PHASE-I FINAL REPORT

BY NORTH DESIGN A/E/P
3601 GLENN LN.
MIDDLETON, WI 53562
608 831 8900

FOR GORDON D. KIEFFER GRANTEE
821 TURNER STREET
WAUSAU, WI 54401

US DEPT OF ENERGY
PASSIVE SOLAR COMMERCIAL
DEMONSTRATION PROGRAM

COOPERATIVE AGREEMENT #:
DE-FC02-80CS30343

INDEX

GENERAL PROJECT DOCUMENTATION

OVERVIEW: The following narrative is essentially a summary of the entire report. It documents the main or critical points of our work on this project over the last three-fourths of the year. Details of all the tasks and activities are more fully explained in each subsection. Essentially the overall outcome of this project was one which made our firm far more cognizant of the energy aspects of commercial buildings. At the beginning of the project we realized that the design and analytical process involved would be far different from that used in residential work, which has been the main facet of our practice. However, we perceived the process as just involving a different look at the thermal functioning of the building. The pre-design energy analysis revealed a far different perspective. It became evident that thermal factors were only one of a number of critical energy consumption parameters. The process we went through through and the decisions we made are more fully documented later in this report. The final design solution we arrived at is a reflection of all the varying energy related demands put on both the architectural programming (pre-design) and design process. A description of the program and our resulting design solution follows. The drawings accompanying this report further illustrates the solution.

DESIGN PROGRAM AND SOLUTION: The original program and intention was the passive solar retrofit of a small existing commercial/residential building. The final solution is a passive solar retrofit concept addressing the major energy consumption factors for this type of use. We feel the solution also represents a design strategy for other similar buildings in northern climates. The owner's needs centered around the rehabilitation of a +60 year old building which needed both additional space and an energy retrofit to make it an economically viable entity. The final solution consists of an add on gallery/sunspace which is integrated into the existing structure both in terms of energy and architectural functioning. The sunspace solution solves a number of interrelated design problems presented both by the owner's requirements for additional –

OVERVIEW

space and the needs of making the retrofit building as energy efficient as possible. It also presented a number of potential problems which had to be addressed. The existing building is elongated in a north-south direction and has only a minimal southern exposure. The additional space could only be constructed at the south side of the existing building, thus adding to the north-south elongation. The sunspace solution maximizes the amount of south facing glass for solar heat gain, while still allowing a deep penetration of daylight into the existing building. In the design solution the spaces which require the highest levels of general illumination are located in the area with the highest amount of daylight. Essentially the back of the building becomes the front and vice versa. The main entry has changed location to the side with more ready access from the parking area, but still in close proximity to the street. To call attention to the entry, it is framed by a wood trellis which then continues around the building giving the diverse facade unity and relating it to its context (scaled to adjacent buildings to the east and the ivy covered fence to the west). Solar heated air can be circulated from the sunspace into either the upper or lower level (but only one at a time). This circulation pattern or loop is completed with return air plenums through the floors on the north side of the building.

Roof top light monitors provide a minimum of 30 fc of illumination over 50% of the time at the upper level. The monitors have overhangs to prevent excessive heat gain in summer, but allow it in winter. These concepts are more fully illustrated in the accompanying drawings.

DESIGN PROCESS: Our overall design procedure is documented in detail in later sections of this report. As opposed to ordinary design efforts this project saw a heavy involvement in architectural programming or as it has been described by DOE, as pre-design energy analysis. In terms of overall time this analysis represented about 50% of the entire (NONreporting) design effort. The first step was to analyze the existing building and what its energy needs would be if a "normal addition/rehabilitation" design was proposed. This energy usage became the "base case" by which all other concepts were to be compared to. The method used for the analysis was that developed by Booz, Allen and Hamilton as described in their book"ENERGY GRAPHICS". This same method was later used to evaluate the three alternative schematic design solutions.

The second task was to evaluate the natural energy potentials that existed at the site. This included climatic and solar characteristics, heating and cooling degree days, etc. This phase is also described in more detail later. From this data base we assessed the potential for solar heating, natural cooling and daylighting of the existing building and the proposed addition. These potential energy savings were then used to establish goals for energy conservation in the building.

The next step was to develop and evaluate three alternative design schemes which seemed to meet the established goals. These alternatives were then evaluated according to their energy use, cost and overall architectural function. One of these alternatives was selected for final design development.

UNAVAILABLE DESIGN TOOLS AND INFORMATION: In summary, I would have to say that in comparison to a few years ago, there are a number of well suited design tools available. The single area of weakness is that of daylighting, but it appears not to be much worse than the techniques available for any other lighting analysis. Specific site information was also weak at this location, but we felt enough information was available from surrounding areas to make reasonable interpolations. The major area of weakness was the links and interrelationships between the techniques. However, this may be a problem for all but the most sophisticated computer simulation techniques.

DESIGN
INFORMATION
AVAILABILITY

INCREMENTAL PASSIVE DESIGN/COST: The amount of effort involved in this project was an enormous burden financially and time wise. A good share of that effort must be considered educational. The total amount of time for energy analysis was three times that of design. In the future an effort of this type would cost a client a minimum of an additional 1 % more than our standard 7 % - 10 % commission, but probably 2 % more, or about a 25 % total increase in our normal fee structure.

INCREMENTAL
PASSIVE DESIGN
COSTS

PERFORMANCE ANALYSIS SUMMARY

THE FOLLOWING IS A TABULATED SUMMARY OF PREDICTED BLDG. ENERGY PERFORMANCE. IT CONTAINS TWO SEPERATE PERFORMANCE PREDICTIONS. THE FIRST IS BASED ON THE "ENERGY GRAPHICS" APPROACH FOR SPACE CONDITIONING AND UTILIZED SKY BRIGHTNESS ONLY IN THE CALCULATION OF LIGHTING MET BY SOLAR. IT IS A CONSERVATIVE ESTIMATE. THE SECOND ESTIMATE OF PERFORMANCE, ALTHOUGH MORE LIBERAL, WE BELIEVE IS MORE ACCURATE FROM OUR OWN EXPERIENCE. SPACE HEATING PREDICTION IS BASED ON THE SLR METHODS DEVELOPED AT LASL AND DAYLIGHTING MET BY SOLAR INCLUDES THE CALCULATED ADDITIONAL LIGHTING PROVIDED BY REFLECTED DIRECT BEAM SUNLIGHT.

SUMMARY PERFORMANCE ($\times 10^6$ BTU)

	HEATING	COOLING	LIGHTING	DHW & EQUIP	TOTAL	BTU/SF
BASE CASE	73	16.75	31.82	10*	131.57	41,116 BTU/SF**
FINAL (CONSERVATIVE)	41.7	9.9	19.2	10	80.8	25,156 BTU/SF
PASSIVE SOLAR SAVINGS	31.3	6.85	12.62	–	50.77	15,960 BTU/SF
% REDUCTION	43%	41%	40%	–	39%	39%
BASE CASE	73	16.75	31.82	10*	131.57	41,116 BTU/SF
FINAL (POTENTIAL)	38.5	9.9	15.363	10	73.763	22,965 BTU/SF
SOLAR SAVINGS	34.5	6.85	16.457	10	57.81	21,184 BTU/SF
% REDUCTION	47%	41%	52%	–	44%	44%

** OBVIOUSLY THE BASE CASE BUILDING BEING USED FOR COMPARISON PURPOSES IS QUITE ENERGY EFFICIENT TO BEGIN WITH @ 4.37 BTU/SF/DD FOR TOTAL ENERGY LOAD OR 2.68 BTU/SF/DD SPACE HEATING LOAD.

* REVISED FROM ORIGINAL ESTIMATED OF 7.5×10^6 BTU

ECONOMICS ANALYSIS SUMMARY

THIS SUMMARY ECONOMICS ASSESSMENT IS BASED ON THE ENERGY SAVINGS ATTRIBUTABLE TO THE SECOND PERFORMANCE ESTIMATE (THE MORE LIBERAL VS THE MORE CONSERVATIVE.) THE ECONOMIC APPROACH & CALCULATIONS ARE MORE FULLY DETAILED IN LATER SECTIONS OF THIS REPORT. THE FOLLOWING IS A SUMMARY OF THE PASSIVE SOLAR SAVINGS, COSTS AND PAYBACKS.

	HEATING	COOLING	LIGHTING
ENERGY SAVINGS (MMBTU)	34.4	9.9	16.46
ENERGY COSTS (MMBTU)	6^{80} *	16^{00} *	16^{00} *
1ST YEAR SAVINGS	$233.^{92}$	109^{60}	263^{36}
PASSIVE COMPONENT COSTS	$ $8,794^{00}$	$ $2,516^{00}$	$ 6053^{00}
COST/SAVINGS RATIO (1ST YR)	37.6	22.99	22.99
YEARS TO SIMPLE PAYBACK	37.6	22.99	22.99
YEARS TO DISC. PAYBACK	G.T 19 YRS	LT 19 YR	LT 19 YR.

* ELECTRICITY COST (1981 EST) $.054/Kwh = $$16^{00}$/MMBTU
GAS COSTS (1981 EST) $.58/CCF = $$6^{80}$/MMBTU

DESIGN PROCESS DOCUMENTATION

PRE-DESIGN TASKS

BUILDING ENERGY NEEDS

OVERVIEW: In order to establish a basis for comparison, it was necessary to define a hypothetical building. In our case an existing structure had to be redefined in terms of energy use. Certain basic levels of performance were assumed. Some of these assumptions were based on the building's historic energy performance. Primarily, the historic gas consumption levels were recorded to determine thermal performance of the building. This data seemed as a good base to correlate calculated thermal performance. The correlation was very close. Historic energy consumption data could not be used in determining electrical consumption because the previous occupant was more of a warehousing operation than an active retail establishment. Thus lighting levels were calculated based on providing a standard level of lighting (30 fc) for a commercial space in a fairly typical form. Equipment loads were also based strictly on conventional kwh per square foot figures for retail establishments. Due to anticipated higher levels of ventillation due to increased occupancy standard, minimum ventillation rates were assumed. In periods of overheating maximum levels of ventillation were assumed. The basic assumptions were also utilized in determining the additional energy consumption levels of the areas that were part of the anticipated building expansion.

The basic technique (or tool) used to evaluate this so-called typical or conventional solution was that as developed in the publication "Energy Graphics" published by the Energy & Environment Division of the firm of Booz, Allen & Hamilton Inc. as funded by U.S. Department of Energy. The techniques predict typical building thermal performance on a seasonalbasis. Since the method is useful only in predicting average conditions, the additional atypical days of peak summer and peak winter conditions were also calculated. These peak conditions were simulated in a computer assisted network analysis of thermal performance. Once the thermal performance was documented, the energy use of electricity for lighting was added to the total to develop a comprehensive energy budget for the building. We also intend to use this same technique and format to analyze the performance of the alternative concepts developed in the schematic design phase.

OVERVIEW

UNAVAILABLE INFORMATION: In terms of actual data that would have been useful, the following listing is provided. Primarily, it would have been very useful to have listings of actual conventional building energy consumption patterns based on varying assumptions of thermal envelope structure, ventillation rates, illumination levels and related interior architectural characteristics and resulting electrical energy consumption levels and summer air conditioning costs and energy use. The statistical studies compiled by the AIA/RE in the process of developing the Building Energy Performance Standards were useful for ballpark types of figures, but were difficult to fully utilize because no specific example and building descriptions were provided. Also, it would have been very useful to see the same type of detailed information on the "Technical Redesign" developed during the same operation. To have historic information of typical buildings or calculated performance of redesigned buildings could have shortened the activities necessary in assigning energy use levels in the proposed building t the pre-design phase.

The most obvious design (or pre-design) tool would be some type of computer aided building performance simulation program which could mirror the manual process described in "Energy Graphics." To increase accuracy the typical seasonal days could be analyzed on a hourly basis. It appears that the annual performance figures predicted by the method are fairly accurate. One additional tool related to this method, whether it be manually or computer assisted, would be a means or technique to define the "typical" seasonal days used in the analysis. More comments on this will be detailed in a similar section of this report concerning schematic design evaluation.

UNAVAILABLE INFORMATION

INCREMENTAL PASSIVE DESIGN COSTS

INCREMENTAL PASSIVE DESIGN COST

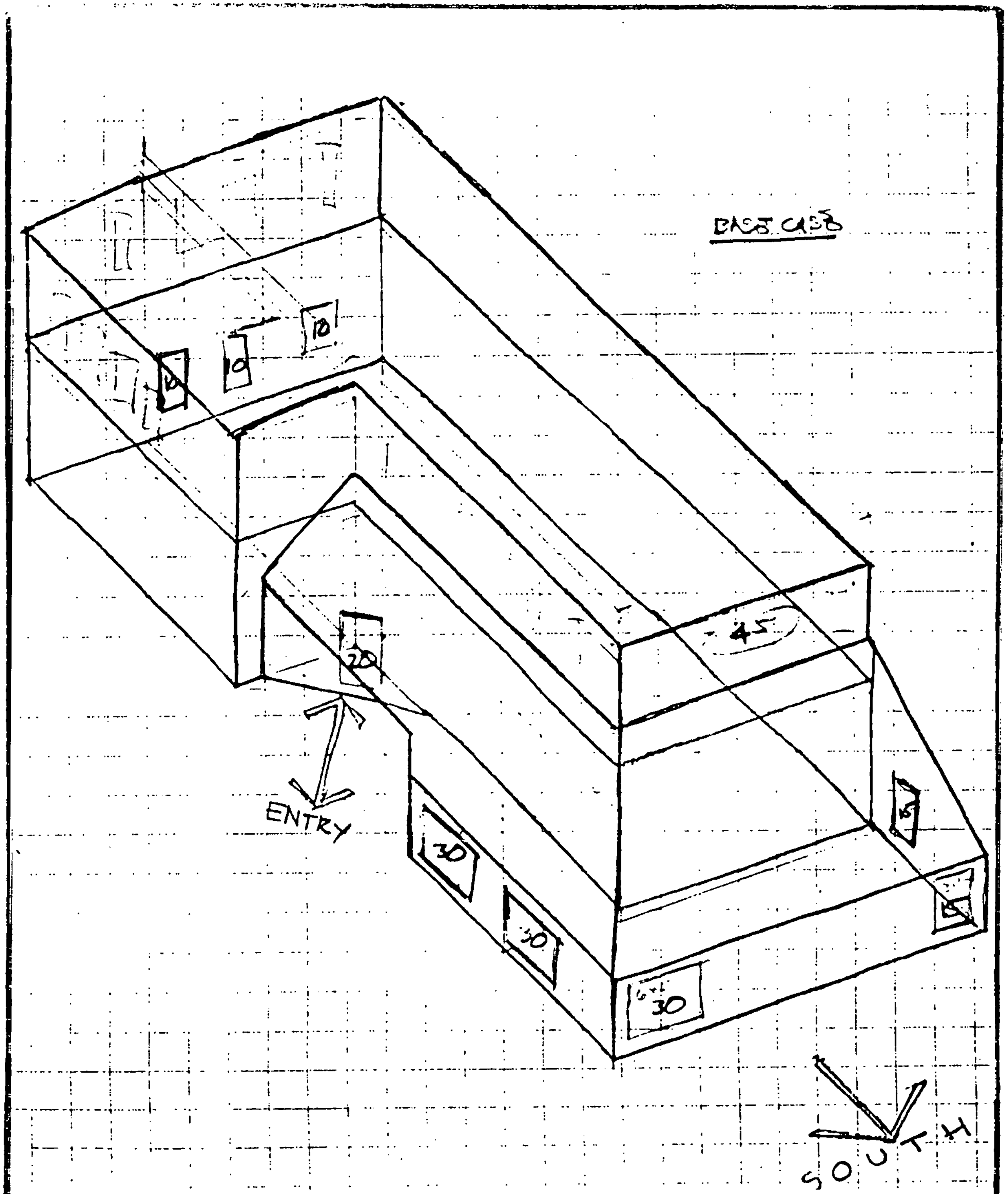
a) Breakdown: The added design costs associated with the definition and evaluation of a "base case" conventional building are detailed as follows:

PREVIOUS BUILDING'S ENERGY PERFORMANCE	
DATA COLLECTION/LITERATURE SURVEY	6 HRS.
DATA ASSESSMENT	4 HRS.
TYP. PERFORMANCE CONCLUSIONS	3 HRS.
CONVENTIONAL SOLUTION (BASE CASE) EVALUATION	
REVIEW OF ENERGY GRAPHIC APPRAISAL	10 HRS.
MODIFICATION & ELABORATION OF APPROACH	2 HRS.
DEFINITION OF CONVENTIONAL SOLUTION	4 HRS.
PREPARATION OF BLDG. DATA FOR ANALYSIS	3 HRS.
MANUAL ANALYSIS OF CONVENTIONAL BLDG. (THERMAL PERFORMANCE)	8 HRS.
ASSESSMENT OF LIGHT & EQUIP. LOADS	1 HR.
DOCUMENTATION OF BASE CASE DATA	6 HRS.
	47 HRS.

(GRAPHIC COSTS & COMPUTER TIME WERE MINIMAL)

b) The early activities alone were primarily staff learning costs (25 hrs.). One could expect to repeat this process in the future in approximately 16 hrs. given the right data. Hopefully with computer processing support and the proper software, the process could be accomplished with 6-7 hours of staff time and perhaps $14.00 of com puter time (HIGH).

