470.48 QS=499362.32 QB=     0.00 P=4449.90 Y=848134.97
EF= 3.129 EX=.213
```

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****************MARCH***********
TL= 20 Q= 40000 AR= 90
TS= 7 TH= 4.51463996 TL= 19.2630677 TR= 40  LA=27354.38
HP=.357 BO=0 SO=0 SYS=.288 EF=3.236
QC=27479.47 QE=19876.06 W=8449.24 QB=0 QS=0 Y=0 P=  4.40
TS= 8 TH= 5.28214198 TL= 19.9148625 TR= 40  LA=26114.52
HP=.353 BO=0 SO=.322 SYS=.231 EF=3.096
QC=26237.11 QE=18977.45 W=8066.29 QB=0 QS=  9996.25 Y=  30772.28 P=368.90
TS= 9 TH= 6.15081625 TL= 19.6858512 TR= 40  LA=24661.73
HP=.345 BO=0 SO=.512 SYS=.178 EF=3.041
QC=24781.40 QE=17924.52 W=7618.75 QB=0 QS= 40505.65 Y=  77799.22 P=490.40
TS= 10 TH= 7.05867792 TL= 21.4426431 TR= 40  LA=23099.67
HP=.335 BO=0 SO=.567 SYS=.143 EF=3.028
QC=23216.19 QE=16792.40 W=7137.54 QB=0 QS= 67231.33 Y= 115347.92 P=490.40
TS= 11 TH= 7.94094587 TL= 23.8354944 TR= 40  LA=21539.80
HP=.322 BO=0 SO=.580 SYS=.117 EF=3.014
QC=21653.19 QE=15661.87 W=6657.02 QB=0 QS= 84133.22 Y= 140649.99 P=490.40
TS= 12 TH= 8.73466525 TL= 26.5185443 TR= 40  LA=20093.44
HP=.309 BO=0 SO=.578 SYS=.100 EF=2.998
QC=20203.91 QE=14613.60 W=6211.45 QB=0 QS= 91383.64 Y= 153463.73 P=490.40
TS= 13 TH= 9.38319965 TL= 29.1882063 TR= 40  LA=18863.78
HP=.298 BO=0 SO=.566 SYS=.089 EF=2.983
QC=18971.78 QE=13722.40 W=5832.65 QB=0 QS= 90235.48 Y= 155105.98 P=490.40
TS= 14 TH= 9.84027245 TL= 31.5332839 TR= 40  LA=17938.58
HP=.288 BO=0 SO=.544 SYS=.085 EF=2.971
QC=18044.71 QE=13051.84 W=5547.63 QB=0 QS= 80521.27 Y= 144912.71 P=490.40
TS= 15 TH= 10.0732689 TL= 33.253577 TR= 40  LA=17383.84
HP=.282 BO=0 SO=.501 SYS=.089 EF=2.963
QC=17488.86 QE=12649.79 W=5376.74 QB=0 QS= 62583.87 Y= 122944.53 P=490.40
TS= 16 TH= 10.0655633 TL= 34.0309645 TR= 40  LA=17239.15
HP=.279 BO=0 SO=.404 SYS=.107 EF=2.961
QC=17343.88 QE=12544.93 W=5332.17 QB=0 QS= 35927.97 Y=  88036.80 P=490.40
TS= 17 TH= 9.81770558 TL= 33.7644486 TR= 40  LA=17514.84
HP=.280 BO=0 SO=.173 SYS=.158 EF=3.027
QC=17620.13 QE=12744.74 W=5417.10 QB=0 QS=  6677.00 Y=  38511.44 P=368.90
TS= 18 TH= 9.34738178 TL= 33.2442357 TR= 40  LA=18191.24
HP=.284 BO=0 SO=0 SYS=.260 EF=3.231
QC=18297.88 QE=13234.96 W=5625.47 QB=0 QS=0 Y=0 P=  4.40
TS= 19 TH= 8.68815216 TL= 32.6974876 TR= 40  LA=19220.08
HP=.290 BO=0 SO=0 SYS=.263 EF=3.232
QC=19328.79 QE=13980.62 W=5942.41 QB=0 QS=0 Y=0 P=  4.40
TS= 20 TH= 7.88705654 TL= 32.1167629 TR= 40  LA=20527.94
HP=.297 BO=0 SO=0 SYS=.267 EF=3.233
QC=20639.28 QE=14928.51 W=6345.30 QB=0 QS=0 Y=0 P=  4.40
TS= 21 TH= 7.00125766 TL= 31.4971439 TR= 40  LA=22021.59
HP=.306 BO=0 SO=0 SYS=.272 EF=3.234
QC=22135.96 QE=16010.99 W=6805.41 QB=0 QS=0 Y=0 P=  4.40
TS= 22 TH= 6.09396233 TL= 30.8365893 TR= 40  LA=23594.20
HP=.314 BO=0 SO=0 SYS=.279 EF=3.235
QC=23711.72 QE=17150.82 W=7289.89 QB=0 QS=0 Y=0 P=  4.40
TS= 23 TH= 5.22991125 TL= 30.1360737 TR= 40  LA=25133.80
HP=.323 BO=0 SO=0 SYS=.281 EF=3.235
QC=25254.42 QE=18266.66 W=7764.17 QB=0 QS=0 Y=0 P=  4.40
*****THE DAY'S CUMULATIVE*****
TOTAL HEATING LOAD:LA=367002.04
W=113428.91 QS=569195.69 QB=     0.00 P=4692.90 Y= 1067544.60
EF= 3.107 EX=.163
```

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***************DECEMBER**********
TL= 20 Q= 40000 AR= 120
TS= 7 TH= 5.42261632 TL= 19.4803797 TR= 40  LA=25473.49
HP=.348 BO=0 SO=0 SYS=.282 EF=3.235
QC=25594.80 QE=18512.86 W=7868.82 QB=0 QS=0 Y=0 P=  4.40
TS= 8 TH= 5.84625626 TL= 18.9728212 TR= 40  LA=24930.18
HP=.346 BO=0 SO=0 SYS=.280 EF=3.235
QC=25050.38 QE=18119.09 W=7701.44 QB=0 QS=0 Y=0 P=  4.40
TS= 9 TH= 6.52345916 TL= 18.6377406 TR= 40  LA=23908.80
HP=.342 BO=0 SO=.267 SYS=.238 EF=3.099
QC=24026.95 QE=17378.83 W=7386.80 QB=0 QS=  5676.16 Y=  21122.68 P=328.40
TS= 10 TH= 7.37449707 TL= 19.2171482 TR= 40  LA=22529.61
HP=.335 BO=0 SO=.483 SYS=.172 EF=2.959
QC=22644.98 QE=16379.25 W=6961.93 QB=0 QS= 39054.37 Y=  79596.58 P=652.40
TS= 11 TH= 8.29917622 TL= 20.5006873 TR= 40  LA=20954.98
HP=.325 BO=0 SO=.549 SYS=.142 EF=2.939
QC=21067.19 QE=15238.01 W=6476.86 QB=0 QS= 64426.45 Y= 114773.35 P=652.40
TS= 12 TH= 9.18863298 TL= 22.1001374 TR= 40  LA=19370.29
HP=.314 BO=0 SO=.560 SYS=.123 EF=2.917
QC=19479.31 QE=14089.50 W=5988.68 QB=0 QS= 75211.81 Y= 130867.52 P=652.40
TS= 13 TH= 9.9381505 TL= 23.7279671 TR= 40  LA=17962.12
HP=.303 BO=0 SO=.554 SYS=.112 EF=2.894
QC=18068.30 QE=13068.91 W=5554.89 QB=0 QS= 75320.05 Y= 132798.22 P=652.40
TS= 14 TH= 10.4594871 TL= 25.097838 TR= 40  LA=16896.24
HP=.294 BO=0 SO=.529 SYS=.110 EF=2.874
QC=17000.28 QE=12296.40 W=5226.53 QB=0 QS= 64902.12 Y= 120356.96 P=652.40
TS= 15 TH= 10.6912652 TL= 25.8687124 TR= 40  LA=16298.15
HP=.289 BO=0 SO=.459 SYS=.123 EF=2.862
QC=16400.98 QE=11862.92 W=5042.29 QB=0 QS= 41973.02 Y=  90308.77 P=652.40
TS= 16 TH= 10.6061973 TL= 25.7543004 TR= 40  LA=16238.26
HP=.287 BO=0 SO=.235 SYS=.172 EF=2.945
QC=16340.97 QE=11819.52 W=5023.84 QB=0 QS=  8621.85 Y=  36631.26 P=490.40
TS= 17 TH= 10.2142985 TL= 25.4015587 TR= 40  LA=16723.61
HP=.290 BO=0 SO=0 SYS=.255 EF=3.230
QC=16827.30 QE=12171.28 W=5173.35 QB=0 QS=0 Y=0 P=  4.40
