DOE/CS/69097--T2

DE85 015762

SOLAR AIR COLLECTORS:

How Much Can You Save?

April, 1985

written by
Jeff D. Newburn
Energy Specialist
Iowa Energy Policy Council
Lucas State Office Building
Des Moines, Iowa 50319

This paper is for informational purposes only and is not intended to endorse or discourage and particular product from being purchased.

This material was prepared with the support of the United States Department of Energy grant number DE-FG47-80CS69097. However, any opinion, findings, conclusions, or recommendations expressed herein are those of the authors' and do not necessarily reflect the views of DOE.

DISCLAIMER

SOLAR AIR COLLECTORS: HOW MUCH CAN YOU SAVE?

The purpose of this paper is to explore how much energy can be saved from a solar air collector with no thermal storage. There are several factors which determine how much you can save through using this type of system: 1) the size and 2) efficiency of the collector(s), 3) how the system is installed, 4) solar access, 5) the heating load of the home, 6) the amount of south glass the home has, and 7) whether the system is used for zoned heating or not. It may be noted that if a house has a large amount of south glass, there may be enough passive solar gain during the day that the heat contribution through the collector is not useful.

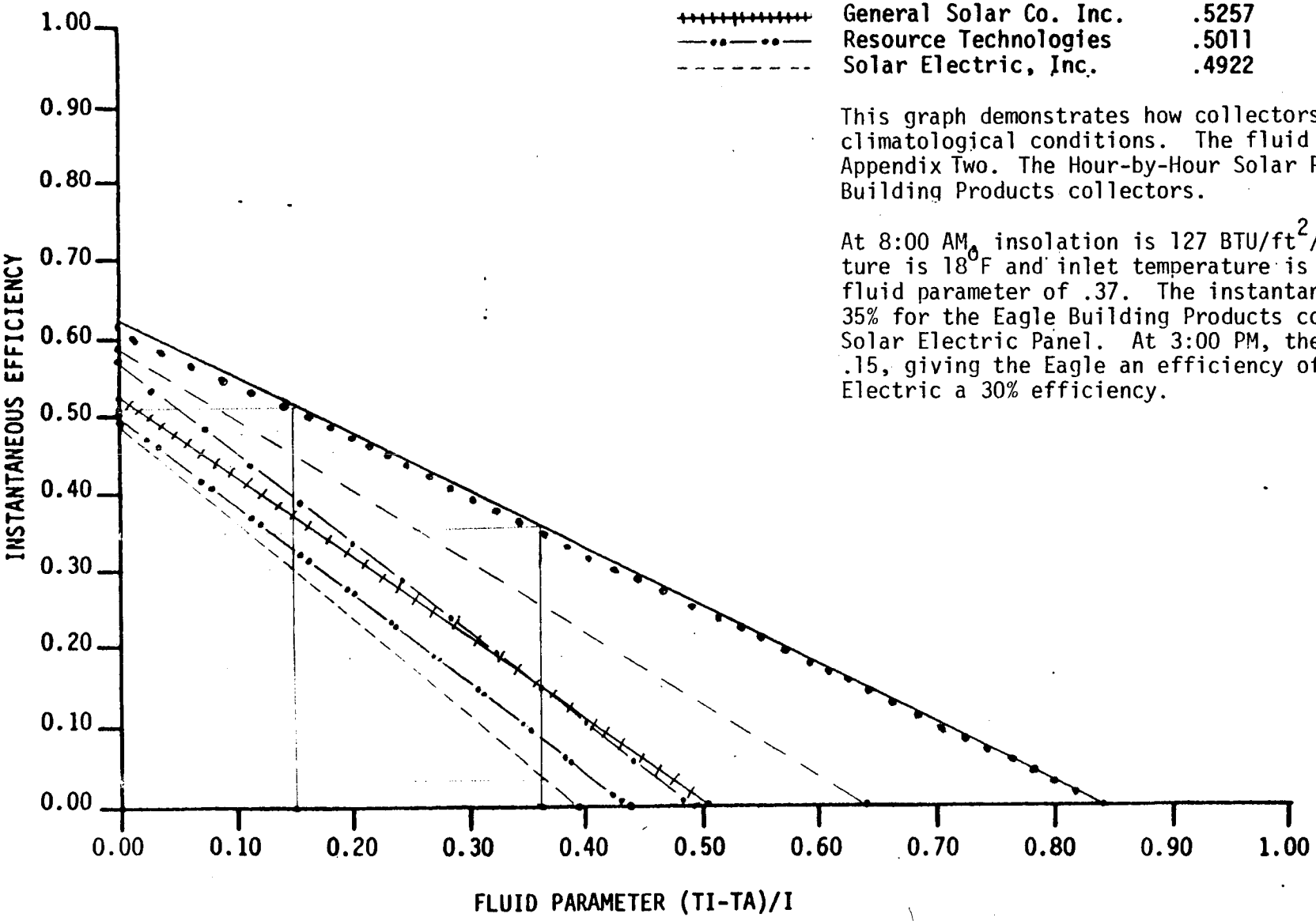
A standard methodology developed by the solar industry to determine collector output is using a collector efficiency curve, which is derived from laboratory tests, to see how the system would perform under various climatological parameters.

