

AHRI Guideline T (I-P)

**2017 Guideline for
Specifying the
Performance of Cool Thermal
Storage Equipment**



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and Refrigeration Institute**

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IMPORTANT

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Note:

This guideline supersedes AHRI Guideline T (I-P)-2013.

For SI, see AHRI Guideline T (SI)-2017.

FOREWORD

Cool thermal energy storage (TES) is a proven technology which enables the use of lower cost, off-peak electricity (usually at night) to produce and store cool energy. This cool energy in storage is used the next day for air-conditioning or process cooling. With TES, relatively small equipment operates at night, reducing the use of expensive electricity during the day.

The types of equipment used in connection with this technology may vary widely.

Unlike most air-conditioning and refrigeration equipment, Cool Thermal Storage Devices have no sustained, steady-state operating point which can be used to characterize the product performance.

Similarly, the usable capacity of a particular Cool Thermal Storage Device may vary appreciably with the application. For example, very high loads discharged over a short period, and/or relatively low discharge temperatures may reduce the usable capacity to a fraction of the theoretical value.

These intrinsic characteristics of Cool Thermal Storage Equipment can add complexity to the tasks of rating, selecting and specifying such devices. This guideline has been prepared by the Air-Conditioning, Heating and Refrigeration Institute to establish a common, consistent nomenclature and terminology for the industry, and to set forth the minimum performance information that designers should include in their specifications and manufacturers should provide in their proposals for Cool Thermal Storage Equipment. In addition, all of the member manufacturing companies in the AHRI Thermal Storage Equipment Product Section are available to assist the designer in properly specifying the product. To obtain the list of member companies refer to AHRI website at www.ahrinet.org/TSE.aspx.

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GUIDELINE FOR SPECIFYING THE PERFORMANCE OF COOL THERMAL STORAGE EQUIPMENT

Section 1. Purpose

1.1 Purpose. The purpose of this guideline is to establish for specifying thermal performance data for Cool Thermal Storage Equipment: definitions; classification; minimum information recommendations (user-specified application recommendations and supplier-specified thermal performance data).

1.1.1 Intent. This guideline is intended for guidance of the industry, including manufacturers, engineers, installers, contractors and users.

1.1.2 Review and Amendment. This guideline is subject to review and amendment as technology advances.

Section 2. Scope

2.1 Scope. This guideline applies to Cool Thermal Storage Equipment, for use in cooling systems, which may be charged and discharged with any of a variety of heat transfer fluids, and is either fully factory assembled, assembled on site from factory supplied components or field erected in accordance with pre-established design criteria, all as further described in Sections 3 and 4.

2.2 Exclusions. This guideline does not apply to Thermal Storage Equipment with thermal storage capacities of 7 ton-hours or less.

Section 3. Definitions

All terms in this document will follow the standard industry definitions in the *ASHRAE Terminology* website (<https://www.ashrae.org/resources--publications/free-resources/ashrae-terminolog>) unless otherwise defined in this section.

3.1 Ambient Air. The air in the space surrounding the Cool Thermal Storage Device.

3.2 Ambient Heat Load. The load (typically expressed in tons) imposed on the storage device due to heat gain from the ambient.

3.3 Charge Fluid. The heat transfer fluid used to remove heat from a Cool Thermal Storage Device.

3.4 Charge Period. The period of time when energy (heat) is removed from the Cool Thermal Storage Device.

3.5 Charge Rate. The rate (typically expressed in tons) at which energy (heat) is removed from the Cool Thermal Storage Device during the Charge Period.

3.6 Cool Thermal Storage Device. Equipment which stores cooling capacity using sensible and/or latent heat. May consist solely of a storage means or be packaged with one or more components of a mechanical refrigeration system.