PERFORMANCE
ANALYSIS
RESULTS



BUILDING SCHEMATIC

BUILDING/SPACE NAME COMMERCIAL/RETROFIT

APPROXIMATE AREA 1500 SF. HEIGHT 10/8 FT. VOLUME 14,000 CF

ENVIRONMENTAL CONTROL

TEMPERATURE VARIATION:	TIME OF DAY:	SEASON:
65° - 80° °F	8:00A - 8:00P	W/SP/SU/F
50° - 90° °F	8:00P - 8:00A	W/SP/SU/F
°F		

VENTILATION REQUIRED: BY CODE

215/1300 MIN/MAX CFM	ALL	ALL
MIN/MAX CFM		

(OVER)

BUILDING/SPACE DESCRIPTION

(OVER)

INTERNAL HEAT GENERATION

CODE: 30SF/PERSON → 43 PEOPLE
LIKELY: MAX 3EMPLOY + 6CUST = 9 } 7
AVE 3EMPLOY + 3CUST = 5 }

			TIME OF DAY:	SEASON:
PEOPLE: (#, HEAT)				
5	2,250	Btuh	8:00A - 12:00N	ALL
8	3,600	Btuh	12:00N - 8:00P	ALL
0	0	Btuh		
EQUIPMENT: (WATTS, HEAT)				
1Kw	3,400	Btuh	8:00A - 8:00P	ALL
0Kw	0	Btuh	8:00P - 8:00A	ALL
ILLUMINATION: (Fc, HEAT)				
30 fc	10,000	Btuh	8:00A - 8:00P	ALL
0 fc	1,000	Btuh	8:00P - 8:00A	ALL
TOTAL				
	15,650	Btuh	8:00A - 12:00N	ALL
	17,000	Btuh	12:00N - 8:00P	ALL
	1,000	Btuh	8:00P - 8:00A	ALL

(BUILDING DESCRIPTION CONTINUED)

ENVIRONMENTAL CONTROL & SCHEDULE

TEMPERATURE INSIDE (T_i) °F T_{LO} / T_{HI}

	12 MID	4 A.M.	8 A.M.	NOON	4 P.M.	8 P.M.	12 MID
WINTER	50/90	50/90	65/80	65/80	65/80	65/50	50/90
SPRING	50/90	50/90	65/80	65/80	65/80	65/80	50/90
SUMMER	50/70	[illegible]	65/80	65/80	65/80	65/80	60/90
FALL	[illegible]/90	[illegible]	[illegible]/80	65/80	65/50	65/80	50/90

VENTILATION (TOTAL FOR ALL SPACES) CFM   MIN / MAX

215 = 1 AC/HR.
1300 = 6AC/HR

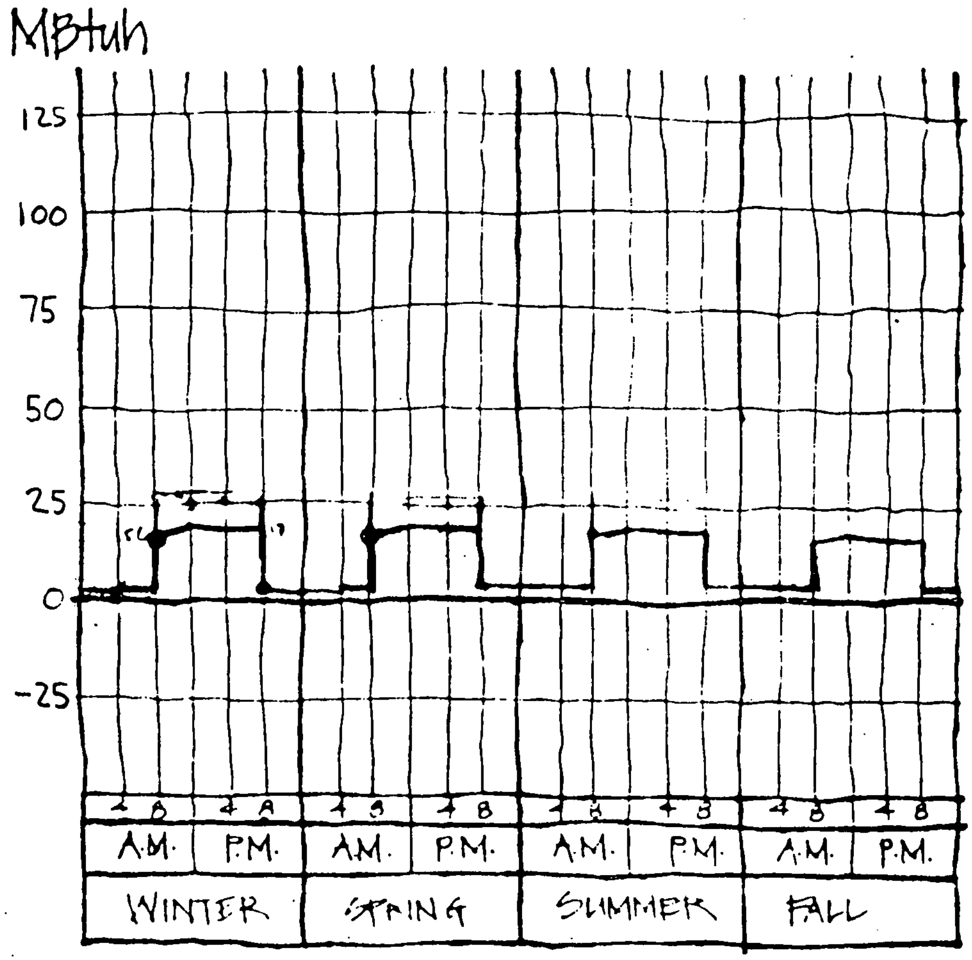
	12 MID.	4 A.M.	8 A.M.	NOON	4 P.M.	8 P.M.	12 MID
WINTER	215/13[illegible]	215/130	215/1300	215/1300	215/1300	215/1300	215/1300
SPRING	215/1300	215/130	215/1300	215/1300	215/1300	215/1300	215/1300
SUMMER	215/1300	215/1300	215/1300	215/1300	215/1300	215/1300	215/1300
FALL	215/1300	215/1300	215/1300	215/1300	215/1300	215/1300	215/1300

HEAT GENERATION & SCHEDULE (TOTAL) MBtuh. FROM TE[illegible]

	12 MID.	4 A.M.	8 A.M.	NOON	4 P.M.	8 P.M.	12 MID
WINTER	1	1	15.7	15.7	17.0	1.0	1
SPRING	1	1	15.7	15.7	17.0	1	1
SUMMER	1	1	15.7	15.7	17.0	1	1
FALL	1	1	15.7	15.7	17.0	1	1

(BUILDING DESCRIPTION CONTINUED)

INTERNAL HEAT GENERATION



SITE INFORMATION

OUTSIDE TEMPERATURE, To

	MID	4AM	8AM	NOON	4PM	8PM	MID
WINTER JAN	5	5	15	25	25	15	5
SPRING APR	31	31	41	51	51	41	31
SUMMER JULY	57	57	67	77	77	67	57
FALL OCT	36	36	46	56	[illegible]	46	36

INSOLATION, Btuh/sf

WINTER, JAN

	MID	4AM	8AM	NOON	4PM	8PM	~~MID~~
HORIZONTAL	—	—	70	229	70	—	701
SOUTH	—	—	111	229	111	—	—
WEST	—	—	11	27	177	—	—
NORTH	—	—	11	27	11	—	—
EAST	—	—	177	27	11	—	—

SPRING, APR

	MID	4AM	8AM	NOON	4PM	8PM	MID
HORIZONTAL	—	—	160	315	160	—	2059
SOUTH	—	—	26	93	26	—	—
WEST	—	—	24	39	222	—	—
NORTH	—	—	24	39	24	—	—
EAST	—	—	222	39	24	—	—

SUMMER, JULY

	MID	4AM	8AM	NOON	4PM	8PM	MID
HORIZONTAL	—		172	315	172	—	2363
SOUTH	—	—	28	55	28	—	—
WEST	—	—	28	42	206	—	—
NORTH	—	—	34	42	34	—	—
EAST	—	—	206	42	28		—

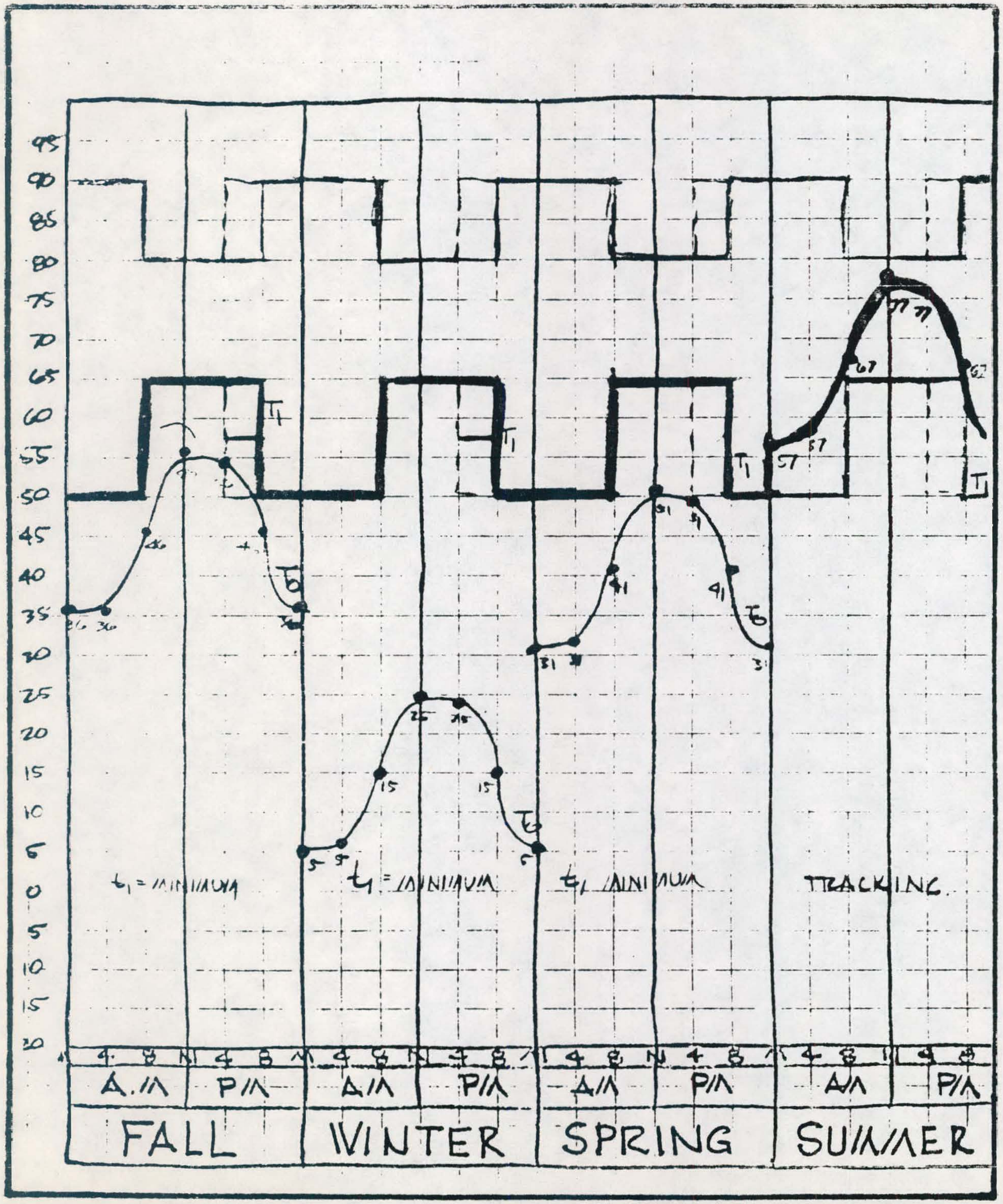
FALL, OCT

	MID	4AM	8AM	NOON	4PM	8PM	MID
HORIZONTAL	—	—	101	264	101	—	1093
SOUTH	—	—	88	201	88	—	—
WEST	—	—	16	32	202	—	—
NORTH	—	—	16	32	16	—	—
EAST	—	—	202	32	16	—	—

(SITE INFORMATION CONTINUED)

SITE INFORMATION

GRAPH



SOLAR HEAT GAIN

SHG = I × A × TRANSMISSION (MBtuh)

		MID	4 AM	8 AM	NOON	4 PM	6 PM	MID
I(108)=	WINTER, H			4.9	16.9	4.9		
I(114)=	[illegible]			8.1	17.4	8.1		
I(195)=	W			1.4	3.4	22.4		
I(97)=	N			.6	1.5	.6		
I(68)=	E			2.6	1.1	.5		
	TOTAL			17.6	39.3	30.5		

	MID	4 AM	8 AM	NOON	4 PM	6 PM	MID
SPRING, H			11.9	23.4	11.9		
[illegible]			2.0	7.3	2.0		
W			3.4	5.3	30.[illegible]		
N			1.5	2.3	1.5		
E			3.4	1.8	1.2		
TOTAL			22.2	50.1	46.9		

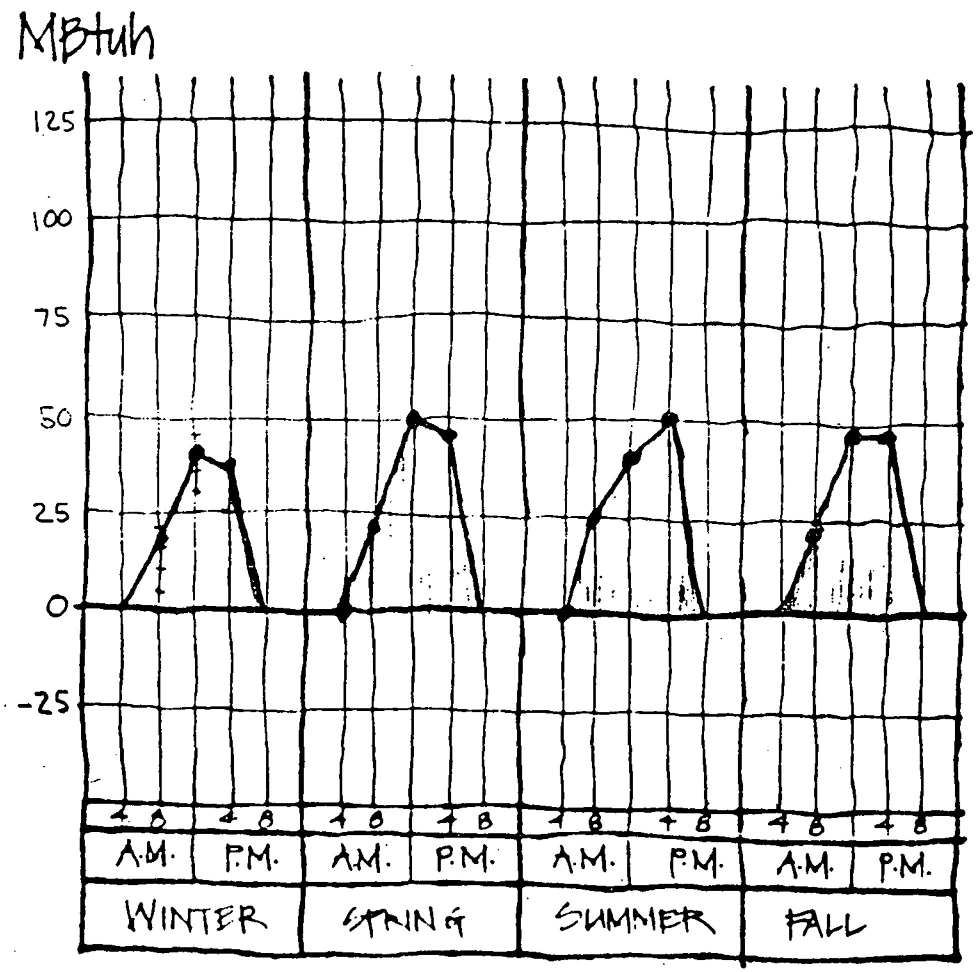
SHG = I x A x Transmission /Btu

		MID	4AM	8AM	NOON	4PM	8PM	MID
SUMMER	H			13.9	25.5	13.9		
	S			2.4	4.7	2.4		
	W			4.2	6.3	30.7		
	N			2.3	2.8	2.3		
	E			3.5	2.2	1.4		
	TOTAL			26.3	41.5	50.7		

		MID	4AM	8AM	NOON	4PM	8PM	MID
FALL	H			8.2	21.4	8.2		
	S			7.5	17.2	7.5		
	W			2.4	4.8	30.1		
	N			1.0	2.1	1.0		
	E			(3.3)	1.6	.8		
	TOTAL			22.4	47.1	47.6		

Solar Heat Gain Continued

SOLAR HEAT GAIN GRAPH



ENVELOPE HEAT GAIN AND LOSS

INSIDE TEMPERATURE, T_i

	MID	4 AM	8 AM	NOON	4 PM	8 PM	MID
WINTER, °F	50	50	65	65	65	65	50
SPRING	50	50	65	65	65	65	50
SUMMER	57	57	67	77	77	67	57
FALL	50	50	65	65	65	65	50

TEMPERATURE DIFFERENCES (ΔT / ΔT_{HL})

	MID	4 AM	8 AM	NOON	4 PM	8 PM	MID
WINTER, °F	-45 / 40	-45 / 40	-50 / 15	-40 / 15	-40 / 15	-50 / 15	-45 / 40
SPRING	-20 / 40	-20 / 40	-25 / 15	-15 / 15	-15 / 15	-25 / 15	-20 / 40
SUMMER	0 / 33	0 / 33	0 / 13	0 / 3	0 / 3	0 / 13	0 / 33
FALL	-15 / 40	-15 / 40	-20 / 15	-10 / 15	-10 / 15	-20 / 15	-15 / 40

ENVELOPE GAIN OR LOSS, MBtu

EHG/L = U·A·ΔT

U = 516 / ΔT

	MID	4 AM	8 AM	NOON	4 PM	8 PM	MID
WINTER	23.2	23.2	25.8	20.6	20.6	25.8	23.2
SPRING	10.3	10.3	12.9	7.7	7.7	12.9	10.3
SUMMER	0	0	0	0	0	0	0
FALL	7.7	7.7	10.3	5.2	5.2	10.3	7.7

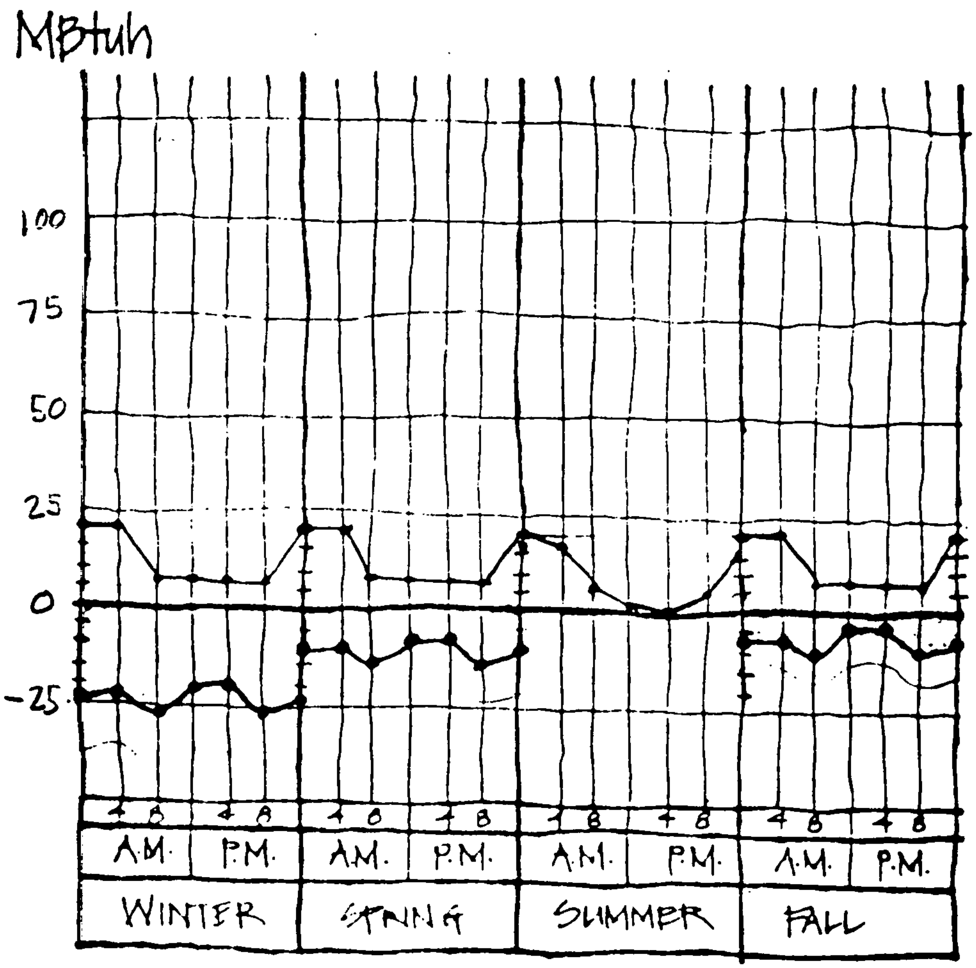
ALLOWABLE ENVELOPE GAIN

U·A·ΔT_{HL}

516·ΔT_{HL}

	MID	4 AM	8 AM	NOON	4 PM	8 PM	MID
WINTER, MBtu	20.6	20.6	7.7	7.7	7.7	7.7	20.6
SPRING	20.6	20.6	7.7	7.7	7.7	7.7	20.6
SUMMER	17.0	17.0	6.7	1.5	1.5	6.7	17.0
FALL	20.6	20.6	7.7	7.7	7.7	7.7	20.6