Graph One on page 2 is a collector efficiency graph featuring a sample of seven solar collectors sold in Iowa. To obtain the instanteous efficiency, you first obtain the fluid parameter. This is the ambient (outdoor) temperature (TA) subtracted from the temperature going into the collector (TI), divided by the solar insolation,(I in Btu/sq. ft.) When you calculate the fluid parameter, you go up on the graph until you hit the line of the curve representing the collector you are looking at. When you hit the line, you make a 90 degree angle left and when you intersect the Y axis you have the instantaneous efficiency. The higher the Y intercept and the lower the slope, the more effi-

COLLECTOR EFFICIENCY GRAPH

A SAMPLE OF SEVEN SOLAR COLLECTORS SOLD IN IOWA

Company Name	Y Intercept	Slope	X Intercept
Eagle Building Products	.6306	- .7548	.84
G S Energy Industries	.6190	- .7357	.84
Solar Gold, Inc.	.5905	- .9186	.64
Sully Mfg. Inc.	.5813	-1.1828	.49
General Solar Co. Inc.	.5257	-1.0216	.51
Resource Technologies	.5011	-1.1263	.44
Solar Electric, Inc.	.4922	-1.2485	.39



GRAPH ONE

This graph demonstrates how collectors perform under various climatological conditions. The fluid parameters are from Appendix Two. The Hour-by-Hour Solar Performance of Eagle Building Products collectors.

At 8:00 AM, insolation is 127 BTU/ft^2/hr, outdoodr temperature is 18^{0}F and inlet temperature is 65^{0}F. This gives a fluid parameter of .37. The instantaneous efficiency is 35% for the Eagle Building Products collector and 3% for the Solar Electric Panel. At 3:00 PM, the fluid parameter is .15, giving the Eagle an efficiency of 51% and the Solar Electric a 30% efficiency.

cient the solar collector. Such collectors tend to be well insulated, have glazings with a high solar transmission, and collector plates with a high absorptivity and low emissivity. When the instantaneous efficiency is obtained, this figure is multiplied by the solar insolation and square footage of the collector to come up with the total solar output from the collector. The BTU output would then diminish because of duct losses on the way to the room.

In most applications, solar collectors are used to heat one particular zone in the house. This enables the occupant to allow the temperature to drop in areas outside the zone, and to dump the solar heated air to keep the zone at a higher temperature. In this application, the solar heater is being used as a space heater, similiar to an electrical space heater. In calculating out how much savings can be attributable to solar through zone heating, we find that this is diffcult thing to do, depending on many parameters. Some of these are size of the zone, how tightly closed off it is from the rest of the house, the location of the thermostat and how well insulated the zone is from the rest of the house. Heat loss is calculated using the UA method: Average U-value times area, plus exfiltration. Calculating the UA of a zone is diffcult.

