DOE/NASA CONTRACTOR REPORT

DOE/NASA CR-150559

SITE SELECTION FEASIBILITY ANALYSIS FOR A SOLAR ENERGY SYSTEM ON THE FAIRBANKS FEDERAL BUILDING

Prepared by

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Under Contract NAS8-32036 with

National Aeronautics and Space Administration
George C. Marshall Space Flight Center, Alabama 35812

For the U. S. Department of Energy

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This work was done under the technical management of Mr. Earle G. Harris, Marshall Space Flight Center, Alabama.

16. ABSTRACT

A feasibility study has been performed for the installation of a solar energy system on the Federal Building in Fairbanks, Alaska, a multi-floor office building with an enclosed parking garage. The study consisted of determining the collectable solar energy at the Fairbanks site on a monthly basis and comparing this to the monthly building heating load. Potential conventional fuel savings were calculated on a monthly basis and the overall economics of the solar system applications were considered. Possible solar system design considerations, collector and other system installation details, interface of the solar system with the conventional HVAC systems, and possible control modes were all addressed. Conclusions, recommendations and study details are presented.

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TABLE OF CONTENTS

INTRODUCTION

In response to a MSFC Technical Directive (Number 20) under the SIMS Program, a feasibility study was performed for the installation of a solar energy system on the Fairbanks, Alaska, Federal Building.

This is a multi-floor office building with an enclosed parking garage. Located nearby is a motor pool shop. The main building has four-floor office wings along the north and east sides and a three-floor parking garage within the southwest corner.

HVAC requirements are currently met by an oil fired boiler, a heat recovery system comprised of air conditioning and heat pump units, and ventilation and supply fans. Main building heat is also supplied to the detached motor pool shop.

The study consisted of determining the collectable solar energy at the Fairbanks site on a monthly basis and comparing this to the monthly building heating load. Potential conventional fuel savings were calculated on a monthly basis and the overall economics of the solar system applications were considered. Possible solar system design considerations, collector and other system installation details, interface of the solar system with the conventional HVAC systems, and possible control modes were all addressed. Conclusions, recommendations and study details are presented in following sections of this report.

CONCLUSIONS

The following conclusions resulted from this feasibility study:

- A solar system can be physically installed at the Fairbanks site, although the collector array will have to be ground mounted.

- Conventional yearly fuel savings up to 19.3%, corresponding to 8,000 gallons of fuel oil, are possible with installation of the conceived solar system, assuming 4,000 ft^2 of effective collector area.

- Although the first-cut calculations contained in this report indicates that some economic savings over a 20-year period are feasible, uncertainties associated with purchase and installation costs (which are expensive in the Fairbanks area) of a final system design and with projected fuel oil costs over this period make an economic conclusion unrealistic from a study of this brevity. In fact, an overall economic loss is quite possible.

Overall, whether a solar energy system is deemed feasible for the Fairbanks site will depend upon the importance of each of the three listed conclusions to the user.

CLIMATOLOGICAL FACTORS

Fairbanks is located in the interior of Alaska at latitude 64.8^{o}N and longitude 147.9^{o}W. The surrounding mountain ranges toward the south are approximately one degree above true horizon. During the months of June and July the sun is above the horizon from 18 to 21 hours each day. Conversely, during December and January, the sun is above the horizon only 3 to 6 hours each day. A sun path diagram for Fairbanks is provided as Figure 1. Amounts of cloudiness are low, on the average, the year around. The period from January through April is particularly clear.

Figure 2 presents the available solar energy on the horizontal, as well as on tilted surfaces of 60, 75 and 90 degrees. Wintertime insolation values are quite low because of the short period of sunlight at that time of year. It can be seen that available solar energy peaks in March. The latter months of the year are significantly degraded by cloudiness and precipitation.

Table 1 presents a monthly summary of climatic conditions associated with the collection of solar energy.

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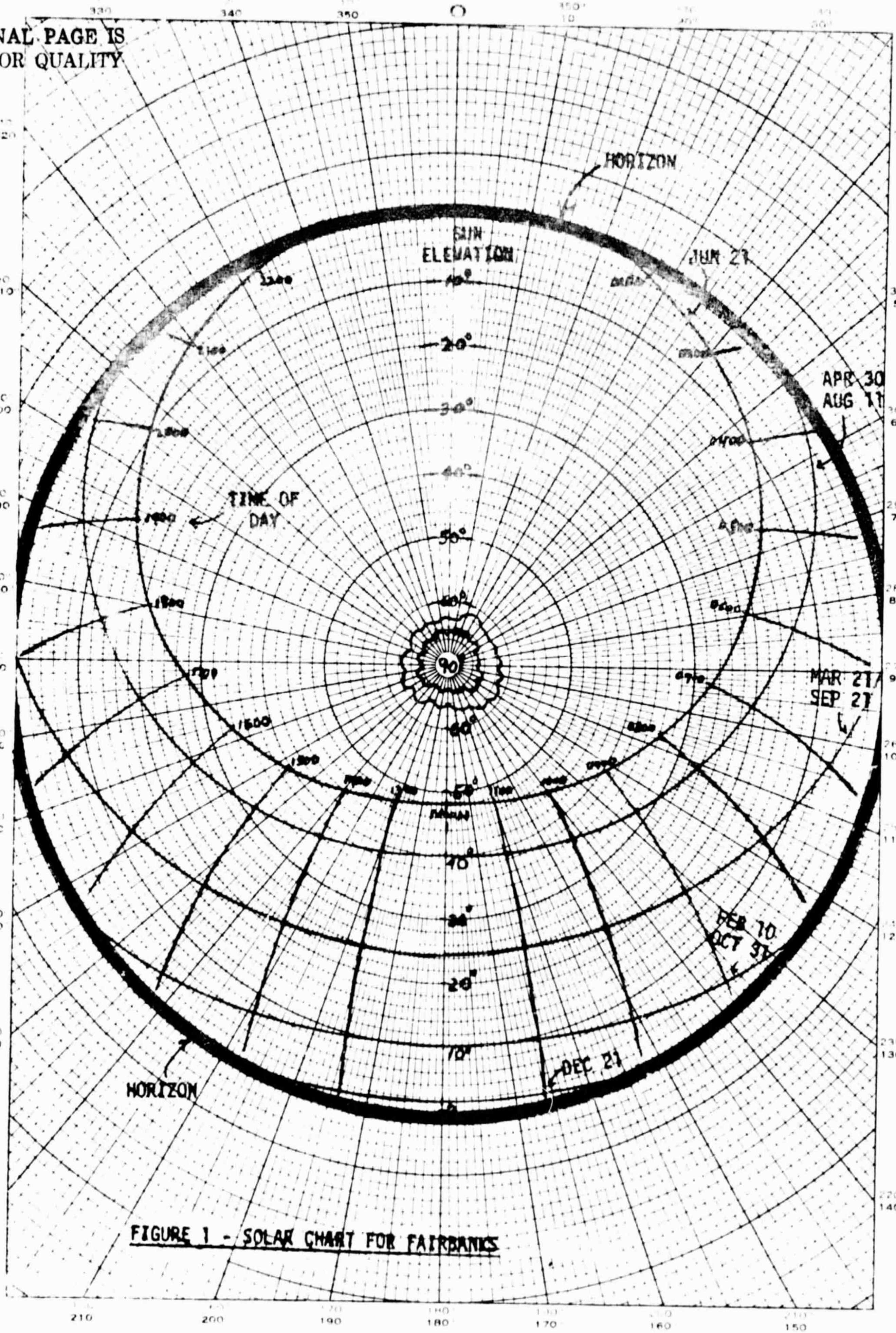