TS= 18 TH= 9.56170752 TL= 25.0296927 TR= 40  LA=17697.08
HP=.296 BO=0 SO=0 SYS=.259 EF=3.231
QC=17802.73 QE=12876.81 W=5473.24 QB=0 QS=0 Y=0 P=  4.40
TS= 19 TH= 8.72525479 TL= 24.6311408 TR= 40  LA=19044.04
HP=.304 BO=0 SO=0 SYS=.262 EF=3.232
QC=19152.40 QE=13853.04 W=5888.18 QB=0 QS=0 Y=0 P=  4.40
TS= 20 TH= 7.80341687 TL= 24.2015823 TR= 40  LA=20605.93
HP=.313 BO=0 SO=0 SYS=.267 EF=3.233
QC=20717.43 QE=14985.04 W=6369.33 QB=0 QS=0 Y=0 P=  4.40
TS= 21 TH= 6.90472296 TL= 23.7404466 TR= 40  LA=22198.85
HP=.322 BO=0 SO=0 SYS=.272 EF=3.234
QC=22313.56 QE=16139.53 W=6860.04 QB=0 QS=0 Y=0 P=  4.40
TS= 22 TH= 6.13437738 TL= 23.2509792 TR= 40  LA=23635.28
HP=.330 BO=0 SO=0 SYS=.276 EF=3.235
QC=23752.88 QE=17180.59 W=7302.54 QB=0 QS=0 Y=0 P=  4.40
TS= 23 TH= 5.58480326 TL= 22.7398604 TR= 40  LA=24746.09
HP=.336 BO=0 SO=0 SYS=.280 EF=3.235
QC=24865.93 QE=17985.67 W=7644.74 QB=0 QS=0 Y=0 P=  4.40
*****THE DAY'S CUMULATIVE*****
TOTAL HEATING LOAD:LA=355521.76
W=109892.33 QS=375185.84 QB=     0.00 P=4773.90 Y=  726455.33
EF= 3.100 EX=.197
```

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**************JANUARY***********
TL= 12.5 Q= 40000 AR= 120
TS= 7 TH= 2.53563095 TL= 11.8326059 TR= 40  LA=30501.31
HP=.392 BO=0 SO=0 SYS=.297 EF=3.237
QC=30632.74 QE=22156.83 W=9417.67 QB=0 QS=0 Y=0 P=  4.40
TS= 8 TH= 2.95367916 TL= 11.297516 TR= 40  LA=29354.43
HP=.391 BO=0 SO=0 SYS=.296 EF=3.237
QC=30084.76 QE=21760.48 W=9249.20 QB=0 QS=0 Y=0 P=  4.40
TS= 9 TH= 3.60836932 TL= 11.074336 TR= 40  LA=28961.97
HP=.388 BO=0 SO=.424 SYS=.254 EF=3.070
QC=29090.30 QE=21041.18 W=8943.47 QB=0 QS=13205.28 Y=  30739.03 P=490.40
TS= 10 TH= 4.42751619 TL= 11.7935312 TR= 40  LA=27633.35
HP=.381 BO=0 SO=.568 SYS=.213 EF=3.008
QC=27759.01 QE=20078.25 W=8534.18 QB=0 QS=47903.97 Y=  82028.50 P=652.40
TS= 11 TH= 5.32080824 TL= 13.1710993 TR= 40  LA=26115.06
HP=.370 BO=0 SO=.598 SYS=.186 EF=2.995
QC=26237.66 QE=18977.85 W=8066.46 QB=0 QS=71159.10 Y= 114588.97 P=652.40
TS= 12 TH= 6.18975525 TL= 14.8343133 TR= 40  LA=24574.50
HP=.358 BO=0 SO=.601 SYS=.168 EF=2.981
QC=24693.99 QE=17861.31 W=7591.88 QB=0 QS=81070.14 Y= 129689.54 P=652.40
TS= 13 TH= 6.93855214 TL= 16.5208198 TR= 40  LA=23181.52
HP=.347 BO=0 SO=.594 SYS=.156 EF=2.966
QC=23298.21 QE=16851.73 W=7162.76 QB=0 QS=81002.88 Y= 131526.32 P=652.40
TS= 14 TH= 7.48464087 TL= 17.9613801 TR= 40  LA=22089.70
HP=.337 BO=0 SO=.575 SYS=.152 EF=2.954
QC=22204.19 QE=16060.42 W=6826.41 QB=0 QS=71021.91 Y= 119792.72 P=652.40
TS= 15 TH= 7.76781285 TL= 18.8444652 TR= 40  LA=21419.42
HP=.330 BO=0 SO=.529 SYS=.163 EF=2.945
QC=21532.56 QE=15574.62 W=6619.93 QB=0 QS=49607.12 Y=  91938.54 P=652.40
TS= 16 TH= 7.75684718 TL= 18.8547039 TR= 40  LA=21244.58
HP=.328 BO=0 SO=.351 SYS=.195 EF=2.943
QC=21357.37 QE=15447.90 W=6566.07 QB=0 QS=16646.19 Y=  47180.15 P=652.40
TS= 17 TH= 7.45295288 TL= 18.4164237 TR= 40  LA=21584.46
HP=.330 BO=0 SO=0 SYS=.270 EF=3.234
QC=21697.93 QE=15694.24 W=6670.77 QB=0 QS=0 Y=0 P=  4.40
TS= 18 TH= 6.88963554 TL= 17.9623657 TR= 40  LA=22401.58
HP=.336 BO=0 SO=0 SYS=.273 EF=3.234
QC=22516.70 QE=16286.46 W=6922.49 QB=0 QS=0 Y=0 P=  4.40
TS= 19 TH= 6.12900333 TL= 17.4846838 TR= 40  LA=23605.86
HP=.343 BO=0 SO=0 SYS=.276 EF=3.235
QC=23723.40 QE=17159.27 W=7293.48 QB=0 QS=0 Y=0 P=  4.40
TS= 20 TH= 5.25491914 TL= 16.9792489 TR= 40  LA=25064.51
HP=.352 BO=0 SO=0 SYS=.281 EF=3.235
QC=25194,99 QE=18216.45 W=7742.93 QB=0 QS=0 Y=0 P=  4.40
TS= 21 TH= 4.36375446 TL= 16.4412136 TR= 40  LA=26616.72
HP=.361 BO=0 SO=0 SYS=.286 EF=3.236
QC=26740.33 QE=19341.43 W=8221.00 QB=0 QS=0 Y=0 P=  4.40
TS= 22 TH= 3.55376397 TL= 15.8752162 TR= 40  LA=28091.35
HP=.369 BO=0 SO=0 SYS=.290 EF=3.236
QC=28217.92 QE=20410.18 W=8675.26 QB=0 QS=0 Y=0 P=  4.40
TS= 23 TH= 2.91425255 TL= 15.2851997 TR= 40  LA=29325.81
HP=.377 BO=0 SO=0 SYS=.294 EF=3.237
QC=29454.86 QE=21304.87 W=9055.55 QB=0 QS=0 Y=0 P=  4.40
*****THE DAY'S CUMULATIVE*****
TOTAL HEATING LOAD:LA=439848.81
W=135869.87 QS=431622.60 QB=     0.00 P=5097.90 Y=747483.77
EF= 3.120 EX=.230
```

```
***************FEBRUARY**********
TL= 12.5 Q= 40000 AR= 120
TS= 7 TH= 3.17849708 TL= 11.9129208 TR= 40  LA=29502.88
HP=.387 BO=0 SO=0 SYS=.294 EF=3.237
QC=29632.30 QE=21433.21 W=9110.10 QB=0 QS=0 Y=0 P=  4.40
TS= 8 TH= 3.72060401 TL= 11.4649238 TR= 40  LA=28691.07
HP=.385 BO=0 SO=.304 SYS=.263 EF=3.123
QC=28818.85 QE=20844.84 W=8860.01 QB=0 QS=  4573.11 Y=  14910.26 P=328.40
TS= 9 TH= 4.42305666 TL= 11.9784409 TR= 40  LA=27566.24
HP=.380 BO=0 SO=.546 SYS=.218 EF=3.007
QC=27691.76 QE=20029.60 W=8513.50 QB=0 QS= 39908.44 Y=  71455.39 P=652.40
TS= 10 TH= 5.2225553 TL= 13.5116445 TR= 40  LA=26229.75
HP=.370 BO=0 SO=.600 SYS=.180 EF=2.996
QC=26352.57 QE=19060.97 W=8101.79 QB=0 QS= 77348.81 Y= 123775.04 P=652.40
TS= 11 TH= 6.04705515 TL= 15.7068266 TR= 40  LA=24802.03
HP=.358 BO=0 SO=.608 SYS=.150 EF=2.983
QC=24921.98 QE=18026.21 W=7661.97 QB=0 QS=101314.55 Y= 159204.92 P=652.40
TS= 12 TH= 6.82225853 TL= 18.1911367 TR= 40  LA=23411.74
