AHRI Guideline T (I-P)

2013 Guideline for

Specifying the Thermal Performance of Cool Storage Equipment

Air-Conditioning, Heating, and Refrigeration Institute

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IMPORTANT

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Note:

This guideline supersedes AHRI Guideline T-2002.

For SI, see AHRI Guideline T (SI)-2013.

FOREWORD

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, 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 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 nominal value.

These intrinsic characteristics of 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 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.

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GUIDELINE FOR SPECIFYING THE THERMAL PERFORMANCE OF COOL STORAGE EQUIPMENT

Section 1. Purpose

1.1 *Purpose.* The purpose of this guideline is to establish the minimum information required for specifying cool storage equipment:

a. User-specified application recommendations
b. 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 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 Wikipedia website (http://wiki.ashrae.org/index.php/ASHRAEwiki) unless otherwise defined in this section.

3.1 *Ambient Air.* The air in the space surrounding the thermal energy 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 thermal storage device.

3.4 *Charge Period/Cycle.* The period of time when energy (heat) is removed from the storage device.

3.5 *Charge Rate.* The rate (typically expressed in tons) at which energy (heat) is removed from the storage device during the charge period.

3.6 *Discharge Fluid.* The heat transfer fluid used to add heat to the thermal storage device.

3.7 *Discharge Period/Cycle.* The period of time when energy (heat) is added to the storage device.

3.8 *Discharge Rate.* The rate (typically expressed in tons) at which energy (heat) is added to the storage device during the Discharge Period.

3.9 *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.

3.10 *Latent Heat of Fusion.* 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.

3.11 *Net Storage Inventory*. Net accumulated measured storage capacity at a given period of time during a 24 hour cycle.

3.12 *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.

3.13 *Nominal Storage Capacity.* A theoretical capacity of the storage device as defined by the storage device manufacturer (which in most cases is greater than the Net Usable Storage Capacity) typically expressed in ton-hours.

3.14 *Phase Change Material (PCM).* A substance that undergoes changes of phase while absorbing or rejecting thermal energy, normally at a constant temperature.

3.15 *Saturated Evaporator Temperature.* The dew point temperature of the refrigerant corresponding to the saturation pressure at the outlet connection of the evaporator.

3.16 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.

3.17 *Sensible Heat.* Heat that causes a change in fluid temperature.

3.18 *Should.* This term is used to indicate provisions which are not mandatory but which are desirable as good practice.

3.19 *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.

3.20 *Thermal Storage Equipment.* Any one of, or a combination of, Thermal Storage Devices and/or Generators, that may include various other components of a mechanical or absorption refrigeration package, as indicated in Section 4. Also referred to as “Cool Storage Equipment.”

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

3.22 *Thermal Storage System Load (or Load).* A specified cooling load to be met by the Thermal Storage System. Typically, it is expressed in tons (often referred to in this guideline as "the Load").

3.23 *Ton-Hour*. A quantity of thermal energy equal to 12,000 Btu or 1.0 ton of refrigeration provided for one hour.

3.24 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.

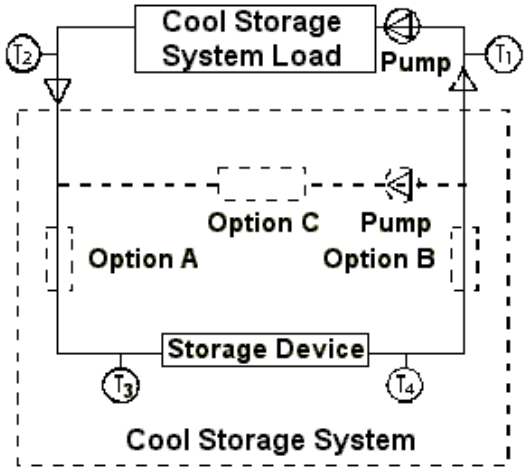

Figure 1. Cool Storage System

Where:
T_1 = Temperature of coolant supplied to the Load
T_2 = Temperature of coolant returning from the Load
T_3 = Temperature of coolant entering the Cool Storage Device.
T_4 = Temperature of coolant leaving the Cool Storage Device.