FIGURE 1 - SOLAR CHART FOR FAIRBANKS

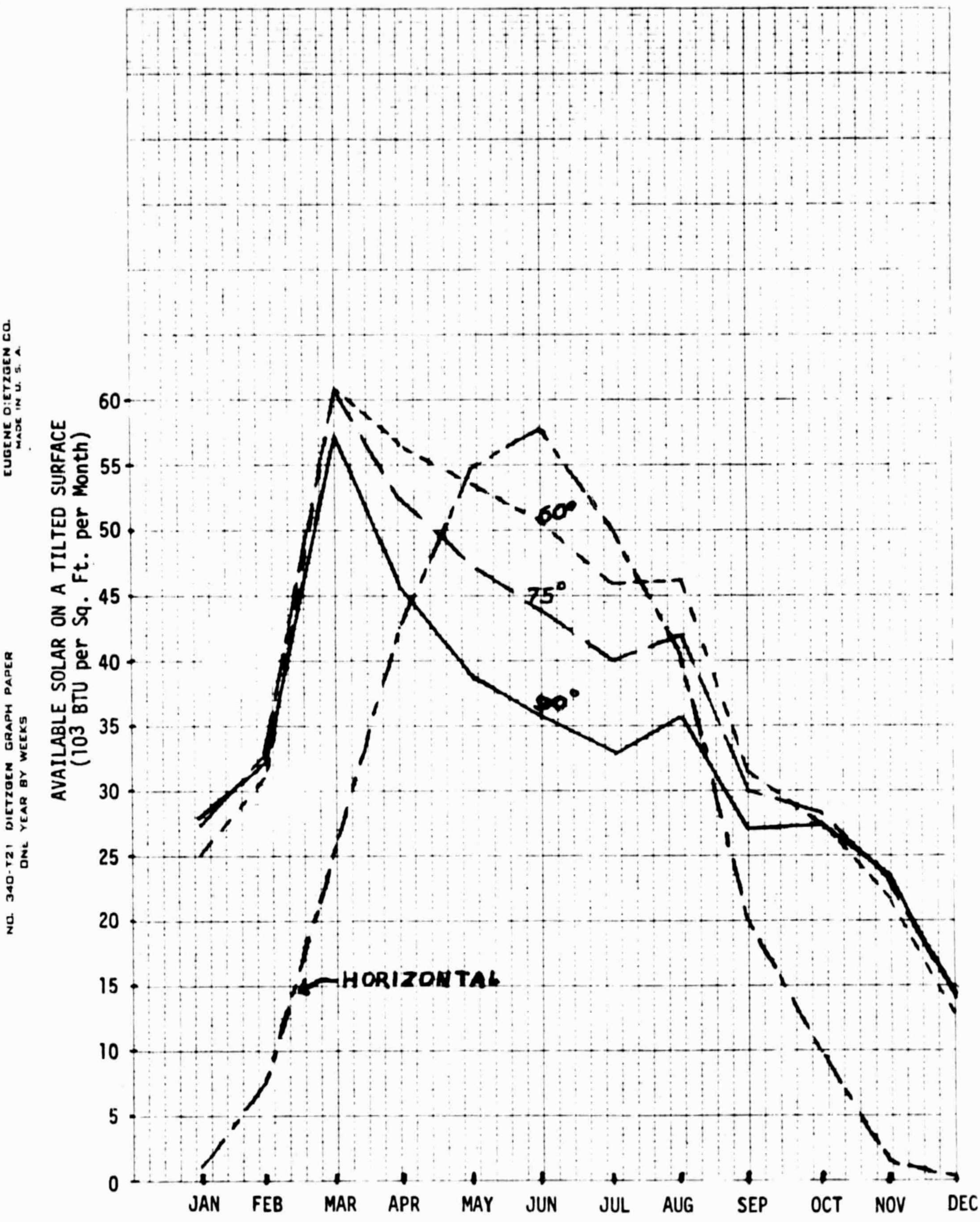

FIGURE 2. AVAILABLE SOLAR ENERGY

	Average Monthly Temp.	$\overline{K}_t$ *	Insolation on Horizontial (10^3 BTU/FT^2/ Month	Heating Degree Days
January	-11°F	0.64	2.2	2359
February	- 2	0.56	7.8	1901
March	9	0.67	26.6	1739
April	30	0.65	42.5	1068
May	46	0.55	54.5	555
June	57	0.53	58.2	222
July	59	0.49	50.7	171
August	54	0.46	41.4	332
September	43	0.42	20.3	642
October	27	0.42	9.8	1203
November	3	0.47	3.0	1833
December	- 8	0.46	0.7	2254

Table 1. Monthly Summary of Climatic Conditions for Fairbanks, Alaska

* Fraction of extraterrestrial radiation transmitted through the atmosphere.

BUILDING HEATING REQUIREMENTS

The building heat loss calculations and present HVAC system design and operational modes were reviewed for the following purposes:

- determine the heat loss rate of the building.
- determine the methods utilized by the HVAC system in meeting the various building heating loads
- identify HVAC system loads and/or modes of operation for which solar provided heat could be effectively utilized

The overall heat loss rate (U_0) of the main building and motor pool shop including makeup air ventilation was calculated as approximately 25,900 BTU/HR-^oF. The internal heat generated by lights and people was determined to be an average of $4(10^6)$ BTU/day. An assumption was made that 50 percent of this heat went to offset heat losses and the balance became a heat gain to the cooling subsystem.

A breakdown of the HVAC system is basically as follows:

- Boiler (Oil Fired)
  - Lower floor (unit heaters)
  - Stairways and vestibules (unit heaters)
  - Motor Pool Shop (unit heaters; floor coils, vent heat exchanger)
  - Make-up Air and Vent Subsystem (Vent Heat Exchange)

- Parking Garage (liquid to air heat exchanger)
- Loading Dock (unit heaters)
- Supplemental Heat to Heat Recovery System (L to L Heat Exchanger)
- Hot Water (L to L Heat Exchanger)

o Heat Recovery System (with water source tank)

- Water to air Heat Pumps on 1, 2, and 3 floors (100+ units)
- Air conditioners for 1, 2, and 3 floors (3 units)
- Hot water (L to L Heat Exchanger)

Initially, the heat recovery system, make-up air and vent subsystem, and motor pool shop (floor coils, vent heat exchanger) were selected as promising areas for a retrofit type interface with a liquid storage solar system. The heat recovery system's net load at the source tank, where

net load = AC load (in) - heat pump load (out),

could not be established from available information. The average monthly loads on the total HVAC system, on the main building unit heater, on the main building make-up air and vent subsystem (HV3), and on the Motor Pool Shop floor coil and vent subsystems are listed in Table 2.

Month	Total HVAC System (MBTU)	Main Bldg. Vent (MBTU)	Motor Pool Shop Vent & Floor (MTBU)	Main Bldg. Unit Heater (MTBU)
January	1404	667	51	200
February	1126	534	41	179
March	1019	481	38	142
April	604	281	23	79
May	283	126	12	30
June	78	27	5	4
July	44	11	4	3
August	144	59	7	10
September	339	154	14	39
October	685	320	26	91
November	1079	511	40	151
December	1339	636	49	190
Total	8136	3809	311	1118

Table 2 - Average Building Heating Loads

Figure 3 presents the heat load profiles given in Table 2 versus the total incident solar energy on 4000 square feet of collector array at a 65° tilt angle. The efficiency of converting the incident energy into useable thermal energy varies from month to month and will be disucssed later.

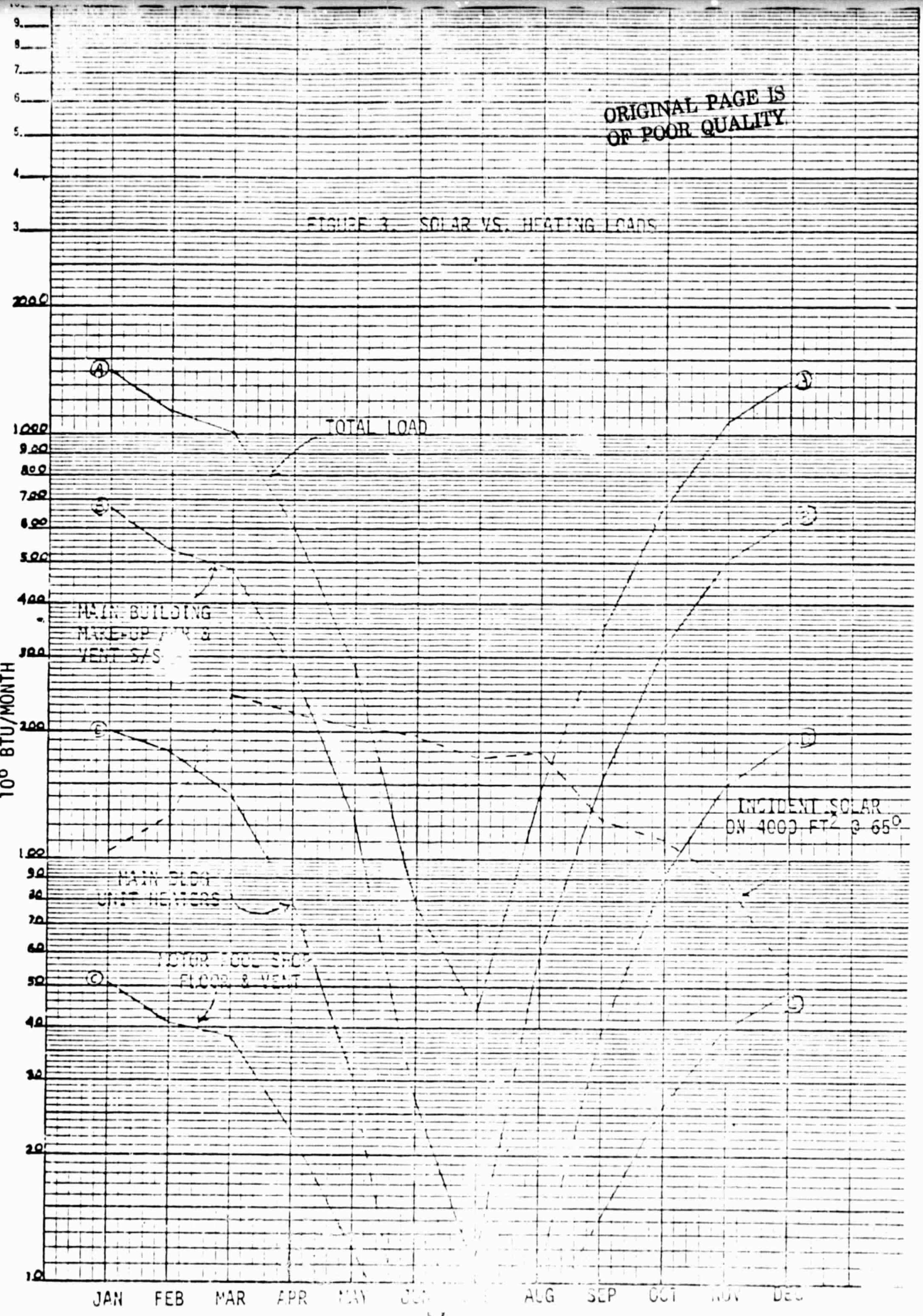

FIGURE 3. SOLAR VS. HEATING LOADS

Key to the performance of a solar energy system are the parameters associated with the collectors and the heat transfer and storage fluid.

A high performance liquid flatplate collector, such as the Lennox Model LSC 18-1, was selected as the best type of collector for this application. Tracking collectors were eliminated because of operational risks caused by severe temperature extremes plus the ice and snow loading problems expected with a mechanical system. System interface difficulties and high duct work costs made air collectors to be unsuitable for this application.

A liquid flatplate collector using ethylene glycol/water (60/40) heat transfer and storage fluid was most compatible in interfacing with the present HVAC system. A high performance collector is recommended over a lower performance collector in order to realize the cost savings associated with the labor rates in use during array construction. Higher performance collectors allow smaller arrays for the same amount of collected energy. Thus, the additional hardware money spent for performance will be saved in construction costs.

Collector parameter values (see Figure 4) for the Lennox, a typical high performance unit, were utilized during the collector array tilt and sizing investigations. An energy storage factor of two gallons per square foot of effective collector area was used. The building loads discussed in an earlier section (Building Heating Requirements) were included in this analysis. The F-CHART program developed at the Solar Energy Laboratory of the University of Wisconsin was used as the primary analysis tool.

