# Laboratory Grade Refrigerator and Freezer
# Data Analysis and Framework Document

September 7, 2010

## 1. BACKGROUND AND SUMMARY OF THIS DOCUMENT

In late 2007, EPA relayed its interest in evaluating whether a unique specification for Laboratory Grade Refrigerators and Freezers would meet the ENERGY STAR guiding principles. Doing so would provide tailored requirements for these products that EPA believed differ from Commercial (Food Service) Refrigerator/Freezers, a current ENERGY STAR product category. The first step in this evaluation was the development of a test method that measured the performance of laboratory grade equipment under typical operating conditions.

EPA reviewed the applicability of ASHRAE Standard 72-2005: Method of Testing Commercial Refrigerators and Freezers, and requested recommendations on modifications to the procedure for testing laboratory grade products. Following stakeholder meetings in May 2008 and January 2009, EPA developed, with stakeholder input, a supplement to ASHRAE Standard 72-2005 that provided a means of evaluating the performance of laboratory grade refrigerators and freezers. The final version of the supplement was released on December 30, 2009, at which point, manufacturers began testing equipment and sharing data with EPA. This document presents the analysis of the manufacturer-supplied test results and identifies specific topics for discussion regarding the potential development of an ENERGY STAR specification for laboratory grade refrigerators and freezers. In general, EPA is interested in feedback on:

- The test data, and whether it is representative of the diversity and differentiation of products in the marketplace.
- The importance of consistency with the commercial refrigerator and freezer specification.
- General recommendations on approaches in cases when the data is limited or equivocal.

These issues and any others recommended by stakeholders will be discussed in an upcoming Webinar, scheduled for September 22, 2010.

The remainder of this document presents an analysis of the data and documents how EPA plans to use the data in the development of a potential ENERGY STAR specification for laboratory grade equipment.

### 1.1 Definitions

#### 1.1.1 Laboratory Grade Refrigerator

A refrigerated cabinet used for storing non-volatile reagents and biological specimens at temperatures between 23 and 53.6 ºF (-5 and 12 ºC), typically marketed through laboratory equipment supply stores for laboratory and medical use. This definition includes both upright and under-counter units.

### 1.1.2 Laboratory Grade Freezer

A refrigerated cabinet used for storing volatile reagents and biological specimens at temperatures between -40 and 50 ºF (-40 and 10 ºC), typically marketed through laboratory equipment supply stores for laboratory and medical use. This definition includes both upright and under-counter units.

### 1.1.3 Combination Laboratory Grade Refrigerator/Freezer

A product composed of two or more refrigerated cabinets, one of which meets the definition of Laboratory Grade Refrigerator and another that meets the definition of Laboratory Grade Freezer.

### 1.1.4 Portable Laboratory Refrigerator/Freezer

A refrigerated cabinet used for transporting perishable samples or products, and includes an integral battery or DC power cable to power the refrigeration process when disconnected from AC mains.

### 1.1.5 Explosion Proof Refrigerator/Freezer

A product that is composed of a refrigerated cabinet that prevents arcing both inside and outside the cabinet and is typically used when flammable vapors are present, resulting in an explosive atmosphere during standard operation.

### 1.1.6 Ultra-Low Temperature Laboratory Freezer

A refrigerated cabinet used for long-term preservation volatile reagents and biological specimens at temperatures below -40 ºF (-40 ºC).

### 1.1.7 Walk-in Laboratory Grade Refrigerator

A larger laboratory grade refrigerator that is either built-in or composed of prefabricated sectional walk-in units.

## 1.2 Overview of Data Submitted

Only three participating manufacturers reported test results on a total of 32 units. The test procedures were documented in the ENERGY STAR Supplement to ANSI/ASHRAE Standard 72-2005 for Laboratory Grade Refrigerators and Freezers. The test data covered a range of equipment, including refrigerators and freezers of various sizes, temperatures, door options, and defrost settings. The types of equipment tested by manufacturers are summarized in Table 1, below.

