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CHILLED-WATER STORAGES-AN ALTERNATIVE SOLUTION TO THE PROBLEM OF BROWNOUTS IN THE PHILIPPINES

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ABSTRACT

The problem of brownouts in the Philippines, specifically in Luzon, has been largely due to the high value of the peak power demand which our local utilities have difficulty supplying. This paper discusses the merits to both the consumers and the electric utilities of installing chilled-water storages --- in addition to the benefit of reducing the possibilities of having power outages that these systems may potentially bring. Written in a form that is readable by persons with varied backgrounds in engineering or allied fields.

INTRODUCTION

The problem of brownouts in the Philippines, specifically in Luzon, has been largely due to the high value of the peak power demand which our local utilities have difficulty supplying because their capacity to supply this is just about enough. Hence, when the local electric utility had problems with their turbines during the last quarter of 1989 and had to rehabilitate them, they had to cut off the power on a rotating basis in different localities because of their decreased ability to meet the power demand requirements.

Conventional cooling systems in industrial and commercial establishments use roughly 60% of their electricity requirements. This means that 60% of the electricity used by a commercial or industrial complex, which has a refrigeration system installed, is used for cooling purposes. Since conventional cooling systems commonly operate during hours of peak-power demand, they serve to increase the demand for peak power and therefore, indirectly, also increase the possibility of having brownouts. Cooling systems with thermal storage, on the other hand, decrease the possibility of having brownouts because they generate cooling capacity at off-peak times and store it for later use, specially during hours of peak-power demand.

A major factor in the design of chilled-water storage systems is blending of the return water from the load, which is relatively warm, with the stored chilled-water. Several anti-blending techniques have been developed and used. One method uses a flexible membrane, fastened at midheight in the storage tank, which separates the stored chilled-water from warm return water as shown in Fig. 1. The problem with this approach occurs when the membrane ruptures because of rubbing against the tank walls or because of being pulled into the outlet connection, permitting mixing.

The multiple-tank concept is the most effective approach to anti-blending. Here the warm return water is completely isolated from the chilled-water by storing each in separate tanks, as in Fig. 2. Several tanks are used with valves that permit either draining or filling from either the chilled- or warm-water tanks. Chilled-water is drawn from one tank while warm return water fills another tank -- and this occurs on a rotating basis [1].

Two cost-related problems arise with the multiple-tank concept. In actual operation, two tanks are always only partially filled, which means that tank capacity must exceed the thermal storage capacity -- this increases the storage cost. Secondly, control of the multiple-tank concept is very complicated and it is not unusual to find that computerized controls are necessary, which substantially increases the cost of the system.

Still another approach to anti-blending is to thermally stratify the water in storage. Mixing is avoided during charging and discharging by taking advantage of the buoyancy of warmer water. Compared to the two above-mentioned approaches, this is the simplest. It will be discussed in the next section.

The Stratified Water Thermal Storage Tank

The stratified water thermal storage tank (SWTST) takes advantage of the buoyancy of warmer water to avoid mixing. The storage tank may either be unpartitioned or partitioned. It was the Japanese who first developed the concept of resisting temperature blending through the use of many interconnected compartments with high and low transfer apertures. This concept developed logically from the first installation in 1950 by Dr. Yanagimachi [2]. Little modification was needed to form a container for water storage. One such scheme is shown in Fig. 3. This set-up takes advantage of the buoyancy principle. Since the warmer return water will have a density which is lower than the stored chilled-water, the warm water mass will remain above the cold water mass.

However, a problem arises when the warm water mass starts entering the second compartment (and other even-numbered compartments) where the denser cold mass will be above the warm mass. Mixing becomes inevitable because of the difference in densities (see Fig. 4). This will be specially true when the area of the interface is large.

If, therefore, the area of the interface could be reduced, the interface would be more stable and thus minimize the possibility of blending [3]. Furthermore, if the volume where possible mixing could occur were reduced, then the unfavorable effects of blending in the compartmentalized SWTST would also be reduced.