HP=.345 BO=0 SO=.605 SYS=.128 EF=2.969
QC=23528.89 QE=17018.58 W=7233.68 QB=0 QS=111306.13 Y= 176384.45 P=652.40
TS= 13 TH= 7.47830997 TL= 20.6624778 TR= 40  LA=22184.16
HP=.333 BO=0 SO=.594 SYS=.115 EF=2.955
QC=22298.85 QE=16128.88 W=6855.52 QB=0 QS=110059.38 Y= 178540.75 P=652.40
TS= 14 TH= 7.95609108 TL= 22.8146964 TR= 40  LA=21229.92
HP=.322 BO=0 SO=.574 SYS=.110 EF=2.943
QC=21342.68 QE=15437.28 W=6561.55 QB=0 QS= 97483.67 Y= 165013.43 P=652.40
TS= 15 TH= 8.21254783 TL= 24.3258422 TR= 40  LA=20634.99
HP=.315 BO=0 SO=.532 SYS=.116 EF=2.935
QC=20746.56 QE=15006.10 W=6378.28 QB=0 QS= 73028.30 Y= 134500.30 P=652.40
TS= 16 TH= 8.22457028 TL= 24.8574608 TR= 40  LA=20453.00
HP=.312 BO=0 SO=.418 SYS=.142 EF=2.932
QC=20564.20 QE=14874.20 W=6322.22 QB=0 QS= 36087.90 Y=  85484.25 P=652.40
TS= 17 TH= 7.99107506 TL= 24.4937012 TR= 40  LA=20700.34
HP=.313 BO=0 SO=.119 SYS=.216 EF=3.077
QC=20812.03 QE=15053.46 W=6398.41 QB=0 QS=  2570.19 Y=  21577.82 P=328.40
TS= 18 TH= 7.533103 TL= 24.0491766 TR= 40  LA=21354.72
HP=.317 BO=0 SO=0 SYS=.269 EF=3.233
QC=21467.73 QE=15527.73 W=6600.00 QB=0 QS=0 Y=0 P=  4.40
TS= 19 TH= 6.89192307 TL= 23.585116 TR= 40  LA=22357.17
HP=.323 BO=0 SO=0 SYS=.273 EF=3.234
QC=22472.20 QE=16254.27 W=6908.81 QB=0 QS=0 Y=0 P=  4.40
TS= 20 TH= 6.12531355 TL= 23.0963136 TR= 40  LA=23617.37
HP=.330 BO=0 SO=0 SYS=.276 EF=3.235
QC=23734.94 QE=17167.61 W=7297.02 QB=0 QS=0 Y=0 P=  4.40
TS= 21 TH= 5.30235551 TL= 22.5798842 TR= 40  LA=25021.75
HP=.338 BO=0 SO=0 SYS=.281 EF=3.235
QC=25142.14 QE=18185.45 W=7729.65 QB=0 QS=0 Y=0 P=  4.40
TS= 22 TH= 4.4972077 TL= 22.0355231 TR= 40  LA=26443.75
HP=.346 BO=0 SO=0 SYS=.285 EF=3.236
QC=26567.01 QE=19216.07 W=8167.71 QB=0 QS=0 Y=0 P=  4.40
TS= 23 TH= 3.78242394 TL= 21.465533 TR= 40  LA=27755.25
HP=.354 BO=0 SO=0 SYS=.289 EF=3.236
QC=27881.15 QE=20166.59 W=8571.73 QB=0 QS=0 Y=0 P=  4.40
*****THE DAY'S CUMULATIVE*****
TOTAL HEATING LOAD:LA=419075.42
W=129470.48 QS=653680.38 QB=     0.00 P=5907.90 Y= 1130846.62
EF= 3.096 EX=.194
```

```
****************MARCH************
TL= 20 Q= 40000 AR= 120
TS= 7 TH= 4.51463996 TL= 19.4421141 TR= 40  LA=27354.38
HP=.357 BO=0 SO=0 SYS=.288 EF=3.236
QC=27479.47 QE=19876.06 W=8448.24 QB=0 QS=0 Y=0 P=  4.40
TS= 8 TH= 5.28214198 TL= 19.2562334 TR= 40  LA=26114.52
HP=.352 BO=0 SO=.315 SYS=.216 EF=3.052
QC=26237.11 QE=18977.45 W=8066.29 QB=0 QS= 13021.79 Y=  41029.71 P=490.40
TS= 9 TH= 6.15081625 TL= 20.17152 TR= 40  LA=24661.73
HP=.344 BO=0 SO=.506 SYS=.157 EF=2.982
QC=24781.40 QE=17924.52 W=7618.75 QB=0 QS= 53390.51 Y= 103732.29 P=652.40
TS= 10 TH= 7.05867792 TL= 22.0566654 TR= 40  LA=23099.67
HP=.333 BO=0 SO=.563 SYS=.121 EF=2.965
QC=23216.19 QE=16792.40 W=7137.54 QB=0 QS= 88809.71 Y= 153797.23 P=652.40
TS= 11 TH= 7.94094587 TL= 24.5627981 TR= 40  LA=21539.80
HP=.321 BO=0 SO=.576 SYS=.097 EF=2.947
QC=21653.19 QE=15661.87 W=6657.02 QB=0 QS=111154.88 Y= 187533.31 P=652.40
TS= 12 TH= 8.73466525 TL= 27.3455337 TR= 40  LA=20093.44
HP=.308 BO=0 SO=.573 SYS=.081 EF=2.927
QC=20203.91 QE=14613.60 W=6211.45 QB=0 QS=120654.07 Y= 204618.30 P=652.40
TS= 13 TH= 9.38319965 TL= 30.1032965 TR= 40  LA=18863.78
HP=.296 BO=0 SO=.561 SYS=.071 EF=2.909
QC=18971.78 QE=13722.40 W=5832.65 QB=0 QS=118975.20 Y= 206807.98 P=652.40
TS= 14 TH= 9.84027245 TL= 32.5273141 TR= 40  LA=17938.58
HP=.287 BO=0 SO=.537 SYS=.068 EF=2.893
QC=18044.71 QE=13051.84 W=5547.63 QB=0 QS=105891.56 Y= 193216.94 P=652.40
TS= 15 TH= 10.0732689 TL= 34.3200705 TR= 40  LA=17383.84
HP=.280 BO=0 SO=.492 SYS=.071 EF=2.883
QC=17488.86 QE=12649.79 W=5376.74 QB=0 QS= 81856.36 Y= 163926.04 P=652.40
TS= 16 TH= 10.0655633 TL= 35.166203 TR= 40  LA=17239.15
HP=.277 BO=0 SO=.390 SYS=.087 EF=2.881
QC=17343.88 QE=12544.93 W=5332.17 QB=0 QS= 46204.97 Y= 117382.40 P=652.40
TS= 17 TH= 9.81770558 TL= 34.9202299 TR= 40  LA=17514.84
HP=.278 BO=0 SO=.200 SYS=.158 EF=3.048
QC=17620.13 QE=12744.74 W=5417.10 QB=0 QS=  7582.19 Y=  37733.33 P=328.40
TS= 18 TH= 9.34738178 TL= 34.5797653 TR= 40  LA=18191.24
HP=.282 BO=0 SO=0 SYS=.260 EF=3.231
QC=18297.88 QE=13234.96 W=5625.47 QB=0 QS=0 Y=0 P=  4.40
TS= 19 TH= 8.68815216 TL= 34.1591426 TR= 40  LA=19220.08
HP=.287 BO=0 SO=0 SYS=.263 EF=3.232
QC=19328.79 QE=13980.62 W=5942.41 QB=0 QS=0 Y=0 P=  4.40
TS= 20 TH= 7.88705654 TL= 33.7127241 TR= 40  LA=20527.94
HP=.295 BO=0 SO=0 SYS=.267 EF=3.233
QC=20639.28 QE=14928.51 W=6345.30 QB=0 QS=0 Y=0 P=  4.40
TS= 21 TH= 7.00125766 TL= 33.2367818 TR= 40  LA=22021.50
HP=.303 BO=0 SO=0 SYS=.272 EF=3.234
QC=22135.86 QE=16010.99 W=6805.41 QB=0 QS=0 Y=0 P=  4.40
TS= 22 TH= 6.09396233 TL= 32.7237634 TR= 40  LA=23594.20
HP=.311 BO=0 SO=0 SYS=.276 EF=3.235
QC=23711.72 QE=17150.82 W=7289.89 QB=0 QS=0 Y=0 P=  4.40
TS= 23 TH= 5.22991125 TL= 32.1924025 TR= 40  LA=25133.80
HP=.319 BO=0 SO=0 SYS=.281 EF=3.235
QC=25254.42 QE=18266.66 W=7764.17 QB=0 QS=0 Y=0 P=  4.40
*****THE DAY'S CUMULATIVE*****
TOTAL HEATING LOAD:LA=367002.04
W=113428.91 QS=747541.24 QB=     0.00 P=6069.90 Y= 1409777.54
EF= 3.071 EX=.142
```

```
READY.

