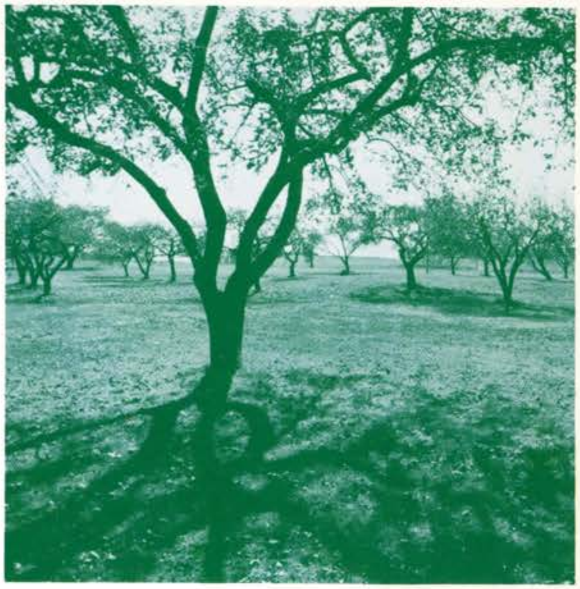
Humber College of Applied Arts and Technology

Humber Lakeshore 1 Campus Master Plan Report



Appendix

Humber College of Applied Arts and Technology

Humber Lakeshore 1 Campus Master Plan Report Appendix

August 1975

Moffat Moffat & Kinoshita
Architects and Planners

Accommodation Requirements at Former Lakeshore Teachers' College

Adjacent Site: View to Lake Ontario

ACCOMODATION REQUIREMENTS AT FORMER LAKESHORE TEACHERS' COLLEGE

Registrar	Net Area (sq. ft.)
Admissions and Records Office	100
Open Office for 4	250
Storage	25
Information/Switchboard	50
Reception/Waiting Area	120
Test Centre (35 student station)	600
Storage and Grading	80
	1225

Financial Services	
Bursar's Office	100
Purchasing Agent's Office	100
Open Office for 4	250
Stationery Storage	50
Receiver's Office	100
Receiving and Shipping Area	150
	750

Centre for Professional & Programme Development	
Professional Development Mgr's Office	100
Director of Academic Services's Office	100
Secretary/Typist	80
Open Office for 7	420
Equipment Storage	50
	750

Administrative Office	
Principal or Dean's Office	120
Secretary/Typist	80
	200

Learning Resources Management	
Learning Resources Mgr's Office	100

Learning Resources Centre	
Entrance/Circulation/Distribution	800
Reading/Browsing/Individual Study	3450
Viewing and Listening	
Conference Area	150
Office Space for 3	300
Workroom	300
Stacks	600
Magazine Storage	300
	5900

Bookstore

Display/Storage/Sales	900
Manager's Office	100
	1000

Word Processing Centre

3 Typing Units	160
Storage for Paper and Supplies	40
	200

Printing Centre

Print Room (incl. darkroom)	500
Paper Storage	175
Workroom for stapling/binding/collating	425
Manager's Office	60
	1160

Instructional Materials Centre

Equipment Storage and Distribution	250
Screening Room	150
	400

Secretarial Studies

1 Typing Lab for 70	1350
3 Typing Labs for 35	2325
1 Shorthand Lab for 40	600
1 General Office Machines Lab for 50	1000
1 Office Simulation Lab for 15	450
	5725

Business

5 Classrooms for 25 to 30	4000
1 Complex Business Machines Lab for 30	750
Dean's Office	120
Secretary	80
25 Faculty Offices @ 70 s.f	1750
	6700

English Communications

1 Lab for 50	1350
3 Discussions/Seminar Rooms for 30	1500
	2850

Accounting/Bookeeping

1 Classroom for 40	1000

Mathematics

1 Classroom for 30	750

Humanities

2 Classrooms for 30	1500

Applied Arts

1 Metal Arts Lab for 20	1500
1 Travel and Tourism Classroom for 30	750
1 Law Enforcement Classroom for 30	750
	3000

Placement and Counselling

Counsellor's Office	100

Health Services

Nurse's Office	80
Exam Room	80
Reception/Waiting Area	80
2 Sick Bays @ 100 s.f.	200
Treatment Room	80
2 Washrooms @ 30 s.f.	60
Storage	40
	620

Athletics

Programme Director's Office	100
2 Male Locker/Toilet/Shower Areas	900
2 Female Locker/Toilet/Shower Areas	1100
Equipment Room- Rental	200
Equipment Room- Storage	150
	2450

Student Union Facilities

Office/Workroom	150
Recreation/Seating Area	1170
Vending Area	380
	1700

Custodial Services

Caretaking Office/Lunchroom	200
2 Custodial Rooms @ 100 s.f.	200
4 Custodial Rooms @ 25 s.f.	100
	500

Groundskeeping

Storage (can be external to building)	200

Total Net Area of New Facilities 38,780 sq. ft.

Mechanical Appendix

Lake Ontario: View Southeast

MECHANICAL APPENDIX

GENERAL

To carry out this analysis, a building of 150,000 square feet, similar to the second phase of new construction, was used.

Since population and classroom usage vary as a function of the daytime, utilization profiles were developed from data established by the north campus of Humber College, Chart One.

This information was used to derive the combined loss/gain diagram for occupied periods, Figure Three, and also the hourly cooling profile on a peak day, Chart Three.

HEAT RECLAIM

The validity for using the heat of lights, people and equipment, Figure Three, to offset fabric losses can be shown in two ways.

The electrical energy required to drive a heat pump to reclaim 14,730 BTU's is approximately 0.8 kilowatts. At a cost of 1.8 cents/kilowatt hour, the cost for reclaimed heat equals $\frac{0.8 \times 1.8}{14.73}$ 0.0978 cents for each 1,000 BTU/hour reclaimed.

Natural gas at 125 cents for 1,000 cubic feet and 75 per cent combustion efficiency costs $\frac{125}{1,000 \times 0.75}$ 0.167 cents for each 1,000 BTU/hour.

A heat pump reclaiming free heat therefore shows a saving of 42 per cent over fossil fuel.

To justify the capital expenditure of a heat pump necessary to achieve this saving, sufficient heat has to be reclaimed. This is shown on Chart