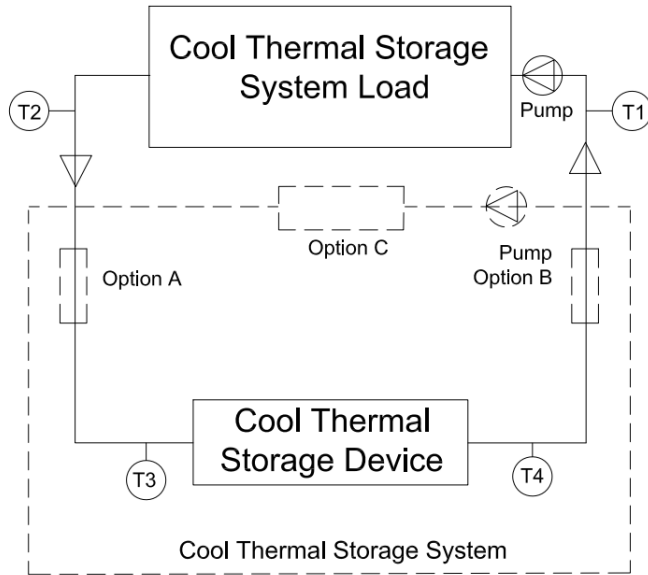
3.7 Cool Thermal Storage Equipment. Any one of, or a combination of, Cool Thermal Storage Devices and/or generators, that may include various other components of a mechanical or absorption refrigeration package, as indicated in Section 4.

3.8 Cool Thermal Storage System. All of the equipment installed to meet a specified Cool Thermal Storage System Load which may include mechanical or absorption refrigeration equipment, see Figure 1.

3.9 Cool Thermal Storage System Load (Load). A specified cooling load to be met by the Thermal Storage System. Typically, it is expressed in tons.

3.10 Discharge Fluid. The heat transfer fluid used to add heat to the Cool Thermal Storage Device.

- 3.11** *Discharge Period.* The period of time when energy (heat) is added to the Cool Thermal Storage Device.
- 3.12** *Discharge Rate.* The rate (typically expressed in tons) at which energy (heat) is added to the Cool Thermal Storage Device during the Discharge Period.
- 3.13** *Initial Charge Cycle.* The elapsed time required to bring the storage device from ambient conditions to its fully charged condition and the minimum temperature of the heat transfer fluid attained during the cycle.
- 3.14** *Latent Heat.* The change in enthalpy accompanying the conversion of a unit mass of a solid to a liquid at its melting point at constant pressure and temperature.
- 3.15** *Net Storage Inventory.* Net accumulated measured storage capacity at a given period of time during a 24-hour cycle.
- 3.16** *Net Usable Storage Capacity.* The amount of stored cooling, that can be supplied from the storage device at or below the specified cooling supply temperature for a given Charge and Discharge Cycle, typically expressed in ton-hours.
- 3.17** *Parasitic Electrical Input.* The energy generated by the accessories (e.g., air compressor, dedicated recirculation pump).
- 3.18** *Phase Change Material (PCM).* A substance that undergoes changes of phase while absorbing or rejecting thermal energy, normally at a constant temperature.
- 3.19** *Saturated Evaporator Temperature.* The dew point temperature of the refrigerant corresponding to the saturation pressure at the outlet connection of the evaporator.
- 3.20** *Saturated Suction Temperature.* The dew point temperature of the refrigerant corresponding to the saturation pressure at the inlet of the refrigeration equipment.
- 3.21** *Secondary Coolant.* Any liquid cooled by a refrigerant and used for heat transmission without a change in state, having no flash point or a flash point above 150 °F.
- 3.22** *Sensible Heat.* Heat that causes a change in fluid temperature.
- 3.23** *Should.* This term is used to indicate provisions which are not mandatory but which are desirable as good practice.
- 3.24** *Ton-hour.* A quantity of thermal energy equal to 12,000 Btu or 1.0 ton of refrigeration provided for one hour.
- 3.25** *Unitary Thermal Storage System (UTSS).* An assembly of components including a Thermal Storage Device and refrigeration equipment for charging, whose overall performance as a Unitary Thermal Storage System is rated by the manufacturer.



Where:
 T₁ = Temperature of coolant supplied to the Load
 T₂ = Temperature of coolant returning from the Load
 T₃ = Temperature of coolant entering the Cool Thermal Storage Device.
 T₄ = Temperature of coolant leaving the Cool Thermal Storage Device.

Option A, B, C: Mechanical or absorption refrigeration equipment (chiller)

Figure 1. Cool Thermal Storage System

Section 4. Classifications

4.1 Classification. Cool Thermal Storage Equipment is broadly classified as either "sensible" or "latent", with further delineations as shown in Table 1 and explained in subsequent paragraphs.

