Thermal Battery™ Ice-Enhanced Air-Cooled Chiller Plant

Partial Ice Storage: Rules of Thumb

Site Qualifiers

- ✓ Building cooling loads should be greater than 100 tons, so that a financial analysis of the chiller+ice storage system would realistically use a chiller as the basis of comparison.
- ✓ At existing sites, the chillers are ready to be replaced, and/or the owner is committed to spending money on the chilled-water system.
- ✓ Existing building load has increased and capacity must be added.
- ✓ The owner of the building cares about long-term energy costs.
- ✓ Nighttime loads are zero or small, or dedicated equipment serves nighttime loads.
- ✓ Building owner/designer is designing to the USGBC LEED® criteria.
- ✓ Utility rebates, tax incentives, or other funding programs may be available to reduce installation costs, improve project economics, and accelerate payback.

Best-Fit Vertical Markets

- **Schools: K-12, Community Colleges, Universities**
- **Offices**
- **Churches**
- **Auditoriums or Theaters**
- **Any system with a load profile that is much higher during the day than it is at night**

Target Audience

Consulting engineers, contractors, owners, and architects who value:

- Operating cost savings
- Sustainable design
- Long-term solutions *(tanks last over 25 years)*
- Fuel source flexibility – a smart building for the smart grid
- Transparent demand response

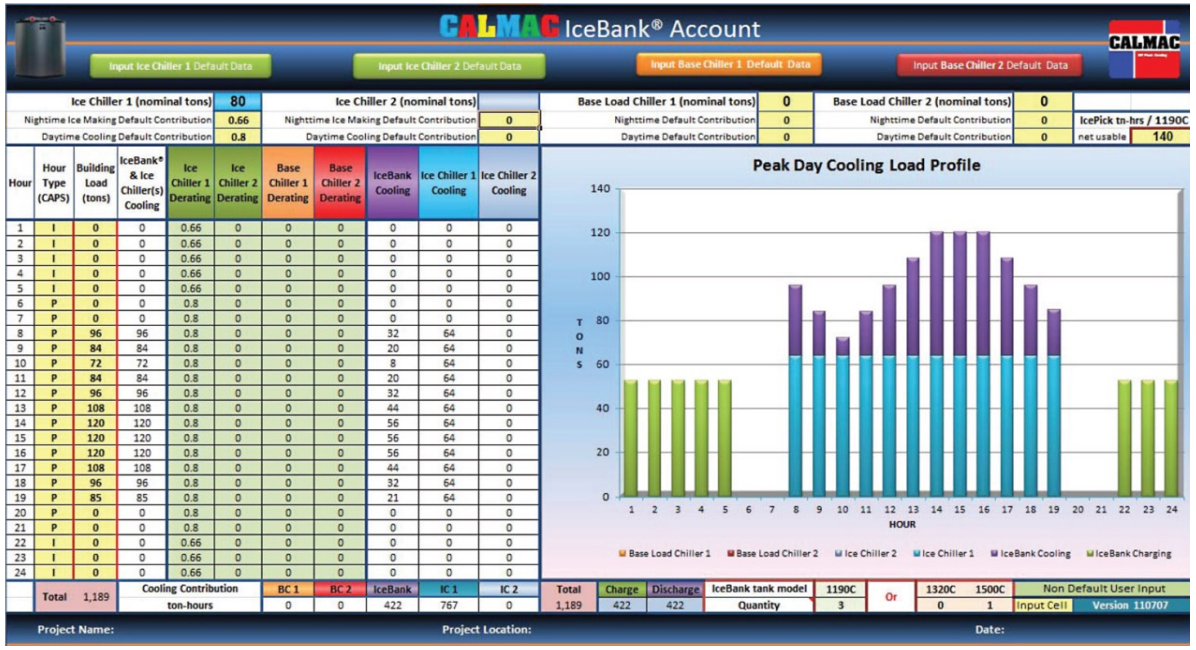
PARAMETER	RULE OF THUMB	NOTES & EXAMPLES
Chiller Size	Size the chiller for 66% of the design day peak load. Schools can sometimes downsize the chiller more in northern climates.	Depends on building cooling load profile. Can downsize more aggressively with an elementary school vs. office building. Example: a 120-ton design day building load: 80-ton (0.66 × 120 tons) nominal chiller.
Number of Tanks	Size 2 to 2.5 tanks per 100 tons of design day peak load.	Example: 120-ton design day load: 3 tanks [(120/100) × 2.5]. Rule of thumb only; actual count varies with system delta T, leaving temperature, and amount of storage desired.
Model 1190 Net Usable Storage Capacity	Assume 140 ton-hours per single Model 1190 tank.	Actual net usable capacity depends on load profile, temperatures, and discharge time. See table on back.
Model 1190 Average Discharge Rate	Assume 20-ton average discharge rate per each Model 1190 over 7 hours, or 17.5 tons over 8 hours.	Instantaneous cooling capacity ranges from 10 to 30 tons, depending on operating conditions, temperatures, and remaining inventory.
Storage Capacity Charge Time & Chiller Ice-Making De-Rate	Typical ice-making duration: 7–10 hours. Average air-cooled chiller ice-making capacity ≈ 65% of nominal.	An 80-ton nominal chiller makes ~52 tons/hr of ice (80 × 0.65). Three tanks = 420 ton-hrs (3 × 140). At 52 tons/hr, charging 3 tanks takes 8 hours (420/52). Charge rate = 17.3 tons/tank/hr.
System Delta T & Average Ice-Making Temperatures	Size air-handling units for 14°–16° delta T. Higher flow during charge mode: ~6° delta T; average ice-making supply/return ≈ 23°/30°F; end-of-cycle ≈ 20°/26°F.	Actual supply/return temperatures depend on chiller size vs. tank count/model. Better estimates via IcePick. Chiller must be stable at end-of-charge temperatures with sufficient freeze protection.
Storage Footprint	Partial storage typically requires ¼ of 1% (0.25%) of conditioned space for a footprint.	Two Model 1190 tanks fit in a typical parking space.
Plate & Frame Heat Exchangers	Used to separate the glycol loop from the water loop.	Required when: (1) air handlers in existing buildings are designed for water and are not being replaced, or (2) the building is large / campus-fed, making antifreeze solution throughout the system cost-prohibitive.