A CLOSE-UP LOOK AT ONE DAY

To get an idea what a set of solar collectors can do to heat a home, we can see that it would do on a clear day in the winter. We are going to look at Feb. 21 in Des Moines, which is two months after the winter solstice. In our example house, we are assuming UA of 700, which would give you a design heat loss of

56,000 BTUs per hour. This is fairly common for an average moderate sized home. If we would assume that for a period of 8 hours that we could turn down the temperature in the rest of the house to 55 degrees and the zone could be heated by the solar collector, we would see the savings listed at the bottom of the computer calculation sheet. In our example, we assume that our zone has a UA of 200, which would be about 30% of our home's living area.

We are using two Solar Max collectors which are made by Eagle Building Products. The "Directory of the Solar Rating and Certification Corporation's Certified Solar Collector Ratings, Fall 1984, lists this as the top performing air collector. This gives us the "best case"; other air collectors would perform at a lessor level, all other things being equal.

We are assuming that the rest of the house is heated to 55 degrees by the central heating system, the internal heat gain by people, lights and appliances, and by the solar radiation through the windows.

On page 5, Daily Solar Performance of Active Collectors, are three charts that illustrates the overall impact of our two high performing 4 X 8 collectors on our "typical" house. The best that it performs is at noon, where the combination of solar and zone heating is meeting 47% of our heating demand. At 3 P.M., solar and zone heating is meeting 36% of the demand.

Chart Three shows the summary of the solar contribution for the day. Savings from the combination of zone heating and the solar collector input account for a 12% savings.

DAILY SOLAR PERFORMANCE OF ACTIVE COLLECTORS

Collector: Solar Max (Eagle Building Products)

Technical notes: 66 sq. ft., faced due south at 60 degrees

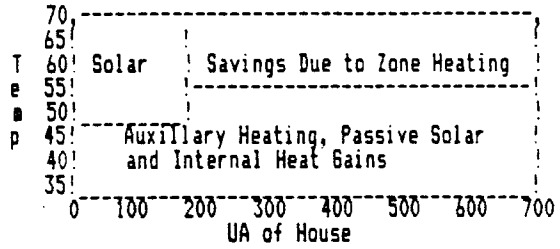


Chart One: Heating Characteristics on a Typical House from 12-1 p.m. on Feb. 21

Savings due to zone heating= (70-55) x 500 UA= 7500 BTU or 29%
Input from solar collectors= 4569 BTU
Savings due to zone and solar= 12,096 BTU or 47%

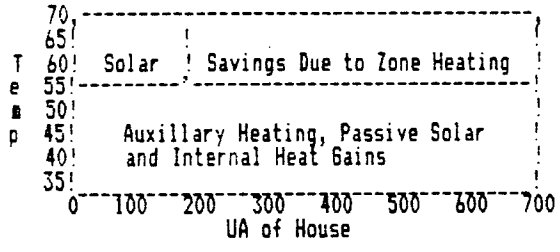


Chart Two: Heating Characteristics on a Typical House from 3-4 p.m. on Feb. 21

Savings due to zone heating= (70-55) x 500 UA= 7500 BTU or 29%
Input from solar collectors= 2782 BTU
Savings due to zone and solar= 9282 BTU or 36%

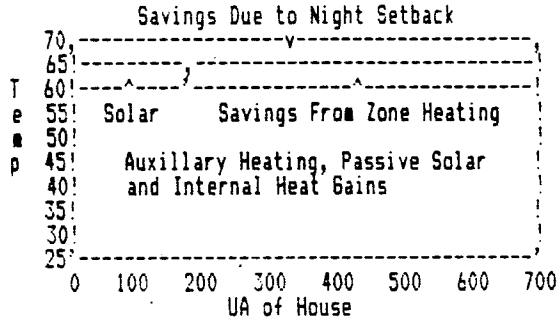


Chart Three: Heating Characteristics on a Typical House on Feb. 21 for Entire Day

DAILY TOTALS

Base heat loss= (70-26) x 700 UA x 24 hr=	739,200 BTU
Savings due to night setback= 15F x 700 UA x 8 hr=	84,000 BTU or 11%
Savings due to day zone heating= 15F x 500 UA x 8 hr=	60,000 BTU or 8%
Total input from solar collector=	28,646 BTU or 4%
Savings due to solar collector and zone heating=	88,646 BTU or 12%

It should be noted that there are many factors that enter in the total picture of a home's heating needs. If there are very many south windows, this may provide a significant part of the heating requirement during the day. Internal heating gains from cooking, people, lights and appliances may also play a big role.