Table 1. Classification of Cool Thermal Storage Equipment				
Classification	Type	Storage Media	Charge Fluid	Discharge Fluid
Sensible Heat	Chilled Water	Water or other Aqueous Solution	Water or other Aqueous Solution	Water or other Aqueous Solution
Latent Heat	Ice-on-Coil (External Melt)	Ice or other Phase Change Material	Secondary Coolant	Water or Secondary Coolant
			Refrigerant	
	Ice-on-Coil (Internal Melt)	Ice or other Phase Change Material	Secondary Coolant	Secondary Coolant
	Encapsulated Ice or Phase Change Material	Ice or other Phase Change Material	Water	Water
			Secondary Coolant	Secondary Coolant
Unitary	Ice or other Phase Change Material	Refrigerant	Refrigerant	
		Secondary Coolant	Water or Secondary Coolant	

4.1.1 Sensible Cool Thermal Storage Equipment. Sensible Cool Thermal Storage Equipment used for cooling typically employs water as the storage medium. During the Charge Period, warm water from the storage device is chilled to the

desired temperature by a water chiller and returned to the storage vessel. During the Discharge Period (cooling), the chilled water is pumped from the storage vessel to the Load and the resultant warm water returned to storage. Any of several methods may be used to keep the warm return water separated from the stored chilled water, including separate or compartmentalized tanks or where only one tank is employed, labyrinths, membranes, or thermal stratification.

4.1.2 Latent Cool Thermal Storage Equipment. Latent Cool Thermal Storage Equipment is further categorized as ice-on-coil, encapsulated ice or PCM, or unitary.

4.1.2.1 Ice-on-Coil. A Cool Thermal Storage Device consisting of coils, plates, or other heat transfer surface submerged in a water filled tank. During the Charge Period, an evaporating refrigerant or cold Secondary Coolant is circulated through the coils/plates causing ice to form on the external surfaces. During the Discharge Period (cooling), either of two methods is typically employed:

4.1.2.1.1 External Melt. With external melt, warm, return water is circulated through the tank, external to the ice formation, whereby it is cooled by the melting ice.

Some ice-on-coil devices may also serve as water chillers by circulating warm return water through the tank and over the external surface of the heat exchanger where it is cooled by Secondary Coolant or refrigerant circulating within the exchanger.

4.1.2.1.2 Internal Melt. With internal melt, typically a warm, return, Secondary Coolant is circulated through the coils/plates and cooled as the ice external to the coils/plates is melted.

4.1.2.2 Encapsulated Ice or PCM. Cool Thermal Storage Equipment consisting of a tank or vessel densely packed with numerous, relatively small containers in which the storage medium (water-ice or other PCM such as eutectic salt) is encapsulated. During the Charge Period, water or Secondary Coolant, at a temperature below the phase change temperature of the storage, media is circulated through the tank/vessel to effect a phase change (freezing) in the storage medium. During the Discharge Period, warm return water or Secondary Coolant is circulated through the tank/vessel and cooled as the encapsulated storage media changes phase (melts).

4.1.2.3 Unitary. An assembly of components including a Cool Thermal Storage Device and refrigeration equipment for charging which is rated by the manufacturer as a UTSS. The Cool Thermal Storage Device consists of a heat exchanger submerged in a water filled tank. During the Charge Period, an evaporating refrigerant or cold Secondary Coolant is circulated through the heat exchanger causing ice to form on the external surface. During the Discharge (cooling) Period, a condensing refrigerant or warm Secondary Coolant is cooled by internal and/or external melt processes.

Section 5. Minimum Information Recommendations

5.1 User-specified Application Recommendations. When specifying the application requirements for Cool Thermal Storage Equipment, the user should provide, as a minimum, the following data for a design day (or design week, or other design period). A sample format and example of the user-specified data are provided as Appendices C and D, respectively.

5.1.1 Load for each hour of the design day, tons.

5.1.2 Operating mode (charge, partial cooling or off) of the thermal storage refrigeration equipment for each hour of the design day.

5.1.3 Design heat sink rejection temperature, °F; information for each hour of the design day is preferred, but not required.

5.1.4 Supply temperature to the Load during the hour of maximum load, T_1 , °F; information for each hour of the day is preferred, but not required) (Figure 1).

5.1.5 Return temperature from the Load during the hour of maximum load, T_2 , °F; information for each hour of the day is preferred, but not required (Figure 1).

5.1.6 Flow rate to the Load during the hour of maximum load or each hour if variable rate pumping is used, gpm.

- 5.1.7 Maximum time available to charge from fully discharged condition, h.
- 5.1.8 Minimum temperature available to charge from fully discharged condition, °F.
- 5.1.9 Identify the Charge and Discharge Fluids (e.g., water, 25% ethylene glycol/75% water).