**Table 1. Overview of test data**

| Equipment Type | Nominal Temperature | Door Type | Defrost Strategy | Total |
|---|---|---|---|---|
| **Freezer** | -20° C (-4° F) | Solid | Automatic | 1 |
| | | | Manual | 3 |
| | | | Continuous | 1 |
| | -30° C (-22° F) | Solid | Automatic | 7 |
| | | | Manual | 1 |
| **Freezer Total** | | | | **13** |
| **Refrigerator** | +4° C (+39° F) | Glass | Automatic | 5 |
| | | | Manual | 2 |
| | | | Continuous | 2 |
| | | Solid | Automatic | 6 |
| | | | Manual | 1 |
| **Refrigerator Total** | | | | **16** |
| **Refrigerator /Freezer Combination** | | | | **3** |
| **Grand Total** | | | | **32** |

**Note:** EPA seeks comment on:

- whether the definitions in section 1.1 correctly describe the major distinctions between various types of laboratory grade equipment. (Q1)

- whether the temperature ranges, door types, and defrost strategies listed in Table 1 adequately cover the majority of the laboratory grade market. (Q2)

- the prevalence of refrigerator/freezer combination units in laboratory settings as well as recommendations on how best to address them in a specification development process. (Q3)

## 2. ANALYSIS OF THE DATA AND DATA RELATED QUESTIONS

Figure 1 shows an overview of the Total Energy Input data (accumulated over 24-hours) versus the measured interior volume for the various equipment types.

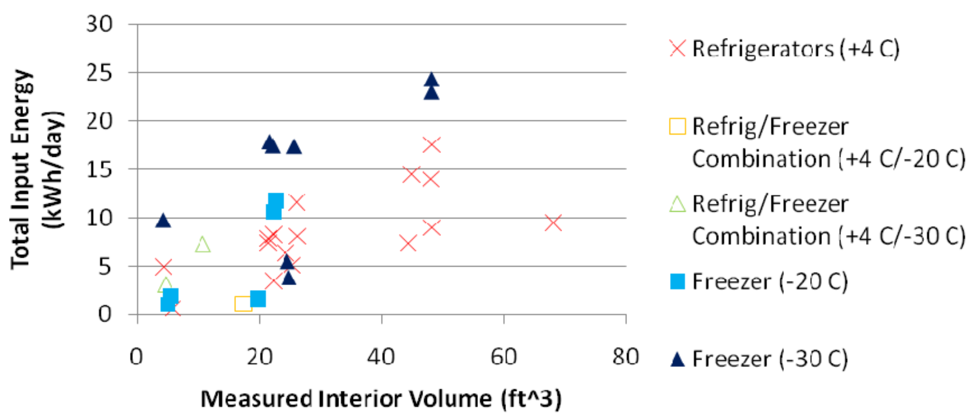


**Figure 1. 24-hour energy consumption by equipment type and interior volume.**

**Note:** EPA seeks comment on whether the range of volumes for each equipment type tested, shown in Figure 1, is representative of the majority of the laboratory grade market. (Q4)

In this initial analysis, EPA evaluated the impact of several product characteristics on energy consumption. Additionally, manufacturers reported, and EPA evaluated, the impact on the average of standard deviations of the data collected by each thermocouple inside the cabinet.

Although some of this data was collected as part of a Temperature Uniformity test, EPA concludes that the average of the standard deviations provides a better measure of temperature *stability*, *i.e.*, the variability of temperature over time at different locations throughout the cabinet. This is because the average standard deviation metric does not capture variability between thermocouple locations, and not all the manufacturers provided the raw thermocouple data from which such a metric could have been calculated.

**Note:** EPA seeks comment on

- the appropriateness of the average standard deviation metric for measuring temperature variation or uniformity in the refrigerated compartment, versus any of other metrics listed in the Appendix, or calculated from those listed in the Appendix. (Q5)

- the relative importance that laboratory grade equipment customers assign to the magnitude versus duration of temperature deviations. (Q6)

The impacts on the above performance metrics were then evaluated for each equipment type and the following product characteristics:

1. Door type
2. Defrosting strategy
3. Intended application

**Note:** EPA seeks comment on:

- the impact of the above product characteristics on performance metrics such as energy consumption and temperature stability or uniformity. (Q7)

- other product characteristics that may significantly impact performance and should be taken into account by EPA when developing the specification. (Q8)

### 2.1 Door Type

As can be seen in Table 1, the refrigerators tested featured either glass or solid metal doors. Glass doors provide customer utility by allowing easy inspection of the contents of the cabinet; however, the maximum potential insulation of glass doors is lower than that of solid doors. As expected, all the freezers tested by manufacturers featured solid doors. Therefore, EPA analyzed the relationship for refrigerators between door type and temperature stability and energy consumption during the 24-hour test, which is illustrated in Figure 2, below.

