Part II: How to do Thermal Energy Storage

By Eric A. Woodroof, Ph.D., CEM, CRM

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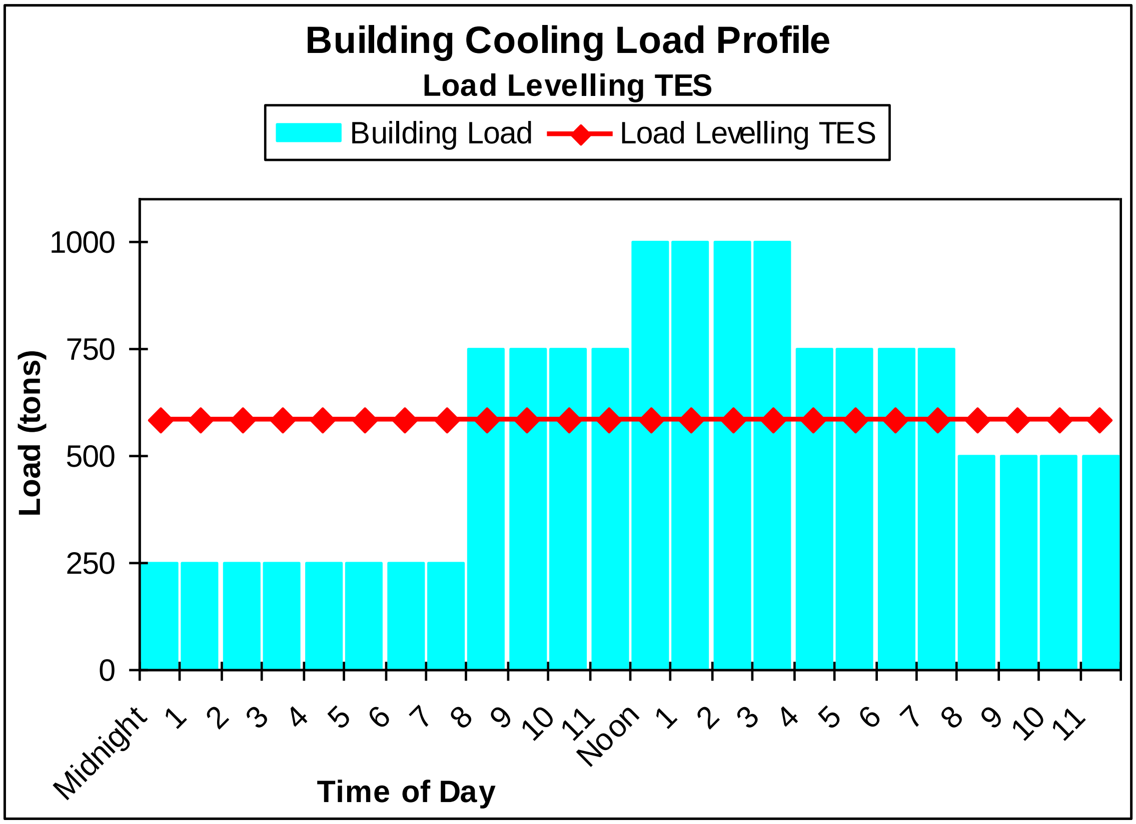
In last month's article, we described the rationale for using thermal energy storage to reduce peak electrical demand costs. In this month's article, we will go further into the calculations required for sizing as well as some design considerations and heat transfer media.

Design Considerations

There are typically two types of TES Strategies: "Partial Load Shift" and "Full Load Shift". There is also the option to have chilled water storage, ice storage or a hybrid heat transfer media.

<u>Design Option #1:</u>

"Partial Load Shift" is when your goal is to partially reduce your peak load by running your chiller near constant output for 24 hours per day. The idea is best illustrated by the graph below. In this example, from midnight til 8AM, the chiller's cooling output is greater than the building load, so the "excess cooling" is stored in a tank. This "stored cold energy" is then used to supplement the chiller during the day whenever the building load is greater than the chiller's output, which is indicated by the red line in the graph below. This strategy is also called "load leveling".