5.2 *Supplier-specified Thermal Performance Data.* When specifying the thermal performance of Cool Storage Equipment, the supplier should provide, as a minimum, the following data on an hourly basis for a design day (or design week, or other design period) A sample format and example of the supplier-specified data are provided as Appendices E and F respectively.

Note: It is intended that hour-by-hour changes in Net Storage Inventory track the hour-by-hour effects of Charge Rate, Discharge Rate, parasitic load and Ambient Heat Load. As such, the data should represent a theoretically endlessly repeatable cycle for back-to-back design days, weeks, or whatever basis is chosen for the cycle.

- 5.2.1 Thermal Storage System Load, tons.
- 5.2.2 Load on Refrigeration Equipment, tons.
- 5.2.3 Cool Thermal Storage Device Charge or Discharge Rate, tons.
- 5.2.4 Parasitic and accessory heat load (e.g., air compressor, dedicated recirculation pump) into the storage device, tons.
- 5.2.5 Ambient Heat Load into the storage device due to the temperature of the Ambient Air and solar radiation.
- 5.2.6 Net Storage Inventory, Ton-hours.
- 5.2.7 Saturated Evaporator or Suction Temperature when this equipment is to be supplied by other than the thermal storage supplier, °F.
- 5.2.8 Temperature of supply and return fluid to the Load, T_1 and T_2 (Figure 1), °F.
- 5.2.9 Flow rate of fluid to the Load, gpm.
- 5.2.10 Temperatures of fluid entering and leaving the Cool Thermal Storage Device, T_3 and T_4 (Figure 1), and any other heat exchanger(s) provided by the supplier, °F.
- 5.2.11 Flow rate of fluid through the Cool Thermal Storage Device and any heat exchanger(s) provided by the supplier, gpm.
- 5.2.12 Pressure drop across the Cool Thermal Storage Device and any heat exchanger(s) provided by the supplier, psi.
- 5.2.13 Energy input to thermal storage refrigeration equipment provided by the supplier, kWh (for electric chiller) or kBtu (for gas-fired chiller).
- 5.2.14 Total heat rejection for the refrigeration system if the supplier provides the condenser, Btu.
- 5.2.15 Storage device parasitic electrical input kW-h.

Additional recommended data to be supplied by the supplier from literature includes the following, which is not shown in Appendices E or F.

- 5.2.16 Listing of all equipment included in the scope of supply.
- 5.2.17 Net Usable Storage Capacity for the Thermal Storage Device(s), Ton-hours.
- 5.2.18 Time required to charge from the fully discharged state, h.

5.2.19 Time required to recharge after discharge on design day, h (for purposes of this guideline, the design day is to be considered to be the peak day unless otherwise specified by the design engineer).

5.2.20 Identification of the Charge and Discharge Fluids, including the physical properties if these are not readily available from conventional sources.

APPENDIX A. REFERENCES - NORMATIVE

A1 Listed here are all standards, handbooks and other publications essential to the formation and implementation of the standard. All references in this appendix are considered as part of the standard.

None.

APPENDIX B. REFERENCES - INFORMATIVE

B1 Listed here are standards, handbooks, and other publications which may provide useful information and background but are not considered essential.

B1.1 AHRI Standard 900 (I-P)-2014, *Performance Rating of Thermal Storage Equipment used for Cooling*, 2014, Air-Conditioning, Heating, and Refrigeration Institute, 2111 Wilson Boulevard, Suite 500, Arlington, VA 22201, U.S.A.

B1.2 *ASHRAE Design Guide for Cool Thermal Storage*, 1993, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, N.E., Atlanta, GA 30329, U.S.A.

B1.3 *ASHRAE Handbook – HVAC Applications-IP Edition*, 2015, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, N.E., Atlanta, GA 30329, U.S.A.

B1.4 *ASHRAE Successful Cool Storage Projects: From Planning to Operation*, 1996, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, N.E., Atlanta, GA 30329, U.S.A.

B1.5 ASHRAE Standard 150-2000 (RA 2004), *Method of Testing the Performance of Cool Storage Systems*, 2004, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, N.E., Atlanta, GA 30329, U.S.A.

B1.6 *ASHRAE Terminology*, <https://www.ashrae.org/resources--publications/free-resources/ashrae-terminology>, 2017, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, N.E., Atlanta, GA 30329, U.S.A.

APPENDIX C. USER-SPECIFIED APPLICATION RECOMMENDATIONS DATA - INFORMATIVE

Note: Shaded areas in Tables C1 and C2 are optional.