A better way of compartmentalizing the tank is shown in Fig. 5. When the warm water mass starts entering the smaller "compartments" or direction-change passages, the weight of the denser cold water mass will tend to disturb the interface. However, by virtue of the narrowness of the passageways, any mixing that might occur because of the disturbance of the interface will be minimal. Also, the narrower flow paths could add stability to the fragile interface because now there would be a significantly smaller area of contact between warm and cold masses [4].

The SWTST has the potential of being the type of chilled-water storage tank system to be used in the local setting of its promising practical usefulness --- it is both simple and has minimal maintanance costs.

In the Philippines, chilled-water storage systems are still in the introductory stage. These systems are expected to gain wider acceptance as an increasing number of people from the commercial and industrial sectors become more concerned about reducing energy-related costs. The lack of information about the performance of these cool storage systems hinders their wider use.

The Advantages of Installing an SWTST System

The concept of thermal as applied to cooling systems is not new. Not long after mechanical refrigeration for airconditioning became a practical reality, in the 1930's, the technology was extended to include thermal storage to handle infrequent short-term cooling loads (such as in big churches and theaters) and in process applications (such as in dairies) [1].

Take for example a university theater having a cooling load of 50 tons of refrigeration (50 TR) for 5 hours once weekly. Rather than installing a 50 TR system to operate for 5 hours, it is more sensible to install a 5 TR system to operate and store cooling for 50 hours. The first cost and maintenance costs of the system can thus be substantially reduced --- even when the cost of installing an SWTST system is included.

Electric utility companies experience the greatest demand for electricity during daylight hours when cooling requirements are highest. When the demand for power approaches the limit of the electric utility's generating capacity, the utility company must implement a rate structure that will discourage use of large kWhr values during times of peak usage.

Since conventional cooling systems produce cooling only when it is needed, they operate when the demand for power approaches the utility's generating capacity --- hence, increasing the possibility of a power outage when this capacity is exceeded. The SWTST system, however, would help in lowering the demand for electricity by generating cooling at off-peak times and storing it for future use --- hence decreasing the possibility of a power outage.

To appreciate the concept of storage of cooling better, let us examine the relationship between storage and electrical demand based on electricity rates for large commercial buildings in Toronto, Canada.

The load curve shown in Fig. 6 is a typical load profile of a 1000 TR chiller. The area under the curve represents the amount of cooling capacity that the refrigeration system must handle in one day (in ton-hours)

From this load profile, it can be seen that 20% of the chiller capacity can be eliminated if 10% of the cooling load is stored. Another option would eliminate 60% of the chiller capacity if 50% of the cooling load is stored.

The graphs in Fig. 7 show three different ways of meeting a 1000 TR load. The first case, having no storage, requires a 1000 TR chiller. The demand charge is based on how high the peak of the load curve is. The energy charge is based on the area under the load curve.

The second case uses a 385 TR chiller operating constantly ---- that is, it stores cooling during the evening and generates cooling during the daytime. The stored chilled water is used together with the chiller-generated chilled water to handle the cooling load during the daytime.

The third case uses an 800 TR chiller operating during off-peak hours. The stored chilled water is used during the daytime to handle the cooling load.

Either of cases two or three would be beneficial both to the establishment that uses storage of cooling (because of lower electricity costs) and to the electric utility (because of the contribution to load levelling that this system would give).

Aside from the benefits due to load levelling that will result from using electricity during off-peak hours, the establishment that implements this kind of system will have:

1. Reduced first costs, because it is cheaper to install a smaller airconditioning system with storage than to install a large airconditioning system that will handle the entire load.

2. Better cost effectivity should they decide to extend the cooling capacity of an existing system, because it would be cheaper to install a thermal storage system than to increase the size of the refrigerationing system. A study was made by the National Engineering Center in 1984 to determine methods of reducing energy related costs for the Metropolitan Waterworks and Sewerage System Building Complex. One of their recommendations was that it would be an energy saving opportunity for the MWSS Complex to sell two of its chillers and install a thermal storage system [5].

