



DESIGN OF SUNSPAN INFRA-RED HEATING SYSTEMS

INTRODUCTION

This booklet is intended to guide those who are interested in the design of commercial or industrial heating systems utilizing infra-red heaters.

Although several types of SUNSPAN infra-red heaters are available to the designer, the basic principles in determining the amount of heat required are the same for each type.

SUNSPAN HIGH INTENSITY – GAS FIRED – SINGLE STAGE HEATERS.

Utilizes a perforated ceramic combustion surface. Available in inputs from 30,000 BTUH to 200,000 BTUH. These units are not directly vented, but enough infiltration or ventilation must be available to dilute the products of combustion to acceptable levels.

SUNSPAN HIGH INTENSITY – GAS FIRED – 2-STAGE HEATERS.

Utilizes a perforated ceramic combustion surface. Variable BTUH inputs with optimal combustion in both operating stages. Must be used with special 2-stage thermostats. Available in inputs from 50,000 BTUH to 200,000 BTUH. These units are not directly vented, but enough infiltration or ventilation must be available to dilute the products of combustion to acceptable levels.

SUNSPAN LOW INTENSITY – 1 OR 2-STAGE GAS FIRED – VENTED

Does not require dilution air. Utilizes a power burner firing into a 4" O.D. tubular metal combustion chamber and heat exchangers. Available in inputs from 40,000 BTUH to 200,000 BTUH. Tube lengths are from 10 feet up to 70 feet.

SUNSPAN LOW INTENSITY – 1 OR 2-STAGE GAS FIRED – UNVENTED

Same as above but requires dilution air to dilute the products of combustion to acceptable levels.

The amount of heat required to heat any space with four walls and a roof can best be determined by computing the heat loss of the space. The most widely accepted standards for computing heat losses are outlined in the **American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) Handbook**. Procedures, tables, etc. presented in this guide will closely follow those found in the ASHRAE handbooks.

SOFTWARE FOR ESTIMATING HEAT LOSS AND FUEL COSTS

Fast and easy to use *EvalU-HEAT* SOFTWARE analyzes heat loss for a given building and forecasts annual fuel costs. The PC based program generates a printed report. Call Sunspan at 1-866-664-3824 for your FREE *EvalU-HEAT* program or contact us at sales@sunspanheaters.com.

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HEAT LOSS SURVEY AND CALCULATIONS

1. Survey the space to be heated:

Determine the following:

- a. Inside temperature desired by customer. This will usually be related to his experience with warm air heating.
- b. Outside design temperature.
- c. Usage of the building.
- d. Number of doors and frequency of use.
- e. Amount of powered exhaust.
- f. Estimate of air changes - refer to Table 1 for guidance.
- g. Building construction - walls, roof, windows, insulation, etc.
- h. Present method of fueling.
- i. Present yearly fuel consumption.
- j. Night & weekend temperature setback and hours per week setback is in effect.
- k. Heat gain in BTUH. Obtain from customer's electric and gas (for process heat) utility bills. If not available make estimate using table 8.
- l. See survey check list (page 15) for additional checks to be made.

2. Calculate transmission losses for each wall separately (including slab loss) and of the roof. Common practice is to gross all walls and roof, but infra-red heat must be placed where heat losses occur if maximum fuel conservation is to be attained. Use Heat Loss Calculation Form - Page 11.

The heat loss from the warm side of a wall, roof, partition or portion thereof to the cooler outside air can be calculated by the following formula:

Heat Loss = Area of wall, roof, etc. (sq. ft.) times the heat transfer coefficient ("U" value) times the temperature difference between the outside and inside design temperature.

Abbreviating: $HL = A \times "U" \times TD$

For the loss through the edge of an uninsulated slab this becomes:

$$HL = L \times 0.81 \times TD$$

"L" is the length of the floor at the outside wall.

3. From Step 1-f above - estimate the number of cubic feet of air that will pass through the space. Particular care must be exercised in the estimate of air changes that will occur in the building. It is in this phase where most errors are made in calculating the overall heat loss. The heat required to raise the incoming cold air up to the desired inside temperature can be calculated by:

Heat required or air loss = The cubic feet of air movement per hour \times the factor 0.018 \times the temperature difference between inside and outside design temperature.

Abbreviating: $AL = CFH \times 0.018 \times TD$

4. The sum of the transmission losses (Step 2) and the air losses (Step 3) will provide the standard heat loss of the building.

5. Calculate minimum air required for dilution. Multiply the total transmission losses (Step 2) by the factor given in Table # 2. Compare this amount with the air changes (in CFH) decided upon in 1-f above. If dilution CFH exceeds air changes (CFH) use the dilution CFH in determining the air loss in Step 3 above. If the air changes CFH exceed the dilution CFH use the results given in Step 3 above.

At this point a decision should be made to use either **Vented or Unvented Systems**. In most cases the following conditions will mandate the use of vented equipment.

1. Presence of chlorinated or fluorinated hydrocarbons.
2. High condensation possibility.
3. Dirty or dusty atmosphere.
4. Low volume, low infiltration.

However, advantages of unvented equipment are:

1. Not affected by negative pressure.
2. Automatic humidification - improved comfort.
3. Lower first cost.
4. Easier to install.
5. Better IR heat pattern with small units.

For **Vented and Electric** infra-red heaters proceed to Step 6.

FOR UNVENTED SYSTEMS - Powered Ventilation - tied into thermostats may be required by building code even if the expected infiltration exceeds the air required for dilution. When the reverse is true - dilution air exceeds infiltration - the 4 CFM per 1000 BTUH requirement results in a waste of energy during the better part of the heating season. The 4 CFM is based on steady state conditions - heaters running continuously - which seldom occurs.

This situation has led to humidistat actuation of exhaust fans. A CO₂ detector would be preferable. In the southern states powered exhaust fans have not been required because of lower heating needs and higher infiltration. Present construction practices (ASHRAE / ANSI 90) and insulation retrofitting is bringing buildings in the north close to the southern situation.

The following may be a guide in determining the need of powered roof exhauster.

Ratio - Unvented Input - BTUH / Building Volume - FT ³	Infiltration air changes per hour required to Dilute CO ₂
1	0.2
2	0.4
3	0.61
4	0.81
5	1.01
6	1.22

If the ratio of unvented input to building volume is high, a combination system of vented and unvented units will bring down the required infiltration and will also provide automatic humidification.

6. Decide what size heater is to be used and what the heater height will be. (See Table 4). This may be dictated by cranes, activity or obstructions, such as lights, etc. Remember that as distance between heaters and ceiling increases the system efficiency will increase, because stratification is reduced.
7. In order to provide the ultimate customer with the best possible heating system at the lowest cost, less heat than that indicated by a standard building heat loss can be provided. The reason for this is that an infra-red heating system - properly designed - will provide equivalent comfort at air temperatures 5° to 10° lower than that provided by warm air systems. This is true because of a higher MRT (mean radiant temperature). Reduce the standard heat loss by the factor of 10° / TD or multiply × TD - 10° / TD. This means that when outside conditions reach and maintain design temperatures for a long period of time the inside air temperature may be lower than the initial inside temperature considered - but if this does occur all infra-red heaters will be on and direct radiation will be received by personnel. This is in addition to the high MRT and will usually provide a satisfactory comfort condition.

CAUTION: This reduction will not be valid if heaters are in close proximity to the ceiling or are not located to overcome heat losses where they occur. The method will be valid if the ratio of heater height to ceiling height is less than $\frac{2}{3}$. See table 3.

Another method of heat reduction is to multiply the standard heat loss by the factor given in Table 3. The factors given change with heater relation to ceiling. The greater the heater distance from the ceiling, the cooler the roof. This means heat loss will automatically reduce.

Most engineers prefer to provide a factor of safety in their designs and will not reduce the input. This will provide a faster pickup if thermostats are set back at night or on weekends. However, installed costs will increase.

8. Sketch a floor plan of areas to be heated. Decide where heater rows are to be - remember that a perimeter placement will place heat where heat loss occurs. Use Table 5 as a guide for distance between heater rows. Total the length of all rows.
9. Select heater input. Use height selected in Step 6. Refer to Table 4 and select unit on basis of building usage - whether the units are to be horizontal or angle mounted and if personnel are held captive directly under a heater or will be transient. Heater heights are minimum - units can be at greater heights.
10. Divide the total input (Step 7) by input of the individual heater - this will provide the number of heaters required. Divide this number into the total length of rows (Step 8) - this will give spacing between heaters. Check this against twice the mounting height (Table 5) - spacing should not exceed this. If it does, the next smaller size heater will be required.
11. Allocate heaters to the perimeter in the ratio of individual wall losses to total wall losses - this will insure placement of units where heat losses occur.
12. Add additional heat at areas with frequent door openings.
13. If required, provide piping layout - See section on pipe sizing in Engineering Manual.
14. Locate thermostats. Normal practice is to control 3 to 10 heaters per thermostat for the gas (unvented) and the electric type.
Suntube vented systems must not have more than one (1) thermostat per vent stack. Place thermostats at areas of heat loss.
15. Locate exhausters-if required. Use CFM selected in Step 5. Be sure sufficient inlet area is available to feed exhausters. This area may be provided by cracks around doors, windows, etc Total area can be computed by dividing exhaust CFM by 600 feet per minute.
16. Estimate the fuel consumption and cost for both infra-red and warm air. Be sure the potential customer is aware of the fuel conservation and economy produced by infra-red heating systems.