1 REM KULLANILAN SISTEM (BO$SO)
10 CLR
20 OPEN4,4
25 CMD4
40 Z=75
50 DIM LA(Z),P(Z),QB(Z),QS(Z),Y(Z),E3(Z),E4(Z)
60 DIM E5(Z),E6(Z),E7(Z),E8(Z),F1(Z),F2(Z),F3(Z),F4(Z)
70 READTR,Q
80 READE,BY,S,D,ZD,TM,DT,HT,HD,AR
90 DATA40,40000
100 DATA41,29,51,-2.42,-9.1,6.7,6.8,11,5.1,120
110 TS=6
120 PI=3.1415/180
130 X=-TAN(PI*E)*TAN(PI*D)
140 H=(1.5708-ATN(X/SQR(1-X*X)))/PI
150 TG=2/15*H
160 MC=13.5*AR
180 MR=.002*Q
190 UU=Q/23/60
210 UR=17.763*(MR/1000)↑.643/60
300 PRINT#4,"*****************MARCH*****************"
305 PRINT#4,"AR=";AR
380 HOUR=(TS-6)*4
390 GOSUB 650:REM AMBIENT TEMP
410 GOSUB 690:REM LOAD
440 GOSUB 980:REM SOL.COLL
445 TK=TR+.24/MR*(QS(HOUR)-LA(HOUR)-UR*15*(TR-TH)+QB(HOUR))
450 IF TK<=40 THEN GOSUB 890:REM BOILER
460 MN=MN+1
470 GOSUB 1340
480 GOSUB 800:REM HOT WATER TANK
500 TS=TS+.25:IFTS>23 THEN GOTO 530
510 IF MN=4 THEN GOSUB 1540
515 IF MN=4 THEN MN=0
520 GOTO 380
530 GOSUB 1200:PRINT#4,"***********THE DAY'S CUMULATIVE***********"
532 PRINT#4,"HEATING LOAD:LA="USING"######.##";LA
534 PRINT#4,"QB="USING"######.##";QB;
536 PRINT#4," QS="USING"#######.##";QS;
538 PRINT#4," Y="USING"#######.##";Y;
540 PRINT#4," P="USING"####.##";P
542 PRINT#4,"EX="USING".###";SY;
544 PRINT#4," EF="USING"##.###";EF;
546 PRINT#4," M3="USING"##.###";M3;
548 PRINT#4," M4="USING"##.###";M4;
550 END
640 REM *****AMBIENT TEMPERATURE******
650 Z=TS-4/60*(45-BY)+ZD/60
660 TH=TM+DT/2*COS(3.14/TG*(Z-14))
670 RETURN
680 REM *********LOAD***************
690 LA(HOUR)=UU*(20-TH)*15
700 D4=TR-LA(HOUR)*2.5E-3
710 P(HOUR)=1+P(HOUR)
```

```
720 RETURN
790 REM ********HOT WATER TANK*******
800 TR=TR+.24/MR*(QS(HOUR)-LA(HOUR)-UR*15*(TR-TH)+QB(HOUR))
810 RETURN
880 REM ******BOILER***************
890 QB(HOUR)=LA(HOUR)+UR*15*(TR-TH)+MR*4.18*(40-TR)
900 D3=QB(HOUR)*2.5E-3+TR
910 P(HOUR)=1+P(HOUR)
920 RETURN
970 REM ******SOLAR COLLECTOR*******
980 HH=15*(12-TS)
990 FI=EXP(-4*(1-ABS(HH)/H)↑2)
1000 RT=.785/TG*(COS(1.57*HH/H)+1.129*(1-FI))
1010 I=RT*HT*277.8
1020 RY=.131*(COS(PI*HH)-COS(PI*H))/(SIN(PI*H)-PI*H*COS(PI*H))
1030 HY=HT-HD
1040 IY=RY*HY*277.8
1050 ID=I-IY
1060 R1=(COS(PI*(E-S))*COS(PI*D)*COS(PI*HH)+SIN(PI*(E-S))*SIN(PI*D))
1070 R2=(COS(PI*E)*COS(PI*D)*COS(PI*HH)+SIN(PI*E)*SIN(PI*D))
1080 RD=R1/R2
1090 R=RD*ID/I+IY*(1+COS(PI*S))/I/2+.2*(1-COS(PI*S))/2
1100 Y(HOUR)=I*R*.9*AR
1110 TA=.8
1120 QS(HOUR)=.81*(I*R*TA-4*(TR-TH))*AR
1121 IF QS(HOUR)<=0 OR TS>18 THEN QS(HOUR)=0:I=0:R=0:Y(HOUR)=0:GOTO 1150
1125 TP=TR+QS(HOUR)/AR*8E-3+QS(HOUR)/AR*.0022
1130 TC=QS(HOUR)/4.18/MC+TR
1140 P(HOUR)=P(HOUR)+1.35*AR
1150 RETURN
1200 FOR AA=0 TO 23
1210 LA=LA(AA)+LA
1220 Y=Y+Y(AA)
1230 QB=QB(AA)+QB
1240 QS=QS(AA)+QS
1250 F3=F3+F3(AA)
1260 F4=F4+F4(AA)
1270 P=P(AA)+P
1280 E8=E8(AA)+E8
1290 E7=E7(AA)+E7
1300 NEXT AA
1304 M2=E8/F3
1308 M4=E8/F4
1310 EF=LA/(QB/.75+P)
1320 SY=E8/E7
1330 RETURN
1340 Y1=TH+273.15
1360 Y3=TR+273.15
1410 E3(HOUR)=QB(HOUR)/.75
1415 F1(HOUR)=QB(HOUR)/.75*(1-Y1/1400)
1420 E4(HOUR)=QB(HOUR)-95.7*4.18*Y1*LOG((D3+273.15)/Y3)
1430 IF QB(HOUR)=0 THEN E3(HOUR)=0
1440 IF QB(HOUR)=0 THEN E4(HOUR)=0
1450 E5(HOUR)=Y(HOUR)*(1-Y1/(TP+273.15))
1455 F2(HOUR)=Y(HOUR)*(1-Y1/4500)
1460 E6(HOUR)=QS(HOUR)-MC*4.18*Y1*LOG((TC+273.15)/Y3)
1470 IF QS(HOUR)=0 THEN E5(HOUR)=0
```

```
1480 IF QS(HOUR)=0 THEN E6(HOUR)=0
1490 E7(HOUR)=E5(HOUR)+E3(HOUR)+P(HOUR)
1500 E8(HOUR)=LA(HOUR)-95.7*4.18*Y1*LOG(Y3/(D4+273.15))
1502 F3(HOUR)=F1(HOUR)+F2(HOUR)+P(HOUR)
1504 F4(HOUR)=F2(HOUR)+E3(HOUR)+P(HOUR)
1510 IF LA(HOUR)=0 THEN E7(HOUR)=0
1520 IF LA(HOUR)=0 THEN E8(HOUR)=0
1521 C3=C3+E3(HOUR)
1522 C4=C4+E4(HOUR)
1523 C5=C5+E5(HOUR)
1524 C6=C6+E6(HOUR)
1525 C7=C7+E7(HOUR)
1526 C8=C8+E8(HOUR)
1527 W1=W1+F1(HOUR)
1528 W2=W2+F2(HOUR)
1529 W3=W3+F3(HOUR)
1530 W4=W4+F4(HOUR)
1531 Q1=Q1+LA(HOUR)
1532 Q5=Q5+QB(HOUR)
1533 Q6=Q6+QS(HOUR)
1537 Q7=Q7+P(HOUR)
1538 Q8=Q8+Y(HOUR)
1539 RETURN
1540 PRINT#4,"TS="TS"TH="USING"##.##";TH;
1545 PRINT#4," TR="USING"##.##";TR;
1546 PRINT#4," LA="USING"#####.##";Q1;
1550 PRINT#4," QB="USING"#####.##";Q5;
1555 PRINT#4," QS="USING"#####.#";Q6;
1556 PRINT#4," P="USING"###.##";Q7;
1557 PRINT#4," Y="USING"######.##";Q8
1560 IF C3=0 THEN PRINT#4,"BO=0";
1570 IF C3<>0 THEN PRINT#4,"BO="USING".###";C4/C3;
1580 IF Q6=0 THEN PRINT#4," SO=0";
1590 IF Q6<>0 THEN PRINT#4," SO="USING".###";C6/C5;
1592 PRINT#4," M3="USING".###";C8/W3;
1594 PRINT#4," M4="USING".###";C8/W4;
1600 PRINT#4," SYS="USING".###";C8/C7;
1620 EF=Q1/(Q5/.75+Q7)
1630 PRINT#4," EF="USING"###.###";EF
1635 C1=0:C2=0:C3=0:C4=0:C5=0:C6=0:C7=0:C8=0:W1=0:W2=0:W3=0:W4=0
1636 Q1=0:Q5=0:Q6=0:Q7=0:Q8=0
1660 RETURN

READY.