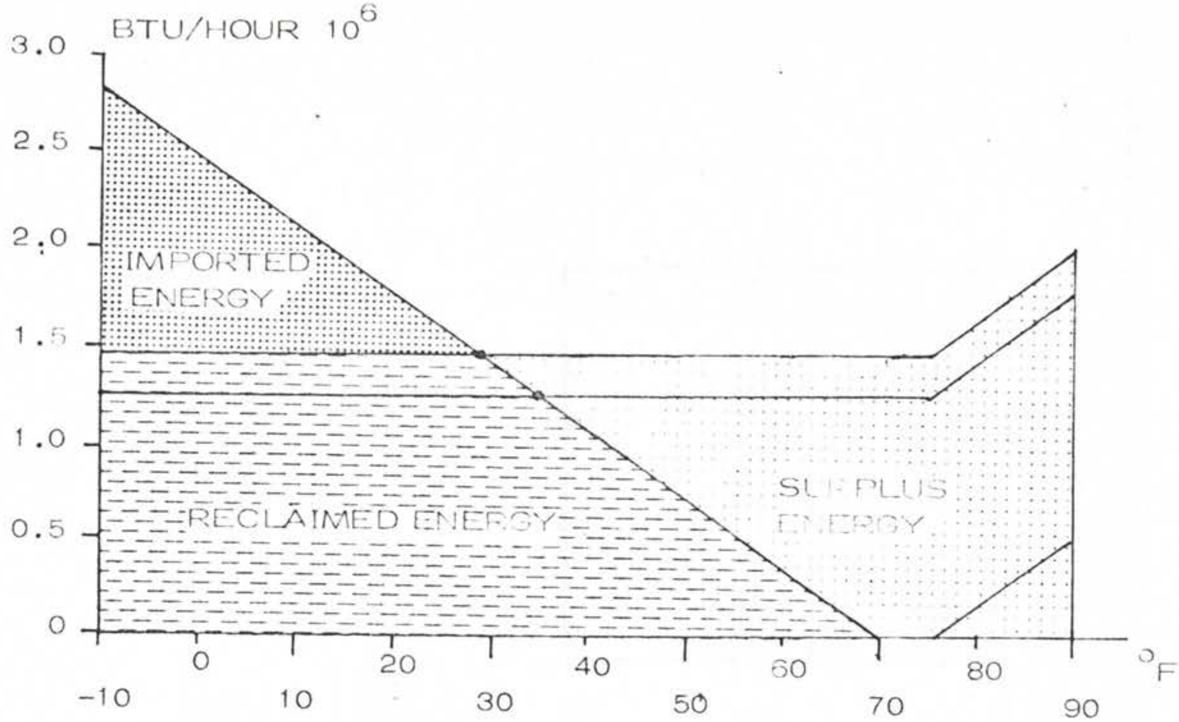


FIGURE THREE - COMBINED LOSS/GAIN DIAGRAM FOR OCCUPIED PERIODS

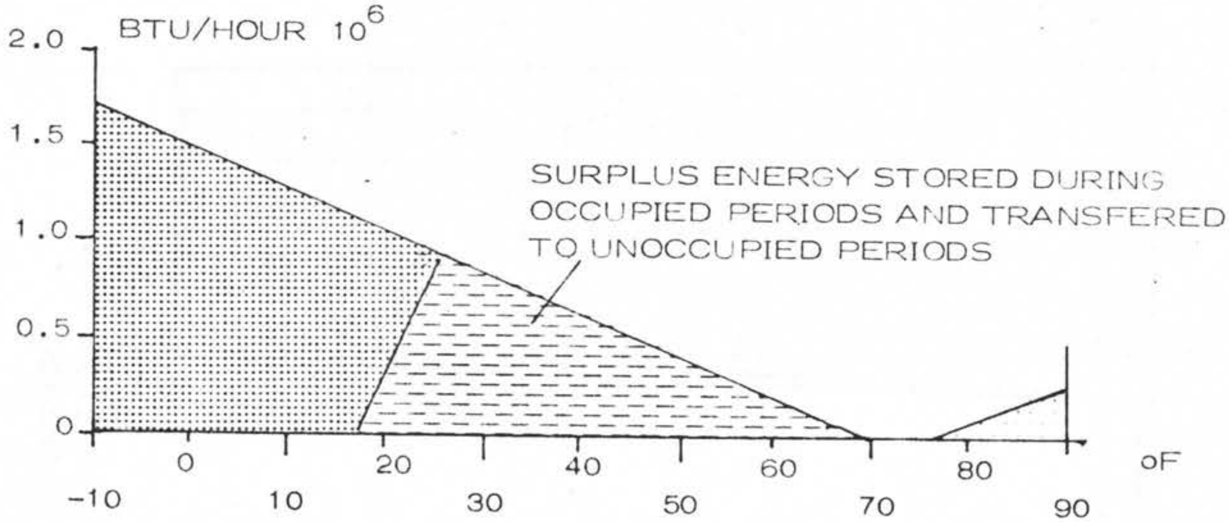


FIGURE FOUR - LOSS/GAIN DIAGRAM FOR UNOCCUPIED PERIODS

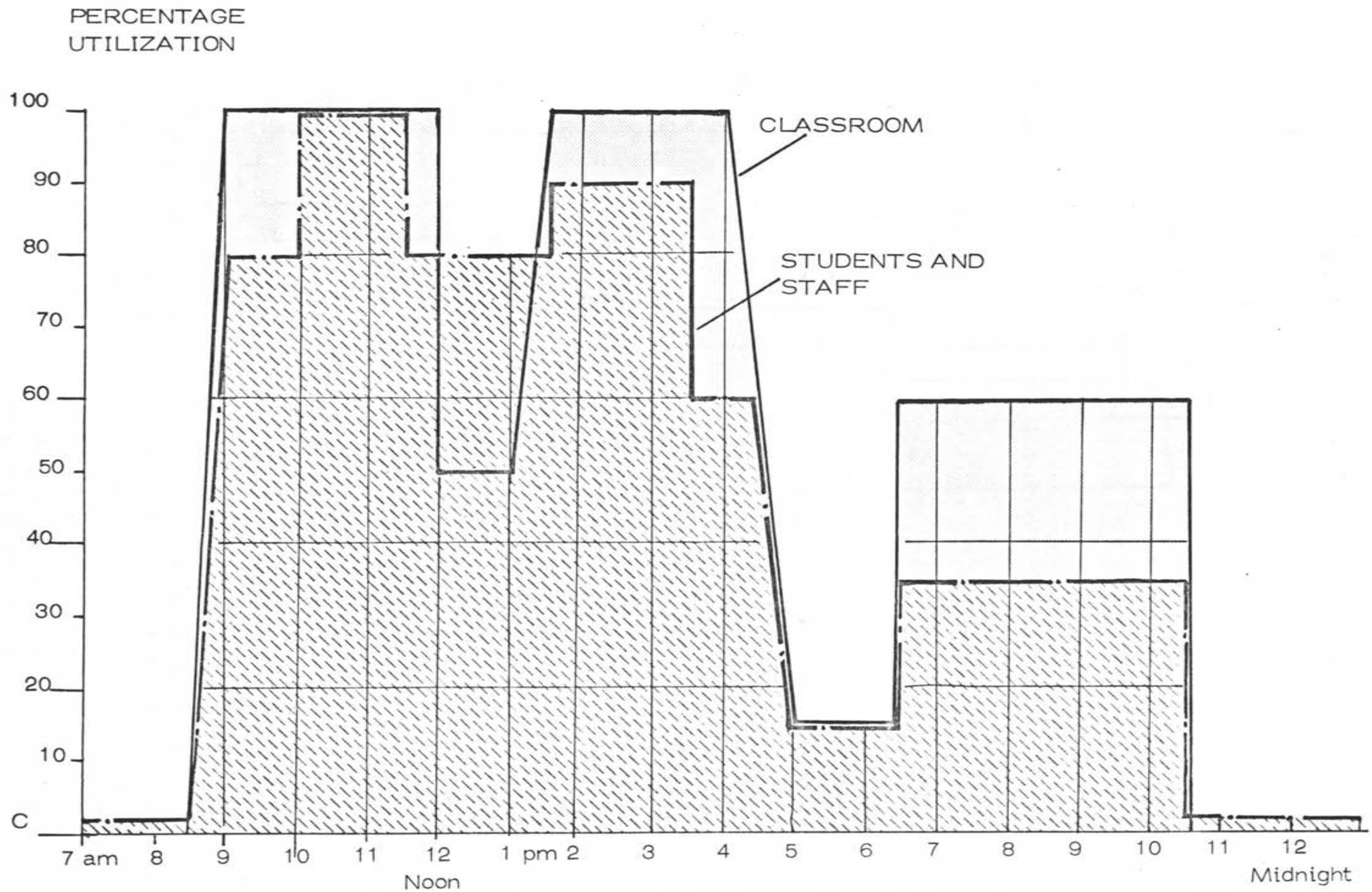


CHART ONE

UTILIZATION PROFILES

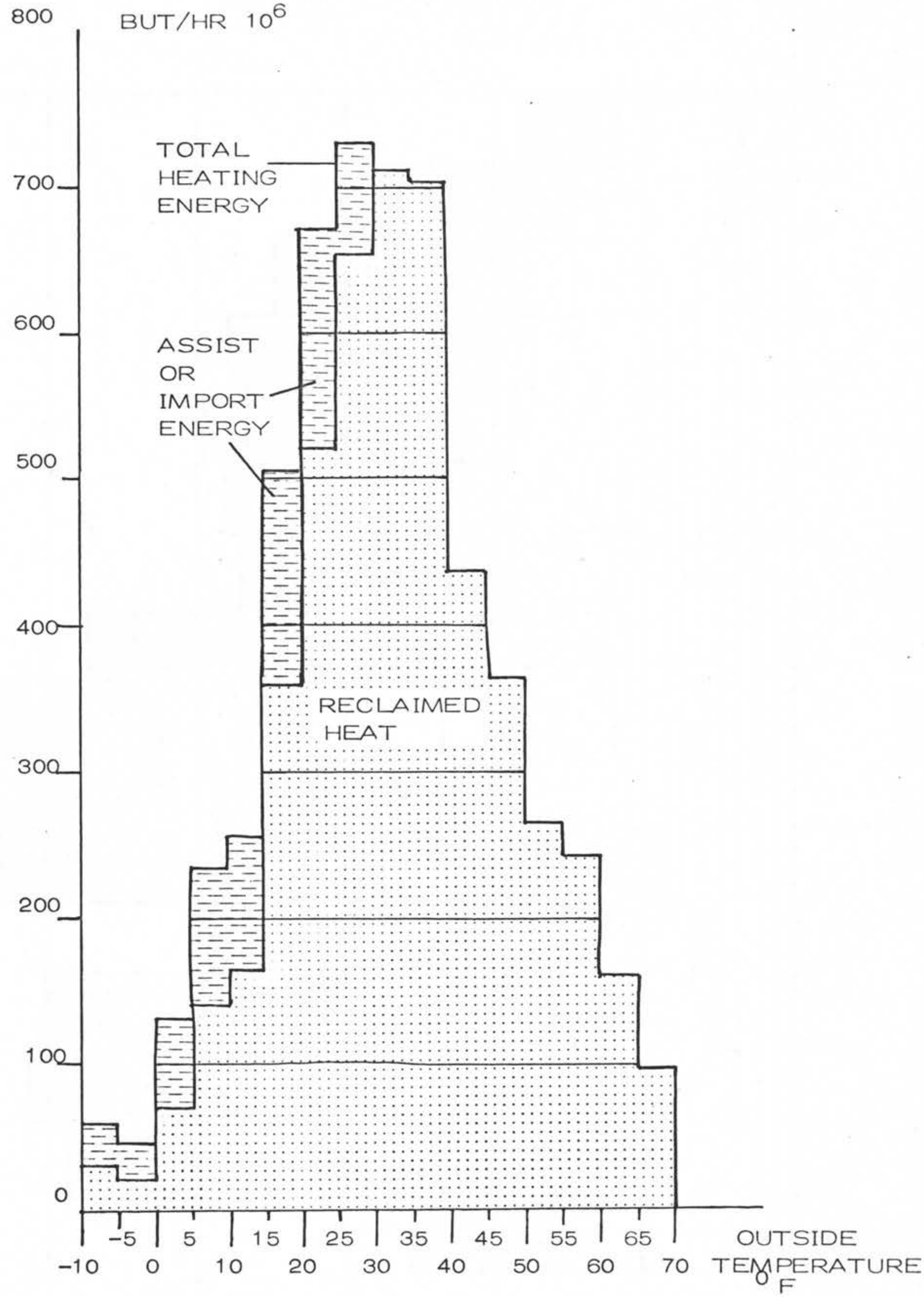


CHART TWO
YEARLY ENERGY REQUIREMENTS
OCCUPIED PERIODS

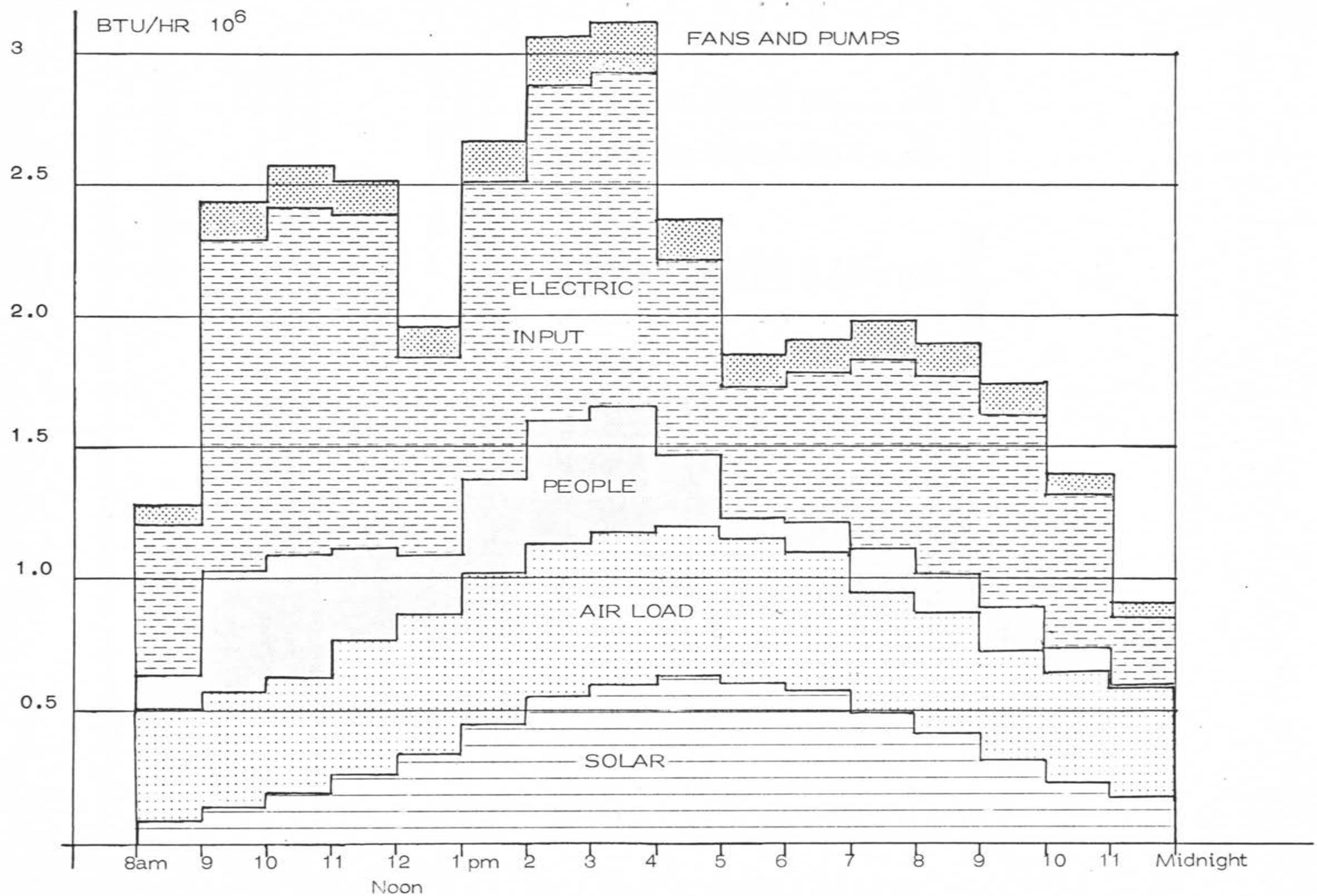


CHART THREE

PEAK DAY COOLING

Two and was calculated as follows:

1. Temp. Band	2. No. Hours	3. Average Loss BTU/hr.	4. Maximum Reclaim Heat Available BTU/hr.	5. Reclaimed Heat Col. 2 × Lowest Value of Cols. 3 or 4
-10 / -5	21	2,870,000	1,400,000	29.4×10^6
- 5 / 0	16	2,690,000	1,400,000	22.4×10^6
0 / 5	51	2,511,250	1,400,000	71.4×10^6
5 / 10	101	2,331,875	1,400,000	141.4×10^6
10 / 15	119	2,152,500	1,400,000	166.6×10^6
15 / 20	256	1,973,125	1,400,000	358.4×10^6
20 / 25	373	1,793,750	1,400,000	522.2×10^6
25 / 30	465	1,614,375	1,400,000	651×10^6
30 / 35	509	1,435,000	1,400,000	712.6×10^6
35 / 40	561	1,255,625	1,400,000	704.4×10^6
40 / 45	403	1,076,250	1,400,000	433.7×10^6
45 / 50	406	896,875	1,400,000	364.1×10^6
50 / 55	372	717,500	1,400,000	266.9×10^6
55 / 60	450	538,125	1,400,000	242.1×10^6
60 / 65	470	358,750	1,400,000	168.6×10^6
65 / 70	548	179,375	1,400,000	98.3×10^6

The total energy saved per year amounts to 4953.5×10^6 BTU. This saving for reclaimed heat over natural gas, translated into 1975 dollars, equals $3,429.00.

$$\frac{4953.5 \times 10^6}{10^3} \times \frac{0.167 - 0.0978}{100}$$

With the cost of reclaim equipment at $100.00 per 15,000 BTU/hour reclaimed, the pay off period is approximately three years. Assuming energy escalates in cost 20 per cent per year, this period reduces to 2.4 years.

THERMAL STORAGE

Further energy savings can be achieved using thermal storage.

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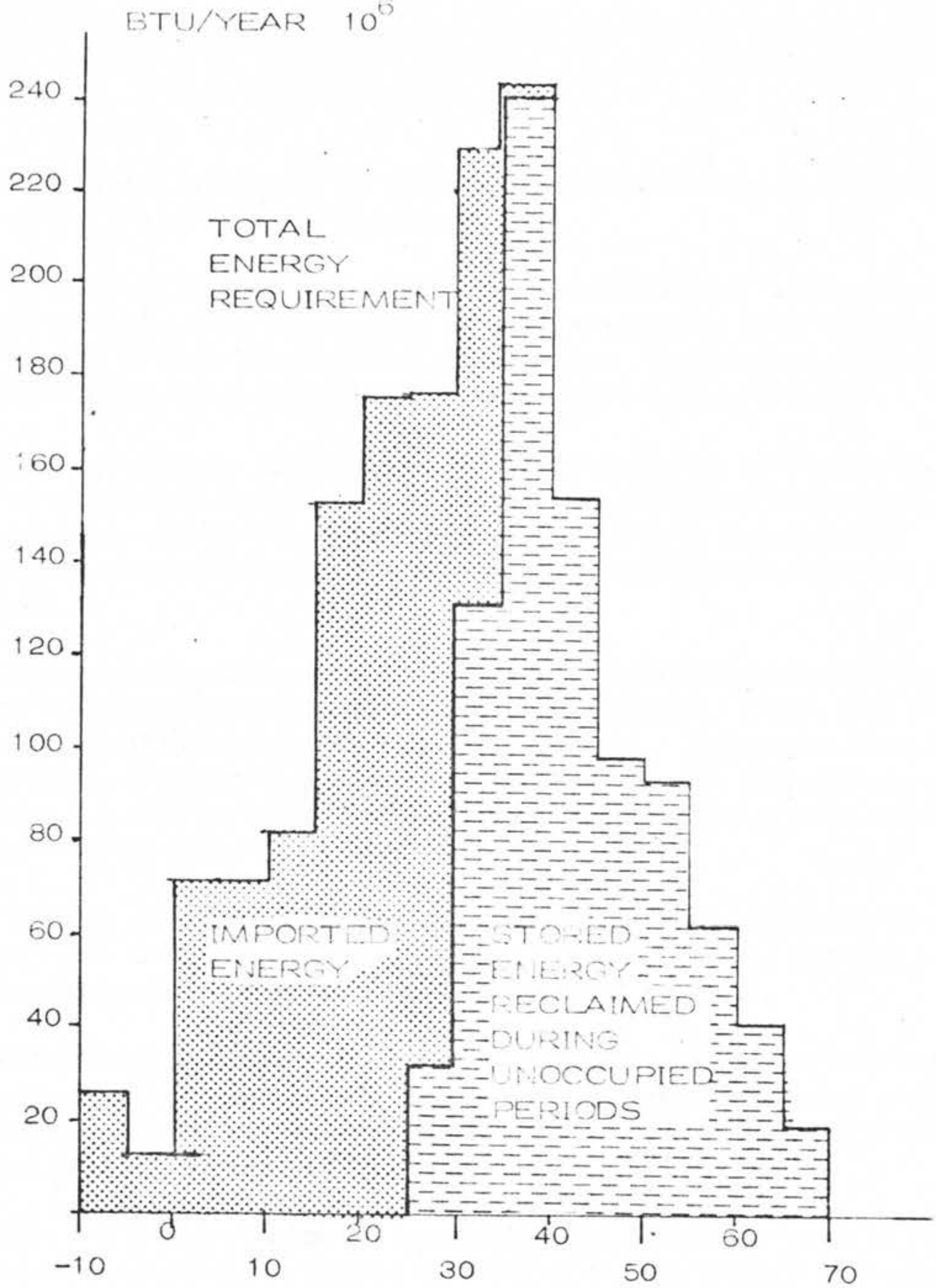

FIGURE FIVE - YEARLY ENERGY REQUIREMENTS FOR UNOCCUPIED PERIODS

$\sum$ RECLAIMED ENERGY = 877×10^6 BTU/YEAR
UNOCCUPIED PERIODS

In the past, storage has been discounted because of the problems of blending and transfer pumping energy.

