DETERMINING ELECTRICAL DEMAND SAVINGS FOR SMALL COMMERCIAL BUILDINGS WITH OVERNIGHT STORAGE OF CHILLED WATER
A SIMPLIFIED PROCEDURE FOR PRELIMINARY ECONOMIC ANALYSIS

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ABSTRACT

Small commercial and institutional buildings are a prime target for reducing electrical demand through chilled water storage. To determine the economic benefit from the reduced chiller size and electrical demand, a detailed engineering analysis of the month-by-month cooling loads with and without thermal storage is required. For small buildings the design budget and engineering skills may be so limited as to discourage such analysis.

This paper develops a simplified procedure using nomograms to quickly estimate the reduced chiller size, storage capacity and monthly electrical demand savings which will result for a continuously operated chiller with nighttime storage. To illustrate the method, nomograms are developed for two typical building plans, which represent a size range of 25,000 to 100,000 sq.ft. gross area, each in both a low envelope (energy conscience) and high envelope design.

Computer calculations are performed for three categorized weather regions in North Carolina and four air conditioning systems, viz, dual-duct, terminal reheat, variable air volume, and unitary. The nomograms allow for variation of internal load and air ventilation rate. Chiller demand savings are quickly estimated on a month-by-month basis. These demand savings, combined with the utility rate schedules and cost of conventional and thermal-storage systems, provide the basis for the economic analysis and energy conservation benefit.

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INTRODUCTION

The peak cooling and heating requirements of buildings generally coincide with the utility peak power demand. They occur in the late afternoon and are a major contributor to the summer electric utility peak. Moving large amounts of HVAC power requirements from the peak electric demand hours to periods of low demand can be accomplished by thermal energy storage (TES). The technology for achieving this shift is well developed. Nevertheless, the engineering analysis for TES adds considerably to the complexity, time and expense of the HVAC design. The additional cost, and lack of experience by consulting engineering firms employed for small commercial buildings, will often preclude the consideration of thermal energy storage.

The economic benefit of including TES in the design of a building HVAC system involves an assessment of changes in first cost and operating costs. Reduction of chiller size, and of its associated cooling tower and other auxiliaries, can offset the costs of storage. Operating cost savings are achieved by night-time operation of the cooling plant (when outdoor dry-bulb and wet-bulb temperatures are lower), and by higher load factor operation of the equipment. Both operating conditions contribute to higher efficiency of the plant.

The cost savings through reduced electrical demand during peak generation hours by the servicing utility will depend on their rate schedules. Demand charges are generally billed on a monthly basis and the monthly billing demand can be affected by the historical demand record of the building.

The chiller sizing, electrical demand, and energy usage for a TES system requires the calculation of the cooling load profile for the maximum "design day", and also on the peak load day in each month. These calculations go well beyond those required for sizing a conventional HVAC system without TES. The required informational and computational resources may not be readily accessible to the typical small consulting engineering office. Moreover, the cost of the analysis would not be covered in the usual design contract, and the architect or owner could be reluctant to incur the additional engineering costs.

The simplified procedure for sizing and analyzing the cost benefit of thermal energy storage presented herein, is the result of a study performed for the North Carolina Energy Institute. It was developed for two "typical" small commercial building types and for North Carolina weather conditions. The results are presented in the form of nomograms applicable to the "typical" buildings and three weather zones defined for North Carolina. To extend the procedure to other geographical regions and building types will require additional computations and nomograms following the method outlined in the following sections.

DEVELOPMENT SELECTIONS AND ASSUMPTIONS

The goal of our study was the development of a simplified procedure for the sizing and the determination of the monthly demand and energy savings of a TES system in a small commercial building. Such results require calculation of the hourly cooling and heating requirements and the other electrical requirements for the building on each of the peak days for twelve months. The local weather conditions, utility rate schedules, system operating hours, and building occupancy schedules are input to the calculations. The calculations must be performed for the HVAC system with and without the thermal storage to assess the costs benefiting of the TES system.

Building Types and Weather Conditions

Two small commercial building types, to be representative of common office-type commercial or institutional structure, were selected. One was to be representative of a 20,000 to 50,000 square foot building and the second a 50,000 to 100,000 square foot structure. Skeleton architectural plans for these two buildings were prepared by an architect experienced in North Carolina building practices. The smaller is a two story building with a gross floor area of 35,640 ft^2, illustrated in Figure 1. The larger building is five story with a gross floor area of 78,732 ft^2, illustrated in Figure 2.

The weather data for 63 cities, widely distributed throughout North Carolina, was collected and analyzed for grouping into localized weather zones. Three weather zones were selected and named: the Coastal Plains, the Piedmont, and the Mountains. The mean values for the heating degree days (HDD) and cooling degree days (CDD) and the standard deviations (σ) thereto, for the three regions are as follows:

North Carolina Weather Zones

Name	HDD	σ_h	CDD	σ_c
Coastal Plains	2879	233	1724	99
Piedmont	3440	233	1488	146
Mountains	4523	575	721	290

Economical TES Design Concept

The design of a TES system is based on the operating schedule of the plant. Two options are possible, continuous 24 hour operation on the peak design cooling load day or off-peak (nighttime) operation only. A preliminary analysis for a 50,000 gross square foot building was carried out to compare the economic benefit of these two options. Using typical electric loads during the cooling season for commercial buildings in North Carolina the chiller size, storage size and maximum monthly demand were calculated as follows:

System	Chiller	Storage	Demand
Conventional (No TES)	143 tons	0	129 kw
Continuous Operation	55 tons	75,000 gallons	50 kw
Off-Peak Operation	112 tons	145,000 gallons	101 kw*

*off peak

Using installed cost figures for chillers, auxiliaries, storage tanks, piping and controls, the simple payback for the continuous system was estimated as less than 3 years and the off-peak system as greater than 15 years. These paybacks were calculated at an electrical demand cost of $5.50/KWD.

The preliminary analysis clearly indicates the continuous operating TES systems as the more cost effective. The superior economic benefit for continuous operating cooling plants has also been reported in other TES studies. Because of the large difference in payback the continuous system was chosen as the design concept for this study.