**TABLE 1
SUGGESTED AIR CHANGES FOR HEAT LOSS CALCULATIONS**

BUILDING USAGE	CONSTRUCTION	DOOR OPENINGS	SUGGESTED AIR CHANGE PER HOUR
Aircraft Hangar	All types	Min. Heavy	1 to 1½ 2 to 3
Manufacturing	Sheet Steel - Insulated Sheet Steel - Insulated Con. Block - Unpainted Con. Block - Unpainted Con. Block - Painted Con. Block - Painted Con. Tilt Up Con. Tilt Up	Min. Heavy Min. Heavy Min. Heavy Min. Heavy	½ to 1 1 to 1½ ¾ to ½ 1 to 1½ ¼ to ½ 1 to 1½ ¼ to ½ 1 to 1½
Service Garage * (Separate exhaust for Engine)	Sheet Steel - Insulated Sheet Steel - Insulated Con. Block Con. Block Tilt Up Tilt Up	Min. Heavy Min. Heavy Min. Heavy	1 to 1½ 1½ to 3 1 to 1½ 1½ to 3 ½ to 1 1½ to 3
Tennis Courts	Sheet Steel - Insulated Con. Block	0 0	¼ ¼
Warehouse	Sheet Steel - Insulated Sheet Steel - Insulated Con. Block Con. Block Tilt Up Tilt Up	Min. Heavy Min. Heavy Min. Heavy	½ 1 to 2 ¼ to ½ 1 to 2 ¼ to ½ 1 to 2

**TABLE 2
MINIMUM AIR REQUIREMENT FACTORS**

Multiply Total Transmission Losses by Factor Given Below to Obtain CFH

TD	FACTORS	
	Natural Gas	Propane Gas
30	0.257	0.320
35	0.264	0.330
40	0.270	0.340
45	0.277	0.351
50	0.283	0.362
55	0.291	0.374
60	0.299	0.387
65	0.307	0.401
70	0.316	0.416
75	0.325	0.432
80	0.335	0.450
85	0.345	0.469
90	0.356	0.489

**TABLE 3
HEAT LOSS FACTORS**

BUILDING HEIGHT - FT.	HEATER HEIGHT - FT.																				
	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
50	-	-	-	-	-	-	-	-	.77	.81	.84	.87	.89	.91	.93	.95	.96	.98	.99	1.0	-
48	-	-	-	-	-	-	-	.75	.79	.83	.86	.88	.91	.93	.95	.96	.98	.99	1.0	-	-
46	-	-	-	-	-	-	-	.77	.81	.85	.88	.90	.92	.94	.96	.97	.99	1.0	-	-	-
44	-	-	-	-	-	-	.75	.80	.83	.87	.89	.92	.94	.96	.97	.99	1.0	-	-	-	-
42	-	-	-	-	-	.78	.82	.85	.89	.91	.93	.95	.97	.99	1.0	-	-	-	-	-	-
40	-	-	-	-	.75	.80	.84	.88	.90	.93	.95	.97	.99	1.0	-	-	-	-	-	-	-
38	-	-	-	.78	.83	.87	.90	.92	.95	.97	.99	1.0	-	-	-	-	-	-	-	-	-
36	-	-	.75	.81	.85	.89	.92	.94	.96	.98	1.0	-	-	-	-	-	-	-	-	-	-
34	-	.78	.83	.86	.91	.94	.96	.98	1.0	-	-	-	-	-	-	-	-	-	-	-	-
32	.75	.81	.86	.90	.93	.96	.98	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-
30	.79	.84	.89	.93	.96	.98	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28	.75	.82	.88	.92	.95	.98	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26	.79	.86	.91	.95	.98	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
24	.75	.83	.89	.94	.97	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22	.80	.88	.93	.97	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	.75	.85	.92	.97	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	.81	.90	.96	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16	.75	.87	.95	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	.83	.94	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	.91	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

**TABLE 3A
AIR TEMPERATURE DIFFERENCE**

BUILDING HEIGHT	HEATER HEIGHT															
	10	12	14	16	18	20	22	24	26	28	30	32	34	36	40	
12	4.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
14	6.4	4.0	-	-	-	-	-	-	-	-	-	-	-	-	-	
16	7.9	5.8	3.7	-	-	-	-	-	-	-	-	-	-	-	-	
18	9.1	7.2	5.4	3.5	-	-	-	-	-	-	-	-	-	-	-	
20	10.0	8.3	6.7	5.0	3.3	-	-	-	-	-	-	-	-	-	-	
22	10.8	9.2	7.7	6.2	4.7	3.2	-	-	-	-	-	-	-	-	-	
24	11.4	10.0	8.6	7.2	5.8	4.4	3.0	-	-	-	-	-	-	-	-	
26	11.9	10.6	9.4	8.1	6.8	5.5	4.2	2.9	-	-	-	-	-	-	-	
28	12.4	11.2	10.0	8.8	7.6	6.4	5.2	4.0	2.8	-	-	-	-	-	-	
30	12.8	11.7	10.6	9.4	8.3	7.2	6.1	5.0	3.9	2.8	-	-	-	-	-	
32	13.1	12.1	11.0	10.0	9.0	7.9	6.9	5.8	4.8	3.7	2.7	-	-	-	-	
34	13.4	12.4	11.5	10.5	9.5	8.5	7.5	6.6	5.6	4.6	3.6	2.6	-	-	-	
36	13.7	12.8	11.8	10.9	10.0	9.1	8.1	7.2	6.3	5.4	4.4	3.5	2.6	-	-	
38	13.9	13.1	12.2	11.3	10.4	9.6	8.7	7.8	6.9	6.0	5.2	4.3	3.4	2.5	-	
40	14.2	13.3	12.5	11.7	10.8	10.0	9.2	8.3	7.5	6.7	5.8	5.0	4.2	3.3	2.5	
42	14.4	13.6	12.8	12.0	11.2	10.4	9.6	8.8	8.0	7.2	6.4	5.6	4.8	4.0	3.2	2.5
44	14.5	13.8	13.0	12.3	11.5	10.8	10.0	9.2	8.5	7.7	7.0	6.2	5.4	4.7	3.9	3.2
46	14.7	14.0	13.3	12.5	11.8	11.1	10.4	9.6	8.9	8.2	7.5	6.7	6.0	5.3	4.6	3.8
48	14.9	14.2	13.5	12.8	12.1	11.4	10.7	10.0	9.3	8.6	7.9	7.2	6.5	5.8	5.1	4.4
50	15.0	14.3	13.7	13.0	12.3	11.7	11.0	10.3	9.7	9.0	8.3	7.7	7.0	6.3	5.7	5.0

TABLE 4

SUGGESTED MINIMUM MOUNTING HEIGHT - FT.

NOTE: Use lower mounting height if personnel are not kept directly under heater.

TABLE 4A

LOW INTENSITY GAS INFRA-RED TUBE HEATERS

Reflector Mounting Angle Input - BTUH	Standard				Parabolic				Standard & Parabolic
	Horizontal	45°	Horizontal	45°	Horizontal	45°	Horizontal	45°	Horizontal or 45° Max. Distance Between Rows
40,000	9.5-11.5	7.5-9.5	6.0	1.0	11.5-13.5	9.5-11.5	4.0	1.0	80.0
45,000-50,000	10.0-12.0	8.0-10.0	6.0	1.0	12.0-14.0	10.0-12.0	4.0	1.0	80.0
55,000-60,000	10.5-12.5	8.5-10.5	6.0	1.0	12.5-14.5	10.5-12.5	4.0	1.0	80.0
65,000-75,000	11.0-13.0	9.0-11.0	8.0	1.0	13.0-15.0	11.0-13.0	6.0	1.0	90.0
80,000-85,000	11.5-13.5	9.5-11.5	8.0	1.0	13.5-15.5	11.5-13.5	6.0	1.0	90.0
90,000-95,000	12.0-14.0	10.0-12.0	8.0	1.0	14.0-16.0	12.0-14.0	6.0	1.0	95.0
100,000-105,000	12.5-14.5	10.5-12.5	8.0	1.0	14.5-16.5	12.5-14.5	6.0	1.0	95.0
110,000-115,000	13.0-15.0	11.0-13.0	12.0	1.0	15.0-17.0	13.0-15.0	6.0	1.0	100.0
120,000	13.5-15.5	11.5-13.5	12.0	1.0	15.5-17.5	13.5-15.5	6.0	1.0	100.0
125,000	14.0-16.0	12.0-14.0	12.0	1.0	16.0-18.0	14.0-16.0	6.0	1.0	105.0
130,000	14.5-16.5	12.5-14.5	12.0	1.0	16.5-18.5	14.5-16.5	6.0	1.0	105.0
135,000-140,000	15.0-17.0	13.0-15.0	12.0	1.0	17.0-19.0	15.0-17.0	6.0	1.0	105.0
145,000	15.5-17.5	13.5-15.5	12.0	1.0	17.5-19.5	15.5-17.5	6.0	1.0	105.0
150,000	16.0-18.0	14.0-16.0	12.0	1.0	18.0-20.0	16.0-18.0	9.0	1.0	105.0
155,000-160,000	16.5-18.5	14.5-16.5	13.0	1.0	18.5-20.5	16.5-18.5	10.0	1.0	105.0
165,000-170,000	17.0-19.0	15.0-17.0	13.0	1.0	19.0-21.0	17.0-19.0	10.0	1.0	110.0
175,000-180,000	17.5-19.5	15.5-17.5	14.0	1.0	19.5-21.5	17.5-19.5	11.0	1.0	110.0
185,000-190,000	18.0-20.0	16.0-18.0	14.0	1.0	20.0-22.0	18.0-20.0	11.0	1.0	115.0
195,000-200,000	18.5-20.5	16.5-18.5	15.0	1.0	20.5-22.5	18.5-20.5	12.0	1.0	115.0