Table C1. Recommended Specification Information - Example	
Discharge Fluid used to define the following design data	
Supply Temperature to Load at peak conditions, T ₁ , °F	
Return Temperature from Load at peak conditions, T ₂ , °F	
Flow rate to Load at peak conditions, gpm	
Maximum allowable pressure drop through storage device, psi	
System Schematic (attached to data sheets)	
Charge Fluid	
Maximum time and minimum temperature available to charge Cool Thermal Storage Device from fully discharged condition (Initial Charge Cycle), h and °F	
Design Heat Sink Rejection Temperature, °F	

Table C2. Preferred User-specified Data - Example Design Day						
Hour	Thermal Storage System Load, Tons	Supply Temperature to Load (T ₁), °F	Return Temperature from Load (T ₂), °F	Flow Rate to Load, gpm	Heat Sink Rejection Temperature (Wet-Bulb or Dry-Bulb), °F	Thermal Storage Refrigeration Equipment use during this hour? (Charge / Partial Cooling / Off)
0 - 1						
1 - 2						
2 - 3						
3 - 4						
4 - 5						
5 - 6						
6 - 7						
7 - 8						
8 - 9						
9 - 10						
10 - 11						
11 - 12						
12 - 13						
13 - 14						
14 - 15						
15 - 16						
16 - 17						
17 - 18						
18 - 19						
19 - 20						
20 - 21						
21 - 22						
22 - 23						
23 - 0						
Totals						

APPENDIX D. SAMPLE USER-SPECIFIED APPLICATION RECOMMENDATIONS DATA – INFORMATIVE

Note: Shaded areas in Tables D1 and D2 are optional.

Table D1. Recommended Specification Information - Sample		
Discharge Fluid Used to define the following design data	25% Ethylene Glycol/ 75% Water	
Supply Temperature to Load at peak conditions, T ₁ , °F	44°F	
Return Temperature from Load at peak conditions, T ₂ , °F	58°F	
Flow rate to Load at peak conditions, gpm	1,822 gpm	
Maximum allowable pressure drop through storage device, psi	14 psi	
System Schematic (attached to data sheets)	Yes	
Charge Fluid (if applicable)	Same as Above	
Maximum time and minimum temperature available to charge Cool Thermal Storage Device from fully discharged condition (Initial Charge Cycle), h and °F	16 hours	22 °F
Design Heat Sink Rejection Temperature, °F		

Table D2. Preferred User-specified Data - Sample Design Day						
Hour	Thermal Storage System Load, tons	Supply Temperature to Load (T ₁), °F	Return Temperature from Load (T ₂), °F	Flow Rate to Load, gpm	Heat Sink Rejection Temperature (Wet-Bulb or Dry-Bulb), °F	Thermal Storage Refrigeration Equipment use during this hour? (Charge/Partial-Cooling/ Off)
0 - 1	0					Charge
1 - 2	0					Charge
2 - 3	0					Charge
3 - 4	0					Charge
4 - 5	0					Charge
5 - 6	0					Charge
6 - 7	0					Charge
7 - 8	800	44.0	55.2	1,822		Partial Cooling
8 - 9	700	44.0	53.8	1,822		Partial Cooling
9 - 10	600	44.0	52.4	1,822		Partial Cooling
10 - 11	700	44.0	53.8	1,822		Partial Cooling
11 - 12	800	44.0	55.2	1,822		Partial Cooling
12 - 13	900	44.0	56.6	1,822		Off
13 - 14	1,000	44.0	58	1,822		Off
14 - 15	1,000	44.0	58	1,822		Off
15 - 16	900	44.0	56.6	1,822		Off
16 - 17	800	44.0	55.2	1,822		Partial Cooling
17 - 18	700	44.0	53.8	1,822		Partial Cooling
18 - 19	0					Charge
19 - 20	0					Charge
20 - 21	0					Charge
21 - 22	0					Charge
22 - 23	0					Charge
23 - 0	0					Charge
Totals	8,900 ton-h					

APPENDIX E. SUPPLIER-SPECIFIED PERFORMANCE DATA – INFORMATIVE

Example Design Day

Net Usable Storage Capacity: _____ Ton-hours (Total Column D)