Building Characteristics and Operating Conditions

To provide for differences in architectural design, two envelope versions of the typical buildings illustrated in Figure 1 and 2 were defined. The low envelope load version has 25% glass area and a high envelope load version has 75% glass area. Table 1 summarizes the characteristics of the high and low load building designs and gives the result of the peak envelope cooling and heating load calculation. The 5 story building represents the size range of 50,000 to 100,000 ft^2. The 2 story building represents the size range of 25,000 to 50,000 ft^2.

The building air conditioning is assumed to be operating from 7 a.m. to 7 p.m. During the 12 hour nighttime shutdown hours an infiltration rate of 0.15 cfm/ft^2 is assumed for the building.

The outdoor summer design conditions for the three weather zones of North Carolina are the 2.5% summer design values from the ASHRAE HANDBOOK OF FUNDAMENTALS. The values chosen, typical of each weather zone are:

Zone	Dry Bulb	Wet Bulb	Range
Coastal	90 F	78 F	18 F
Piedmont	92 F	75 F	20 F
Mountains	87 F	72 F	21 F

Two summer indoor design temperatures are used, namely, 78 F and 72 F. In both the relative humidity is 50% Interior electrical loads also have two values, i.e., 1.96 W/ft^2 (low) and 5.17 W/ft^2 (high). An occupancy of 109 persons is assumed for the 2 story and 241 for the 5 story building.

Chiller and Storage Sizing

Figure 3 illustrates (somewhat idealized) the design day cooling profile for a small commercial building. The system operating hours of 7 a.m. to 7 p.m. are labeled on the figure. The criteria for sizing the chiller and storage is the availability of adequate cooling capacity for the daytime operating conditions. The chiller rating in Btu/hr is calculated from the relation:

$$\text{Chiller Rating} = (\text{Sum of hourly cooling loads})/(24 \times e_1) \qquad (1)$$

The sum is performed for the design day cooling loads, and e_1 is an efficiency factor to account for system thermal losses. e_1 is assigned a value of 0.90 in the sizing of the chiller. In Figure 3 the chiller capacity calculated by Equation (1) is shown by the dashed line.

It is assumed for this study that cooling of the building is provided only during the daytime hours. The entire nighttime output of the cooling plant is used to charge the storage. The storage capacity in Btu is calculated by the relation:

$$\text{Storage Capacity} = [12 \times \text{Chiller Rate} + \sum (\text{Chiller Rate} - \text{Load})]/e_2 \qquad (2)$$

The summation indicated in the second right-hand term of Equation (2) is only over those hours of the design daytime operating period when the chiller rating exceeds the building cooling load. The divisor e_2 of Equation (2) is the storage efficiency, and for this study was assigned a value of 0.80. It should be pointed out that when nighttime cooling is not provided, some fraction of the nighttime load carries to the early morning hours, thus Figure 3 is not an accurate representation for that load profile.

The storage tank volume is calculated from the relation

$$\text{Storage Volume (gallons)} = \frac{\text{Storage Capacity}}{8.3 \times 15} \qquad (3)$$

Equation (3) is based on a 15°F temperature change between inlet and outlet water.

COMPUTER SIMULATIONS

Chiller and Storage Sizing

The procedure, equations, and tabulated data for calculating the design cooling load are presented in the ASHRAE HANDBOOK OF FUNDAMENTALS Chapter on

Air Conditioning Cooling Load. They were written into a computer program for execution in HP-2000 BASIC to calculate the monthly hourly peak cooling loads. The program also sizes the chiller and storage tank using Equations (1), (2) and (3) as presented above. The program runs interactively and the user is prompted to input information related to the building and its operational characteristics.

Table 2 summarizes the results of the computer program for chiller and storage sizing for the conditions: mountain weather zone, 5-story building and low envelope load version of architecture. This table represents the results of 12 computer runs. There are 2 indoor temperatures, 3 daytime ventilation rates, and 2 internal electrical loadings. Similar computer calculations were made for the Piedmont and Coastal weather zones and for the high and low envelope versions of both the 5-story and 2-story buildings. In all, then, there were 12 x 3 x 4 = 144 computer runs for sizing the chiller and storage of a TES system and the chiller of a conventional (No TES) system. Table 3 compares the sizings for the three weather zones for the low envelope building load version at an indoor temperature of 78 F and daytime ventilation rate of 0.2 cfm/ft^2.

Monthly Demand and Demand Savings

The key benefit of thermal storage in an air conditioning system is the shift of electrical demand to off peak. Electrical demand charges by the utility company are usually on a monthly basis. The billing demand for a given month is often based on considerations of the peak demand measured during the preceding twelve month period. Such billing of demand is said to be on a "ratcheted" system. Demand charges may also vary with summer or non-summer periods and on-peak and off-peak hours as well as with the total quantity of electric usage.

Because of the fairly involved and different billing procedures of the utilities, it is necessary to determine the peak electrical demand of a building on a month-by-month basis to determine demand savings. The savings in usage of electricity by a TES system result from operation at nighttime when outdoor temperatures are lower and from improved chiller load factors. These energy savings will be offset by storage losses, and longer operating hours for chilled water pumps and auxiliaries. The net savings in usage are not expected to be large. Consequently our procedure concentrates on the determination of the monthly demand and demand savings.

A computer simulation program ACCESS, developed and marketed by the Edison Electric Institute, was selected for the hourly building calculations of cooling load, electrical energy usage and power demand. The AXCESS program, as written, did not have the capability to provide hourly outputs for twelve selected days of maximum peak demand. The service code was modified to provide this run option. In all, sixty AXCESS runs were made with up to six alternatives per run. In situations where the building peak demand was not clearly caused by the cooling peak, the entire month was analyzed on an hour-by-hour basis. The peak day was selected from this analysis.

The 24 hour load profiles, obtained for the peak demand day of each month by AXCESS, were fed into a program TESSAV that simulated the performance of the previously sized TES system. TESSAV was developed for this project and produced the monthly peak power demand of the building with thermal storage, as well as the monthly demand savings in relation to the building without thermal storage.