```

```
***************DECEMBER***************
AR= 75
TS= 7 TH= 5.42 TR=40.00 LA=25473.49 QB=25594.80 QS=    0.00 P=  8.00
BO=.099 SO=0 M3=.081 M4=.065 SYS=.065 EF= 0.746
TS= 8 TH= 5.85 TR=40.00 LA=24930.18 QB=25050.38 QS=    0.00 P=  8.00
BO=.098 SO=0 M3=.081 M4=.065 SYS=.065 EF= 0.746
TS= 9 TH= 6.52 TR=40.00 LA=23908.80 QB=24026.95 QS=    0.00 P=  8.00
BO=.096 SO=0 M3=.080 M4=.064 SYS=.064 EF= 0.746
TS= 10 TH= 7.37 TR=45.50 LA=22529.61 QB=20876.11 QS= 3605.20 P=311.75
BO=.095 SO=.091 M3=.033 M4=.030 SYS=.061 EF= 0.800
TS= 11 TH= 8.30 TR=43.52 LA=20954.98 QB= 3585.63 QS=16834.83 P=410.00
BO=.038 SO=.229 M3=.028 M4=.027 SYS=.147 EF= 4.037
TS= 12 TH= 9.19 TR=51.13 LA=19370.29 QB=    0.00 QS=22041.98 P=409.00
BO=0 SO=.268 M3=.025 M4=.025 SYS=.190 EF=47.360
TS= 13 TH= 9.94 TR=52.18 LA=17962.12 QB=    0.00 QS=18458.49 P=409.00
BO=0 SO=.222 M3=.026 M4=.026 SYS=.181 EF=43.917
TS= 14 TH=10.46 TR=46.13 LA=16896.24 QB=    0.00 QS=15021.20 P=409.00
BO=0 SO=.199 M3=.026 M4=.026 SYS=.187 EF=41.311
TS= 15 TH=10.69 TR=42.85 LA=16298.15 QB= 7903.54 QS= 7423.46 P=412.00
BO=.085 SO=.130 M3=.025 M4=.024 SYS=.088 EF= 1.488
TS= 16 TH=10.61 TR=40.00 LA=16238.26 QB=15391.94 QS=    0.00 P=  8.00
BO=.082 SO=0 M3=.080 M4=.064 SYS=.064 EF= 0.791
TS= 17 TH=10.21 TR=40.00 LA=16723.61 QB=16827.30 QS=    0.00 P=  8.00
BO=.082 SO=0 M3=.074 M4=.059 SYS=.059 EF= 0.745
TS= 18 TH= 9.56 TR=40.00 LA=17697.08 QB=17802.73 QS=    0.00 P=  8.00
BO=.084 SO=0 M3=.075 M4=.060 SYS=.060 EF= 0.745
TS= 19 TH= 8.73 TR=40.00 LA=19044.04 QB=19152.40 QS=    0.00 P=  8.00
BO=.087 SO=0 M3=.076 M4=.061 SYS=.061 EF= 0.746
TS= 20 TH= 7.80 TR=40.00 LA=20605.93 QB=20717.43 QS=    0.00 P=  8.00
BO=.090 SO=0 M3=.077 M4=.062 SYS=.062 EF= 0.746
TS= 21 TH= 6.90 TR=40.00 LA=22198.85 QB=22313.56 QS=    0.00 P=  8.00
BO=.093 SO=0 M3=.078 M4=.063 SYS=.063 EF= 0.746
TS= 22 TH= 6.13 TR=40.00 LA=23635.28 QB=23752.88 QS=    0.00 P=  8.00
BO=.096 SO=0 M3=.080 M4=.064 SYS=.064 EF= 0.746
TS= 23 TH= 5.58 TR=40.00 LA=24746.09 QB=24865.93 QS=    0.00 P=  8.00
BO=.098 SO=0 M3=.081 M4=.065 SYS=.065 EF= 0.746
***********THE DAY'S CUMULATIVE***********
HEATING,LOAD:LA=355521.76
QB=274200.55 QS=  83385.16 Y= 408245.5! P=2450.75
EX=.076 EF= 0.966 M3= 0.047 M4= 0.042
***************DECEMBER***************
AR= 75
```

```
****************JANUARY****************
AR= 75
TS= 7 TH= 2.54 TR=40.00 LA=30501.31 QB=30632.74 QS=     0.0 P=  8.00
BO=.109 SO=0 M3=.085 M4=.069 SYS=.069 EF= 0.747
TS= 8 TH= 2.95 TR=40.00 LA=29954.43 QB=30084.76 QS=     0.0 P=  8.00
BO=.108 SO=0 M3=.085 M4=.068 SYS=.068 EF= 0.747
TS= 9 TH= 3.61 TR=40.00 LA=28961.97 QB=29090.30 QS=     0.0 P=  8.00
BO=.106 SO=0 M3=.084 M4=.068 SYS=.068 EF= 0.747
TS= 10 TH= 4.43 TR=44.28 LA=27633.35 QB=26573.76 QS= 2616.1 P=210.50
BO=.105 SO=.091 M3=.045 M4=.040 SYS=.065 EF= 0.775
TS= 11 TH= 5.32 TR=49.54 LA=26115.06 QB=17124.91 QS=10889.9 P=413.00
BO=.109 SO=.152 M3=.033 M4=.031 SYS=.086 EF= 1.123
TS= 12 TH= 6.19 TR=42.27 LA=24574.50 QB=    0.00 QS=22281.1 P=409.00
BO=0 SO=.269 M3=.031 M4=.031 SYS=.232 EF=60.084
TS= 13 TH= 6.94 TR=43.28 LA=23181.52 QB=    0.00 QS=23645.7 P=409.00
BO=0 SO=.286 M3=.028 M4=.028 SYS=.217 EF=56.679
TS= 14 TH= 7.48 TR=41.81 LA=22089.70 QB= 5030.94 QS=16702.7 P=410.00
BO=.094 SO=.213 M3=.029 M4=.029 SYS=.136 EF= 3.103
TS= 15 TH= 7.77 TR=39.98 LA=21419.42 QB=15217.53 QS= 5722.3 P=311.75
BO=.096 SO=.120 M3=.035 M4=.033 SYS=.080 EF= 1.040
TS= 16 TH= 7.76 TR=40.00 LA=21244.58 QB=21362.72 QS=     0.0 P=  8.00
BO=.091 SO=0 M3=.078 M4=.062 SYS=.062 EF= 0.746
TS= 17 TH= 7.45 TR=40.00 LA=21584.46 QB=21697.93 QS=     0.0 P=  8.00
BO=.092 SO=0 M3=.078 M4=.062 SYS=.062 EF= 0.746
TS= 18 TH= 6.89 TR=40.00 LA=22401.58 QB=22516.70 QS=     0.0 P=  8.00
BO=.093 SO=0 M3=.079 M4=.063 SYS=.063 EF= 0.746
TS= 19 TH= 6.13 TR=40.00 LA=23605.86 QB=23723.40 QS=     0.0 P=  8.00
BO=.096 SO=0 M3=.080 M4=.064 SYS=.064 EF= 0.746
TS= 20 TH= 5.25 TR=40.00 LA=25064.51 QB=25184.99 QS=     0.0 P=  8.00
BO=.099 SO=0 M3=.081 M4=.065 SYS=.065 EF= 0.746
TS= 21 TH= 4.36 TR=40.00 LA=26616.72 QB=26740.33 QS=     0.0 P=  8.00
BO=.102 SO=0 M3=.082 M4=.066 SYS=.066 EF= 0.746
TS= 22 TH= 3.55 TR=40.00 LA=28091.35 QB=28217.92 QS=     0.0 P=  8.00
BO=.105 SO=0 M3=.083 M4=.067 SYS=.067 EF= 0.746
TS= 23 TH= 2.91 TR=40.00 LA=29325.81 QB=29454.86 QS=     0.0 P=  8.00
BO=.107 SO=0 M3=.084 M4=.068 SYS=.068 EF= 0.747
***********THE DAY'S CUMULATIVE************
HEATING LOAD:LA=439848.81
QB=360199.04 QS=  81858.00 Y= 384052.00 P=2253.25
EX=.076 EF= 0.912 M3= 0.054 M4= 0.048
****************JANUARY****************
AR= 75
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***************FEBRUARY***************
