A SOLAR HEATED OFFICE BUILDING

Submitted in Partial Fulfillment
of the Requirements for the Degree
of Bachelor of Architecture

Massachusetts Institute of Technology

School of Architecture and Planning

May 25, 1953

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Dear Dean Belluschi:

In partial fulfillment of the requirements for the Degree of Bachelor of Architecture, I submit the following thesis entitled, "A Solar Heated Office Building".

Very truly yours,

John B. Hampshire

ACKNOWLEDGMENTS

The author takes this opportunity to express his sincere thanks to the staff and students of the School of Architecture and Planning for their guidance and concern during the past years of study.

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INTRODUCTION

Suppose all the earth's coal, lignite, peat, tar sands, crude petroleum, natural gas, and oil shale that we are ever likely to produce in the future (according to the most optimistic of forecasts) were collected and that all our timber were cut into cordwood. Suppose we segregate all the uranium and thorium that we are likely to produce in the future (based on estimates by Lawrence R. Hafstad) and that it is purified for nuclear fission. Then, suddenly, we extinguish the sun. We ignite our fuel in such a fashion as to give us energy at the rate at which we are accustomed to receive it from the sun. In about three days our entire supply of combustible fuel would be gone. Then we would get the nuclear reactions under way. This would last us less than an hour if the "breeder principle" could be applied--otherwise only a few seconds. At the end of a few days the earth with its load of ashes and radioactive wastes would begin its descent toward some temperature only slightly above absolute zero.

This gives a rough idea of what it would mean to try to compete with the sun.[1]

Annually, space heating consumes nearly 30 percent of the fuel in the United States. The value of this fuel has been estimated at 3,500 million dollars.[2] This consumption maintains comfortable working and living climates in commercial and residential buildings during the average heating period of October 1 to May 1. Large quantities of fuel are also used during the warm summer months to reduce space temperature and humidity to a point within the psychometric "comfort zone".

Technicians throughout this country and parts of the world have been investigating the possibilities of heating buildings by utilizing the incident solar energy that reaches the earth's surface. Technically, the problem is twofold. First, the development of an efficient energy collector, secondly, the development of an efficient means of storing collected heat for future use.

The first commercially available building designed to receive a portion of its heat requirements from the sun was the so-called "solar" house. This type of house uses large south facing vertical windows admitting the sun's energy directly into the living spaces which act as collectors and also provide a small amount of storage. In general, a 16 percent fuel saving can be realized.[3] The "solar" house often becomes overheated during the daytime, and cool during the night or cloudy days due to large heat losses through the window areas. Window losses can be reduced by various types of curtaining devices. More efficient methods have been developed for collecting and storing solar energy.

A "sun-wall collector" installation was designed and built at M.I.T. This structure used large, double-glazed, vertical, south facing windows to provide required insulation while transmitting solar energy to the "collector wall". Small cans containing a variety of storage media were stacked like building blocks and comprised the "collector wall". A small air space was left between windows and collector wall to provide room for a double insulating curtain necessary for reducing the nightly heat losses. The exterior surface of the containers was painted black to absorb solar energy. The interior surface served to distribute heat into the rooms.[4] An additional automatic curtain was used to vary the amount of exposed room transfer area in accordance with the varying heat load. The space enclosed by the structure was divided into nine small cubicles in order to concentrate seven years research into one year.[5]

A second structure was built at M.I.T. incorporating flat, black metal plates as collectors, and a 1,200 gallon water tank as a storage device.[6] The flat plate collectors form the south slope of the roof and are insulated against outward loss by three sheets of glass separated by air spaces. The building also uses large areas of south facing window to transmit additional solar energy into the living space. During the night a curtain, drawn across the window, greatly reduces the outward heat loss. The 1,200 gallon water tank, located in the attic, provides 25 pounds of water storage per square foot of collector area. This capacity has been found sufficient to take care of two average sunless winter days. A larger storage system would, of course, carry over for a longer period. If the house were redesigned the water storage would be placed in the living area instead of in the "attic", where it is now. This would bring any heat leakage into the area where it is needed. About one-third of the total heating load is contributed by the south windows,...one-half by the roof collector, and the remainder by combustion.[7]

In December 1948, an experimental house, located in Dover, Mass., was completed. The house uses the heat of fusion principle for solar heat storage.[8]

Most chemicals, water included, when changing from a solid to a liquid state absorb large amounts of heat. The heat necessary to achieve a solid to liquid phase change is called the "heat of fusion". When the chemical is cooled and re-solidifies the heat absorbed in melting is released as the "heat of solidification". In heat storage applications collected heat can be used to melt certain chemicals; when needed the heat can be withdrawn, completing a simple heat exchange cycle.

The Dover house uses air as the absorbing and heating medium rather than water, as in the M.I.T. solar house. Air is circulated over vertical flat plate collectors and passed into a "storage bin" containing small cans of chemicals that exhibit "heat of fusion" properties within the collection temperature range. The "bin" volume, 470 cubic feet (3,500 gallons), is capable of storing 4 million B.T.U. at 88° - 90°F and when completely charged, is capable of providing space heating for ten consecutive sunless winter days.[9]

Of the foregoing examples, the most efficient, by far, has been the Dover house. The weaknesses of the structures that preceeded it were, in part, eliminated, while their advantages were used.

The question now is, why not attempt to design an office building that would utilize more of the solar energy incident on the thousands of square feet of exposed surface area in meeting the building's heat requirements?

I propose to determine the type of building, its characteristics and uses, that could incorporate a solar heating installation; to set forth a design in principle; to present a design for such a building; to determine what essential mechanical and electrical elements are necessary to fulfill the heating and cooling cycle requirements, and to evaluate the feasibility of such an undertaking.

THE TYPE OF BUILDING

First of all it should be noted that, at this time, any attempts to condition an existing building for solar heating is highly impractical. The building must be designed to receive the various components if a solar installation is to be at all successful. They cannot be added like pasting a postage stamp on an envelope.

The problem is not one of finding the building that possesses the maximum volume for the minimum area. The optimum would be one that could devote sufficient area for collection purposes, and yet expose a minimum exterior surface, while enclosing a maximum volume. Practically the limiting factor is the volume; more specifically, the population per unit volume. Sufficient energy can be collected for current, as well as, near future demands if only conduction and radiation losses are considered. Code requirements specify the amount of fresh outdoor air, in cubic feet per minute per person, for healthy working conditions. Make up air displaces an equivalent volume of warm air from the building. The heat that is lost is, practically, unrecoverable. The ideal structure would be one with a fairly large flank area exposed to the sun and yet not very thick. Thus, a building with a double loaded corridor would probably fulfill most of the requirements. It almost goes without saying that the building can have no undulations or breaks that would cast shadows on the solar collectors.

A DESIGN IN PRINCIPLE

The building will be designed for the Boston area. The plot will be assumed to be relatively flat with an unobstructed southern exposure. An ideal location would be on the north shore of the Charles River, between the Harvard Bridge and the Boston University Bridge, in Cambridge. The nearest building to the south would be in Boston approximately a quarter of a mile away; thus, there would be no diverse effects due to shading.

The structure proper will encompass approximately 34,000 square feet at the ground floor and contain space that can easily be divided in accordance with tenant requirements. A central core separating office bays will supply the required space for heat storage, ventilating equipment, control equipment, elevators, fire stairs, and toilets and, where possible, additional space for commercial use. The ratio of length to width will be from 3-4 to 1, with one of the large flanks facing south.

Heat losses will be controlled as best as possible without disturbing the function of the structure. Overheating of inside space will be carefully controlled, attempts will be made to develop a system that will maintain a fairly constant temperature. The structure will be well insulated where possible. No thermal insulation will be used in interior partitions, floors or ceilings since all spaces will be, approximately, at the same mean temperature.

The building heat load will be calculated as the sum of all outward losses through wall and glass areas, in maintaining an internal air temperature of 70°F, minus the energy inputs from solar and diffuse radiation through window areas, animal gain, and fixture gain. Fixture gain includes only the heat generated by luminares which are assumed to run a continuous eight hours on cloudy days (scale 8-10) only. They are assumed to be