Preliminary AXCESS runs were made to establish the base loads, i.e., the cooling loads independent of the HVAC equipment and system and with no outdoor ventilation. This was done by using the AXCESS program option of unitary heating and cooling equipment with 100% efficiency, and specifying 0% ventilation. The final AXCESS runs considered the following secondary system types:

- Dual Duct
- Constant Volume Terminal Reheat
- Variable Air Volume, 30% Stop and Reheat
- Unitary Heating and Cooling

The first three system types were modelled with supply air temperature resets. Alternatives in the AXCESS runs provided for outdoor air ventilation rates of either 0.2 and 0.5 cfm/ft^2 and either a temperature or enthalpy economizer.

In the Part B runs the chiller was assumed to have a constant COP of 4.39 or an 0.8 kw electrical input per ton of cooling effect. This value should be treated as a reference value, and the results presented in the following section should be adjusted to reflect the actual COP of the chiller being considered. Additionally the demand and demand savings plots do not reflect the energy requirements of the cooling tower and the chilled and condenser water pumps. It should be relatively easy to add the power demand of these auxiliaries as a function of the chiller load.

The TESSAV program calculates and compares the maximum chiller demand by the TES system. A positive day cooling load occurs when the chiller operates during the hours of building occupancy. A zero or negative day cooling load occurs when the chiller-TES system can store sufficient cooling during the nighttime to meet the daily cooling load. On a positive load day the minimum electrical load imposed by the chiller is at 30% of full load. Thus

$$(\text{Chiller Demand})_{\text{min}} = \frac{\text{chiller capacity x 0.8 x 0.3}}{12{,}000} \qquad (4)$$

A check is made to determine the availability of cooling at every hour of the day by calculating the available cooling from:

$$\text{Cooling Capacity} = \text{Stored Cooling} + \text{Chiller Rate} - \text{Cooling Load} \qquad (5)$$

The operation of the chiller during the day is automatically increased if this check at each daytime hour does not show a positive number.

The demand savings by the TES system are determined from:

$$\text{Demand Savings} = (\text{Chiller Demand})_{\text{conv.}} - (\text{Chiller Demand})_{\text{TES}} \qquad (6)$$

The chiller operating strategy assumed by TESSAV is as follows:

- Chiller start at 7 p.m. and run at full capacity to charge the chilled water storage. (On the peak design day the storage will be just charged at 7 a.m.)
- During occupied hours the chiller will run at the minimum load necessary to meet the fraction of cooling load not met by the cooled storage. (Minimum chiller operating capacity is 30% of chiller rating).

The version of the AXCESS program used does not have the capability of accounting for heat storage within the building structure. To account for structural heat storage it was assumed that the accumulated nighttime loads would be one-half of that for a constant indoor temperature; as if the building were cooled to design temperature overnight. These accumulated loads were then assumed to be removed during the first four hours of morning operation. 40%, 30%, 20%, and 10% of the residual night load is added to the calculated cooling load for the morning hours starting at 7, 8, 9 and 10 a.m., respectively.

RESULTS

It was our judgement that a useful and simple form, for estimating the sizing and demand savings of thermal energy storage systems in small commercial buildings, would be a series of nomographs developed from the computer simulations. The nomographs would be related to the two sizes of buildings studied, the 2-story and 5-story structures, in both the high and low envelope cooling load versions. Further, sets of nomographs would be developed for the three weather zones (Coastal, Piedmont and Mountains) selected to represent cooling and heating seasonal requirements for North Carolina.

The results of the simulations were used to plot six sets of nomographs. Each set consists of 13 single page charts, one for sizing the TES chiller and storage tank, and 12 for determining the monthly electrical demand and demand savings. The procedure of using these nomographs is based on the assumption that the results for buildings with design and operating conditions between the extremes can be obtained by interpolation.

Chiller and Storage Sizing

A nomograph for sizing the chiller and storage tank is presented in Figure 4. It is for the 5-story building, representing the size range of 50,000 to 100,000 ft^2, and for the Coastal Plains weather zone of North Carolina. The figure consists of three separate plots, and a "key" to identifying the options of internal load, ventilation rate, and indoor design temperature.

The use of the Figure 4 nomograph begins by entering the plot at the upper right with a value for the peak envelope cooling load (PECL). This value is the usual design day cooling load less the sum of the internal building load and the ventilation load. It includes the heat transmission and solar loads and is, therefore, referred to as the envelope cooling load. The PECL is expressed in Btu/hr-ft^2 and incorporates the effect of indoor design temperature, since that temperature is required in the calculation procedure for transmission heat gain. The output of the first graph is the total design day cooling load without ventilation expressed in Btu/day-ft^2. Interpolation between low and high values of internal building loads of 1.96 to 5.17 watts/ft^2 is used to obtain the result.

The second graph of Figure 4 produces the total design day cooling load including ventilation. This result is obtained by interpolation for an outdoor ventilation rate between 0 and 0.5 cfm/ft^2. Indoor design temperature effects the ventilation load and an interpolation is also required between extreme values of 78F and 72F.

The third graph of Figure 4 sizes the chiller and storage tank volume for a TES system. The chiller size or rating is obtained on the right scale of the graph in tons of refrigeration per 1000 square feet of building area. The storage tank volume comes from the scale on the left in units of gallons per square foot of building area.

Monthly Demand and Demand Savings

The determination of the monthly peak electrical demand and demand savings of a TES system, as compared to a conventional air conditioning system without thermal storage, starts again with the PECL. Figure 5 presents a graph for the 5-story building in the Coastal Plains weather zone for the month of August. Interpolation between internal loads from 1.96 to 5.17 W/ft^2 produces the August peak cooling load without ventilation expressed as Btu/hr-ft^2.