A brief description of this program inputs and outputs is provided in the following paragraphs. Figures 4 and 5 present the input listing and thermal printout for a typical run.

```
INPUT ERROR, TRY AGAIN

CODE        VARIABLE DESCRIPTION                                 VALUE UNITS

  1   AIR SYSTEM*1,LIQUID SYSTEM*2..................         2.00
  2   COLLECTOR AREA................................      4000.00 FT2
  3   FRPRIME-TAU-ALPHA PRODUCT*NORMAL INCIDENCE ..         0.74
  4   FRPRIME-UL PRODUCT............................         0.55 BTU/H-F-F2
  5   NUMBER OF TRANSPARENT COVERS..................         2.00
  6   COLLECTOR SLOPE...............................        65.00 DEGREES
  7   AZIMUTH ANGLE \E.G. SOUTH*0, WEST*90 ........         0.00 DEGREES
  8   STORAGE CAPACITY..............................        15.00 BTU/F-FT2
  9   EFFECTIVE BUILDING UA......................... 12500.00 BTU/HR-F
 10   CONSTANT DAILY BLDG HEAT GENERATION..........********* BTU/DAY
 11   HOT WATER USAGE...............................         0.0  GAL/DAY
 12   WATER SET TEMPERATURE.........................       140.00 F
 13   WATER MAIN TEMPERATURE........................        51.80 F
 14   CITY CALL NUMBER..............................        34.00
 15   THERMAL PRINT OUT BY MONTH*1, BY YEAR*2......         1.00
 16   ECONOMIC ANALYSIS   YES*1, NO*2..............         2.00
TYPE IN CODE NUMBER AND NEW VALUE
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* VALUE LARGER THAN SPACE ALLOCATED
ACTUAL VALUE = 2,000,000 BTU/DAY

Figure 4. Input Listing

FAIRBANKS AK 64.49

****THERMAL ANALYSIS****

TIME	PERCENT SOLAR	INCIDENT SOLAR (MBTU)	HEATING LOAD (MBTU)	WATER LOAD (MBTU)	DEGREE DAYS (F-DAY)	AMBIENT TEMP (F)
JAN	7.4	104.25	667.39	0.0	2359.	-11.
FEB	12.7	127.4[illegible]	533.91	0.0	1901.	-2.
MAR	29.2	245.19	461.41	0.0	1739.	9.
APR	42.2	222.16	281.40	0.0	1068.	30.
MAY	71.9	205.45	126.20	0.0	555.	46.
JUN	100.0	194.79	27.60	0.0	222.	57.
JUL	100.0	176.89	11.00	0.0	171.	59.
AUG	100.0	130.57	59.31	0.0	332.	54.
SEP	38.5	124.06	153.60	0.0	642.	43.
OCT	17.5	111.34	320.60	0.0	1203.	27.
NOV	8.1	39.56	510.90	0.0	1933.	3.
DEC	2.3	53.87	635.89	0.0	2254.	-8.
YR	19.3	1836.10	3809.20	0.0	14279.	

TYPE IN CODE NUMBER AND NEW VALUE

Figure 5. Thermal Analysis Printout

- The meteorological data required to use the F-CHART method are: the long term monthly average of daily total solar radiation on a horizontal surface, the long term monthly average ambient temperature, and the long term monthly average heating degree days ($65^{o}F$ base).

- The solar energy system data needed for the F-CHART method includes: The F_RU_L and $F_R(\tau\alpha)$ products for the collector (which are the slope and intercept of collector efficiency versus $(T_{in} - T_{ambient})$/(incident radiation) curves); the effectiveness of heat exchangers between collector and tank (for liquid-based systems); the storage capacity per unit area of collector; and the orientation of the collector.

- The building heating load is incorporated either by specifying the monthly load (calculated by any standard technique), or by specifying the building overall loss coefficient (energy-per-degree-day concept), which is the design heating load divided by the design temperature difference. In addition, a service hot water load can be added to the heating load.

- Given these numbers, the fraction of monthly total loads, and the fraction of the annual loads to be carried by solar energy can readily be determined for any collector area.

The collector tilt angle sensitivity was evaluated using the main building vent subsystem load profile and 8,000 square feet of collector area. Tilt angles of 0, 60, 65, 70, 75, 80, and 90 degrees were examined. The resulting thermal analysis is presented in Figures 6 through 12 respectively. Annual solar contribution for each case is presented at the bottom of the first column. The highest percent solar contribution was obtained at 70 degrees of tilt. The variations at 65 and 75 degrees were slightly lower. These conclusions are valid for other collector areas.

CODE	VARIABLE DESCRIPTION	VALUE	UNITS
1	AIR SYSTEM=1, LIQUID SYSTEM=2..................	2.00	
2	COLLECTOR AREA...........................	8000.00	FT2
3	FRPRIME-TAU-ALPHA PRODUCT(NORMAL INCIDENCE)..	0.74	
4	FRPRIME-UL PRODUCT.......................	0.55	BTU-H-F-F2
5	NUMBER OF TRANSPARENT COVERS..............	2.00	
6	COLLECTOR SLOPE..........................	0.0	DEGREES
7	AZIMUTH ANGLE (E.G. SOUTH=0, WEST=90)........	0.00	DEGREES
8	STORAGE CAPACITY.........................	15.00	BTU/F-FT2
9	EFFECTIVE BUILDING UA....................	12500.00	BTU/HR-F
10	CONSTANT DAILY BLDG HEAT GENERATION..........	*********	BTU/DAY 1.3×10^6
11	HOT WATER USAGE..........................	0.0	GAL/DAY
12	WATER SET TEMPERATURE....................	140.00	F
13	WATER MAIN TEMPERATURE...................	51.80	F
14	CITY CALL NUMBER.........................	34.00	
15	THERMAL PRINT OUT BY MONTH=1, BY YEAR=2......	1.00	
16	ECONOMIC ANALYSIS YES=1, NO=2............	2.00	

TYPE IN CODE NUMBER AND NEW VALUE

FAIRBANKS AK 64.49

****THERMAL ANALYSIS****

TIME	PERCENT SOLAR	INCIDENT SOLAR (MBTU)	HEATING LOAD (MBTU)	WATER LOAD (MBTU)	DEGREE DAYS (F-DAY)	AMBIENT TEMP (F)
JAN	0.0	17.36	667.39	0.0	2359.	-11.
FEB	0.0	62.69	533.91	0.0	1901.	-2.
MAR	0.0	212.79	481.41	0.0	1739.	9.
APR	46.8	340.25	281.40	0.0	1068.	30.
MAY	100.0	435.63	126.20	0.0	555.	46.
JUN	100.0	465.76	27.60	0.0	222.	57.
JUL	100.0	4[illegible].49	11.00	0.0	171.	59.
AUG	100.0	331.50	59.31	0.0	332.	54.
SEP	27.7	162.62	153.60	0.0	642.	43.
OCT	0.0	72.53	320.60	0.0	1203.	27.
NOV	0.0	23.86	510.90	0.0	1833.	3.
DEC	0.0	5.48	635.89	0.0	2264.	-8.
YR	11.6	2541.97	3809.20	0.0	14279.	

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Figure 6. 0° Tilt Angle

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CODE        VARIABLE DESCRIPTION                                     VALUE     UNITS

  1   AIR SYSTEM=1,LIQUID SYSTEM=2.........................       2.00
  2   COLLECTOR AREA.......................................    8000.00  FT2
  3   FRPRIME-TAU-ALPHA PRODUCT(NORMAL INCIDENCE)..........       0.74
  4   FRPRIME-UL PRODUCT...................................       0.55  BTU/H-F-F2
  5   NUMBER OF TRANSPARENT COVERS.........................       2.00
  6   COLLECTOR SLOPE......................................      60.00  DEGREES
  7   AZIMUTH ANGLE (E.G. SOUTH=0, WEST=90)................       0.00  DEGREES
  8   STORAGE CAPACITY.....................................      15.00  BTU/F-FT2
  9   EFFECTIVE BUILDING UA................................   12500.00  BTU/HR-F
 10   CONSTANT DAILY BLDG HEAT GENERATION..................  *********  BTU/DAY     1.3 x 10^6
 11   HOT WATER USAGE......................................       0.0   GAL/DAY
 12   WATER SET TEMPERATURE................................     140.00  F
 13   WATER MAIN TEMPERATURE...............................      51.80  F
 14   CITY CALL NUMBER.....................................      34.00
 15   THERMAL PRINT OUT BY MONTH=1, BY YEAR=2..............       1.00
 16   ECONOMIC ANALYSIS   YES=1, NO=2......................       2.00
TYPE IN CODE NUMBER AND NEW VALUE

FAIRBANKS       AK    64.49

****THERMAL ANALYSIS****
 TIME PERCENT INCIDENT HEATING WATER DEGREE AMBIENT
       SOLAR    SOLAR     LOAD   LOAD   DAYS    TEMP
               (MBTU)   (MBTU) (MBTU) (F-DAY)  (F)
 JAN    13.3   200.69   667.39   0.0   2359.   -11.
 FEB    23.2   248.77   533.91   0.0   1901.    -2.
 MAR    52.5   486.75   481.41   0.0   1739.     9.
 APR    73.9   452.31   281.40   0.0   1068.    30.
 MAY   100.0   425.57   126.20   0.0    555.    46.
 JUN   100.0   406.17    27.60   0.0    222.    57.
 JUL   100.0   367.81    11.00   0.0    171.    59.
 AUG   100.0   370.88    59.31   0.0    332.    54.
 SEP    66.1   250.04   153.60   0.0    642.    43.
 OCT    31.7   220.03   320.60   0.0   1203.    27.
 NOV    14.5   173.11   510.90   0.0   1833.     3.
 DEC     4.0   103.39   635.89   0.0   2254.    -8.
 YR     31.5  3705.52  3809.20   0.0  14279.

TYPE IN CODE NUMBER AND NEW VALUE
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Figure 7. 60° Tilt Angle

TYPE IN CODE NUMBER AND NEW VALUE

CODE	VARIABLE DESCRIPTION	VALUE	UNITS
1	AIR SYSTEM=1, LIQUID SYSTEM=2..................	2.00	
2	COLLECTOR AREA.................................	8000.00	FT2
3	FRPRIME-TAU-ALPHA PRODUCT(NORMAL INCIDENCE)..	0.74	
4	FRPRIME-UL PRODUCT............................	0.55	BTU/H-F-F2
5	NUMBER OF TRANSPARENT COVERS..................	2.00	
6	COLLECTOR SLOPE...............................	65.00	DEGREES
7	AZIMUTH ANGLE (E.G. SOUTH=0, WEST=90).........	0.00	DEGREES
8	STORAGE CAPACITY..............................	15.00	BTU/F-FT2
9	EFFECTIVE BUILDING UA.........................	12500.00	BTU/HR-F
10	CONSTANT DAILY BLDG HEAT GENERATION..........	*********	BTU/DAY
11	HOT WATER USAGE...............................	0.0	GAL/DAY
12	WATER SET TEMPERATURE.........................	140.00	F
13	WATER MAIN TEMPERATURE........................	51.80	F
14	CITY CALL NUMBER..............................	34.00	
15	THERMAL PRINT OUT BY MONTH=1, BY YEAR=2......	1.00	
16	ECONOMIC ANALYSIS YES=1, NO=2................	2.00	

1.3 x10^6

TYPE IN CODE NUMBER AND NEW VALUE
1

FAIRBANKS AK 64.49

****THERMAL ANALYSIS****

TIME	PERCENT SOLAR	INCIDENT SOLAR (MBTU)	HEATING LOAD (MBTU)	WATER LOAD (MBTU)	DEGREE DAYS (F-DAY)	AMBIENT TEMP (F)
JAN	14.3	208.51	667.39	0.0	2359.	-11.
FEB	24.2	254.93	533.91	0.0	1901.	-2.
MAR	52.9	430.39	481.41	0.0	1739.	9.
APR	72.6	444.31	281.40	0.0	1068.	30.
MAY	100.0	410.89	126.20	0.0	555.	46.
JUN	100.0	389.58	27.60	0.0	222.	57.
JUL	100.0	353.78	11.00	0.0	171.	59.
AUG	100.0	361.14	59.31	0.0	332.	54.
SEP	65.6	248.13	153.60	0.0	642.	43.
OCT	32.6	223.68	320.60	0.0	1203.	27.
NOV	15.6	179.13	510.90	0.0	1833.	3.
DEC	4.6	107.74	635.89	0.0	2254.	-8.
YR	32.1	3672.20	3809.20	0.0	14279.	

TYPE IN CODE NUMBER AND NEW VALUE

Figure 8. 65^{o} Tilt Angle

CODE	VARIABLE DESCRIPTION	VALUE	UNITS
1	AIR SYSTEM=1,LIQUID SYSTEM=2................	2.00	
2	COLLECTOR AREA..............................	3200.00	FT2
3	FRPRIME-TAU-ALPHA PRODUCT(NORMAL INCIDENCE)..	0.74	
4	FRPRIME-UL PRODUCT..........................	0.55	BTU/H-F-F2
5	NUMBER OF TRANSPARENT COVERS................	2.00	
6	COLLECTOR SLOPE.............................	70.00	DEGREES
7	AZIMUTH ANGLE (E.G. SOUTH=0, WEST=90).......	0.00	DEGREES
8	STORAGE CAPACITY............................	15.00	BTU/F-FT2
9	EFFECTIVE BUILDING UA.......................	12500.00	BTU/HR-F
10	CONSTANT DAILY BLDG HEAT GENERATION.........	**********	BTU/DAY
11	HOT WATER USAGE.............................	0.0	GAL/DAY
12	WATER SET TEMPERATURE.......................	140.00	F
13	WATER MAIN TEMPERATURE......................	51.80	F
14	CITY CALL NUMBER............................	34.00	
15	THERMAL PRINT OUT BY MONTH=1, BY YEAR=2.....	1.00	
16	ECONOMIC ANALYSIS YES=1, NO=2..............	2.00	

1.3 x 10^6

TYPE IN CODE NUMBER AND NEW VALUE

FAIRBANKS AK 64.49

****THERMAL ANALYSIS****

TIME	PERCENT SOLAR	INCIDENT SOLAR (MBTU)	HEATING LOAD (MBTU)	WATER LOAD (MBTU)	DEGREE DAYS (F-DAY)	AMBIENT TEMP (F)
JAN	15.2	214.77	667.39	0.0	2359.	-11.
FEB	24.8	259.28	533.91	0.0	1901.	-2.
MAR	53.0	450.63	481.41	0.0	1739.	9.
APR	70.7	433.61	281.40	0.0	1068.	30.
MAY	100.0	394.21	126.20	0.0	555.	46.
JUN	100.0	371.33	27.60	0.0	222.	57.
JUL	100.0	338.20	11.00	0.0	171.	59.
AUG	100.0	349.47	59.31	0.0	332.	54.
SEP	64.7	244.72	153.60	0.0	642.	43.
OCT	33.1	225.81	320.60	0.0	1203.	27.
NOV	16.4	183.83	510.90	0.0	1833.	3.
DEC	5.2	111.27	636.89	0.0	2254.	-8.
YR	32.4	3617.13	3809.20	0.0	14279.	

TYPE IN CODE NUMBER AND NEW VALUE

Figure 9. 70^{0} Tilt Angle

CODE	VARIABLE DESCRIPTION	VALUE	UNITS
1	AIR SYSTEM=1,LIQUID SYSTEM=2..................	2.00	
2	COLLECTOR AREA................................	8000.00	FT2
3	FRPRIME-TAU-ALPHA PRODUCT(NORMAL INCIDENCE)..	0.74	
4	FRPRIME-UL PRODUCT............................	0.55	BTU/HR-F-FT2
5	NUMBER OF TRANSPARENT COVERS..................	2.00	
6	COLLECTOR SLOPE...............................	75.00	DEGREES
7	AZIMUTH ANGLE (E.G. SOUTH=0, WEST=90).........	0.00	DEGREES
8	STORAGE CAPACITY..............................	15.00	BTU/F-FT2
9	EFFECTIVE BUILDING UA.........................	12500.00	BTU/HR-F
10	CONSTANT DAILY BLDG HEAT GENERATION...........	*********	BTU/DAY
11	HOT WATER USAGE...............................	0.0	GAL/DAY
12	WATER SET TEMPERATURE.........................	140.00	F
13	WATER MAIN TEMPERATURE........................	51.80	F
14	CITY CALL NUMBER..............................	34.00	
15	THERMAL PRINT OUT BY MONTH=1, BY YEAR=2.....	1.00	
16	ECONOMIC ANALYSIS YES=1, NO=2.............	2.00	

1.3x10^6

TYPE IN CODE NUMBER AND NEW VALUE

FAIRBANKS AK 64.49

****THERMAL ANALYSIS****

TIME	PERCENT SOLAR	INCIDENT SOLAR (MBTU)	HEATING LOAD (MBTU)	WATER LOAD (MBTU)	DEGREE DAYS (F-DAY)	AMBIENT TEMP (F)
JAN	15.9	219.43	667.39	0.0	2359.	-11.
FEB	35.2	261.79	533.91	0.0	1981.	-2.
MAR	52.6	437.48	481.41	0.0	1739.	9.
APR	69.3	420.29	281.40	0.0	1068.	30.
MAY	97.7	375.64	126.20	0.0	555.	46.
JUN	100.0	351.56	27.60	0.0	222.	57.
JUL	100.0	321.20	11.00	0.0	171.	59.
AUG	100.0	335.95	59.31	0.0	332.	54.
SEP	63.2	239.85	153.60	0.0	642.	43.
OCT	33.3	226.40	320.60	0.0	1203.	27.
NOV	16.9	187.19	510.90	0.0	1833.	3.
DEC	5.6	113.98	635.89	0.0	2254.	-8.
YR	32.3	3540.76	3809.20	0.0	14279.	

TYPE IN CODE NUMBER AND NEW VALUE

Figure 10. 75^{0} Tilt Angle

CODE	VARIABLE DESCRIPTION	VALUE	UNITS
1	AIR SYSTEM=1, LIQUID SYSTEM=2..................	2.00	
2	COLLECTOR AREA..................................	8000.00	FT2
3	FRPRIME-TAU-ALPHA PRODUCT(NORMAL INCIDENCE)..	0.74	
4	FRPRIME-UL PRODUCT..............................	0.55	BTU/H-F-F2
5	NUMBER OF TRANSPARENT COVERS....................	2.00	
6	COLLECTOR SLOPE.................................	80.00	DEGREES
7	AZIMUTH ANGLE (E.G. SOUTH=0, WEST=90).........	0.00	DEGREES
8	STORAGE CAPACITY................................	15.00	BTU/F-FT2
9	EFFECTIVE BUILDING UA...........................	12500.00	BTU/HR-F
10	CONSTANT DAILY BLDG HEAT GENERATION............	*********	BTU/DAY
11	HOT WATER USAGE.................................	0.0	GAL/DAY
12	WATER SET TEMPERATURE...........................	140.00	F
13	WATER MAIN TEMPERATURE..........................	51.80	F
14	CITY CALL NUMBER................................	34.00	
15	THERMAL PRINT OUT BY MONTH=1, BY YEAR=2.......	1.00	
16	ECONOMIC ANALYSIS YES=1, NO=2................	2.00	

1.3 x 10^6

TYPE IN CODE NUMBER AND NEW VALUE

FAIRBANKS AK 64.49

****THERMAL ANALYSIS****

TIME	PERCENT SOLAR	INCIDENT SOLAR (MBTU)	HEATING LOAD (MBTU)	WATER LOAD (MBTU)	DEGREE DAYS (F-DAY)	AMBIENT TEMP (F)
JAN	16.2	222.45	667.39	0.0	2359.	-11.
FEB	25.3	262.43	533.91	0.0	1901.	-2.
MAR	51.7	420.95	481.41	0.0	1739.	9.
APR	65.3	424.45	281.40	0.0	1068.	30.
MAY	92.9	355.36	126.20	0.0	555.	46.
JUN	100.0	330.44	27.60	0.0	222.	57.
JUL	100.0	302.93	11.00	0.0	171.	59.
AUG	100.0	320.69	59.31	0.0	332.	54.
SEP	61.3	233.55	153.60	0.0	642.	43.
OCT	33.1	225.46	320.60	0.0	1203.	27.
NOV	17.3	189.17	510.90	0.0	1833.	3.
DEC	5.8	115.82	635.59	0.0	2254.	-8.
YR	31.9	3443.69	3809.20	0.0	14279.	

TYPE IN CODE NUMBER AND NEW VALUE

Figure 11. 80° Tilt Angle