Perhaps the most straight forward method to compare the savings is to see what it would cost to produce that same amount of heat with an electric space heater. Whether or not a BTU comes from the sun or a space heater, it has the same effect. From our example, total BTUs produced is 28,646, when divided by 3412, the number of BTUs in a kilowatt hour (KWH), we see that it would have taken about 8.4 KWH or 67¢ worth of electricity to produce the same amount of heat.

Conclusion

A solar collector would perform better or worse than shown in this analysis depending on the efficiency of the collector, the number of collectors and the quality of installation. We saw in this case, a clear winter day with average temperatures that we achieved a 4% savings from solar and a total of 12% savings when combined with zone heating.

How much would a system like this reduce heating bills for the entire winter? In an average Iowa winter, the sunshines 51% of the time in the day from November through March, where 83% of the annual heating load falls. Could a case be made to save 10% through a combination of solar and zone heating?

Appendix One shows a computer analysis fo the F-chart method of determining the expected solar performance of the Solar Max system for an entire year, which is generally accepted by the

solar industry. It shows an 8% savings for the entire year, which correlates with our projected performance for our one day.

One final note is that often times people who install collectors do indeed experience a savings greater than 10%. This raises an interesting question: Why did they save so much? If other energy conservation items are installed simultaneously, savings will of course increase. Another possible explanation is that usually if someone makes a monetary committment to purchase of a solar collector, they may become more conscious of the energy they consume. They may very well make other changes in their life style or implement other energy conservation practices as well. This also may result in significant changes, resulting in a reduction of consumption.

```
1  CITY CALL NUMBER.............................. 60
2  COLLECTOR AREA................................ 66  FT2
3  FR*UL......................................... .7548  BTU/HR-FT2-F
4  FR*TAU*ALPHA.................................. .6306
5  NUMBER OF GLAZINGS............................ 2
6  COLLECTOR SLOPE............................... 60  DEG
7  COLLECTOR AZIMUTH (SOUTH=0)................... 0  DEG
8  INC ANGLE MOD (0 IF NOT AVAIL)................ .175

9  RELATIVE STORAGE SIZE (.5 - 4)................ .5
10 BUILDING UA................................... 700  BTU/HR-F
11 RELATIVE AIR FLOWRATE (.5 - 2)................ 1
12 FUEL (1=ELEC,2=NG,3=OIL,4=LP)................. 2
13 EFFICIENCY OF FUEL USAGE...................... 70  %
14 DOMESTIC HOT WATER (1=Y,2=N)................... 2
15   HOT WATER USAGE............................. 79.3  GAL/DAY
16   WATER SET TEMPERATURE....................... 140  F
17   WATER MAINS TEMPERATURE..................... 52  F

18   ENVIRONMENT TEMPERATURE..................... 68  F
19   REL. DHW STORAGE SIZE (.5-4)................ 1
20   UA OF AUX STORAGE TANK...................... 7.6  BTU/HR-F
21 DUCT LOSSES (1=Y,2=N)......................... 2
22   INLET DUCT UA............................... 19  BTU/HR-F
23   OUTLET DUCT UA.............................. 19  BTU/HR-F
24   PERCENT DUCT LEAK RATE...................... 0  %
25   LEAK LOC (1=IN,2=OUT,3=BOTH)................ 3


?C

****************************************
*                F-CHART               *
*   APPLE ][  VERSION 3.3 11/26/82     *
*            COPYRIGHT BY              *
*      S.A. KLEIN & W.A. BECKMAN       *
*              ANALYSIS BY             *
*      IOWA ENERGY POLICY COUNCIL      *
*            LUCAS BUILDING            *
*       DES MOINES, IOWA  50319        *
*     800/532-1114 OR 515/281-7017     *
****************************************

DES MOINES       IA

SOLAR MAX (EAGLE BUILDING PRODUCTS)

*** AIR SYSTEM ***

      SOLAR    HEAT     DHW     AUX       F
      MMBTU   MMBTU   MMBTU   MMBTU
 JAN   2.04   23.77    0.00   23.07    0.03
 FEB   2.28   19.17    0.00   18.28    0.05
 MAR   2.72   16.21    0.00   15.12    0.07
 APR   2.85    7.80    0.00    6.63    0.15
 MAY   2.98    3.11    0.00    1.97    0.37
 JUN   3.04    0.42    0.00    0.00    1.00
 JUL   3.21    0.00    0.00    0.00    1.00
 AUG   3.24    0.22    0.00    0.00    1.00
 SEP   3.02    1.58    0.00    0.47    0.70
 OCT   3.04    5.86    0.00    4.55    0.22
 NOV   2.15   13.69    0.00   12.87    0.06
 DEC   1.75   20.83    0.00   20.29    0.03
  YR  32.32  112.66    0.00  103.25    0.08
```

