# Codes and Standards Enhancement Initiative
## For PY2004: Title 20 Standards Development

# Analysis of Standards Options For Commercial Packaged Refrigerators, Freezers, Refrigerator-Freezers and Ice Makers

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April 28, 2004

This report was prepared by Pacific Gas and Electric Company and funded by California utility customers under the auspices of the California Public Utilities Commission

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# 1. Introduction

The Pacific Gas and Electric Company (PG&E) Codes and Standards Enhancement (CASE) Initiative Project seeks to address energy efficiency opportunities through development of new and updated Title 20 standards. Individual reports document information and data helpful to the California Energy Commission (CEC) and other stakeholders in the development of these new and updated standards. The objective of this project is to develop CASE Reports that provide comprehensive technical, economic, market, and infrastructure information on each of the potential appliance standards. This CASE report covers standards and options for commercial packaged refrigerators, freezers, refrigerator-freezers and ice-makers.

# 2. Product Description

*Commercial Packaged Refrigerators and Freezers*

Commercial packaged refrigerators and freezers are upright, refrigerated cases with solid or transparent doors. They consist of a case, insulation, shelves, refrigeration system, and defrost system. Systems include standard reach-in (with doors on one side), roll-in (the bottom is level with the outside floor, permitting wheeled carts to be rolled in), pass-through (with doors on opposite sides), and roll-through (combination of roll-in and pass-through) cabinet types. Beverage merchandisers are a special type of reach-in with glass doors to permit customers to see beverages for sale (see Figure 1 for illustrative examples). Beverage merchandisers also generally have a fluorescent lighting system to illuminate logos and contents. Transparent-door reach-in refrigerators and freezers are also sold without the extra beverage merchandising features. Two other special types of equipment are worth mentioning. First, some reach-in freezers are marketed as "ice cream freezers" and optimized to store ice-cream at –5° F, which is 5 degrees colder than a typical freezer. Second, while most beverage merchandisers have glass doors, a few models are open in front (without doors), which increases ease of access to drinks but also increases energy use.

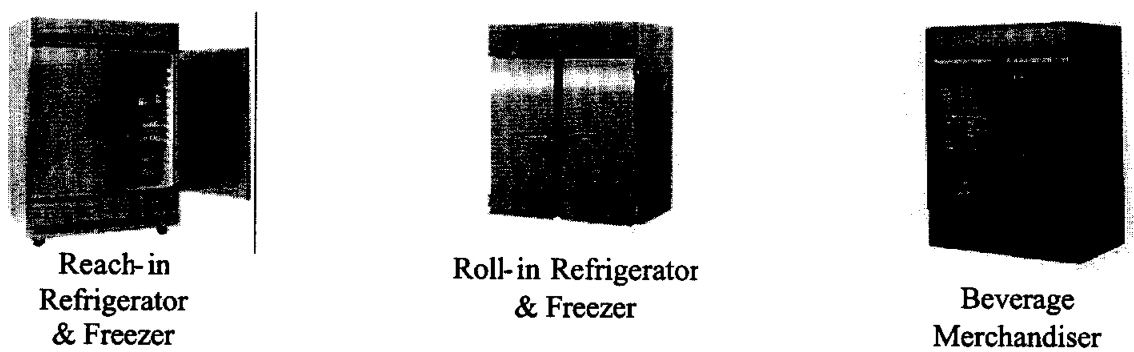


**Figure 1. Illustrations of Common Food Service Refrigeration Systems**

For commercial refrigerators and freezers, equipment tends to be grouped into two lines— "standard line" units, representing about 70% of the market, and "specification line" units. Standard-line units, which tend to be less expensive, are primarily sold to commercial food establishments. Specification-line units have improved cosmetics and durability (but not necessarily reduced energy consumption) and are sold primarily to institutional food service establishments (Easton 1993). Major manufacturers include True, Beverage Air, Delfield, Hobart, Traulsen, McCall and Victory. While no manufacturer dominates the market for solid-door units, True and Beverage Air each have a very large portion of the glass-door market (ADL 1996).

*Ice-Makers*

A typical ice-maker consists of a case, insulation, refrigeration system, and a water supply system. Some of the smaller models have an integrated ice storage bin, but most ice-makers have only an ice-making system and are installed on top of a separate insulated ice-storage bin. Approximately 80% of ice-makers sold have integrated air-cooled condensers, while others have remote air-cooled or integral water-cooled configurations. All rated ice-makers use vapor compression refrigeration to produce ice (Nadel 2002a).

Ice-makers consist of two major subsystems: the refrigeration system and water supply system. Most of the energy savings potential exists in the refrigeration system. Energy use for commercial ice-makers can vary considerably from product to product—depending on the machine's capacity, the type of ice produced (e.g., cubes, flakes, chips, nuggets, etc.), and the coolant used—but in general, energy use per pound of ice produced decreases as the capacity of the machine increases.

Ice-makers are generally classified into three types of machines:

- Ice-making head units: standard ice-makers with the ice-making mechanism and the condensing unit in a single package, but with a separate ice storage bin;
- Self-contained units: models in which the ice-making mechanism and storage compartment are in an integral cabinet; and
- Remote condensing units: split-system models in which the ice-making mechanism, the condensing unit, and the ice storage bins are in separate sections.

Ice-making head units and self-contained units are subdivided into models that use air or water as their cooling medium.

Ice cube-makers account for more than 80% of ice-maker sales, but models are also available that produce ice flakes, chips, crushed ice, and nugget ice. End-users usually purchase ice-makers from manufacturers' regional distributors. There are five major manufacturers: Manitowoc Equipment Works; Scotsman Ice Systems/Crystal Tips; Hoshizaki America; Mile High Equipment; and IMI Cornelius, all members of ARI (Nadel 2002a).

# 3. Market Status

## 3.1. Market penetration

*Commercial Packaged Refrigerators and Freezers*

Arthur D. Little, Inc. (ADL), in a 1996 study for DOE, estimated the size of the equipment stock for the most common types of commercial packaged refrigerators and freezers. This information is summarized in Table 1. All told, they estimated that 2.9 million units are in use in the U.S. Since California accounts for about 9% of U.S. commercial sector electricity use (EIA 2001), we would expect California to account for about 9% of the U.S. commercial packaged refrigerator and freezer stock, or about 260,000 units. To this we need to add transparent door freezers, which are not included in the ADL study. Based on the stock of solid-door freezers in California as estimated from Table 1, and based on the number of solid and transparent door freezers listed in the CEC product database (421 and 94 respectively), we estimate that there are roughly 16,000 transparent-door freezers in use in California.