AR= 75
TS= 7 TH= 3.18 TR=40.00 LA=29502.88 QB=29632.30 QS=     0.0 P=  8.00
BO=.107 SO=0 M3=.085 M4=.068 SYS=.068 EF= 0.747
TS= 8 TH= 3.72 TR=40.00 LA=28691.07 QB=28818.85 QS=     0.0 P=  8.00
BO=.106 SO=0 M3=.084 M4=.067 SYS=.067 EF= 0.747
TS= 9 TH= 4.42 TR=45.01 LA=27566.24 QB=27523.54 QS= 1833.0 P=210.50
BO=.104 SO=.063 M3=.045 M4=.040 SYS=.062 EF= 0.747
TS= 10 TH= 5.22 TR=42.97 LA=26229.75 QB= 9557.46 QS=16134.3 P=411.00
BO=.108 SO=.205 M3=.033 M4=.032 SYS=.118 EF= 1.994
TS= 11 TH= 6.05 TR=57.59 LA=24802.03 QB=    0.00 QS=29825.5 P=409.00
BO=0 SO=.297 M3=.030 M4=.030 SYS=.197 EF=60.641
TS= 12 TH= 6.82 TR=65.71 LA=23411.74 QB=    0.00 QS=26308.8 P=409.00
BO=0 SO=.237 M3=.033 M4=.033 SYS=.181 EF=57.241
TS= 13 TH= 7.48 TR=66.34 LA=22184.16 QB=    0.00 QS=22602.9 P=409.00
BO=0 SO=.202 M3=.033 M4=.033 SYS=.173 EF=54.240
TS= 14 TH= 7.96 TR=59.64 LA=21229.92 QB=    0.00 QS=19194.0 P=409.00
BO=0 SO=.186 M3=.033 M4=.033 SYS=.179 EF=51.907
TS= 15 TH= 8.21 TR=43.74 LA=20634.99 QB=    0.00 QS=15498.9 P=409.00
BO=0 SO=.184 M3=.032 M4=.032 SYS=.205 EF=50.452
TS= 16 TH= 8.22 TR=39.99 LA=20453.00 QB=14786.34 QS= 4543.1 P=311.75
BO=.093 SO=.101 M3=.034 M4=.032 SYS=.078 EF= 1.021
TS= 17 TH= 7.99 TR=40.00 LA=20700.34 QB=20814.97 QS=     0.0 P=  8.00
BO=.090 SO=0 M3=.077 M4=.062 SYS=.062 EF= 0.746
TS= 18 TH= 7.53 TR=40.00 LA=21354.72 QB=21467.73 QS=     0.0 P=  8.00
BO=.091 SO=0 M3=.078 M4=.062 SYS=.062 EF= 0.746
TS= 19 TH= 6.89 TR=40.00 LA=22357.17 QB=22472.20 QS=     0.0 P=  8.00
BO=.093 SO=0 M3=.079 M4=.063 SYS=.063 EF= 0.746
TS= 20 TH= 6.13 TR=40.00 LA=23617.37 QB=23734.94 QS=     0.0 P=  8.00
BO=.096 SO=0 M3=.080 M4=.064 SYS=.064 EF= 0.746
TS= 21 TH= 5.30 TR=40.00 LA=25021.75 QB=25142.14 QS=     0.0 P=  8.00
BO=.099 SO=0 M3=.081 M4=.065 SYS=.065 EF= 0.746
TS= 22 TH= 4.50 TR=40.00 LA=26443.75 QB=26567.01 QS=     0.0 P=  8.00
BO=.101 SO=0 M3=.082 M4=.066 SYS=.066 EF= 0.746
TS= 23 TH= 3.79 TR=40.00 LA=27755.25 QB=27881.15 QS=     0.0 P=  8.00
BO=.104 SO=0 M3=.083 M4=.067 SYS=.067 EF= 0.746
***********THE DAY'S CUMULATIVE***********
HEATING LOAD:LA=418075.42
QB=295555.74 QS= 135940.60 Y= 656050.49 P=3052.25
EX=.089 EF= 1.092 M3= 0.046 M4= 0.043
***************FEBRUARY***************
AR= 75
```

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*****************MARCH*****************
AR= 75
TS= 7 TH= 4.51 TR=40.00 LA=27354.38 QB=27479.47 QS=    0.0 P=  8.00
BO=.103 SO=0 M3=.083 M4=.066 SYS=.066 EF=  0.746
TS= 8 TH= 5.28 TR=40.00 LA=26114.52 QB=26237.11 QS=    0.0 P=  8.00
BO=.101 SO=0 M3=.082 M4=.066 SYS=.066 EF=  0.746
TS= 9 TH= 6.15 TR=41.44 LA=24661.73 QB=15916.54 QS= 9358.9 P=412.00
BO=.101 SO=.147 M3=.031 M4=.029 SYS=.082 EF=  1.140
TS= 10 TH= 7.06 TR=60.19 LA=23099.67 QB=    0.00 QS=29492.1 P=409.00
BO=0 SO=.304 M3=.027 M4=.027 SYS=.189 EF= 56.478
TS= 11 TH= 7.94 TR=75.83 LA=21539.80 QB=    0.00 QS=26962.1 P=409.00
BO=0 SO=.228 M3=.031 M4=.031 SYS=.160 EF= 52.665
TS= 12 TH= 8.73 TR=84.08 LA=20093.44 QB=    0.00 QS=23090.0 P=409.00
BO=0 SO=.180 M3=.031 M4=.031 SYS=.142 EF= 49.128
TS= 13 TH= 9.38 TR=84.66 LA=18863.78 QB=    0.00 QS=19325.1 P=409.00
BO=0 SO=.149 M3=.031 M4=.031 SYS=.134 EF= 46.122
TS= 14 TH= 9.84 TR=77.94 LA=17938.58 QB=    0.00 QS=15953.5 P=409.00
BO=0 SO=.132 M3=.030 M4=.030 SYS=.136 EF= 43.860
TS= 15 TH=10.07 TR=62.81 LA=17383.84 QB=    0.00 QS=12558.9 P=409.00
BO=0 SO=.122 M3=.030 M4=.030 SYS=.153 EF= 42.503
TS= 16 TH=10.07 TR=46.60 LA=17239.15 QB= 2395.68 QS= 9599.0 P=410.00
BO=.090 SO=.130 M3=.029 M4=.029 SYS=.151 EF=  4.783
TS= 17 TH= 9.82 TR=40.00 LA=17514.84 QB=14920.54 QS=  505.2 P=210.50
BO=.085 SO=.022 M3=.039 M4=.036 SYS=.066 EF=  0.871
TS= 18 TH= 9.35 TR=40.00 LA=18191.24 QB=18297.88 QS=    0.0 P=  8.00
BO=.085 SO=0 M3=.075 M4=.060 SYS=.060 EF=  0.745
TS= 19 TH= 8.69 TR=40.00 LA=19220.08 QB=19328.79 QS=    0.0 P=  8.00
BO=.087 SO=0 M3=.076 M4=.061 SYS=.061 EF=  0.746
TS= 20 TH= 7.89 TR=40.00 LA=20527.94 QB=20639.28 QS=    0.0 P=  8.00
BO=.090 SO=0 M3=.077 M4=.062 SYS=.062 EF=  0.746
TS= 21 TH= 7.00 TR=40.00 LA=22021.50 QB=22135.86 QS=    0.0 P=  8.00
BO=.093 SO=0 M3=.078 M4=.063 SYS=.063 EF=  0.746
TS= 22 TH= 6.09 TR=40.00 LA=23594.20 QB=23711.72 QS=    0.0 P=  8.00
BO=.096 SO=0 M3=.080 M4=.064 SYS=.064 EF=  0.746
TS= 23 TH= 5.23 TR=40.00 LA=25133.80 QB=25254.42 QS=    0.0 P=  8.00
BO=.099 SO=0 M3=.081 M4=.065 SYS=.065 EF=  0.746
***********THE DAY'S CUMULATIVE************
HEATING LOAD:LA=367002.04
QB=222857.46 QS= 146844.73 Y= 855467.39 P=3552.50
EX=.092 EF= 1.221 M3= 0.040 M4= 0.038
*****************MARCH*****************
AR= 75
```

```
READY.

