



Energy Modeling Guideline for Cold Storage and Refrigerated Warehouse Facilities

December 19, 2013

The International Association for Cold Storage Construction (IACSC) and the International Association of Refrigerated Warehouses USGBC Committee is seeking to provide a formal guidance document that designers of cold storage and refrigerated facilities can use to certify buildings for the LEED rating system.

Many elements of the design and construction of cold storage and refrigerated facilities are not regulated by existing ASHRAE standards. However there are many guides and references which establish a standard of care. These have been noted in the references and bibliography section.

LEED version 4.0 currently references (ASHRAE 90.1-2010 and ASHRAE 62.1-2010). Many areas exist where there is no regulation, therefore there is no basis for comparison. This committee has worked to develop recommendations for best practice design that could be used and interpreted as the minimum baseline building.

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Version 1.0

1 Introduction

This document describes the treatment of refrigerated storage facilities or any section of that building that achieves controlled storage conditions using thermal insulation and refrigeration equipment in the LEED v4.0 Design & Construction and Interior Design & Construction rating systems. The document applies to refrigerated buildings or buildings that contain refrigerated areas.

2 Executive Summary

The purpose of this guidance document is to assist designers of refrigerated storage facilities or any section of that building that achieves controlled storage conditions using thermal insulation and refrigeration equipment, to define energy performance per the methodology established in ANSI/ASHRAE/IES Standard 90.1-2010 Normative Appendix G – Performance Rating Method. Such facilities can typically be classified into two groups: (1) coolers with commodities stored at temperatures usually above 32°F (0°C); and (2) freezers or low-temperature rooms operating below 32°F (0°C). They can also be classified into small, intermediate, and large storage rooms ranging from small rooms utilizing prepackaged refrigerator units to mammoth cold storage cooler/freezer warehouses.

ANSI/ASHRAE/IES Standard 90.1-2010 defines the minimum energy performance of buildings except for low-rise residential, but when applied to refrigerated storage facilities, envelope requirements and parts of the Performance Rating Methodology are not relevant. Additionally, refrigeration equipment is not addressed. This guidance document adds procedures necessary for rating energy performance of refrigerated storage facilities.



3 Disclaimer

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4 Definitions

Exceptional Calculation Methodology: Section G2.5 of ASHRAE 90.1–2010 stipulates that when no simulation program can adequately model a design, material, or device, the rating authority (here, USGBC) may approve an exceptional calculation method to demonstrate above-standard performance. Applications for approval of an exceptional method must include documentation of the calculations performed and theoretical and/or empirical information supporting the accuracy of the method. The LEED reviewer evaluates whether the exceptional calculations can substantiate the energy savings and whether the energy and costs saved are entered appropriately in the LEED credit form.

Evaporator Efficiency: Total rated evaporator fan brake horsepower (bhp) divided by the rated evaporator refrigeration capacity in Tons of Refrigeration (TR) at design conditions.

Condenser Efficiency: Condenser nominal rated heat rejection (BTUh) divided by the total fan and water pump nameplate horsepower converted to Watts.

Wet Bulb Approach: The temperature difference between the design wet bulb temperature and the design saturated condensing temperature.



5 Baseline Guidance

Any building or portion of a building that is refrigerated shall create a baseline building model in accordance with this guideline. All non-refrigerated portions of the building, as well as Service Water Heating (Section 7), Power (Section 8), Lighting (Section 9), and Other Power (Section 10) within refrigerated portions shall reference *ANSI/ASHRAE/IES Standard 90.1-2010 Normative Appendix G Performance Rating Method* without exception.

5.1 Qualifying Buildings or Portions of a Building.

Facilities with either: (1) coolers with commodities stored at temperatures usually above 32°F (0°C), (2) freezers or low-temperature rooms operating below 32°F (0°C), or (3) any combination of (1) and (2).

5.2 Simulation Program.

Energy modelers should be aware that modeling of refrigeration systems is not standard. Many commercially available programs do not have the ability to accurately model refrigeration systems. If a simulation program cannot model the system, *exceptional calculation methodology* per LEED requirements shall be used.

5.3 Proposed Building.

Buildings with refrigerated spaces shall be consistent with the design drawings including proper accounting of envelope types and areas; interior lighting power density and controls; refrigeration system types; sizes and controls; and service water heating systems and controls.

5.4 Baseline Building.

Buildings with refrigerated spaces shall follow the modeling rules and recommendations from this guideline.