**Table 1. Inventory, Energy Consumption and Annual Sales for Commercial Packaged Refrigerators and Freezers in the United States**

| Unit Type | Estimated Inventory | Average Unit Energy Consumption (kWh/year) | Total Energy Consumption (TWh/year) | % of Total Energy Consumption | Approximate Annual Sales in U.S. |
|---|---|---|---|---|---|
| *Solid Door Refrigerators* | | | | | |
| One-door | 390,000 | 2,300 | 0.90 | 6 | 43,000 |
| Two-door | 845,000 | 4,300 | 3.63 | 23 | 94,000 |
| Three-door (or more) | 65,000 | 6,300 | 0.41 | 3 | 7,000 |
| Subtotal | 1,300,000 | | 4.94 | 32 | 144,000 |
| | | | | | |
| *Solid-Door Freezers* | | | | | |
| One-door | 440,000 | 5,200 | 2.29 | 15 | 49,000 |
| Two-door | 320,000 | 9,800 | 3.14 | 20 | 36,000 |
| Three-door (or more) | 40,000 | 14,400 | .58 | 4 | 4,000 |
| Subtotal | 800,000 | | 6.00 | 38 | 89,000 |
| | | | | 0 | |
| *Beverage Merchandisers* | | | | | |
| One-door | 400,000 | 3,900 | 1.56 | 10 | 47,000 |
| Two-door | 360,000 | 7,600 | 2.74 | 17 | 42,000 |
| Three-door (or more) | 40,000 | 11,200 | 0.45 | 3 | 5,000 |
| Subtotal | 800,000 | | 4.74 | 30 | 94,000 |
| | | | | | |
| TOTAL | 2,900,000 | | 15.68 | 100% | 327,000 |

Source: ADL 1996 for all but annual sales. Annual sales estimated by ACEEE based on inventory and average equipment life. Data on refrigerator-freezer sales and transparent-door freezer sales were not included but these units are much less common than the products listed here.

Commercial packaged refrigerators are generally used in food service establishments (e.g. restaurants, institutional cafeterias, fastfood establishments, deli's, and bars), food sales (e.g. convenience stores), hospitals, and hotels. Many of the refrigeration units used in small convenience stores are beverage merchandisers (i.e. low-cost units designed to display and market soft drinks). Refrigeration systems used in supermarkets and large convenience stores like 7-11 are primarily built-up systems (multiple display cases served by a set of refrigeration compressors) and not the commercial packaged units covered by this CASE study.

*Ice-Makers*

Arthur D. Little, Inc., also estimated that in 1996, there were about 1.2 million ice-makers in use in the U.S. However, this figure seems low if we look at annual sales of ice-cube machines and the average life of these units. Annual sales of ice-cube machines are about 234,000-282,000 units per year (discussed below) and the average equipment life about 8.5 years (also discussed below), which implies a total stock of about 1.99-2.40 million units in the U.S. Thus, the total stock of ice-makers in use in the U.S. is likely somewhere in the range of 1.38[1] and 2.40 million units. The average of these three estimates is 1.92. If California accounts for about 9% of the U.S. stock (see above), then there are about 173,000 ice-makers in California.

Ice-makers are commonly used in hospitals, hotels, food service, and food preservation. Figure 2 shows the end-use segments of the ice-maker market by electricity consumption.

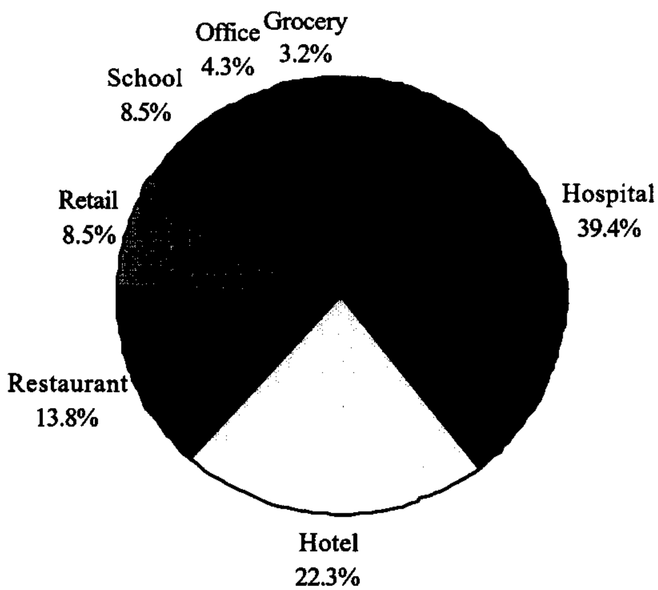


**Figure 2. End-Use Segments of the Ice-Maker Market by Electricity Consumption**
Source: ADL 1996

### 3.2. Sales Volume

Based on the data in Table 1, and assuming a 9-year average equipment life (the midpoint of the range discussed below), then about 327,000 commercial packaged refrigerators and freezers are sold annually in the U.S. If California is 9% of U.S. sales, then about 29,000 units are sold each year in California, including approximately 13,000 solid-door refrigerators, 8,000 solid-door freezers, and 8,000 transparent-door freezers. In addition, based on the stock data discussed above, we estimate that about 1,760 transparent-door freezers are sold in California each year.

The U.S. Census Bureau Current Industrial Reports tracks ice-maker sales by year. Their estimates of sales at a national level in 2001 and 2002 are summarized in Table 2. Energy efficiency programs and specifications have thus far targeted ice-cube machines (the first

[1] 1996 stock plus a 2%/year estimated growth rate for the 1996-2003 period.

three categories), with sales of about 234,000-282,000 units annually. If California accounts for 9% of sales, then annual sales in California are approximately 23,000 ice-cube machines.

**Table 2. U.S. Ice-Making Machine Sales**

| Equipment Description | Unit Sales | |
|---|---|---|
| | 2001 | 2002 |
| Self-contained cubers 200 lb/day and under | 124,326 | 121,007 |
| Self-contained cubers over 200 lb/day | 64,405 | 87,712 |
| Not self-contained (mostly cubers) | 45,222 | 72,986 |
| Self-contained flake machines 300 lb/day and under | 3,421 | 2,752 |
| Self-contained flake machines over 300 lb/day | 8,688 | 11,875 |
| Combination ice machines and ice/drink dispensers | 49,506 | 63,793 |
| TOTAL | 295,568 | 360,125 |

Source: U.S. Census Bureau 2003.