TABLE 4B

HIGH INTENSITY GAS INFRA-RED HEATERS

Reflector Mounting Angle Input - BTUH	Standard		Parabolic	
	Horizontal	@ 30°	Horizontal	@ 30°
30,000	11.0-13.0	10.0-12.0	—	—
40,000	12.0-14.5	11.5-13.5	—	—
50,000	13.5-15.5	12.5-14.5	15.5-18.5	14.0-17.0
60,000	14.5-16.5	13.0-15.0	16.0-20.0	15.0-18.0
70,000	15.0-17.0	13.5-15.5	17.5-20.5	16.0-19.0
80,000	15.5-18.0	14.0-16.5	18.5-21.5	17.0-20.0
90,000	16.0-18.5	14.5-17.0	19.5-22.5	17.5-20.5
100,000	17.0-19.5	15.0-17.5	20.5-23.5	18.5-21.5
110,000	17.0-20.0	15.0-18.0	21.0-24.5	19.0-22.0
120,000	17.5-21.0	15.5-18.5	21.5-25.0	20.0-23.0
130,000	18.0-21.0	16.0-19.0	22.5-26.0	20.5-23.5
140,000	—	—	—	—
150,000	18.5-22.5	16.5-20.0	24.0-27.5	21.5-24.5
160,000	19.0-23.0	17.0-20.5	25.0-28.5	22.5-25.5
175,000	19.5-23.5	17.5-21.0	25.5-29.0	23.0-26.5
200,000	20.5-25.0	18.5-22.5	27.0-31.0	24.5-28.0

**TABLE 5
HEATER PLACEMENT TABLES**

* *CAUTION: Observe clearance to combustibles in all cases.*

**A. MAXIMUM DISTANCE BETWEEN HEATERS
— ALL TYPES —
2 Times Mounting Height**

**B. DISTANCE - HEATER FROM WALL
HORIZONTAL MOUNT - FT.**

(Long Axis Parallel to Wall)

HEATER HEIGHT	REFLECTOR	
	GAS STRAIGHT SIDE	ELECTRIC OR GAS PARABOLIC
10	8	6
15	12	9
20	16	12
25	20	15
30	24	18
35	28	21
40	32	24
45	36	27
50	40	30

**C. DISTANCE - HEATER FROM WALL
ANGLE MOUNT 30° - FT.**

(Long Axis Parallel to Wall - All Types)

Sufficient to provide clearance for service of unit

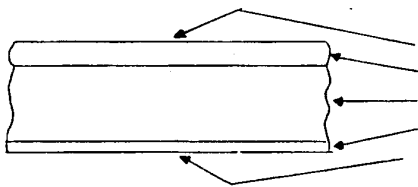
**D. MAXIMUM DISTANCE BETWEEN HEATER ROWS
ALL TYPES - FT.**

HEATER HEIGHT	MAXIMUM DISTANCE BETWEEN ROWS
10	90
15	100
20	105
25	111
30	117
35	122
40	128
45	134
50	140

TABLE 6
"U" Values - Continued
MISCELLANEOUS

CONSTRUCTION	"U"	CONSTRUCTION	"U"
INTERIOR WALLS		GLASS - HORIZONTAL	
Sheet Metal	0.74	Single Pane - Horizontal	1.22
1/2" Plywood	0.50	Double Pane - Horizontal	
8" Concrete Block	0.32	3/16" Air Space	0.75
3/8" Gypsum Board	0.60	1/4" Air Space	0.70
		1/2" Air Space	0.66
GLASS - VERTICAL		EXTERIOR DOORS	
Single Pane - Vertical	1.13	Flat Metal	1.20
Double Pane - Vertical		1" Wood	0.64
3/16" Air Space	0.69	2" Wood	0.43
1/4" Air Space	0.65		
1/2" Air Space	0.58	FLOOR SLABS	BTUH/LN.FT./F
Triple Pane - Vertical		Uninsulated	0.81
1/4" Air Space	0.47	Insulated	0.55
1/2" Air Space	0.36		
Storm Windows		AIR LOSS = CFH × 0.018 × TD	
1" Air Space	0.56	DILUTION AIR - per 1,000 BTUH	
PLASTIC		Natural Gas - 4 CFM	
Vertical - single sht.	1.09	Propane Gas - 5 CFM	
PLASTIC BUBBLES			
Single Wall	1.15		
Double Wall	0.70		

SAMPLE "U" VALUE CALCULATION



	Resistance (R)
Outside Film (15 mph)	0.17
3/8" Built Up Tar & Gravel	0.33
2" Pre-formed Insulation	5.56
Steel Deck	0.0
Inside Film - (Horizontal)	0.61
	6.67
	R_{Total}

$$U = \frac{1}{R_{Total}} = \frac{1}{6.67} = 0.150$$

BUILDING HEAT LOSS CALCULATION SHEET

	BUILDING MATERIAL	SIZE	AREA OR LENGTH	"U"	TD	BTUH	TOTAL WALL OR ROOF LOSS BTUH	HEATERS PER WALL = INDIVIDUAL WALL LOSS + TOTAL WALL LOSS X TOTAL NO. OF HEATERS
N. WALL							↓	
	SLAB LOSS							
E. WALL							↓	
	SLAB LOSS							
S. WALL							↓	
	SLAB LOSS							
W. WALL							↓	
	SLAB LOSS							

① TOTAL WALL LOSSES _____ BTUH ①

ROOF	BUILDING MATERIAL	SIZE	AREA OR LENGTH	"U"	TD	BTUH

② TOTAL ROOF LOSS _____ BTUH ②

① + ② = TOTAL TRANSMISSION LOSSES _____ BTUH ③

MINIMUM AIR FOR DILUTION (Unvented Heaters Only)

CFH = TOTAL TRANSMISSION LOSSES X FACTOR (Table 2)

CFH = _____ X _____ = _____ ④

AIR CHANGE - INFILTRATION (See Table 1)

CFH = VOLUME X AC/HR

CFH = _____ X _____ = _____ ⑤

AIR LOSS - USE LARGEST CFH OF ④ OR ⑤

BTUH = CFH x 0.018 x TD

BTUH = _____ x 0.018 x _____ = _____ BTUH ⑥

TOTAL HEAT LOSS = ③ + ⑥ = _____ BTUH

SIZE OF HEATER _____ BTUH TOTAL NO. OF HEATERS _____

INFRA-RED YEARLY FUEL CONSUMPTION

Fuel consumption in any space is directly related to the difference between the inside and outside air temperature. A well designed infra-red heating system will provide a smaller difference than will a warm air heating system and thereby lies the tremendous potential savings in energy usage. A 10° difference between the two systems can often provide a 50% savings in fuel costs. This will be illustrated in the examples provided.

Assuming that a good infra-red design has been made, the only factors that will influence yearly fuel consumption are the thermostat setting and heat gains.

Fuel consumption is also directly related to the degree days in a certain locality and degree days are directly related to the average inside temperature maintained.

The formula for estimating yearly fuel consumption using average degree days is

$$(1) \quad F = \frac{H.L \times 24 \times DD}{EFF \times TD \times C}$$

Where: F = Fuel consumption expressed in units of C.
 H.L. = Heat loss computed at TD.
 24 = Hours per day.
 DD = Degree days and will vary considerably dependent upon the average inside temperature maintained.
 EFF = Efficiency of energy utilization.

Heating System	EFF (Efficiency)
Unvented Infra-Red (Gas)	0.92
Vented Infra-Red (Gas)	0.70 to 0.90
Electric Infra-Red	1.00
Unit Heaters (Gas)	0.75
Unit Heaters (Steam)	0.60

TD = Temperature difference between the average inside temperature and the outside design temperature.
 C = Heating value of one unit of one unit of fuel, usually one of the following:

100,000 BTU	(Therms)
1,000,000 BTU	(MCF)
91,500 BTU	(Gallons propane)
140,000 BTU	(Gallons - #2 Fuel Oil)
3,413 BTU	(KW)

The portion of the formula:

$$\frac{H.L \times 24}{EFF \times TD}$$

will be constant for any particular building because as the inside temperature increases so do the TD & Heat Loss increase. Therefore, for any particular building degree days are the governing factor and degree days vary substantially as the inside temperature varies. Degree days for most cities and for bases 40° to 80° are listed in Table 9. Caution every customer that an inside air temperature increase of 5° will increase fuel consumption 20 to 50% depending upon geographic location and base inside temperature.

Warm air systems in industrial and commercial applications will usually require approximately 10° higher average air temperature to provide equivalent comfort provided by an infra-red system. This is true because an infra-red system provides a higher MRT (warm floors, equipment, etc.) and because stratification is lower.