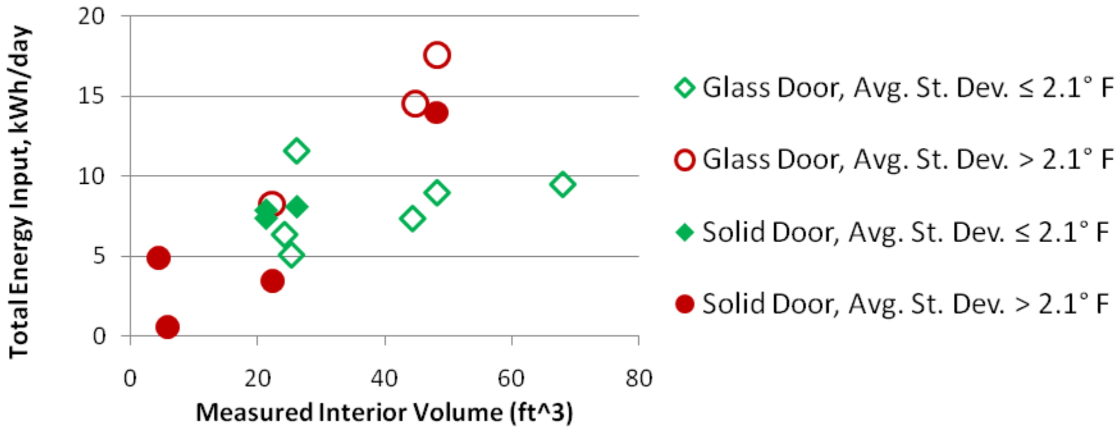


**Figure 2. Performance comparison between glass and solid door refrigerators tested at +4° C (+39° F). (Mean average standard deviation of temperature was 2.1° F)**

As can be seen in the Figure, there appears to be no clear relationship between door type and energy consumption or temperature stability (*i.e.*, average standard deviation) for the units tested. For example, at interior volumes around 25 $ft^3$ both glass- and solid-door refrigerators can maintain better than average temperature stability while consuming similar amounts of energy. However, at higher volumes (approximately 45 $ft^3$), there are a few glass-door refrigerators that offer both significantly lower energy consumption and better stability.

This lack of a clear relationship between door type and equipment performance is in potential conflict with the precedent set by the commercial-grade refrigerators and freezer ENERGY STAR specification, which provides different criteria depending on the door type. Possible explanations for this discrepancy include additional insulation (*e.g.*, triple panes) in the glass doors of laboratory refrigerators as well as insufficient data and impacts of defrosting. Defrosting is discussed in the next section.

**Note:** EPA seeks comment on:

-the representativeness of the above data or whether further tests could be expected to reveal a clearer relationship between refrigerator performance and door type. (Q9)

-the prevalence of glass doors at lower temperatures (i.e., freezers) or specific applications. Are there any applications/temperature ranges that could not be served by equipment with either glass or solid doors? (Q10)

-the impact of additional insulation or any other design features that may explain the lower impact of door type in laboratory grade versus commercial refrigerators. (Q11)

- any differences in usage (e.g., fewer door opening events) that may further differentiate the performance of solid-door and glass-door refrigerators in practical use? (Q12)

## 2.2 Defrosting Strategy

Laboratory grade refrigerators and freezers typically feature a defrost feature, which warms the refrigeration coils to remove any condensed water vapor and prevent the formation of ice crystals. However, since heating may unacceptably increase the temperature inside the refrigerated compartment, some freezer models leave defrosting at the discretion of the operator (manual defrosting) rather than performing it at fixed intervals using a timer (automatic defrosting).

To evaluate the impact of defrosting on temperature stability, EPA compared the average standard deviation of temperature over a 3-hour period that included an explicit, separate defrosting cycle (either automatic or manually initiated by an operator) to the average standard deviation of temperature over a 3-hour steady state period that did not include defrosting. The results are shown in Figure 3.