5.4.1 Baseline Envelope.

Refrigerated storage facilities shall follow Table 4.4.1-1 for opaque envelope assemblies and Table 4.4.1-2 for doors. Listed values apply to all Roof Insulation, Above-Grade Wall Insulation, Below-Grade Wall Insulation, Floor Insulation, Slab-on-Grade Floor Insulation, and Exterior Overhead Doors.



Table 4.4.1-1 – Baseline Insulation for Refrigerated Storage Facilities

Type of Facility	Temperature Range °F (°C)	Thermal Resistance R, °F ft ² h Btu ⁻¹ (m ² K W ⁻¹)			
		Floors	Walls / Suspended Ceilings	Roofs	Exterior Overhead Doors*
Cooler	32 to 55 (0 to 13)	Perimeter Insulation Only per 90.1	25 (4.4)	30 (5.3)	10 (1.7)
Chill Cooler	25 to 32 (-4 to 0)	20 (3.5)	25 (4.4)	35 (6.2)	15 (2.6)
Holding Freezer	-20 to 25 (-29 to -4)	27 (4.8)	35 (6.2)	45 (7.9)	20 (3.5)
Blast Freezer	-20 to -50 (-29 to -46)	30 (5.3)	45 (7.9)	50 (8.8)	Not Applicable

*Operation of the exterior overhead doors shall be modeled consistently between

Table 4.4.1-2 – Interior Partition Door Selection for Refrigerated Storage Facilities

Operational Temperature °F (°C)	Low Frequency of Usage (0-100 cycles/day)	Medium Frequency of Usage (101-400 cycles/day)	High Frequency of Usage (400-1500 cycles/day)
50 to 40 (10.0 to 4.4)	Manual hinged or sliding door, 2 inch (51 mm) poly-urethane or 3 inch (76 mm) expanded polystyrene panel.	Power-operated sliding or fabric door.	High-speed sliding or fabric door.
40 to 32 (4.4 to 0.0)	Manual hinged or sliding door, 3 inch (76 mm) polyurethane or 4 inch (102 mm) expanded polystyrene panel.	Power-operated sliding or fabric door.	High-speed sliding or fabric door.
32 to -10 (0.0 to -23.3)	Manual hinged or sliding door, 4 inch (102 mm) polyurethane or 6 inch (152 mm) expanded polystyrene panel with trace heating.	Power-operated sliding door with 4 inch (102 mm) polyurethane or 6 inch (152 mm) expanded polystyrene panel with trace heating.	High-speed sliding door with 4 inch (102 mm) polyurethane panel with trace heating.
-10 to -40 (23.3 to 40.0)	Manual hinged or sliding door, 6 inch (152 mm) polyurethane or 8 inch (203 mm) expanded polystyrene panel with trace heating.	Power-operated sliding door with 6 inch (152 mm) polyurethane or 8 inch (203 mm) expanded polystyrene panel with trace heating.	High-speed sliding door with 6 inch (152 mm) polyurethane or 8 inch (203 mm) expanded polystyrene panel with trace heating.

5.4.2 Process Loads.

Process equipment loads shall be held equivalent to the proposed model. *Exceptional Calculation Methodology* may be used to justify process energy efficiency.

5.4.3 Thermal Blocks.

Refrigerated buildings shall be modeled using at least one thermal block per temperature zone. Blocks shall be modeled identically between the Baseline and Proposed models.



5.5 Baseline Refrigeration Systems.

The Refrigeration System type and all related performance parameters in the proposed design, such as equipment capacities and efficiencies, shall be determined as follows:

5.5.1 Proposed Refrigeration System

- A. Where a complete Refrigeration system exists, the model shall reflect the actual system type using actual component capacities and efficiencies.
- B. Where a Refrigeration system has been designed, the Refrigeration model shall be consistent with design documents.
- C. Where no refrigeration system exists or no refrigeration system has been specified, the refrigeration system classification shall be identical to the system modeled in the baseline building design.

5.5.2 Baseline Refrigeration System Requirements.

Refrigeration systems in the baseline building design shall conform to the following baseline requirements:

5.5.2.1 Baseline System Selection.

Systems shall be selected based on Table 4.5.2.1-1.