```
CODE        VARIABLE DESCRIPTION                                VALUE   UNITS

  1    AIR SYSTEM=1,LIQUID SYSTEM=2.......................     [illegible]
  2    COLLECTOR AREA.....................................    6000.00 FT2
  3    FRPRIME-TAU-ALPHA PRODUCT(NORMAL INCIDENCE)........       0.74
  4    FRPRIME-UL PRODUCT.................................       0.55 BTU/H-F-FT2
  5    NUMBER OF TRANSPARENT COVERS.......................       2.00
  6    COLLECTOR SLOPE....................................      90.00 DEGREES
  7    AZIMUTH ANGLE (E.G. SOUTH=0, WEST=90)..............       0.00 DEGREES
  8    STORAGE CAPACITY...................................      15.00 BTU/F-FT2
  9    EFFECTIVE BUILDING UA..............................   12500.00 BTU/HR-F
 10    CONSTANT DAILY BLDG HEAT GENERATION................  ********* BTU/DAY      1.3 X10^6
 11    HOT WATER USAGE....................................        0.0 GAL/DAY
 12    WATER SET TEMPERATURE..............................     140.00 F
 13    WATER MAIN TEMPERATURE.............................      51.80 F
 14    CITY CALL NUMBER...................................      34.00
 15    THERMAL PRINT OUT BY MONTH=1, BY YEAR=2............       1.00
 16    ECONOMIC ANALYSIS   YES=1, NO=2....................       2.00
TYPE IN CODE NUMBER AND NEW VALUE
r
 FAIRBANKS        AK    64.49