3. Reduced electricity costs, because cooling will be generated during hours when electricity rates are lowest.

Current electricity rate structures in the Philippines do not encourage users to seriously consider thermal storage. The demand charge is a measly P12.60 per kW.

But because of the present power crisis (as I write this paper there have been a number of brownouts), the electric utilities should soon implement such a rate structure.

Any way one looks at it, storage of cooling is beneficial both to the local electric utility and to the consumer. For the electric utility in that the demand for power curve will be lowered and flatten off, which would mean a greater capacity to supply power. For the consumer in that this converts into minimal power outages.

CONCLUSION

The primary objective of this paper is to increase public awareness on this attractive solution to decrease the occurrences of brownouts. This solution involves encouraging the industrial and commercial sectors, which have conventional refrigeration and airconditioning systems installed, to use thermal storage systems. The electric utilities can help implement this by reformatting their rate structures to encourage users to use electricity during off-peak hours (i.e. make electricity expensive during the peak hours of usage and cheap during off-peak hours).

During these times when metropolises are growing rapidly and technological advancement is becoming a thrust for national development, the need for more reliable energy sources becomes a must. But this should not be a one-sided affair. Energy consumers must also help ---- and one way they can is by building SWTST's.

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2. Tamblyn, R.T., "Thermal Storage: Resisting Temperature Blending", ASHRAE Journal, Vol. 22, No. 1, 1 January 1980.

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4. Santos, A. B., "A One-Dimensional Model for Predicting the Temperature Distribution in Stratified-Water Thermal Storage Tanks", M.S. Thesis, University of the Philippines, Diliman, November 1988.

5. Benito, R.G., Private communications, 1986.

FIGURES

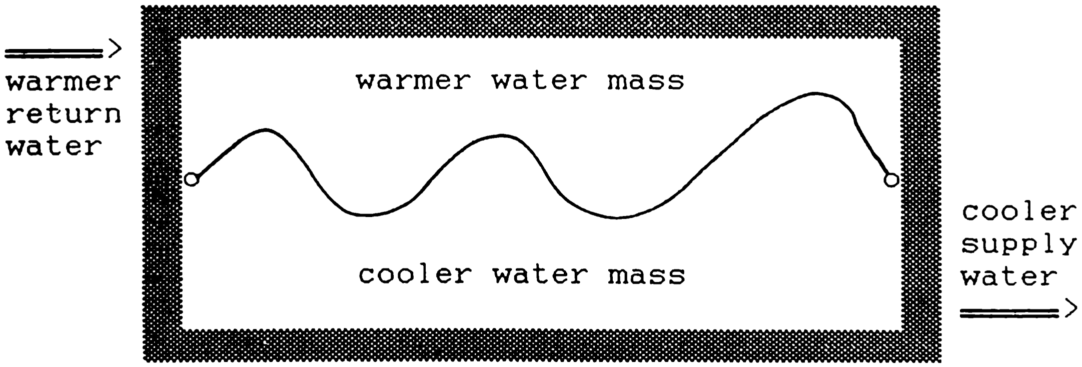


Fig. 1 - Chilled-water Storage Tank with Flexible membrane.

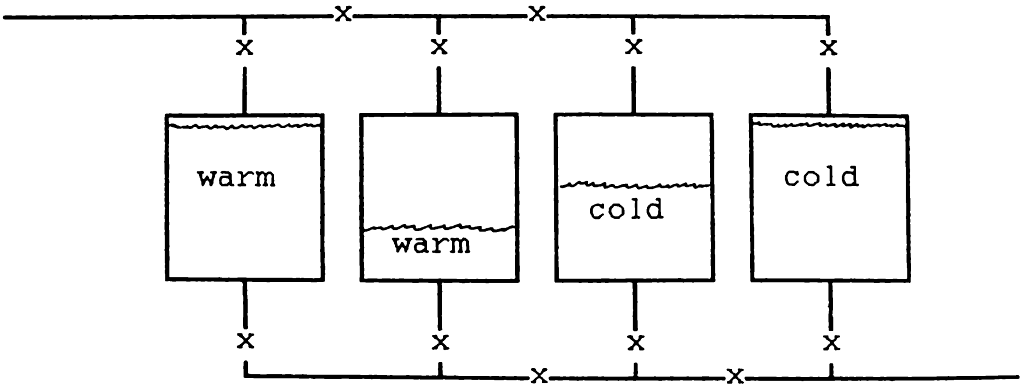


Fig. 2 - Chilled-water Storage System with Multiple Storage Tanks.

