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**TRANSPORTABLE SOLAR
LABORATORY PROGRAM TEST
RESULTS AND UTILIZATION STUDY
FOR DALLAS, TEXAS**

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Honeywell

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Honeywell

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LABORATORY PROGRAM TEST
RESULTS AND UTILIZATION STUDY
FOR DALLAS, TEXAS

NSF Grant PTP74-01555

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SECTION I INTRODUCTION

This is the second in a series of reports on the Transportable Solar Laboratory (TSL), co-sponsored by the National Science Foundation and Honeywell, Inc. These reports present findings and results of data taken while the TSL was located in several cities around the country. The purpose of the TSL is to provide information on solar energy collection which can be used for evaluation of heating and cooling of domestic buildings in various climates.

The second location for the TSL was Dallas, Texas, from August 24, 1974, to October 19, 1974. During this time, the TSL was stationed at the Greater Southwest Airport. This report for Dallas/Fort Worth presents collected solar energy data and total daily efficiency based on instantaneous collection values. A heating and cooling load analysis for a typical 1500 square foot Dallas house is given along with the portion of this load that can be provided by solar energy. The final part of this report provides an estimate of collector array area and storage tank size required for residential use of solar collector systems in the Dallas/Fort Worth area.

SECTION II

TSL TEST RESULTS FOR DALLAS

INSOLATION

One purpose of the TSL is to collect solar insolation data at various geographic locations it visits. It is hoped that this information can be used to derive a correlation between true insolation levels and U.S. Weather Bureau data for percent cloud cover and/or percent sky cover. Unfortunately, the Weather Bureau in Dallas did not log percent of possible sunshine data for September and October, so a correlation was not possible.

The data in Table 1 presents a summary of the Dallas insolation measured while testing the TSL collector system. The table gives the date and time of testing and total insolation on a 30-degree tilted plane with a southern orientation. The totals are only for the testing period, and insolation curves would have to be extrapolated to arrive at total daily insolation values. Figures 1 through 6 are graphs of the six best insolation days measured. The daily peak insolation and the time at the peak value are taken from these figures and listed in Table 1 along with weather type and cloud cover information from the Weather Bureau. The Weather Bureau summaries for September and October have been included in Appendix A, pages A-5 through A-8. The effect of passing clouds can be seen in Figures 2 and 3. It should also be noted that peak insolation on partly cloudy days may be higher than on clear days due to reflection off clouds. This effect is shown in Figure 3.

One method of describing geographic solar radiation intensity is given by Threlkeld-Jordan in a clearness number¹. By multiplying the clearness number to the calculated peak insolation a close approximation to measured insolation data may be determined. The calculated insolation curve is a function of geographic location and sun angle and can be found through use of an ASHRAE computer subroutine called SUN. This subroutine is an algorithm to find solar position and intensity of direct normal and diffuse radiation without cloud cover. The clearness number modifies this calculation by a factor that incorporates local climatological data, such as average relative humidity, pollution, and elevation into the insolation estimate. Figure 7 is a graph of the calculated daily insolation on a plane tilted at an angle of 30° to the horizontal with a southern exposure. Using this curve and the TSL insolation data, calculated clearness numbers at the peak fluxes are determined. These values are listed in Table 1. The clearness number in the ASHRAE Handbook of Fundamentals determined by Threlkeld-Jordan is given as 0.95, and the average of the calculated clearness numbers is 0.94, showing good correlation.

COLLECTION

The solar collector array on the TSL consists of two collector housings each having an effective collection area² of 286 square feet. A detailed description of the Transportable Solar Laboratory may be found in a report to the National Science Foundation entitled "Design and Test Report for Transportable Solar Laboratory Program."³ The TSL was designed as a test facility and is not intended as a design prototype for future solar collector systems. The TSL collector system does not operate like a typical solar HVAC system because specific tests are performed that cause disruptions in the continuous daily operation.

- 1 ASHRAE Handbook of Fundamentals, Chapter 22, Figure 4, page 394.
- 2 Overall collector housing area is 700 ft², but aperture area for collection calculation is taken to be 571 ft².
- 3 NSF Grant PTP74-01555.

Table 1. Dallas/Fort Worth Insolation Summary

Test Date	CDT Time On	CDT Time Off	Test Duration (Hrs)	Daily Total ³ (Btu/ft ²)	Ave Insol. Over Time Period (Btu/hr-ft ²)	CDT At Peak	Daily Peak (Btu/hr-ft ²)	Weather Type	Percent of Pos. Sunshine	Sky Cover Tenth ¹ (Sunrise to Sunset)	Calculated Clearness Number ² (Peak)
9/11	11:37	2:00	2.7	495	183	1:03	331	Cloudy	N/A	6	-
21	9:00	11:20	2.3	79	34	N/A	51	Rain	N/A	10	-
27	11:00	3:00	4.0	1042	260	1:00	299	Occ Cloudy	N/A	2	0.95
29	10:20	17:40	7.3	1679	230	12:35	297	Clear	N/A	2	0.94
10/3	9:00	17:00	8.0	1811	226	12:45	292	Clear	N/A	0	0.93
4	9:00	17:00	8.0	1756	220	12:45	320	Clear	N/A	3	1.01
5	9:00	17:00	8.0	1134	142	1:40	333	Partly Cloudy	N/A	3	-
7	9:00	16:40	7.7	850	110	12:52	172	Cloudy	N/A	10	-
8	9:20	17:00	7.6	1615	212	2:00	281	Clear	N/A	4	0.89
10	10:00	17:00	7.0	1442	206	1:00	294	Occ Cloudy	N/A	5	0.93
11	11:00	17:00	6.0	1122	187	1:40	281	Cloudy	N/A	8	0.89
15	9:00	17:20	8.3	2026	243	1:00	310	Clear	N/A	0	0.98
17	9:40	16:40	7.0	1693	242	1:00	289	Clear	N/A	0	0.92
Average											0.94

NOTES:

1. NAT WEATHER SERVICE MET OBSY., Dal-Ft Worth Regional Airport, Local Climatological Data Summaries for September and October 1974.
2. ASHRAE 1972 Handbook of Fundamentals, page 394. Threlkeld-Jordan clearness number for Dallas summer = 0.95; calculated by daily peak ÷ daily calculated peak.
3. Pyranometer located at a 30° tilt angle with a southern exposure.

Calculated insolation for standard atmosphere at Dallas location in October for same orientation is as follows:

October	6:56	5:32	10.6	2124	200	12:13	315	Clear	105	0	1:00
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Figure 1. Daily Insolation Curve - Sept. 29, 1974

Figure 2. Daily Insolation Curve - Oct. 3, 1974

Figure 3. Daily Insolation Curve - Oct. 4, 1974

Figure 4. Daily Insolation Curve - Oct. 8, 1974

Figure 5. Daily Insolation Curve - Oct. 15, 1974

Figure 6. Daily Insolation Curve - Oct. 17, 1974

Figure 7. Calculated Daily Insolation Curve - Oct. 21

Figure 8. Daily Insolation Curve - Sept. 29, 1974

Figure 9. Daily Insolation Curve - Oct. 3, 1974

The results of seven test days are shown in Table 2. This table summarizes test duration, available flux, collected energy, efficiency over test period, amount of energy stored, average solar flux over the collection period, and average energy collection rate. Data from two of these days is presented in Figures 8 and 9. Normal system operation prohibits collector fluid flow until the collector plate temperature reaches a desired set point. This allows the collector to store up early morning incident flux in the thermal mass of the system. When collector fluid flow begins, a transient collection period occurs during which collection efficiencies can approach or exceed 100%. This can be readily seen in Figures 8 and 9.

The average daily efficiency over the seven test days was 55%. If the tests had been run from sunrise to sunset, the daily efficiencies would be lower. This is due to lower collector efficiency for the low intensity radiation incurred during early morning and late afternoon hours. The collector operation for the tests was for an air conditioning mode requiring collector fluid inlet temperatures between 180°F and 200°F.

A load analysis for a 1500 ft² residence in Dallas/Fort Worth has been completed and the degree of energy utilization potentially available from a 750 ft² collector array has been calculated. This analysis is presented in the remaining sections of this report.

Table 2. Computer Data Reduction Summary for Solar Energy Collection in Dallas

Date	Collection Time (Hrs.)	Total Available (Btu)	Total Collected (Btu)	η ¹ (%)	Total Stored (Btu)	Average Available Insolation (Btu/hr ft ²)	Average Collected Insolation (Btu/hr ft ²)
9/29	2.00	290,000	191,000	70		254	179
10/1	1.75	294,000	174,000	58	7,000	290	173
10/3	3.10	500,000	322,000	64	17,000	292	181
10/5	5.67	799,000	424,000	53	39,000	246	131
10/15	6.66	1,027,000	389,000	37	34,000	270	100
10/16	2.35	407,000	231,000	56	11,000	303	171
10/18	7.00	962,000	472,000	49	157,000	240	117

1. The average collector efficiency for these seven test days is 55%.

SECTION III UTILIZATION

TYPICAL HOUSE

For the purpose of this analysis, it is necessary to approximate the makeup of a "typical" house. The house load used in this analysis has an area of 1500 ft² and a volume of 12,000 ft³. Two types of construction have been considered for comparison purposes. They are a masonry wall structure and a wood frame with brick veneer structure. Two types of roofing are also considered. Table 3 gives the coefficients of heat transmission for each of these and a detailed breakdown of their construction is given in Appendix B. The wood frame house is typical of newer, well insulated house; whereas the masonry house is not well insulated.