Table 4.5.2.1-1 – Baseline System Selection Matrix

Baseline	Sample Efficiency Upgrades*
System Type System type based on space temperature and square footage as shown in Figure 1 below.	Upgrade to a system with increased efficiency, such as: Package Halocarbon → Single Stage (ammonia) Single Stage (ammonia) → Single Stage Economized Single Stage Economized → Two Stage
Compressor Configuration Minimum number of equally sized compressors required for the design load.	Increased number of compressors for the same required design load.
Compressor Capacity Control Control Method: Slide Valve or Unloaders	Control Method: Variable Frequency Drive (VFD)
Evaporator Selection & Control Design Temperature Differential (TD): 12°F Evaporator Efficiency: 0.54 bhp/TR Fan Operation: Continuous or Cycling	Design Temperature Differential (TD): <12°F Evaporator Efficiency: <0.54 bhp/TR Fan Operation: VFD Control
Baseline (cont.)	Sample Efficiency Upgrades* (cont.)



<p>Condenser Selection & Control Wet Bulb (WB) Approach 20°F</p> <p>Condenser Efficiency: 275 BTUh/Watt (Evaluated at 78°F degree wet bulb temperature and 96.3° F condensing temperature)</p> <p>Capacity Control: Fan Cycling</p>	<p>Wet Bulb (WB) Approach: For, WB ≤ 76°F: Wet Bulb Approach < 20°F For, 76°F < WB < 78°F: Wet Bulb Approach < 19°F For, WB ≥ 78°F: Wet Bulb Approach < 18°F</p> <p>Condenser Efficiency: > 275 BTUh/Watt</p> <p>Capacity Control: Fan VFD</p>
<p>Refrigeration Controls Central Control System</p>	<p>No Upgrade Available</p>
<p>Evaporator Defrost Main Hot Gas Pressure Control: None</p> <p>Evaporator Hot Gas Control: Back Pressure Regulator</p> <p>Defrost Return: Relieves to same suction</p>	<p>Main Hot Gas Pressure Control: Master Regulator</p> <p>Evaporator Hot Gas Control: Defrost Float Drainer</p> <p>Defrost Return: Relieves to higher suction where possible</p>
<p>Number of Suction Pressures For Space Temp. > 0°F: One suction pressure per 30°F difference in space temperature.</p> <p>For Space Temp. ≤ 0°F: One suction pressure per 20°F difference in space temperature.</p>	<p>For Space Temp. > 0°F: More than one suction pressure per 25°F difference in space temperature.</p> <p>For Space Temp. ≤ 0°F: More than one suction pressure per 20°F difference in space temperature.</p>
<p>Minimum Condensing Pressure Minimum Condensing Setpoint: 120 psig</p> <p>(This is not the operating condensing pressure or a yearly average, but a minimum condensing pressure where the system can operate during times of low ambient temperature and/or reduced refrigeration loads.)</p>	<p>Minimum Condensing Setpoint: < 120 psig</p>
<p>Sub-Floor Heat Total Freezer Space ≤ 10,000 ft²: Electric Heat</p> <p>Total Freezer Space > 10,000 ft²: Non-Electric Heat</p>	<p>Total Freezer Space ≤ 10,000 ft²: Non-Electric Heat</p> <p>Total Freezer Space > 10,000 ft²: No Upgrade Available</p>

*Sample items are not exclusive or mandatory.