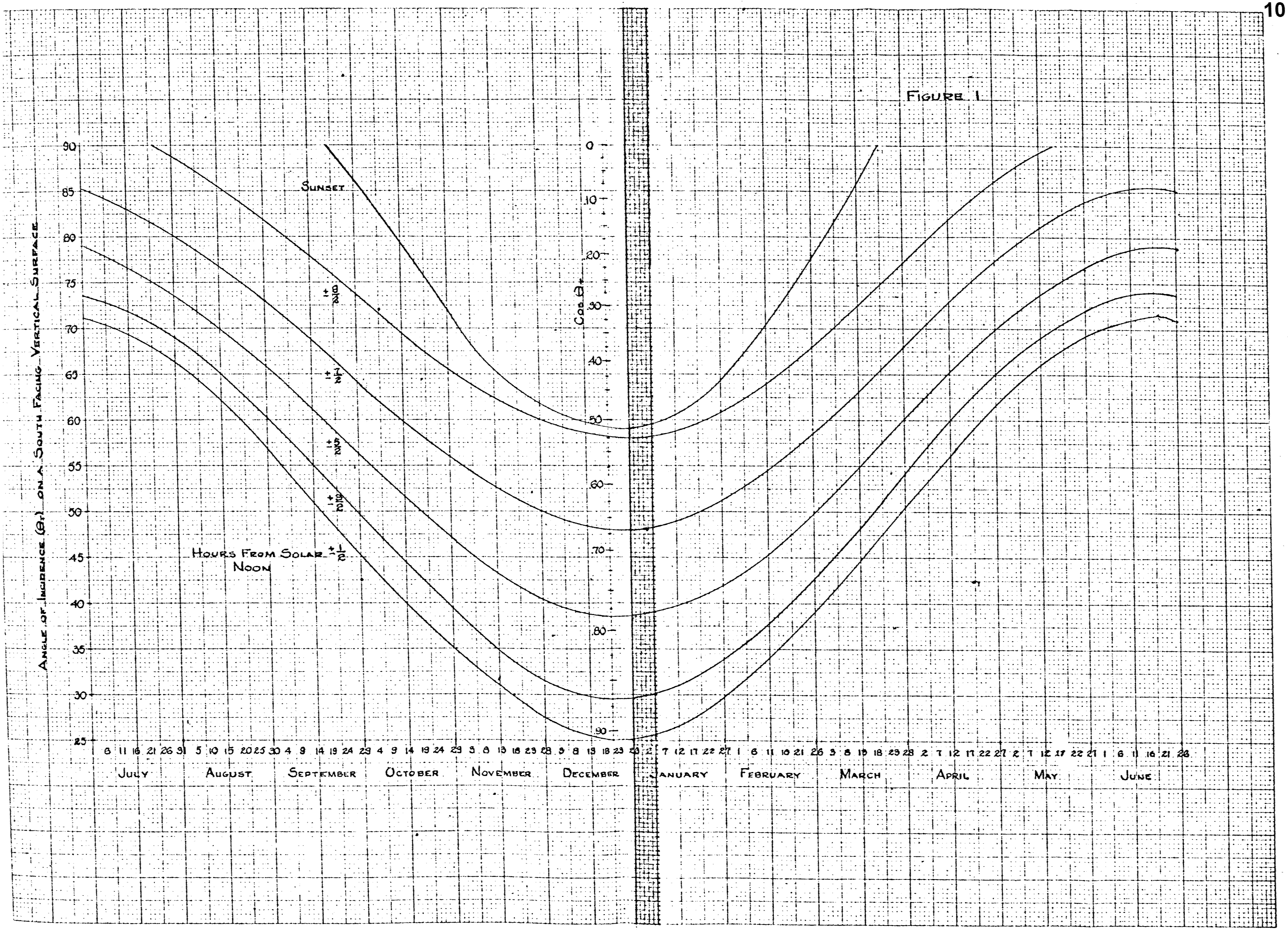


FIGURE 1

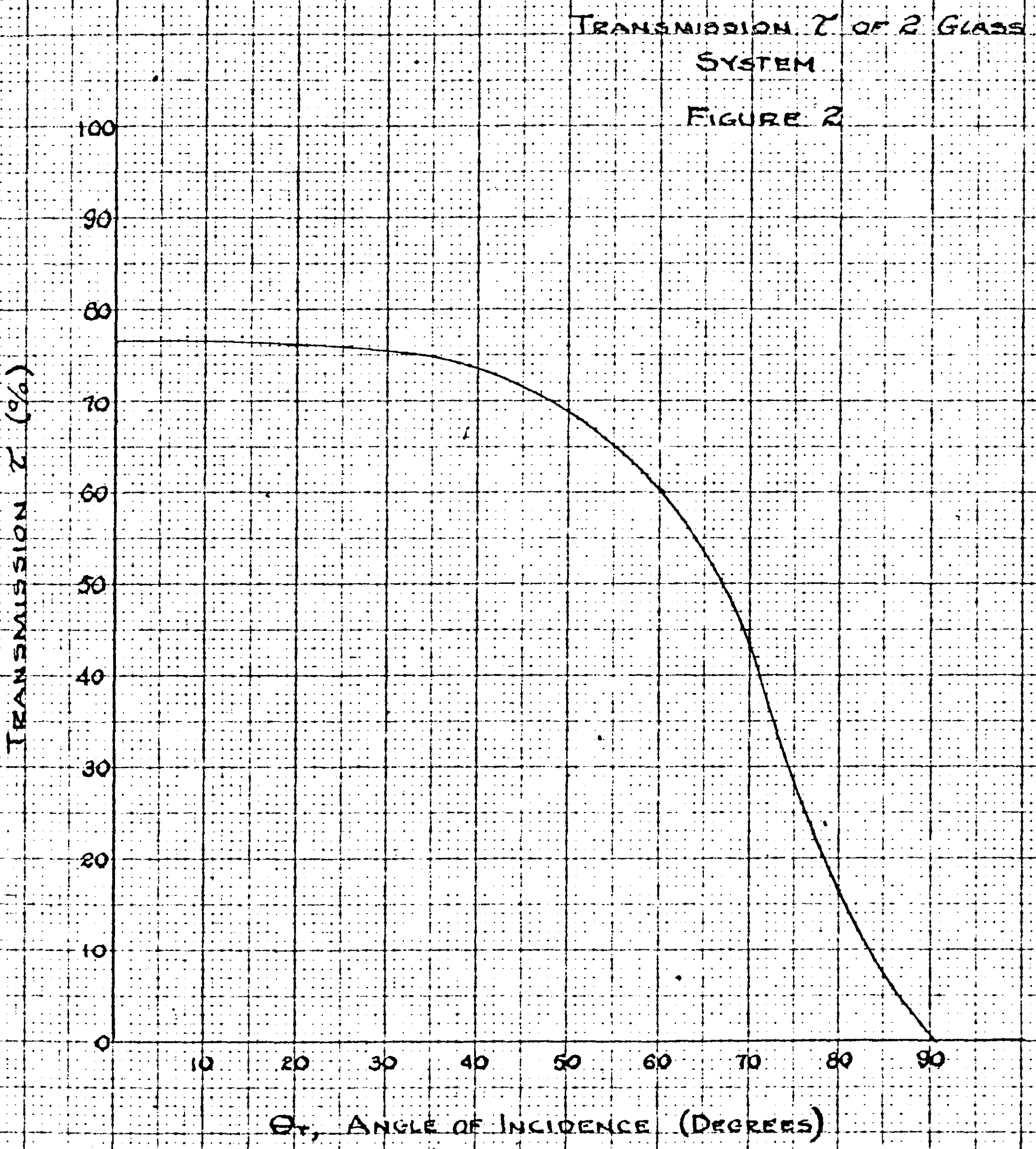
Angle of Incidence (θ_T) on a South Facing Vertical Surface
90
85
80
75
70
65
60
55
50
45
40
35
30
25
Cos θ_T
0
.10
.20
.30
.40
.50
.60
.70
.80
.90
Sunset
$\pm\frac{9}{2}$
$\pm\frac{7}{2}$
$\pm\frac{5}{2}$
$\pm\frac{3}{2}$
Hours From Solar Noon $\pm\frac{1}{2}$
6 11 16 21 26 31 5 10 15 20 25 30 4 9 14 19 24 29 4 9 14 19 24 29 3 8 13 18 23 28 3 8 13 18 23 28 2 7 12 17 22 27 1 6 11 16 21 26 3 8 13 18 23 28 2 7 12 17 22 27 2 7 12 17 22 27 1 6 11 16 21 26
July
August
September
October
November
December
January
February
March
April
May
June

totally inoperative during all other sky conditions. Also, there will be no account taken of the energy gain from equipment located in the central core.

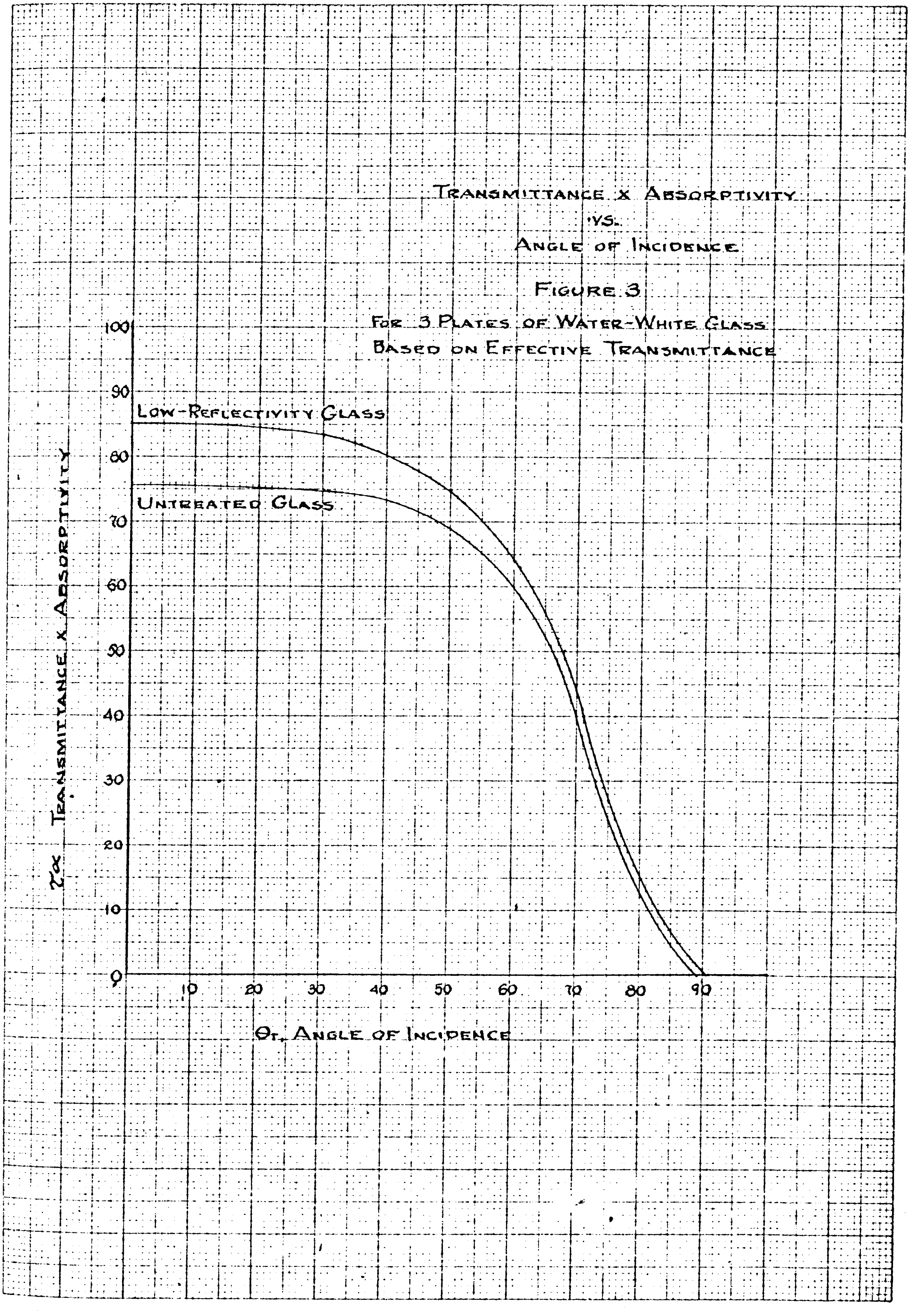
Calculations will be made for a single bay only. The volume, exclusive of corridors and central core, will be assumed to be 24' x 72' x 10' for all calculations. This space shall contain 128-100 watt flourescent lamps and a minimum of 12 people.