NAME OF PROJECT: SOLAR MAX (EAGLE BUILDING PRODUCTS)
Y INTERCEPT=.6706
SLOPE (FRUL)=.7548
UA OF ENTIRE HOUSE=700
INLET TEMPERATURE=65
GROSS COLLECTOR AREA=66
DESIRED TEMPERATURE OF LIVING AREA WHILE OCCUPIED= 70
ALLOWABLE MINIMUM TEMPERATURE=55
COST ELECTRICITY= $.08
UA OF ZONE=200
AVERAGE AMBIENT TEMPERATURE=26

INSOLATION AND AVERAGE AMBIENT TEMP FOR FEB AT 60 DEGREE ANGLE

7A.M.
AVG HOURLY TEMP=16
INSOLATION IN BTU'S/SQ. FT. =24
FLUID PARAMETER=2.04
EFFICIENCY=0
SOLAR BTU'S COLLECTED=0
HEAT LOSS AT 70DEGREES=37800 BTU'S
SOLAR CONTRIBUTION=0 PERCENT
SAVINGS DUE TO SOLAR AND ZONE HEATING=19.84 PERCENT
SAVINGS DUE TO ZONE HEATING ONLY=19.84 PERCENT

8A.M.
AVG HOURLY TEMP=18
INSOLATION IN BTU'S/SQ. FT. =127
FLUID PARAMETER=.37
EFFICIENCY=.35
SOLAR BTU'S COLLECTED=1159.88
HEAT LOSS AT 70DEGREES=36400 BTU'S
SOLAR CONTRIBUTION=3.19 PERCENT
SAVINGS DUE TO SOLAR AND ZONE HEATING=23.79 PERCENT
SAVINGS DUE TO ZONE HEATING ONLY=20.6 PERCENT

9A.M.
AVG HOURLY TEMP=21
INSOLATION IN BTU'S/SQ. FT. =208
FLUID PARAMETER=.21
EFFICIENCY=.47
SOLAR BTU'S COLLECTED=2546.79
HEAT LOSS AT 70DEGREES=34300 BTU'S
SOLAR CONTRIBUTION=7.43 PERCENT
SAVINGS DUE TO SOLAR AND ZONE HEATING=29.29 PERCENT
SAVINGS DUE TO ZONE HEATING ONLY=21.87 PERCENT

10A.M.
AVG HOURLY TEMP=29
INSOLATION IN BTU'S/SQ. FT. =267
FLUID PARAMETER=.13
EFFICIENCY=.53
SOLAR BTU'S COLLECTED=3671.13
HEAT LOSS AT 70DEGREES=28700 BTU'S
SOLAR CONTRIBUTION=12.79 PERCENT
SAVINGS DUE TO SOLAR AND ZONE HEATING=38.92 PERCENT
SAVINGS DUE TO ZONE HEATING ONLY=26.13 PERCENT

11A.M.
AVG HOURLY TEMP=31
INSOLATION IN BTU'S/SQ. FT. =304
FLUID PARAMETER=.11
EFFICIENCY=.55
SOLAR BTU'S COLLECTED=4317.02
HEAT LOSS AT 70DEGREES=27300 BTU'S
SOLAR CONTRIBUTION=15.81 PERCENT
SAVINGS DUE TO SOLAR AND ZONE HEATING=43.29 PERCENT
SAVINGS DUE TO ZONE HEATING ONLY=27.47 PERCENT