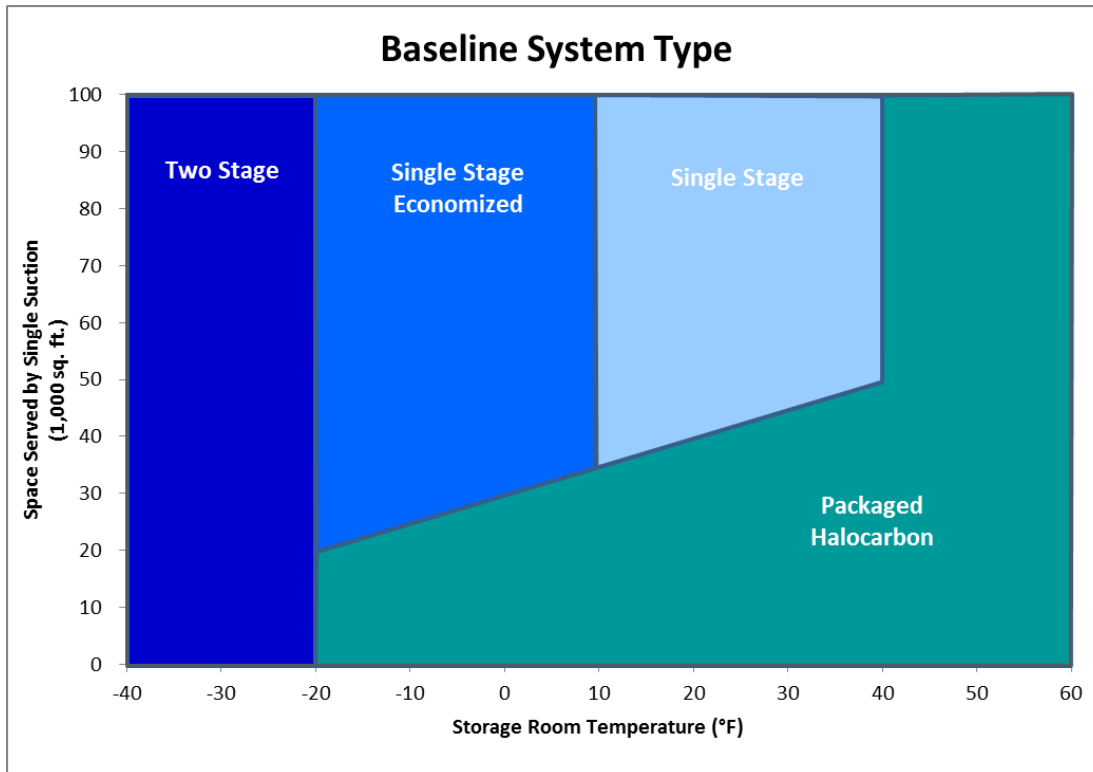


Figure 5.5.2.1-1 – Baseline System Selection Chart

5.5.2.2 Equipment Efficiencies

All Refrigeration equipment in the baseline building design shall be modeled at the minimum efficiency levels, both part and full load, identical to those in the Proposed Design.

5.5.2.3 Equipment Capacities.

The equipment capacities (i.e. system coil capacities) for the *baseline building design* shall be based on sizing runs with no oversizing.

5.5.2.4 Unmet Loads.

Unmet load hours for the *proposed design* or *baseline building designs* shall not exceed 300 (of the 8760 hours simulated). Alternatively, *unmet load hours* exceeding these limits may be accepted at the discretion of *the rating authority* provided that sufficient justification is given indicating that the accuracy of the simulation is not significantly compromised by these unmet loads.

5.5.2.5 Fan System Operation.

Fans shall be modeled as continuous operation or cycling, as necessary to maintain space conditions.

5.5.2.6 Ventilation.

Refrigerated spaces should be modeled per to ASHRAE 62.1 Addenda L for both the Baseline and Proposed Models.



5.5.2.7 System Fan Power.

System fan electrical power for all evaporator fans combined shall be calculated using the following formulas:

$$P_{fan} = CFMs \times 0.3$$

Table 5.5.2.7-1 - Baseline Fan Brake Horsepower

Constant Volume
CFM • 0.00094 + A

Where A is calculated according to ANSI/ASHRAE/IES 90.1-2010 Section 6.5.3.1.1 using the pressure drop adjustment from the proposed building design and the design flow rate of the baseline building system.

Do not include pressure drop adjustments for evaporative coolers or heat recovery devices that are not required in the baseline building system by ANSI/ASHRAE/IES 90.1-2010 Section G3.1.2.10.

Table 5.5.2.7-2 - Fan Power Limitation Pressure Drop Adjustment

TABLE 6.5.3.1.1B Fan Power Limitation Pressure Drop Adjustment

Device	Adjustment
Credits	
Fully ducted return and/or exhaust air systems	0.5 in. w.c. (2.15 in. w.c. for laboratory and vivarium systems)
Return and/or exhaust airflow control devices	0.5 in. w.c.
Exhaust filters, scrubbers, or other exhaust treatment	The pressure drop of device calculated at fan system design condition
Particulate Filtration Credit: MERV 9 through 12	0.5 in. w.c.
Particulate Filtration Credit: MERV 13 through 15	0.9 in. w.c.
Particulate Filtration Credit: MERV 16 and greater and electronically enhanced filters	Pressure drop calculated at 2× clean filter pressure drop at fan system design condition
Carbon and other gas-phase air cleaners	Clean filter pressure drop at fan system design condition
Biosafety cabinet	Pressure drop of device at fan system design condition
Energy Recovery Device, other than Coil Runaround Loop	(2.2 × Energy Recovery Effectiveness)—0.5 in. w.c. for each airstream
Coil Runaround Loop	0.6 in. w.c. for each airstream
Evaporative humidifier/cooler in series with another cooling coil	Pressure drop of device at fan system design condition
Sound Attenuation Section	0.15 in. w.c.
Exhaust system serving fume hoods	0.35 in. w.c.
Laboratory and vivarium exhaust systems in high-rise buildings	0.25 in. w.c./100 ft of vertical duct exceeding 75 ft