Option A, B, C: Mechanical or Absorption Refrigeration Equipment (chiller)

Section 4. Classifications

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

4.1.1 *Sensible Thermal Storage Equipment.* Sensible 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 (cooling) Period, 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 Thermal Storage Equipment.* Latent Thermal Storage Equipment is further categorized as ice-on-coil, encapsulated ice or Phase Change Material, or unitary.

4.1.2.1 *Ice-on-Coil.* A 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 (cooling) Period, 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 Phase Change Material.* 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 Phase Change Material 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 thermal storage device and refrigeration equipment for charging which is rated by the manufacturer as a UTSS. The 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.

Table 1. Classification of Thermal Storage Equipment

Classification	Type	Storage Media	Charge Fluid	Discharge Fluid
Sensible	Chilled Water	Water or other Aqueous Solution	Water or other Aqueous Solution	Water or other Aqueous Solution
Latent	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 or Secondary Coolant	Refrigerant, Water or Secondary Coolant

Section 5. Minimum Information Recommendations

5.1 *User-Specified Application Recommendations.* When specifying the application requirements for cool storage equipment, the user should provide, as a minimum, the following data for a design day (or design week, or other design period):

5.1.1 Thermal Storage System Load for each hour of the design day, tons (referred to as "the Load" throughout this guideline)

5.1.2 Operating mode of the Thermal Storage Refrigeration Equipment (charge, partial cooling or off) for each hour of the design day

5.1.3 Design Heat Sink Rejection Temperature, ºF (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, etc.)

A sample format and example of the user-specified data are provided as Appendices C and D, respectively.

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):

5.2.1 Thermal Storage System Load, tons

5.2.2 Load on Refrigeration Equipment, tons

5.2.3 Thermal Storage Device Charge or Discharge Rate, tons

5.2.4 Parasitic and accessory heat load (e.g., air compressor, dedicated recirculation pump, etc.) into the storage device, tons

5.2.4.1 Ambient Heat Load into the storage device due to ambient air temperature and solar radiation,

5.2.5 Net Storage Inventory, ton-hours

5.2.6 Saturated suction temperature and refrigeration load or other design parameters for the refrigeration plant, when this equipment is to be supplied by other than the thermal storage supplier

5.2.7 Temperature of supply and return Fluid to the Load, T_1 and T_2, °F

5.2.8 Flow rate of Fluid to the Load, gpm

5.2.9 Temperatures of Fluid entering and leaving the Thermal Storage Device, T_3 and T_4 (Figure 1), and any other heat exchanger(s) included in the vender's scope of supply, °F

5.2.10 Flow rate of Fluid through the Thermal Storage Device and any heat exchanger(s) included in the supplier's scope of supply, gpm

5.2.11 Pressure drop across the Thermal Storage Device and any heat exchanger(s) included in the supplier's scope of supply, psi

5.2.12 Energy input to thermal storage refrigeration equipment included in the supplier's scope of supply, kWh (for electric chiller) or kBtu (for gas-fired chiller)

5.2.13 Total heat rejection, Btu and condensing temperature for the refrigeration system if within the supplier's scope of supply. If the heat rejection device is included in the supplier's scope of supply, the temperature, °F (and flow rate, gpm, if applicable) of the heat rejection sink, °F - e.g. condenser water supply temperature and flow rate for water cooled condensers, entering dry-bulb temperature for air-cooled condensers, entering wet-bulb temperature for evaporative condensers, etc.

5.2.14 Energy input to essential storage device parasitics and accessories, i.e. air compressors or air pumps, in kWh

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.

Additional minimum data to be supplied by the supplier includes:

5.2.15 Listing of all equipment included in the scope of supply

5.2.16 Net Usable Storage Capacity for the Thermal Storage Device(s) , ton-hours

5.2.17 Time required to charge from the fully discharged state, h

5.2.18 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)

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

A sample format and example of the supplier-specified data are provided as Appendices E and F respectively.