### 3.3. Market penetration of high efficiency options

*Commercial Packaged Refrigerators and Freezers*

High-efficiency solid-door commercial refrigerators and freezers are generally defined in terms of the Energy Star specification and the CEE tier 2 specification. The Energy Star specification was developed in 2001 to reflect the performance of the upper-quartile of the market. CEE tier 2 is an even higher level of efficiency that was based on the most efficient models available in 2002. A recent analysis by ACEEE for NYSERDA estimated that about 51% of solid door refrigerators and 64% of solid door freezers in the CEC database as of June 2003 met the Energy Star spec. The figures for CEE tier 2 were 5% and 12%, respectively. Discussions with manufacturers and distributors estimated a roughly similar market share, with average estimates of about 38-45% market share for Energy Star (Smith et al. 2003). Energy Star has compiled a list of nearly 700 models that meet the Energy Star specification, including models from nearly all manufacturers (Energy Star 2003).

For transparent-door commercial refrigerators, CEE has recently established tier 1 and tier 2 specifications. The CEE tier 1 spec calls for energy use 30% below the levels in the California August 2004 standard. There is also a tier 2 specification with energy use 50% below the California 2004 standard. A review of the April 2003 version of the CEC database indicates that 24% of the unique transparent-door units in the database meet the tier 1 specification and 6% meet tier 2. Six manufacturers have at least some models meeting the tier one specification; four manufacturers have at least one model meeting the draft tier 2.

For transparent-door freezers, there is currently no formal efficiency specification that goes beyond the current California standard. However, as discussed in section 4.4, a suggested specification was derived as part of this CASE study. Of the unique models listed in the CEC database, 31% meet this specification.

*Ice-Makers*

High-efficiency ice-maker models are commonly defined in terms of specifications developed by the Federal Energy Management Program (FEMP) and the Consortium for Energy Efficiency (CEE). The CEE spec has two tiers – tier 1, which is very similar in stringency to the FEMP spec, and tier 2, which allows 20% less energy consumption per pound of ice produced than tier 1 (Nadel 2002a). A recent analysis by ACEEE for NYSERDA estimated that about 22% of models on the market and about 25% of units sold meet CEE tier 1 (Smith et al. 2003). As of the date of this analysis, no units met CEE tier 2, but in September 2003, Manitowac (the largest manufacturer) announced their new S-series of ice-makers, claiming energy savings of up to 30% (Manitowac 2003). With these types of savings, many models are likely to meet CEE tier 2 although this still needs to be verified. Of the models meeting CEE tier 1, three manufacturers (Manitowac, Mile High and Hoshizaki) have a fairly full product line, but the other manufacturers have only a few complying models (CEE 2003).

# 4. Savings Potential

## 4.1. Baseline energy use

*Commercial Packaged Refrigerators and Freezers*

For both solid-door and glass-door reach in units, the California August 2004 standard defines baseline conditions. The energy use of commercial packaged refrigerators varies with unit size. Table 3 provides several pieces of energy use data for different types and sizes of machines based on the California August 2004 standard.

**Table 3. Comparison of Base Case, Energy Star and CEE Tier 2 Energy Use for Commercial packaged Refrigerators and Freezers**

| Unit Capacity (cubic feet) | Annual Energy Use of Average Base Case Model (kWh/year) | Annual kWh Savings Relative to Base Case | |
|---|---|---|---|
| | | Energy Star (CEE Tier 1) | CEE Tier 2 |
| Solid-door refrigerators | | | |
| 24 (one door) | 2,102 | 563 | 1,179 |
| 48 (two door) | 3,197 | 826 | 1,774 |
| 72 (three door) | 4,292 | 1,088 | 2,370 |
| | | | |
| Solid-door freezers | | | |
| 24 (one door) | 4,319 | 511 | 1,654 |
| 48 (two door) | 7,805 | 669 | 2,810 |
| 72 (three door) | 11,292 | 827 | 3,966 |
| | | | |
| Transparent-door refrigerators | | CEE Tier 1 | CEE Tier 2 |
| 24 (one door) | 3,248 | 1,091 | 1,705 |
| 48 (two door) | 4,754 | 1,599 | 2,496 |
| 72 (three door) | 6,261 | 2,107 | 3,287 |

Notes: Base Case energy use from CEC August 2004 standard. Tier 1 and Tier 2 savings assume average qualifying model 5% below the qualifying threshold.

Source: Nadel 2002a, Nadel 2002b. Savings for transparent-door units meeting CEE Tier 2 calculated by ACEEE.

*Ice-Makers*

The energy use of ice-makers also varies with unit type, size and efficiency. ACEEE has analyzed the data in the ARI Directory and developed a set of "best fit" lines that indicate the average energy performance of units now on the market as a function of system type and capacity. Comparing these "best fit" lines to the CEE Tier 1 and Tier 2 specifications allows us to estimate energy savings. Table 4 provides these figures.

**Table 4. Comparison of Base Case, Tier 1 and Tier 2 Energy Use for Ice-Makers**

| Unit Type and Capacity (Pounds Ice/24 hours) | Annual Energy Use of Average Base Case Model (kWh/year) | Annual kWh Savings Relative to Base Case | |
|---|---|---|---|
| | | Tier 1 | Tier 2 |
| Ice-Making Heads (water cooled) | | | |
| 200 | 2,213 | 316 | 695 |
| 500 | 4,154 | 578 | 1,293 |
| 1000 | 7,373 | 1028 | 2,190 |
| Ice-Making Heads (air cooled) | | | |
| 200 | 2,768 | 349 | 834 |
| 500 | 4,920 | 431 | 1,337 |
| 1000 | 8,964 | 765 | 2,436 |
| Remote-condensing (air-cooled) | | | |
| 400 | 4,257 | 105 | 926 |
| 800 | 7,580 | 998 | 2,278 |
| 1200 | 10,056 | 1,389 | 3,123 |
| 1600 | 13,596 | 2,039 | 4,351 |
| Self-Contained (water cooled) | | | |
| 100 | 1,609 | 264 | 533 |
| 175 | 2,041 | 40 | 440 |
| 250 | 2,847 | 156 | 694 |
| Self-Contained (air cooled) | | | |
| 50 | 1,260 | 152 | 373 |
| 100 | 2,018 | 133 | 509 |
| 150 | 2,272 | 0 | 408 |
| 200 | 3,066 | 290 | 845 |

Notes: Base Case energy use from "best fit" line from ACEEE analysis. Energy use figures assume average unit operates at 40% of capacity (based on data in ADL 1996). Tier 1 and Tier 2 savings assume average qualifying model 3% below the qualifying threshold.