To prevent blending of usable and return water, baffles and diaphragms may be used. In Japan, honeycomb baffles have achieved anti-blending efficiencies in excess of 85 per cent. A patented diaphragm by Engineering Interface Limited eliminates blending completely.

By themselves, diaphragms or baffles are not sufficient to ensure effective use of the stored water. All useful energy of any water taken from storage must be transferred if savings are to be realized. This is achieved by maintaining the system temperature range under all operating conditions.

Excessive pumping energy can be involved when transferring water from an atmospheric tank to a pressurized system. Costs and limits of the pressurized tanks tend to dictate this route. To reduce this energy requirement, Engineering Interface Limited has, in conjunction with others, developed a pump/turbine combination to transfer the pressure energy of the return water to assist the pump motor.

The use of these components to save energy is demonstrated by Figures Four and Five. Surplus energy from occupied periods can be transferred to unoccupied periods via thermal storage.

Additional savings in energy are achieved due to the normal 10°F to 20°F reduction in temperature that occurs during unoccupied night periods. This can be seen by reviewing the energy requirement at 60°F during occupied periods against 40°F during unoccupied periods.

For the chosen building, heating of 358,750 BTU/hour is required during occupied periods, whilst the heat of lights, people and equipment for reclaim amounts to 1,400,000 BTU/hour. An occupied surplus of 1,041,250 BTU/hour exists which would be lost without storage.

With storage, this can be transferred to satisfy an unoccupied heating requirement of 637,500 BTU/hour. Thus, energy is not only saved but is shifted to conditions where it can do more useful work.

The total energy saved, calculated in a manner previously indicated in this Appendix, is shown on Figure Five and amounts to 876,000,000 BTU/year. Using the 1975 dollars, the value of the saved energy amounts to $\left(\frac{876 \times 10^6}{10^3} \times \frac{0.167 - 0.0978}{10^2} \right)$ \$606, assuming the electric costs of operating the heat pump are a mix of demand and energy.

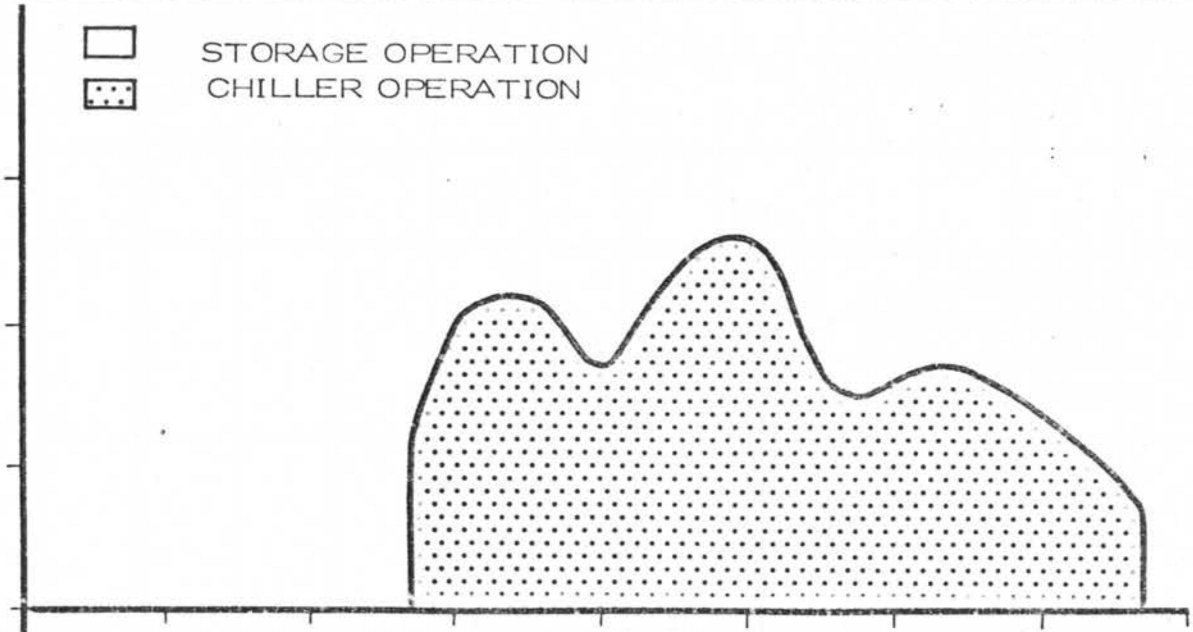

FIGURE A — CONVENTIONAL CHILLER OPERATION WHEN LOAD OCCURS

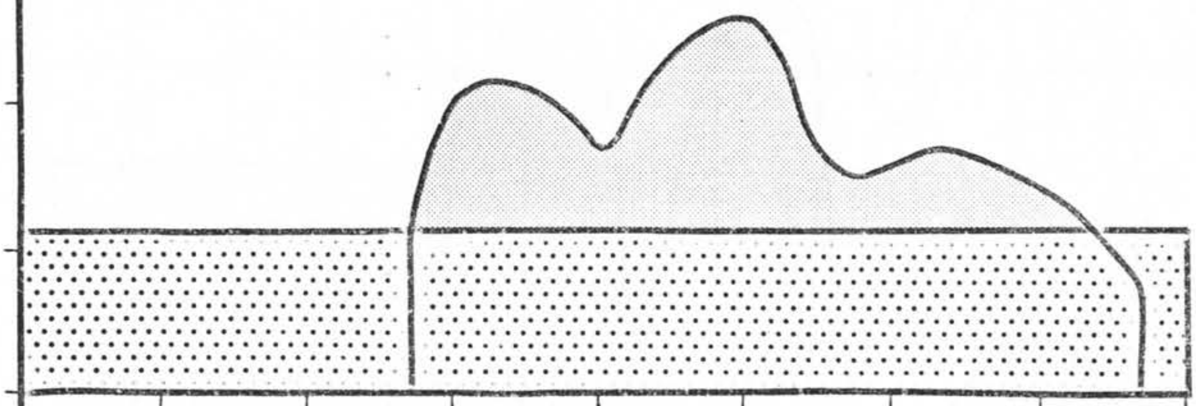

FIGURE B — COMBINED CHILLER AND STORAGE OPERATION WHEN LOAD OCCURS

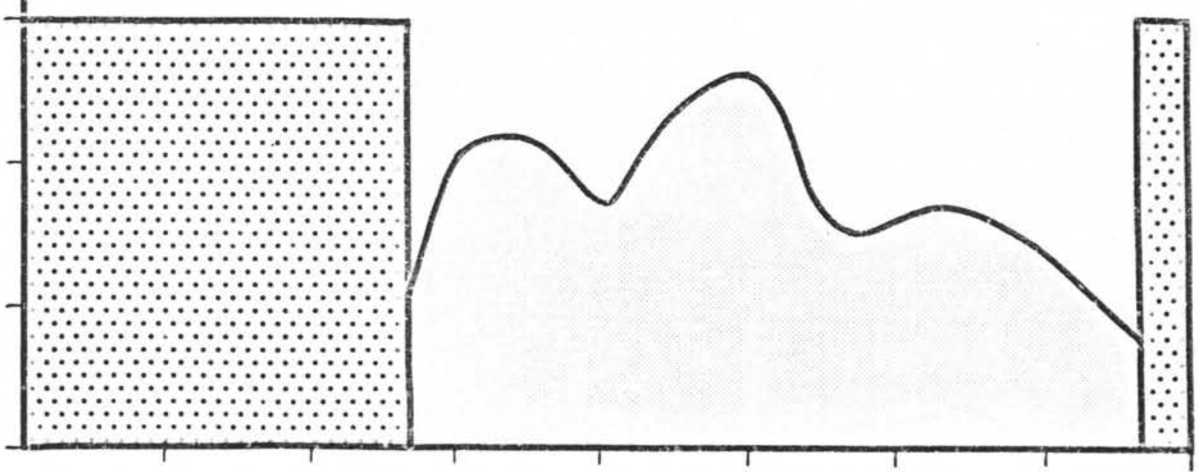

FIGURE C — STORAGE OPERATION WHEN LOAD OCCURS

CHART FOUR -- CHILLER AND STORAGE OPERATION

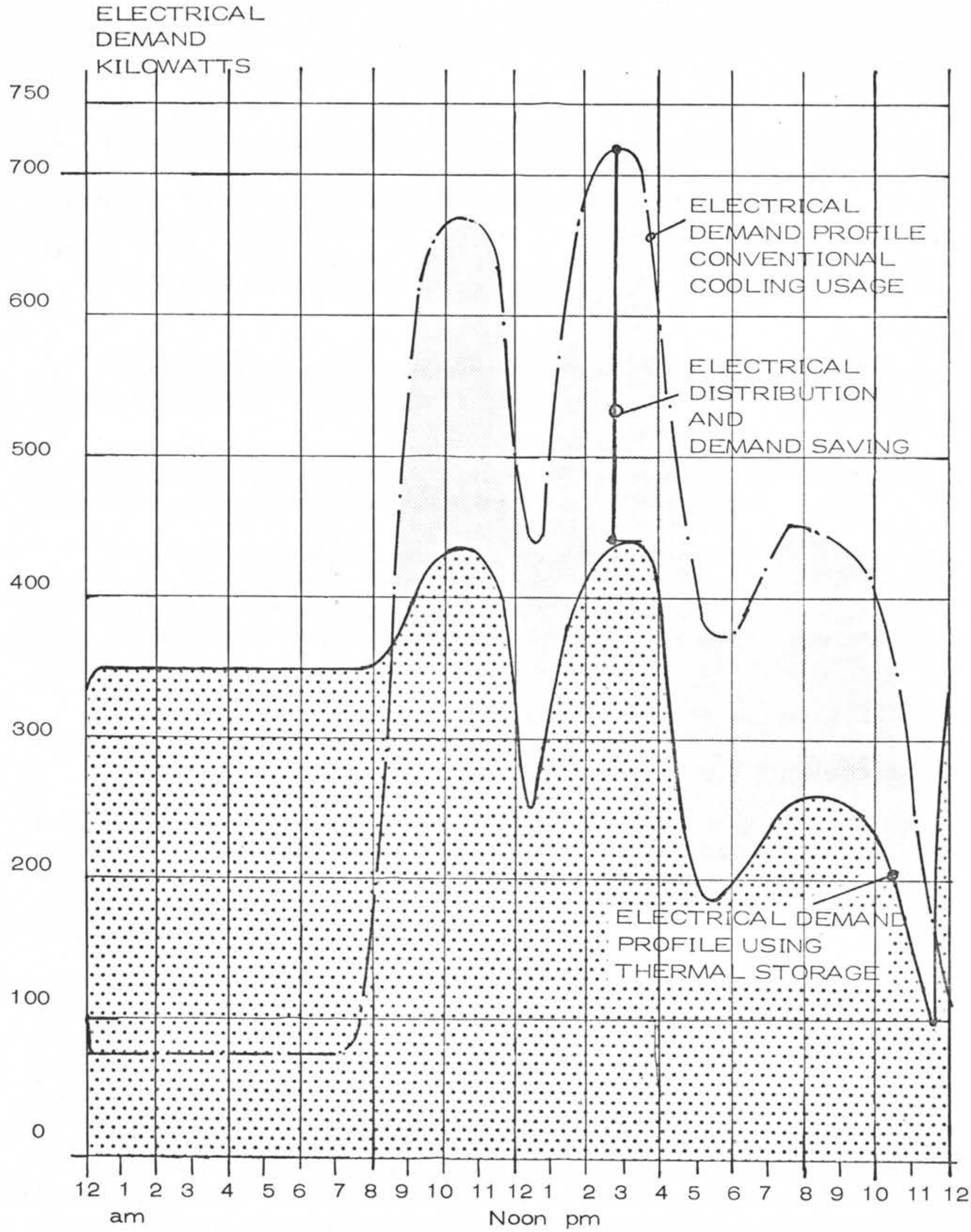

CHART FIVE ELECTRIC DEMAND PROFILES

If, as will be shown later, the heat pump can be operated outside of demand, only electric energy costs are involved at 0.65 cents per kilowatt/hour. Thus the value of the energy saved during both occupied and unoccupied periods amounts to

$$\left[\frac{(876 + 4953.5)}{10^3} \times 10^6 \times 0.167 - \frac{0.65}{15} \times \frac{1}{100}\right] = \$7,209.$$

Without storage, costs are reduced only $3,429. Therefore, the savings attributable to storage amount to $3,780.