In Figure 6 the August peak cooling load without ventilation is converted to a total cooling load demand expressed as chiller demand in KW/ft^2. The conversion is made by the choice of one of four HVAC system types, and by the interpolation for an outdoor ventilation rate and the use of a temperature or enthalpy economizer. The four HVAC system types represented, from the computer simulations, are Unitary, Dual Duct, Variable Air Volume and Terminal Reheat. The last three system types were modelled with supply air temperature resets. In terms of cooling loads, these system types can also be used to approximate a multizone system. The unitary system can be used as a good approximation to a fan coil system. In the computer simulations the effect of fan energy on the thermal loads was not considered. The fan energy should be calculated and added to the monthly peak cooling load if it is significant.

The final plot for determining demand and demand savings is presented in Figure 7. Herein, the monthly peak chiller demand for a conventional air conditioning system is converted to the chiller demand savings by the use of a TES system. Again the conversion is made by the choice of HVAC system type (unitary, dual duct, etc.) and the ventilation rate and economizer type used.

In Figure 8 the three graphs of Figures 5, 6 and 7 are combined to a single nomograph for ease of usage. This nomograph for the 5 story building (50,000 to 100,000 ft^2 size range) and Coastal Plains weather zone, is one of twelve such monthly plots needed for determining the total yearly chiller demand savings. When the conventional chiller demand is added to the building base electrical demand (lights and equipment), the total electric utility billing demand on a monthly basis will be estimated. The utility rate structure is then used to calculate the yearly demand cost and the cost savings by the TES system.

Example

Consider the building plan represented in Figure 2, a 5 story building with total floor area of 93,000 ft^2. The building will be located in New Bern, North Carolina (Coastal Plains weather zone). The calculated design peak envelope cooling load (PECL) is 10 Btu/hr-ft^2. The internal building load is 3.57 W/ft^2 and the mechanical equipment and auxiliaries require an additional 0.39 W/ft^2. The indoor design temperature is 75 F and the daytime ventilation rate is 0.5 cfm/ft^2.

The nomograph of Figure 4 is used to determine the chiller and storage sizes for a TES system. The values determined from the graph, as shown in Table 4, are: 2.25 Tons/1000 ft^2 and 3.58 gallons/ft^2. For the 93,000 ft^2 building example the sizes are 210 Tons and 333,000 gallons.

The monthly demand and demand savings for August are determined from the nomograph of Figure 8. As shown in Table 4 the values obtained are: a conventional chiller demand of 2.5 KW/1000 ft^2 and a chiller demand savings of 2.08 KW/1000 ft^2.

The August billing demand for a conventional air conditioning system is calculated as:

$$(2.5 + 3.57 + 0.39)93 = 601 \text{ KW}$$

Figure 9 presents a sample plot of the monthly building demand for a conventional and a TES system as sized by the procedures presented herein. The monthly savings in electrical billing demand, represented by the difference in values of the two curves form the basis of the economical analysis for evaluating the benefit of the TES system.

Acknowledgement:

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Table I. Characteristics of the High and Low Envelope Load Building Designs

Building Size	Envelope Load	U (Btu/hr-ft^2-F) Wall	Roof	Glass	Glass Amt. N/S	E/W	shading Coef.	Peak Load* Btu/hr-ft^2 Heat	Cool
5-story 78,732 ft^2	High	0.28	.10	1.0	75%	75%	.60	15.3	11.0
	Low	.07	.06	0.47	25%	25%	.52	4.0	3.6
2-story 35,640 ft^2	High	.28	.10	1.0	75%	75%	.60	23.8	14.7
	Low	.07	.06	0.47	25%	25%	.52	6.2	5.0

*Averaged values over three North Carolina weather zones

Table II. Chiller and Storage Sizing - Mountains (Asheville), N.C.
Five Story Building (78,732 ft^2)
Low Envelope Load Version

		Internal Load - 5.17 W/ft^2			Internal Load = 1.9 W/ft^2		
Indoor Temp. F	Ventilation Rate* cfm/ft^2	Chiller Capacity No TES Tons	Chiller Capacity TES Tons	Storage Volume Gallons	Chiller Capacity No TES Tons	Chiller Capacity TES Tons	Storage Volume Gallons
72	0.0	150	76	125000	83	43	69000
78	0.0	147	73	121000	80	40	64000
72	0.2	208	112	180000	143	79	124000
78	0.2	182	89	146000	117	56	89000
72	0.5	299	146	236000	234	113	180000
78	0.5	239	107	177000	173	74	121000

*Daytime (7 a.m. - 7 p.m.) ventilation rate. Nighttime rate is 0.15 cfm/ft^2

Table III. Chiller and Storage Sizing
Low Envelope Load Version
Indoor Temperature = 78F, Ventilation Rate = 0.2 cfm/ft^2

	Mountain Zone			Piedmont Zone			Coastal Zone		
Int. Load W/m^2	Chiller No TES Tons	Capacity TES Tons	Storage Volume Gallons	Chiller No TES Tons	Capacity TES Tons	Storage Volume Gallons	Chiller No TES Tons	Capacity TES Tons	Storage Volume Gallons
Five Story Building									
5.17	182	89	146000	196	104	168000	215	116	187000
1.9	117	56	89000	130	71	112000	149	83	130000
Two Story Building									
5.17	84	41	67000	90	48	78000	99	54	86000
1.9	54	26	42000	60	33	52000	69	39	61000

Table IV. Example Use of Nomographs
5-Story Building (93,000 ft^2) in Coastal Weather Zone

A.	Assumptions	
1.	Peak Envelope Cooling Load (PECL)	10.0 Btu/hr-ft^2
2.	Internal Load	3.57 W/ft^2
3.	Mechanical equipment	0.39 W/ft^2
4.	Indoor design temperature	75 F
5.	Outdoor ventilation rate	0.5 cfm/ft^2
6.	System Type	VAV, 30% stop and reheat
B.	Chiller & Storage Sizing	
7.	Total Cooling Load (without ventilation)	265 Btu/day-ft^2
8.	Total Cooling Load (0.5 cfm/ft^2 vent.)	587 Btu/day-ft^2
9.	Chiller Size with TES	2.25 Tons/1000 ft^2
10.	Storage Size	3.58 gals/ft^2
C.	August Demand & Demand Savings	
11.	Conventional Chiller Demand	2.5 KW/1000 ft^2
12.	Chiller Demand Savings	2.08 KW/1000 ft^2