Table 3. Coefficients of Transmission

Masonry Wall	.166 Btu/hr ft ² °F
Wood Frame with Brick Veneer	.074 Btu/hr ft ² °F
Slate Roof	.041 Btu/hr ft ² °F
Wood Shingle Roof	.041 Btu/hr ft ² °F

The two roof types have the same thermal resistance and therefore their coefficients of transmission are equivalent. It is also necessary to set indoor design temperatures. For this analysis, it is assumed that the indoor temperature is 70°F in the winter and 75°F in the summer with a 40% relative humidity comfort level in the summer. It is also assumed that the household uses 100 gallons of hot water and 25 kwh of electricity for appliances each day.

MONTHLY INSOLATION AND COLLECTED SOLAR ENERGY

The energy that can be collected in a particular geographic region by an array of solar collectors can be calculated using two subroutines prepared for the ASHRAE task group on energy requirements, weather tapes for the city, and a semi-empirical expression for collector performance ⁴. The ASHRAE subroutines are called SUN and CCM (Cloud Cover Modifier). The SUN subroutine is an algorithm to find solar position and intensity of direct normal and diffuse radiation without cloud cover. The CCM subroutine is an algorithm for modifying the solar radiation available in accordance with cloud cover. Input for the CCM subroutine is provided from the weather tape. Incident radiation is also modified by a subroutine that calculates the energy transmitted through the collector cover sheets due to hourly changes in the incident angle.

Tests on collectors similar to those on the TSL have generated a performance curve that may be expressed as:

$$\eta = \frac{Q}{Q_{inc}} = .712 - .551 \frac{T_{in} - T_{amb}}{Q_{inc}}$$

4. R. W. Bliss, The Derivation of Several "Plate Efficiency Factors" Useful in the Design of Flat Plate Solar Heat Collectors, Solar Energy 3, 55 (1959).

where Q = heat collected (Btu/hr ft²)
 Q_{inc} = incident solar flux (Btu/hr ft²)
 T_{in} = collector fluid inlet temperature (°F)
 T_{amb} = ambient temperature (°F)
 η = collection efficiency

The program calculates the collection levels hourly using this performance equation and then sums the total energy collected for each month. Calculations are made for two inlet temperatures: 140°F, typical of a heating application, and 200°F, typical of an air conditioning application. Ambient temperature is input from the weather tapes, and incident solar flux is taken from the SUN and CCM algorithm. The mass flow used in obtaining this performance curve was held constant at 10 lbm/hr-ft².

Table 4 presents the monthly summaries of insolation and collection data for Dallas. The collection results are for a 750 ft² collector array tilted at an angle of 25° from the horizontal. The average monthly insolation for a calendar year for Dallas is shown in the graph of Figure 10. The effect of the collector tilt angle is to shift the accent of energy collection to the time of year it is needed most. A tilt angle equal to the latitude of the site would give the maximum of the total yearly collection for that area and collector configuration. An increase or decrease in this angle would influence the collector toward winter heating or summer cooling, respectively, while not significantly decreasing the total yearly energy collection. A 25° tilt angle was chosen for the Dallas (32° N. latitude) analysis because the cooling loads are significantly larger than the heating loads.

AVERAGE MONTHLY HOUSE LOADS

The monthly heating and cooling loads in Btu's were found by converting Degree Days to Btu's using the load equations presented in Appendix C. An additional cooling load results from drying out any infiltrating humid air. By using the average monthly humidity and dry-bulb temperature levels, the average monthly enthalpy of the infiltrating air can be found on a psychrometric chart. If the value is above the enthalpy at an assumed comfort design level of 75°F and 40% relative humidity, then an additional load is added to the total monthly cooling load. A table listing these enthalpy values is given in Appendix C. The domestic hot water heating load and the internal sensible load are also included in this analysis. Table 5 is a summary of the monthly loads for the "typical" Dallas house. It includes the average monthly temperature and humidity used in determining the average monthly enthalpy for calculating the energy needed to dry any infiltrating humid air. Heating and cooling degree days⁵ are also listed. Load levels for domestic hot water, space heating, space cooling of dry air, and space drying of humid air are included and were calculated using the method described in Appendix C. Internal sensible heat is the amount of heat added to the building due to electrical power consumption. This load must be added to the space cooling load but subtracted from the space heating load. The sum of the loads is the final column of Table 4.

The design loads are also calculated and graphed in Appendix C.

5. Degree days are defined as the temperature difference between the average daily ambient temperature and 65°F.

Table 4. Dallas Insolation and Solar Energy Collection

Month	Insolation (10^3 Btu/ft ²)		Collected Solar Energy (10^3 Btu/ft ²)		Provided Energy from Collector Array ⁵
	Without Clouds ¹	With Clouds ²	For Heating ³	For Cooling ⁴	(10^6 Btu)
1	59.6	25.8	6.4	3.7	4.8
2	59.8	28.1	9.4	5.4	7.1
3	73.4	43.9	18.2	11.7	13.6
4	73.7	40.3	16.8	10.0	12.6
5	75.7	40.3	20.9	13.1	9.9
6	72.4	51.3	26.3	17.9	13.4
7	74.6	60.4	33.6	23.8	17.9
8	74.5	59.4	32.9	23.8	17.9
9	70.3	49.7	25.3	17.4	13.0
10	67.4	43.1	19.2	12.7	9.5
11	57.9	30.1	10.1	6.1	7.6
12	<u>54.7</u>	<u>37.8</u>	<u>15.2</u>	<u>9.4</u>	<u>11.4</u>
Total	813.8	515.1	234.3	155.0	138.7

1. Data calculated from SUN algorithm, 25 deg tilt angle.
2. Data calculated from SUN and CCM algorithm and U. S. Weather Bureau Tapes for 1952.
3. Collector inlet temperature for heating is 140°F.
4. Collector inlet temperature for cooling is 200°F.
5. Provided by 750 ft² of selectively coated, 2 glass cover collector; operated for heating from November to April and cooling from May to October.

3-4

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Figure 10. Dallas Available Insolation Curve

Table 5. Total Load for a 1500 Ft² House in Dallas, Texas

Month	T _{avg} °F	Hum _{avg} %	Degree Days		Hot Water 10 ⁶ Btu	Heating 10 ⁶ Btu	- Internal Sensible Heat When Heating 10 ⁶ Btu	Cooling Dry Air 10 ⁶ Btu	+ Internal Sensible Heat When Cooling 10 ⁶ Btu	Drying Humid Air 10 ⁶ Btu	Total 10 ⁶ Btu
			Heating	Cooling							
1	45.5	68.0	614	0	2.3	9.0	- 2.6	0	0	0	8.7
2	49.2	65.2	448	6	2.1	6.6	- 2.4	0.1	0	0	6.4
3	55.9	65.5	319	21	2.3	4.8	- 2.4	0.3	0.2	0	5.2
4	64.8	69.2	99	71	2.2	1.5	- 1.5	1.0	1.1	0	4.3
5	72.7	73.2	0	195	2.3	0	0	2.9	2.6	4.9	12.7
6	81.5	66.8	0	546	2.2	0	0	8.0	2.6	9.8	22.6
7	85.4	59.5	0	606	2.3	0	0	8.9	2.6	11.3	25.1
8	85.4	63.2	0	456	2.3	0	0	6.7	2.6	11.5	23.1
9	78.4	61.2	0	382	2.2	0	0	5.6	2.6	8.9	19.3
10	67.9	68.0	65	171	2.3	1.0	- .7	2.5	1.9	1.0	8.0
11	57.8	67.5	324	36	2.2	4.8	- 2.3	.5	0.3	0	5.5
12	47.7	70.5	536	1	2.3	7.9	- 2.6	0	0	0	7.6
Total	65.8	67.2	2405	2491	27.0	35.6	-14.5	36.5	16.5	47.4	148.5

40072

Percentage of Load Satisfied by Solar System

Figure 11 has two graphs of the monthly space heating and cooling loads (i. e., not including internal sensible or hot water heat) for the two building types and also the solar supplied energy for heating or cooling from the 750 ft² solar collector array. For space heating, the heat exchange efficiency is considered to be 100 percent, but for cooling the typical absorption air conditioner Coefficient of Performance (COP) is 0.6. The shaded part of the graph is the portion of the load that can be supplied by solar energy. If the system has sufficient storage capability for 100-percent utilization of the collected heat, then the collectors would provide 67% of the yearly load for a building in Dallas with a U value of .166 Btu/hr ft² °F. The array would provide 71% of the yearly load for a building with a U value of .074 Btu/hr ft² °F.