The following example will help in preparing a comparison of fuel consumption between warm air and infra-red systems:

Building Standard Heat Loss	- 1,169,600 BTUH	
Inside Temperature	- 65° F.	
Outside Design Temperature	- 5° F.	
Degree Days for Infra-Red		} Grand Rapids, MI
Base of 60°	- 5514	
Degree Days for Warm Air		
Base of 70°	- 8288	

WARM AIR GAS CONSUMPTION

$$\text{Heat Loss} = \frac{1,169,600 \times 70 \text{ TD}}{60 \text{ TD}} = 1,364,533 \text{ BTUH}$$

$$\text{Efficiency} = 75\%$$

$$C = \text{MCF} = 1,000,000 \text{ BTU}$$

$$F = \frac{1,364,533 \times 24 \times 8288}{0.75 \times 70 \times 1,000,000} = 5170 \text{ MCF}$$

INFRA-RED GAS CONSUMPTION

$$F = \frac{1,169,600 \times 24 \times 5514}{0.92 \times 60 \times 1,000,000} = 2803 \text{ MCF}$$

SAVINGS OVER WARM AIR

$$\frac{5170 - 2803}{5170} = 45.8\%$$

ADDITIONAL CONSIDERATIONS

Night and weekend temperature setback will reduce fuel usage and must be considered in any estimate. Another influencing factor is the building heat gain from lights, equipment, process heat, etc.

If night setback is the only influence use equations No. 2 & No. 3.

If heat gain only use equations 4 & 5.

With both night setback and heat gain use equations 3 & 4.

With none of the above use equation 1.

NOTE: Where 2 equations are used - the sum of the two calculations will provide the fuel consumption estimate.

NIGHT & WEEKEND SETBACK

$$(2) \quad F_2 = \frac{H.L. \times 24 \times DH \times DD_d}{TD \times \text{EFF} \times 168 \times C}$$

$$(3) \quad F_3 = \frac{H.L. \times 24 \times \text{NSH} \times DD_n}{TD \times \text{EFF} \times 168 \times C}$$

Where	DH =	Hours/Week at Normal Temperature
	DD _d =	Degree Days at Normal Temperature
	168 =	Hours in One Week
	NSH =	Hours/Week at Setback Temperature
	DD _n =	Degree Days at Setback Temperature

Degree Days at 5° intervals for all major cities are listed in Table 9.

HEAT GAIN

When a considerable Heat Gain is involved - a balance point temperature must first be determined. Above this temperature (outside) the Heat Gain will maintain the desired inside temperature.

$$T_b = T_i - \left(\frac{TD \times Q_i}{H.L.} \right)$$

Where T_b = Balance Point Temperature — °F
 T_i = Normal Inside Temperature — °F
 Q_i = Internal Heat Gain from Lights, Equipment, Occupants, etc. — BTUH
 TD = Temperature Difference between Average Inside Temperature and the Outside Design Temperature — °F
 $H.L.$ = Heat Loss Computed at Normal Inside Temperature — BTUH

Equations for estimating fuel consumption when heat gain is present are:

$$(4) \quad F_4 = \frac{H.L. \times 24 \times HGH \times DD_{HG}}{TD \times EFF \times 168 \times C}$$

Where DD_{HG} = Degree Days based on T_b
 HGH = Hours/Week of Heat Gain

$$(5) \quad F_5 = \frac{H.L. \times 24 \times (168 - HGH) \times DD_d}{TD \times EFF \times 168 \times C}$$

An example will illustrate the above:

Building Standard Heat Loss	1,169,600 BTUH
Inside Temperature	65°F
Outside Design Temperature	5°F
Night & Weekend Setback Temperature	55°F
Hours/Week of Setback Temperature	123 Hours
Heat Gain	140,000 BTUH
Hours/Week of Heat Gain	45 Hours
Degree Days (Columbus, Ohio)	
Normal (Base 60°F)	4513
Night (Base 50° F)	2597

Balance Point Temperature

$$T_b = T_i - \left(\frac{TD \times Q_i}{H.L.} \right) = 65 - \left(\frac{60 \times 140,000}{1,169,600} \right)$$

$$T_b = 57.82^\circ\text{F}$$

Degree Days for Heat Gain (Base 57.82)

$$DD_{HG} = 0.0455452 (57.82 - 4.0)^{2.8563} = 4004$$

$$\begin{aligned} \text{Equation (4)} \quad F_4 &= \frac{H.L. \times 24 \times HGH \times DD_{HG}}{TD \times EFF \times 168 \times C} \\ &= \frac{1,169,600 \times 24 \times 45 \times 4004}{60 \times .92 \times 168 \times 1,000,000} = 545.4 \text{ MCF} \end{aligned}$$

$$\begin{aligned} \text{Equation (3)} \quad F_3 &= \frac{H.L. \times 24 \times NSH \times DD_n}{TD \times EFF \times 168 \times C} \\ &= \frac{1,169,600 \times 24 \times 123 \times 2597}{60 \times .92 \times 168 \times 1,000,000} = 966.9 \text{ MCF} \end{aligned}$$

$$\text{TOTAL} = 1512.3 \text{ MCF/YR}$$

A gas fired vent heater system under the same conditions would consume 3137 MCF/YR.

BUILDING SURVEY CHECK LIST

The design of the heating system is based on facts obtained from the building survey. The care utilized in surveying the building will determine the accuracy of the heat loss, and the adequacy of the system design.

Drawings of the building are obtained or made with details of wall construction, roof construction, door location, insulation, glass area, type of windows, etc. as indicated on the Infra-Red Heating Survey Sheet.

Special attention should be given to the following:

- a. Location of fuel supply, fuel pressure available or voltage and amperage available.
- b. Exhaust system
 1. Location and CFH or CFM capacity of exhausters.
 2. Location and area of gravity exhausters or roof openings.
 3. Location and capacity of make-up air heaters.
- c. Location of spray booths or hazardous areas. Maintain heaters at a minimum of 20' from paint spray areas. Check with insurance companies and local codes for additional requirements.
- d. Location of Extra Heat Requirements:
Extra heaters may be required in loading dock areas where doors are opened frequently or in areas where incoming cold materials are located.
- e. Location of work areas and type of work done in these areas. This may be required for heater placement.
- f. Location of combustible material storage:
When combustible materials are stacked in close proximity to any heater a hazardous condition may result.
- g. Location of material storage along outside walls:
Material cannot be maintained at inside temperature if the infra-red energy cannot reach the floor slab. Normally, an aisle must be left along or near the outside wall to satisfy the heat loss.
- h. Percentage of floor coverage by stored materials storage. If more than 60-70% of the floor is covered by stored materials, heat energy cannot reach the entire slab and heaters should be installed over open floor areas and then only those areas will be heated.
- i. Location of degreasing operations:
Trichloroethylene, Perchloroethylene and other chlorinated or fluorinated hydrocarbons yield hazardous products when passed through a flame. Unvented heaters should not be installed unless the solvent vapors are isolated from the heated areas by partitions or an efficient degreaser exhaust system or outside air is supplied to the burners. Vented or electric infra-red heaters can be used. However, vented heaters must be supplied with outside air for combustion or heat exchangers will corrode rapidly.
- j. Check roof construction for the following:
 1. No positive vapor seal below roof insulation.,
 2. Compressed insulation.
 3. Attic spaces or suspended ceilings.
 4. "T" bar roof construction.
 5. Uninsulated skylights.

These are condensation trouble spots. Unless a solution to these condensation possibilities is worked out vented or electric infra-red heaters should be used.
- k. Crane clearances:
Determine the distance from crane to roof and crane rail to the floor slab. This is required for heater placement.
- l. Location of lights and sprinklers:
Determine the positions of lights and sprinklers to assist in heater location. Heaters cannot be positioned under sprinkler heads unless high temperature heads are installed. Clearances to combustibles above the heaters are usually low. Check heater rating plate for exact clearance.

Evaluate Condensation Possibilities

Condensation of water occurs when warm moist air contacts a cold surface. In uninsulated buildings it is not uncommon for condensation to occur regardless of the heating system.

Normally condensation can be prevented by insulating the cold surfaces to keep their inside surface temperatures above the dew point of the inside air, or by diluting the products of combustion to lower the dew point of the air.

Insulation will not only eliminate condensation, but will reduce the number of heaters required as well as provide yearly fuel savings.

The possibility of condensation formation on building surfaces should be evaluated for every installation anticipating the use of unvented infra-red heaters.

By comparing the dew point temperature of the air within the building with the surface temperature of the underside of the roof, a check can be made on condensation possibilities. The accompanying charts are provided for this purpose.

If the inside temperature is above the dew point of the air, no condensation will result.