Electric demand saving using storage is best shown by considering the daily cooling requirements, Chart Three, in conjunction with the possible modes of operating the cooling equipment, Chart Four.

If the cooling load is handled in a conventional manner as in Figure A, Chart Four, the chiller electric demand occurs concurrent with the maximum building lighting and equipment electric demand. The chiller, therefore, increases the instantaneous demand and electric demand cost penalties are incurred.

These penalties can be reduced or eliminated using storage and two methods are shown on Chart Four, Figures B and C.

Figure B shows a smaller chiller combined with water storage. During unoccupied periods the chiller cools down the stored water. When cooling is required, the chiller and storage combine to satisfy the load. The smaller chiller requires less electrical input and the concurrent instantaneous maximum electrical demand of chiller, lights and equipment during occupied periods is reduced.

A further refinement is shown in Figure C, Chart Four. During unoccupied periods the chiller cools the storage water. When cooling is required, the storage alone satisfies the load. This way the instantaneous maximum electrical demand occurs either during the occupied periods as a function of the lights and equipment, or during unoccupied periods as a function of the chiller. Demand penalties are eliminated.

Chart Five identifies the electric demand profiles associated with the chiller operated in a conventional manner as in Figure A, Chart Four, and with storage as in Figure C, Chart Four. From this it can be seen that with storage, the chiller demand is totally eliminated and chiller operation is taken at base energy rates. If this principle is also applied when using the heat pump, that is the storage is used for heating, then

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heat energy is obtained at the basic energy rate.

The cost savings for cooling using 1975 hydro rates are:

(A) Conventional chiller operation peak day. Figure A, Chart Four.

Peak demand - 714 kilowatts
Total daily demand - 8,542 kilowatt hours over 22 occupied days/month

Costs:

714 x 0.35	=	$ 250
100 x 714 x 0.0295	=	2,106
100 x 714 x 0.01	=	714
(22 x 8542 - 200) x 0.0065	=	1,220
		$4,290

Average rate - 2.28¢/kilowatt hour.

(B) Storage use during occupied periods, chiller use during unoccupied periods. Figure C, Chart Four.

Peak demand - 435 kilowatts
Total daily demand - 8,205 kilowatt/hours
Occupied days - 22/month

Costs:

435 x 0.35	=	$ 152
100 x 435 x 0.0295	=	1,283
100 x 435 x 0.1	=	435
(22 x 8205 - 200) x 0.0065	=	1,172
		$3,042

Average rate - 1.69¢/kilowatt hour.

Over the 5 months requiring cooling, total savings amount to $5,340, allowing progressive reduction in the cooling load.

Thus, storage can result in total savings of \$9,120 per year, resulting from \$3,780 for heating and \$5,340 for cooling. The amount of storage required to achieve this saving is determined from the peak day cooling and the intermediate heating/cooling requirements.

On the peak day, Chart Three, the total cooling required is 2,964 ton hours. With a twenty degree differential on the water, the total storage required amounts to $\frac{2{,}964 \times 12{,}000}{20 \times 8.35} \times 1.05$ 224,000 U.S. gallons.

By compartmentalizing the tank, it can be used for both heating and cooling. At intermediate conditions, when cooling and heating balance, 1,620 ton hours of cooling are required with 117,000 U.S. gallons of storage devoted to cooling. Heating and cooling balance at this intermediate condition; assuming the same temperature range, a similar amount of water should be devoted to heating storage. Thus, the total storage required at intermediate conditions amounts to 234,000 U.S. gallons.

With additional allowance for losses, approximately five per cent this becomes the design volume.

Based on the chosen building, the most desirable approach to storage is that shown by Figure Three, Chart Four.

For 250,000 U.S. gallons of storage, installation costs would be approximately:

Storage Tank	-	\$119,000
Baffle	-	18,000
Transfer Pumping	-	3,000
Controls	-	1,000
		\$141,000

Assuming that storage is only used on the second phase of the project and the first phase chiller is used for regeneration, the cost premium for storage equals \$141,000 minus the cost of an equivalent 260 ton chiller of \$56,800, i.e., \$84,200. For cost savings of \$9,120 per year and 20 per cent escalation in energy cost rates, the write-off period is approximately 12 years.

The alternate approach of combining chiller and storage to satisfy the load would, based on similar calculation, take 18 years to write off.

Probably the best demonstration of storage is shown in a comparison of life cycle costs developed later.

WASTE HEAT BY INCINERATION

With the adoption of thermal storage, it is possible to save further energy using a waste incinerator. The heat energy developed during pyrolysis can be reclaimed at efficiencies up to 60% and stored for use when required. Additionally, the waste heat can be used to provide low temperature domestic hot water.

Based on North Campus data, approximately 9,000 lbs. per week of number one waste will be generated at the Lakeshore Campus. This equals 6,480,000 BTU/day of reclaimed heat, allowing incineration six hours per day for five days.

Additional reclaim heat is available if the waste from the North Campus is trucked to Lakeshore Campus for incineration. Based on 25,000 lbs. per week, the reclaim heat would equal 18,000,000 BTU/day.

From Figure Five and Chart Two of this Appendix, it is possible to establish that 1,320,109,200 BTU are required per year as assist energy.

For the temperature range that heat is required for assist energy, approximately 65 days are available for incineration. Thus 1,170,000,000 BTU's are reclaimed and a $1,950 fuel saving is realized.

$\frac{1,170,000,000}{750,000} \times 1.25$. Additionally, dumping costs are saved at North and Lakeshore Campuses for three months at a total cost of $900. Trucking of waste to Lakeshore Campus would cost approximately $270, allowing 33 days of 30 miles per day and 27 cents per mile. Therefore, the total savings for incineration would equal $2,580 (1,950 + 900 - 270).

With the cost of incineration at $98,000, the write-off period equals 20 years, assuming escalation at 20 per cent per year. Savings in energy make this system worthy of consideration; costs, however, show no gain since the average life expectancy of incineration equipment is also 20 years.

SOLAR HEATING

Whenever there is a requirement for heating and solar gain exists,

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advantage should be taken of this energy.

This is only possible if individual room control is provided on the heating system. If such turn-down capability is not provided, the gain will be additive to internal gains of lights and people. Despite reclaim through a heat pump, this will involve additional use of motors and hence, energy waste.

Solar collection is difficult to predict in view of the lack of information on cloud duration at the various outside temperatures. Assuming average solar data are worthy of consideration, together with average cloud cover, then the following average solar heat would be collected each hour related to all twenty-four hours of the day:

Month	Average BTU/hour, sq.ft. of collector related to 24 hours
January	19.1
February	22.8
March	20.9
April	16.5
May	12.8
June	12.4
September	27.0
October	26.8
November	24.0
December	21.6

Allowing the maximum gain occurs at 70^{o}F and the minimum at -10^{o}F with linear variation between, the following amount of solar heat could be collected by one square foot of collector each year:

Temp. Band	Hours	Average Collection	BTU/Year sq.ft. Collector
-10 / -5	36	13.6	489
-5 / 0	24	14.7	353
0 / 5	100	15.6	1,560
5 / 10	152	16.5	2,508
10 / 15	184	17.3	3,183
15 / 20	387	18.2	7,043
20 / 25	538	19.1	10,276
25 / 30	650	20	13,000

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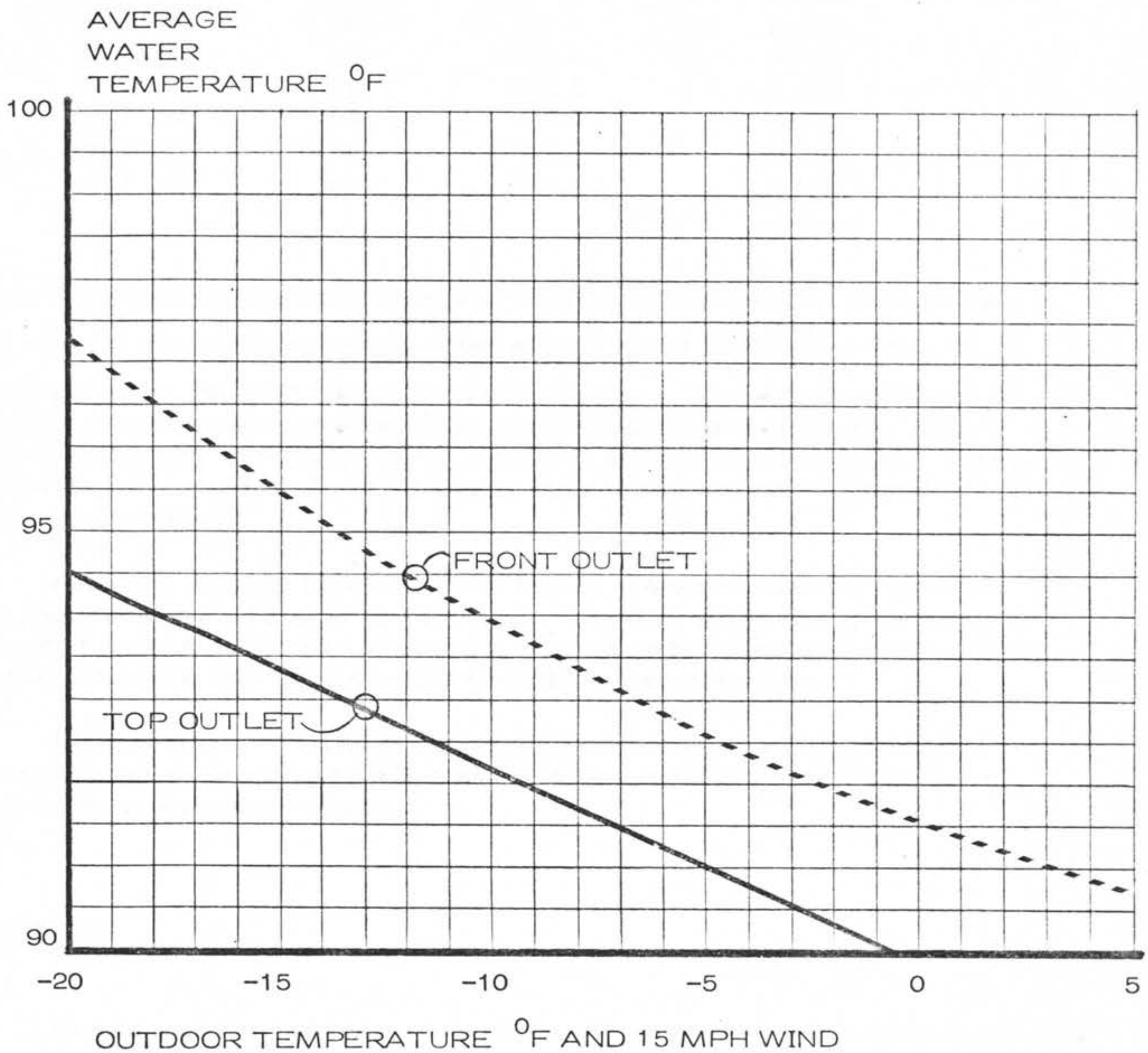

CHART SIX - DOWNDRAFT LIMITATIONS OVER
STANDING RADIATION
8' - 0" DOUBLE GLASS

Temp. Band	Hours	Average Collection	BTU/Year sq.ft. Collector
30 / 35	269	20.9	5,622
35 / 40	333	21.8	7,260
40 / 45	240	22.7	5,448
45 / 50	184	23.6	4,342
50 / 55	220	24.5	5,390
55 / 60	193	25.4	4,902
60 / 65	195	26.3	5,128
65 / 70	184	27.0	4,968
			81,470

Assuming this replaces gas energy at 125¢ per 750,000 BTU useful heat, the savings using this collected solar energy equal $\frac{81,470}{750,000} \times 125 = 13.5$ cents per year for each square foot of collector. Based on a collector of decking with channels, double glass and insulation, the costs per square foot of collector, including piping, would be approximately $6.00. Thus, the write-off period would be 21 years, assuming fuel escalation at 20 per cent annually.

Allowing 30 year collector life, this is not unreasonable; however, too many unknowns have to be resolved. Cloud duration has to be established, together with solar intensities related to temperature ranges, and useful collection has to be equated to building requirements.

In view of the viability of storage, it would seem worthwhile providing a pilot solar collection system on this campus to determine these data by suitable measurement.