ENVELOPE
GAIN & LOSS
GRAPH



VENTILATION HEAT GAIN & LOSS

VENTILATION GAIN OR LOSS, MBtuh.		MID.	4AM	8AM	NOON	4PM	8PM	MID.
1.08 · CFM ΔT* 1.08 × 200 × ΔT 216 × ΔT	WINTER	9.7	9.7	10.8	8.6	8.6	10.8	9.7
216	SPRING	4.3	4.3	5.4	3.2	3.2	5.4	4.3
1.08 · [illegible] ΔT·D	SUMMER	—	—	—	—	—	—	—
216	FALL	3.2	3.2	4.3	2.2	2.2	4.3	3.2

ALLOWABLE VENTILATION GAIN, MBtuh.		MID.	4AM	8AM	NOON	4PM	8PM	MID.
1.08 · CFM · ΔTHI*	WINTER	104	104	39	39	39	39	104
[illegible] 1.08 × 2400 CFM	SPRING	104	104	39	39	[illegible]	39	104
1.08 ×	SUMMER	85.8	85.8	33.8	7.8	7.8	33.8	85.8
	FALL	104	104	39	39	[illegible]	39	104

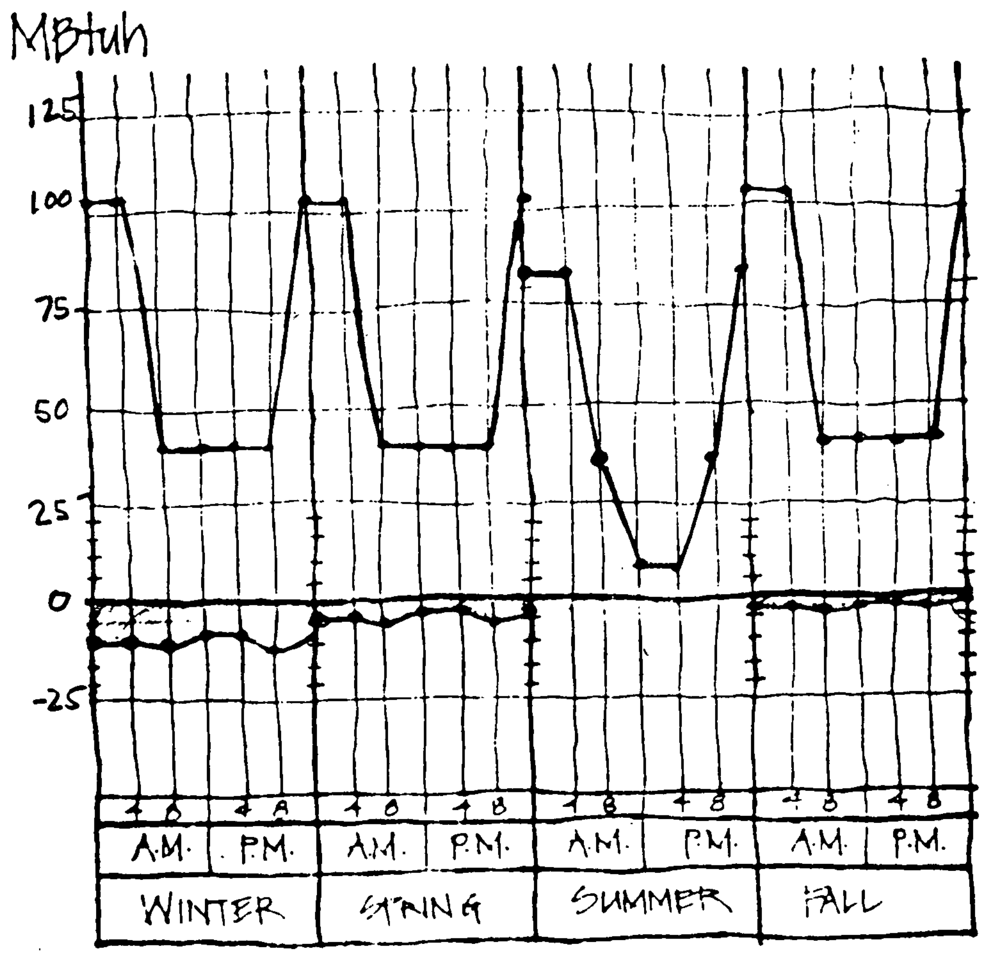
* USE TEMPERATURE DIFFERENCES RECORDED ON FORM #7

[illegible]

× 4,000 4300 × ΔTHI W/SP [illegible] [illegible] 112.8 64.5 [illegible] 64 [illegible] 172.8

[illegible] 14 43 56.1 [illegible] 56.1 142

VENTILLATION GAIN & LOSS GRAPH



TOTAL ALLOWABLE HEATGAIN

		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
WINTER	VENTILATION	104	104	39	39	39	39	104
	ENVELOPE	20.6	20.6	7.7	7.7	7.7	7.7	20.6
	TOTAL [illegible]	124.6	124.6	46.7	46.7	46.7	46.7	124.6
SPRING	VENTILATION	104	104	39	39	39	39	104
	ENVELOPE	20.6	20.6	7.7	7.7	7.7	7.7	20.6
	TOTAL	124.6	124.6	46.7	46.7	46.7	46.7	124.6
SUMMER	VENTILATION	85.8	85.8	33.8	7.8	7.8	33.8	85.8
	ENVELOPE	17.0	17.0	6.7	1.5	1.5	6.7	17.0
	TOTAL	102.8	102.8	40.7	9.3	9.3	40.7	102.8
FALL	VENTILATION	104	104	39	37	39	39	104
	ENVELOPE	20.6	20.6	7.7	7.7	7.7	7.7	20.6
	TOTAL	124.6	124.6	46.7	46.7	46.7	46.7	124.6

WINTER,

	MID	4 A.M.	8 A.M.	NOON	4 P.M.	8 P.M.	MID
INTERNAL GENERATION	1	1	15.7	15.7	17.0	1	1
SOLAR			17.6	34.3	36.5		
ENVELOPE	-23.2	-23.2	-25.8	-20.6	-20.6	-25.8	-23.2
VENTILATION	-9.7	-9.7	-10.8	-8.6	-8.6	-10.8	-9.7
TOTAL [illegible]	-31.9	-31.9	-3.3	+28.8	+24.3	-35.6	-31.9

SPRING,

	MID	4 A.M.	8 A.M.	NOON	4 P.M.	8 P.M.	MID
INTERNAL GENERATION	1	1	15.7	15.7	17.0	1	1
SOLAR			22.2	50.1	46.9		
ENVELOPE	-10.3	-10.3	-12.9	-7.7	-7.7	-12.9	-10.3
VENTILATION	-4.3	-4.3	-5.4	-3.2	-3.2	-5.4	-4.3
TOTAL	-13.6	-13.6	+19.6	+54.9	+53.0	-17.9	-13.6

TOTAL HEAT GAIN OR LOSS

SUMMER,

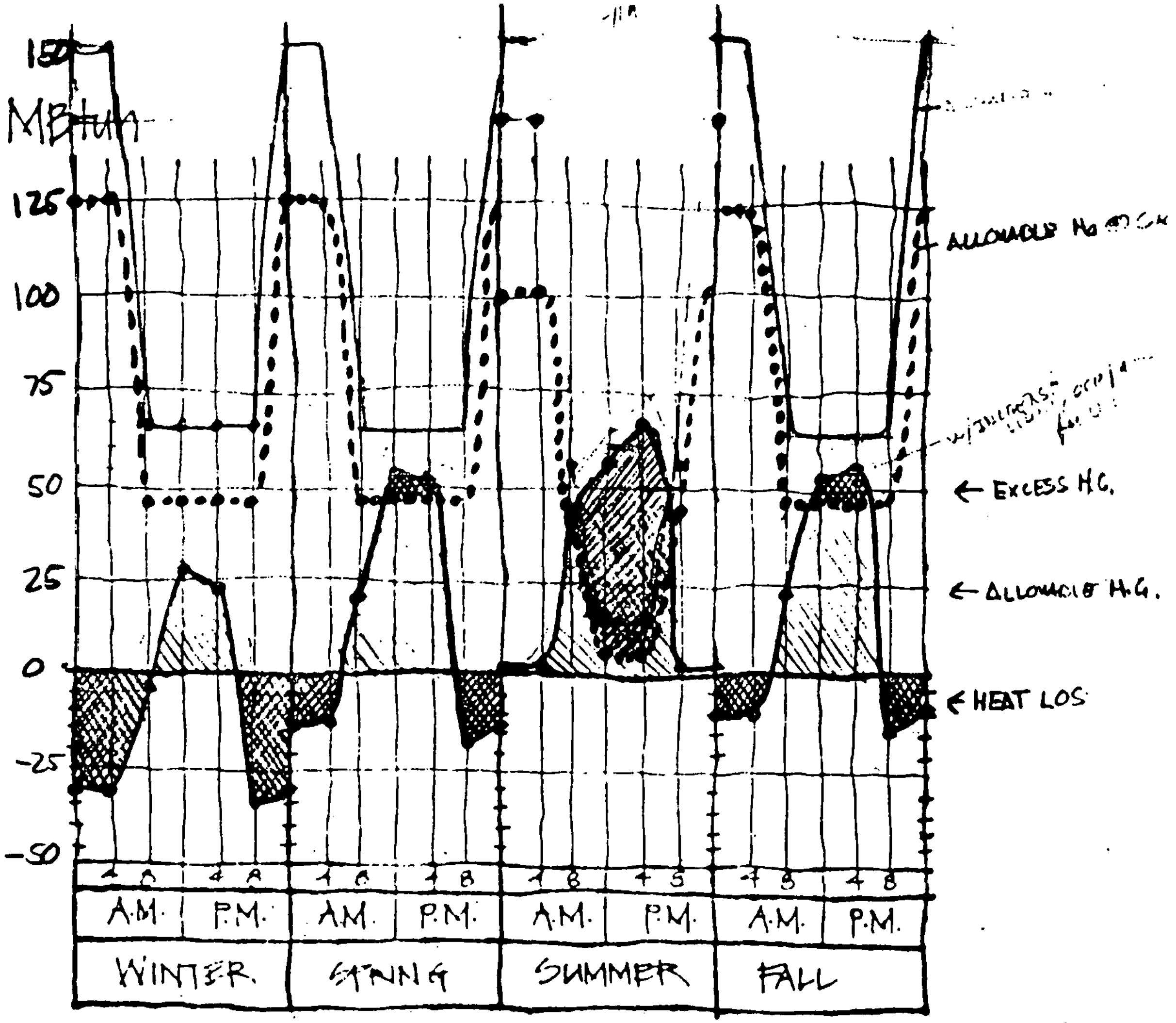
	MID.	4 AM	8 AM	NOON	4 PM	8 PM	MID.
INTERNAL GENERATION	1	1	15.7	15.7	17.0	1	1
SOLAR	–	–	26.3	41.5	50.7	–	–
ENVELOPE							
VENTILATION		–	–	–	–	–	–
TOTAL	+1	+1	+42	+57.2	+67.7	+1	+1

FALL,

	MID.	4 AM	8 AM	NOON	4 PM	8 PM	MID.
INTERNAL GENERATION	1	1	15.7	15.7	17.0	1	1
SOLAR			22.4	47.1	47.6		
ENVELOPE	-7.7	-7.7	-10.3	-5.2	-5.2	-10.3	-7.7
VENTILATION	-3.2	-3.2	-4.3	-2.2	-2.2	-4.3	-3.2
TOTAL	-9.9	-9.9	+23.5	+55.4	+57.2	-13.6	-9.9

TOTAL [illegible]

TOTAL HEAT GAIN & LOSS GRAPH



ESTIMATION OF ENERGY COSTS/ SPACE CONDITIONING

AVERAGE TOTAL ALLOWABLE HEAT GAIN (24) @10 ACH/H

MID-4	4-8	8-NOON	NOON-4	4-8	8-MID
173	173	65	65	65	173
173	173	65	65	65	173
162	111	40	15	38	112
173	173	65	65	65	173

INITIAL CONFIGURATION: X

FINAL CONFIGURATION:

AVERAGE TOTAL HEAT GAIN/LOSS (FORM #15) per hour

MID-4	4-8	8-NOON	NOON-4	4-8	8-MID	TOTALS		SEASONAL HEATING ENERGY	
-32	-18	+13	+27	-6	-34	-90	x K	46.3	8.1
-14	+3	+37	+54	+18	-16	-30		15.4	2.7
+1	+21	+50 +10	+62 +47	+34	+1	0		0	
-10	+7	+39	+56	+22	-12	-22		11.3	1.9

$K = 4 \times 90 / .7 = 514$

		COST/MMBTU.	HEATING COST
ANNUAL HEATING TOTAL	73	$4.20	307

AVERAGE EXCESS GAINS

MID-4	4-8	8-NOON	NOON-4	4-8	8-MID			SEASONAL COOLING
							x m	
		+20	+48	+25		93		16,740

$m = \frac{4 \times 90}{2.0} = 180$

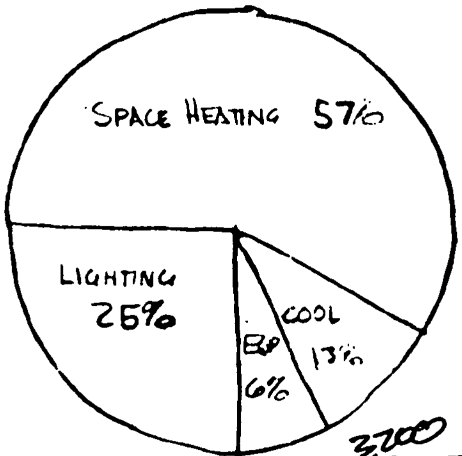
		COST/MMBTU.	COOLING COST
ANNUAL COOLING TOTAL	16.75	$12	201
ANNUAL HEATING AND COOLING (MMBTU)	83.26	TOTAL COST	508
ANNUAL HEATING AND COOLING (MBTU/SF)	29.7		

÷ 2800 SF

BUILDING ENERGY USE SUMMARY

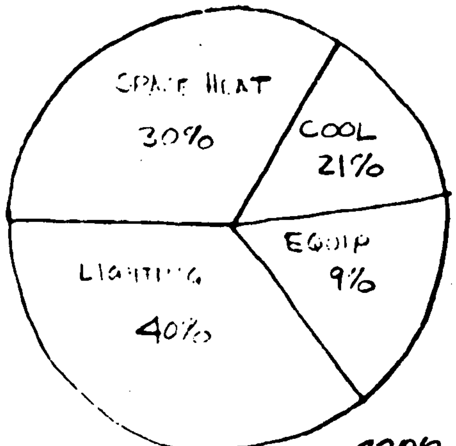
	END USE ENERGY	/ RUF /	SOURCE ENERGY
<u>THERMAL REQUIREMENTS</u>			
SPACE HEATING	73 X 10^6 BTU	X 1.0 =	73 X 10^6 BTU
SPACE COOLING	16.74 X 10^6 BTU	X 3.0	50. X 10^6 BTUS
<u>ELECTRICAL</u> UTILIZATION			
*LIGHTING	31.82 X 10^6 BTU	X 3.0 =	95. X 10^6 BTUS
* *EQUIPMENT (VARIABLE THRU [illegible] OUTLETS)	(24.75 X 10^6 BTU)	X 3.0 =	(74 X 10^6 BTUS
**INTEGRAL EQUIP (FANS)	7.5 X 10^6 BTU	X 3.0	22.5 X 10^6 BTU
TOTALS	129 X 10^6 BTU		240.5 X 10^6 BTU

END USE ENERGY



3200
@ ~~2400~~ SF
41116
~~53,7?? BTU/SF/YR~~

SOURCE ENERGY



3200
@ ~~2400~~ S.F.
75,000
~~100,2?? BTU/SF/YR~~

* LIGHTING 30fc @ HIGH C.U. FACTOR [illegible] .09 W/FC

ELECTRICAL [illegible] 30fc/sf X 2400 SF X .04 W/fc X 3.412 BTU/W = 9826 BTUH [illegible]

L.L. 6,000 BTU X 12 HR/DAY X 312 D/YR = 22,464,000 BTU

U.L. 4000 BTU X 9 HR/DAY X 260 [illegible] = 9,360,000 [illegible]

31,824,000 BTU/YR

(POWER L.L. 1,000 [illegible] 1kw X 12 HR/DAY X 312 [illegible] X 3412 [illegible] = 12,774,528 [illegible]

U.L. 150 [illegible] 1.5 [illegible] /DAY [illegible] 11,976,120 BTU/YR

24,750,648 BTU/YR

** INTEGRAL EQUIP FANS [illegible] X 1.2 kwh X 412 [illegible] [illegible] BTU/YR

SITE ENERGY POTENTIAL

OVERVIEW

NARRATIVE OVERVIEW

It is our belief that the first point of departure in any building programming process which concerns energy needs is an evaluation of the site energy potential. This specific task must come before even the characterization of building energy needs. This appraisal is based on a number of factors. The first is our fundamental approach to any building project, which is to hold conventional energy use to a minimum. We attempt to achieve this without substantially altering the way people use and occupy a building. The second reason is the institutional framework in which buildings are designed and constructed in their day. One can no longer consider just the energy use of a typical or conventional building. In our state as well as

many others, new or substantially altered buildings, must conform with more and more restrictive building energy performance standards. With any building, these use patterns directly reflect the natural environment it exists in. Thus, even a conventional building must be analyzed according to energy code limitations and the effect of the climate it is located in. We consider it necessary to have the basic climatic data and building energy use patterns before even the base case can be developed