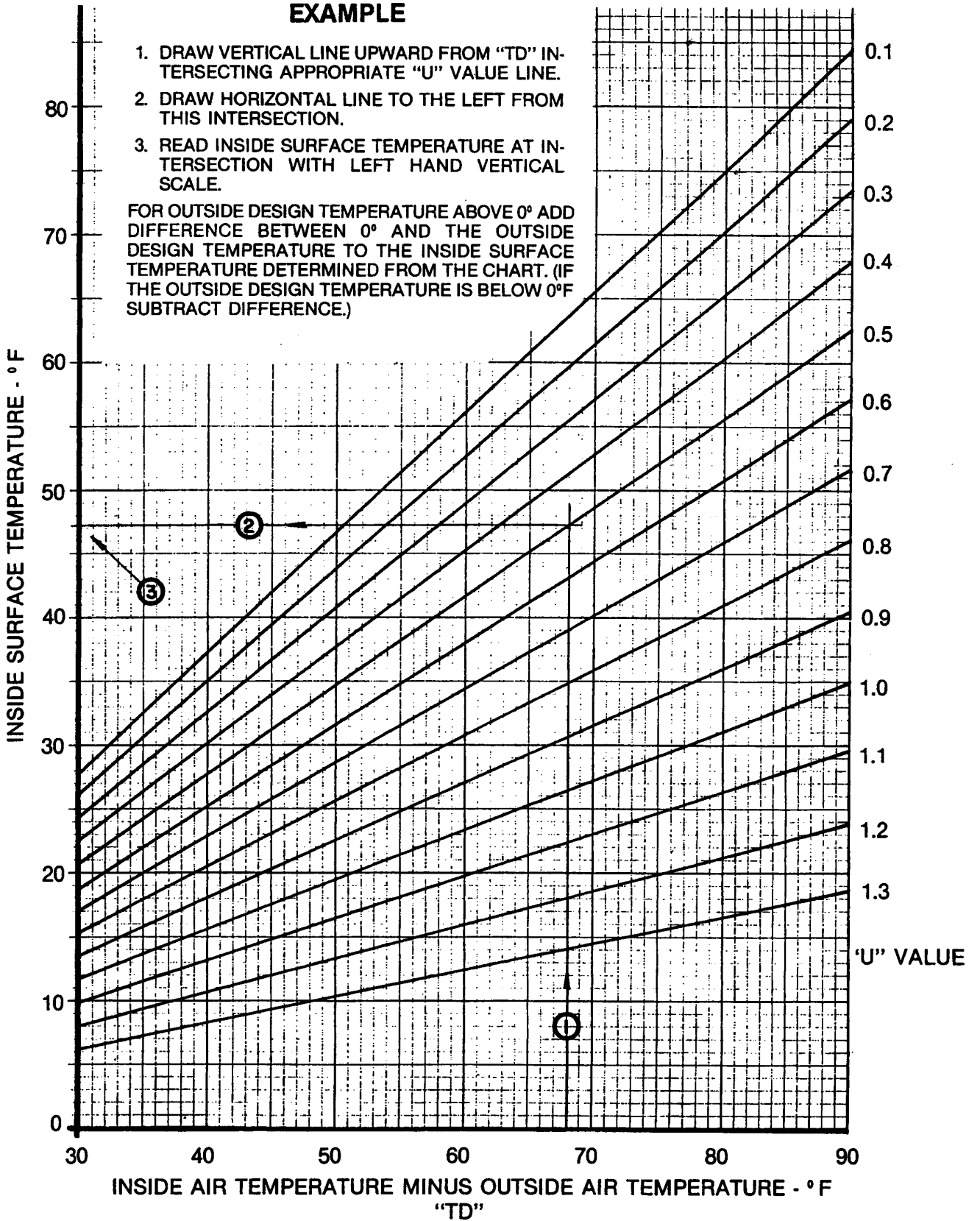
"T" bar roof construction, compressed insulation, skylights, or no vapor seal below roof insulation may be condensation trouble spots. Evaluation must be made and steps taken to correct the condition.

INSIDE SURFACE TEMPERATURE CHART

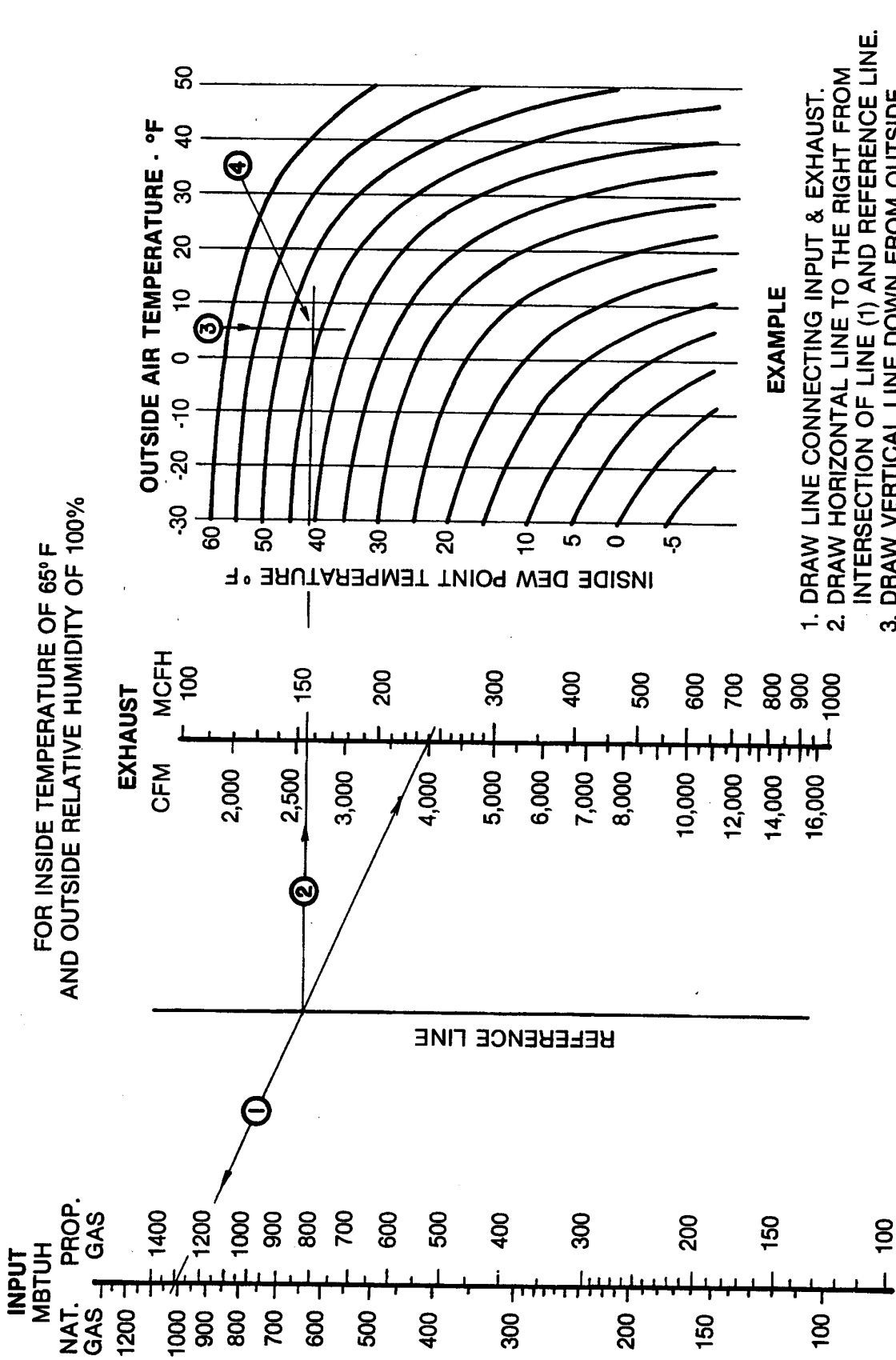
EXAMPLE

1. DRAW VERTICAL LINE UPWARD FROM "TD" INTERSECTING APPROPRIATE "U" VALUE LINE.
2. DRAW HORIZONTAL LINE TO THE LEFT FROM THIS INTERSECTION.
3. READ INSIDE SURFACE TEMPERATURE AT INTERSECTION WITH LEFT HAND VERTICAL SCALE.

FOR OUTSIDE DESIGN TEMPERATURE ABOVE 0° ADD DIFFERENCE BETWEEN 0° AND THE OUTSIDE DESIGN TEMPERATURE TO THE INSIDE SURFACE TEMPERATURE DETERMINED FROM THE CHART. (IF THE OUTSIDE DESIGN TEMPERATURE IS BELOW 0°F SUBTRACT DIFFERENCE.)



INSIDE AIR DEW POINT TEMPERATURE



EXAMPLE

1. DRAW LINE CONNECTING INPUT & EXHAUST.
2. DRAW HORIZONTAL LINE TO THE RIGHT FROM INTERSECTION OF LINE (1) AND REFERENCE LINE.
3. DRAW VERTICAL LINE DOWN FROM OUTSIDE TEMPERATURE AND INTERSECT LINE (2).
4. READ DEW POINT TEMPERATURE AT INTERSECTION.

TABLE 7

NATURAL GAS	# 2 FUEL OIL	PROPANE	ELECTRICITY
1,000 BTU/Ft ³ (approx.) 100,000 BTU/Therm 1,000,000 BTU/MCF (approx.)	140,000 BTU/Gal.	2,500 BTU/Ft ³ 21,500 BTU/Lb. 91,500 BTU/Gal.	3,413 BTU/KW

PRESSURE
27.7 in H ₂ O/psi 2.036 in Hg/psi 1.732 in H ₂ O/psi 14.70 psi/atmosphere 29.92 in Hg/atmosphere

VOLUME
One (1) Barrel (Oil) = 42 gallons One gallon (U.S. liquid) = 231 in. ³

POWER
1 BTU/Hr. = 0.2928 watts 1 KW = 56.91 BTU/Min. 1HP = 0.746 KW 1HP = 2546 BTU/Hr.