Figure 12 shows the same type of monthly load curve but it includes internal sensible and hot water heat. Note the solar supplied curve changes from a heating mode (140°F) to a cooling mode (200°F) between April and May and from a cooling mode to a heating mode between October and November. The load shown here for a structure with a U value of $0.166 \frac{\text{BTU}}{\text{hr ft}^2 \text{°F}}$ results in 56 percent of the load being supplied by solar energy. Again this assumes sufficient storage capability for complete utilization of the collected energy. By scaling this solar supplied level proportionately for various collector areas, Figure 13 may be drawn. This graph approximates the percentage of solar energy required to supply the load that can be provided by various collector array sizes, assuming sufficient storage capacity.

ECONOMIC UTILIZATION ANALYSIS

An analysis can be made to estimate the amount of yearly fuel savings that can be expected after installation of a solar collector system. Figure 14 is a diagram of the method used, and it includes some of the efficiency approximations. Either conventional fuels (gas or electricity) or solar energy may be used to supply the loads. Conventionally fueled equipment such as gas furnaces, and hot water heaters and electric mechanical air conditioners are presently used. Solar fuel can be used to heat directly, or cool with an absorption air conditioner.

Table 6 gives the cost analysis for a typical house with a 750 ft² solar collector array incorporated into the heating and cooling system. The required conventional energy is the amount of fuel heat required for the particular conventional heating or cooling system. Conventional fuel costs can then be determined from these values. The energy required for the HVAC system to run on solar energy is analogous to the conventional system energy requirements. The solar supplied energy is then subtracted from the required solar energy quantities and any excess is converted back to conventional fuel requirements and priced accordingly. Conventional fuel saving is the difference between energy cost without the 750 ft² solar HVAC system and with the system. The natural gas and electric power costs were obtained from local Dallas companies and do not necessarily reflect present fuel costs in Dallas. These rate scales are presented in Table 7. The result of the analysis states that 50 percent of the fuel cost may be saved by installation of a 750 ft² solar collector system for the typical house in Dallas.

There are other cost considerations for incorporating a solar energy collection system: a recently enacted law⁶ provides federal loan guarantees or loan insurance in the solar HVAC area; tax credits on the installation cost and continued usage of solar heating and cooling systems may be offered; and funds may also be made available to homeowners by the Solar Heating and Cooling Demonstration Act of 1974, PL 93-409.

6. The housing and Community Development Act of 1974 PL 93-383.

Figure 11. Space Heating and Cooling Load Curve and Portion of Load Supplied by Solar Energy

Figure 12. Total Residential Load Curve and Portion of Load Supplied by Solar Energy

Figure 13. Percent of the Solar Supplied Portion of the Residential Load Provided by Various Collector Areas

SPACE HEATING AND HOT WATER HEATING

SPACE COOLING

Figure 14. Utilization Analysis Schematics

Table 6. Fuel Savings Analysis for Residential House
with a 750 ft² Solar Collection Array

Month	Required Conventional			Conventional Fuel Cost ³		Required if Solar				Conventional Supplemental Energy Required		Conventional Fuel Savings ³		Total Saving
	Hot Water ¹	Heating ¹	Cooling ²	Gas for Hot Water and Heating	Elect for Mechanical Cooling	Hot Water ⁴	Heating ⁴	Cooling ⁵	Solar ⁶ Supplied	Hot Water and Heating ⁷	Cooling ⁸	Hot Water and Heating	Cooling	
	10 ⁶ Btu	10 ⁶ Btu	10 ⁶ Btu	(Dollars)	(Dollars)	10 ⁶ Btu	10 ⁶ Btu	10 ⁶ Btu	10 ⁶ Btu	10 ⁶ Btu	10 ⁶ Btu	(Dollars)	(Dollars)	(Dollars)
1	2.9	8.0	0	8.21	0	2.3	6.4	0	4.8	4.9	0	3.44	0	3.44
2	2.6	5.3	.1	7.35	1.72	2.1	4.2	.2	7.1	0	0	7.35	1.72	9.07
3	2.9	3.0	.3	5.63	4.11	2.3	2.4	.8	13.6	0	0	5.63	4.11	9.74
4	2.8	0	1.1	2.97	9.88	2.2	0	3.5	12.6	0	0	2.97	9.88	12.85
5	2.9	0	5.2	3.05	30.12	2.3	0	17.3	9.9	0	2.9	3.05	10.65	13.70
6	2.8	0	10.2	2.97	53.27	2.2	0	34.0	13.4	0	6.8	2.97	15.74	18.71
7	2.9	0	11.4	3.05	58.82	2.3	0	38.0	17.9	0	6.7	3.05	21.76	24.81
8	2.9	0	10.4	3.05	54.19	2.3	0	34.7	17.9	0	5.7	3.05	21.76	24.81
9	2.8	0	8.6	2.97	45.86	2.2	0	28.5	13.0	0	5.3	2.97	15.28	18.25
10	2.9	0.4	2.7	3.40	18.55	2.3	.3	9.0	9.5	0	.6	3.40	11.75	15.15
11	2.8	3.1	.4	5.63	5.01	2.2	2.5	1.3	7.6	0	0	5.63	5.01	10.64
12	2.9	6.6	0	8.73	0	2.3	5.3	0	11.4	0	0	8.73	0	8.73
Total	34.1	26.4	50.4	57.01	281.53	27.0	21.1	167.3	138.7	4.9	28.0	52.24	117.66	169.90 (50%)

1. Load ÷ boiler efficiency (.8)

2. Load ÷ COP of mechanical air conditioner (2.0)

3. Costs based on local fuel rates as given in Table 7

4. Load ÷ heat exchanger efficiency (1.0)

5. Load ÷ COP of absorption air conditioner (.6)

6. 750 square feet of collectors at 25° tilt angle

7. (Required if solar - solar supplied) $\eta_{\text{solar}} + \eta_{\text{conventional}}$ where $\eta_{\text{solar}} = 1.0$
 $\eta_{\text{conventional}} = .8$

8. (Required if solar - solar supplied) $\text{COP}_{\text{solar}} + \text{COP}_{\text{conventional}}$ where $\text{COP}_{\text{solar}} = .6$
 $\text{COP}_{\text{conventional}} = 2.0$

Table 7. Fuel Rate Scales

Residential Electricity Rate Schedule

Dallas Power & Light Company 11/22/74

(214/747-4011)

first 24 kwh	\$1.50
next 56 kwh	4.23 ¢/kwh
next 100 kwh	3.06 ¢/kwh
next 400 kwh	2.07 ¢/kwh
over 580 kwh	1.58 ¢/kwh

Natural Gas Rate Schedule

Lone Star Gas 4/4/75

(214/741-3750)

first 700 ft ³	16.60 ¢/100 ft ³
next 7,300 ft ³	8.60 ¢/100 ft ³
next 12,000 ft ³	7.90 ¢/100 ft ³
next 30,000 ft ³	7.40 ¢/100 ft ³
over 50,000 ft ³	6.90 ¢/100 ft ³

COLLECTOR AREA AND STORAGE REQUIREMENTS

The collector areas required for different residential applications in Dallas are given in Table 8. A corresponding storage volume is given that will allow the system to run for 48 hours for heating and 12 hours for cooling. The space heating and cooling loads are again based on a typical 1500 ft² house and are only intended to give a rough estimate of the collector square footage and storage volume required for these applications. The calculations of these values are presented in Appendix D. A detailed cost analysis of any particular application should be made before the collector array and storage sizes are chosen. As fuel costs rise, however, solar HVAC systems will look more and more economically desirable.

Table 8. Collector Area and Storage Requirements
for Different Residential Applications in
Dallas

<u>Use</u>	<u>Square Footage¹</u>	<u>Storage Capacity² (gal)</u>	<u>Approximate Sizing Factor (gal/ft² day)</u>
Domestic Hot Water ³	359	360	.5
Heating Only ⁴	1080	530	.3
Heating and Cooling or Cooling Only ⁵	1275	1175	1.8
Domestic Hot Water, Heating, and Cooling ⁶	1750	1325	1.5

Notes

1. Square footage for supplying 100% of average load assuming total utilization of monthly supplied solar.
2. 48 hours for hot water and heating, 12 hours for cooling. Fully charged at 190°F for heating, 230°F for cooling.
3. Provides 100 gal/day at 100°F temp rise. January is worst case (25° tilt).
4. January is worst case for heating. Assume 80°F water for heating, 25° tilt.
5. July is worst case for cooling. Assume 200°F water for A/C, 25° tilt.
6. Collector tilt angle of 25°.

APPENDICES
DATA AND CALCULATIONS FOR DALLAS UTILIZATION STUDY

- A Climatological Data: Normals, Means and Extremes Summary and
September, October, 1974 Summaries
- B Coefficients of Transmission for Two Residential Housing Structures
- C House Load Equations
 - Residential Design Load Analysis
 - Design Load Calculation and Curves
 - Monthly Latent Load Calculation
- D Collector Area and Storage Calculations

APPENDIX A
CLIMATOLOGICAL SUMMARY FOR FORT WORTH, TEXAS

Fort Worth is located in North Central Texas approximately 250 miles north of the Gulf of Mexico. Headwaters of the Trinity River lie just northwest of the city on the Fort Worth Prairie. Rolling hills in the area range from about 600 to 800 feet in elevation.