Heat Transfer Fluid: _____

Specific Gravity: _____ @ _____ °F

Specific Heat Btu/lb/°F : _____ @ _____ °F

Hours to recharge from fully discharged condition: _____ hours

Hours to recharge on design day: _____ hours

Table E1. Supplier-specified Data^{1,2}

Hour	A Thermal Storage System Load, tons	B Refrigeration Equipment Load, tons	C Storage Device Charge Rate, tons	D Storage Device Discharge Rate ³ , tons	E Parasitic and Accessory Heat Load into Storage Device, tons	F Ambient Heat Load into Storage Device, tons	G Net Storage Inventory ⁴ , Ton-hours	H Supply Temperature to Load (T ₁), °F	I Return Temperature from Load (T ₂), °F	J Flow Rate to Load, gpm
0 - 1										
1 - 2										
2 - 3										
3 - 4										
4 - 5										
5 - 6										
6 - 7										
7 - 8										
8 - 9										
9 - 10										
10 - 11										
11 - 12										
12 - 13										
13 - 14										
14 - 15										
15 - 16										
16 - 17										
17 - 18										
18 - 19										
19 - 20										
20 - 21										
21 - 22										
22 - 23										
23 - 0										
Totals										

Table E1. Supplier-specified Data^{1,2} (Continued)

Hour	K Fluid Temperature Entering Storage Device (T ₃), °F	L Fluid Temperature Leaving Storage Device (T ₄), °F	M Flow Rate Through Storage Device, gpm	N Pressure Drop for Storage Device, psi	O Storage Device Refrigeration Energy Input, kWh (electric chiller) or kBtu (gas-fired chiller)	P Saturated Evaporator or Suction Temperature ⁵ , °F	Q Storage Device Parasitic Electrical Input, kW·h	R Refrigeration System Total Heat Rejection, Btu
0 - 1								
1 - 2								
2 - 3								
3 - 4								
4 - 5								
5 - 6								
6 - 7								
7 - 8								
8 - 9								
9 - 10								
10 - 11								
11 - 12								
12 - 13								
13 - 14								
14 - 15								
15 - 16								
16 - 17								
17 - 18								
18 - 19								
19 - 20								
20 - 21								
21 - 22								
22 - 23								
23 - 0								
Totals								

Notes:

1. Totals for column B must be greater than or equal to the sum of totals for columns A, E and F.
2. The values in Column I must always be less than maximum temperature defined on the "User-Specified Data" Sheet.
3. Greater Discharge Rates may not be possible at defined discharge temperature (T₄)
4. Net Storage Inventory values are not available for instantaneous discharge
5. Applicable where refrigerant is the Charge Fluid.

APPENDIX F. SUPPLIER-SPECIFIED THERMAL PERFORMANCE DATA FOR UNITARY THERMAL STORAGE SYSTEMS – INFORMATIVE

Example Design Day

Net Usable Storage Capacity: _____ Ton-hours (Total Column D)

Heat Transfer Fluid: _____

Specific Gravity: _____ @ _____ °F

Specific Heat Btu/lb/°F : _____ @ _____ °F

Hours to recharge from fully discharged condition: _____ hours

Hours to recharge on design day: _____ hours

Table F1. Supplier-specified Data^{1,2}

Hour	<u>A</u> Thermal Storage System Load, tons	<u>B</u> Refrigeration Equipment Load, tons	<u>C</u> Storage Device Charge Rate, tons	<u>D</u> Storage Device Discharge Rate ³ , tons	<u>E</u> Parasitic and Accessory Heat Load into Storage Device, tons	<u>F</u> Ambient Heat Load into Storage Device, tons	<u>G</u> Net Storage Inventory ⁴ , Ton-hours	<u>H</u> Storage Device Refrigeration Energy Input, kW·h	<u>I</u> Saturated Suction Temperature ⁵ , °F	<u>J</u> Storage Device Parasitic Electrical Input, kW·h
0 - 1										
1 - 2										
2 - 3										
3 - 4										
4 - 5										
5 - 6										
6 - 7										
7 - 8										
8 - 9										
9 - 10										
10 - 11										
11 - 12										
12 - 13										
13 - 14										
14 - 15										
15 - 16										
16 - 17										
17 - 18										
18 - 19										
19 - 20										
20 - 21										
21 - 22										
22 - 23										
23 - 0										
Totals										

Notes:

1. Totals for column B must be greater than or equal to the sum of totals for columns A, E and F.
2. The values in Column I must always be less than maximum temperature defined on the "User-Specified Data" Sheet.
3. Greater Discharge Rates may not be possible at defined saturated return temperature
4. Net Storage Inventory values are not available for instantaneous discharge
5. Applicable where refrigerant is the charge fluid.