SINGLE PHASE
Watts = Volts x Amp Amp = Watts/Volts

THREE PHASE
Watts = Amp x Volts x $\sqrt{3}$ Amp = Watts/Volts x $\frac{1}{\sqrt{3}}$

TABLE 8
HEAT GAINS

LIGHTS

WATTS x 3.41 = BTUH

OCCUPANTS - Per Person	BTUH
SEATED	350
Very Light Work	420
Light Work	510
STANDING	
Light Work or Walking Slowly	640
Light Bench Work	780
WALKING @ 3 mph or	
Light Machine Work	1040
HEAVY WORK	
Heavy Machine Work, Lifting	1600

MISCELLANEOUS

Gains such as those from ovens, furnaces, welding, etc. must be obtained from the plant engineer or manager.

A Rough Estimate of the Solar Heat Gain can be made by multiplying the ratio of unobstructed glass area in the East, South and West Walls and Roof to the Total Area of these surfaces. If a more precise estimate is required refer to the ASHRAE Guide Books.

ELECTRIC MOTORS*

H.P	PHASE	RPM	BTUH
1/8	1	1500	900
1/4	1	1750	1180
1/3	1	1750	1500
1/2	1	1750	2120
3/4	3	1750	2650
1	3	1750	3340
1 1/2	3	1750	4960
2	3	1750	6440
3	3	1750	9430
5	3	1750	15500
7 1/2	3	1750	22700
10	3	1750	29900
15	3	1750	44400
20	3	1750	58500
25	3	1750	72300
30	3	1750	85700
40	3	1750	114000
50	3	1750	143000
60	3	1750	172000
75	3	1750	212000
100	3	1750	283000
125	3	1750	353000
150	3	1750	420000
200	3	1750	559000

* At Full Load

TABLE 9

OUTSIDE DESIGN TEMPERATURES AND DEGREE DAYS

City	Outside Design Temperature °F		Degree Days Base Temperature - °F								Average Winter Temp. °F	
	99%	97.5%	80	75	70	65	60	55	50	45		40
ALABAMA												
BIRMINGHAM	17	21	6671	5147	3856	2844	1995	1333	838	488	246	54.2
HUNTSVILLE	11	16	7284	5720	4374	3302	2414	1670	1103	686	396	51.3
MOBILE	25	29	4946	3585	2504	1684	1062	619	330	148	61	59.9
MONTGOMERY	22	25	5856	4398	3194	2269	1508	945	547	282	124	55.4
ALASKA												
ANCHORAGE	-23	-18	17586	15095	12736	10911	9122	7492	6081	4896	3860	23.0
FAIRBANKS	-51	-47	20270	18125	16126	14345	12661	11115	9714	8451	7312	6.7
ARIZONA												
FLAGSTAFF	-2	4	13716	11331	9027	7322	5776	4421	3267	2299	1500	35.6
PHOENIX	31	34	5351	3727	2398	1552	899	431	165	45	6	58.5
TUCSON	28	32	4750	3582	2634	1752	1050	541	229	65	17	58.1
WINSLOW			9066	7447	5998	4733	3623	2683	1882	1249	772	
ARKANSAS												
ELDORADO	18	23				2645						
FORT SMITH	12	17	7243	5745	4382	3336	2442	1687	1075	613	306	50.3
LITTLE ROCK	15	20	7417	5843	4417	3354	2442	1687	1075	624	319	50.5
CALIFORNIA												
BAKERSFIELD	30	32	6351	4629	3198	2185	1367	760	371	147	44	55.4
FRESNO	28	30	7124	5322	3764	2650	1724	995	493	205	58	53.3
LOS ANGELES (A)	37	40			3208	1819	833	295	66	7		57.4
RED BLUFF			7060	5309	3770	2688	1762	1018	505	208	60	53.8
SACRAMENTO	30	32	7671	5738	4056	2843	1837	1043	493	186	50	53.9
SAN FRANCISCO	35	38	10890	7490	4762	3042	1668	769	289	67	8	53.4
COLORADO												
DENVER (A)	-5	1	11007	9152	7465	6016	4723	3601	2653	1852	1211	37.6
DENVER (C)			10523	8634	6907	5505	4246	3175	2271	1533	958	40.8
PUEBLO	-7	0	10315	8470	6729	5394	4221	3220	2351	1628	1059	40.4
CONNECTICUT												
BRIDGEPORT	.6	9	10244	8465	6845	5461	4264	3216	2321	1583	1003	39.9
HARTFORD	3	7	11435	9959	7811	6350	5085	3971	3005	2173	1507	37.3
DELAWARE												
WILMINGTON	10	14	9265	7669	6226	4940	3824	2839	2003	1330	816	42.5
D.C., WASHINGTON (DULLES) (NATIONAL)												
	14	17	9660	7911	6309	5005	3881	2898	2054	1380	860	45.7
			8250	6742	5383	4211	3182	2293	1563	984	569	
FLORIDA												
JACKSONVILLE	29	32	4373	3085	2090	1327	788	429	194	70	21	61.9
PENSACOLA	25	29	4751	3420	2377	1578	991	575	302	135	56	60.4
TALAHASSEE	27	30	4773	3429	2374	1563	966	550	279	116	48	60.1
TAMPA	36	40	3572	2216	1257	718	364	151	50	14		66.4
GEORGIA												
ATHENS	25	29	6986	5407	4047	2975	2084	1370	830	462	213	51.8
ATLANTA	17	22	7328	5645	4195	3095	2189	1461	911	524	262	51.7
MACON	21	25	5773	4345	3159	2240	1492	934	536	271	111	56.2
SAVANNAH	24	27	5318	3947	2830	1952	1258	751	413	185	72	57.8
IDAHO												
BOISE	3	10	11045	9092	7273	5833	4533	3399	2434	1626	1029	39.7
POCATELLO	-8	-1	12380	10414	8617	7063	5687	4454	3401	2504	1759	34.8
ILLINOIS												
CHICAGO (O'HARE)	-8	-4	11425	9601	7942	6497	5245	4163	3220	2404	1742	35.8
CHICAGO (MIDWAY)	-5	0	10875	9133	7486	6127	4952	3912	2998	2219	1574	37.5
MOLINE	-9	-4	10946	9275	7758	6395	5202	4170	3263	2462	1816	36.4
PEORIA	-8	-4	10621	8955	7432	6098	4930	3910	3013	2239	1612	38.1
ROCKFORD	-9	-4	11588	9850	8274	6845	5600	4507	3555	2713	2011	34.8
SPRINGFIELD	-3	2	10022	8364	6848	5558	4437	3468	2615	1913	1324	40.6
INDIANA												
EVANSVILLE	4	9	9029	7355	5838	4624	3578	2685	1929	1327	857	45.0
FORT WAYNE	-4	1	11111	9296	7605	6209	4992	3930	2996	2193	1537	37.3
INDIANAPOLIS	-2	2	10256	8503	6887	5577	4430	3431	2568	1856	1277	39.6
SOUTH BEND	-3	1	11450	9605	7899	6462	5213	4118	3156	2333	1656	36.6
TERRE HAUTE	-2	4				5351						