5 REM BO$HP
10 CLR
12 OPEN4,4
14 CMD4
20 Z=68
30 DIM LA(Z),P(Z),QC(Z),LE(Z),W(Z),QB(Z),E1(Z),E2(Z),E3(Z),E4(Z),E5(Z),E6(Z
50 READT3,T4,NC,TR,Q
60 READE,BY,S,D,ZD,TM,DT
70 DATA50,-5,.7,40,40000
80 DATA41,29,51,-20.92,-8.8,5.1,5.4
90 TS=6
100 PI=3.1415/180
110 X=-TAN(PI*E)*TAN(PI*D)
120 H=(1.5708-ATN(X/SQR(1-X*X)))/PI
130 TG=2/15*H
160 MR=.002*Q
170 UU=Q/23/60
180 PRINT#4,"************JANUARY************"
190 UR=17.763*(MR/1000)↑.643/60
200 P4=.3164*EXP(.0283*T4)
210 P3=.3944*EXP(.02246*T3)
220 H3=30.87589+1.08344*T3
230 S3=.13515+.00338*T3
240 H4=H3
250 H1=187.502+.3968*T4
260 H5=35.59425+.9741*T4
270 X8=(H4-H5)/(H1-H5)
280 S1=.69576-3.634*10↑-4*T4
290 S5=.1413+.0033*T4
300 S4=S5+(S1-S5)*X8
310 S2=S1
320 H2=-267.7477+30.611*P3+640.41*S2
330 H2=H1+(H2-H1)/NC
340 S2=.443703+1.5615*10↑-3*H2-4.7799*10↑-2*P3
350 PRINT#4,H1,H2,H3,H4,H5,S1,S2,S3,S4,S5,X8
360 HOUR=(TS-6)*4
370 GOSUB 520:REM AMBIENT TEMP
380 GOSUB 560:REM LOAD
428 IF TH<5 THEN GOTO 445
430 GOSUB 610:REM CONDENSOR
440 GOSUB 700:REM EVAP&COMP
442 GOTO 455
445 GOSUB 760:REM BOILER
455 MN=MN+1
458 GOSUB 1160
465 GOSUB 670:REM SICAK TANK
470 TS=TS+.25:IFTS>23 THEN GOTO 500
480 IF MN=4 THEN GOSUB 2000
485 IF MN=4 THEN MN=0
490 GOTO 360
500 GOSUB 1070:PRINT#4,"***********THE DAY'S CUMULATIVE**********"
502 PRINT#4,"HEATING LOAD:LA="USING"######.##";LA
503 PRINT#4,"QC="USING"######.##";QC;
504 PRINT#4," QB="USING"######.##";QB;
```

```
505 PRINT#4," W="USING"######.##";W;
506 PRINT#4," P="USING"####.##";P
507 PRINT#4,"EX="USING".###";SY;
508 PRINT#4," EF="USING"##.###";EF
509 END
510 REM *****AMBIENT TEMPERATURE******
520 Z=TS-4/60*(45-BY)+ZD/60
530 TH=TM+DT/2*COS(3.14/TG*(Z-14))
540 RETURN
550 REM *********LOAD***************
560 LA(HOUR)=UU*(20-TH)*15
570 D4=TR-LA(HOUR)*2.5E-3
580 P(HOUR)=1+P(HOUR)
590 RETURN
600 REM *****CONDENSOR***********
610 QC(HOUR)=15*UU*(20-TH)+UR*(TR-TH)*15
620 MH=QC(HOUR)/(H2-H3)
630 D1=QC(HOUR)*9.56E-4+TR
640 P(HOUR)=0.5+P(HOUR)
650 RETURN
660 REM *********HOT WATER TANK*******
670 TR=TR+.24/MR*(QC(HOUR)-LA(HOUR)-UR*15*(TR-TH)+QB(HOUR))
680 RETURN
690 REM ****COMPRESSOR&EVAPORATOR*****
700 LE(HOUR)=MH*(H1-H4)
710 W(HOUR)=MH*(H2-H1)/.9
730 P(HOUR)=0.5+P(HOUR)
740 RETURN
750 REM *******BOILER****************
760 QB(HOUR)=UU*(20-TH)*15+UR*15*(TR-TH)
770 D3=QB(HOUR)*2.5E-3+TR
780 P(HOUR)=1+P(HOUR)
790 RETURN
1070 FOR AA=0 TO 68
1080 LA=LA(AA)+LA
1090 W=W(AA)+W
1100 QB=QB(AA)+QB
1110 QC=QC+QC(AA)
1120 P=P(AA)+P
1121 E5=E5+E5(AA)
1122 E6=E6+E6(AA)
1130 NEXT AA
1140 EF=LA/(QB/.75+W+P):SY=E6/E5
1150 RETURN
1160 Y1=TH+273.15
1170 Y2=TR+273.15
1180 E1(HOUR)=W(HOUR)
1190 E2(HOUR)=QC(HOUR)-250*4.18*Y1*LOG((D1+273.15)/Y2)
1195 IF MN<>4 THEN GOTO 1220
1220 E3(HOUR)=QB(HOUR)/.75
1225 E4(HOUR)=QB(HOUR)-95.7*4.18*Y1*LOG((D3+273.15)/Y2)
1226 IF QC(HOUR)=0 THEN E1(HOUR)=0:E2(HOUR)=0
1230 IF QB(HOUR)=0 THEN E3(HOUR)=0:E4(HOUR)=0
1231 C1=C1+E1(HOUR)
1232 C2=C2+E2(HOUR)
1233 C3=C3+E3(HOUR)
1234 C4=C4+E4(HOUR)
1235 Q1=Q1+LA(HOUR)
```

```
1236 Q2=Q2+QC(HOUR)
1237 Q3=Q3+LE(HOUR)
1238 Q4=Q4+W(HOUR)
1239 Q5=Q5+QB(HOUR)
1240 Q6=Q6+P(HOUR)
1241 E5(HOUR)=E1(HOUR)+E3(HOUR)+P(HOUR)
1242 E6(HOUR)=LA(HOUR)-85.7*4.18*Y1*LOG(Y2/(D4+273.15))
1250 C5=C5+E5(HOUR)
1260 C6=C6+E6(HOUR)
1300 RETURN
2000 PRINT#4,"TS="TS"TH="USING"##.##";TH;
2002 PRINT#4," LA="USING"#####.##";Q1;
2004 PRINT#4," QC="USING"#####.##";Q2;
2005 PRINT#4," QB="USING"#####.##";Q5;
2006 PRINT#4," W="USING"#####.##";Q4
2110 IF Q5=0 THEN PRINT#4,"BO=0";
2120 IF Q5<>0 THEN PRINT#4,"BO="USING".###";C4/C3;
2130 IF Q2=0 THEN PRINT#4," HP=0";
2140 IF Q2<>0 THEN PRINT#4," HP="USING".###";C2/C1;
2170 PRINT#4," SYS="USING".###";C6/C5;
2180 PRINT#4," EFF="USING"##.###";Q1/(Q4+Q5/.75+Q6)
2190 Q1=0:Q2=0:Q3=0:Q4=0:Q5=0:Q6=0:C1=0:C2=0:C3=0:C4=0:C5=0:C6=0
3000 RETURN

READY.
```

```
************DECEMBER***********
 185.518              229.20754            85.04789            85.04789
 30.72375              .897577             .743658574           .30415
.32581275              .1248              .350944173
TS= 7 TH= 5.42 LA=25473.49 QC=25594.80 QB=    0.00 W= 8618.72
BO=0 HP=.357 SYS=.257 EFF= 2.953
TS= 8 TH= 5.85 LA=24930.18 QC=25050.38 QB=    0.00 W= 8435.40
BO=0 HP=.353 SYS=.256 EFF= 2.953
TS= 9 TH= 6.52 LA=23908.80 QC=24026.95 QB=    0.00 W= 8090.77
BO=0 HP=.347 SYS=.253 EFF= 2.952
TS= 10 TH= 7.37 LA=22529.61 QC=22644.98 QB=    0.00 W= 7625.41
BO=0 HP=.338 SYS=.249 EFF= 2.951
TS= 11 TH= 8.30 LA=20954.98 QC=21067.19 QB=    0.00 W= 7094.11
BO=0 HP=.328 SYS=.245 EFF= 2.951
TS= 12 TH= 9.19 LA=19370.29 QC=19479.31 QB=    0.00 W= 6559.41
BO=0 HP=.318 SYS=.240 EFF= 2.949
TS= 13 TH= 9.94 LA=17962.12 QC=18068.30 QB=    0.00 W= 6084.27
BO=0 HP=.309 SYS=.236 EFF= 2.948
TS= 14 TH=10.46 LA=16896.24 QC=17000.28 QB=    0.00 W= 5724.63
BO=0 HP=.302 SYS=.233 EFF= 2.947
TS= 15 TH=10.69 LA=16298.15 QC=16400.98 QB=    0.00 W= 5522.82
BO=0 HP=.298 SYS=.232 EFF= 2.947
TS= 16 TH=10.61 LA=16238.26 QC=16340.97 QB=    0.00 W= 5502.61
BO=0 HP=.297 SYS=.232 EFF= 2.947
TS= 17 TH=10.21 LA=16723.61 QC=16827.30 QB=    0.00 W= 5666.38
BO=0 HP=.301 SYS=.233 EFF= 2.947
TS= 18 TH= 9.56 LA=17697.08 QC=17802.73 QB=    0.00 W= 5994.84
BO=0 HP=.307 SYS=.236 EFF= 2.948
TS= 19 TH= 8.73 LA=19044.04 QC=19152.40 QB=    0.00 W= 6449.33
BO=0 HP=.316 SYS=.240 EFF= 2.949
TS= 20 TH= 7.80 LA=20605.93 QC=20717.43 QB=    0.00 W= 6976.33
BO=0 HP=.326 SYS=.244 EFF= 2.950
TS= 21 TH= 6.90 LA=22198.85 QC=22313.56 QB=    0.00 W= 7513.81
BO=0 HP=.336 SYS=.248 EFF= 2.951
TS= 22 TH= 6.13 LA=23635.28 QC=23752.88 QB=    0.00 W= 7999.49
BO=0 HP=.345 SYS=.252 EFF= 2.952
TS= 23 TH= 5.58 LA=24746.09 QC=24865.93 QB=    0.00 W= 8373.29
BO=0 HP=.352 SYS=.255 EFF= 2.953
***********THE DAY'S CUMULATIVE**********
HEATING LOAD:LA=355521.76
QC=357445.35 QB=     0.00 W=120365.19 P= 138.00
EX=.245 EF= 2.950
```

```
************JANUARY************
 185.518              229.20754             85.04789              85.04789
 30.72375              .697577             .743658574              .30415