6 References

- ANSI/ASHRAE/IES 90.1-2010 - Energy Standard for Buildings Except Low-Rise Residential Buildings
- ASHRAE Design Essentials for Refrigerated Storage Facilities - 2005
- California 2008 Building Energy Efficiency Standards for Residential and Nonresidential Buildings – Section 126 (Title 24)

7 Bibliography

- *Ammonia Data Book: the Profile of a Sustainable Refrigerant*. 2nd ed. Alexandria, VA: IIAR, 2008. Print.
- Bonar II, Henry B. "1.4.3 Ammonia Refrigeration." *Successful Refrigerated Warehousing*. 12th ed. Alexandria, VA: World Food Logistics Organization, 2011. 60-71. Print.
- *Guidelines for IIAR Minimum Safety Criteria for a Safe Ammonia Refrigeration System*. Alexandria, VA.: IIAR, 1997. Print.
- *2009 ASHRAE Handbook: Fundamentals*. Inch-pound ed. Atlanta, GA: American Society of Heating, Refrigeration and Air-Conditioning Engineers, 2009. Print.
- *2010 ASHRAE Handbook Refrigeration*. Inch-pound ed. Atlanta, Ga.: American Society of Heating, Refrigerating and Air Conditioning Engineers, 2010. Print.
- *ASHRAE Standards:*
- Standard 15-2010 Safety Standard for Refrigeration Systems (ANSI Approved) Standard 34-2010 -- Designation and Classification of Refrigerants 2010
- *IIAR's Ammonia Refrigeration Piping Handbook*. 2nd ed. Alexandria, VA: IIAR, 2012. Print.
- IIAR Bulletins:
- Bulletin 107 - Guidelines for: Suggested Safety and Operating Procedures when Making Refrigeration Plant Tie-Ins
- Bulletin 108 - Guidelines for: Water Contamination in Ammonia Refrigeration Systems
- Bulletin 109 - Guidelines for: IIAR Minimum Safety Criteria for a Safe Ammonia Refrigeration System
- Bulletin 110 - Guidelines for: Start-Up, Inspection and Maintenance of Ammonia Mechanical Refrigerating Systems
- Bulletin 114 - Guidelines for: Identification of Ammonia Refrigeration Piping and System Components
- ANSI/IIAR Standards - American National Standard for Equipment, Design & Installation of Ammonia Mechanical Refrigerating Systems:
- ANSI/IIAR 1-2012
- ANSI/IIAR Standard 2-2008 (Addendum A)
- ANSI/IIAR 3-2005
- *Industrial Refrigeration*. Rev. ed. Glenview, IL: Refrigerating Engineers and Technicians Association, 2003. Print.
- King, Guy R. *Basic Refrigeration: Principles, Practice, Operation: a Simplified Presentation of the Fundamentals of Refrigeration*. 3rd ed. Troy, Mich., USA: Business News Pub. Co. 1986. Print.



- *RSES Basic Refrigeration*. Des Plaines, IL: Refrigeration Service Engineers Society, 1990. Print.
- Stoecker, W. F. *Industrial Refrigeration*. Troy, Mich.: Business News Publishing Company, 1988. Print.
- Stoecker, Wilbert F. *Industrial Refrigeration Handbook*. New York: McGraw-Hill, 1998. Print.
- Stoecker, W. F. *Industrial Refrigeration Volume II*. Troy, Mich.: Business News Pub. Co., 1995. Print.
- Vallort, Ronald P. "1.8.1 Facility Design and Construction." *Successful Refrigerated Warehousing*. 12th ed. Alexandria, VA: World Food Logistics Organization, 2011. 111-122. Print.
- Vallort, Ronald P. "1.8.2 The Contractor's Perspective." *Successful Refrigerated Warehousing*. 12th ed. Alexandria, VA: World Food Logistics Organization, 2011. 123-127. Print.