Source: Nadel 2002a.

## 4.2. Proposed test method

Commercial packaged refrigerator and freezers are covered by existing CEC standards. The same test methods can be used for updated standards (this is ANSI/ASHRAE standard 117-1992 for measuring energy use and ANSI/AHAM HRF1-1979 for measuring volume, the former as clarified in Table A-2 of the CEC Appliance Efficiency Regulations). For ice-makers, the main test procedure in use is ARI 810. This method in turn is based on an ASHRAE test method. We recommend that the CEC use ARI 810-2003 for ice-makers (the 2003 edition is the most recent).

### 4.3. Efficiency measures

*Commercial Packaged Refrigerators and Freezers*

Efficiency of commercial refrigerators and freezers can be improved through use of better compressors, better fan motors, better controls, and improved insulation (including triple pane and/or low-e glass for transparent door units). For example, DOE, Arthur D. Little, Inc. and Delfield, (a major commercial refrigerator and freezer manufacturer) worked together recently on the design of the new Delfield Vantage 6000 series of refrigerators and freezers. The new series uses a new cabinet design and innovative materials to improve insulation and decrease thermal leakage. They also feature brushless DC evaporator fans, reduced anti-sweat heater wattage, a condensate trap, and optimized refrigeration design. The new units reduce energy use up to 68% relative to comparable prior Delfield models. Furthermore, according to Delfield, the more efficient models cost less to produce than the baseline models due to production cost savings from improved design (production cost savings are greater than the cost to improve efficiency) (ADL 2001; Sunderman 2002).

*Ice-Makers*

Ice-maker efficiency can also be improved with improved compressors, heat exchangers and controls. Also, better insulation and gaskets can improve the performance of ice-storage bins. For example, in September 2003 Manitowac (the largest U.S. ice-maker manufacturer introduced their new S series of units. The units include full insulation, increased evaporator area, and an improved ice-harvest system. The new units also feature sanitation improvements, easier cleaning and lower noise. They claim up to 30% energy savings relative to other ice-makers on the market. Energy performance data on the machines are not yet public but will be included in upcoming ARI Directories. They expect many of the models to reach CEE Tier 2 (Manitowac 2003; Rimrodt 2003)

### 4.4. Standards Options

**Table 5. Energy Star and CEE Specification for Solid-Door Commercial Packaged Refrigerators and Freezers**

| Equipment | Tier | Description of Specification | Maximum Energy Use (kWh/day) |
|---|---|---|---|
| Refrigerator | 1 | Energy Star | 0.10V + 2.040 |
| | 2 | Energy Star + 40% | 0.06V + 1.220 |
| Freezer | 1 | Energy Star | 0.40V + 1.380 |
| | 2 | Energy Star + 30% | 0.28V + 0.097 |
| Refrigerator-Freezer | 1 | Energy Star (not a CEE tier) | 0.27AV - 0.710 |

V = Internal Volume

AV = Adjusted volume [refrigerator volume + 1.63 * freezer volume]

The most viable standards options are defined by specifications already in use including the Energy Star and CEE tier 2 specifications for solid-door commercial packaged refrigerators, freezers, and refrigerator-freezers; the CEE tier 1 and 2 specifications for ice-makers, and the CEE tier 1 and tier 2 specifications for glass-door refrigerators. These specifications are summarized in Tables 5, 6 and 7.

**Table 6. CEE Specifications for Ice-Makers**

| Equipment Type | Harvest Rate (100lbs ice/24 hrs) | Tier | Corresponding Base Specification | Max. Daily Energy Use (kWh per 100 lbs. Ice) | Max. Daily Water Use (gallons per 100 lbs. ice) |
|---|---|---|---|---|---|
| Ice-Making Head Water Cooled | <500 lbs./day | 1 | Approx. FEMP | 7.80 - .0055H | 200 - .022H |
| | | 2 | 20% below Tier 1 | 6.24 - .0044H | 200 - .022H |
| | ≥500 lbs./day | 1 | Approx. FEMP | 5.58 - .0011H | 200 - .022H |
| | | 2 | 20% below Tier 1 | 4.46 - .0008H | 200 - .022H |
| Ice-Making Head Air Cooled | <450 lbs./day | 1 | Approx. FEMP | 10.26 - .0086H | Not Applicable |
| | | 2 | 20% below Tier 1 | 8.21 - .0069H | Not Applicable |
| | ≥450 lbs./day | 1 | Approx. FEMP | 6.89 - .0011H | Not Applicable |
| | | 2 | 20% below Tier 1 | 5.51 - .0009H | Not Applicable |
| Remote-Condensing Air Cooled | <1000 lbs./day | 1 | Approx. FEMP | 8.85 - .0038H | Not Applicable |
| | | 2 | 20% below Tier 1 | 7.08 - .0030H | Not Applicable |
| | ≥1000 lbs./day | 1 | Approx. FEMP | 5.10 | Not Applicable |
| | | 2 | 20% below Tier 1 | 4.08 | Not Applicable |
| Self-Contained Water Cooled | <200 lbs./day | 1 | Approx. FEMP | 11.40 - .0190H | 191 - .0315H |
| | | 2 | 20% below Tier 1 | 9.12 - .0152H | 191 - .0315H |
| | ≥200 lbs./day | 1 | Approx. FEMP | 7.60 | 191 - .0315H |
| | | 2 | 20% below Tier 1 | 6.08 | 191 - .0315H |
| Self-Contained Air Cooled | <175 lbs./day | 1 | Approx. FEMP | 18.0 - .0469H | Not Applicable |
| | | 2 | 20% below Tier 1 | 14.4 - .0375H | Not Applicable |
| | ≥175 lbs./day | 1 | Approx. FEMP | 9.80 | Not Applicable |
| | | 2 | 20% below Tier 1 | 7.84 | Not Applicable |

H = harvest rate in 100 lbs. ice per 24 hours.
Source: Nadel 2002a.