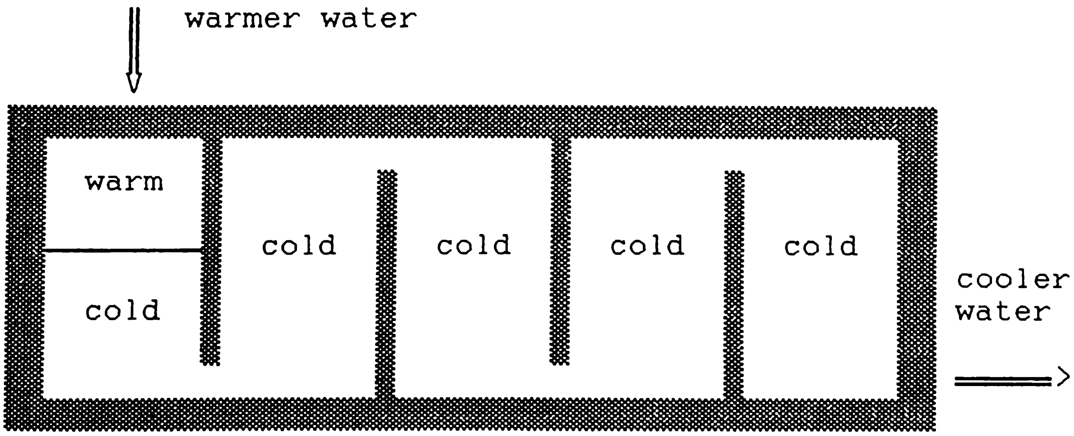


Fig. 3 - A Compartmentalized SWTST.

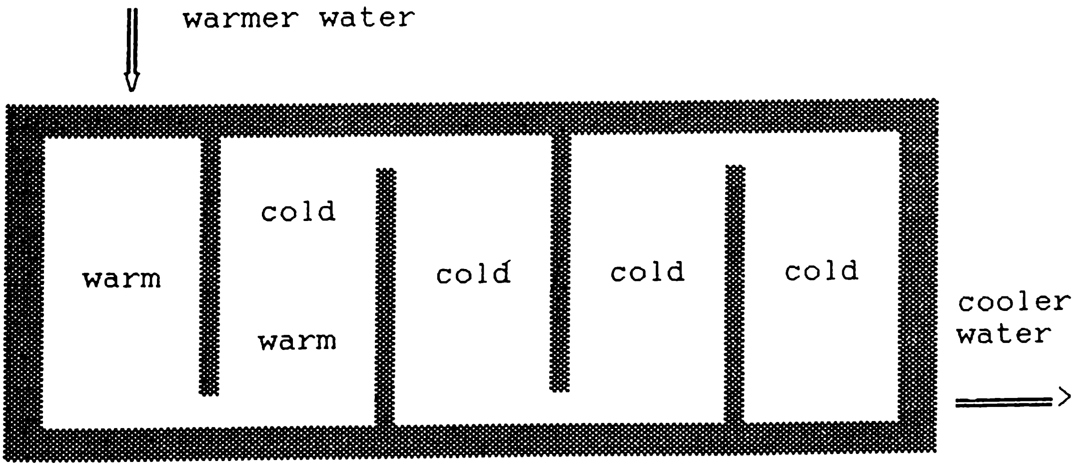


Fig. 4 - Blending in a Compartmentalized SWTST.