SYSTEMS

In keeping with heat reclaim, the heating equipment should be sized to suit the maximum temperature that can be achieved off the heat pump. Based on low pressure machines, the most efficient operation for combined cooling and heating applications is obtained using a maximum water temperature of 105°F. At this temperature the motor horsepower per ton is not significantly increased above that required for cooling only. In any case, as can be seen from Chart Six, the maximum temperature required for a 4¼" square finned tubed element beneath 8 ft. high double glass is 104°F, assuming a twenty °F range.

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Air/water systems are compatible with heat reclaim and are most suitable to multiple perimeter spaces. On this project the ventilation requirements may preclude air/water systems in view of the penalty applied by increasing air quantities. In any case, all-air systems, in view of their application to both internal and perimeter spaces, show greater adaptability. This is particularly true when considering variable air volume all-air systems.

Multiple control and heat reclaim is possible, together with savings in energy. This is best demonstrated by comparing energy budgets of a variable air volume system against a change-over air/water system for the perimeter 20 feet spaces and air reheat system for all internal spaces. The manual derivation of these budgets is shown on following pages. Computer techniques can also be used. To maintain simplicity of procedure, thermal storage has been ignored. Its impact would, however, be of almost equal magnitude and would not affect the relationship between system budgets.

ENERGY BUDGETS

Energy Budget - Internal Spaces

Gain per square foot, based on gross area.

	Room S.H.	Return Air S.H.	L.H.
Lights	3.36	1.62	
Equipment	0.78		
People	.86		0.71
	5.00	1.62	0.71

$20^{o}F\ \Delta T$ = 0.23 cfm/square foot.

Air mixtures with outside air mixed to provide free cooling or heat reclaim:

Summer Cycle

O.A. $87^{o}F$ DB $75^{o}F$ WB
Minimum O.A. based on gross area - 0.06 cfm/square foot
Room $76^{o}F$ DB 50% RH

Return air temperature rise $\frac{1.62}{.23 \times 1.08} = 6.5^{o}F$

Thus, return air temperature = 82.5^{o}F DB

$$^{o}F\ DB\ mix = \frac{.06}{.23} \times 87 + \frac{.17}{.23} \times 82.5$$

$$= 22.7 \quad + 61 \quad = 83.7^{o}F\ DB$$

$$M.C.\ gain = \frac{.71}{.23 \times .68} = 4.5\ grains/lb.$$

From a psychometric chart allowing 2^{o}F supply fan gain and coil by-pass factor of 0.05 - off cooling coil = 54^{o}F DB, 96% RH and the actual room condition is maintained at 78^{o}F DB, 48% RH.

Total heat transferred = 8.95 BTU/lb.

Total heat/sq.ft. = 4.5 x 8.95 x .23
= 9.26 BTU/hour, sq.ft.

Sensible heat/sq.ft. = 1.08 x .23 x (83.7 - 54)
= 7.38 BTU/hour, sq.ft.

Intermediate Cycle

Outside air 76^{o}F DB, 48% RH
No perimeter heating required
Maximum free cooling

Total heat transferred = 7.0 BTU/lb.

Total heat/sq.ft. = 4.5 x 7.0 x .23
= 7.25 BTU/hour, sq.ft.

Sensible heat/sq.ft. = 1.08 x .23 x (76 - 54)
= 5.46 BTU/hour, sq.ft.

Intermediate Cycle

Outside air 50^{o}F DB, 50^{o}F WB.

Perimeter loss/square foot gross area - 2.83 BTU/hour, square foot.

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False cooling load required to achieve this heating = 2.83 x .81 = 2.30 BTU/hour, sq.ft.

Related to 0.23 cfm/sq.ft., this equals 2.23 BTU/lb.

From a psychometric chart, the required mix conditions to achieve this false cooling = 60.8^{O}F DB, 71% RH.

Total heat transferred = 2.3 BTU/hour, sq.ft.

Sensible heat = 1.08 x .23 x (60.8 − 54)
= 1.69 BTU/hour, sq.ft.

Winter Cycle

Outside air 30^{O}F DB (Balance Point)

Perimeter loss/sq.ft. gross area − 5.68 BTU/hour.

Outside air load = .06 x 1.08 x (76 − 30) = 2.98

$\therefore$ Total Gain available = 7.33 BTU/hour, sq.ft.

Heat Pump heat = $\frac{7.33 - 2.98}{.81}$ = 5.4 BTU/sq.ft., close enough to the above perimeter loss/sq.ft., based on initial graphical solution.

Related to 0.23 cfm/sq.ft. this equals 5.22 BTU/lb.

From a psychometric chart, the required mix conditions to achieve the necessary false cooling = 74^{O}F DB, 21% RH.

Total heat = 5.40 BTU/hr., sq.ft.

Sensible heat = 1.08 x .23 x (74 − 54)
= 4.97 BTU/hr., sq.ft.

Winter Cycle

Outside air −10^{O}F DB saturated.

N.B. − In order to obtain maximum reclaim false cooling load, minimum outside air is maintained below balance point.

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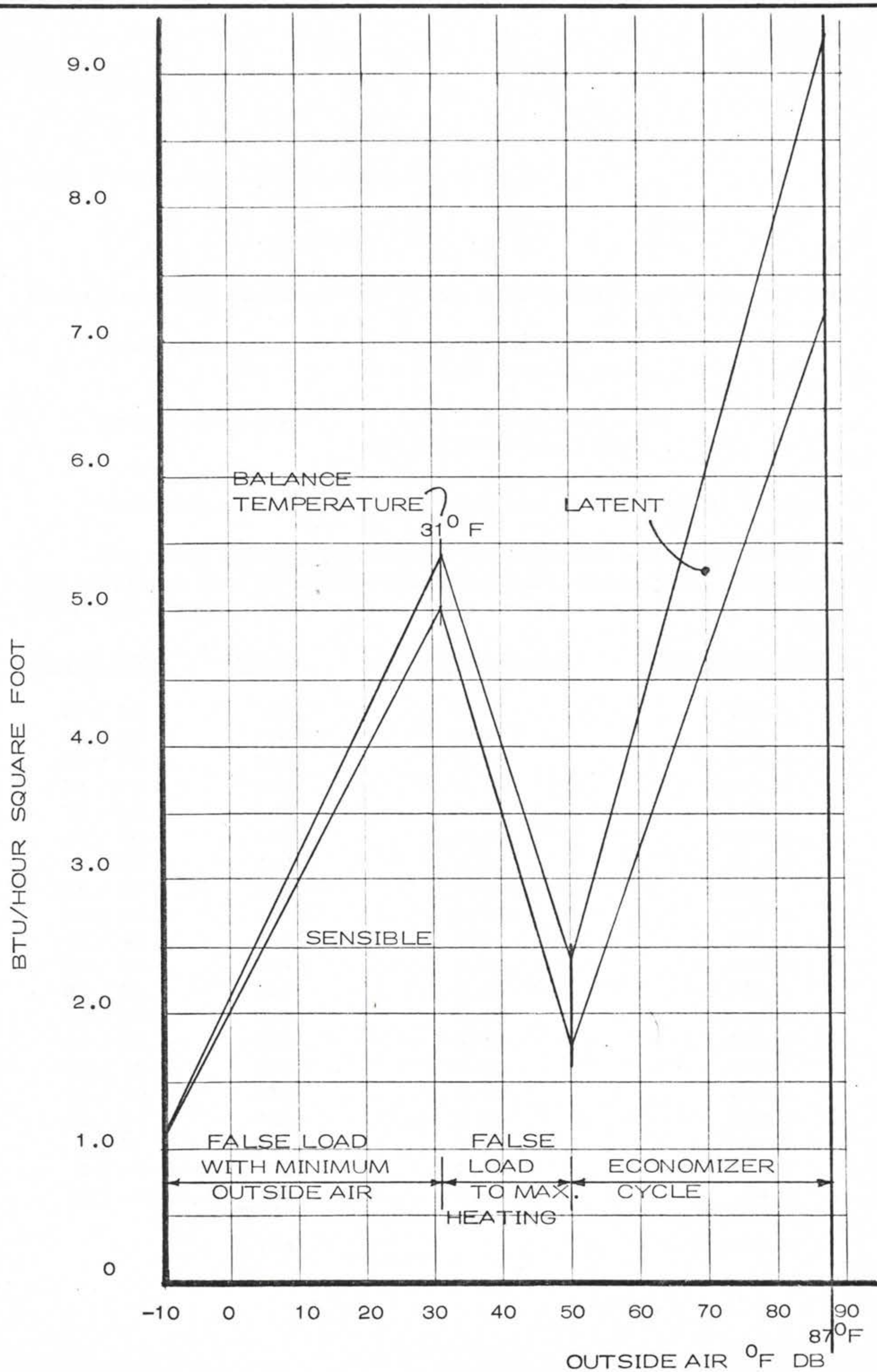

CHART SEVEN HEAT PUMP LOAD PROFILE

$$\text{Thus } {}^{o}\text{F DB mix} = \frac{.06}{.23} \times -10 + \frac{.17}{.23} \times 82.5$$
$$= -2.6 \quad + 61$$
$$= 58.4^{o}\text{F}.$$

Since the off coil condition = 54^{o}F DB, total heat transferred = 1.7 BTU/lb.

Total heat/sq.ft. = 4.5 x .23 x 1.05
= 1.09 BTU/hour, sq.ft.

Sensible heat/sq.ft. = 1.08 x .23 x (58.4 - 54)
= 1.09 BTU/hour, sq.ft.

The above data, in graphical form, are shown on Chart Seven.

The actual operating hours in 5 degree bands multiplied by the average heat pump load for that band in BTU/hour, square foot, establishes the equipment load per year.

Temp. Band	Hours	BTU/hr.,sq.ft.	BTU/sq.ft.,yr.
90 / 85	60	9.26	555.6
85 / 80	176	9.0	1,584
80 / 75	364	8.1	2,948.4
75 / 70	463	7.15	3,310.5
70 / 65	548	6.2	3,397.6
65 / 60	470	5.25	2,467.5
60 / 55	450	4.25	1,912.5
55 / 50	372	3.25	1,209
50 / 45	406	3.15	1,278.5
45 / 40	403	3.9	1,571.7
40 / 35	561	4.75	2,664.8
35 / 30	509	5.35	2,723.1
30 / 25	465	5.30	2,464.5
25 / 20	373	4.76	1,775.5
20 / 15	256	4.25	1,088
15 / 10	119	3.75	446.3
10 / 5	101	3.25	328.3
5 / 0	51	2.70	137.7
0 / -5	16	2.15	334.4
-5 / -10	21	1.65	34.6
	6,184		31,932.5

.... 14.

Energy Requirements of Equipment

Refrigeration

Design Tons $\frac{9.26}{12,000}$ = .00077 tons/sq.ft.

0.8 kilowatt/ton

Cooling Tower

0.045 Kilowatt/ton

Condenser Water Pumps

3 USGPM/ton, 60 foot head, 70% efficiency

$$\text{Pump Kw} = \frac{3 \times 60 \times .746}{3,960 \times .7} = 0.05 \text{ Kw/ton}$$

Chilled Water Pumps

1.2 USGPM/ton, 80 foot head, 70% efficiency

$$\text{Pump Kw} = \frac{1.2 \times 80 \times .746}{3,960 \times .7} = 0.026 \text{ Kw/ton}$$

Fans

1.0 cfm, 3.5 inches w.g., 64% efficiency

$$\frac{1.0 \times 3.5 \times .746}{6,350 \times .64} = 0.0006 \text{ Kw/cfm}$$

@ 0.23 cfm/sq.ft. = 0.00014 Kw/sq.ft.

Equipment Loads

Refrigeration 0.8 Kw/ton

Auxiliaries (.045 + .05 + .026) .00077 + .00014

= 0.000233 Kw/sq.ft.

Refrigeration tons/sq.ft., year = $\frac{31,932.5}{12,000}$ = 2.66

Refrigeration KWH/sq.ft., year = 2.66 x 0.8 = 2.13

Auxiliaries 6,184 x 0.000233 = 1.44

Total energy for internal spaces = 3.57 KWH/sq.ft., year, based on gross area.

Energy Budget Perimeter Spaces

Walls glazed on north and south aspects.

	Areas	Transmission/^{O}F
N Glass	6,720	4,368
S Glass	6,720	4,368
N Wall	6,720	1,008
S Wall	6,720	1,008
E Wall	13,440	2,016
W Wall	13,440	2,016
Roof	58,800	5,880
Floor	58,800	588
		21,252

Gross building area - 150,000 sq.ft.
Glass shading factor - 0.60

Transmission loads BTU/hr., sq.ft. related to gross area

$$= \frac{21,252}{150,000} = 0.142$$

Outside 87^{O}F DB Room 76^{O}F DB

Transmission = 0.142 x 11 = 1,562 BTU/hr., sq.ft.

Outside 76^{O}F DB Room 76^{O}F DB

Transmission = 0

Outside 70^oF DB   Room 70^oF DB

Transmission = 0

Outside -10^oF DB   Room 70^oF

Transmission = 0.142 x 80 = 11.36 BTU/hr.,sq.ft.

Time-averaged Solar Factors for the operating hours between 8:00 a.m. and 11:00 p.m., derived from six hour ASHRAE averaged solar heat gain factors.