 ****THERMAL ANALYSIS****
  TIME PERCENT INCIDENT HEATING WATER DEGREE AMBIENT
        SOLAR    SOLAR    LOAD   LOAD   DAYS    TEMP
                 (MBTU)  (MBTU) (MBTU) (F-DAY)  (F)
  JAN   16.4    223.50   667.39   0.0   2359.   -11.
  FEB   24.8    258.10   533.91   0.0   1901.    -2.
  MAR   48.5    458.01   481.41   0.0   1739.     9.
  APR   57.3    365.75   281.40   0.0   1068.    30.
  MAY   79.8    310.31   126.20   0.0    555.    46.
  JUN  100.0    294.89    27.60   0.0    222.    57.
  JUL  100.0    263.18    11.00   0.0    171.    59.
  AUG  100.0    225.48    59.31   0.0    332.    54.
  SEP   55.6    216.86   153.60   0.0    642.    43.
  OCT   31.8    219.01   320.60   0.0   1203.    27.
  NOV   17.3    138.96   510.90   0.0   1833.     3.
  DEC    6.0    116.50   635.80   0.0   2254.    -8.
  YR    30.2   3190.94  3809.20   0.0  14279.

TYPE IN CODE NUMBER AND NEW VALUE
```

Figure 12. 90^{0} Tilt Angle

Various collector array sizes were analyzed to determine affects on solar contribution. The main building vent load and the total HVAC system load was evaluated at 4000, 6000, 8000, and 10,000 square feet of collector array at a tilt of 65 degrees (Figures 8 and 13 through 19). The load for the motor pool shop vent and heated floor was analyzed for an array of 1000, 2000 and 4000 square feet (Figures 20 through 22).

Although increasing effective collector area increases the solar contribution, it also increases solar system purchase and installation costs, such that final determination of an array size must result from performance/cost studies.

CODE	VARIABLE DESCRIPTION	VALUE	UNITS
1	AIR SYSTEM=1, LIQUID SYSTEM=2..................	2.00	
2	COLLECTOR AREA.................................	4000.00	FT2
3	FRPRIME-TAU-ALPHA PRODUCT(NORMAL INCIDENCE)..	0.74	
4	FRPRIME-UL PRODUCT............................	0.55	BTU/H-F-F2
5	NUMBER OF TRANSPARENT COVERS..................	2.00	
6	COLLECTOR SLOPE...............................	65.00	DEGREES
7	AZIMUTH ANGLE (E.G. SOUTH=0, WEST=90)........	0.00	DEGREES
8	STORAGE CAPACITY..............................	15.00	BTU/F-FT2
9	EFFECTIVE BUILDING UA.........................	12500.00	BTU/HR-F
10	CONSTANT DAILY BLDG HEAT GENERATION..........	**********	BTU/DAY 1.3×10^6
11	HOT WATER USAGE...............................	0.0	GAL/DAY
12	WATER SET TEMPERATURE.........................	140.00	F
13	WATER MAIN TEMPERATURE........................	51.80	F
14	CITY CALL NUMBER..............................	34.00	
15	THERMAL PRINT OUT BY MONTH=1, BY YEAR=2......	1.00	
16	ECONOMIC ANALYSIS YES=1, NO=2................	2.00	

TYPE IN CODE NUMBER AND NEW VALUE

FAIRBANKS AK 64.49

****THERMAL ANALYSIS****

TIME	PERCENT SOLAR	INCIDENT SOLAR (MBTU)	HEATING LOAD (MBTU)	WATER LOAD (MBTU)	DEGREE DAYS (F-DAY)	AMBIENT TEMP (F)
JAN	7.4	104.25	667.39	0.0	2356.	-11.
FEB	12.7	127.47	633.91	0.0	1901.	-2.
MAR	29.2	245.19	481.41	0.0	1739.	9.
APR	42.2	222.16	281.40	0.0	1068.	30.
MAY	71.9	205.45	126.20	0.0	555.	46.
JUN	100.0	194.79	27.60	0.0	222.	57.
JUL	100.0	176.39	11.00	0.0	171.	59.
AUG	100.0	180.57	59.31	0.0	332.	54.
SEP	36.5	124.06	153.60	0.0	642.	43.
OCT	17.5	111.84	320.60	0.0	1203.	27.
NOV	2.1	69.56	510.90	0.0	1833.	3.
DEC	2.3	53.87	635.89	0.0	2254.	-8.
YR	19.3	1836.10	3809.20	0.0	14279.	

TYPE IN CODE NUMBER AND NEW VALUE

Figure 13. Main Building Vent Load (4000 FT_c^2)

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```
CODE        VARIABLE DESCRIPTION                               VALUE UNITS

  1   AIR SYSTEM=1, LIQUID SYSTEM=2.....................     2.00
  2   COLLECTOR AREA....................................  6000.00 FT2
  3   FRPRIME-TAU-ALPHA PRODUCT(NORMAL INCIDENCE)..          0.74
  4   FRPRIME-UL PRODUCT................................     0.55 BTU/HR-F-FT2
  5   NUMBER OF TRANSPARENT COVERS......................     2.00
  6   COLLECTOR SLOPE...................................    65.00 DEGREES
  7   AZIMUTH ANGLE (E.G. SOUTH=0, WEST=90).........         0.00 DEGREES
  8   STORAGE CAPACITY..................................    15.00 BTU/F-FT2
  9   EFFECTIVE BUILDING UA.............................  12500.00 BTU/HR-F
 10   CONSTANT DAILY BLDG HEAT GENERATION...........**********  BTU/DAY    1.3 x10^6
 11   HOT WATER USAGE...................................     0.0  GAL/DAY
 12   WATER SET TEMPERATURE.............................   140.00 F
 13   WATER MAIN TEMPERATURE............................    51.60 F
 14   CITY CALL NUMBER..................................    34.00
 15   THERMAL PRINT OUT BY MONTH=1, BY YEAR=2.......         1.00
 16   ECONOMIC ANALYSIS   YES=1, NO=2...............         2.00
TYPE IN CODE NUMBER AND NEW VALUE

 FAIRBANKS        AK   64.49

 ****THERMAL ANALYSIS****
 TIME PERCENT INCIDENT HEATING LATER  DEGREE  AMBIENT
       SOLAR    SOLAR    LOAD   LOAD   DAYS    TEMP
               (MBTU)   (MBTU) (MBTU) (F-DAY)  (F)
 JAN   10.9    156.33   667.39   0.0   2359.   -11.
 FEB   12.6    191.20   533.91   0.0   1901.    -2.
 MAR   41.7    367.79   481.41   0.0   1739.     9.
 APR   53.8    333.24   281.40   0.0   1068.    30.
 MAY   92.2    308.17   126.20   0.0    555.    46.
 JUN  100.0    292.18    27.60   0.0    222.    57.
 JUL  100.0    265.33    11.00   0.0    171.    59.
 AUG  100.0    270.86    59.31   0.0    332.    54.
 SEP   53.4    186.10   153.60   0.0    642.    43.
 OCT   25.3    167.76   320.60   0.0   1203.    27.
 NOV   11.9    134.34   510.90   0.0   1833.     3.
 DEC    3.5     80.80   635.89   0.0   2254.    -8.
 YR    26.2   2754.15  3809.20   0.0  14279.

TYPE IN CODE NUMBER AND NEW VALUE
```

Figure 14. Main Building Vent Load ($6000\ FT_c^2$)

```
CODE        VARIABLE DESCRIPTION                              VALUE UNITS

  1   AIR SYSTEM=1, LIQUID SYSTEM=2.....................      2.00
  2   COLLECTOR AREA....................................  10000.00 FT2
  3   FPRPIME-TAU-ALPHA PRODUCT(NORMAL INCIDENCE)..           0.74
  4   FPRPIME-UL PRODUCT................................      0.55 BTU/H-F-F2
  5   NUMBER OF TRANSPARENT COVERS......................      2.00
  6   COLLECTOR SLOPE...................................     65.00 DEGREES
  7   AZIMUTH ANGLE (E.G. SOUTH=0, WEST=90).........          0.00 DEGREES
  8   STORAGE CAPACITY..................................     15.00 BTU/F-FT2
  9   EFFECTIVE BUILDING UA.............................  12500.00 BTU/HR-F
 10   CONSTANT DAILY BLDG HEAT GENERATION...........     ********* BTU/DAY     1.3 x10^6
 11   HOT WATER USAGE...................................       0.0 GAL/DAY
 12   WATER SET TEMPERATURE.............................    140.00 F
 13   WATER MAIN TEMPERATURE............................     51.80 F
 14   CITY CALL NUMBER..................................     34.00
 15   THERMAL PRINT OUT BY MONTH=1, BY YEAR=2......           1.00
 16   ECONOMIC ANALYSIS   YES=1, NO=2...............          2.00
TYPE IN CODE NUMBER AND NEW VALUE
'
 FAIRBANKS       AK    64.45

 ****THERMAL ANALYSIS*****
  TIME PERCENT INCIDENT HEATING WATER DEGREE AMBIENT
        SOLAR    SOLAR    LOAD   LOAD   DAYS    TEMP
                 (MBTU)  (MBTU) (MBTU) (F-DAY)  (F)
  JAN   17.6    260.63   667.39   0.0   2359.   -11.
  FEB   29.5    313.67   533.91   0.0   1901.    -2.
  MAR   63.0    612.39   481.41   0.0   1736.     9.
  APR   84.0    555.39   281.40   0.0   1068.    30.
  MAY  100.0    513.61   126.20   0.0    555.    46.
  JUN  100.0    486.97    27.60   0.0    222.    57.
  JUL  100.0    442.22    11.00   0.0    171.    59.
  AUG  100.0    451.43    59.31   0.0    332.    54.
  SEP   75.5    310.16   153.60   0.0    642.    43.
  OCT   39.3    279.60   320.60   0.0   1203.    27.
  NOV   19.1    223.91   510.90   0.0   1833.     3.
  DEC    5.8    134.67   635.89   0.0   2254.    -8.
  YR    37.1   4590.24  3809.20   0.0  14279.

TYPE IN CODE NUMBER AND NEW VALUE
```