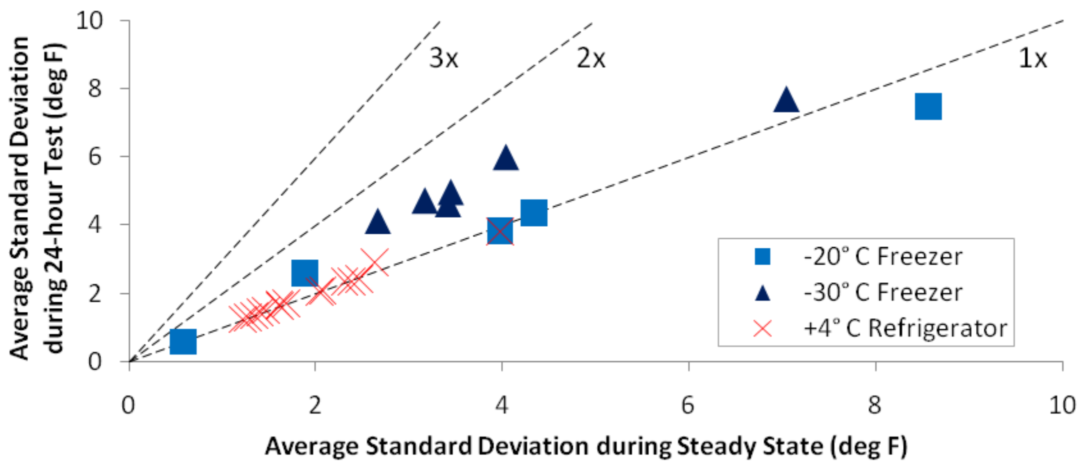


**Figure 3. Relationship between average standard deviation of temperature during defrost and steady state for different equipment types. (Data includes relevant compartment of a refrigerator/freezer combination unit)**

The 1x line in the figure indicates equality between the average standard deviations during defrost and steady-state. Units falling on this line experienced no measureable increase in temperature instability during defrost, while units falling on the 2x line would experience twice the instability during defrost, and so on. As can be seen, with the exception of one -20° C freezer, only -30° C (-22° F) freezers experienced significantly increased temperature instability during defrosting.

**Note:** EPA seeks comment on:

-the apparent lack of temperature variation during the defrost cycle at temperatures warmer than -30° C (-22° F). (Q13)

- how laboratory managers deal with periodic frost build-up in manual-defrost refrigerators. (Q14)

- whether there are any laboratory storage applications that could be served by either automatic or manual defrosting, i.e., are there any applications that are unaffected by defrosting, or could be unaffected given sufficient temperature uniformity during defrosting cycles. (Q15)

EPA also evaluated the impact of defrosting on energy consumption by plotting the energy consumption of laboratory grade equipment using different defrosting strategies. In addition to manual and automatic defrosting, one manufacturer’s products defrost the coils continuously after each and every compressor cycle, *i.e.*, every 7–10 minutes. Because the defrosting action is more frequent, it can be shorter, resulting in smaller temperature variation than automatic defrosting (but greater than manual defrosting). The results are presented in Figure 4 for refrigerators, and Figure 5 and Figure 6 for freezers at -20° C and -30° C, respectively.

**Note:** EPA seeks comment on:

- the utility of continuous defrosting and whether it can be used in applications that typically require manual defrosting. (Q16)

- the relative market share of the three defrosting strategies (manual, automatic, and continuous) for each equipment type and operating temperature. (Q17)

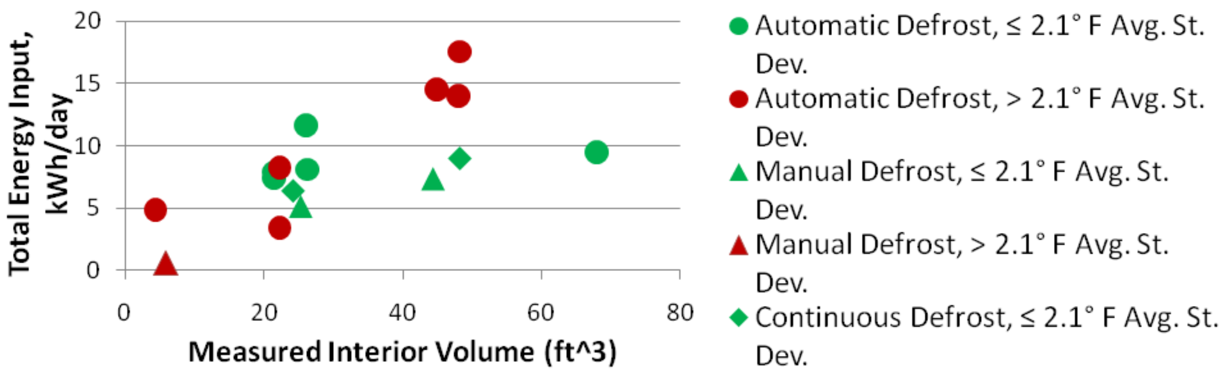


**Figure 4. Impact of defrost strategy on energy consumption and temperature stability over 24 hours for refrigerators at +4° C (+39° F). Mean average standard deviation was 2.1° F.**