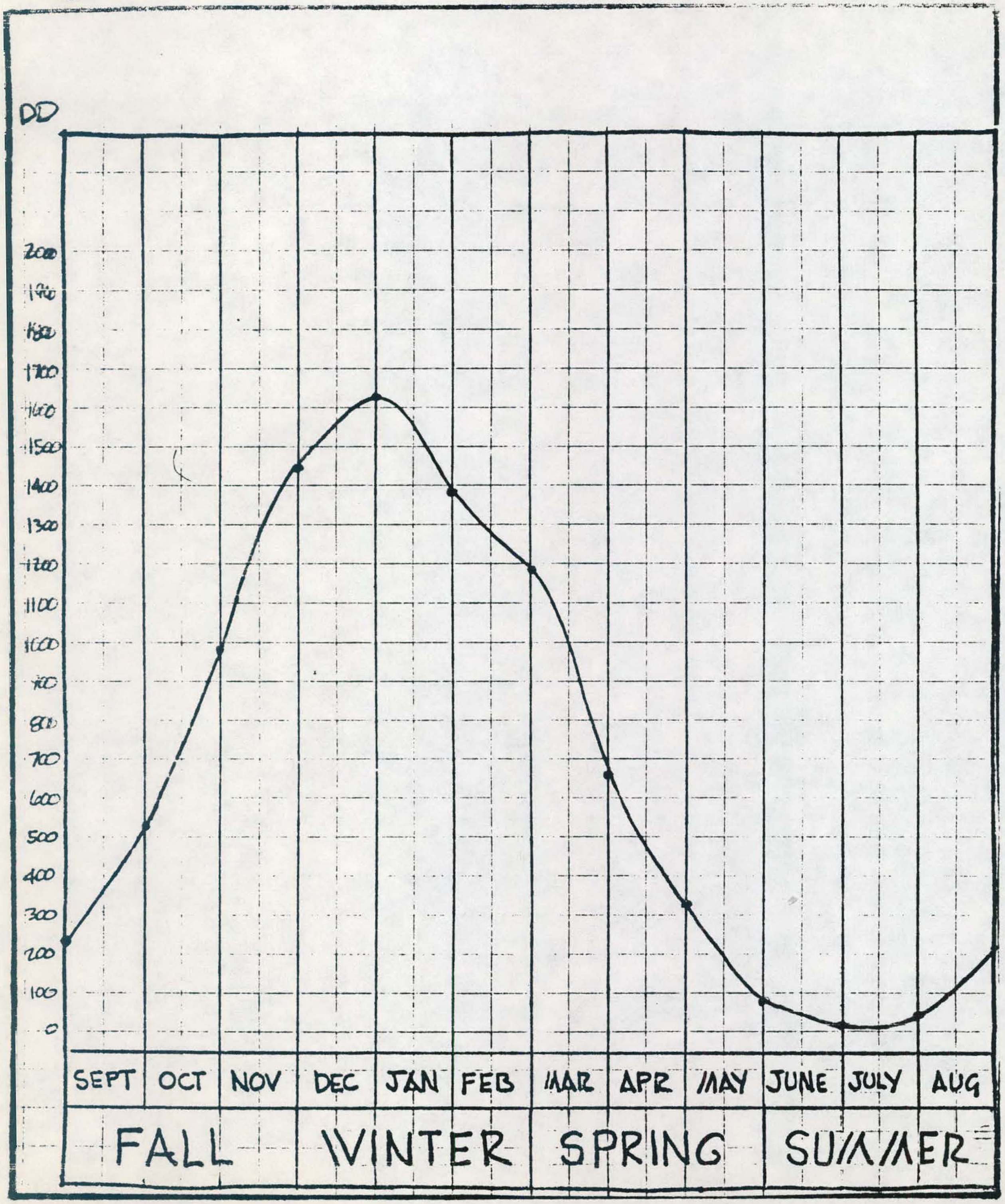
WEATHER DATA

GENERAL WEATHER DATA

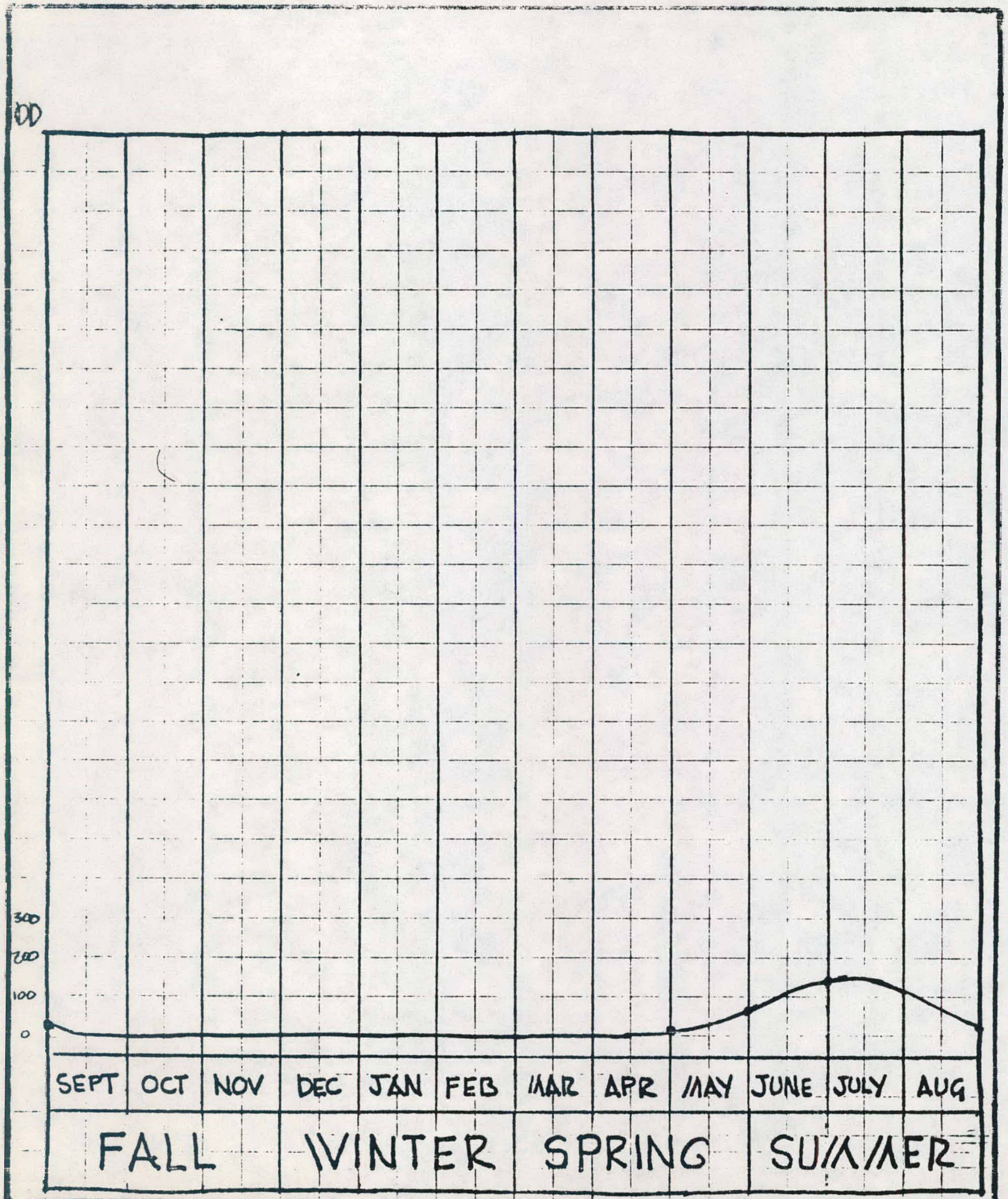
MONTH	HTG. D.D	CLG D.D	# DAYS ABOVE 90°F	AVE LOW TEMP	AVE HIGH TEMP	AVE DAILY TEMP	TEMP SWING	NIGHT AVE R.H	DAY AVE RH	GROUND TEMP @ 8"	WIND SPEED DIR
SEPT	227	6	2	49.7	65.5	57.6	15.8	79%	58%	54.4°	7.8 W/SW
OCT	533	–	–	39.7	55.9	47.8	16.2	(FALL)		43.2°	
NOV	996	–	–	23.6	40.0	31.8	16.4			34.2	
DEC	1451	–	–	9.9	26.5	18.2	16.6	77%	69%	28.9	8.2 NW
JAN	1631	–	–	3.8	21.0	12.4	17.2	(WINTER)		28.3	
FEB	1392	–	–	7.1	23.5	15.3	16.4			28.3	
MAR	1190	–	–	18.5	34.7	26.6	16.2	80%	55%	26.9	8.5 SW W
APR	660	–	–	35.3	50.7	43.0	15.4	(SPRING)		33.3	
MAY	333	10	1	46.8	62.5	54.6	15.7			46.5	
JUNE	95	77	3	57.1	71.8	64.5	14.7	90%	57%	53.9	7.2 S/SW
JULY	22	146	6	61.6	76.2	68.9	14.6	(SUMMER)		58.4	
AUG	56	112	5	59.5	74.7	67.1	15.1			58.4	
TOTALS	8586	351	17							41.2	
	(1)	(2)	(3)	(4)	(4)	(4)	(4)	(5)	(5)	(6)	(7)

(1) WAUSAU AIRPORT, IN VALLEY, 20 YEAR AVERAGE (BASE 65) FAA # 8968 OZ
(2) MERRILL WISCONSIN, 11 MILES NORTH IN RIVER VALLEY (BASE 65)
(3) WAUSAU, 20 YEAR AVE TOTALS (COULD EXPECT 2°F LOWER @ SITE OR ∴ 9 DAYS)
(4) WAUSAU AIRPORT WEATHER BUREA DATA
(5) INTERPOLATED, MINNEAPOLIS MN & MADISON WISC.
(6) ONLY WISCONSIN REPORTING STATION ≈ 100 WNW ≈ SAME (POSSIBLY LOWER IN WAUSAU DUE TO LOWER SNOW COVER IN WINTER @ 8"
(7) LACROSS WISCONSIN – 140 MILES S.W. BUT IN A RIVERVALLEY (MADISON WI AIRPORT DATA ≈ 2 MPH HIGH EA SEASON)

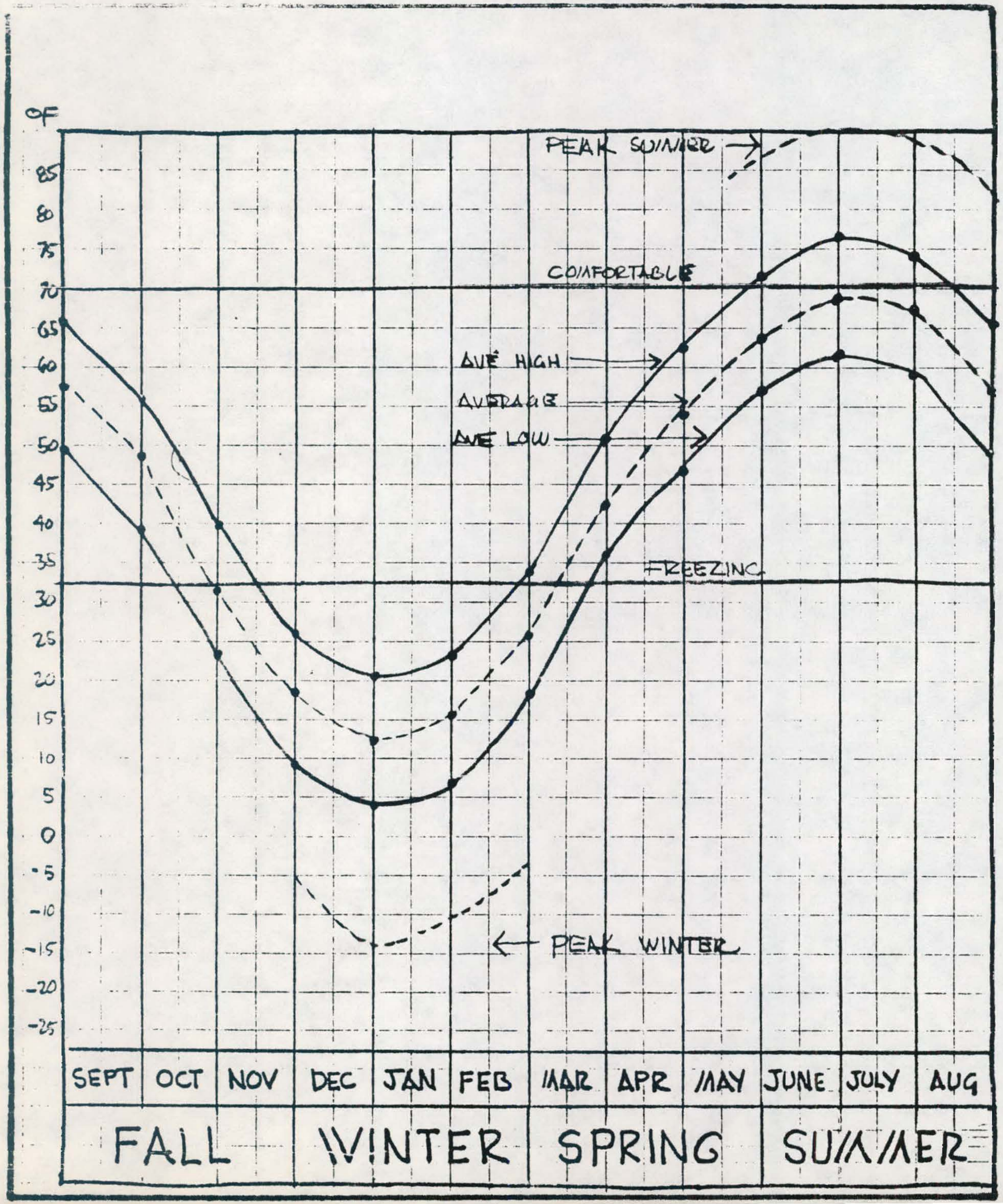
LATITUDE 44° 55'
ELEV 1200' ABOVE SEE LEVEL