**Table 7. CEE Specification for Transparent-Door Refrigerators.**

| Equipment | Tier | Description of Specification | Maximum Energy Use (kWh/day) |
|---|---|---|---|
| Refrigerator | 1 | CEE tier 1 (30% below CEC 2004 standard) | 0.12V + 3.34 |
| | 2 | CEE tier 2 (50% below CEC 2004 standard) | 0.082V + 2.29 |

V = Internal Volume

Three other product categories also merit discussion under the topic of potential standard levels. First, while neither CEE nor Energy Star has developed a specification for transparent door freezers, as part of this CASE study we examined data in the CEC database on these products. Specifically, the CEC database contains 48 unique units. We plotted these on a graph and drew lines for various levels of savings below the CEC 2004 standard. At 20% below the CEC 2004 standard, there are a significant number of models that meet the specification across the size spectrum, so this level may be appropriate for a new standard. The specific equation is:

Maximum Daily Energy Consumption (kWh) = 0.75 V + 4.1.

Of the 48 unique units in the CEC database, 15 meet this standard. The full graphic analysis is shown in Figure 3.

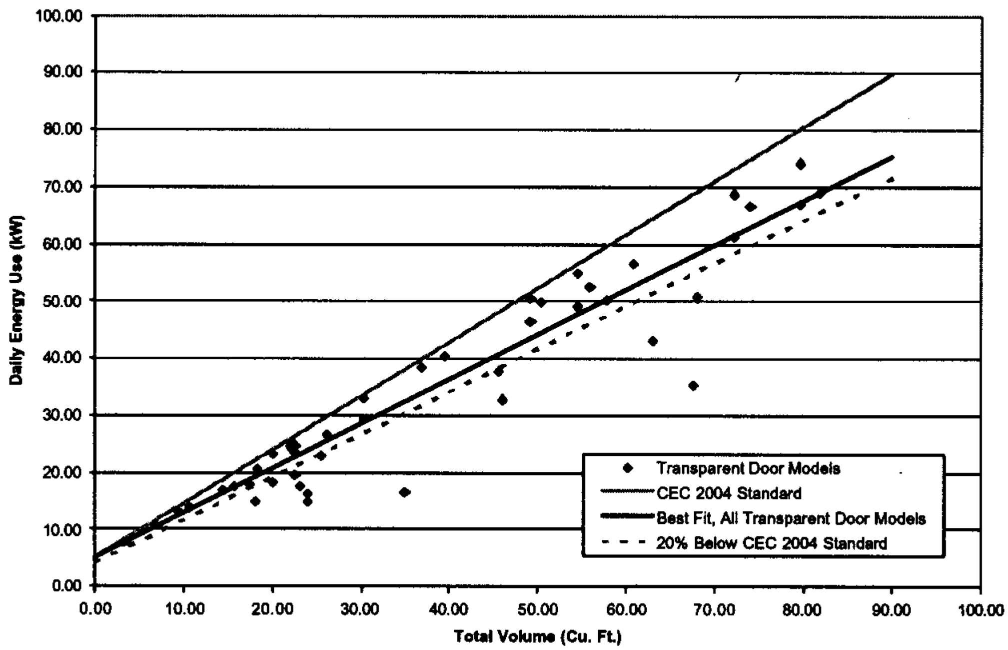


**Figure 3. Analysis of Transparent Door Freezers in CEC Database.**

Second, Energy Star has also established a separate specification for solid-door ice-cream freezers. An ice-cream freezer is designed for a slightly colder temperature than a normal freezer (-5° F vs. 0° F). California could adopt this as a minimum standard. If such a standard were adopted, a specific definition for this product class is needed. For example, Energy Star defines "commercial ice cream freezer" as "a cabinet designed for storing food or other perishable items at temperatures of –5 degrees F or below." To qualify for Energy Star, an ice cream freezer must meet the following performance levels:

Maximum Daily Energy Consumption (kWh) = 0.39 V + 0.82

The CEC database contains 29 solid-door ice-cream freezers, of which 7 meet the Energy Star specification.

Third, there are beverage merchandisers without doors. Units without doors use more energy than units with doors. It appears that no-door units are becoming more common. To keep these units at least moderately efficient, a standard could be set for no-door units. For example, the 2004 standard for glass-door units could be extended to no-door units. The CEC has data in its database on two no-door units. One of these passes the 2004 transparent-door standard, the other does not. This indicates that such a standard may be feasible, although the sample size is very small.

### 4.5. Energy Savings

*Commercial Packaged Refrigerators and Freezers*

Per unit savings for commercial refrigerators and freezers and ice-makers are shown in Table 3 and 4 respectively.

For commercial packaged refrigerators, energy savings for Energy Star units range from approximately 500 to 1100 kWh per year, depending on unit size. Savings from the CEE Tier 2 values are more than twice as great (ranging from about 1100 to 2400 kWh per year). In other words, CEE Tier 2 will provide incremental savings of 600 to 1300 kWh per year beyond what the Energy Star specification provides. For commercial packaged freezers, savings from Energy Star units are a little smaller than for refrigerators (since the Energy Star specification is only marginally different from the average unit on the market). Savings for Energy Star freezers range from approximately 500-800 kWh per year, depending on unit size. On the other hand, savings from CEE Tier 2 for freezers are more than three times greater than savings from Energy Star. Tier 2 freezer savings range from about 1600 to 4000 kWh per year for each unit (1100-3200 kWh per year more than Energy Star).

Savings with transparent-door refrigerators are substantially larger than those for solid-door refrigerators, with savings ranging from about 1100-2100 kWh per year for Tier 1 and 1700-3300 kWh per year for Tier 2 (an increment of 600-1200 kWh per year relative to Tier 1). Similarly, transparent-door freezers are substantial – 2,647 kWh per unit on average to go from the current California standard to the proposed new standard.

*Ice-Makers*

For ice-making heads, the most widely sold equipment type, savings range from about 300-1000 kWh/year for tier 1 (depending on equipment type and size), and from 700-2400 kWh/year for tier 2. Details are provided in Table 4.

In order to estimate the total savings in California from each of the standard options, we applied the per unit savings to the data on estimated equipment stock discussed in section 3.1. This analysis also includes an adjustment for the current market share of efficient equipment (as discussed in section 3.3). Included in this analysis are estimates of peak demand impact. We estimate peak demand for commercial refrigerator and freezers and ice-makers based on the ratio of annual energy use as peak demand as calculated by Kubo et al. (2001). Their calculations estimate that peak demand from commercial packaged refrigeration systems is a little (not a lot) higher on warm peak days than on normal days. Our analysis is contained in Table 8.