THE BASIS FOR CALCULATIONS

Calculations were conducted as follows. First, data was obtained on the amounts of solar, sky and ground reflected radiation incident on a south facing vertical surface.[10] These values were tabulated in gram calories per square centimeter for each sunlight hour as received at the Blue Hills Observatory. The values were averaged over a three year period and converted to B.T.U. per square foot. The first thirty or less B.T.U. of this value was assumed to be diffuse radiation,[11] and tabulated as such and subtracted from the total incident energy in the second step. Third, the angle of incidence for month, day and hour was determined from the accompanying plot (Figure 1). This in turn was plotted against transmittance for two and three glass systems (Figs.2 & 3). In the fourth step the amount of direct and diffuse radiation was calculated by multiplying the incident energy by the transmittance factor. Finally, the diffuse and direct radiation were totalled. This represents the amount of usable energy received, on a clear (scale 0-3) day, by the window and collector areas and is tabulated in B.T.U. per square foot per day.



Transmission τ of 2 Glass System
Figure 2
Transmission τ (%)
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
θ_T, Angle of Incidence (Degrees)



TRANSMITTANCE X ABSORPTIVITY
VS.
ANGLE OF INCIDENCE

FIGURE 3

FOR 3 PLATES OF WATER-WHITE GLASS
BASED ON EFFECTIVE TRANSMITTANCE

Average values of 65 percent and 70 percent were used as the transmission factor for the diffuse radiation transmitted through two and three plate systems respectively.

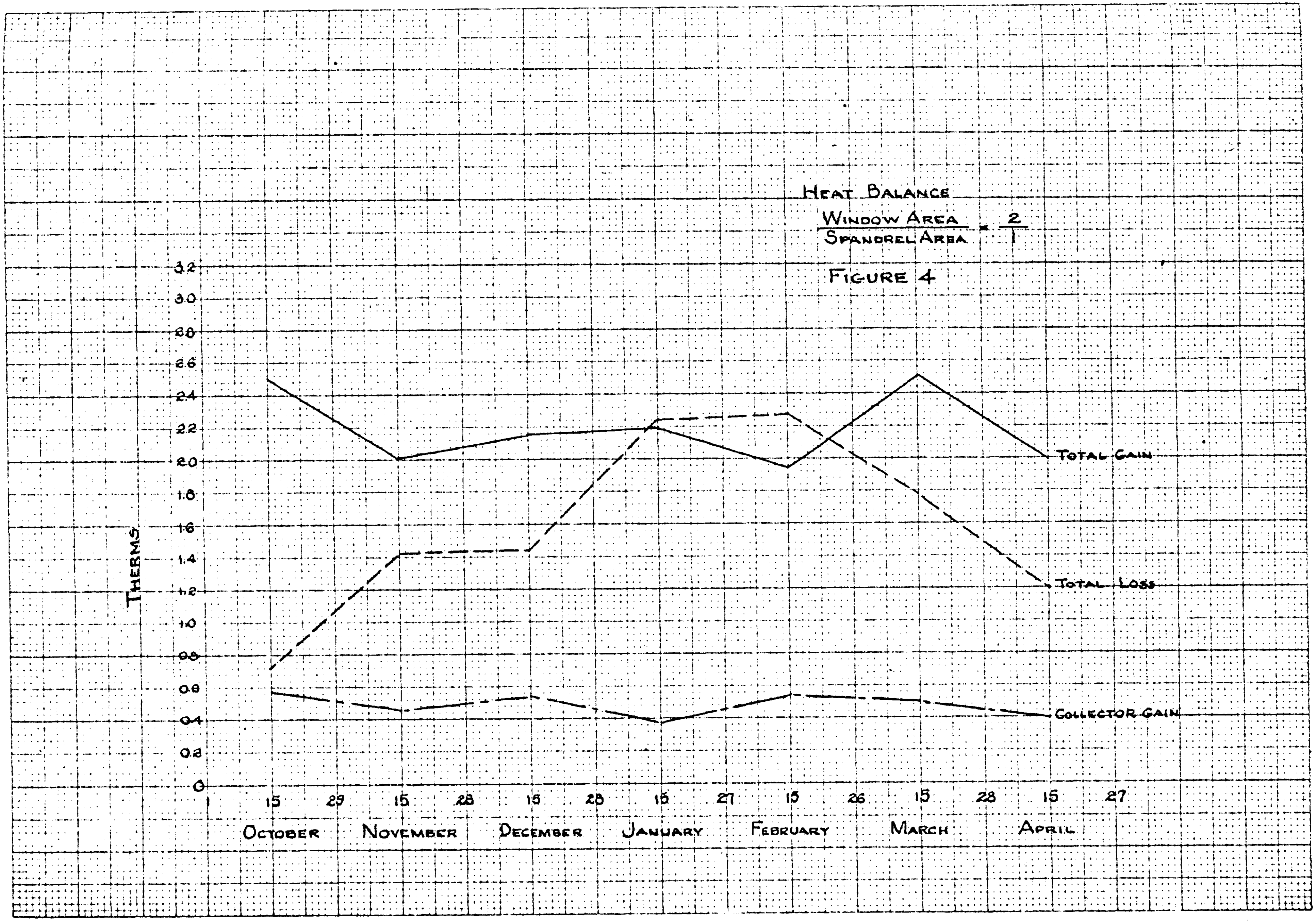
Since the system must function during any year, calculations were based on three year average value for degree days in determining the average temperature. Heat losses were then calculated for the three ratios of window to spandrel area of 2/1, 1/1, and 0.846/1. Solar and diffuse gain was based on the percentage of total sunlight hours. Diffuse radiation was assumed to be a constant during all weather conditions.

MONTHLY ANALYSIS

In Figures 4, 5, 6 comparison plots are made for total gain, total loss, and collector gain for the three window to spandrel ratios, of 2/1, 1/1 and 0.846/1, on a monthly basis for an entire bay. It becomes quite evident, from the tables and calculations, that the luminous ceiling used in each bay acts as a sizable radiating panel in heating the space in question.

Transmission coefficients for both solar and conventional spandrels were assumed to be $U \doteq 0.06$, while those for the twin paned windows were assumed to be 0.45.[12] Also, the temperature difference was assumed to remain constant throughout the month.