City	Outside Design Temperature °F		Degree Days Base Temperature - °F								Average Winter Temp. °F	
	99%	87.5%	80	75	70	65	60	55	50	45		40
	IOWA											
BURLINGTON	-7	-3	10636	8984	7479	6149	4988	3970	3077	2308	1681	37.6
DES MOINES	-10	-5	11170	9545	8082	6710	5521	4470	3546	2728	2045	35.5
DUBUQUE	-12	-7	10917	9277	8761	7277	5992	4871	3893	3028	2286	32.7
SIOUX CITY	-11	-7	11431	9800	8329	6953	5745	4674	3738	2898	2196	34.0
WATERLOO	-15	-10	12015	10347	8821	7433	6180	5059	4065	3194	2442	32.6
KANSAS												
CONCORDIA			10136	8466	6911	5623	4498	3509	2646	1912	1320	40.4
DODGE CITY	0	5	9280	7716	6297	5046	3963	3011	2184	1512	962	42.5
GOODLAND	-5	0	11105	9262	7508	6119	4891	3804	2857	2041	1387	37.8
RUSSELL	0	4	9538	7976	6561	5312	4220	3259	2423	1735	1167	
SALINA	0	5				4992						
TOPEKA	0	4	9656	8017	6492	5243	4152	3203	2378	1700	1131	41.7
WICHITA	3	7	8831	7287	5876	4687	3654	2750	1977	1346	842	44.2
KENTUCKY												
BOWLING GREEN	4	10										
LEXINGTON	3	8	9293	7566	5974	4729	3652	2743	1963	1350	879	43.8
LOUISVILLE	5	10	9241	7482	5866	4640	3584	2676	1906	1303	836	44.0
LOUISIANA												
ALEXANDRIA	23	27	5780	4328	3118	2200	1443	880	490	234	94	57.5
BATON ROUGE	25	29	4983	3603	2495	1670	1036	582	295	120	45	59.8
LAKE CHARLES	27	31	4681	3345	2291	1498	908	500	240	91	34	60.5
MONROE	20	25										
NEW ORLEANS	29	33	4675	3315	2251	1465	893	492	239	96	36	61.0
SHREVEPORT	20	25	5596	4220	3067	2167	1438	883	490	233	88	56.2
MAINE												
CARIBOU	-18	-13	15370	13269	11360	9632	8044	6634	5409	4319	3379	24.4
OLD TOWNE			14414	12293	10321	8648	7133	5800	4628	3589	2704	
PORTLAND	-6	-1	13251	11121	9141	7498	6035	4764	3658	2705	1908	33.0
MARYLAND												
BALTIMORE	10	13	9314	7577	5976	4729	3631	2682	1873	1236	753	43.7
CUMBERLAND	6	10										
MASSACHUSETTS												
BLUE HILL			11692	9698	7852	6335	5020	3885	2895	2071	1406	
BOSTON	6	9	10801	8849	7049	5621	4383	3313	2405	1659	1081	40.0
NANTUCKET			11464	9395	7546	5929	4520	3323	2311	1513	912	40.2
WORCESTER	0	4	12218	10236	8403	6848	5498	4326	3296	2421	1697	34.7
MICHIGAN												
ALPENA	-11	-6	14067	12034	10191	8518	6982	5635	4473	3464	2586	29.7
DETROIT (A)			11384	9564	7864	6419	5167	4072	3113	2280	1597	37.1
DETROIT (C)	3	6	11089	9302	7639	6228	5004	3936	2991	2178	1506	37.2
FLINT	-4	1	12070	10235	8581	7041	5705	4540	3529	2640	1892	33.1
GRAND RAPIDS	1	5	11713	9925	8288	6801	5514	4383	3396	2524	2213	34.9
LANSING	-3	1	11836	10037	8404	6904	5608	4464	3470	2595	1860	34.8
MARQUETTE	-12	-8	13727	11767	10015	8351	6835	5517	4379	3378	2507	30.2
MUSKEGON	2	6	12008	10138	8421	6890	5550	4390	3373	2482	1732	36.0
SAULT STE. MARIE	-12	-8	14679	12681	10913	9193	7614	6215	5017	3971	3050	27.7
TRAVERSE CITY	-3	1	12931	11022	9294	7698	6272	5035	3953	3013	2200	
MINNESOTA												
BEMIDJI	-31	-26				10203						
DULUTH	-21	-16	15320	13278	11450	9756	8185	6793	5581	4540	3625	23.4
INTERNAT'L FALLS	-29	-25	16048	14037	12237	10547	8995	7623	6413	5348	4412	
MINNEAPOLIS	-16	-12	12815	11128	9657	8159	6842	5677	4668	3765	2960	28.3
ROCHESTER	-17	-12	13029	11285	9768	8227	6868	5682	4643	3739	2916	28.8
ST. CLOUD	-15	-11	13745	11976	10427	8868	7481	6255	5187	4241	3385	
MISSISSIPPI												
JACKSON	21	25	5855	4407	3206	2300	1548	988	590	319	147	55.7
MERIDIAN	19	23	5978	4526	3315	2388	1621	1042	623	339	159	55.4
MISSOURI												
COLUMBIA REG	-1	4	4312	7739	6329	5078	3997	3064	2259	1605	1058	42.3
KANSAS CITY	2	6	9520	7892	6390	5161	4089	3157	2351	1694	1140	43.9
ST. JOSEPH	-3	2	9901	8235	6696	5435	4341	3378	2544	1847	1275	40.3
ST. LOUIS	2	6	9116	7464	5959	4750	3701	2798	2031	1419	925	43.1
SPRINGFIELD	3	9	8844	7241	5799	4570	3517	2611	1844	1235	745	44.5
MONTANA												
BILLINGS	-15	-10	12911	10781	8799	7265	5898	4697	3641	2766	2034	34.5
CUT BANK	-25	-20	15271	12918	10748	9033	7474	6096	4907	3886	3084	
DILLON	-18	-10	14395	12155	10031	8354	6821	5457	4255	3237	2375	
GLASGOW	-22	-18	14292	12315	10533	8969	7572	6329	5238	4302	3481	26.4
GREAT FALLS	-21	-15	13464	11256	9250	7652	6248	5022	3965	3074	2334	32.8
HAVRE	-22	-15	14091	12068	10267	8687	7282	6073	5005	4104	3304	28.1

City	Outside Design Temperature °F		Degree Days Base Temperature - °F								Average Winter Temp. °F	
	99%	97.5%	80	75	70	65	60	55	50	45		40
	MONTANA, Cont'd.											
HELENA	-21	-16	14118	11907	9834	8190	6710	5389	4247	3258	2419	31.1
KALISPELL	-14	-7	14972	12580	10281	8554	6959	5542	4304	3233	2350	31.4
LEWISTON	-22	-16	14794	12462	10270	8586	7038	5676	4487	3467	2620	
MILES CITY	-20	-15	13010	11105	9353	7889	6552	5392	4369	3479	2706	31.2
MISSOULA	-13	-6	13085	10852	9609	7931	6410	5066	3884	2876	2039	31.5
NEBRASKA												
GRAND ISLAND	-8	-3	11014	9330	7772	6420	5224	4166	3239	2434	1761	36.0
LINCOLN	-5	-2	10677	9041	7539	6218	5062	4040	3139	2362	1717	38.8
NORFOLK	-8	-4	11605	9913	8362	6981	5745	4663	3710	2863	2156	34.0
NORTH OMAHA			11131	9468	7963	6601	5400	4349	3427	2624	1954	
NORTH PLATTE	-8	-4	11717	9884	8161	6743	5470	4345	3354	2509	1787	35.5
OMAHA	-8	-3	10335	8746	7346	6049	4907	3911	3037	2290	1669	35.6
SCOTTSBLUFF	-8	-3	11983	10065	8235	6774	5473	4304	3289	2415	1684	35.9
VALENTINE			12179	10398	8752	7300	6006	4859	3847	2956	2193	32.6
NEVADA												
ELKO	-8	-2	13114	11033	9103	7483	6027	4714	3586	2625	1827	34.0
ELY	-10	-4	13340	11325	9473	7814	6327	5004	3826	2829	1977	33.1
LAS VEGAS	25	28	6196	4785	3541	2601	1770	1120	625	306	112	53.5
RENO	5	10				6022						39.3
NEW HAMPSHIRE												
BERLIN	-14	-9										
CONCORD	-8	-3	12795	10834	8947	7360	5967	4757	3682	2762	1978	33.0
MANCHESTER	-8	-3				7101						
MT. WASHINGTON			20571	18187	15703	13878	12053	10253	8534	6960	5585	15.2
NEW JERSEY												
NEWARK	10	14	9929	8082	6327	5034	3911	2920	2074	1391	863	42.8
TRENTON	11	14	9614	7859	6248	4947	3818	2832	1996	1323	810	42.4
NEW MEXICO												
ALBUQUERQUE	12	16	8424	6892	5504	4292	3234	2330	1557	963	522	45.0
CLAYTON			10006	8218	6610	5207	3999	2966	2089	1374	821	42.0
ROSWELL	13	18	7979	6339	4836	3697	2729	1898	1226	706	364	47.5
TRUTH OR CONSEQU.	14	18	7339	5845	4520	3392	2447	1636	1007	542	258	
NEW YORK												
ALBANY	-6	-1	11964	10093	8375	6888	5596	4451	3457	2595	1885	34.6
BINGHAMTON	-2	1	12557	10618	8855	7285	5908	4714	3677	2767	2009	36.6
BUFFALO	2	6	12170	10249	8464	6927	5591	4429	3403	2508	1766	34.5
ELMIRA	-4	1										
MASSENA	-13	-8	13501	11570	9828	8237	6827	5596	4510	3552	2733	
NEW YORK - JFK	12	15	9903	8140	6525	5184	4023	2994	2130	1422	880	41.4
NEW YORK - LaGuard.	11	15	9484	7767	6192	4909	3787	2806	1980	1311	798	43.1
OSWEGO	1	7	11852	10014	8340	6792	5544	4274	3243	2376	1636	
ROCHESTER	1	5	11827	9948	8217	6719	5417	4285	3291	2434	1715	35.4
SYRACUSE	-3	2	11738	9868	8164	6678	5379	4250	3267	2429	1725	35.2
NORTH CAROLINA												
ASHEVILLE	10	14	9045	7179	5548	4237	3129	2224	1488	937	549	46.7
CHARLOTTE	18	22	7425	5760	4328	3218	2300	1552	984	585	308	50.4
GREENSBORO	14	18	8171	6479	4997	3825	2811	1984	1324	825	483	47.5
RALEIGH/DURHAM	16	20	7863	6155	4662	3514	2542	1744	1123	670	367	49.4
WILMINGTON	23	26	6243	4694	3411	2433	1632	1028	610	321	142	54.6
NORTH DAKOTA												
BISMARCK	-23	-19	14161	12283	10596	9044	7656	6425	5326	4374	3542	26.6
FARGO	-22	-18	14237	12431	10816	9271	7891	6663	5573	4615	3753	24.8
MINOT	-24	-20	14673	12740	11005	9407	7964	6685	5564	4573	3717	24.9
WILLISTON	-25	-21	14402	12470	10735	9161	7753	6504	5387	4450	3598	25.5
OHIO												
AKRON/CANTON	1	6	11448	9492	7675	6224	4971	3883	2936	2126	1482	38.1
CINCINNATI (A)	1	6	9754	7978	6353	5070	3965	3001	2189	1527	1004	41.4
CINCINNATI (C)	1	6	9434	7683	6088	4844	3763	2830	2040	1412	921	45.1
CLEVELAND	1	5	11329	9395	7610	6154	4901	3819	2876	2079	1433	37.2
COLUMBUS (A)	0	5	10730	8835	7068	5702	4513	3480	2597	1846	1280	39.7
DAYTON	-1	4	10463	8653	6970	5641	4483	3468	2600	1866	1282	39.8
MANSFIELD	0	5	10824	8943	7197	5818	4618	3573	2679	1917	1317	36.9
TOLEDO	-3	1	11395	9541	7815	6381	5136	4049	3091	2274	1602	36.4
YOUNGSTOWN	-1	4	11698	9735	7922	6426	5145	4032	3054	2232	1558	36.8
OKLAHOMA												
OKLAHOMA CITY	9	13	7662	6151	4796	3695	2760	1962	1326	804	455	48.3
TULSA	8	13	7594	6113	4759	3680	2750	1950	1306	778	418	47.7