January	N	S	Total
8:00 a.m.	2	39	41
9:00 a.m.	6	90	96
10:00 a.m.	10	133	143
11:00 a.m.	12	169	181
Noon	14	198	212
1:00 p.m.	16	217	233
2:00 p.m.	16	218	234
3:00 p.m.	14	196	210
4:00 p.m.	11	147	158
			1,508

Averaged and weighted factor -

$$\frac{1,508}{2 \times 16} = 47 \text{ BTU/hr.,sq.ft. glass}$$

Based on similar calculations -

February	51 BTU/hr.,sq.ft. glass
March	45 BTU/hr.,sq.ft. glass
April	38 BTU/hr.,sq.ft. glass
May	33 BTU/hr.,sq.ft. glass
June	33 BTU/hr.,sq.ft. glass
July	34 BTU/hr.,sq.ft. glass
August	37 BTU/hr.,sq.ft. glass
September	45 BTU/hr.,sq.ft. glass
October	50 BTU/hr.,sq.ft. glass
November	46 BTU/hr.,sq.ft. glass
December	45 BTU/hr.,sq.ft. glass

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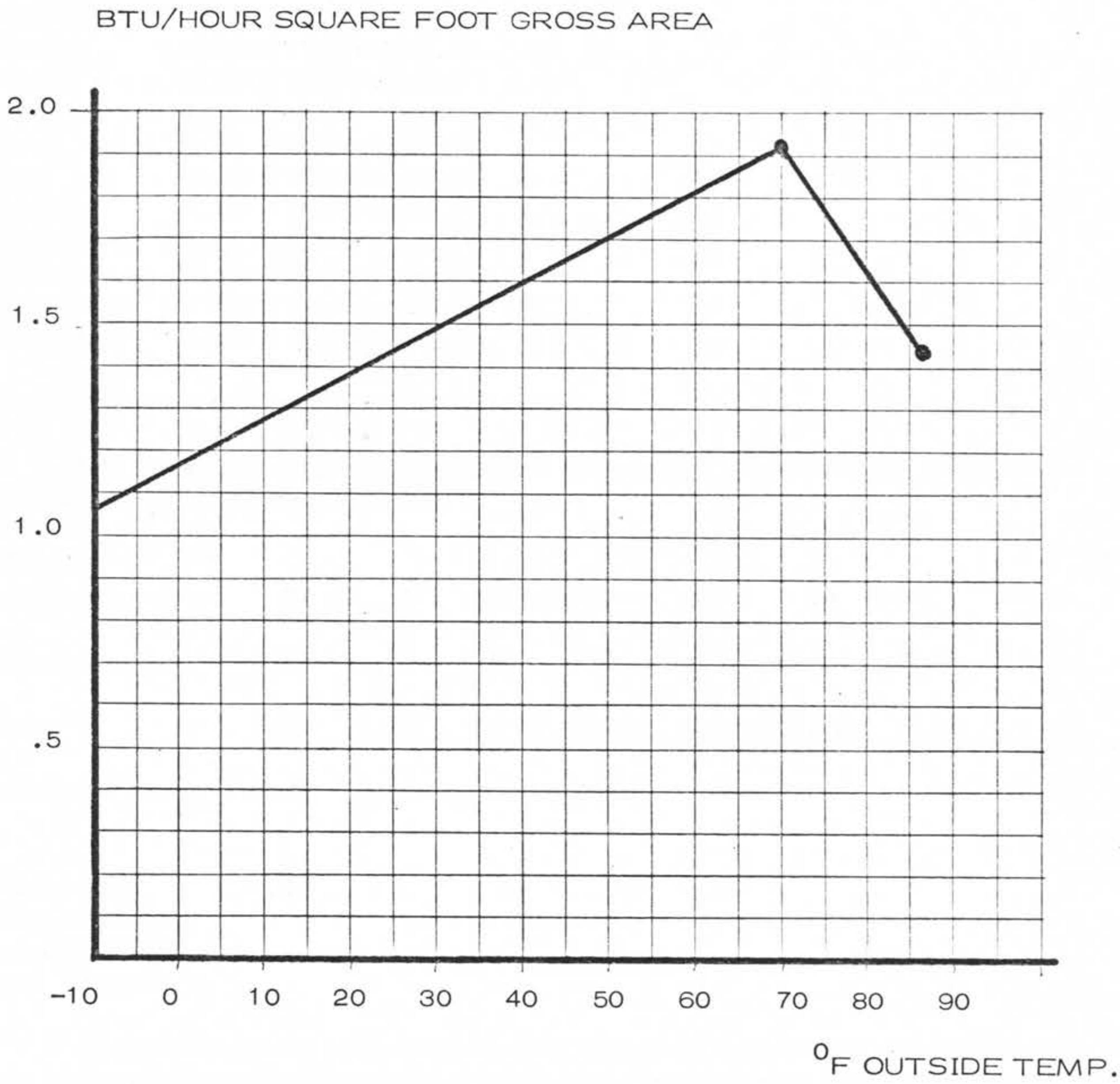

CHART NO. EIGHT AVERAGE BLOCK SOLAR LOAD

Average block solar gain BTU/hr.,sq.ft. gross area –

January	$\frac{47 \times 6{,}720 \times 2}{150{,}000} \times 0.6 \times 0.42$ (% sun) = 1.06
February	1.32 BTU/hr.,sq.ft.
March	1.26 BTU/hr.,sq.ft.
April	1.18 BTU/hr.,sq.ft.
May	1.10 BTU/hr.,sq.ft.
June	1.21 BTU/hr.,sq.ft.
July	1.35 BTU/hr.,sq.ft.
August	1.43 BTU/hr.,sq.ft.
September	1.50 BTU/hr.,sq.ft.
October	1.56 BTU/hr.,sq.ft.
November	1.92 BTU/hr.,sq.ft.
December	1.16 BTU/hr.,sq.ft.

These values are profiled on Chart Eight.

Net loss/gain and air modulation as a result of perimeter solar and transmission therefore equals:

Outside temperature	87	80	76	70	60	50	31	−10
Transmission	1.56	.57	0	0	−1.42	−2.84	−5.54	−11.36
Solar	1.43	1.62	1.78	1.92	1.80	1.70	1.50	1.06
Net gain/loss	2.99	2.19	1.78	1.92	.38	−1.14	−4.04	10.30
Average Perimeter air cooling 20°F diff. cfm/sq.ft.	.14	.1	.08	.09	.02			

Since this air is additional to that required to cool the internal gains, the associated cooling load required is that necessary to cool from room conditions to supply conditions plus any fan gains, i.e., 76°F DB, 50% RH to 54°F DB, 96% RH. Cooling load = 8.9 BTU/lb. of air.

Obviously, where the gain condition occurs at outside conditions below those maintained in the space, free cooling is used to reduce the refrigeration load, i.e., at 70°F outside cooling load = 5.1 BTU/lb.; 65°F outside cooling load = 3.6 BTU/lb., and 60°F outside cooling load = 2.2 BTU/lb.

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Thus cooling load BTU/hr.,sq.ft. equals BTU/lb. air x cfm/sq.ft. x 4.5.

Temp. Band	Operating Hours	BTU/hr. gross sq.ft.	BTU/year gross sq.ft.
87 / 85	60	5.61	336.6
85 / 80	176	4.81	846.6
80 / 75	364	4.01	1,459.6
75 / 70	463	3.06	1,416.8
70 /65	548	2.07	1,134.4
65 / 60	470	0.89	418
60 / 55	450	0.20	90
	2,531		5,702.0

Tons/gross sq.ft. $= \frac{5,702}{12,000} = 0.475$

KWH/ton of refrigeration - 0.8

KWH/gross sq.ft. = 0.475 x 0.8 = 0.38

Maximum tons/sq.ft. at 87°F due to perimeter

Transmission	1.56
Solar	1.99
	3.55 BTU/hr., gross sq.ft.

Maximum perimeter air 20°F temperature difference = 0.16 cfm/sq.ft.

Cooling load = 8.9 x 0.16 x 4.5 = 6,408

$\frac{6,408}{12,000}$ = .000534 tons/sq.ft.

Auxiliary Energy Requirements

Cooling tower	-	.045 kilowatt/ton
Condenser pumps	-	0.05 kilowatt/ton
Chilled Water pump	-	0.026 kilowatt/ton
Total	-	0.121 kilowatt/ton

.121 x .000534 = .000065 kilowatt/gross sq.ft.

2,531 x .000065 = 0.16 KWH/gross sq.ft.

Fans = 0.0006 Kw/cfm.

Thus, fan energy equals:

Temp. Band	Hours	cfm/sq.ft.	KWH/sq.ft.
87 / 85	60	.14	0.005
85 / 80	176	.12	0.013
80 / 75	364	.10	0.022
75 / 70	463	.08	0.022
70 / 65	548	.09	0.030
65 / 60	470	.06	0.017
60 / 55	450	.02	0.005
			0.114

Therefore, total energy requirements as a function of cooling at the perimeter equal:

Refrigeration	-	0.38
Auxiliaries	-	0.16
Fans	-	0.12
		0.66 KWH/gross sq.ft.

Occupied heating using a heat pump, is satisfied down to 31 °F DB. Below 31°F DB, supplementary heating is required. From Chart Seven it is possible to determine the heat available from the heat pump in BTU/hr. gross square foot. Reducing the transmission by this amount indicates the quantity of imported heat required.

Temp. Band	A Hours	B Transmission BTU/hr.,sq.ft.	C Heat Pump BTU/hr.,sq.ft.	A(B - C) BTU/sq.ft.,yr.
-10/-5	21	11.36	1.70	203
- 5/ 0	16	10.65	2.10	137
0/ 5	51	9.94	2.70	369
5/10	101	9.23	3.10	619
10/15	119	8.52	3.70	574

.... 20.

	A	B	C	A(B − C)
Temp. Band	Hours	Transmission BTU/hr., sq.ft.	Heat Pump BTU/hr., sq.ft.	BTU/sq.ft., yr.
15/20	256	7.81	4.20	924
20/25	373	7.10	4.70	895
25/30	465	6.39	5.30	507
				4,228

Unoccupied Heating Requirements:

Temp. Band	Hours	Transmission BTU/hr., sq.ft.	BTU/year sq.ft.
−10/−5	15	11.36	170
− 5/ 0	8	10.65	85
0/ 5	49	9.94	487
5/10	51	9.23	470
10/15	65	8.52	554
15/20	131	7.81	1,023
20/25	165	7.10	1,172
25/30	185	6.39	1,182
30/35	269	5.68	1,527
35/40	333	4.97	1,655
40/45	240	4.26	1,022
45/50	184	3.55	653
50/55	220	2.84	625
55/60	193	2.13	411
60/65	195	1.42	277
65/70	184	0.71	131
			11,444

Thus, total heating requirements, occupied and unoccupied periods = 15,672

$$\frac{15,672}{3,410} = 4.60 \text{ KWH/gross sq.ft.}$$

Total number of hours when heating is required = 7,608.

Peak heating requirement = 11.36 BTU/hr., sq.ft.

Based on 20°F temperature range, 60 ft. head, 70% efficiency

$$\text{Pump Kw} = \frac{11.36 \times 60 \times .746}{20 \times 500 \times 3,960 \times .7}$$

$$= .00002 \text{ Kw/sq.ft.}$$

Pumping = 7,608 x 0.00002 = 0.15 KWH/gross sq.ft.

Thus, total energy budget for a variable air volume system with heat pump reclaim:-

3.57
0.66
4.60
0.15

8.98 Kilowatt hours/gross square foot.

On a similar basis, an air/water changeover system with heat reclaim would have an energy budget of 10.69 Kilowatt hours/gross square foot.

LIFE CYCLE COSTS

In addition to Energy Budget comparisons, some relationship between costs also has to be developed. To provide a complete picture, the cost relationship should include elements of the first cost, annual energy, annual cost of labour, materials for upkeep, and replacements to plant as required throughout the term.

Life cycle costing offers one method of achieving this. The present day value (P.D.V.) is used as the comparator and translates future expense back to net equivalent cost at the time of the analysis.

The interest rate is expressed as P.D.V. discount. The P.D.V. is, therefore, the amount of money invested at the time of the analysis which, at the P.D.V. rate of discount, will yield enough money in the future to retire the future expense.

The value of this technique is that it permits the effects of escalation and short equipment life to be incorporated and compared. Not that anyone can predict these; rather, the sensitivity of the costs to various escalation rates and equipment life can be established.

Present Day values come in various forms. For this project, since deficit funding is not being considered, only three P.D.V.'s need be used.