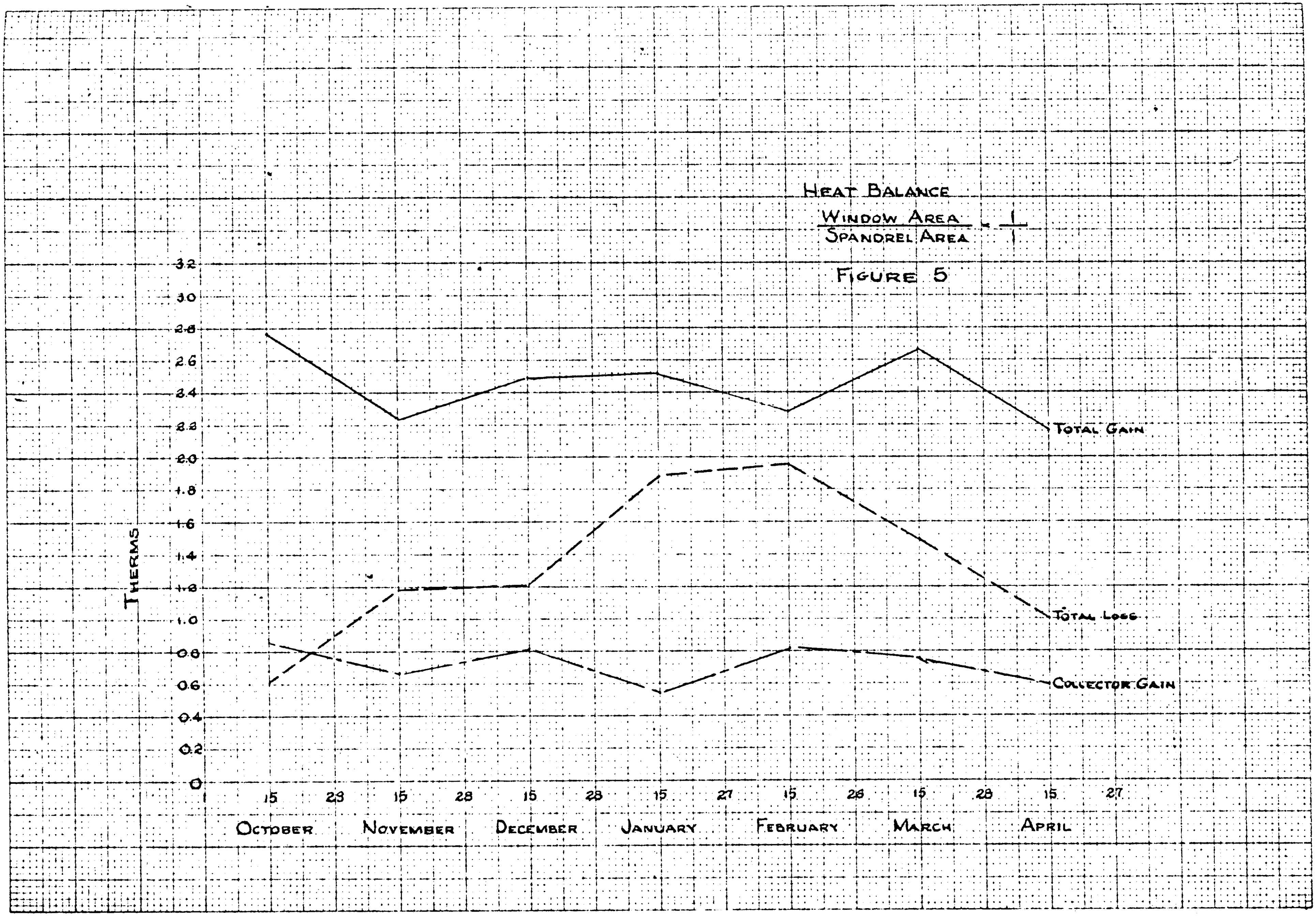
Figure 6 appears to provide the greatest overall gain. However, it is questionable whether a real gain is realized when one considers that the function of the building is altered. The drawings in the appendix show that the north and south walls are entirely different.



Heat Balance

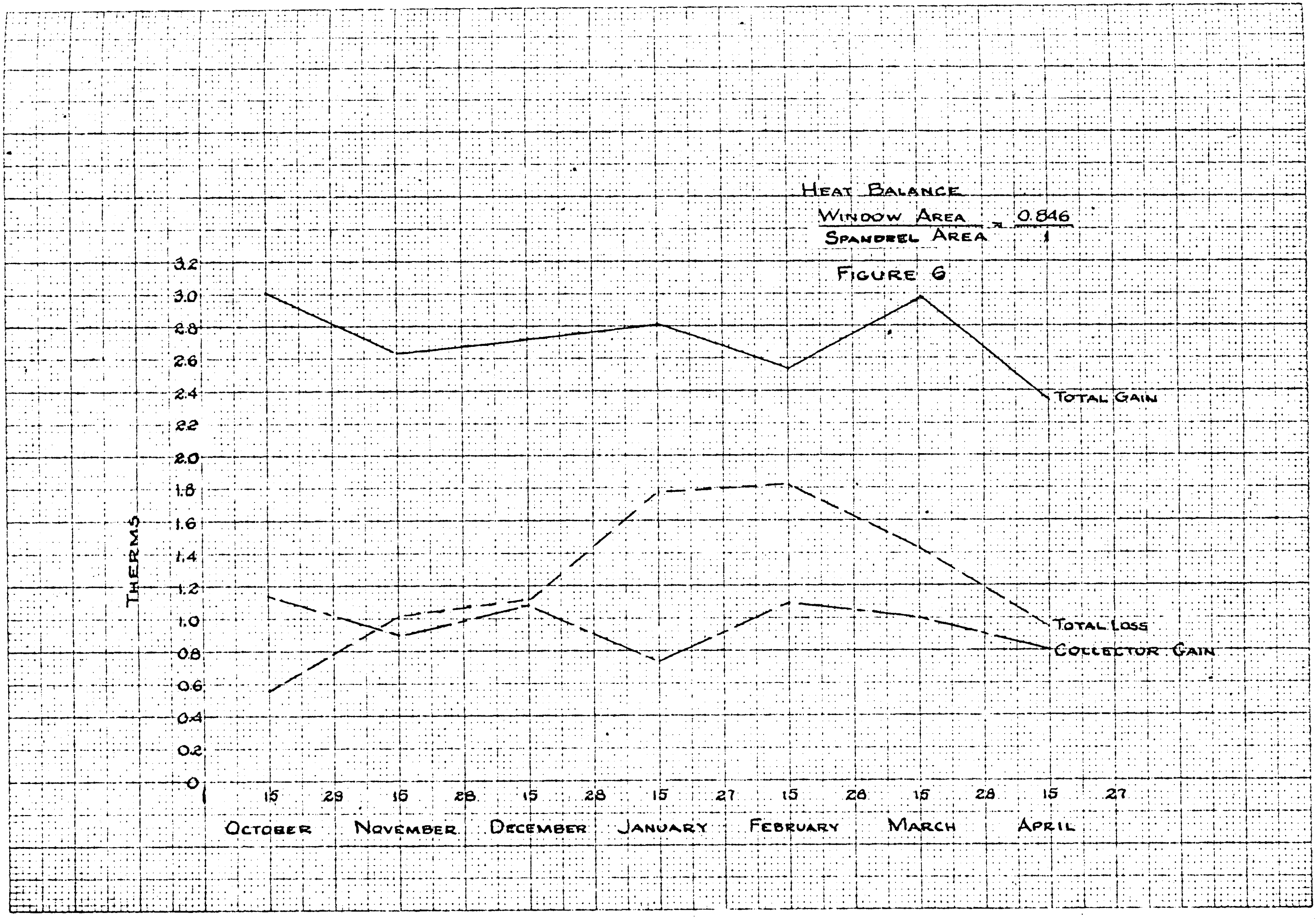
$\frac{\text{Window Area}}{\text{Spandrel Area}} = \frac{2}{1}$

Figure 4


HEAT BALANCE

$\frac{\text{WINDOW AREA}}{\text{SPANDREL AREA}} = \frac{1}{1}$

FIGURE 5



HEAT BALANCE

$\frac{\text{WINDOW AREA}}{\text{SPANDREL AREA}} = \frac{0.846}{1}$

FIGURE 6

The north wall has seven foot windows while the south wall has windows only four feet high. It would be difficult to justify such a difference. Esthetically it is poor, economically it is worse. Tenants would be reluctant in renting space in the south side of the building.

Figure 5, with a window to spandrel area ratio of 1/1, falls well within the load requirements, what is more, the building faces are uniform in appearance. A compromise between the 1/1 ratio and the 2/1 ratio (Figure 4) was used to design the solar collector, and as a direct result, the building facade.

THE PROBLEM OF HEAT STORAGE

"Storage bins" shall provide space heating for ten consecutive sunless winter days. This amounts to about 2 million B.T.U.. Glauber's salt ($Na_2SO_4 \cdot 10H_2O$) is the storage medium. This chemical, melts at temperatures from 88° - 90°F, is capable of storing nearly 10,000 B.T.U. per cubic foot[13] and has a density of 91.4 pounds per cubic foot. Therefore, each collector requires 200 cubic feet of chemicals, weighing about nine tons, that are packed into a volume of approximately 400 cubic feet. A special four point star shaped can has been designed to contain the chemicals. The can ends telescope and tall stacks are built up like building blocks. The "tanks" are baffled to provide even heating. The tanks for each floor are grouped together and comprise a heat tower that rises up through the core of the structure. Two additional roof collectors are used to provide heat to keep all tanks on various floors at an even temperature.

THE DISTRIBUTION OF HEAT

Primary air is drawn from the space to be heated and passed through the solar collector where it is heated. It is then passed through the "storage bin" where it loses a portion of absorbed heat to the chemicals. The exit air temperature from the tank is well above room temperature and at this point it is mixed with cold outdoor air and dropped to the desired room temperature and exhausted into the space to be heated. A constant volume of air is continually bled from each bay and exhausted to the atmosphere. The volume of fresh air introduced to the space balances the volume exhausted.

In the summer the "storage bin" is used to cool air. At night the bin is purged with outdoor air and cooled, during the majority of the time, to below room temperature. During the day both space and make up air are passed through the "bin" and loose heat to the chemicals. High tonage cooling systems are not required.

CONTROL EQUIPMENT

Control equipment includes thermocouples, a recording thermometer, a selector, a standard, and an amplifier that actuates pilot valves for damper control, and small gear pumps that control fan speed. In all, they occupy only a few cubic feet. Fans, out of necessity, are large.