City	Outside Design Temperature °F		Degree Days Base Temperature - °F								Average Winter Temp. °F	
	99%	97.5%	80	75	70	65	60	55	50	45		40
	OREGON											
EUGENE	17	22	10732	8432	6378	4739	3313	2141	1226	607	255	45.6
MEACHAM			13978	11729	9598	7863	6249	4817	3556	2495	1620	34.2
MEDFORD	19	23	10095	8167	6426	4930	3614	2496	1577	882	419	43.2
NORTH BEND	29	32	12846	9509	6504	4688	2985	1642	756	292	84	42.6
PENDLETON	-2	5	10297	8399	6698	5240	3968	2868	1970	1264	779	42.6
PORTLAND	17	23	10696	8424	6407	4792	3385	2234	1333	708	338	45.6
PENNSYLVANIA												
ALLENTOWN	4	9				5827						38.9
BRADFORD			15118	11367	9478	7804	6294	5006	3894	2931	2139	
ERIE	4	9	12317	10286	8419	6851	5485	4304	3283	2411	1684	36.8
HARRISBURG	7	11	9759	8067	6517	5224	4087	3097	2238	1541	990	41.2
PHILADELPHIA	10	14	9470	7731	6125	4865	3753	2788	1965	1312	809	41.8
PITTSBURGH (A)	1	5	11127	9172	7366	5930	4694	3637	2720	1938	1326	38.4
PITTSBURGH (C)	3	7	10112	8276	6591	5278	4135	3138	2294	1603	1065	42.2
SCRANTON/												
WILKES-BARRE	1	5	11188	9379	7735	6277	5018	3928	2972	2149	1486	37.2
WILLIAMSPORT	2	7	11044	9162	7404	5981	4757	3695	2764	1971	1341	38.5
RHODE ISLAND												
BLOCK ISLAND			11287	9216	7340	5771	4432	3289	2306	1517	917	40.1
PROVIDENCE	5	9	11083	9181	7458	5972	4682	3565	2599	1803	1172	38.8
SOUTH CAROLINA												
CHARLESTON	25	28	5687	4246	3070	2146	1406	864	496	240	102	56.4
COLUMBIA	20	24	6381	4867	3592	2598	1783	1154	686	374	165	54.0
GREENVILLE/												
SPARTANBURG	18	22	7234	5646	4276	3163	2246	1493	921	519	250	
SOUTH DAKOTA												
ABERDEEN	-19	-15	13500	11718	10129	8617	7267	6078	5014	4087	3272	
HURON	-18	-14	12780	11057	9513	8055	6751	5600	4582	3678	2889	28.8
PIERRE	-15	-10	12424	10681	9095	7677	6401	5271	4273	3409	2647	
RAPID CITY	-11	-7	12589	10634	8804	7324	5982	4799	3762	2868	2115	33.4
SIoux FALLS	-15	-11	12507	10811	9296	7838	6543	5401	4394	3498	2712	30.6
TENNESSEE												
BRISTOL	13	18	8905	7122	5550	4306	3255	2373	1646	1093	687	46.2
CHATTANOOGA	13	18	7735	6068	4610	3505	2574	1785	1180	737	433	50.3
KNOXVILLE	13	19	7627	5997	4590	3478	2557	1775	1187	744	439	49.2
MEMPHIS	13	18	7123	5601	4260	3227	2352	1624	1058	640	349	50.5
NASHVILLE	9	14	7802	6210	4817	3696	2758	1964	1338	852	518	48.9
OAK RIDGE			8343	6632	5132	3944	2955	2119	1445	933	576	47.7
TEXAS												
ABILENE	15	20	6165	4774	3560	2610	1801	1162	664	342	139	53.9
AMARILLO	6	11	8544	6891	5399	4183	3156	2278	1548	976	555	47.0
AUSTIN	24	28	4968	3643	2560	1737	1097	620	316	127	44	59.1
DALLAS	18	20	5715	4358	3190	2290	1544	949	526	250	94	53.3
DEL RIO	26	31	4632	3339	2284	1523	923	494	230	80	23	
EL PASO	20	24	6469	4974	3670	2678	1833	1149	653	326	129	52.9
FORT WORTH	17	22	5879	4496	3304	2382	1616	1007	562	274	105	55.1
GALVESTON (C)	31	36	4285	2964	1947	1224	704	369	157	54	18	62.0
HOUSTON	27	32	4620	3274	2210	1434	864	471	215	81	26	61.0
LUBBOCK	10	15	7626	6069	4661	3545	2603	1807	1163	666	336	48.8
LUFKIN	25	29	5251	3912	2796	1940	1253	731	385	163	53	
SAN ANGELO	18	22	5853	4301	3138	2240	1498	918	493	227	83	56.0
SAN ANTONIO	25	30	4905	3503	2374	1570	956	518	242	92	25	60.1
WACO	20	25	5526	4132	2985	2058	1357	807	437	195	62	57.2
WICHITA FALLS	14	18	6534	5141	3936	2904	2061	1384	832	451	192	53.0
UTAH												
SALT LAKE CITY	3	8	10720	8976	7362	5983	4733	3633	2676	1864	1220	38.4
WENDOVER			10483	8714	7096	5760	4558	3511	2621	1870	1281	39.1
VERMONT												
BURLINGTON	-12	-7	13140	11207	9443	7876	6488	5270	4190	3246	2442	29.4
VIRGINIA												
LYNCHBURG	12	16	8533	6909	5471	4233	3172	2269	1536	966	570	46.0
NORFOLK	20	22	7847	6127	4635	3488	2516	1710	1100	663	366	49.2
RICHMOND	14	17	8555	6751	5119	3939	2916	2061	1388	866	508	47.3
ROANOKE	12	16	8762	7073	5595	4315	3227	2321	1586	1010	580	46.1
WALLOPS ISLAND			8770	7043	5540	4250	3161	2262	1538	976	561	
WASHINGTON												
BELLINGHAM	10	15				5738						
OLYMPIA	16	22	11747	9397	7267	5530	3970	2653	1617	854	396	44.2
QUILLAYUTE			12828	10209	7765	5951	4232	2750	1603	813	354	

City	Outside Design Temperature °F		Degree Days Base Temperature - °F								Average Winter Temp. °F	
	98%	97.5%	80	75	70	65	60	55	50	45		40
WASHINGTON, Cont'd.												
SEATTLE	22	27	10887	8366	6148	4487	3046	1893	1045	501	197	46.9
SEATTLE/TACOMA	21	26	11516	9085	6902	5185	3657	2386	1416	731	325	44.2
SPOKANE	-6	2	12438	10353	8423	6835	5420	4173	3088	2188	1464	36.5
STAMPEDE PASS			15847	13510	11209	9400	7643	6006	4532	3256	2203	
WALLA WALLA	0	7	9748	7882	6224	4835	3616	2600	1760	1126	685	43.8
YAKIMA	-2	5	11673	9522	7551	6009	4655	3483	2502	1688	1084	39.1
WEST VIRGINIA												
BECKLEY			10883	8879	7106	5615	4356	3279	2390	1652	1093	
CHARLESTON	7	11	9301	7487	5858	4590	3500	2590	1809	1216	766	44.9
ELKINS	1	6	11603	9453	7525	5975	4659	3533	2616	1834	1245	40.1
HUNTINGTON	5	10	9427	7570	5889	4624	3533	2624	1843	1249	797	45.0
PARKERSBURG	7	11	9486	7701	6098	4817	3720	2786	1987	1363	885	43.5
WISCONSIN												
EAU CLAIRE	-15	-11	13176	11443	9934	8388	7033	5832	4786	3860	3028	
GREEN BAY	-13	-9	13043	11246	9678	8098	6689	5473	4405	3478	2644	30.3
LA CROSSE	-13	-9	11975	10323	8868	7417	6158	5050	4088	3219	2458	31.5
MADISON	-11	-7	12644	10855	9274	7730	6373	5188	4156	3250	2447	30.9
MILWAUKEE	-8	-4	12535	10671	8989	7444	6080	4898	3860	2946	2176	32.6
WYOMING												
CASPER	-11	-5	12985	10998	9106	7555	6167	4914	3813	2857	2041	33.4
CHEYENNE	-9	-1	12942	10849	8859	7255	5825	4562	3452	2512	1717	34.2
LANDER	-16	-11	13390	11354	9439	7889	6471	5207	4080	3140	2321	31.4
ROCK SPRINGS	-9	-3	14142	12033	10059	8410	6922	5592	4412	3393	2533	
SHERIDAN	-14	-8	13353	11251	9286	7708	6298	5024	3935	3000	2200	32.5