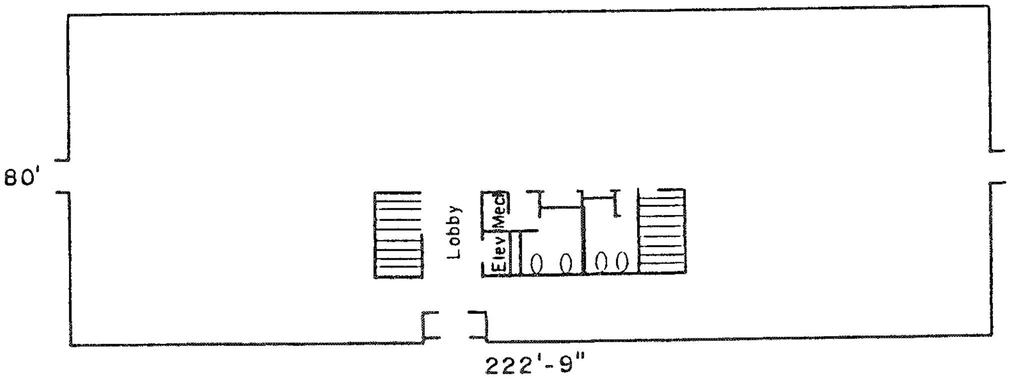


Figure 1. Two Story Building Floor Plan.

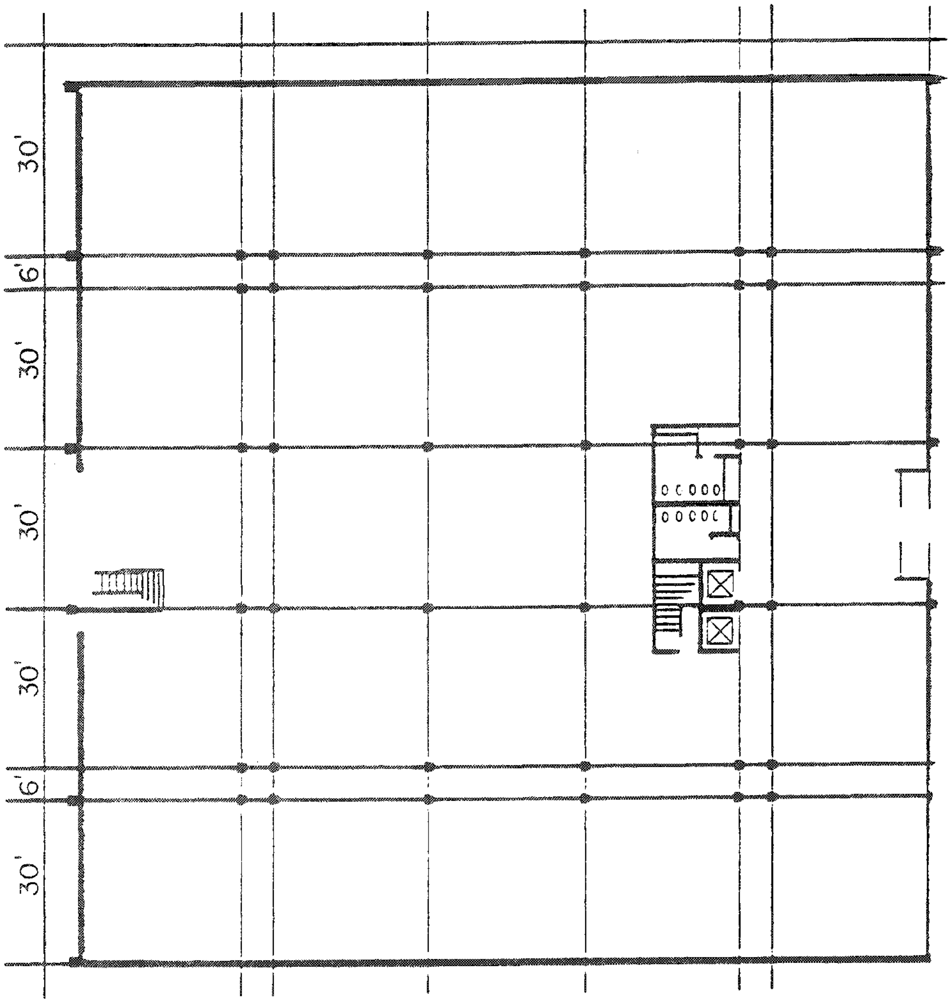


Figure 2. Five Story Building Floor Plan.

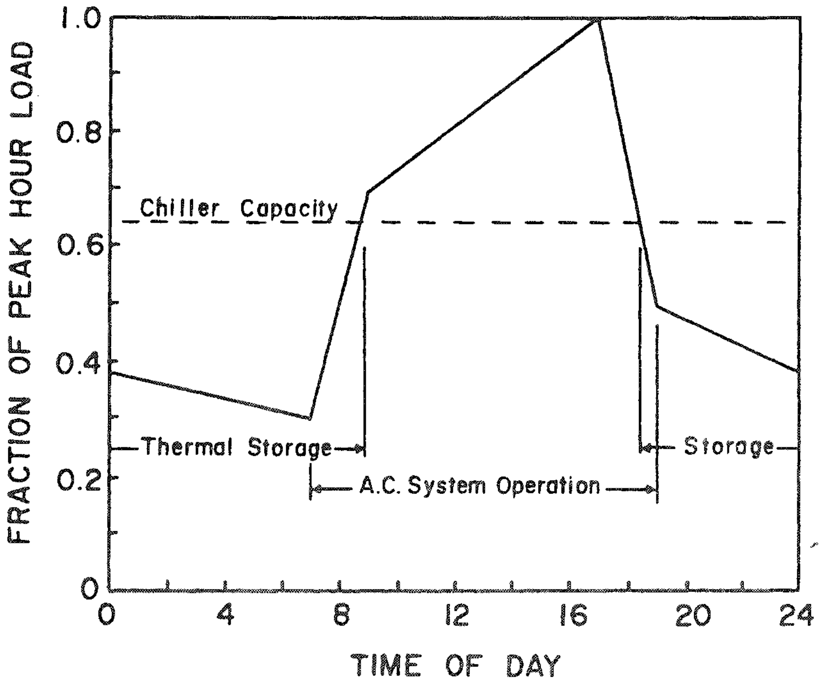


Figure 3. Design Day Cooling Profile.