The climate of Fort Worth is humid subtropical with hot summers. It is also continental, characterized by a wide range in annual temperature extremes. Precipitation averages near 32 inches annually but varies considerably from year to year ranging from less than 20 to more than 50 inches.

Winters are mild, but "northers" occur about three times each month, and often are accompanied by sudden drops in temperature. Cold spells rarely last longer than two or three days. In an average year, temperature minima of 20° or below occur on only six days.

The highest temperatures of summer are associated with fair skies, westerly winds and low humidities. Characteristically, hot spells in summer are broken into three-to-five day periods by thunderstorm activity. There are only a few nights each summer when the minimum temperature exceeds 80°. Refrigerated-type air conditioners are recommended for maximum comfort indoors, and for traveling via automobile.

Throughout the year, rainfall occurs more frequently during the night. Usually, periods of rainy weather last for only a day or two, and are followed by several days with fair skies. Greatest amounts of rain occur during the months of April, May, June, September and October. July and August are relatively dry months. Thunderstorms occur throughout the year, but are most frequent in the spring. Hail falls on about two or three days a year, ordinarily with only slight and scattered damage. Windstorms occurring during thunderstorm activity are sometimes destructive. Snowfall is rare, with a measurable fall occurring only once in an average year.

The average length of the warm season (freeze free period) at Fort Worth is 249 days. Since 1940 the longest was 290 days in both 1946 and 1953; the shortest was 196 days in 1957. The average date of the last occurrence of 32° or below is March 16. During the period 1940-1970, the earliest occurrence was February 14, 1946; the latest was April 13, 1957. The average date of the first occurrence of 32° or below in the fall is November 21. The earliest occurrence, during the period 1940-1970, was October 27, 1957; the latest was December 25, 1965.

METEOROLOGICAL DATA FOR THE CURRENT YEAR

Station: FORT WORTH, TEXAS GREATER SW INTL AIRPORT Standard time used: CENTRAL Latitude: 32° 50' N Longitude: 97° 03' W Elevation (ground): 537 feet Year: 1971

Month	Temperature							Degree days (Base 65°)		Precipitation						Relative humidity				Wind &						Average sky cover sunrise to sunset	Number of days										Average daily solar radiation - langley																																																																																																																																																																																																																																																																																																																																																																																																																																																								
	Averages			Extremes						Total	Greatest in 24 hrs.	Date	Snow, ice pellets			Hour	Hour	Hour	Hour	Resultant		Fastest mile					Percent of possible sunshine	Sunrise to sunset				Precipitation .01 inch or more	Snow, ice pellets 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures																																																																																																																																																																																																																																																																																																																																																																																																																																																									
	Daily maximum	Daily minimum	Monthly	Highest	Date	Lowest	Date	Heating	Cooling				Total	Greatest in 24 hrs.	Date					Total	Greatest in 24 hrs.	Date	Hour	Hour	Hour			Hour	Direction	Speed	Average speed					Speed		Direction	Date	Clear	Partly cloudy	Cloudy	90° and above	37° and below	32° and below	0° and below																																																																																																																																																																																																																																																																																																																																																																																																																																															
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† DATA CORRECTED AFTER PUBLICATION OF THE MONTHLY ISSUE.

NORMALS, MEANS, AND EXTREMES

Month	Temperature								Normal heating degree days (Base 65°)	Precipitation										Relative humidity				Wind &				Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days										Average daily solar radiation - langleys																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
	Normal				Extremes ⁶					Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Snow, ice pellets					Hour				Fastest mile				Mean speed	Prevailing direction	Speed	Direction	Year	Clear	Partly cloudy	Cloudy	Precipitation 0.1 inch or more	Snow, ice pellets 1.0 inch or more		Thunderstorms	Heavy fog 90° and above	Temperatures																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
	Daily maximum	Daily minimum	Monthly	Record highest	Year	Record lowest	Year	Mean total									Maximum monthly	Year	Maximum in 24 hrs.	Year	Hour 00	Hour 06	Hour 12	Hour 18	Mean speed	Prevailing direction	Speed																Direction	Year	Precipitation	Snow, ice pellets	Thunderstorms	Heavy fog	90° and above	32° and below	32° and below	90° and below	Max.	Min.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
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Ø For period July 1963 through the current year.

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows:
Highest temperature 112 in August 1936; lowest temperature -8 in February 1899; maximum monthly precipitation 17.64 in April 1922; minimum monthly precipitation 0.00 in November 1903; maximum precipitation in 24 hours 9.57 in September 1932.

- (a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
(b) Climatological standard normals (1931-1960).
+ Less than one half.
* Also on earlier dates, months, or years.
† Trace, an amount too small to measure.
‡ Below zero temperatures are preceded by a minus sign.
§ The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.
‡ ≥ 70° at Alaskan stations.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65° F. Cooling degree day totals are the sums of positive departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. The term "ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square cent

LOCAL CLIMATOLOGICAL DATA
U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
ENVIRONMENTAL DATA SERVICE

LATITUDE 32° 50' N LONGITUDE 97° 03' W ELEVATION (GROUND) 537 FT. STANDARD TIME USED: CENTRAL WBAN #03927

DALLAS-FORT WORTH, TEXAS
NAT WEATHER SERVICE MET OBSY
REGIONAL AIRPORT
SEPTEMBER 1974

DATE	TEMPERATURE ° F								WEATHER TYPES ON DATES OF OCCURRENCE 1 FOG 2 HEAVY FOG 3 THUNDERSTORM 4 ICE PELLETS 5 HAIL 6 GLAZE 7 DUSTSTORM 8 SMOKE, HAZE 9 BLOWING SNOW	SNOW- ICE PELLETS OR ICE ON GROUND AT OBSAM IN.	PRECIPITATION		AVO. STATION PRESSURE IN. ELEV. 576 FEET M.S.L.	WIND				SUNSHINE		SKY COVER TENTHS		DATE	
	MAXIMUM	MINIMUM	AVERAGE	DEPARTURE FROM NORMAL	AVERAGE DEW POINT	DEGREE DAYS BASE 65°		WATER EQUIVA- LENT IN			SNOW. ICE PELLETS IN.	RESULTANT DIRECTION		RESULTANT SPEED M.P.H.	AVERAGE SPEED M.P.H.	FASTEST MILE		HOURS AND TENTHS	PERCENT OF POSSIBLE	SUNRISE TO SUNSET	MIDNIGHT TO MIDNIGHT		
						HEATING	COOLING									SPEED M.P.H.	DIRECTION						
1	2	3	4	5	6	7A	7B	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
1	95*	75	85*	3	71	0	0		0	0	0	0	29.26	18	10.4	11.5	17	19		5	5	1	2
2	86	62	74	-8	68	0	0		0	0	0	0	29.28	33	4.3	13.5	25	35		9	7	2	1
3	78	60	69	-12	50	0	4		0	0	0	0	29.40	36	16.1	16.5	25	36		4	5	3	4
4	79	55	67	-14	49	0	2		0	0	0	0	29.48	05	3.9	5.9	10	08		5	4	3	4
5	81	55	68	-13	49	0	3		0	0	0	0	29.47	07	3.5	4.0	12	10		1	0	9	6
6	84	55	70	-11	50	0	5	8	0	0	0	0	29.43	05	2.5	2.0	12	02		0	0	9	6
7	87	60	74	-6	58	0	9	8	0	0	0	0	29.39	02	6.1	6.6	10	05		2	1	7	7
8	89	65	77	-3	60	0	12	1	0	0	0	0	29.29	01	14.5	14.8	23	36		6	5	8	8
9	84	71	78	-2	69	0	13	1	0	.22	0	0	29.20	02	12.2	13.5	21	05		10	10	9	10
10	80	70	75	-4	70	0	10	1	0	.10	0	0	29.22	15	3.6	4.9	16	18		10	9	10	10
11	93	73	83	4	72	0	18		0	0	0	0	29.24	18	17.2	17.3	23	18		6	4	11	11
12	87	67	77	-2	72	0	12		0	.12	0	0	29.29	16	8.8	9.2	17	36		10	10	12	12
13	67	60	64	-14	59	1	0	1	0	.24	0	0	29.47	01	17.6	17.8	23	01		10	10	13	13
14	73	61	67	-11	62	0	2		0	.07	0	0	29.55	03	8.4	8.9	14	03		10	10	14	14
15	73	69	71	-7	66	0	6	8	0	T	0	0	29.50	12	3.8	3.9	9	12		10	10	15	15
16	83	70	77	-1	70	0	12	13	0	1.10	0	0	29.42	18	2.1	6.3	17	34		10	10	16	16
17	76	70	73	-4	69	0	8		0	1.70	0	0	29.41	04	6.1	6.5	10	06		10	10	17	17
18	78	70	74	-3	69	0	9	2	8	0	0	0	29.43	06	3.1	3.5	8	01		10	9	18	18
19	89	70	80	3	70	0	15	1	8	0	0	0	29.40	17	5.2	5.5	12	19		8	5	19	19
20	87	71	79	3	71	0	14	13	8	1.43	0	0	29.41	29	1.9	5.9	15	31		8	7	20	20
21	73	64	69	-7	64	0	4	1	8	.04	0	0	29.51	02	11.4	11.8	20	36		10	9	21	21
22	74	62	68	-8	53	0	3		0	0	0	0	29.58	06	9.3	9.9	20	08		6	6	22	22
23	66	55	61	-14	49	4	0		0	.02	0	0	29.57	06	7.1	7.3	12	05		10	9	23	23
24	60	54	57*	-18	54	8	0	1	0	.78	0	0	29.49	05	8.2	8.5	20	06		10	10	24	24
25	61	55	58	-17	56	7	0	1	0	.22	0	0	29.43	02	8.7	10.1	13	01		10	10	25	25
26	70	60	65	-10	60	0	0	1	0	T	0	0	29.24	08	.1	2.0	7	15		10	8	26	26
27	85	60	73	-1	63	0	8		0	0	0	0	29.03	18	13.9	14.1	23	18		2	2	27	27
28	75	59	67	-7	56	0	2		0	0	0	0	29.25	29	8.2	14.7	22	31		2	1	28	28
29	78	51*	65	-9	47	0	0		0	0	0	0	29.56	34	2.2	3.2	7	35		0	0	29	29
30	82	52	67	-6	49	0	2		0	0	0	0	29.60	13	1.0	1.0	5	08		0	0	30	30