Rules of Thumb

This graph shows a selection using conservative rules of thumb.

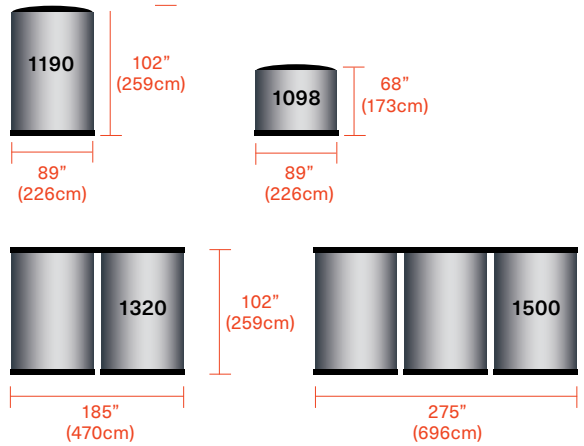
The load profile has a 12-hour discharge and an 8-hour charge. Four hours of chiller time are unassigned, to allow for unexpected situations, such as higher-than-anticipated loads, higher ambient temperatures/ reduced chiller capacity during charge mode, system expansion, and changes to the schedule for charging and discharging. The 80-ton chiller is demand limited during the design day to 64 tons. Because the chiller is not operating to its full capacity, even on a design day, the chiller size and the number of tanks could be reduced if desired.

This is one reason why entering a reasonably accurate load profile into the selection software is important. Of course, rules of thumb should only be used as a starting point, not for a final selection and system design.



AVERAGE ICE-MAKING TEMPERATURES				
CHARGE TIME (HOURS)	6	8	10	12
CHARGE RATE	25 tons	18.75 tons	15 tons	12.5 tons
Average ice-making temperature	21.6°F	23.2°F	24.2°F	24.8°F
End of charge ice-making temperature	19.3°F	20.4°F	21.5°F	22.4°F

CALMAC MODEL 1190 NET USABLE STORAGE CAPACITY				
DISCHARGE TEMPERATURE	45°F	42°F	40°F	38°F
Net usable ton-hours	152	143	140	135



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