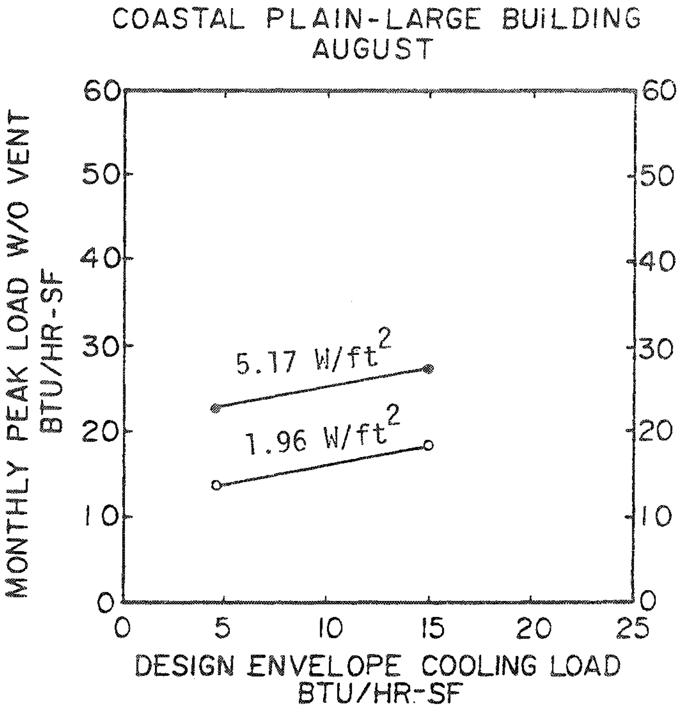
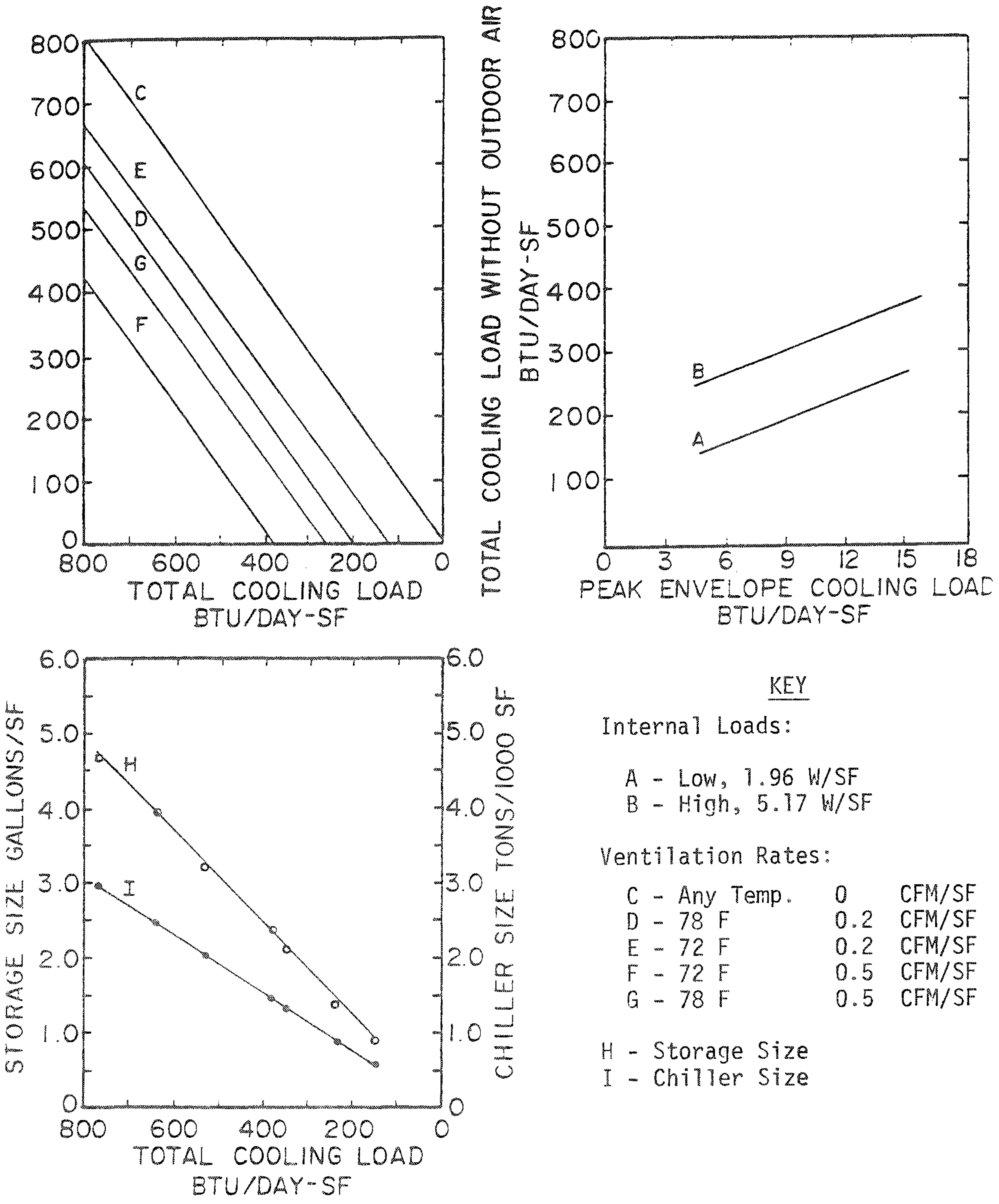


Figure 5. Nomograph for Monthly Peak Load.