CONCLUSION

The foregoing analysis has shown that commercial buildings can be heated with solar energy. If solar components could be mass produced, as most building equipment is today, it would be economically feasible to build such a structure. Solar collectors would cost approximately the same, per square foot, as equivalent areas of finished spandrel. Duct work is not greatly increased. Cooling can be achieved with the same system. With all this, the building still functions well.

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APPENDIX

Table No. 1

AVAILABLE ENERGY

October	Year													
Apparent Time-Hour Ending		7	8	9	10	11	12	1	2	3	4	5	6	Total
Solar & Sky Radiation Incident on a Vertical South Facing Surface (gram-calories/cm^2)	1946	1.7	14.7	29.8	42.3	49.6	50.5	51.4	48.3	39.6	27.7	13.4	1.6	
	1947	1.6	14.9	30.9	44.3	52.0	59.8	57.5	54.3	42.8	28.8	13.9	1.6	
	1948	1.0	9.6	18.8	28.3	35.4	37.1	36.8	30.4	27.3	18.6	10.1	1.3	
3 Year Mean Value (gm-cal/cm^2)		1.4	13.7	26.5	38.3	45.7	49.1	48.6	44.3	36.6	25.0	12.5	1.5	
3 Year Mean Value BTU/ft^2		5.2	50.5	97.7	141.2	168.8	181.0	179.0	163.5	135.0	92.3	46.1	5.5	1266.0
Diffuse Sky Radiation 1st 30 or less BTU/ft^2		5.2	30	30	30	30	30	30	30	30	30	30	5.5	
Direct Solar Radiation		-	20.5	67.7	111.2	138.2	151.0	149.0	133.5	105.0	62.3	16.1	-	
Angle of Incidence		-	69.0	59.5	51.0	44.2	40.5	40.5	44.2	51.0	59.5	69.0	-	

Table No. 2. TRANSMITTED ENERGY THROUGH 1 SQUARE FOOT OF DOUBLE GLAZED WINDOW

October Year Apparent Time-Hour Ending	7	8	9	10	11	12	1	2	3	4	5	6	Total
Transmittance % (Windowed Area - 2 Plates)	-	44.5	61.5	68.5	71.5	73.0	73.0	71.5	68.5	61.5	44.5	-	
Transmitted Direct Radiation (BTU/ft^2)	-	9.1	41.7	76.3	99.2	111.0	109.0	95.5	72.0	38.4	7.2	-	
Transm.Diffuse Radiation (Assumed Ang.Diffuse Transmittance - 65%) BTU/ft^2	3.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	3.6	202.0
Total Radiation (BTU/ft^2) Designated Hour	3.5	28.6	61.2	95.8	118.7	130.5	128.5	115.0	91.5	57.9	26.7	3.6	862.0

Table No. 3. TRANSMITTED ENERGY THROUGH 1 SQUARE FOOT OF TRIPLE GLAZED COLLECTOR

October Year Apparent Time-Hour Ending	7	8	9	10	11	12	1	2	3	4	5	6	Total
Transmittance x Absorbtivity ($\tau\alpha$) in % (3 Plates-Low Reflectivity Glass)	-	47	65	74	79	81	81	79	74	65	47	-	
Transmitted Direct Radiation (BTU/ft^2)	-	9.7	44.0	82.3	109.0	122.4	120.8	105.5	77.6	40.5	7.6	-	
Transmitted Diffuse Radiation (Assumed Avg. Diffuse Transmission - 75%) BTU/ft^2	3.9	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	4.1	233
Total Radiation		32.2	66.5	104.8	131.5	144.9	143.3	128.0	100.1	63.0	30.1	4.1	949

Table No. 4

AVAILABLE ENERGY

November Year

Apparent Time-Hour Ending		7	8	9	10	11	12	1	2	3	4	5	6	Total
Solar & Sky Radiation	1946		7.0	23.1	33.1	36.5	40.9	40.4	39.0	30.1	20.3	6.0		
Incident on a Vertical	1947		7.3	21.4	34.0	38.2	39.8	40.9	37.7	29.1	17.5	5.3		
South Facing Surface (gram-cal/cm^2)	1948		6.0	18.9	27.9	33.3	36.6	36.8	34.3	24.9	14.8	4.9		
3 Year Mean (gm-cal/cm^2)			6.7	21.1	31.6	36.0	39.1	39.4	37.0	28.0	17.5	5.4		
3 Year Mean (BTU/ft^2)			24.7	77.6	116.6	133.0	144.2	145.2	136.5	103.2	64.6	19.9		965.0
Diffuse Sky Radiation (1st 30 or less BTU/ft^2)			24.7	30	30	30	30	30	30	30	30	19.9		
Direct Solar Radiation			-	43.6	86.6	103.0	114.2	115.2	106.5	73.2	34.6	-		
Angle of Incidence			-	51.9	42.6	35.0	30.7	30.7	35.0	42.6	51.9	-		

Table No. 5. TRANSMITTED ENERGY THROUGH 1 SQUARE FOOT OF DOUBLE GLAZED WINDOW

NOVEMBER Year

Apparent Time-Hour Ending	7	8	9	10	11	12	1	2	3	4	5	6	Totals
Transmittance % (Windowed Area - 2 Plates)		-	68.0	72.5	74.0	75.0	75.0	74.0	72.5	68.0	-		
Transmitted Direct Radiation (BTU/ft^2)		-	29.6	64.3	76.2	85.8	86.5	78.8	53.1	23.6	-		
Transmitted Diffuse Radiation (Assumed Aug. Diffuse Transmittance - 65%) BTU/ft^2		16.1	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	13.0		224.0
Total Radiation (BTU/ft^2) Designated Hour		16.1	49.1	83.8	95.7	105.3	106.0	98.3	72.6	53.1	13.0		693.0

Table No. 6. TRANSMITTED ENERGY THROUGH 1 SQUARE FOOT OF TRIPLE GLAZED COLLECTOR

NOVEMBER Year

Apparent Time-Hour Ending	7	8	9	10	11	12	1	2	3	4	5	6	Totals
Transmittance x Absorbtivity $(\tau\alpha)$ in % (3 Plates-Low Reflectivity Glass)		-	73	80	83	84	84	83	80	73	-		
Transmitted Direct Radiation (BTU/ft^2)		-	31.8	69.5	85.5	96.0	97.0	88.5	58.5	25.2	-		
Transmitted Diffuse Radiation (Assumed Aug. Diffuse Transmission - 75% BTU/ft^2		18.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	14.9		258.0
Total Radiation (BTU/ft^2)		18.5	54.3	92.0	108.0	118.5	119.5	111.0	81.0	47.7	14.9		765.0

Table No. 7

AVAILABLE ENERGY

DECEMBER	Year													
Apparent Time-Hour Ending		7	8	9	10	11	12	1	2	3	4	5	6	Total
Solar & Sky Radiation	1946		2.4	14.9	25.2	30.6	34.8	37.5	35.4	23.4	13.2	2.5		
Incident on a Vertical	1947		3.2	20.5	39.0	51.0	57.9	57.4	52.1	37.9	19.9	3.3		
South Facing Surface (gram-cal/cm^2)	1948		2.9	21.4	31.1	37.0	40.3	39.1	34.9	26.5	14.2	1.8		
3 Year Mean Value (gm-cal/cm^2)			2.8	18.9	31.8	39.5	44.3	44.7	40.8	29.3	15.8	2.5		
3 Year Mean Value (BTU/ft^2)			10.3	69.7	117.2	145.0	163.2	165.0	151.0	108.1	56.2	9.2		
Diffuse Sky Radiation 1st 30 or less BTU/ft^2			10.3	30	30	30	30	30	30	30	30	9.2		
Direct Solar Radiation			-	39.7	87.2	115.0	133.2	135.0	121.0	78.0	26.5	-		995
Angle of Incidence			-	48.1	38.8	29.8	24.5	24.5	29.8	38.8	48.1	-		

Table No. 8. TRANSMITTED ENERGY THROUGH 1 SQUARE FOOT OF DOUBLE GLAZED WINDOW

DECEMBER Year

Apparent Time-Hour Ending	7	8	9	10	11	12	1	2	3	4	5	6	Total
Transmittance % (Windowed Area - 2 Plates)		-	70.0	73.5	75.0	75.5	75.5	75.0	73.5	70.0	-		
Transmitted Direct Radiation (BTU/ft^2)		-	27.8	65.0	86.2	100.5	102.0	90.7	57.3	18.6	-		
Transm. Diffuse Radiation (Assumed Aug. Diffuse Transmittance - 65%BTU/ft^2		6.7	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	6.0		208.0
Total Radiation (BTU/ft^2) Designated Hour		6.7	47.3	84.5	105.7	120.0	121.5	110.2	76.8	38.1	6.0		717.0

Table No. 9. TRANSMITTED ENERGY THROUGH 1 SQUARE FOOT OF TRIPLE GLAZED COLLECTOR

DECEMBER Year

Apparent Time-Hour Ending	7	8	9	10	11	12	1	2	3	4	5	6	Total
Transmittance x Absorbtivity (τα) in % (3 Plates-Low Reflectivity Glass)		-	75	81	84	84	84	84	81	75	-		
Transmitted Direct Radiation (BTU/ft^2)		-	29.6	70.5	96.5	112.0	113.0	101.5	63.2	19.9	-		
Transmitted Diffuse Radiation (Assumed Aug. Diffuse Transmission - 75%) BTU/ft^2		7.7	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	6.9		240.0
Total Radiation		7.7	52.1	93.0	119.0	134.5	135.5	123.0	85.7	42.4	6.9		798.0