Firstly, there is the cost of the initial installation. Assuming lump

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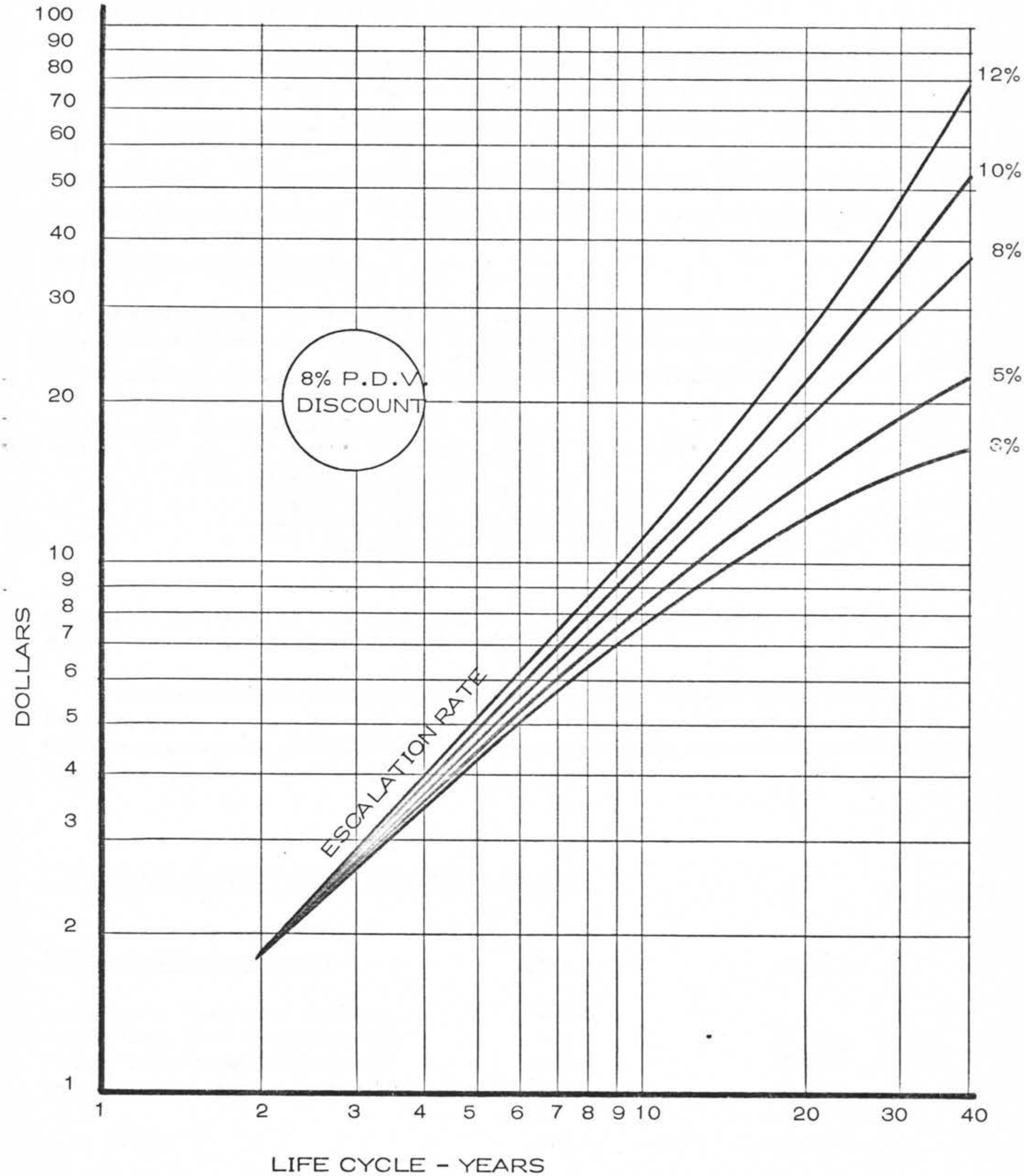

LIFE CYCLE COST

CHART NO. NINE

sum bidding, the lump sum cost is the P.D.V.

Secondly, there is the P.D.V. of a fixed future expense. This can be established by taking the future dollars and multiplying by the equation $\frac{1}{(1+i)^n}$, where i is the interest rate and n is the number of years to the future expense. When only current dollars of the future expense are known, then the equation becomes $\frac{(1+E)^n}{(1+i)^n}$, where i and n are as before and E is the percentage escalation.

Finally, there is the P.D.V. of a recurring annual expense. This may be established by multiplying the expense in dollars by the equation $\frac{1}{i}\left[1 - \frac{1}{(1+i)^n}\right]$ where i and n are as before. When the annual expense escalates, the equation becomes

$$\frac{\left(\frac{1+E}{1+i}\right)\left[\left(\frac{1+E}{1+i}\right)^n - 1\right]}{\left(\frac{1+E}{1+i}\right) - 1}$$

Graphical solutions of this equation, related to an annual expense of one dollar, are shown on Chart Nine.

To demonstrate the use of life cycle costing, two examples follow. Firstly, central plant for this campus is compared to diversified equipment located in each new phase of construction. Secondly, the use of thermal storage against conventional equipment is compared.

LIFE CYCLE COST ONE - CENTRAL PLANT

Equipment Requirements	Cooling Tons	Heating MBH
Lakeshore Teachers' College	300	-
Phase One, New Construction	100	2,900
Phase Two, New Construction	260	2,900
Phase Three, New Construction	260	2,900
Total	920	8,700

Initial Costs

3 x 3,000 MBH boilers	–	$ 24,000
Gas vents	–	6,000
Heating pumps, 600 USGPM	–	3,000
1,200 ft. 6" heating pipe	–	30,000
2 x 460 ton chillers	–	138,000
2 x 240 ton reclaim condensers	–	24,000
Chilled water pumps, 1,100 USGPM	–	6,600
Condenser water pumps, 2,760 USGPM	–	13,800
920 ton cooling tower	–	27,600
1,200 ft. 8" chilled water pipe	–	48,000
1,050 Kw electrical distribution	–	31,500
Building enclosure	–	40,000
Total	–	$392,500

Future Cost 1 (1975 dollars)

Additional distribution pipework		
Phase Two New Construction		
600 ft. 5" heating pipe	–	$ 12,000
600 ft. 6" chilled water pipe	–	18,000
		$ 30,000

Future Cost 2 (1975 dollars)

Additional distribution pipework		
Phase Three New Construction		
300 ft. 3" heating pipe	–	$ 4,500
300 ft. 4" chilled water pipe	–	6,000
		$ 10,500

Annual Energy Costs (1975 dollars)

Each Phase

Cooling	–	$18,360		
Heating	–	7,970	–	$ 26,330

Annual Labour Costs (1975 dollars)

Four operators	–	$ 60,000

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Annual Maintenance Costs (1975 dollars)

Clean boilers	-	$ 500
Clean chillers	-	1,200
		$ 1,700

Replacement Costs (1975 dollars)

Boilers - year 20	-	$ 24,000
Chillers - year 25	-	162,000

Life Cycle Cost - 30 Years 8% P.D.V. Discount for Central Equipment

Initial Costs - $ 392,500

Future Costs, Phase Two (6% escalation)

$30,000 \times \left(\frac{1.06}{1.08}\right)^2 =$ - 28,900

Future Costs, Phase Three (6% escalation)

$10,500 \times \left(\frac{1.06}{1.08}\right)^2 =$ - 9,750

Annual Energy Costs (10% escalation)

Phase One

$26,330 \times 40$ - 1,053,200

Phase Two

$26,330 \times 38 \times \left(\frac{1.1}{1.08}\right)^2$ - 1,037,940

Phase Three

$26,330 \times 36 \times \left(\frac{1.1}{1.08}\right)^4$ - 1,020,070

Annual Labour Costs (10% escalation)

$60,000 \times 40$ - 2,400,000

Annual Maintenance Costs

$1,700 \times 40$ - 68,000

.... 25.

Replacement Costs

Year 20

$$24,000 \times \left(\frac{1.1}{1.08}\right)^{20} \quad - \quad \$ \ 34,640$$

Year 25

$$162,000 \times \left(\frac{1.1}{1.08}\right)^{25} \quad - \quad 256,290$$

$6,301,290

LIFE CYCLE COST TWO - DIVERSE PLANT

Initial Costs Year One

1 x 3,000 MBH boiler	-	$ 8,000
Gas vent	-	2,000
Heating pump, 200 USGPM	-	1,000
1,000 4" heating pipe	-	16,000
1 400-ton chiller	-	60,000
1 100-ton reclaim condenser	-	10,000
Cooling tower, 400 ton	-	12,000
Chilled water pump, 480 USGPM	-	2,880
Condenser pump, 1,200 USGPM	-	6,000
1,000 5" chilled water pipe	-	20,000
360 Kw electrical distribution	-	10,800
Building enclosure	-	10,000
		$ 158,680

Future Cost - Phase Two, Year Two (1975 dollars)

1 x 3,000 MBH boiler	-	$ 8,000
Gas vent	-	2,000
Heating pump, 200 USGPM	-	1,000
600 - 4" heating pipe	-	9,600
1 x 260 ton chiller	-	39,000
1 x 100 ton reclaim condenser	-	10,000
Cooling tower - 260 ton	-	7,800
Chilled water pump, 312 USGPM	-	1,860
Condenser water pump, 780 USGPM	-	3,900
600 - 5" chilled water pipe	-	12,000
250 Kw electrical distribution	-	7,500
Building enclosure	-	10,000
		$ 110,660

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Future Cost - Phase Three, Year Four (1975 dollars)

1 300 MBH boiler	-	$	8,000
Gas vent	-		2,000
Heating pump, 200 USGPM	-		1,000
300 ft. 4" heating pipe	-		4,800
1 260-ton chiller	-		39,000
1 100-ton reclaim condenser	-		10,000
Cooling tower - 260 ton	-		7,800
Chilled water pump, 312 USGPM	-		1,860
Condenser water pump, 780 USGPM	-		3,900
300 ft. 5" chilled water pipe	-		6,000
250 Kw electrical distribution	-		7,500
Building enclosure	-		10,000
		$	101,860

Annual Energy Costs (1975 dollars)

Each Phase					
Cooling	-	$18,360			
Heating	-	7,970	-	$	26,330

Annual Labour Costs (1975 dollars)

Initial			
Three operators	-	$	45,000
Year Three onward - four operators	-	$	60,000

Annual Maintenance Costs (1975 dollars)

Year One			
Clean one boiler	-	$	200
Clean one chiller	-		500
		$	700
Year Two			
Clean two boilers	-	$	400
Clean two chillers	-		900
		$	1,300
Year Four			
Clean two boilers	-	$	500
Clean two chillers	-		1,200
		$	1,700

.... 27.

Replacement Costs (1975 dollars)

Year 20 – Replace boiler	–	$	8,000
Year 22 – Replace boiler	–		8,000
Year 24 – Replace boiler	–		8,000
Year 25 – Replace chiller	–		70,000
Year 27 – Replace chiller	–		49,000
Year 29 – Replace chiller	–		49,000

Thus the Life Cycle Cost, 30 years, with 8% P.D.V. discount – Diverse Equipment:

Initial Costs – $ 158,680

Future Costs – Phase Two (6% escalation)

$$110{,}660 \times \left(\frac{1.06}{1.08}\right)^2 = \quad - \quad 106{,}600$$

Future Costs – Phase Three (6% escalation)

$$101{,}860 \times \left(\frac{1.06}{1.08}\right)^2 = \quad - \quad 94{,}520$$

Annual Energy Costs (10% escalation)

Phase One

$$26{,}330 \times 40 \quad - \quad 1{,}053{,}200$$

Phase Two

$$26{,}330 \times 38 \times \left(\frac{1.1}{1.08}\right)^2 \quad - \quad 1{,}037{,}940$$

Phase Three

$$26{,}330 \times 36 \times \left(\frac{1.1}{1.08}\right)^4 \quad - \quad 1{,}020{,}070$$

Annual Labour Costs (10% escalation)

First Two Years

$$45{,}000 \times 2 \quad - \quad \$\ 90{,}000$$

After Two Years

$$60{,}000 \times 38 \times \left(\frac{1.1}{1.08}\right)^2 \quad - \quad 2{,}365{,}230$$

Annual Maintenance Costs (10% escalation)

Year One	–	$	700
Years Two and Three $1,300 \times 2 \times \left(\frac{1.1}{1.08}\right)^2$	–		2,700
Year Four on $1,700 \times 36 \times \left(\frac{1.1}{1.08}\right)^4$	–		65,860
			$5,995,500

Replacement Costs (10% escalation)

Year 20 $8,000 \times \frac{(1.1)^{20}}{(1.08)^{20}}$	–	$	11,550
Year 22 $8,000 \times \frac{(1.1)^{22}}{(1.08)^{22}}$	–		12,000
Year 24 $8,000 \times \frac{(1.1)^{24}}{(1.08)^{24}}$	–		12,430
Year 25 $70,000 \times \frac{(1.1)^{25}}{(1.08)^{25}}$	–		110,750
Year 27 $49,000 \times \frac{(1.1)^{27}}{(1.08)^{27}}$	–		80,420
			$6,222,650

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LIFE CYCLE COSTS - DIVERSE EQUIPMENT WITH STORAGE

Equipment Requirements	Cooling Tons	Heating MBH
Lakeshore Teacher's College	300	–
Phase One,. New Construction	100	2,900
Phase Two, New Construction	–	2,900
Phase Three, New Construction	260	2,900

Initial Costs - Year One

1 x 3,000 MBH boiler	–	$ 8,000
Gas vent	–	2,000
Heating pump, 200 USGPM	–	1,000
1,000 ft. 4" heating pipe	–	16,000
1 - 400 ton chiller	–	60,000
1 - 200 ton reclaim condenser	–	20,000
Cooling tower, 400 ton	–	12,000
Chilled water pump, 480 USGPM	–	2,880
Condenser water pump, 1,200 USGPM	–	6,000
1,000 ft. 5" chilled water pipe	–	20,000
360 Kw electrical distribution	–	10,800
Building enclosure	–	10,000
Storage tank	–	141,000
		$ 309,680

Future Cost - Phase Two, Year Two

1 300 MBH boiler	–	$ 8,000
Gas vent	–	2,000
Heating pump, 200 USGPM	–	1,000
600 ft. 4" heating pipe	–	9,600
1 260-ton chiller	–	39,000
1 100-ton reclaim condenser	–	10,000
Cooling tower, 260 ton	–	7,800
Chilled water pump, 312 USGPM	–	1,860
Condenser water pump, 780 USGPM	–	3,900
600 ft. 5" chilled water pipe	–	12,000
250 Kw electrical distribution	–	7,500
Building enclosure	–	10,000
		112,660

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Future Cost - Phase Three, Year Four

1 x 3,000 MBH boiler	-	$	8,000
Gas vent	-		2,000
Heating pump	-		1,000
300 ft. 4" heating pipe	-		4,800
Chilled water pump	-		1,860
30 Kw electrical distribution	-		900
Building enclosure	-		2,500
		$	21,060

Annual Energy Costs (1975 dollars)

Years One and Two			
Cooling	-	$	13,020
Heating	-		4,190
		$	17,210
Years Three and Four			
Cooling	-	$	31,380
Heating	-		12,160
		$	43,540
Year Five on			
Cooling	-	$	49,740
Heating	-		20,130
		$	69,870

Annual Labour Costs (1975 dollars)

Initial			
Three operators	-	$	45,000
Year Three onward			
Four operators	-		60,000

Annual Maintenance Costs (1975 dollars)

Year One	-	$	700
Years Two and Three	-		1,300
Year Four on	-		1,400

.... 31.