COASTAL PLAINS LARGE BUILDING



KEY

Internal Loads:

A - Low, 1.96 W/SF
B - High, 5.17 W/SF

Ventilation Rates:

C - Any Temp.	0	CFM/SF
D - 78 F	0.2	CFM/SF
E - 72 F	0.2	CFM/SF
F - 72 F	0.5	CFM/SF
G - 78 F	0.5	CFM/SF

H - Storage Size
I - Chiller Size

Figure 4. Nomograph for Sizing the Chiller and Storage Tank of a TES System.

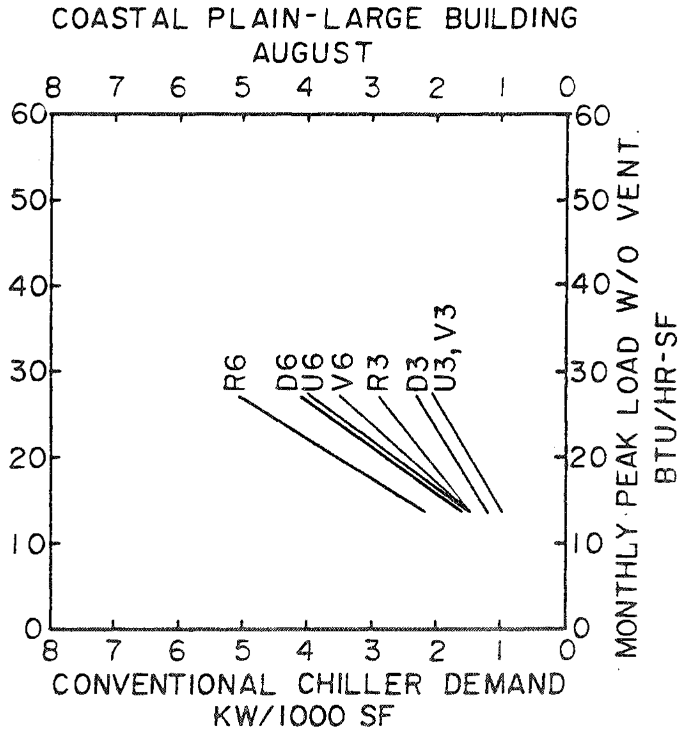


Figure 6. Nomograph for Conventional Chiller Demand.
(See Figure 8 for key to letter and number symbols).

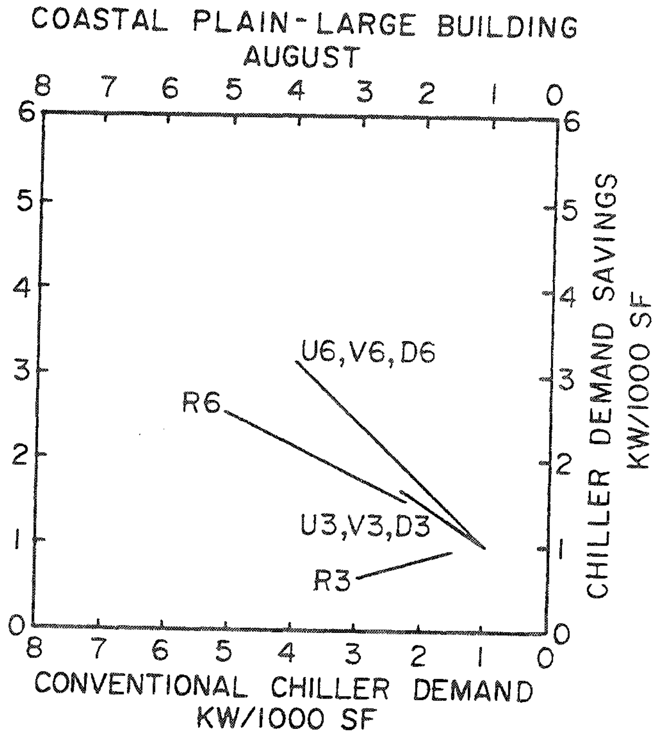


Figure 7. Nomograph for Chiller Demand Savings of TES vs
Conventional Cooling System.
(See Figure 8 for key to letter and number symbols).