[illegible]

78.1	62.7	70.9	-3.6	61	SEASON TO DATE	SNOW, ICE PELLETS ≥ 1.0 INCH	0	GREATEST IN 24 HOURS AND DATES	GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE
NUMBER OF DAYS					TOTAL	THUNDERSTORMS	2	PRECIPITATION	SNOW, ICE PELLETS
MAXIMUM TEMP.		MINIMUM TEMP.		20	2403	HEAVY FOG X	1	1.70	17
> 90 °	≤ 32 °	< 32 °	≤ 0 °	DEP.	DEP.	CLEAR	7	PARTLY CLOUDY	6
20	0	0	0	20	-32	CLOUDY	17		

6-HOURLY PRECIPITATION (WATER EQUIVALENT IN INCHES)

[illegible]

- * EXTREME TEMPERATURES FOR THE MONTH. MAY BE THE LAST OF MORE THAN ONE OCCURRENCE.
- BELOW ZERO TEMPERATURE OR NEGATIVE DEPARTURE FROM NORMAL.
- * - 2 TO AT ALASKAN STATIONS.
- * ALSO ON AN EARLIER DATE. OR DATES.
- X HEAVY FOG RESTRICTS VISIBILITY TO 1/4 MILE OR LESS.

IN THE MONTHLY PRECIPITATION TABLE AND IN COLUMNS 9, 10, AND 11 INDICATES AN AMOUNT TOO SMALL TO MEASURE

MEASURE FOR DEGREE DAYS BEGINS WITH JULY FOR HEATING AND JANUARY FOR COOLING.

DATA IN COLUMNS 6, 12, 13, 14, AND 15 ARE BASED ON 3 OBSERVATIONS PER DAY AT 3-HOUR INTERVALS.

WIND DIRECTION ARE THOSE FROM THE MOST FREQUENT WINDS. RESULTANT DIRECTION IS THE VECTOR SUM OF WIND DIRECTIONS AND SPEEDS DIVIDED BY THE NUMBER OF OBSERVATIONS.

FIGURES FOR DEGREE DAYS ARE TENS OF DEGREES FROM TRUE NORTH (I.E., DR-EAST, 18-SOUTH, 27-NORTH, 36-NORTH, 45-NORTH, 54-NORTH, 63-NORTH, 72-NORTH, 81-NORTH, 90-NORTH).

WIND SPEEDS ARE IN MILES PER HOUR. 100 DEGREES IN COL. 17, ENTIRES IN COL. 18 ARE FASTEST OBSERVED 1-MINUTE SPEEDS. IF A / APPEARS IN COL. 17, SPEEDS ARE DUSTY.

ERRATA DETECTED WILL BE CORRECTED AND CHANGES IN SUMMARY DATA WILL BE ANNOTATED IN THE ANNUAL SUMMARY.

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I CERTIFY THAT THIS IS AN OFFICIAL
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AND ATMOSPHERIC ADMINISTRATION, AND
IS COMPILED FROM RECORDS ON FILE AT
THE NATIONAL CLIMATIC CENTER, ASHE-
VILLE, NORTH CAROLINA, 28801

William H. Haggard

DIRECTOR, NATIONAL CLIMATIC CENTER

SUMMARY BY HOURS

AVERAGES											RESULTANT WIND
HOUR	LOCAL TIME	SHIP'S COURSE	STATION	PRESSURE IN.	TEMPERATURE			RELATIVE HUMIDITY %	WIND SPEED M.P.H.	DIRECTION	SPEED M.P.H.
					AIR °F	WET BULB °F	DEN. PT.				
00	9	28.40	67	63	60	79	7.9	04	1.6		1.6
03	9	28.38	66	63	61	84	6.8	05	1.6		1.6
06	7	29.40	65	62	60	85	8.1	02	2.5		2.5
09	7	29.43	68	64	61	77	9.1	03	2.0		2.0
12	7	29.42	75	66	61	65	10.2	05	3.4		3.4
15	7	29.37	77	67	61	61	11.2	03	3.7		3.7
18	6	29.37	75	66	61	65	9.7	05	4.7		4.7
21	5	29.40	69	63	60	75	6.9	05	2.6		2.6

DALLAS-FORT WORTH, TEXAS

DIRECTOR, NATIONAL CLIMATIC CENTER

USCUMM - NOAA - ASHEVILLE

750

10/18/74

OBSERVATIONS AT 3-HOUR INTERVALS

NOTES

CEILING COLUMN-
UNL INDICATES AN UNLIMITED
CEILING

WEATHER COLUMN-

T	TORNADO
I	THUNDERSTORM
D	SQUALL
R	RAIN
RW	RAIN SHOWERS
FR	FREEZING RAIN
L	DRIZZLE
ZL	FREEZING DRIZZLE
S	SNOW
SP	SNOW PELLETS
IC	ICE CRYSTALS
SH	SNOW SHOWERS
SG	SNOW GRAINS
IP	ICE PELLETS
A	HAIL
F	FOG
IF	ICE FOG
GF	GROWING FOG
BD	BLOWING DUST
BS	BLOWING SAND
BS	BLOWING SNOW:
BT	BLOWING SPRAY
K	SMOKE
H	HAZE
D	DUST

WIND COLUMNS-

DIRECTIONS ARE THOSE FROM WHICH THE WIND BLOWS. INDICATED IN TENS OF DEGREES FROM TRUE NORTH: I.E.. 09 FOR EAST. 18 FOR SOUTH. 27 FOR WEST. ENTRY OF 00 IN THE DIRECTION COLUMN INDICATES CALM.

SPEED IS EXPRESSED IN KNOTS;
MULTIPLY BY 1.15 TO CONVERT
TO MILES PER HOUR.

ADDITIONAL DATA

OTHER OBSERVATIONAL DATA CONTAINED IN RECORDS ON FILE CAN BE FURNISHED AT COST VIA MICROFILM, MICROFICHE, OR PAPER COPIES OF THE ORIGINAL RECORDS. INQUIRIES AS TO AVAILABILITY AND COSTS SHOULD BE ADDRESSED TO: DIRECTOR, NATIONAL CLIMATIC CENTER, FEDERAL BUILDING, ASHEVILLE, NORTH CAROLINA 28801.