Table No. 10

AVAILABLE ENERGY

JANUARY Apparent Time-Hour Ending	Year	7	8	9	10	11	12	1	2	3	4	5	6	Total
Solar & Sky Radiation	1947		3.5	14.0	30.8	37.0	42.8	43.7	40.5	31.5	18.7	4.2		
Incident on a Vertical	1948		3.7	14.8	25.2	30.5	32.1	31.3	32.4	29.0	19.8	5.0		
South Facing Surface (gram-cal/cm^2)	1949		2.3	11.9	21.5	29.8	37.0	37.1	34.4	24.6	10.5	1.7		
3 Year Mean Value (gm-cal/cm^2)			3.2	13.6	25.8	32.4	37.3	37.4	35.8	28.4	16.3	3.6		
3 Year Mean Value (BTU/ft^2)			11.8	50.2	95.1	119.6	137.8	138.0	132.0	104.8	60.2	13.3		995.0
Diffuse Sky Radiation 1st 30 or less BTU/ft^2			11.8	30	30	30	30	30	30	30	30	13.3		
Direct Solar Radiation			-	20.2	65.1	89.6	107.8	108.0	102.0	74.8	30.2	-		
Angle of Incidence			-	49.6	40.2	32.0	27.4	27.4	32.0	40.2	49.6	-		

Table No. 11. TRANSMITTED ENERGY THROUGH 1 SQUARE FOOT OF DOUBLE GLAZED WINDOW

JANUARY Year

Apparent Time-Hour Ending	7	8	9	10	11	12	1	2	3	4	5	6	Total
Transmittance % (Windowed Area - 2 Plates)		-	68.5	73.0	74.5	75.5	75.5	74.5	73.0	68.5	-		
Transmitted Direct Radiation (BTU/ft^2)		-	13.7	47.9	66.8	81.3	81.5	76.0	54.6	20.7	-		
Transm. Diffuse Radiation (Assumed Aug. Diffuse Transmittance - 65%)BTU/ft^2		7.7	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	8.6		211.0
Total Radiation (BTU/ft^2) Designated Hour		7.7	33.2	67.0	86.3	100.8	101.0	95.5	74.1	40.2	8.6		614.0

Table No. 12. TRANSMITTED ENERGY THROUGH 1 SQUARE FOOT OF TRIPLE GLAZED COLLECTOR

JANUARY Year

Apparent Time-Hour Ending	7	8	9	10	11	12	1	2	3	4	5	6	Total
Transmittance x Absorbtivity ($\tau\alpha$) in % (3 Plates-Low Reflectivity Glass)		-	75	81	83	84	84	83	81	75	-		
Transmitted Direct Radiation (BTU/ft^2)		-	15.3	52.7	74.4	89.7	90.6	84.6	60.6	22.8	-		
Transmitted Diffuse Radiation (Assumed Avg. Diffuse Transmission - 75%)BTU/ft^2		8.9	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	10.0		244.0
Total Radiation		8.9	37.8	75.2	96.9	112.2	113.1	107.1	83.1	45.3	10.0		690.0

Table No. 13

AVAILABLE ENERGY

FEBRUARY Apparent Time-Hour Ending	Year	7	8	9	10	11	12	1	2	3	4	5	6	Total
Solar & Sky Radiation	1947	0.4	8.9	21.8	33.5	45.9	53.0	45.1	38.4	32.0	22.9	9.9	0.6	
Incident on a Vertical	1948	0.6	11.2	29.9	41.1	49.4	53.3	54.6	53.3	42.2	27.1	10.9	0.8	
South Facing Surface ($gram-cal/cm^2$)	1949	0.2	7.5	19.5	31.8	43.0	49.2	43.6	37.9	31.4	21.0	8.0	0.3	
3 Year Mean Value ($gm-cal/cm^2$)		0.4	9.2	23.7	35.5	46.1	50.2	47.8	43.2	35.2	23.7	9.6	0.6	
3 Year Mean Value (BTU/ft^2)		1.5	34.0	87.0	131.0	170.0	185.0	176.0	159.0	130.0	87.5	35.4	2.2	
Diffuse Sky Radiation 1st 30 or less BTU/ft^2		1.5	30	30	30	30	30	30	30	30	30	30	2.2	
Direct Solar Radiation		-	4.0	57.0	101.0	140.0	155.0	146.0	129.0	100.0	57.5	5.4	-	
Angle of Incidence		-	65.2	55.6	46.8	39.1	35.2	35.2	39.1	46.8	55.6	65.2	-	

Table No. 14. TRANSMITTED ENERGY THROUGH 1 SQUARE FOOT OF DOUBLE GLAZED WINDOW

FEBRUARY Year

Apparent Time-Hour Ending	7	8	9	10	11	12	1	2	3	4	5	6	Total
Transmittance % (Windowed Area - 2 Plates)	-	53.0	65.5	70.5	73.0	74.0	74.0	73.0	70.5	65.5	53.0	-	
Transmitted Direct Radiation (BTU/ft^2)	-	2.1	37.6	71.2	102.1	115.0	108.0	94.2	70.5	37.6	2.9	-	
Transm. Diffuse Radiation (Assumed Aug. Diffuse Transmittance - 65%)BTU/ft^2	1.0	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	1.4	197.0
Total Radiation (BTU/ft^2) Designated Hour	1.0	21.6	57.1	90.7	121.6	134.5	127.5	113.7	90.0	57.1	22.4	1.4	838.0

Table No. 15. TRANSMITTED ENERGY THROUGH 1 SQUARE FOOT OF TRIPLE GLAZED COLLECTOR

FEBRUARY Year

Apparent Time-Hour Ending	7	8	9	10	11	12	1	2	3	4	5	6	Total
Transmittance x Absorbtivity ($\tau\alpha$) in % (3 Plates-Low Reflectivity Glass	-	55	70	77	81	83	83	81	77	70	55	-	
Transmitted Direct Radiation (BTU/ft^2)	-	2.2	40.0	77.8	113.3	128.5	121.0	104.5	77.0	40.3	3.0	-	
Transmitted Diffuse Radiation (Assumed Aug. Diffuse Transmission - 75%)BTU/ft^2	1.1	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	1.7	228.0
Total Radiation	1.1	24.7	42.5	100.3	135.8	151.0	143.5	127.0	99.5	62.8	25.5	1.7	913.0

Table No. 16

AVAILABLE ENERGY

MARCH Apparent Time-Hour Ending	Year	7	8	9	10	11	12	1	2	3	4	5	6	Total
Solar & Sky Radiation Incident on a Vertical South Facing Surface (gram-cal/cm^2)	1947	2.6	14.7	28.4	36.6	39.0	43.3	41.5	37.7	32.3	25.7	13.2	3.0	
	1948	1.8	10.5	22.4	32.3	32.2	42.1	40.2	35.3	28.8	19.0	10.0	1.9	
	1949	2.1	11.0	23.3	30.1	35.8	39.8	41.8	37.4	31.7	21.2	10.8	2.2	
3 Year Mean Value (gm-cal/cm^2)		2.2	12.1	23.7	33.0	35.7	41.7	41.2	36.8	30.9	21.9	11.3	2.4	
3 Year Mean Value BTU/ft^2		8.1	44.6	87.5	122.0	132.0	154.0	152.0	136.0	114.0	80.8	41.7	8.8	1080.0
Diffuse Sky Radiation 1st 30 or less BTU/ft^2		8.1	30	30	30	30	30	30	30	30	30	30	8.8	
Direct Solar Radiation		-	14.6	57.5	92.0	102.0	124.0	122.0	106.0	84.0	50.8	11.7	-	
Angle of Incidence		-	73.3	63.8	55.7	49.1	45.7	45.7	49.1	55.7	63.8	73.3	-	

Table No. 17. TRANSMITTED ENERGY THROUGH 1 SQUARE FOOT OF DOUBLE GLAZED WINDOW

MARCH   Year

Apparent Time-Hour Ending	7	8	9	10	11	12	1	2	3	4	5	6	Total
Transmittance % (Windowed Area - 2 Plates)	-	34.5	55.5	68.5	69.5	71.0	71.0	69.5	68.5	55.5	34.5	-	
Transmitted Direct Radiation (BTU/ft^2)	-	5.0	31.9	63.0	70.8	88.0	86.6	73.7	57.5	28.2	4.0	-	
Transm. Diffuse Radiation (Assumed Aug. Diffuse Transmittance - 65%) BTU/ft^2	5.3	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	5.7	206.0
Total Radiation (BTU/ft^2) Designated Hour	5.3	24.5	51.4	82.5	90.3	107.5	106.1	93.2	77.0	47.7	23.5	5.7	718.0

Table No. 18. TRANSMITTED ENERGY THROUGH 1 SQUARE FOOT OF TRIPLE GLAZED COLLECTOR

MARCH   Year

Apparent Time-Hour Ending	7	8	9	10	11	12	1	2	3	4	5	6	Total
Transmittance x Absorbtivity ($\tau\alpha$) in % (3 Plates-Low Reflectivity Glass)	-	33	58	69	76	78	78	76	69	58	33	-	
Transmitted Direct Radiation (BTU/ft^2)	-	4.8	33.4	63.4	77.5	96.7	95.2	80.5	57.8	29.5	3.9	-	
Transmitted Diffuse Radiation (Assumed Aug. Diffuse Transmission - 75%) BTU/ft^2	6.1	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	6.6	238.0
Total Radiation	6.1	27.3	55.9	85.9	100.0	129.2	117.7	103.0	80.3	52.0	26.4	6.6	790.0