APPENDIX G. SAMPLE SUPPLIER-SPECIFIED THERMAL PERFORMANCE DATA – INFORMATIVE

Example Design Day

Net Usable Storage Capacity: 4,700 Ton-hours (Total Column D)

Heat Transfer Fluid: 25% EG / H₂O

Specific Gravity: 1.027 @ 60 °F

Specific Heat Btu/lb/°F: 0.93 @ 60 °F

Hours to recharge from fully discharged condition: 15 hours

Hours to recharge on design day: 13 hours

Table G1. Supplier-specified Data – Sample^{1,2}

Hour	A Thermal Storage System Load, tons	B Refrigeration Equipment Load tons	C Storage Device Charge Rate, tons	D Storage Device Discharge Rate ³ , tons	E Parasitic and Accessory Heat Load into Storage Device, tons	F Ambient Heat Load into Storage Device, tons	G Net Storage Inventory ⁴ , Ton-hours	H Supply Temperature to Load (T ₁), °F	I Return Temperature from Load (T ₂), °F	J Flow Rate to Load, gpm
0 - 1	0	390	390			2	2,730	31.4	31.4	0
1 - 2	0	390	390			2	3,120	31.2	31.2	0
2 - 3	0	390	390			2	3,510	30.9	30.9	0
3 - 4	0	390	390			2	3,900	30.4	30.4	0
4 - 5	0	390	390			2	4,290	29.7	29.7	0
5 - 6	0	390	390			2	4,680	28.9	28.9	0
6 - 7	0	390	390			2	5,070	27.8	27.8	0
7 - 8	800	600		200		2	4,870	44.0	55.2	1,822
8 - 9	700	600		100		2	4,770	44.0	53.8	1,822
9 - 10	600	600		0		2	4,770	44.0	52.4	1,822
10 - 11	700	600		100		2	4,670	44.0	53.8	1,822
11 - 12	800	600		200		2	4,470	44.0	55.2	1,822
12 - 13	900	0		900		2	3,570	44.0	56.6	1,822
13 - 14	1,000	0		1,000		2	2,570	44.0	58.0	1,822
14 - 15	1,000	0		1,000		2	1,570	44.0	58.0	1,822
15 - 16	900	0		900		2	670	44.0	56.6	1,822
16 - 17	800	600		200		2	470	44.0	55.2	1,822
17 - 18	700	600		100		2	370	44.0	53.8	1,822
18 - 19	0	390	390			2	390	31.8	31.8	0
19 - 20	0	390	390			2	780	31.7	31.7	0
20 - 21	0	390	390			2	1,170	31.7	31.7	0
21 - 22	0	390	390			2	1,560	31.6	31.6	0
22 - 23	0	390	390			2	1,950	31.6	31.6	0
23 - 0	0	390	390			2	2,340	31.5	31.5	0
Totals	8,900	9,270	5,070	4,700		48				

Table G1. Supplier-specified Data^{1,2} (continued)

Hour	K Fluid Temperature Entering Storage Device (T ₃), °F	L Fluid Temperature Leaving Storage Device (T ₄), °F	M Flow Rate Through Storage Device, gpm	N Pressure Drop for Storage Device, psi	O Storage Device Refrigeration Energy Input, kWh (electric chiller) or kBtu (gas-fired chiller)	P Saturated Evaporator or Suction Temperature ⁵ , °F	Q Storage Device Parasitic Electrical Input, k-Wh	R Refrigeration System Total Heat Rejection, Btu
0 - 1	26.0	31.4	1,821	9.3				
1 - 2	25.8	31.2	1,821	9.4				
2 - 3	25.4	30.9	1,821	9.4				
3 - 4	24.9	30.4	1,821	9.4				
4 - 5	24.3	29.7	1,821	9.4				
5 - 6	23.4	28.9	1,821	9.5				
6 - 7	22.3	27.8	1,821	9.5				
7 - 8	46.8	32.1	347	1.2				
8 - 9	45.4	32.1	192	0.6				
9 - 10	44.0	32.1	0	0.0				
10 - 11	45.4	32.2	192	0.6				
11 - 12	46.8	32.3	353	1.2				
12 - 13	56.6	36.2	1,128	4.4				
13 - 14	58.0	38.8	1,330	5.4				
14 - 15	58.0	41.2	1,519	6.4				
15 - 16	56.6	43.7	1,773	7.9				
16 - 17	46.8	39.6	710	2.6				
17 - 18	45.4	41.6	679	2.4				
18 - 19	26.4	31.8	1,821	9.3				
19 - 20	26.3	31.7	1,821	9.3				
20 - 21	26.2	31.7	1,821	9.3				
21 - 22	26.2	31.7	1,821	9.3				
22 - 23	26.2	31.6	1,821	9.3				
23 - 0	26.1	31.6	1,821	9.3				
Totals								