STATION: DALLAS-FORT WORTH TEXAS YEAR & MONTH: 74 09

U.S. DEPARTMENT OF COMMERCE
NATIONAL CLIMATIC CENTER
FEDERAL BUILDING
ASHEVILLE, N.C. 28801

LOCAL CLIMATOLOGICAL DATA
U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
ENVIRONMENTAL DATA SERVICE

DALLAS-FORT WORTH, TEXAS
NAT WEATHER SERVICE MET OBSY
REGIONAL AIRPORT
OCTOBER 1974

LATITUDE 32° 50' N LONGITUDE 97° 03' W ELEVATION (GROUND) 537 FT. STANDARD TIME USED: CENTRAL WBAN #03927

DATE	TEMPERATURE ° F							WEATHER TYPES ON DATES OF OCCURRENCE 1 FOG 2 HEAVY FOG X 3 THUNDERSTORM 4 ICE PELLETS 5 HAIL 6 CLARE 7 DUSTSTORM 8 SMOKE, HAZE 9 BLOWING SNOW	SNOW- ICE PELLETS OR ICE ON GROUND AT 06AM IN.	PRECIPITATION		AVG. STATION PRES- SURE IN. ELEV. 576 FEET M.S.L.	WIND				SUNSHINE		SKY COVER TENTHS			
	MAXIMUM	MINIMUM	AVERAGE	DEPARTURE FROM NORMAL	AVERAGE DEW POINT	DEGREE DAYS				WATER EQUIVA- LENT IN.	SNOW- ICE PELLETS IN.		RESULTANT DIRECTION	RESULTANT SPEED M.P.H.	AVERAGE SPEED M.P.H.	FASTEST MILE		HOURS AND TENTHS	PERCENT OF POSSIBLE	SUNRISE TO SUNSET	MIDNIGHT TO MIDNIGHT	DATE
						HEATING	COOLING									SPEED M.P.H.	DIRECTION					
1	2	3	4	5	6	7A	7B	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	85	54	70	-3	49	0	5		0	0	0	0	20.57	21	4.9	5.2	12	0	0	0	1	
2	85	54	70	-3	51	0	5		0	0	0	0	20.61	20	4.8	5.0	8	13		0	2	
3	84	60	72	0	57	0	7		0	0	0	0	20.64	16	10.7	11.2	17	17		0	3	
4	86	63	75	3	58	0	10		0	0	0	0	20.50	18	17.5	17.7	28	18		3	4	
5	85	64	75	3	60	0	10		0	0	0	0	20.50	17	15.0	15.2	21	18		3	5	
6	85	67	76	5	64	0	11		0	0	0	0	20.57	17	7.3	8.3	17	02		3	6	
7	73	59	66	-5	57	0	1		0	0	0	0	20.65	36	7.6	0.3	12	35		9	7	
8	83	57	70	-1	59	0	6	1	8	0	0	0	20.52	23	1.5	2.6	12	23		10	7	
9	87	61	74	4	60	0	9	1	8	0	0	0	20.44	03	3.4	4.9	9	01	4	1	8	
10	87	60	74	4	58	0	9	1	8	0	0	0	20.46	12	3.3	3.7	10	14	4	1	9	
11	86	65	76	6	62	0	11		8	0	0	0	20.46	17	9.6	10.1	22	19	5	3	10	
12	86	65	76	7	60	0	11			0	0	0	20.46	17	7.9	8.5	13	13	8	6	11	
13	87*	65	76*	7	63	0	11	1	8	0	0	0	20.55	17	7.9	8.5	13	13	7	6	12	
14	70	53	62	-6	61	3	0	1		1.00	0	0	20.45	18	9.3	9.5	21	19	9	9	13	
15	66	50	58*	-10	44	7	0			0	0	0	20.42	36	7.1	10.1	23	36	10	9	14	
16	77	45*	61	-7	47	4	0			0	0	0	20.65	35	12.6	13.1	23	01	0	0	15	
17	82	52	67	0	52	0	2			0	0	0	20.54	24	4.8	5.8	10	21	1	0	16	
18	86	56	71	4	53	0	6			0	0	0	20.50	22	3.5	3.7	7	25	0	0	17	
19	76	55	66	-1	52	0	1			0	0	0	20.49	31	1.3	1.7	9	35	0	0	18	
20	74	52	63	-3	48	2	0			0	0	0	20.54	03	7.3	7.9	12	01	3	3	19	
21	76	57	67	1	45	0	2			0	0	0	20.60	12	4.3	4.5	12	13	7	5	20	
22	78	53	66	1	48	0	1			0	0	0	20.69	13	6.4	6.9	14	17	6	5	21	
23	78	59	69	4	61	0	4		8	0	0	0	20.78	13	4.3	4.5	12	14	7	6	22	
24	75	63	69	4	61	0	4	1	8	0	0	0	20.73	15	3.6	3.7	12	14	9	9	23	
25	71	62	67	3	62	0	2	1	8	0	0	0	20.59	18	5.4	7.1	16	20	10	10	24	
26	79	57	68	4	58	0	3	1	8	0	0	0	20.62	12	2.8	2.9	8	13	10	9	25	
27	79	57	68	5	53	0	3		8	0	0	0	20.61	18	2.9	3.3	8	20	4	5	26	
28	71	62	67	4	63	0	2	1	8	0	0	0	20.43	14	5.8	5.9	14	15	6	6	27	
29	81	62	72	9	66	0	7	2	0	0	0	0	20.15	15	8.5	8.9	17	28	10	9	28	
30	81	65	73	11	70	0	8	3	0	0	0	0	20.23	17	9.1	9.6	21	19	5	5	29	
31	81	65	73	11	70	0	8	3	0	0	0	0	20.33	16	16.6	16.7	25	18	10	10	30	
31	75	60	68	6	60	0	3	3	0	0	0	0	20.31	29	1.4	9.5	23	18	7	6	31	
SUM		1814				16	153			5.93	0	20.52	16	3.8	7.6	28	18	164	144			
AVG		58.5	59.2	1.6	57	-44	12			7	3.25											
NUMBER OF DAYS																						
MAXIMUM TEMP						36	2556															
MINIMUM TEMP																						
DEP.																						
CLEAR						-24	-20															
PARTLY CLOUDY																						
CLOUDY																						

6-HOURLY PRECIPITATION (WATER EQUIVALENT IN INCHES)

A. M. HOUR ENDING AT													P. M. HOUR ENDING AT													
1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12			
1																								1		
2																								2		
3																								3		
4																								4		
5																								5		
6																	T							6		
7																								7		
8																								8		
9																								9		
10																								10		
11																								11		
12																								12		
13																	.02					.90		13		
14						.25					.72						.03							14		
15																								15		
16																								16		
17																								17		
18																								18		
19																								19		
20																								20		
21																								21		
22																								22		
23																								23		
24						.01											.02					T		24		
25						T					.03										.03			25		
26																								26		
27																								27		
28						.55					.50						.12							28		
29																								29		
30											.24						.04					.60		30		
31						1.34					.52													31		

* EXTREME TEMPERATURES FOR THE MONTH, MAY BE THE LAST OF MORE THAN ONE OCCURRENCE.
- BELOW ZERO TEMPERATURE OR NEGATIVE DEPARTURE FROM NORMAL.
* 70° AT ALASKAN STATIONS.
* ALSO ON AN EARLIER DATE, OR DATES.
X HEAVY FOG RESTRICTS VISIBILITY TO 1/4 MILE OR LESS.
T IN THE HOURLY PRECIPITATION TABLE AND IN COLUMNS 9, 10, AND 11 INDICATES AN AMOUNT TOO SMALL TO MEASURE

THE SEASON FOR DEGREE DAYS BEGINS WITH JULY FOR HEATING AND JANUARY FOR COOLING.
DATA IN COLUMNS 6, 12, 13, 14, AND 15 ARE BASED ON 8 OBSERVATIONS PER DAY AT 3-HOUR INTERVALS.
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RESULTANT WIND IS THE VECTOR SUM OF WIND DIRECTIONS AND SPEEDS DIVIDED BY THE NUMBER OF OBSERVATIONS.
FIGURES FOR DIRECTIONS ARE TENS OF DEGREES FROM TRUE NORTH: I.E., 09-EAST, 18-SOUTH, 27-WEST, 36-NORTH, AND 00-CALM. WHEN DIRECTIONS ARE IN TENS OF DEGREES IN COL. 17, ENTRIES IN COL. 16 ARE FASTEST OBSERVED 1-MINUTE SPEEDS. IF THE / APPEARS IN COL. 17, SPEEDS ARE GUSTS.
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William H. Haggard
DIRECTOR, NATIONAL CLIMATIC CENTER

SUMMARY BY HOURS

HOUR	LOCAL TIME	SKY COVER TENTHS	AVERAGES						RESULTANT WIND	
			STATION PRESSURE IN.	TEMPERATURE			RELATIVE HUMIDITY %	WIND SPEED M.P.H.	DIRECTION	SPEED M.P.H.
				AIR °F	WET BULB °F	DEW P. °F				
00	4	20.52	65	60	57	76	6.8	16	2.8	
03	4	20.51	62	59	57	81	6.2	17	3.4	
06	5	20.53	61	58	56	85	4.9	16	2.2	
09	5	20.57	67	61	58	74	8.2	16	4.2	
12	5	20.55	75	65	58	58	10.4	18	6.2	
15	5	20.48	78	65	56	49	10.4	17	5.1	
18	5	20.49	74	63	56	55	8.0	16	3.6	
21	4	20.51	68	61	57	69	6.1	15	3.1	