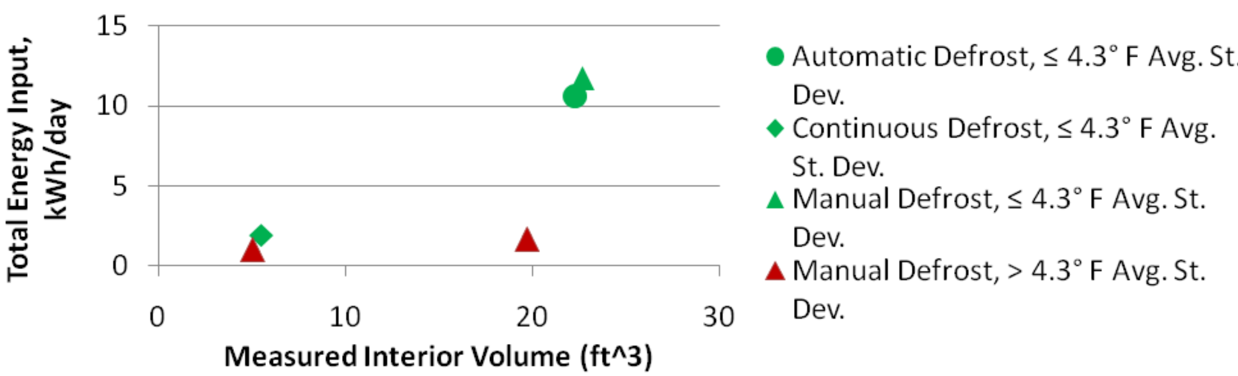


**Figure 5. Impact of defrost strategy on energy consumption and temperature stability over 24 hours for freezers at -20° C (-4° F). Mean average standard deviation was 4.3° F.**

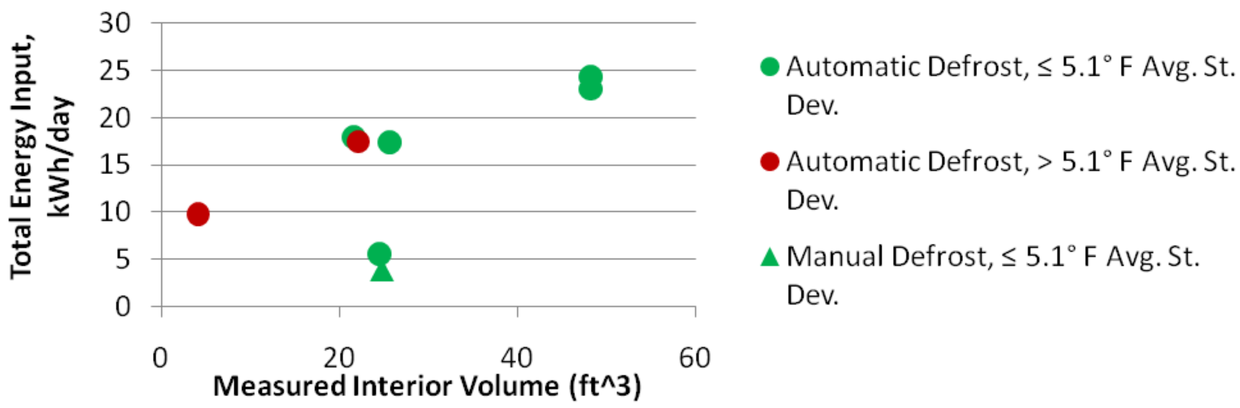


**Figure 6. Impact of defrost strategy on energy consumption and temperature stability over 24 hours for freezers at -30° C (-22° F). Mean average standard deviation was 5.1° F.**

The impact of defrosting on energy consumption is unclear. If temperature stability and defrosting had an unambiguous impact on energy consumption, one would expect a stratification of the data such that automatic defrost and high stability would consume more energy than manual defrost and low stability.