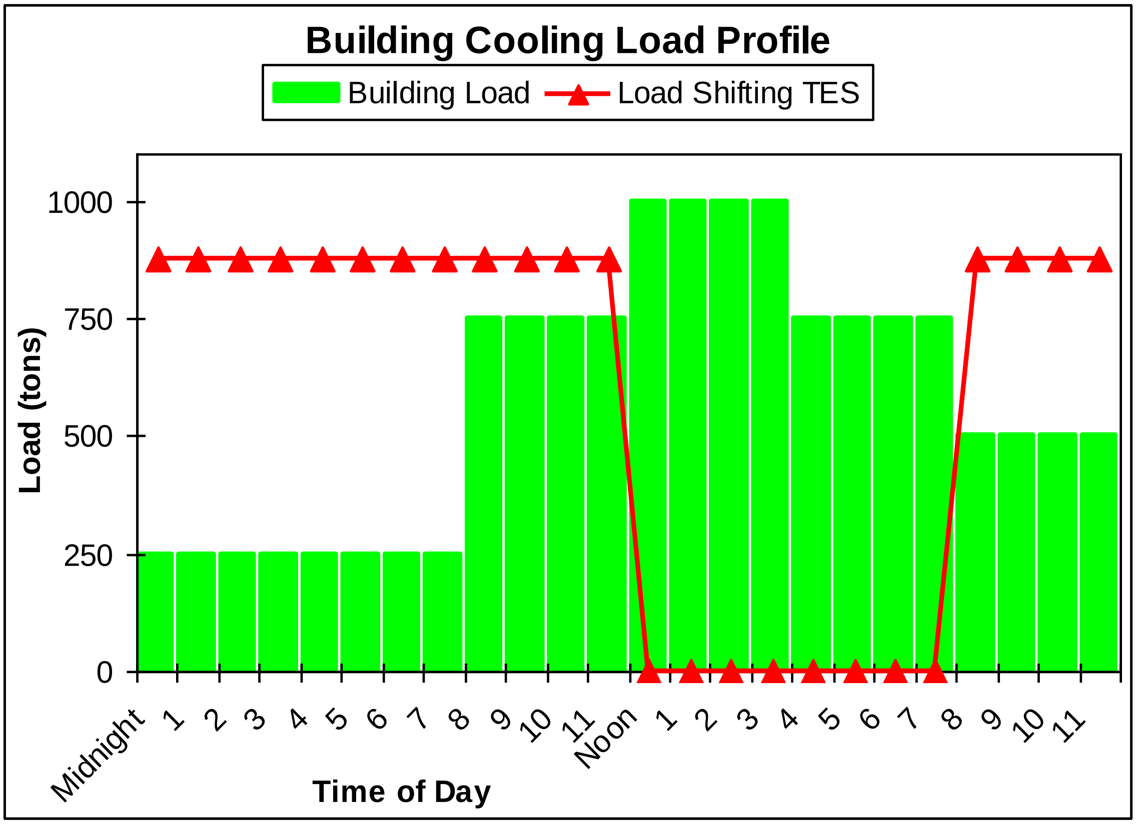


To determine the constant load that the chiller will operate, we need to determine the total number of cooling ton-hours and then divide by 24 hours in a day. In the example above, there are 14,000 ton-hours of cooling required during an entire day. Thus, 14,000 ton-hours / 24 hours:
= 583 tons is the rate that the chiller runs constantly.

A load-leveling strategy is usually ideal for new construction because if you can estimate the building loads, you can purchase a smaller chiller (600 tons versus 1,000 tons).

<u>Design Option #2:</u>

“Full Load Shift” is when your goal is to eliminate your peak load (from your chiller) by running your chiller at high output during non-peak hours (thereby storing cold water/ice). As the graphic below shows, during the daytime, when the utility rates are highest, you turn off the chiller and utilize the cold storage to cool the building.



Using the example above, if the peak electrical demand rate period is from noon to 8pm, we would want to minimize electrical use during that time, so we would shut off the chiller during that window. To determine the load that the chiller will run during the "storage periods", we must remember that we now only have 16 hours per day to run the chiller. During the storage periods, we must make enough "cold storage" (and probably a little more to have a surplus) to "coast" through the peak periods of the day. Thus, we divide the total number of cooling ton-hours by 16:

= 14,000 ton-hours / 16 hours:
= 875 tons is the rate that the chiller runs during the "storage periods".

A load-shifting strategy is usually ideal for retrofits because if you already have a large chiller (1,000 tons in the example above), you can use the large chiller to obtain a greater peak savings.

Ice vs Chilled Water:
Chilled water can store 1 BTU per pound of energy and systems are easily set up because most chillers already are pretty good at making cold water. There is a space-saving advantage of using ice storage because the phase change can store or release 144 BTUs per pound (when ice changes to water and vice

versa). You have to weigh this advantage of smaller storage tanks against the chiller modifications required to actually make ice. Some companies choose to make "slush", or use eutectic salts and other media for different types of applications. For these details, you will want to consult with experts in TES, who can advise on the technical merits of each approach.

Sizing TES tanks.

Lets assume we chose chilled water as a storage media and we wanted to do use load shifting strategy, as illustrated by the graphic that has the building cooling load shaded as a green color. In that example, the green area represents the cooling load during the peak period amounts to:

= (1000 tons)*(4 hours) + (750 tons)*(4 hours)
= 7,000 ton-hours

Converting "tons" into BTU/hour (1 ton + 12,000 BTU/hour):
= (7,000 ton-hours)*(12,000 BTU/hour)
= 84,000,000 BTU
= 84 MMBTU needs to be stored

If we have a chiller that takes 55 degree water and makes 40 degree water, then our delta T is 15 degrees. Remembering that a 1 degree water temperature change represents 1 BTU per pound of water, then a 15 degree delta T means that each pound of water has 15 BTUs of storage/release capacity. To determine the amount of water required, we simply divide the total BTUs required by the 15 BTUs/pound.
= (84 MMBTU) / (15 BTU/pound)
= 5.6 million pounds of water can store 84 MMBTU (when delta T = 15)

Converting from pounds to gallons (1 gallon of water weighs 8.34 pounds)
= 5.6 million pounds * (1 gallon / 8.34 pounds)
= 671,462 gallons of water

This volume of water is comparable to an olympic size swimming pool… which is pretty large. It may be hard to imagine how you could install that volume on your premises. However, as the pictures below show… chilled water systems do exist in some high profile venues, such as the DFW airport, which has a TES system that can store 15 MW and the water tanks store 6 million gallons.

For a comparison, you can find ice storage tanks as shown in the photo below (4700 tons of storage), which is at the National Air and Space Museum. This is a much smaller “footprint”, but obviously is more complex, because it uses ice.

There are of course many factors to consider when choosing a thermal energy storage system such as:

- The amount of space available in a basement, outside or below ground.
- The availability of contractors that could service the system.
- The availability of utility rebates in your area for TES systems.

However, hopefully- this article can assist you with some of the main considerations about thermal energy storage and help you determine if it is possible at your facility.