HEATING DEGREE DAYS GRAPH

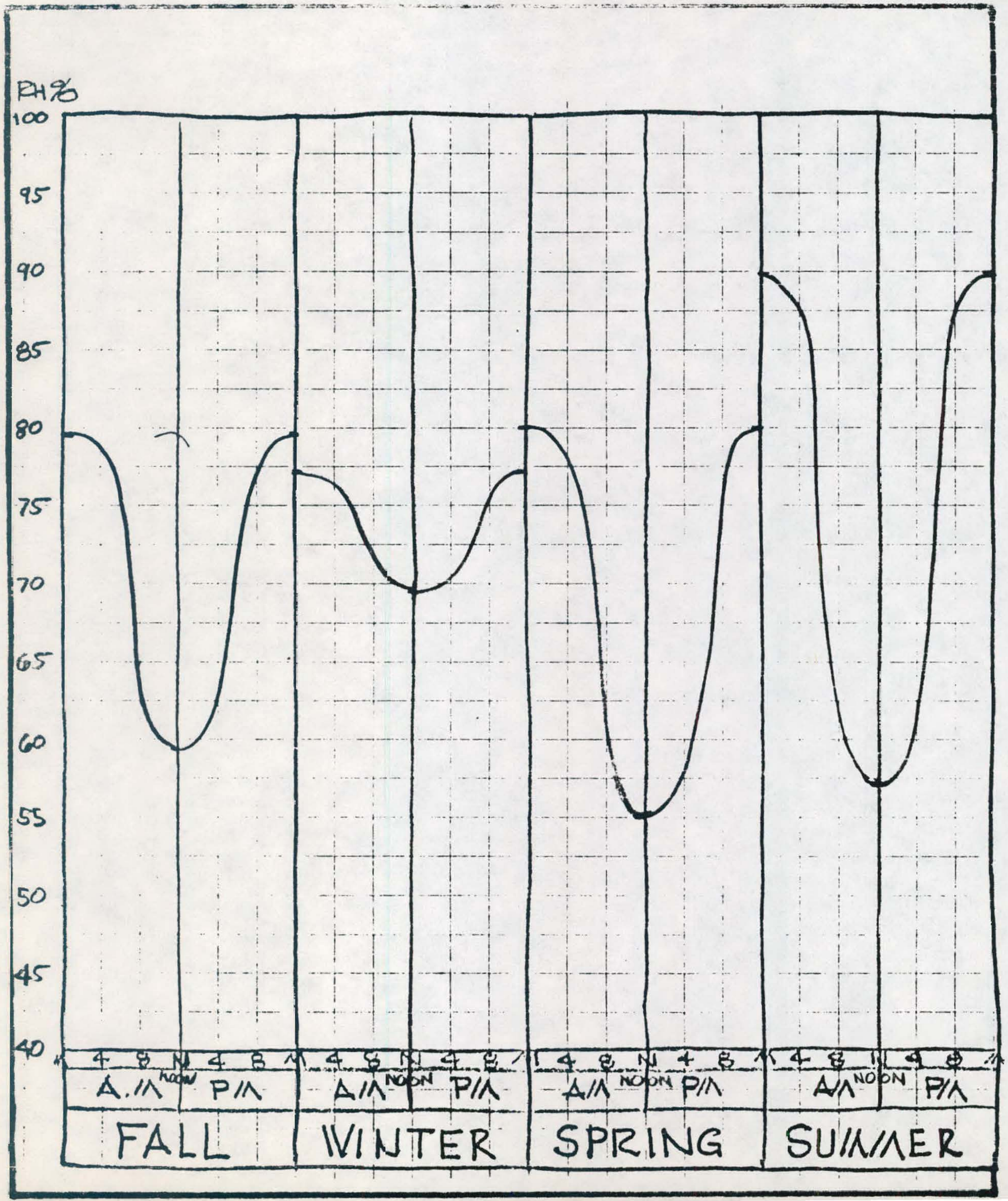


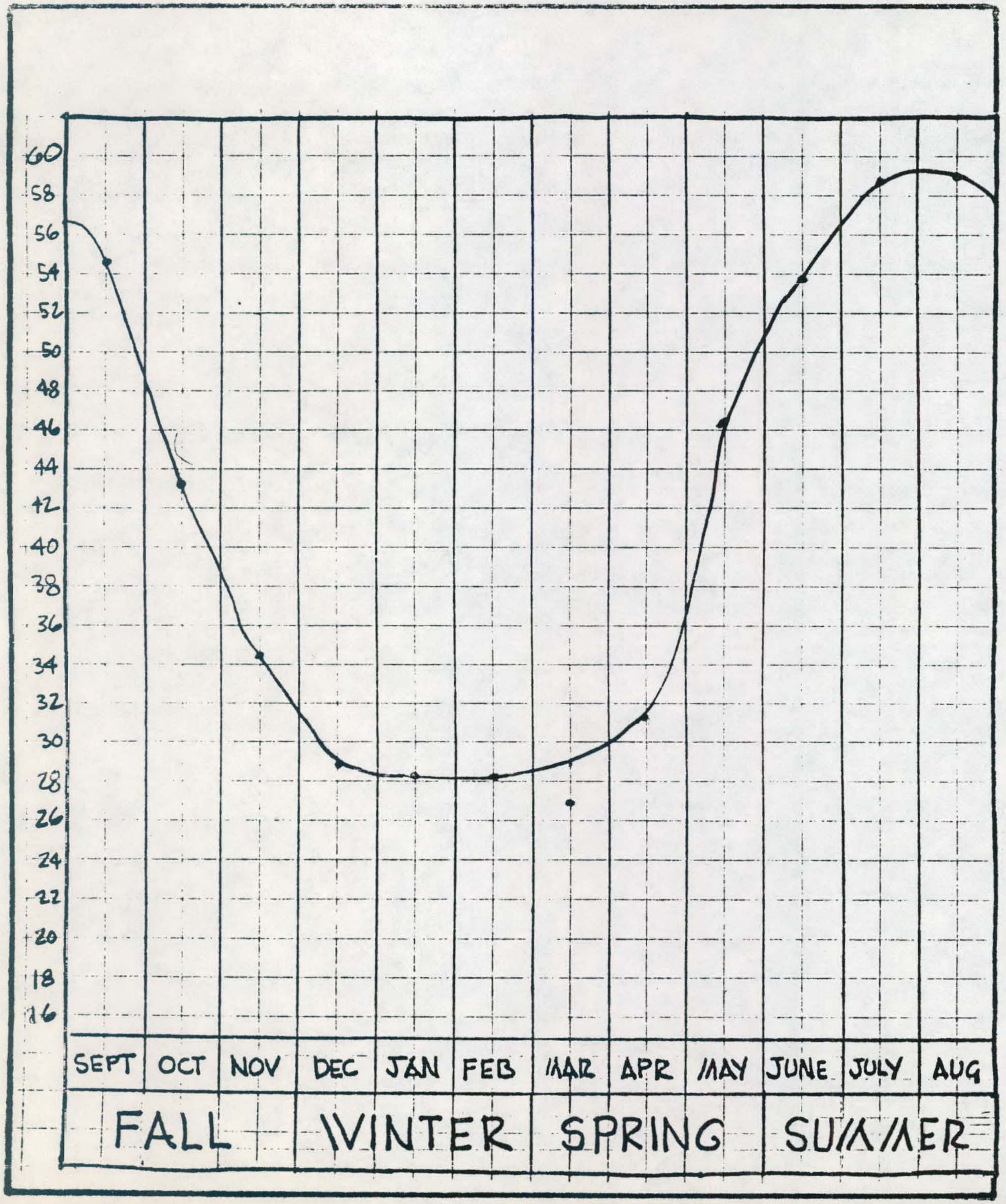
COOLING DEGREE DAYS GRAPH



AMBIENT TEMPERATURE CHARACTERISTICS GRAPH

RELATIVE HUMIDITY GRAPH

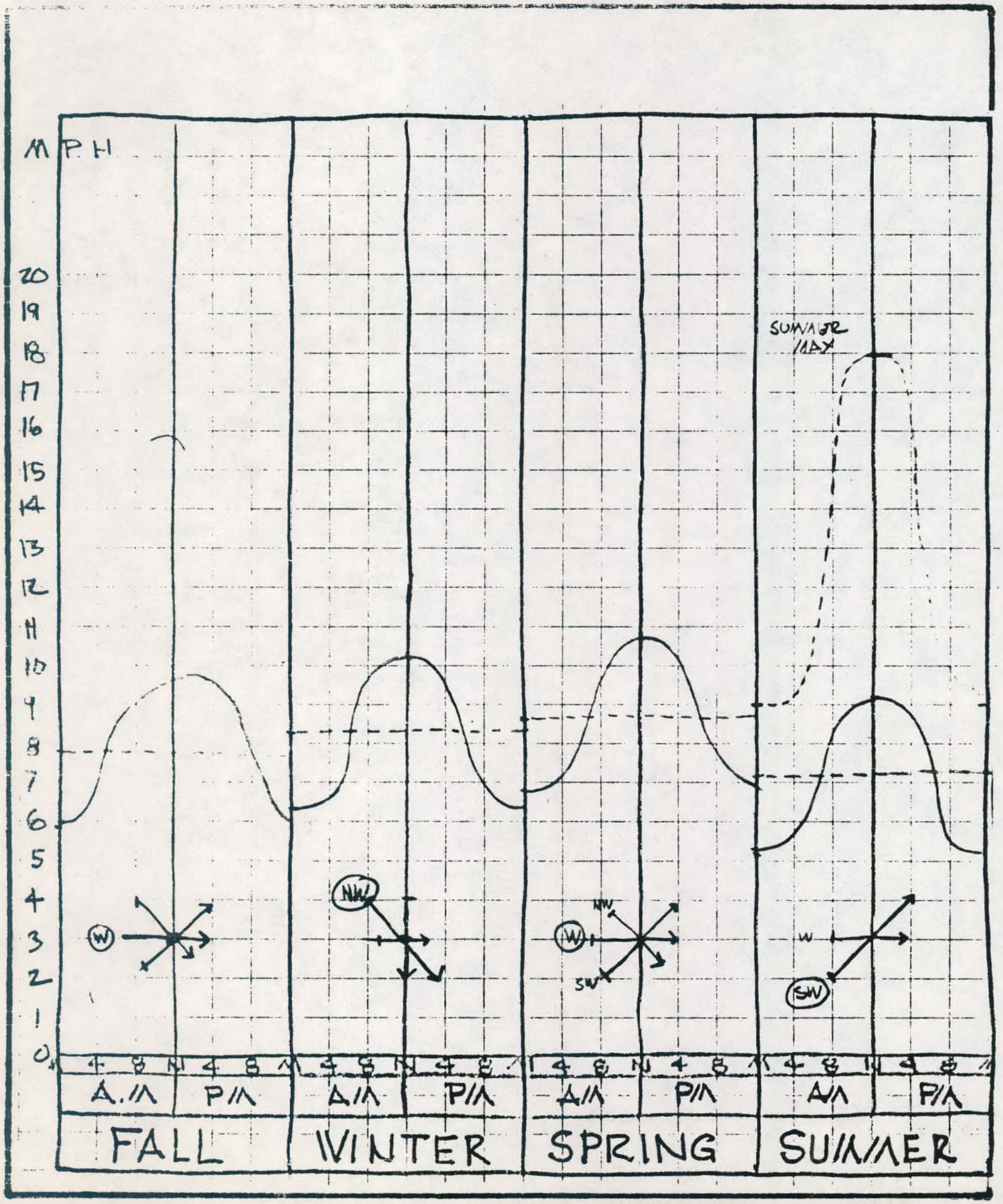




GROUND TEMPERATURES

@8"
RAINBOW FLOWAGE STATION
110 MILES N.W.

WIND SPEED &
DIRECTION
GRAPH



SOLAR / CLIMATE DATA

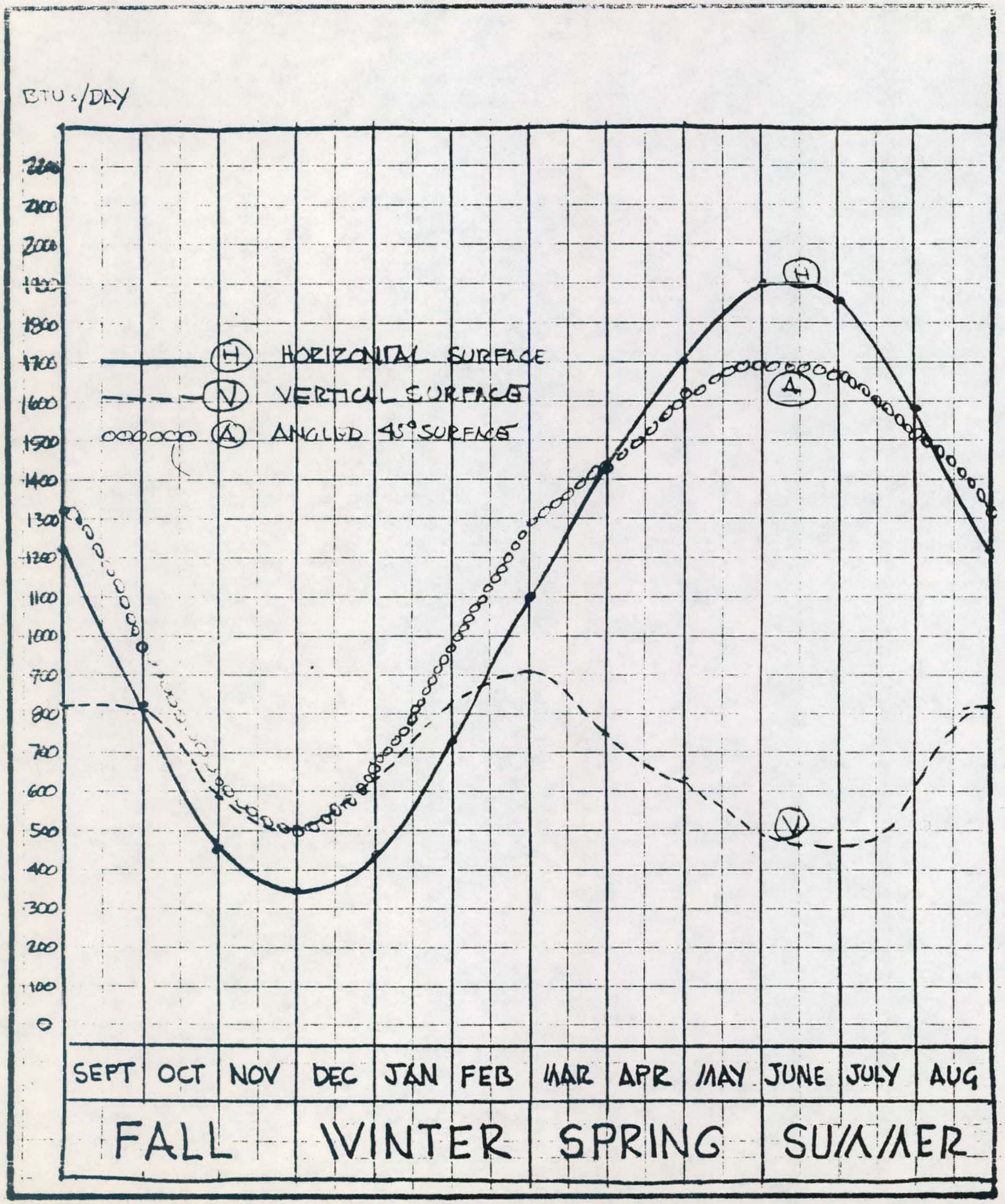
SOLAR/CLIMATE RELATED DATA (MONTHLY)

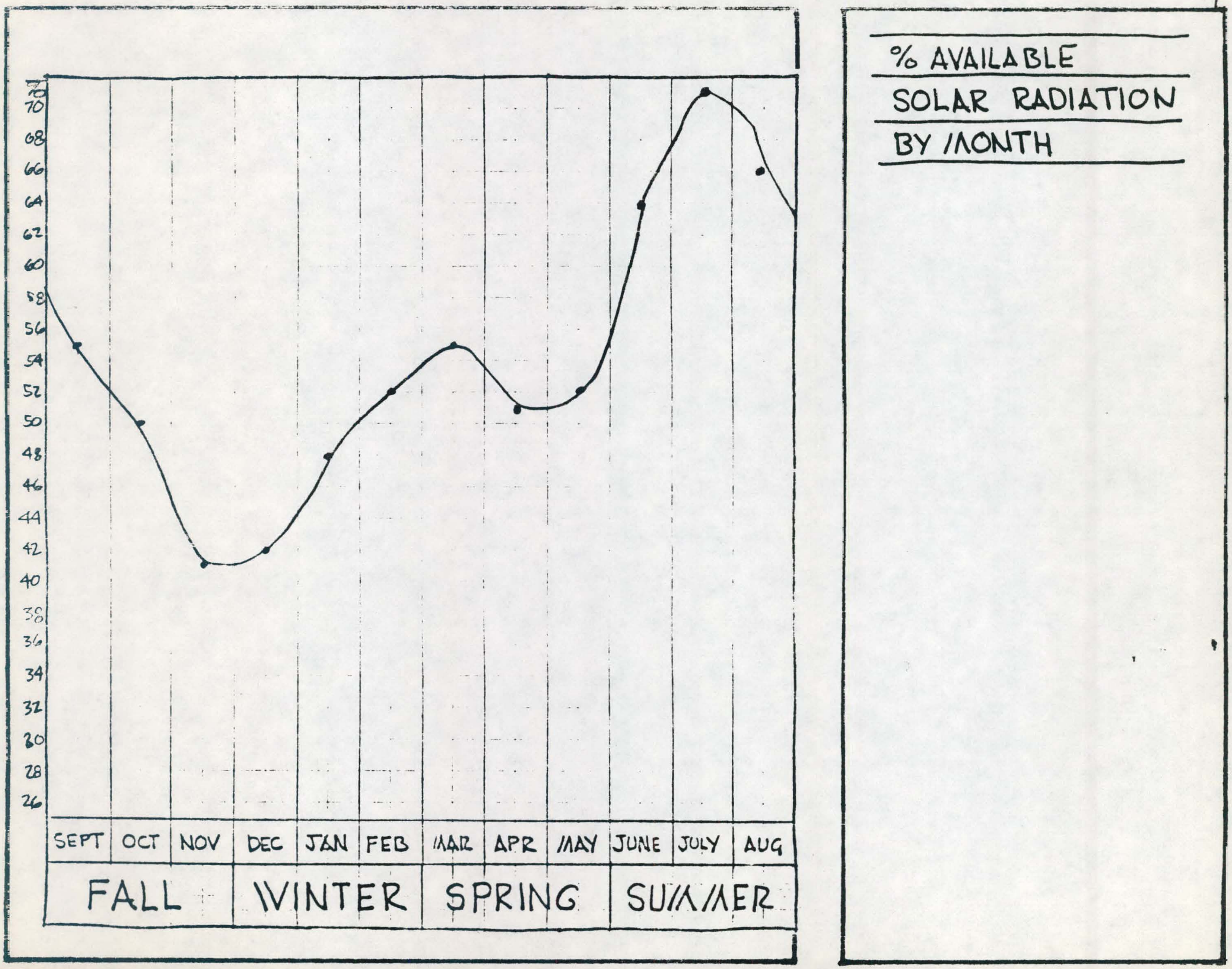
AVE MONTHLY/SOUTH FACE — AVE/DAY-MONTH

MONTH	ON A HORIZ SURF	% SUN	CLEAR DAY AT LATITUDE HORIZ	MOD FACTOR V	MOD FACTOR 45	SOUTH VERTICAL DBL GLS	SOUTH 45° ANGLE DBL GLS
SEPT	1210	55		.67	1.1	811	1331
OCT	825	50		.98	1.20	809	990
NOV	460	41		1.30	1.35	598	621
DEC	345	42		1.47	1.45	507	500
JAN	450	48		1.40	1.48	630	666
FEB	735	52	SEE NEXT CHART	1.13	1.34	831	985
MAR	1100	55		.82	1.18	902	1298
APR	1430	51		.52	1.03	744	1430
MAY	1700	52		.37	.96	629	1632
JUNE	1900	64		.32	-	NA	NA
JULY	1860	71		.34	-	NA	NA
AUG	1580	66		.45	-	NA	NA
	①			③	④	⑤	⑥

① SOLMT - INTERPOLATED BETWEEN/MADISON/LACROSS/GREEN BAY
② WEATHER BUREAU SOLAR % NOT RADIATION READINGS
③ FROM HUD/MSL SOLAR DECLINATION CALCULATIONS METHODS
④ CALCULATED & ADJUSTED USING RATIOS OF CLEAR DAY DATA
⑤ PRODUCT OF HORZ. DATA x Vertical MOD FACTOR
⑥ PRODUCT OF HORZ. DATA x 45° ANGLE CORRECT FACTOR

AVERAGE DAILY RADIATION BY MONTH




% AVAILABLE SOLAR RADIATION BY MONTH
72
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
38
36
34
32
30
28
26
SEPT
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUNE
JULY
AUG
FALL
WINTER
SPRING
SUMMER

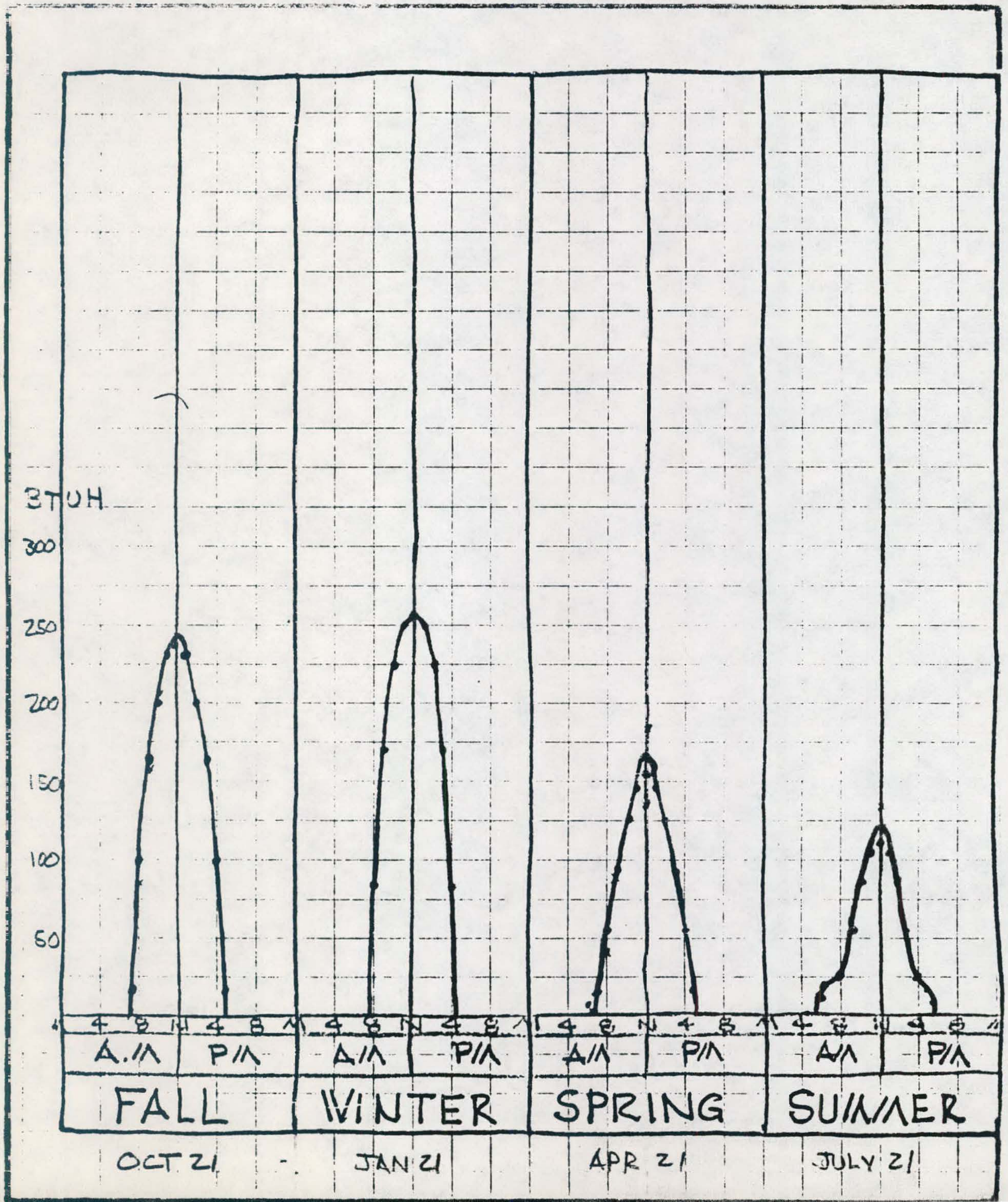
CLEAR DAY INSOLATION

CLEAR DAY INSOLATION DATA (FOR PEAK CONDITIONS)