In the case of refrigerators (Figure 4), the manual defrost units do achieve lower energy consumption than automatic defrost units for a given volume; however, there is no apparent relationship between energy consumption and stability. Similarly, -30° C (-22° F) freezers consumed comparable amounts of energy regardless of their temperature stability.

Despite the limitations of the current data, there does appear to be an impact of defrosting on temperature stability (-30° C (-22° F) freezers) and energy consumption (refrigerators). Therefore, it may be appropriate to classify these—and perhaps all—product types depending on their defrost strategy.

**Note:** EPA seeks comment on:

- the representativeness of the above data and whether manual defrosting can generally be expected to provide lower temperature variation and lower energy consumption across all temperatures and interior volumes. (Q18)

- the aggregate impact on temperature stability or uniformity of the regular compressor cycle compared to the defrosting cycle. (Q19)

## 2.3 Intended Application and Other Configuration Options

Laboratory grade refrigerators and freezers are intended for a variety of applications, and manufacturers reported the following in their data submissions:

- Refrigerators: General Purpose/Unspecified, Blood Bank, Chromatography, Pharmaceutical
- Freezers at -20° C (-4° F): General Purpose/Unspecified, Enzyme
- Freezers at -30° C (-22° F): General Purpose/Unspecified, Plasma, Pharmaceutical

Only a few units with niche applications were tested, so it is difficult to ascertain the impact of any additional utility on energy consumption.

**Note:** EPA seeks comment on:

- any additional applications that may require differences in design of laboratory grade equipment. (Q20)

– whether any application-specific design options (e.g., data loggers, portholes, etc.) significantly impact equipment performance, making it more difficult for application-specific equipment to meet consistent specification requirements). (Q21)

## 3. PRODUCT CLASSIFICATIONS FOR CONSIDERATION

Based on the above analysis, EPA developed six sub-categories for laboratory grade equipment, presented in Table 2. EPA is considering refrigerator/freezer combination units as both a refrigerator and freezer (as opposed to providing a separate category or categories), and apportioning any requirements by the volume devoted to refrigeration or freezing.

For example, a combination unit with a 8 $ft^3$ refrigerator cabinet and a 4 $ft^3$ freezer cabinet would have its energy consumption apportioned between the refrigerator and freezer cabinet based on volume, and would be qualified similarly to an 8 $ft^3$ refrigerator with 2/3 the total energy consumption of the combination unit and a 4 $ft^3$ freezer with 1/3 the total energy consumption of the combination unit.

**Table 2: Product Classifications for Consideration**

| Equipment Type | Defrost Strategy |
|---|---|
| **Refrigerators at +4° C (39° F)** | **Automatic** |
| | **Manual or Continuous** |
| **Freezers at -20° C (-4° F)** | **Automatic** |
| | **Manual or Continuous** |
| **Freezers at -30° C (-22° F)** | **Automatic** |
| | **Manual or Continuous** |

**Note:** EPA seeks comment on:

- the classification for laboratory grade equipment, currently under consideration, presented in Table 2. (Q22)

- any potential classifications of refrigerator/freezer combination units. (Q23)

## 4. Next Steps

EPA will work with stakeholders to address the need for additional data to determine efficiency requirements as well as the related questions posed throughout this document. Once these questions and additional data gaps are resolved, EPA will make the final determination regarding development of a unique specification for lab grade refrigerators and freezers. Should EPA determine that moving forward to develop a specification fits with the program's principles, EPA will develop for stakeholder review a Draft 1 specification. EPA will release this draft or will communicate its decision not to develop this spec no later than December 2010.

These draft milestones and future specification development goals are listed below.

**Table 3. Specification Development Milestones**

| Document Publication or Milestone | Date |
|---|---|
| *Laboratory Grade Testing Supplement* | *December 2009* |
| *Data Analysis and Framework document released* | September 7, 2010 |
| Webinar with Stakeholders to discuss EPA analysis | September 22, 2010 |
| Comments due on Framework document | September 30, 2010 |
| Additional manufacturer product testing and data collection/analysis | September–November 2010 |
| EPA decision regarding the development of ENERGY STAR specification | December 2010 |
| Potential Draft 1 Lab Grade Refrigerator/Freezer specification released for comment | January 2011 (Potential) |
| Potential Stakeholder meeting to discuss Draft 1 | February 2011 (Potential) |

EPA looks forward to discussing these topics with stakeholders on **September 22 from 12:30pm to 2:00pm EDT**. Please RSVP to labgraderefrigeration@energystar.gov no later than Monday, September 20, 2010, if you would like to participate. EPA also welcomes written comments on this document and posted questions by September 30, 2010. Please send written comments to labgraderefrigeration@energystar.gov. All comments will be posted to the ENERGY STAR Product Development Web site unless the submitter requests otherwise.