Figure 15. Main Building Vent Load (1000 FT_c^2)

CODE	VARIABLE DESCRIPTION	VALUE	UNITS
1	AIR SYSTEM=1, LIQUID SYSTEM=2..................	2.00	
2	COLLECTOR AREA..............................	4000.00	FT2
3	FRPRIME-TAU-ALPHA PRODUCT(NORMAL INCIDENCE)..	0.74	
4	FRPRIME-UL PRODUCT..........................	[illegible]	BTU/HR-F-FT2
5	NUMBER OF TRANSPARENT COVERS..................	[illegible]	
6	COLLECTOR SLOPE.............................	65.00	DEGREES
7	AZIMUTH ANGLE (E.G. SOUTH=0, WEST=90)........	0.0	DEGREES
8	STORAGE CAPACITY............................	15.00	BTU/F-FT2
9	EFFECTIVE BUILDING UA.......................	25?00.00	BTU/HR-F
10	CONSTANT DAILY BLDG HEAT GENERATION..........	*********	BTU/DAY
11	HOT WATER USAGE.............................	0.0	GAL/DAY
12	WATER SET TEMPERATURE.......................	140.00	F
13	WATER MAIN TEMPERATURE......................	51.80	F
14	CITY CALL NUMBER............................	34.00	
15	THERMAL PRINT OUT BY MONTH=1, BY YEAR=2......	1.00	
16	ECONOMIC ANALYSIS YES=1, NO=2...............	2.00	

2.0 x 10^6

TYPE IN CODE NUMBER AND NEW VALUE

FAIRBANKS AK 64.[illegible]

****THERMAL ANALYSIS****

TIME	PERCENT SOLAR	INCIDENT SOLAR (MBTU)	HEATING LOAD (MBTU)	WATER LOAD (MBTU)	DEGREE DAYS (F-DAYS)	AMBIENT TEMP (F)
JAN	[illegible]	104.25	1424.34	0.0	2353.	-11.
FEB	[illegible].2	127.47	1125.66	0.0	1921.	-2.
MAR	14.5	245.19	1018.58	0.0	1735.	9.
APR	21.3	222.16	603.87	0.0	1068.	30.
MAY	37.[illegible]	235.45	262.99	0.0	555.	46.
JUN	93.1	194.79	78.00	0.0	222.	57.
JUL	100.0	176.83	44.29	0.0	171.	59.
AUG	59.0	180.57	144.39	0.0	332.	54.
SEP	19.2	124.22	339.07	0.0	642.	43.
OCT	8.5	111.24	685.78	0.0	1203.	27.
NOV	3.9	39.56	1079.39	0.0	1833.	3.
DEC	[illegible]	53.27	1339.07	0.0	2254.	-8.
YR	10.9	1236.10	8145.82	0.0	14279.	

TYPE IN CODE NUMBER AND NEW VALUE

Figure 16. Total HVAC System Load (4000 FT_c^2)

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```
CODE        VARIABLE DESCRIPTION                                  VALUE    UNITS

  1   AIR SYSTEM=1,LIQUID SYSTEM=2.........................      2.00
  2   COLLECTOR AREA.......................................   6000.00 FT2
  3   FRPRIME-TAU-ALPHA PRODUCT(NORMAL INCIDENCE)..........      0.74
  4   FRPRIME-UL PRODUCT...................................      0.55 BTU/H-F-F2
  5   NUMBER OF TRANSPARENT COVERS.........................      2.00
  6   COLLECTOR SLOPE......................................     65.00 DEGREES
  7   AZIMUTH ANGLE (E.G. SOUTH=0, WEST=90)................      0.00 DEGREES
  8   STORAGE CAPACITY.....................................     15.00 BTU/F-FT2
  9   EFFECTIVE BUILDING UA................................  25900.00 BTU/HR-F
 10   CONSTANT DAILY BLDG HEAT GENERATION.................. ********* BTU/DAY      2.0 X 10^6
 11   HOT WATER USAGE......................................      0.0  GAL/DAY
 12   WATER SET TEMPERATURE................................    140.00 F
 13   WATER MAIN TEMPERATURE...............................     51.80 F
 14   CITY CALL NUMBER.....................................     34.00
 15   THERMAL PRINT OUT BY MONTH=1, BY YEAR=2..............      1.00
 16   ECONOMIC ANALYSIS   YES=1, NO=2......................      2.00
TYPE IN CODE NUMBER AND NEW VALUE
.
.
.

INPUT ERROR, TRY AGAIN

 FAIRBANKS       AK    64.42

 ****THERMAL ANALYSIS****
 TIME PERCENT INCIDENT HEATING WATER DEGREE AMBIENT
        SOLAR   SOLAR     LOAD   LOAD   DAYS    TEMP
               (MBTU)   (MBTU) (MBTU) (F-DAY)  (F)
 JAN     5.3   156.38  1404.34    0.0   2359.   -11.
 FEB     9.1   191.20  1125.68    0.0   1901.    -2.
 MAR    21.3   367.79  1018.98    0.0   1739.     9.
 APR    30.2   333.24   503.87    0.0   1068.    30.
 MAY    53.2   308.17   282.95    0.0    655.    46.
 JUN   100.0   292.18    78.00    0.0    222.    57.
 JUL   100.0   265.33    44.29    0.0    171.    59.
 AUG    73.5   270.86   144.39    0.0    332.    54.
 SEP    27.5   186.10   339.07    0.0    642.    43.
 OCT    12.5   167.76   685.78    0.0   1203.    27.
 NOV     5.8   134.34  1079.39    0.0   1833.     3.
 DEC     1.7    80.80  1339.07    0.0   2254.    -8.
 YR     15.1  2754.15  8145.82    0.0  14279.

TYPE IN CODE NUMBER AND NEW VALUE
```

Figure 17. Total HVAC System Load (6000 FT_c^2)

CODE	VARIABLE DESCRIPTION	VALUE	UNITS
1	AIR SYSTEM=1, LIQUID SYSTEM=2..................	2.00	
2	COLLECTOR AREA.................................	8000.00	FT2
3	FRPRIME-TAU-ALPHA PRODUCT(NORMAL INCIDENCE)..	0.74	
4	FRPRIME-UL PRODUCT.............................	0.55	BTU/H-F-F2
5	NUMBER OF TRANSPARENT COVERS...................	2.00	
6	COLLECTOR SLOPE................................	65.00	DEGREES
7	AZIMUTH ANGLE (E.G. SOUTH=0, WEST=90).........	0.0	DEGREES
8	STORAGE CAPACITY...............................	15.00	BTU/F-FT2
9	EFFECTIVE BUILDING UA..........................	25500.00	BTU/HR-F
10	CONSTANT DAILY BLDG HEAT GENERATION..........	*********	BTU/DAY 2.0 x 10^6
11	HOT WATER USAGE................................	0.0	GAL/DAY
12	WATER SET TEMPERATURE..........................	140.00	F
13	WATER MAIN TEMPERATURE.........................	51.80	F
14	CITY CALL NUMBER...............................	34.00	
15	THERMAL PRINT OUT BY MONTH=1, BY YEAR=2......	1.00	
16	ECONOMIC ANALYSIS YES=1, NO=2...............	2.00	

TYPE IN CODE NUMBER AND NEW VALUE

FAIRBANKS   AK   64.43

****THERMAL ANALYSIS****

TIME	PERCENT SOLAR	INCIDENT SOLAR (MBTU)	HEATING LOAD (MBTU)	WATER LOAD (MBTU)	DEGREE DAYS (F-DAY)	AMBIENT TEMP (F)
JAN	7.0	208.51	1404.34	0.0	2359.	-11.
FEB	12.2	254.93	1125.68	0.0	1901.	-2.
MAR	27.7	490.39	1018.58	0.0	1739.	9.
APR	39.9	444.31	603.87	0.0	1068.	30.
MAY	66.3	410.89	282.99	0.0	555.	46.
JUN	100.0	389.58	78.00	0.0	222.	57.
JUL	100.0	353.78	44.29	0.0	171.	59.
AUG	92.5	361.14	144.39	0.0	332.	54.
SEP	35.4	248.13	339.07	0.0	642.	43.
OCT	16.4	223.68	685.78	0.0	1203.	27.
NOV	7.6	179.13	1079.39	0.0	1833.	3.
DEC	2.2	107.74	1339.07	0.0	2254.	-8.
YR	19.0	3672.20	8145.82	0.0	14279.	

TYPE IN CODE NUMBER AND NEW VALUE

Figure 18. Total HVAC System Load (8000 FT_c^2)