OBSERVATIONS AT 3-HOUR INTERVALS

HOUR	TEMPERATURE				WIND				VISI- BILITY				WEATHER				TEMPERATURE				WIND				VISI- BILITY				WEATHER			
	SKY COVER	CEILING	WIND DIR.	WIND SPD.	REL. HUM.	DEW PT.	WIND DIR.	WIND SPD.	REL. HUM.	DEW PT.	WIND DIR.	WIND SPD.	REL. HUM.	DEW PT.	WIND DIR.	WIND SPD.	REL. HUM.	DEW PT.	WIND DIR.	WIND SPD.	REL. HUM.	DEW PT.	WIND DIR.	WIND SPD.	REL. HUM.	DEW PT.	WIND DIR.	WIND SPD.	REL. HUM.	DEW PT.	WIND DIR.	WIND SPD.
00	0 UNL	20			63	56	50	63	23	3	0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20
03	0 UNL	20			60	54	48	60	25	4	0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20
06	0 UNL	20			59	51	48	60	25	4	0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20
09	0 UNL	20			60	50	52	57	00	0	0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20
12	0 UNL	20			70	63	52	39	23	5	0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20
15	0 UNL	20			83	62	47	28	20	9	0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20
18	0 UNL	20			78	60	46	31	20	10	0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20
21	0 UNL	20			66	57	51	58	19	5	0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20
DAY 01																																
00	0 UNL	20			70	62	57	64	17	12	0 UNL	15			0 UNL	15			0 UNL	15			0 UNL	15			0 UNL	15			0 UNL	15
03	0 UNL	20			66	61	57	73	18	11	0 UNL	15			0 UNL	15			0 UNL	15			0 UNL	15			0 UNL	15			0 UNL	15
06	0 UNL	20			63	61	58	87	17	9	0 UNL	15			0 UNL	15			0 UNL	15			0 UNL	15			0 UNL	15			0 UNL	15
09	0 UNL	20			69	63	60	73	18	16	1 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10
12	0 UNL	20			78	66	58	50	19	22	4 UNL	15			0 UNL	15			0 UNL	15			0 UNL	15			0 UNL	15			0 UNL	15
15	0 UNL	20			85	67	56	37	19	20	3 UNL	15			0 UNL	15			0 UNL	15			0 UNL	15			0 UNL	15			0 UNL	15
18	0 UNL	20			80	66	58	47	17	20	2 UNL	15			0 UNL	15			0 UNL	15			0 UNL	15			0 UNL	15			0 UNL	15
21	0 UNL	20			74	65	59	60	17	13	0 UNL	15			0 UNL	15			0 UNL	15			0 UNL	15			0 UNL	15			0 UNL	15
DAY 04																																
00	0 UNL	20			67	63	61	81	36	10	0 UNL	15			0 UNL	15			0 UNL	15			0 UNL	15			0 UNL	15			0 UNL	15
03	0 UNL	20			60	58	56	87	01	6	0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10
06	0 UNL	20			60	57	55	84	33	8	0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10
09	0 UNL	20			61	57	55	81	34	8	0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10
12	0 UNL	20			70	62	57	54	33	7	0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10
15	0 UNL	20			73	64	58	59	32	7	2 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10
18	0 UNL	20			69	62	58	68	03	7	2 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10
21	0 UNL	20			63	59	57	81	03	4	1 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10
DAY 07																																
00	0 UNL	20			63	59	57	81	05	3	4 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10
03	0 UNL	20			61	58	57	87	00	0	0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10
06	0 UNL	20			60	58	58	87	00	0	0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10
09	0 UNL	20			71	65	62	73	14	8	0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10
12	0 UNL	20			80	68	63	56	15	3	0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10
15	0 UNL	20			85	69	60	43	13	4	7 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10
18	0 UNL	20			80	66	58	47	13	4	6 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10
21	0 UNL	20			70	63	58	66	08	3	6 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10
DAY 10																																
00	0 UNL	20			72	65	60	66	16	8	10	40	5		0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10
03	0 UNL	20			60	63	60	76	17	3	10	100	5		0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10
06	0 UNL	20			66	63	62	87	19	8	10	100	5		0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10
09	0 UNL	20			73	68	65	76	18	6	10	18	2		0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10
12	0 UNL	20			84	70	63	48	18	10	10	38	5		0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10
15	0 UNL	20			85	70	63	48	17	14	10	12	10		0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10
18	0 UNL	20			76	69	66	71	20	9	10	18	10		0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10
21	0 UNL	20			71	68	67	87	00	0	7	80	15		0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10
DAY 13																																
00	0 UNL	20			63	59	57	81	05	3	4 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10
03	0 UNL	20			61	58	57	87	00	0	0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10
06	0 UNL	20			60	58	58	87	00	0	0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10
09	0 UNL	20			71	65	62	73	14	8	0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10
12	0 UNL	20			80	68	63	56	15	3	0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10
15	0 UNL	20			85	69	60	43	13	4	7 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10
18	0 UNL	20			80	66	58	47	13	4	6 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10
21	0 UNL	20			70	63	58	66	08	3	6 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10			0 UNL	10
DAY 16																																
00	0 UNL	20			52	47	41	66	29	5	0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20
03	0 UNL	20			47	45	42	83	21	4	0 UNL	15			0 UNL	15			0 UNL	15			0 UNL	15			0 UNL	15			0 UNL	15
06	0 UNL	20			47	44	41	80	23	5	0 UNL	15			0 UNL	15			0 UNL	15			0 UNL	15			0 UNL	15			0 UNL	15
09	0 UNL	20			58	52	47	67	22	2	0 UNL	15			0 UNL	15			0 UNL	15			0 UNL	15			0 UNL	15			0 UNL	15
12	0 UNL	20			70	58	49	47	22	7	0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20
15	0 UNL	20			74	61	51	49	29	6	0 UNL	25			0 UNL	25			0 UNL	25			0 UNL	25			0 UNL	25			0 UNL	25
18	0 UNL	20			73	60	50	44	27	4	0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20
21	0 UNL	20			73	57	53	70	20	4	0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20
DAY 19																																
00	0 UNL	20			66	60	59	68	35	8	5 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20
03	0 UNL	20			62	57	53	73	01	9	0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20			0 UNL	20			0 UNL</	

APPENDIX B
COEFFICIENTS OF TRANSMISSION FOR TWO
RESIDENTIAL HOUSE STRUCTURES

Masonry Wall

	R
1. Outside surface (15 mph)	.17
2. Stucco	.20
3. Concrete Block	1.72
4. Air Space	2.80
5. Wall Board $\frac{1}{2}$ "	.45
6. Inside Surface (still air)	<u>.68</u>
	6.02

$$U = .166 \text{ Btu/hr ft}^2\text{°F}$$

Slate Roof

	R
1. Outside surface (15 mph)	.17
2. Slate Roof $\frac{1}{2}$ "	20.00
3. Plywood Deck	.78
4. Air space (3.5")	2.06
5. Gypsum Wall Board $\frac{1}{2}$ "	.45
6. Inside surface (still air)	<u>.62</u>
	24.08

$$U = .041 \text{ Btu/hr ft}^2\text{°F}$$

Wood Frame/Brick Veneer

$$R = 13.5 \quad U = .074 \text{ Btu/hr ft}^2\text{°F}$$

Wood Shingle Roof

$$R = 24 \quad U = .041 \text{ Btu/hr ft}^2\text{°F}$$

APPENDIX C

HOUSE LOAD EQUATIONS

The design heating load for a typical Dallas house is based on an extreme winter design of 19°F. The design load is a combination of heat losses due to infiltrating outside air, transmission losses through the walls and roof, and internal heat generated by electrical appliances.

The domestic hot water heating load is also included in this analysis. An average hot water usage level for a typical home is 100 gallons per day. For an assumed temperature rise of 100°F, the water heating load would be 75,000 Btu/day or 3125 Btu/hr.

The internal sensible load is the amount of energy added to the house by electrical power consumption. It is assumed that all of the electrical power consumed is converted to radiated heat. The average electricity usage level for a typical home is approximately 25 kwh/day. At 3413 Btu/kwh, the average amount of heat added to the house is 3555 Btu/hour. This load is added to the cooling load but subtracted from the heating load because it supplies a portion of the required heat. Both the hot water load and the internal sensible load are assumed to remain constant throughout the year.

The design heating load is given by the following equation:

$$\begin{aligned}
 H_{\text{required}} &= H_{\text{infiltration}} + H_{\text{transmission}} + H_{\text{hot water}} - H_{\text{internal}} \\
 &\quad \text{(sensible)} \qquad \qquad \qquad \text{(sensible)} \\
 &= C_p V N \rho (t_i - t_o) + \sum_{j=1}^n A_j U_j (t_i - t_o) + H_{\text{hot water}} - H_{\text{internal}} \\
 &\qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \text{(sensible)}
 \end{aligned}$$

where

$$\begin{aligned}
 C_p &= .240 \text{ Btu/lbm } ^\circ\text{F} \\
 V &= \text{house volume ft}^3 \\
 N &= \text{number of volume exchanges per hour}^1 = 1.5 \\
 \rho &= .075 \text{ lbm/ft}^3 \\
 t_i - t_o &= \text{inside/outside temperature difference (} ^\circ\text{F)} \\
 A_j &= \text{surface area of wall or roof } j \text{ (ft}^2\text{)} \\
 U_j &= \text{coefficient of transmission of wall or roof } j \text{ (Btu/hr-ft}^2 \text{ } ^\circ\text{F)}
 \end{aligned}$$

The design cooling load is based on summer design temperatures of 101°F dry bulb and 79°F wet bulb. Again, the energy required for space cooling is based on infiltration and transmission losses. From the wet bulb temperature, the energy needed to remove the excess water from the infiltrating air can be determined. This is the latent portion of the transmission losses. The dry bulb temperature is used to calculate the energy needed to lower the temperature of infiltrating dry air to 75°F. This is the sensible portion of the transmission losses. The following equation gives the design cooling load.

$$H_{\text{required}} = H_{\text{infiltration}} + H_{\text{transmission}} + H_{\text{hot water}} + H_{\text{internal}} \\ \text{(sensible \& latent)} \qquad \qquad \qquad \text{(sensible)}$$

$$= 1VN\rho C_p(t_o - t_i) + VN\rho(h_o - h_i) + \sum_{j=1}^n A_j U_j(t_o - t_i) + H_{\text{hot water}} \\ + H_{\text{internal}} \\ \text{(sensible)}$$

where

h_o = outside enthalpy of air determined from wet bulb temperature on psychrometric chart for design condition $h_o = 42.6$ Btu/lbm.

h_i = inside enthalpy of 75° dry bulb temperature and 40% relative humidity = 26.2 Btu/lbm

RESIDENTIAL DESIGN LOAD ANALYSIS FOR DALLAS/FT. WORTH

Table C-1 lists the design weather data used in the analysis. Dallas and Fort Worth have a humid subtropical climate with hot summers and a wide range of annual temperature extremes.