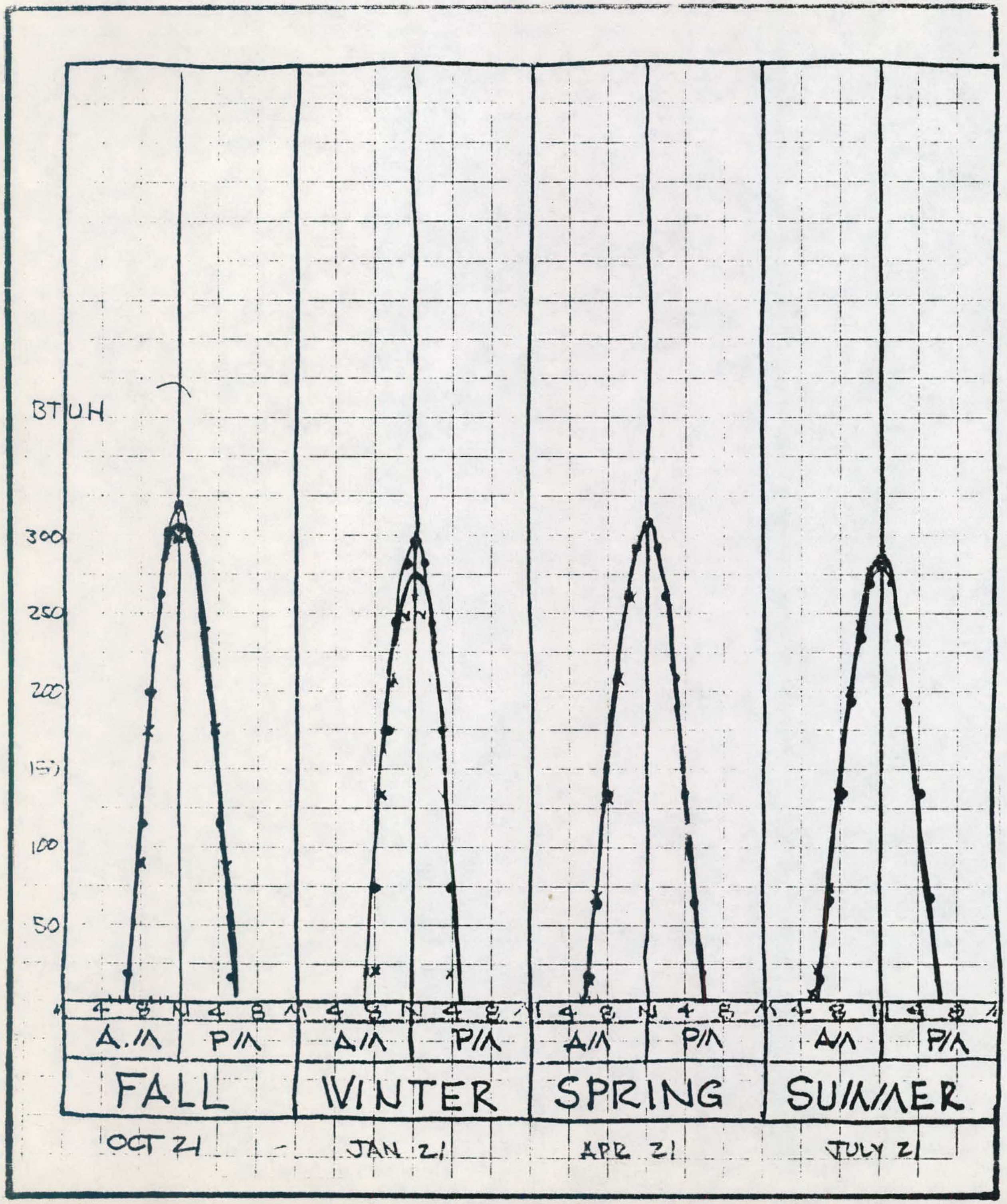
MONTH	SOUTH VERTICAL			SOUTH 45° ANGLE			HORIZONTAL		
↓ LAT →	40°	44°	48°	40	44°	48°	40°	44°	48°
SEPT	1416	1481	1546	2205	2156	2110	1788	1655	1522
OCT	1654	1640	1626	2079	1977	1875	1348	1185	1022
NOV	1686	1564	1442	1824	1620	1415	942	769	596
DEC	1646	1475	1304	1687	1449	1210	782	614	446
JAN	1726	1602	1478	1868	1649	1429	948	772	596
FEB	1730	1730	1729	2182	2062	1942	1414	1247	1080
MAR	1484	1558	1632	2252	2239	2226	1852	1715	1578
APR	1022	1142	1262	2244	2272	2300	2274	2190	2106
MAY	724	853	982	2152	2221	2290	2552	2517	2482
JUN	606	740	874	2099	2200	2300	2648	2637	2626
JULY	702	829	956	2118	2159	2200	2534	2504	2474
AUG.	978	1093	1208	2181	2190	2200	2244	2165	2086
	①	②	①	③	④	⑤	⑥	⑦	⑥

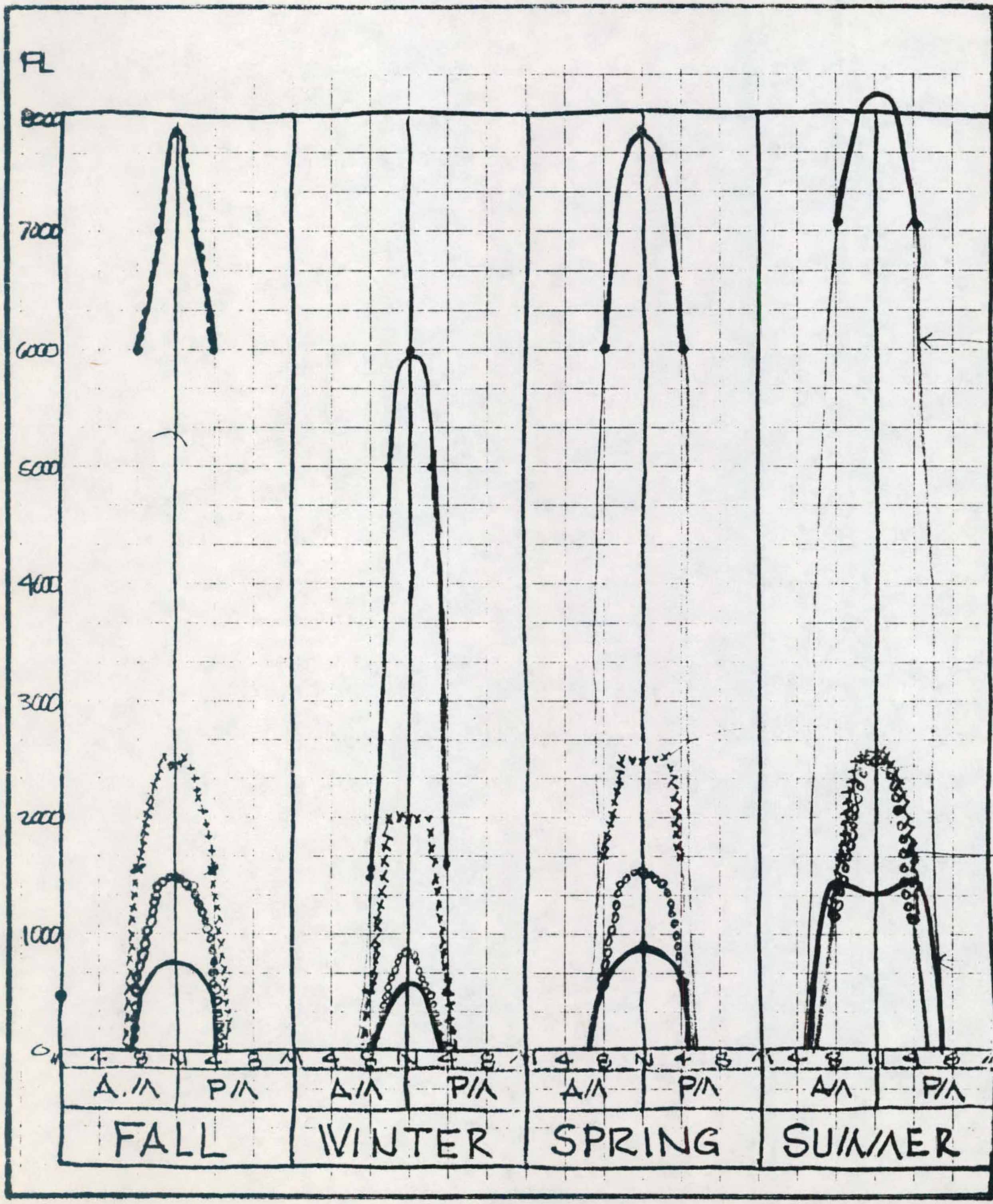
① ASHRAE CLEAR DAY INSOLATION VALUE-TOTAL DAY ASHRAE 40°N & 48°N
② INTERPOLATED ASRAE VALUE
③ INTERPOLATED ASHRAE 40° & 50° TILT
④ INTERPOLATED ASHRAE
⑤ INTERPOLATED ASHRAE CLEAR DAY VALUE @ 48°N 38 & 48 TILT
⑥ FROM ASHRAE CLEAR DAY INSOLATION VALUES
⑦ INTERPOLATED BETWEEN 40°N & 48° N DATA ASHRAE

DYNAMIC CLEAR DAY
RADIATION BY SEASON
VERTICAL SURFACES



DYNAMIC CLEAR DAY
RADIATION BY SEASON
45° ∠ SURFACES





DYNAMIC DAILY
SKY BRIGHTNESS
BY SEASON

DIRECT BEAM SUNLIGHT

CLEAR DAY

OVERCAST

NORTH

*@ ANN ARBOR MICHIGAN ≈
SAME SOLAR % & SAME
SKY CLEARNESS

PEAK WEATHER CONDITIONS

WINTER PEAK CONDITIONS

- MIN NIGHT TEMP. WINTER DESIGN CONDITION -25°F
- 24 HR TEMP AVERAGE -15°F
- MAX DAY TEMP @ WINTER DESIGN CONDITION - 5°F
- (NORMALLY THIS CONDITION COULD BE EXPECTED ONCE A YEAR FOR A 3-4 DAY PERIOD - QUALITATIVE ASSESSMENT)
- THIS CONDITION WILL INVARIABLY OCCURE LATE IN DECEMBER, JANUARY OR VERY EARLY FEBRUARY. THE GENERAL CLIMATIC PATTERN AT THIS CONDITION IS STRONGLY INFLUENCED BY CONTINENTAL HIGH PRESSURE ATMOSPHERIC SYSTEMS. IT IS ALWAYS ACCOMPANIED BY EXTREMELY CLEAR SKYS. JANUARY CLEAR DAY INSOLATION FIGURES CAN BE UTILIZED

SUMMER PEAK CONDITIONS

- MAX DAY TEMP 95°F (3-4 DAYS PER YEAR)
- MAX NIGHT TEMP 75°F
- PEAK DAY AVE 85°F
- NORMALLY THIS PEAK WILL OCCURE IN LATE JUNE, JULY OR EARLY AUGUST IN THE PRESENCES OF SLOW MOVING CONTINENTAL HIGH PRESSURE CENTERED ON THE UPPER MISSISSIPPI VALLEY IN THE MIDWEST
- THE HUMIDITY LEVEL ASSOCIATED WITH THESE SUMMER PEAKS IS USUALLY AT OR SLIGHTLY BELOW AVE LEVELS OF 57% DAY & 90% NIGHT. HOWEVER ON OCCASION IT CAN BE IN THE 70% LEVEL DAY & 95% EVENING.
- GENERALLY DURING THESE "HEAT STORM" PERIODS AVE WIND SPEED WILL BE HIGHER THAN AVE OVER A 24HR PERIOD. DAY WINDS WOULD BE IN THE NEIGHBORHOOD 18 mph and EVENING SPEEDS ABOUT 9mph on AVE.

CONVENTIONAL ENERGY SOURCES

DUE TO THE NATURE OF THIS PROJECT, THE SUBSTANTIAL REHAB OF AN EXISTING COMMERCIAL STRUCTURE ALONG WITH A THROUGH RETROFIT FOR ENERGY CONSERVATION, THE USUAL CONVENTIONAL ENERGY SOURCES WERE ALREADY INCORPORATED IN THE BUILDING. CURRENTLY SPACE HEATING AND HOT WATER IS SUPPLIED BY GAS, WHILE ILLUMINATION AND EQUIPMENT NEEDS ARE SUPPLIED BY ELECTRIC. AVAILABILITY OF BOTH THESE FUELS IS GOOD (AS GOOD AS ANY PART OF THE NATION). HISTORIC FUEL COST DATA IS LISTED BELOW, WITH THE MOST RECENT FUEL COST PROJECTION'S AS PREDICTED BY THE STATE OF WISCONSIN'S ENERGY DIVISION.

HISTORIC COST DATA

YEAR	FUEL		
	OIL	GAS	ELECTRIC
1970	.32/GAL	.16/THERM	.019/KWH
1971	.33	.17	.020
1972	.34	.17	.021
1973	.35	.18	.022
1974	.38	.19	.024
1975	.43	.22	.026
1976	.44	.24	.028
1977	.47	.27	.033
1978	.45	.31	.035
1979	.58	.36	.041
1980	.98	.42	.048
PROJECTION	25%/YR THRU 1982 15%/YR AFTER 1982.	15%/YR	12%/YR

NOTE: THIS SCALE OF PROJECT IS NOT ELIGIBLE FOR SPECIAL OR PREFERENTIAL RATES SUCH AS INTERUPTIBLE SERVICE TIME OF DAY RATES AS OF THIS DATE HAVE NOT YET BEEN APPROVED.

MATCHING ENERGY NEEDS AND POTENTIALS

MATCHING ENERGY NEEDS & POTENTIAL

OVERVIEW: The fundamental approach was to first assess the constructed building concept to see where the greatest energy use occurred. From the previous step of site energy sources assessment it was realized that numberous natural

energy sources were available to reduce the conventional energy load. The two major factors in the energy project were that used for space heating and lighting. Since the basic techniques used to harness natural sources to meet space heating and lighting needs are often similar and because one is often a consequence of the other, and because of a limited budget we determined at this stage of the process to develop solutions that which reduced both these loads.

The overall effort concentrated on preliminary assessments of the design team being able to affect significant energy reductions in these two areas. Because of our previous design experience with passive solar heating in the residential sector we were aware that we could reduce the space heating requirement with south facing solar heat gain. Our approach to this assessment was to determine what a reasonable level of south facing glazing could be. We arrived at a figure of from 200-300 SF of south facing passive solar collector. We then input these figures into the solar load ratio calculation to determine approximately the number of space heating BTU's which could be saved per year.

OVERVIEW

°Assessing the potential for daylighting was a far more difficult process. In a previous task we had identified at a reasonable level the expected amount of skybrightness in various weather situations during the four seasons. Our basic approach was to determine the number of hours of building operation where a significant portion of the illumination could be met by daylight. The techniques used were the basic daylight determination at a minimum skybrightness of 600 fL. Our preliminary analysis indicated that a basic daylight configuration of high clerestory setback in combination with side lighting could produce a minimum of 30 fL at the work place throughout 75% of the leaseable space 50% of the time. We also determined that higher skybrightness could easily increase the illumination in further parts of the building. This initial assessment indicated a possible 37.5% reduction in lighting energy use which we felt was very significant and should thus be a major design input.

°Although cooling was not a major consideration in the initial assessment it appeared that a solution which increased light and solar gain when desired could also increase it when not desired. Thus it was determined that these elements should also be controllable in terms of heat gain. Our past experience indicated that the ambient level of wind and the height present in the building could be utilized to both ventillate excessive heat gain and to flush the building during summer evenings. This feature also became a major design input. These techniques were developed primarily from theoretical data and calculation method published by ASHRAE and our own field testing of installation in our previous work.

UNAVAILABLE INFORMATION

UNAVAILABLE: This task which is in essence the first step in the design process could use a great deal of input in areas such as rules of thumb. The primary area we found lacking was natural daylighting. There is good data available from the Illuminating Engineers Society for certain daylighting configuration. However, there should be many more fiqurations with measured and predictable daylighting configuration. The techniques developed at the University of Washington (as published in the 3rd & 4th Passive Solar Proceedings) were also useful but they need much better documentation and actual correlation. The The other area that is woefully inadequate is that concerning the lighting effects of direct and reflected beam sunlight and its ability to produce general lighting levels. We would like to see such information documentated in specific "genaric" type examples of daylighting configuration. It appears that a designer could accomplish this by constructing daylighting models, but such an effort would be prohibitively expensive in a normal design effort.

The overall effect of passive solar heating has been well documented by LASL in the solar load ratio technique but it again would be quite useful to see rules of thumb for assessing its potential with respect to the given climate and type and use of specific commercial occupancies rather than having to run through a separate SLR calculation at this stage of design.

In terms of cross ventillation and wind and solar induced ventillation for cooling it would be helpful again to see well documented genaric examples related to wind and solar conditions of specific buildings, and have these be related to and correlated to the current ASHRAE calculation methods. We have found these ASHRAE formulas to be fairly accurate, but would also like to see other peoples' experience documented.

INCREMENTAL PASSIVE DESIGN COSTS

PASSIVE SOLAR SPACE HEATING POTENTIAL/ASSESSMENT	
SLR METHOD DATA SET UP	1.5 HRS.
SLR MANUAL CALCULATIONS	4.0 HRS.
ASSESSMENT OF ENERGY & COST SAVINGS	1.0 HRS.
DOCUMENTATION OF RESULTS	3.0 HRS.
	9.5 HRS.
NATURAL DAYLIGHTING POTENTIAL ASSESSMENT	
STUDY & EVALUATION OF BASIC DAYLIGHT METHODS	10 HRS.
ANALYSIS OF DAYLIGHT LEVELS AT MINIMUM SKYBRIGHTNESS	
LOWER LEVEL SIDELIGHT/CLEARSTORY CONFIG.	6 HRS.
UPPER LEVEL TOPLIGHTING CONFIGURATION	5 HRS.
UPPER LEVEL BEAM SUNLIGHT CALCULATIONS	4 HRS.
COMPOSITE ANNUAL DAYLIGHTING CONTRIBUTIONS	8 HRS.
DOCUMENTATION OF RESEARCH	4 HRS.
NATURAL CROSS & INDUCED VENTILLATION ASSESSMENT	
BRIEF ANALYSIS BASED ON PAST EXPERIENCE	2 HRS.
(MORE THOROUGH ANALYSIS AT DESIGN DEVELOPMENT)	
(FROM PAST EXPERIENCE WE ASSUMED IT COULD BE DONE)	

The passive solar heating assessment would involve a similar effort. A good prportion of the daylighting assessment was part of staff learning experience. The total of 37 hours involved in daylighting assessment could probably be cut in half or equal to 20 hours in future projects. Ventillation cooling assessment would be a similar effort in the future.

MATHCING NEEDS AND POTENTIAL/ ANALYSIS

BRIEF ASSESSMENT OF BUILDING ENERGY NEEDS

A BRIEF ASSESSMENT OF CONVENTION ENERGY NEEDS

- THE BUILDING PRIMARY ENERGY CONSUMER IS FOR SPACE HTG 57%
- IN TERMS OF COST IT REPRESENTS 40% OF ENERGY EXPENDITURES.
- IN TERMS OF SOURCE ENERGY LIGHTING IS THE LARGEST CONSUMER AT 40%. IN ENDUSE ENERGY IT IS ONLY 25% OF TOTAL ENERGY. IN TERMS OF COST IT REPRESENTS 35% OF ENERGY EXPENDITURES

- THUS IT APPEARS THAT THE DESIGN EFFORT MUST CONCENTRATE BOTH ON THE REDUCTION OF ENERGY USE FOR BOTH LIGHTING AND SPACE HEATING.

NATURAL ENERGY ALTERNATIVES / SPACE HEATING

QUANTITATIVE ASSESMENT - NATURAL ENERGY ALTERNATIVES

TO QUANTITATIVELY ASSESS THE SPACE HEATING POTENTIAL OF PASSIVE SOLAR ELEMENTS RETROFIT TO THE BUILDING WE CALCULATED THE USEABLE SOLAR GAIN BY THE SOLAR LOAD RATIO METHOD AS DEVELOPED BY DOUG BALCOMB AT LASL. ESSENTIALLY WE ASSUMED A REASONABLE AMOUNT OF SOUTH FACING GLASS AND THE ADDITION OF A REQUISITE AMOUNT OF MASS. WE THEN RAN THROUGH THE CALCULATION BASED ON THE PREVIOUSLY DOCUMENTED HEAT LOSS & HEATING REQUIREMENTS. THIS PRODUCED A MONTHLY SOLAR LOAD RATIO FROM WHICH WE COULD QUANTITATIVELY ASSESS POTENTIAL REDUCTIONS IN SPACE HEATING REQUIREMENTS. THOSE CALCULATIONS FOLLOW ON THE NEXT PAGES.

