

MEASURED PERFORMANCE OF COOL STORAGE IN BUILDINGS: SUMMARY OF INITIAL ANALYSIS

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In the past several years, utilities and state agencies throughout the country have sponsored a large number of programs and incentives to encourage better energy efficiency in buildings. Some recent efforts have been made in the area of peak demand savings, and thermal energy storage has been one of these load management techniques that have garnered a lot of attention. However, most of the analysis of thermal storage system performance has been done with predictions and simulation, generally in the design stage. Our intention has been to compile and analyze *measured* data on the performance and costs of cool storage systems installed in commercial buildings. The 1986 Santa Cruz presentation will offer a more detailed analysis of measured performance of thermal storage systems.

The tracking of thermal storage systems in commercial buildings is part of a larger effort at LBL to assess measured data on the energy performance and economic cost-effectiveness of all types of buildings. This Buildings Energy-use Compilation and Analysis project has resulted in a large database (BECA), organized by sector. BECA-LM is our compilation of load management measures, including cool storage systems.

Our study began with the concept that the quality of analysis increases with the level of data available for each building. For a thorough study, we have stressed the importance of submetered data on the cooling system itself--electricity, demand and flow meters. In addition to energy use and peak demand (with descriptive and operational conditions), compressor efficiency and hourly load profiles on the peak cooling day are also desirable pieces of information to have. We began contacting about two dozen buildings known to contain cool storage systems, and requesting the type of data just described.

Immediately apparent was the lack of monitoring of this nature in most buildings--partly due to expense, and partly due to the lack of interest in knowing more about a building's operation. We started by looking at whole building data, which are much more readily available. The idea was that building energy consumption would reflect the operation of the cooling system.

From the current level of analysis, three major points can be drawn:

- Although readily available, whole building data are insufficient to adequately study the operation of a particular system within a building.
- A thoughtful combination of indicators is necessary to evaluate actual thermal storage performance.
- Several years of data should be examined, as systems tend to significantly improve over the first few years of operation.

We will now briefly illustrate each of these points.

1. Whole building data: We observed that in several buildings, thermal storage was quite successful in shifting air conditioning demand to off-peak periods, but that the buildings' overall demand profiles did not reflect this trend. There could be several reasons for this, including increased process loads. Figure 1 shows how the lack of submetered cooling system data would have prevented us from knowing of the success of the thermal storage system. The data are from an office building in the midwest.

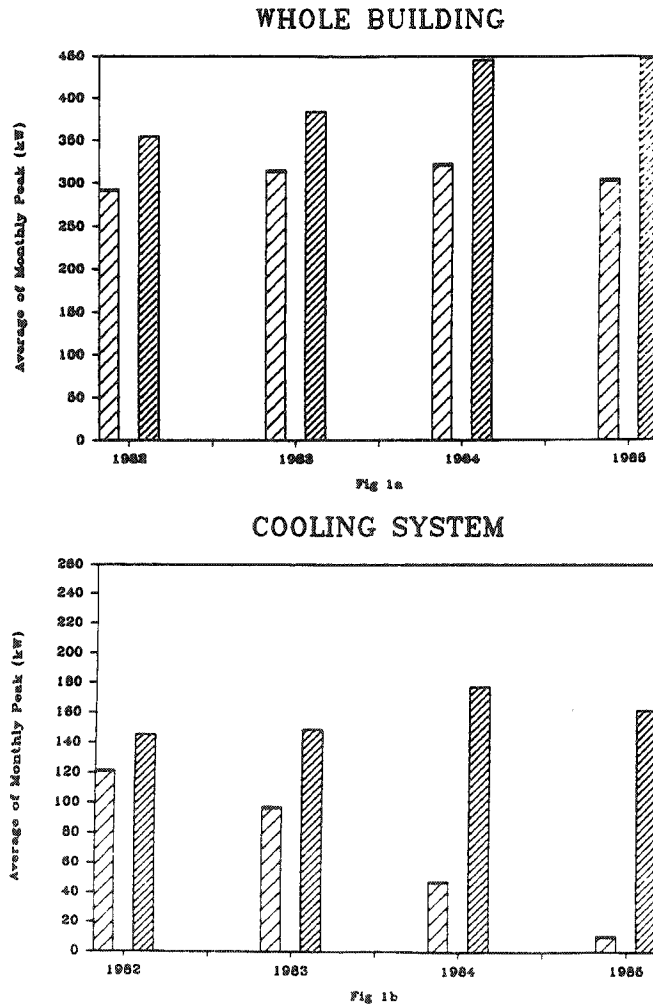


Figure 1: Average of monthly demands for the whole building (Fig. 1a) and for the cooling system only (Fig. 1b) during on-peak periods (from 8am to 5pm) in four successive cooling seasons. For each set of bars, the left represents the measured peak demand for the actual system with thermal storage; the right shows a calculated value of demand for a conventional cooling system. [Note the difference in scales between Fig. 1a and Fig. 1b.]