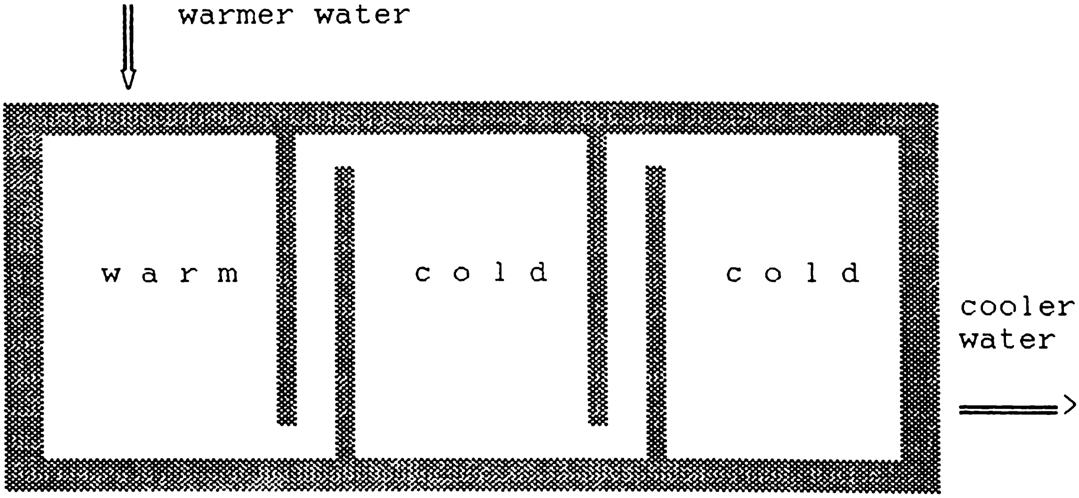


Fig. 5 - Minimizing the Effect of a Fragile Interface in a Compartmentalized SWTST.