Table No. 19

AVAILABLE ENERGY

APRIL Apparent Time-Hour Ending	Year	6	7	8	9	10	11	12	1	2	3	4	5	6	7	Total
Solar & Sky Radiation	1947	0.4	3.3	9.2	18.9	28.4	32.8	34.1	34.7	32.4	28.0	18.9	10.2	3.6	0.6	
Incident on a Vertical	1948	0.4	3.0	9.6	19.4	29.1	34.2	35.3	31.5	28.7	25.1	18.5	9.2	3.2	0.5	
South Facing Surface (gram-cal/cm^2)	1949	0.2	2.3	8.3	16.0	24.9	30.2	33.3	33.3	28.2	20.8	14.7	7.0	2.5	0.3	
3 Year Mean Value (gm-cal/cm^2)		0.3	2.9	9.0	18.1	27.5	32.4	34.2	33.2	29.8	24.6	17.4	8.8	3.1	0.5	
3 Year Mean Value (BTU/ft^2)		1.0	10.7	33.2	66.8	101.5	119.5	126.0	122.5	110.0	90.8	64.2	32.4	11.4	1.8	892.0
Diffuse Sky Radiation 1st 30 or less BTU/ft^2		1.0	10.7	30	30	30	30	30	30	30	30	30	30	11.4	1.8	
Direct Solar Radiation		-	-	3.2	36.8	71.5	89.5	96.0	92.5	80.0	60.8	34.2	2.4	-	-	
Angle of Incidence		-	-	82.5	73.8	66.0	60.8	57.8	57.8	60.8	66.0	73.8	82.5	-	-	

Table No. 20. TRANSMITTED ENERGY THROUGH 1 SQUARE FOOT OF DOUBLE GLAZED WINDOW

APRIL Year

Apparent Time-Hour Ending	6	7	8	9	10	11	12	1	2	3	4	5	6	7	Total
Transmittance % (Windowed Area - 2 Plates)	-	-	8.0	33.5	52.0	59.5	63.5	63.5	59.5	52.0	33.5	8.0	-	-	
Transmitted Direct Radiation (BTU/ft^2)	-	-	0.3	12.3	37.2	53.2	61.0	58.7	47.6	31.6	11.5	0.2	-	-	
Transm. Diffuse Radiation (Assumed Aug. Diffuse Transmittance - 65%) BTU/ft^2	0.6	6.8	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	7.4	1.2	201.0
Total Radiation (BTU/ft^2) Designated Hour	0.6	6.8	19.8	32.8	56.7	72.7	80.5	78.2	67.1	56.1	31.0	19.7	7.4	1.2	530.0

Table No. 21. TRANSMITTED ENERGY THROUGH 1 SQUARE FOOT OF TRIPLE GLAZED COLLECTOR

APRIL Year

Apparent Time-Hour Ending	6	7	8	9	10	11	12	1	2	3	4	5	6	7	Total
Transmittance x Absorbtivity ($\tau\alpha$) in % (3 Plates-Low Reflectivity Glass)	-	-	11	30	54	63	68	68	63	54	30	11	-	-	
Transmitted Direct Radiation (BTU/ft^2)			3.5	11.0	38/6	56.5	65.4	62.8	50.5	32.8	10.3	2.6	-	-	
Transmitted Diffuse Radiation (Assumed Aug. Diffuse Transmission - 75%) BTU/ft^2	0.8	8.0	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	8.6	1.4	244.0
Total Radiation	0.8	8.0	26.0	33.5	61.1	79.0	87.9	85.3	73.0	55.3	32.8	25.1	8.6	1.4	578.0

To find Net Usable Solar Energy From Collector = Q_c

Per cent Sunshine = S

Transmitted Diffuse Radiation = R_{D_c}

Transmitted Direct Radiation = R_{S_c}

Total Transmitted Radiation = R_{T_c}

)Reradiation,
)Conduction and Convection Losses (in percent of R_T) = C_L

$$10^{-3}\cdot(R_s S + 100\, R_D)(100-C_L) = Q_c \text{ - (BTU/Ft}^2\text{/Day)}$$

Month	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Year							
1949	596	466	564	484	563	524	416

N.B. An Average Value for S = 9% used in calculations

Net Useful Diffuse and Direct Gain Through

Window = Q_w - (BTU/Ft^2/Day)

$$Q_w = \frac{R_{S_w}\cdot S}{100} + R_{D_w}$$

South Facing Vertical Window (Reradiation,Conduction & Convection Not Included)

Month	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Year							
1949	623	458	553	373	562	518	411

North Facing Vertical Window (Reradiation & Convection & Conduction Losses Not Included)

$$Q_w = R_{D_w} \text{ (BTU/Ft}^2\text{/Day)}$$

Month	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Q_w	202	224	208	211	197	206	201

Table No. 22

DEGREE DAYS

Days	31	28	31	30	31	30	31	31	30	31	30	31
Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Year 1947	1001	992	847	537	286	86	0	4	137	164	715	1073
1948	1294	1118	837	511	313	113	3	1	76	341	461	892
1949	940	855	799	423	192	30	0	1	105	230	644	872
Mean	1078	988	828	490	264	73	1	2	106	245	607	646
Average T (re 65°)	34.8	35.3	26.7	16.3	8.5	2.4	0.1	0.3	3.4	7.9	20.2	20.8
Average T (re 70°)	39.8	40.3	31.7	21.3	13.5	7.4	5.1	5.3	8.4	12.9	25.2	25.8

Mean Total = 5328

Table No. 23

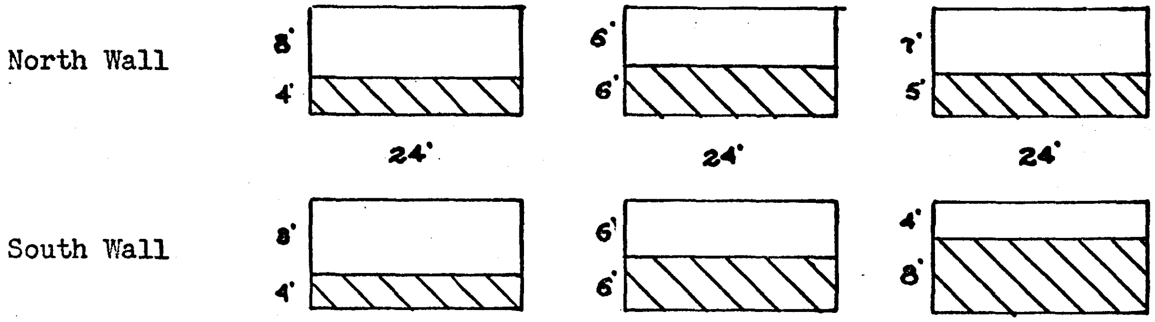
AVERAGE TEMPERATURE

Month Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1947	32.6	29.6	37.7	47.2	56.9	65.4	74.4	73.2	64.8	61.6	41.2	30.4
1948	23.4	26.6	38.0	48.0	55.0	63.6	74.5	73.7	65.7	54.2	49.6	36.3
1949	34.6	34.4	39.2	50.8	60.4	71.6	76.2	74.4	63.2	58.4	43.5	36.8
Mean	30.2	30.2	38.3	48.7	57.4	66.9	73.0	73.8	64.6	58.1	44.8	34.5
t (re 70°)	39.8	39.8	31.7	21.3	12.6	3.1	-3.0	-3.8	5.4	11.9	25.2	35.5
t (re 110°)	79.8	79.8	71.7	61.3	52.6	43.1	37.0	37.2	45.4	51.9	65.2	75.5

Table No. 24

PER CENT SUNSHINE

Month Year	Jan.	Feb.	Mar.	Apr.	–	Oct.	Nov.	Dec.
1949	40	57	61	63		59	50	68



Area Glass $\qquad \frac{384}{192} = \frac{2}{1} \qquad \frac{288}{288} = \frac{1}{1} \qquad \frac{264}{312} = \frac{0.846}{1}$

Area Spandrel

Loss

Glass

$$Q_L = \frac{\qquad\qquad}{100{,}000}$$

$$= \frac{0.45 \cdot A. \quad T \cdot 24}{100{,}000} \qquad k = 0.0415 \qquad k = 0.0311 \qquad k = 0.0290$$

$$= \frac{10.8 . A. \quad T}{100{,}000}$$

$= k. \quad T$ Therms

North Spandrel

$$Q_L = \frac{0.06 . A. \quad T . 24}{100{,}000} \qquad k = 0.0014 \qquad k = 0.0021 \qquad k = 0.0017$$

$= k. \quad T$

Solar Spandrel

$$Q_L = \frac{0.06 . A. \quad T . 16}{100{,}000} \qquad k = 0.0009 \qquad k = 0.0014 \qquad k = 0.0019$$

$= k. \quad T$

Air Loss

$$Q_L = \underline{C_{pa}.V.da.\quad T.}$$

V = Ft^3/Min/Person.   #of People =Ft^3/Hr.

$$= \frac{0.24.8640.0.075.\quad T.8}{100,000}$$

Ft^3/Min/Person = 12 C.F.M.
12 People/Bay
t = Time (Hrs.)

$$= k \quad T, \quad - \quad k = 0.0124$$

Animal Gain $Q_G = \frac{\text{BTU/Person/Hour-Hours Occupancy}}{100,000} = \frac{\text{490.Hours Occupancy}}{100,000}$