While the average of monthly (on-)peak demand for the system in this building dramatically falls from 121 kW in 1982 to 12 kW in 1985, the same indicator for the building as a whole remains fairly constant--from 293 kW to 305 kW over the same period. Reliance only on whole building data (Fig. 1a) would have obscured this fact.

One way of supplementing whole building data, if no submetered data are available, would be the utilization of good simulation. Caution must be exercised here because of inaccuracies inherent in most simulations, and because predicted data may be also difficult to obtain.

2. Combination of indicators: Thermal storage systems are designed to be optimized against multiple variables (rate structures, profiles and coincidence of building loads, capital costs vs. operational strategy). Dependence on a single indicator would be misleading. Load factor (the ratio of average demand to the highest demand, for a given period) illustrates the problem with single indicator reliance. This performance parameter has been regarded as a good measure of the swings in demand in a building. Utilities desire a large load factor, because their capacity is more effectively used. By shifting demand so that the peak demand is reduced, the load factor is increased. The following figure is based on data from the same midwestern building.

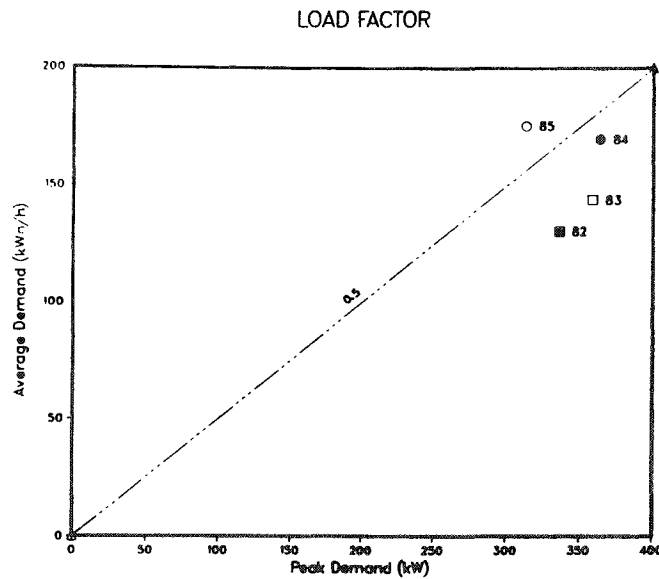


Figure 2: Comparison of peak demand with average demand for four successive cooling seasons (5 months per season). Average demand is calculated by dividing the number of hours in each season (3672) into the total electrical use in that period.

Figure 2 shows how the value of this indicator depends on both energy use and on the level of peak demand. The load factor for this building increases from year to year (the slope of the line that would connect the origin with each data point is the annual load factor). From this figure, we can see that the increase in load factor from 1983 to 1984 was due mainly to an increase in energy use rather than a reduction in peak demand, while the increase for 1985 was due more to a decline in peak demand. Thus an increase in load factor may be the result either of a successful shift in demand or an increase in energy use.

As a result, an analysis of thermal storage systems must use load factor *in conjunction with other indicators*. Some of these include looking at monthly energy use versus peak demand, and the ratio of on-peak to off-peak demand and energy. Operating cost is a significant indicator, because the major purpose of thermal storage is to reduce electricity bills. However, it too is insufficient on its own as a parameter because:

- rate structures can change over time, affecting system economics
- different rate structures make it difficult to compare across buildings
- potential improvements in cooling systems cannot be observed. In one case we have analyzed, the storage system uses about 30% more energy than a conventional system; money is still saved in operating costs, even though energy losses are quite large and could be reduced.

Another important consideration in all indicators is the need to choose an appropriate period for averaging values. A simple time clock malfunction or a building operator's error could produce a spike in the load curve that could match the annual peak for a conventional system while the average monthly peak could significantly decline.

3. Multiple years of data: Figure 1b illustrates how four years were necessary for the storage to effectively move the cooling loads to off-peak periods. This same trend has been observed in another building in the database. To be assured of noticing this tendency and to be aware of when the storage system is functioning effectively, one should attempt to obtain as many years of performance data as is possible. Unfortunately, due to the expense of submetering, often only one year of data are collected and analyzed. We strongly advise that monitoring and analysis take place over longer periods of time (even if at a less detailed level).

At this point, we are continuing to survey and collect data in order to expand the newly-formed BECA-LM database.