APPENDIX A. REFERENCES - NORMATIVE

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 (IP)-2010 , *Performance Rating of Thermal Storage Equipment used for Cooling*, 2010, 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*, 2011, 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 *ASHRAEwiki, Terminology.* American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc, Web. 21 Sept. 2012 <http://wiki.ashrae.org/>

APPENDIX C. USER-SPECIFIED APPLICATION RECOMMENDATIONS DATA - INFORMATIVE

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 Thermal Storage Device from fully discharged condition (Initial Charge Cycle), h and °F		
Design Heat Sink Rejection Temperature, °F		

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

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

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	1822 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 Thermal Storage Device from fully discharged condition (Initial Charge Cycle), h and °F	16 hours	22 °F
Design Heat Sink Rejection Temperature °F		

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

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	1822		Partial Cooling
8 - 9	700	44.0	53.8	1822		Partial Cooling
9 - 10	600	44.0	52.4	1822		Partial Cooling
10 - 11	700	44.0	53.8	1822		Partial Cooling
11 - 12	800	44.0	55.2	1822		Partial Cooling
12 - 13	900	44.0	56.6	1822		Off
13 - 14	1000	44.0	58	1822		Off
14 - 15	1000	44.0	58	1822		Off
15 - 16	900	44.0	56.6	1822		Off
16- 17	800	44.0	55.2	1822		Partial Cooling
17 - 18	700	44.0	53.8	1822		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 THERMAL PERFORMANCE DATA – INFORMATIVE[3,4]

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

Hour	A Thermal Storage System Load tons	B Refrigeration Equipment Load tons	C Storage Device Charge Rate tons	D Storage Device Discharge Rate[1] tons	E Parasitic and Accessory Heat Load into Storage Device tons	F Ambient Heat Load into Storage Device tons	G Net Storage Inventory[2] 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										

Notes:
1. Greater Discharge Rates may not be possible at defined discharge temperature (T_4)
2. Net Storage Inventory values are not available for instantaneous discharge
3. Totals for column B must be greater than or equal to the sum of totals for columns A, E and F.
4. The values in Column I must always be less than maximum temperature defined on the "User-Specified Data" Sheet.

Table E1. Supplier-specified Data (continued)

Hour	K Fluid Temp. Entering Storage Device T_3 °F	L Fluid Temp. 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 Suction Temp.[5] °F	Q Storage Device Parasitics Electrical Input
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 (continued):
5. Applicable where refrigerant is the charge fluid.

APPENDIX F. SUPPLIER-SPECIFIED THERMAL PERFORMANCE DATA FOR UNITARY THERMAL STORAGE SYSTEMS – INFORMATIVE[4,5]

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

Hour	A Thermal Storage System Load tons	B Refrigeration Equipment Load tons	C Storage Device Charge Rate tons	D Storage Device Discharge Rate[1] tons	E Parasitic and Accessory Heat Load into Storage Device tons	F Ambient Heat Load into Storage Device tons	G Net Storage Inventory[2] Ton-Hours	H Storage Device Refrigeration Energy Input, kWh	I Saturated Return Temp.[3] °F	J Storage Device Parasitics Electrical Input
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. Greater Discharge Rates may not be possible at defined saturated return temperature
2. Net Storage Inventory values are not available for instantaneous discharge
3. Applicable where refrigerant is the charge fluid.
4. Totals for column B must be greater than or equal to the sum of totals for columns A, E and F.
5. The values in Column I must always be less than maximum temperature defined on the "User-Specified Data" Sheet.

APPENDIX G. SAMPLE SUPPLIER-SPECIFIED THERMAL PERFORMANCE DATA – INFORMATIVE[3,4]

Example Design Day

Net Usable Storage Capacity: 4700 Ton-Hours (Total Column D)

Heat Transfer Fluid: 25% EG / H_2O
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