Overall, we estimate that adoption of the Tier 1 standards on all three products would save approximately 203 million kWh/year in California after the existing stock turns over, resulting in peak demand savings of about 39 MW. About 38% of the savings come from beverage merchandisers and other glass door refrigerators, 34% from solid-door refrigerators and freezers, and 28% from ice-makers. Annualized savings after one year of implementation will total approximately 22.9 million kWh/year and 4.4 MW.

For Tier 2 standards, savings are about three-times greater than the Tier 1 savings. Savings total 637 million kWh and 122 MW once the equipment stock turns over. For Tier 2, 51% of the savings come from solid-door refrigerators and freezers, 26% from ice-makers, and 23% from glass-door refrigerators. Annualized savings after one year of implementation will total approximately 72.0 million kWh/year and 13.9 MW.

## 5. Economic Analysis

### 5.1. Incremental cost

*Commercial Packaged Refrigerators and Freezers*

ACEEE recently completed a survey for NYSERDA on the market for commercial refrigerators, freezers and ice-makers (Smith et al. 2003). The survey included several questions on the incremental cost of tier 1 and tier 2 equipment. Responses were obtained from equipment manufacturers and distributors. Overall, the survey found significant variation in incremental costs from one respondent to another, but also included computation of average cost increments across many respondents.

For solid-door commercial refrigerators and freezers, respondents estimated that tier 1 equipment costs ranged from 10% less than standard equipment to 25% more. The average response was 5-8% more expensive. For tier 2, responses ranged from no cost increase to 50% higher cost, with an average response of 13-14% higher. We then applied these percentage estimates to typical equipment costs from a previous NYSERDA study (as cited in Nadel 2002a) to estimate incremental costs. Using this method, incremental costs for tier 1 equipment range from $94-233 depending on the size of the equipment, while those for tier 2 range from $196-485. In our lifecycle cost analysis we also developed a sensitivity case in which incremental costs were doubled from the primary values.

**Table 8. Energy and Demand Savings from More California Efficiency Standards on Reach-Ins and Ice-Makers.**

| | Estimated California Stock | Basecase kWh/unit | Basecase GWh for CA | Basecase MW for CA | Tier 1 Savings kWh/unit | Tier 1 Savings Mkt Share | Tier 1 Savings GWh for CA | Tier 1 Savings MW for CA | Tier 2 Savings kWh/unit | Tier 2 Savings Mkt Share | Tier 2 Savings GWh for CA | Tier 2 Savings MW for CA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reach-In Refrigerators and Freezers** | | | | | | | | | | | | |
| Solid-door refrigerators | | | | | | | | | | | | |
| 24 cf (one door) | 35,100 | 2,102 | 74 | 14 | 563 | 45% | 11 | 2 | 1,179 | 5% | 39 | 8 |
| 48 cf (two door) | 76,050 | 3,197 | 243 | 47 | 826 | 45% | 35 | 7 | 1,774 | 5% | 128 | 25 |
| 72 cf (three door) | 5,850 | 4,292 | 25 | 5 | 1,088 | 45% | 4 | 1 | 2,370 | 5% | 13 | 3 |
| Solid-door freezers | | | | | | | | | | | | |
| 24 cf (one door) | 39,600 | 4,319 | 171 | 33 | 511 | 55% | 9 | 2 | 1,654 | 10% | 59 | 11 |
| 48 cf (two door) | 28,800 | 7,805 | 225 | 43 | 669 | 55% | 9 | 2 | 2,810 | 10% | 73 | 14 |
| 72 cf (three door) | 3,600 | 11,292 | 41 | 8 | 827 | 55% | 1 | 0 | 3,966 | 10% | 13 | 2 |
| Beverage merchandisers | | | | | | | | | | | | |
| 24 cf (one door) | 36,000 | 3,248 | 117 | 22 | 1,091 | 20% | 31 | 6 | 1,705 | 5% | 58 | 11 |
| 48 cf (two door) | 32,400 | 4,754 | 154 | 30 | 1,599 | 20% | 41 | 8 | 2,496 | 5% | 77 | 15 |
| 72 cf (three door) | 3,600 | 6,261 | 23 | 4 | 2,107 | 20% | 6 | 1 | 3,287 | 5% | 11 | 2 |
| Transparent-door freezer | 1,760 | 13,149 | 23 | 4 | 2,647 | 31% | 3 | 1 | NA | NA | NA | NA |
| Subtotal | 262,760 | | 1,095 | 210 | | | 150 | 29 | | | 472 | 91 |
| **Ice-makers** | | | | | | | | | | | | |
| Self-contained | 106,131 | 2,272 | 241 | 46 | 148 | 22% | 12 | 2 | 408 | 0% | 43 | 8 |
| IMH & RCU | 66,869 | 6,085 | 407 | 78 | 848 | 22% | 44 | 8 | 1,831 | 0% | 122 | 24 |
| Subtotal | 173,000 | | 648 | 124 | | | 56 | 11 | | | 166 | 32 |
| TOTAL | 435,760 | | 1,743 | 334 | | | 207 | 40 | | | 637 | 122 |

cf = cubic feet.

For glass-door refrigerators, two cost estimates for tier 1 equipment are available. First, in 2002 ACEEE examined the list price of units that do and do not meet the draft tier 1 specification. Essentially no price difference was found (Nadel 2002b). Second, ADL in 1996 estimated the incremental cost of different technical improvements needed to improve unit efficiency. Based on these estimates, the incremental cost of reaching tier 1 could be as much as $244 for a typical one-door unit. Nadel (2002b) examined this $0-244 range and concluded that the likely incremental cost is toward the lower end of this range (Nadel 2002b). Based on this analysis, we estimate a $100 incremental cost for a tier 1 one-door unit and then increase this by 50% for a two-door unit (in line with the difference in base equipment costs between one- and two-door units – ADL 1996). Data on tier 2 costs is not available, but based on the data for solid-door units, we estimate that the incremental cost of tier 2 will be twice the incremental cost of tier 1.

For glass-door freezers, we could not find any published cost estimates but we would expect the incremental costs to be similar to those for tier 1 for solid-door freezers and glass-door refrigerators (the incremental costs for these two product classes are similar to each other – see Table 9).

*Ice-Makers*

In the case of ice-makers, the study for NYSERDA found that often tier 1 ice-makers cost the same as standard ice-makers due to strong price competition between manufacturers. However, some respondents estimated that the price of tier 1 equipment was a little higher. Overall, on average, respondents estimated that tier 1 ice-makers cost 4% more than standard ice-makers (Smith et al. 2003). These percentages were then applied to basecase costs obtained for a previous ACEEE study (Nadel 2002a).