Notes:

1. Totals for column B must be greater than or equal to the sum of totals for columns A, E and F.
2. The values in Column I must always be less than maximum temperature defined on the "User-Specified Data" Sheet.
3. Greater Discharge Rates may not be possible at defined discharge temperature (T₄).
4. Net Storage Inventory values are not available for instantaneous discharge.
5. Applicable where refrigerant is the charge fluid.

APPENDIX H. SUPPLIER-SPECIFIED THERMAL PERFORMANCE DATA FOR UNITARY THERMAL STORAGE SYSTEMS – INFORMATIVE

Example Design Day

Net Usable Storage Capacity: 32 Ton-hours (Total Column D)

Heat Transfer Fluid: R410A

Specific Gravity: _____ @ _____ °F

Specific Heat Btu/lb/°F: _____ @ _____ °F

Hours to recharge from fully discharged condition: 11 hours

Hours to recharge on design day: 10.3 hours

Table H1. Supplier-specified Data^{1,2}

Hour	A Thermal Storage System Load, tons	B Refrigeration Equipment Load, tons	C Storage Device Charge Rate, tons	D Storage Device Discharge Rate ³ , tons	E Parasitic and Accessory Heat Load into Storage Device, tons	F Ambient Heat Load into Storage Device, tons	G Net Storage Inventory ⁴ , Ton-hours	H Storage Device Refrigeration Energy Input, kWh (electric chiller) or kBtu (gas-fired chiller)	I Saturated Suction Temperature ⁵ , °F	J Storage Device Parasitics Electrical Input, k-Wh
0 - 1	0.0	3.1	3.1	0.0		0.03	16.5		-	
1 - 2	0.0	3.1	3.1	0.0		0.03	19.6		-	
2 - 3	0.0	3.1	3.1	0.0		0.03	22.7		-	
3 - 4	0.0	3.1	3.1	0.0		0.03	25.8		-	
4 - 5	0.0	3.1	3.1	0.0		0.03	28.9		-	
5 - 6	0.0	3.1	3.1	0.0		0.03	32.0		-	
6 - 7	0.0	3.1	3.1	0.0		0.03	33.0		-	
7 - 8	0.0	0.0	0.0	0.0		0.03	33.0		-	
8 - 9	0.0	0.0	0.0	0.0		0.03	33.0		-	
9 - 10	1.0	0.0	0.0	1.0		0.03	32.0		39.5	
10 - 11	2.0	0.0	0.0	2.0		0.03	30.0		39.5	
11 - 12	2.5	0.0	0.0	2.5		0.03	27.5		39.5	
12 - 13	3.5	0.0	0.0	3.5		0.03	24.0		40.0	
13 - 14	4.5	0.0	0.0	4.5		0.03	19.5		41.3	
14 - 15	5.0	0.0	0.0	5.0		0.03	14.5		41.9	
15 - 16	5.0	0.0	0.0	5.0		0.03	9.5		41.9	
16 - 17	4.5	0.0	0.0	4.5		0.03	5.0		41.3	
17 - 18	3.0	0.0	0.0	3.0		0.03	2.0		39.5	
18 - 19	1.0	0.0	0.0	1.0		0.03	1.0		39.5	
19 - 20	0.0	0.0	0.0	0.0		0.03	1.0		-	
20 - 21	0.0	3.1	3.1	0.0		0.03	4.1		-	
21 - 22	0.0	3.1	3.1	0.0		0.03	7.2		-	
22 - 23	0.0	3.1	3.1	0.0		0.03	10.3		-	
23 - 0	0.0	3.1	3.1	0.0		0.03	13.4		-	
Totals	32.0	34.1	34.1	32.0		0.72				

Notes:

1. Totals for column B must be greater than or equal to the sum of totals for columns A, E and F.
2. The values in Column I must always be less than maximum temperature defined on the "User-Specified Data" Sheet.
3. Greater Discharge Rates may not be possible at defined saturated return temperature.
4. Net Storage Inventory values are not available for instantaneous discharge.
5. Applicable where refrigerant is the charge fluid.