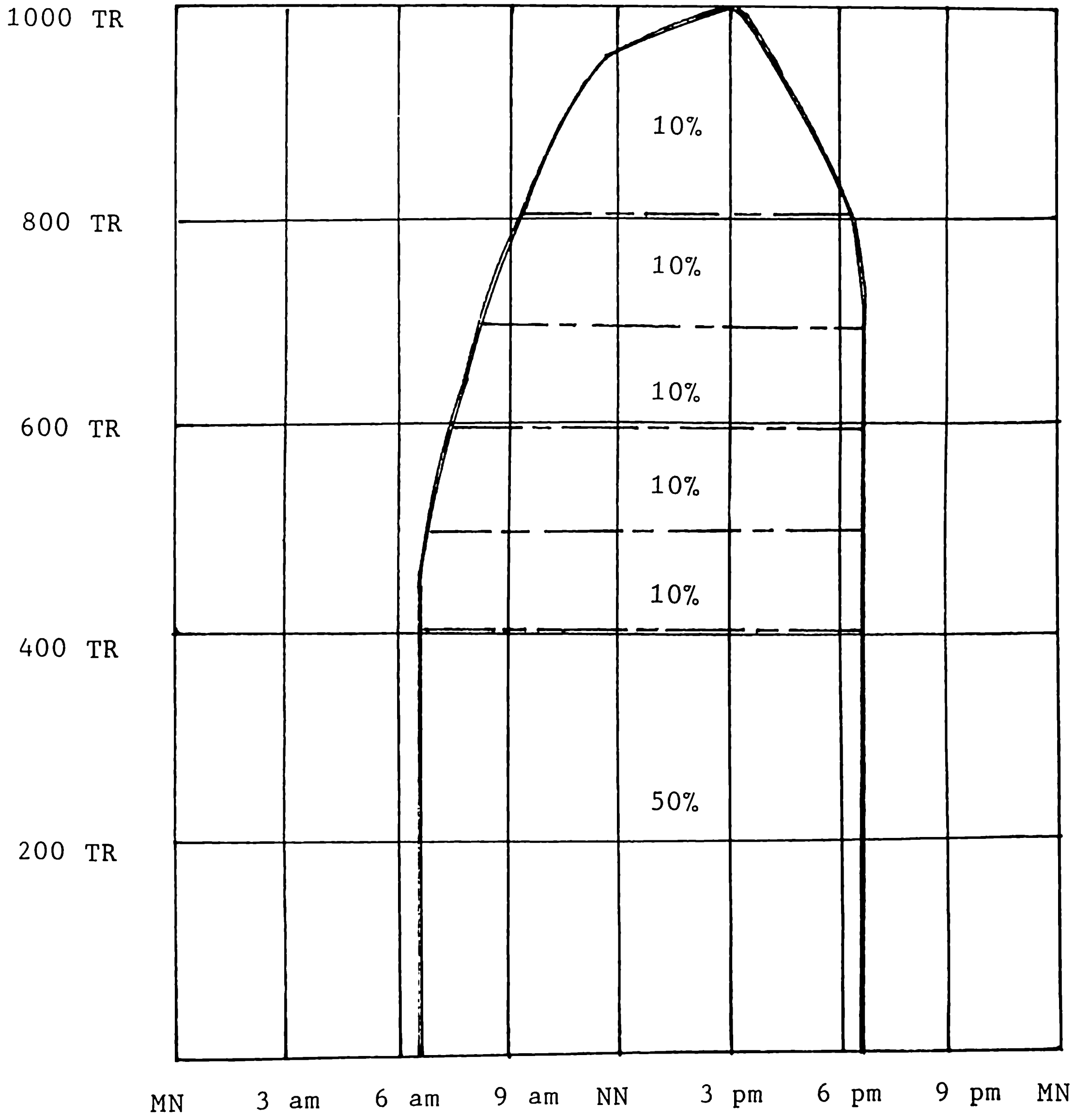


Fig. 6 - Typical load profile of a 1000 TR chiller.

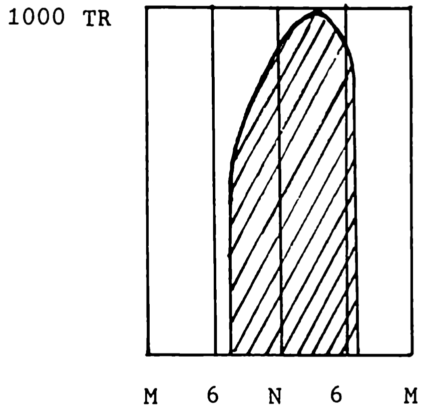
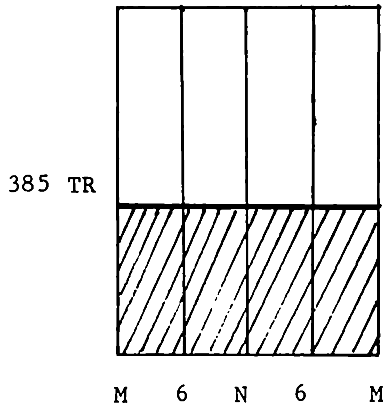
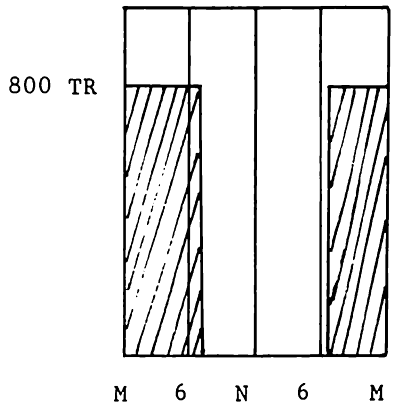
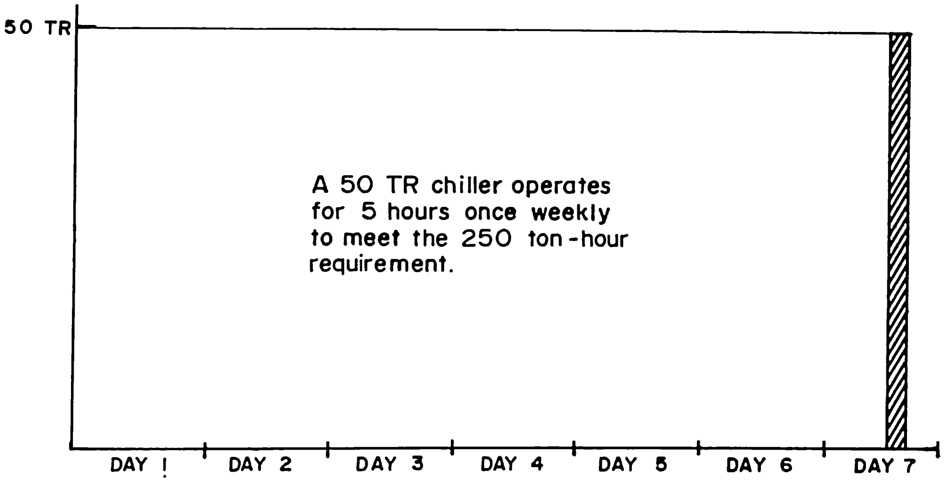
OPERATING MODE	NO STORAGE	CONSTANT OPERATION AT FULL LOAD WITH STORAGE	FULL-LOAD OPERATION DURING OFF-PEAK HOURS WITH STORAGE
CHILLER LOAD PROFILE			
CHILLER SIZE	1000 TR	385 TR	800 TR
STORAGE SIZE	NONE	330,000 gallons	550,000 gallons
ELECTRICITY COST	DEMAND CHARGE $ 4,210 ENERGY CHARGE 1,625 TOTAL $ 5,835	DEMAND CHARGE $ 1,620 ENERGY CHARGE 1,625 TOTAL $ 3,245	DEMAND CHARGE --- ENERGY CHARGE 1,625 TOTAL $ 1,625