```
CODE        VARIABLE DESCRIPTION                                      VALUE UNITS

  1    AIR SYSTEM=1,LIQUID SYSTEM=2..................            2.00
  2    COLLECTOR AREA................................        10000.00 FT2
  3    FRPRIME-TAU-ALPHA PRODUCT(NORMAL INCIDENCE)...            0.74
  4    FRPRIME-UL PRODUCT............................            0.55 BTU/H F**2
  5    NUMBER OF TRANSPARENT COVERS..................            3.00
  6    COLLECTOR SLOPE...............................           65.00 DEGREES
  7    AZIMUTH ANGLE (E.G. SOUTH=0, WEST=90).........            0.00 DEGREES
  8    STORAGE CAPACITY..............................           15.00 BTU/F-FT2
  9    EFFECTIVE BUILDING UA.........................        25000.00 BTU/HR-F
 10    CONSTANT DAILY BLDG HEAT GENERATION...........       ********* BTU/DAY    2.0 x 10^6
 11    HOT WATER USAGE...............................            0.0  GAL/DAY
 12    WATER SET TEMPERATURE.........................          140.00 F
 13    WATER MAIN TEMPERATURE........................           51.80 F
 14    CITY CALL NUMBER..............................           34.00
 15    THERMAL PRINT OUT BY MONTH=1, BY YEAR=2.......            1.00
 16    ECONOMIC ANALYSIS   YES=1, NO=2...............            2.00
TYPE IN CODE NUMBER AND NEW VALUE

 FAIRBANKS        AK   64.49

 ****THERMAL ANALYSIS****
  TIME PERCENT INCIDENT HEATING WATER DEGREE AMBIENT
        SOLAR    SOLAR     LOAD   LOAD   DAYS    TEMP
                (MBTU)   (MBTU) (MBTU) (F-DAY) (F)
  JAN     9.7   260.63  1404.34   0.0   2359.   -11.
  FEB    14.9   313.67  1125.68   0.0   1901.    -2.
  MAR    33.9   612.59  1018.98   0.0   1739.     9.
  APR    43.0   555.39   603.87   0.0   1068.    30.
  MAY    77.4   513.61   282.99   0.0    555.    46.
  JUN   100.0   486.97    78.00   0.0    222.    57.
  JUL   100.0   442.22    44.29   0.0    171.    59.
  AUG   100.0   451.43   144.39   0.0    332.    54.
  SEP    42.7   310.16   339.07   0.0    642.    43.
  OCT    20.2   279.60   685.78   0.0   1203.    27.
  NOV     9.5   223.91  1079.39   0.0   1833.     3.
  DEC     2.8   134.67  1339.07   0.0   2254.    -8.
  YR     22.5  4590.24  8145.82   0.0  14279.

TYPE IN CODE NUMBER AND NEW VALUE
```

Figure 19. Total HVAC System Load (10,000 FT_c^2)

```
CODE        VARIABLE DESCRIPTION                                VALUE UNITS

  1     AIR SYSTEM=1, LIQUID SYSTEM=2.......................     2.00
  2     COLLECTOR AREA......................................  1000.00 FT2
  3     FRPRIME-TAU-ALPHA PRODUCT(NORMAL INCIDENCE)..........     0.74
  4     FRPRIME-UL PRODUCT..................................     0.55 BTU/H-F-F2
  5     NUMBER OF TRANSPARENT COVERS........................     2.00
  6     COLLECTOR SLOPE.....................................    65.00 DEGREES
  7     AZIMUTH ANGLE (E.G. SOUTH=0, WEST=90)...............     0.00 DEGREES
  8     STORAGE CAPACITY....................................    15.00 BTU/F-FT2
  9     EFFECTIVE BUILDING UA...............................   903.00 BTU/HR-F
 10     CONSTANT DAILY BLDG HEAT GENERATION.................     0.0  BTU/DAY
 11     HOT WATER USAGE.....................................     0.0  GAL/DAY
 12     WATER SET TEMPERATURE...............................   140.00 F
 13     WATER MAIN TEMPERATURE..............................    51.80 F
 14     CITY CALL NUMBER....................................    34.00
 15     THERMAL PRINT OUT BY MONTH=1, BY YEAR=2.............     1.00
 16     ECONOMIC ANALYSIS   YES=1, KO=2.....................     2.00
TYPE IN CODE NUMBER AND NEW VALUE

FAIRBANKS        AK    64.42

****THERMAL ANALYSIS****
 TIME PERCENT INCIDENT HEATING WATER  DEGREE   AMBIENT
       SOLAR    SOLAR    LOAD   LOAD   DAYS     TEMP
               (MBTU)   (MBTU) (MBTU) (F-DAY)   (F)
 JAN   22.4     26.06    51.41   0.0   2359.    -11.
 FEB   36.7     31.87    41.43   0.0   1901.     -2.
 MAR   74.7     61.30    37.90   0.0   1739.      9.
 APR   93.5     55.54    23.27   0.0   1068.     30.
 MAY  100.0     51.36    12.09   0.0    555.     46.
 JUN  100.0     48.70     4.84   0.0    222.     57.
 JUL  100.0     44.22     3.73   0.0    171.     59.
 AUG  100.0     45.14     7.24   0.0    332.     54.
 SEP   79.6     31.02    13.99   0.0    642.     43.
 OCT   46.2     27.96    26.22   0.0   1203.     27.
 NOV   23.9     22.39    39.94   0.0   1833.      3.
 DEC    7.4     13.47    49.12   0.0   2254.     -8.
 YR    45.3    459.02   311.17   0.0  14279.

TYPE IN CODE NUMBER AND NEW UALLE
```

Figure 20. Motor Pool Shop Vent and Floor Load (1000 FT_c^2)

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```
CODE        VARIABLE DESCRIPTION                                VALUE UNITS

  1    AIR SYSTEM=1,LIQUID SYSTEM=2.......................       2.00
  2    COLLECTOR AREA.....................................    2000.00 FT2
  3    FRPRIME-TAU-ALPHA PRODUCT(NORMAL INCIDENCE)..           0.74
  4    FRPRIME-UL PRODUCT.................................       0.55 BTU-H-F-F2
  5    NUMBER OF TRANSPARENT COVERS.......................       2.00
  6    COLLECTOR SLOPE....................................      65.00 DEGREES
  7    AZIMUTH ANGLE (E.G. SOUTH=0, WEST=90)..............       0.00 DEGREES
  8    STORAGE CAPACITY...................................      15.00 BTU/F-FT2
  9    EFFECTIVE BUILDING UA..............................     908.00 BTU/HR-F
 10    CONSTANT DAILY BLDG HEAT GENERATION................       0.0  BTU/DAY
 11    HOT WATER USAGE....................................       0.0  GAL/DAY
 12    WATER SET TEMPERATURE..............................     140.00 F
 13    WATER MAIN TEMPERATURE.............................      51.80 F
 14    CITY CALL NUMBER...................................      34.00
 15    THERMAL PRINT OUT BY MONTH=1, BY YEAR=2......            1.00
 16    ECONOMIC ANALYSIS   YES=1, NO=2...............           2.00
TYPE IN CODE NUMBER AND NEW VALUE
 FAIRBANKS        AK    64.49

****THERMAL ANALYSIS*****
 TIME PERCENT INCIDENT HEATING WATER DEGREE AMBIENT
       SOLAR    SOLAR    LOAD   LOAD   DAYS    TEMP
               (MBTU)   (MBTU) (MBTU) (F-DAY) (F)
 JAN   40.4     52.13    51.41   0.0   2359.   -11.
 FEB   62.6     63.73    41.43   0.0   1301.    -2.
 MAR  100.0    122.60    37.90   0.0   1739.     9.
 APR  100.0    111.03    23.27   0.0   1068.    30.
 MAY  100.0    102.72    12.09   0.0    555.    46.
 JUN  100.0     97.33     4.84   0.0    222.    57.
 JUL  100.0     88.44     3.73   0.0    171.    59.
 AUG  100.0     90.25     7.24   0.0    332.    54.
 SEP  100.0     62.03    13.99   0.0    642.    43.
 OCT   73.8     55.92    26.22   0.0   1203.    27.
 NOV   42.6     44.78    39.94   0.0   1833.     3.
 DEC   14.3     26.93    49.12   0.0   2254.    -8.
 YR    62.1    918.05   311.17   0.0  14279.

TYPE IN CODE NUMBER AND NEW VALUE
```

Figure 21. Motor Pool Shop Vent and Floor Load (2,000 FT_c^2)

```
CODE        VARIABLE DESCRIPTION                                  VALUE   UNITS

  1   AIR SYSTEM=1,LIQUID SYSTEM=2..........................     2.00
  2   COLLECTOR AREA........................................  4000.00  FT2
  3   FRPRIME-TAU-ALPHA PRODUCT(NORMAL INCIDENCE)...........     0.74
  4   FRPRIME-UL PRODUCT....................................     0.55  BTU/HR-F-FT2
  5   NUMBER OF TRANSPARENT COVERS..........................     2.00
  6   COLLECTOR SLOPE.......................................    65.00  DEGREES
  7   AZIMUTH ANGLE (E.G. SOUTH=0, WEST=90).................     0.00  DEGREES
  8   STORAGE CAPACITY......................................    15.00  BTU/F-FT2
  9   EFFECTIVE BUILDING UA.................................   908.00  BTU/HR-F
 10   CONSTANT DAILY BLDG HEAT GENERATION...................     0.0   BTU/DAY
 11   HOT WATER USAGE.......................................     0.0   GAL/DAY
 12   WATER SET TEMPERATURE.................................   140.00  F
 13   WATER MAIN TEMPERATURE................................    51.80  F
 14   CITY CALL NUMBER......................................    34.00
 15   THERMAL PRINT OUT BY MONTH=1, BY YEAR=2...............     1.00
 16   ECONOMIC ANALYSIS   YES=1, NO=2.......................     2.00
TYPE IN CODE NUMBER AND NEW VALUE

FAIRBANKS        AK     64.49
```

****THERMAL ANALYSIS****

TIME	PERCENT SOLAR	INCIDENT SOLAR (MBTU)	HEATING LOAD (MBTU)	WATER LOAD (MBTU)	DEGREE DAYS (F-DAY)	AMBIENT TEMP (F)
JAN	65.4	104.25	51.41	0.0	2359.	-11.
FEB	90.1	127.47	41.43	0.0	1901.	-2.
MAR	100.0	245.19	37.90	0.0	1739.	9.
APR	100.0	222.16	23.27	0.0	1068.	30.
MAY	100.0	205.45	12.05	0.0	555.	46.
JUN	100.0	194.79	4.84	0.0	222.	57.
JUL	100.0	176.89	3.73	0.0	171.	59.
AUG	100.0	180.57	7.24	0.0	332.	54.
SEP	100.0	124.06	13.99	0.0	642.	43.
OCT	94.5	111.84	26.22	0.0	1203.	27.
NOV	67.6	89.56	35.94	0.0	1833.	3.
DEC	27.1	53.87	49.12	0.0	2254.	-8.
YR	76.8	1836.10	311.17	0.0	14279.	