Thank you for your continued support of the ENERGY STAR program. If you have any questions or comments about this document in the meantime, please feel free to contact Christopher Kent, EPA, at kent.christopher@epa.gov or (202) 343-9046, or Matt Malinowski, ICF International, at mmalinowski@icfi.com or (202) 862-2693.

# APPENDIX: DATA COLLECTION FORM

In its Data Collection Form from December 30, 2009, EPA requested that manufacturers provide a description of the unit under test, the particular configuration tested, the ambient environmental data, as well as a schematic indicating the locations of the thermocouples within the unit. Finally, EPA requested the energy and performance data listed below:

| | | |
|---|---|---|
| ***Product Description*** | | |
| **1** | **Manufacturer** | |
| **2** | **Brand** | |
| | **Equipment (Refrigerator or Freezer)** | |
| **3** | **Product Type (General Purpose Refrigerator, Blood Bank Refrigerator, Pharmacy/Chromatography Refrigerator, General Purpose Freezer, -30 Freezer, -20 Freezer, Other [specify])** | |
| **4** | **Model Number Tested** | |
| **5** | **Dates Tested** | |
| **6** | **Size, H x W x D, in.** | |
| **7** | **# Outer Doors** | |
| **8** | **Door Type (Glass, Solid, Other [specify])** | |
| **9** | **Measured Interior Volume, Cubic Feet (AHAM Volume)** | |
| **10** | **Method of Access to Refrigerated Compartment (from above, from front, from front and back, other [specify])** | |
| **11** | **Illumination (Type and Watts)** | |
| **12** | **Refrigerant** | |
| **13** | **Please List Options of Tested Equipment** | |
| | | |
| **14** | **Voltage** | |
| **15** | **Frequency** | |
| **16** | **Phase** | |
| **17** | **Current** | |
| | | |
| **18** | **Every X Minutes for Y Hours** | |
| **19** | **Total Number of Openings** | |
| | | |
| **20** | **Steady State as defined by ANSI/ASHRAE 72 reached (i.e., average temperature of all Thermocouples changes less than 0.2 degrees C from one 24-hour period or refrigeration cycle to the next)? (Y/N)** | |
| **21** | **If No to question above, please describe average temperature change of all Thermocouples after 5 hours with no door openings (± degrees C)** | |
| | | |
| **22** | **Voltage** | |
| **23** | **Frequency** | |
| | | |
| **24** | **Thermostat Setting** | |
| **25** | **Energy Input During Refrigerating Time, kWh/day** | |
| **26** | **Total Energy Input, kWh/day** | |
| **27** | **Total Time Test Period, Min** | |
| **28** | **Percent Compressor Running Time, %** | |
| | | |
| **29** | **Minimum Dry Bulb, Degrees F** | |
| **30** | **Maximum Dry Bulb, Degrees F** | |
| **31** | **Average Dry Bulb, Degrees F** | |
| **32** | **Minimum Wet Bulb, Degrees F** | |
| **33** | **Maximum Wet Bulb, Degrees F** | |
| **34** | **Average Wet Bulb, Degrees F** | |
| | | |
| **35** | **Average Temperature of All Thermocouples, Degrees F** | |
| **36** | **Average Standard Deviation of All Thermocouples, Degrees F** | |
| **37** | **Coldest Thermocouple Average Temperature, Degrees F** | |

| | | |
|---|---|---|
| **38** | **Warmest Thermocouple Average Temperature, Degrees F** | |
| **39** | **Coldest Thermocouple Temperature, Degrees F** | |
| **40** | **Warmest Thermocouple Temperature, Degrees F** | |
| | | |
| **41** | **Average Temperature of All Thermocouples during Defrost Cycle, Degrees F** | |
| **42** | **Average Standard Deviation of All Thermocouples during Defrost Cycle, Degrees F** | |
| **43** | **Average Temperature of All Thermocouples during Steady State, Degrees F** | |
| **44** | **Average Standard Deviation of All Thermocouples during Steady State, Degrees F** | |