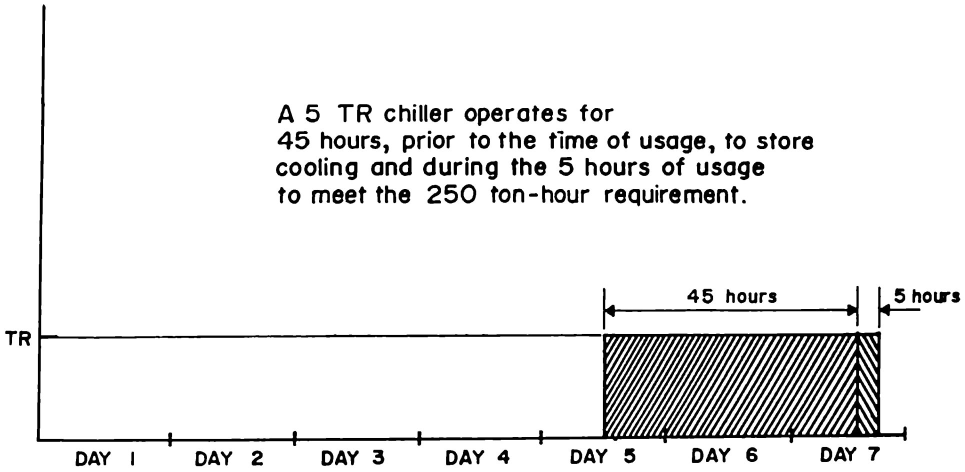
Fig. 7(a) - Three different ways of meeting a 1000 TR cooling load.

Case one : No storage

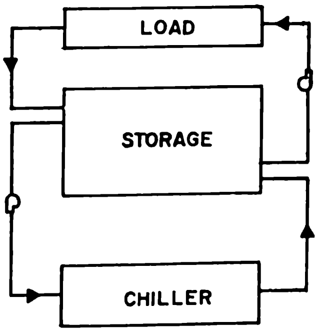


A 50 TR chiller operates for 5 hours once weekly to meet the 250 ton-hour requirement.

Case two: With storage



A 5 TR chiller operates for 45 hours, prior to the time of usage, to store cooling and during the 5 hours of usage to meet the 250 ton-hour requirement.



SCHEMATIC DIAGRAM

Fig. 7(b) - Two different ways of meeting a 50 TR cooling load for 5 hours once weekly.