Hour	A Thermal Storage System Load tons	B Refrigeration Equipment Load tons	C Storage Device Charge Rate tons	D Storage Device Discharge Rate[1] tons	E Parasitic and Accessory Heat Load into Storage Device tons	F Ambient Heat Load into Storage Device tons	G Net Storage Inventory[2] 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	2730	31.4	31.4	0
1 - 2	0	390	390			2	3120	31.2	31.2	0
2 - 3	0	390	390			2	3510	30.9	30.9	0
3 - 4	0	390	390			2	3900	30.4	30.4	0
4 - 5	0	390	390			2	4290	29.7	29.7	0
5 - 6	0	390	390			2	4680	28.9	28.9	0
6 - 7	0	390	390			2	5070	27.8	27.8	0
7 - 8	800	600		200		2	4870	44.0	55.2	1822
8 - 9	700	600		100		2	4770	44.0	53.8	1822
9 - 10	600	600		0		2	4770	44.0	52.4	1822
10 - 11	700	600		100		2	4670	44.0	53.8	1822
11 - 12	800	600		200		2	4470	44.0	55.2	1822
12 - 13	900	0		900		2	3570	44.0	56.6	1822
13 - 14	1000	0		1000		2	2570	44.0	58.0	1822
14 - 15	1000	0		1000		2	1570	44.0	58.0	1822
15 - 16	900	0		900		2	670	44.0	56.6	1822
16- 17	800	600		200		2	470	44.0	55.2	1822
17 - 18	700	600		100		2	370	44.0	53.8	1822
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	1170	31.7	31.7	0
21 - 22	0	390	390			2	1560	31.6	31.6	0
22 - 23	0	390	390			2	1950	31.6	31.6	0
23 - 0	0	390	390			2	2340	31.5	31.5	0
Totals	8900	9270	5070	4700		48				

Notes:
1. Greater Discharge Rates may not be possible at defined discharge temperature (T_4)
2. Net Storage Inventory values are not available for instantaneous discharge
3. Totals for column B must be greater than or equal to the sum of totals for columns A, E and F.
4. The values in Column I must always be less than maximum temperature defined on the "User-Specified Data" Sheet.

Table G1. Supplier-specified Data (continued)

Hour	K Fluid Temp. Entering Storage Device T_3 °F	L Fluid Temp. 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 Suction Temp.[5] °F	Q Storage Device Parasitics Electrical Input (kWh)
0 - 1	26.0	31.4	1821	9.3			
1 – 2	25.8	31.2	1821	9.4			
2 - 3	25.4	30.9	1821	9.4			
3 - 4	24.9	30.4	1821	9.4			
4 - 5	24.3	29.7	1821	9.4			
5 - 6	23.4	28.9	1821	9.5			
6 - 7	22.3	27.8	1821	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	1128	4.4			
13 - 14	58.0	38.8	1330	5.4			
14 - 15	58.0	41.2	1519	6.4			
15 - 16	56.6	43.7	1773	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	1821	9.3			
19 - 20	26.3	31.7	1821	9.3			
20 - 21	26.2	31.7	1821	9.3			
21 – 22	26.2	31.7	1821	9.3			
22 - 23	26.2	31.6	1821	9.3			
23 – 0	26.1	31.6	1821	9.3			
Totals							

Notes (continued):
5. Applicable where refrigerant is the charge fluid.

APPENDIX H. SUPPLIER-SPECIFIED THERMAL PERFORMANCE DATA FOR UNITARY THERMAL STORAGE SYSTEMS – INFORMATIVE[4,5]

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

Hour	A Thermal Storage System Load tons	B Refrigeration Equipment Load tons	C Storage Device Charge Rate tons	D Storage Device Discharge Rate[1] tons	E Parasitic and Accessory Heat Load into Storage Device tons	F Ambient Heat Load into Storage Device tons	G Net Storage Inventory[2] Ton-Hours	H Storage Device Refrigeration Energy Input, kWh (electric chiller) or kBtu (gas-fired chiller)	I Saturated Suction Temp.[3] °F	J Storage Device Parasitics Electrical Input
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. Greater Discharge Rates may not be possible at defined saturated return temperature
2. Net Storage Inventory values are not available for instantaneous discharge
3. Applicable where refrigerant is the charge fluid.
4. Totals for column B must be greater than or equal to the sum of totals for columns A, E and F.
5. The values in Column I must always be less than maximum temperature defined on the "User-Specified Data" Sheet.