For tier 2, the only price estimate we obtained was a $200 incremental cost relative to a tier 1 unit for an average-sized ice-making head unit. This estimate came from a major manufacturer who wished to remain anonymous (Nadel 2002a). No tier 2 self-contained models are now produced, so we could not obtain market prices for these units. Instead, based on the $200 price increment discussed above and the relationship between the cost of standard ice-making head and self-contained units, we estimate an incremental cost of $100 relative to tier 1.

The base and incremental costs for all three types of equipment are provided in Table 9. Additional details on base costs by type of equipment can be found in Nadel 2002a.

### 5.2. Design life

The expected equipment life of commercial packaged refrigerators and freezers is approximately 8–10 years. The expected equipment life of ice makers and beverage merchandisers is in the range of 7-10 years (ADL 1996).

### 5.3. Life cycle cost

Lifecycle cost for different type and size units can be estimated using the data described above including the data on energy savings, incremental equipment cost, and equipment life. Two other assumptions are needed – discount rate and electricity price. In 2001, the CEC developed estimates of the present value of statewide energy costs for different

**Table 9. Economics of Standards on Reach-Ins and Ice-Makers.**

| | | Tier 1 | | | | Tier 2 | | | | NPV ($) Sensitivity Case (if cost doubled) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Base Cost ($) | Cost Increment ($) | kWh Saved | PV of Benefits | NPV($) | Cost Increment ($) | kWh Saved | PV of Benefits ($) | NPV ($) | Tier 1 | Tier 2 |
| **Reach-In Refrigerators and Freezers** | | | | | | | | | | | |
| Solid-door refrigerators | | | | | | | | | | | |
| 24 (one door) | 1,450 | 94 | 563 | 491 | 397 | 196 | 1,179 | 1,028 | 832 | 302 | 637 |
| 48 (two door) | 1,980 | 129 | 826 | 720 | 592 | 267 | 1,774 | 1,547 | 1,280 | 463 | 1,012 |
| 72 (three door) | 2,710 | 176 | 1,088 | 949 | 773 | 366 | 2,370 | 2,067 | 1,701 | 596 | 1,335 |
| Solid-door freezers | | | | | | | | | | | |
| 24 (one door) | 1,900 | 124 | 511 | 446 | 322 | 257 | 1,654 | 1,442 | 1,186 | 199 | 929 |
| 48 (two door) | 2,600 | 169 | 669 | 583 | 414 | 351 | 2,810 | 2,450 | 2,099 | 245 | 1,748 |
| 72 (three door) | 3,590 | 233 | 827 | 721 | 488 | 485 | 3,966 | 3,458 | 2,974 | 254 | 2,489 |
| Beverage merchandisers | | | | | | | | | | | |
| 24 (one door) | 1,400 | 100 | 1,091 | 951 | 851 | 200 | 1,705 | 1,487 | 1,287 | 751 | 1,087 |
| 48 (two door) | 1,920 | 150 | 1,599 | 1,394 | 1,244 | 300 | 2,496 | 2,177 | 1,877 | 1,094 | 1,577 |
| 72 (three door) | 2,630 | 200 | 2,107 | 1,837 | 1,637 | 400 | 3,287 | 2,866 | 2,466 | 1,437 | 2,066 |
| Transparent-door freezer | NA | 138 | 2,647 | 2,308 | 2,170 | NA | NA | NA | NA | 2,032 | NA |
| **Ice-makers** | | | | | | | | | | | |
| Self-contained | 1,565 | 31 | 148 | 129 | 98 | 131 | 408 | 356 | 224 | 66 | 93 |
| IMH & RCU | 2,846 | 114 | 848 | 739 | 626 | 314 | 1,831 | 1,597 | 1,283 | 512 | 969 |

Notes:
* Used present value energy costs for small commercial customers from Martin and Holland 2001.
* 9 year life for refrigerators and freezers, 8.5 for ice-makers
* Used only a 2% cost increment for tier 1 self-contained units since for a 150 lbs/day machine, there is little difference in efficiency between a basecase and tier 1 machine.

customer classes and different average measure lives. In the case of small commercial customers, for measures with a 9 year average life (e.g., the equipment discussed in this report), the present value of electricity savings is $0.872 for a measure that saves one kWh per year. Using these assumptions, we calculated the life cycle cost of different types and sizes of packaged commercial refrigeration equipment. The results are provided in Table 9.

Overall, based on this analysis we conclude that the net present value benefits of tier 1 equipment to the end-user ranges from $300-800 for solid-door refrigerators and freezers, $800-1600 for glass-door refrigerators, nearly $2200 for a typical glass-door freezer, $100 for a typical small ice-maker, and $600 for a typical large ice-maker. For tier 2, net present value benefits are generally around twice those of tier 1 equipment.

We also ran a series of sensitivity cases in which incremental costs were doubled relative to the primary case. Even in each of these sensitivity cases, there were substantial net present value benefits. These results are also included in Table 9.

## 6. Acceptance Issues

### 6.1. Infrastructure Issues

In the case of commercial packaged refrigerators and freezers, reach-ins meeting tier 1 are widely available, including units from many manufacturers. However, some of the niche products such as roll-ins, pass-throughs, and roll-throughs are not as widely available and manufacturers may need a little extra time to bring more units to market. There is also tier 2 equipment on the market, although availability is more limited. Some time will be needed for manufacturers to upgrade all their models to tier 1, and significantly more time will be needed to upgrade to tier 2.

For beverage merchandisers, some equipment has oversized compressors in order to rapidly cool-down drinks. With these oversized compressors, these machines can cool a full load of warm drinks by 5.5° F or more an hour (Martin 2003, based on conversations with CEC contract test laboratory). We have examined the CEC database and found several beverage merchandisers from a major manufacturer that meet the CEE tier 1 standard. However, these units narrowly miss the draft CEE tier 2 standard. It is likely that these units can be "tweaked" to meet tier 2, either with small changes to system components or with more major changes such as use of "low-e" glass or variable-speed compressors.

For glass-door freezers, most manufacturers listed in the CEC database have complying models and complying models are available in a range of sizes (see Figure 3).

In the case of ice-makers, units meeting tier 1 are extensively available from 3 out of 5 of the major manufacturers. The other two manufacturers will need some time to bring the more efficient units to market. The technologies are fairly basic, but time will be required for unit redesign and production line retooling.