POTENTIAL

SOLAR RADIATION ABSORBED

VERTICAL DIRECT GAIN TYPE SYSTEM

SOLAR ABSORPTION · SYSTEM 1 – VERTICAL DIRECT GAIN ✓

MONTH	DAILY AVG SOLAR RAD HORIZ	TILT ORIENT MODIF. FACTOR	DAILY NORMAL INCIDENT RADIATION	SQ FT COLLECTOR AREA	X 30 DAY /MONTH	SHADE FACTOR	TRANSMITTANCE	ABSORB. FACTOR	SOLAR RADIATION ABSORBED/ MONTH
AUG	–	–	–	140	30		.74		$\times 10^6$ BTU
SEP	1210	.63	762	140	30	.80	.74	.9	1.705
OCT	825	.94	776	140	30	.90	.74	.9	1.953
NOV	460	1.24	570	140	30	1.00	.74	.9	1.594
DEC	345	1.41	486	140	30	1.00	.74	.9	1.631
JAN	450	1.35	608	140	30	1.00	.74	.9	2.041
FEB	735	1.08	794	140	30	.90	.74	.9	2.664
MAR	1100	.77	847	140	30	.80	.74	.9	2.369
APR	1430	.50	715	140	30	.7	.74	.9	1.999
MAY	1700	.34	578	140	30	.5	.74	.9	1.617
JUNE		.30	–			.2			
JULY	* SOLMET – INTERPOLATED		–						

POTENTIAL
SOLAR RADIATION ABSORBED
ANGLED INDIRECT GAIN SYSTEM

SOLAR ABSORPTION - SYSTEM 2 - ANGLED DIRECT GAIN 45°

MONTH	DAILY AVE SOL. RAD ON A HORIZ SURF	TILT/ ORIENT MODIF FACTOR	DAILY NORMAL INCIDENT RADIATION	SQ FT COLLECT AREA	AVE 300/M	SHADE FACTOR	TRANS, MITTANCE	ABSORP FACTOR	SOLAR RADIATION ABSORBED/ MONTH
AUG				280			.68		X10⁶ BTU
SEPT	1210	1.18	1428	280	30	1	.68	.9	7.341
OCT	825	1.45	1196	280	30	1	.68	.9	6.148
NOV	460	1.68	773	280	30	1	.68	.9	3.974
DEC	345	2.01	693	280	30	1	.68	.9	3.563
JAN	450	1.95	878	280	30	1	.68	.9	4.514
FEB	735	1.55	1139	280	30	1	.68	.9	5.855
MAR	1100	1.28	1408	280	30	1	.68	.9	7.238
APR	1430	1.02	1456	280	30	1	.68	.9	7.485
MAY	1700	.90	1530	280	30	1	.68	.9	7.866
JUNE									
JULY	* SOLMET DATA - INTERPOLATED								

POTENTIAL
SOLAR RADIATION ABSORBED
SUN TEMPERED GAIN @ UPPER LEVEL

SOLAR ABSORPTION · SYSTEM 3 – SUN TEMP DIRECT GAIN U.L.

MONTH	DAILY AVG SOLAR RAD HORZ.	TILT ORIENT MODIF. FACTOR	DAILY NORMAL INCIDENT RADIATION	SQ FT. COLLECTOR AREA	X 30 DAY /MO.	SHADE FACTOR	TRANS MITTANCE	ABSOB. FACTOR	
AUG				120	1		.74	.27	
SEP			762	120	30	.6	.74	.27	.329
OCT			776	120	30	.7	.74	.27	.391
NOV			570	120	30	.9	.74	.27	.368
DEC			486	120	30	1.0	.74	.27	.349
JAN			608	120	30	.9	.74	.27	.393
FEB			794	120	30	.7	.74	.27	.399
MAR			847	120	30	.6	.74	.27	.365
APR			715	120	30	[illegible]	.74	.27	.103
MAY			578	120	30	—	—	—	—
JUNE									
JULY									

NET POTENTIAL PASSIVE SOLAR ENERGY UTILIZED

SOLAR CONTRIBUTION CALCULATION / LASL-SLR METHOD

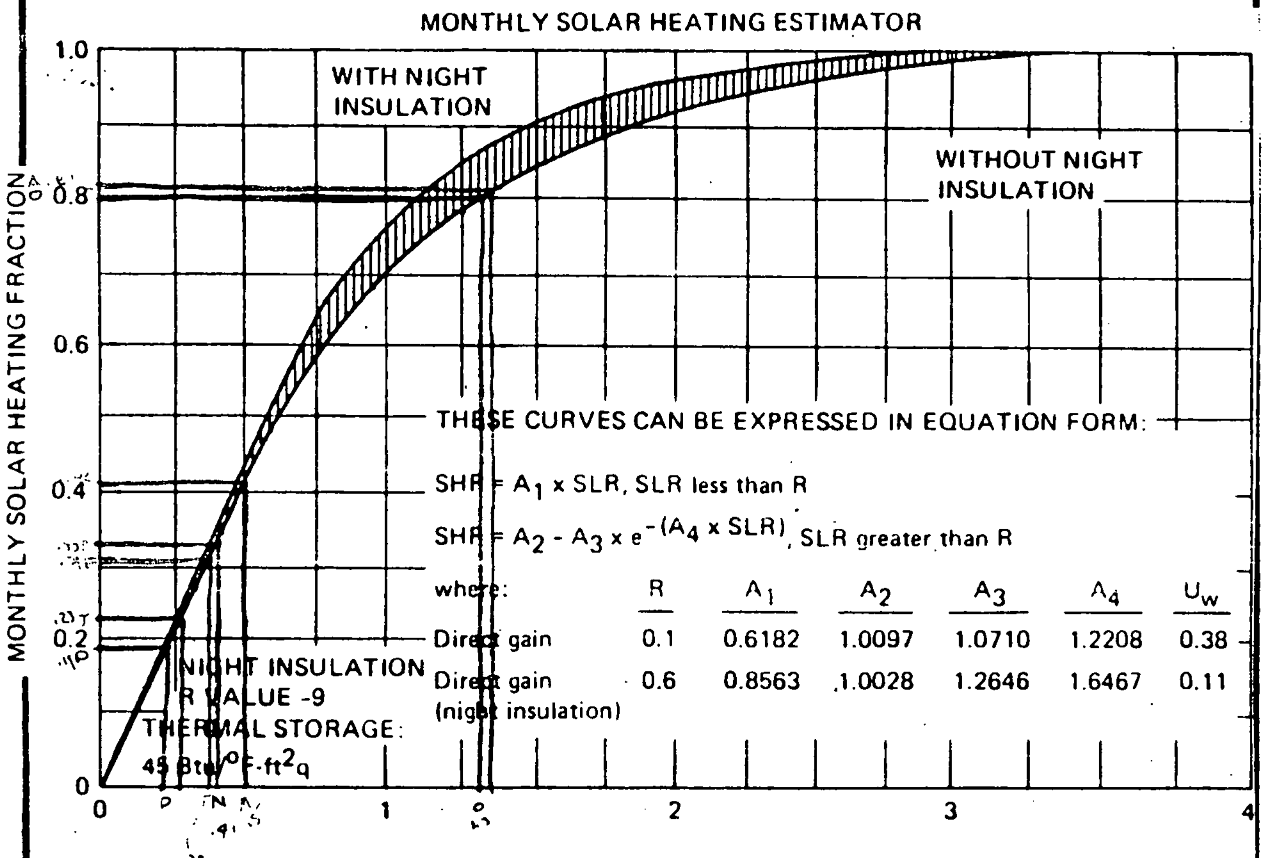
MONTH	DEGREE DAYS	MONTHLY HEAT LOSS	MONTHLY INT. GAINS	NET HEATING LOAD	TOTAL SOLAR RAD ABS	S.L.R.	SHF	PASSIVE CONTRIBUTION
AUG				—				
SEP	227	4.509	4.0	[illegible].509	9.325	18	1.0	.509
OCT	533	10.587	4.0	6.587	8.492	1.29	.8	5.264
NOV	996	19.783	5.0	14.783	5.936	.41	.33	4.878
DEC	1451	28.820	5.0	23.82	5.543	.23	.19	4.526
JAN	1631	32,396	5.0	27.346	6.948	.26	.23	6.301
FEB	1392	27.648	4.0	23.648	8.918	.38	.31	7.331
MAR	1190	23.636	4.0	19.636	9.972	.50	.42	8.247
APR	560	11.123	4.0	7.123	9.587	1.34	.81	5.77
MAY	333	6.614	4.0	2.614	9.483	3.626	1.00	2.614
JUNE				—				
JULY				126.[illegible]				45.44

36% SOLAR

NET PASSIVE SOLAR CONTRIBUTION	45.44
NET OPERATING ENERGY	− 0
NET SOLAR	
NET AUXILIARY REQUIRED	80.676

O/1.323 | N/9.905 | D/19.294 | J/21.095 | F/16.317 | M/11.389 | A/1.353 (ASSUMES 65°F T_{SET}

CALCULATION CHART FOR POTENTIAL PASSIVE SOLAR SPACE HEATING



1. MONTHLY SOLAR LOAD RATIO (SLR) = $\dfrac{\textit{MONTHLY SOLAR ENERGY ABSORBED}}{\textit{NET MONTHLY THERMAL LOAD}}$

(including the static conduction through the solar wall, $A_W \times U_W \times DD$*)*

DAYLIGHTING

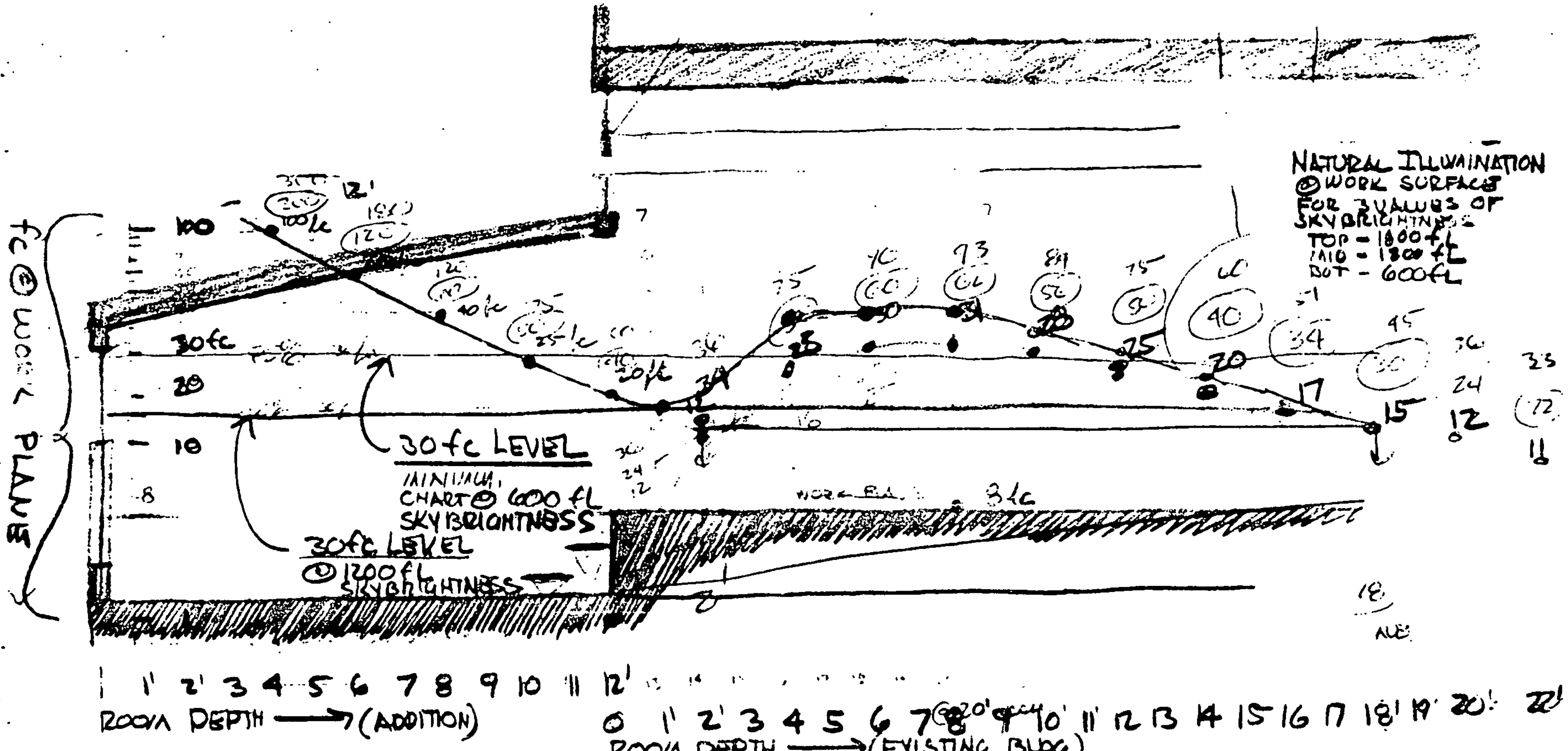
- THE QUANTITATIVE ASSESMENT OF THE DAYLIGHTING ALTERNATIVE WAS A FAR MORE DIFFICULT PROCESS THAN THAT ENVOLVED IN SPACE HEATING. OUR APPROACH WAS TO FIRST DEVELOP A SCHEMATIC OF THE DAYLIGHTING CONFIGURATIONS ON BOTH THE FIRST FLOOR AND THE UPPER LEVEL. SUPERIMPOSED ON THIS SCHEMATIC WE CALCULATED THE DAYLIGHT ILLUMINATION LEVELS ACCROSS THE BUILDING SECTION BASED ON STANDARD DAYLIGHTING CONFIGURATION DEVELOPED BY IES. THESE WERE DONE FOR 3 LEVELS OF SKYBRIGHTNESS (600fL, 1200fL and 1800fL) WE THEN CORRELATED THESE INTERIOR ILLUMINATION LEVELS WITH BUILDING OCCPANCY TIME AND PROBABLE (GROSS WEATHER PATTERNS)

- THE FIRST SCHEMATIC ON THE FOLLOWING PAGE IS THE LIGHT LEVEL CALCULATIONS FOR THE LOWER LEVEL IN A SIDELIGHTING/ CLEAR STORY DAYLIGHTING CONFIGURATION.
THE GRAPHS FOLLOWING THE SCHEMATIC ARE CHARTS OF SKYBRIGHTNESS DURING THE SEASONS (SUMMER, SPRING/FALL, WINTER) ON A TIME OF DAY BASIS. THE NUMBERS @ THE RIGHT OF THE GRAPH ARE THE NUMBER OF HOURS WHEN SKYBRIGHTNESS WAS HIGHER THAN THE MINIMUM REQUIRED. THE CALCULATIONS FOLLOWING THE GRAPHS ARE A TOTAL HOUR ASSESSMENT OF DAYLIGHT POTENTIAL COMBINED WITH ARTIFICIAL LIGHTING REQUIREMENT. THIS DATA IS THEN WEIGHTED AND REDUCED TO AN ARTIFICIAL ILLUMINATION BUDGET ON A WATTS/SF TO ALLOW EASY COMPRISON W/CONVENTIONAL ILLUMINATION BUDGETS.

- THE SCHEMATIC/GRAPHS AND CALCULATIONS FOLLOWING THAT, ENVOLVE THE SAME PROCESS FOR THE UPPER LEVEL WHICH IS A SIDE AND TOPLIGHTING CONFIGURATION

DAYLIGHTING ASSESSMENT

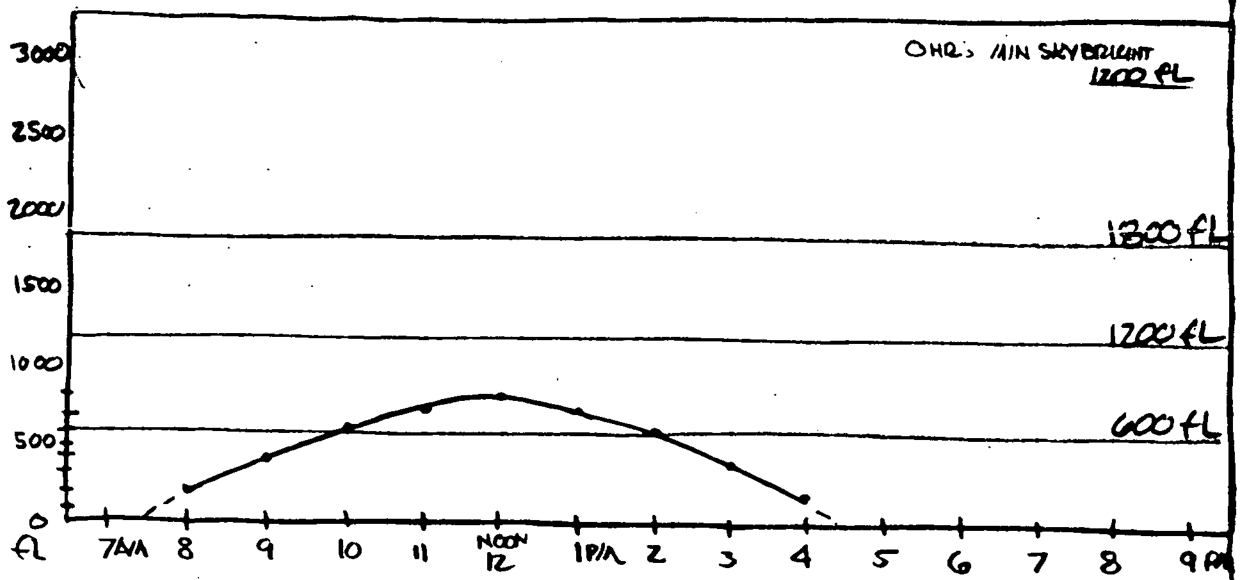
MAIN LEVEL-DAYLIGHTING SCHEMATIC



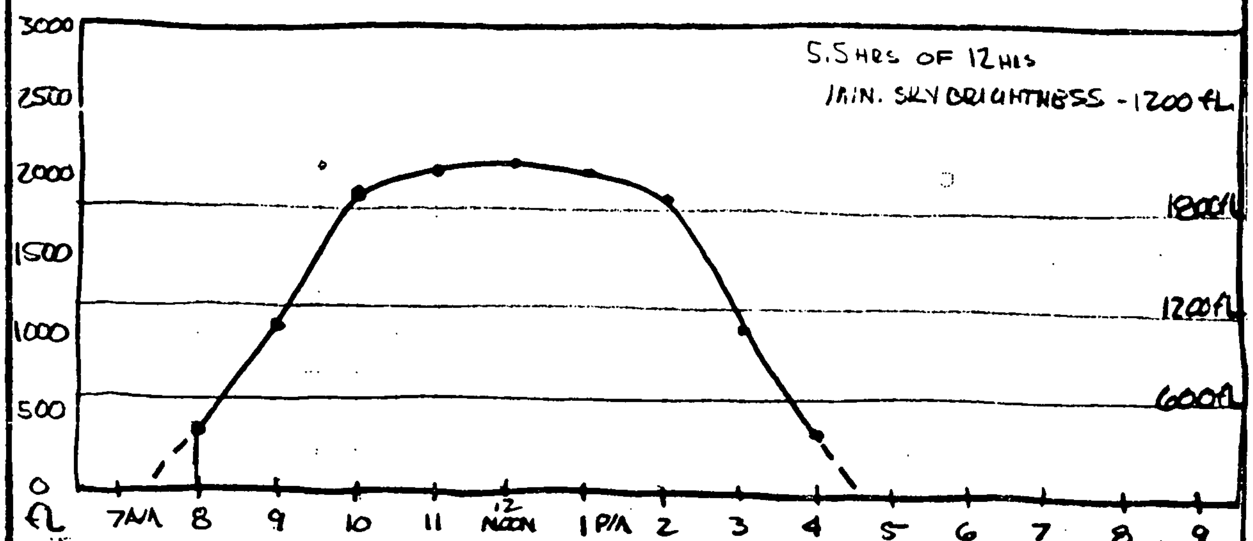
LATE AFTERNOON OVERCAST/DECEMBER

30fc = 85% CONDITION 600 fL SKY BRIGHTNESS
60fc = 50% CONDITION 1200 fL SKY BRIGHTNESS
90fc = 15% CONDITION 1800 fL SKY BRIGHTNESS