COASTAL PLAIN-LARGE BUILDING
AUGUST

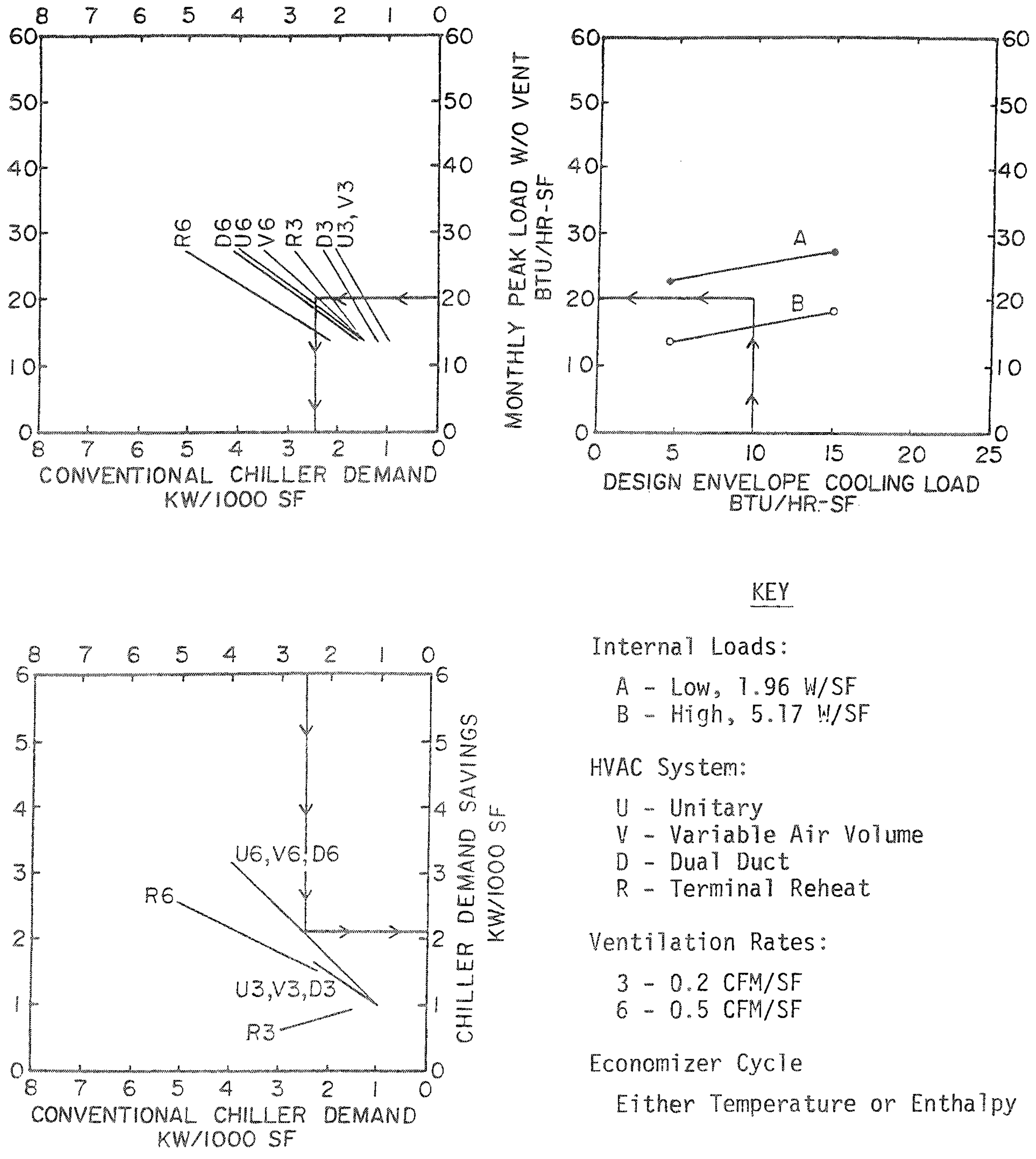


Figure 8. Nomograph for Determining Conventional and TES Chiller Demands for a Five Story Building in New Bern, N.C.

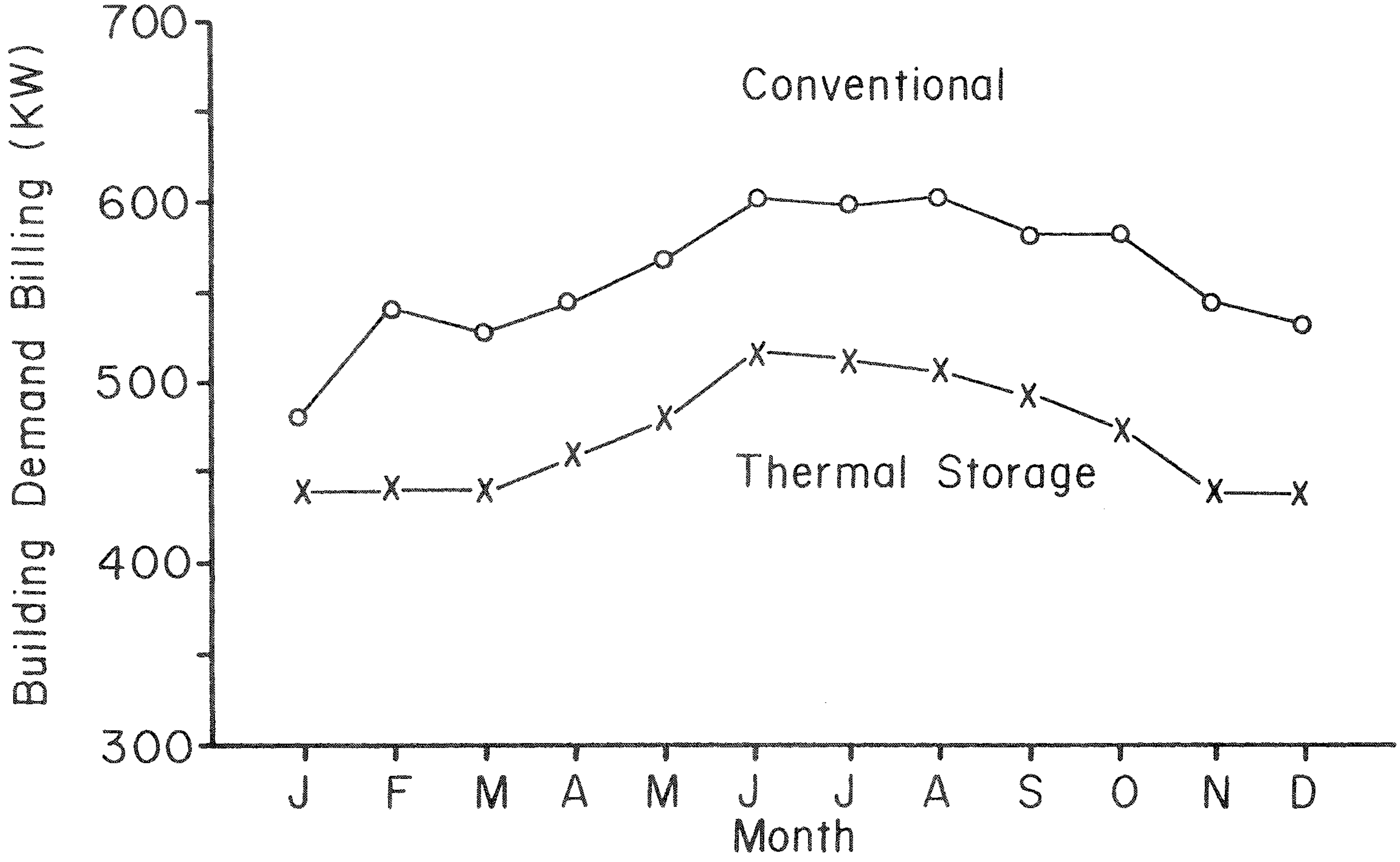


Figure 9. Monthly Billing Demand - Conventional vs TES Cooling System.