### 6.2. Existing Standards

The only existing mandatory standards for packaged commercial refrigeration equipment are California's own 2003 and 2004 minimum efficiency standards for commercial packaged refrigerators and freezers. Similar standards are being considered by other states. For example, the Maryland legislature passed a bill in 2003 establishing such standards. The Governor vetoed the bill (primarily due to other more controversial standards in the same bill) and the veto was overridden by the legislature in January 2004. Similar legislation is pending in many northeastern states. In addition, the U.S., House and Senate have passed bills directing DOE to establish standards on commercial packaged refrigerators and freezers. Assuming the bill passes in early-2004, DOE is instructed to set a standard by early 2009, with the standard going into effect three years later (U.S. Senate 2003).

Otherwise, there are a series of voluntary standards for this equipment. The CEE and Energy Star standards were discussed previously. In addition, FEMP has established a purchasing specification for ice-makers, which while different in format from CEE tier 1, is approximately similar in stringency (FEMP 2000). There are also voluntary standards developed by the Canadian Standards Association for both ice-makers (CSA 1998a) and commercial packaged refrigerators and freezers (CSA 1998b).

## 7. Recommendations

Both the tier 1 and tier 2 standards are cost-effective to end-users. Both will save a substantial amount of energy. Equipment meeting the tier 1 standard is available from many manufacturers. We recommend that the CEC adopt this set of standards. For solid-door reach-in refrigerators and freezers, this equipment already accounts for nearly half of sales, and an effective date of Jan 1, 2006 is appropriate -- nearly 18 months after the August 2004 California standard for commercial refrigerators and freezers takes effect.

For ice-makers, transparent-door refrigerators, and roll-in, pass-through and roll-through refrigerators and freezers, manufacturers need a little more time to prepare. We recommend an effective date of Jan. 1, 2007. In addition, the CEC should probably include a standard for solid-door ice-cream freezers at the Energy Star level, probably effective Jan. 1, 2007. In addition, in order to discourage use of no-door beverage merchandisers, CEC should also consider applying the August 2004 standard for glass-door refrigerators to no-door refrigerators. We recommend the same Jan. 1, 2007 effective date. A revised standard on transparent-door freezers, 20% lower than the 2004 standard, is also viable. Again, manufacturers will need time to prepare, so we recommend an effective date of Jan. 1, 2007.

In sum, we recommend that the following information be added to Table A-6 in the current CEC *Appliance Efficiency Regulations* (new language is in *italics*):

| Appliance | Doors | Maximum Daily Energy Consumption (kWh) | |
|---|---|---|---|
| | | *January 1, 2006* | *January 1, 2007* |
| Reach-in cabinets, pass-through cabinets, and roll-in or roll-through cabinets that are refrigerators; and wine chillers that are not consumer products | Solid | *0.10V + 2.04* | Same as 2006 std. |
| | Transparent | 0.172V + 4.77 (same as 2004 std.) | *0.12V + 3.34* |
| | *Open in front (no door)* | -- | *0.172V + 4.77* |
| Reach-in cabinets, pass-through cabinets, and roll-in or roll-through cabinets that are freezers | Solid | *0.40V + 1.38* | Same as 2006 std. |
| | Transparent | 0.94 + 5.1 | *0.75V + 4.1* |
| *Ice-cream freezers* | *Solid* | -- | *0.39V + 0.82* |
| Reach-in cabinets that are refrigerator-freezers | Solid | 0.273 + 1.65 (same as 2004 std.) | *0.27AV - 0.71* |
| V = total volume ($ft^3$)<br>AV = Adjusted Volume = [1.63 x freezer volume ($ft^3$)] + refrigerator volume ($ft^3$) | | | |

In addition, we recommend that the following be added to Section 1605.3(a) of the current regulations in order to include ice-makers:

(6) ***Energy Efficiency Standards for Commercial –Ice-Maker.*** *The daily energy use and the daily water use of commercial ice makers manufactured on or after January 1, 2007, shall be no greater than the applicable values shown in Table A-7.*

***Table A-7***
***Standards for Commercial Ice Makers***

| ***Equipment Type*** | ***Type of Cooling*** | ***Harvest Rate*** *(100 lbs ice/ 24 hrs)* | ***Maximum Daily Energy Use*** *(kWh/100 lbs. Ice)* | ***Maximum Daily Water Use*** *(gallons/100 lbs. ice)* |
|---|---|---|---|---|
| *Ice-Making Head* | *Water* | *<500 lbs./day* | *7.80 - .0055H* | *200 - .022H* |
| | | *≥500 lbs./day* | *5.58 - .0011H* | *200 - .022H* |
| *Ice-Making Head* | *Air* | *<450 lbs./day* | *10.26 - .0086H* | *Not Applicable* |
| | | *≥450 lbs./day* | *6.89 - .0011H* | *Not Applicable* |
| *Remote-Condensing* | *Air* | *<1000 lbs./day* | *8.85 - .0038H* | *Not Applicable* |
| | | *≥1000 lbs./day* | *5.10* | *Not Applicable* |
| *Self-Contained* | *Water* | *<200 lbs./day* | *11.40 - .0190H* | *191 - .0315H* |
| | | *≥200 lbs./day* | *7.60* | *191 - .0315H* |
| *Self-Contained* | *Air* | *<175 lbs./day* | *18.0 - .0469H* | *Not Applicable* |
| | | *≥175 lbs./day* | *9.80* | *Not Applicable* |

H= harvest rate, expressed in 100 lbs. of ice per 24 hours.

Several of the terms in the above table need defining. We suggest the following definitions:

"Commercial ice-maker" means a factory-made assembly (not necessarily shipped in one package) consisting of a condensing unit and ice-making section operating as an integrated unit, with means for making and harvesting ice. It may also include means for storing or dispensing ice, or both.

"Air-cooled" means a condensing unit which utilizes refrigerant-to-air heat transfer means.

"Water-cooled" means a condensing unit which utilizes a refrigerant-to-water heat transfer means.

"Ice-making head" means a commercial ice-maker that does not include a storage compartment in an integral cabinet and that is not a *remote condensing unit*.

"Self-contained ice-maker" means an automatic commercial ice-maker in which the ice-making mechanism and storage compartment are in an integral cabinet.

"Remote condensing ice-maker" means an automatic commercial ice-maker in which the icemaking mechanism and condenser or condensing unit are in separate sections.

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