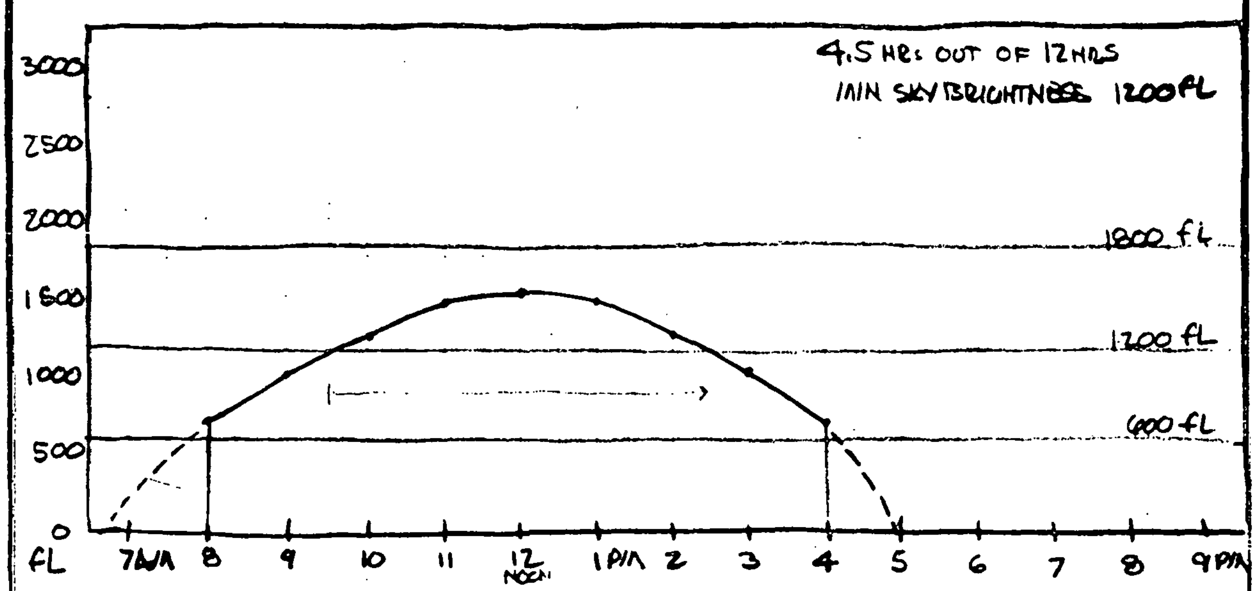
SKYBRIGHTNESS CHARTS



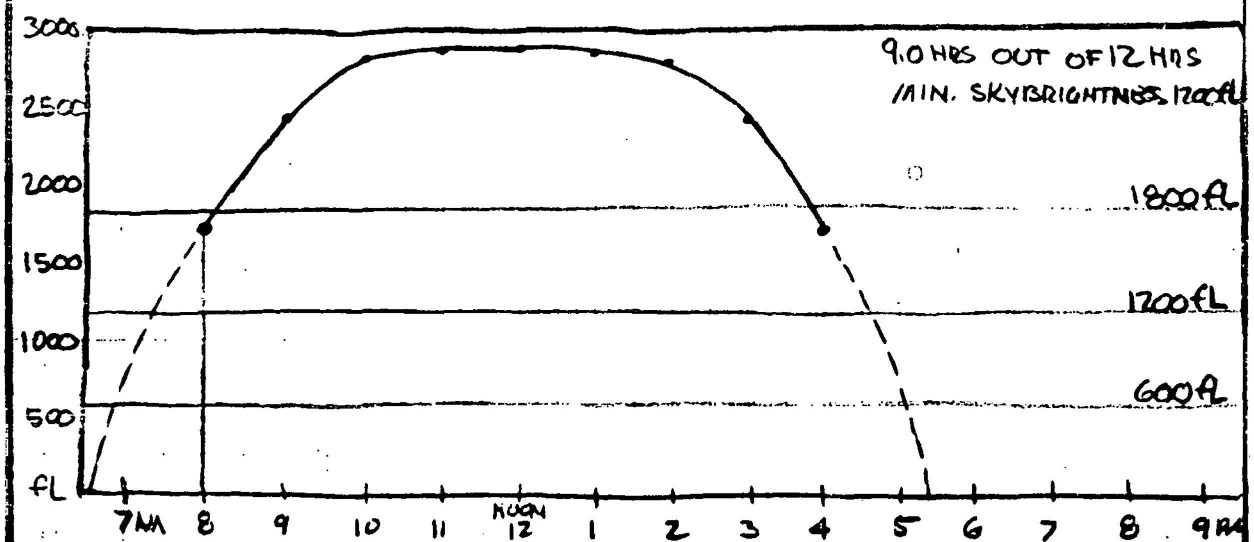
WINTER - OVERCAST / SKYBRIGHTNESS vs TIME



WINTER - CLEAR / SKYBRIGHTNESS vs TIME



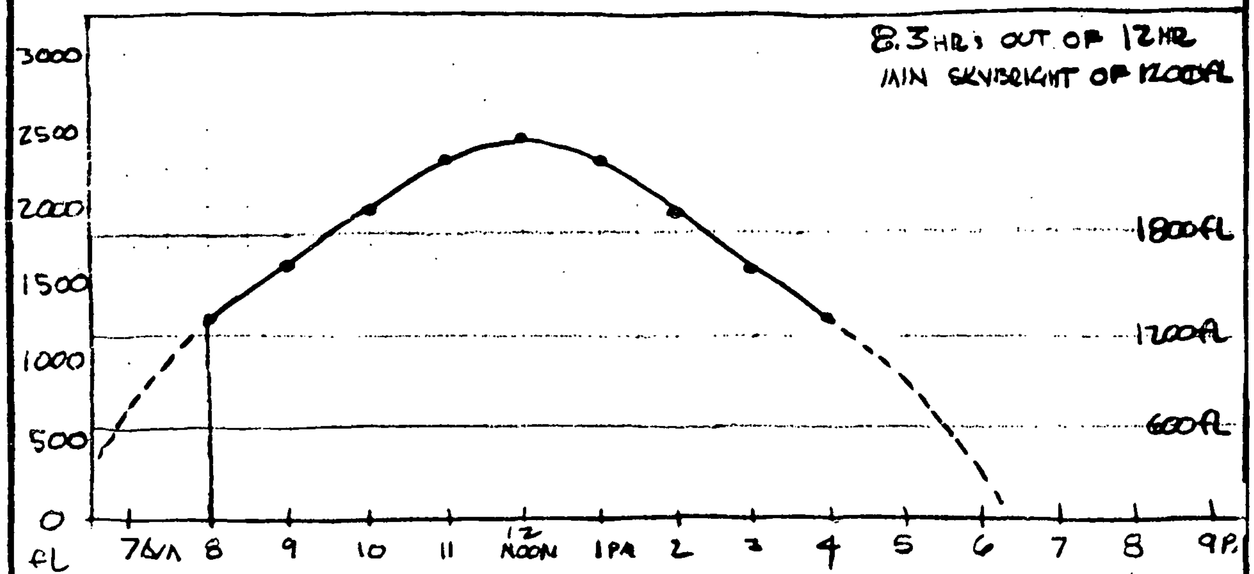
SPRING/FALL- OVERCAST/ SKYBRIGHTNESS VS TIME



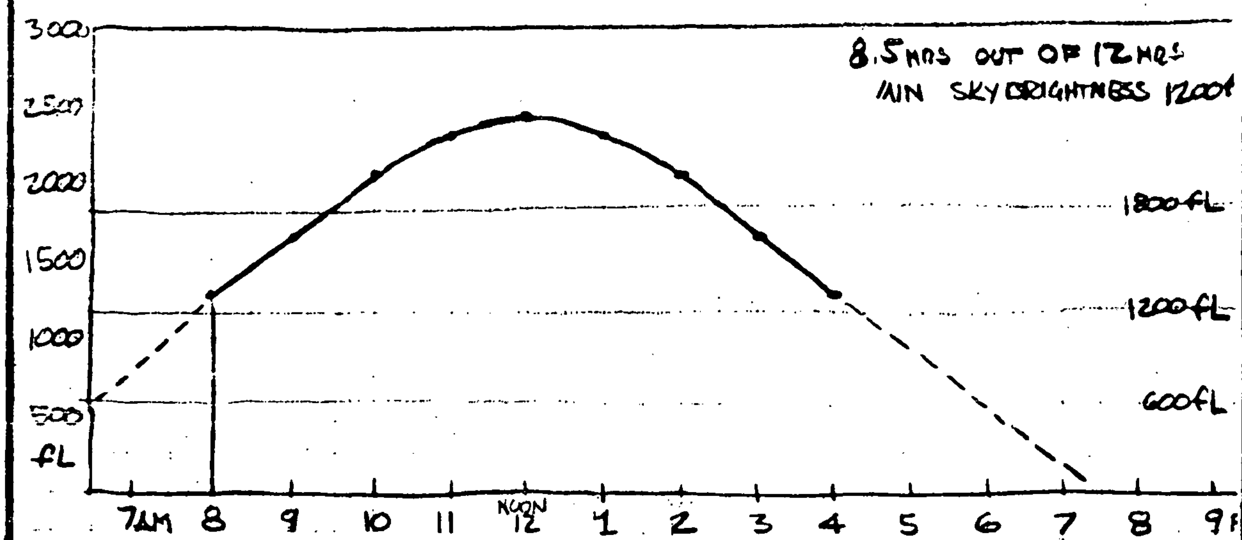
SPRING/FALL- CLEAR /SKYBRIGHTNESS VS TIME

SKYBRIGHTNESS CHART

SKYBRIGHTNESS CHART



SUMMER - OVERCAST / SKYBRIGHTNESS vs TIME



SUMMER - CLEAR / SKYBRIGHTNESS vs TIME

LOWER LEVEL DA[illegible]

• FROM THE LIGHT CONFIGURATION SCHEMATIC IT CAN BE SEEN THAT 1200 fL OF SKYBRIGHTNESS PRODUCES IN EXCESS OF 30 fc OF ILLUMINATION COMPLETELY IN THE PROPOSED 12' ADDITION WHICH IS SIDE-LIT AND TO A DEPTH OF 18' IN THE EXISTING PORTION OF THE BUILDING (CIRCLED VALUES)
WE USED THIS LEVEL 1200 fL AS THE STANDARD MINIMUM AND CALCULATED THE NUMBER OF HOURS IN EACH SEASON (ACCORDING TO CLOUD COVER) THAT THE DAYLIGHT WAS SUFFICIENT TO ELIMINATE THE NEED FOR ARTIFICIAL ILLUMINATION IN THE SOUTHERN 30' OF THE BUILDING LOWER LEVEL. THIS SPACE IS ABOUT 80% OF THE BUILDING PUBLIC RETAIL SPACE REQUIRING 30 fc MIN. ILLUMINATION

THE FOLLOWING CALCULATION BASED ON THE PREVIOUS GRAPHS ARE A CALCULATION OF % OF LIGHTING LEVELS WEIGHTED BY TIME (OF NO ARTIFICIAL ILLUMINATION REQUIRED IN .82 (82%) OF THE FLOOR SPACE. OCCUPIED HOURS PER SEASON — 884 HRS or 13 WEEK/SEASON

WINTER OVERCAST 60% — NO USEABLE DAYLIGHT AS DEFINED ...

CLEAR 40% — 5.5 HR/DAY-DAYLIGHT × 6 DAY/WK = 33 HR/WK × 5.2 WK 172 HR

$\left(\frac{172}{884}\right)(.82 \text{ sp}) + (1)(.12) = .16 + .18 = .34 \doteq .348$

O.C. CLEAR

$(.6)(1) + (.4)(.34) = .6 + .14 = .74$ (26% REDUCTION)

SPRING/FALL OVERCAST 50% — 4.5 HR/D × 6 DAY/WK = 27 HR/WK × 6.5 WK 175.5 HR.

$\left(\frac{175.5}{884}\right)(.82) = (.2)(.82) = .16$

CLEAR 50% — 9 HR/D × 6 DAY/WK = 54 HR/WK × 6.5 WK = 351 HR

$\left(\frac{351}{884}\right)(.82) = (.4)(.82) = .33$

$.16 + .33 = .49 \approx$ (50% REDUCTION)

SUMMER OVERCAST 40% — 8 HR/D × 6 DAY/WK = 48 HR/WK × 7.8 WK — 374 HR

$(374/884)(.82) = (.42)(.82) = .35$

CLEAR 60% — 9 HR/DAY × 6 DAY/WK = 54 HR/WK × 5.2 WK = 281 HR

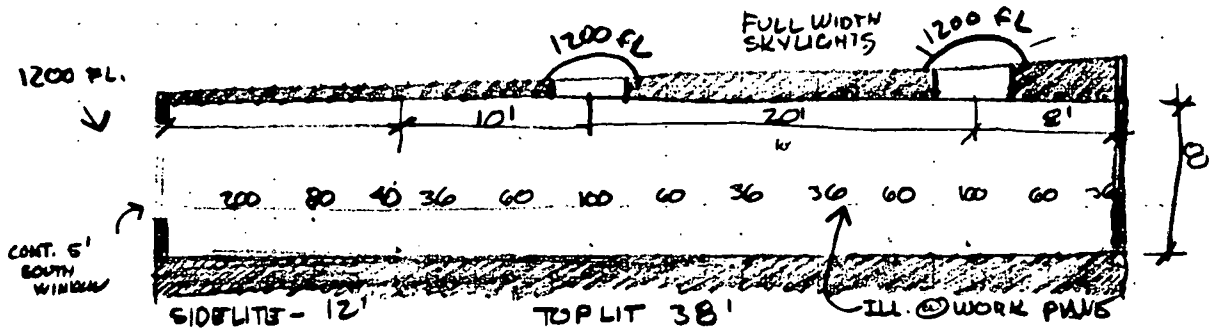
$(281/884)(.82) = (.32)(.82) \quad .26$

$.35 + .26 =$ (61% REDUCTION)

AVE ANNUAL REDUCTION $= \frac{26+50+50+61}{4} = 187/4 = 47\%$ REDUCTION (LOWER LEVEL)

AVERAGE ANNUAL REDUCTION = 47%

UPPER LEVEL - DAYLIGHT SCHEMATIC



ASSESSMENT

THE ABOVE SCHEMATIC INDICATES THAT AT 1200 fL OF SKY BRIGHTNESS, THUS THE ENTIRE SPACE CAN BE MAINTAINED AT IN EXCESS OF 30 fC MIN ON THE WORK PLANE. WE ASSUMED BECAUSE OF WALL REFLECTION / DEAD SPACE ETC. THAT ONLY 87% OF THE SPACE COULD BE DAYLIT. THESE ARE THE SAME RATIOS FOR THE LOWER LEVEL THUS THE SAME DATA & PROPORTION HOLD TRUE. HOWEVER OCCUPANCY HOURS ARE DIFFERENT DAILY OCCUPANCY PERIOD 8AM-5PM 9HR x 5 DAYS/WK x 13 WK/SEASON = 585 HR/SEASON

EXACT CALCULATION OF ILLUMINATION ENERGY REDUCTIONS FOLLOW ON THE NEXT PAGE.

NET POTENTIAL ARTIFICIAL (ELEC) ILLUMINATION REDUCTIONS

WINTER OVERCAST (60%) NO USEABLE DAYLIGHT AS DEFINED

CLEAR 40% - 5.5HRS/DAY X 5 DAYS/WK X 5.2WK CLEAR = 143 HR of DAYLIGHT

$\left(\frac{143}{585}\right)(.82) = .24 \times .82 =$ (20% REDUCTION)

SPRING/FALL OVERCAST 50% - 4.5HR/DAY X 5 DAYS/WK X 6.5WK = 146HR.

$\left(\frac{146}{585}\right)(.82) = .20$

CLEAR 50% 9HR/DAY X 5DAYS/WK X 6.5WK = 292HR

$\left(\frac{292}{585}\right)(.82) = .41$

$.2 + .41 = .61$ (61% REDUCTION)

SUMMER OVERCAST 40% - 8HR/DAY X 5DAY/WK X 7.8WKS = 312HR

$\left(\frac{312}{585}\right)(.82) = (.53)(.82) = .44$

CLEAR 60% - 9HR/DAY X 5DAYS/WK X 5.2WK = 234HR

$\left(\frac{234}{585}\right)(.82) = (.4)(.82) = .33$

(77% REDUCTION)

AVERAGE ANNUAL REDUCTION

$\frac{20+61+61+77}{4} = \frac{219}{4} = 55\%$

BUILDING ENERGY USE GOALS

– BASED ON THE PREVIOUS ENERGY REDUCTION POTENTIALS ANALYSIS IT WILL BE OUR GOAL TO ACHIEVE THE FOLLOWING ENERGY REDUCTIONS, WITHOUT INCREASING SPACE COOLING REQ'S

	CONVENTIONAL BLDG ENERGY USE	ELEMENT / REDUCTION	RETROFIT BLDG ENERGY USE GOAL
END USE ENERGY	73×10^6 BTU	SPACE HEATING (30%)	51×10^6 BTU
	17×10^6 BTU	SPACE COOLING (–)	17×10^6 BTU
	32×10^6 BTU	LIGHTING (50%)	16×10^6 BTU
	7.5×10^6 BTU	EQUIPMENT (–)	7.5×10^6 BTU
	129.5×10^6 BTU · 53,958 BTU/SF/YR		91.5×10^6 BTU 38,125 BTU/SF/YR (30% REDUCTION)
SOURCE ENERGY	73×10^6 BTU	SPACE HEATING	51×10^6 BTU
	50×10^6 BTU	SPACE COOLING	50×10^6 BTU
	95×10^6 BTU	LIGHTING	48×10^6 BTU
	22×10^6 BTU	EQUIPMENT	22×10^6 BTU
	240×10^6 BTU 100,000 BTU/SF/YR		171×10^6 BTU 71,250 BTU/SF/YR (29% REDUCTION)

THESE GOALS COMPARE WITH THE FOLLOWING FROM BERS STATISTICAL STUDIES FOR OUR CLIMATIC ZONE (BTU/SF/YR)

MERCANTILE/RETAIL	30% BASELINE EXISTING BUILDINGS (THE BEST 30% EXISTING BUILDINGS)	96,000
	80% TECHNICAL REDESIGN	78,000
	BEST TECHNICAL REDESIGN (ZONE 2 NOT ZONE 3)	65,000
OFFICE BUILDINGS	30% BASELINE	56,000
	80% TECHNICAL REDESIGN	49,000
	BEST TECHNICAL REDESIGN	29,000

NOTE: THE DESIGN CONCEPTS WE INTEND TO PURSUE WILL STRIVE FOR AN EVEN GREATER ENERGY USE REDUCTION. HOWEVER A 30% REDUCTION IS SIGNIFICANT FOR AN EXISTING BLDG & WILL BE OUR MINIMUM GOAL

DESIGN INDICATORS

OVERVIEW

DESIGN INDICATORS: Because of the rather limited scope of the project no "design indicator" schematics were developed. Essentially the design solution had to maximize solar heat gain and provide for deep penetration of natural daylighting on the first level. It is our belief that the solution which has been proposed was really the only one that could be made. The heart of the design was the necessary details that would make this overall solution work in its given context (such as measures to prevent overheating and the proper integration of the solar space addition both in terms of architecture, thermal and energy performance). These elements and concepts are more fully illustrated in the drawings of the design solution.