12P.M.
AVG HOURLY TEMP=33
INSOLATION IN BTU'S/SQ. FT. =317
FLUID PARAMETER=.1
EFFICIENCY=.55
SOLAR BTU'S COLLECTED=4569.41
HEAT LOSS AT 70DEGREES=25900 BTU'S
SOLAR CONTRIBUTION=17.64 PERCENT
SAVINGS DUE TO SOLAR AND ZONE HEATING=46.6 PERCENT
SAVINGS DUE TO ZONE HEATING ONLY=28.96 PERCENT

1P.M.
AVG HOURLY TEMP=34
INSOLATION IN BTU'S/SQ. FT. =304
FLUID PARAMETER=.1
EFFICIENCY=.55
SOLAR BTU'S COLLECTED=4375.89
HEAT LOSS AT 70DEGREES=25200 BTU'S
SOLAR CONTRIBUTION=17.36 PERCENT
SAVINGS DUE TO SOLAR AND ZONE HEATING=47.13 PERCENT
SAVINGS DUE TO ZONE HEATING ONLY=29.76 PERCENT

2P.M.
AVG HOURLY TEMP=34
INSOLATION IN BTU'S/SQ. FT. =267
FLUID PARAMETER=.12
EFFICIENCY=.54
SOLAR BTU'S COLLECTED=3769.26
HEAT LOSS AT 70DEGREES=25200 BTU'S
SOLAR CONTRIBUTION=14.96 PERCENT
SAVINGS DUE TO SOLAR AND ZONE HEATING=44.72 PERCENT
SAVINGS DUE TO ZONE HEATING ONLY=29.76 PERCENT

3P.M.
AVG HOURLY TEMP=33
INSOLATION IN BTU'S/SQ. FT. =208
FLUID PARAMETER=.15
EFFICIENCY=.51
SOLAR BTU'S COLLECTED=2782.29
HEAT LOSS AT 70DEGREES=25900 BTU'S
SOLAR CONTRIBUTION=10.74 PERCENT
SAVINGS DUE TO SOLAR AND ZONE HEATING=39.7 PERCENT
SAVINGS DUE TO ZONE HEATING ONLY=28.96 PERCENT

4P.M.
AVG HOURLY TEMP=33
INSOLATION IN BTU'S/SQ. FT. =127
FLUID PARAMETER=.25
EFFICIENCY=.44
SOLAR BTU'S COLLECTED=1454.25
HEAT LOSS AT 70DEGREES=25900 BTU'S
SOLAR CONTRIBUTION=5.61 PERCENT
SAVINGS DUE TO SOLAR AND ZONE HEATING=34.57 PERCENT
SAVINGS DUE TO ZONE HEATING ONLY=28.96 PERCENT

5P.M.
AVG HOURLY TEMP=32
INSOLATION IN BTU'S/SQ. FT. =24
FLUID PARAMETER=1.38
EFFICIENCY=0
SOLAR BTU'S COLLECTED=0
HEAT LOSS AT 70DEGREES=26600 BTU'S
SOLAR CONTRIBUTION=0 PERCENT
SAVINGS DUE TO SOLAR AND ZONE HEATING=28.2 PERCENT
SAVINGS DUE TO ZONE HEATING ONLY=28.2 PERCENT

DAILY TOTALS FOR FEB AT 60 DEGREE ANGLE

BASE HEAT LOSS=	739200 BTU
SAVINGS DUE TO NIGHT SETBACK=	84000 BTU OR 11.4%
SAVINGS DUE TO DAY ZONE HEATING=	60000 BTU OR 8.1%
TOTAL INPUT FROM SOLAR COLLECTOR=	28646 BTU OR 3.9%
SAVINGS DUE TO SOLAR COLLECTOR AND ZONE HEATING=	88646 BTU OR 12%
COST TO REPLACE SOLAR HEAT WITH ELECTRIC SPACE HEATER=	$.67

DSF 6.3