Fixture Gain $Q_G = \frac{\text{3.416.\#Lamps.Watts/Lamp.\% Cloudy Days.t}}{107}$

$= k.\%$ Cloudy Days $k = 0.0322$

128 Lamps/Bay

SKY CONDITIONS

Year - 1947 Month	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Clear (Scale 0-3)	8	8	10	8	10	6	10
Partly Cloudy (Scale 4-7)	5	9	5	5	9	5	10
Cloudy (Scale 8-10)	10	14	14	18	11	17	12

Year - 1948 Month	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Clear (Scale 0-3)	8	8	10	8	10	6	10
Partly Cloudy (Scale 4-7)	2	8	11	6	10	7	6
Cloudy (Scale 8-10)	21	13	13	16	11	17	15

Year - 1949 Month	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Clear (Scale 0-3)	12	7	12	8	8	9	8
Partly Cloudy (Scale 4-7)	5	9	5	5	9	5	10
Cloudy (Scale 8-10)	14	14	14	18	11	17	12
Mean(Cloudy)	16	12	13	17	10	16	12
% Cloudy (Scale 8-10)	51.7	40.0	42.0	55.0	36.8	51.7	40.0

	Month									
$\frac{\text{Window Area}}{\text{Spandrel Area}} =$		$\frac{384}{192} = \frac{2}{1}$	k = 0.0415		$\frac{288}{288} = \frac{1}{1}$	k = 0.0311		$\frac{264}{312} = \frac{0.846}{1}$	k = 0.0290	
		k	ΔT	Therms/Day	k	ΔT	Therms/Day	k	ΔT	Therms/Day
Conduction Glass - 24 Hours	Oct.	0.0415	x 12.9	= 0.535	0.0311	x 12.9	= 0.401	0.029	x 12.9	= 0.364
$Q_c = \frac{U.A.\Delta T.24}{100,000}$	Nov.	"	x 25.2	= 1.046	"	x 25.2	= 0.784	"	x 25.2	= 0.731
$= k\Delta T$	Dec.	"	x 25.8	= 1.070	"	x 25.8	= 0.802	"	x 25.8	= 0.748
	Jan.	"	x 39.8	= 1.652	"	x 39.8	= 1.237	"	x 39.8	= 1.152
	Feb.	"	x 40.3	= 1.673	"	x 40.3	= 1.253	"	x 40.3	= 1.164
	Mar.	"	x 31.7	= 1.316	"	x 31.7	= 0.985	"	x 31.7	= 0.920
	Apr.	"	x 21.3	= 0.884	"	x 21.3	= 0.662	"	x 21.3	= 0.616
			Total	= 8.176		Total	= 6.124		Total	= 5.695

			k = 0.0014			k = 0.0021			k = 0.0017	
Conduction North Spandrel 24 Hours	Oct.	0.0014	x 12.9	= 0.018	0.0021	x 12.9	= 0.027	0.0017	x 12.9	= 0.022
	Nov.	"	x 25.2	= 0.035	"	x 25.2	= 0.053	"	x 25.2	= 0.043
$Q_c = k \cdot \Delta T$	Dec.	"	x 25.8	= 0.036	"	x 25.8	= 0.054	"	x 25.8	= 0.044
U = 0.06	Jan.	"	x 39.8	= 0.056	"	x 39.8	= 0.084	"	x 39.8	= 0.068
	Feb.	"	x 40.3	= 0.056	"	x 40.3	= 0.085	"	x 40.3	= 0.069
	Mar.	"	x 31.7	= 0.044	"	x 31.7	= 0.067	"	x 31.7	= 0.054
	Apr.	"	x 21.3	= 0.030	"	x 21.3	= 0.045	"	x 21.3	= 0.036
			Total	= 0.275		Total	= 0.415		Total	= 0.336

		k = 0.0009			k = 0.0014			k = 0.0019		
		k	ΔT	Therms/Day	k	ΔT	Therms/Day	k	ΔT	Therms/Day
Conduction Solar Spandrel 16 hours	Oct.	0.0009	x 12.9	= 0.012	0.0014	x 12.9	= 0.018	0.0019	x 12.9	= 0.024
	Nov.	"	x 25.2	= 0.023	"	x 25.2	= 0.035	"	x 25.2	= 0.048
$Q = k.\Delta T$	Dec.	"	x 25.8	= 0.023	"	x 25.8	= 0.036	"	x 25.8	= 0.049
$U = 0.06$	Jan.	"	x 39.8	= 0.036	"	x 39.8	= 0.056	"	x 39.8	= 0.076
	Feb.	"	x 40.3	= 0.036	"	x 40.3	= 0.056	"	x 40.3	= 0.077
	Mar.	"	x 31.7	= 0.028	"	x 31.7	= 0.044	"	x 31.7	= 0.060
	Apr.	"	x 21.3	= 0.019	"	x 21.3	= 0.030	"	x 21.3	= 0.041
			Total	= 0.177		Total	= 0.275		Total	= 0.375

		k = 0.0124				
Loss Fresh Air Makeup 12 C.F.M./Person 8 Hours	Oct.	0.0124	x 12.9	= 0.160		
	Nov.	"	x 25.2	= 0.312	SAME AS 1st COLUMN	SAME AS 1st COLUMN
$Q = \frac{C_{pa} \cdot V \cdot da \cdot \Delta T \cdot t}{100{,}000}$	Dec.	"	x 25.8	= 0.320		
$= k \cdot \Delta T$	Jan.	"	x 39.8	= 0.493		
	Feb.	"	x 40.3	= 0.500		
	Mar.	"	x 31.7	= 0.393		
	Apr.	"	x 21.3	= 0.264		
			Total	= 2.442		

			Therms/Day		Therms/Day		Therms/Day
	Oct.		0.725		0.606		0.570
Total Daily Loss	Nov.		1.416		1.184		1.134
	Dec.		1.449		1.212		1.161
	Jan.		2.237		1.870		1.789
	Feb.		2.265		1.894		1.810
	Mar.		1.781		1.489		1.427
	Apr.		1.197		1.001		0.957
		Total	10.970	Total	9.256	Total	8.848
		Mean	1.579	Mean	1.322	Mean	1.264

			$A_w = 192$ Therms/Day		$A_w = 144$ Therms/Day		$A_w = 96$ Therms/Day
Window Gain-South Wall Direct and Diffuse Radiation	Oct.		0.119		0.092		0.061
	Nov.		0.088		0.066		0.044
$Q_G = \frac{\text{B.T.U./Ft}^2\text{/Day}\cdot A_W}{100,000}$	Dec.	From Results PP.15	0.106	From Results PP.15	0.080	From Results PP.15	0.053
	Jan.		0.072		0.054		0.036
	Feb.		0.108		0.082		0.054
	Mar.		0.100		0.075		0.050
	Apr.		0.079		0.059		0.039
		Total	0.672	Total	0.508	Total	0.337

			$A_w = 192$ Therms/Day		$A_w = 144$ Therms/Day		$A_w = 168$ Therms/Day
Window Gain-North Wall Diffuse Radiation	Oct.		0.039		0.029		0.034
	Nov.		0.043		0.032		0.038
$Q_G = \frac{\text{B.T.U./Ft}^2\text{/Day}\cdot A_W}{100,000}$	Dec.		0.040		0.030		0.035
	Jan.	From Results PP.15	0.041	From Results PP.15	0.030	From Results PP.15	0.035
	Feb.		0.038		0.028		0.033
	Mar.		0.040		0.030		0.035
	Apr.		0.039		0.029		0.034
		Total	0.280	Total	0.208	Total	0.244

		Therms/Day		
Animal Gain Sensible & Latent 8 Hr.Occupancy $Q_G = \frac{\text{BTU/Hr.}8}{100,000}$	Avg.	0.069	Same as 1st Column	Same as 1st Column

Fixture Gain
Illumination
8 Hr.-Cloudy
days only

$Q_G = k \cdot \%$ Cloudy Days

k = 0.032

	k		%Cloudy Days		Therms/Day
Oct.	0.032	x	51.7	=	1.714
Nov.	"	x	40.0	=	1.408
Dec.	"	x	42.0	=	1.480
Jan.	"	x	55.0	=	1.936
Feb.	"	x	36.8	=	1.296
Mar.	"	x	51.7	=	1.816
Apr.	"	x	40.0	=	1.408
			Total		11.058

Same as 1st Column

Same as 1st Column

	Month	$A_c = 96$ Therms/Day	$A_c = 144$ Therms/Day	$A_c = 192$ Therms/Day
Solar Collector Gain	Oct.	0.572	0.860	1.145
	Nov.	0.447	0.671	0.894
$Q = \frac{BTU/Ft^2/Day \cdot A_c}{100,000}$	Dec.	0.542	0.813	1.082
	Jan.	0.368	0.553	0.737
	Feb.	0.542	0.813	1.082
	Mar.	0.503	0.755	1.005
	Apr.	0.400	0.598	0.798
	Total	3.374	5.063	6.743

	Month	Therms/Day	Therms/Day	Therms/Day
Total Gain	Oct.	2.516	2.764	3.023
	Nov.	2.055	2.246	2.639
	Dec.	2.168	2.472	2.719
	Jan.	2.187	2.573	2.813
	Feb.	1.953	2.288	2.534
	Mar.	2.528	2.676	2.975
	Apr.	1.995	2.163	2.348
	Total	15.402	17.182	19.051
	Mean	2.200	2.455	2.721