TYPE IN CODE NUMBER AND NEW VALUE

Figure 22. Motor Pool Shop Vent and Floor Load (4000 FT_c^2)

ECONOMIC CONSIDERATIONS

A brief look at the costs associated with the installation of a solar energy heating system was performed. A general design was formulated for the purpose of identifying the significant cost items. This system utilized a liquid flatplate collector array installed on the south facing side of a ground mounted A-frame structure. The A-frame structure was enclosed for structural reasons and to provide storage space for the liquid storage tanks beneath the array. The interface with the conventional HVAC system was assumed to be in the make-up air and supply duct of the main building vent fan (HV3). A liquid-to-air heat exchanger was located upstream of the present boiler-fed heat exchanger for pre-heating the makeup and supply air for the building. This configuration required a collector pump, a heat exchanger pump, the controllers for each, and the associated piping.

The heat transfer and storage fluid was assumed to be a 60/40 solution of ethylene glycol. The cost of the pumps, controls, piping, heat exchangers and their installation were estimated and considered separately from the collector/storage subsystem. A summary of these costs are:

Collector + installation	$\$20.00/Ft_c^2$
A-frame structure	$7.60/FT_c^2$
Storage and transfer fluid	$4.70/FT_c^2$
	$\$32.30/FT_c^2$

Other Costs $25,000

- Pumps
- Pipings
- Heat Exchanger
- Controls
- Installation

Using the above data, the cost of a system with 4,000 square feet of collector area was estimated as:

Collector/storage	(32.30 x 4000)	=	129,200
Other		=	25,000
	Total		$154,200

A savings can be obtained for larger arrays on the relative cost per square foot of collector for the A-frame structure and storage. An array of 8000 FT_c^2 was estimated as:

Collector/storage	(32.30 x 8000)	=	258,400
	Less	=	(20,000)
Other		=	25,000
			$263,400

The thermal analysis for a 4000 and 8000 square foot array is presented in Figure 13 and 10. The annual savings are 735 MBTU/year (8K gallons of oil) and 1,223 MBTU/year (13K gallons of oil) respectively. When the cost of each system was examined over a twenty year period, the 4000 square foot array has a slight advantage. Table 3 presents the fuel cost savings and system cost data over a twenty year period. An initial cost of $0.50 per gallon of oil was assumed and a ten percent per year fuel inflation rate was used. The system cost data is derived by dividing the total system cost by twenty years and adding an annual maintenance cost.

A more detail cost analysis is required to select an optimal array size and to produce accurate economic conditions. Because other factors can change these results and cause an economic loss, these calculated results should be used with this consideration in mind prior to more accurate calculations.

Table 3 . Economic Data

Year	4000 FT^2 Saved Fuel Cost	4000 FT^2 System Cost & Maintenance	8000 FT^2 Saved Fuel Cost	8000 FT^2 System Cost & Maintenance
1	4,000	8,210	6,500	13,670
2	4,000	8,240	7,150	13,700
3	4,840	8,272	7,865	13,732
4	5,324	8,306	8,652	13,766
5	5,856	8,341	9,517	13,801
6	6,442	8,379	10,468	13,839
7	7,086	8,419	11,515	13,879
8	7,795	8,402	12,667	13,922
9	8,574	8,507	13,933	13,967
10	9,432	8,555	15,327	14,015
11	10,375	8,605	16,859	14,065
12	11,412	8,659	18,545	14,119
13	12,554	8,716	20,400	14,176
14	13,809	8,776	22,440	14,236
15	15,190	8,840	24,684	14,300
16	16,708	8,908	27,152	14,368
17	18,380	8,980	29,867	14,440
18	20,218	9,056	32,854	14,516
19	22,240	9,137	36,139	14,683
20	24,463	9,223	39,753	14,683
Total	229,098	172,591	372,287	281,791

SOLAR AND CONVENTIONAL HEATING SYSTEM INTERFACE

A study of the conventional heating system was made in order to understand its equipment's interface and operating modes and to determine where solar energy could be interfaced with that system. An explanation of the operation of the conventional system is followed by a discussion of possible solar-to-conventional system interface concepts.

Conventional System Description

The conventional heating system for the Fairbanks Federal Building consist of two major subsystems, a boiler subsystem and a heat recovery subsystem.

Boiler Subsystem

The boiler subsystem consists of a modular boiler, heat transfer medium and units to transfer the heat from the medium to the heated space.

The boiler subsystem uses a 60 percent ethylene glycol - 40 percent water solution to transfer the heat from the boiler to the heating units. The solution temperature leaving the boiler is reset from 200^{O}F to 105^{O}F as - outdoor temperature varies from minus 50^{O}F to plus 65^{O}F. The boilers are shutdown when the outdoor temperature is above 65^{O}F. The heat from the solution is transferred into the heated space by unit heaters, fin tube radiators, convectors, air make-up/ventilating units, and through floor coils in the motor pool shop.

The unit heaters have constant heating solution flow through their coils with the thermostats cycling the unit fans to maintain the selected setpoint temperature.

The heating solution flow, through the fin tube radiators and convectors, is controlled by thermostat driven modulating values to maintain setpoint temperature.

Three-way modulating valves in the heating solution lines of the air make-up/ventilating units are modulated to maintain a predetermined day and night duct temperature.

The shop floor coils have constant heating solution flow with the solution temperature being reset from 105^{0} to 78^{0}F as outdoor temperature varies from minus 60^{0}F to plus 65^{0}F.

Heat Recovery Subsystem

The heat recovery subsystem consists of approximately 100 small heat pumps placed along the perimeter of the upper three floors, one air conditioning unit for each of the floors and a water system to transfer and store heat.

The water temperature is maintained between 60^{0}F and 90^{0}F by accepting heat from the boiler subsystem through heat exchange as the recovery supply temperature drops below 60^{0}F, or by rejecting heat to the domestic and city water supply as temperatures rise above 75^{0}F. Heat will also be added through heat exchange from the emergency generator if loop temperature is below 90^{0}F.

Under normal conditions the heat recovery subsystem will operate during the day and be shut down during the night. The heatpumps will operate under thermostat control to provide heating for a 70^{0}F setpoint, or to provide cooling for a 78^{0}F setpoint. Neither heating nor cooling occur between 72 and 78^{0}F. The air conditioners will be controlled to maintain 82^{0}F return air temperature.

Solar-Conventional System Interface

During the systems study it was determined that solar energy could be integrated with the conventional system in the following ways:

- o Preheat Domestic Hot Water

  Although this load is small, energy could be added through heat exchange to a tank down stream of the present domestic water sink/storage and not affect the heat transfer from the heat recovery loop.

- o Heat Recovery Loop

  With the heat recovery loop being maintained between 60^{o} and 90^{o}, it appears that this is an ideal place to use solar energy. Energy could be added to the system through heat exchange; however, there appear to be some problems. At the time that most solar energy is available the recovery subsystem would probably have excess heat which would be rejected to the city water supply. Available data and study time was insufficient to make the necessary analysis of this interface.

- o Main Building Make-Up Air

  Heat from the solar energy system could be added through a fin coil upstream from the existing coil in HV-3. This would allow the makeup air to be pre-heated, therefore reducing the load on the boiler. The leaving air temperature of the added coil could be controlled in the same way as in the existing system.

- o Motor Pool Shop Make-Up Air

  Energy could be added here in the same manner as in the main building make-up air.

- Motor Pool Shop Floor Coils

  These coils operate in a good temperature range for utilization of solar energy. Solar energy can service these coils, and heat can be added to the loop through heat exchange from the boiler when solar is insufficient.

- Shop Unit Heaters

  Solar energy may be used to service these heaters with heat added through heat exchange from the boiler when solar is insufficient.

- Main Building Boiler Loop

  The time of year when temperatures are moderate and the boiler loop is setback toward 105^{o}F is also the time when more solar energy is available such that the temperature necessary to service the load is attainable from the solar collectors. A more complete study is needed to determine best interface method and control.

Because of its size and the necessity to orient it for maximum exposure to available insolation, the installation of the collector array has the biggest impact on the Fairbanks site. Consideration must be given, however, to installation space for storage tanks, pumps, associated equipment and piping.

Collector Installation

Four possible locations for the collector array were studied and then rejected. Consideration was given to exposure to available insolation, support for the array, possible building modifications, and desireability of locating the storage tanks in close proximity. The rejected alternatives are discussed below.

- Main Building Roof

  This is the ideal location for most array installations, but it is not recommended for this application because:

  - building structural modifications would be extensive and impact the construction schedule
  - effective utilization of roof area could not be made due to shadowing effects
  - lack of nearby space for storage tanks.

- Parking Area

  - Although this area would require minimum modifications, shadowing from the office structures in the morning hours would decrease system performance.

- Main Building South Face

  - This alternative was rejected because of need for extensive structural modifications, preclusion of required tilt angle (see section on Solar Energy System Design and Performance Factors) and lack of sufficient installation area.

- Motor Pool Building Roof

  - Need for structural modifications and lack of sufficient installation area eliminated this alternative.

Based upon the above analysis, it is recommended that the collectors be mounted on a surface constructed array frame. Although this is not the ideal location, it does provide the best tradeoff result when evaluated against the cost of building modifications, reduced performance of the solar system and possible impact on the building construction schedule.

It is proposed that the array be constructed in the gravel storage area on the south side of the site between the main building and the Motor Pool Building. This location provides an area of approximately 200' x 30' without impacting the paved area. Locating the collector mounting in this area will also provide the option of contracting for the installation independent of the building construction program.

System Installation

The recommended array location calls for the construction of an "A" frame structure mounted on concrete footings. The interior of the structure would be used to house the storage tanks, pumps and associated piping. The size and structural design will depend upon the number of collectors to be installed, availability of materials and the amount of space within the recommended area that can be allocated to the solar installation.

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