Replacement Costs (1975 dollars)

Year 20	Replace boiler	–	$ 8,000
Year 22	Replace boiler	–	8,000
Year 24	Replace boiler	–	8,000
Year 25	Replace chiller	–	70,000
Year 27	Replace chiller	–	49,000

Life Cycle Cost – 30 years, 8% P.D.V. Discount for Diverse Plant with Thermal Storage

Initial Costs – $ 309,680

Future Costs, Phase Two (6% escalation)

$$112{,}660 \times \frac{(1+0.06)^2}{(1+0.08)^2}$$ – 108,530

Future Costs, Phase Three (6% escalation)

$$21{,}060 \times \frac{(1.06)^4}{(1.08)^4}$$ – 19,540

Annual Energy Costs (10% escalation)

Years One and Two

$$17{,}210 \times 2$$ – 34,420

Years Three and Four

$$43{,}540 \times 2 \times \frac{(1.1)^2}{(1.08)^2}$$ – 90,335

Year Five on

$$69{,}870 \times 35 \times \frac{(1.1)^4}{(1.08)^4}$$ – 2,445,450

Annual Labour Costs (10% escalation)

Years One and Two

$$45{,}000 \times 2$$ – 90,000

Year Three on

$$60{,}000 \times 38 \times \frac{(1.1)^2}{(1.08)^2}$$ – 2,365,230

C/F $5,463,185

.... 32.

B/F $5,463,185

Annual Maintenance Costs (10% escalation)

Years One and Two	-	700
Years Two and Three $1{,}300 \times 2 \times \frac{(1.1)^2}{(1.08)^2}$	-	2,700
Year Four on $1{,}400 \times 36 \times \frac{(1.1)^4}{(1.08)^4}$	-	54,240

Replacement Costs (10% escalation)

Year 20 $8{,}000 \times \frac{(1.1)^{20}}{(1.08)^{20}}$	-	11,550
Year 22 $8{,}000 \times \frac{(1.1)^{22}}{(1.08)^{22}}$	-	12,000
Year 24 $8{,}000 \times \frac{(1.1)^{24}}{(1.08)^{24}}$	-	12,430
Year 25 $70{,}000 \times \frac{(1.1)^{25}}{(1.08)^{25}}$	-	110,750
Year 27 $49{,}000 \times \frac{(1.1)^{27}}{(1.08)^{27}}$	-	80,420
		$ 5,747,975

In summary, the life cycle costs are:

- Central Equipment	-	$ 6,301,290
- Diverse Equipment	-	$ 6,222,650
- Diverse Equipment with Storage	-	$ 5,747,975

Thus, despite high initial expenditure, thermal storage shows considerable saving over the life cycle.

CONCLUSIONS

Presuming the final design closely follows the building used in this analysis, the following are recommended system approaches:

- Diverse equipment.
- Heat pump reclaim for two phases.
- Thermal storage for one phase.
- Pilot solar collector, first phase.
- Waste incineration, if suitable rebate can be obtained for energy saved.
- Gas boilers.
- Radiation at perimeter sized for low temperature water of heat reclaim cycle. Individual control on rooms subject to direct solar gain.
- Variable air volume systems with economizer cycles modulated to ensure heat reclaim.

PROJECT COSTS

Using these conclusions as a basis for design, the estimated budget costs for each phase of construction, based on first quarter 1975 dollars, are as follows:

First Phase, New Construction

Heating, Ventilating and Air Conditioning	-	$ 840,000
Plumbing, Drainage and Fire Protection	-	$ 375,000

Second Phase, New Construction

Heating, Ventilating and Air Conditioning including Storage Tank	-	$ 850,000
Plumbing, Drainage and Fire Protection	-	$ 245,000

Third Phase, New Construction

Heating, Ventilating and Air Conditioning	–	$ 750,000
Plumbing, Drainage and Fire Protection	–	$ 245,000

Cost Appendix

Adjacent Site: View to Lake Ontario

Project: HUMBER - LAKESHORE CAMPUS - PHASE I

Preliminary Estimate
Date: June 18, 1975

Sheet No: A.1

	Element	Amount $	Total Cost $	Rate $/SF Floor Area		%	Comments
1	**Substructure**		116,750		0.73	2.2	
(a)	Normal foundations	91,360		0.57			
(b)	Basement excavations	-		-			
(c)	Special conditions	25,390		0.16			
2	**Structure**		865,790		5.44	16.4	
(a)	Lowest floor construction	96,790		0.61			
(b)	Upper floor construction	473,000		2.97			
(c)	Roof construction	296,000		1.86			
3	**Exterior Cladding**		844,480		5.31	16.0	
(a)	Roof finish	258,000		1.62			
(b)	Walls below ground floor	-		-			
(c)	Walls above ground floor	447,480		2.82			
(d)	Windows	114,000		0.72			
(e)	Exterior doors & screens	10,000		0.06			
(f)	Balconies & projections	15,000		0.09			
4	**Interior Partitions**		304,610		1.92	5.8	
(a)	Permanent partitions	204,170		1.28			
(b)	Movable partitions	2,500		0.02			
(c)	Doors	97,940		0.62			
5	**Vertical Movement**		78,000		0.49	1.5	
(a)	Stairs	30,000		0.19			
(b)	Elevators & escalators	48,000		0.30			
6	**Interior Finishes**		281,850		1.77	5.3	
(a)	Floor finishes	119,250		0.75			
(b)	Ceiling finishes	79,500		0.50			
(c)	Wall finishes	83,100		0.52			
7	**Fittings & Equipment**		238,500		1.50	4.5	
(a)	Fittings & fixtures	119,250		0.75			
(b)	Equipment	119,250		0.75			

Project: HUMBER - LAKESHORE CAMPUS - PHASE I

Preliminary Estimate
Date: June 18, 1975

Sheet No: A.2

Element	Amount $	Total Cost $	Rate $/SF Floor Area		%	Comments
8 Services		2,065,000		12.99	39.2	
(a) Electrical	850,000		5.34			
(b) Plumbing & drainage	375,000		2.36			
(c) Heating, ventilation & air conditioning	840,000		5.29			
9 Overheads & Profit		479,500		3.02	9.1	10% of 4,794,980
Net Building Cost		5,274,480		33.17	100	
10 Site Development		538,450		3.39		including contingencies
(a) General	334,950		2.11			
(b) M & E site services	203,500		1.28			
(c) Alterations	-		-			
(d) Demolition	-		-			
11 Contingencies		527,450		3.32		10% of NBC
12 Link to L.T.C.		250,000		1.57		Allowance
		6,590,380		41.45		Gross Floor Area 159,000 GSF
F.S.T. Rebate		(89,110)		(0.56)		1.25% of all but element 10
		6,501,270		40.89		

Net Building Cost	33.17
Contingencies	3.32
F.S.T. Rebate	(0.56)
	$35.93/GSF

Hanscomb Roy Associates

Elemental Cost Summary Part 2 of 2

Project: HUMBER - LAKESHORE CAMPUS - PHASE II — Preliminary Estimate — **Date:** June 18, 1975 — **Sheet No:** A.3

Element	Amount $	Total Cost $	Rate $/SF Floor Area		%	Comments
1 Substructure		95,400		0.61	2.0	
(a) Normal foundations	75,780		0.48			
(b) Basement excavations	-		-			
(c) Special conditions	19,620		0.13			
2 Structure		872,840		5.56	18.0	
(a) Lowest floor construction	66,120		0.42			
(b) Upper floor construction	559,900		3.57			
(c) Roof construction	246,820		1.57			
3 Exterior Cladding		546,960		3.48	11.3	
(a) Roof finish	98,560		0.63			
(b) Walls below ground floor	-		-			
(c) Walls above ground floor	336,200		2.14			
(d) Windows	67,800		0.43			
(e) Exterior doors & screens	10,000		0.06			
(f) Balconies & projections	34,400		0.22			
4 Interior Partitions		319,640		2.04	6.6	
(a) Permanent partitions	196,560		1.25			
(b) Movable partitions	2,500		0.02			
(c) Doors	120,580		0.77			
5 Vertical Movement		49,500		0.32	1.0	
(a) Stairs	22,500		0.15			
(b) Elevators & escalators	27,000		0.17			
6 Interior Finishes		339,620		2.16	7.0	
(a) Floor finishes	157,000		1.00			
(b) Ceiling finishes	78,500		0.50			
(c) Wall finishes	104,120		0.66			
7 Fittings & Equipment		274,750		1.75	5.7	
(a) Fittings & fixtures	117,750		0.75			
(b) Equipment	157,000		1.00			

Project: HUMBER - LAKESHORE CAMPUS - PHASE II

Preliminary Estimate
Date: June 18, 1975

Sheet No: A.4

Element	Amount $	Total Cost $	Rate $/SF Floor Area		%	Comments
8 Services		1,900,000		12.10	39.3	
(a) Electrical	805,000		5.13			
(b) Plumbing & drainage	245,000		1.56			
(c) Heating, ventilation & air conditioning	850,000		5.41			
9 Overheads & Profit		439,870		2.80	9.1	10% of 4,398,710
Net Building Cost		4,838,580		30.82	100	
10 Site Development		608,630		3.87		including contingencies
(a) General	499,730		3.18			
(b) M & E site services	108,900		0.69			
(c) Alterations	-		-			
(d) Demolition	-		-			
11 Contingencies		483,870		3.08		10% of NBC
		5,931,080		37.77		Gross Floor Area: 157,000 SF
Federal Sales Tax Rebate		(74,140)		(0.47)		1.25% of all but element 10
		5,856,940		37.30		

Net Building Cost	30.82
Contingency	3.08
F.S.T. Rebate	(0.47)
	$33.43 /GSF

Hanscomb Roy Associates

Elemental Cost Summary Part 2 of 2

Project: HUMBER - LAKESHORE CAMPUS - PHASE III	Preliminary Estimate Date: June 18, 1975	Sheet No: A.5

Element	Amount $	Total Cost $	Rate $/SF Floor Area		%	Comments
1 Substructure		98,630		0.70	2.1	
(a) Normal foundations	74,200		0.53			
(b) Basement excavations	-		-			
(c) Special conditions	24,430		0.17			
2 Structure		767,040		5.46	16.4	
(a) Lowest floor construction	89,400		0.64			
(b) Upper floor construction	382,250		2.72			
(c) Roof construction	295,390		2.10			
3 Exterior Cladding		800,220		5.70	17.0	
(a) Roof finish	542,940		3.87			
(b) Walls below ground floor	-		-			
(c) Walls above ground floor	179,320		1.28			
(d) Windows	38,160		0.27			
(e) Exterior doors & screens	10,000		0.07			
(f) Balconies & projections	29,800		0.21			
4 Interior Partitions		269,680		1.92	5.8	
(a) Permanent partitions	180,690		1.29			
(b) Movable partitions	2,500		0.02			
(c) Doors	86,490		0.61			
5 Vertical Movement		33,000		0.23	0.7	
(a) Stairs	15,000		0.11			
(b) Elevators & escalators	18,000		0.13			
6 Interior Finishes		307,040		2.19	6.6	
(a) Floor finishes	140,400		1.00			
(b) Ceiling finishes	70,200		0.50			
(c) Wall finishes	96,440		0.69			
7 Fittings & Equipment		175,300		1.25	3.7	
(a) Fittings & fixtures	105,300		0.75			
(b) Equipment	70,000		0.50			

Project: HUMBER - LAKESHORE CAMPUS - PHASE III	Preliminary Estimate Date: June 18, 1975	Sheet No: A.6

Element	Amount $	Total Cost $	Rate $/SF Floor Area		%	Comments
8 Services		1,800,000		12.82	38.4	
(a) Electrical	805,000		5.73			
(b) Plumbing & drainage	245,000		1.75			
(c) Heating, ventilation & air conditioning	750,000		5.34			
9 Overheads & Profit		425,100		3.03	9.3	10% of 4,250,910
Net Building Cost		4,676,010		33.30	100	
10 Site Development		454,080		3.23		including contingencies
(a) General	366,080		2.60			
(b) M & E site services	88,000		0.63			
(c) Alterations	-		-			
(d) Demolition	-		-			
11 Contingencies		467,610		3.33		10% of NBC
		5,597,700		39.86		Gross Floor Area: 140,400 SF
Federal Sales Tax Rebate		(64,300)		(0.46)		1.25% of all but element 10
		5,533,400		39.40		

Net Building Cost	33.30
Contingencies	3.33
F.S.T. Rebate	(0.46)
	$36.17/GSF

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