Table C-1. Dallas Design Weather Data

Number of heating degree days	2405 (average since 1932)
Number of cooling degree days	2491 (1971 data)
Winter extreme design temperature	19°F
Summer extreme dry bulb design temperature	101°F
Summer extreme wet bulb design temperature	79°F
Summer outdoor daily temperature range	20°F
Latitude	32°5'
Altitude	481'

The analysis for maximum summer and winter house loads includes calculations of latent and sensible infiltration, sensible transmission, sensible internal heat, and domestic hot water heat. These values have been described and will be calculated later.

The summary of the design heating and cooling levels for the Dallas house is given in Table C-2 for the two structure configurations.

¹ ASHRAE Handbook of Fundamentals, 1972, pp. 337-370.

Table C-2. Design Heating and Cooling Levels for Dallas

Load (Btu/hr)	U = .166 Btu/hr ft ² °F		U = .074 Btu/hr ft ² °F	
	Heating Btu/hr	Cooling Btu/hr	Heating Btu/hr	Cooling Btu/hr
Infiltration (sensible)	16524	8424	16524	8524
Infiltration (latent)	---	22140	---	22140
Transmission	14645	7466	7413	3830
Hot Water	- 3125	3125	3125	3125
Internal (sensible)	3555	3555	- 3555	3555
Total	30739	44710	23607	41074

The design building loads versus outside dry bulb temperature are shown in graphs in Figures C-1 and C-2. The dotted lines are for a masonry type house and the solid lines are for a wood frame/brick veneer house. Figure C-2 includes the internal sensible and hot water loads, whereas Figure C-1 does not. These graphs may be used to obtain an approximate load level for a given outside dry bulb temperature. Note that the actual building load for cooling would fall somewhere between the two cooling design load lines because generally the maximum humidity level would not be present.

The design temperature set points used to draw Figure C-2 are the same as for Figure C-1. They appear different because the hot water and internal sensible loads are assumed constant and always present. The set points are 430 Btu/hr at 70°F for heating and 6680 Btu/hr at 75°F for cooling.

DESIGN LOADS

Heating design load:

$$H = C_p V N_p (t_i - t_o) + \sum_{j=1}^n A_j U_j (t_i - t_o) + H_{\text{Hot Water}} - H_{\text{Internal Sensible}}$$

$$\left. \begin{array}{l} U_w = .166 \\ U_r = .041 \end{array} \right\} H = 16524 + 14645 + 3125 - 3555 = 30739 \text{ Btu/hr Average insulation}$$

or

$$\left. \begin{array}{l} U_w = .074 \\ U_r = .041 \end{array} \right\} H = 16524 + 7513 + 3125 - 3555 = 23607 \text{ Btu/hr Good insulation}$$

Cooling design load:

$$H = V N_p C_p (t_o - t_i) + V N_p (h_o - h_i) + \sum_{j=1}^n A_j U_j (t_o - t_i) + H_{\text{Hot Water}} + H_{\text{Internal Sensible}}$$

$$\left. \begin{array}{l} U_w = .166 \\ U_r = .041 \end{array} \right\} H = 8424 + 22140 + 7466 + 3125 + 3555 = 44710 \text{ Btu/hr Average insulation}$$

or

$$\left. \begin{array}{l} U_w = .074 \\ U_r = .041 \end{array} \right\} H = 8424 + 22140 + 3830 + 3125 + 3555 = 41074 \text{ Btu/hr Good insulation}$$

Figure C-1. Building Load versus Outside Dry Bulb Temperature

Figure C-2. Building Loads versus Outside Dry Bulb Temperature (with internal sensible and hot water loads)

TABLE OF DALLAS MONTHLY LATENT LOAD CALCULATION

	Relative Humidity (%)	Average Monthly Dry Bulb Temp- erature (°F)	h ^{1.} (Btu/lbm)	Δh ^{2.} (Btu/lbm)	Latent Load (10 ⁶ Btu)
1	68.0	45.5	15.7	0	0
2	65.2	49.2	17.1	0	0
3	65.5	55.9	20.1	0	0
4	69.2	64.8	25.4	0	0
5	73.2	72.7	31.2	5.0	4.9
6	66.8	81.5	36.2	10.0	9.8
7	59.5	85.4	37.7	11.5	11.3
8	63.2	85.4	37.9	11.7	11.5
9	71.2	78.4	35.2	9.0	8.9
10	68.0	67.9	27.2	1.0	1.0
11	67.5	57.8	21.2	0	0
12	70.5	47.7	16.8	0	0
Average	67.2	65.8		Total	47.4

1. Enthalpy at average temperature and relative humidity.
2. Enthalpy difference where $\Delta h = h - 26.2$ Btu/lbm where 26.2 is the enthalpy at the comfort level of 40% relative humidity and 75°F dry bulb temperature.

APPENDIX D
COLLECTOR AREA AND STORAGE CALCULATIONS
FOR DALLAS

AREA ¹ .		STORAGE
Hot Water Only	$7500 \text{ Btu/day} = 2.3 \times 10^6 \text{ Btu/Jan.}$ $750 \text{ ft}^2 \text{ yields } 4.8 \times 10^6 \text{ Btu/Jan.}$ $\therefore 750 \times 2.3 \div 4.8 = 359 \text{ ft}^2$	$150,000 \text{ Btu/2 days}$ $T = 190^\circ - 140^\circ = 50^\circ\text{F}$ $V = \frac{150,000 \text{ Btu}}{(8.33 \text{ Btu/gal}^\circ\text{F})(50^\circ\text{F})} = 360 \text{ gal}$
Space Heating Only ²	$\text{Required} = 6.9 \times 10^6 \text{ Btu/January}$ $750 \text{ ft}^2 \text{ yields } 4.8 \times 10^6 \text{ Btu/Jan.}$ $\therefore 750 \times 6.9 \div 4.8 = 1078 \text{ ft}^2$	$\text{Required} = (6.9 \times 10^6 \text{ Btu}) \left(\frac{2}{31} \text{ days}\right)$ $T = 190^\circ - 90^\circ = 100^\circ\text{F}$ $V = \frac{445,000 \text{ Btu}}{(8.33 \text{ Btu/gal}^\circ\text{F})(100^\circ\text{F})} = 534 \text{ gal}$
Space Heating & Cooling Only ²	$\text{Required} = 18.2 \times 10^6 \text{ Btu/July}$ $750 \text{ ft}^2 \text{ yields } 10.7 \text{ Btu/July}$ $\therefore 750 \times 18.2 \div 10.7 = 1275 \text{ ft}^2$	$\text{Required} = 18.2 \times 10^6 \text{ Btu} \left(\frac{1}{2} \text{ days}\right)$ $T = 230^\circ - 200^\circ = 30^\circ\text{F}$ $V = \frac{293,550 \text{ Btu}}{(8.33 \text{ Btu/gal}^\circ\text{F})(30^\circ\text{F})} = 1175 \text{ gal}$
Domestic Hot Water, Space Heating & Cooling ³	$\text{Required} = 25.0 \times 10^6 \text{ Btu/July}$ $750 \text{ ft}^2 \text{ yields } 10.7 \text{ Btu/July}$ $\therefore 750 \times 25.0 \div 10.7 = 1725 \text{ ft}^2$	$\text{Required} = 75,000 \text{ Btu} \left(\frac{1}{2} \text{ day}\right)$ $T = 230^\circ - 200^\circ = 30^\circ\text{F}$ $V = 1175 + \frac{37500 \text{ Btu}}{(8.33 \text{ Btu/gal}^\circ\text{F})(30^\circ\text{F})}$ $= 1325 \text{ gal.}$

1 Areas figured are for 100% solar supply to worst case average monthly load (25° tilt angle).

2 No internal sensible considered

3 Including internal sensible heat