.32581275              .1248              .350944173
TS= 7 TH= 2.54 LA=30501.31 QC=    0.00 QB=30632.74 W=    0.00
BO=.109 HP=0 SYS=.069 EFF= 0.747
TS= 8 TH= 2.95 LA=29954.43 QC=    0.00 QB=30084.76 W=    0.00
BO=.108 HP=0 SYS=.068 EFF= 0.747
TS= 9 TH= 3.61 LA=28961.97 QC=    0.00 QB=29090.30 W=    0.00
BO=.106 HP=0 SYS=.068 EFF= 0.747
TS= 10 TH= 4.43 LA=27633.35 QC=    0.00 QB=27759.01 W=    0.00
BO=.104 HP=0 SYS=.067 EFF= 0.746
TS= 11 TH= 5.32 LA=26115.06 QC=12923.21 QB=13314.45 W= 4351.73
BO=.101 HP=.358 SYS=.104 EFF= 1.181
TS= 12 TH= 6.19 LA=24574.50 QC=24693.99 QB=    0.00 W= 8315.39
BO=0 HP=.351 SYS=.255 EFF= 2.952
TS= 13 TH= 6.94 LA=23181.52 QC=23298.21 QB=    0.00 W= 7845.38
BO=0 HP=.342 SYS=.251 EFF= 2.952
TS= 14 TH= 7.48 LA=22089.70 QC=22204.19 QB=    0.00 W= 7476.98
BO=0 HP=.335 SYS=.248 EFF= 2.951
TS= 15 TH= 7.77 LA=21419.42 QC=21532.56 QB=    0.00 W= 7250.82
BO=0 HP=.331 SYS=.246 EFF= 2.951
TS= 16 TH= 7.76 LA=21244.58 QC=21357.37 QB=    0.00 W= 7191.82
BO=0 HP=.330 SYS=.246 EFF= 2.951
TS= 17 TH= 7.45 LA=21584.46 QC=21697.93 QB=    0.00 W= 7306.50
BO=0 HP=.332 SYS=.247 EFF= 2.951
TS= 18 TH= 6.89 LA=22401.58 QC=22516.70 QB=    0.00 W= 7582.21
BO=0 HP=.337 SYS=.249 EFF= 2.951
TS= 19 TH= 6.13 LA=23605.86 QC=23723.40 QB=    0.00 W= 7988.55
BO=0 HP=.345 SYS=.252 EFF= 2.952
TS= 20 TH= 5.25 LA=25064.51 QC=25184.99 QB=    0.00 W= 8480.73
BO=0 HP=.354 SYS=.256 EFF= 2.953
TS= 21 TH= 4.36 LA=26616.72 QC= 6539.37 QB=20200.95 W= 2202.05
BO=.102 HP=.360 SYS=.081 EFF= 0.913
TS= 22 TH= 3.55 LA=28091.35 QC=    0.00 QB=28217.92 W=    0.00
BO=.105 HP=0 SYS=.067 EFF= 0.746
TS= 23 TH= 2.91 LA=29325.81 QC=    0.00 QB=29454.86 W=    0.00
BO=.107 HP=0 SYS=.068 EFF= 0.747
***********THE DAY'S CUMULATIVE**********
HEATING LOAD:LA=439848.81
QC=225671.92 QB=216270.24 W= 75992.16 P= 139.00
EX=.106 EF= 1.207
```

```
************FEBRUARY***********
 185.518              229.20754            85.04789            85.04789
 30.72375              .697577             .743658574           .30415
.32581275              .1248              .350944173
TS= 7 TH= 3.18 LA=29502.88 QC=    0.00 QB=29632.30 W=    0.00
BO=.107 HP=0 SYS=.068 EFF= 0.747
TS= 8 TH= 3.72 LA=28691.07 QC=    0.00 QB=28818.85 W=    0.00
BO=.106 HP=0 SYS=.067 EFF= 0.747
TS= 9 TH= 4.42 LA=27566.24 QC=    0.00 QB=27691.76 W=    0.00
BO=.104 HP=0 SYS=.067 EFF= 0.746
TS= 10 TH= 5.22 LA=26229.75 QC=13000.19 QB=13352.38 W= 4377.65
BO=.102 HP=.359 SYS=.104 EFF= 1.182
TS= 11 TH= 6.05 LA=24802.03 QC=24921.98 QB=    0.00 W= 8392.16
BO=0 HP=.352 SYS=.256 EFF= 2.953
TS= 12 TH= 6.82 LA=23411.74 QC=23528.89 QB=    0.00 W= 7923.06
BO=0 HP=.343 SYS=.252 EFF= 2.952
TS= 13 TH= 7.48 LA=22184.16 QC=22298.85 QB=    0.00 W= 7508.85
BO=0 HP=.336 SYS=.248 EFF= 2.951
TS= 14 TH= 7.96 LA=21229.92 QC=21342.68 QB=    0.00 W= 7186.88
BO=0 HP=.329 SYS=.246 EFF= 2.951
TS= 15 TH= 8.21 LA=20634.99 QC=20746.56 QB=    0.00 W= 6986.14
BO=0 HP=.326 SYS=.244 EFF= 2.950
TS= 16 TH= 8.22 LA=20453.00 QC=20564.20 QB=    0.00 W= 6924.73
BO=0 HP=.325 SYS=.243 EFF= 2.950
TS= 17 TH= 7.99 LA=20700.34 QC=20812.03 QB=    0.00 W= 7008.19
BO=0 HP=.326 SYS=.244 EFF= 2.950
TS= 18 TH= 7.53 LA=21354.72 QC=21467.73 QB=    0.00 W= 7228.99
BO=0 HP=.330 SYS=.246 EFF= 2.951
TS= 19 TH= 6.89 LA=22357.17 QC=22472.20 QB=    0.00 W= 7567.23
BO=0 HP=.337 SYS=.249 EFF= 2.951
TS= 20 TH= 6.13 LA=23617.37 QC=23734.94 QB=    0.00 W= 7992.44
BO=0 HP=.345 SYS=.252 EFF= 2.952
TS= 21 TH= 5.30 LA=25021.75 QC=25142.14 QB=    0.00 W= 8466.30
BO=0 HP=.354 SYS=.256 EFF= 2.953
TS= 22 TH= 4.50 LA=26443.75 QC= 6510.34 QB=20056.67 W= 2192.27
BO=.102 HP=.359 SYS=.080 EFF= 0.914
TS= 23 TH= 3.76 LA=27755.25 QC=    0.00 QB=27881.15 W=    0.00
BO=.104 HP=0 SYS=.067 EFF= 0.746
***********THE DAY'S CUMULATIVE**********
HEATING LOAD:LA=419075.42
QC=266542.73 QB=154584.22 W= 89754.88 P= 138.00
EX=.122 EF= 1.416
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***************MARCH***********
 185.518              229.20754            85.04789          85.04783
 30.72375              .697577             .743658574          .30415
.32581275              .1249              .350944173
TS= 7 TH= 4.51 LA=27354.38 QC=     0.00 QB=27479.47 W=     0.00
BO=.103 HP=0 SYS=.066 EFF= 0.746
TS= 8 TH= 5.29 LA=26114.52 QC=12947.64 QB=13289.48 W= 4359.95
BO=.101 HP=.359 SYS=.104 EFF= 1.182
TS= 9 TH= 6.15 LA=24661.73 QC=24781.40 QB=     0.00 W= 8344.82
BO=0 HP=.351 SYS=.255 EFF= 2.953
TS= 10 TH= 7.06 LA=23039.67 QC=23216.19 QB=     0.00 W= 7817.76
BO=0 HP=.341 SYS=.251 EFF= 2.952
TS= 11 TH= 7.94 LA=21539.80 QC=21653.19 QB=     0.00 W= 7291.44
BO=0 HP=.332 SYS=.246 EFF= 2.951
TS= 12 TH= 8.73 LA=20093.44 QC=20203.91 QB=     0.00 W= 6803.41
BO=0 HP=.322 SYS=.242 EFF= 2.950
TS= 13 TH= 9.39 LA=18863.78 QC=18971.78 QB=     0.00 W= 6388.51
BO=0 HP=.314 SYS=.239 EFF= 2.949
TS= 14 TH= 9.84 LA=17938.58 QC=18044.71 QB=     0.00 W= 6076.33
BO=0 HP=.308 SYS=.236 EFF= 2.948
TS= 15 TH=10.07 LA=17383.84 QC=17488.86 QB=     0.00 W= 5889.15
BO=0 HP=.305 SYS=.235 EFF= 2.948
TS= 16 TH=10.07 LA=17239.15 QC=17343.89 QB=     0.00 W= 5840.33
BO=0 HP=.304 SYS=.234 EFF= 2.948
TS= 17 TH= 9.82 LA=17514.84 QC=17620.13 QB=     0.00 W= 5933.35
BO=0 HP=.306 SYS=.235 EFF= 2.948
TS= 18 TH= 9.35 LA=18191.24 QC=18297.89 QB=     0.00 W= 6161.59
BO=0 HP=.310 SYS=.237 EFF= 2.949
TS= 19 TH= 8.69 LA=19220.08 QC=19329.79 QB=     0.00 W= 6508.72
BO=0 HP=.317 SYS=.240 EFF= 2.949
TS= 20 TH= 7.89 LA=20527.94 QC=20639.28 QB=     0.00 W= 6950.02
BO=0 HP=.325 SYS=.244 EFF= 2.950
TS= 21 TH= 7.00 LA=22021.50 QC=22135.86 QB=     0.00 W= 7453.97
BO=0 HP=.335 SYS=.248 EFF= 2.951
TS= 22 TH= 6.09 LA=23594.20 QC=23711.72 QB=     0.00 W= 7984.62
BO=0 HP=.345 SYS=.252 EFF= 2.952
TS= 23 TH= 5.23 LA=25133.80 QC=25254.42 QB=     0.00 W= 8504.10
BO=0 HP=.354 SYS=.256 EFF= 2.953
***********THE DAY'S CUMULATIVE***********
HEATING LOAD:LA=367902.04
QC=328179.79 QB= 40768.95 W=110510.39 P= 138.00
EX=.189 EF= 2.224
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